MR. WAYNE'S PHYSICS
STUDENT WORKBOOK &
OBJECTIVES

This workbook is a collection of word problems and unit objectives to augment or replace the problems found in textbooks. Students are to show all work in their physics notebooks. The physics notebook is a bound collection of papers such as a composition notebook or spiral bound notebook.

8/2018 Edition

This workbook is meant to supplement the textbook problems. Every problem, (over 1400 of them,) in this workbook will not be assigned. It provides the teacher with choices on what to assign. Because the class is always changing, additional problems and worksheets will be downloaded. Some of these worksheets will be copied to paper because of their visual nature. But if you forgot a worksheet and need to do a problem at home, you can print it off from this document.

If you are reading this document in WORD, you may need to install a free font called GROBOLD and DECADE. The remaining fonts are standard fonts.

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For Mr. Wayne’s Students (2017 Edition)  
Another fine worksheet by T. Wayne
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Capacitance and simple circuits

Physics Tools Manual
Background

I’ve been teaching physics since 1986 at Albemarle High School. My first textbook was the PSSC textbook. After my first year I realized that the problems in the book were great for my brightest students. But I was teaching any student that passed through my doors. Then I realized that the problems were not “scaffolded” well. I started to teach better and make up my own worksheets to correlate with my presentations. I began to teach every level of physics students and the worksheets also took on a similar diversity. I go back and forth about providing answers to the sections. That’s why some sections have answers and others do not. I used to copy them all on a ditto duplicator that printed purple letters. (I hope the ink wasn’t carcinogenic 😐.) In 2001 I was part of a research group to investigating how a permanently LCD projected would impact my instruction. This was a learning explosion because at the same time I learned Flash and began to create animation to better help student envision the things I see. And I made more worksheets because I was scaffolding and involving the students with more small-group work. In 2010, I was given the opportunity to see how my instruction would change if I went 1:1 with laptops in my classroom. Not I teach a blended class whose primary resource is a website I’ve working on for several years. Now I teach in flipped model that is a blend of modeling, traditional presentation, demonstrations, activities incorporating old school problems, open ended problems/activities, online interactive activities, “conceptests” and ranking-tasks.

The point in all this background is to let you know the worksheets reflect a broad spectrum of teaching techniques. Some worksheet may stand alone very well while others seem incomplete. (The ones that are incomplete are that way because when I hand them out I don’t want the students to know the questions before I’m ready. This keeps some from jumping ahead and making some missteps.)

I’m sharing them all in hopes that you may find some of them useful. Every year I update them by correcting typos and spelling mistakes on the sheets I use. Every year, until retire in 2033 or so I’ll post that the updated version in mid-August at http://www.mrwaynesclass.com/workbook

If you download the WORD version for your own use, note that I use a variety of fonts. Tahoma, Arial, Arial Black, Helvetica, GROBOLD, Inconsolata, Impact, Symbol, Incised901 BT BD, and few others. I chose these fonts because of research I did about the fonts’ readability and visual appearance when printed. If something in the WORD version looks, “off.” Then you probably need to install one of these fonts.

This book’s first edition was in 2010.
Constants Table

ADVANCED PLACEMENT PHYSICS 2 TABLE OF INFORMATION, EFFECTIVE 2015

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<td>Proton mass, ( m_p = 1.67 \times 10^{-27} \text{ kg} )</td>
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<td>Neutron mass, ( m_n = 1.67 \times 10^{-27} \text{ kg} )</td>
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<tr>
<td>Electron mass, ( m_e = 9.11 \times 10^{-31} \text{ kg} )</td>
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<tr>
<td>Avogadro’s number, ( N_0 = 6.02 \times 10^{23} \text{ mol}^{-1} )</td>
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<tr>
<td>Universal gas constant, ( R = 8.31 \text{ J/(mol-K)} )</td>
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<td>Boltzmann’s constant, ( k_B = 1.38 \times 10^{-23} \text{ J/K} )</td>
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<td>Electron charge magnitude, ( e = 1.60 \times 10^{-19} \text{ C} )</td>
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<td>1 electron volt, ( 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} )</td>
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<td>Speed of light, ( c = 3.00 \times 10^8 \text{ m/s} )</td>
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<td>Universal gravitational constant, ( G = 6.67 \times 10^{-11} \text{ m}^3/\text{kg.s}^2 )</td>
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<td>Acceleration due to gravity at Earth’s surface, ( g = 9.8 \text{ m/s}^2 )</td>
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<td>1 unified atomic mass unit, ( 1 \text{ u} = 1.66 \times 10^{-27} \text{ kg} = 931 \text{ MeV/c}^2 )</td>
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<td>1 atmosphere pressure, ( 1 \text{ atm} = 1.0 \times 10^5 \text{ N/m}^2 = 1.0 \times 10^5 \text{ Pa} )</td>
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UNIT SYMBOLS

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<th>meter, m</th>
<th>kilogram, kg</th>
<th>mole, mol</th>
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<td>10^{9}</td>
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<td>10^{6}</td>
<td>mega</td>
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</tr>
<tr>
<td>10^{-12}</td>
<td>nano</td>
<td>n</td>
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VALUES OF TRIGONOMETRIC FUNCTIONS FOR COMMON ANGLES

\[
\begin{array}{cccccccc}
\theta & 0^\circ & 30^\circ & 45^\circ & 60^\circ & 90^\circ & 120^\circ & 135^\circ & 150^\circ & 180^\circ \\
\sin \theta & 0 & 1/2 & 3/4 & \sqrt{3}/2 & 1 & \sqrt{3}/2 & 1/2 & 0 & 0 \\
\cos \theta & 1 & \sqrt{3}/2 & 1 & \sqrt{3}/2 & 3/4 & 1/2 & 0 & 0 & 1 \\
\tan \theta & 0 & \sqrt{3}/3 & 1 & \sqrt{3}/3 & 1 & 0 & -\sqrt{3} & -\sqrt{3} & \infty \\
\end{array}
\]

The following conventions are used in this exam:

I. The frame of reference of any problem is assumed to be inertial unless otherwise stated.
II. In all situations, positive work is defined as work done on a system.
III. The direction of current is conventional current: the direction in which positive charge would drift.
IV. Assume all batteries and meters are ideal unless otherwise stated.
V. Assume edge effects for the electric field of a parallel plate capacitor unless otherwise stated.
VI. For any isolated electrically charged object, the electric potential is defined as zero at infinite distance from the charged object.
# Equations for the AP Exam

## ADVANCED PLACEMENT PHYSICS 2 EQUATIONS, EFFECTIVE 2015

### MECHANICS

- \( v_x = v_{x0} + a_x t \)
- \( x = x_0 + v_{x0} t + \frac{1}{2} a_x t^2 \)
- \( v_x^2 = v_{x0}^2 + 2a_x (x - x_0) \)
- \( \mathbf{a} = \frac{\sum \mathbf{F}}{m} = \frac{\mathbf{F}_{\text{net}}}{m} \)
- \( |\mathbf{F}| \leq \mu |\mathbf{F}_n| \)
- \( a_c = \frac{v^2}{r} \)
- \( \mathbf{p} = m\mathbf{v} \)
- \( \Delta \mathbf{p} = \mathbf{F} \Delta t \)
- \( K = \frac{1}{2} m v^2 \)
- \( \Delta E = W = F_{\parallel} d = F d \cos \theta \)
- \( P = \frac{\Delta E}{\Delta t} \)
- \( \theta = \theta_0 + \omega_0 t + \frac{1}{2} \alpha t^2 \)
- \( \omega = \omega_0 + \alpha t \)
- \( x = \lambda \cos(\alpha t) = \lambda \cos(2\pi ft) \)
- \( x_{\text{ave}} = \frac{\sum m_i x_i}{\sum m_i} \)
- \( T = \frac{2\pi}{\omega} = \frac{1}{f} \)
- \( \mathbf{a} = \frac{\sum \mathbf{x}}{I} = \frac{\mathbf{x}_{\text{ave}}}{I} \)
- \( \tau = \mathbf{r} \times \mathbf{F} = rF \sin \theta \)
- \( L = I \omega \)
- \( \Delta L = \tau \Delta t \)
- \( K = \frac{1}{2} I \omega^2 \)
- \( |\mathbf{F}| = k|\mathbf{x}| \)
- \( U_g = -\frac{Gm_1m_2}{r} \)

### ELECTRICITY AND MAGNETISM

- \( |\mathbf{E}| = \frac{1}{4\pi \varepsilon_0} \frac{|q_1 q_2|}{r^2} \)
- \( \mathbf{E} = \frac{\mathbf{F}}{q} \)
- \( |\mathbf{E}| = \frac{1}{4\pi \varepsilon_0} \frac{|q|}{r^2} \)
- \( \Delta U_E = q \Delta V \)
- \( V = \frac{1}{4\pi \varepsilon_0} \frac{Q}{r} \)
- \( |\mathbf{E}| = \frac{\Delta V}{\Delta r} \)
- \( \Delta V = \frac{Q}{C} \)
- \( U_C = \frac{1}{2} Q \Delta V = \frac{1}{2} C (\Delta V)^2 \)
- \( I = \frac{\Delta Q}{\Delta t} \)
- \( \mathbf{E}_M = q \mathbf{v} \times \mathbf{B} \)
- \( R = \frac{\rho l}{A} \)
- \( P = I \Delta V \)
- \( I = \frac{\Delta V}{R} \)
- \( \mathbf{F}_M = I \mathbf{\ell} \times \mathbf{B} \)
- \( \frac{1}{R_p} = \sum \frac{1}{R_i} \)
- \( C_p = \sum C_i \)
- \( \frac{1}{C_s} = \sum \frac{1}{C_i} \)
- \( \mathbf{E} = -\frac{\Delta \Phi_B}{\Delta t} \)
- \( B = \frac{\mu_0}{2\pi} \frac{I}{r} \)

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Another fine worksheet by T. Wayne
AP Physics 2 Objectives – by Topic

AP Physics 2 Objectives - by Topic

These are basically the test questions.

Intro and Review

Kinematics

Students should be able to:

1. Be able to write, from memory, the 4 kinematics equations.
   
   \[ x = x_o + v_o t + \frac{1}{2}at^2 \]
   \[ v = v_o + at \]
   \[ v^2 = v_o^2 + 2ax \]
   \[ v_{avg} = \frac{x}{t} = \frac{v + v_o}{2} \]

2. Solve basic kinematics problems
3. Show all work in our standard solution form
   a. Givens list
      i. Variables
      ii. Numbers
      iii. Units
      iv. Unknown’s variable
   b. Equation to use with only variables
   c. Equation with number, units, & unknown variable
   d. Math steps (when needed)
   e. Answer with
      i. Units
      ii. Significant figures

Projectile Motion

For a problem when a “ball” rolls horizontally off a table, students should be able to

1. Calculate
   a. The initial velocity
   b. The time in the air
   c. The range for the impact

2. Show all solution steps

Energy

Students should be able to:

1. Define (Concept & math model):
   a. Kinetic energy
   b. Gravitational potential energy
   c. Work

2. Use these concepts and the conservation of energy to solve problems
3. Define the “system” exchanging energy.
Fluids
Student will be able to:
1. Define density
2. Calculate density of an object.
3. Determine the density of a material from a graph
4. Answer ranking task/"conceptest" questions regarding density
5. Calculate the pressure from the force and area
6. Use Bernoulli’s equation to make calculations relating to fluids.
   a. Pressure at depth calculations for stationary fluids.
   b. Describe the relationship between pressure differences and forces as it relates to moving fluids.
   c. Combine Bernoulli’s equation with pressure and force calculations
      i. e.g. forces in removing a house’s roof during a hurricane.
      ii. Force to move any object due to a difference in pressure from two different wind speeds.
   d. Use Bernoulli’s equation with the continuity equation for calculations
   e. Describe how Bernoulli relates to conservation of energy
   f. Describe how the continuity equation is conservation of mass
   g. Use Bernoulli to do venturi tube calculations and explanations.
7. Answer ranking task/"conceptest" questions regarding Bernoulli’s equation and the continuity equation.
8. Relate a fluid’s velocity, cross sectional area, and internal pressure.
   (Continuity/Bernoulli equation.)
9. Calculate the buoyant force on an object.
10. Draw a free body diagram showing all the forces acting on an object in a fluid.
    a. (Weight, tension, normal, spring, and/or buoyant forces.)
    b. The body can be submerged or floating.
    c. The body can be at a constant velocity or accelerating
    d. Write a summation of the forces equation from the free body diagram.
    e. Determine position or velocity at a function of time for a body with multiple forces acting on it.
11. Determine the weight/mass of a body when placed on a floating body, (like a barge.)
12. Determine if a body will float or sink from the body densities.
13. Determine the height, or volume, of a floating body that is above or below the fluid line.
Thermodynamics
Students should be able to:

Molecular Model of Gases
1. Define temperature
2. Define the 3 characteristics of an “Ideal gas”
3. Describe on molecular level how changes in pressure affect the force on walls of a container/system
4. Describe on molecular level how changes in pressure affect the thermal equilibrium of a container/system.
5. Calculate the force on a wall of a container from the pressure and the wall’s area.
6. Define Internal energy, U, (concept & math model):
7. Relate the temperature and internal energy of a system.
8. Relate the average kinetic energy to the root mean square speed of a velocity distribution curve.
9. Calculate the average kinetic energy of collection of molecules given the system’s temperature.

Thermal Conductivity
10. Define the thermal conductivity property (concept & math model):
11. Use thermal conductivity to solve problems

Thermal Energy Transfers (Including PV diagrams)
12. Predict how the direction of energy transfer between two mediums of different temperatures.
13. Describe the three process that describe energy transfer.
   a. Conduction
   b. Convection
   c. Radiation
14. Describe how energy is transferred on a microscopic scale through kinetic energy transfers.
15. Use the ideal gas law, PV = nRT to calculate the temperature or internal energy at a given state on a PV diagram.
16. Apply the four laws of thermodynamics
   a. 0th Law: Temp_A = Temp_B, and Temp_B = Temp_C therefore Temp_A = Temp_C.
   b. 1st Law: All energy is conserved
   c. 2nd Law: Entropy in a closed system only remains the same or increases.
   d. 3rd Law: The entropy approaches zero as the temperature approaches zero.
17. Calculate the work done by a gas on the piston of a syringe/system
18. Apply ΔU = Q + W
19. Know how the signs U, Q, and W are applied to gas system
20. Define the four ways thermal energy can be transferred between a gas system and the environment.
   a. Isovolumetric, also known as Isochoric
   b. Isobaric
AP Physics 2 Objectives – by Topic

c. Isothermal
d. Adiabatic

21. Know what does not change in each of the thermal energy transfer processes.
22. Describe the difference between work being done “by” a system and “on” a system.
23. Apply the prepositions, “on,” and, “by,” to the signs of the energy in the 1st law, \( \Delta U = Q + W \)
24. Describe how the four transfer process (outlined above) affect, \( \Delta U = Q + W \) and its physical reality between the gas system and environment.
25. Identify/calculate the following from a PV diagram;
   a. draw a PV diagram for each of the four thermal energy transfer processes
   b. Define a “state” on the PV diagram.
   c. Given the number of moles calculate temperature at any state.
   d. Calculate the internal energy of a state.
   e. Calculate the work “by” a system and “on” a system.
   f. Calculate the work “by” the environment and “on” the environment.
   g. Rank the internal energy of a system at various states
   h. Change in internal energy for gas system during a cycle.
   i. Use all this in conjunction with the 1st law, \( \Delta U = Q + W \)

Entropy

26. Qualitatively describe when a process is reversible or irreversible.
27. Describe how entropy only depends on current states and not how they were arrived.
28. Compare the entropy of two states of a system.
29. Describe how the entropy changed when comparing two energy states.
30. Describe how the entropy of the universe is always changing.
31. Describe how by “organizing” an energy system’s entropy changes, and how the entropy in the universe is changed.
**Electric Force, Field, and Potential**

Students should be able to:

1. Describe the only two types of charges
2. Describe how a body can be neutral
3. Describe the charges on a proton, electron and neutron.
4. On a molecular level, define “insulator” and “conductor.”
5. Define and use the “law of attraction:” (like charge repel and opposites attract)
6. Describe the three ways bodies obtain charge.
   a. Triboelectric effect (Frictional rubbing)
   b. Charge sharing
   c. Induction
7. Describe the two ways a neutral object can become polarized.
8. Define “grounding” and what it does with regards to the stored charges.
9. Describe how neutral bodies can be attracted to objects with a net positive or negative charge.
10. Make qualitative predictions about the distribution of positive and negative charges with neutral systems as they undergo various processes. (Sticky tape activity)
11. Qualitatively describe the electric field strength inside of a conductor, (whether is be a hollow metal sphere or solid metal wire,) to the inside of an insulator such as a latex rubber balloon or Styrofoam™ cup.
12. Identify the smallest charge that can be ISOLATED.
13. Define an “elementary charge.”
14. Compare the magnitudes of the charge of an electron and a proton.
15. Describe what a fundamental particle are.
16. Describe what a quark is and what its function is to the particles found in the nucleus of an atom.
17. Describe why quarks are not the smallest isolated charges even though their charges are smaller than the elementary charge.
18. Describe the force felt on a charge when immersed in a uniform electric field, (concept & math model)
19. Describe the direction of the exerted force for a charge placed in a uniform electric field.
20. Solve problems relating to a charge placed in a uniform electric field.
21. Qualitatively draw a vector e-field for a point charge of any sign.
22. Use a vector e-field to compare, (rank,) the magnitude of a force.
23. Given a vector e-field determine what charges made the vector e-field and their relative signs and magnitudes.
24. Identify the vector field associated with point charges, large spheres with uniform e-fields and parallel plates with uniform fields.

**Point Charges**

25. Define Coulomb’s Law: (concept & math model)
26. Describe the nature of an “Inverse square law” and it corollary.
AP Physics 2 Objectives – by Topic

27. Using Coulomb’s law calculate the magnitude and direction of the net force acting on charge due to 1 to 3 charges in a line or in a plane.
28. Solve problems that use Coulomb’s law in conjunction with other forces, e.g. gravity, tension, etc.
29. Show a graph of the force vs distance graph between two charged particles.
30. Define an, “electric field,”
31. Calculate the magnitude and direction of the net ELECTRIC field acting in point in space due to 1 to 4 charges in a line or in a plane.
32. Define a vector field
33. Determine charges and their distribution based on the vector e-field.
34. Define an, “electric potential,”
35. Calculate the electric potential ENERGY for a given charge in an external e-field.
36. Calculate the magnitude of the electric potential in point in space due to 1 to 4 charges in a line or in a plane when compared a starting position of infinity.
37. Define an “isoline” of potential.
38. Use isolines to determine charges and their distribution.
39. Determine the direction of the e-field based on the isolines of potential.

Parallel Plates of Uniform Charge
40. Determine the potential difference between two parallel plates given the e-field and separation distance.
41. Determine characteristics of a particle with a net charge that travels perpendicular to the uniform electric field created by two parallel plates.
AP Physics 2 Objectives – by Topic

Capacitance/Capacitors (The application of charged parallel plates)
Students will be able to.
1. Define the “permittivity” of matter.
2. Compare the permittivity of matter to the permittivity of “free space.”
3. Define capacitance and its units; (concept & math model.)
4. Define and use the math model for capacitance in terms of plate area, separation
distance and the dielectric between the plates.
5. Calculate the internal/potential energy stored in a capacitor. (This is the energy stored in
parallel plates.)
6. Define electrical current, (concept & math model.)
   a. Current is defined as the flow of energy and therefore the movement of positive
charges.
7. Describe what it means for electrical components, like capacitors, to be placed in
   “parallel”
8. Identify “what” stays the same on a set of capacitors in parallel with each other.
9. Calculate the equivalent capacitance for capacitors in parallel. (i.e. Add capacitors in
   parallel.)
10. Describe what it means for electrical components, like capacitors, to be placed in
   “series.”
11. Identify “what” stays the same on a set of capacitors in series with each other.
12. Calculate the equivalent capacitance for capacitors in series. (i.e. Add capacitors in
   series.)
13. Take a compound circuit consisting of capacitors in series and parallel and reduce it
down to a single circuit.
14. Calculate the total energy stored in a compound circuit.
15. Calculate the charge stored on each capacitor in a compound circuit.
16. Calculate the potential difference across each capacitor in a compound circuit.
17. Calculate the energy stored in each charged capacitor in a compound circuit.
18. Show all steps when breaking down and rebuilding a compound circuit to solve the
   objectives above.
19. For a either a series or parallel circuit of only capacitors, calculate the percentage of the
   emf’s potential difference across each component.
20. For a either a series or parallel circuit of only capacitors, calculate the percentage of the
   total charge stored in each capacitor.
Electrical circuits with resistors
Students will be able to.

1. Define resistivity, (concept & math model.)
2. Define the relationship between resistivity and resistance, (concept & math model.)
3. Define the temperature dependence of resistivity, resistance and temperature, (concept & math model.)
4. Define Ohm’s law (concept & math model.)
5. Use Ohm’s law on a graph
6. Define electrical power (concept & math model.)
7. Define and use emf, ”electromotive force.” in solving problems
8. Describe what it means for electrical components, like resistors, to be placed in “parallel”
9. Identify “what” stays the same on a set of resistors in parallel with each other.
10. Calculate the equivalent resistance for resistors in parallel. (i.e. Add resistors in parallel.)
11. Describe what it means for electrical components, like resistors, to be placed in “series.”
12. Identify “what” stays the same on a set of resistors in series with each other.
13. Calculate the equivalent resistance for resistors in parallel. (i.e. Add resistors in parallel.)
14. Rank the dissipated energy in resistors in a circuit.
15. Rank currents through various resistors in series or parallel.
16. For either a series or parallel circuit of only resistors, calculate the percentage of the emf’s potential difference across each component.
17. For either a series or parallel circuit of only resistors, calculate the percentage of the input current that flow through each resistor.

Kirchoff’s Rules
18. Define and use Kirchoff’s two rules to analyze compound circuits.
   a. Find the direction of the current(s) in a circuit.
   b. Find the potential difference across each capacitor.
   c. Find the power dissipated by each resistor in a circuit.
19. Utilize the rules to find the internal resistance of battery.

RC Circuits (Resistors in series with a capacitor)
20. Describe what happens to a circuit when it is first turned on
21. Describe what happens to a circuit after it has been on for a VERY long time.
22. Describe the potential differences across the resistor and capacitor when the circuit is first turned on.
23. Describe the potential differences across the resistor and capacitor after the circuit has been on for a VERY long time.
**Magnetism and Electromagnetic Induction**

Student will be able to:

1. Define the magnetic dipole moment.
   a. Dipoles have both a north and south

2. List the source of the magnetic dipole moment.

3. Describe what gives a material its magnetic property or magnetic strength.

4. Magnetic fields align with other magnetic fields.

5. Recall the Earth has a magnetic field and geographic north is magnetic south

6. Recall that a compass needle is a magnetic dipole.

7. Recall Magnetic fields are called b-fields
   a. Magnetic fields are continuous loops that travel inside materials.
   b. Magnetic field seek the south pole of a magnet - outside of the magnet.
   c. Draw magnetic fields for bar magnets and 2 magnets in any position oriented to each other.

8. Recall Breaking a magnet creates smaller magnets w/a north & south ... down to the electron.

9. Recall stable monopoles do not exist.

10. Define
   a. Ferromagnetism
   b. Paramagnetism
   c. Diamagnetism

11. Define and apply the Ampere’s Law (concept & math model)
   a. Magnitude of the b-field
   b. Direction of the magnetic field (Closed Right hand rule)
   c. Net magnetic field due to multiple moving charges/currents
   d. Represent/Describe the magnetic field around a current carrying wire.
   e. Graph magnetic field’s magnitude as a function of current and distance.
   f. Determine the magnitude of a b-field around a current carrying wire or collection of wires.

12. Define and apply the Lorentz force (Using 0°, 90° and 180°)
   a. Magnitude
   b. Direction of force, current, or external b-field (open right hand rule)
   c. Single charges
   d. Current of + or – charges

**Induction**

13. Define magnetic flux, its math symbol, and unit.

14. Define Lenz’s Law
   a. Determine the current’s due to change in magnetic flux

15. Define Faraday’s Law (concept & math model)
   a. Be prepared to use this in conjunction with Ohm’s law.
   b. Use a graph of flux vs t to determine/compare current & emf characteristics.
16. Calculate the potential difference generated by a moving straight wire across a perpendicular magnetic field.

**Light (Basics)**

Students will be able to:
1. Define what the “duality of light” means?
2. Define wavelength
3. Define period
4. Define wave speed (concept & math model.)
5. Define amplitude
6. Recall the speed of light in m/s to 3 sig figs.
7. Rank wavelength, frequency as a function of time from a series of pictures of waves
8. Define/describe the two types of waves
   a. transverse
   b. longitudinal
9. Recall mechanical wave can be either type
10. Identify the type of wave that exists in the electromagnetic spectrum.
11. Define light polarization.
    a. Describe how a polarizing filter works to polarize light
    b. Define the orientation of a polarized wave that bounces off of a smooth surface.
12. Recall only the type of wave that can be polarized.
13. Light, specifically visible light, is a form of electromagnetic waves.
14. Rank electromagnetic waves by their wavelength, frequency, and energy: (FM radio, microwave, infrared, ROYGBIV, UV-A, UV-B, UV-C, x-rays)
15. List the range of wavelengths considered to be visible light.
16. Define how the index of refraction relates to the speed of light
17. Define how the index of refraction relates to wavelengths of light.
18. Determine the angle of refraction for a light ray that travels between to substances.
19. Categorize light as bending towards or away from the normal line as it passes between two substances of different indices of refraction.
20. Calculate the critical angle.
21. Determine is an incident light ray is either reflected or refracted and at what angle as is passes between substances.
22. Define the “principle of superposition.”
23. Draw the resulting summed wave when two standing waves or wave pulse overlap.
24. Define the condition when the superimposed waves and to zero
25. Recall longitudinal waves require a medium and electromagnetic waves do not require a medium.

**Wave Optics**

Students will be able to:
1. Define diffraction
2. Define the condition for generating a diffraction pattern.
   a. Light passes through an opening comparable to the wavelength.
3. Define the condition for constructive and destructive interference for light passing through a **DOUBLE** slits. (concept & math model.)
4. Define the condition for constructive and destructive interference for light passing through a **SINGLE** slits. (concept & math model.)
5. Recall that waves can also bend, (and therefore carry energy,) around edges/corners because of diffraction.
6. Recall that when light is transferred from one medium to another three things happen
   a. Some is transmitted
   b. Some is reflected
   c. Some is absorbed

**Geometric Optics**
Students will be able to:

**Thin Spherical Mirrors**
1. Draw a ray diagram to locate an image from a plane mirror (all 4 rays)
2. Draw a ray diagram to locate an image from a concave mirror (all 4 rays)
3. Draw a ray diagram to locate an image from a convex mirror (all 4 rays)
4. Recall the mirror equation
5. Recall the magnification equations
6. Calculate an image or objects orientation (upright or upside down) in a curved mirror
7. Calculate is an image is real or virtual in a curved mirror.
8. Recall the two types of mirrors’ image properties as a function of an object’s location (upright/inverted and real/virtual, image location)

**Thin, Symmetrical, Spherical Lenses**
9. Draw a ray diagram to locate an image from a thin, symmetrical, concave lens (all 4 rays)
10. Draw a ray diagram to locate an image from a thin, symmetrical, double convex lens (all 4 rays)
11. Recall the lens equation
12. Recall the magnification equations
13. Calculate an image or objects orientation (upright or upside down) in symmetrical spherical thin lens
14. Calculate is an image is real or virtual in a symmetrical spherical thin lens.
15. Recall the two types of lenses’ image properties as a function of an object’s location (upright/inverted and real/virtual, image location)
AP Physics 2 Objectives – by Topic

Atomic/Quantum/Modern Physics
Students will be able to:
1. List the nucleons and their charges
2. Define what makes a “fundamental” particle
3. List what neutrons and protons are made of.
4. Describe why neutrons do not exist outside of the nucleus
5. Describe how the charge on a quark compare to the elementary charge.
6. List the names of the 6 quarks.
7. Describe what defines an element.
8. Describe where the number of isotope comes from.
9. List the three type of radioactive decays
   a. alpha
   b. beta
   c. Gamma
10. Define half life
11. Apply half life to calculate the amount of the original material left after a given number of half lives.
12. Describe how the number of electrons relates to the number of protons in a neutrally charged atom.
13. Describe how the arrangement and number of electrons can give an element different properties.
14. Recall and use the wave equation
15. Convert the energy of a single photon, or a collection of photons, to its frequency/wavelength.
16. Describe the Bohr model in terms of discrete energy states.
17. Describe the transitions between energy states leads to spectra.
18. Calculate the the first couple of spectral lines in terms of how many and what their frequencies would be.
19. Define “stimulated absorption” as it relates to energy levels
20. Define “spontaneous emission” as it relates to energy levels
21. Compare the probability of spontaneously jumping to higher state compared to spontaneously jumping to a lower state.
22. Use use E=mc² as evidence that we changed the “law of conservation of energy” to the “law of conservation of mass-energy.”
23. Describe the duality property of some particles, electrons and photons, and the evidence
24. Describe the quantum equation relating momentum and wavelength for quantum sized particle.
25. Relate the energy of a photon to the frequency and wavelength. E=hf and E=(hλ)/c
26. Recall space and time is not constant because they depend on speed.
   a. Describe the conditions for time contraction (speed and gravity*)
   b. Describe the conditions for length contraction (speed)
27. Define the "strong force"
   a. Describe its distance of interaction
   b. Describe where it is found
28. Convert between mass and energy (E=mc²)
29. Calculate the mass deficit for particles
30. Describe what an emission spectra looks like
31. Describe and calculate the frequency/wavelength of an emission line is on an energy level diagram.
32. Describe what an absorption spectra looks like
33. Describe and calculate the frequency/wavelength of an absorption line is on an energy level diagram.
34. Describe how/why an emission spectrum can be used to determine the elements of a light source.
35. Convert between an electronvolt, eV, and a Joule. (Do not memorize the conversion factor)
36. Describe the photoelectric effect with a focus on
   a. Wave function
   b. Bias energy
   c. And how to increase the intensity of the emitted photoelectrons.
37. Describe the conditions when the particle properties of a photon are more readily observable.
38. Describe the conditions when the wave properties of a photon are readily observable.
39. Calculate the de Broglie wavelength of an body with energy
40. Describe the regime where modeling using de Broglie is appropriate
41. Describe the inverse relationship between de Broglie wavelength and a particle’s momentum.
42. Describe the experiments of Clinton Joseph Davisson, Lester Germer and George Paget Thomson as it relates to the wave property and diffraction of electrons.
43. Describe qualitatively how the wave function models the probability of finding a particle in a region of space.
Nuclear Physics

Students will be able to:

1. List the particle liberated during each of these four nuclear decay processes.
   a. Alpha decay
   b. “Beta plus” decay
   c. “Beta minus” decay
   d. Gamma decay

2. Balance nuclear decay chemical equations for
   a. Alpha decay
   b. “Beta plus” decay
   c. “Beta minus” decay
   d. Gamma decay

3. Describe how conservation of charge is utilized in nuclear decay

4. Describe how conservation of energy is utilized in nuclear decay

5. Describe how conservation of nucleons is utilized in nuclear decay

6. Compare nuclear fission decay with nuclear fusion decay in terms of the daughter particles in a reaction.
AP Physics 2 Review: Kinematics

AP 2 REVIEW: Kinematics by the Numbers

\[
\begin{align*}
x &= x_0 + v_0 t + \frac{1}{2} a t^2 \\
v &= v_0 + a t \\
v^2 &= v_0^2 + 2a x
\end{align*}
\]

\[1g = 9.80 \text{ m/s}^2\]
All projectiles accelerate down at 9.80 m/s^2
Rest = v_o = 0

When solving every problem include
- a simple drawing showing the initial and final state being described,
- a list of givens with units next to each number,
- the equation being used with only variables,
- rearranged equation with only letters to isolate the unknown variable,
- equation with plugged in number and units at least once,
- any math steps -as needed,
- the answer with numbers AND correct units. (The units should match the units given in the problem. I.e. mph in the problem means the answer should be in miles, hours or mph. Centimeters in the problems means the answer should be in cm, cm/s or m/s^2.

1. How much distance is covered by a runner who starts from rest in the race and accelerate at 5.00 m/s^2 in 2.00 seconds?

2. While Calvin is doing a physics experiment outside with a radar gun, he notices that after 3 seconds a car reaches a speed of 20.0 m/s while accelerating at 3 m/s^2. What was the initial velocity of the car?

3. A squirrel drops 1.50 m from a tree branch to the ground. How much time did it take for him to reach the ground?

4. A billiard ball is rolling at 0.50 m/s the it slows to 0.15 m/s in 2.00 m. What is the ball’s acceleration?

5. Calvin hears a loud roar that causes him to turn around and notice a rocket traveling at 25 m/s. The rocket undergoes an acceleration of 3 g’s. How fast is the rocket traveling after 100 m?

6. A dragster starts from rest and undergoes an acceleration of 4 g’s before reaching its top speed of 100 m/s. How much time did it take to reach this top speed?

7. While trying to leave school in hurry, a senior, Deathwish Dan, starts from rest and floor’s his Smart Car™ to reach a speed of 10 m/s in 100m. What was his car’s acceleration in m/s^2 and g’s?
8. A baseball player throws a ball straight up until it reaches an apogee of 5.0 m above it release point. How fast was the ball traveling when it left his hand. (“Apogee” means the highest point of flight. As such a projectile’s velocity is zero.)

9. While traveling down the road you notice a state trooper’s car accelerate from 25 m/s to 35 m/s on 1.5 seconds. What was the acceleration of the car in m/s²?

10. At the Indy 500 race the car at the front of the pack at the start of the race is traveling at 36 m/s when it accelerates at 15.0 m/s² for 4 seconds? What is the final velocity of the race car?

Answers: 1) 10.0m  2) 11.0 m/s  3) 0.553s  4) -0.0569 m/s²  5) 80.7 m/s  
6) 2.55 s  7) 0.500 m/s²  8) 9.90 m/s  9) 6.67 m/s²  
10) 96.0 m/s
**Dimensional Analysis**

50  A car tire has an area of 355 in$^2$. How many mm$^2$ is this?

51  Our football stadium covers 0.460 acres. How many decameters$^2$ is this?

52  Hurricane “Harvey” dropped 27 trillion gallons in Houston, Texas. Our “large” gym has a volume equal to 756,000 ft$^3$. How many gyms would be needed to hold all of the water that fell in Houston?

53  Albemarle County is the third largest county in Virginia. It is 742 miles$^2$. How many km$^2$ is this?

54  An adult Ostrich can run at 0.0961 furlongs per second. How fast is this in miles per hour?

55  The fastest growing plant is a specific type of bamboo that grows at $8.33 \times 10^{-9}$ km/s. How many in/h is this?

**ANSWERS:**

50) 229,000 mm$^3$  
51) 18.6 decameters$^3$  
52) 4,770,000 gyms  
53) 1920 km$^2$  
54) 43.2 mph  
55) 2.07 in/h
50. \[ 355 \text{ in}^2 \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right)^2 \left( \frac{10 \text{ mm}^2}{1 \text{ cm}^2} \right) = 229.03 \text{ in}^2 \left( \frac{1 \text{ mm}^2}{2.54 \text{ cm}} \right) = 229.00 \text{ mm}^2 \]

51. \[ 10 \text{ m} = \text{ decameter} \]

\[ (0.460 \text{ acres}) \left( \frac{43560 \text{ ft}^2}{1 \text{ acre}} \right) \left( \frac{12 \text{ in}^2}{1 \text{ ft}^2} \right) \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right)^2 \left( \frac{100 \text{ cm}}{1 \text{ m}} \right)^2 \left( \frac{1 \text{ decameter}^2}{10 \text{ m}^2} \right) = 19.06 \text{ decameter}^2 \]

52. \[ 27 \times 10^{12} \text{ gal} \left( \frac{128 \text{ cu in}}{1 \text{ gal}} \right) \left( \frac{1 \text{ liter}}{1 \text{ ml}} \right) \left( \frac{1 \text{ cm}^3}{1 \text{ m}^3} \right) \left( \frac{1 \text{ in}^3}{2.54 \times 12^3 \text{ in}^3} \right) \left( \frac{1 \text{ ft}^3}{1 \text{ m}^3} \right) = 4.73 \times 10^4 \text{ gal} \left( \frac{1 \text{ gal}}{1 \text{ m}^3} \right) \approx 4.77 \times 10^4 \text{ gal/m}^3 \]

53. \[ (1.42 \text{ m}^2) \left( \frac{5280 \text{ ft}^2}{1 \text{ m}^2} \right) \left( \frac{12 \text{ in}^2}{1 \text{ ft}^2} \right) \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right)^2 \left( \frac{1 \text{ km}^2}{100 \text{ m}^2} \right) = 19.21 \text{ km}^2 \]

54. \[ (0.096 \text{ fur/mile}) \left( \frac{5280 \text{ ft}}{1 \text{ mile}} \right) \left( \frac{60 \text{ s}}{1 \text{ min}} \right) \left( \frac{60 \text{ min}}{1 \text{ hr}} \right) = 43.2 \text{ mi/h} \]

55. \[ (9.33 \times 10^9 \text{ km}^3) \left( \frac{1000 \text{ m}}{1 \text{ km}} \right) \left( \frac{100 \text{ cm}}{1 \text{ m}} \right) \left( \frac{2.54 \text{ cm}}{1 \text{ in}} \right) \left( \frac{3600 \text{ s}}{1 \text{ min}} \right) = 2.07 \text{ in/h} \]
AP Physics 2 Review: Projectile Motion

AP Physics 2: Projectile Motion Review Problems

1. A ball rolls horizontally off a table 1.2 meters high. If the ball travels along the table at a constant 2.0 m/s than how far from the table’s edge will it land?

2. A person runs horizontally off a ledge that is 5.0 m high and lands in a lake 3.0 meters, horizontally, from the edge. How fast was the person traveling then they were running on the ledge?

3. A car is traveling at 25 m/s per second when it traveled horizontally off a road and lands 3.0 m below. How much time did it spend in the air?

4. At the King’s Dominion water park a teenager shoots horizontally off a water slide at 9.0 m/s. They land horizontally 4.5 m from the edge of the slide’s bottom. How high is the bottom of the slide from the water?

5. A baby slides a Cheerio horizontally off the high chair’s tray. The tray is 0.95 m above the floor and the Cheerio is traveling at 1.5 m/s when it leaves the tray, how far horizontally will the Cheerio land from the edge of the tray?

6. A ball rolls 0.75 meters horizontally across a table top in 0.40 seconds before leaving the edge of the table. The table is 1.1 m above the floor. How far from the edge of the table will the ball land?

7. You’ve just discovered these guys horizontally off a cliff at the edge of a deep river while doing some crazy flips in the air. If they run off the cliff at 5 m/s and land 8.0 meters from the edge of the cliff, then how high is the cliff?

Answers: (1) 0.990 m (2) 2.97 m/s (3) 0.782 s (4) 1.23 m (5) 0.660 m (6) 0.888 m (7) 12.5 m
**Significant Figures**

**Significant Figures**

There are three rules on determining how many significant figures are in a number:

1. Non-zero digits are always significant.
2. Any zeros between two significant digits are significant.
3. A final zero or trailing zeros in the decimal portion **ONLY** are significant.

Identify how many significant figures are in each number AND circle the estimated number.

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**For Mr. Wayne’s Students (2017 Edition)**

Another fine worksheet by T. Wayne
For each number write the number of significant digits in the number and identify which one is the estimated number.

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<td>48. 5.685 X 10^2</td>
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Solve each problem below while following the rules of significant figures.

138) 34.5 + 23.45 = 145) 903 + 5 = 152) 0.034 + 2.3 =
139) 330 + 400 = 146) 300.03 + 34 = 153) 400 + 2 =
140) 30,000 + 5600 = 147) 0.034 + 0.20 = 154) 76 + 0.03 =
141) 34 + 5 = 148) 1.034 + 0.005 = 155) 54 + 4.03 =
142) 56.03 + 4530 = 149) 2.34 + 23 = 156) 65.03 + 1.354 =
143) 3405 + 400 = 150) 30.05 + 2.40 = 157) 0.43 + 4.1 =
144) 50 + 0.50 = 151) 100 + 20 = 158) 432 + 23.44 =

Solve each problem below while following the rules of significant figures.

159) 34.5 x 23.45 = 166) 903 x 5 = 173) 0.034 x 2.3 =
160) 330 x 400 = 167) 300.03 x 34 = 174) 400 x 2 =
161) 30,000 x 5600 = 168) 0.034 x 0.20 = 175) 76 x 0.03 =
162) 5² = 169) 1.034 x 0.005 = 176) 54 x 4.03 =
163) 56.03 x 4530 = 170) 2.34 x 23 = 177) 65.03 x 1.354 =
164) 3405 x 400 = 171) 25² = 178) 0.43 x 4.1 =
165) 50 x 0.50 = 172) 100 x 20 = 179) 432 x 23.44 =
Follow the rules of significant figures to solve the problems below. (All "1/2’s" are perfect counting numbers)

180) \[23 + 0.0094 = \]
181) \[256.9 - 0.25 = \]
182) \[1002 + 25.2 = \]
183) \[45.23 + 1.2356 = \]
184) \[200 + 95 = \]
185) \[50 + 7.89 = \]
186) \[0.0024 + 0.0254 = \]
187) \[12.02 - 0.1235 = \]
188) \[12.589 + 0.12 + 1.256 = \]
189) \[0.235 - 1.24 + 0.0235 = \]
190) \[58 + 220 - 5.4 = \]
191) \[0.00215 + 1.0224 + 12.2 = \]
192) \[2356 + 12.56 - 125.46 = \]
193) \[0.0025 + 0.25 - 0.00011 = \]
194) \[1.23 \times 0.0094 = \]
195) \[256.9 \times 0.25 = \]
196) \[1002 \div 25.2 = \]
197) \[45.23 \div 1.2356 = \]
198) \[200 \div 95 = \]
199) \[50 \times 7.89 = \]
200) \[0.0024 \times 0.0254 = \]
201) \[12.02 \times 0.1235 = \]
202) \[12.589 \times 0.12 \times 1.256 = \]
203) \[0.235 \times 1.24 \div 0.0235 = \]
204) \[58 \times 220 \div 5.4 = \]
205) \[0.00215 \times 1.0224 \div 12.2 = \]
206) \[2356 \div 12.56 \times 125.46 = \]
207) \[0.0025 + 0.25 \times 0.00011 = \]
208) \[1002 \div 25.2 + 12.5 = \]
209) \[45.23 \div 1.2356 + 2.335 = \]
210) \[200 \div 95 - 8.56 = \]
211) \[50 \times 7.89 + 0.25 = \]
212) \[0.0024 \times 0.0254 + 0.00245 = \]
213) \[12.02 \times 0.1235 + 5.68 = \]
214) \[12.589 \times 0.12 + 1.256 = \]
215) \[0.235 + 1.24 \div 0.0235 = \]
216) \[58 + 220 \div 5.4 = \]
217) \[0.00215 \times 1.0224 - 12.2 = \]
218) \[2356 \div 12.56 + 125.6 = \]
219) \[25.36^2 = \]
220) \[0.125^3 = \]
221) \[12.0256^2 = \]
222) \[(1/2)4.56 + 12/(2.3)\]
223) \[5^2 + 2.3(5)\]
224) \[82\]
### Scientific Notation

Express each number in scientific notation.

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Introduction to using math prefixes.

**Objectives**

Students will be able to:
- Write the power of ten associated with the prefixes, “G, n, M, µ, k, m and c,” from memory.
- Write the “math” word that describes “G, n, M, µ, k, m and c.” from memory.
- Convert to and from any unit with an, “G, n, M, µ, k, m and c” as a unit prefix without a conversion chart.
  - Examples include but are not limited to:
    - Grams to kilograms
    - Meters to kilometers
    - Meters to centimeters

**Problems**

1. 35 g to kg
2. 6.0 cm to m
3. 500 cm to m
4. 10kmi to mi
5. $6M to $
6. 2400 Gm to m
7. 45 µs to s
8. 15 mNs to Ns
9. 4320 cRad to Rad
10. 35 mft to ft
11. 15 m to cm
12. 14 lb to mlb
13. 13 cs to s
14. 0.001 s to ms
15. 1000 T to MT
16. 1500 A to kA
17. 390s to µs
18. 54 H to cH
19. 0.0400 V to µV
20. 355,944 lumens to Glumens
21. 8000 Mg to g
22. 35 mg to g
23. 9415 m² to Gm²
24. 7800 F to kF
25. 0.2909 Pa to µPa
26. 6900 m to km
27. 45.00 MΩ to Ω
28. 93 µT to T
29. 5.60 GA to A
30. 5cy to y
31. 35.6 A to mA
32. 8,948 GV to V
33. 12 km to m
34. 55 nC to C
35. 82 V to mV
36. 22,000 cG to G
37. 809,398 MN to N
38. 35 µΩ to Ω
39. 238 H to mH
40. 45Gg to g
41. 1892 A to kA
42. 80,233 F to mF
43. 1.329 MW to kW
44. 0.034 mi to kmi
45. 28,025,400 mN to kN
46. 560,000 cm to km
47. 45 MH to cH
48. 903 kg to g
49. 39 µm to m
50. 890 Gb to Mb
Dimensional Analysis Facts Sheet

(Do not memorize. You will receive a clean copy of this on your assessment.)

**POWERS of TEN**
- Thousand = $10^3$
- Million = $10^6$
- Billion = $10^9$
- Trillion = $10^{12}$
- Quadrillion = $10^{15}$
- Quintillion = $10^{18}$

**DISTANCE UNITS**
- Parsec = $1.91738 \times 10^{13}$ miles
- Furlong = $\frac{1}{8}$ mile
- Rod = 16.5 feet
- Rod = 25,000 links
- Football field = 100 yards
- Soccer field = 100 METERS
- Rod = 5.50 yards
- Fathom = 6 feet
- Yard = 3 feet
- foot = 12 inches
- inch = 2.54 centimeters (exactly)
- centimeter = 10 millimeters
- decimeter = 10 centimeters
- meter = 100 centimeters
- 5280 feet = 1 mile
- dekameter or decameter = 10 meters
- Walking pace (avg) = 31 inches
- Story on a building = 3 m
- Light year = $9.467 \times 10^{15}$ meters
- Barn = $10^{-24}$ cm$^2$
- League = 3 miles
- Cubit = 20 inches
- 4 rods = chain

**ROTATIONS**
- 1 Revolution = 360°
- $2\pi$ Radians = 1 Revolution

**TIME UNITS**
- millennium = 1,000 years
- century = 100 years
- decade = 10 years
- years = 365 days
- day = 24 hours
- hour = 60 minutes
- minute = 60 seconds
- Blink of an eye = 1/10 second
- fortnight = 14 days
- 1 score = 20 years

**WEIGHTS and METRIC MASSES**
- Pound = 16 ounces
- Ton = 2000 pounds
- Tonne = 1000 kilograms (metric ton)
- Long ton = 2240 pounds
- Gram = 1000 milligrams
- Kilogram = 1000 grams
- Kilogram = 2.205 pounds
- Pound = 453.5923 grams
- Newton = 7.233014 Poundal
- Dram = 27.34375 grains
- Pound= 7000 grains
- Pound = 4.448 Newtons
- Poundal = 14.0980814039 gram
- Pennyweight = 24 grains
- Stone = 14 pounds
- Clove = ½ Stone

**VOLUME MEASUREMENTS**
- 1 liter = 1000 milliliters
- 2 liters = 67.63 ounces
- 1 gallon = 128 ounces
- 1 milliliter = cm$^3$
- 1 milliliter = 20 drops
- 2 pints = 1 quart
- 4 quarts = 1 gallon
- peck = 2 gallons
Dimensional Analysis

Objectives

You will get a sheet like this at the beginning of almost every unit. This sheet identifies the kinds of questions and the content you will need to know for the end of unit test.

Dimensional Analysis (ww04)

Students will be able to:
1. Create a fraction from an equality relationship.
2. Solve unit conversion problems involving single variables.
3. Solve unit conversion problems involving fractions.
4. Solve unit conversion problems where a unit or part of the unit is raised to a power.

There is an online pretest (http://www.mrwaynesclass.com).
Do not memorize the unit conversion sheet.

Refer to the “Dimensional Analysis Fact Sheet”
1. How many inches are there in a football field?
2. How many feet are there in a mile?
3. How many yards are there in a mile?
4. How many yards are there in a soccer field?
5. How many feet are there in a furlong?
6. How many paces make up a football field?
7. How many paces make up a furlong?
8. How many fathoms deep is a 20 foot deep diving well?
9. Every 75 feet down a scuba diver goes makes him feel like he has had a martini. How many fathoms is this?
10. How feet are between the first and second floor of a building (one story)?
11. How many parsecs make up a light year?
12. How many rods make up a mile?
13. How many centimeters are in a fathom?
14. How many seconds are in a year?
15. How many hours are in a fortnight?
16. The average life span a tortoise is 200 years. How many scores is this?
17. A housefly's life span is 3 days. How many minutes is this?
18. If a person blinks their eyes once every 3 minutes on the average, then how many times do they blink their eye in a day?
19. How many grams are in a pound?
20. How many poundals are in a pound?
21. How many pounds are in a metric ton?
22. A typical locomotive weighs 40,000 tons. How many dramms is this?
23. A typical car manufactured in 1974 weighs 4000 pounds. How many McDonald's Quarter Pounders™ is this? If the Quarter Pounder™ costs $0.65 in 1974 and the car costs $6,000, then which is cheaper the car or the car's weight in Quarter Pounders™?
24. What is the speed of a car in feet/second that is traveling at 60 miles/hour?
**25.** The space shuttle travels at 28,000 mph while orbiting the Earth. How far does the shuttle travel in feet in the blink of an eye?

**26.** How much time, in seconds, passes before a beam of light, traveling at 3.00 \(\times 10^8\) meters/second travels one foot?

**27.** A stack of ten 3.5 inch diskettes is 34 millimeters high. How many diskettes does it take to make a stack 100 yards high?

**28.** A physics book is 1.5 inches thick. How many books would it take to make a stack 2 stories high?

**29.** If you earned one penny every 10 seconds of your life then how many dollars would you have after 65 years?

**30.** A 5.25 inch diskette spins around once every 0.200 seconds. The disk's diameter is 5.25 seconds. If you were an insect sitting on the edge of the diskette, then how fast would you travel in mph?

31. A container holds 16 ounces. What is the volume of this container in inches\(^3\)?
   - If the container is a glass with a diameter of 2 inches, what is its height?

32. An "acre" is a measure of land that is 43,560 feet\(^2\). How many square meters is this?
   - How many meters on each side of a square is this?

33. A car is traveling at 88 ft/sec. What is the car's speed in miles/hour?

34. In a crazed neighborhood they are replacing the speed limit signs that give the speed in m/s. What would the new sign say if it were to replace a 25 mph sign?

35. When the space shuttle is at its maximum orbit radius it is traveling at 28,000 mph. How many miles/second is this?

36. A tennis ball leaves a racket during a serve at 29.22 fathoms/s. During a yellow flag at a race on the Indianapolis speedway the cars travel 82 mi/h. A runner travels 0.125 furlong/s. Which object is traveling the fastest?

37. A swimming pool can hold 20,000 gallons of water. A pond holds 2,000,000 cm\(^3\) of water. A well holds 12,000 liters of water. Which vessel holds the most amount of water?

38. A peregrine falcon can travel at 537,600 furlong/fortnight. A racecar travels at 212 ft/s. A spider can jump with a maximum velocity of 9,000,000 cm/h. Which travels the fastest? Show numbers to support your answer.

39. A 2 liter bottle of Pepsi costs $0.99. A gallon of milk costs $1.89. A 12-ounce can of "Food Lion" cola costs $0.20. Which fluid is the cheapest per unit?

40. Which is the greatest volume; a human’s 8 pints of blood, a 2 liter bottle, a gallon jug of milk, or an old car engine whose displacement is 320 in\(^3\)?

41. A quart has an area of 5.06 cm\(^2\). How many square yards is this?

42. A teaspoon of oil can cover the surface of a pond about 10,000 cubits\(^2\) in size. How many square yards is this?

43. A fingerprint is about 1.25 in\(^2\). How many cm\(^2\) is this?

44. The continental United States covers about 16,000,000 miles\(^2\). How squared walking paces is this?

45. The walls of a room have a total area of 60 square meters. How many rolls of wallpaper will it take to cover all the walls is a single roll can cover 24 ft\(^2\)?
Vectors & Trig - Introduction

Students will be able to:

1. Define Sine, Cosine and Tangent in terms of the opposite, adjacent and hypotenuse of a triangle.
2. Use the above trig functions to find angles and right triangle side lengths.
3. Define a vector in a sentence.
4. Describe a vector’s two main features.
5. Define a scalar in a sentence.
6. Give examples of vectors and scalars.
7. Be able to identify if two vectors are equal
8. Graphically show the result of multiplying a vector by a positive scalar.
9. Graphically show the result of multiplying a vector by a negative scalar.
10. Graphically add vectors.
11. Graphically subtract vectors.
12. Graphically add, subtract and multiply vectors by a scalar in one equation.
13. Given a graphical representation of a vector equation, come up with the formula.
14. Calculate the magnitude of any vector’s horizontal and vertical components.
15. Draw a vector’s horizontal and vertical components.
16. Use trig to calculate a vector’s direction.
17. Calculate a vector’s direction as a degree measurement combined with compass directions.
18. Calculate a vector’s magnitude using trig or Pythagorean theorem.
19. Add and subtract vectors by their components.
20. Draw the equilibrant vector.
21. Calculate the equilibrant vectors magnitude and direction.
Find the missing variable

SHEET A

A

\[
\begin{align*}
\text{x} & \quad 10 \\
\angle A & \quad 28°
\end{align*}
\]

B

\[
\begin{align*}
\text{x} & \quad 8 \\
\angle B & \quad 5°
\end{align*}
\]

C

\[
\begin{align*}
\angle C & \quad 40° \\
\text{x} & \quad 40
\end{align*}
\]

D

\[
\begin{align*}
\angle D & \quad 8° \\
\text{x} & \quad 10
\end{align*}
\]

E

\[
\begin{align*}
\text{x} & \quad 30 \\
\angle E & \quad 35°
\end{align*}
\]

F

\[
\begin{align*}
\angle F & \quad 12° \\
\text{x} & \quad 9
\end{align*}
\]

G

\[
\begin{align*}
\angle G & \quad 45° \\
\text{x} & \quad 3
\end{align*}
\]

H

\[
\begin{align*}
\angle H & \quad 25° \\
\text{x} & \quad 8
\end{align*}
\]

I

\[
\begin{align*}
\angle I & \quad 24° \\
\text{x} & \quad 12
\end{align*}
\]

J

\[
\begin{align*}
\angle J & \quad 68° \\
\text{x} & \quad 1.5
\end{align*}
\]

K

\[
\begin{align*}
\angle K & \quad 55° \\
\text{x} & \quad 15
\end{align*}
\]

L

\[
\begin{align*}
\angle L & \quad 55° \\
\text{x} & \quad 375
\end{align*}
\]

M

\[
\begin{align*}
\angle M & \quad 49° \\
\text{x} & \quad 0.70
\end{align*}
\]

N

\[
\begin{align*}
\angle N & \quad 62° \\
\text{x} & \quad 37
\end{align*}
\]

O

\[
\begin{align*}
\angle O & \quad 70° \\
\text{x} & \quad 115
\end{align*}
\]

P

\[
\begin{align*}
\angle P & \quad 21° \\
\text{x} & \quad 1.5
\end{align*}
\]

Q

\[
\begin{align*}
\angle Q & \quad 53° \\
\text{x} & \quad 352
\end{align*}
\]
Find the angle $\theta$
Find the missing variable

A

θ

B

5

θ

C

52

41°

D

10

θ

E

59.6

θ

F

102

73°

53°

G

0.025

45°

H

110

θ

I

12

θ

J

0.2

23°

K

18

38

L

0.058

73°

M

6005

6005

N

25

0

14

O

37

θ

P

θ

71

Q

9.5

57°
For the vectors below, calculate the vector’s magnitude, and direction.
Vectors and Right Triangle Trigonometry

For each vector drawn below on a coordinate axis, label the shown \( \theta \) with its proper compass headings, e.g. N of W, S, S of E, etc.
For each vector drawn below, calculate its magnitude and direction. NOTE: For the vector’s direction, there will be two possible correct answers for each problem. The two answers are complimentary to each other.
VECTORS - GRAPHICAL MEANS

Find the resultants, (R#):

A + B = R1,   B + C = R2,   E + D = R3,   A - B = R4,   B - D = R5,   E - C = R6,
A + B + D = R7,   E + A + C = R8,   A + (-B) = R9,   -B + C + (-D) = R10,
E - A + C - D = R11,

Find the equilibrants to: A + B;   E - A;   B - 3C;   E + 3C;   A + B + D;   E + A + C
Vectors and Right Triangle Trigonometry

You are given a set of reference vectors. Your task is to create an equation from each picture using the reference vectors and draw a non-negative resultant for each set of components.

