Wild Waves

THEME & WATER PARK

Outdoor Classroom Workbook

Name:

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School:

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Class:

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Teacher:

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Date:

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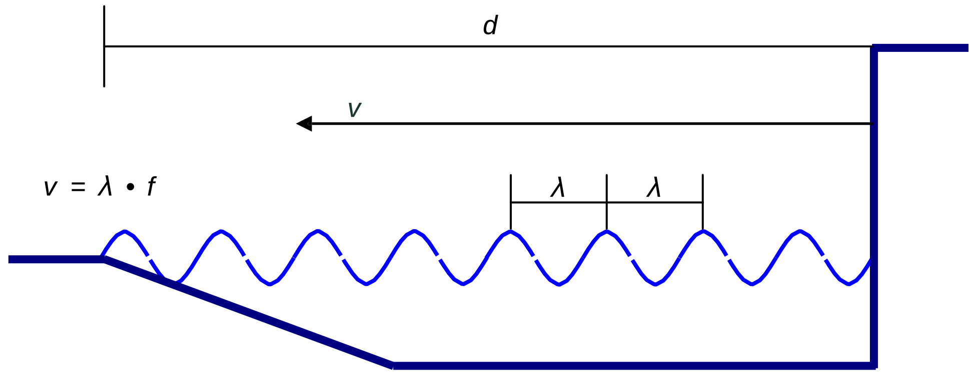
Materials needed: Pencil, stopwatch, and scientific calculator

WAVE POOL



Wave Pool—Side View

During wave cycles, waves crash along the shore every few seconds. The number of waves observed in a given amount of time is called the frequency (*f*). Let's find the frequency of waves in the Wave Pool. First, count the number of waves that hit the bank in one minute. Record your findings below.

Waves per minute: ______________________/ min

Wave frequency is normally recorded as waves per second. Next, we need to convert your recorded waves per minute to the proper unit time. Find the frequency of the waves by **dividing** your waves per minute by **60**. Show your work and record the frequency below.

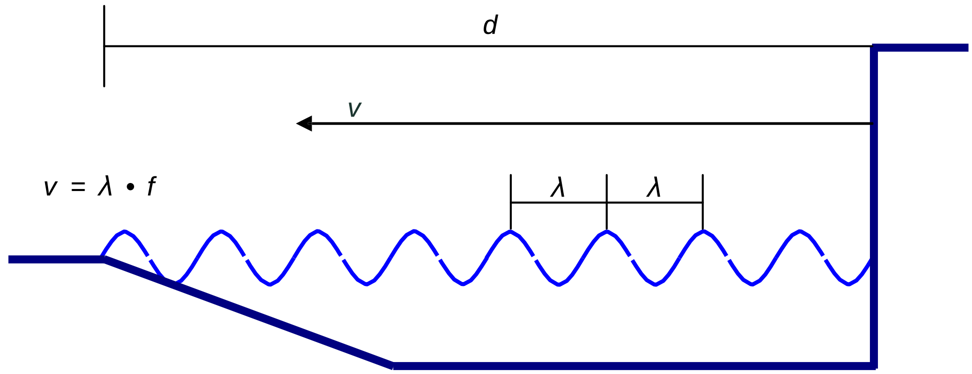
f = ______________________/ second

Velocity (*v*) is the speed at which a wave moves across the pool. Let's find the velocity of waves in the Wave Pool. First, time (*t*) a single wave to find out how long it takes to travel the length of the pool. Because velocity is measured in meters per second (m/s), be sure to measure the time in seconds.

t = ______________________seconds

We can find the velocity (*v*) by dividing the distance (*d*) the wave traveled by the amount of time (*t*) it took; or ***v* = *d*/*t***. Our Wave Pool is **75 meters** long. Use this equation and the information you have collected to find the velocity of the waves. Show your work and record the velocity below.

v = ______________________m/s



Wave Pool—Side View

The distance between the tops, or crests, of waves is called the wavelength. The symbol for wavelength is Greek letter λ (lambda). Now that we have measured two components of the wave equation, we are able to find the wavelength. Wavelength (λ) equals velocity (v) divided by frequency (f); or $\boldsymbol{\lambda = v/f}$. Use this equation to find the wavelength of waves in the pool. Show your work and record the wavelength below.

λ = ______________________m

We are all constantly immersed in waves. The vibrations of the Wild Thing, the sound in the air from the Ring of Fire, and the light we see on the Carousel all travel in waves around us. Some of these waves may have wavelengths as long as those in the Wave Pool. Others may be much longer or shorter, just as the frequency and velocity may also vary. If a sound wave travels at **343 m/s** (v) and has the same λ as the waves in the pool, use the wave equation to find its frequency. We can use algebra to rearrange the equation to solve for f; or $\boldsymbol{f = v/\lambda}$. Show your work and record the frequency below.

f = ______________________/ second

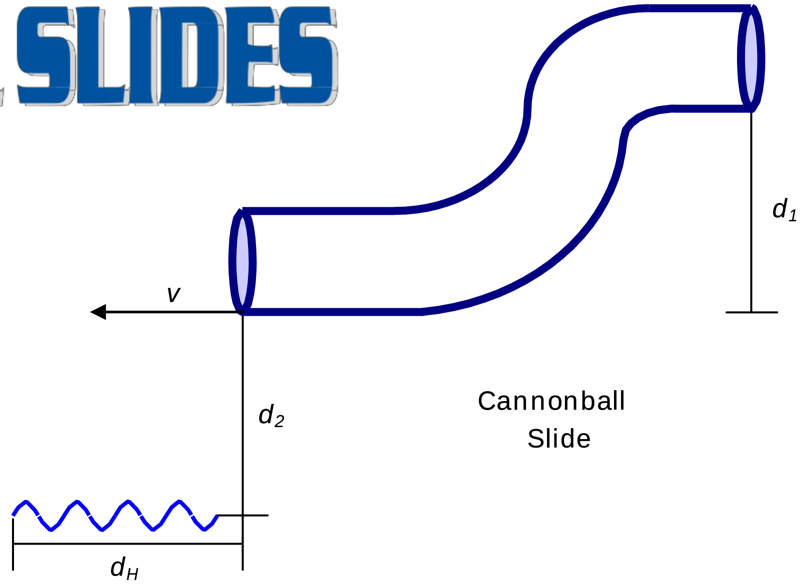
This would sound like a very low note.

An electromagnetic wave could also have the same wavelength, but its frequency would be much, much higher. If the frequency of an electromagnetic wave is **50,000,000/s**, what do you think its velocity would be? Give it a try. Use the wave equation $\boldsymbol{v = \lambda \cdot f}$. Show your work and record the velocity below.

v = ________________________________m/s

This should be about the speed of light, a very large number.

