CIRCULAR MOTION COMPUTER ACTIVITES **Teacher Notes**

PURPOSE

- To help students visualize circular motion applications.
- To give student practice at use the formulae for uniform circular motion.
- To aide students in visualizing circular motion concepts.

MATERIALS

- Computers with internet access. 2 students per computer works well.
- Web browser with a Flash 6 or newer plug-in.
- Web browser with the QuickTime plug-in. (From http://www.apple.com/quicktime -you do not need the professional version to run these movies. You only need the FREE player.) Superfluous technical stuff: The movies are mpeg4 files using the “H.264” compression codec.

TIME

- 90 minutes for the activity,
- 20 minutes to grade as a class. I grade this in class by projecting the answers using an LCD projector.

COST

Are you kidding? It free of course.

INFORMATION

- These activities are made to run from the internet from http://www.mrwaynesclass.com/circular/activity I use these activities in place of the typical pen and paper problems. Anecdotally, I’ve noticed that the animations and movies (1) make a memorial impression on the students and (2) help those students (new to the country) who do need help with English and student who have a difficulty visualizing to understand the concepts, math and applications.

- The points for each section is listed at the top of each section’s page on the answer sheets.

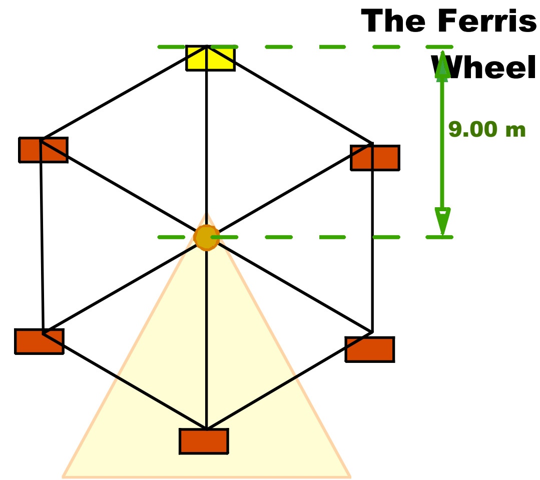
- Suggested points for every answer is given on the key. This points can be scaled as needed.

By Tony Wayne

CIRCULAR MOTION COMPUTER ACTIVITES 18 points — Ferris Wheel

Insert the cd-rom and open up the web page file titled, “home.html” Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity

Select “Ferris Wheel.” After the animation pops up press the “Play” button.



QUESTIONS AND PROCEDURE:

1.1) Use the stopwatch to measure the period of motion for the Ferris wheel. What is its period?

One rotation takes 13.5 seconds

T = 13.5 s +1 ____________________

1.2) Calculate it’s tangential velocity:

$v = \frac{2\pi r}{T}$ +1 $\quad v = \frac{2\pi(9.00\ \text{m})}{13.5\ \text{s}}$ +2

$v = 4.19\ \frac{\text{m}}{\text{s}}$ +2

v = 4.19 m/s ____________________

1.3) Calculate its centripetal acceleration:

$a_c = \frac{4\pi^2 R}{T^2}$ +1 $\quad a_c = \frac{4\pi^2(9.00\ \text{m})}{(13.5\ \text{s})^2}$ +2

$a_c = 1.95\ \frac{\text{m}}{\text{s}^2}$ +2

a_c = 1.95m/s² ____________________

1.4) If the mass of a rider is 65 kg, then what is the rider’s centripetal force?

$F = ma$ +1 $\quad F = (65\ \text{kg})\left(1.95\ \frac{\text{m}}{\text{s}^2}\right)$ +2

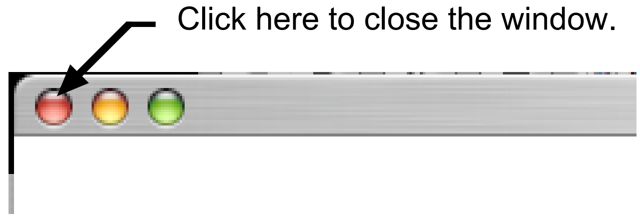
$F_C = 127\ \text{N}$ +2

F_C = 127 N ____________________

1.5) The term, "centripetal force," is a generic term. If you were to talk about gravity, you would know that only mass exerts a gravitational force. But many different things can exert a “centripetal force”. What is supplying the centripetal force to keep the rider going in a circle at the bottom of the motion?