Example A

\[ \overrightarrow{A} + \overrightarrow{B} = \overrightarrow{R_A} \]

"A" & "B" meet tip-to-tail so they are added. \( \overrightarrow{R_A} \) is from the tail to the tip so it's the answer.

Answer A

Example B

\[ \overrightarrow{B} + \overrightarrow{F} = \overrightarrow{R_B} \]

\( \overrightarrow{F} \) is backwards from above and meets tip-to-tail with \( \overrightarrow{B} \).

Answer B

Example C

\[ 2\overrightarrow{B} + \overrightarrow{A} = \overrightarrow{R_C} \]

Which vector was used and what scalar it was multiplied by had to be determined before writing the equation.

Answer C
You are given a set of reference vectors. Your task is to create an equation from each picture using the reference vectors and draw a non-negative resultant for each set of components.
Vectors and Right Triangle Trigonometry

Using the information below a piece of graph paper, a protractor, and ruler, marked in cm, calculate the magnitude and direction of the resultant by drawing the vectors and measuring the answer.

Vector “A” is 2.5 cm long at an angle of exactly 30°
Vector “B” is 3.0 cm long at an angle of exactly 120°
Vector “C” is 1.5 cm long at an angle of exactly 330°
Vector “D” is 2.0 cm long at an angle of exactly 210°
Vector “E” is 3.5 cm long at an angle of exactly 170°

(1) \( \text{A} + \text{B} = \text{R}_1 \)
(2) \( \text{C} + \text{D} = \text{R}_2 \)
(3) \( \text{E} - \text{A} = \text{R}_3 \)
(4) \( \text{A} - \text{C} = \text{R}_4 \)
(5) \( \text{D} + \text{C} = \text{R}_5 \)
(6) \( \text{A} + \text{D} + \text{E} = \text{R}_6 \)
(7) \( \text{B} - \text{C} - \text{D} = \text{R}_7 \)
(8) \( \text{D} - \text{B} + \text{A} = \text{R}_8 \)
(9) \( \text{E} - \text{A} - \text{C} = \text{R}_9 \)
(10) \( \text{C} + \text{D} - \text{E} = \text{R}_1 \)

In science terms the adjective “net” means the same thing as “resultant.” The net force is found by adding up the force vectors. The net acceleration is found by adding up the acceleration vectors. The net magnetic field is found by adding up all of the magnetic field vectors. The main difference is in how the answer is reported. Because these are now physical measurements, you will need to include units on your magnitudes.

Using the information below a piece of graph paper, a protractor, and ruler, marked in cm, calculate the magnitude and direction of the resultant by drawing the vectors and measuring the answer. You will need to create a scale so draw the vectors.

(11) **Calculate the net force if...**
- Force “A” is 1500 pounds at an angle of exactly 60°
- Force “B” is 2000 pounds an angle of exactly 120°

(12) **Calculate the net acceleration if...**
- Acceleration “C” is 30 m/s² at an angle of exactly 130°
- Acceleration “D” is 15 m/s² at an angle of exactly 350°

(13) **Calculate the net electric field if...**
- Electric field “E” is 20 000 Volts/meter at an angle of exactly 240°
- Electric field “F” is 15 000 Volts/meter at an angle of exactly 160°

(14) **Calculate the net magnetic field if...**
- Magnetic field “H” is 250 Teslas at an angle of exactly 50°
- Magnetic field “G” is 100 Teslas at an angle of exactly 245°

(15) **Calculate the net force if...**
- Force “J” is 4 000 000 Newtons at an angle of exactly 130°
- Force “K” is 2 000 000 Newtons at an angle of exactly 310°
Adding by Vector Components

1. 8 m/s at 55°
   10 m/s at 25°

2. 15 m/s at 10°
   8 m/s at 25°

3. 3 N at 40°
   7 N at 44°

4. 8 m at 33°
   10 m at 33°
Adding by Vector Components

5

15 m/s

50°

35°

10 m/s

8 m/s

6

6 N

72°

3 N

10 N

20°

2

10 N

6 N

35°

15°

2

10 m/s

4 m/s

8

8 m/s²

9 m/s²

15°

50°

43°

9 m/s²

8 m/s²

10 m/s

13 m/s

5 m/s
Vectors and Right Triangle Trigonometry

Reading Examples: http://www.mrwaynesclass.com/vectors/reading/index06.html

(1)
Vectors and Right Triangle Trigonometry

Reading Examples: http://www.mrwaynesclass.com/vectors/reading/index06.html

(2)
Vectors and Right Triangle Trigonometry

Reading Examples: http://www.mrwaynesclass.com/vectors/reading/index06.html (3)
Basic Math by Vector Components

FIND THE RESULTANT’S LENGTH AND ACUTE ANGLE WITH THE HORIZONTAL FOR EACH R#:

\[
\begin{align*}
A + B &= R_1, \\
B + C &= R_2, \\
E + D &= R_3, \\
A - B &= R_4, \\
B - D &= R_5, \\
E - C &= R_6, \\
A + B + D &= R_7, \\
E + A + C &= R_8, \\
A + (-B) &= R_9, \\
-B + C + (-D) &= R_{10}, \\
E - A + C - D &= R_{11},
\end{align*}
\]

<table>
<thead>
<tr>
<th>Vector</th>
<th>Magnitude</th>
<th>Direction</th>
<th>OR</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>R_1</td>
<td>2√17 = 8.25</td>
<td>18.43° N of E</td>
<td>71.57° E of N</td>
<td></td>
</tr>
<tr>
<td>R_2</td>
<td>2√13 = 7.21</td>
<td>56.31° N of W</td>
<td>33.69° W of N</td>
<td></td>
</tr>
<tr>
<td>R_3</td>
<td>√5 = 2.24</td>
<td>63.43° S of W</td>
<td>26.57° W of S</td>
<td></td>
</tr>
<tr>
<td>R_4</td>
<td>2√41 = 12.81</td>
<td>38.66° W of S</td>
<td>51.34° S of W</td>
<td></td>
</tr>
<tr>
<td>R_5</td>
<td>17</td>
<td>28.07° N of E</td>
<td>61.93° E of N</td>
<td></td>
</tr>
<tr>
<td>R_6</td>
<td>11</td>
<td>Due East</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>R_7</td>
<td>1</td>
<td>Due West</td>
<td>----</td>
<td></td>
</tr>
<tr>
<td>R_8</td>
<td>17</td>
<td>14.04° E of S</td>
<td>75.96° S of E</td>
<td></td>
</tr>
<tr>
<td>R_9</td>
<td>2√41 = 12.81</td>
<td>38.66° W of S</td>
<td>51.34° S of W</td>
<td></td>
</tr>
<tr>
<td>R_{10}</td>
<td>2√13 = 7.21</td>
<td>56.31° W of S</td>
<td>33.69° S of W</td>
<td></td>
</tr>
</tbody>
</table>

For Mr. Wayne’s Students (2017 Edition)
**BOMB DISPOSAL DUTY**

**READ COMPLETELY BEFORE BEGINNING!!!**

**THE MISSION:**

Your team has been recruited by the FBI to assist with the disarmament of a dirty bomb disguised as cafeteria refuse resembling food. The device is located in another room on the first floor of the school. To ensure success of your mission the explosive’s location is found by combining a location on a vector map with a clear distorted map of the school. Our agents have obtained (from a spy masquerading as a principal) a complex vector description of the location of the bomb. Your job is to follow the directions to create the vector map. Another FBI operative is bringing a distorted map of the school drawn on clear acetate. You have 30 minutes, from the time you begin reading this, to locate this spot by drawing the whole scenario out on the provided piece of paper and marking the spot with an X. Then notify "the chief" (that would be your teacher).

**THE GRADE:**

Your grade on this project depends on the accuracy (percent error) of your spot location. However, if you fail to locate a spot before time expires, you will earn a zero. If you finish early, re-do your calculations and check your answer. You must clean your lab table before you leave class.

**THE MATERIALS:**

The only materials you will be allowed for this lab are your calculators, graph paper, ruler, and protractor.

**THE SPOT LOCATION:**

*From the center of the circle on the provided paper:*

1. Go 1.00 inch due south
2. Go 6.1 cm east
3. Go 0.0000489 miles in a direction 45° north of west
4. Go 2.0 cm in a direction 45° south of east
5. Rotate 115° clockwise from the last vector direction and travel 100,000,140 nm
6. Go 0.0200 feet west
7. Go 0.152 yards in a direction 67.0° east of south
8. Go 0.00018288 km in a direction 20° north of west
9. Go 8.0 x 10^4 µm in a direction 79.0° south of west

**THE CONVERSION FACTORS:**

(Use Google to convert the given values to a measurement on your ruler -centimeters.)

…Or use these conversions to work it out by hand.

1 mile = 5280 ft, 1 in = 2.54 cm, 1.609 km = 1 mile
(1) Draw a scale diagram of the appropriate vectors to solve the problem.

A sailboat experiences three forces across the water. The wind’s force points with the components of 400 Newtons to the East and 100 N to the South. The keel underneath the boat exerts a force that points with the force components of 600 Newtons to the West and 100 N to the South. (a) What is the net force acting on the boat due to these two forces? Describe it in terms of its components.

When the little motor on the back of the boat is turned on, the boat does not move anywhere. (b) What is the force of this motor. Describe it in terms of its components. (c) Draw a new set of forces and this time draw this motor’s force on the diagram.
Draw a scale diagram of the appropriate vectors to solve the problem.

In calm water a boat’s motor can push the boat along at 6 mph. But today the wind is blowing $45^\circ$ towards the NE. This wind pushes the boat in this direction with a speed of 4 mph. What direction and at what speed will the boat travel?

What is the scale for each square?
Draw a scale diagram of the appropriate vectors to solve the problem.

Picture: [link to image]

Over 100 years ago merchandise was moved on the water in barges that floated in man made canals that held water. The canals looked like narrow man made rivers and the barges were large box shapes.

To move a barge more efficiently Anita Jenius has an idea to use 2 mules to pull the barge. One mule walks on the right path of the canal, the other mule walks on the opposite side. Unfortunately the mules do not pull evenly. The mule on the left path pulls with a force whose components are 2500 Newtons to the East and 1000 Newtons to the North. The mule on the right path pulls the boat with a force whose components are 1000 N to the East and 2000 N to the South. The mule on the right path is pulling too hard the and barge will crash into the right bank. To fight this you attach a 3rd rope to the barge and pull perpendicular to the barge. How much force do you apply to the barge through this rope to keep the barge traveling in straight line? Which side do you stand on? What scale did you use on the graph paper?
Draw a scale diagram of the appropriate vectors to solve the problem.

A plane is climbing with an upwards component of force of 10,000 Newtons while traveling with a 14,000 Newton force pushing the plane forward. The plane has a “weight” force acting straight down of 8,000 N. The plane moves as if it has a net force pulling up with a force of 1000N and forward with a force of 6000 N. The plane also experiences a drag force. What is the magnitude and direction of this drag force?
(5) Draw a scale diagram of the appropriate vectors to solve the problem.

A car is traveling down a 15° incline. Gravity applies a force pulling the car straight down with a force of 8000N. The road applies a force of 3000 N. This force is perpendicular to the road and points upwards from the road. It is called the “normal” force. What force does the car’s brakes apply to stay in place? Magnitude and direction. (This means a net force of zero.)
(6) Draw a scale diagram of the appropriate vectors to solve the problem.

On a snowy winter day you decide to go sleigh riding down some terrific hills. Because of over crowding you have been relegated to small hill while you wait for the big hill to open up. You sit on the sled while on the small hill. The sled does not move. How sad. :-( The hill is at a 10.0° angle. There is a normal force perpendicular to the hill with a force of 500 N pointing up away from the hill. A frictional force, cleverly called, “friction,” points parallel to the hill and towards the top of the hill with a magnitude of 87 N. What is the magnitude of the force of gravity pulling straight down?
Objects

The concepts of kinematics

Student’s will be able

- Define the concepts of displacement, velocity and acceleration,
- Calculate changes in displacement or velocity without math or graphs.

Problems:

1. A runner is moving with a velocity of 4 m/s when they accelerate at 2 m/s for 3 seconds. How fast are they traveling now?

2. In a football game, running back is at the 10 yard line and running up the field towards the 50 yard line, (10, 20, 30, 40 yard line etc.) and runs for 3 seconds at 8 m/s. What is his current position?

3. A cat is moving at 18 m/s when it accelerates at 4 m/s for 2 seconds. What is his new velocity?

4. A race car is traveling at 76 m/s when is slows down at 9 m/s for 4 seconds. What is his new velocity?

5. An alien spaceship is 500 m above the ground and moving at a constant velocity of 150 m/s upwards. How high above the round is the ship after 5 seconds?

6. A bicyclist is traveling at 25 m/s when he begins to decelerate at 4 m/s. How fast is he traveling after 5 seconds?

7. A squirrel is 5 ft away from your while moving at a constant velocity of 3 ft/s away from you. How far away is the squirrel after 5 seconds?

8. A ball is dropped off a very tall canyon ledge. Gravity accelerates the ball at 22 mph/s. How fast is the ball traveling after 5 seconds?

9. During a race, a dragster is 200 m from the starting line and something goes wrong and is stops accelerating. It travels at a constant velocity of 100 m/s for 3 seconds to try to finish the race. How far from the starting line of the dragster after 3 seconds?

10. A dog is 60 yards away while moving at a constant velocity of 10 yds/s towards you. Where is the dog after 4 seconds?
Kinematics by Graphical Means

Objectives

Student should be able to:

1. **In a sentence define**
   - vector (give examples too)
   - scalar (give examples too)
   - displacement
   - speed
   - acceleration
   - jerk
   - velocity

2. **Mathematically describe**
   - instantaneous velocity

Kinematics & Graphing:

3. **From a displacement vs time graph be able to answer questions about velocity**
   - Example:
     - a. Find position
     - b. Find instantaneous velocity
     - c. Identify regions, line segments, of constant velocity
     - d. Identify regions, line segments, of positive velocity
     - e. Identify regions, line segments, of negative velocity
     - f. Identify regions, line segments, of acceleration

4. **From a velocity vs. time graph be able to answer questions about acceleration and displacement**
   - Example:
     - a. Find instantaneous velocity
     - b. Find instantaneous acceleration
     - c. Find displacement
     - d. Identify regions, line segments, of positive displacement
     - e. Identify regions, line segments, of negative displacement
     - f. Identify regions, line segments, of constant acceleration
     - g. Identify regions, line segments, of changing acceleration
     - h. Identify regions, line segments, of positive acceleration
     - i. Identify regions, line segments, of negative acceleration

5. **From an acceleration vs. time graph be able to answer questions about velocity**
   - Example:
     - a. Find instantaneous jerk
     - b. Identify regions, line segments, of positive change in velocity
     - c. Identify regions, line segments, of negative change in velocity

6. **From a described situation draw either the displacement vs. time graph or a velocity vs. time graph**

7. **From an acceleration vs. time graph be able to answer questions about velocity**
   - Example:
     - a. Find instantaneous acceleration
     - b. Find the change in velocity
     - c. Calculate the instantaneous jerk
This is a note summary page for the unit on kinematics by graphical means.

\[ x \text{ vs } t \quad v \text{ vs } t \quad a \text{ vs } t \quad j \text{ vs } t \]

## Definitions

<table>
<thead>
<tr>
<th>Variable</th>
<th>Name</th>
<th>Definition</th>
<th>Math</th>
</tr>
</thead>
<tbody>
<tr>
<td>“x”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“t”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“v”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“a”</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“j”</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This is a note summary page for the unit on kinematics by graphical means.

In the chart below you can describe how to calculate the different concepts from each graph.

<table>
<thead>
<tr>
<th>GRAPH</th>
<th>position</th>
<th>velocity</th>
<th>acceleration</th>
<th>jerk</th>
</tr>
</thead>
<tbody>
<tr>
<td>x vs t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>v vs t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>a vs t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>j vs t</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
In each empty square, describe how to find the answer to the question.

<table>
<thead>
<tr>
<th>Question</th>
<th>x vs t</th>
<th>v vs t</th>
<th>a vs t</th>
</tr>
</thead>
<tbody>
<tr>
<td>Which section of the graph has a positive/negative velocity?</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which section of the graph has a constant velocity?</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Which section of the graph has a velocity of zero?</td>
<td></td>
<td></td>
<td>N/A</td>
</tr>
<tr>
<td>Which section of the graph has a change in velocity?</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which section of the graph has a positive displacement?</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which section of the graph has a displacement of zero?</td>
<td></td>
<td>N/A</td>
<td></td>
</tr>
<tr>
<td>Which section of a graph has a positive/negative acceleration</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which section of the graph has a constant acceleration?</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Which section of the graph has a change in acceleration?</td>
<td>N/A</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This worksheet is done in conjunction with a projected series of graphs. The animated graphs can be found at [http://www.mrwaynesclass.com/teacher/KinematicsGraph/animatedgraphs/home.html](http://www.mrwaynesclass.com/teacher/KinematicsGraph/animatedgraphs/home.html)

**GRAPH 1**

Watch the animation (several times) and draw what you think the position vs time graph should look like for the beetle’s motion.

![Graph 1](image)

After seeing the animation and the solutions, answer the following:

1) Circle the piece(s) of your graph where the beetle is moving towards the “more negative” direction.

2) What is the sign of the SLOPE of these circle sections of the graph? (Pos or Neg)

3) Draw a dark “X” on the graph where the beetle is not moving?

4) What is the value of the slope for these section(s)? ____________

5) During which time interval is the beetle traveling the slowest? ____________

6) During which time interval on the graph is the slope the smallest number, (absolute value), without being zero? ____________

7) What does the slope represent on this graph? ____________

**GRAPH 2**

Watch the animation (several times) and draw what you think the position vs time graph should look like below.

![Graph 2](image)

**GRAPH 3**

Watch the animation (several times) and draw what you think the position vs time graph should look like below.

![Graph 3](image)
GRAPH 4
Watch the animation (several times) and draw what you think the position vs time graph should look like below.

GRAPH 5
This time you will see a graph. Write the motion of the beetle down. Do not use numbers in your descriptions. (You do not have to use all the blanks below.)

1. ____________________________________________________________
2. ____________________________________________________________
3. ____________________________________________________________
4. ____________________________________________________________
5. ____________________________________________________________
6. ____________________________________________________________
7. ____________________________________________________________
8. ____________________________________________________________

GRAPH 6
This time you will see a graph. Write the motion of the beetle down. Do not use numbers in your descriptions. (You do not have to use all the blanks below.)

1. ____________________________________________________________
2. ____________________________________________________________
3. ____________________________________________________________
4. ____________________________________________________________
5. ____________________________________________________________
6. ____________________________________________________________
7. ____________________________________________________________
8. ____________________________________________________________
Kinematics Graphs Worksheet

For each situation described below draw a displacement vs. time graph that accurately as possible describes the situation.

1. A man steps out of his house and walks to the mailbox in front of his house.
   - At the mailbox he pauses while fumbling though the mail.
   - He turns and walks back to his house pausing half way there to smell a flower.
   - After smelling the flower he runs into the house.

2. A flea watches a yo-yo pass him while he rests on a drawer that is at the mid-point of the yo-yo’s motion.
   - The first thing the flea sees is the yo-yo passing him at a constant velocity on the way down.
   - The yo-yo pauses at the bottom.
   - It then travels past him on the way up to the yo-yo master’s hand.
   - The yo-yo’s motion never ceases as the yo-yo master throws it down again.
   - On the way down the string gets twisted and yo-yo stops at the exact height of the flea.
   - After a moment it slowly drifts down to the end of the string.
3. A cat and mouse are playing together. The cat has baited the mouse with a piece of cheese resting in front of him.

- The mouse slowly walks towards the cheese. \( \frac{1}{4} \) the way to the cheese he gets spooked and runs back to the safety of a small rock.
- The mouse, this time, walks more quickly towards the cheese. \( \frac{1}{2} \) the way to the cheese he gets scared and runs back to the safety of a small rock.
- The mouse runs towards the cheese. \( \frac{3}{4} \) the way to the cheese he gets nervous and runs back to the safety of a small rock. But \( \frac{1}{4} \) the way to the rock the changes his mind and runs back towards the cheese faster than ever before.
- The mouse picks up the cheese and begins to run back to the rock a little slower now.
- The cat begins to chase the mouse and the mouse begins to move his fastest yet by taking big jump towards the rock.
- He passes the rock and continues \( \frac{1}{4} \) the distance past the rock
- Pauses (He realizes the cat was actually being chased by a dog)
- Walks back to the rock.
Part 1  Find the slope of the line with its appropriate units.

Kinematics Graphs Worksheet

For Mr. Wayne’s Students (2017 Edition)
Given the position vs. time graph below, draw the appropriate velocity vs. time graph.
6 From the given velocity vs. time graph, draw the appropriate acceleration vs. time graph.

**Velocity vs Time**

**Acceleration vs Time**
Given the velocity vs. time graph below, draw the appropriate acceleration vs. time graph.
Find the slope with its appropriate units on the curve at each arrow.
Kinematics Graphs Worksheet

8 Part 2  Find the slope with its appropriate units on the curve at each arrow.

- Graph I: Position (ft) vs. Time (s)
- Graph M: Velocity (m/s) vs. Time (s)
- Graph J: Velocity (m/s) vs. Time (yrs)
- Graph N: Position (km) vs. Time (s)
- Graph K: Position (km) vs. Time (s)
- Graph P: Velocity (m/s) vs. Time (hr)
- Graph L: Position (km) vs. Time (min)
- Graph Q: Position (km) vs. Time (min)
Plot the slopes of tangent lines on the semi-circle curve below. (Use at least 8 pts on each side of the center.)
Kinematics Graphs Worksheet

9. Draw the corresponding velocity vs. time graph for each position vs. time graph shown below.

For Mr. Wayne’s Students (2017 Edition)
Kinematics Graphs Worksheet

Draw the corresponding velocity vs. time graph for each position vs. time graph shown below.

A

B
11. For the graph below, estimate what a corresponding velocity vs time would look like.

12. For the graph below, estimate what a corresponding acceleration vs time would look like.
For the graph below estimate what a corresponding jerk vs. time would look like.
Kinematics Graphs Worksheet

14 Which single second time interval(s) contains the greatest positive acceleration?
15 Which single second time interval(s) contains the greatest negative acceleration?
16 Which single second time interval(s) contains the greatest positive velocity?
17 Which single second time interval(s) or point in time contains the greatest negative velocity?

18 Which single second time interval(s) contains the greatest positive acceleration?
19 Which single second time interval(s) contains the greatest negative acceleration?

20 What is the jerk at 2 seconds?
21 Which single second time interval(s) shows a changing jerk?
22 Which single second time interval(s) shows a constant acceleration?
23 Which single second time interval(s) contains a constant jerk?
24 Which single second time interval(s) contains a constant velocity?
25 Which single second time interval(s) contains a positive acceleration?
26 Which single second time interval(s) contains a non-zero velocity?
27 Which single second time interval(s) contains a positive velocity?

28 Which single second time interval(s) contains a positive velocity?
29 Which single second time interval(s) contains a negative acceleration?
30 Which single second time interval(s) contains constant velocity?

31 Which single second time interval(s) contains a positive velocity?
32 Which single second time interval(s) contains a negative acceleration?
33 What is the velocity at 3.5 seconds?
34 What is the displacement from 0 to 2 seconds
Kinematics Graphs Worksheet

200 What does the word “constant” mean?
201 How can you tell when a piece of a graph on an x vs t graph is showing a constant velocity?
202 How can you tell when a piece of a graph on a v vs t graph is showing a constant velocity?
203 How can you tell when a piece of an x vs t graph is showing an acceleration of zero?

204 Which 5 second interval(s) show a negative velocity?
205 Which 5 second interval(s) show a positive acceleration?
206 Which 5 second interval(s) show a velocity that is constant?
207 Which 5 second interval(s) show a velocity of zero?
208 What is the velocity at 6 seconds?
209 What is the velocity at 19 seconds?
210 What is the displacement from 5 to 15 seconds?
211 What are the units of slope from the graph above?

212 Which 5 second interval(s) show a negative velocity?
213 Which 5 second interval(s) show a positive acceleration?
214 Which 5 second interval(s) show a velocity that is constant?
215 Which 5 second interval(s) show a velocity of zero?
216 What is the velocity at 6 seconds?
217 What is the velocity at 19 seconds?
218 What are the units of slope from the graph above?

For Mr. Wayne’s Students (2017 Edition)
219 Which 5 second interval(s) show a positive acceleration?
220 Which 5 second interval(s) show a negative acceleration?
221 Which 5 second interval(s) show a negative jerk?
222 Which 5 second interval(s) show a constant acceleration?
223 Which 5 second interval(s) show an acceleration of zero?
224 Which 5 second interval(s) show a jerk equal to zero?
225 What are the units of slope from the graph above?
226 Which 5 second interval(s) show a positive change in velocity?
227 Which 5 second interval(s) show no change in velocity?
228 Which 5 second time interval(s) contains positive jerk?
229 Which 5 second interval(s) show a positive velocity?
230 Which 5 second interval(s) show a positive acceleration?
231 What is the acceleration at 17 seconds?
232 Which 5 second interval(s) show a negative velocity?
233 Which 5 second time interval(s) shows a negative acceleration and a positive velocity?
234 What is the displacement from 0 to 5 seconds?
235 What is the displacement from 15 to 20 seconds?
236 Which section contains a positive displacement and a negative acceleration that is changing?
Kinematics Graphs Worksheet

What is the displacement from 0 to 5 seconds?
What is the displacement from 15 to 20 seconds?
Which 5 second interval(s) show a positive acceleration?
Which 5 second interval(s) show constant velocity?
Which 5 second interval show a displacement equal to zero?
Which 5 second interval(s) show an acceleration of zero?
What are the units of slope from the graph above?

Which 5 second interval(s) contain a constant velocity?
Which 5 second interval(s) contain a negative velocity?
Which 5 second interval(s) contain a positive acceleration?
What are the units of the slope that are found from this graph?
Which 5 second interval has a net displacement of zero?
Which 5 second time interval(s) contains a negative displacement and an acceleration of zero?
What are the units of the “area” found from this graph?
Each change or bend is a segment of the line. The letters in the circles identifies them.

35 Which straight line shows the greatest (absolute value) constant velocity?
36 Which straight line segment(s) has the greatest absolute value of velocity?
37 Which line segment(s) contains the smallest non-zero velocity? (absolute value)
38 Which segment(s) shows an acceleration?
39 Which segment(s) or single point in time shows a constant velocity?
40 Which segment(s) shows a positive velocity?
41 Which segment(s) shows a negative velocity?
42 Which segment(s) shows the smallest non-zero velocity?
43 At which time or region is the distance away from the origin the greatest?
44 Which segment(s) has the greatest negative velocity?
45 Which segment(s) has the greatest positive velocity?
46 Which segment(s) has the greatest negative acceleration?
47 Which segment(s) has the greatest positive acceleration?
48 What is the velocity at 4.5 seconds?
49 What is the velocity at 1.8 seconds?
50 What is the displacement during segment “C”?
51 What is the displacement between 2 and 4 seconds?
52 Which show segment(s) no motion?
Kinematics Graphs Worksheet

Each change or bend is a segment of the line. The letters in the circles identifies them.

50. Which line segment(s) or point in time shows the object moving the fastest? __________
51. Which segment(s) shows a non-zero acceleration? __________________________
52. Which segment(s) or single point in time shows a constant velocity? _________
53. Which segment(s) shows the object speeding up? _________________________
54. Which segment(s) shows the object at rest for more than 0.4 s? _____________
55. Which segment(s) shows a positive change in acceleration? ______________
56. Which segment(s) shows the smallest, positive, non-zero acceleration? ___
57. Which segment(s) has the most negative velocity? _______________________
58. Which segment(s) has the most positive velocity? _________________________
59. Which segment(s) has the most negative acceleration? ___________________
60. Which segment(s) has the most positive acceleration? ___________________
61. Which segment(s) shows a positive jerk? ________________________________
62. What is the instantaneous velocity at 9.0 seconds? ______________________
63. What is the instantaneous acceleration at 9.0 seconds? __________________
64. What is the instantaneous acceleration at 4.0 seconds? ___________________
What is the instantaneous acceleration at 9.5 seconds? ________________

Each change or bend is a segment of the line. The letters in the circles identifies them. (NOTE “C” AND “E” ARE CURVES AND “D” and F” are straight lines.)

Which line segment(s) shows the fastest constant velocity? __________

Which line segment(s) shows the slowest, constant, non-zero velocity? __

Which segment(s) shows a positive displacement? _________________

Which segment(s) or single point in time shows a constant velocity? ____

Which segment(s) shows a positive acceleration? ________________

Which segment(s) shows a negative acceleration? ________________

At which time or region is the positive displacement from initial position the greatest? _______________________________________________________

Which segment(s) shows the object speeding up? __________________

Which segment(s) shows the object slowing down? _________________

What is the instantaneous velocity at 0.8 seconds? _________________

How fast is the object moving at 4.2 seconds? ____________________

What is the instantaneous velocity at 5.0 seconds? _________________
69  Find the displacement from 0 to 2 seconds.
70  Find the displacement from 1 to 3 seconds.
71  Find the displacement from 0 to 4 seconds.

72  Find the total change in velocity from 0 to 1 seconds.
73  Find the total change in velocity from 0 to 3 seconds.

74  Find the displacement from 2 to 4 seconds. 
75  Find the displacement from 0 to 1 seconds.
76. What is the displacement from 0 to 4 seconds? __________________
77. What is the displacement from 4 to 6 seconds? __________________
78. What is the displacement from 6 to 12 seconds? __________________
79. What is the displacement from 12 to 14 seconds? __________________
80. What is the displacement from 14 to 22 seconds? __________________
81. What is the displacement from 22 to 30 seconds? __________________
82. What is the acceleration at 2 seconds? __________________________
83. What is the acceleration at 5 seconds? __________________________
84. What is the acceleration at 13 seconds? __________________________
85. What is the acceleration at 17 seconds? __________________________
86. What is the acceleration at 19 seconds? __________________________
Answer the following whenever possible

87. Calculate the displacement from 0 to 10 seconds.
88. Calculate the displacement from 10 to 20 seconds.
89. Calculate the displacement from 20 to 30 seconds.
90. Calculate the displacement from 10 to 30 seconds.
91. Calculate the displacement from 30 to 40 seconds.
92. Calculate the displacement from 40 to 60 seconds.
93. Which lettered 10-second time interval(s) contains a positive displacement and a negative acceleration?
94. Which lettered 10-second time interval(s) contains a negative displacement and a positive velocity?
95. Which lettered 10-second time interval(s) contains a positive displacement, a negative velocity and a negative acceleration?
96. Which lettered 10-second time interval(s) contains a negative displacement, a negative velocity and a negative acceleration?
97. Which lettered 10-second time interval(s) contains a positive displacement, a negative velocity and a positive acceleration?
Draw a velocity graph that meets the following criteria.
If a section cannot be drawn that meets given criteria, skip it.

<table>
<thead>
<tr>
<th>Time Interval</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 - 10</td>
<td>positive displacement, positive velocity, zero acceleration</td>
</tr>
<tr>
<td>10 - 20</td>
<td>negative displacement, negative velocity, positive acceleration</td>
</tr>
<tr>
<td>20 - 30</td>
<td>positive displacement, positive velocity, positive acceleration</td>
</tr>
<tr>
<td>30 - 40</td>
<td>negative displacement, negative velocity, negative acceleration</td>
</tr>
<tr>
<td>40 - 50</td>
<td>positive displacement, positive velocity, negative acceleration</td>
</tr>
<tr>
<td>50 - 60</td>
<td>positive displacement, negative velocity, positive acceleration</td>
</tr>
<tr>
<td>60 - 70</td>
<td>zero displacement, positive and negative velocities, negative acceleration</td>
</tr>
</tbody>
</table>
Draw a velocity graph that meets the following criteria.
If a section cannot be drawn that meets given criteria, skip it.

<table>
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<tr>
<th>Time Interval</th>
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</tr>
</thead>
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<tr>
<td>0 - 10</td>
<td>negative displacement, negative velocity, zero acceleration</td>
</tr>
<tr>
<td>10 - 20</td>
<td>negative displacement, negative &amp; positive velocity, positive acceleration</td>
</tr>
<tr>
<td>20 - 30</td>
<td>negative displacement, negative velocity, positive acceleration</td>
</tr>
<tr>
<td>30 - 40</td>
<td>positive displacement, positive velocity, zero acceleration</td>
</tr>
<tr>
<td>40 - 50</td>
<td>positive displacement, positive &amp; negative velocity, positive acceleration</td>
</tr>
<tr>
<td>50 - 60</td>
<td>zero displacement, positive and negative velocities, negative acceleration</td>
</tr>
<tr>
<td>60 - 70</td>
<td>negative displacement, negative velocity, negative acceleration</td>
</tr>
</tbody>
</table>
98. Which 15-second interval(s) have the greatest positive velocity? ___________
99. Which 15-second interval(s) have the greatest negative velocity? __________
100. Which 15-second interval(s) have the greatest velocity? _________________
101. Which 15-second interval contains the location that is the greatest absolute value of displacement? ____________________________________________
102. Which 15-second interval(s) indicates no movement? _________________
103. Which 15-second interval(s) contains a position that is positive and a velocity that is positive? ________________________________
104. Which 15-second interval(s) contains a position that is positive and a velocity that is negative? ________________________________
105. Which 15-second interval(s) contains a position that is negative and a velocity that is positive? ________________________________
106. Which 15-second interval(s) contains a position that is negative and a velocity that is negative? ________________________________
107. Which 15-second interval(s) contains a position that is positive and a velocity that is zero? ________________________________
108. What is the velocity at 39 seconds? ________________________________
109. What is the velocity at 48 seconds? ________________________________
110. What is the position at 21 seconds? ________________________________
111. What is the displacement from 20 seconds to 75 seconds? ____________
112. Which 10-second interval(s) have the most positive velocity?
113. Which 10-second interval(s) have the most negative velocity?
114. Which 10-second interval(s) have the greatest absolute value of velocity?
115. Which 10-second interval contains the location that is the positive displacement from the origin?
116. Which 10-second interval(s) indicates no movement?
117. Which 10-second interval(s) contains a position that is positive and a velocity that is positive?
118. Which 10-second interval(s) contains a position that is positive and a velocity that is negative?
119. Which 10-second interval(s) contains a position that is negative and a velocity that is positive?
120. Which 10-second interval(s) contains a position that is negative and a velocity that is negative?
121. Which 10-second interval(s) contains a position that is positive and a velocity that is zero?
The graph above is for the motion of a car in the senior parking lot. Answer each question below with a range of time(s), e.g. (10-12 s).

122  What is the acceleration over the 1st 10 seconds?
123  Over which region(s) is the acceleration constant?
124  Over which region(s) is the acceleration changing?
125  Over which region(s) is the car moving in a negative direction?
126  Over which region(s) is the car speeding up?
127  Over which region(s) is the car slowing down?
128  Over which region(s) is there no acceleration?
129  What is the acceleration at 30 seconds?
130  What is the acceleration at 39 seconds?
131  What is the acceleration at 20 seconds?
132  What is the acceleration at 46 seconds?

133  How do you find the instantaneous velocity?
Kinematics Graphs Worksheet

134 How can you tell if a piece of the curve is negative acceleration?

135 How can you tell if a piece of the curve is positive acceleration?

136 How do you find displacement?

137 How can you tell if a piece of the curve has a zero acceleration?

138 How can you tell if an acceleration is constant?

139 How can you tell if an acceleration is changing?
How do you find:

1. the velocity at 4 seconds?

2. if the acceleration is positive or negative?

3. the displacement from 1 to 3 seconds?

4. the change in position from 1 to 3 seconds?

5. if the velocity is positive or negative at 3 seconds?

6. the velocity at 9 seconds?

7. the velocity at 4 seconds?

8. if the acceleration is positive or negative?

9. the displacement from 1 to 3 seconds?

10. the change in position from 1 to 3 seconds?

11. if the velocity is positive or negative at 3 seconds?

12. the velocity at 9 seconds?
Kinematics Graphs Worksheet

Motion Diagrams

1. Draw the motion diagram for a car that travels a constant velocity for 4 minutes, slows down to a slower speed and continues at at constant velocity in the positive direction.
2. What is the direction of the acceleration?
3. Draw the motion diagram for a sprinter that is at rest, accelerates, travels at a constant velocity and then slows down to a stop.
4. What is the direction of the acceleration?
5. A baseball is pitched in the negative direction towards a batter. The ball travels at a constant velocity. The batter instantaneously hits the ball in a line drive at a constant velocity in the opposite direction with the same magnitude. Draw the motion diagram.
6. A gymnast travels down towards a trampoline’s surface. She accelerates down until she touches the trampoline. The trampoline stretches down as it slows her down and throws, accelerates, the gymnast back upwards. As the gymnast travels up she slows down with the same acceleration’s magnitude as when she fell. Draw a motion diagram of this action.
7. A car travels down the road at a constant velocity for 4 seconds to the right, slows down to a stop in 3 seconds, waits for 2 seconds and then speeds up to a velocity faster than before in 5 seconds. Draw the motion diagram.
8. A rock is thrown upwards and slows down as it travels up for 6 seconds until it is come to a stop. Without pausing the rock begins to fall down and speeds up as until it reaches the height is was thrown from. Draw a motion map for this motion.
9. Draw a \( v \ vs \ t \) graph for the motion diagram below.

10. Draw a \( v \ vs \ t \) graph for the motion diagram below.

11. Draw a \( v \ vs \ t \) graph for the motion diagram below.

12. Draw a \( v \ vs \ t \) graph for the motion diagram below.

13. Draw a \( v \ vs \ t \) graph for the motion diagram below.
Solve for the letter in each equation.

1) $3 = 4 + 4t + \frac{1}{2}(5)2^2$

2) $6 = x_o + 3t + \frac{1}{2}(4)3^2$

3) $2 = 5 + 4(5) + \frac{1}{2}(8)t^2$

4) $9 = x_o + 3(2) - \frac{1}{2}(7)4^2$

5) $1 = -5 - 2t + \frac{1}{2}(4)2^2$

6) $8 = 3 - 5(6) + \frac{1}{2}(g)5^2$

7) $3 = 4 - 3(t) + \frac{1}{2}(5)t^2$

8) $x = -2 + 5(3) - \frac{1}{2}(3)5^2$

9) $1 = x_o - 5(3) - \frac{1}{2}(8)2^2$

10) $4 = 5 + 4(2) + \frac{1}{2}(g)3^2$

11) $3 = 1 - 3t + \frac{1}{2}(2)3^2$

12) $-6 = x_o + 2t + \frac{1}{2}(2)8^2$

13) $4 = 1 + 3(-2) + \frac{1}{2}(-4)t^2$

14) $-7 = x_o + 6(8) + \frac{1}{2}(7)5^2$

15) $3 = 3 - 9t + \frac{1}{2}(2)t^2$

16) $-3 = 4 - 1(5) + \frac{1}{2}(g)6^2$
<table>
<thead>
<tr>
<th>Equation</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>17) $-3 = -2 + 8(t) + \frac{1}{2}(6)t^2$</td>
<td></td>
</tr>
<tr>
<td>18) $x = -2 + 5(3) - \frac{1}{2}(3)5^2$</td>
<td></td>
</tr>
<tr>
<td>19) $1 = x_o - 5(3) - \frac{1}{2}(8)2^2$</td>
<td></td>
</tr>
<tr>
<td>20) $-3 = 2 + 8(4) + \frac{1}{2}(g)4^2$</td>
<td></td>
</tr>
<tr>
<td>21) $3^2 = 4^2 + 2a10$</td>
<td></td>
</tr>
<tr>
<td>22) $v^2 = 8^2 + 2(3)(-6)$</td>
<td></td>
</tr>
<tr>
<td>23) $(-3)^2 = v_o^2 + 2(-2)4$</td>
<td></td>
</tr>
<tr>
<td>24) $8 = 4^2 + 2(3)x$</td>
<td></td>
</tr>
<tr>
<td>25) $v^2 = 2^2 + 2(-3)(-2)$</td>
<td></td>
</tr>
<tr>
<td>26) $4^2 = v_o^2 + 2(-3)2$</td>
<td></td>
</tr>
<tr>
<td>27) $l^2 = 5^2 + 2a(-2)$</td>
<td></td>
</tr>
<tr>
<td>28) $(-2)^2 = (-5)^2 + 2(6)x$</td>
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</tr>
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<tr>
<td>30) $2 = (-4)^2 + 2(-4)x$</td>
<td></td>
</tr>
<tr>
<td>31) $5^2 = 2^2 + 2a3$</td>
<td></td>
</tr>
<tr>
<td>32) $v^2 = 8^2 + 2(5)(-2)$</td>
<td></td>
</tr>
</tbody>
</table>
The Math of Kinematics
Solve for the letter in each equation.

33) \( \frac{3}{t} = \frac{3 + 4}{2} \)
34) \( \frac{x}{2} = \frac{5 + 2}{2} \)
35) \( \frac{3}{5} = \frac{\upsilon + 6}{2} \)
36) \( 5 = \frac{3 + \upsilon_o}{2} \)
37) \( \frac{x}{3} = \frac{2 + 6}{2} \)
38) \( \frac{7}{2} = \frac{\upsilon + 2}{2} \)
39) \( \frac{3}{6} = \frac{8 + \upsilon_o}{2} \)

40) \( \frac{6}{t} = \frac{4 + 3}{2} \)
41) \( \frac{1}{3} = \frac{6 + 2}{d} \)
42) \( \frac{1}{t} = \frac{5 + 2}{2} \)
43) \( \frac{x}{3} = \frac{5 + 6}{4} \)
44) \( \frac{7}{2} = \frac{\upsilon + 3}{3} \)
45) \( \frac{4}{7} = \frac{2 + \upsilon_o}{5} \)
46) \( \frac{6}{t} = \frac{2 + 6}{8} \)
47) \( \frac{x}{4} = \frac{3 + 6}{6} \)
48) \( 5 = \frac{6 + 1}{w} \)
49) \( \frac{8}{3} = \frac{\upsilon + 4}{3} \)
50) \( 4 = \frac{5 + \upsilon_o}{8} \)
51) \( \frac{1}{t} = \frac{2 + 4}{3} \)
52) \( 2 = \frac{4 + 2}{y} \)
53) \( \frac{2}{7} = \frac{\upsilon + 2}{7} \)
Kinematics by Algebraic Means

Objectives

Kinematics by Algebraic Means

Students will be able to:
1. Describe the basic VECTOR motion concepts of;
   • displacement, velocity, acceleration
2. Identify a number as being either displacement, velocity, acceleration, jerk or time based solely on its units.
3. List the values given in a word problem.
   These values will be listed and identified as either...
   • initial position
   • final position
   • initial velocity
   • final velocity
   • average velocity
   • acceleration
   • time
   • Also list the “implied” givens. (Implied from the context of the problem and/or the wording such as the use “stop, drop, rest, and freefall.”
4. From memory, the following formulae will need to listed

   \[ x = x_0 + v_0 t + \frac{1}{2} at^2 \quad v = v_0 + at \]
   \[ v^2 = v_0^2 + 2ax \quad v_{AVG} = \frac{x}{t} = \frac{v + v_0}{2} \]

   A. You will only be given the right side of each equation

5. List what the variables of \( x_0, x, v_0, v, v_{avg}, a \) and \( t \) stand for
6. Write the proper S.I. units for the variables listed in the previous objective.
7. Solve word problems while demonstrating proper solution-communication techniques. This includes but is not limited to:
   • List all the variables in a problem with units
   • Show the formula(s) used to solve the problem with only variables
   • Show the formula(s) used to solve the problem with only numbers
   • Show any necessary math
   • Show the answer with proper units
8. Solve word problems are involve multiple accelerations. (segmented problems).
10. Solve vertical free fall problems.
11. Be able to convert between accelerations in m/s² and g’s.
Conceptual Kinematics Problems

1. A runner is moving with a velocity of 4 m/s when they accelerate at 2 m/s\(^2\) for 3 seconds. How fast are they traveling now?

2. In a football game, running back is at the 10 yard line and running up the field, (10, 20, 30, 40 yard line etc.) and runs for 3 seconds at 8 yd/s. What is his current position?

3. A cat is moving at 18 m/s when it accelerates at 4 m/s\(^2\) for 2 seconds. What is his new velocity?

4. A race car is traveling at 76 m/s when it slows down at 9 m/s\(^2\) for 4 seconds. What is his new velocity?

5. An alien spaceship is 500 m above the ground and moving at a constant velocity up of 150 m/s. How high above the ground is the ship after 5 seconds?

6. A bicyclist is traveling at 25 m/s when he begins to decelerate at 4 m/s\(^2\). How fast is he traveling after 5 seconds?

7. A squirrel is 5 ft away from your while moving at a constant velocity of 3 ft/s. How far away is the squirrel after 5 seconds?

8. A ball is dropped off a very tall canyon ledge. Gravity accelerates the ball at 22 mph/s. How fast is the ball traveling after 5 seconds?

9. A dragster is 200 m from the starting line when something goes wrong and is stops accelerating. It travels at a constant velocity of 100 m/s for 3 seconds to try to finish the race. How far from the starting line of the dragster after 3 seconds?

10. A dog is 60 yards away while moving at a constant velocity of 10 yds/s. Where is the dog after 4 seconds?
Unit Identification: Identify the following as either, time, displacement, velocity, acceleration. Use the abbreviation “t, x, v,” or “a” respectively.

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For problems 1 – 9, list the given and the variable to be found in each problem.

1. An angry mob lynches a physics teacher after receiving their grades. They throw the physics teacher off a tall building. They throw the physics teacher straight down with a velocity of $20 \text{ m/s}$. The teacher falls for $3.0$ seconds before landing on a stack of empty cardboard boxes. How high was he thrown from?

2. A baseball is rolled horizontally along the ground at $45 \text{ m/s}$. The ball slows down at a rate of $5 \text{ m/s}^2$. How long is the ball rolling before coming to rest?

3. A meteor falls from the sky to the Earth. The meteor already had an initial velocity downward when it was spotted. If it hit the Earth at $335 \text{ m/s}$ after being seen for $30$ seconds, then what was the initial velocity of the meteor?

4. A car started from a rest and accelerated at $9.54 \text{ m/s}^2$ for $6.5$ seconds. How much distance did the car cover?

5. A paper airplane is thrown horizontally with a velocity of $20 \text{ mph}$, $8.941 \text{ m/s}$. The plane is in the air for $7.43$ s before coming to a stand still on the ground. (Magically, the planes flies horizontally without losing any altitude.) What is the acceleration of the plane?

6. A pile driver drops from a height of $35$ meters before landing on a piling. What is the speed of the driver when it hit the piling?

7. An arrow leaves a bow with a speed of $42 \text{ m/s}$. Its velocity is reduced to $34 \text{ m/s}$ by the time it hits its target. How much distance did the arrow travel over if it were in the air for $2.4$ seconds?

8. At a drag race, a jet car travels $\frac{1}{4}$ mile in $5.2$ seconds. What is the final speed of the car and its acceleration?

9. A rock is dropped on a newly explored planet. The rock is dropped $1.22$ meters. The acceleration due to gravity is $1.3 \text{ m/s}^2$. How much time did it take for the rock to fall?
10. A cheetah can run from 0 to 70 mph, (31.29 m/s) in 2.2 seconds.
   a. What is the cheetah’s top speed in m/s?
   b. What is the cheetah’s acceleration in m/s²?
   c. What is the cheetah’s average speed in mph and m/s?
   d. How much distance did the cheetah cover in traveling from 0 to 70 mph?

11. A ball rolls down a hill with a constant acceleration of 3.0 m/s².
   a. If it starts from rest, what is its speed at the end of 4.0 s?
   b. How far did the ball move in that 4.0 s?

12. A car can accelerate from 0 to 60 mph, 26.8224 m/s, in 8.5 seconds.
   a. What is the acceleration of the car?
   b. If the car were to maintain the acceleration in 2b, how long would it take to reach 70 mph from rest?
   c. How much distance would the car travel by the time it reached 70 mph?

13. A bicyclist brakes from 21 m/s to a stop in 32.3 m.
   a. What is the acceleration of the bicyclist?
   b. How much time does it take for the bicyclist to stop?
   c. What is the bicyclist’s average speed?

14. A car moving on a straight road increases its speed at a uniform rate from 10 m/s to 20 m/s in 5.0 s.
   (a) What is its acceleration?
   (b) How far did it go during those 5.0 seconds?

15. On a roller coaster ride at an amusement park, a car travels from 7.6 m/s to 56 m/s in 3.0 seconds.
   a. What is the car’s acceleration?
   b. How much distance did the car travel in 3.0 seconds?
   c. If the car continued this acceleration, how fast would it be traveling after 150 m?

16. 6.0 seconds after launch, the space shuttle is 529.2 m above the ground.
   a. What is the space shuttle’s acceleration?
   b. What is the space shuttle’s velocity after 3.0 seconds?
   c. What is the space shuttle’s velocity at 6.0 seconds?
   d. What is the space shuttle’s average velocity after the first 6.0 seconds?
   e. How high is the space shuttle after 3.0 seconds?

17. Melissa threw a penny straight down off the Empire State building. The building is 354 m tall. If Melissa threw the penny down such that it left her hand at 35 m/s,
   a. How fast will the coin be traveling when it hits the pavement?
   b. How long will the coin be in the air?

18. An hour later, after the sidewalk damage was cleaned up, Paul dropped a coin off the top of the Empire State building.
   a. How fast will the coin be traveling when it hits the pavement?
   b. How long will the coin be in the air?
19. A methanol-powered dragster travels a 1/4-mile from a stand still. The final speed of the best dragster will reach 300 mph.
   a. Convert all units to standard SI units
   b. Assuming the dragster’s acceleration to be constant, what will it be?
   c. How much time will the dragster take to finish the 1/4-mile?

20. Phoebe threw a Frisbee horizontally that traveled 125 m. The Frisbee left her hand traveling 45 m/s. As the Frisbee travels in the air it slows down with a de-acceleration of 5.6 m/s².
   a. How long was the Frisbee in the air?
   b. When Mike caught the Frisbee, how fast was it traveling?

21. In order for Mike to catch the Frisbee Phoebe threw; he had to run 45 m in 7.0 seconds. Mike began his sprint from a resting position.
   a. What was Mike’s average velocity?
   b. Assuming Mike accelerated the whole time he was running, what was his acceleration?
   c. What was his final speed if he accelerated the whole time?

22. A bullet it fired at Wonder Woman. The bullet leaves the gun’s muzzle at 1000 m/s. Wonder Woman is standing 8.4 meters in front of the bullet. The instant bullet is fired Wonder Woman begins to move her hand to block the bullet. Her hand starts from rest. She has to move her hand 1.25 meters to block the bullet.
   a. When the bullet is in the air it will slow down at a rate 35.68 m/s². How long did it take for the bullet to reach Wonder Woman?
   b. How fast was the bullet traveling when Wonder Woman deflected it?
   c. What was the average speed that Wonder Woman moved her hands to deflect the bullet?
   d. What was the final speed of Wonder Woman’s hand when she deflected the bullet?
   e. What was the acceleration of her hand?
   f. Wonder Woman stopped her hand in 0.3 m. What is the acceleration of her hand now?

23. A jet plane lands with a velocity of 100 m/s and can accelerate at a maximum of -9.0 m/s² as it comes to rest.
   a. From the minute that the plane touches the runway, what is the minimum time needed before it can come to rest?
   b. Can this plane land on a small island airport where the runway is 0.80 km long? (Hint: Is the distance needed with this size acceleration greater than 0.80 km?)

24. A bullet is fired through a board 10.0 cm thick in such a way that the bullet's line of motion is perpendicular to the face of the board. If the initial speed of the bullet is 400 m/s and it emerges from the other side of the board with a speed of 300 m/s, find
   a. The acceleration of the bullet as it passes though the board, and
b. The total time the bullet is in contact with the board.

25. While doing an experiment, Tom drops a ball out of a window 2.3 meters above the ground. The instant he does this he fires a starters pistol. Jerry sees the ball hit the ground at the instant he hears the pistol’s shot. (It takes time for the pistol’s sound to reach Jerry.) The speed of pistol’s sound is 344 m/s - it is constant and will not change.
   a. How long did it take for Tom’s ball to reach the ground?
   b. How far away was Jerry standing?

26. A certain automobile manufacturer claims that its super-deluxe sports car will accelerate uniformly from rest to a speed of 87 mi/h in 8 s.
   a. Determine the acceleration of the car in ft/s² and mph/s
   b. Find the distance the car travels in the first 8 s (in feet).
   c. What is the velocity of the car 10 s after it begins its motion, assuming it continues to accelerate at the rate of 16 ft/s²?

27. Flossy Fletcher was curling her hair when she dropped the curling iron. The curling iron fell 1.651 m to the floor.
   a. How fast was the iron traveling when it hit the floor?
   b. How long was it in the air?

28. An electron in a cathode ray tube of a TV set enters a region where it accelerates uniformly from a speed of \( (3 \times 10^4) \) m/s to a speed of \( (5 \times 10^6) \) m/s in a distance of 2 cm.
   b. How long is this electron in this region where it accelerates?
   c. What is the acceleration of the electron in this region?

29. A 400-m train is moving on a straight track with a speed of 82.4 km/h. The engineer applies the brakes at a crossing, and later the last car passes the crossing with a speed of 16.4 km/h. Assuming constant acceleration, how long did the train take to pass the crossing?

30. A driver in a car traveling at a speed of 60 km/h sees a deer 100 m away on the road. What is the minimum constant acceleration that the car must undergo so as to avoid hitting the deer (assuming that the deer does not move)?

31. An F-15 jet fighter starts from rest and reaches a speed of 165 m/s in 2 seconds when launched off of an aircraft carrier.
   a. What is the planes acceleration?
   b. How much distance did the jet cover in the 2 seconds?
   c. How fast was the jet traveling after 1 second?

32. To calculate the depth of a well a physics student drops a rock into the well. 4.5 seconds after the rock is dropped the student sees it hit the bottom.
   a. How deep is the well?
   b. How fast is the rock traveling the instant before it hits the bottom?
33. A bicyclist traveled from 15.6 m/s to 21.1 m/s over a distance of 30 meters.
   a. What is the acceleration of the bicyclist?
   b. How much time does it take the bicyclist to travel the 30 meters?

34. While looking out of her office, Hillary Clinton notices a republican falling past her window at 15 m/s.
   a. How fast is the republican traveling after falling 30 m past Hillary’s window?
   b. How long does it take to travel those 30 meters down?
   c. The republican safely lands in some bushes an additional 15 meters farther down from the 30m.
      o What was his speed the instant before he hit the bushes?
      o How long did it take to travel the total 45 meters down from the window?

35. A sandbag dropped from a balloon ascending at 4.2 m/s lands on the ground 10.0 s later. What was the altitude of the balloon at the time the sandbag was dropped?

36. A parachutist descending at a speed of 10 m/s drops a camera from an altitude of 50 m.
   a. How long does it take the camera to reach the ground?
   b. What is the velocity of the camera just before it hits the ground?

37 While looking out a window you see a ball traveling upwards. Resulting from your fine tuned skills of observation you notice the ball is traveling 22.0 m/s upward. How much time will it take to travel up another 15.0 m?

38 While watching a baseball game, from behind the backstop on the second level, you observe a pop foul traveling straight up past you at 41 m/s. How much time will it take for the ball to travel up an additional 55.0 m?
In a car crash test, the sled used to test the effects of crashes on a car’s occupants is called a “buck”. A buck weighs about 1500 pounds (688 kg). A typical impact speed is 30 mph (13.39 m/s). The test track that the buck slides down is 70 ft (21.21 m).

39. A buck starts from rest and travels up to 30 mph with an acceleration of 0.818 g’s. How much time does this test run take?

40. A Mustang GT travels from rest to 55 mph (24.55 m/s) in 7.8 seconds. What is the acceleration of the Mustang in g’s? (This will give some feel for the acceleration of the buck).

41. Car seats are designed not to come loose below a 20 g collision. If a car were traveling at 30 mph, how quickly would it have to stop if the seats were to just come loose?

42. What distance would a car have to come to a stop in if it were to undergo the 20 g collision described in the collision in the previous question?

43. If a car collides with a wall at 30 mph and bounces off at 8 mph in the opposite direction, what would be the impact time if the deceleration were 20 g’s?

44. In a collision the car changes direction in 0.100 seconds. If a car were to collide with a wall in a 20 g collision with an impact velocity of 30 mph, then what would be the car’s rebound speed off the wall?

45. In a collision the air bags deploy and collapse in 0.300 seconds. This is the time for the car to change direction. A car collides with a wall in a 20 g collision. If the car’s rebound speed equaled its impact speed, what would be this speed?

46. A seat belt is designed to slow a passenger down with a 10 g deceleration. A typical collision lasts 0.055 seconds. 6 inches are between the passenger’s torso, and the steering wheel -this distance is called the rattle distance. At what speed can the car impact, with a final speed of zero, such that the belt is to just do its job and save the passenger’s life?