CANNONBALL SLIDES



In physics, potential energy is the energy of an object due to the position of the object. If we pick up a cannonball, we put potential energy into the ball because of the forces that may now act upon it due to the cannonball's new position above the ground. We can find this potential energy (E_p) by multiplying the mass of an object (m, measured in kilograms; kg) by the distance the mass is lifted (d_1, measured in meters, m) by the acceleration of a falling object (g); or $\boldsymbol{E_p = mgd_1}$. The acceleration of an object on earth equals **9.8m/s^2** (meters per second squared). Energy is measured in Joules (J).

Let's find the potential energy of a rider on the Cannonball Slides at the Activity Pool. If the distance (d_1) from the top of the slide to the bottom is **6.5m** and our example rider's mass (m) is **50kg**, find the potential energy the rider has while sitting at the top of the slide. Show your work and record the potential energy below.

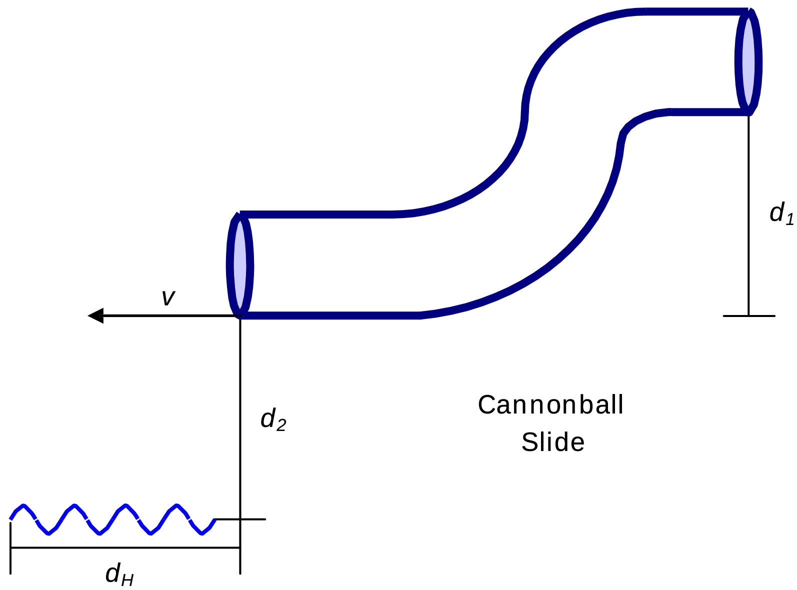
E_p = ______________________J

If we drop our cannonball, its potential energy turns into kinetic energy (E_k), or the energy of movement. Kinetic energy can be found by multiplying the mass (m) of an object by its velocity squared (v^2) divided by two; or $E_k = mv^2/2$. Friction is the force resisting motion of surfaces sliding against each other. If the friction is very low, then all of an object's potential energy is converted to kinetic energy. Because waterslides are designed to create as little friction as possible, we will assume the kinetic energy at the bottom of the slide is equal to the potential energy of the rider at the top; or $\boldsymbol{mv^2/2 = mgd_1}$ (kinetic energy = potential energy). Use your algebra skills to rearrange this equation to solve for velocity (v).

v = __________________________________(*equation*)

Use your new equation and the information given above to find our rider's velocity at the end of the slide. Show your work and record the velocity below.

v = ______________________m/s



We learned at the Wave Pool that velocity is the speed at which an object changes position. However, this is only one specification of velocity. Speed only describes how fast an object is moving; velocity tells us both how fast and in what direction an object is moving.

In this case, we are only interested in two directions: the vertical (d_2) and horizontal (d_H) rate of change after a rider exits the slide. These directions act separately because of the effects of gravity on vertical movement. Horizontal movement is unaffected by gravity so the velocity the rider exits the slide with remains the same until the rider hits the water below.

Vertically, the rider exits the slide with a velocity of zero. The rider accelerates as gravity (*g*) pulls him down. On earth, everything falls at the same rate of **$9.8 m/s^2$** (meters per second squared). If we know the height of an object before it falls, we know how long it will take to fall. Vertical time and velocity depend only on how far an object falls and how rapidly gravity accelerates.

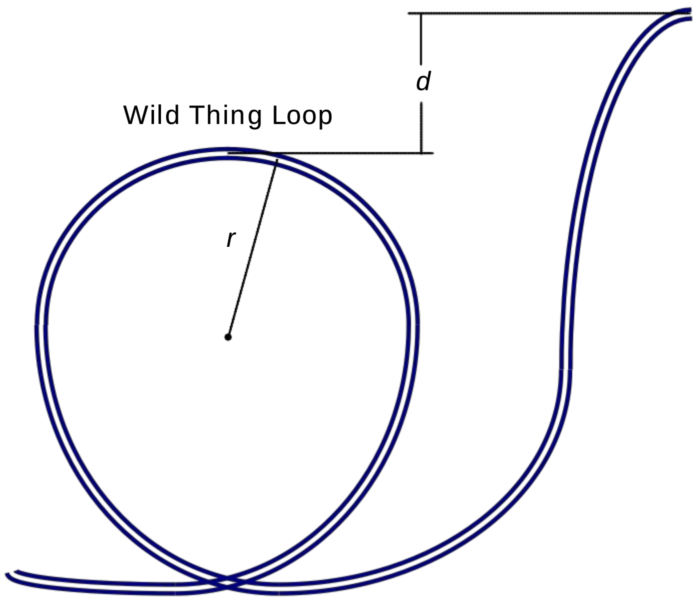
The equation to find the amount of time it takes for an object to fall is $\boldsymbol{t^2 = 2d_2/g}$; or the time squared ($t^2$) equals two times the distance (d_2) divided by the acceleration of gravity (*g*). If we know that the bottom of the Cannonball slide is **2.8m** above the water, how many seconds (*t*) does it take the rider to reach the water? Show your work and record the time below.

t = ______________________seconds

As the rider exits the slide, the amount of time that the rider falls is the same amount of time he has to move forward, or horizontally. Now that we know how fast the rider is moving horizontally (*v*) and the amount of time he has to fall (*t*) we can figure out how far the rider will travel forward (d_H) before splashing into the water. Distance equals the velocity multiplied by the amount of time; or $\boldsymbol{d_H = v \cdot t}$. Given the velocity and time we found above, how far from the slide with the rider land in the water? Show your work and record the distance below.

d_H = ______________________m

WILD THING



Many rollercoasters turn riders completely upside down as they travel through vertical loops. For your safety, and to keep your stomach in place, it is a good idea to avoid what is called a negative G-force. In other words, you should always feel your apparent weight pushing you into your seat, even when you turn upside down. Even through the loops, riders will never hang from their safety restraints.

Riders always feel like gravity is holding them in place, even when upside down. However, it is not the acceleration of gravity that causes a rider to feel this apparent weight holding them down. Gravity is still working to pull riders out of an upside down car. There is acceleration, greater than gravity, keeping the riders in their seats called centripetal acceleration.

