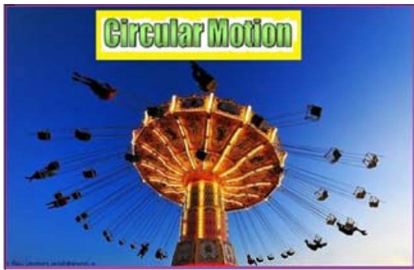


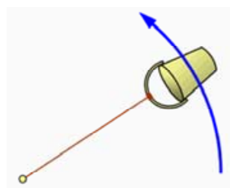
Unit 3: Circular Motion, Work, Energy

3.1 Uniform Circular Motion

With everything we have studied so far (Kinematics, Dynamics, Gravity), objects have always been moving in a straight line. Now we are talking about circles.

Uniform Circular Motion - constant circular movement

Eg. hammer throw, bucket of water on a string, fair rides, etc.



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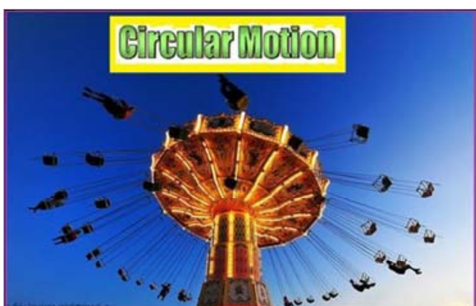
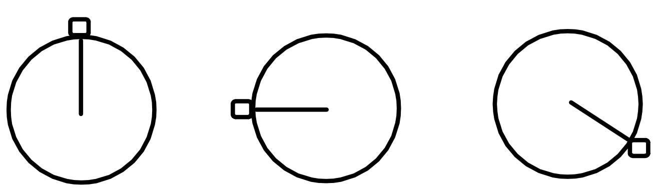
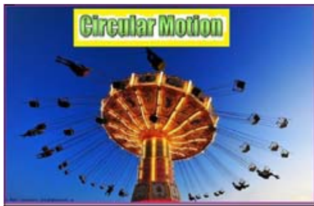


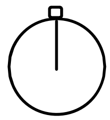
Let's analyze the bucket of water on a string. As long as SPEED stays the same we can say the object has uniform circular motion.



If we look at the velocity at different points in the path of the bucket, we will see the magnitude of velocity remains the same but direction changes.

Jan 20-11:11 AM





The instantaneous velocity (velocity of the bucket at any given point in time) is always perpendicular to the radius of the circle and tangent to the circle.

So if the magnitude of velocity remains constant, we have:

$$\vec{v}_{\text{ave}} = \frac{\Delta \vec{d}}{\Delta t}$$

However, time means something different with circular motion. We use *T* to represent the time it takes to complete one revolution around the circle(called the period).

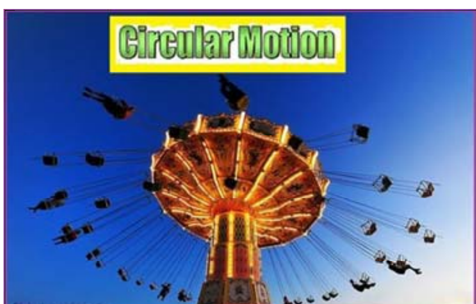
Now, distance will also mean something different when we go around a circle. Distance around a circle is circumference, or *2πr.*

If we make all the substitutions to the formula to take into account the fact that we are moving around a circle, we get the formula for velocity of an object moving in a circle:

$$\left|\vec{v}_{\text{c}}\right| = \frac{2\pi r}{T}$$

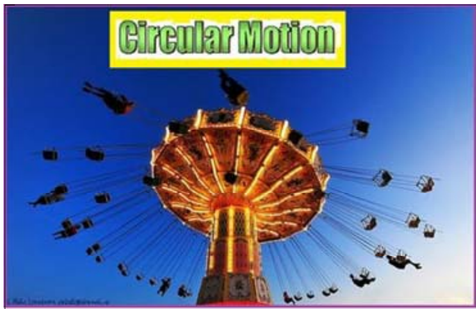
*formula found in Kinematics sections of formula sheet