Other facts of interest:
- Airplane seats are designed to withstand a 9 g horizontal deceleration before ripping out of the floor.
- Car seats are designed to withstand a 20 g horizontal deceleration before ripping out of the floor.
- The human body can withstand a 40 g horizontal deceleration before dying -due to compression and tearing of the internal organs. This number is less for older fragile people and higher for people of a more robust nature.
- “60 Minutes,” did a story in February 1992 that warned of car seats that collapse during a rear end collision. What they failed to mention was that the probability of injury sustained because of these seats versus non-collapsing seats is the same. Injury occurs with non-collapsing seats by rebounding the passenger into the dash.
g’s section

47. During a space shuttle launch an astronaut experiences an acceleration of 3.0 g’s.
   a. What is the acceleration of the astronaut in m/s²?
   b. If the space shuttle started from rest, how far did it travel in 10 seconds?

48. A top fuel dragster experiences an acceleration of 5 g’s during a drag race.
   c. What is the acceleration of the drive in m/s²?
   d. If a driver were to maintain this acceleration for 200.0 m, then how much time and how fast was the driver traveling at this point? The car started from rest.

49. On Jupiter a rock will fall to the ground with an acceleration of 26.94 m/s².
   e. What is the acceleration of the rock in Earth g’s?

50. When a golf ball is hit off a tee, it will experience an acceleration of 1000 g’s while the club makes contact with the ball. Typically the club will make contact for 0.0080 seconds.
   f. What is the acceleration of the ball in m/s²?
   g. How fast is the ball traveling when it leaves the club?

51. A jet is flying at 175 m/s when it begins to accelerate at 3.50 g’s. How much time will it take to travel 1.00 mile?

52. The space shuttle is traveling at 7650 m/s when it begins to accelerate at 0.100 g. How much time will it take to travel across the continental United States - a distance of 4.00 X 10³ miles?
53 A car is at rest at a stoplight. The moment the light turns green a truck rolls up the line with a constant velocity of 11.6 m/s. At the instant the truck is next to the car, the car begins to accelerate as shown.

a. How much time does it take for the car to catch up to the truck?

b. How much distance is covered when the from the start line to when the car catches up to the truck?

c. What is the velocity of the car when it catches up to the truck?

54 In the Savannahs of Africa a gazelle is running in a straight line with a constant velocity is 16.25 m/s. The gazelle startles a cheetah when she runs past. At the instant the cheetah and gazelle are side by side the cheetah accelerates after the gazelle from rest at 12.00 m/s².

a. How much time does it take for the cheetah to catch up to the gazelle?

b. How much distance is covered when the from the start line to when the cheetah catches up to the gazelle?

c. What is the velocity of the cheetah when it catches up to the gazelle?

55 Tom, the cat, is chasing Jerry, the mouse. Jerry runs past Tom at 10.00 m/s. At the instant Jerry passes Tom, Tom starts from rest and accelerates at 3.00 m/s².

a. How much time does it take for the Tom to catch up to Jerry?

b. What is the velocity of the Tom when he catches up to the Jerry?

c. The mouse hole is 2.1 meters away from Jerry when Tom began to chase Jerry. Will Jerry make it to the hole without being caught? (Support your answer with numbers.)
56. A Helicopter is hovering when a jet flies past it as shown. The instant the jet flies past the helicopter, it fires a rocket with the acceleration shown.

a. The pilot of the jet will wait until the last possible moment to roll the jet from the incoming rocket. How much time does it take for the rocket to catch up to the jet?

b. How much distance is covered from where the rocket is fired to where the rocket would catch up to the jet?

c. What is the velocity of the rocket when it catches up to the jet?

57. A pedestrian is running at his maximum speed of 6.0 m/s to catch a bus stopped at a traffic light. When he is 15 m from the bus, the light changes and the bus accelerates uniformly at $1.00 \, \text{m/s}^2$. Does he make it to the bus? If so, what is the minimum distance he has to run in order to catch it? If not, how close does he get?

58. A car starts from rest and accelerates at $0.500 \, \text{g's}$ for 50.0 m. The car then travels for 8.52 seconds at a constant velocity. It then slows down for 3.12 seconds with an acceleration of $-2.50 \, \text{m/s}^2$.

a. What is the final velocity of the car?

b. What was the total distance traveled by the car?

c. What was the car’s final acceleration in g’s?

59. A top fuel dragster accelerates from a rest with an acceleration of $5.10 \, \text{g's}$. Once the dragster reaches its top velocity of $145 \, \text{m/s}$, it travels at a constant velocity for the rest of the $1/4$ miles track. How much time did it take for the dragster to travel the length of the track?

60. A bus picks up a passenger and accelerates from a rest at $1.50 \, \text{m/s}^2$ for 6.00 seconds. After the initial 6.0 seconds the bus accelerates at $2.50 \, \text{m/s}^2$ for an additional 35.5 m. The bus then slams on the brake and accelerates at $-0.75 \, \text{g's}$ until it comes to a rest.

a. What is the total time for the bus ride?

b. What is the total distance covered by the bus?

61. Suppose that while traveling at a constant velocity of $12.0 \, \text{m/s}$, a driver sees a traffic light turn red. After 0.510 s has elapsed (their reaction time), the driver applies the brakes and the car slows at $-6.20 \, \text{m/s}^2$ until coming to a rest. What is the stopping distance of the car, as measured from the point where the light turns red to when he stops?

62. A drag racer-starting from rest-speeds up for 402 m with an acceleration of $+17.0 \, \text{m/s}^2$. A parachute then opens, slowing the car down with an acceleration of $-6.10 \, \text{m/s}^2$. How fast is the racer moving $350 \, \text{m}$ after the parachute opens?
Segmented Problems setup up the given practice
When solving kinematics problems, every acceleration goes into a separate list of givens. These problems are segmented and have several accelerations. In kinematics, to solve a typical problem, you will need to identify at least 3 variables in each list of givens. For these problems identify at least 3 givens in each list (other than \( x_0 = 0 \)). If you need to calculate a given, show your work.

When a moving car was first seen, it was traveling at 5 m/s. It traveled with an acceleration of 2 m/s\(^2\) for 4 s. It then moved at a constant velocity for 20 m.

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<td>( v_o = 5 \text{ m/s} )</td>
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<td>( a = 2 \text{ m/s}^2 )</td>
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<td>( t = 4 \text{ s} )</td>
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<td>( \begin{align*} v &amp;= v_o + at \ v &amp;= 5 \text{ m/s} + \left( 2 \text{ m/s}^2 \right) 4 \text{ s} \ v &amp;= 13 \text{ m/s} \end{align*} )</td>
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| **Given: Segment 2** |
| \( a = 0 \) ...constant \( v \) |
| \( x = 20 \text{ m} \) |
| \( v_o = 13 \text{ m/s} \) |

63. A bus starts from rest and travels for 30 m with an acceleration of 3 m/s\(^2\). It then travels with a deceleration of 2 m/s for 5 seconds.

64. A fish is swimming at a velocity of 8 m/s with a deceleration of 1 m/s\(^2\). The fish swam like this for 3 m before it swam with a new acceleration of 2 m/s for 4 seconds.

65. A man drops out of a helicopter with a net downward acceleration of 6 m/s\(^2\) for 10 seconds. When the parachute opens, the skydiver experiences a net acceleration of -2 m/s\(^2\) until he reached a velocity of 10 m/s.

66. A bicyclist is traveling down the road for 20 m with an acceleration of 3 m/s\(^2\). After this distance, he travels with an acceleration of 1 m/s\(^2\) for 10 seconds to reach a speed of 31 m/s.

67. A rock is thrown straight down off a cruise ship with a speed of 5 m/s. The rock travels 27 m before hitting the water’s surface. Once in the water, it slows down to a speed of 3 m/s in 5 m.

68. A space probe is dropped into Venus’s atmosphere when its net acceleration is 8.0 m/s\(^2\). It travels a distance of 6000 m with this acceleration. After this, it reaches a new layer of the atmosphere where it experiences an acceleration of 2 m/s\(^2\) until it reaches an incredible speed of 2500 m/s after falling for 10 seconds with this new acceleration.

69. A raindrop is moving at 2 m/s when it accelerates downwards at 8 m/s\(^2\) for 0.40 seconds. It then gets caught in an up-draft and accelerates upwards at 3 m/s\(^2\) for 25 m.

70. While playing “kickball”, the ball starts from rest and is accelerated at 8 m/s\(^2\) in the pitcher’s hand for \( \frac{1}{2} \) a meter. Once released, it then rolls the remaining 9 meters at a constant velocity. When it is kicked, it accelerates in the opposite direction at 35 m/s\(^2\) for 0.1 seconds.
SHORT REVIEW

71. A kid jumps off the high dive board at a pool in such a way that he passes the board, 3.00 m above the water with a downward velocity of 4.00 m/s. How much time passes before he hits the water?

72. While talking with your friends in the senior parking lot, you notice a car moving to the left at 2.00 m/s. You turn away from looking at the car and 2.00 seconds later you turn back towards the car and now see it traveling 3.00 m/s to the right. What is the acceleration of the car?

73. In the game of Bocce Ball, a ball is rolled across the ground. If a ball is released at 4.00 m/s and slows down at 1.50 m/s², then how far did the ball roll by the time it reached velocity of 2 m/s?

74. A base jumper drops off a very high bridge, he falls 150.0 m before opening his parachute. How much time did this take?

75. A skateboarder changes speed from 4 m/s to 8 m/s in 12 m. How much time did maneuver take?

76. A teacher is roller blading along a level roll at a constant velocity of 8.00 m/s for 5.00 seconds before slowing down at 2.00 m/s² for 3.00 m. How much total time did his journey take?
Newton’s Laws of Motion

Students should be able to:

1. Describe Aristotle's Horse Cart theory and what was wrong with it.
2. Describe Galileo's experiment that lead to his conclusions about inertia
   (a) Describe how this experiment is exemplified in modern day amusement parks
3. Define in a sentence Galileo's Law of Inertia (Alias-Newton's first Law of Motion)
4. Describe what affects an object's inertia.
5. Characterize rotational inertia
   (a) Describe the relationship between an objects rate of spin and the object's distribution of its mass.
6. Define “inertial mass” and compare it to “gravitational mass.”
7. Give examples of how inertia is demonstrated in everyday life (TOYS)
8. Write in words Newton's Second Law of Motion.
   (a) Describe a force
   (b) Give the SI and English unit of force.
   (c) Give the symbols for force in SI and English systems.
9. Describe the relationship between force and acceleration.
10. Describe the relationship between force and mass.
11. Do problems that make proportionality predictions based on Newton’s second law of motion. (F=ma) [ Ratio problems ]
12. Describe the formula for calculating weight from mass. (w=mg)
   (a) Describe what is means to experience a certain number of g’s.
   (b) Convert back and forth between g’s and m/s².
13. Write in a complete sentence Newton's Third Law of Motion.
14. Apply Newton’s Third Law of Motion to Problems.
15. Be able to identify the "reaction force" in a given situation.
16. Distinguish between the concepts of mass and weight.
17. Memorize the value for the acceleration of any object near the surface of the Earth.
   (a) Describe what it means to be weightless.
18. Utilize Newton's Laws in conjunction with the Kinematics equations to solve problems.
1. A little boy pushes a wagon with his dog in it. The mass of the dog and wagon together is 45 kg. The wagon accelerates at 0.85 m/s\(^2\). What force is the boy pulling with?

2. A 1650 kg car accelerates at a rate of 4.0 m/s\(^2\). How much force is the car's engine producing?

3. A 68 kg runner exerts a force of 59 N. What is the acceleration of the runner?

4. A crate is dragged across an ice-covered lake. The box accelerates at 0.08 m/s\(^2\) and is pulled by a 47 N force. What is the mass of the box?

5. 3 women push a stalled car. Each woman pushes with a 425 N force. What is the mass of the car if the car accelerates at 0.85 m/s\(^2\)?

6. A tennis ball, 0.314 kg, is accelerated at a rate of 164 m/s\(^2\) when hit by a professional tennis player. What force does the player's tennis racket exert on the ball?

7. In an airplane crash a woman is holding an 8.18 kg, 18-pound, baby. In the crash the woman experiences a horizontal de-acceleration of 88.2 m/s\(^2\). How many g's is this de-acceleration? How much force must the woman exert to hold the baby in place?

8. When an F-14 airplane takes-off an aircraft carrier it is literally catapulted off the flight deck. The plane's final speed at take-off is 68.2 m/s. The F-14 starts from rest. The plane accelerates in 2 seconds and has a mass of 29,545 kg. What is the total force that gets the F-14 in the air?

9. A sports car accelerates from 0 to 60 mph, 27 m/s, in 6.3 seconds. The car exerts a force of 4106 N. What is the mass of the car?

10. A sled is pushed along an ice-covered lake. It has some initial velocity before coming to a rest in 15 m. It took 23 seconds before the sled and rider come to a rest. If the rider and sled have a combined mass of 52.5 kg, what is the magnitude and direction of the stopping force? What do "we" call the stopping force?

11. A car is pulled with a force of 10,000 N. The car's mass is 1267 kg. But, the car covers 394.6 m in 15 seconds.
   (a) What is expected acceleration of the car from the 10,000 N force?
   (b) What is the actual acceleration of the car from the observed data of x and t?
   (c) What is the difference in accelerations?
   (d) What force caused this difference in acceleration?
   (e) What is the magnitude and direction of the force that caused the difference in acceleration?

12. A little car has a maximum acceleration of 2.57 m/s\(^2\). What is the new maximum acceleration of the little car if it tows another car that has the same mass?

13. A boy can accelerate at 1.00 m/s\(^2\) over a short distance. If the boy were to take an energy pill and suddenly have the ability to accelerate at 5.6 m/s\(^2\), then how would his new energy-pill-force compare to his earlier force? If the boy's earlier force was 45 N, what is the size of his energy-pill-force?

14. A cartoon plane with four engines can accelerate at 8.9 m/s\(^2\) when one engine is running. What is the acceleration of the plane if all four engines are running and each produces the same force?

15. While dragging a crate a workman exerts a force of 628 N. Later, the mass of the crate is increased by a factor of 3.8. If the workman exerts the same force, how does the new acceleration compare to the old acceleration?
Newton’s Laws Worksheets

16. A rocket accelerates in a space at a rate of "1 g." The rocket exerts a force of 12,482 N. Later in flight the rocket exerts 46,458 N. What is the rocket's new acceleration? What is the rocket's new acceleration in g's?

17. A racecar exerts 19,454 N while the car travels at a constant speed of 201 mph, 91.36 m/s. What is the mass of the car?

(18-31 Weight and Mass)

18. A locomotive’s mass is 18181.81 kg. What is its weight?

19. A small car weighs 10168.25 N. What is its mass?

20. What is the weight of an infant whose mass is 1.76 kg?

21. An F-14’s mass is 29,545 kg. What is its weight?

22. What is the mass of a runner whose weight is 648 N?

23. The surface gravity of the Sun is 274 m/s². How many Earth g’s is this?

24. The planet Mercury has 0.37 g’s compared to the Earth. What is the acceleration on Mercury in m/s²?

25. A plane crashes with a deceleration of 185 m/s². How many g’s is this?

26. A baseball traveling 38 m/s is caught by the catcher. The catcher takes 0.1 seconds to stop the ball. What is the acceleration of the ball and how many g’s is this?

27. A very fast car accelerates from a rest to 32 m/s, (71.68 mph), in 4.2 seconds. What is acceleration of the car and how many g’s is this?

28. The Space Shuttle travels from launch to 529.2 m in 6.0 seconds. What is the acceleration of the shuttle and how many g’s is this?

29. The space shuttle’s mass, (with boosters) is 654,506 kg. The average force of the shuttle’s engines is 25,656,635.2 N. What is the acceleration of the shuttle in m/s² and g’s?

30. How can the answers to #28 and #29 both be correct?

31. What is the SI weight of a McDonald’s Quarter Pounder™ sandwich?
32. A little boy, mass = 40 kg, is riding in a wagon pulled by his HUGE dog, Howard. What is the acceleration of the wagon if the dog pulls with a force of 30 N? (Assume the wagon rolls on a friction less surface).

33. The wagon and boy mentioned in the previous problem are let loose by Howard the dog. The wagon freely rolls until it hits a patch of ground that slows down the wagon until it comes to a rest. If it takes 10 seconds to come to a stop in 15 meters, what if the frictional force stopping the wagon?

34. A speedboat in the water experiences an acceleration of 0.524 m/s². The boat's mass is 842 kg. What is the force that the boat's engines are putting out?

35. A stalled car is pushed with a force of 342 N from rest. How far does the car travel in 12 seconds if its mass is 989 kg?

36. How far does the car travel in the previous problem if the pushing force is doubled?

37. A little boy is pulling a wagon full of 10 bricks. The mass of the wagon is too small to be considered. If the boy later is pulling the wagon with the same force and the wagon has 45 bricks in it, then how does the acceleration of the 45 brick wagon compare to the acceleration of the 10 brick wagon?

38. A car accelerates with a given force. Later the same car accelerates with 1/6 its original acceleration and it now has 1.4 times its earlier mass. (A) How does the car’s later force compare with the earlier force? (B) If its earlier force is 1523 N, then what is the car’s later force?

39. What force does the car exert if its mass is 1201 kg and the car goes from 5.4 m/s to 16.3 m/s in 107 meters?

40. What are Newton's 3 Laws and which ones are used in shaking a ketchup bottle to get the ketchup out when it is "stuck" in the bottle.

41. An ice skater is spinning when she begins to draw in her arms. As she does this what happens to her rate of spin? Which law does this fall under?

42. A 1027 kg car is resting at a stoplight. The car moves with a force of 1528 N for 22 s. Then the car travels at a constant velocity for 10 seconds. Finally, the car stops with a force of 4056 N. HOW MUCH DISTANCE IS TRAVELED BY THE CAR DURING THIS JOURNEY?

43. By what factor would the acceleration of a car change by if the net force the engine exerted tripled and the mass remained unchanged? What is the new acceleration if the initial acceleration is 2 m/s²?

44. A truck is traveling down the road carrying a large roll of hay equal in mass to the truck. The roll is delivered to a customer. By what factor would the force the truck must exert change by if the truck is to achieve the same acceleration as before.

45. While tossing a medicine ball back and forth it rips and its mass changes by a factor of $3/10$th 's. If the person catching the ball slowed it down with an acceleration that changed by a factor of ½ then how does the new stopping force compare to a previous stopping force from an earlier catch?

46. A wiffleball has a mass that is 1/50th the mass of a baseball. If the ball is hit with 3 times the force of a baseball, then how does the acceleration of the baseball bat compare with the acceleration of the wiffleball?

47. A runner, whose weight is 515 N, travels from rest to 12.0 m/s in 4.50 seconds. What force did the runner exert?
Newton's Laws of Motion

48. A fully loaded 18 wheeled tractor trailer truck travels while exerting a 63,492 N force. The truck travels from 4.44 m/s to 14.13 m/s in 45.0 m. What is the weight of the tractor trailer?

49. A boat with a mass of 1550 kg, accelerates with a force of 4560 N. If the boat begins to exerts this force while traveling 5.00 m/s and continues to exert this force for 8.50 seconds, then what is the final velocity of the boat?

50. A Cheetah with a weight of 601 N, runs with a force of 956 N. This cat runs from rest to 31.25 m/s. How much distance did this run take?

SOME ANSWERS

1) 38.25 N    2) 6600 N    3) 0.87 m/s²    4) 587.5 kg    5) 1500 kg
6) 51.50 N    7) 9 g's; 721.48 N    8) 1,007,484.5 N    9) 958.07 kg    10) 2.98 N
11a) 7.89 m/s²    11b) 2.62 m/s²    11c) 5.27 m/s²    11d) ???    11e) 6682.15 N
12) 1.285 N    13) 252 N    14) 35.6    15) New Accel = (0.26) Old Acceleration
16) 3.72 g's    17) ???    18) 178181.74 N    19) 1037.58 kg    20) 17.25 N
21) 289541 N    22) 66.12 kg    23) 27.96 g's    24) 3.63 m/s²    25) 18.88 g’s
26) 380 m/s², 38.78 g/s    27) 134.4 m/s², 13.71 g’s    28) 29.4 m/s, 3 g’s    29) 29.4 m/s, 3 g’s    30) ???
31) ???    32) 0.75 m/s²    33) 40 N (0.3 m/s²)    34) 441.21 N    35) 24.90 m, (0.34 m/s²)
36) 49.80 (twice as far)    37) accel of 45 brick wagon = (1/(4.5))(accel of the 10 brick wagon)
38) new froce = 0.233(old force; 355.37 N)    39) 1327.44 N, (1.1053 m/s²)
41) Spin faster (1st)    42) 360.05m + 327.32 + 135.64m = 823.02
47) 140 N    48) 311,209 N    49) 30.01 m/s    50) 31.32 m
Newton’s Laws of Motion (Free Body Diagrams)

Objectives

Students will be able to:

1. Identify when to include any of the forces listed below in a free body diagram, (abbreviated - fbd).
   a. Normal force
   b. Friction (Surface)
   c. Friction (Air resistance)
   d. Tension
   e. Weight
   f. Net force

2. Define the directions of any of the forces listed above, (a–f).

3. Define friction in words and mathematically.

4. Define weight mathematically.

5. Define what is wrong with a “weightless” object near the surface of the Earth.

6. Explain what it means on a free body diagram to travel at a constant velocity.

7. Create an equation based on a free body diagram.
1. Draw a free body diagram of the box. There is friction between the box and the surface. The box is accelerating down the incline.

2. A box is sliding across the floor from your left to your right. The box is slowing down as it moves. Draw a free body diagram of the forces acting on the box.
3

A pair of boxes are connected to each other by a strong massless rope. These boxes are moving up an incline but are slowing down. Draw the free body diagram of the larger box. There is no friction acting on the larger box.

4

Draw a free body diagram of the box. It is not moving and there is no friction.

5

A car is moving up an incline at a constant velocity. The car’s engine exerts a force along the incline. There is friction on the incline. Draw a free body diagram of the forces acting on the car.
1. \[ F_{\text{net}} \]

\[ F_1 \quad F_2 \quad F_3 \]

\textbf{Sum up the forces in the x and y directions}

2. \[ F_{\text{net}} \]

\[ F_5 \quad F_6 \quad F_7 \quad F_8 \]

\textbf{Sum up the forces in the x and y directions}

3. \[ F_{\text{net}} \]

\[ F_9 \quad F_{10} \quad F_8 \]

\textbf{Sum up the forces in the x and y directions}
Newton's Laws of Motion– Free Body Diagrams (fdb)

For Mr. Wayne's Students (2017 Edition)
Newton's Laws of Motion—Free Body Diagrams (fbd)

1. A 6 kg object is suspended by two strings, $T_1$ and $T_2$, at $40^\circ$ angles from the horizontal. The strings are inclined at $40^\circ$ and $60^\circ$ from the vertical.

2. A 10 kg object is suspended by a string, $T_1$, at a $40^\circ$ angle from the horizontal. Another string, $T_2$, is inclined at $60^\circ$ from the vertical.

3. A 50 kg object is suspended by three strings, $T_1$, $T_2$, and $T_3$. The strings are inclined at $20^\circ$, $40^\circ$, and $60^\circ$ from the vertical, respectively.
Newton's Laws of Motion—Free Body Diagrams (fbd)

DRAW A FREE BODY DIAGRAM FOR EACH MASS
THERE IS FRICTION WITH THE ROAD. THERE IS AIR RESISTANCE. THE FRONT ENGINE IS SUPPLYING A FORWARD FORCE TO MOVE THE TRAIN.

DRAW A FREE BODY DIAGRAM FOR EACH MASS
THERE IS FRICTION WITH THE ROAD. NO AIR RESISTANCE. THE CAR IS SUPPLYING THE ONLY FORWARD FORCE

DRAW A FREE BODY DIAGRAM FOR EACH MASS AND THE PULLEY.
Newton's Laws of Motion– Free Body Diagrams (fdb)

For Mr. Wayne’s Students (2017 Edition)
Draw the appropriate free body diagram, Label all forces according to the legend.

**LEGEND**

Normal force = \( \eta \)
W = mg
Tension = \( T \)
Net force = \( ma_{\text{net}} \)
Friction = \( \mathcal{F} \) (cursive “F”)
All other forces use and “F” followed by a subscript identifying the force.

(1) Draw a free body diagram of the box. There is friction between the box and the surface. The box is accelerating down the incline.

(2) A box is sliding across the floor from your left to your right. The box is slowing down as it moves. Draw a free body diagram of the forces acting on the box.

(3) A pair of boxes are connected to each other by a strong massless rope. These boxes are moving up an incline but are slowing down. Draw the free body diagram of the larger box. There is no friction acting on the larger box.

(4) Draw a free body diagram of the box. It is not moving and there is no friction.

(5) A car is moving up an incline at a constant velocity. The car’s engine exerts a force along the incline. There is friction on the incline. Draw a Free body diagram of the forces acting on the car.
<table>
<thead>
<tr>
<th>Net Force</th>
<th>Weight</th>
<th>Tension</th>
<th>Normal</th>
<th>Friction</th>
<th>&lt;-Force’s &lt;-Name</th>
</tr>
</thead>
</table>

1. When is it on the diagram? 2. How is its direction determined?

Notes: (Include any Formulas and variables)
Write the expression for summing up the forces in the x and y directions for each free body diagram shown below.

1. The body is moving from left to right and is slowing down.

2. The body is speeding up as it slides down the incline.

3. The body is moving up the incline at a constant velocity.
Write the expression for summing up the forces in the x and y directions for each free body diagram shown below.

4. Moves at a constant velocity

\[ F_1 + F_2 - F_3 - F_4 \]

The body is not moving.

5. Body is not moving.

\[ F_8 + F_9 + F_{10} - F_{11} \]

The body is not moving.

6. Does this have a net acceleration or is it moving at a constant velocity?

\[ F_{14} + F_{15} - F_{17} - F_{19} \]

The body is not moving.
Newton's Laws of Motion—Free Body Diagrams (fdb)

Doing the math

1. In a problem the following summations have been created. Write an expression for the net acceleration, \( a_{\text{net}} \), in terms of the given variables.
   
   Given: \( \mu, g \)  
   Unknowns: \( \mathcal{F}, m, a_{\text{net}} \)
   
   \[
   \sum F_x = ma_{\text{net}} = \mathcal{F} \quad \sum F_y = 0 = mg - \eta
   \]
   Example Solution to #1 is "\( a = \mu g \)"
   Now prove it.

2. In a problem the following summations have been created. Write an expression for the coefficient of friction, \( \mu \), in terms of the given variables.
   
   Given: \( F, m, g, T \)  
   Unknown: \( \mathcal{F}, \eta, \mu \)
   
   \[
   \sum F_x = 0 = T - F + \mathcal{F} \quad \sum F_y = 0 = mg - \eta
   \]

3. In a problem the following summations have been created. Write an expression for the net acceleration, \( a_{\text{net}} \), in terms of the given variables.
   
   Given: \( m_1, m_2, g, \mu \)  
   Unknown: \( \mathcal{F}, T, a_{\text{net}}, \eta_1 \)
   
   \[
   \sum F_x = m_1 a_{\text{net}} = T - \mathcal{F} \quad \sum F_x = 0 \quad \sum F_y = 0 = m_1 g - \eta_1 \quad \sum F_y = m_2 a_{\text{net}} = m_2 g - T
   \]

4. In a problem the following summations have been created. Write an expression for the force labeled with \( \text{V} \), "\( V \), in terms of the given variables.
   
   Given: \( H, m_1, m_2, g \)  
   Unknown: \( T, V \)
   
   \[
   \sum F_x = 0 = T \cos 40^\circ - H \quad \sum F_y = 0 = m_1 g + m_2 g - T \sin 40^\circ + V
   \]

5. In a problem the following summations have been created. Write an expression for the force, \( F \), in terms of the given variables.
   
   Given: \( m_1, m_2, g, a, \mu \)  
   Unknown: \( T, F, \eta_1, \eta_2 \)
   
   \[
   \sum F_x = 0 = T - m_2 g \cos 20^\circ \quad \sum F_x = 0 = m_1 g \sin 30^\circ - T - F \quad \sum F_y = 0 = \eta_2 - m_2 g \sin 20^\circ \quad \sum F_y = 0 = \eta_1 - m_1 g
   \]
6. In a problem the following summations have been created. Write an expression for the tension, \( T \), in terms of the given variables.

\[
\begin{align*}
\text{Givens: } & m_1, m_2, g, \mu, a & \text{Unknown: } & T, \theta \\
\sum F_x & = m_1 a = T - \theta - m_1 g \sin 10^\circ & \sum F_x & = 0 \\
\sum F_y & = 0 = \eta - m_1 g \sin 10^\circ & \sum F_y & = m_2 a = m_2 g - T
\end{align*}
\]

7. In a problem the following summations have been created. Write an expression for the net force on object \( #1 \), \( F_{net1} \) in terms of the given variables.

\[
\begin{align*}
\text{Givens: } & m_2, \mu, g, F, a_{net} & \text{Unknown: } & T, \theta, m_1 \\
\sum F_x & = m_2 a_{net} = T - \theta & \sum F_x & = m_1 a_{net} = F - T \\
\sum F_y & = 0 = \eta - m_2 g & \sum F_y & = 0 = \eta_1 - m_1 g
\end{align*}
\]
Projectile Motion Problems

Please do all of your work on a separate piece of paper.

Find as many mistakes as you can for the problems below. If you find a math error in one line proceed to the next lines as if the error was not there.

1) A 10kg box is on an incline where the coefficient of friction is equal to 0.20 on the right and 0.80 on the left. What is the tension if both boxes do not move? (Only a partial solution is shown below. There at least 7 mistakes in this problem.)

\[ \sum f_x = 0 = T - \Sigma + m_{10}g \sin(30^\circ) \]
\[ \sum f_y = 0 = \eta - m_{10}g \cos(30^\circ) \]
\[ \Sigma = \mu \eta \]
\[ 0 = T - \Sigma + m_{10}g \sin(30^\circ) \]
\[ T = -\Sigma + m_{10}g \sin(30^\circ) \]
\[ \eta = m_{10}g \cos(30^\circ) \]
\[ T = -\mu \eta + m_{10}g \sin(30^\circ) \]
\[ T = -\mu m_{10}g \cos(30^\circ) + m_{10}g \sin(30^\circ) \]

2) A 5 kg block is pressed against a wall by a 200 N force. The coefficient of friction between the wall and block is 0.200. What is the blocks acceleration along the wall? Only a partial solution is shown below)

\[ \sum F = 0 = T - F \cos(65^\circ) \]
\[ \sum F = m_{\text{net}} = \eta - \Sigma - mg \cos + F \sin(65^\circ) \]
\[ \Sigma = \mu \eta \]

\[ m_{\text{net}} = \eta - \Sigma - mg \cos + F \sin(65^\circ) \]
\[ m_{\text{net}} = \eta - \mu \eta - mg \cos + F \sin(65^\circ) \]
\[ a_{\text{net}} = \eta - \mu \eta - g \cos + F \sin(65^\circ) \]
Find as many mistakes as you can for the problems below. If you find a math error in one line proceed to the next lines as if the error was not there.

3) Problem: A 10kg box accelerates downwards along an incline with a coefficient of friction equal to 0.30 while being pushed by a force that acts opposite the direction of friction with a magnitude equal to friction. Calculate the unknown force's magnitude. (There are at least 8 mistakes.)

\[
\begin{align*}
\sum x &= 0 = 3 - F_{\text{unknown}} - mg \cos(28^\circ) \\
\sum y &= 0 = \eta - mg \sin(28^\circ)
\end{align*}
\]

\[
3 - F_{\text{unknown}} - mg \cos(28^\circ) = 0
\]

\[
\mu \eta - F_{\text{unknown}} - mg \cos(28^\circ) = 0
\]

\[
F_{\text{unknown}} = mg \cos(28^\circ) - \mu \eta
\]

\[
F_{\text{unknown}} = mg \cos(28^\circ) - \mu \left( mg \sin(28^\circ) \right)
\]

\[
F_{\text{unknown}} = \left( 10 \text{ kg} \right) \left( 9.80 \text{ m/s}^2 \right) \cos(28^\circ) - 0.3 \left( 9.80 \text{ m/s}^2 \right) \left( 10 \text{ kg} \right) \sin(28^\circ)
\]

\[
F_{\text{unknown}} = 102 \text{ N}
\]
Projectile Motion Problems
Please do all of your work on a separate piece of paper.
Projectile Motion

**Students should be able to:**

1. Calculate the horizontal and vertical components of a velocity vector given the initial vector.

2. Define givens as being either horizontal or vertical.

3. Place appropriate S.I. units on all givens and answers.

4. Calculate the apogee of any projectile motion.

5. Calculate the time in the air for any projectile motion.

6. Calculate the impact SPEED of any projectile motion.

7. Calculate the time to any given height in a projectile’s motion.

**Honors**

A. Calculate the impact velocity (magnitude and direction)

B. Calculate the velocities angle and speed at any given location in a projectile’s path.
Slylock Fox and three of Santa’s elves, Hermey, Thelma, and Edgar, were sitting around a fireplace eating s’mores while regaling stories of repurposing the inhabitants on the “Island of Misfit Toys.” Legend says that because of the barrier of “forgotten” walls and constant sideways current surrounding the island, King Moonrazer will only let toys fly off the island with Santa on Christmas eve.

In great detail, each of the elves told their harrowing story of what it took to leave on a day other than Christmas eve. However, Slylock Fox suspects one of the three elves of not being completely honest. **Were all three elves telling the truth or not?**

Here are some details from their stories: Each elf grabbed a different water vehicle. Unfortunately, because it is the “Island of Misfit Toys,” each vehicle has a rudder that cannot be steered. This means that each machine can only power itself to the right with the characteristics shown. Each watercraft will also be moving downwards at a speed equal to the shown water current.
You have been hired for a show on the “SyFy” channel to investigate bizarre happenings. The show is called, That Ain’t No Jive. On your pilot episode you are investigating a report that a man floated down from the top of a building being built while holding a 4 ft x 8 ft piece of plywood as a parachute over his head. Below are the facts as we know it so far.

Witness name: Miss Creant,
Witness location: Position “A”
Account: Miss Creant saw the construction worker, Lucky Chance, leap off the top of an unfinished building. When she saw Lucky, he was moving at a fast jog off the building. When he got to the edge, he moved horizontally without leaping up or down. As Lucky descended, he disappeared from her sight because a tree blocked her view at some point. But later he saw Lucky standing on the ground inside the orange fence.

Witness name: Mr. Meanor,
Witness location: Position “B”
Account: Mr. Meanor saw Lucky Chance jump horizontally off the top edge of the building. Witness says he did not jump up or downwards as he left the ledge. He leapt of the 6th floor of the building. He was walking off the edge with a piece of plywood over his head. While Lucky was in the air he seemed to drift to the left. Mr. Meanor fell backwards and did not see where Mr. Chance landed. Later Mr. Meanor saw Lucky carrying the wood outside the orange fence.

Because this is your television show, you have a team of researchers to do the dirty work for you. Here is what they have come up with so far.

Each floor of this building is 3.50 m above the previous one. According to other measurements and experiments from your team, the time Mr. Chance took to fall was 3.10 seconds. Mr. Chance is 6’4’ tall, (1.93 m). On the next page is a map your team created of the construction site. This map includes the footprints left by Mr. Chance as he left the 6th floor. Your team has also looked at weather reports and determined that there was a wind blowing from right to left on the map. They further concluded that a person using a piece of plywood as a parachute would drift sideways at a constant velocity of 5 m/s.

Determine who is the more reliable witness and figure out if Lucky could have landed while missing all the obstacles on the map.

ESTIMATING SPEED FROM FOOTPRINTS

\[ \nu = 0.25 \sqrt{g(S)^{1.87}(h)^{-1.17}} \]

\( \nu \) = speed in m/s
\( h \) = height from the ground to the hip. Typically this is half the height of the person.
\( g \) = the acceleration due to gravity
\( S \) = length of the stride as measured from the heel of the right/left foot to the heel of the same foot.

1 Stride length
Map of the construction site

Each small square is 2 m x 2m

5 m/s drift velocity
There are many legends surrounding the lost continent of Atlantis. One of the legends is about an island used as a prison. It was rumored that nobody ever escaped from this island ...until a recently unearthed “Scrolls of Posiden” describes a tale where a young lad, Jo Kerr Hilarius, made an inflatable boat from whale skin and intestines. A rudder was made from whale bone. It was truly an engineering marvel. Under the cover of a moonless night Jo left the shores of the prison. Unfortunately his boat had some problems and he could only row it straight out into the harbor towards Atlantis. This harbor had a swift current that moved perpendicular to the motion of the boat. At the point where Jo entered the harbor, the current was traveling at 5.00 m/s and was slowing down at 0.142 m/s². Because of shape of the harbor entrance, this current had a constant acceleration. The legend goes that Jo landed at a house of bacchanalia where he partied as a free man for the rest of his life.

Recently evidence of this Island was discovered and a map was made. Assuming Jo Kerr Hilarius’s adrenaline was flowing, he rowed his boat at 2.00 m/s and he started with an initial velocity of 2.00 m/s, determine if this legend could be true of not.
CLASS EXAMPLE

A bicyclist travels off the ramp with an initial velocity of 20 m/s as it leaves the ramp. The 30° angle is between the ramp and the top of the building.

Calculate the RANGE.
Calculate the impact velocity and its angle.
Projectile Motion Problems

Please do all of your work on a separate piece of paper.

For each problem below you are given the initial velocity for a projectile. Label the vertical and horizontal components in the same manner that we did in class. Use the angle that is given. Do not use its complementary or supplementary angle.

EXERCISE A

1. A baseball is thrown from center field to second base. It is released 42 m/s at an angle of 35° with the ground. In the space above, draw the initial velocity’s triangle with its components.

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11. A baseball is thrown from center field to second base. It is released 42 m/s at an angle of 35° with the ground. In the space above, draw the initial velocity’s triangle with its components.
A package of food supplies is air dropped into Africa in such a way that it is ejected at 16 m/s downwards at an angle of 62° with the vertical. In the space above draw the initial velocity’s triangle with its components.

Find the vertical and horizontal components for each of the velocities given below.
Do not use any angles other than the ones you are given.
1. A rock is thrown with a speed of 46.5 m/s at an angle of 38° with the ground.
2. A Volvo lands after driving off a cliff. It impacted the ground at 32 m/s at an angle of 68° with the ground.
3. An alien space-egg is catapulted from the planet Ork at an angle of 75° with the ground and a speed of 459 m/s.
4. A meteor hits the Earth with a speed of 86 m/s at an angle of 21° with the ground.
5. A girl jumps off a swing at 7 m/s and at an angle of 39° with the vertical.

6. A jet lands on an aircraft carrier with a horizontal speed of 109 m/s and a downward vertical speed of 9.0 m/s. What is the VELOCITY (Magnitude and Direction) of the jet?
# Projectile Motion Problems

Please do all of your work on a separate piece of paper.

## Class practice for determining the variables’ signs

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Projectile Motion Problems

Please do all of your work on a separate piece of paper.

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Projectile Motion Problems

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Projectile Motion Problems
Please do all of your work on a separate piece of paper.

### Problem 15

![Diagram of projectile motion](image1)

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### Problem 16

![Diagram of projectile motion](image2)

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1. A “peasant-a-pult” launches peasants at a 35° with the ground at a speed of 42 m/s.
   a. How long is the peasant in the air?
   b. How far did the peasant travel before hitting the ground? (Horizontal distance is called "range.")
   c. What speed did the peasant hit the ground with?

2. In a Superbowl™ dream, Eli Manning threw a ball with a speed of 26 m/s at a 43° angle with the ground for a touchdown. The ball was caught at nearly the same height it was thrown from. (Neglect this height difference.)
   a. How long is the ball in the air?
   b. How far did the ball travel before being caught? (Horizontal distance is called "range.")
   c. What speed was the ball traveling when it was caught?

3. A bicyclist travels off the ramp with an initial velocity of 20 m/s as it leaves the ramp. The 30° angle is between the ramp and the top of the building
   a. Calculate the RANGE.
   b. Calculate the impact velocity and its angle.
Projectile Motion Problems

Please do all of your work on a separate piece of paper.

4.

a. Calculate the RANGE.

b. Calculate the impact velocity and its angle.

5.

Assume the projectile lands at the same height it is launched from.

a. What is the height of apogee?

b. Calculate the projectile’s range.

c. Calculate the projectile’s impact velocity and angle with the ground.

6.

Neglect the height of the batter.

a. What is the height of apogee?

b. Calculate the projectile’s range.

c. Calculate the projectile’s impact velocity and angle with the ground.
Symmetrical Projectile Motion

7. Mike Easter threw a javelin at 57 m/s and at an angle of 25 degrees with the ground. Neglect the height of the athlete when the javelin was thrown. It lands at the same height it was thrown from.
   a. How high did the javelin travel?
   b. How long was it in the air?
   c. How far along the ground did the javelin travel?
   d. How fast, (direction and magnitude), was it traveling when it hit the ground?

8. An arrow is shot up at a 37° angle with the horizontal. The Arrow leaves the bow traveling 68 m/s. Eventually it lands on the ground.
   a. How high above the ground did the arrow travel? Neglect the height of the arrow from the ground when shot.
   b. How long was it in the air?
   c. How far across the ground did it travel?

9. The motorcycle daredevil Evil Kinevil is about to make a world record distance jump. He leaves the jump ramp at 45m/s. The ramp is at a 22° angle with the ground. He lands at the same height he took off from.
   a. How high does he travel?
   b. How much time did he spend in the air?
   c. What is the distance of his jump?
   d. What is his velocity when he lands?

10. Robbie Knievel is about to make another world record distance jump. He leaves the jump ramp at 45m/s. The ramp is at a 68° (90°-22°) angle with the ground. He lands at the same height he took off from.
    a. How high does he travel?
    b. How much time did he spend in the air?
    c. What is the distance of his jump?
    d. What is his velocity when he lands?

11. A spear is thrown with velocity of 30 m/s at a 34° angle with the ground? Neglect the initial height the spear was thrown from. The spear lands at the same height it was thrown from.
    a. How far did the spear travel?
    b. How long was the spear in the air?
    c. How high did the spear travel?
12. A dare devil stunt man travels off a jump with velocity of 50 m/s at a 20° angle with the ground? The stunt man lands at the same height he took off from.
   a. How far away should the landing ramp be placed?
   b. How long was the motorcycle dare devil in the air?
   c. How high did the motorcycle dare devil travel?

13. A baseball player bats a ball with a velocity of 60 m/s at an angle of 80° with the ground. Neglect the height the ball was hit from. The ball landed at the same height is was hit from.
   a. How far, horizontally, did the ball travel?
   b. How much time did the baseball spend in the air?
   c. How high did the ball travel?
   d. A baseball player from the opposing team is standing 30 m from where the ball is going to land. What average speed does the player have to run to catch the ball?

14. Typically an assault rifle shoots a bullet at 1000 m/s. The rifle is aimed at 10.0° and the bullet lands on the ground. Neglect the height the bullet was shot from.
   a. How far did the bullet travel?
   b. How long was the bullet in the air?
   c. How high did the bullet travel?

15. Not knowing any better, Tom hit Jerry with a tennis racquet. Jerry left the racquet with a velocity of 60 m/s at a 75° angle. Neglect the height Jerry was hit from.
   a. How much time passes before Jerry hits the ground?
   b. How high does Jerry travel?
   c. How far along the ground does Jerry travel?
   d. How fast is Jerry traveling when he hits the ground?
   e. How far along the ground will Jerry travel if he is launched at a 15° angle with the ground at 60 m/s?
   f. What is the relationship between 75° and 15°?
   g. Who is Tom and Jerry?

16. In a football game, a quarterback throws a ball to a receiver. The quarterback takes the hike from the center. 3.0 seconds later he passes the ball with a velocity of 20 m/s at a 30° angle with the ground. The ball is caught at the same height it is thrown from and the quarter back released the ball from the starting point of the receiver before he began to run.
   a. How high did the ball travel?
   b. How much time did the ball spend in the air?
   c. How far down the field did the ball travel?
   d. What speed will the ball hit the ground with and at what angle?
   e. With what average velocity will the receiver have to run with in order to catch the ball the moment it gets to the ground?
17. While traveling down the road, a driver loses control of his car the bounces off a curb at an 8.5° angle with the ground. The car lands at the same height is takes of from. The car was traveling 40.0 m/s when it bounced at 8.5°.
   a. How much time did the car spend in the air?
   b. How far did the car travel?
   c. What velocity did the car impact the ground with? (Magnitude **AND** direction)

18. Waldo Walenda, one of The Flying Walenda’s, was swinging on a trapeze. He let go of the trapeze when it was traveling 20.0 m/s at a 40.0° angle with the vertical. Waldo is to catch another trapeze that is **at the same height** as the one he left. When he catches the other trapeze it is to be at the end of its swinging motion. Try to recreate the situation using these questions as a guide.
   a. How long was Waldo in the air?
   b. How high above the trapeze did Waldo travel?
   c. How far from the trapeze was the waiting trapeze (Horizontal distance)?
   - d. If the waiting trapeze has a length of 6 meters, at what time -relative to the moment when Waldo lets go of the trapeze- does the waiting trapeze need to be released?
Projectile Motion Problems

Please do all of your work on a separate piece of paper.

**Vo is Horizontal**

19. In a movie, Borris Badenough is pushed horizontally out of a window. He exits the window horizontally at 5.0 m/s. Borris lands 15 m from the edge of the building.
   
   a. What is the Borris Badenough’s initial horizontal velocity?
   
   b. What is the Borris Badenough’s initial vertical velocity?
   
   c. How fast, vertically, is Borris traveling when it hits the ground?
   
   d. How long was Borris in the air?
   
   e. How high was the window Borris fell from?
   
   f. What SPEED did he impact the ground?
   
   g. What VELOCITY did he impact the ground? (magnitude AND direction).

20. A penny is kicked horizontally off the roof of a 10-story building (33.3 m high). It is kicked at 22 m/s.

   a. What is the penny's initial horizontal velocity?
   
   b. What is the penny's initial vertical velocity?
   
   c. How long is the penny in the air?
   
   d. How far away from the building did the penny land?
   
   e. What is the penny’s SPEED when it hits the ground?
   
   f. How fast, vertically, is the ball traveling when it hits the ground?
   
   g. How fast, horizontally, is the penny traveling when it hits the ground?
   
   h. What is the penny's VELOCITY (magnitude and direction) when it hits the ground?

21. A ball is rolled horizontally out a second story window (7 m high) with a velocity of 10.0 m/s.

   a. What is the ball's initial horizontal velocity?
   
   b. What is the ball's initial vertical velocity?
   
   c. How long is the ball in the air?
   
   d. How far away from the building did the ball land?
   
   e. What is the ball’s SPEED when it hits the ground?
   
   f. How fast, horizontally, is the ball traveling when it hits the ground?
   
   g. How fast, vertically, is the ball traveling when it hits the ground?
   
   h. What is the ball's VELOCITY (magnitude and direction) when it hits the ground?
22. The Wile E. Coyote was chasing the Road Runner when he ran horizontally off a cliff at 46 m/s. Wile E. Coyote is falling for 12 seconds before hitting the ground.
   a. How high is the cliff?
   b. How far from the edge of the cliff did the coyote travel before hitting the ground?
   c. What was the coyote’s impact speed?
   d. What was the coyote’s impact velocity, (MAGNITUDE and DIRECTION)?

23. The Charlottesville parking garage on Market Street is 6.0 stories high, 19.8 m. A car travels horizontally off the top of the garage at 2.2 m/s, (5 mph.)
   a. How far from the edge of the building did the car land?
   b. How long was the car in the air?
   c. With what speed was the car traveling when he hit the ground?
   d. What velocity did the car impact the ground? (Magnitude AND direction)

24. A student is at a quarry and attempting to run off the edge of a cliff. They run off the cliff at horizontally at 10 m/s. The edge of the cliff is 5 m above the water.
   a. How far from the edge of the building did the student land?
   b. How long was the student in the air?
   c. With what speed was the student traveling when he hit the water?
   d. What velocity did the student impact the ground? (Magnitude AND direction)

Vo is an angle and x & xo are not equal

25

A stunt rider is making a motorcycle jump. Through a planning error the landing ramp’s end does not match the take-off ramp’s height. The landing ramp is 25 m high. The take off ramp is 10 meters high at the end.

a. Where should the ramp be placed (x)?
b. How long is the rider in the air?
26. A skier was traveling 20 m/s when they hit a hill and launched themselves up into the air at a 30° angle. They hit a tree when they were at the highest part of the motion.
   a. How long was the skier in the air?
   b. How high did the skier travel?
   c. How far along the ground did the skier travel?

27. A rock is thrown off a tall building at 45 m/s at an angle of 30° below the horizontal.
   a. How long is the rock in air?
   b. How far from the building did the rock land?
   c. What is rock’s velocity (magnitude and direction)? At impact?
28. A rock is thrown off a tall building at 45 m/s at an angle of 60.0° above the horizontal.
   a. How high did the rock travel?
   b. How long is the rock in air?
   c. How far from the building did the rock land?
   D. What is rock's velocity (magnitude and direction) at impact?
Projectile Motion Problems

Please do all of your work on a separate piece of paper.

29. A snowball is thrown out a second story window (7 m high) with a speed of 32 m/s. It is thrown at an angle of 57° beneath the horizontal.
   a. What is the ball's initial horizontal velocity?
   b. What is the ball's initial vertical velocity?
   c. How long is the ball in the air?
   d. How far away from the building did the ball land?
   e. How fast, vertically, is the ball traveling when it hits the ground?
   f. How fast, horizontally, is the ball traveling when it hits the ground?
   g. What is the ball's VELOCITY (magnitude and direction) when it hits the ground?

30. A snowball is thrown out a second story window (7 m high) with a speed of 32 m/s. It is thrown at an angle of 57° beneath the horizontal.
   a. What is the ball's initial horizontal velocity?
   b. What is the ball's initial vertical velocity?
   c. How long is the ball in the air?
   d. How far away from the building did the ball land?
   e. How fast, vertically, is the ball traveling when it hits the ground?
   f. How fast, horizontally, is the ball traveling when it hits the ground?
   g. What is the ball's VELOCITY (magnitude and direction) when it hits the ground?

31. A Penny is thrown out of the Eiffel Tower (303 m high) with a speed of 43 m/s. It is thrown at an angle of 83° beneath the horizontal.
   a. What is the penny's initial horizontal velocity?
   b. What is the penny's initial vertical velocity?
   c. How long is the penny in the air?
   d. How far away from the building did the penny land?
   e. How fast, horizontally, is the penny traveling when it hits the ground?
   f. How fast, vertically, is the penny traveling when it hits the ground?
   g. What is the penny's VELOCITY (magnitude and direction) when it hits the ground?
32. While sitting in a tree, Tarzan tried to get a trapper's attention by throwing a banana with a velocity of 20.0 m/s at a 30.0 degree angle beneath the horizontal.
   a) How high was Tarzan if the banana took 2 seconds to hit the ground?
   b) With what speed did the banana hit the ground?
   c) With what angle did the banana hit the ground?

33. Tina, the golfer, tees off the tip-top of a tall turf laden hill. Her golf ball is in the air for 6.00 seconds before coming to a rest 5.00 meters below the tee's height.
   a) If the golf is hit with a velocity of 60.00 m/s then what angle was the ball hit with?
   b) How far horizontally did the ball travel before coming to a rest?

34. Tarzan was swinging on a vine when it snapped. At the moment it snapped the vine was 30° from the VERTICAL in an upwards direction. Tarzan was traveling 25 m/s. Tarzan landed 16 meters along the ground from where the vine broke.
   a. How long was Tarzan in the air?
   b. How fast was Tarzan traveling when he hit the ground, (MAGNITUDE and DIRECTION)?

35. A rock is thrown at a house with a speed of 30 m/s at an angle of 39 degrees with the ground. If the house is 83 meters away, will the rock hit the house?

36. In a backyard baseball game Billy Bats bats a ball beyond the bases. The ball is hit at a 58-degree angle with the ground with some yet unknown initial speed. The ball travels 235 meters along the ground.
   a) With what speed does the ball hit the ground?
   b) How long is the ball in the air?
   c) How high did the ball travel?
37. At THE bodacious mud-bog of the year, a car makes a jump at an angle of 22 degrees with the ground. The truck travels up as high as 5.0 meters.
   a) What is the truck's initial speed when it leaves the ramp?
   b) How long was the truck in the air?
   c) How far across the ground did the truck travel?

38. Young Billy Joe Bobby Brucey shoots a rock out of a sling shot at an angle of 41 degrees with the ground. The rock travels 78 meters before hitting the ground.
   a) What is the rock's initial speed?
   b) How long is the rock in the air?
   c) How high did the rock travel?

39. A cannon ball is fired from a cannon that it titled at a 33° angle with respect to the horizontal. The cannon ball travels 568 m down range. It also has a vertical velocity component of 60.12 m/s.
   a. How high did the cannon ball travel from the launch position?
   b. What was the cannon ball's initial velocity?
   c. How long was it in the air?
8 REVIEW QUESTIONS COVERING THE DIFFERENT SETUPS

40. While delivering toys Santa Claus slips off the top of a roof. At the edge of the roof he is traveling 12 m/s.
   a. How long is Santa in the air?
   b. How far from the edge of the house will he land?
   c. With what speed and direction will Santa impact the ground?

41. A roller coaster car travels off a hill while traveling downward.
   a. How much time does the roller coaster car spend in the air?
   b. How far from the edge of the broken track will the roller coaster car land?
   c. With what speed and direction will roller coaster car impact the ground?

42. A grape rolls off the top of the leaning tower of Pisa at 9 m/s. The tower is 80 m high and tilts at an 11° angle with the vertical.
   a. How long is the grape in the air?
   b. How far from the edge will the grape land?
   c. With what speed and direction will the grape impact the ground?

43. A dog is in a field catching a Frisbee. The dog leaves the ground at 7.53 m/s at an angle of 50° with the ground to catch a Frisbee at his apogee.
   a. How long was the dog in the air until it caught the Frisbee?
   b. How far, horizontally, did the dog jump to the location where he caught the Frisbee?
   c. How high did the dog jump?
44. Calvin was flicking pennies at Hobbes. One of his pennies flew upwards at 5.0 m/s at a 75° angle with the tabletop. When it landed, it was 0.75 meters higher than it started.
   a. How long was the penny in the air?
   b. How far, horizontally, did the penny travel?
   c. How high did the penny travel?
   d. With what speed and angle will the penny impact the counter top across the room?

45. Little baby Herman threw a green bean upwards with a velocity of 3 m/s at a 30° angle. The bean landed 1.25 meters below where it was thrown.
   a. How long was the bean in the air?
   b. How far, horizontally, did the bean travel?
   c. How high did the bean travel?
   d. With what speed and angle will the bean impact the ground?

46. A bug, 0.06 kg, bounces upwards off a windshield while traveling 55 mph, 26.5 m/s. The bug bounces at a 37° angle with the horizontal. The bug hit the windshield of a truck behind the car at a height of 0.82 m above the bounce.
   a. How long was the bug in the air?
   b. How far, horizontally, did the bug travel?
   c. How high did the bug travel?
   d. With what speed and angle will the bug impact the windshield?

47. While chasing the “Road Runner,” Wile E. Coyote makes a wrong turn and ends up sliding horizontally off the edge of a high cliff. He leaves the edge of the cliff while traveling 55 m/s. The cliff’s edge is 1505 m above a canyon floor.
   a. For how much time was the coyote in the air?
   b. Horizontally, how far did the coyote travel before impacting the canyon floor?
   c. With what speed and angle did the coyote impact the canyon floor?
Projectile Motion and Roller Coaster Hill Shape

A person throws 2 balls. The first ball it thrown horizontally at 10 m/s. The second ball is thrown at 40 m/s. Draw as much of each path as possible. Draw the ball’s position every second it is in flight. Draw a smooth line to show the curve’s shape. Any object that follows this path will feel weightless. The object is in “freefall.” Roller coasters have hills that are designed to follow this path.

<table>
<thead>
<tr>
<th>Time in seconds</th>
<th>Vertical Position with an $v_0 = 10$ m/s</th>
<th>Horizontal Position with an $v_0 = 10$ m/s</th>
<th>Vertical Position with an $v_0 = 40$ m/s</th>
<th>Horizontal Position with an $v_0 = 40$ m/s</th>
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Circular Motion (Non-Uniform: Polar Form)

**ANGULAR VELOCITY, ACCELERATION & ROTATION**

1. The wheel on a car rotates with an angular acceleration of 10 \( \text{r}/\text{s}^2 \). It the wheel starts from 20 \( \text{r}/\text{s} \), then...
   a) How fast will it be traveling after 20 seconds?
   b) How many rotations will the wheel have undergone?
   c) If the wheel’s radius is 35 cm, then what linear distance will the car have traveled?

2. An ice skater spins on one skate. If she starts with an angular velocity of zero and ends up with an angular velocity of 10 \( \text{r}/\text{s} \) in 1 second, then...
   a) What is her angular acceleration?
   b) How many rotations did she undergo in reaching 10 \( \text{r}/\text{s} \)?
   c) How long will it take for her to spin 50 times?
Circular Motion (polar form)

Rotational Momentum, Energy, Torque

**MOMENT OF INERTIA**

1. Calculate the moment of inertia of a solid merry-go-round like the type found in a child’s playground.

2. Find the moment of inertia for a spinning disk with 2 objects, (1 and 2,) resting on it.

3. Find the moment of inertia of the rod that is resting on top of a disk.
4. Find the moment of inertia of the rod that is resting on top of a disk.

\[ \text{Overhead view} \]

5. What is the moment of inertia if 4 people, average mass 50 kg, ride 1.00 m from the center of the merry go round mentioned in the problem above?