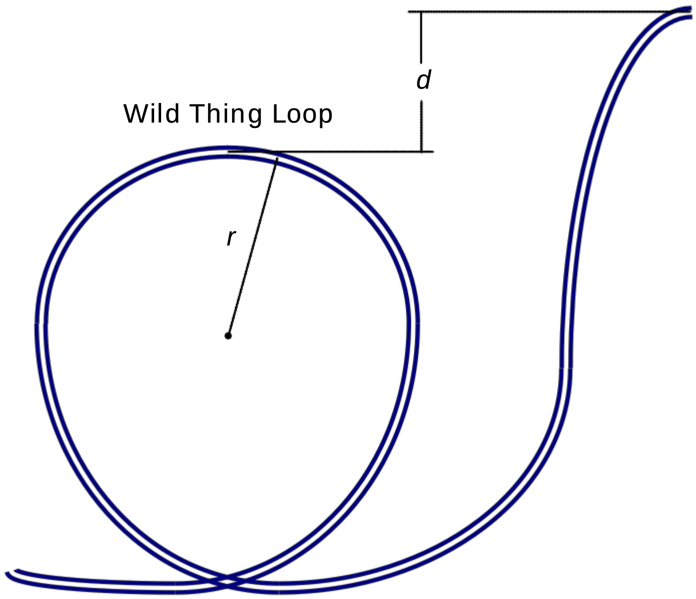
Once the train reaches the top of the loop, upside down, the riders begin to fall. However, as the train continues moving down and out of the loop, it is travelling faster than gravity can pull the riders to the ground. The train is pulling the riders down causing them to feel their seat pushing up, imitating the feeling of gravity. Our question is, given the radius of the loop, how fast does the train have to move to keep riders feeling like they have a weight, avoiding a negative G-force?

We have learned that normal gravitational acceleration, or one G, is **$9.8 m/s^2$**. We will assume that riders must feel at least ½ of their weight to feel comfortable. In this case, the centripetal acceleration (a_c) must be **½ G more** than gravity. Given this information, what is the required value of centripetal acceleration? Record the centripetal acceleration below.

a_c = ____________________ m/s^2

Centripetal acceleration (a_c) can be found using the equation $\mathbf{a_c = v^2/r}$. The radius (r) of the loop is **2.5m**. Since we know the values of both a_c and r, we must solve this equation for v. Use your algebra skills to rearrange this equation to find the velocity. Show your work and record the equation below.

v = ____________________ (*equation*)



Now it is possible to find the velocity (*v*) of the train at the top of the loop. Use the information you have gathered to solve your equation for *v*. Show your work and record the velocity below.

v = ____________________m/s

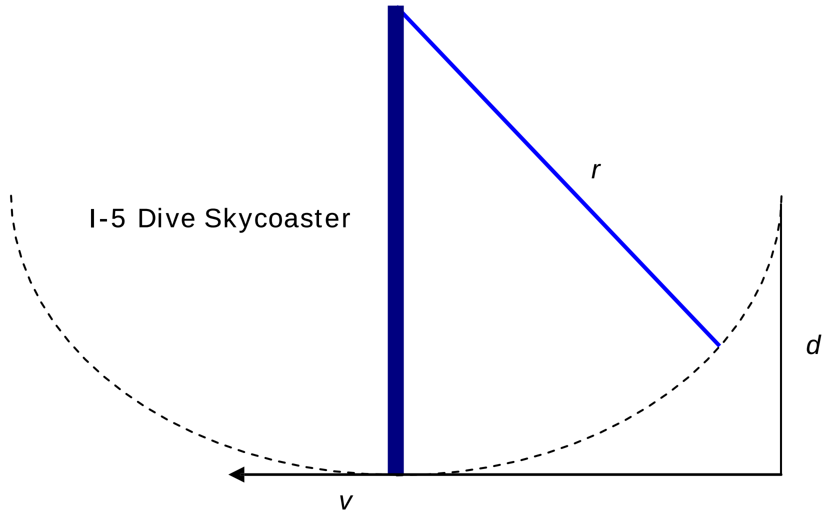
Rollercoaster trains have no motors. They must gain velocity by converting potential energy into kinetic energy. In other words, they roll downhill. When a rollercoaster rolls down a hill, or drop, it picks up speed. As the train enters the loop, now traveling uphill, it begins to lose the speed it gained in the drop.

If the loop was built as high as the top of the drop, the train would not retain enough speed to complete the loop. This is why looping rollercoasters are designed with the loop shorter than the drop. This prevents the train from slowing to a stop during the loop. The height difference between the top of the drop and the top of the loop provides the velocity just calculated.

Remember the waterslide lab. We learned that the equation to find the kinetic energy of an object is $E_K = mv^2/2$ (*m* mass; v^2 velocity squared). We also learned that the equation to find the potential energy of an object is $E_P = mgd$ (*m* mass; *g* acceleration of gravity; *d* distance object is lifted). We will assume there is no friction at work and these two energies, kinetic and potential, must equal each other. Use this equation (**$mv^2/2 = mgd$**) and the information collected to calculate *d*, the height of the drop above the loop. Show your work and record the distance below.

d = ____________________m

I-5 DIVE



When we lift an object we have an expectation of how heavy the item will feel. A pencil feels very light and easy to lift, while a bowling ball is much heavier. This apparent weight that we feel is the force of gravity (F_G, measured in Newtons, N). This force is found by multiplying the objects' mass (*m*) and the acceleration of gravity (*g*); or $\boldsymbol{F_G = m \bullet g}$. We have learned that on Earth, one G is equal to **9.8m/s²**. The stronger the gravity, the faster an object falls. On a larger planet, gravity may be twice as strong, or 2 G's. On the moon, gravity is much weaker, about $^1/_6$ G.

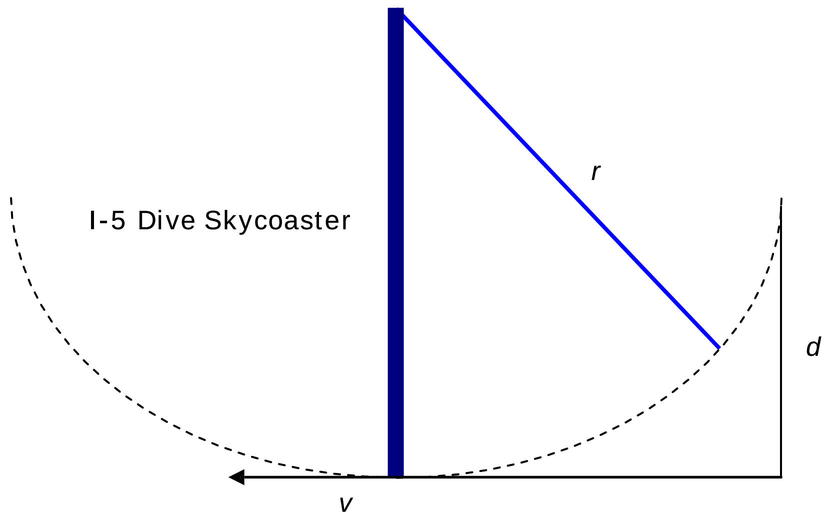
If we want to change the apparent weight of a person, we must either change their mass or their gravitational acceleration. One way we can change gravitational acceleration is by using a swing. If a rider were to sit in the I-5 Dive swing, resting at the bottom, the seat would push up on the rider with a force equal to gravity. Assume our example rider's mass (*m*) is **50kg**. Find his weight, the force of the swing pushing up on the rider. Show your work and record the force of gravity below.