The seat of the chair the riders sits in is pushing him/her to the center. +2

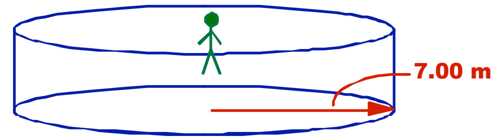
Click here to close the window.



CIRCULAR MOTION COMPUTER ACTIVITES 18 points — The "Anti-Gravity" Ride

Insert the cd-rom and open up the web page file titled, "home.html" Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity

Select, "Anti-Gravity Machine," from the menu. Press the, "Play," button when the animation opens up.



QUESTIONS AND PROCEDURE:

2.1) Use the stopwatch to measure the period of motion for the ride's wheel. What is its period?

T = 3.58 s +1 ______________________

2.2) Calculate it's tangential velocity:

$$v = \frac{2\pi r}{T} \quad +1 \qquad v = \frac{2\pi(7.00\text{ m})}{3.58\text{ s}} \quad +2$$

$$v = 12.27412944 \quad \Rightarrow \quad v = 12.3\ \frac{\text{m}}{\text{s}} \quad +2$$

v = 12.3 m/s ______________________

2.3) Calculate its centripetal acceleration:

$$a_c = \frac{4\pi^2 R}{T^2} \quad +1 \qquad a_c = \frac{4\pi^2(7.00\text{ m})}{(3.58\bar{3}\text{ s})^2} \quad +2$$

$$a_c = 21.52203621 \quad \Rightarrow \quad a_c = 21.5\ \frac{\text{m}}{\text{s}^2} \quad +2$$ ...(2.2 g's)

a_c = 21.6 m/s² ______________________

2.4) If the mass of a rider is 55 kg, then what is the rider's centripetal force?

$$F = ma \quad +1 \qquad F = (55\text{ kg})\left(21.56213314\ \frac{\text{m}}{\text{s}^2}\right) \quad +2 \qquad F = 1185.92\text{ N}$$

$$F_C = 1190\text{ N} \quad +2$$

F_C = 11.90 N ______________________

2.5) The term centripetal force is a generic term. If you were to talk about gravity, you would know that only mass exerts a gravitational force. But many different things can exert a "centripetal force". What is supplying the centripetal force to keep the rider going in a circle?

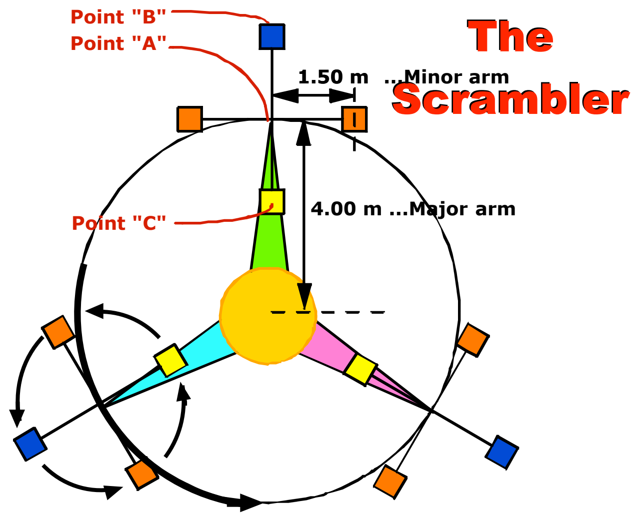
The walls of the ride are pushing the passengers to the center. +2

Click here to close the window.

Insert the cd-rom and open up the web page file titled, “home.html” Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity

Select, “The Scrambler,” from the menu. Press the, “Play,” button when the animation opens up.

The “Scrambler’s” motion is a complex circular motion. When rider is the farthest away from the center, point B, the rider is moving with a speed equal to the tangential velocities about the minor axis AND the major axis. The rider’s radius is equal to the distance between his/herself, at point B, and the center. When the rider is closest to the center, point C, the rider experiences a velocity that is the difference between the major and minor axis. The rider’s radius is equal to the minor arm’s length.