6. In the previous problem above a new person jumps on the merry go round. What is the mass of this person if the moment of inertia is now 675 kg\(\cdot\)m\(^2\) and the person is 1.55 m from the center?
7. (a) If the middle disk is dropped onto the bottom disk, then what is the new rotational velocity of the 2 disks. (b) If all of the disks and ball are dropped onto the bottom disk, then when is the new rotational velocity of the combination of pieces.

KINETIC ENERGY
8. If the merry go round in problem 3 spins at 10 m/s then what is it’s kinetic energy?

9. A ball is rolling at 15 m/s with a rotational kinetic energy of 500 J. If the ball’s radius is 1.2 cm, then what is its rotational inertia and mass?

10. What is the diameter of a rolling pin that rolls at 15 m/s with 500 J of rotational kinetic energy and has a mass of 10 grams?
11. A car rolls down a ramp as shown below. What is the moment of inertia of each of its wheels?

12. How fast is the granite ball rolling at the bottom of the incline - taking into rotational inertia account? It has a diameter of 3.55 m and drops from rest from a height of 3.10 m. Can Indiana Jones out run the boulder?

13. The Fred Flintstone’s Car. How much power is required to get Fred’s car moving? The car’s parts, minus the cylindrical wheels made of granite, is 311 kg. The wheels have a 1.24 m diameter and a length of 1.897 m.

14. A grinding wheel is rotating at 15 r/s. A chisel is sharpened on the wheel. It is slowing down at a rate of 3.50 r/s². What force was applied to the grinding wheel?

15. A string is wrapped around a disk as shown. A weight is attached to the end of the string and dropped. How long will it take to fall
   d) If the wheel exerts no torque to slow down the wheel.
   e) If the wheel exerts a resistive torque of 20.0 N•m
Circular Motion ( Uniform: non-polar )

**Students will be able to:**

1. Define the period of motion
2. Define the frequency for motion
3. Mathematically relate the period and frequency
4. Convert from RPM’s (revolutions per second) to Hertz
5. Use the definitions of period and frequency to solve word problems
6. Discuss the relationship between centrifugal and centripetal forces.
7. Describe why a person slides to the outside of a curve in a car as observed from inside the car.
8. Discuss what supplies the centripetal forces
9. Correctly write the units equations from memory
10. List the S. I. units associates with each quantity
11. Solve word problems utilizing the formulae and concepts in the unit.
12. Calculate the g’s felt by a rider in an amusement park when
   a. He/she is spun in a horizontal circle (carousel)
   b. He/she is spun in a vertical circle (roller coaster loops, playground swings.)
13. Describe why an irregular shaped roller coaster loop is better than a circular loop.
14. Solve problems based on an automobiles ability to supply a lateral acceleration and “cornering.”
15. Solve problems utilizing formulae and ratios.
Uniform Circular Motion (non-polar form)

**Formulae**

\[ v_T = \frac{2\pi r}{T} \]
\[ a_c = \frac{2\pi v_T}{T} \]
\[ a_c = \frac{v_T^2}{r} \]
\[ a_c = \frac{4\pi^2 r}{T^2} \]
\[ F_c = ma_c \]

\[ v_T = \text{tangential velocity} \quad \left[ \frac{m}{s} \right] \]
\[ a_c = \text{centripetal acceleration} \quad \left[ \frac{m}{s^2} \right] \]
\[ r = \text{radius} \quad \left[ m \right] \]
\[ F_c = \text{centripetal force} \quad \left[ N \right] \]
\[ T = \text{period of motion} \quad \left[ s \right] \]

*You are expected to memorize the material on this page.*

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<table>
<thead>
<tr>
<th>More dimensional analysis</th>
<th>Definitions (mathematically)</th>
</tr>
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<tbody>
<tr>
<td>360° = 2\pi \text{ Radians}</td>
<td>frequency = \frac{# \text{ of Cycles}}{\text{Time}}</td>
</tr>
<tr>
<td>1 Revolution = 360°</td>
<td>Period = \frac{\text{Time}}{# \text{ of Cycles}}</td>
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<tr>
<td>1 Revolution = 2\pi \text{ Radians}</td>
<td>RPM = \frac{\text{Revolutions}}{\text{Minute}}</td>
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<tr>
<td>1 Revolution = 1 \text{ Cycle}</td>
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<tr>
<td>1 Cycle = 360° = 2\pi \text{ Radians}</td>
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*You are expected to memorize the material on this page.*
Imagine sitting in the ceiling and looking down on a person spinning the bolo bear around. Below are eight different positions that the person let go of the string. Draw the direction the bear will travel for each position.
Go the the link below. Both links take you to the same page. one is just shorter than the other.
http://goo.gl/aZAZA
http://www.mrwaynesclass.com/teacher/circular/TargetPractice/home.html

Below is a diagram showing the locations of a ball that is being swung in a vertical circle when the string is cut. Draw the direction the ball travels for each position after pressing the button that looks like a pair of scissors. (The scissors button cuts the string.)
A plane flies in a horizontal circle. If the plane turns with twice the centripetal acceleration and 3 times the speed then how does the new period of motion compare to the old?

A rock is twirled around in a horizontal circle overhead. The centripetal force applied to the string is doubled and the period is halved while the rock’s mass remains unchanged. By what factor did the radius change?
Answer all questions in standard SI units.

**Frequency and Period Problems**

1. A turntable rotates an album at 33 revolutions per minute, RPM. What frequency is this?

2. A car’s engine spins at 1500 RPM. What is the frequency of the rotating engine?

3. Little Bobby Bolo noticed his bolo swung around his head 3 times every 1.40 seconds. What is the period and frequency is of the rotating bolo?

4. A baton twirler spins her baton 12 times in a second when it is tossed into the air. What is the period and frequency of the rotating baton?

5. Middle “c” on the musical scale has a frequency of 256 Hz. How many times a seconds is the sound wave vibrating?

6. Little Ms. Watchful noticed that some kids rotated on a carousel with a frequency of 0.66 Hz. How many times a second did the carousel rotate?

**Discussion Problems**

**Directions:** Pair up with a partner if possible and discuss the following situations in terms of ideas related to centripetal force and circular motion: Identify the direction of the centripetal force and the source of the centripetal force. Write down your conclusions for each problem on a separate sheet of paper.

7. Turns on a racetrack are banked inward.

8. An earth satellite will stay in orbit at some distance from the earth only if it going at the right speed.

9. If a satellite is going faster than the required speed, it will leave its orbit.

10. If a satellite slows down, it will fall to the earth.

11. It is difficult to make a sharp turn if a car is going very fast.

12. A small sports car can negotiate a winding road easier than a large car.

13. A centrifuge is used as a separator in lab.


15. A scale attached with a string to a mass shows a greater reading when the mass is swinging than when it is stationary.

16. A small bucket full of water can be swung in a vertical circle without the water spilling out.

17. Astronauts could experience variable g forces in a human centrifuge before manned rocket launches were tried.

18. Riding a bike without a rear fender though a puddle produces a spray of water down the rider's back.
**GENERAL PROBLEMS**

19. A children's carousel rotates 3 times every 2 seconds. The diameter of the carousel is 3.0 meters.
   - What is the period of motion?
   - What is the tangential velocity of the carousel?
   - What is the centripetal acceleration of the rider at the edge of the carousel?

20. When traveling down the road at a constant speed of 55 mph, 24.6 m/s, the tangential velocity of the wheels is also 55 mph. If a car's tire is 65.0 cm in diameter, then;
   - What is the period and frequency of the spinning car tire?
   - What is the centripetal acceleration of a rock stuck in the tire's tread?

21. Given that the Earth is $1.49 \times 10^{11}$ m from the Sun. And the earth's period of motion is 365.25 days. Calculate how fast it is revolving around the Sun. Put your answer in m/s.

22. Do the same thing for the Moon: Given it is $3.8 \times 10^{8}$ m from the Earth and revolves around the Earth every 27.31 days. Put your answer in m/s.

23. Given the Earth has a mass of $5.98 \times 10^{24}$ kg and the Moon has a mass of $7.34 \times 10^{22}$ kg, what centripetal force is necessary to keep each in orbit.

24. A bicycle wheel of radius 0.325 m rotates at a speed of 10.0 m/s (22.4 mph).
   - If a person is riding the bike, how fast are they traveling?
   - What is the frequency and period of rotation of the bicycle's wheel?

25. The time shaft ride at King's Dominion has a radius of 5.0 m and spins with a period of 1.3 seconds (only a guess).
   - What is the tangential velocity of the ride?
   - What is the centripetal acceleration of the ride?
   - How many g's is this?

26. An upright clothes washer spins clothes around 50 times in 20 seconds. Its radius is 0.30 m.
   - What is the period and frequency of the clothes dryer?
   - What is the tangential velocity of the clothes in the washer?
   - What is the centripetal acceleration of the clothes in the washer?

27. A car is traveling at 24.6 m/s (55 mph). The radius of the tire is 0.40 m. A rock is stuck in the tire.
   - What is the tangential velocity of the rock?
   - What is the centripetal acceleration of the rock?
   - What is the frequency and period of motion?
   - If the rock flies off the tire, how fast will it be traveling and how will its path of motion be related to the radius vector?
   - If the rock's mass is 0.0010 kg, what force holds the rock in the tread of the tire?
28. While playing with a HOT WHEELS race set, a child puts together 2 pieces of track on the loop-the-loop. Normally the loop-the-loop is made with only one piece of track. So now the circumference of the track is doubled.
   a. How is the radius affected?
   b. A car that supplies its own velocity runs along the loop-the-loop. If the same car is used on each size loop-the-loops, then;
      - How do the periods compare?
      - How do the centripetal accelerations compare?
      - How do the centripetal forces compare?

29. While playing Bolo-Master of the world, the radius the rock is twirled around with is held constant and the velocity is doubled a moment later.
   a. How do the centripetal accelerations compare?
   b. How do the periods of motion compare?

30. As a car goes around a flat curve, what supplies the centripetal force necessary for the car to go in a curved path?

31. A car spins out on an ice-covered road. The car’s length is 4 meters. The driver is 1 meter from the car’s spin center. The car spins 4 times around in 3 seconds.
   • What is the period and frequency of the spinning car?
   • What is the period and frequency of the driver in the car?
   • What is the tangential velocity of the driver?
   • What is the centripetal acceleration of the driver?
   • What is the centripetal acceleration in g’s?
32. In the movie Top Gun, an F-14 fighter jet gets stuck in a flat spin. The jet rotates such that the pilot, 4 meters from the plane's spin center, feels a centripetal acceleration of 6 g's. (The pilot's hand weighs 6 times as much as normal.)
   - What is the centripetal acceleration of the pilot in m/s²?
   - What is the period of motion of the pilot?
   - What is the tangential velocity of the pilot?

33. For every problem that describes a person's motion, calculate the centripetal force felt on each rider if their mass is 60 kg.

34. While playing "Bolo Master of the World" little Lisa was spinning a rock around her head on a string 1.32 m long. The rock travels around once every 1.43 seconds.
   (A) What is the speed of the rock?
   (B) What is the centripetal acceleration of the rock?
   (C) If the rock has a mass of 0.15 kg then, what is the centripetal force acting on the rock?

35. A racecar is traveling around a race at an average speed of 65.625 m/s (147 mph). The racecar takes 2 minutes and 44 seconds to go around the track once.
   (A) What is the centripetal acceleration of the car?
   (B) Is the car WEIGHS 7840 N, then what is the centripetal force acting on the car?
   (C) What do you think supplies the centripetal force to turn the car?

36. An ice skater spins with her hands stretched out from her body. Her hand is 1.12 meters from the axis she is spinning along. Her hands are spinning at 5.74 m/s.
   (A) What is the centripetal acceleration of her hand?
   (B) How many g's is your answer in (A)?
   (C) If her hand has a mass of 0.200 kg then what is the centripetal force acting on her hand?
   (D) How long does it take for her to spin around once?

37. A dog is chasing his tail. The radius of the circle that dog makes is 0.62 meters. The dog runs in a circle 10 times in 7.2 seconds.
   a) What is the period of motion of the dog?
   b) What is the speed of the dog?
   c) What is the centripetal acceleration of the dog?
Uniform Circular Motion (non-polar form)

d) If the dog has a bandanna tied to his neck, mass is 0.024 kg, then what is the centripetal force acting on the bandanna?

38 A merry-go-round travels with a tangential speed of 3.5 m/s. Its diameter is 34 m across?
  a) What is the centripetal acceleration of the merry-go-round?
  b) How long does the merry-go-round take to go around once?
  c) What is the centripetal force acting on a 45 kg rider 15 meters from the center of merry-go-round?

39 In an amusement park, there is a ride called the “Mexican Hat.” The ride is basically a big barrel that spins very rapidly. The rides rest standing up against the barrel’s wall. While spinning, the floor drops down while inertia holds the passengers in place.
  a. A rider feels a force associated with 2 g’s of centripetal acceleration when riding this ride. How fast is the ride spinning?
  b. How long does it take to complete one cycle of motion?
  c. How many times does the ride go around in 1 minute?

40. In an amusement park, there is a ride called the “Mad Hatter’s Teas Party.” The ride is basically a pair of teacups that spin very rapidly. The pair itself spin on a larger circle.

  a. How many g’s of centripetal acceleration does the rider feel at the outer most edge of the circle? (The radius at this point is the large radius plus the small circle’s radius.)
  b. How many g’s of centripetal acceleration does the rider feel at the inner most edge of the circle? (The radius at this point is the large radius minus the small circle’s radius.)
  c. Use an average velocity between the inner and outer most point to determine the time it takes for the passenger to spin around once in the smaller circle of motion.
41. For the circular loop, how many g’s are felt by the rider at the bottom of the loop as they enter the loop? (7.5 g’s)

43. For the circular loop, how fast is the roller coaster car traveling at the top of the loop? (13.1 m/s)

44. For the Spiral of Archimedes loop, how many g’s are felt by the rider at the top of the loop as they enter the loop? (2.5 g’s)

45. For the Spiral of Archimedes loop, how many g’s are felt by the rider at the bottom of the loop as they enter the loop? (2.3 g’s)

46. How fast is the car traveling if the passenger’s feel 1.5 g’s at the bottom of the road’s dip? (20.41 m/s)

47. How many g’s does the child on the swing feel if they are traveling as shown at the right? (1.32 g’s)
48. A roller coaster travels in a circular loop of radius 5.0 m. At the bottom of the loop the roller coaster car is traveling 25.00 m/s. At the top of the loop the roller coaster car is traveling 20.17 m/s.

![Diagram of circular loop]

a. What is the centripetal acceleration exerted by the track at the top and the bottom of the loop in g's.

b. How many g's are felt by the rider at the top and the bottom of the loop?

49. A roller coaster travels in a loop whose shape is irregular. The shape is called the spiral of Archimedes or Klothoid. The spiral of Archimedes is a circular shape whose radius changes as its height increases. This spiral has a radius of 5 m at the top.

![Diagram of spiral of Archimedes]

a. What is the centripetal acceleration exerted on the rider by the track at the top of the loop if the rider is traveling 20 m/s at the top in m/s².

b. How many g's are felt by the rider at the top of the loop?

c. If the track is to be designed so that the same number of g's are to be felt by the rider at the bottom of the track, what must the radius be?

d. If the rider’s mass is 70 kg, what centripetal force is exerted on the rider at the bottom?
The Berserker is a ride where the passengers are fastened into a "boat." The boat swings back and forth like a swing. Finally, it swings with so much speed that it makes a complete revolution. This ride is not a true example of the type of circular motion that we are studying because its tangential velocity decreases and increases as the ride swings up and down. However, we can still analyze parts of its motion if we ignore the period of motion and remember that it does travel in a circle. (Assume a “Dr. Seuss” world of physics)

The diameter of the Berserker is 25.1 m. When the Berserker reaches the bottom of the ride it is traveling with a speed of 22.2 m/s.

(a) What is the centripetal acceleration of the ride?
(b) How many g's does a rider feel at the bottom of the ride?

**Vehicular Applications**

50. A 1000 kg car travels around a turn whose radius is 302 m at 20 m/s.
   a. What is the centripetal acceleration of the car?
   b. What is the centripetal force applied to the car?
   c. How much time does it take for the car to travel around the curve if the curve is 90°?

51. A 500 kg car travels around a curve with a centripetal force of 2500 N. The curve’s radius is 200 m.
   a. What is the velocity of the car?
   b. What is the centripetal acceleration of the car?
   c. How much time does it take to complete the curve if the curve travels around 60°?
52. A 1500 kg car can travel around in a circle of radius 30 m at a maximum speed of 12.124 m/s.
   a. What is the car's centripetal acceleration in m/s²? (This is the maximum centripetal acceleration.)
   b. What is the car's lateral acceleration in m/s²?
   c. What is the car's centripetal acceleration in g's?
   d. The maximum centripetal acceleration for a car will remain the same for the car no matter what size circle it travels in. What is the maximum velocity this car could travel around a curve of radius 300 m?
   e. What is the quickest time this car could travel around a curve with a radius of 200 m and 45°?

53. Two cars are traveling around a two-lane curve as shown. The cars stay side by side around the turn. Therefore, the take the same amount of time to finish the 90° curve. The radius of curve “A” is 50 m. Curve “B” is 3.5 m longer. Car “A” is traveling at a constant velocity of 10 m/s. Car “A” has a mass of 1200 kg.
   a. How much time does it take for car “A” to finish the curve?
   b. How fast must car “B” travel to keep up with car “A”?
   c. What centripetal force must car “A” exert to make it around the curve without slipping?
   d. If car “B” is to exert the same centripetal force as car “A,” then what must car “B”’s mass be to make it around the curve in the same amount of time as car “A”?

Car's and Cornering Problems
Use your car's acceleration chart to solve the following.

55. What is the maximum velocity that a Lamborghini Diablo can go around a curve if it the curve has a radius of 50 m?

56. What is the maximum velocity that a Range Rover can go around a curve if it the curve has a radius of 50 m?

57. a. How much centripetal acceleration is needed so a car can go around a curve at 21 m/s if the curve’s radius is 50 m? (Answer in g's and m/s²)
   b. Which cars can navigate the curve without slipping?

58. What is the smallest radius curve that a “Nissan 300ZX” can travel around at 25 m/s.

59. How fast could a “Geo Metro LSI” take the same curve as the Nissan in #58?
Uniform Circular Motion (non-polar form)

60. Professor Layton was looking at an accident when he noticed something. He saw that the car traveled around a curve of radius 30 m at 15.43 m/s, 34.6 mph, before the car began to slip to the outside. Professor Layton sends this information to you in the crime lab. It is up to you to send him a list of possible cars that the perpetrator may have been driving. Using physics, which possible cars could the suspect have been driving?

61. In a court trial a suspect is accused of fleeing the scene of an accident. The suspect’s car is a dark green “Toyota 4Runner 4WD”. A witness testified that they saw a dark green vehicle traveling about 30 mph around the nearby corners. Could he have been at the scene of the crime?

62. A 1000 kg car can travel around in a circle with a centripetal acceleration of 0.7 g’s without slipping. When the car loses traction on a road, it exerts a centripetal acceleration of 0.3 g’s.
   a. What is the car’s centripetal acceleration in m/s² when it is not slipping?
   b. What is the car’s centripetal acceleration in m/s² when it is slipping?
   c. How big of a turn could the car turn at a constant velocity of 20 m/s without slipping?
   d. How big of a turn could the car turn at a constant velocity of 20 m/s when it begins to slip on a road?
   e. Here is the scenario. A car is going around a turn without slipping. Suddenly the tires begin to slip thereby reducing the centripetal acceleration. Assuming the curve has a radius equal to that in problem “c,” what velocity does the car need to travel at in order to safely navigate the same curve?
   f. In each problem (c,d,) how much time does it take to complete a turn of 180°?
Ratio's

Describe the how the first variable is affected assuming the changes mentioned in the other variables.

63. $a_C$: The velocity is constant while the radius is tripled
64. $T$: The velocity is constant while the radius is tripled
65. $v$: The acceleration is constant, the radius is halved
66. $T$: The acceleration is constant, the radius is halved
67. $F_C$: The velocity doubles and the period remains constant, The mass remains unchanged.
68. $v$: The radius is doubled and the period is tripled
69. $R$: The force is changed by a factor of $5/8$ and the period is changed by a factor of $3/2$. The mass remain unchanged.
70. $T$: The force changes by $3/7$ and the velocity changes by a factor of $3$. The mass remains unchanged.
71. $R$: The force changes by $3/7$ and the velocity changes by a factor of $3$. The mass remains unchanged.
72. $F_C$: The radius is tripled and the period changes a factor of $2/3$. The mass remains unchanged.
73. $a_C$: The velocity changes by a factor of $7/8$ and the radius changes by a factor of $6$
74. $T$: The radius is quadrupled and the force is tripled
75. $v$: The radius is quadrupled and the force is tripled
76. $r$: The acceleration changes by $1/4$ and the period changes by a factor of $5/6$
77. $r$: $a_C$ triples, v remains constant
78. $T$: $v$ changes by a factor of $3/8$, $R$ changes by a factor of $5/2$
79. $F_C$: The radius triples, the velocity remains constant. The mass remains unchanged.
80. $v$: $a_C$ remains constant, the time to go around once triples
81. $a_C$: the velocity changes by a factor of $4/6$, the radius is halved
82. $T$: the velocity changes by a factor of $2/3$, the centripetal acceleration changes by a factor of $5/4$
83. $r$: Centripetal force doubles, velocity triples, the mass remains unchanged.
84. $v$: Centripetal acceleration changes by a factor of $1/3$, period changes by a factor of $4/3
Kepler and Newton’s Law of Universal Gravity

Students will be able to:

- Define what an “Inverse Square” Law is.
- Use the generic inverse square law to solve word problems
- Define the formula for Newton’s Law of Universal Gravity.
- Calculate the gravitational pull between 2 objects with mass.
- Define the relationship between “g,” 9.80 m/s\(^2\), and The Law of Universal Gravity.
- Identify the relationship between centripetal force and gravity for orbiting satellites.
- Use the Law of Universal Gravity and Circular motion concepts to solve orbital mechanics problems.
- Define Kepler’s 3 Law of Planetary motion by number.
- When given the location of one object being orbited by a satellite in an eccentric elliptical orbit, identify the location of the other orbited body.

Givens: (Do not memorize.)

\[ G = 6.673 \times 10^{-11} \text{(N\cdot m}^2)/\text{kg}^2 \]

Body’s Radius 		 Body’s Mass

Earth’s Radius: 6.37 x 10^6 m 	 Earth’s Mass: 5.98 x 10^{24} kg 	 Orbit: 1.50 x 10^{11} m
Moon’s Radius: 1.74 x 10^6 m 	 Moon’s Mass: 7.35 x 10^{22} kg 	 Orbit: 3.85 x 10^8 m
Sun’s Radius: 6.96 x 10^8 m 	 Mass: 1.99 x 10^{30} kg

Another fine worksheet by T. Wayne
Circular Motion and Planetary Mechanics
( Kepler and Newton’s Law of Universal Gravity )

<table>
<thead>
<tr>
<th>Given: (Do not memorize.)</th>
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1. What is the force of attraction between a 60.0 kg student in the senior parking lot and the school? The distance between the two is 100.000 m and the mass of the school 65,000,000 kg.

2. You’re on a date with “the significant other.” You are getting close. Your centers of masses are 0.50 meters apart. If you have a mass’s of 50.00 kg and 70.00 kg then what is the actual scientific force of attraction between the two of you?

3. Two asteroids, \( m_1 = 1.00 \times 10^{12} \text{ kg} \) and \( m_2 = 5 \times 10^{12} \text{ kg} \), are floating in space. The force of attraction between them is 10.000 N. How far apart are their centers of mass?

4. In a car race, the force of attraction between the 1st and 2nd place cars is 3.0349 \times 10^{-7} \text{ N}. If the 1st place car has a mass of 700 kg and the 2nd place car has a mass of 650 kg, then what is the distance between the two cars?

5. While on the surface of the Earth a student has a weight of 450 N. If she is moved twice as far from the center of the Earth, then how does her new weight compare to her old?

6. How many Earth Radii distances could fit between the center of the Earth and the Center of the moon when it is in orbit around the Earth? If the same 50 kg student in problem #5 is moved out from the surface of the Earth to this distance away from the center of the Earth, then how does her new weight compare to her old?

7. An alien spacecraft is out in space leaving an unknown planet. It detects the pull of gravity due to this unknown planet to be 100 N. Later the alien rechecks the pull on their spacecraft when it is 9 times farther away from the surface. By what factor has their force of attraction changed since they left the unknown planet?

8. The space shuttle travels at 17,000 mph, 7,589.288 \text{ m/s} while in orbit. How far away from the \text{ SURFACE OF THE EARTH} is the shuttle?

9. How fast is the moon traveling as it orbits the Earth?

10. A geosynchronous orbit is one where a satellite orbits the Earth with the \text{ SAME} period of motion as the Earth on it own axis. How far from the center of the Earth is the Satellites orbit?

11. Using Kepler’s 3rd Law of Planetary motion, determine the distance between the center of the Earth and the center of the \text{ Moon}.
12 Using Kepler’s 3rd Law of Planetary motion, determine the distance between the center of the Earth and the center of the Sun.

13 A planet is in orbit as shown below. Where are the two possible locations for a Sun?

14 The moon Io revolves around Jupiter in 0.0048 years. Io has a mean orbital radius of 0.0028 Au’s. If another Jupiter moon, Europa, has a period of rotation of 0.0097 years, then how far away is Europa from the center of Jupiter?

15 The planet Mercury takes 0.24 years to go around the sun. What is the distance from the center of Mercury to the center of the sun?

16 The moon takes 27.32 days to revolve around the Earth once. The moon is 242,000 mi from the center of the Earth. The International Space Station orbits in the same orbit as the space shuttle. The International Space Station makes an orbit around the Earth in 90 minutes, then how high up is the International Space Station from the center of the Earth and the surface of the Earth? (The radius of the Earth is 3950 miles.) Why is this answer different from question #8?

17 The Planet Jupiter’s mean orbital radius is 5.2025 Au’s. What is the period of Jupiter in sidereal years?

18 The planet Pluto is 39.5 Au’s from the Sun. How long does it take to go around the Sun once?

19 There is belt of asteroids between Mars and Jupiter. This belt circles the “inside” of our solar system and is called the Asteroid belt. This belt has a mean radius from the Sun of 2.6 Au’s. How long does it take for 1 asteroid to in the belt to travel around the Sun once?

**ORBITAL VELOCITY**

20 A satellite is placed in an orbit 16,090,000 meters above the Earth’s Surface. How fast is the satellite traveling to remain in orbit?

21 A space ship is to orbit a planet with a mass of 8 X 10^{20} kg. How far, from the plant’s center, must the ship travel if it is to travel with a velocity 10,000 m/s?

22 A spacecraft is to orbit an asteroid of mass 5.00 X 1015 kg at a distance of 55,555 m from the asteroid’s center. What is the spacecraft’s period of motion and orbital velocity?

23 The Hubble Telescope orbits the Earth 596,000 m ABOVE THE SURFACE of the earth. What is the Telescope’s Period and tangential velocity?

24 A spaceship is traveling to a planet called Orpheus. The astronauts aboard the ship have a weight of 250 N at one point in their flight. Later they are 5 times closer than when they made the first weight measurement. What will be the new weight at this closer distance?

25 On the Surface of the Earth a test pilot has a weight of 965 N. In an effort to earn her astronaut wings, our pilot travels the necessary distance of 1 000 000 ft above the Earth’s surface to be recognized for astronaut wings.
   a. What is the ratio of the two radii?
   b. What was her weight at this altitude?

26 Calculate the value of “g” using the Earth’s radius and its mass.
Circular Motion and Planetary Mechanics
( Kepler and Newton's Law of Universal Gravity )

27 The Hubble Telescope orbits the Earth 598 km above the surface. How fast is it traveling to stay in its stable orbit?

28 At one time an infamous computer company had an idea to put its own satellite in a low orbit about 25 km above the Earth’s Surface. How fast would these satellites travel?

29 A communications satellite stays in the same spot in the sky above the Earth’s surface. It also takes 24 hours to complete a single orbit - just like the Earth’s rotation. This orbit is unique and called a “geosynchronous orbit.” How high above the Earth’s surface is the satellite orbiting?

**INVERSE SQUARE LAW**

30. A space ship is moved twice as far away from the moon. By what factor does the gravitational force of attraction change?

31. A space ship is moved to 1/3 the distance to the moon. By what factor does the gravitational force of attraction change?

32. By what factor would the gravitational force change by it the Earth was moved twice as far away from the Sun?

33. A space ship is moved to a position around the Moon where the force of gravitational attraction changes by a factor of 9. By what factor did the new distance to the Moon compare to the old?

34. A couple is sitting side-by-side. By what factor should the distance between them be changed by if the attractive force is to be halved?

35. A space ship is moved to a position around the Moon where the force of gravitational attraction changes by a factor of 1/5. By what factor did the new distance to the Moon compare to the old?

36. An asteroid feels a force of attraction due to its proximity to the Earth of 600 N. The Asteroid has moved to a new position where the gravitational force of attraction is now 4200N. By what factor did the distance between the ship and the Earth change?

37. While watching a concert, at the John Paul Jones Arena, you notice the distance between the speakers and the front row is 200 feet. You are sitting 500 feet away from the speakers. By what factor does sound intensity in your seat compare to the sound intensity in the front row?
ORBITAL MECHANICS

Below are the statistics for the solar system containing the snow covered planet “Hoth.” Hoth has 6 moons orbiting it and it is home to the Tauntaun snow beast. It is in the Anoat Sector of the Ivax Nebula. [ FYI: This is “Star Wars” stuff. ☺ ]

\[ G = 6.673 \times 10^{-11} \text{(N\cdot m}^2)/\text{kg}^2 \]

<table>
<thead>
<tr>
<th>Body’s Radius</th>
<th>Body’s Mass</th>
<th>Orbit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hoth’s Radius: 9.00 \times 10^7 m</td>
<td>Hoth’s Mass: ?</td>
<td>2.20 \times 10^{12} m</td>
</tr>
<tr>
<td>Moon #1’s Radius: 1.74 \times 10^6 m</td>
<td>Moon #1’s Mass: 2.35 \times 10^{22} kg</td>
<td>1.08 \times 10^8 m</td>
</tr>
<tr>
<td>Moon #2’s Radius: 3.33 \times 10^4 m</td>
<td>Moon #2’s Mass: 8.05 \times 10^{20} kg</td>
<td>8.91 \times 10^8 m</td>
</tr>
<tr>
<td>Hoth’s Sun’s Radius: 1.55 \times 10^7 m</td>
<td>Mass: 1.01 \times 10^{31} kg</td>
<td></td>
</tr>
</tbody>
</table>

38. Some intrepid scientists from the “Rebel Alliance” sent a 100.0 kg probe to Hoth. The probe landed on the surface of Hoth. On Hoth the probe had a WEIGHT of 595.627 N. What’s the mass of Hoth? (Answer: 7.23 \times 10^{26} kg)

39. How fast is Hoth traveling around it’s sun?

40. How many Earth years does it take for Hoth to travel around it’s sun once?

41. How fast is Hoth’s moon #1 traveling around Hoth?

42. What is the period of motion for Hoth’s moon #1?

43. Hoth has 6 moons. Unfortunately, due its distance from our observatories, it is difficult to measure all the statics of the other moons. One observatory measured the speed of Hoth’s moon #3 to be \(4.50 \times 10^4 \text{ m/s}\). How much time does it take for this moon to travel around Hoth?

44. Hoth’s moon #4 has captured 2 Asteroids. These asteroids have been named “Calvin” and “Hobbes.” Calvin orbits 4.44 \times 10^6 m from the center of moon #4 with period of motion of 32.5 Earth hours. Hobbes is more difficult to see. But its period of motion is 189.0 Earth hours. How large is the radius that Hobbes travels in?

45. What is the mass of moon #4 given the asteroid information in the previous question?

**Some Section Answers**

1. 2.6023 \times 10^{-5} \text{N}
2. 9.3416 \times 10^{-7} \text{N}
3. 5.774,945,887 m
4. 10.0 m
5. 1/4 the weight, therefore 112.5 N
6. \(60 \text{ N} = (1/60^2) \text{OLD}\)
7. 1/81 times the 100N
8. 54,7771.53 m (340 mi)
9. 1018.05 m/s
10. 4225942.3 m
11. 1/4 the weight, therefore 112.5 N
12. 1/81 times the 100N
13. 54,7771.53 m (340 mi)
14. 1018.05 m/s
15. 5.76 \times 10^{10} \text{m}
16. 437.65 miles
17. 11.87 \text{Au’s}
18. 248 sidereal years
19. 11., 12., 13., 19. 4.192 sidereal years
20. 4979.89 m/s
21. 5, 338,872

Another fine worksheet by T. Wayne 195
Calculating the mass of the Earth.

[A] We call the force of attraction between us and the Earth, “weight.” When you step on a scale, you are measuring the force of attraction between the Earth and you. The radius of the Earth is very well known. (It was first measured accurately by the Greeks using shadows at the vernal equinox.) Using these concepts and Universal Gravity, calculate the mass of the Earth.

[B] The space shuttle orbits the Earth about 417,000 m, 250 miles, above it’s surface. This is about 6,797,000 from the center of the Earth. How much time, in minutes, does it take to travel around the Earth?

[C] Using the information in [B] calculate the speed of the shuttle in m/s and miles per hour.
Circular Motion and Planetary Mechanics Class Examples

Given: (Do not memorize.)

\[ G = 6.673 \times 10^{-11} \frac{\text{N} \cdot \text{m}^2}{\text{kg}^2} \]

- Earth’s Radius: \(6.37 \times 10^6\) m
- Earth’s Mass: \(5.98 \times 10^{24}\) kg
- Orbit: \(1.50 \times 10^{11}\) m
- Moon’s Radius: \(1.74 \times 10^6\) m
- Moon’s Mass: \(7.35 \times 10^{22}\) kg
- Orbit: \(3.85 \times 10^8\) m
- Sun’s Radius: \(6.96 \times 10^8\) m
- Mass: \(1.99 \times 10^{30}\) kg

How much force is felt in each situation?

1. The Asteroid tractor. Suppose the proposed “Asteroid Tractor’s” 1000 kg end hovers 150 meters from a 50,000 kg asteroid. What force will the tractor pull with?
2. What is the pull of gravity on a person on the surface of the Earth if the person’s mass is 55.5 kg?
3. What is the period of motion for Earth’s moon?
4. What is the velocity of the Earth as it travels around the Sun?
5. How high above the Earth’s surface is a geosynchronous orbit?

Another fine worksheet by T. Wayne

197
Go to http://www.mrwaynesclass.com/gravity

A page with a simulation looking the one below should open up.

The spaceship can be dragged left and right with the mouse. The, “Nudge,” buttons can be used to easily move the spaceship small distances.

Your task is to work with a partner to figure out what affects the pull of gravity. You are to create an experiment to PREDICT how the pull of gravity will be affected by multiplying the distance by some number, “X,” and how the pull of gravity will be affected by changing the mass by multiplying it by a number, “N.” From these rules that you create you should be able to correctly answer the following questions.

1. If the initial force at some distance, r, is $1.00 \times 10^2$ N, then what is the force of attraction at a distance of exactly $3r$? ________________

2. If the initial force at some distance, r, is $1.00 \times 10^2$ N, then what is the force of attraction at a distance of exactly $4r$? ________________

3. If the initial force at some distance, r, is $1.00 \times 10^2$ N, then what is the force of attraction at a distance of exactly $\frac{1}{10}r$? ________________

4. How does the force of attraction change as the space ship is moved closer to asteroid, “Ida?”

5. If the initial force at some distance, r, is $1.00 \times 10^2$ N, then what is the force of attraction when the mass of asteroid, “Ida,” is halved? ________________

<table>
<thead>
<tr>
<th>DATA</th>
<th>F-factor</th>
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<tbody>
<tr>
<td>R-factor</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>1</td>
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<tr>
<td>$\frac{1}{2}$</td>
<td></td>
</tr>
<tr>
<td>$\frac{1}{3}$</td>
<td></td>
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<tr>
<td>$\frac{1}{4}$</td>
<td></td>
</tr>
<tr>
<td>$\frac{1}{5}$</td>
<td></td>
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</tbody>
</table>

The factor “r” changes by is given. However, the factor the force changes by will need to be calculated. Let’s say the original force is 200 N and the new force is 800 N. What number must 200 N be multiplied by to equal 800 N? This number is the factor the force changes by. In this case, $200 \times 4 = 800$. Therefore the force factor of change is “4.”
Universal Gravity Presentation Example Problems

6. If the initial force at some distance, r, is $1.00 \times 10^2$ N, then what is the force of attraction when the mass of asteroid, “Ida,” is tripled and the mass of the spaceship is doubled? ________________________________

7. If the initial force at some distance, r, is $1.00 \times 10^2$ N, then what is the force of attraction if the mass of asteroid, “Ida,” changes by a factor of 6, the spaceship’s mass is tripled and the spaceship is moved away from asteroid, “Ida,” to a distance of the spaceship is increased to 3r? ________________________________

8. By what factor has the spaceship’s distance, “r,” changed by if the masses are unchanged from the initial condition and the force of attraction has changed from $3,60 \times 10^2$ N to $4.00 \times 10^2$ N ________________________________
EXAMPLE 1
What is the pull of gravity on a person on the surface of the Earth if the person’s mass is 55.5 kg?

EXAMPLE 2
What is the period of motion for Earth’s moon?
EXAMPLE 3
What is the velocity of the Earth as it travels around the Sun?

EXAMPLE 4
How high above the Earth’s surface is a geosynchronous orbit?
Newton’s Law of Universal Gravity

Students should be able to:

- List the three basic types of harmonic motion and give an example of each.
- Identify the beginning and ending points for the pendulum arm’s length.
- Identify the name of the mass on the end of a pendulum.
- Describe what supplies the “restoring force” for a pendulum.
- Mathematically describe the effect of a pendulum’s mass on the period of motion.
- Mathematically describe the effect of the distance a pendulum is pulled back from its equilibrium position on the period of motion.
- Identify the variables used in the simple harmonic motion problems.
- Solve mathematical problems involving a pendulum’s harmonic motion’s formula.
- Solve pendulum problems utilizing ratio methods.
- Write the equation for a spring’s restoring force while identifying what each variable stands for and its units.
- Use a graph of restoring force versus displacement from equilibrium to calculate a spring force constant.
- Solve mathematical problems involving a spring’s restoring force formula.
- Mathematically describe the effect of the distance, a mass attached to a spring’s end, is pulled back from its equilibrium position on the period of motion.
- Solve mathematical problems involving a pendulum’s harmonic motion’s formula.
- Solve spring problems utilizing ratio methods.

74 A pendulum swings back and forth on the Earth once every 3 seconds. What is the length of the pendulum arm?

75 A pendulum arm is 0.5 meters long. How long does it take to go back and forth once?

76 A pendulum is placed on another planet. The pendulum’s arm is 2.0 meters long. The mass of the bob on the end is 0.30 kg. The time to swing back and forth once is 10 seconds. What is the acceleration due to gravity on this planet?
77 How long does a pendulum have to be to have a period of 1 second?

78 A child is swinging on a swing. The child takes 2 seconds to swing back and forth. The child’s mass is 35 kg. How long are the ropes holding the swing up?

79 The pendulum arm on a clock is to swing back and forth once every 0.5 seconds. The bob on the end of the pendulum is 20 grams. How long does the pendulum arm need to be?

80 Tarzan swings on a vine in the jungle. He takes 3.0 seconds to swing across a river once. How long is the vine?

81 Fuzzy dice hang from the rear view mirror of a car. They swing back and forth once every 0.85 seconds. How long is the string the dice are attached to?

82 The fuzzy dice from the problem above are taken to another planet. On this other planet the dice swing back and forth every second. What is the acceleration due to gravity on this other planet?

83 A wrecking ball swings into a house. The ball takes 4 seconds to swing across the yard and into the side of a building. How long is the cable attached to the wrecking ball?

84 Kings Dominion has a ride called the "Berserker". The "Berserker" swings back and forth. The length of the arms attached to the "Berserker" are 30 m. How long does the "Berserker" take to swing from one side to the other?

85 The Yo-yo Man is doing a stunt with a yo-yo called “Rocking the Cradle.” The yo-yo swings on the end of a segment of string 25 cm long. How long does it take to swing back and forth once?

86 If the Yo-yo Man does this exact trick in the moon where the pull of gravity is $1.67 \text{ m/s}^2$. How long will it take for the yo-yo to swing back and forth once?

87 If the mass of the yo-yo is quadrupled and the trick is done on the Earth, then what will be its period of motion?

88 A traffic light is swinging from its cable. It takes 3.6 second to swing back and forth 3 times how long is the cable holding the traffic signal up.

89 A cat catches a mouse by the tail. Upon catching the mouse, the mouse proceeds to swing back and forth 5 times in 3.173 seconds. How long is the mouse’s tail?

90 In a science fiction story a civilization inhabits the Earth long before man. This civilization is constructing plans to build a pendulum that will swing from a space platform. The pendulum will swing back and forth once every hour. How long is the pendulum arm in meters and miles?

91 A pendulum has a pendulum arm of length 3.3 meters. What is the pendulum's period of motion on the Earth and on the Moon ($g_{\text{moon}}=1.67 \text{ m/s}^2$)?
Newton's Law of Universal Gravity

92. What is the period of motion of a pendulum on the Earth that has an arm length of 0.5 meters?

93. What is the length of pendulum arm that has a period of motion of 1 hour?

94. Ned Numb-Skull took his pendulum clock with him to the moon. On the Earth the pendulum swung back and forth once every second. Was the clock faster or slower on the Moon than on the Earth? What was the period of motion on the moon? \((g_{\text{moon}}=1.67 \text{ m/s}^2)\)

95. A pendulum with an arm length of 2.25 m was taken to a spot on the Earth where the period of the pendulum is 3.44 seconds. What is the acceleration of gravity? Where do you think this spot might be?

RATIOS

96. Describe the effects on the period of motion when multiplying the mass on pendulum by 4.

97. Describe the effects on the period of motion when multiplying the length of a pendulum by 4.

98. Describe the effects on the period of motion when the gravitational pull on the pendulum is changed by a factor of 4.

99. Describe the effects on the period of motion when the pendulum's mass is tripled.

100. By what factor has the length on a pendulum bob changed if the period is doubled?

101. How has the acceleration due to gravity changed if the pendulum's period is held the same but its length has changed by a factor of 6?

102. By what factor has the length changed of a pendulum if the period has changed by a factor of \(1/3\)?

103. By what factor has the mass changed of a pendulum bob if the period has changed by a factor of 5?

104. By what factor has the period changed of a pendulum if the acceleration due to gravity is 6 times greater and the length is 1/2 of what is was?

105. By what factor has the length changed of a pendulum if the acceleration due to gravity is 6 times greater and the period is 1/2 of what is was?

106. By what factor has the length changed of a pendulum if the acceleration due to gravity is 1/2 times what it was, the period is 1/2 of what is was and the mass is doubled?
107. By what factor has the acceleration changed due to gravity if the length is doubled and the period has changed by a factor of 5?

108. By what factor has the period changed for a pendulum if the acceleration due to gravity is 1/2 times what it was and the length is also 1/2 of what it was?

109. Define what a spring constant is:

110. Compare and contrast the properties of two springs; one with a high spring constant and the other with a low spring constant.

111. A spring is stretch 0.10 m by a 30 N force. What is its spring constant?

112. A spring with a spring constant of 12 N/m is stretched 30 cm. What is the restoring force of the spring?

113. How far is a spring stretched if it has a spring constant of 200 and is stretched by a 20 N force?

114. A spring is stretched 0.01 m by a 25 N force. What is its spring constant?

115. A spring with a spring constant of 8 N/m is stretched 30 cm. What is the restoring force of the spring?

116. How far is a spring stretched if it has a spring constant of 10 and is stretched by a 20 N force?

117. What is the period of motion of a spring with a spring constant of 200 N/m, if a 10 newton weight is attached to it?

118. A spring is observed to oscillate at 10 seconds/oscillation. A 30 N weight is attached to it. What is the spring's spring constant?

119. A spring with a spring constant of 20 N/m oscillates with a period of 2 sec. How much weight is attached to the spring?

120. A spring in compressed 0.10 m by a force of 10 N. What is the spring’s force constant?

121. A spring is hung vertically from a horizontal beam. The spring is stretched 0.30 m by an object whose is weight of 50 N. What is the spring’s force constant?

122. What force stretches a spring, with a force constant of 100 N/m, 0.3 meters?

123. How far is spring stretched by a 20 N force. The spring's force constant is 5 N/m.

124. A plastic slinky is stretched by a 3.0 N force. The slinky has a force constant of 4 N/m. How far did the slinky stretch?

125. A retractable ball point pen has a spring connected to its “clicker.” The clicker moves 1 cm by a 8 newton force. What is the spring’s spring constant?
Newton’s Law of Universal Gravity

126 A child’s Nerf™ gun toy is “souped up” by replacing the spring. The spring’s force constant is 1000 \( \text{N/m} \) now. The spring is compressed by the Nerf™ dart 10 cm. What force is required to compress the spring in the gun.

127 Kangaroo shoes are shoes with spring attached to the bottom of them. An 80 kg person compresses the springs on each shoe 2.5 cm. What is the spring’s force constant on each shoe?

128 The spring in a pogo stick is compressed 8 cm by a 75 kg person. What is the spring’s force constant in the pogo stick?

129 Many push button switches have springs behind them. The springs are what move the buttons to its original position after being pressed. The push button on/off switch on a car stereo moves 1 millimeter when pressed by a 2 N force. What is the spring’s force constant for this button?

130 The sliding button on a disposable camera has a spring attached to it. How much force is required to move this spring if its force constant is 0.5 \( \text{N/m} \) and the switch moves 3 millimeters?

**Oscillation**

131 A spring is hanging from a post. It oscillates up and down 20 cm. It oscillates once every 0.5 seconds. If the mass attached to the end of the spring is 0.20 kg, then what is the spring’s force constant?

132 A spring with a force constant of 10 \( \text{N/m} \) is stretched 0.5 meters from its equilibrium position. The spring has a 2 kg mass attached to it. What is its period of motion?

133 A spring oscillates 10 times in 30 seconds. The spring’s force constant is 100 \( \text{N/m} \). What is the mass of the bob attached to the end of the spring?

134 A “Pogo Swing” is a 1.5 m long tube that has a spring attached to the top of it. The pogo swing attaches to a swing set in place of the swing. The user is allowed to bounce up and down. If the Pogo swing has a spring constant of 1000 \( \text{N/m} \) and the rider has a mass of 50 kg, then how long does it take to bounce up and down once?

135 In the 1970’s there was a special toy that consisted of a 1 m long spring attached to the ceiling. On the other end of the spring was a heavy plastic bird. A person is supposed to pull stretch the spring down and let go. The bird would then oscillate up and down. What force constant is necessary for a 0.75 kg toy bird to oscillate once every 0.60 seconds?

136 The shocks on a car have failed. Spring is also used to hold up the car. The car generally has 1 spring over each wheel. Therefore, the spring hold up, simplistically, \( \frac{1}{4} \) of the car’s mass. The car is pressed down, and the car begins to bounce up and down on its springs. If it takes 0.33 seconds to for a 1200 kg car to oscillate up and down once, then what is the force constant on the spring?

137 A popular baby toy is called a “Johnny Jump Up.” The Johnny Jump Up is a seat that a 12 month old would sit in. The seat is attached to a long spring that is connected to the frame of a door. If a 10 kg baby bounces up and down 10 times every 2 seconds, then what is the spring’s force constant?

138 In a crazy stunt, a jeep is dropped off a bridge. The car is attached to a long spring. Once dropped, the car bounces up and down once every 5 seconds. If the car’s mass is 2000 kg, then what is the spring’s force constant?
A paddleball is a small hand held paddle attached to a rubber ball by a 1 meter long piece of rubber. The elastic has a force constant of 10 N/m. If the ball’s mass is 0.10 kg, then how long does it take for the ball to go up and down once?

What is the effect on the period of motion if the bob mass on the end an oscillating spring is changed by a factor of 6/7 and the spring’s spring constant is tripled?

By what factor did the mass change by if the period is halved and the spring's force constant is quadrupled?

By what factor did the spring constant change by if the mass is changed by a factor of 16/9?

By what factor did the mass change if the spring constant is unchanged, the period is tripled and the distance the spring is pulled from equilibrium is tripled?

By what factor did the springs force constant change if its period was doubled, the mass attached to the end is changed by a factor of 5 and it is stretched twice as far as before from equilibrium?

By what factor did the mass attached to the end of an oscillating spring change by if the period changes by a factor of 3/4 and the spring's force constant changed by a factor of 3/16?
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<td>7.51 m/s²: Way above the surface of the Earth greater than mountains or passenger jets fly</td>
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Another fine worksheet by T. Wayne
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\[ \sqrt{6} \]

\[ \sqrt{21} \]
Newton's Law of Universal Gravity

Students should be able to:

- List the three basic types of harmonic motion and give an example of each.
  - **forced**
    - Pushing a person on a swing
    - Person "pumping" on a swing
    - Dribbling a basketball
    - Stereo speakers
    - Wave machine in a pool
    - Paddle ball
    - Rocking chair
    - Tacoma Narrows Bridge (Movie Clip)
  - **simple**
    - Coasting on a swing (short term)
    - A car antenna that "flops" back and forth (short term)
  - **damped**
    - Coasting on a swing long term
    - A car antenna that flops back and forth (long term)
    - Car shocks (Animation?)
    - stopping a swing from swinging (short term)

- Identify the beginning and ending points for the pendulum arm’s length.
  - define the center of mass
    - Meter stick
    - Meter stick with a clamp on it
    - Person’s balance point

- Identify the name of the mass on the end of a pendulum.
  - bob

- Describe what supplies the “restoring force” for a pendulum.
  - gravity
    - acts lineararly with an angle less than 10 degrees

- Mathematically describe the effect of a pendulum’s mass on the period of motion.
  - Ratio problems using the formula

- Mathematically describe the effect of the distance a pendulum is pulled back from its equilibrium position on the period of motion.
  - concept ... no effect b/c it is not in the formula

- Identify the variables used in the simple harmonic motion problems.
  - Inertia versus restoring force
    - T, L, g
• Solve mathematical problems involving a pendulum’s harmonic motion’s formula.

• Solve pendulum problems utilizing ratio methods.

• Write the equation for a spring’s restoring force while identifying what each variable stands for and its units.
  • \( F = -kx \)

• Use a graph of restoring force versus displacement from equilibrium to calculate a spring force constant.
  • Slope = \( k \)

• Solve mathematical problems involving a spring’s restoring force formula.
  • \( F = -kx \)

• Mathematically describe the effect of the distance, a mass attached to a spring’s end, is pulled back from its equilibrium position on the period of motion.
  • concept : no effect b/c it is not in the equation

• Solve mathematical problems involving a pendulum’s harmonic motion’s formula.
  • \( T, m, k \)

• Solve spring problems utilizing ratio methods.
Mechanical Energy Objectives

Mechanical Energy

**Students will be able to:**

1. For all equations, write what each variable stands for and its S.I. unit.
2. Identify the correct S.I. units for **ALL** forms of Energy.
3. Recall the name of the person who the energy unit is named after.
4. Write the equation for kinetic energy.
5. Define kinetic energy.
6. Identify when an object possesses kinetic energy.
7. Calculate the kinetic energy of an object.
8. Write the equation for potential energy due to gravity.
10. Identify when an object possesses potential energy.
11. Calculate the potential energy of an object.
12. Solve problems based on conservation of mechanical energy. -Neglect friction and normal forces.
13. Correctly identify the S.I. unit of “work.”
14. Define what “work” is.
15. Write the equation for “work.”
16. Calculate “work” when the force and displacement are parallel.
17. Calculate “work” when the force and displacement are not parallel.
18. Identify “work” as being positive or negative.
19. Identify “work” as being done “on” or “by” the system.
20. Calculate the work on a graph of force vs. displacement.
22. Write the equation for potential energy due to a spring.
23. Define potential energy due to a spring.
24. Identify when an object possesses potential energy due to a spring.
25. Calculate the potential energy due to a spring.
26. Solve problems involving all three types of energies and work.
27. Recall the person who the unit of power is named after.
28. Write the two equations for power.
29. Define power 2 ways – in terms of work and in terms of force.
30. Calculate the power delivered or received by an object.
Coasting at 5 mph

Coasting at 10 mph

No friction anywhere on the hill.

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Assume no friction

The coaster car is traveling at 15 m/s at “A.”

A

B

C

D

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A

B

C

D
Mechanical Energy

Assume no friction

The coaster car is traveling at 15 m/s at “A.”
Mechanical Energy

Assume no friction or air resistance.

Makes it around the loop. “B” and “E” are the same height.

The coaster car is traveling at 8 m/s at, “A.”

---

Another fine worksheet by T. Wayne
If you are having a difficult time envisioning this motion, watch this YouTube video, http://youtu.be/P52-nGXrrFQ.

The mass drops and the “wright Flyer” is launched.
Conservation of Mechanical Energy Example

Find the speed at the lowest point in the swinging motion.

\[ v = 8 \text{ m/s} \]

32m

12m
Mechanical Energy

**Work**

- **Force**
- **35°**
- **BOX**
- **d: Displacement**

*Another fine worksheet by T. Wayne*
Conservation of Mechanical Energy Example

Find the speed at a height of 52 m

\[ m = 550 \text{ kg} \]

\[ 18 \text{ m/s} \]

\[ 65 \text{ m} \]

\[ 52 \text{ m} \]

\[ 4.0 \text{ m} \]

\[ \text{STOP} \]

\[ d_1 \]

\[ d_2 \]

Another fine worksheet by T. Wayne
Ena G. (44kg) is trying to invent a new ride. She swings from a position 21 m above the ground and lands into a massless wagon 7 m above the ground. The wagon rolls for 11 meters until it comes to a rest. What is the magnitude of the stopping force?
Ena G. (44kg) is trying to invent a new ride. She swings from a position 21m above the ground and lands into a massless wagon 7m above the ground. The wagon rolls until it comes to a rest 4m above the left end of the ramp. The same frictional force stops the wagon. How far along the incline did the wagon travel?
Ena G’s swing starts from rest and drops down 5.00 until she collides with the horizontal, spring. What is the spring’s force constant if she compresses the spring 8.00 m to its maximum compression? Ena’s mass is 44.0 kg.
Kinetic Energy Basics
1. What is the kinetic energy of an 80 kg football player running at 8 m/s?

2. What is the kinetic energy of a 0.01 kg dart that is thrown at 20 m/s?

3. What is the kinetic energy of the space shuttle (mass = 68,000 kg) when it is orbiting the Earth at 13,000 m/s?

4. What is the kinetic energy of a bolt (0.002 kg) -lost off the space shuttle in a previous flight- floating in space at 13,000 m/s?

5. If the bolt lost off the space shuttle above hit an astronaut at 13,000 m/s, it would feel like a 105 kg running at what velocity? (Hint: Use energy to solve.)

6. What is the kinetic energy of a 20,000 kg locomotive traveling at 2 m/s?

7. How fast must a 0.0050 kg bullet travel if it is to have the same kinetic energy as a 20,000 kg locomotive traveling at 2 m/s?

8. How does the kinetic energy change if a car’s mass changes by a factor of 1/4?

9. How does the kinetic energy change if a car’s mass changes by a factor of 1/3 and changes its speed by a factor of 4/3?

10. The kinetic energy of a bicyclist changes by a factor of 2 while his velocity changes by a factor of 2. What factor did the rider’s mass change by?

11. By what factor did the velocity change by if the kinetic energy changed by a factor of 7/5 and the mass changed by a factor of 7/8?

12. How must the velocity change if the kinetic energy is to be quadrupled, and the mass changed by a factor of 4/6?

13. How must the velocity change if the kinetic energy is to be tripled, and the mass changed by a factor of 2/5?

Gravitational Potential Energy Basics
14. A 7.3 kg gallon paint can is lifted 1.78 meters vertically to a shelf. What is the change in potential energy of the paint can?
Mechanical Energy

15. A roller coaster car of mass 465 kg rolls up a hill with a vertical height of 75 m from the ground. What is the change in potential energy relative to the ground?
16. A 783 kg elevator rises straight up 164 meters. What is the change in potential energy of the elevator relative to the ground?
17. A car coasts 62.2 meters along a hill that makes a $28.3^\circ$ angle with the ground. If the car's mass is 1234 kg, then what is the change in potential energy?

18. A mountain climber scales a cliff that makes a $10.0^\circ$ degree angle with the vertical. The climber climbs 231 meters up along the cliff. What is the change in potential energy relative to the ground of the 823.2 Newton mountain climber?
19. An 18,000 kg jet, the F/A-18 "Hornet," climbs up at $75^\circ$ angle with the ground. The F/A-18 travels a distance of 8345 m. What is the change in potential energy of the F/A-18?
20 Class Practice

80 kg, 10 m/s

21 Class Practice

The engines flame out and the jet begins to coast at 250 m/s.