F_G = ______________________N

If the swing is in motion, the swing must push harder on the rider to keep him traveling in a circle. This centripetal force (F_C) that pushes the rider toward the center of the swing causes centripetal acceleration (a_c). Centripetal acceleration is measured by dividing the velocity (*v*) squared by the radius (*r*) of the turn; or $a_c = v^2/r$. To measure the centripetal acceleration we must first find the value of *r*, the length of the swing.

A swing is a large pendulum. By the pendulum law, if we know the period (*t*, measured in seconds), or the amount of time the swing takes to complete one full cycle, we can find the length of the pendulum. Use a stopwatch to time one full swing cycle of the I-5 Dive. Wait for riders to be lifted to the top of the dropping tower. Start your timer when they are dropped. Continue timing as the swing makes two passes by the loading area. One pass toward the lake and another back toward the dropping tower. Stop your timer when the riders reach the highest point on their swing back toward the dropping tower. Record the period below.

t = ______________________seconds



The equation we will use to find the radius of the swing is $\boldsymbol{r = t^2 g / 4\pi^2}$. Use the information you have gathered to replace the variables and solve for *r*. Show your work and record the radius below.

r = ______________________m

In order to find the centripetal acceleration (a_c) we now need to find the velocity (*v*). As we learned at the Cannonball Slides, if we pick up an object it now has potential energy. We can measure this potential energy (E_P) by multiplying the mass of the object (*m*) by the distance the object is lifted (*d*) by the acceleration of gravity (*g*); or $\boldsymbol{E_P = mgd}$. Energy is measured in Joules (J). We are going to measure the potential energy of the lifted swing. If the vertical distance from the lowest and highest points of the swing is **23m** and our rider's mass is still **50kg**, find the potential energy a rider would have before the swing is released. Show your work and record the potential energy below.

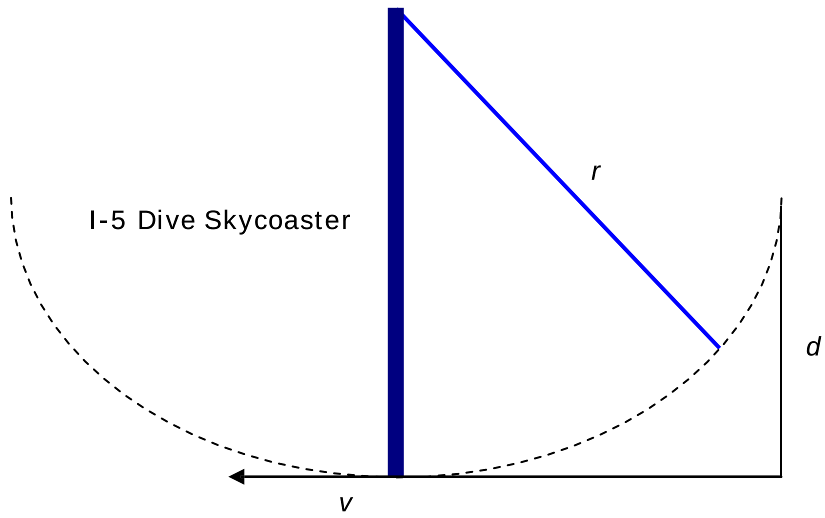
E_P = ______________________J

When the swing is released, the potential energy turns into kinetic energy. Kinetic energy can be found by multiplying the mass (*m*) by the velocity squared (v^2) divided by 2; or $E_K = mv^2/2$. We will again assume there is no friction at work and the potential energy of the swing equals the kinetic energy after it is released, $\boldsymbol{mv^2/2 = mgd}$. Remember the waterslide lab when you used your algebra skills to solve for *v*. Rearrange this equation to solve for velocity, record the equation below.

v = ______________________(*equation*)

If our **50kg** rider is lifted **23m** on the swing, what is his velocity when the rider reaches the bottom? Use your equation to find the velocity. Show your work and record the velocity below.

v = ______________________m/s



Now that we have found the radius (r) and velocity (v), we can calculate the centripetal acceleration, $\boldsymbol{a_c = v^2 / r}$. Use the information that you have collected to find the centripetal acceleration. Show your work and record your answer below.

a_c = ______________________m/s²

The total acceleration (a_T) that a rider feels is the acceleration of gravity (g) plus the centripetal acceleration (a_c), or $\boldsymbol{a_T = g + a_c}$. Find the total acceleration. Show your work and record the total acceleration below.

a_T = ______________________m/s²

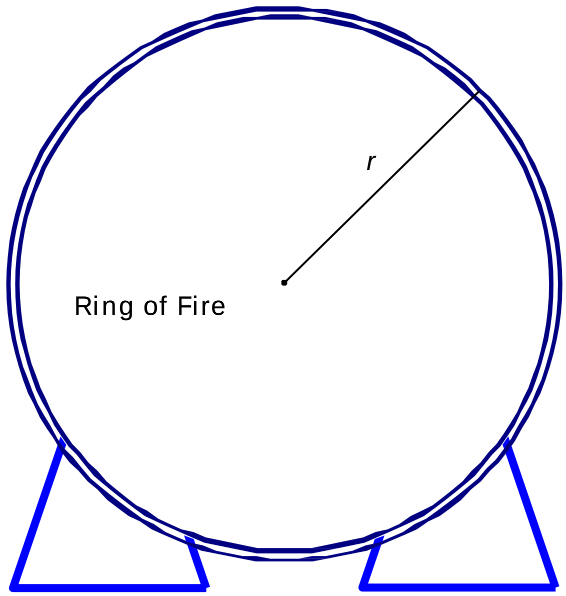
If one G is $9.8 m/s^2$, how many G's does a rider feel while on the swing? Show your work and record your answer below.

______________________G's

Remembering that the force of gravity people feel is the product of the person's mass and the acceleration of gravity, we can find the maximum force (F) acting upon a rider. Using the equation $\boldsymbol{F = m \cdot a_T}$, multiply our **50kg** rider's mass by the total acceleration of the rider. Show your work and record the maximum force below.