QUESTIONS AND PROCEDURE:

3.1) What is the period of motion when the MINOR arm is the radius? **T = 3.17 s** +2

3.2) What is the tangential velocity when the MINOR arm is the radius?

$$v = \frac{2\pi r}{T} \; \boxed{+1} \qquad v = \frac{2\pi(1.50\text{ m})}{3.17\text{ s}} \; \boxed{+2} \qquad v = 2.973116076 \Rightarrow v = 2.97\,\frac{\text{m}}{\text{s}} \; \boxed{+2}$$

v = 2.97 m/s ____________

3.3) What is the period of motion when the MAJOR arm is the radius? **T = 6.33 s** +2

3.4) What is the tangential velocity when the MAJOR arm is the radius?

$$v = \frac{2\pi r}{T} \; \boxed{+1} \qquad v = \frac{2\pi(4.00\text{ m})}{6.33\text{ s}} \; \boxed{+2} \qquad v = 3.970417256 \Rightarrow v = 3.97\,\frac{\text{m}}{\text{s}} \; \boxed{+2}$$

v = 3.97 m/s ____________

3.5) What is the centripetal acceleration in g’s at point A? (When the major arm is the axis.)

$$a_c = \frac{4\pi^2 R}{T^2} \; \boxed{+1} \qquad a_c = \frac{4\pi^2(4.00\text{ m})}{(6.33\text{ s})^2} \; \boxed{+2} \quad a_c = 3.941053296 \; \boxed{+1} \Rightarrow g's = 3.94105 / 9.80 = 0.402 \text{ g's} \; \boxed{+2}$$

a_c = 0.402 g’s ____________

3.6) What is the centripetal acceleration in g’s a point C? (The radius is the major axis – the minor axis. The tangential velocity to use will be the difference of the two tangential velocities due to the major and minor arms.) **R=4.00 m – 1.50 m = 2.50 m** +1 **: v=3.97m/s – 2.97 m/s= 1.00 m/s** +1

$$a_c = \frac{\upsilon^2}{r} \; \boxed{+1} = \frac{(1.00\text{ m/s})^2}{2.50} \; \boxed{+2} = 0.400\,\frac{\text{m}}{\text{s}^2} \; \boxed{+1} \Rightarrow g's = \frac{0.400\text{ m/s}^2}{9.80\text{ m/s}^2} = 0.0408 \text{ g's} \; \boxed{+2}$$

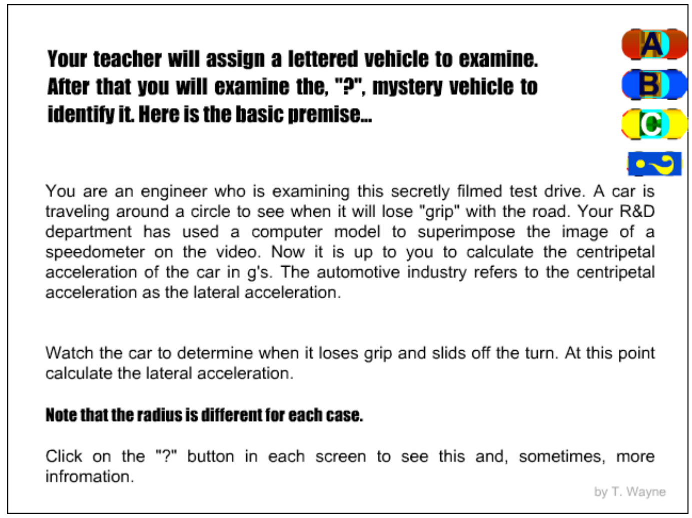
a_c = 0.0408 g’s ____________

CIRCULAR MOTION COMPUTER ACTIVITES 26 points

Insert the cd-rom and open up the web page file titled, "home.html" Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity

Select, "Cars and Cornering," from the menu.

The animation's title screen explains the situation. **READ IT**. When you watch the clips, remember, the speedometer you see is in m/s and it is based on a computer model of the video clip. That's why when the can spins of the track the speedometer does not change.



4.1) Which clip were you assigned? +1

The radius is given on the "video clip."

4.2) Watch the "video clip" and observe when the car loses traction and slides off the track. Record the speed at which this happens.

v = "A" 17 m/s, "B" 9.1 m/s, "C" 23.8 m/s +2

4.3) What is the lateral acceleration of the car in g's?

CASE A

$$a_C = \frac{\upsilon^2}{r} \text{ [+1]},\ a_C = \frac{\left(17\,m/s^2\right)^2}{70\text{ m}} \text{ [+2]}$$

$$a_C = 4.13\ m/s^2 \text{ [+2]}$$

CASE B

$$a_C = \frac{\upsilon^2}{r} \text{ [+1]},\ a_C = \frac{\left(9.1\,m/s^2\right)^2}{65\text{ m}} \text{ [+2]}$$

$$a_C = 1.27\ m/s^2 \text{ [+2]}$$

CASE C

$$a_C = \frac{\upsilon^2}{r} \text{ [+1]},\ a_C = \frac{\left(23.8\,m/s^2\right)^2}{75\text{ m}}$$