22 Class Practice

A bungie jumper drops down from the edge of a bridge. She falls 50 meters when the bungie cable begins to become taught.

Way to go, Idaho!
Mechanical Energy

Conservation of Potential and Kinetic Energy

23. How fast is the bicyclist traveling at the bottom of the hill?

24. a. How fast is the bicyclist traveling when she jumps off the ramp at 4 m?
   b. What is the maximum vertical height the bicyclist will reach?

25. What is the highest height Tarzan can travel to given the information above?

26. What is the jet’s new velocity if it coasts to its new, lower, altitude?

27. How much velocity did Calvin give the ball when he hit it?
28. A bicyclist is coasting on level ground at 32.25 m/s. The bicyclist coast up an incline and grabs an overhanging tree limb. How fast is the bicyclist traveling when he grabs the limb?

29. What is the velocity of the dropped package after falling 1500 m?

30. What is the velocity of the rider at the bottom of the swing?

31. A flying trapeze artist starts her swing from rest.
   a. How fast is she traveling at the lowest point?
   b. How fast is she traveling 3.33 meters below the starting height?
   c. If she drops from the lowest point of her swinging motion to a net 22.55 m below this lowest point, how far down will she have traveled, from the lowest point, before reaching a velocity of 15.22 m/s?
   d. How fast will she be traveling when she hits the net below?
   e. In a different acrobatic stunt, the trapeze artist is traveling 2.987 m/s when she is 1.322 m above her starting height. What was her initial velocity?
Conservation of Kinetic and Potential Energy

A bullet is shot into a can filled with 19.880 kg of clay. The filled can is tied to the end of a string so that it can act like a pendulum. The bullet (mass = 0.012 kg) is traveling 342 m/s before it impacts the clay filled can.

32. What is the mass of the can-bullet combination after the bullet strikes the can?
33. What is the kinetic energy of the bullet before it strikes the can?
34. What is the kinetic energy of the can-bullet when the can is raised to its maximum height?
35. What is the potential energy due to gravity when the can is at its maximum height?
36. What is the maximum height of the can?

A bullet is shot into a can filled with 19.88 kg of clay. The filled can is tied to the end of a string so that it can act like a pendulum. The bullet (mass = 0.012 kg) is traveling 342 m/s before it impacts the clay filled can. The bullet passes though the can. The bullet exits the back of the can at 325 m/s.

37. What is the maximum height of the can? (Assume no loss of energy due to friction.)
A roller coaster car, 500 kg, is to travel from 8 m/s down a wavy hill. It will coast without friction. Near the end of the ride it will make a death-defying jump.

38. What is the total energy of the system at the top of the hill?
39. What is the total energy of the system at the bottom of the hill?
40. What is the speed of the car at a height of 30 m?
41. What is the speed of the car at the bottom of the hill?
42. What is the speed of the car after landing on the 15 m hill?
43. How many g's does the rider feel as he enters the loop?
44. How fast is the rider traveling at the top of the loop?
45. How many g’s does the rider feel at the top of the loop?
46. Later a different rider travels into the loop at a different velocity. The rider feels 4.5 g's at the bottom of the loop as they enter it. How fast were they traveling?

A roller coaster rolls over the top of a hill with a speed of 10 m/s. The roller coaster's mass is 500 kg. (Ignore friction)
47. What is the speed of the roller coaster car half way down the hill?
48. What is the speed of the roller coaster car at the bottom of the hill?
49. What is the speed of the roller coaster car as it enters the loop?
50. How many g’s are felt by the rider as they enter the loop?
51. What is the speed of the roller coaster car when it is 10 m above the ground?
52. What is the speed of the roller coaster car at the top of the loop?
53. How many g's are felt by the rider at the top of the loop?
54. What is the speed of the rider at the bottom of the loop?
55. What is the speed of the rider as they enter the hill’s curve?
56. How many g’s are felt by the rider as they enter this part of the curve?
57. How high will the roller coaster travel until it comes to a stop?
58. How fast is the car traveling after rolling down the hill to the 5 m mark?
59. How fast is the car traveling after making the jump up to 14 m?
60. How fast is the car traveling as it enters the loop?
61. What is the centripetal acceleration at this point in the loop?
62. How many g’s does the rider feel at the bottom of the loop?
63. How fast is the car traveling at the top of the loop?
64. What is the centripetal acceleration at this point in the loop?
65. How many g’s does the rider feel at the top of the loop?
66. How fast is the car traveling at the very bottom?
The 800 kg roller coaster car begins the run traveling 31.3 m/s. It makes the jump and travels around the loop before going up the hill at the end. The coaster rolls up the hill until it comes to a rest. From there, it rolls backwards though the ride.

67. How fast is the car traveling after completing the jump?

68. How fast if the car traveling when is enters the loop?

69. How fast is the car traveling at the top of the loop?

70. What is the centripetal acceleration at top of the loop?

71. How many g’s is the centripetal acceleration at top of the loop?

72. How many g’s does the rider FEEL at the top of the loop?

73. How fast is the rider traveling at the bottom of the loop?

74. What is the centripetal acceleration at the bottom of the loop assuming the car is still barely in the loop?

75. How many g’s is the centripetal acceleration at the bottom of the loop assuming the car is still barely in the loop?

76. How many g’s does the rider FEEL at the bottom of the loop assuming the car is still barely in the loop?

77. What is the maximum height the car rolls up the hill?
A dog pulls a 40 kg wagon with a force of 300 N over distance of 50 m. How much work was done by the dog?

A car exerts a force of 10,000 N while driving on a horizontal stretch of road. How much work is done when the car travels 100 m?

A bucket is lifted out of a well by a 200 N force. If the well is 30 m deep, then how much work is done in lifting the bucket?

A 60,000 kg jet exerts a force of 1,000,000 N over a distance of 70 m. How much work is done by the jet?

A runner exerts 2,000 J of work while traveling 10 m along a horizontal stretch of track. How much force did the runner exert?

In order to insert a nerf dart into a toy gun, 50 J of energy needed to be exerted. It the dart was inserted 6 cm, then how much force was required to install the nerf dart?

A bicyclist exerted 30,000 J of work while traveling with a force of 10,000 N. How much distance was covered by the bicyclist?

A 1200 kg car is pushed by 3 people. Each person pushes with a force of 500 N. If the car is pushed 100 m, then how much work is done?

A St. Bernard dog pulls a 20 kg sled 50 meters with a 300 N force. The force act parallel to the ground. How much work does the dog do?

A 1500 kg does 20,000 J of work when is travels 200 m. How much force did the car exert, if the force acts parallel to the ground?

A model rocket exerted 1200 J of work in flight. If the rocket exerted 2 N of force, what is the maximum height the rocket can reach, without air resistance?

How much work is done by pushing a 100 kg box 5 m across a floor by a 20 N force?

How much work is done by a 500 N force that pushes a 1200 kg car 50 m if the car is moving 20 m/s when the force is applied? (The force is applied in the direction of motion.)

2000 J of work is done in running 50 meters. What average force does the runner exert?

A bullet penetrates 30 cm below the surface of water. If 2940 J of work is used to stop the bullet, then what is the stopping force? Ignore the effects of gravity?
93  A box is pushed by a 600 N force that acts at a 30° angle with the ground. The force pushes a 500 N box 10 meters from rest. How much work is done?

94  An 80 kg water skier is being towed behind a speedboat as shown to the right. The 600 kg boat travels 400 m. At the beginning of the run the boat is traveling 5 m/s. The force in the tether line is 2000 N. The boat travels with a net force of 4000 N. How much work is done by the tether on the skier?

95  A 100 kg dockworker pushes a 50 kg box across a floor. He pushes the box such that his arms are at an angle as shown below. How much work is done by the person on the box?

96  An 80 kg trucker loads a crate as shown below. He pushes the 40 kg box such that his arms are parallel to the ground. He pushes with a 100 N force. How much work is done by the trucker on the box?
97 Sidney, 60 kg, on a walk-about with his pet snake Cecil. Cecil’s weight is 5 kg. Cecil is pulling Sidney with 40 N force. (The two travel across a distance of 125 m.) They start their trip from rest. How much work is done by Cecil?

98 A 120 N sled & rider is pulled by a 200 N for 100 m. The force acts at a 60° angle with the ground. How much work is done by the applied force?

99 A 175 kg bobsled is stopped by a force applied at a 20° angle with the ground. The sled is stopped in 25 m with 800 J of work. What is the magnitude of the force?
A musket ball, 0.20 kg, is shot with a speed of 313 m/s into a metal can holding some clay. The musket ball penetrates 13.4 cm into the clay before coming to a stop.

100 What is the kinetic energy of the musket ball before it hits the clay if its mass is 0.20 kg?

101 How much work does the clay do in stopping the musket ball?

102 What average force does the clay exert in stopping the musket ball?

103 Using your answer in the previous problem, calculate the speed of the musket ball when it has penetrated the clay only 4.3 and 9.8 cm.

104 A 1500 kg car does 20,000 J of work when it accelerates across 200 m. The car starts from 20 m/s before traveling the 200 m. What is the final velocity of the car?

105 A 50 kg runner exerts 500 J of work while accelerating to a final velocity of 10 m/s in 50 m along the ground. What was the runner’s initial velocity?

106 A bullet, 10 g, is shot through a piece of wood. The bullet enters the wood at 600 m/s. The wood is 5 cm thick. The wood exerts 10,000 N of force to slow the bullet down. How fast is the bullet traveling when it leaves the piece of wood on the opposite side?

107 An 800 kg dragster finishes the race with some unknown velocity. A parachute is deployed after crossing the finish line and exerts a stopping force of 20,000 N across a distance of 300 m before the dragster slows down to 20 m/s. What was the speed of the dragster when it passes the finish line?
A bicycle stunt rider, 100.00 kg, is about to make a great jump over some buses. His bicycle exerts a force of 5,000 N in the direction of motion. He pedals along the entire distance shown. Given the diagram below, how fast will he be traveling when he leaves the ramp?

Wile E. Coyote is at it again. This time he is in a rocket boosted glider.

How much force is exerted by the boost motor if the glider is to leave the launch tower at 100 m/s?

How fast is the glider going to leave the launch tower if the glider’s boost motor exerts 5,000,000 J of work?

The Coyote is not having much success. So he trades in the glider for a jet. His launcher will now propel him using the spring and the force of the jet’s engines. The spring is compressed 25 meters along the launch tower and its force constant is 75,000 N/m. If the engine exerts a constant force of 90,000 N, then what is the velocity of the jet when it leaves the launch tower?

Suppose the launcher is at a 30° with the ground and the jet motor exerts the same force. What is the velocity of the plane as it leaves the ramp? (It is using the same spring as stated in the previous problem.)
Jet starts from rest

Force of jet

mass = 10000 kg

Jet moves 25 m

30°
Mechanical Energy

**POWER AND WORK**

746 watts = 1 horsepower (hp)

113 A 2800 kg car exerts a constant force of 20,000 N while traveling across 50 m. The car starts from rest.
(a) How much work is done by the car?
(b) How much power is exerted by the car, in watts and horsepower?

114 A student lifts a bucket with a 98 N force in 30 seconds out of a well at a constant velocity. If the bucket is lifted 30 m then;
(a) How much work is done on the bucket by the student?
(b) How much power is exerted by the student, in watts and horsepower?

115 A car 2400 kg is traveling down the road at 26.1 m/s. If the car accelerates up to 35 m/s over a distance of 200 m then
(a) How much work is done by the car?
(b) How much power is exerted by the car, in watts and horsepower?

116 After accelerating, the car mentioned in the previous problem now locks the brakes and skids to a stop in 350 m.
(a) How much work is done by the brakes?
(b) How much power is exerted by the car's brakes, in watts and horsepower?

117 A 1400 kg car travels up a 20° incline, as shown below. The car exerts a constant force of 30,000 N across and parallel to the 100 m incline. The car starts from rest at the bottom of the incline. The car takes 10 minutes to do this.
(a) How much work is done by the car?
(b) How much power is exerted by the car, in watts and horsepower?

118 A 0.050 kg arrow is accelerated by the bow from rest to a velocity of 140 m/s in 0.60 m.
(a) How much work is done by the bow?
(b) How much power is exerted by the bow?

119 A 30 g toy car exerts a constant force of 4 N while traveling over the hill shown below. It starts from rest.
(a) How much work is done by the car?
(b) How much power is exerted by the car?
120. What is the work done over the first 12 meters? Is it “on” or “by” the body?
121. What is the work done over the first 24 meters? Is it “on” or “by” the body?
122. What is the work done over the first 32 meters? Is it “on” or “by” the body?
123. What is the work done over the first 52 meters? Is it “on” or “by” the body?
124. How much work is done between 32 and 52 meters? Is it “on” or “by” the body?

125. How much energy is stored in the sling shot launcher when it is pulled back 30 cm?
126. How much energy is stored in the sling shot launcher when it pulled back 60 cm?
127. How much energy is stored in the sling shot launcher when it is pulled back 80 cm?
128. If the plane was pulled back 80 cm and it held horizontally -not like the above picture – then how fast would it leave the launcher?
If the plane were pulled back 80 cm and was held like the picture above, how fast would it leave the launcher?
The top picture shows the path the car follows. The graph describes the force that is produced by the car as a function of displacement along the shown path.

130 What is the car’s speed after traveling 30 m?

131 What is the car’s speed after traveling 50 m?

132 What is the car’s speed after traveling 100 m?

133 What is the car’s speed after traveling 120 m?

After 100 m, the car coasts without any non-conservative forces acting on it.

The top picture shows the path the car follows. The graph describes the force that is produced by the car as a function of displacement along the shown path.
A toy plane of mass is placed on a hand held launcher. The plane is pressed against a spring until it reaches the handle. Below is a force versus displacement graph for when the plane is compressed to the handle.

134 How much work is done in compressing the spring all the way back to the handle?

135 If the launcher is held horizontally and the 20.0 gram plane is fired off of it, then with what speed will the plane leave the launcher is the spring is completely compressed (to 0.0)?

136 What is the spring’s spring constant across the first 10 cm (from 0.25 to 0.15)?

137 If the launcher is held horizontally and the spring is completely compressed by being pushed back to 0.0 and the plane is fired off of it from rest, then with what speed will the plane be traveling at 15 centimeters from the equilibrium position?
The graph above is a force versus distance graph for a 300 kg Dr. Seuss mobile. The reason for the graph’s peculiar nature is due to a wrench left under the hood. The vehicle travels horizontally along the entire time.

138. How much work is done between 0 and 16 meters?
139. How much work is done between 16 and 40 meters?
140. How much work is done between 12 and 21 meters?
141. How much work is done between 5 and 12 meters?
142. How much work is done between 20 and 28 meters?
143. How much work is done between 18 and 32 meters?
144. What is the car’s speed after traveling from 0 to 16 meters if it started from rest?
145. What is the car’s speed after traveling from 0 to 21 meters if it started from rest?
146. What is the car’s speed after traveling from 0 to 40 meters if it started from rest?
The graph above is for a bicyclist’s ride on level ground. The bicyclist’s mass is 90 kg. The bicyclist starts from rest.

147 What is the work done over the first 12 meters?

148 What is the speed of the bicyclist after traveling 12 m?

149 What is the work done over the first 20 meters?

150 What is the speed of the bicyclist after traveling 20 m?

151 What is the work done over the first 32 meters?

152 What is the speed of the bicyclist after traveling 32 m?

153 What is the work done over the first 52 meters?

154 What is the speed of the bicyclist after traveling 52 m?

155 How much work is done between 32 and 52 meters?

156 Suppose at 52 meters the bicyclist rose to a path 5.00 meters above the starting height. How fast would they be traveling?

157 If the bicyclist drops 10.0 meters below the starting height at 52 meters. Then how fast would they be traveling?
The graph above is a force versus distance graph for a Dr. Seuss mobile. The reason for the graph peculiar nature is due to a wrench left under the hood. The vehicle’s mass is 500 kg.

158 How much work is done between 0 and 16 meters?
159 How much work is done between 16 and 40 meters?
160 How much work is done between 12 and 21 meters?
161 How much work is done between 5 and 12 meters?
162 How much work is done between 20 and 28 meters?
163 How much work is done between 18 and 32 meters?
164 What is the speed after traveling from 0 to 16 meters along the diagramed path?
165 What is the speed after traveling from 0 to 21 meters along the diagramed path?
166 What is the speed after traveling from 0 to 32 meters along the diagramed path?
167 What is the maximum height the car will travel to after traveling from 0 to 40 m?
168 How much work is done from location “A” to location “B”?

169 How fast is the car traveling at location “B”?

170 How much work is done from location “B” to “C”?

171 What is the velocity of the car at location “C”?

172 What is the velocity of the car cat at location “D”?

173 How many g’s are felt by the rider at location “D”?

174 How fast is the car traveling at location “E”?

175 How many g’s does the rider feel at location “E”?

176 How fast is the car traveling at location “F”?

177 How much distance is traveled from location “F” to location “G” if the car comes to rest at location “G”

**Answers to the “Work Coaster”**

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<thead>
<tr>
<th>Question</th>
<th>Value</th>
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*Another fine worksheet by T. Wayne*
Answer the following based on the coaster shown below.

178 At each number calculate the $E_T$.
179 At each number calculate the car’s velocity.
180 Calculate the acceleration due to each force in $\text{m/s}^2$ and g’s.
181 Calculate the acceleration felt by the car as it enters each vertical curve.

$m = 200 \text{ kg}$

10 Braking Force = 100 N

11 Braking Force = 100 N

8 Braking Force = 100 N

7 Accelerating Force = 800 N

6 Accelerating Force = 800 N

5

4 Braking Force = 200 N

3

2 Accelerating Force = 4000 N

1 Accelerating Force = 5000 N

0 Starts at rest.
**Mechanical Energy**

**The Jerk**

(A roller coaster for the fool in your life.)

The car accelerates up the hill here for these 15.0 meters according to graph “A.”

The engine propels the car forward for these 10.0 meters with a constant force of 4450 N.

The car’s brakes apply a stopping force of 400.0 N along a distance of 12.0 meters here.

---

Questions about “The Jerk” roller coaster

182 What is the velocity of the roller coaster car at location “B”?

183 What is the velocity of the roller coaster car at location “C”?

184 How much power in watts and horsepower is generated by the car as it travels from location “B” to “C.”

185 What is the velocity of the car at location “D”?

186 What amount of power is applied to the car to slow it down between location “D” and “E”?

187 What is the spring’s force constant?
187.1 Work summary problem

In another well thought out plan, and after hours of debate on the taxpayers’ dime, the city council decided to respond to an email from a Nigerian prince expressing a need for financial assistance for the Living Brain Donors of Nigeria. 5 council members volunteered for the race. The racetracks are horizontal unless it is described to be different. In the race, the 82kg councilman #1 and 58 kg councilwomen #1 started from rest. The 71kg mayor start with a speed of 1.5 m/s and traveled to the finish line 12.0 m away. Councilman #2, 65 kg, crossed the start line at 1.0 m/s and did 1100 J of work. However, his track ended 1 m higher than the other first two tracks. Councilwoman #2, 51kg, applied a constant force of 90.0 N for 8.0 m followed by applying the brakes with a force of 200N for the remaining 4.0 m after starting from 1.5 m/s. Councilwoman #2 ends up 0.5 m higher than the first two tracks. At the finish line everyone had to slow down because there was parking curb there to mark the end of the racecourse. In an effort to get the community involved they decided the winner will be determined by the person hitting the curb with the greatest speed. Unfortunately, they aren’t very good at rational thought, so they have brought this information to you to calculate who won the race.

![Graphs of force vs. displacement for The Mayor, Councilman #1, and Councilwoman #1]
Energy Flow Bar Charts

Wyle E. Coyote is still trying to catch that road runner - when will he learn? As part of this new ACME trap he throws a 200 kg ball down on a spring as shown to the right. The spring compresses 6.00 m

228. What is the spring’s spring constant?

\[ v_o = 5 \text{ m/s} \]

**Mass of the rider and bicycle = 80 kg**

Spring’s maximum compression
Spring Questions

189. What is the potential energy of a spring that is compressed 0.53 meters from equilibrium if the spring constant is 219 N/m?

190. What is the spring potential energy of a spring that is stretched 0.23 meters from equilibrium if the spring constant is 12 N/m?

191. What is the spring potential of a spring that is stretched 11.42 centimeters beyond equilibrium if the spring constant is 81 N/m?

192. What is the spring constant of a spring that is stretched 34.2 centimeters if 1298 J of energy is used to stretch the spring?

193. What is the stretched distance of spring with a spring constant of 12.5 N/m if the spring uses 127 J?

194. What is the spring constant of a spring that is stretched 123.2 cm while storing 93 J of energy in it?
A roller coaster car is to travel from rest down a wavy hill. Then it will coast without friction into the spring. The roller coaster will compress the spring until it comes to rest. The spring constant is 200 N/m. The mass of the roller coaster is 500 kg.

195. What is the total energy of the system at the top of the hill?
196. What is the total energy of the system at the bottom of the hill?
197. What is the total energy of the system before it hits the spring?
198. What is the total energy of the system when the spring is completely compressed?
199. What is the speed of the car at a height of 30 m?
200. What is the speed of the car at the bottom of the hill?
201. What is the speed of the car before it hits the spring?
202. What is the maximum distance the spring is compressed?
Death-Wish Hershey just finished his design of a new dare devil amusement park ride. The rider coasts down on a special bicycle. The rider starts from rest. This bicycle will not jump off the track. The track is frictionless. The spring constant is 1960 N/m and the mass of the bicyclist and bicycle is 80 kg.

203. How fast is the rider at the bottom of the hill?
204. How fast is the rider traveling halfway up the loop?
205. How fast is the rider traveling at the top of the loop?
206. How fast is the rider traveling at the bottom of the loop?
207. What is the maximum compression distance of the spring?
208. How fast will the rider be traveling when the spring is compressed 1/3 the maximum distance?
209. After the rider bounces off the spring and starts to roll backwards he applies the brakes. He applies the brakes as soon as the spring is back to its equilibrium position. If he is to come to a stop in the 160.0 meters before reaching the loop again, then what average force must the brakes must apply?
Below is a ride at Dr. Seuss’s amusement park in “Whoville.” Based on the information diagramed below. Answer the following questions.

210. What is the speed of the car at the top of the hill before it hits the spring?
211. What is the spring’s spring constant?
212. What is the speed of the car when the spring is compressed 5 meters?
213. At which compression distance of the spring is the speed of the car half of what was at the instant it hit the spring?
214. At which compression distance of the spring is the speed of the car half of what it was at the very beginning of the ride?
215. Suppose, by some weird quirk of Seuss’ Science, the spring bounces the car with 3 times the total energy it hit the spring with.
   a. What is the velocity of the car when it comes of the spring?
   b. What is the new velocity of the car at the very beginning of the ride?
The roller coaster’s car starts from rest.
Convert ALL heights to stories -even the ones given in the questions.
Put ALL speeds in m/s and mph.
Put ALL accelerations in m/s² and g’s.
Put ALL powers in watts and horsepower.
(NOTE - It takes 0.100 seconds to blink the human eye)

216. What is the speed of the car after it just looses contact with the spring at the top of the first hill?
217. What is the speed of the car when it is 18 meters above the ground?
218. What is the speed of the car as it enters the loop?
219. How many g’s are felt by the rider as the car enters the loop?
220. What is the speed of the car when it reaches the top of the loop?
221. How many g’s are felt by the rider at this point loop?
222. What is the speed of the car as the instant before it makes contact with the spring on the right?
223. What is the spring’s spring constant?
224. What is the speed of the car after the spring has been compressed 4.0 m from equilibrium?
225. What average force did the spring exert to stop the car?
226. How much time did it take to stop the car?
227. How much power was used by the spring to stop the car?
Wyle E. Coyote is still trying to catch that roadrunner - when will he learn? As part of this new ACME trap he throws a ball down on a spring as shown to the right.

228. What is the velocity of the ball the instant it makes contact with the spring?

229. What is the spring’s spring constant?

230. How fast is the ball traveling when the spring is compressed 2 meters from the equilibrium position of the spring?

In a later experiment, the coyote drops the ball. A different spring compresses 6 meters.

231. What is this spring’s spring constant?
Wile E. Coyote is at it again. This time he is in a rocket boosted glider.

232. The spring is compressed 25 meters. What is the spring’s spring constant if the glider leaves the launch tower at 100 m/s?

![Diagram of a glider with a spring](image)

233. The spring is compressed 25 meters. What is the spring’s spring constant if the glider is leave the launch tower at 100 m/s?

![Diagram of a glider with a spring](image)

233-B A bungie jumper drops from a tall bridge. The bungie cable is 50 m long when it is not stretched. The bungie jumper falls for 50 m until the bungie cord begins to stretch. The bungie cord stretches an additional distance of 35 m. If the bungie cord behaves like a spring, then what is the bungie cord’s “spring constant?” (Draw a picture of this problem.)
Write the math expression for the total energy relationships between the following locations: (Leave out an energy if its value is zero.)

1 & 2 \[ KE_1 + PE_1 = KE_2 \] <-- EXAMPLE ANSWER

1 & 3
2 & 4
3 & 5
5 & 6
5 & 7
3 & 7
1 & 9
Energy Flow
When answering these questions, anytime the answer is about “work” also describe the force that causes this work and the distance.

234. A ball rolls down a hill on the Earth. It starts from rest and rolls at 5 m/s when it reaches the bottom of the hill.
   a. What type of energies does it have at the bottom of the hill?
   b. What type of energy does it have at the top of the hill?
   c. Where did the energy at the bottom of the hill come from?
   d. In the real world are these two energies equal?
   e. Write a conservation of energy equation comparing the ball at the top and bottom of the hill.

235. In a cartoon Bugs Bunny is pretending to be a matador. At one point a bulls races towards Bugs Bunny. Bug’s grabs the bull by the horns, locks his elbows to keep his arms straight and he and the bull slide to a stop.
   a. What type of energy did the bull have before he ran into Bugs Bunny?
   b. When the bull stopped the energy had to go somewhere, where did it go?
   c. What force was responsible for removing the bull’s energy?
   d. Write a conservation of energy equation comparing the running bull and when the bull has stopped.

236. In a game of Tee-Ball, a baseball rests on a plastic stick that raises the ball to waist height. A player stands next to the ball and hits it with a bat. After being hit, the ball flies off the Tee into the field.
   a. What type of energy did the ball have when it was hit?
   b. Where did this energy come from?
   c. Write a conservation of energy equation comparing the resting ball and the ball after it has been hit.

237. An arrow is placed on a bow, The bow is drawn back and the arrow is fired straight up into the air.
   a. How much energy does the arrow have when it is resting on the bow?
   b. What type of energy does the arrow have when it begins to move upwards?
   c. What type of energy does the arrow have when it reaches the highest apogee?
   d. Where did the last two energies come from?
   e. Write a conservation of energy equation comparing the arrow’s energy when the bow is drawn back and when the arrow is at apogee.
1) 2560 J
2) 2 J
3) 5.746 x 1012 J
4) 169,000 J
5) 56.74 m/s, 127.09 mph
6) 40,000 J
7) 4000 m/s
8) Changes by 1/4
9) 16/27 = 0.592 repeating
10) 2
11) $\frac{2\sqrt{10}}{5} = 1.26$
12) $\sqrt{6}$
13) $\frac{\sqrt{30}}{2} = 2.74$
14) 127,3412 J
15) 341,775 J
16) 1,258,437.6 J
17) 356,607.75 J
18) 187,270.2 J
19) 1,421,898,840 J
20) Class
21) Class
22) Class
23) 16.025 m/s
24a) 13.357 m/s
24b) 13.102 m
25) 7.347 m
26) 662.116 m/s
27) 34.409 m/s
28) 28.97 m/s
29) 271.11 m/s
30) 5.4 m/s
31a) 10.551 m/s
31b) 8.079 m/s
31c) 6.139 m below the lowest point of 5.68 m
31d) 25.781 m/s
31e) 5.902 m/s
32) 20.000 kg
33) 701.78 J
34) 0
35) 701.78 J
36) 3.58 m
37) 0.486 m
38) 408,000 J
39) 408,000 J
40) 32.31 m/s
41) 40.398 m/s
42) 36.58 m/s
43) 6 g's
44) 6.26 m/s
45) 0 g's
46) 11.71 m/s
47) 26.23 m/s
48) 35.72 m/s
49) 35.72 m/s

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### Objectives

Another fine worksheet by T. Wayne

264
Momentum and Impulse

Students will be able to:

1. Define momentum.
2. Calculate the momentum of an object.
3. Describe the relationship between momentum and concept of inertia.
4. State the law of Conservation of Momentum 2 ways.
   - as $\Delta p$.
   - as before and after system p’s.
5. Define impulse in terms of
   - Force and time
   - Momentum
   - Mass & velocity
6. Identify the number of impulses in a given situation.
7. Describe the relationship between Newton's 3rd Law and Impulse.
8. Solve impulse momentum word problems using vectors.
9. Use impulse to solve word problems.
10. Calculate impulse from a graph of force versus time.
11. A

\[ M_R = 60 \text{ kg} \]
\[ M_B = 20 \text{ kg} \]
\[ V = 5 \text{ m/s} \]

Impulse: __________
Momentum of the bike: __________
Momentum of the rider: __________

11. B

\[ V_0 = 30 \text{ m/s} \]
\[ m = 0.150 \text{ kg} \]
Calvin catches the ball

11. C

Before

\[ V_0 = 20 \text{ m/s} \]
\[ m = 0.150 \text{ kg} \]

After

\[ V = 35 \text{ m/s} \]
Line drive - straight back at the pitcher.

11. D

\[ V_0 = 10 \text{ m/s} \]
\[ m = 0.1 \text{ kg} \]

The snow ball hits Susie on the head and sticks there.
**Momentum and Impulse**

**E**

**BEFORE**

\[ V_A = 10 \text{ m/s} \quad V_B = 2 \text{ m/s} \]

\[ M_A = 1000 \text{ kg} \quad M_B = 2000 \text{ kg} \]

**AFTER**

\[ V_A = ? \quad V_B = 4 \text{ m/s} \]

\[ M_A = 1000 \text{ kg} \quad M_B = 2000 \text{ kg} \]

**F**

**BEFORE**

\[ V_A = ? \quad V_B = 3 \text{ m/s} \]

\[ M_A = 1000 \text{ kg} \quad M_B = 2000 \text{ kg} \]

**AFTER**

\[ V_A = 2 \text{ m/s} \quad V_B = 4 \text{ m/s} \]

\[ M_A = 1000 \text{ kg} \quad M_B = 2000 \text{ kg} \]
G

**BEFORE**

\[ V_A = ? \quad V_B = 3 \text{ m/s} \]

\[ M_A = 2000 \text{ kg} \quad M_B = 4000 \text{ kg} \]

**UMPH**

**AFTER**

\[ V_B = 5 \text{ m/s} \]

\[ M_A = 2000 \text{ kg} \quad M_B = 4000 \text{ kg} \]

STICK TOGETHER

H

**BEFORE**

\[ V = 5 \text{ m/s} \]

\[ M_R = 60 \text{ kg} \quad M_B = 20 \text{ kg} \]

**Whoa!**

**AFTER**

\[ V_R' = 2 \text{ m/s} \quad V_B' = ? \text{ m/s} \]

\[ M_R = 60 \text{ kg} \quad M_B = 20 \text{ kg} \]
Hobbes, the stuffed tiger, has a mass of 31.8 kg. Calvin, the little boy, has a mass of 25.1 kg. In a game of football, Hobbes runs at Calvin at 11 m/s. Calvin is running in the same direction as Hobbes, away from Hobbes, at 8.33 m/s.

(a) If the two collide and stick together, what is their final velocity?
(b) What impulse is exerted on Hobbes by Calvin?
(c) What impulse is exerted on Calvin by Hobbes?
(d) If the collision occurred in 0.109 seconds, then what force was exerted on Hobbes?

Hobbes, the stuffed tiger, has a mass of 31.8 kg. Calvin, the little boy, has a mass of 25.1 kg. In a game of football, Hobbes runs at Calvin at 7.22 m/s. Calvin is running at Hobbes.

(a) If the two collide, stick together, and are then at rest, what was Calvin’s initial velocity?
(b) What impulse is exerted on Hobbes by Calvin?
(c) What impulse is exerted on Calvin by Hobbes?
(d) If the collision occurred in 0.0600 seconds, then what force was exerted on Hobbes?
Calvin & Hobbes, 45 kg, are sleigh riding down a hill. The hill they are on is irregular shaped, slopes up and down and has snow of varying depths and textures. Below is a force vs. time graph of the force acting on their sled. The initial velocity when they hit the part of the hill depicted on the graph at 11 m/s.

(a) How do you find the impulse from 30 to 60 seconds?
(b) Which 30 seconds time interval contains a net negative impulse?
(c) What is the impulse from 30 to 60 seconds?
(d) What is the impulse from 90 to 120 seconds?
(e) What is the impulse from 150 to 180 seconds?
(f) Using the information from text above combined with the graph; calculate the final velocity at the 60-second mark.
(g) Calculate the final velocity at the 120-second mark.
(h) Calculate the final velocity at the end of the ride?
(i) What was the average velocity for the entire ride?
(j) What is the (average) acceleration over the entire ride?
(k) What must the initial velocity be so that Calvin and Hobbes come to a rest at the end of the ride?
A toy car, 3.0 kg exerts the force shown on the graph.

Express all answers in standard S.I. units.

(a) What is the change in speed from 1 to 2 minutes?

(b) What is the change in speed from 2 to 3 minutes?

(c) If the final velocity at 3 minutes is 10 m/s, then what is the initial velocity at 2 minutes?

(d) If the initial velocity is of the car is 5 m/s at 1 minute, then what is the velocity of the car at 2 minutes?

(e) If the car starts from rest at 0 minutes, then what is the velocity of the car after the first 4 minutes?

(f) What is the momentum of the car at 3 minutes if the car started from rest?
Momentum and Impulse

To the right is a force versus time graph for a child’s toy car. The toy is malfunctioning and is producing the force shown.

37 What is velocity of the toy car, 0.756 kg, after 20 seconds if it starts from rest?

38 What is velocity of the toy car, 0.756 kg, after 20 seconds if it starts from 10 m/s?

To the right is a force versus time graph for a child’s toy dart gun. The toy is malfunctioning and is producing the force shown.

39 What is the mass of the dart if the change in velocity is 25 m/s during the 20 s?

To the right is a force versus time graph for an automobile.

40 If the partially loaded tractor-trailer truck is traveling 20 m/s when a force accelerated it to 30 m/s after 15 seconds, then what is the mass of the truck?
In an effort to impress his physics class, Mr. Meanor has been working on another cow launcher featuring Tessie his “tea cup” cow. Tessie’s mass is 155.5 kg. In a test run of his launcher, the machine launches Tessie with the force diagrammed below. It takes 2.0 seconds for Tessie to travel along the launcher. Not wanting to hurt Tessie, Mr. Meanor has designed a large soft, foam pit for Tessie to land in. The foam pit stops Tessie with a force of magnitude 533.33 N. How much time does the foam pit take to stop Tessie?
Momentum and Impulse

Momentum, \( p \), is the product of \( mv \). The mass and velocity must be put in standard SI units.

1. What is the momentum of a 70 kg runner traveling at 10 m/s?
2. What is the momentum of a 800 kg car traveling at 20 m/s?
3. What is the momentum of a 47 gram tennis ball that is traveling at 40 m/s?
4. What is the momentum of a 120 pound bicyclist that is traveling at 25 mph?
5. What is the momentum of a 1500 pound car that is traveling 5 mph?
6. What is the speed of a 0.050 kg bullet that is to have the same momentum as the car in problem #5?
7. What is the speed of a 60 kg runner that travels with the same momentum as the car in problem #5? (Answer in m/s and mph).

8. What is the momentum of a 453 gram football that is thrown with a speed of 30 m/s?
9. How fast must a 150 g baseball be traveling to have the same momentum as the football in problem #8? (Answer in m/s and mph)

Changes in momentum, \( \Delta p \). \( \Delta p = mv_{\text{final}} - mv_{\text{initial}} \). Direction counts! If the object switches directions then the \( \Delta p \) is added.

10. What is the change in momentum of a 950 kg car that travels from 40 m/s to 31 m/s?
11. What is the change in momentum of a 40 kg runner that travels from 5 m/s to 11 m/s?
12. A mud blob, 0.350 kg, is thrown at a wall at 10 m/s. The blob sticks to the wall. What is the change in momentum of the blob?
13. A 0.095 kg tennis ball is traveling 40 m/s when it bounces of a wall and travels in the opposite direction it came from. It left the wall with a speed of 30 m/s. What is the change in momentum of the ball?
14. A baseball, 167 grams, is pitched at 50 m/s when is hit by the batter. The ball travels in the opposite direction it was thrown from with a speed of 70 m/s. What is the change in momentum of the baseball?
15. In a football game a 70 kg player is running at 10 m/s when another player hits him. When the other player hits him he bounces off in the opposite direction at 5 m/s. What is the player’s change in momentum?

IMPULSE \( (J = Ft = \Delta p) \)

16. If the runner, in #11, took 30 seconds to change its speed, then what force caused the change?
17. If the car, in #10, took 2 minutes to change its speed, then what force caused the change?

18. How much time was taken to stop the blob in #12 if the mud blob was stopped by 400 N force?

19. Contact with the ball in #13 lasts for 0.05 seconds. What force caused the ball’s change in speed?

20. The baseball in #14 is hit by a 1608 N force. How long is the ball in contact with the bat?

21. When the two players collide in #15, their contact took 0.05 seconds. What force did each player in the collision exert?

22. Baseball pitcher throws a fastball with a 100 Ns impulse. If he applied the force in 0.15 seconds, what force did he apply?

23. A hockey puck is hit by a hockey player at the goalie. The puck is hit with a 1200 Newton force. The stick made contact for 0.1 seconds. What impulse was given to the puck?

If a goalie stopped it with a force that acts for 0.65 seconds, then what force did he apply?

24. In a lacrosse game a ball is thrown with a force of 2000 N. The throwing force acted for 0.8 seconds. Another player stopped the ball in 0.3 seconds with their helmet. What force did their helmet use to stop the ball?

25. A 1000 kg car crashed into a bearer. The car changed speed from 30 m/s to 20 m/s in 2 seconds. What force did the bearer apply to stop the car?

26. A 60 kg skateboarder accelerated from 5 m/s to 12 m/s. She applied a force of 4200 N. How quickly did she accelerate?

27. An outfielder stops a ball that is originally hit with an impulse of 2000 Ns. The ball's mass is 0.25 kg. What was the ball's change in speed when the outfielder stopped it?
Specific Impulse

Model rocket engines are marked by a letter, a number, hyphen, and another number. The first number is the thrust of the motor in Newtons, the second is the time delay between when the motor burns out and the ejection charge is ignited. Figure out what the letters stand for.

Calculate the impulse for each of the graphs that represent the rocket motors thrust time curve.

28. THE A5-3

[Graph of thrust time curve]

29. THE B5-3

[Graph of thrust time curve]

30. THE C5-3

[Graph of thrust time curve]
31. THE D5-3

DRAW AN FORCE VERSUS IMPULSE GRAPH FOR THE FOLLOWING ROCKET MOTORS

32. THE D12-3

33. THE B6-5
Momentum and Impulse

34. THE A8-3

35. THE 1/2A3-4

36. THE B6-6
ELASTIC COLLISIONS

37. Two cars collide head on. Car A has a mass of 1000 kg car B has a mass of 2000 kg. What is the speed of car B after the collision?

\[ M_A = 1000 \text{ kg} \quad M_B = 2000 \text{ kg} \]
\[ V_A = 5 \text{ m/s} \quad V_B = 2 \text{ m/s} \]
\[ V_A' = 3 \text{ m/s} \quad V_B = ? \]

38. Two cars bump going the same direction. Car A has a mass of 1000 kg car B has a mass of 500 kg. What is the speed of car A after the collision?

\[ M_A = 1000 \text{ kg} \quad M_B = 500 \text{ kg} \]
\[ V_A = 6 \text{ m/s} \quad V_B = 2 \text{ m/s} \]
\[ V_A' = ? \quad V_B = 4 \text{ m/s} \]
39. Two skateboarders collide while traveling in the same direction. Skateboarder 1 has a mass of 70 kg and skateboarder 2 has a mass of 55 kg. What is the speed of skateboarder 2 after the collision?

\[
\begin{align*}
&\text{BEFORE} & & \text{AFTER} \\
&V_1 = 6 \text{ m/s} & & V_1' = 4 \text{ m/s} \\
&M_1 = 70 \text{ kg} & & M_2 = 55 \text{ kg} \\
&V_2 = 5 \text{ m/s} & & V_2 = ?
\end{align*}
\]

Oh my!?

40. Two football players collide head-on. The defensive player has a mass of 100 kg and the offensive player has a mass of 90 kg. What is the speed of the offensive player after the collision?

\[
\begin{align*}
&\text{defense} & & \text{offense} & & \text{defense} \\
&100 \text{ kg} & & \leftarrow & & \rightarrow \\
&6 \text{ m/s} & & 2 \text{ m/s} & & 1 \text{ m/s}
\end{align*}
\]

INELASTIC

41. A loaded train freight car (10 metric tons) rolls at 2 m/s towards a resting car (mass = 2 metric tons). Upon collision, the two cars couple (lock together).

a. What is the speed of the two cars after the collision?
b. Calculate the impulse felt by each car.

42. A loaded train freight car (10 metric tons) rolls at 2 m/s towards another freight car. The second freight car is traveling towards the first at 3 m/s. Its mass is 15 metric tons. Upon collision, the two cars couple (lock together).

a. What is the speed and direction of the two cars after the collision?
b. Calculate the impulse felt by each car.

43. In the previous problem, suppose the initial velocity of the 15 metric ton car was not known. After the collision the two cars came to a rest.

a. What was the speed of the second freight car before the collision?
b. What impulse was felt by each car?
44. Two cars collide in a head on collision. They lock together.

\[ \begin{array}{cc}
1200 \text{ kg} & 1500 \text{ kg} \\
28 \text{ m/s} & 20 \text{ m/s}
\end{array} \]

a. What is the speed and direction of the two cars after the collision?
b. Calculate the impulse felt by each car.
c. If the collision lasted 0.7 seconds, what force is felt by each car?

45. Two football players collide. The offensive player, mass = 100, was running at 8.00 m/s. A defensive player catches up to the offensive player from behind. The defensive player was traveling 11 m/s when he tackled the other player.
a. What was the speed of the two players after the collision?
b. What impulse is felt by each player?
c. If the collision lasted 0.05 seconds, then what was the force felt by each player?

46. Two football players collide head-on. The defensive player has a mass of 100 kg the offensive player has a mass of 90 kg. What is the speed of the two players after the collision if they don’t separate?

\[ \begin{array}{cc}
100 \text{ kg} & \langle \langle \text{-} 90 \text{ kg} \\
6 \text{ m/s} & 2 \text{ m/s}
\end{array} \]

47. Two cars collide and then stick together in an accident. Car A has a mass of 1000 kg car B has a mass of 2000 kg. What is the speed of the cars after the collision?

\[ \begin{array}{cc}
1000 \text{ kg} & \langle \langle 2000 \text{ kg} \\
5 \text{ m/s} & 2 \text{ m/s}
\end{array} \]

48. Two cars bump going the same direction and stick together. Car A has a mass of 1000 kg car B has a mass of 2000 kg. What is the speed of the cars after the collision?

\[ \begin{array}{cc}
1000 \text{ kg} & \langle \langle 2000 \text{ kg} \\
5 \text{ m/s} & 2 \text{ m/s}
\end{array} \]
49. Two vehicles collide as shown below. For each collision calculate:
   (a) ...the unknown velocity.
   (b) ...the impulse on vehicle “A.”
   (c) ...the impulse on vehicle “B.”
   (d) ...the force of the collision given the times shown. -When shown.

   **[A]**
   \[\text{BEFORE} \quad 3 \text{ m/s} \]
   \[\begin{array}{c}
   \text{25,000 kg} \\
   \text{A} \\
   \end{array} \quad \begin{array}{c}
   \text{2 m/s} \\
   \text{1200 kg} \\
   \text{CRUNCH} \\
   \end{array} \quad \begin{array}{c}
   \text{1 m/s} \\
   \text{? m/s} \\
   \end{array} \quad \begin{array}{c}
   \text{25,000 kg} \\
   \text{A} \\
   \end{array} \quad \begin{array}{c}
   \text{1200 kg} \\
   \end{array} \quad \text{AFTER}
   \]

   \[t = 0.224 \text{ sec} \]

   **[B]**
   \[\begin{array}{c}
   \text{255 m/s} \\
   \text{A} \\
   \end{array} \quad \begin{array}{c}
   \text{145 m/s} \\
   \text{B} \\
   \end{array} \quad \begin{array}{c}
   \text{BOOM} \\
   \end{array} \quad \begin{array}{c}
   \text{? m/s} \\
   \end{array} \quad \begin{array}{c}
   \text{15,000 kg} \\
   \text{A} \\
   \end{array} \quad \begin{array}{c}
   \text{34,000 kg} \\
   \text{B} \\
   \text{STUCK TOGETHER} \\
   \end{array} \quad \text{t = 0.00541 sec}
   \]

   **[C]**
   \[\begin{array}{c}
   \text{11.2 m/s} \\
   \text{KA-BOOM} \\
   \end{array} \quad \begin{array}{c}
   \text{5.36 m/s} \\
   \end{array} \quad \begin{array}{c}
   \text{? m/s} \\
   \end{array} \quad \begin{array}{c}
   \text{2512 kg} \\
   \text{A} \\
   \end{array} \quad \begin{array}{c}
   \text{1122 kg} \\
   \text{B} \\
   \end{array} \quad \text{KA-BOOM}
   \]

   **[D]**
   \[\begin{array}{c}
   \text{15.3 m/s} \\
   \text{BA-BANG} \\
   \end{array} \quad \begin{array}{c}
   \text{2.33 m/s} \\
   \end{array} \quad \begin{array}{c}
   \text{7.52 m/s} \\
   \text{?? m/s} \\
   \end{array} \quad \begin{array}{c}
   \text{3125 kg} \\
   \text{A} \\
   \end{array} \quad \begin{array}{c}
   \text{755 kg} \\
   \text{B} \\
   \end{array} \quad \text{BA-BANG}
   \]

\[\text{BEFORE} \quad \text{AFTER} \]
[E]
The Baltimore Cannon Club tried to recreate Jules Verne’s cannon/rocket ship. They cast a canon 402 m long to fire the projectile. Given the charge, they calculated a muzzle velocity of 15,800 m/s.

[F]
A student is sitting on a lake of frictionless ice at rest. (How he got there nobody knows.) To slide to the other side, he throws his boot.

Additional question: If he has to slide 9.43 m to get to the other side and he slides at a constant velocity, then how much time will it take to reach the shore?

[G]
\[
\begin{align*}
20 \text{ m/s} & \quad \quad 5 \text{ m/s} \\
3125 \text{ kg} & \quad \quad 2155 \text{ kg} \\
\text{BA-BANG} & \\
3125 \text{ kg} & \quad \quad 2155 \text{ kg} \\
\end{align*}
\]

\[ t = 0.0242 \text{ sec} \]

Calculate the time of the launch assuming the projectile accelerates at a constant rate from rest.

\[
\begin{align*}
A & \quad \quad 7540 \text{ kg} \\
15800 \text{ m/s} & \\
B & \quad \quad 138000 \text{ kg} \\
?? \text{ m/s} & \\
\end{align*}
\]
50. A toy car experience the force graph above as it travels from 2 m/s to 20 m/s during the first 3 seconds of the graph. What is the mass of the car?

51. A large truck slows down according to the force graph above. The car’s initial velocity is 35 m/s. After 10 seconds, what is the truck’s final velocity if its mass is 11,000 kg?

52. What is the magnitude of the average force that slowed the truck mentioned in the previous problem?

53. A device shoots a heavy rock. The device is very dramatic and takes 15 seconds to launch the rock according to the force graph above. If the rock has a mass of 50 kg, then what is the change in velocity of the rock across after the 15 seconds above?

54. How much force did this take?
These problems combine previously taught concepts with impulse and momentum

55. A car and a truck collide as shown. But before the collision, the car rolled down a hill from rest. The hill has a height of 0.46 meters. What was the speed and direction of the car after it collided with the truck?

56. In a parking lot, two cars collide as shown. The driver of the red truck says that he was traveling at less than 1 m/s when he hit the car in front of him. He knows this because his truck can accelerate 10 m/s$^2$ from rest and he only pressed in the accelerator pedal for 0.1 seconds. The truck has been taken back to CSI central and tested. It does accelerate at 10 m/s$^2$ from a rest. Using the information below, and your smarts about physics, determine if it took more or less than 0.1 seconds to accelerate to the collision speed.

57. A boy and girl on skateboards are at rest touching hands. In one motion they push off of each other as shown below. If the frictional force slowing them down is 200 N, how much does each person travel until he or she comes to a rest?

58. In a tennis match, a ball hits a bird as shown below. After hitting the bird the ball falls 15 m to the ground. What speed was the ball moving with when it hit the ground?

59. A cue ball hits a billiard ball as shown below. The billiard ball was hit by a cue stick. Assuming the billiard ball started from rest before accelerating to the impact velocity, then how much time was the billiard’s cue stick in contact with the ball if it moved 0.50 cm while making contact with the cue ball?

60. A 145 gram baseball is traveling at 45 m/s when it collides head on with a 0.92 kg bat moving at 29 m/s. The bat make contact for with the ball for 0.000402 seconds. After contact with the ball the bat is moving at 15.8 m/s. The ball travels straight to the pitcher, 18.288 m away. Assuming the ball decelerates at 5 m/s$^2$, calculate how much time the ball took to reach the pitcher.
## Momentum and Impulse

### ANSWERS

<p>| | | | | |</p>
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<tbody>
<tr>
<td>1)</td>
<td>700 kg•m/s</td>
<td>2)</td>
<td>16,000 kg•m/s</td>
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</tr>
<tr>
<td>4)</td>
<td>607.39 kg•m/s</td>
<td>5)</td>
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<td>6)</td>
<td>30,369.29 m/s</td>
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<td>9)</td>
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<td>12)</td>
<td>3.5 kg•m/s</td>
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<td>15)</td>
<td>1050 kg•m/s</td>
<td>16)</td>
<td>285 N</td>
<td>17)</td>
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<tr>
<td>18)</td>
<td>0.00875 s</td>
<td>19)</td>
<td>133 N</td>
<td></td>
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<td></td>
<td>35)</td>
<td></td>
<td>36)</td>
</tr>
<tr>
<td>37)</td>
<td>-1 m/s</td>
<td>38)</td>
<td>5 m/s</td>
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<tr>
<td>40)</td>
<td>3.56 m/s</td>
<td>41a)</td>
<td>5/3 m/s</td>
<td>41b)</td>
</tr>
<tr>
<td>42a)</td>
<td>-1 m/s</td>
<td>43b)</td>
<td>± 20,000 N•s</td>
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<td>1.33 m.s</td>
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<td>44c)</td>
</tr>
<tr>
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<td>45b)</td>
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<td>3142.86</td>
<td>46)</td>
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<tr>
<td>48)</td>
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<td>49[A]b)</td>
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<tr>
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<td>22.55 M/S LEFT</td>
<td>49[B]b)</td>
<td>4,163,265.31N•s</td>
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<tr>
<td>49[B]c)</td>
<td>-4,163,265.31N•s</td>
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<td>769,549,964 N</td>
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<tr>
<td>49[C]a)</td>
<td>24.57 m/s</td>
<td>49[C]b)</td>
<td>18,581.32 N•s</td>
<td></td>
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<tr>
<td>49[C]c)</td>
<td>-18,581.32 N•s</td>
<td>49[C]d)</td>
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<tr>
<td>49[D]a)</td>
<td>46.87 m/s</td>
<td>49[D]b)</td>
<td>OMIT</td>
<td></td>
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<tr>
<td>49[D]c)</td>
<td>OMIT</td>
<td>49[D]d)</td>
<td>OMIT</td>
<td></td>
</tr>
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<td>49[E]a)</td>
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<td>49[E]b)</td>
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<td>49[E]c)</td>
</tr>
<tr>
<td>49[E]d)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49[F]a)</td>
<td></td>
<td>49[F]b)</td>
<td></td>
<td>49[F]c)</td>
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<tr>
<td>49[F]d)</td>
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</table>
Fluid Dynamics

1. Define a fluid, gas, density, and pressure.
2. Give the standard S.I. units for the new concepts above.
3. Define the value in understanding pressure though applications.
4. Define one atmosphere of pressure in Pascals.
5. Explain how a barometer works.
6. Define “Pascal’s Principle.”
7. Explain when to use Pascal’s Principle to solve problems.
8. Explain the various applications of pressure.
9. Compare “hydraulics” and “pneumatics”
10. Define “pressure at depth.”
11. Describe what happens to a bubble’s size as it moves about in fluid.
12. Define gauge pressure two ways.
13. Describe what affects the pressure at the bottom of a fluid.
14. Explain application of this pressure at depth.
15. Describe why water towers are made the way they are.
16. Define the continuity equation.
17. Use the continuity equation to solve problems.
18. Define Bernoulli’s equation.
19. Apply Bernoulli’s equation to solving problems.
1. The circular top of a can of soda has a radius of 0.0320 m. The pull-tab has an area of $3.80 \times 10^{-4} \text{ m}^2$. The absolute pressure of the carbon dioxide in the can is $1.40 \times 10^5 \text{ Pa}$. Find the force that this gas generates
   a. on top of the can (including the pull-tab’s area) and
   b. on the pull-tab itself.
2. High-heeled shoes can cause tremendous pressure to be applied to a floor. Suppose the radius of a heel is $6.00 \times 10^{-3} \text{ m}$. At times during normal walking motion, nearly the entire body weight acts perpendicular to the surface of such a heel. Find the pressure that is applied to the floor under the heel because the weight of a 50.0 kg woman.
3. A cylinder is fitted with a piston, beneath which is a spring, as in the drawing. The cylinder is open at the top. There is no friction. The spring constant of the spring is 2900 N/m. The piston has negligible mass and a radius of 0.030 m. When the air beneath the piston is completely pumped out,
   a. how much does the atmosphere’s pressure cause the piston to compress?
   b. How much work does the atmosphere to in compressing the spring?
4. The Mariana trench is located in the Pacific Ocean and has a depth of approximately 11,000 m. The density of seawater is approximately 1025 kg/m$^3$. 
   a. If a diving chamber were to explore such depths, what force would the water exert on the chamber’s observation window (radius = 0.10 m)?
   b. For comparison, determine the weight of a jumbo jet whose mass is $1.2 \times 10^5 \text{ kg}$.
5. A water tower has a vertical pipe that is filled with water. The pipe is open to the atmosphere at the top. The pipe is 22 m high. At the bottom of this pipe is a hole with a cork in it.
   a. What is the pressure at this hole when the cork is in the hole?
   b. What is the pressure when the cork is removed and the water is allowed to squirt onto the ground?
6. A buoyant force of 26 N acts on a piece of quartz that is completely immersed in ethyl alcohol. What is the volume of the quartz? $\rho_{\text{ethanol}} = 785.06 \text{ kg/m}^3$
7. Oil is flowing with a speed of 1.22 m/s though a pipeline with a radius of 0.305 m. How many gallons of oil (1 gal = $3.79 \times 10^{-3} \text{ m}^3$) flow in a day?
8. A small crack forms at the bottom of a 15.0 m high dam. The effective crack area though which the water leaves is $1.00 \times 10^{-3} \text{ m}^2$.
   a. What is the speed of the water flowing though this crack?
   b. How many cubic meters of water per second flow though the crack?
9. An airplane wing is designed so that the speed of the air across the top of the wing is 248 m/s when the speed below the wing is 225 m/s. The density of air is $1.29 \text{ kg/m}^3$. What is the lifting force on a wing that is rectangular and 2 m x 10 m?
10. Water is running out of a faucet, falling straight down, with an initial speed of 0.50 m/s. At what distance below the faucet is the radius of the stream reduced to half of its original radius at the faucet?

**ANSWERS**

<p>| | | | |</p>
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<th></th>
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<tbody>
<tr>
<td>1)</td>
<td>a. 450 N</td>
<td>b. 53.2 N</td>
<td>5) ???</td>
</tr>
<tr>
<td>2)</td>
<td>$4.33 \times 10^6 \text{ Pa}$</td>
<td>6) $3.3 \times 10^{-3} \text{ m}^3$</td>
<td>9) $1.40 \times 10^5 \text{ N}$</td>
</tr>
<tr>
<td>3)</td>
<td>0.097 N</td>
<td>b. 14 J</td>
<td>7) $0.356 \text{ m}^3/\text{kg}$, $8.12 \times 10^6 \text{ gal}$</td>
</tr>
</tbody>
</table>
11. A fireboat is like a fire truck that travels on the water. In 1933 a fire boat could shoot a stream of water vertically 111 m, (that's higher than a football field is long,) out of one of its water canons with a diameter of 0.075 m.
   a) How much gauge pressure is generated behind the water cannon to accomplish this task?
   b) How many m$^3$/s could this water cannon shoot?

12. At a water park a water slide drops a height of 25.0 meters. The water at the top of the slide is ejected horizontally at 9.00 m/s.
   a) How fast is the water traveling at the bottom of the slide assuming the slides diameter does not change.
   b) How much gauge pressure is generated behind the nozzle at the top of the slide where the water comes out?