F = ______________________N

RING OF FIRE



In the previous lab we learned that the apparent weight we feel is actually the force of gravity acting upon us. The force of gravity (F_G, measured in Newtons, N) can be found by multiplying our mass (*m*) by the acceleration of a falling object (*g*). We have also learned that on Earth, one G is equal to $9.8 m/s^2$. The only way we are able to change our apparent weight is by changing our mass or adding additional acceleration to G.

When an astronaut is sitting in a rocket before takeoff, he feels his normal weight because his acceleration is still at $9.8 m/s^2$, or one G. If he takes off and accelerates upward, against gravity, at $9.8 m/s^2$ his total acceleration is the sum of the acceleration of gravity and his upward acceleration (*a*); or $9.8 m/s^2 + 9.8 m/s^2$. His total acceleration is now 2 G's, which equals $19.6 m/s^2$. The force on the astronaut would now be $F = m \cdot 2g$, or twice his normal weight. If the acceleration of the takeoff was $39.2 m/s^2$, his total acceleration, after adding the acceleration of gravity, would be $49 m/s^2$, or 5 G's. In this case, the astronaut would feel five times heavier than before takeoff.

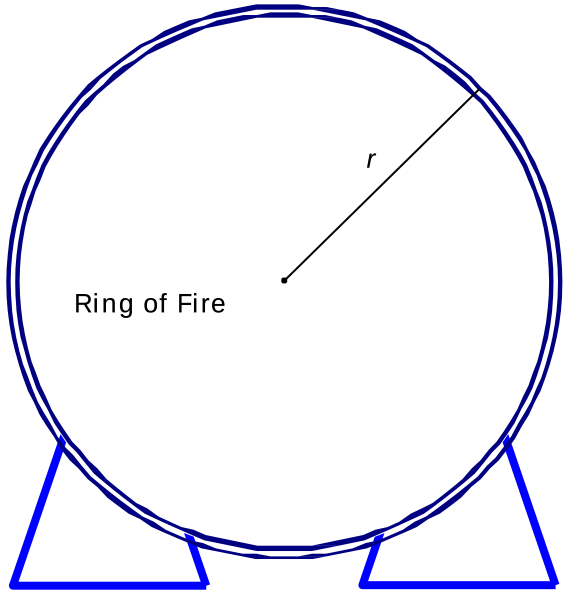
While there is no rocket at the park, most rides do add changing amounts of acceleration to G. On the Ring of Fire, the additional acceleration comes from traveling in a circle. This acceleration, as we have learned, is called centripetal acceleration (a_c). We know that centripetal acceleration can be found by dividing the velocity (*v*) squared by the radius (*r*) of the turn; or $a_c = v^2/r$.

We will need to determine the velocity of the train in order to find the centripetal acceleration. We will again set the equations for potential and kinetic energy equal to each other; or $\boldsymbol{mv^2/2 = mgd}$. Remember the previous labs when you used your algebra skills to solve for *v*. Rearrange the equation to solve for velocity, record the equation below.

v = ______________________(*equation*)

If we know that the radius (*r*) of the Ring of Fire is **6.5m**, we also know the distance (*d*) between the top of the ride and the bottom, $\boldsymbol{d = 2r}$. Use this information to solve your equation for *v*. Show your work and record the velocity below.

v = ______________________m/s



Now that we have found the velocity (v) and radius (r), we are able to calculate the centripetal acceleration; $\boldsymbol{a_c = v^2 / r}$. Find the centripetal acceleration. Show your work and record the acceleration below.

a_c = ______________________m/s^2

A rider's total acceleration (a_T) at the bottom of the ride is equal to the sum of centripetal acceleration (a_c) and gravitational acceleration (g); or $\boldsymbol{a_T = a_c + g}$. Find the total acceleration. Show your work and record the total acceleration below.

a_T = ______________________m/s^2

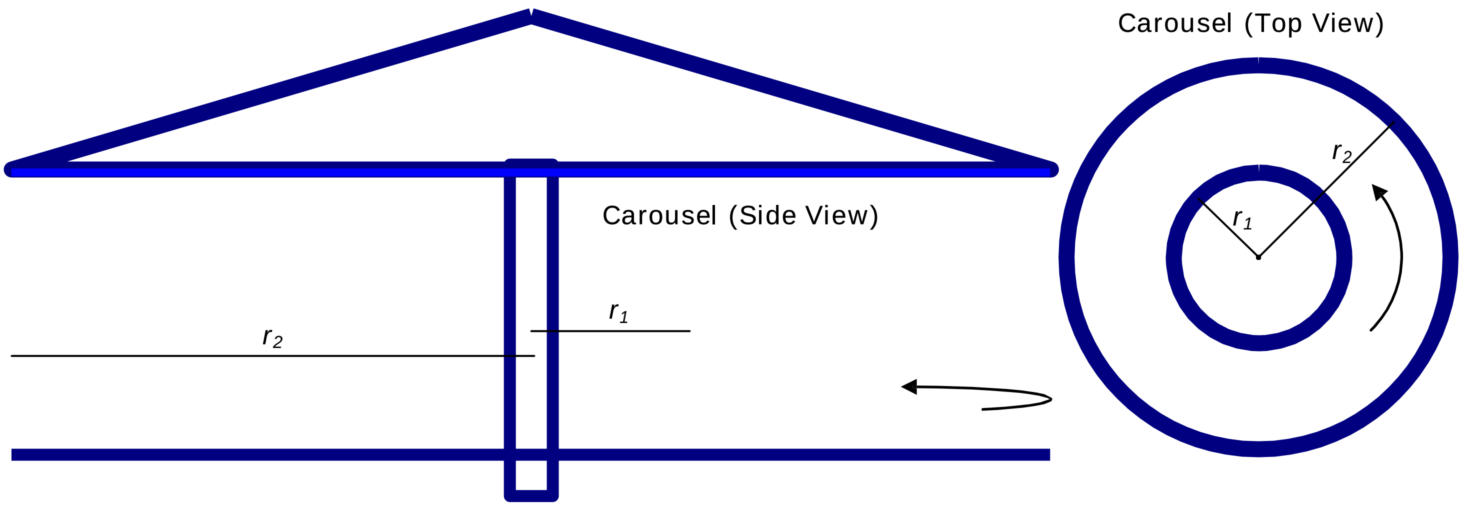
If we know that one G is equal to **9.8m/s2**, how many G's does the rider feel at the bottom of the ride? Show your work and record the number of G's below.

______________________G's

How many times heavier does this make the rider feel?

______________________times heavier

CAROUSEL



When a rider stands on a Carousel that is not moving, there is only one major force acting upon them, gravity. Gravity pulls a rider straight down while the floor pushes back with the same amount of force. When the Carousel begins to move, a new force comes into play. We have learned that the force that pulls riders toward the center of a circle is called centripetal force. Without centripetal force, riders would continue in a straight line, flying off of the Carousel. Centripetal force (F_C) and the force of gravity (F_G), when added together, tell us the total force acting upon a rider on a moving Carousel.