$$a_C = 7.55\ m/s^2 \text{ [+2]}$$

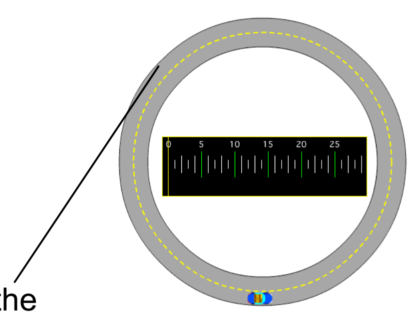
4.4) Now click on the question mark button. 
This will take you to the mystery car.
For this car you are going to calculate the lateral acceleration and compare it to a table to determine which car is under the question mark. (Note, the track's radius has changed.) Which car do you have under the question mark? Show support for your answer.

Car Name	Lateral Acceleration In g's
Lexus GX 470	0.72
Lexus ES300	0.74
Lexus GS300	0.76
Lexus S300 Sport Cross	0.80

$$a_C = \frac{\upsilon^2}{r} \text{ [+1]} = \frac{\left(20.0\,m/s^2\right)^2}{55.0\text{ m}} \text{ [+2]} = 7.\overline{27}\,\frac{m}{s^2} \text{ [+1]}$$

$$\Rightarrow 7.\overline{27}\,\frac{m}{s^2} \Big/ 9.80\,\frac{m}{s^2} = 0.74\text{ g's} \text{ [+2]}$$

<u>Lexus ES300</u> +2 if car matches g's

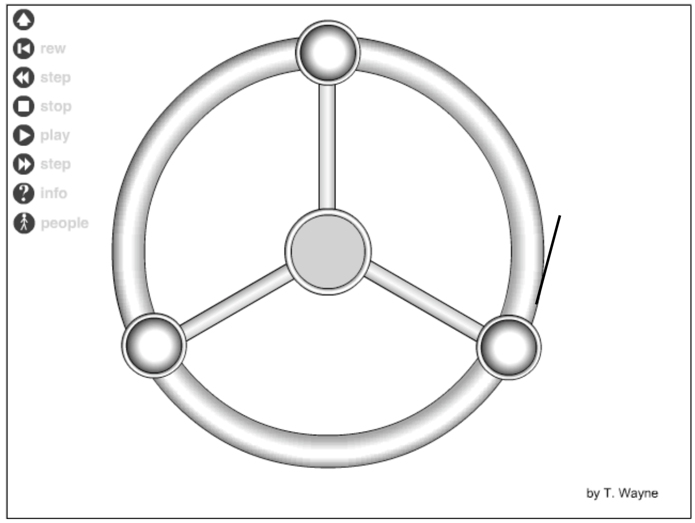


4.5) Draw the path of the mystery car when it spins off the track at the location where it comes off the track. +2 Line drawn tangent to the circle AND straight

CIRCULAR MOTION COMPUTER ACTIVITES **29 points** **Space Station**

Insert the cd-rom and open up the web page file titled, "home.html" Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity

Select, "Space Station," from the menu.



Note: This is nothing like the I.S.S. currently being built. It is the typical science fiction design I remember reading about as a kid.

5.1) Using a stop watch measure the period of motion of the space station.

T = 41.0 s +1 ________

5.2) Click on the "people" button, people to see where a person would stand to experience "artificial gravity." Why do you think standing here would give a passenger the feeling of standing on a planet?

The floor is pushing up on the person with a force equal to his/her weight. +2

5.3) What would the radius at the edge of the outer ring have to be for the centripetal acceleration to equal 1 g on Earth?

$$a_C = 1\,g = 9.80\,\frac{m}{s^2} \; +1 \;\therefore a_C = \frac{4\pi^2 r}{T^2} \; +1, \; 9.80\,\frac{m}{s^2} = \frac{4\pi^2 r}{(41\,s)^2} \; +2, \; r = 417\,m \; +2$$

r = 417 m ____________

5.4) Then center compartment of the space station has a radius that is 1/5th the radius to the edge of the outer ring. If the centripetal acceleration replaced the acceleration due to gravity (artificially), then how much time would it take for a pen to hit the floor if it was dropped from 1.00 m above the floor? **Acceleration due to artificial gravity = a_c at this location**

T is still 41 s. +1 "r" is now 1/5(417m) = 83.5 m. +1

$$a_C = 1\,g = 9.80\,\frac{m}{s^2} \; +1 \;\therefore a_C = \frac{4\pi^2 r}{T^2} \; +1, \; a_C = \frac{4\pi^2 (83.5m)}{(41\,s)^2} \; +2, \; a_C = 1.96\,\frac{m}{s^2} \; +2$$