13. In an experiment, one of the captains was convinced by a university to attach a crab-callers to the crab pot in an effort to draw crabs to the pot. The crab-caller is a speaker with a recording of some crabby sounds. However when the crab-callers were retrieved, every single one was crushed.
   a) If the Golden King Crabs were at a maximum depth of 700 m below the surface, then how much gauge pressure was generated by the ocean, $\rho_{\text{ocean water}} = 1024$ kg/m$^3$.
   b) If the speaker in the crab-caller had a diameter of 0.100 m, then how much force acted on the crab-caller when it was under water.
   c) Is this force more or less than the weight of 2017 "Honda Odyssey" van?

14. In order to get a loveseat home, a buyer decides to hold it in place while driving 18 m/s along the road. If the couch has a cross-sectional area of 2.00 m$^2$, then how much force acts on the couch?
Fluid Dynamics

15 A NASCAR race car is designed to generate down force to help hold it to the track. According to the 2017 rules a car at 110 m/s can not generate more than 1600 lbs, (7170 N,) of down force. This is in addition to the weight of the car when it is at rest. The down force comes from the fact that a NASCAR vehicle is designed to move like an upside down airplane wing. If a Dodge Charger, (5.083 m long by 1.890 m wide,) travels such that the air across the top of the car is moving at 110 m/s, then how fast is the air moving underneath the car?

16 A DC-3 is a 60+ year old airplane that can lift up to a maximum of 114,300 N. The wings have a surface area of 91.7 m². If the plane is flying at 150 m/s, then how fast is the air flowing over the top of the wings which this maximum load? (Note: In reality Bernoulli’s equation only accounts for a very small amount of a plane’s lifting force.) Assume the planes flying speed is the speed of the air underneath the wings.
Fluids Review

1. In a famous 1887 Michelson–Morley experiment, a disk made of sandstone, density of 2710 kg/m$^3$, that was 1.80 m in diameter and 25 cm thick was floated in a 1.90 diameter pool of mercury, density 13,560 kg/m$^3$, that was 20.0 cm deep. This giant floating stone disk could spin with nearly no resistance when pushed. What is the net force on the floor of the pool containing all of these pieces? (Answer: 94,200 N)

2. A jeep with ragtop was traveling down the road at 26.0 m/s. The windows, doors and vents were closed. If the rag top has a surface area of 3.00m$^2$, then how much force was applied to try to lift the rag top up. (Answer: 1310 N)

3. The water pressure at your house is created by storing water in a water tower that elevates the water many meters above your house. It the gauge pressure of the water at your house is 413,685 Pa, when the faucets are closed, then how high above your house is the top of the water in the tower? (Answer: 42.2 m)

4. Fluid flows through the pipe at the right. As it does it also rises up into the vertical tubes. Draw the relative heights of the fluid at the other locations along the pipe. (If you have not printed out this sheet, just draw the 4 vertical pipes on a piece of paper and show their water lines.)

5. For the problem at the top of this page, what percentage of the sandstone is below the fluid line of the mercury? How many centimeters of the sandstone disk is above the fluid line? (Answer: 5 cm)

6. Water is pumped up from a river to a sink faucet in a house by a pump on the river. The house’s faucet is 25.0 m above the river.
   a. How much gauge pressure is at the pump when the water is pumped up the faucet in the house when when the faucet is closed? (Answer: 245,000 Pa)
   b. How much gauge pressure is at the pump when the faucet is open and water is flowing out a 5.0 m/s? (Answer: 257,500 Pa)
7. A 95.0 kg human will have a volume of about 0.095 m$^3$. If this human exhales the air out of their lungs and stands on a scale in chlorinated water, density 990 kg/m$^3$, then what will the scale read in Newtons? (Answer: 9.31 N)
Fluid Dynamics

**demo vacuum bazooka**

\[ m_{\text{ball}} = 2.8 \text{ g} \]

\[ 3.80 \text{ cm} \]

\[ 1.25 \text{ m} \]

\[ P_{\text{inside}} = \frac{1}{10} \text{ atm} \]

\[ P_{\text{outside}} = 1 \text{ atm} \]

How fast is the ping pong ball traveling when it exits the tube?
The opening on garden hose has a diameter of 2.54 cm. and water lands 0.500 m away from the opening when the hose is held horizontally 1.25 m above the ground. If your thumb is placed over the opening such that the effective diameter of the opening is reduced to 0.500 cm, then where will the water land on the ground now?
Pressure at Depth

Find the pressure felt on the middle of the ball at depth “h.”

Find the pressure felt on the middle of the ball at depth “h.”
At location 1 the river is 6 m wide and 2 meters deep. At location 2 the river is 2 meter wide and 0.75 meters deep. If the current is 1 m/s at location 1, then how fast is the current in the river at location 2?
Bernoulli’s Equation

Bernoulli’s Equation is the conservation of energy as applied to ideal fluids.
The water enters the slide with a small velocity.
Wind speed = 75 mph

\[ \rho_{\text{air}} = 1.275 \frac{\text{kg}}{\text{m}^3} \]

This house has its doors and windows shut. Its roof has a thickness of about zero. How much force is generated to lift the roof?
Electrostatics

Students should be able to:

1. Define and list Insulators
2. Define and list Conductors
3. Describe the "charge model"
4. Describe charging due to induction
5. Describe charging due to charge sharing
6. Ben Franklin’s Kite experiment.
   a. Describe what lightning was though to be prior to June, 1752.
   b. Describe its importance.
7. Lightning Safety
8. Define a FARADAY cage
9. Give examples of a Faraday cage
10. Solve problems involving charge sharing
11. Describe the ionization of gasses
12. Describe the ionic wind
13. Define an E-Field.
14. Draw an electric field (E-field) between two charged objects
15. Identify the charge of an object based upon its E-field
16. Describe the direction a positively or negatively charged object will travel when immersed in an E-field
17. List the rules for drawing an E-field
18. Describe the relative E-field strengths between two objects based upon their E-fields
19. Define the SI units of an E-field
20. Calculate the magnitude of the force felt on a charged particle when immersed in an E-field
21. Use the relationship $F=QE$ in solving word problems
22. Ratio problems
23. Numerical evaluation problems
24. Draw the symbol for a battery
25. Label the positive and negative terminals on a battery symbol
26. Define what is meant by electrical “current.”
27. Give the symbol for current.
28. Describe in physics terms what a dead battery represents
29. Describe the recharging of a battery
30. Calculate how long a battery will last before becoming dead or how long it will take to recharge a battery.
31. Use $V=Ed$ in solving word problems
32. Use the relationship $V=Ed$ in solving word problems
   a. Ratio problems
   b. Numerical evaluation problems
33. Define an “electronVolt” and use it in calculations
DRAWING ELECTRIC FIELDS
Follow the rules of electric fields and draw what the electric fields looks like.

1

2

3

4

5

6

3 times the charge of the other
**Electrostatics**

**Charging Batteries Worksheet**

Recharge units is the consumer unit A•hs ...not Coulombs

7. A battery can produce 1.2 amps for 1 hour before going "dead." What is the battery's charge value?
8. A battery can produce 0.4 amps for 4 hours before going "dead." What is the battery's charge value?
9. A battery can produce 0.2 amps for 6 hours before going "dead." What is the battery's charge value?
10. The batteries for many radio control cars are rated at 1.2 A•hs. How much current should be pumped into the batteries if they are to be recharged in 15 minutes?
11. In a radio shack catalog a light bulb is rated to draw 0.045 amps at 6.0 Volts. If a 6.0 Volt battery has a charge rating of 2.2A•hs, then how much time can the light be run by the battery before the battery goes "dead."
12. A toy motor draws 2.4 amps from a 1.5 Volt battery when turned on. If the battery runs the motor before it goes dead, then what is the A•h rating of the battery?
13. A flashlight will last for 2.5 hours before the batteries go dead. The batteries A•h rating is 1.2 A•hs (combined). The flashlight's batteries produce 3.0 Volts. How much current does the flashlight's bulb draw?
14. A cassette player runs off of a batteries. The two batteries put out 3.0 Volts (together) in the player. The player is rated at 5 watts. If the batteries have a charge rating of 1.2 A•hs then, how long will the cassette player run before the batteries go dead?

**E-FIELDS F=qE; V=Ed; W=qU**

15. An electron is immersed in an E-field (electric field) of 20 n/C. What force does it feel?
16. A charged particle with the charge of 3 electrons feels a force of $1.6 \times 10^{-18}$N. What size is the E-field that it is immersed in?
17. A charged particle is immersed in an E-field of 1028 n/C and feels a force of $5 \times 10^{-6}$N. What is the charge of this particle?
18. A proton feels a force of $9.5 \times 10^{-21}$. What is the strength of the E-field that is in?
19. An electron is immersed in an E-field of 0.067 n/C when place between 2 plates connected to a 4.5 Volt battery. What is the distance between the two plates?
20. What Voltage is connected to two plates that create an E-field of 10,000 n/C that are separated 0.00068 cm?
21. A proton is immersed in an E-field of $32 \times 10^8$ n/C. The plates that create the E-field are separated 0.082 mm. What voltage is connected to the plates?
22. A charged particle feels a force of $9.2 \times 10^{-18}$N. The particle is placed between two plates that are separated by a distance of 0.025cm and are connected two a 6.0 volt battery. What is the charge of the particle?
23. A proton is placed between two plates that are separated by a distance of 4.35 m. The plates are connected to a 60.0 Volt battery. What force does the proton feel? And which plate will the proton travel to? (The positive or the negative?)
24. An electron is immersed in an E-field of $2.0 \times 10^{25}$ n/C. What force does it feel?
25. A proton feels a force of $8.0 \times 10^{-17}$N. What size is the E-field that it is immersed in?
26. A particle with a charge equal to 11 elementary charges is immersed in an E-filed of 30 N/C. What force does this charged particle feel?
27. A charged particle is immersed in an E-field of 1000 N/C and feels a force of \(15 \times 10^{-14}\) N. What is the charge of this particle?

28. A proton feels a force of \(1 \times 10^{-17}\). What is the strength of the E-field that is in?

29. What force does an electron feel when it is immersed in an electric field of 456 N/C?

30. What is the charge on a particle that feels a force of \(4.35 \times 10^{-16}\) when it is immersed in an E-field of 10 N/C?

31. What is the force on a particle with a charge of \(1 \times 10^6\) elementary charges when immersed in an E-field of 1200 N/C?

32. What is the charge on a particle that feels a force of 20.0 N when it in immersed in an E-field of 5.5 N/C?

33. What is the electric field surrounding a particle with a charge of 2500 C that feels a force of 33 N?

34. A proton is placed between two plates that are attached to a 6 Volt battery. The plates are 0.56 m apart. What is the strength of the E-field?

35. An electron feels an E-field of 10 N/C when placed between two plates connected to a 9 Volt battery. What is the distance between the two plates?

36. What voltage is connected to two plates that create an E-field of 1000 N/C that are separated 6.8 cm?

37. A proton is immersed in an E-field of 12 N/C. The plates that create the E-field are separated 8.2 cm. What voltage is connected to the plates?

38. A 12 Volt battery is connected to two plates separated 0.23 m. What E-field is generated between these plates?

39. What distance are two plates separated by if they are connected to a 9.0 Volt battery and generate an electric field of 1258 N/C?

40. An electron feels a force of 10 N while being immersed in an electric field. A distance of 0.57 m separates the plates that create that E-field. What is the voltage of the battery connected to the plates?

41. A charged particle feels a force of \(12 \times 10^{-14}\) N. The particle is placed between two plates that are separated by a distance of 25 cm and are connected to a 3.0 Volt battery. What is the charge of the particle?

42. A proton is placed between two plates that are separated by a distance of 4.35 cm. The plates are connected to a 45.0 Volt battery. What force does the proton feel? And which plate will the proton travel to? (The positive or the negative?)

43. What is the distance between two plates that are connected to a 24 Volt battery? An electron placed between the plates feels a force \(1.6 \times 10^{-16}\) N.

44. A charged particle feels a force of \(8 \times 10^{-17}\) N. The particle is placed between two plates that are separated by a distance of 6.8 cm and are connected to a 9.0 Volt battery. What is the charge of the particle?

45. A charged particle with a charge of 2 protons feels a force of 50 N while being immersed in an electric field. A distance of 2.4 cm separates the plates that create that E-field. What is the voltage of the battery connected to the plates?

46. An electron is placed between two plates that are separated by a distance of 0.0076 cm. The plates are connected to a 90.0 Volt battery. What force does the electron feel? And
which plate will the electron travel to? (The positive or the negative?) Will the electron go in the direction of the E-field or in the opposite direction of the E-field?

**RATIO STYLE PROBLEMS**

46. A small particle feels a force when placed in an electric field. By what factor is the force acting on the particle changed if the e-field strength is tripled? (All other factors remain unchanged.)

47. A small particle feels a force when placed in an electric field. By what factor is the force acting on the particle changed if the e-field strength is tripled and the particles charge is halved? (All other factors remain unchanged.)

48a. A small particle feels a force when placed in an electric field. By what factor is the e-field changed by if the particle’s charge is tripled? (All other factors remain unchanged.)

48b. An electric field exists between two plates connected to a battery. How is the e-field affected if the battery’s voltage is changed by a factor of \( \frac{2}{3} \)? (All other factors remain unchanged.)

49. An electric field exists between two plates connected to a battery. How is the distance between the plates affected if the e-field’s strength is tripled and the voltage on the battery is changed by a factor of \( \frac{6}{20} \)? (All other factors remain unchanged.)

50. An electric field exists between two plates connected to a battery. A particle is placed in this electric field. How is the force the particle feels affected if the voltage on the battery is changed by a factor of \( \frac{4}{3} \)? (All other factors remain unchanged.)

51. An electric field exists between two plates connected to a battery. A particle is placed in this electric field. How is the force the particle feels affected if the distance between the plates is changed by a factor of \( \frac{3}{7} \)? (All other factors remain unchanged.)

52. An electric field exists between two plates connected to a battery. A particle is placed in this electric field. How is the force the particle feels affected if the distance between the plates is changed by a factor of \( \frac{4}{3} \) and the voltage on the battery changes by a factor of 6? (All other factors remain unchanged.)

53. An electric field exists between two plates connected to a battery. A particle is placed in this electric field. How is the force the particle feels affected if the voltage on the battery is changed by a factor of \( \frac{5}{3} \) and the distance between the plates changes by a factor of 9 and the change on the particle changes by a factor of \( \frac{2}{3} \)? (All other factors remain unchanged.)

54. An electric field exists between two plates connected to a battery. A particle is placed in this electric field. How is the e-field affected if the voltage on the battery is changed by a factor of \( \frac{5}{2} \) and the distance between the plates changes by a factor of 4? (All other factors remain unchanged.)

55. An electric field exists between two plates connected to a battery. A particle is placed in this electric field. How is the force the particle feels affected if the voltage on the battery is changed by a factor of \( \frac{2}{5} \) and the distance between the plates changes by a factor of \( \frac{3}{7} \) and the charge itself is doubled? (All other factors remain unchanged.)

**E-field follow-up**

56. An electron is immersed in an E-field (electric field) of 20 n/c. What force does it feel? What is its acceleration? How fast will the electron be traveling after 0.001 seconds if it starts from rest?
Electrostatics

57. A particle with a charge of 11 elementary charges and a mass of $5.0 \times 10^{-30}$ kg is immersed in an E-field of $30 \text{ N/C}$. What force does this charged particle feel? What is its acceleration?

58. What force does an electron feel when it is immersed in an electric field of $456 \text{ N/C}$? What is its acceleration? If it starts from rest how long will it take to reach a speed of $24.6 \text{ m/s}$ (55 mph)? How much distance will it need to reach $24.6 \text{ m/s}$?

59. What is the force on a particle with a charge of $1 \times 10^6$ elementary charges when immersed in an E-field of $1200 \text{ N/C}$? What is its acceleration? If it starts from rest, how much distance will it need to reach $1.0 \text{ m/s}$? How much time will this take?

60. A proton is placed between two plates that are separated by a distance of $4.35 \text{ cm}$. The plates are connected to a $45.0 \text{ Volt}$ battery. What force does the proton feel? And which plate will the proton travel to? (The positive or the negative?) What is its acceleration? How fast will the electron be traveling after $0.0010 \text{ seconds}$ if it starts from rest? How much distance will it travel in $0.0010 \text{ S}$?

61. An electron is placed between two plates that are separated by a distance of $0.0076 \text{ cm}$. The plates are connected to a $90.0 \text{ Volt}$ battery. What force does the electron feel? And which plate will the electron travel to? (The positive or the negative?) Will the electron go in the direction of the E-field or in the opposite direction of the E-field? What is its acceleration? How fast will the electron be traveling after $1.0 \text{ year}$ if it starts from rest? How much distance will it travel in $1.0 \text{ year}$?
62. How much work is done in traveling across the plates, in joules?

63. Does the electron slow down or speed up?

64. What form of energy does the electron have when it reaches the other side?

65. How fast is the electron traveling when it reaches the opposite plate assuming it started from rest?

66. How much energy does the particle have when it reaches plate “B” in eV’s?

67. How much energy does the particle have when it reaches plate “C” in eV’s?

68. How much energy, in eV’s, will the charge have when it reaches the opposite plate?
74. Two plates are separated as drawn below. A 45 Volt battery is connected to them. An electron is emitted from the negative plate and is attracted towards the positive plate.
   a. How much work is done by the electric field in moving the electron across the plates?
   b. How much energy does the electron have when it reaches the opposite plate assuming it started at rest?
   c. How fast is the electron traveling when it hits the positive plate?
   d. How much energy is gained by the electron in eV's?

75. Two plates are separated as drawn below. A 9.0 Volt battery is connected to the plates. An electron is emitted from the negative plate and is attracted towards the positive plate.
   a. How much work is done by the electric field in moving the electron across the plates?
   b. How much energy does the electron have when it reaches the opposite plate assuming it started at rest?
   c. How fast is the electron traveling when it hits the positive plate?
   d. How much energy is gained by the electron in eV's?

76. Three plates are separated as drawn below. A 9.0 Volt battery is connected to the 1st set of plates. A 3.0 Volt battery is connected to the second series of plates. An electron is emitted from the negative of the first series of plates and is attracted towards the positive plate; then passes through a hole in the second plate to the third plate.
   a. How much work is done by the electric field in moving the electron across the 1st set of plates?
   b. How much work is done by the electric field in moving the electron across the 2nd set of plates?
   c. How much work is done by the electric field in moving the electron across all of the plates?
   d. How much energy does the electron have when it reaches the middle plate assuming it started at rest?
   e. How much energy does the electron have when it reaches the final plate?
   f. How fast is the electron traveling when it hits the final plate?
   g. Answer (d) and (e) in eV's instead of joules.
Electrostatics: Electric Potential

Go to https://goo.gl/v5QuRS

1. Pull up a single charge.
2. Pull out the equipotential meter.
3. Click on the pencil.
4. What are these lines?
5. Move the meter along a line, what do you notice?
Can you create equipotential lines like the gravitational equipotential lines?

Create an experiment that shows the direction of the electric field vectors compared to the equipotential lines. How are the e-field vectors oriented compared to the equipotential lines?

Describe the equipotential lines between two parallel plates where one plate is positive & the other is negative.
Potentials and e-fields

1. The equipotential lines below represent potentials of 20V, 10V, 0V, & −10V. Correctly label the potentials on the diagram below.

2. The equipotential lines below represent potentials of 20V, 10V, 0V, & −10V. Correctly label the potentials on the diagram below.

3. Draw a POSITIVE charge and show the electric field vectors on the charge. (Don’t forget to include the arrowheads.)
4. Draw a NEGATIVE charge and show the electric field vectors on the charge. (Don’t forget to include the arrowheads.)
5. All charges have the same magnitude. Red charges are positive and blue charges are negative. Rank the various amounts of work for all the equipotential transitions shown below. (10 is greater than −10, & −10 is greater than −20.)

6. All charges have the same magnitude. Red charges are positive and blue charges are negative. Rank the various amounts of change's in electric potential energy for all the equipotential transitions shown below. (10 is greater than −10, & −10 is greater than −20.)
7. All charges have the same magnitude. Red charges are positive and blue charges are negative. Rank the various amounts of change’s in kinetic energy for all the equipotential transitions shown below. (10 is greater than –10, & –10 is greater than –20.)
8. Below are 4 collections of equipotential lines. Rank each collection from the greatest FORCE to the smallest FORCE.

Electrostatics Formula Summary Table

<table>
<thead>
<tr>
<th>Formula</th>
<th>How it is used and/or notes about its use. Draw a picture for each space as write some words.</th>
</tr>
</thead>
<tbody>
<tr>
<td>$F = qE$</td>
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<tr>
<td>$W = qEd$</td>
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<tr>
<td>Formula</td>
<td>Description</td>
</tr>
<tr>
<td>---------</td>
<td>-------------</td>
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<tr>
<td>$V = Ed$</td>
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<tr>
<td>$W = qV$</td>
<td></td>
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<tr>
<td>$F = \frac{kq_1 q_2}{r^2}$</td>
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<tr>
<td>$E = \frac{kq}{r^2}$</td>
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<tr>
<td>$V = \frac{kq}{r}$</td>
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Okay. This is not a formula. But it is important.
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<td>46</td>
<td>The new force is 3 times the old force</td>
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<tr>
<td>47</td>
<td>The new force is $3/2$ times the old force</td>
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<tr>
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<td>The new charge is $1/3$ times the old charge</td>
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</tr>
<tr>
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<td>51</td>
<td>The new force is $7/3$ times the old force</td>
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<tr>
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<td>The new force is $9/2$ times the old force</td>
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<tr>
<td>53</td>
<td>The new force is $10/81$ times the old force</td>
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<td>54</td>
<td>The new e-field is $5/8$ times the old e-field</td>
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<td>55</td>
<td>The new e-field is $14/15$ times the old e-field</td>
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<td>56</td>
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<tr>
<td>81</td>
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Coulomb's Law – Just the Basics

Electrostatics Constant Cover Sheet

Electrostatics Constants Sheet

You will be given a new copy of this sheet for your test. None of the values on this page need to be memorized.

\[ e = 1.60 \times 10^{-19} \text{ C (Elementary charge, assumed positive unless noted otherwise.)} \]

\[ 1 \text{ eV} = 1.60 \times 10^{-19} \text{ J} \]

\[ C = 6.25 \times 10^{18} \text{ elementary charges} \]

\[ 1 \text{ J} = 6.25 \times 10^{18} \text{ eV} \]

\[ \text{electron's charge} = -1.6 \times 10^{-19} \text{ C} \]

\[ \text{electron's mass} = 9.109 \times 10^{-31} \text{ kg} \]

\[ \text{proton's charge} = 1.6 \times 10^{-19} \text{ C} \]

\[ \text{proton's mass} = 1.672 \times 10^{-27} \text{ kg} \]

\[ \text{constant in coulomb's Law: } k = 2.306 \times 10^{-28} \left( \frac{\text{Nm}^2}{\text{e}^2} \right) = 8.99 \times 10^{9} \left( \frac{\text{Nm}^2}{\text{C}^2} \right) \]
Coulomb’s Law

Students will be able to:

1. Identify the correct variables in a word problem.
2. Convert from prefixes such as m, μ, and p to the corresponding powers of 10.
3. Find the electrostatic force of attraction or repulsion between two charges.
4. Find the electrostatic force due to more than one charge on a single charge. (Includes magnitude and direction.)

5.
Problem 1

\[ 6 \mu C \quad 2 \text{ mm} \quad 1 \text{ mm} \quad -3 \mu C \quad 2 \mu C \]
Problem 2

\[ \text{12 mC} \quad \text{2 mC} \quad \text{-4 mC} \]

4 µm 3 µm
Problem 3

\[ 6 \mu C \quad \text{---} \quad 1 \mu m \quad \text{---} \quad 4 \mu C \]

\[ -10 \mu C \quad \text{---} \quad 2 \mu m \quad \text{---} \quad \]
Problem 4

-6 \mu C \hspace{1cm} -9 \mu C

\hspace{1cm} 8 \text{ mm} \hspace{1cm}

5 \text{ mm}

2 \mu C
Problem 5

[A] 2 mC

8 mC [B]

9 µm

4 µm

5 mC [C]
Problem 6

[C]
3 μC

[A]
-1 μC

4 nm

(B)
-6 μC

2 nm
Example problem from class practice.  
Find the net force acting on particle “A.”

\[ A = 3.2 \times 10^{-19} \text{C} \]
\[ B = -4.8 \times 10^{-19} \text{C} \]
\[ C = 7.2 \times 10^{-19} \text{C} \]
1. Below are two electrons separated by some diagramed distance. What is the net force (DIRECTION and MAGNITUDE) felt on the electron to the right due to the electron on the left?

\[ e^- \quad 1 \times 10^{-6} \text{ m} \quad e^- \]

2. Below are an electron and a proton separated by some diagramed distance. What is the net force (DIRECTION and MAGNITUDE) felt on the proton due to the electron?

\[ p \quad 1 \times 10^{-9} \text{ m} \quad e^- \]

3. Below is a particle \( q_1 \) with a charge equal to 3 electrons and another charged particle with a charge of 2 protons separated by some diagramed distance. What is the net force (DIRECTION and MAGNITUDE) felt on the \( q_1 \) due to the \( q_2 \)?

\[ q_1 \quad 1 \times 10^{-10} \text{ m} \quad q_2 \]
4. Below are the charges. \( q_1 \) has a charge of 3 elementary charges. \( q_2 \) has a charge of 3 negative elementary charges. \( q_3 \) has a charge equal to 3 protons. What is the net force (DIRECTION and MAGNITUDE) felt on the charge containing 3 negative elementary charges?

\[ 3 \times 10^{-6} \text{ m} \]

\[ 3e \]

\[ 3e^- \]

\[ 2 \times 10^{-6} \text{ m} \]

\[ q_2 \]

\[ q_3 \]

\[ 3p \]
5. Below are the charges. \( q_1 \) has a charge of 6 electron charges. \( q_2 \) has a charge of 2 electrons. \( Q_3 \) is a proton. What is the net force (DIRECTION and MAGNITUDE) felt on \( q_2 \)?

![Diagram of charges](image-url)
5. Find the net force on 8 mC.
6. Find the net force on -2 mC.

7. Find the net force on -11 µC.
8. Find the net force on -3 µC.

9. Find the net force on -8 mC.
10. Find the net force on 1 mC.

11. Find the net force on 4 µC.
12. Find the net force on -7 µC.

13. Find the net force on 1 µC.
14. Find the net force on 2 µC.
15 Find the net force on the “C” particle due to the electrostatic force.

16 Find the net force on the “E” particle due to the electrostatic force.

17 Find the net force on the “H” particle due to the electrostatic force.

18 Find the net force on the “N” particle due to the electrostatic force.

19 Find the net force on the “S” particle due to the electrostatic force.
Electric Fields and Point Charges

Calculate the electric field due to the 2 shown charges at the indicated point in space.

\[ B = -4.8 \times 10^{-19} \text{ C} \]
\[ C = 7.2 \times 10^{-19} \text{ C} \]
Electric Potential due to Point Charges

Find the potential difference if a charge is moved from infinity to the indicated point in space.

\[ \text{Potential at point } A = +3.0 \times 10^{-17} \text{ C} \]
\[ \text{Potential at point } B = -5.0 \times 10^{-17} \text{ C} \]
\[ \text{Potential at point } C = +2.0 \times 10^{-17} \text{ C} \]
\[ \text{Potential at point } D = -4.0 \times 10^{-17} \text{ C} \]
E-fields and Potentials due to Point Charges

Find the potential difference if a charge is moved from infinity to the indicated point in space.

\[ B = -4.8 \times 10^{-19} \text{ C} \]
\[ C = 7.2 \times 10^{-19} \text{ C} \]

Distance from point B to point C: 6.55 \mu m

Distance from point C to point B: 4.11 \mu m
Electricity Basics

**Objectives**

Electricity Basics

**Students should be able to:**

1. Write all the chapter’s formulae
2. Define all the S.I. units of each variable.
3. Define Ohm’s Law
4. Calculate the power used by an appliance.
5. Use the power relationships to solve problems.
6. Define a.c. and d.c. and give examples of each.
7. Identify the current graph associated with an a.c. or d.c. current.
8. Select the appropriate AC/DC battery adapter.
9. Describe what happens to an adapter or the appliance it is plugged in to if the adapter’s voltage is greater than, equal to, or less than the batteries voltage.
10. Describe what happens to an adapter or the appliance it is plugged in to if the adapter’s current is greater than, equal to, or less than the appliance’s current.
11. Describe what happens to an adapter or the appliance it is plugged in to if the adapter’s polarity does not match the appliance’s polarity.
12. Describe, simplistically, what a battery is.
13. Calculate the charge value of a battery.
14. Calculate the life of a battery when it is connected to an electrical device.
15. Calculate the cost of running a certain appliance that is plugged into the standard a.c. outlet.
16. Calculate how long an appliance needs to run to use up a specified amount of money.
17. Describe how a household circuit works in relation to a circuit breaker or fuse.
18. Describe how a replaceable fuse works.
19. Describe what each “hole” in a household outlet “does” or means.

Another fine worksheet by T. Wayne
**Electricity Basics**

**Current Definition**
1. 3.00 C of charge pass a point in a wire in 3.0 ms. how much current is this?

2. $3.00 \times 10^{12}$ electrons pass a point in a wire in 0.0060 seconds. What is the current in the wire in amps?

3. How many electrons pass a point in a conductor in 1 second if the wire’s current is 0.05 amps?

**Ohm’s Law**
4. The fuse for a car radio is a thin wire. The wire is made to burn apart is the current is too high. What is the resistance of a fuse if it is to burn apart when 2.00 amps pass though it at 240 volts?

5. A light bulb is plugged into a wall outlet. It uses 0.68 A. What is the light bulb’s resistance?

6. A flash light bulb is labeled to uses 1.77 A. Its resistance is 1.60 Ω. What voltage is the light bulb rated for?

7. A 1.5 volt battery is has a wire connecting its positive side to its negative side. The battery draws 0.10 amps of current. What is the resistance in the battery to create this current?

8. A flashlight light bulb is rated to take 2.83 Volts and use 0.300 amps. What is the resistance of the filament?

9. Another flash light bulb is rated to use 0.300 A and has a resistance of 4.0 Ω. How much voltage does this bulb use?

10. A stereo speaker has a resistance of 8.00 Ω. When it is operating at full power (exactly 100 watts) it uses 35 volts of electricity. What is the current drawn by the speaker?

11. A 100 Watt light bulb draws 0.83333 amps from a wall outlet (120 volts). What is the resistance of the light bulb’s filament?

12. A toaster plugged into the wall, (120 volts), uses 14 amps of electricity. What is the resistance of the toaster?

13. The thermostat in a house turns on and off the air conditioner and furnace using 24 volts. What is the resistance in the thermostat when it is turned on it if draws 0.100 amps?
14 A motor in a radio control car uses 7.2 volts and draws 14.4 amps of electricity. What is the resistance of the motor?

15 The volume knob on a radio varies the resistance on a line that goes to the speakers. At a low volume the resistance is 10,000 Ω. At a high volume the resistance is 10 Ω. If the stereo maintains 35 volts into the speaker then, what are the two currents going into the speaker?

16 When a battery “dies” the resistance inside the battery rises while the voltage it can produce almost always remains the same. A new 1.5 volt alkaline battery has a resistance of 0.15 ohms. An older battery may have a resistance of 15 Ω. how much current is drawn by a new and old battery?

17 The resistance of dry human skin is about 500,000 Ω and wet, sweaty, human skin is about 1000 Ω. How much current passes across someone’s fingers if they touch the leads of a 9 Volt battery when their skin is wet or dry?

18 0.010 A causes involuntary muscle contractions. How much voltage is required to cause involuntary muscle contractions on wet and dry skin?

**Power**

19 A watch battery produces a voltage of 1.5 volts. How much power is used by the watch if it draws 0.001 A?

20 A high-tension power line carries 1,000,000 volts of electricity. If the line is to carry 200 A’s, then how much power does the power line carry? What is the resistance of the power line?

21 A battery is rated at 1.5 volts. This battery can produce a maximum of 15 W of power.
   • How much current can this battery produce?
   • What is the resistance of the wire attached to the battery?

22 A stereo speaker is rated at 8 ohms and 40 Watts. A fuse is going to be installed in the speaker. How much current does the fuse need to handle if it is to “blow” at 40 watts?

23 A radio control car uses 7.2 volts and 14 amps. How much power does the car use?

24 What are the resistances of a 50, 100 and 150 Watt light bulb that is plugged into a wall outlet, 120 volts?
Electricity Basics

25 A shorted out 12 V car battery can generate 4800 amps! (Never do this. a shorted out battery will explode.) What is the battery's resistance and how much power is generated by the battery before it explodes?

26 A hair dryer says it generates 1400 Watts. It is plugged into a wall outlet, 120 volts. What is the current drawn by the hair dryer and what is its resistance?

27 On most home each circuit in a house can handle 15 amps at 120 volts. How much power is this? Will a 1400 Watt hair dryer and four 75 Watt light bulbs blow this circuit?

28 The heating element on a stove is connected to a 240 V outlet. The element draws 20 amps when it is turned on. What is the resistance and power of the element?

29 A motor on a band saw can generate 1/2 horsepower on high. If the motor is plugged into a wall outlet, how much current will it require? (746 W = hp)

30 The garbage disposal in a sink can generate 3/4 horsepower. If the disposal is plugged into a wall outlet, then how much current does it draw?

31 A small car can generate 95 hp. An equivalent electric vehicle is to be built such that it can generate the same power as its gasoline counter part. If the electric vehicle’s motor uses 12 volts, then what is the resistance of the motor? What is the current drawn by the motor? How many charges are moved by the current if the car runs for 1 hour?

32 What is the current drawn by a household clock radio using 12 watts?

33 A fan draws 0.184 amps while connected to a wall outlet. What is the power rating of this fan?

34 What is the current drawn by a hair dryer using 1500 watts?

35 What is the current drawn by car stereo that is connected to the car's 12.0 volt battery, if the car stereo draws 40 watts?

36 What is the battery voltage of a portable radio that draws 0.500 amps and is rated at 1.5 watts?

37 You've just invented a "Do-Hickie" that uses 3.0 volts and draws 3.0 amps. What is the power rating of your "Do-Hickie?"

38 What is the power rating of a household light bulb that draws 0.60 amps?
Electricity Basics

39 How much current would it take to burn apart the wire inside of a 5 Amp fuse if it were connected to a 120 Volt or a 12 Volt source?

40 Stereo speaker is rated to take 100 watts. If the speaker’s resistance is 8 Ω, how much voltage does the speaker use?

41 What is the power rating of a space heater that draws 9.6 amps while connected to a wall outlet?

Choosing the Right AC Adapter

NOTES

The purpose of an adapter is to adapt the 120 volts from a wall to lower voltage that equals the batteries total voltage. This is done by two coils of wire wrapped around each other. One coil of wire has more turns than the other.

The voltage on the battery side of the adapter is determined by the sum of the voltages of all the batteries. For example; if a radio uses four 1.5 V batteries then the adapter would have to be rated at 6 Volts \( \rightarrow (1.5 \text{ V } + 1.5 \text{ V } + 1.5 \text{ V } + 1.5 \text{ V } = 6.0 \text{ V}) \). If the adapter is less than 6 volts, then not enough energy will be supplied to run the radio. If the adapter is rated at more than 6 volts then electronics inside the radio can physically melt. The other variable to take into consideration when choosing an adapter is the current.

This is a question of supply and demand. The radio demands a specific amount of current. The adapter must be able to meet this demand. If the adapter cannot supply enough current then it overheats. This will cause it to do one of two things. (1) Get so hot the case melts -fire is a possibility. (2) The electronics inside the box melt. To summarize, the current rating on the adapter must meet or exceed the current needs of the device it is plugged into.

The plug and the appliance are polarized. The polarization of the device and the adapter must be identical. If they are backwards, it’s like putting the batteries in backwards. The device will not work.
Inside of the plug has this part of the symbol.

Outside of the plug has this part of the symbol.

This is the symbol you may see on the side of a device that can use an adapter.

(-) (+)  

The center of the adapter’s tip is negative. The outside is positive.

(+) (-)  

The center of the adapter’s tip is positive. The outside is negative.
Below are the symbols found on various appliances. Which adapters on the beneath them on this page, if any, will run each device?

<table>
<thead>
<tr>
<th>Device Description</th>
<th>Symbol</th>
<th>Current</th>
<th>Voltage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Uses 5 batteries (1.2 volts each) 0.4 A</td>
<td>(-) (+)</td>
<td>(-) (+)</td>
<td>120 v AC 6 v DC/0.5 A [center positive]</td>
</tr>
<tr>
<td>Uses 2 batteries (1.5 volts each) 0.8 A</td>
<td>(+)</td>
<td>(-)</td>
<td>120 v AC 3 v DC/0.9 A [center negative]</td>
</tr>
<tr>
<td>Uses 6 batteries (1.5 volts each) 0.3 A</td>
<td>(+)</td>
<td>(-)</td>
<td>120 v AC 9 v DC/0.4 A [center negative]</td>
</tr>
<tr>
<td>Uses 3 batteries (1.5 volts each) 0.3 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 9 v DC/1.0 A [center negative]</td>
</tr>
<tr>
<td>Uses 9 batteries (1.5 volts each) 0.4 A</td>
<td>(+)</td>
<td>(-)</td>
<td>120 v AC 1.5 v DC/1.2 A [center negative]</td>
</tr>
<tr>
<td>Uses 10 batteries (1.2 volts each) 0.25 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 12 v DC/0.8 A [center positive]</td>
</tr>
<tr>
<td>Uses 2 batteries (1.5 volts each) 0.2 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 4.5 v DC/1.5 A [center negative]</td>
</tr>
<tr>
<td>Uses 4 batteries (1.5 volts each) 0.1 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 9 v DC/0.7 A [center positive]</td>
</tr>
<tr>
<td>Uses 3 batteries (1.2 volts each) 0.6 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 9 v DC/0.6 A [center positive]</td>
</tr>
<tr>
<td>Uses 9 batteries (3 volts each) 0.2 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 3 v DC/0.2 A [center negative]</td>
</tr>
<tr>
<td>Uses 4 batteries (1.2 volts each) 0.3 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 9 v DC/3.0 A [center negative]</td>
</tr>
<tr>
<td>Uses 6 batteries (1.5 volts each) 0.5 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 9 v DC/0.5 A [center negative]</td>
</tr>
<tr>
<td>Uses 10 batteries (3 volts each) 0.1 A</td>
<td>(-)</td>
<td>(+)</td>
<td>120 v AC 3 v DC/0.5 A [center negative]</td>
</tr>
</tbody>
</table>
Notes about battery types

<table>
<thead>
<tr>
<th>Battery Type</th>
<th>Voltage per Cell</th>
<th>Typical Charge in Amp•hrs</th>
<th>Recharge Notes</th>
<th>Maximum Current Output in amps</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zinc Carbon</td>
<td>1.5</td>
<td>0.04</td>
<td>Can't Recharge</td>
<td>1</td>
<td>Only good for cheap flashlights</td>
</tr>
<tr>
<td>Alkaline</td>
<td>1.5</td>
<td>0.4</td>
<td>Can't Recharge (Except for a few special types)</td>
<td>10</td>
<td>Good for high current uses (walkmans, toys etc)</td>
</tr>
<tr>
<td>Ni-Cad</td>
<td>1.2</td>
<td>1.2</td>
<td>Recharge 100-500 times</td>
<td>10</td>
<td>Good for high current uses</td>
</tr>
<tr>
<td>Lithium</td>
<td>1.5</td>
<td>1.2</td>
<td>Can't Recharge</td>
<td>10</td>
<td>Longest shelf life (10 yrs)</td>
</tr>
<tr>
<td>Lead Acid</td>
<td></td>
<td>5-50</td>
<td>Recharge 100's to 1000's of times</td>
<td>2000</td>
<td>Super high current drains, Great rechargeable</td>
</tr>
<tr>
<td>Nickle Metal Hydride</td>
<td>1.2</td>
<td>1.6</td>
<td>Recharge up to 500 times</td>
<td>10</td>
<td>High current use</td>
</tr>
</tbody>
</table>

**BATTERY CHARGING & BATTERY LIFE**

50. A 12.6 Volt motorcycle battery can provide 5 Amp-hours of use. The headlight on a particular motorcycle is rated at 75 watts. The headlight on this motorcycle is left on while it is parked. How many hours will pass before the battery is dead?

51. The batteries in a radio control toy are rated at 1.2 Amp-hours (1200 mA•h). The battery's voltage output is a constant 7.2 volts. If the car's motor draws 7.2 Amps from the battery, how many minutes will it take to completely discharge the batteries? How much power is the car's motor using?

52. A flashlight uses 5 nicked batteries. The Ni-cad batteries are rated at 1.2 Amp-hours total. If the light bulb is rated at 6 watts and 6.0 volts, then how much current does the light bulb draw and how long will the batteries last?

53. A battery has a charge value of 1.2 A•h. If the battery is connected to a motor that draws 2 amps, then how many hours will the battery last?

54. A 12 Volt motorcycle battery has a charge value of 5 A•h. If a light lasts for 25 hours when connected to this battery, then how much current is begin drawn by the battery?
A 1.5 Volt rechargeable battery has a charge value of 1.5 A\cdot h. If it is connected to a charging source that delivers 4 Amps, then how long will it take to recharge the batteries?

What is the value of the charge rating on a 3 Volt battery that takes 1.2 hours to recharge is the charging device delivers 2 amps?

What is the charge value on a watch battery the lasts for 1 year is it draws 0.003 amps?

A car battery has a charge rating of 5 A\cdot h. If the car takes 400 A’s to turn the ignition motor on the car, then how many seconds of can the starter be on until the battery dies?

The resistance of dry human skin is 500,000 ohms. If a person with dry skin held on to the battery, how long would it take for the 1.5 Volt battery to completely discharge? The charge rating of the battery is 1.2 A\cdot h.

A flashlight is connected to a voltage source of 6 volts. The light bulb has a resistance of 8.5 \( \Omega \). If a battery has a charge rating of 1.5 A\cdot h, then how long will the battery last?

A motor in a radio controlled car can last for 8 minutes of a 7.2 Volt battery pack. The battery pack has a charge rating of 1.2 A\cdot h. What is the resistance of the car motor?

A cassette player draws 0.10 amps from the batteries. The combined voltage of the batteries is 6 volts. The cassette player lasts for 10 hours before the batteries go dead. What is the charge rating on the batteries?

If held between 2 fingers a certain 1.5 Volt battery will last for 170 days before going dead. What is the resistance if this person’s skin? (The battery has a charge of 1.2 A\cdot h)

A package of good alkaline batteries is about $0.40 per battery, on sale. If the charge rating of this 1.5 Volt battery is 1.2 A\cdot h, then what is the cost/kW\cdot h is it is connected to a light bulb with a resistance of 8.5 \( \Omega \)? What is the cost/kW\cdot h if it is connected to a light bulb of resistance 17 \( \Omega \)?

An “Indy” racecar can generate 1000 hp. Death Wish Hershey is trying to make an electric racecar. To make this car he is going to use regular 12 Volt car batteries. These batteries can safely produce 14,400 W. How many batteries will is take to create an equivalent horsepower? A car battery has a charge rating of 30 Amp\cdot h, how long will one battery last if it produces 14,400 W?

A motor can lift a 10.204 kg mass 2 meters in 10 seconds. What is the horsepower of this motor? If the motor is connected to a 12 Volt battery then how much current does the motor draw?
Electricity Basics

**Electrical Work and Power**

67 A wire connected to the terminals of a battery. The wire poses no resistance, or friction, to the motion of the charges. The battery has a potential difference of 6.0 volts. 1,000,000 electrons travel from one terminal of the battery to the other in 0.001 seconds. How much electrical work is done on moving the charges between the battery poles?

68 A wire connected to the terminals of a battery. The wire poses no resistance, or friction, to the motion of the charges. The battery has a potential difference of 1.5 volts. 1,000,000,000,000 electrons travel from one terminal of the battery to the other in 0.02 seconds. How much electrical work is done on moving the charges between the battery poles?

69 Suppose in problem number 67 that the length of wire that the electrons travel though is 10 centimeters long. What average force moves the electron though the circuit?

70 What supplies the force to move the electrons though the wire?

71 How much power is used in moving the electrons though the wire in both problem #1 and #2?

72 A battery bought from the store is rated at 9.0 volts on the side of the battery? What is the potential difference of the battery?

73 A 12 Volt battery is connected to a motor that is connected to motor that is used to lift a ball from rest. The ball's mass is 0.1 kg. When the motor is turned on it will draw 2.4 amps from the battery. The motor is on for 20 seconds.
   a. How much power is used by the motor?
   b. How much power is used in raising the ball?
   c. How much work is done by the motor?
   d. How high is the ball raised?

74 A 6.0 Volt battery is connected to a motor that is connected to a motor that drags a block from rest across the ACME friction less surface. (Patent pending by Wiley Coyote). The block's mass is 1.0 kg. When the motor is on it draws 4.5 amps from the battery. The motor is only on for 30 seconds at a time. In "real life" motors are not perfect converters from electrical work to mechanical (lifting, sliding, spinning, etc.) work. In the case of this motor only 40 percent of the electrical work is converted into mechanical work.
   a. How much power does the motor use?
   b. How much work is done by the motor?
   c. If the motor pulls with an average force of 2.5 Newtons, then how far will the block be dragged?
   d. What will be the block's final speed?
Electricity Basics

ACME has invented the "Bug's Bunny Buggy." It's an electric car. The car uses 12 Volts. The vehicle's motor draws 20 amps when the car is moving at a constant speed of 24.6 m/s (55 mph). The car has 80 percent conversion efficiency from electrical work to mechanical work. Unfortunately the car only runs for 3 hours at this speed. (HINT: $P=F_{\text{average}}$)

a. How much power does the motor use?
b. How much work is done by the motor?
c. What average force is applied by the car for it to travel at 55 mph?
d. What distance does the car cover in the 3 hours? (Calculate using work relationships).

Power Smart Tips for Appliance Use

Cooking
- Use your microwave oven whenever possible to reduce cooking time and costs.
- Cook by time and temperature, following cooking instructions. Avoid opening oven door or lifting pot lids, which release heat and wastes energy.
- When cooking on the range, lower the temperature setting once the food has heated. It will continue to steam or boil if you use tight-fitting lids.
- Don't preheat the oven or broiler, except when baked goods require a precise starting temperature.

Clothes dryer
- Dry full loads only. Don't use the dryer for just one or two items.
- Dry loads consecutively. This takes advantage of built-up heat.
- On nice days, consider using a clothesline to dry your clothes.

Clothes washer
- Wash full loads only.
- Use warm water instead of hot for washing whenever possible, and cold for rinsing.

Dishwasher
- Use only for full loads.
- Turn off the dishwasher or use the "energy switch" if you have one, and let the dishes dry naturally.

Refrigerator
- Clean the coils in the back of the refrigerator, or near the floor at the front, at least once a year.
- Do not allow ice to build up more than 6 mm on manual defrost refrigerators.
**Electricity Basics**

**Electrical Cost and Usage**

A wall outlet has a potential difference of 120 volts for these problems.

**Cost of Electricity and Electrical Work**

For the following problems, electricity costs \( \frac{\$0.16}{\text{kW} \cdot \text{h}} \) → (A very high rate)

76. The electric company charges for the electrical work they do in supplying your energy needs. If the electric company charges $0.005 for every watt-second used then how much would it cost to run a 40 watt light bulb for 5 minutes?

77. In reality the unit of electrical work the electric company uses is called a KiloWatt-Hour, (abbreviated kWh). Virginia Power charges $0.16 for every kWh used in the winter and early spring. How much does it cost to run a 40 Watt light bulb for 5 minutes? ...For 5 hours? ...For 5 days?

78. You are in charge of analyzing the cost of installing security lighting on a house. The security light consists of three 150 Watt floodlights. Two options are available: (1) leave the lights on for an average of 12 hours a night for 30 days. (2) Use a motion detector that runs the lights an average about 36 minutes a night. How much will each increase the household bill of electricity?

79. How much will it cost to run a 75 Watt light bulb, that is plugged into a wall outlet for 12 hours?

80. A hair dryer uses 1250 watts. If electricity costs $0.16 / (kW•h), then how long can the hair dryer run before it uses up $0.01.

81. A television uses 120 watts. If electricity costs $0.16 / (kW•h), then how long can the television run before it uses up $0.01.

82. A toaster uses 1400 watts and takes 2 1/2 minutes to cook a piece of bread. If electricity costs $0.16 / (kW•h), then how many pieces of bread can be cooked for $0.05.

83. A 75 Watt light bulb is plugged into the wall outlet.
   - How much current does the light bulb draw?
   - How much electrical work is done in 1/2 hour?

84. How much power is used by small black and white TV that draws 0.35 amps at 120 volts AND how much electrical work is done in having the TV on for 3 hours?

85. A 40 Watt curling iron is plugged into the wall.
   - How much current does the curling iron draw?
   - How much electrical work is done in 1/2 hour?

86. A "35 watt" stereo run at full volume may draw 195 watts from the wall outlet.
   - How efficient is this stereo at converting electrical power to "audio" power at full volume?
   - What current is the stereo drawing from the wall at full volume?
Electricity Basics

- How much electrical work is done in running the stereo for 1 hour at full volume?

87. If the stereo in problem #4 is run at "half-volume" it will use 136.5 watts from the wall outlet.
- How efficient is this stereo at converting electrical power to "audio" power at half-volume?
- What current is the stereo drawing from the wall at half-volume?
- How much electrical work is done in running the stereo for 1 hour at half-volume?

The electric company charges for the amount of electrical work they do in moving electrons though the appliances in a house. Instead of using the units of (watt)(second), [Ws], they use the unit of (kiloWatt)(hour), [kW].

For the problems above convert the power rating on the appliances to kilowatts.

For the problems above convert the electrical work rating on the appliances to kW.h.

If the electric company were to charge (11 cents) per kW.h used, then how much would is cost to run each appliance above?

88. Fill in the missing information on the table below.

This table calculates the electrical work in kilowatt-hours. It then estimates the cost for the time period expressed based on the rate of 12 cents per kilowatt-hour.

\[ \text{COST} = (\text{power, in kW})(\text{time, in hs})(\text{price/(kW-h)}) \]

<table>
<thead>
<tr>
<th>Item</th>
<th>Power in Watts</th>
<th>Time of use in a day (minutes)</th>
<th>Electrical work kWh</th>
<th>Cost for an hour's usage</th>
<th>Cost for a day's usage</th>
<th>Cost for a week's usage</th>
<th>Cost for a month's usage</th>
<th>Cost for 30 days of usage</th>
<th>Cost for 365 days of usage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alarm Clock</td>
<td>A 1440</td>
<td>0.0020</td>
<td>$0.00024</td>
<td>$0.01</td>
<td>$0.04</td>
<td>B 2.11</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clock Radio</td>
<td>5 1440</td>
<td>0.0050</td>
<td>C $0.01</td>
<td>$0.05</td>
<td>$0.22</td>
<td>D $1.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>VCR (on)</td>
<td>21 210</td>
<td>0.0031</td>
<td>E $0.00</td>
<td>$0.03</td>
<td>$0.13</td>
<td>$1.61</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stereo Receiver</td>
<td>F 240</td>
<td>0.0317</td>
<td>$0.02280</td>
<td>$0.05</td>
<td>$0.32</td>
<td>G $16.68</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Light bulb</td>
<td>100 210</td>
<td>0.0146</td>
<td>$0.12000</td>
<td>$0.21</td>
<td>$1.47</td>
<td>$6.31</td>
<td>$76.80</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CFL bulb</td>
<td>15 210</td>
<td>H</td>
<td>$0.21312</td>
<td>$0.02</td>
<td>K $0.53</td>
<td>J $6.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Toaster</td>
<td>1776 10</td>
<td>0.0123</td>
<td>$0.21312</td>
<td>$0.02</td>
<td>K $0.53</td>
<td>J $6.50</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Refrigerator</td>
<td>1140 680</td>
<td>12.92</td>
<td>$1.20</td>
<td>$8.42</td>
<td>$36.09</td>
<td>$439.14</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Resistivity, Temperature, and Resistance

<table>
<thead>
<tr>
<th>Material</th>
<th>Resistivity, $\rho$ [Ω•m] at 20 °C</th>
<th>Temperature Coefficient per °C $\alpha$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>$2.65 \times 10^{-8}$</td>
<td>0.00429</td>
</tr>
<tr>
<td>Constantan</td>
<td>$49 \times 10^{-8}$</td>
<td>$-0.00074$</td>
</tr>
<tr>
<td>Carbon (average)</td>
<td>$32000 \times 10^{-8}$</td>
<td>$-0.0005$</td>
</tr>
<tr>
<td>Copper</td>
<td>$1.69 \times 10^{-8}$</td>
<td>0.0068</td>
</tr>
<tr>
<td>Iron</td>
<td>$9.71 \times 10^{-8}$</td>
<td>0.00651</td>
</tr>
<tr>
<td>Nichrome</td>
<td>$100 \times 10^{-8}$</td>
<td>0.0004</td>
</tr>
<tr>
<td>Tungsten</td>
<td>$5.6 \times 10^{-8}$</td>
<td>0.004403</td>
</tr>
</tbody>
</table>

89. A “Snow Cat” is a tractor looking vehicle that is driven in the weather extremes of the North pole. A wire connecting the negative pole of its battery to the engine has a resistance of 2.2010 Ohms at 20°C. What is the resistance of this copper wire when the Snow Cat operates in a temperature of -41°C at the North Pole?

90. A resistor made of Tungsten is placed inside of an electronic thermostat in a house. At 20°C the resistance of the wire is 11 Ohms. While on vacation in the summer you turn the thermostat up to 25°C. What is the wires resistance during your summer vacation?

91. Several cars can determine the temperature of the air outside moving car. One of the ways to do this is to attach a wire underneath/behind the front bumper, away from the engine, and measure the change in resistance at the temperature changes. Actually, car companies don’t use a wire, they use a resistor made from carbon. In Charlottesville, Virginia, the temperature range in a year’s time is from 5.00° F to 105° F. What is the ratio of final resistance to initial resistance?

92. An aluminum wire with a diameter of 0.00200 m experiences a resistance of 0.021 Ω at room temperature, 20.0°C. What is the wire’s resistance at 37.0°C?

93. The diameter of a wire is defined in the United States with a system called the American Wire Gauge, AWG. This antiquated system was developed in 1857 and based on how the machine that makes the wire operates. It is weird in that the larger the number describing a wire, the smaller the wire’s diameter. The 6 Gauge wire, that connects your car battery to your car, is thicker than the 18 gauge wire that connects your car’s speakers to its radio. If both wires are made of copper, then what is the resistance of a 6.00 m long piece of each wire? (Use the Internet to find the diameters of the different gauge wires.)

94. A student is making a homemade resistor using a 10.0 m long piece of wire made from nichrome. If the wire has a radius of 0.00406 m, then is there enough length to make a resistor with a resistance of 3.0 Ω or greater?
95. You are working on replacing some wires on a 1929 car called Packard. You have to have a 2.50 m long wire that has to have a resistance greater than 0.079 Ω. The only available wires are made from Aluminum. What is the smallest gauge wire you should buy to complete this task? (Use the Internet to find the diameters of the different gauge wires.)

96. A 12.0 m long, 20 Gauge wire made from constantan is used on an experiment that is launched from Earth, temperature 20°C to the Space station where it is placed in the shady side of the station where the temperature is -82°C. In space the wire has a resistance of 3.00 Ω @-82°C. What is the resistance at 20°C of the wire?
Electrical Circuits

Students will be able to:

1. Identify a collection of resistors in a circuit as being in parallel, series, or neither.
2. Calculate the equivalent resistance of a set of resistors in parallel or in series using resistor reduction.
3. Reduce a circuit of resistors and one battery to an equivalent resistance.
4. Find the "potential difference" and any point on a circuit.
**Series Resistors**

1. #1
2. #2
3. #3
4. #4
5. #5
6. #6
7. #7
8. #8
9. #9
10. #10

**Parallel Resistors**

- A
- B
- C
- D
- E
- F
- G
- H
- I
- J
- K
- L
- M
- N

**Voltage Sources**

- 6V
- 10V

*Another fine worksheet by T. Wayne*
Equivalent Resistance for a Series Circuit

3

4

5

6

7
Equivalent Resistance for a Parallel Circuit

8

\[ \begin{align*}
2 \Omega & \parallel 4 \Omega & 8 \Omega \\
\end{align*} \]

9

\[ \begin{align*}
20 \Omega & \parallel 40 \Omega \\
\end{align*} \]

10

\[ \begin{align*}
300 \Omega & \parallel 600 \Omega & 1200 \Omega & 200 \Omega \\
\end{align*} \]

11

\[ \begin{align*}
1/2 \Omega & \parallel 3/2 \Omega & 2 \Omega \\
\end{align*} \]

12

\[ \begin{align*}
100 \Omega & \parallel 50 \Omega & 10 \Omega & 20 \Omega & 40 \Omega \\
\end{align*} \]

Another fine worksheet by T. Wayne
Electrical Circuits

14

10v

3Ω

12Ω

5Ω

15

10v

3Ω

12Ω

5Ω

16

14v

2Ω

9Ω

3Ω

6Ω

1/2Ω

Another fine worksheet by T. Wayne
Hint: Imagine an invisible wire connecting the two grounds.
Electrical Circuits
Electrical Circuits

Another fine worksheet by T. Wayne

22

[Diagram of an electrical circuit with resistors and a voltage source.]
Calculate the circuit’s total resistance
Find the voltage drop across and current through each original resistor
Find the voltage’s $V_1$ and $V_2$.