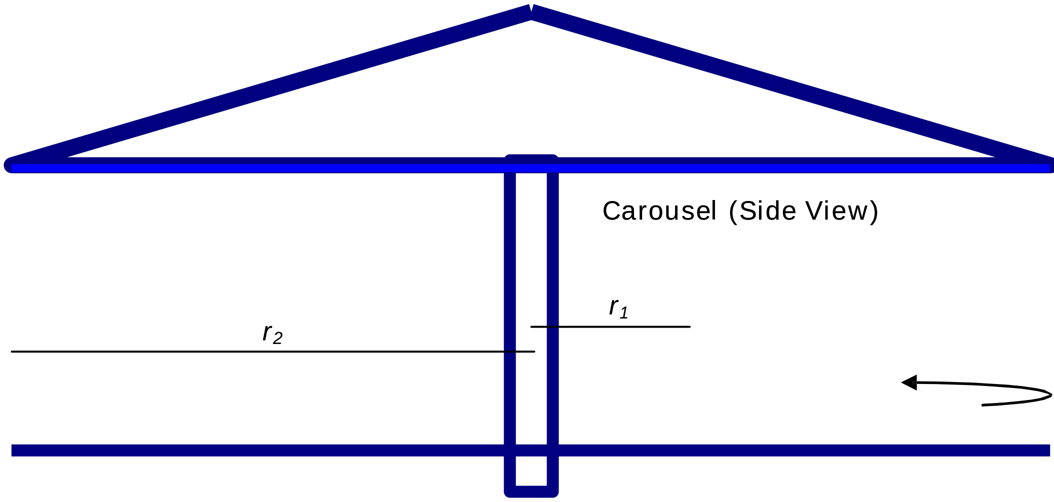
Adding these forces is not as simple as adding two numbers because, in this case, our F_G is a vertical force while F_C is horizontal. The sum of these two forces is somewhere in between, at the angle we call theta (Θ). When riders stand on a moving Carousel, they automatically lean at this angle, but feel as if they are still straight up and down.

The force of gravity is always the same anywhere on the Carousel and, as we have learned, is equal to a rider's mass (m) times the acceleration of gravity (g); or $\boldsymbol{F_G = m \cdot g}$. We know that the acceleration of gravity is **9.8m/s²**. If our rider is **50kg**, find the force of gravity (F_G). Show your work and record the force of gravity below.

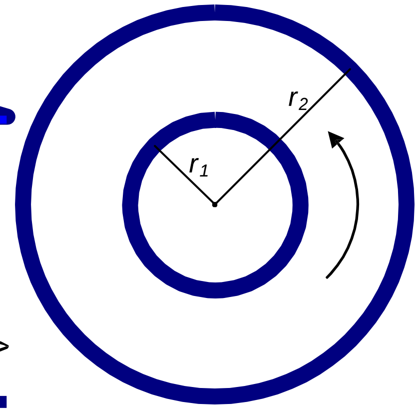
F_G = ______________________N

Just as with gravity, centripetal force is affected by the rider's mass (m). Centripetal force is also affected by the distance between the rider and the center of the circle (radius, r) and the rider's velocity (v). The equation to measure centripetal force can be written as $F_C = mv^2/2$. Measuring velocity can be difficult. However, with a little algebra, we can change the equation to read: $\boldsymbol{F_C = m \cdot 4\pi^2 r / t^2}$. It is much easier to measure the amount of time it takes for the Carousel to make one rotation. This is called the period (t), as we learned at the I-5 Dive. Time a single rotation of the Carousel. Record your time below.

t = ______________________seconds



Carousel (Top View)



The radius of the inner edge of the Carousel is **4.3m** (r_1) while the outer edge is **6.9m** (r_2). Use these two figures and the period to complete the equation to find the centripetal force on a **50kg** rider. We will have two measurements, one while the rider stands at the inner edge, and again at the outer edge. Show your work and record the centripetal force below.

F_C (inside) = ______________________N F_C

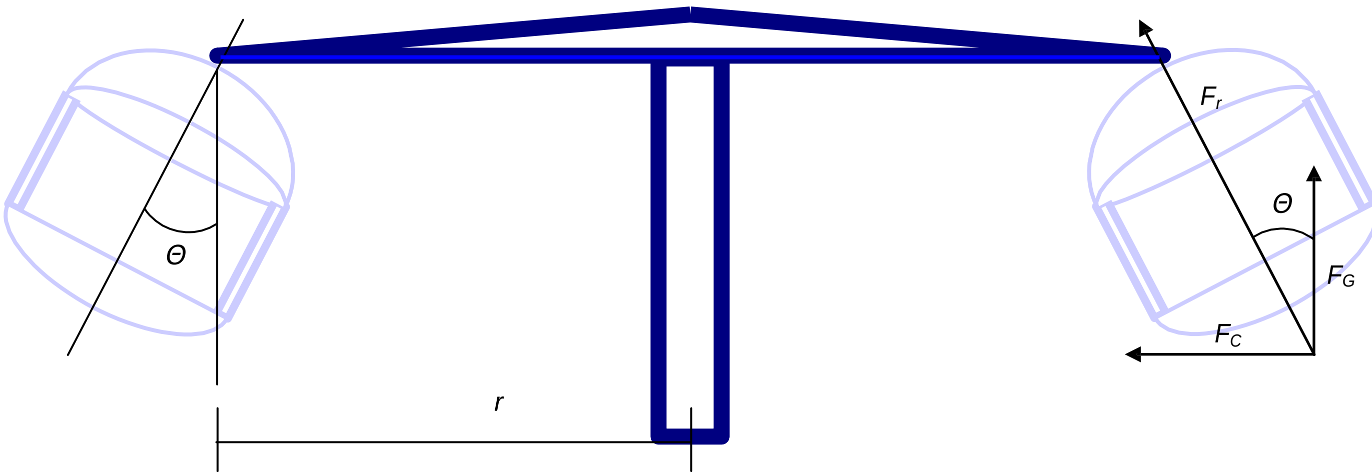
(outside) = ________________________N

Our last step is to find the angle (Θ) at which the rider will lean. Now that we know the force of gravity (F_G) and the centripetal force (F_C) we can add these forces with a little trigonometry. We will find that $\boldsymbol{\Theta = tan^{-1}(F_G / F_C)}$. Use a calculator to find how far a rider would lean. Remember that we have two measurements, one while the rider stands at the inner edge, and again at the outer edge. Record the angle below.