For the drop. $\upsilon_O = 0$ +1, $a_C = 1.96\,\frac{m}{s^2}$ +1, x = 1.00m +1,

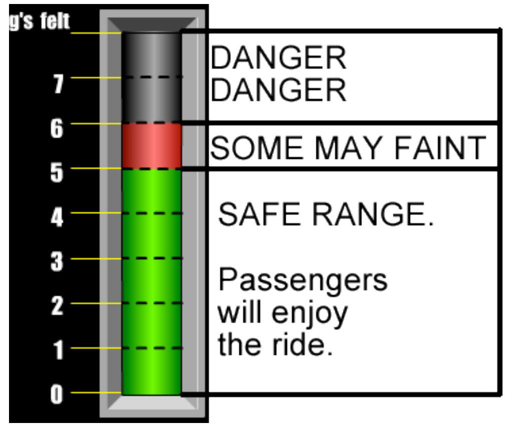
$$x = \frac{1}{2}at^2 \; +1, \; 1.00m = \frac{1}{2}\left(1.96\,\frac{m}{s^2}\right)t^2 \; +2, \; t = 1.01\,s \; +2$$

5.5) How many g's would a passenger experience in the exact center of the space station? Explain your answer. **NONE. Without a radius, a_c = zero ($a_c = v^2/r$)** +2

5.6) At some the spaceship is going to unlock itself from the station, coast, then fire its rockets. On the picture above, draw the path of the spaceship from where it unlocks to where it first fires its rockets. +2 Line drawn tangent to the circle AND straight

CIRCULAR MOTION COMPUTER ACTIVITES **20 points total for 2 'loop' pages** Loop Design

Insert the cd-rom and open up the web page file titled, "home.html" Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity



Select, "Loops," from the menu.

Click on **LOOP A** from the menu screen.

The meter on the right of the animation shows the g's felt on the seat of the rider. This is called a force factor. It describes the amount of weight felt by a rider. 2 g's is twice the normal weight.

Press the play button and watch the "g's felt" meter. Keep in mind the ranges. For every animation, the coaster's velocity is the same

LOOP A

6.1) Where in the motion does the rider feel 1 g?

On the horizontal section of the track. +1

____

6.2) How many g's does the rider feel as he enters the loop at the bottom? **Over 7 g's** +1 _

6.3) How many g's does the rider feel as he passes through the top of the loop? **5.5-6.5g's** +1

6.4) Is this loop safe or unsafe for its passengers? **It's not safe.** +1 ____________________

6.5) Explain **The g's felt by the riders at all times are too high.** It a health issue. +2

____

6.6) Look at the formulae on the left of the screen. Given that the speed of the coaster cannot be changed, how can the loop physically be altered to reduce the g's felt by the rider AT THE BOTTOM OF THE LOOP?

Because, g's felt $\propto \frac{v^2}{r}$, increasing r will decrease g's felt. **+2**

LOOP B

Click on **LOOP B** at the bottom of the animation. Click on play to see what happens.

6.7) How many g's does the rider feel as he enters the loop at the bottom? **1.5-2.25 g's** +1

6.8) How many g's does the rider feel as he passes through the top of the loop? **0 g's** +1 _

6.9) Why does the rider behave this way at the top of the loop? **He feels zero which means gravity pulls him out of the car. The car is held on to the track.** +1 _____

CIRCULAR MOTION COMPUTER ACTIVITES 20 points total for 2 'loop' pages **Loop Design**

6.10) Look at the formulae on the left of the screen. Given that the speed of the coaster cannot be changed, how can the loop physically be altered to increase the g's felt by the rider AT THE TOP OF THE LOOP?

Because, g's felt $\propto \frac{\upsilon^2}{r}$, DECREASING r will increase g's felt. +2

LOOP C

Click on **LOOP C** at the bottom of the animation. Click on play to see what happens.

6.10) What is the name of this loop? **"Circular Spline"** +1

6.11) Does this loop design solve problems with the small and large loop? **Yes** +1

6.12) Explain

This loop's radius is large at the bottom to reduce the g's felt and small at the top to increase the g's. It also has a more narrow range or g changes. +2

LOOP D

Click on **LOOP D** at the bottom of the animation. Click on play to see what happens.