### Diagram 24
![Diagram with a 5 V source, 10 Ω resistor, and a 12 Ω resistor connected in series with a 3 Ω resistor. The voltage across the unknown resistor is to be determined.]

### Diagram 25
![Diagram with a 20 V source, 15 Ω, 10 Ω, 5 Ω, and 10 Ω resistors connected in a closed loop. The voltage across the unknown resistor is to be determined.]
Calculate the circuit’s total resistance
Find the voltage drop across and current through each original resistor
Find the voltage’s \( V_1 \) and \( V_2 \).
Calculate the circuit’s total resistance
Find the voltage drop across and current through each original resistor
Find the voltage’s $V_1$ and $V_2$.
Find the power dissipated by each resistor.
Calculate the circuit’s total resistance
Find the voltage drop across and current through each original resistor
Find the voltage’s $V_1$ and $V_2$. 

![Diagram of an electrical circuit with labeled resistors and voltages.](image)
Calculate the circuit’s total resistance
Find the voltage drop across and current through each original resistor

```
196 V
```

```
3 Ω
```

```
48 Ω
```

```
20 Ω
```

```
2 Ω
```

```
12 Ω
```

```
12 Ω
```
Calculate the circuit’s total resistance
Find the voltage drop across and current through each original resistor

![Circuit Diagram]

- 10 Ω
- 15 Ω
- 8 Ω
- 3 Ω
- 2 Ω
- 80 V
31. The following five circuits have something wrong. Use your understanding of circuits to figure out what is wrong. (Rule number two only works for circuits with one power source.)

1. The sum of the currents going into a junction equals the sum of the currents coming out of that junction.
2. The Voltage drops along any SINGLE path will add up to the battery, or power source’s voltage.
3. Current is the same for all resistors in series with each other.
4. Voltage drops are the same for resistors in parallel.

**Circuit “A” has at least 2 mistakes to find**

![Circuit A Diagram]

**Circuit “B” has at least 4 mistakes to find**

![Circuit B Diagram]
Circuit “C” has at least 3 mistakes to find

Circuit “D” has at least 4 mistakes to find
Circuit “E” has at least 4 mistakes to find
Electrical Circuits Utilizing Kirchoff’s Rules

(1) Which direction is the current flowing? Clockwise or Counter-Clockwise

(2) \( I = \) ?

\( V_{ab} = \)

\( V_{cd} = \)

\( V_{db} = \)

\( P_{8V} = \)

\( P_{2\Omega} = \)
For the circuit below, calculate:
(3) The direction of each current in the top circuit loop.
(4) The direction of each current in the bottom circuit loop.
(5) The current through each resistor.
(6) The total resistance of the circuit.
(7) The power dissipated by each resistor and battery.
For the circuit below, calculate:

(8) The direction of each current in the top circuit loop.
(9) The direction of each current in the bottom circuit loop.
(10) The current through each resistor.
(11) The total resistance of the circuit.
(12) The power dissipated by each resistor and battery.
For the circuit below, calculate:

13) The direction of each current in the top circuit loop.
14) The direction of each current in the bottom circuit loop.
15) The current through each resistor.
16) The total resistance of the circuit.
17) The power dissipated by each resistor and battery.

\[ \begin{align*}
4\Omega & \quad 4\Omega \\
8\Omega & \quad 4v \\
4v & \quad 4\Omega \\
24v & \quad 4\Omega
\end{align*} \]
For the circuit below, calculate:

18) The direction of each current in the left circuit loop.
19) The direction of each current in the right circuit loop.
20) The current through each resistor.
21) The power dissipated by each resistor and battery

![Circuit Diagram]

For the circuit below, calculate:

23) The direction of each current in the left circuit loop.
24) The direction of each current in the right circuit loop.
25) The current through each resistor.
26) The power dissipated by each resistor and battery

![Circuit Diagram]
For the circuit below, calculate:
(27) The direction of each current in the left circuit loop.
(28) The direction of each current in the right circuit loop.
(29) The current through each resistor.
(30) The power dissipated by each resistor and battery
1. Consider the circuit in drawing. Determine (a) the direction of the current in the circuit and (b) the magnitude of voltage between the points lاد A and B. (c) State which point, A or B, is at the higher potential.

![Circuit Diagram 1]

2. Two batteries, each with an internal resistance of 0.015 ohms, are connected as in the drawing. If the 9.0-V battery is to used to charge the 8.0-V battery, what is the current in the circuit?

![Circuit Diagram 2]

3. Determine the voltage across the 5.0 ohm resistor in the drawing. Which end of the resistor is at the higher potential?

![Circuit Diagram 3]

4. For the circuit in the drawing, find the current in the 10.0 ohm resistor. Specify the direction of the current.

![Circuit Diagram 4]
Question: Calculate the current through each branch of the circuit below.

\[ \text{loop}_{\text{abef}} = -6 + I_2(3) + I_1(2) = 0 \]
\[ \text{loop}_{\text{bcde}} = 17 - I_2(3) = 0 \]
\[ \text{loop}_{\text{acdf}} = -6 + 17 + I_1(2) = 0 \]
\[ \text{junction}, I_1 - I_2 + I_3 = 0 \]

SOLUTION
Rearrange three equations so that the variables are in the same columns.

\[
\begin{align*}
6 &= I_1(2) + I_2(3) + (0)I_3 \\
17 &= (0)I_1 + I_2(3) + (0)I_3 \\
0 &= I_1 - I_2 + I_3
\end{align*}
\]

This yields 2 matrices. One of the coefficients and one of the answers.

\[
\begin{bmatrix}
2 & 3 & 0 \\
0 & 3 & 0 \\
1 & -1 & 1
\end{bmatrix}
\begin{bmatrix}
6 \\
17 \\
0
\end{bmatrix}
\]

Now for the TI-83/84 graphing calculator...
Find the matrix button. Press it and use the arrow keys to move the highlight at the top of the screen to “EDIT.”

Enter the coefficients matrix first. Select the [A] matrix and type “3” “ENTER” 3 “ENTER.” Your screen will look like this.

Enter the values in the coefficient matrix. Use the arrow keys to move around the matrices rows and column.

Press the “MATRIX” key again and create a 3 X1 matrix in the “[B]” slot. Enter the answers into the matrix.
Go back to the command screen. To do math with the matrices use the matrix key to call up a list of matrices. Use the arrow keys to highlight the matrix you want and press “ENTER.”

Type Matrix [A] Inverse Matrix [B] and press the “ENTER” key.

The first row is the variable in the 1st column, the second row is the variable in the 2nd column and the third row is the variable in the 3rd column. Therefore $I_1 = -5.5$, $I_2 = 5.7$ and $I_3 = 11.2$.

If the calculator says there is an error when trying to find the answer; either the numbers are entered wrong; the [A] and [B] matrices are backwards or the original equations are incorrect.

**Note:** The values can be converted into fractions using the “Frac” command from the “MATH” menu key.
Solution Method Choice Number 2  
Reduced Row Echelon Form (rref) on the TI-83, 83+, 84, 84+

\[ I_1 = I_2 + I_3 \]
\[ 3 = (I_1)12 + (I_2)6 \]
\[ 6 = -(I_3)3 + (I_2)6 \]

Write in standard form

\[ \begin{align*}
-1 & \quad +1 & \quad +1 & = 0 \\
12 & \quad +6 & \quad 0 & = 3 \\
0 & \quad +6 & \quad -3 & = 6
\end{align*} \]

Rewrite the equation such that the variables are on one side in columns and the answers are after the equality signs.

\[ \begin{align*}
I_1 & \quad I_2 & \quad I_3 & = \text{Ans.} \\
\downarrow & \quad \downarrow & \quad \downarrow & = \downarrow \\
-1 & \quad +1 & \quad +1 & = 0 \\
+12 & \quad +6 & \quad 0 & = 3 \\
0 & \quad +6 & \quad -3 & = 6
\end{align*} \]

Coefficients Matrix
Select “matrix” and choose “EDIT.”

Make this a $3 \times 4$ matrix.

Enter your values. What is not shown is that the answers are in column 4.

Go to the main command screen, 2nd, quit.

Select “MATRX” and MATH. From this menu select “rref.”

Select “MATRX” and “NAMES.” From this menu select your name. Your screen should look like this. Press enter.

**Answers**

$I_1 = -0.071 \, \text{A}$
$I_2 = 0.64 \, \text{A}$
$I_3 = -0.71$
RC Circuits

1) A 220 μF capacitor is connected in series to a 9 V battery and 100 kΩ resistor.
   a) How much current is flowing through the capacitor after 30 seconds if the initial current is 9 × 10^{-5} A?
   b) What is the potential difference across the capacitor after 2 time constants?

2) A 47 μF capacitor is connected in series to a 50 kΩ resistor. The capacitor is charged potential difference of 15 V before being connected to the resistor. How much time does it take for the potential difference across the capacitor to reach 50% of its initial value when it discharges through the resistor?

3) A 6200 μF capacitor is connected in series to a 24 V battery and 10 kΩ resistor as it is charged up from 0 V.
   a) How much time does it take for the current flowing into the capacitor to be reduced by 40%?
   b) How long does it take for the capacitor to reach a full charge from the battery?

4) A 500 Ω resistor is connect to a charged 540 μF capacitor. How long does it take for the capacitor to lose all of its charge?

5) When the switch is closed in the circuit below, the resistor has an initial current of 5 A through it before it begins to decrease. A capacitor with an unknown value is being charged up while being connected to the 20 V battery in an RC circuit with a 1.541 Ω resistor. What is the potential difference across the RESISTOR after 2 time constants?

6) How many time constants must pass before the current running through a capacitor in an “RC” circuit is reduced to 50% of its initial value?

7) A child’s flashlight uses a 6 V battery, capacitor and an LED to operate. When the child presses on the switch, the battery charges up the capacitor up to the battery’s voltage and the LED lights up. When the child releases the switch the battery is disconnect and the LED is powered solely by the capacitor. After 37 seconds the flashlight goes dark when the voltage across the capacitor drops to 0.50 Volts. If the LED has a resistance of 5140 Ω, then what is the value of the capacitor?
Electricity and Magnetism

Objectives

Electricity and Magnetism

Students should be able to:

1. Given a magnet draw its magnetic field
2. From a magnetic field determine the location of a magnet’s poles
3. From the magnetic fields describe if two magnets are attracted or repelled
4. Describe a magnetic domain
5. List the three types of magnetism
6. Define the three types of magnetism & compare their magnetic domains.
7. Identify an example/lab activity from each of the three types of magnetism
8. Describe what makes a material magnetic.
9. Describe how ceramics can be made to be magnetic.
10. Describe the relationship between the Earth’s magnetic and geographic poles.
11. Predict the orientation of a compass needle in a magnetic field and/or source of magnetic fields.
12. Define the relationship between the motion of electrons, protons, and electrical current.
13. Calculate the relationship between a current and the b-field at a distance from the current
   a. Ampere’s Rule formula for magnitude
   b. Ampere’s Rule closed right hand rule for direction
14. Define the components of the CLOSED right hand rule as it relates to magnetism and the current.
15. Calculate the Lorentz force (magnitude and direction) on a current OR flow of individual charges immersed in an EXTERNAL electric field.
   a. Formula for magnitude
   b. Open right hand rule for direction
16. Define the components of the OPEN right hand rule as it relates to magnetism, current and the Lorentz force.
17. Calculate the force on a current or collection of moving charges in a magnetic field.
18. Calculate the force & force/length of two current carrying wires.
Electricity and Magnetism

19. Determine if the two current carrying wires are attracted, repelled, or neither.

20. Add up magnetic fields

21. Determine the net magnetic field, (magnitude and direction,) due to two or more current carrying wires.

22. Determine the direction of a curvature for a charged particle that is moving perpendicular to a magnetic field.

23. Solve problems based on the math model for a charged particle that moves perpendicular to a magnetic field.

24. Describe the connection between magnetism and the Sun’s solar flares (cme’s).

25. Define Lenz’s Law and use it to solve problems.

26. Calculate the clockwise or counter-clockwise direction of an induced current when the flux in an coil is changed

27. Define and calculate flux (specifically magnetic flux).

28. Define Faraday’s law

29. Be able to site and/or identify applications utilizing Faraday’s law

30. Define what happens to the current in a coil of wire as a magnet moves into out of the coil.

31. Define what happens to a second coil that is placed end-to-end to the first coil when the first coil is energized with a current.

32. Calculate the emf generated from a graph of flux vs time

33. Calculate the current generated from a graph of flux vs time given the resistance.

34. Compare the flux’s magnitudes at various parts of a graph of flux vs time.

35. Calculate the emf generated when a wire is moved across a magnetic field by an external force.

36. Describe how the Lorenz Force, (open right hand rule -F=BILsin(θ),) is used when a wire is moved across a magnetic field to separate the charges.

37. Describe the direction of the electric field when a wire moves across an external magnetic field.
An electron enters a b-field as shown.

1. What force does the electron feel? (magnitude and direction)

2. What acceleration does the electron feel?

3. What radius does the electron travel in?

4. How much time does it take for the electron go around in a complete circle?

The electron is traveling perpendicular to the b-field.
Electricity and Magnetism

**5**
- Current = 2.00 Amps
- Wire = 2.00 cm
- B-field = 3.00 T
- Force = ???

**6**
- B-field = 2.00 T
- Force = ???
- Current = 0.50 Amps
- Wire = 0.05 m

**7**
- Current = 4.00 Amps
- Wire = 0.020 m
- Force = ???
- B-field = 0.5 T

**8**
- Current = 2.00 Amps
- Wire = 4.00 cm
- B-field = 5.00 X 10^-4 T
- Force = ???

**9**
- Current = ??? Amps
- Wire = 0.20 cm
- B-field = 0.5 T
- Force = 0.669 N

**10**
- Current = 0.05 Amps
- Wire = 0.0020 m
- B-field = ???
- Force = 0.10 N

**11**
- Current = 2.00 Amps
- Force = 0.030 N
- B-field = 5.00 X 10^-4 T
- \( \theta = ??? \)

**12**
- Current = 4.00 Amps
- Wire = 0.020 m
- B-field = 0.5 T
- Force = 0.0054 N

**13**
- Current = 2.00 Amps
- Force = 0.030 N
- B-field = 4 T
- \( \theta = ??? \)

**14**
- B-field = 2.00 T
- Current = 0.50 Amps
- Force = 0.05 N

- \( l = ??? \)
Electricity and Magnetism

15. A current travels from the right side of the page to the left side of the page. A B-field travels from the top of the page to the bottom of the page. What is the direction of the force?

16. A current is traveling from the top of the page to the bottom of the page. A force pushes a wire to the right side of the page. What is the direction of the magnetic field?

17. A current is traveling from to the ceiling to the floor. The B-field is traveling from the top of the page to the bottom of the page. What is the direction of the force on the current carrying wire?

18. A current travels from the left side of the page to the right side of the page. The B-field travels from the right side of the page to the left side of the page. What is the direction of the force on the wire?

19. A flow of positive ions travels the left side of the page to the right side of the page. The top of the page is the north pole of a magnet and the bottom of the page has the South pole. Protons travel from the ceiling to the floor. What is the direction of the force on the flow of charge?

20. A flow of electrons travel from the top of the page to the bottom of the page. A force pushes the flow of charge to the ceiling. Where is the north pole of the magnetic field?

21. A flow of electrons travel from the top of the page to the bottom of the page. A force pushes the wire the bottom of the page. Where is the south pole of the magnetic field?

22. A flow positive ions travel from the top of the page to the bottom of the page. The south pole of a magnet is on the right side of the page and the north pole of a magnet is on the left side of the page. What direction is the force that pushes the flow of charged particles?

23. Electrons flow from the right side of the page to the left side of the page. They feel a force pulling them to the bottom of the page. Where is the north pole of the magnetic field?

24. Electrons flow from the top of the page to the bottom of the page. The magnetic field points from to the floor to the ceiling. Which direction is the force pointing?

25. The positive terminal of as battery is to your right. The negative terminal is to your left. When this battery is turned on, charge will flow by in front of you. The current carrying wire feels a force pushing it to the ceiling. Where is south pole of the magnetic field?

26. The positive terminal of as battery is above you. The negative terminal is at your feet. When this battery is turned on, charge will flow by in front of you. The magnetic field points from the right side of the page to the left side of the page. Which direction is the force pointing?
Electricity and Magnetism

For problems 27 – 42, a conducting piece of metal is moved from the before situation to the after situation. Determine the direction of the induced current from the before situation to the after situation. The “dots and “x’s” represent the direction and relative strength of the magnetic field the shape is in.

27.

28.

29.

30.
Electricity and Magnetism

31.

BEFORE

32.

BEFORE

33.

BEFORE

34.

BEFORE

35.
Electricity and Magnetism

36. BEFORE

37. BEFORE

38. BEFORE

39. BEFORE

40. BEFORE

AFTER
41. A coil is made up of 100 wraps of wire. The coil is a square 1 cm on each side. The $b$-field changes from 0.50 T to 2.50 T in 1/100 of a second by passing a magnet across the top of the coil. How much voltage does this process generate?

42. A circular coil of wire is made of 1000 loops of wire. The $b$-field in the wire changes from 0.10 T to 0.30 T in 0.03 seconds. This generates a 5 Volt difference in the coil. What is the AREA of the circular coil?

43. A rectangular coil with an area of 10 cm$^2$ is made of 500 wraps of wire. What change in $b$-field is needed to create a 2 Volt difference if the change is to occur in 1/10 of a second?

44. A square coil is made up of 300 wraps of wire. The coil is 5.00 cm on each side. The $b$-field in the coil changes from 0.55 to 0.25 in 1/10 of a second. How much voltage is generated in the coil?

45. A circular coil made from 200 wraps of wire generates 2.0 volts when the $b$-field changes from 1.00 T to 2.5 T in 1/100 of a second. What is the radius of the coil?

46. A square coil is made from 2500 wraps of wire. The coil generates 5.0 volts when the $b$-field changes from 3.4 T to 1.1 T in 1/33 of a second. What is the length of each side of the square shaped coil?

47. A rectangular coil has one side that is 5.0 cm wide. It is made of 1500 wraps of wire. This coil generates 4000 volts when the $b$-field changes from 1.5 T to 1 T in 1/100 of a second. What is the length of the other side of the rectangle?
Electricity and Magnetism

50. A coil with an area of 0.08 m² generates a voltage of 8 volts when the b-field is changes in 1/10 of a second. What is the magnitude of the change if the magnetic field?

51. The pickup assembly of an electric guitar is a rectangular coil of wire made up of 700 wraps of wire. The rectangle is 1.0 cm by 7.0 cm. The b-field across the pickups changes from 0.001 T to 0.0025T in 1/2000 of a second by a vibrating guitar string. How much voltage does the vibrating string generate? (http://entertainment.howstuffworks.com/electric-guitar1.htm)
Electricity and Magnetism

52. A looped single coil of wire has a radius of 5.5 cm. The wire is immersed perpendicular to a 0.66 Tesla b-field. The coil is rotated 90° in 2 seconds. What voltage is generated in the loop?

53. A looped single coil of wire has a radius of 7.5 cm. The wire is immersed perpendicular to a 1.54 Tesla b-field. The coil is rotated 60° in 0.50 seconds. What voltage is generated in the loop?

54. A looped single coil of wire is immersed perpendicular to a 12.5 T b-field. The coil is rotated 80° in 0.05 seconds. 0.10 volts is generated in the loop. If the loop is a circle then what is its radius?

55. A circular coil of wire has a radius if 7.5 cm. The coil has 20 individual coils. The wire is immersed perpendicular to a 0.4 Tesla b-field. The coil is rotated 50° in 0.10 seconds. What voltage is generated in the coil?

56. A circular coil of wire has 300 individual coils. The wire is immersed perpendicular to a 20.2 T magnetic field. The coil is rotated 75° in 0.005 seconds. What is the radius of the coils if 1.5 volts are generated by this action?
57. A looped single coil of wire has a radius of 10.0 cm. The wire is immersed perpendicular to a 1.2 T magnetic field. The radius of the coil is reduced in 0.050 seconds. When this is done, the coil generates 0.0022 volts. What is the new radius of the coil?
Electricity and Magnetism

58. A current carrying wire is perpendicular to a magnetic field. The field strength is 100 N/Am. The current in the wire is 2.0 Amps. 0.37 m of the wire is in the magnetic field. What is the force on the wire?

59. A current carrying wire is perpendicular to a magnetic field. The field strength is 250 N/Am. The current in the wire is 5.5 Amps. 0.78 m of the wire is in the magnetic field. What is the force on the wire?

60. A current carrying wire is 53° to a magnetic field. The field strength is 25 T. The current in the wire is 5.5 Amps. 0.78 m of the wire is in the magnetic field. What is the force on the wire?

61. A current carrying wire is 15° to a magnetic field. The field strength is 15 T. The current in the wire is 1.5 Amps. 1.00 m of the wire is in the magnetic field. What is the force on the wire?

62. A current travels from right to left. What is the direction of the B-field above the wire?

63. A current is traveling from in front of your to behind you. What is the direction of the B-field below the wire?

64. A current is traveling from above you to your feet. What is the direction of the B-field to the right of the wire?

65. A current travels from left to right. What is the direction of the B-field above the wire?

66. A flow of positive ions travels from your left to your right. What is the direction of the B-field above the flow?

67. A flow of electrons travel from in front of your to behind you. What is the direction of the B-field to the right of the flow?

68. A flow of electrons travel from in front of you to behind. What is the direction of the B-field to the left of the flow?

69. What EMF is induced in a 6 cm long wire moving with a speed of 100 cm/s across a field of 200 N/Am?

70. What EMF is induced in a 0.020 cm long wire moving with a speed of 40 cm/s across a field of 1097 N/Am?

71. What EMF is induced in a 10 cm long wire moving with a speed of 4654 cm/s across a field of 1.2 T?

72. An EMF of 1.5 volts is induced in a wire 2.54 cm in length. The wire is traveling across a field of 1970 T. What is the speed of this wire?

73. An EMF of 45 Volts is induced in a wire traveling at 11.5 m/s across a magnetic field. If the length of the wire is 60 cm, then what is the magnitude of the magnetic field?
74. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the right to its new position drawn below. What is the direction of the induced current?

Before

[Diagram of wire loop before movement]

After

[Diagram of wire loop after movement]

75. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the left to its new position drawn below. What is the direction of the induced current?

Before

[Diagram of wire loop before movement]

After

[Diagram of wire loop after movement]
76. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the right to its new position drawn below. What is the direction of the induced current?

Before

After

77. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the left to its new position drawn below. What is the direction of the induced current?

Before

After
78. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the left to its new position drawn below. What is the direction of the induced current? 
   Before
   
   After

79. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the left to its new position drawn below. What is the direction of the induced current? 
   Before
   
   After
80. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the left to its new position drawn below. What is the direction of the induced current?

Before

After

81. Below is a wire loop immersed in a magnetic field. The wire loop is moved to the left to its new position drawn below. What is the direction of the induced current?

Before

After

82. Electrons flow from north to south. The flow feels a force to the west. What is the direction of the b-field?

83. Current flows east to west. The current is in a magnetic field whose north pole is located at the north. What is the direction of the force?

84. The plus pole of a battery is located up and the negative pole of the battery is located down. The wire connected to the battery feels a force to the west. Where is the north pole of the magnetic field that the wire is in?
A coil of wire is moved through a magnetic field in such a way that the magnetic flux versus time graph looks like the one to the right. This graph is created as a conducting loop of metal passes across a varying magnetic field.

85. If the current in the conducting loop is traveling clockwise at 6 seconds, then where on the graph is the current traveling counter-clockwise?

86. Where on the graph is there no current being generated?

87. Rank the magnitude of the current being generated from greatest to smallest.

88. What is the induced emf along segment “C?”

A coil of wire is moved through a magnetic field in such a way that the magnetic flux versus time graph looks like the one to the right. This graph is created as a conducting loop of metal passes across a varying magnetic field.

89. If the current is traveling counter-clockwise in the conducting loop at 0.03 seconds, then which segments show the current traveling clockwise?

90. Which segments show no current being generated?

91. How much voltage is induced along segment “D?”

92. If the coil used in making this has 25 loops of wire, then how much emf is induced along segment “C?”

93. Rank the magnitude of the current being generated from greatest to smallest?

94. If the coil has a resistance of 3Ω, then how much current is generated through the leads going to the coil in segment “C?”
A coil of wire is moved through a magnetic field in such a way that the magnetic flux versus time graph looks like the one to the right. This graph is created as a conducting loop of metal passes across a varying magnetic field.

95. If the current is traveling clockwise in the conducting loop at 0.04 seconds, then which segments show the current traveling counter-clockwise?

96. Which segments show no current being generated?

97. How much voltage is induced along segment “B”?

98. If the coil used in making this has 100 loops of wire, then how much emf is generated along segment “D”?

99. Rank the magnitude of the current being generated from greatest to smallest?

100. If the coil has a resistance of 5Ω, then how much current is generated across the leads going to the coil in segment “A”? 
A coil of wire is moved through a magnetic field in such a way that the magnetic flux versus time graph looks like the one to the right. This graph is created as a conducting loop of metal passes across a varying magnetic field.

101. If the current is traveling clockwise in the conducting loop at 0.04 seconds, then which segments show the current traveling counter-clockwise?

102. Which segments show no current being generated?

103. How much emf is induced along segment “B”?

104. How much potential difference is generated along segment “D”?

105. Rank the magnitude of the emf being generated from greatest to smallest?

106. If the coil has a resistance of 100Ω, then how much current is generated across the leads going to the coil in in segment “D”? 
A coil of wire is moved through a magnetic field in such a way that the magnetic flux versus time graph looks like the one to the right. This graph is created as a conducting loop of metal passes across a varying magnetic field.

107. If the current is traveling counterclockwise in the conducting loop at 3 seconds, then which segments show the current traveling clockwise?

108. Which segments show no current being generated?

109. How much current is induced along segment “A?”

110. How much potential difference is induced along segment “D?”

111. Rank the magnitude of the current being generated from greatest to smallest?

112. If the coil has a resistance of 3Ω, then how much voltage is generated across the leads going to the coil in segment “B?”
The Nature of the Electromagnetic Spectrum (Light)

Objectives

Light: The Nature of the Electromagnetic Spectrum

Students will be able to:

1. Describe Newton's theory of light
2. Describe evidence of Newton's theory
3. Define what a photon is
4. Describe Huygens' theory of light
5. Describe evidence of Huygens' theory
6. Define longitudinal and transverse wave types
7. Give at least one example of each wave type
8. Identify the wavelength of a transverse and longitudinal wave.
9. From a wave's appearance, identify high frequency, low frequency and amplitude.
10. Describe Einstein's light theory
11. List regions of the electromagnetic spectrum from lowest to highest frequency
12. List regions of the electromagnetic spectrum from longest to shortest wavelengths
13. Give an example of an amplification of how each spectrum of light is utilized.
14. Write the speed of light in standard S.I. units from memory.
15. Do calculations utilizing basic velocity relationships.
16. Do calculations utilizing the mathematical relationship between the speed of light, frequency and wavelength.
17. Calculate the energy of light associated with frequency or wavelength.
18. List regions of the electromagnetic spectrum from highest to lowest energy.
19. Utilizes energy relationships to answer questions.
20. List the visible light spectrum (ROY-G-BIV) in order from
21. Longest to shortest wavelength or vice-versa.
22. Lowest to highest frequency or vice-versa.
23. Lowest to highest energy or vice-versa.
24. Explain how a microwave "cooks" food, why the sky is blue, why sunsets are red and what the "color of visible" light represents.
25. Explain the idea behind polarizing light though filters and reflection
26. Memorize and utilize Brewster's Law of Polarization
27. Calculate light intensity though a polarizer and an analyzer.
28. Describe refraction and reflection
29. Define the index of refraction
30. Use the index of refraction to fin the various speeds of light
31. Use the index of refraction in combination with light's energy to find the wavelength of light
32. Write Snell's Law from memory
33. Use Snell's Law to solve problems
34. Describe total internal reflection
35. List some applications of total internal reflection
36. Do calculations based on total internal reflection
1. Mercury is 69.7 \times 10^6 \text{ km from the sun. How much time does it take for a light ray to travel from the Sun to Mercury?}

2. A radio signal takes 2 minutes and 18 seconds to travel from the Earth to Venus. How far away is Venus from the Earth in meters and Miles.

3. How many FEET does light travel in 1 nanosecond (1.0 \times 10^{-9} \text{ s}).

4. The average radius of the sun is 6.96 \times 10^5 \text{ km. If light could bend around the sun, how many times could a ray of light travel around the sun in 1.0 second?}

5. How many miles does light travel in one year's time?

6. The wavelength of red light is about 650 \times 10^{-9} \text{ m.}
   a. What is the frequency of the light?
   b. What is the energy of a photon of light?

7. What is the wavelength of a radio wave whose frequency is 97.5 MHz?

8. What is the wavelength of a radio wave whose frequency is 1040 kHz?

9. What is the frequency of a green light whose wavelength is 741 \times 10^{-9} \text{ m}?

<table>
<thead>
<tr>
<th>Indices of Refraction</th>
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<tbody>
<tr>
<td>SUBSTANCE</td>
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<tr>
<td>CUBIC ZIRCONIA</td>
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<tr>
<td>DIAMOND (C)</td>
</tr>
<tr>
<td>FLUORITE (CAF2)</td>
</tr>
<tr>
<td>FUSED QUARTZ</td>
</tr>
<tr>
<td>GLASS, CROWN</td>
</tr>
<tr>
<td>GLASS, FLINT</td>
</tr>
<tr>
<td>ICE WATER</td>
</tr>
<tr>
<td>POLYSTYRENE</td>
</tr>
<tr>
<td>SODIUM CHLORIDE</td>
</tr>
<tr>
<td>ZIRCON</td>
</tr>
</tbody>
</table>

Planck's Constant is $h = 6.63 \times 10^{-34} \text{ J} \cdot \text{s}$
The Nature of the Electromagnetic Spectrum (Light)

Problems:

10. Draw the relative position of the refracted light ray.
   a   b   c   d
   More dense  More dense  Less dense  More dense
   Less dense  Less dense  More dense  Less dense
   INCIDENT  INCIDENT  INCIDENT  INCIDENT

11. Draw the relative position of the refracted light ray.
   a   b   c   d
   n = 1.24  n = 2.46  n = 3.45  n = 1.65
   n = 2.34  n = 2.21  n = 2.34  n = 2.34
   INCIDENT  INCIDENT  INCIDENT  INCIDENT

   e   f   g   h
   n = 3.54  n = 1.68  n = 2.58  n = 1.65
   n = 1.25  n = 1.56  n = 2.34  n = 1.75
   INCIDENT  INCIDENT  INCIDENT  INCIDENT
12. What is the angle of the refracted light ray?

a
\[ n = 1.24 \]
\[ n = 2.34 \]
\[ \theta = 25° \]
INCIDENT

b
\[ n = 2.46 \]
\[ n = 2.21 \]
\[ \theta = 15° \]
\[ \theta_{\text{incident}} \]

C
\[ n = 3.45 \]
\[ n = 1.67 \]
\[ \theta = 28° \]
\[ \theta_{\text{incident}} \]

D
\[ n = 1.65 \]
\[ n = 2.34 \]
\[ \theta = 42° \]
\[ \theta_{\text{incident}} \]

e
\[ n = 3.54 \]
\[ n = 1.25 \]
\[ \theta = 3° \]
\[ \theta_{\text{incident}} \]

f
\[ n = 1.68 \]
\[ n = 1.56 \]
\[ \theta = 53° \]
\[ \theta_{\text{incident}} \]

g
\[ n = 2.58 \]
\[ n = 2.34 \]
\[ \theta = 21° \]
\[ \theta_{\text{incident}} \]

h
\[ n = 1.65 \]
\[ n = 1.75 \]
\[ \theta = 46° \]
\[ \theta_{\text{incident}} \]

**Critical Angle**

13. Which situation(s) is set up correctly to give a critical angle?

a
\[ n = 1.12 \]
\[ n = 2.45 \]

b
\[ n = 3.05 \]
\[ n = 1.25 \]
\[ \theta_i \]

\[ \theta_i \]
c
\[ n = 4.28 \]
\[ n = 3.56 \]
\[ \theta_i \]
\[ n = 1.82 \]
\[ n = 2.11 \]

14. What is the critical angle for the following situations? (If possible.)

a
\[ n = 2.33 \]
\[ n = 3.45 \]
\[ \theta_c \]

b
\[ n = 1.25 \]
\[ n = 3.45 \]
\[ \theta_c \]

\[ n = 4.58 \]
\[ n = 2.51 \]
\[ \theta_c \]

\[ n = 1.54 \]
\[ n = 1.68 \]
\[ \theta_c \]
15. What will happen to the light ray? (Is it reflected and at what angle? Is it refracted and at what angle?)

<p>| | | | |</p>
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<thead>
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</thead>
<tbody>
<tr>
<td>a</td>
<td>b</td>
<td>c</td>
<td>d</td>
</tr>
<tr>
<td>n = 1.33</td>
<td>n = 1.25</td>
<td>n = 4.25</td>
<td>n = 3.6</td>
</tr>
<tr>
<td>n = 1.90</td>
<td>n = 2.45</td>
<td>n = 2.50</td>
<td>n = 6.9</td>
</tr>
<tr>
<td>46°</td>
<td>25°</td>
<td>36°</td>
<td>36°</td>
</tr>
</tbody>
</table>
16. Find the light intensity as the ray passes to the end polarizer. Express your answer as a percentage.
17. Two pairs of polarized sunglasses are held at 90° and 50° from the horizontal. By what factor has the intensity of the transmitted light been changed?

18. Three pairs of polarized sunglasses are held up in front of one another. The first pair the light hits is held at 20° from the vertical. The second pair is held at 70° from the vertical. The third pair is held at 90° from the vertical. By what factor has the intensity of the transmitted light been changed?

19. Three pairs of polarized sunglasses are held up in front of one another. The first pair the light hits is held at 70° from the vertical. The second pair is held at 90° from the vertical. The third pair is held at 20° from the vertical. By what factor has the intensity of the transmitted light been changed?
20. Identify if the conditions are right for maximum polarization of the outgoing light ray in each problem below.

- **a**: $\theta_i = 45^\circ$, $n = 2.33$, $n = 3.45$
- **b**: $\theta_i = 45^\circ$, $n = 3.45$, $n = 1.25$
- **c**: $\theta_i = 60^\circ$, $n = 2.50$, $n = 4.58$
- **d**: $\theta_i = 45^\circ$, $n = 1.68$, $n = 1.94$
- **e**: $\theta_i = 45^\circ$, $n = 3.45$, $n = 2.45$
- **f**: $\theta_i = 45^\circ$, $n = 2.25$, $n = 2.25$
- **g**: $\theta_i = 45^\circ$, $n = 1.50$, $n = 2.58$
- **h**: $\theta_i = 45^\circ$, $n = 2.22$, $n = 2.54$
21. For the problems below, calculate the angle of maximum polarization.

\begin{align*}
\text{a} & \quad \theta_i \\
& \quad \frac{n=1.34}{n=3.45} \\
& \quad \frac{n=2.44}{n=4.33} \\
& \quad \frac{n=1.23}{n=1.89} \\
& \quad \frac{n=1.55}{n=1.99} \\
\text{b} & \quad \theta_i \\
\text{c} & \quad \theta_i \\
\text{d} & \quad \theta_i \\
\text{e} & \quad \theta_i \\
\text{f} & \quad \theta_i \\
\text{g} & \quad \theta_i \\
\end{align*}

22. What is the angle of maximum polarization for the reflected ray of light that bounces off of a diamond?

23. What is the angle of maximum polarization as a light ray bounces off a piece of glass under the water?

24. What is the angle of maximum polarization as a light ray bounces off a piece of glass that is lying in the air next to the water?

25. What is the refracted angle of a light ray that bounces off a piece off plastic whose index of refraction is 1.41 if the reflected angle is at its maximum polarization?

26. A light ray is refracted at a 30° angle from the normal. The reflected light ray is maximally polarized. What is the angle of the incident light ray?

27. A piece of material in the air reflects a light ray at 35°. The reflected ray is maximally polarized. What is the index of refraction of this material?

28. If you are standing such that your eyes are 2.0 meters vertically from the waters smooth surface, then how far away from you is the glare on the water if the glare is at the angle of maximum polarization?
29. Locally, the radio station WWWV broadcasts at 97.5 MHz (97.5 x 10⁶ Hz). Radio waves are electromagnetic waves like light. The waves travel at the speed of light. What is the wavelength of WWWV's wave length?

30. X-Rays have a wavelength of 1.00 x 10⁻¹⁰ m. What is the x-rays frequency?

31. Microwave ovens have a frequency of 2.457 x 10¹⁰ Hz. What is the wavelength of this microwave?

32. What is the energy of 12 photons from a microwave oven?

33. Visible red light has a wavelength of 0.680 mm. What is the energy of a photon from this light?

34. A beam of light travels though a piece of plastic at 2.97 x 10⁸ m/s. What is the index of refraction of this plastic?

35. A beam of light with a frequency of 624 x 10⁹ Hz travels though a fluid with an index of refraction of 1.44. How fast is the light traveling though the fluid?

36. A beam of light travels though a dense sodium vapor at 260.00 m/s. What is the index of refraction of the sodium vapor?

37. A beam of light travels though a piece of plastic with an index of refraction of 1.85. What is the wavelength of this light in the plastic if its frequency in a vacuum is 760 nm?

38. A beam of light has a wavelength of 0.950 mm while in a diamond (n=2.48). What is the energy of a single photon in the diamond?

39. A photon travels though a piece of plastic with 6.63 x 10⁻²³ J of energy. What is the wavelength of light if the index of refraction is 1.49?

40. A beam of light is incident on cubic zirconia. Draw the refracted ray and calculate its refraction angle.
41 A beam of light is incident on cubic zirconia. Draw the refracted ray and calculate its refraction angle.

42 A beam of light is incident on crown glass as shown. Draw the refracted ray and calculate its refraction angle.

43 What is the condition(s) for total internal reflection?

44 What is the critical angle for the situation shown below?
Geometrical Optics: Spherical Mirrors

Students will be able to:

1. Draw the incident and reflection rays for plane, or spherical mirror.
2. Find the image in plane or spherical mirror.
3. Describe an image’s magnification for a plane or spherical mirror.
4. Calculate an image’s position for a plane or spherical mirror.
5. Draw all for possible incident/reflection rays for spherical mirror to visually locate an object’s image.
6. Describe concave and convex mirrors’ characteristics regarding image properties based on an object’s location.
This page is to be printed and used in conjunction with class notes.
Geometrical Optics: Spherical Mirrors

Convex Mirror

This page is to be printed and used in conjunction with class notes.
For each object below, draw the position of its image as formed by the mirror using all the rays when possible.

**CONCAVE MIRRORS**

1

2

3

4

5
For each object below, draw the position of its image as formed by the mirror using all these rays when possible.

**CONVEX MIRRORS**

1. 6
2. 7
3. 8
4. 9
5. 10
6. 11
For the problems listed below, calculate the image’s distance, image height, (real or virtual) and its “invertedness.”

12 1 cm
   C         12 cm
           10 cm

13
   C         10 cm
           80 cm
           30 cm

14
   C         20 cm
           200 cm
           1.4 m

15
   C         15 cm
           0.7 m
           2 m

16
   C         25 cm
           2.5 m
           200 cm

17
   C         15 cm
           0.3 m
           1 m

18
   C         15 cm
           19 m
           20 cm
Draw the location of the floating objects top and bottom. You do \textbf{NOT} need to use all 3 rays.
Geometrical Optics: Spherical Mirrors

Draw a ray tracing diagram to locate the image for each object shown below. Use 2 rays to locate the image’s location. Draw an arrow that represents the image. Label each image with the corresponding object number.

**Ray tracing for spherical mirrors.**

**Concave**

6

5

4

3

2

1

Object c f

Principle Axis

**Ray tracing for spherical mirrors.**

**Convex**

4

3

2

1

Principle Axis f c
Use the “Virtual Optics Bench” at http://webphysics.davidson.edu/physlet_resources/dav_optics/Examples/optics_bench.html to help answer these questions. All the answers will not be found on this web page. This applet uses JAVA. Google’s “Chrome” does not support java.

24. When is an image real?
25. When is an image virtual?
26. Where is an image placed when it is real?
27. Where is an image placed when it is virtual?
28. What is the minimum number of rays to draw to find an image?
29. What is a “virtual ray?”
30. Where on a diagram is the image located when “s’ ” is negative?
31. Where on a diagram is the object located when “s” is positive?
32. What shape is a concave mirror?
33. What is the relationship between the center, radius and focus?
34. What is the sign of the focus when a mirror is a concave mirror?
35. What is the sign of the focus when a mirror is a convex mirror?
36. Which variable indicates a virtual image? How does it indicate a virtual image?
37. Which variable indicates a real image? How does it indicate a real image?
38. What is the minimum number of rays to draw to find an image?
39. Mathematically, when are “s” and “s’ ” negative?
40. What are the four rules for drawing rays?
41. Which type of spherical mirror only has virtual images?
42. Which type of spherical mirror can produce an enlarged image?
43. Which type of mirror can produce an real image?
44. Where is an object located to produce a real image?
45. Where is an object located to produce an inverted image in a concave mirror?

A “characteristic” is described by

• the magnification as being positive or negative
• the magnification as being less than, equal to, or greater than 1.
• s or s’, as being positive or negative
• real or virtual

46. What are the characteristics of an image when the object is at the center of a concave mirror?
47. What are the characteristics of an image when the object is between the center and focus of a concave mirror?
48. What are the characteristics of an image when the object is at the focus of a concave mirror?
49. What are the characteristics of an image when the object is at the inside of the focus of a concave mirror?
50. What are the characteristics of an image when the object is at the center of a convex mirror?
51. What are the characteristics of an image when the object is between the center and focus of a convex mirror?
52. What are the characteristics of an image when the object is at the focus of a convex mirror?
53. What are the characteristics of an image when the object is at the inside of the focus of a convex mirror?
Math & notes relating to spherical mirrors

**Concave Mirror**
- Object
- Image
- C: Center
- R: Radius
- f: focus
- \( C = R = 2f \)

**Convex Mirror**
- Object
- Image
- C: Center
- R: Radius
- f: focus
- \( C = R = 2f \)
**Mirror Detective**

- All mirrors referenced below are spherical mirrors.
- For each question below, identify the mirror being described as concave, convex, neither, or could be either one.

1. This mirror can only produce images that the light does not pass through.
2. This mirror can an inverted image.
3. This mirror’s center is twice as big as its focal length. What kind of mirror is it?
4. This mirror can produce the images that look like you can touch them.
5. This mirror creates an image that is 0.5 times the objects height.
6. This mirror always creates an image with a negative distance for $s’$.
7. This mirror creates a real image.
8. This mirror can generate an image that is upright.
9. This kind of mirror can create an image that is 3.5 times taller than the object.
10. This mirror creates an image that looks like it is behind the front of the mirror when the object is between the focus and center.
11. This mirror creates an inverted image when the object is between the focus and front of the mirror.
12. This mirror’s center is twice as big as its focal length.
13. This mirror creates an image larger than the object.
14. There is a location in front of this mirror where the object can be placed and no image is formed.
15. This mirror creates an image smaller than the object.
16. This mirror cannot create an inverted image.
17. This mirror creates an upright image when the object is away from the face of the mirror at a distance greater than the length of the mirror’s radius.
18. This mirror has a negative focal length.
19. This mirror can create an upright image.
20. This mirror always has an $s’$ distance that is negative.
21. This mirror’s center is twice as big as its focal length. What kind of mirror is it?
22. This mirror cannot produce an image taller than the original object.
23. This mirror can produce the tallest possible image.
24. This mirror can create an image with a positive or negative $s’$ value.
54. A shiny glass Christmas ornament in the shape of a ball is 10.0 cm in diameter. What is the magnification of an object placed 15 cm from the surface of the ball? Is the image upside-down or right-side up. Justify your answer?

55. A makeup mirror is labeled as 5X magnification. The image is upright like the object. How far away from your eye (1.5 cm in height) does the mirror need to be held so the image is 7.5 cm tall? (Answer in terms of “s’.”)

56. When driving a car around a sharp 90° blind corner, sometimes you will see a round mirror that shows you the traffic on the other road. The image appears upright and on the other side of the mirror. What is the focal length of this mirror if the car’s image appears to be 5 m away when the car is 7.5 meters away from the mirror?

57. The focal length of a concave mirror is 17 cm. An object is located 38 cm in front of this mirror. Where is the image located?

58. A clown is using a makeup mirror to get ready for a show and is 27 cm in front of the mirror. A virtual image is formed 65 cm from the mirror. Find (a) the focal length of the mirror and (b) its magnification. (c) Is this a convex or concave mirror?

59. The image behind a convex mirror (radius of curvature = 68 cm) is located 22 cm from the mirror. (a) Where is the object located and (b) what is the magnification of the mirror? Determine whether the image is (c) upright or inverted and (d) larger or smaller than the object.

60. Convex mirrors are being used to monitor the aisles in a store. The mirrors have a radius of curvature of 4.0 m. (a) What is the image distance if a customer is 15 m in front of the mirror? (b) Is the image real or virtual? (c) If a customer is 1.6 m tall, how tall is the image?

61. A dentist’s mirror is placed 2.3 cm from a tooth. The enlarged virtual image is located 5.1 cm from the mirror. (a) What kind of mirror (plane, concave, or convex) is being used? (b) Determine the focal length of the mirror. (c) What is the magnification? (d) How is the image oriented relative to the object?

62. A small postage stamp is placed in front of a concave mirror (radius = R), such that the image distance equals the object distance. (a) In terms of R, what is the object distance? (b) What is the magnification of the mirror? (c) State whether the image is upright or inverted relative to the object.

63. A concave shaving mirror is designed so the virtual image is twice the size of the object, when the distance between the object and the mirror is 20 cm. Determine the radius of curvature of the mirror.
64. Each object shown below is at a different location and are equal in height. Rank images from tallest to shortest.

A

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

B

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

C

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

D

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

65. Each object shown below is at a different location and are equal in height. Rank the image distance from the mirror’s front from farthest to closest.

A

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

B

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

C

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]

D

\[ \begin{array}{c}
\uparrow \\
\text{c} \\
\text{f}
\end{array} \]
66. Each object shown below is at a different location and are equal in height. Rank the image distance from the mirror’s front from farthest to closest.
More Mirror Problems

Do all these problems on a separate sheet of paper.

67. The focal length of a concave mirror is 17 cm. An object is located 38 cm in front of this mirror. Where is the image located?

68. A clown is using a concave makeup mirror to get ready for a show and is 27 cm in front of the mirror. A virtual image is formed 65 cm from the mirror. Find (a) the focal length of the mirror and (b) its magnification. (c) Is this a convex or concave mirror?

69. The image behind a convex mirror (radius of curvature = 68 cm) is located 22 cm from the mirror. (a) Where is the object located and (b) what is the magnification of the mirror? Determine whether the image is (c) upright or inverted and (d) larger or smaller than the object.

70. Convex minors are being used to monitor the aisles in a store. The mirrors have a radius of curvature of 4.0 m. (a) What is the image distance if a customer is 15 m in front of the mirror? (b) Is the image real or virtual? (c) If a customer is 1.6 m tall, how tall is the image?

71. A dentist's mirror is placed 1.5 cm from a tooth. The enlarged virtual image is located 4.3 cm from the mirror. (a) What kind of mirror (plane, concave, or convex) is being used? (b) Determine the focal length of the mirror. (c) What is the magnification? (d) How is the image oriented relative to the object?

72. A small postage stamp is placed in front of a concave mirror (radius = R), such that the image distance equals the object distance. (a) In terms of R, what is the object distance? (b) What is the magnification of the mirror? (c) State whether the image is upright or inverted relative to the object.

73. A concave shaving mirror is designed so the virtual image is twice the size of the object, when the distance between the object and the mirror is 15 cm. Determine the radius of curvature of the mirror.
**MIRRORS SUMMARY**

<table>
<thead>
<tr>
<th><strong>CONVERGING MIRROR</strong></th>
<th>Focal length’s sign is …</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Image real or virtual</td>
</tr>
<tr>
<td>For images where p &gt; f</td>
<td></td>
</tr>
<tr>
<td>For images where p = f</td>
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<tr>
<td>For images where p &lt; f</td>
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</table>

<table>
<thead>
<tr>
<th><strong>DIVERGING MIRROR</strong></th>
<th>Focal length’s sign is …</th>
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<tbody>
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<td></td>
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<td></td>
</tr>
<tr>
<td>For images where p &lt; f</td>
<td></td>
</tr>
</tbody>
</table>
Is the mirror below negative or positive?

Is the lens below negative or positive?

What happens to image of an object that is placed at the center of the mirror shown below.

What happens to image of an object that is placed at the center of the lens shown below.

Where must an object be placed for its image to be virtual? (Circle the location.)

Where must an object be placed for its image to be virtual? (Circle the location.)
Objectives

Geometrical Optics: Spherical Thin Lenses

Students will be able to:

1. Draw the incident and refraction light rays for converging and diverging lenses.

2. Find the image in a converging or diverging lens.

3. Describe an image’s magnification for converging and diverging lenses.

4. Calculate an image’s position for converging and diverging lenses.

5. Draw all for possible incident and refraction rays for converging and diverging lenses to visually locate an object’s image.

6. Describe converging and diverging lens characteristics regarding image properties based on an object’s location.
Draw the location of the object using the 3 rays for lenses.

What trends in the image’s location, height do you see happening as the object moves towards the lenses?
What trends in the image’s location, height do you see happening as the object moves towards the lenses?
Lens Detective

- All lenses referenced below are spherical lenses.
- For each question below, identify the lens being described as converging, diverging, neither, or both.

1. This spherical lens can only produce images where the refracted light does not belong.
2. This spherical lens can an inverted image.
3. This spherical lens’s center is twice as big as its focal length.
4. This spherical lens can produce the images that look like you can touch them.
5. This spherical lens creates an image that is 0.5 times the objects height.
6. This spherical lens always creates an image with a negative distance for \( s' \).
7. This spherical lens creates a real image.
8. This spherical lens can generate an image that is upright.
9. This kind of spherical lens can create an image that is 3.5 times taller than the object.
10. This spherical lens creates an image that looks like it is on the other side of the spherical lens when the object is between the focus and center.
11. This spherical lens creates an inverted image when the object is between the focus and front of the spherical lens.
12. This spherical lens’s center is twice as big as its focal length.
13. This spherical lens creates an image larger than the object.
14. There is a location in front of this spherical lens where the object can be placed and no image is formed. (Do not include when the object is located at infinity.)
15. This spherical lens creates an image smaller than the object.
16. This spherical lens cannot create an inverted image.
17. This spherical lens creates an upright image when the object is away from the face of the spherical lens at a distance greater than the length of the spherical lens’s radius.
18. This spherical lens has a negative focal length.
19. This spherical lens can create an upright image.
20. This spherical lens always has an \( s' \) distance that is negative.
21. This spherical lens’s center is twice as big as its focal length.
22. This spherical lens cannot produce an image taller than the original object.
23. This spherical lens can produce the tallest possible image.
24. This spherical lens can create an image with a positive or negative \( s' \) value.
## LENSES SUMMARY

### CONVERGING LENS

<table>
<thead>
<tr>
<th>Focal length’s sign is …</th>
<th>Image real or virtual</th>
<th>Image upright or inverted</th>
<th>Image magnification</th>
</tr>
</thead>
</table>

| For images where p > f |                       |                           |                     |
| For images where p = f |                       |                           |                     |
| For images where p < f |                       |                           |                     |

### DIVERGING LENS

<table>
<thead>
<tr>
<th>Focal length’s sign is …</th>
<th>Image real or virtual</th>
<th>Image upright or inverted</th>
<th>Image magnification</th>
</tr>
</thead>
</table>

| For images where p > f |                       |                           |                     |
| For images where p = f |                       |                           |                     |
| For images where p < f |                       |                           |                     |

What does it mean when “M” is positive?

What does it mean when “M” is negative?

What does it mean when “M” is >1?

What does it mean when “M” is <1?
1. Two speakers produce a frequency of 254 Hz and are fed a signal that is in phase. If one speaker is placed directly behind the other and no sound is heard, then how far apart of the speakers?

2. Two speakers produce a frequency of 114 Hz and are fed a signal that is 180° out of phase with each other. If one speaker is placed directly behind the other and no sound is heard, then how far apart of the speakers?

3. Anna Litical is walked past a pair of speakers that in phase with each other and producing a frequency of 305 Hz. She noticed than when she was 82 m away and exactly in between the speakers, the sound was the loudest. How far apart were the two speakers? The speed of sound is
5. An AM radio tower emits a 900 kHz radio signal that travels across an open space to a building 865 m away that is the same height as the radio tower. (Horizontal distance.) At the same time the signal also bounces off the ground at a 30° angle to make a symmetrical triangle. If an AM radio is placed at the edge of the building, the signal cannot be picked up by the radio. How high is the building?

6. To light emits the same wavelength, $\lambda$, in phase with each other. Ignore the distance separating the two light sources. Create an equation that relates the vertical distance from the central bright spot, $y$, to the distance to a screen, $L$, the angle, $\theta$, the 1$^{st}$ bright spot. Then do the same thing for the 2$^{nd}$ bright spot. Can you make one equation that uses, $n$, as the number bright spot that works for both spots?

7. A sound wave is produced with a wavelength of 0.60 m. It comes from a coherent source as it passes through two open windows. Below is a diagram showing the distance from each window to a listener’s position. Identify which positions show a maxima and which show a “minima.” For each position identify which order it is?
8. A thin layer of gasoline, $n=1.40$, floats on top of a smooth pool of water, $n=1.33$. White light hits the layer of gasoline from nearly vertically above the gasoline. From all the colors in the incident light, blue, ($\lambda_{\text{BLUE}} = 400 \text{ nm}$,) is the color that is eliminated from the gasoline. What is the minimum thickness of the gasoline? If the gasoline sites a top a piece of flint glass, $n=1.66$, then what is the minimum thickness of the gasoline?

9. A coating is applied to a glass window. It is designed to block out ultraviolet light with a wavelength of 350 nm. (a) If this is this wavelength of light is the most diminished, then what is the thickness of the coating if it has an index of refraction of 1.60 and is covering a pane of glass with an index of refraction of 1.53. (b) What thickness is needed if it is to cover a piece of plastic with an index of refraction of 1.70?

10. Some glasses have a non-reflective coating on them. This coating blocks as much of the reflected light in the visible range (from 390 nm to 790 nm). The coating has an index of refraction of 1.44 and it covers glass, $n=1.53$. If the coating has a thickness of 10.0 nm, what is the longest wavelength of visible light that can be blocked?

11. A screen is placed 4.20 meters from two slits, The distance between the central bright fringe and the 2nd order bright fringe is 0.051 m. If the incident beam of light has a wavelength of 642 nm, then how far apart are the two slits?

12. A hole is poked into a piece of aluminum foil that covers light from a laser with a frequency of 490 nm. The light creates a pattern on a screen that is 5.1 meters away from the hole. An angle of 2.50° is formed between the central bright spot and the 1st order bright fringe. What is the diameter of the opening?
1. The circular top of a can of soda has a radius of 0.0320 m. The pull-tab has an area of $3.80 \times 10^{-4} \text{ m}^2$. The absolute pressure of the carbon dioxide in the can is $1.40 \times 10^5 \text{ Pa}$. Find the force that this gas generates
   a. on top of the can (including the pull-tab’s area) and
   b. on the pull-tab itself.

2. High-heeled shoes can cause tremendous pressure to be applied to a floor. Suppose the radius of a heel is $6.00 \times 10^{-3} \text{ m}$. At times during normal walking motion, nearly the entire body weight acts perpendicular to the surface of such a heel. Find the pressure that is applied to the floor under the heel because the weight of a 50.0 kg woman.

3. A cylinder is fitted with a piston, beneath which is a spring, as in the drawing. The cylinder is open at the top. There is no friction. The spring constant of the spring is 2900 N/m. The piston has negligible mass and a radius of 0.030 m. When the air beneath the piston is completely pumped out,
   c. how much does the atmosphere’s pressure cause the piston to compress?
   d. How much work does the atmosphere to in compressing the spring?

4. The Mariana trench is located in the Pacific Ocean and has a depth of approximately 11,000 m. The density of seawater is approximately 1025 kg/m$^3$.
   e. If a diving chamber were to explore such depths, what force would the water exert on the chamber’s observation window (radius = 0.10 m)?
   f. For comparison, determine the weight of a jumbo jet whose mass is $1.2 \times 10^5 \text{ kg}$.