Θ (inside) = ______________________°

Θ (outside) = ______________________°

PARATROOPER



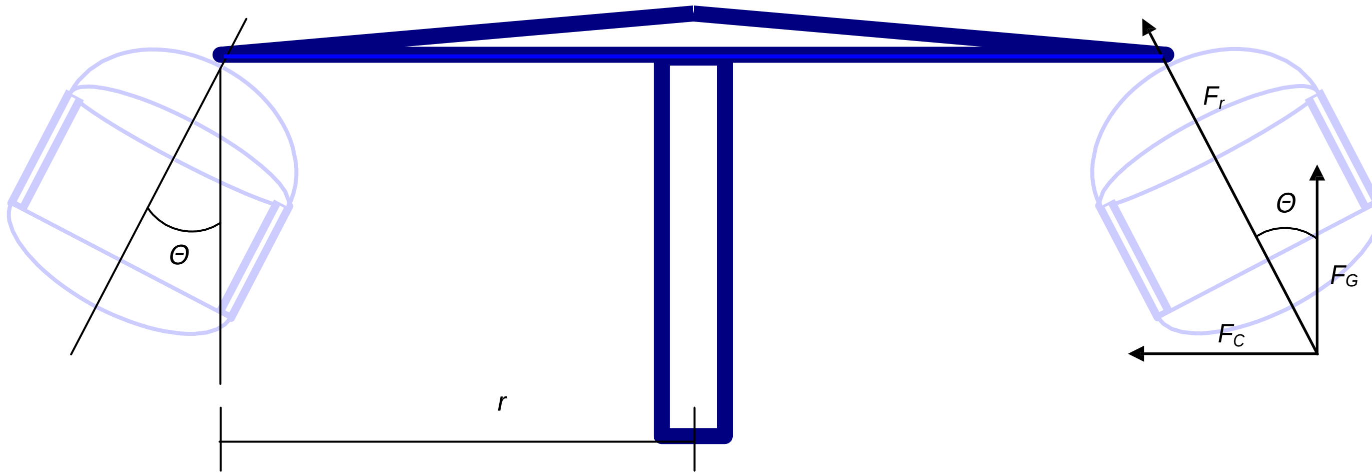
Similar to our last lab, when a rider sits in a gondola of the Paratrooper and the ride is not in motion, the only force acting upon them is gravity (F_G). Once the Paratrooper begins moving, centripetal force (F_C) comes into play. During this lab, we will assume that the Paratrooper does not elevate, and only rotates. We know that these two forces add together to form a total force. However, like at the Carousel, these two forces are not simply added because F_G is a vertical force, while F_C is horizontal (assuming the Paratrooper will remain level). The sum of these two forces is somewhere in between, at the angle we call theta (*Θ*). When the ride begins to rotate, the gondolas will fly out at this angle, but the riders will still feel as if they are sitting upright.

The force of gravity is always the same anywhere on the Paratrooper and, as we have learned, is equal to a rider's mass (*m*) times the acceleration of gravity (*g*); or $F_G = m \cdot g$. We know that the acceleration of gravity is **$9.8 m/s^2$**. If our rider is **50kg**, find the force of gravity (F_G). Show your work and record the force of gravity below.

F_G = ______________________N

Just as with gravity, centripetal force is affected by the rider's mass (*m*). Centripetal force is also affected by the distance between the rider and the center of the circle (radius, *r*) and the rider's velocity (*v*). The equation to measure centripetal force can be written as $F_C = mv^2/2$. Measuring velocity can be difficult. However, with a little algebra, we can change the equation to read: $F_C = m \cdot 4\pi^2 r / t^2$. It is much easier to measure the amount of time it takes for the Paratrooper to make one rotation. This is called the period (*t*), as we learned at the I-5 Dive. Time a single rotation of the Paratrooper. Record your time below.

t = ______________________seconds



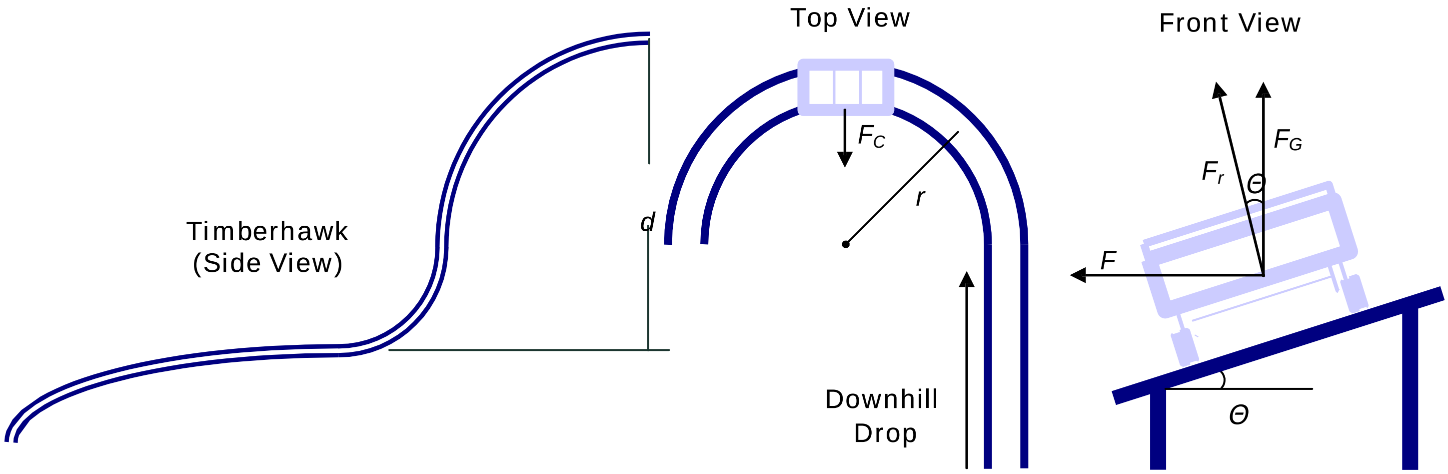
The radius of Paratrooper is **8.3m**. Use this figure and the period to complete the equation and find the centripetal force on a **50kg** rider. Show your work and record the centripetal force below.

F_C = ______________________N

Our last step is to find the angle (Θ) at which the gondola will swing out. Now that we know the force of gravity (F_G) and the centripetal force (F_C) we can add these forces with a little trigonometry. We will find that $\boldsymbol{\Theta = tan^{-1}(F_G / F_C)}$. Use a calculator to find how far a rider would lean. Record the angle below.

Θ = ______________________°

TIMBERHAWK



On a street, turns are banked to help cars stay on the road. Rollercoasters also have banked turns. How steep the bank is depends on how fast the train is moving (velocity, v) and how sharp the turn is (radius, r). When a rollercoaster train goes around a curve there are two forces at work. The track is pushing up on the train to overcome the force of gravity (F_G). The track also pushes the train sideways, into the curve, to allow the train to turn. We know that this force that pulls riders toward the center of a circle is called centripetal force (F_C).

We know that the force of gravity (F_G) equals the acceleration of gravity (g) times the mass (m) of an object; or $\boldsymbol{F_G = m \cdot g}$. We also know that the acceleration of gravity is **$9.8 m/s^2$**. If the train on the Timberhawk has a mass of **1000kg**, find the force of gravity pulling down on the car. Show your work and record the force of gravity below.