6.12) What is the name of this loop's shape? **"Spiral of Archimedes"** +1

6.13) Compare LOOP C and LOOP D, Which is a better solution to the problems with small and large loops (A & B)? **Loop D is the better solution** +1

6.14) Explain

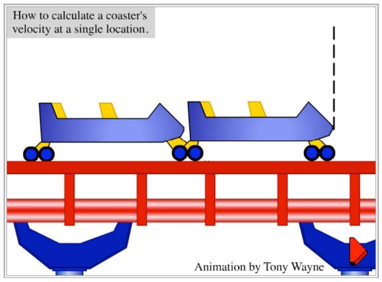
The "g" extremes felt are less (closer together). The transitions are smoother between the top and bottom of the loop. +2

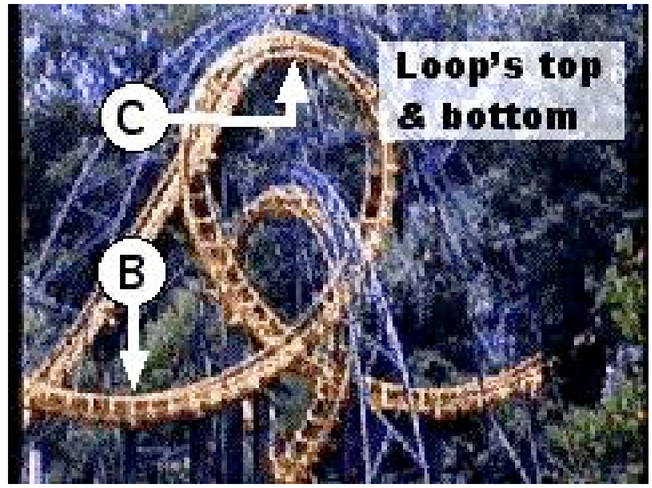
CIRCULAR MOTION COMPUTER ACTIVITES 23 points — Roller Coaster Loops

Insert the cd-rom and open up the web page file titled, "home.html" Or, if the cd-rom is not available go to http://www.mrwaynesclass.com/circular/activity

Select, "Roller Coaster," from the menu.

On the coaster's main page click on the link that says, "Click here to learn how to estimate the coaster's velocity." Follow the animation to see how you are going to calculate the coaster's velocity.





7.1) Go back to the coaster's main page and click on the picture of the roller coaster. From this picture and the train information on the coaster's main page, calculate the length of the **entire train** of cars.

Train length: **(7 cars)(2 m) = 14 m** +1

7.2) Watch the video and calculate the velocity at location "B."

$$t = 0.90\text{ s},\ \upsilon = \frac{x}{t}\ \boxed{+1},\ \upsilon = \frac{14\text{ m}}{0.90\text{ s}}\ \boxed{+2} = 15.6\ \frac{\text{m}}{\text{s}}\ \boxed{+2}$$

Train's velocity @ B: **15.6 m/s** ________

7.3) If the radius of the track is 35 m at location B then how many g's of centripetal acceleration does the track exert?

$$t = 0.90\text{ s},\ a_C = \frac{\upsilon^2}{r}\ \boxed{+1},\ a_C = \frac{\left(15.6\,\frac{\text{m}}{\text{s}}\right)^2}{35\text{ m}},\ \boxed{+2}\ a_C = 0.44\,\frac{\text{m}}{\text{s}^2}\ \boxed{+2}$$

a_C = 0.44 m/s² ________________________

7.4) Watch the video and calculate the velocity at location "C."

$$t = 1.38\text{ s},\ \upsilon = \frac{x}{t}\ \boxed{+1},\ \upsilon = \frac{14\text{ m}}{1.38\text{ s}}\ \boxed{+2} = 10.1\ \frac{\text{m}}{\text{s}}\ \boxed{+2}$$

Train's velocity @ C: **10.1 m/s** _____________

7.5) What is the radius of the track at location "C," if it exerts 2.10 g's at location "C?"

$$a_C = 20.58\,\frac{\text{m}}{\text{s}^2},\ a_C = \frac{\upsilon^2}{r}\ \boxed{+1},\ 19.6\,\frac{\text{m}}{\text{s}^2} = \frac{\left(10.1\,\frac{\text{m}}{\text{s}}\right)^2}{r},\ \boxed{+2}\ r = 4.96\text{ m}\ \boxed{+2}$$

Radius @ C **r = 4.96 m/s** _____________

7.6) Why do you suppose when calculating the g's felt by the rider at the bottom, you have to add 1 g?

To go towards the center you have to go up and over come gravity (1 g). +3