5. A water tower has a vertical pipe that is filled with water. The pipe is open to the atmosphere at the top. The pipe is 22 m high. At the bottom of this pipe is a hole with a cork in it.
   g. What is the pressure at this hole when the cork is in the hole?
   h. What is the pressure when the cork is removed and the water is allowed to squirt onto the ground?

6. A buoyant force of 26 N acts on a piece of quartz that is completely immersed in ethyl alcohol. What is the volume of the quartz? $\rho_{\text{ethanol}} = 785.06 \text{ kg/m}^3$

7. Oil is flowing with a speed of 1.22 m/s through a pipeline with a radius of 0.305 m. How many gallons of oil (1 gal = $3.79 \times 10^{-3} \text{ m}^3$) flow in a day?

8. A small crack forms at the bottom of a 15.0 m high dam. The effective crack area through which the water leaves is $1.00 \times 10^{-3} \text{ m}^2$.
   i. What is the speed of the water flowing through this crack?
   j. How many cubic meters of water per second flow through the crack?

9. An airplane wing is designed so that the speed of the air across the top of the wing is 248 m/s when the speed below the wing is 225 m/s. The density of air is 1.29 kg/m$^3$. What is the lifting force on a wing that is rectangular and 2 m x 10 m?

10. Water is running out of a faucet, falling straight down, with an initial speed of 0.50 m/s. At what distance below the faucet is the radius of the stream reduced to half of its original radius at the faucet?

**ANSWERS**

<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
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<tbody>
<tr>
<td>1) a. 450 N</td>
<td>b. 53.2 N</td>
<td>5) ???</td>
</tr>
<tr>
<td>2) $4.33 \times 10^6 \text{ Pa}$</td>
<td>6) $3.3 \times 10^{-3} \text{ m}^3$</td>
<td>9) $1.40 \times 10^5 \text{ N}$</td>
</tr>
<tr>
<td>3) 0.097 N</td>
<td></td>
<td>7) $0.356 \text{ m}^2/\text{kg}$, $8.12 \times 10^6 \text{ gal}$</td>
</tr>
<tr>
<td></td>
<td>b. 14 J</td>
<td></td>
</tr>
</tbody>
</table>
P1. Below is a Pressure-Volume diagram. In "geek-speak" it is called a "PV diagram." Notice that it looks like a graph, but it’s not. It’s a diagram. This diagram represents 1000 moles of a gas. The dot on the diagram represents a state of the gas. What is the pressure, volume and temperature of this gas at this state?

P2. The dot on the PV diagram below is for the state of an ideal gas that is at 181 K. How many moles of this gas are there?
To the right is a P-V diagram that shows multiple step thermodynamic cycle.

1. What is the name of the thermal dynamic process as the gas goes from point “A” to point B”?
2. What is the name of the thermal dynamic process as the gas goes from point “D” to point “A”?
3. How much work is done as a gas undergoes a change along the curve from point “B” to “C”?
4. How much work is done as a gas undergoes a change along the curve from point “C” to “D”?
5. How much NET work is done on or by the gas as it undergoes a change along the curve from point “A” to “B” to “C” to “D” and back to “A”?
6. If the PV diagram above is for 2 moles of a gas then what is the gas’s temperature at point “A”?
7. If the PV diagram above is for 2 moles of a gas then what is the gas’s temperature at point “D”?
8. If the PV diagram above is for 2 moles of a gas then what is the change in internal energy of the gas during the process from “D” to “A”?
9. How much thermal energy is added to the gas as it undergoes a change from point “D” to “A”?
10. How much work is done either on or by the system during the process from “D” to “A”?
11. How much work is done either on or by the surroundings from the process from “B” to “C”?
12. How much work is done either on or by the surroundings during the cycle from A to B to C to D and back to A?
13. How much thermal energy is entered into the system shown from the P-V diagram’s cycle?
To the right is a P-V diagram that shows a thermal dynamic cycle. Keep in mind that the process from “A” to “B” is not real because it is not one of the four processes.

14. What is the name of the thermal dynamic process as the gas goes from point “C” to point “B”?

15. What is the name of the thermal dynamic process as the gas goes from point “A” to point “C”?

16. How much NET work is done as a gas undergoes a change along the curve from point “A” to “C” to “B” to “A” again?

17. If 12 kJ of thermal energy is leaves the system shown from the P-V diagram, then what is the change in internal energy of the cycle?

18. If this process occurs to a system containing 4 moles of gas then what is the temperature at location “B”?

19. If this process occurs to a system containing 4 moles of gas then what is the change in internal energy during the process from “A” to “C”?

20. How much work is done by the system during the process from “C” to “B”?

21. How much work is done by the surroundings during the process from “B” to “A”?

22. How much thermal energy is added or removed to/from the system from “C” to “B,” if this process occurs to a system containing 4 moles of gas?
22A) What are the signs of $\Delta U$, $Q$, and $W$ for the process shown to the right?

<table>
<thead>
<tr>
<th>$\Delta U$</th>
<th>$Q$</th>
<th>$W$</th>
</tr>
</thead>
<tbody>
<tr>
<td>sign-&gt;</td>
<td></td>
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</table>

22B) What are the signs of $\Delta U$, $Q$, and $W$ for the process shown to the right if 2000 J of thermal energy is added to the system?

<table>
<thead>
<tr>
<th>$\Delta U$</th>
<th>$Q$</th>
<th>$W$</th>
</tr>
</thead>
<tbody>
<tr>
<td>sign-&gt;</td>
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</table>

22C) What are the signs of $\Delta U$, $Q$, and $W$ for the process shown to the right?

<table>
<thead>
<tr>
<th>$\Delta U$</th>
<th>$Q$</th>
<th>$W$</th>
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<tbody>
<tr>
<td>sign-&gt;</td>
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22D) What are the signs of $\Delta U$, $Q$, and $W$ for the process shown to the right?

<table>
<thead>
<tr>
<th>$\Delta U$</th>
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<th>$W$</th>
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<tbody>
<tr>
<td>sign-&gt;</td>
<td></td>
<td></td>
</tr>
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</table>
23. A cylinder has a piston sticking out of its top. The piston is a lid that is allowed to slide up and down.

(A) What kind of thermodynamic process is this?
(B) How much work is done in sliding the piston up?
(C) How much thermal energy does the candle give the can?

24. A container is holding water as shown. All the water is converted to steam. The temperature does not change. This process occurs at a constant 101325 Pa of pressure.

(A) What kind of thermodynamic process(es) is this?
(B) How much thermal energy, Q, is added to the water?
(C) How much work is done by expanding the water into steam?
(D) What is the change in internal energy of the system.

25. A sealed can contains 200 grams of water at 34°C. A candle injects 10,000 J into the can. The can looses 2,000 J through conduction.

(A) What kind of thermal dynamic process is this?
(B) What is the change in internal energy?
(C) What is the change in temperature of the water? $C=4.186 \text{ J/g}$
**Thermodynamics**

Show your work on a separate piece of paper.

**Latent Heat of Fusion and Vaporization**

26. How much heat is required to melt 3.0 kg of ice at 0° C?

27. Ice at 32° C is placed in a Styrofoam cup containing 0.32 kg of water at 27° C. After the ice and water have reached equilibrium, *some ice still remains*. Determine the mass of ice that has melted if no heat loss occurs to the cup or the environment.

28. A 7.00 kg glass bowl [C = 840 J/(kg•C°)] contains 16.0 kg of punch at 25.0° C. 2.5 kg of ice [C = 2000 J/(kg•C°)] is added to the punch. The ice has an initial temperature of -20° C. The punch may be treated as if it is water [C = 4186 J/(kg•C°)]. What is the temperature of the punch, ice and bowl if no heat is lost to the environment?

**Conduction**

29. A portable ice chest has walls 0.020 m thick. The area of the walls is 0.66 m². For a picnic the chest is loaded with 3.0 kg of ice at 0° C. The temperature at the outside surface of the chest is 35° C. Find the time required to melt the ice when the chest is made of (a) Styrofoam (b) wood.

**Stefan-Boltzmann**

30. The emissivity of a person is about 0.900. How much power is radiated by a person whose body temperature is 37° C while sitting in a room whose temperature is 20° C? Assume the area of a person is 1.5 m².

31. Betelgeuse is a distance super giant star in the belt of the Orion constellation. Betelgeuse has a surface temperature of about 2900 K and emits a radiant power of about 4 X 10³⁰ W. The temperature is about one-half the power and about 10,000 times greater than that of our own sun. Assuming the star is a perfect emitter (emissivity = 1) and spherical, find its radius.

A fire is started in a wood stove. The room reaches a constant temperature of 29° C while the stove reaches a temperature of 198° C. The stove’s surface area is 3.5 m². The emissivity of the stove is 0.900.

32. How much power is radiated by the stove?

33. How much power is radiated by the room on the stove?

34. What is the net radiated power of the stove?
Thermodynamics
Show your work on a separate piece of paper.

35. A container maintains a constant pressure of 76700 Pa while changing to a volume of 38 liters. If -66030 J of work was done by the gas, what was the starting volume?

36. 24.4 moles of an ideal gas is held at a temperature of 70°C while expanding from 139 liters to 799 liters. How much work is done by the gas?

37. A container maintains a constant pressure of 39300 Pa and volume of 104 liters while 432.3 of heat is added. How much work is done by the gas?

38. 23.4 moles of an ideal gas is held at a temperature of 55°C while changing to a volume of 175 liters. If 57560 J of work was done by the gas, what was the starting volume?

39. A container maintains a constant pressure of 63600 Pa when the volume experiences a change of 47 liters while 26330 of heat is added. How much work is done by the gas?

40. 27 moles of an ideal gas is held at a temperature of 372°C while expanding from 6 liters to 58 liters. How much work is done by the gas?

41. A container maintains a constant pressure of 20900 Pa while expanding from 83 liters to 911 liters. How much work is done by the gas?

42. 16.2 moles of an ideal gas is held at a temperature of 287°C while changing to a volume of 95 liters. If 797.9 J of work was done by the gas, what was the starting volume?

43. A container maintains a constant pressure of 70 700 Pa while changing to a volume of 25 liters. If -59 100 J of work was done by the gas, what was the starting volume?

44. 21.4 moles of an ideal gas is held at a temperature of 5°C while expanding from 0.026 m3 to 0.631 m3. How much work is done by the gas?

45. A container maintains a constant pressure of 72000 Pa and volume of 64 liters while 51620 of heat is added. How much work is done by the gas?

46. 10.2 moles of an ideal gas is held at a temperature of 124°C while expanding from 147 liters to 424 liters. How much work is done by the gas?

These are the answer to the problems above in no particular order (the units are missing on purpose.)
899, no work is done, 17300, 1.577 x 10^5, no work is done, 35 650, 94, no work is done, 861, 1.216 x 10^5, 3.283 x 10^5 , 71
47. 1200 J of heat spontaneously flows from a hot reservoir at 650 K to a cold reservoir at 350 K. What is the change to the entropy of the universe?

48. 4 kilograms of carbon dioxide sublimes from solid “dry ice” to a gas at a pressure of 1.00 atm and a temperature of 194.7 K. The latent heat of sublimation for carbon dioxide is $5.77 \times 10^5$ J/kg. Find the change in entropy of the carbon dioxide.

49. The spring on a screen door with a force constant of 200 N/m is stretched 30 cm on a day where the temperature is 25 °C. What is the change in entropy of the universe if 25% of the stored energy is lost when the spring is stretched?
Thermodynamics
Show your work on a separate piece of paper.

50. Which process(es) shows a $\Delta Q$ equal to $\frac{5}{2nR}\Delta T$?

51. Which process(es) show a $W=0$?

52. Which process shows a decrease in temperature?

53. For the graph to the right, assuming no molecules are allowed to escape, show that states A and C are at the same temperature?

54. How much work is done along the path from A to B?

55. How much thermal energy is added from state A to B if this represents 3 moles of an ideal gas?

56. How much work is done from states B to C?

57. Is positive work done on the surroundings or by the surroundings as the system undergoes a change along A $\rightarrow$ D $\rightarrow$ C?
58. Assuming the molecules cannot escape the system, rank each point’s internal energy from highest to lowest.

59. Rank the six points according to their temperatures from highest to lowest.

60. There are two possible paths between state F and C. They are F→A→B→C or F→E→D→C. Consider the process of, F→A, B→C, F→E, D→C: Which process shows the greatest amount of heat flowing into the system and least amount of heat flowing into the system?

61. How much thermal energy flows from the system from D→E?

62. How much work is done by the surroundings from C→A?

63. How much work is done by the gas in the system from A→B?

64. How much work is done by the surroundings in the cycle A→B→C?

65. Does thermal energy flow into or out of the system during the cycle, A→B→C?

66. In the process from A→B, how much thermal energy flows from the environment.
Thermodynamics
Show your work on a separate piece of paper.

<table>
<thead>
<tr>
<th>Other Notes</th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\Delta U$ = equation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>P-V diagram</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>What does not change</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Process Name</td>
<td>Isobaric</td>
<td>Isovolumetric (Isochoric)</td>
<td>Isothermal</td>
</tr>
</tbody>
</table>

Another fine worksheet by T. Wayne
Torque and the 2\textsuperscript{nd} Condition of Equilibrium

Draw the extended free body diagram for each situation. You do not need to include the distances on these diagrams unless the instructor tells you otherwise.

Each box has the same weight and they are uniform in density. The center of mass of each box is in its middle. All the systems meet both conditions of equilibrium because they are not moving. The beam is homogeneous and has mass. Symbols: Use “mg” to indicate the weight of the box. To indicate the weight of 3 boxes use the notation “3mg.” T = Tension, n is the normal force. The reaction force for a beam at the wall is to be represented by its two components, V and H. Use a cursive, $\mathcal{F}$, to represent the frictional force. Because of limited space you do not need to write down the moment arm distances. The first problem is done as an example.
**Torque and the 2nd Condition of Equilibrium**

Show your work on a separate piece of paper.

<table>
<thead>
<tr>
<th>BOX</th>
<th>BOX</th>
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<tbody>
<tr>
<td></td>
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<tr>
<td>TABLE</td>
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<table>
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<th>BOX</th>
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<td>TABLE</td>
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<td></td>
</tr>
<tr>
<td>TABLE</td>
</tr>
</tbody>
</table>
Torque and the 2\textsuperscript{nd} Condition of Equilibrium

Show your work on a separate piece of paper.
Torque and the 2nd Condition of Equilibrium
Show your work on a separate piece of paper.
Torque and the 2nd Condition of Equilibrium

Show your work on a separate piece of paper.
Torque and the 2nd Condition of Equilibrium
Show your work on a separate piece of paper.

The beam is not rotating. Sum up the torques about the arrow.

Unless otherwise stated, the forces are perpendicular to the beam.
Torque and the 2nd Condition of Equilibrium
Show your work on a separate piece of paper.

Each extended free body diagram has a red arrow pointing to a location along the body. Write the torque summation equation using the large, red, arrow’s location as the point of rotation. Each letter is a force. Example: \( + \sum \tau_{\text{left end}} = 0 = \) (you fill in this part)

1

2

3

4

Another fine worksheet by T. Wayne 464
Torque and the 2\textsuperscript{nd} Condition of Equilibrium
Show your work on a separate piece of paper.
7 You are given a problem where you have drawn the extended free body diagram below. You do not know the values of force c or d. In the problem you are to find the value of d. What location should you choose as your axis of rotation?

8 You are given a problem where you have drawn the extended free body diagram below. You do not know the values of force b or m. In the problem you are to find the value of m. What location should you choose as your axis of rotation?

9 You are given a problem where you have drawn the extended free body diagram below. You do not know the values of force p, r or v. In the problem you are to find the value of r. What location should you choose as your axis of rotation?
Every hinge has a reaction force made from an “H” and “V” force at the hinge.

1. The beam’s cm is located 3 m from the pivot. The beam’s mass is 800 kg.

2. The beam’s cm is located 2 m from the pivot. The beam’s mass is 800 kg.

3. The beam’s cm is located 2 m from the pivot. The beam’s mass is 800 kg.

4. The beam’s cm is located 4 m from the pivot. The beam’s mass is 1000 kg.

5. The beam’s cm is located 4 m from the pivot. The beam’s mass is 1500 kg.

6. 150 kg person 7 m high along the ladder.

There is friction at both ends of the ladder.

The ladder’s cm is located 2 m from the ground end. The ladder’s mass is 100 kg.
Torque and the 2nd Condition of Equilibrium
Show your work on a separate piece of paper.

1. A 10.0 kg weight is lifted by doing a series of arm curls from the shoulder. The weight remains 40 cm away from the axis of rotation at the shoulder. Calculate the torque due to the weight at the four angles. Use the shoulder as the pivot point.

2. A store’s 55 kg uniform sign hangs from the two ropes as shown. (Uniform means the center of mass is in the middle of the sign.) What is the tension in the left and right ropes holding up the sign?

3. At the John Paul Jones arena, Among other responsibilities, in house electricians are expected to replace all burned out lights. A 700 N electrician is to replace the 80.0 N light fixture that hangs on the end of a 6.00 m long 200.0 N uniform beam.
   a. When the electrician is 1.00 meter from the left edge, calculate the tension in the cable holding up the right end of the beam.
   b. Find the vertical and horizontal components of the reaction force where the beam connects to the wall.
   c. The cable has aged and the maximum tension the cable can withstand is estimated to be 900 N. Can the 700 N electrician safely walk to the end of the beam to replace the light?

4. The 700 N leader of the town of Woodberry stands on a uniform 294 N beam to deliver a lame speech. He is standing exactly ½ m from the left end. The platform is 2.00 m long. The beam is held up by three ropes as shown. What is the tension in each rope?

Another fine worksheet by T. Wayne
5. In an architect’s new building he got the idea to build a swing for his daughters. The swing is attached at the end of an 8.00 m long beam. The beam’s center of mass is exactly ¼ the length of the beam as measured from the wall. A cable is attached at a 55.0° angle halfway along the beam’s length. The beam has a mass of 88.00 kg.
   a. If the only available cable can hold up 900.0 N, then how much weight can the swing hold?
   b. Does the vertical component of the reaction force on the wall point up or down and what is its magnitude if the cable’s tension is 900N?
   c. What is the horizontal component of the reaction force at the wall if the cable’s tension is 900N?

6. A 650N boy and a 450 N girl sit on a 150 N porch swing that is 1.7 meters long. The swing itself is uniform in shape with its center of mass in the middle. If the swing is supported by a chain at each end, what is the tension in each chain when the boy sits 0.75 m from the left end and the girl 0.5 m from the other end?

7. The person has a weight of 725 N as he stands on the very end of a diving board. The clamp exerts a force of 1250 N on the other end of the board. The board is made from a top secret massless material that has been sought out by the Russians for decades. (They didn’t find it because they never thought about shopping at Walmart.) USING ONLY TORQUES, determine the location of the pivot and the force it is using.
8. The person has a mass of 125 kg. The board’s center of mass is located exactly 2 m from the left end and has a mass of 40 kg. The supports holding the board up are 1.5 m from each end. Can the person walk to the end of the board?

![Diagram of a board with a person standing on it, showing the dimensions of the board and supports.]

Board mass = 40 kg

9. A 855 N window washer is standing as shown. One of the ropes on his hoist has broken and his scaffold is perfectly balanced. The scaffolding beam is uniform with a weight of 475 N. Where is the 331 N bucket of cleaning supplies located relative to the right end of the scaffold?

![Diagram of a scaffolding beam with a person and cleaning supplies.]

10. In a musical an actress is held up on a massless board. If the person her up on the left is using 360 N to hold her up and the person on the right is using 310 N to hold her then where is the actress’s center of gravity as measured from the man on the left?

![Diagram of actress on a board with two people holding her.]

**Answers to this section**

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0, 19.6 Nm, 33.9 Nm, 39.2 Nm</td>
</tr>
<tr>
<td>2</td>
<td>T&lt;sub&gt;left&lt;/sub&gt; = 359 N, T&lt;sub&gt;right&lt;/sub&gt; = 180 N</td>
</tr>
<tr>
<td>3a</td>
<td>T = 343 N</td>
</tr>
<tr>
<td>3b</td>
<td>H = 171 N, V = 683 N</td>
</tr>
<tr>
<td>3c</td>
<td>No. he can only walk out 5.14 m</td>
</tr>
<tr>
<td>4</td>
<td>T&lt;sub&gt;1&lt;/sub&gt; = 501 N, T&lt;sub&gt;2&lt;/sub&gt; = 672 N, T&lt;sub&gt;3&lt;/sub&gt; = 384 N</td>
</tr>
<tr>
<td>5a</td>
<td>swing = 153 N</td>
</tr>
<tr>
<td>5b</td>
<td>V = 278 N</td>
</tr>
<tr>
<td>5c</td>
<td>H = 516 N</td>
</tr>
<tr>
<td>6</td>
<td>T&lt;sub&gt;right&lt;/sub&gt; = 679 N, T&lt;sub&gt;left&lt;/sub&gt; = 571 N</td>
</tr>
<tr>
<td>7</td>
<td>d = 1.45 m, F&lt;sub&gt;pivot&lt;/sub&gt; = 1975 N</td>
</tr>
<tr>
<td>8</td>
<td>d = 0.48 m</td>
</tr>
<tr>
<td>9</td>
<td>6.73 m from the right end</td>
</tr>
<tr>
<td>10</td>
<td>0.925 from the left end</td>
</tr>
</tbody>
</table>
Torque and the 2nd Condition of Equilibrium
Show your work on a separate piece of paper.

1. How much mass must be added to get the scale readings above?
2. Where, from the left should the mass be added?
3. How far from the left can 250 g be added so the meter stick just barely does not rotate?
Torque and the 2nd Condition of Equilibrium
Show your work on a separate piece of paper.

Two workers are holding a small car engine on a ladder. The ladder has a mass of 25 kg. The ladder’s center of mass is 1.50 meters from worker “A.” If worker “A” can is lifting with 800 N and worker “B” is lifting with 400 N then:

(A) What is the engine’s mass?
(B) How far away from worker “A” is the engine located?

Class notes:
A 5m, 450N, beam on a pin hinge is suspended by a cable. The beam’s center of mass is 3m from the hinge along the beam.

(A) What is the reaction force at the hinge?
(B) What is the tension in the cable?
A 5 m, 200N, long ladder rests on a wall. The ladder’s center of mass is 3 m from the bottom. There is no friction on the wall, but there a coefficient of friction along the ground of 0.300. How far along the ladder can a 750 N person climb above the ground?

Class notes:
### Capacitance: Simple Circuits

Show your work on a separate piece of paper.

#### Capacitor Circuit Analysis

<table>
<thead>
<tr>
<th>Summary</th>
<th>SERIES</th>
<th>PARALLEL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Charge</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Capacitance</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Capacitance: Simple Circuits
Show your work on a separate piece of paper.

Capacitance and simple circuits

1. \[ \begin{array}{c}
6 \mu F \\
3 \mu F \\
2 \mu F \\
\hline
\hline
6 V
\end{array} \]

2. \[ \begin{array}{c}
2 \mu F \\
4 \mu F \\
4 \mu F \\
\hline
\hline
\end{array} \]

3. \[ \begin{array}{c}
2 \mu F \\
20 \mu F \\
4 \mu F \\
5 \mu F \\
\hline
\hline
20 V
\end{array} \]
Capacitance: Simple Circuits
Show your work on a separate piece of paper.

4
\[ \text{6 V} \quad 2 \, \mu F \quad \text{6} \, \mu F \quad 4 \, \mu F \]

5
\[ \text{10 V} \quad 12 \, \mu F \quad 8 \, \mu F \]

6
\[ \text{12} \, \mu F \quad 8 \, \mu F \quad 20 \, \text{V} \]
For this circuit calculate:
- The equivalent capacitance for the circuit
- The charge of each capacitor
- The potential difference across each capacitor
- The energy stored in each capacitor.
For this circuit calculate:
- The equivalent capacitance for the circuit
- The charge of each capacitor
- The potential difference across each capacitor
- The energy stored in each capacitor.
For this circuit calculate:

- The equivalent capacitance for the circuit
- The charge of each capacitor
- The potential difference across each capacitor
- The energy stored in each capacitor

Capacitance: Simple Circuits
Show your work on a separate piece of paper.
For this circuit calculate:
- The equivalent capacitance for the circuit
- The charge of each capacitor
- The potential difference across each capacitor
- The energy stored in each capacitor.
For this circuit calculate:
- The equivalent capacitance for the circuit
- The charge of each capacitor
- The potential difference across each capacitor
- The energy stored in each capacitor.
12
1. Calculate the equivalent capacitance for the entire circuit.
2. The energy of the entire circuit.
3. The voltage dropped by each capacitor.
4. The charge stored in each capacitor.
**Capacitance: Simple Circuits**

Show your work on a separate piece of paper.

100. If the 2 μF capacitor has a charge of Q, then how much charge, in terms of Q, is on the 4 μF capacitor?

101. If the potential difference across the 2 μF capacitor is 10V, then what is the potential difference across the 4 μF capacitor?

102. If the 2 μF capacitor has a charge of Q, then how much charge, in terms of Q, is on the 4 μF capacitor?

103. If the potential difference across the 2 μF capacitor is 10V, then what is the potential difference across the 4 μF capacitor?

104. Rank these capacitors based on the amount of energy they could hold given infinite time to charge them. Rank from greatest energy storage to lowest.

105. Rank these capacitors based on the amount of energy they could hold given infinite time to charge them. Rank from greatest energy storage to lowest.
106. Rank these capacitors based on the amount of energy they could hold given infinite time to charge them. Rank from greatest energy storage to lowest if they are all connected in parallel with each other. These images represent two parallel metal plates from each capacitor.
# Calculator Tips, Trick, and Use in Lab

## Calculator Tips, Tricks and Use in Lab for the TI-82, 83, and 84

### Finding average and standard deviation - on the TI
- The goal is to find the average and plus or minus error of 2.56, 3.12, 4.58, 6.89 and 3.22.
- Press “Stat” in the 3rd row from the top and the 3rd column from the left. This is the menu you will see.
- Select “Edit”

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1(1)=</td>
<td>2.56</td>
<td></td>
</tr>
</tbody>
</table>

- This is the screen you will see after selecting “Edit.”

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1(1)=2.56</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Type the first number, “2.56”
- Notice that the number shows up at the bottom of the screen

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.56</td>
<td>4.58</td>
<td>6.89</td>
</tr>
<tr>
<td>L1(2)=</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- After each number press enter.
- The list will look like this when all the numbers are entered.
- Note that the bottom of the list shows the entry number you are on.

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>L1(5)=</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- After all the numbers are entered, Press the Stat button again.
- Select CALC and 1-Var Stats.
- Press Enter.

<table>
<thead>
<tr>
<th>1-Var Stats</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The screen will look like this.
- The calculator is waiting for you to tell it which list to perform the statistics on.
- Type “L1.” It is in blue above number “1.”

<table>
<thead>
<tr>
<th>1-Var Stats L1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- The screen will look like this.
- Press “Enter.”

<table>
<thead>
<tr>
<th>1-Var Stats L1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>4.074</td>
<td></td>
</tr>
<tr>
<td>20.37</td>
<td></td>
</tr>
<tr>
<td>95.1049</td>
<td></td>
</tr>
<tr>
<td>4.0811419</td>
<td></td>
</tr>
<tr>
<td>1.38070739</td>
<td></td>
</tr>
<tr>
<td>n=5</td>
<td></td>
</tr>
</tbody>
</table>

- This is the average of the list of numbers.
- This is the “plus or minus” value.
- The answer to the question is 4.07 ± 1.74 to two decimal places. Note that the average and the plus or minus must both have the same number of decimal places.

<table>
<thead>
<tr>
<th>1-Var Stats L1</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2.56</td>
<td></td>
</tr>
<tr>
<td>2.84</td>
<td></td>
</tr>
<tr>
<td>3.22</td>
<td></td>
</tr>
<tr>
<td>5.736</td>
<td></td>
</tr>
<tr>
<td>maxX=6.89</td>
<td></td>
</tr>
</tbody>
</table>

- This is number of entries in the list.
Clearing the list – Method 1 – on the TI

- The goal is to erase the list of numbers in List #1, L₁.
- Press “Stat” in the 3rd row from the top and the 3rd column from the left. This is the menu you will see.
- Select “ClrList”

- Tell the calculator which list the erase. In this example tell it to erase L₁.” L₁” is located in blue above the number “1.”

- The screen will look like this. Press Enter.

Clearing the list – Method 2 – on the TI

- The goal is to erase the list of numbers in List #1, L₁.
- When in the edit mode of the statistics, use the blue arrow keys to move the cursor to the top of the list. It will be highlighted.

- Press the Clear key. DO NOT PRESS ENTER YET.
- The list of numbers at the bottom of the screen will disappear.

When you press Enter, the list will disappear.

Doing the math with a list of numbers at a time – on the TI

- The goal is to take all the numbers in L₁ and multiply them by 4 add 1 and put the answers in L₂. This might be a possibility when you need to use the formula y = 4x + 1 and all the “x” values are in the L₁ list.

- Use the arrow key to move to the top of an empty list, L2 in this example.
- Type “L₁*4+1” It will show up at the bottom of the screen.

- Press Enter and each value in L₁ will be multiplied by 4 and 1 added. The row by row answer will be placed in L₂.
### Calculator Tips, Trick, and Use in Lab

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.56</td>
<td>11.24</td>
<td>10.0673</td>
</tr>
<tr>
<td>3.12</td>
<td>13.98</td>
<td>2.2345</td>
</tr>
<tr>
<td>4.56</td>
<td>19.32</td>
<td>0.24708</td>
</tr>
<tr>
<td>6.89</td>
<td>26.56</td>
<td>0.24125</td>
</tr>
<tr>
<td>3.22</td>
<td>13.88</td>
<td>0.24189</td>
</tr>
</tbody>
</table>

- Answer

### Rounding numbers in a list – on the TI
- The goal is to round all the numbers in a list to 2 decimal places.
- Press the Mode key.
- Use the arrow keys to highlight the “2” in the second row. Press Enter then Quit.
- Look at the lists. They will now be rounded to two decimal places.

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.56</td>
<td>11.24</td>
</tr>
<tr>
<td>3.12</td>
<td>13.98</td>
</tr>
<tr>
<td>4.56</td>
<td>19.32</td>
</tr>
<tr>
<td>6.89</td>
<td>26.56</td>
</tr>
<tr>
<td>3.22</td>
<td>13.88</td>
</tr>
</tbody>
</table>

- Another example: Take the values in L1, divide them by the values in L2 and place the answer in L3.
Older Calculators
Using a non-graphical calculator to calculate the mean and standard deviation

Do the following on your **non-graphical** calculator to calculate the mean and standard deviation of 3, 5 & 7.

- **Put the calculator in statistics mode.**
  - **mode**
  - **###**
  - OR
  - **2nd**
  - **STAT**

- **Enter the data.**
  - \[ \sum \]
  - \[ \sum + \]
  - **DATA**
  - 3
  - \[ \sum \]
  - \[ \sum + \]
  - **DATA**
  - 5
  - \[ \sum \]
  - \[ \sum + \]
  - **DATA**
  - 7

- **Calculate the mean.**
  - **2nd**
  - **INV**
  - **Shift**
  - **Alpha**
  - Usually the mean key is located above another key
  - The display should say **2.333333333**

- **Calculate the standard deviation.**
  - **2nd**
  - **INV**
  - **Shift**
  - **Alpha**
  - \[ \sigma_{n-1} \]
  - The display should say **2**

- **Before entering a new set of data clear the statics memory.** This is done usually by pressing some of the keys below.
  - **CA**
  - OR
  - **2nd**
  - **CLA**

*Another fine worksheet by T. Wayne*
Press the APPS key to a list of applications. Press the up arrow to "go around the list and get to "VST APPS." With VST APPS selected press the "ENTER" key.

<table>
<thead>
<tr>
<th>SELECT A PROGRAM</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: DATAMATCH</td>
</tr>
<tr>
<td>2: DATAGATE</td>
</tr>
<tr>
<td>3: DATARAD</td>
</tr>
<tr>
<td>4: DAROTARY</td>
</tr>
<tr>
<td>5: DATADROP</td>
</tr>
<tr>
<td>6: FUNCTGEN</td>
</tr>
<tr>
<td>7: QUIT</td>
</tr>
</tbody>
</table>

After a title screen this menu screen should up. Select “1:DATAMATCH” by pressing the number “1.”

This is the title screen for the subprogram you just selected.

Scroll down to “MODE:GRAPHMATCH.” Then press the “ENTER” key. It should then read “MODE:TIMEGRAPH–10.”

Press the number “2” to check the settings.

If any settings do not match these, select “2” and change them to match these. Otherwise select “1” and continue.

Press the number “1.” It will show a graph as you move towards and away from the motion detector. If you are using these settings it will be finished in 10 seconds.

Press the “ENTER” key to see the graph you just made. After the graph is displayed you can press the “ENTER” key again to return to this menu. You scroll up or down to display a different graph from the same data, e.g. Velocity, Acceleration, etc.

Press “1” to make another graph.

Press the number “2” to check the settings.

If any settings do not match these, select “2” and change them to match these. Otherwise select “1” and continue.

Press the “ENTER” key to see the graph you just made. After the graph is displayed you can press the “ENTER” key again to return to this menu. You scroll up or down to display a different graph from the same data, e.g. Velocity, Acceleration, etc.
Physics Tools Manual

This manual is to assist you in using the hardware and calculator programs utilized in the physics class. This manual will be referred to in labs and activities.

Unless you’ve downloaded this manual, it is to remain in class.

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<tr>
<td>Air-Rocket launcher set up for VERTICAL flight</td>
<td>509</td>
</tr>
<tr>
<td>Air-Rocket launcher set up for ANGLED flight</td>
<td>511</td>
</tr>
</tbody>
</table>

Significant figures

...are made up of the digits you are absolutely sure of and an estimated digit. The estimated number is because the whole number comes from a measurement and measurements are not exact. When identifying the number of significant figures, the “significant digit” farthest to the right is the estimated digit. Below are the rules for determining the number of significant figures in an expression.

1. Non-zero digits and zeros between non-zero digits are always significant.
   
   **Examples:**
   
   2006..........................4 sig figs .............................................. “6” is estimated
   34.0001...........................6 sig figs .............................. “1” is estimated
   35.04002........................7 sig figs .............................. “2” is estimated
250.04..........................5 sig figs ........................................ “4” is estimated  
806.............................3 sig figs ........................................ “6” is estimated

2. Leading zeroes before the first non-zero digit are not significant.  
   Examples: 
   0.005........................1 sig fig (underlined numbers)…….. “5” is estimated  
   0.0000650..................3 sig figs (underlined numbers)….. “0” is estimated 
   0.000043....................2 sig figs (underlined numbers)….. “3” is estimated

3. Trailing zeroes to the right of the decimal point are always significant.  
   Examples: 
   15.00670.....................7 sig figs ........................................ “0” is estimated 
   21.0..........................3 sig figs ........................................ “0” is estimated 
   34.5000......................6 sig figs ........................................ “0” is estimated

4. Trailing zeroes left of the decimal point are ambiguous 
   Examples: 
   4300........................Was this measured to the tens or ones place?  
   56 000......................Was this measured to the hundreds, tens or ones place? 
   300..........................Was this measured to the tens or one’s place?

5. These numbers need to be expressed in scientific notation showing the 
   significance. For example, all these ambiguous numbers are expressed with 3 sig figs.  
   4300........................4.30 x 10^3........................................ “0” is estimated  
   56 000......................5.60 x 10^4........................................ “0” is estimated 
   300..........................3.00 x 10^2........................................ “0” is estimated

6. Counting numbers are exact. There are missing estimated digits and do not affect 
   a calculation’s significance.  
   Examples: 
   A gross of donuts..........144 donuts are counted out exactly  
   3 feet equals 1 yard......This is exact by definition  
   1 in = 2.54 cm............This is exact by definition  
   A dozen eggs...............12 eggs are counted out -exactly (you can’t have a 1/10 of 
   an egg)
### Finding average and standard deviation on the TI

- **The goal is to find the average and plus or minus error of 2.56, 3.12, 4.58, 6.89 and 3.22.**
- Press “Stat” in the 3rd row from the top and the 3rd column from the left. This is the menu you will see.
- Select “Edit”

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- This is the screen you will see after selecting :"Edit."

- **Type the first number, “2.56”**
- Notice that the number shows up at the bottom of the screen

- **After each number press enter.**
- The list will look like this when all the numbers are entered.
- Note that the bottom of the list shows the entry number you are on.

<table>
<thead>
<tr>
<th>L1</th>
<th>L2</th>
<th>L3</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.58</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6.89</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.22</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- **After all the numbers are entered, Press the Stat button again.**
- Select CALC and 1-Var Stats.
- Press Enter.

- **The screen will look like this.**
- The calculator is waiting for you to tell it which list to perform the statistics on.
- Type “L1.” It is in blue above number “1.”

<table>
<thead>
<tr>
<th>1-Var Stats</th>
</tr>
</thead>
<tbody>
<tr>
<td>n=5</td>
</tr>
<tr>
<td>x̄=3.074</td>
</tr>
<tr>
<td>Sx=95,1049</td>
</tr>
<tr>
<td>Sx1=1,749511419</td>
</tr>
<tr>
<td>p=x=1,556760739</td>
</tr>
<tr>
<td>This is the average of the list of numbers.</td>
</tr>
<tr>
<td>This is the “plus or minus” value.</td>
</tr>
<tr>
<td>The answer to the question is 4.07 ± 1.74 to two decimal places. Note that the average and the plus or minus must both have the same number of decimal places.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>1-Var Stats</th>
</tr>
</thead>
<tbody>
<tr>
<td>min=2.56</td>
</tr>
<tr>
<td>Q1=2.84</td>
</tr>
<tr>
<td>Med=3.22</td>
</tr>
<tr>
<td>Q3=5.76</td>
</tr>
<tr>
<td>max=6.89</td>
</tr>
<tr>
<td>This is number of entries in the list.</td>
</tr>
</tbody>
</table>
### Clearing the list – Method 1 - on the TI
- The goal is to erase the list of numbers in List #1, L₁.
- Press “Stat” in the 3rd row from the top and the 3rd column from the left. This is the menu you will see.
- Select “ClrList”

- Tell the calculator which list the erase. In this example tell it to erase L₁.” L₁” is located in blue above the number “1.”

- The screen will look like this. Press Enter.

### Clearing the list – Method 2 - on the TI
- The goal is to erase the list of numbers in List #1, L₁.
- When in the edit mode of the statistics, use the blue arrow keys to move the cursor to the top of the list. It will be highlighted.

- Press the Clear key.  **DO NOT PRESS ENTER YET.**
- The list of numbers at the bottom of the screen will disappear.

- When you press Enter, the list will disappear.

### Doing the math with a list of numbers at a time - on the TI
- The goal is to take all the numbers in L₁ and multiply them by 4 add 1 and put the answers in L₂. This might be a possibility when you need to use the formula y = 4x + 1 and all the “x” values are in the L₁ list.

- Use the arrow key to move to the top of an empty list, L2 in this example.
  - Type “L₁*4+1” It will show up at the bottom of the screen.

- Press Enter and each value in L₁ will be multiplied by 4 and 1 added. The row by row answer will be placed in L₂.

- Another example: Take the values in L₁, divide them by the values in L₂ and place the answer in L₃.
• **Answer**

### Rounding numbers in a list – on the TI

- The goal is to round all the numbers in a list to 2 decimal places.
- Press the Mode key.
- Use the arrow keys to highlight the “2” in the second row. Press Enter then Quit.
- Look at the lists. They will now be rounded to two decimal places.
Using a non-graphical calculator to calculate the mean and standard deviation

Do the following on your non-graphical calculator to calculate the mean and standard deviation of 3, 5 & 7.

Put the calculator in statistics mode.

<table>
<thead>
<tr>
<th>mode</th>
<th>###</th>
</tr>
</thead>
</table>

OR

| 2nd | STAT |

Enter the data.

<table>
<thead>
<tr>
<th>Σ</th>
<th>Σ+</th>
<th>Σ+</th>
<th>Σ+</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>5</td>
<td>7</td>
<td>DATA</td>
</tr>
<tr>
<td>DATA</td>
<td>M+</td>
<td>DATA</td>
<td>M+</td>
</tr>
<tr>
<td>DATA</td>
<td>M+</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Calculate the mean.

<table>
<thead>
<tr>
<th>2nd</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV</td>
</tr>
<tr>
<td>Shift</td>
</tr>
<tr>
<td>Alpha</td>
</tr>
</tbody>
</table>

Usually the mean key is located above another key

The display should say 2.333333333

Calculate the standard deviation.

<table>
<thead>
<tr>
<th>2nd</th>
</tr>
</thead>
<tbody>
<tr>
<td>INV</td>
</tr>
<tr>
<td>Shift</td>
</tr>
<tr>
<td>Alpha</td>
</tr>
</tbody>
</table>

The display should say 2

Before entering a new set of data clear the statics memory. This is done usually by pressing some of the keys below.

| CA | OR | 2nd | CLA | OR | Sometimes you have to take it out of statics mode.
Using the Ultrasonic Motion Detector

Press the APPS key to a list of applications. Press the up arrow to "go around the list and get to "VST APPS." With VST APPS selected press the "ENTER" key.

After a title screen this menu screen should up. Select "1:DATAMATCH" by pressing the number "1."

This is the title screen for the subprogram you just selected.

Scroll down to "MODE:GRAPHMATCH." Then press the "ENTER" key. It should then read "MODE:TIMEGRAPH–10."

Press the number "2" to check the settings.

If any settings do not match these, select "2" and change them to match these. Otherwise select "1" and continue.

Press the number "1." It will show a graph as you move towards and away from the motion detector. If you are using these settings it will be finished in 10 seconds.

Press the "ENTER" key to see the graph you just made. After the graph is displayed you can press the "ENTER" key again to return to this menu. You scroll up or down to display a different graph from the same data, e.g. Velocity, Acceleration, etc.

Press "1" to make another graph.
**Photogate**

Measuring velocity at a single location using the photogate w/the TI

<table>
<thead>
<tr>
<th>STEP</th>
<th>SCREEN SHOT</th>
<th>INSTRUCTIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>The cbl is the device under the calculator.</td>
<td>The cable plugs into the jack that is labeled “DIG/SONIC.” The plug is made in such a way that this is the only jack that fits.</td>
</tr>
<tr>
<td>1</td>
<td>Click on the “APPS” button in the 3rd row down and 2nd column from the left. It is circled on this picture.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>From the list, scroll down to “VST Apps.” Once highlighted, press the “ENTER” key</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Press the number “2” to select, “DATAGATE.”</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Select option “1:SETUP.”</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Select option, “2:GATE.”</td>
<td></td>
</tr>
</tbody>
</table>

**APPLICATIONS**

- Login
- Prob Sim
- SciTools
- StudyCrd
- TimeSpan
- Transfrm
- VST Apps

**SELECT A PROGRAM**

- 1:DATAMATCH
- 2:DATAGATE
- 3:DATARAD
- 4:DAROTARY
- 5:DATADROP
- 6:FUNCTGEN
- 7:QUIT
- 8:QUIT

**MODE:MOTION**

- 1:SETUP
- 2:START
- 3:GRAPH
- 4:ANALYZE
- 5:QUIT
- 6:FUNCTGEN
- 7:QUIT

**PHOTOGATE SETUP**

- 1:MOTION
- 2:GATE
- 3:PENDULUM
- 4:PULSE
- 5:RETURN TO MAIN SCREEN
**STEP 6**

**SCREEN SHOT**

**INSTRUCTIONS**

The "flag" is the piece of the card that travels through the photogate.

---

**STEP 7**

**SCREEN SHOT**

**SETTINGS**

Mode: Gate
Flag Width (m): 0.2

---

**STEP 8**

**SCREEN SHOT**

**DIG: PHOTOGATE**

---

Mode: Gate

1: Setup
2: Start
3: Graph

---

**STEP 9**

**SCREEN SHOT**

**GATE MODE**

Trail Number: ---
Time Gate 1 (s): ---

---

**STEP 10**

**SCREEN SHOT**

**DIG: PHOTOGATE**

---

Mode: Gate

1: Setup
2: Start
3: Graph

---

**STEP 11**

**SCREEN SHOT**

**GATE 1 TIME IN**

... Vel. in L4

---

**INSTRUCTIONS**

Check the settings. The flag width shown to the left is just an example. Your flag will probably be different. If the settings are acceptable, click on “1: OK” …Otherwise enter the flag’s width.

The screen should look like this. Notice just above the horizontal line in the middle of the screen is the text, “MODE: GATE.” This is what it should say.

When you are set up to take data…

Select option, “2: START.”

Record every piece of data the calculator gives you when it gives you the data.

Every time an object breaks the beam of light in the photogate, the “TRIAL NUMBER:” will increment itself up.

Press, “[STO],” when you have recorded all of your trials.

FYI … Velocity through gate = \( \frac{\text{Flag width}}{\text{CBL’s time}} \)

If you are finished select, “4: QUIT.”

If you decide you need more data, do not select

---

**INSTRUCTIONS**

Note that the software tells you where the times and velocities are stored (L4). L1 is the trial number, L2 are the times.

**Record EVERY piece of data the calculator gives you.**
Using the force probes w/ the TI.

The hook end of the sensor can be pushed or pulled. (That’s what the “+” indicates. 5 N is close to 1 pound of force. The sensor is not to exceed 10 pounds of force on the 50N setting or 2 pounds in the 10N setting. This is easy to do by hand. Please gentle and don’t try to, “max out,” the sensor.

It can break when maxed out.

**APPLICATIONS**
1: Finance...
2: CBL/CBR
3: Cabri Jr
4: Conics
5: DataMIn1
6: Inequalz
7: LearnChk

Plug the magnetic field probe into, “~CH1,” on the side of the CBL unit.

Press the “APPS” button. Use the direction keys to scroll down to a program called, “DataMIn1.” Press enter to select this application.

A title screen will appear for a few seconds before this screen appears. If a different screen appears saying something about, “finished collecting data...” then ignore it and press the enter key.

The applied force is shown in the top right of the screen. Note: The force uses the wrong symbol. It should be, “N.”

To quit taking data choose option 6 on this screen.

**ZERO’ING the force meter.**

Sometimes the meter will give a force when it should read zero Newtons. To make it read zero again select item, “1.”

Select option, “3: ZERO.”
### Force Probe

<table>
<thead>
<tr>
<th>SELECT CHANNEL</th>
<th>CH1:FORCE(n)</th>
<th>PRESS [ENTER] TO ZERO</th>
</tr>
</thead>
<tbody>
<tr>
<td>1:CH1-FORCE(n)</td>
<td>.54</td>
<td>-Done</td>
</tr>
<tr>
<td>2:ALL CHANNELS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>FORCE(n)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CALIBRATION:LINEAR</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Select, “CH1-FORCE(n).”

The screen is reading the current force on the meter. If nothing is pulling or pushing on the meter it should read zero. To make it read zero, press [ENTER].

---

**TEACHER USE**

**NOTE: LINEAR CALIBRATION**

+10N: \( m = -4.9 \text{ N/V}; \ b = 12.25 \text{ V} \)
+50N: \( m = -24.5 \text{ N/V}; \ b = 61.25 \text{ V} \)
# Light Probe

## Measuring light intensity w/the TI

When using the probe you need to either have the light source as the only other light in the room or place a tube made from black paper between the probe and the light source.

![Diagram of Light Source](Image)

### APPLICATIONS

1: Finance...
2: CBL/ CBR
3: CabriJr
4: Conics
5: DataMIn1
6: Inequalz
7: LearnChk

<table>
<thead>
<tr>
<th>PROBE: Temp</th>
<th>Light</th>
</tr>
</thead>
<tbody>
<tr>
<td>Volt Sonic</td>
<td>Meter</td>
</tr>
<tr>
<td>TYPE: Bar</td>
<td></td>
</tr>
<tr>
<td>MIN: 0</td>
<td></td>
</tr>
<tr>
<td>MAX: 5</td>
<td></td>
</tr>
<tr>
<td>UNITS:</td>
<td></td>
</tr>
<tr>
<td>DIRECTNS:</td>
<td></td>
</tr>
</tbody>
</table>

Plug the magnetic field probe into, “~CH1,” on the side of the CBL unit.

Press the “APPS” button. Use the direction keys to scroll down to a program called, “CBL/CBR.” Press enter to select this application.

A title screen will be displayed. Press any key to continue.

SELECT, “1: GAUGE.”

From this screen, move the cursor over the highlighted items and press the, “Enter,” key.

When they have each been selected, move the cursor over, “Go…” and press, “Enter.”

This instruction screen will appear. Press the, “ENTER,” key after the, short, animation is over.

This instruction screen will appear. Press the, “ENTER,” key.

This instruction screen will appear. Press the, “ENTER,” key.

This instruction screen will appear. Press the, “ENTER,” key.
### Troubleshooting and Errors

If the CBL is not connected to the calculator, you will see this screen. Just push the link cable in and make sure the CBL is turned on and the batteries are good.

---

**Press [Enter] to begin.**

Follow the screen’s instructions.

---

Here is where the readings will occur. The units are milli-Watt per cm². So all the displayed values are $10^{-3}$ W. Example: $0.1245 \text{ mW/cm}^2 = 0.1245 \times 10^{-3} \text{ W/cm}^2$.

When you have finished, press the, “CLEAR,” button. The screen will go back to the main menu. See the screen below.

---

**Probe:** Temp Volt Sonic

**Type:** Bar

**Min:** 0

**Max:** 5

**Units:** mW/cm²

**Directions:** Off

Go...

**CBL/CBR App:**

1: GAUGE

2: DATA LOGGER

3: RANGER

4: QUIT

Press, "2nd Mode," to go back a menu screen.

Choose option, “4: QUIT,” to quit the program.

---

**Then turn off the CBL to conserve the batteries’ life.**
**Magnetic Field Probes**

**Measuring magnetic fields using the b-field probe and the TI**

The white dot on the sensor should face a magnet’s south pole. This will give a positive field reading. On the LOW setting, the probe measures up to $0.3 \times 10^{-3}$ T; on HIGH, it measures up to $6.4 \times 10^{-3}$ T.

<table>
<thead>
<tr>
<th>APPLICATIONS</th>
</tr>
</thead>
<tbody>
<tr>
<td>1: Finance...</td>
</tr>
<tr>
<td>2: CBL/CBR</td>
</tr>
<tr>
<td>3: CabriJr</td>
</tr>
<tr>
<td>4: Conics</td>
</tr>
<tr>
<td>5: DataMIn1</td>
</tr>
<tr>
<td>6: Inequalz</td>
</tr>
<tr>
<td>7: LearnChk</td>
</tr>
</tbody>
</table>

Plug the magnetic field probe into, “~CH1,” on the side of the CBL unit.

Press the “APPS” button. Use the direction keys to scroll down to a program called, “DataMIn1.” Press enter to select this application.

A title screen will stay on for a few seconds before this screen shows up.

**The number at the top left of the screen in the magnetic field strength in $10^{-3}$ Tesla’s.** (Pay attention to the lab to see what setting HIGH or LOW is used in the lab.)

**“Zero’ing the probe”**

Every time the magnetic field probe is moved, you will need to subtract out the Earth’s magnetic field from the readings.

To do this, press number “1” on the screen shown above. Press “4:ZERO.”

Press “1” to calibrate the magnetic field probe.

Press the “ENTER” key. You may need to hold the key down for a second before the calculator responds.

This is the screen that shows when you are done. Because you did not make a graph, L2 will be empty.
Multimeter Use

Multimeter: Measuring the voltage

VOLTAGE

Voltage measurements compare the energy on the black lead wire to the energy on the red lead lead. When these two wires sense different energy levels, the meter shows energy difference. This difference is called voltage and has the units of volts (V).

This also means to measure the voltage of something you will need to measure the voltage ACROSS the object.

To measure the voltage output, you need to put across the ends of what you are testing. If you are testing a battery then one lead goes across the positive end. The other lead touches the negative end. The voltage will show up on the meter. If the voltage is negative, don’t worry about it.

1. Plug the black lead into the center hole at the bottom of the meter.
2. Plug the red lead into the hole at the bottom of the meter on the right.
3. Turn on the power by pressing the POWER button.
4. Press the AUTO button.
5. Slide the selector switch all the way to the left.
6. Take a reading
Current measurements read the flow of charges **THROUGH** the meter. To measure the flow, the meter must go between the energy source, (the battery), and the component to be measured. Current is measured in Amperes, “A.”

When measuring the output of battery, the battery must be under “load.” A resistor is a device that makes it more difficult for charges to flow. When connected to a battery it puts a load on the battery. In other words, it makes it harder for the battery to deliver energy. When measure the output of a battery use a 10 ohm resistor. When measuring the current of a fruit battery, use a resistor equal to 1 ohm or less.

**IF** the reading flashes, then move the RED lead to the far left hole at the bottom (10AMAX).

1. Plug the black lead into the center hole at the bottom of the meter.
2. Plug the red lead into the hole at the bottom of the meter on the right.
3. Turn on the power by pressing the **POWER** button.
4. Press the **AUTO** button.
5. Slide the selector switch all the way to the right.
6. Take a reading.

**Multimeter: Calculating the power**

Power is **not** measured with this meter, it is calculated.

Power = (Current)(Volts)

Power is measured in Watts, “W.”
Multimeter: Measuring the resistance

To get a reading, connect the object to be measured to the leads. A battery’s resistance cannot be measured. Do not measure the resistance of an electrical component with a battery in the circuit. The battery must be removed.

1. Plug the black lead into the center hole at the bottom of the meter.
2. Plug the red lead into the hole at the bottom of the meter on the right.
3. Turn on the power by pressing the POWER button.
4. Press the AUTO button.
5. Slide the selector switch all the way to the middle.
6. Read the numbers on the screen.

**NOTE:** Look for the symbol “k” or “M” on the LCD screen. The, “k,” symbol means to multiply the LCD’s number by 1000. The, “M,” symbol means to multiply the LCD’s number by 1,000,000. No extra letter means do not multiply the number by anything.
**Air-Rocket Set Up and Launching Instructions**

*...for VERTICAL LAUNCH*

**Safety first. Never stand in front of the rocket under any circumstances. NEVER LAUNCH or pump the tire pump without the teacher’s permission.**

Air-Rocket launcher set up for VERTICAL flight

<table>
<thead>
<tr>
<th><strong>STEP 1</strong></th>
<th><img src="image1" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place the base on a “level” piece of ground. Open it up. Push two nails through the holes on the base into the ground. This will stabilize the launcher.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>STEP 2</strong></th>
<th><img src="image2" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Close the launcher so that it is pointing vertically.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>STEP 3</strong></th>
<th><img src="image3" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place the yellow washer on top of the launcher.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>STEP 4</strong></th>
<th><img src="image4" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Make sure the white nose cone is on the rocket’s body. Slide the rocket over the launcher.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>STEP 5</strong></th>
<th><img src="image5" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Hold the protractor next to the rocket’s body. The string should hand down. You are checking to see if the rocket is pointed straight up. If the rocket is not straight up, then adjust THE BASE so that the rocket’s points straight up.</td>
<td></td>
</tr>
</tbody>
</table>
Air-Rocket Set Up and Launching Instructions

Safety first. Never stand in front of the rocket under any circumstances. NEVER LAUNCH or pump the tire pump without the teacher’s permission.

---

**STEP 6**
Place the pump’s hose on the bottom of the rocket launcher. The “flip switch” should be down—parallel to the hose. This is shown in the LEFT picture. Once the end is in place, flip the switch up—perpendicular to the hose. This is shown in the RIGHT picture. **Do NOT pump the tire pump without the teacher’s permission.**

**STEP 7**
The hose should be stretched out away from the rocket.
**EVERYONE STANDS BEHIND THE PERSON USING THE PUMP.** When the teacher gives you permission—and only then—launch your rocket. If you launch without teacher permission, your group will receive a ZERO for this activity.

---

**WARNING**
If you launch or pump the tire pump without teacher permission, your group will receive a ZERO for this activity.

Everyone in your group should raise his/her hands when you are ready to launch.

---

**STEP 8**
AFTER RECEIVING TEACHER PERMISSION, stand behind the launcher.

**STEP 9**
Stand on the base of the pump and begin to pump. The rocket will launch between 2 and 6 pumps. It will launch with a POP sound. If you are timing the rocket’s flight, Stand 20 feet away from the rocket and get ready to start. Stop timing when the rocket hits the ground.

**STEP 10**
Do not lose sight of the rocket. It will come NEARLY straight down.

---

Do not lose sight of the rocket. It will come NEARLY straight down.
## Air-Rocket launcher set up for ANGLED flight

<table>
<thead>
<tr>
<th>STEP 1</th>
<th><img src="image1.jpg" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Open up the base. (It is hinged.) Leave the nails in the base.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP 2</th>
<th><img src="image2.jpg" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Insert the wooden wedge into the slot. The base will lean against the wedge at a pre-described angle. The angle is written on the wedge.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP 3</th>
<th><img src="image3.jpg" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Put the yellow cap on the launcher.</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP 4</th>
<th><img src="image4.jpg" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td>Place the rocket on the white launcher and check the angle with the protractor, (astrolabe). <strong>Do not pump the tire pump.</strong></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>STEP 5</th>
<th><img src="image5.jpg" alt="Image" /></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Get permission from the teacher before launching.</strong> Stand behind the rocket when launching. It takes no more than 6 pumps to launch the rocket.</td>
<td></td>
</tr>
</tbody>
</table>