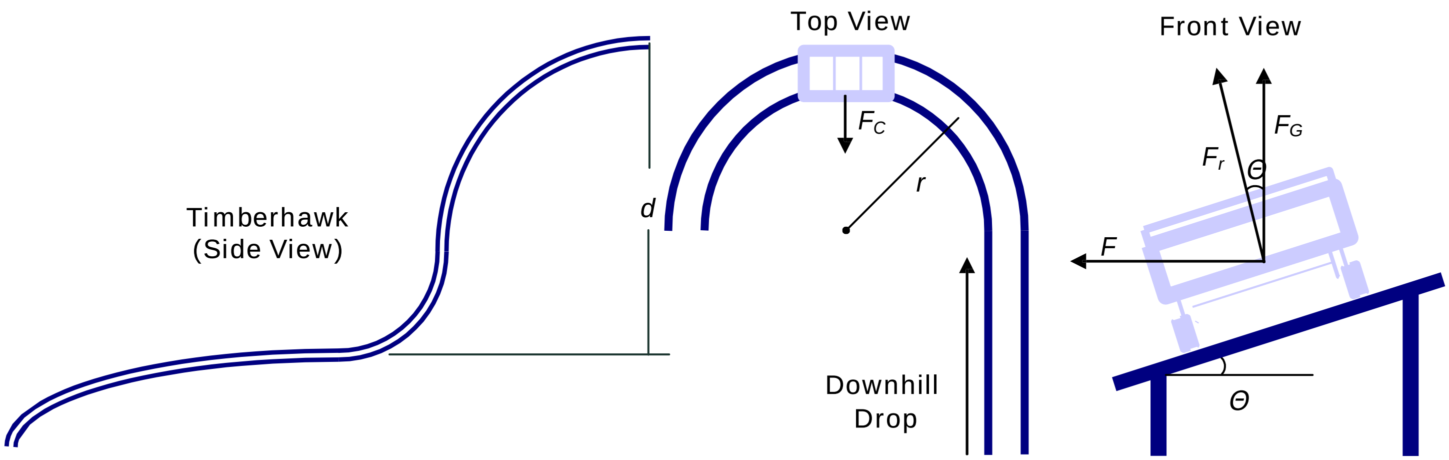
F_G = ______________________N

To find the centripetal force, we will first need to find the train's velocity (v). We will again set the equations for potential and kinetic energy equal to each other, $\boldsymbol{mv^2/2 = mgd}$. Remember the previous labs when you used your algebra skills to solve for v. Rearrange the equation to solve for velocity, record the equation below.

v = ______________________(*equation*)

If the vertical distance (d) between the top of the ride and the turn is **7m**, calculate the train's velocity (v) at the turn. Show your work and record the velocity below.

v = ______________________m/s



The centripetal acceleration (a_c) of the train is equal to the velocity squared (v^2) divided by the radius (r) of the turn; or $a_c = v^2/r$. The radius of the turn is **6.7m**. In order to find the centripetal force (F_C), we need to multiply the centripetal acceleration (v^2/r) by the train's mass; or $\boldsymbol{F_C = mv^2/r}$. Use this equation and the information you have gathered to find the centripetal force on the train. Show your work and record the centripetal force below.

F_C = ______________________N

Our last step is to find the angle of the track. As with the Carousel and Paratrooper, we need to add the force of gravity to the centripetal force. Once again, our forces aren't going the same direction and we will need to use trigonometry. We will find that $\boldsymbol{\Theta = \tan^{-1}(F_G/F_C)}$. Use a calculator to find the angle of the track at the banked curve. Record the angle below.

Θ = ______________________°

DODGEMS

When an object, like a bumper car, is moving it wants to continue moving. This tendency is called momentum (ρ, measured in kg m/s). Momentum is the product of the object's mass (m) and velocity (v); or $\rho = m \bullet v$. Because momentum is affected by the mass of an object, a large truck will have more momentum than a motorcycle traveling at the same speed. Because momentum is also affected by velocity, a baseball thrown at 30mph will have less momentum than a baseball pitched at 90mph.

We know that the force of gravity (F_G) is equal to a rider's mass (m) times the acceleration of gravity (g); or $\boldsymbol{F_G = m \bullet g}$. We also know that the acceleration of gravity on Earth is **$9.8m/s^2$**. If our bumper car rider has a mass of **50kg**, what is the force of gravity? Show your work and record the force of gravity below.

F_G = ______________________N

Bumper cars don't accelerate (a) very quickly, we'll say at ¼ G; or $\boldsymbol{a = .25 \bullet 9.8m/s^2}$. In order to calculate the momentum of a bumper car, we also need to find the velocity. If a rider steps on the 'gas' (bumper cars are actually powered by electricity) for **3 seconds** (t), they will reach a top speed of v. This velocity (v) is the product of acceleration and time; or $\boldsymbol{v = a \bullet t}$. Use this equation and the information you have been given to find the velocity of the bumper car. Show your work and record the velocity below.

v = ______________________m/s

Use the equation for momentum ($\boldsymbol{\rho = m \bullet v}$) and the figures you have calculated to find the momentum of the bumper car. Show your work and record the momentum below.

ρ = ______________________kg m/s

Now that the car has momentum, it will keep its velocity constant until an opposing force acts upon it over a period of time. This is called an impulse, or bump. The bump required to stop the car is equal to the car's momentum (ρ) but also equal to the force (F) applied to the car multiplied by the time (t) it takes to stop. In other words, $m \bullet v = \rho = F \bullet t$.

Our objective is to find the size of the force (F) required to stop the car. To find the force, we must first find the time it takes to decelerate the car. Time (t) equals twice the stopping distance (d) divided by the velocity (v); or $\boldsymbol{t = 2d/v}$. The stopping distance is determined by the thickness of the bumper, which is about **0.1m**. Use the figures you have been given and the velocity you calculated to find the time required to stop. Show your work and record the time below.

t = ____________________

We now have enough information to calculate the size of the stopping force. Use the equation $\boldsymbol{\rho = F \cdot t}$ and the information you have calculated to solve for F. Show your work and record the stopping force below.

F = ____________________N

How large is this force compared to the rider's weight, or the force of gravity (F_G)?

____________________times the rider's weight

Assume the car has no bumper and the stopping distance is **.005m**. Find the time required to stop the car. Use the equation given above ($\boldsymbol{t = 2d/v}$) and the information you have calculated. Show your work and record the time below.

t = ____________________

Find the stopping force required with this new figure. Use the same equation ($\boldsymbol{\rho = F \cdot t}$) with your new information to solve for F. Show your work and record the new stopping force below.

F = ____________________N

How large is this force compared to the rider's weight, or the force of gravity (F_G)?

____________________times the rider's weight

This is why an airbag, which has a long stopping distance, is safer than a windshield, which has a much shorter stopping distance.