Jan 20-11:15 AM



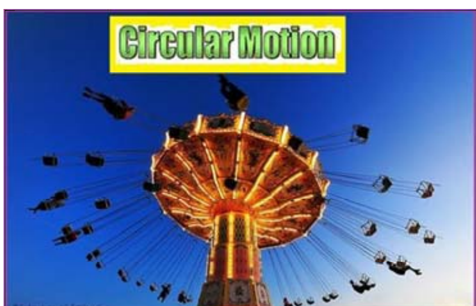
Ex.) If the water bucket has a period of 1.5 s and the string is 1.25 m long, what is the magnitude of the buckets velocity?

Jan 20-11:53 AM



Ex.) A super-plane is flying at a height of 10 000 m above sea level in a circular path around the planet (assume it can hold enough fuel to do this in one trip). If the velocity of the super-plane is 885 km/h, how long does it take the super-plane to go around the world?

Jan 20-11:53 AM

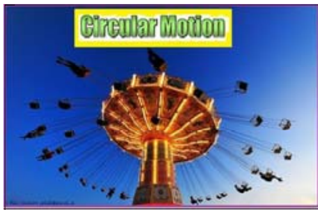


We've looked at velocity around a circle, now let's take a look at acceleration:

$$\left|\vec{a}_c\right| = \frac{v^2}{r}$$

Acceleration around a circle is called *centripetal acceleration(meaning centre seeking)* and is directed toward the centre of the circle.

Jan 20-11:56 AM

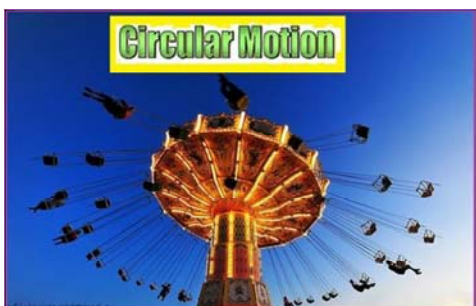


Two "forces" that are often confused in the Physics world are centripetal and centrifugal. Below are the differences:

	Centrifugal Force	Centripetal Force
Meaning	Tendency of an object following a curved path to fly away from the center of curvature. Might be described as "lack of centripetal force."	The force that keeps an object moving with a uniform speed along a circular path.
Direction	Along the radius of the circle, from the center towards the object.	Along the radius of the circle, from the object towards the center.
Example	Mud flying off a tire; children pushed out on a roundabout.	Satellite orbiting a planet
Formula	Fc = mv2/r	Fc = mv2/r
Defined by	Chistiaan Hygens in 1659	Isaac Newton in 1684
Is it a real force?	No; centrifugal force is the inertia of motion.	Yes; centripetal force keeps the object from "flying out".

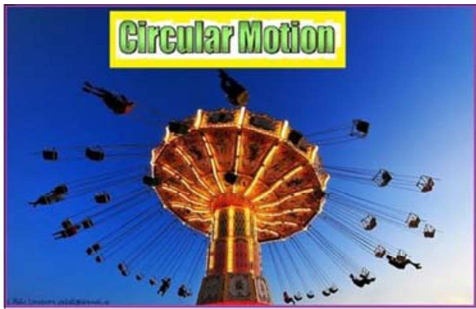
Important for this course: centripetal acceleration always points **towards** the centre of the circle.

Jan 20-12:00 PM



Ex.) A car takes a curve of radius 15 m at 45 km/h. What is the car's acceleration?

Jan 20-12:02 PM



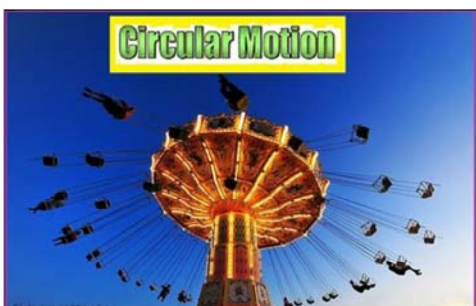
Newton's Second Law tells us that where there is acceleration, there is a force in the same direction.

If we have centripetal acceleration, it follows that we would have centripetal force:

$$F_c = \frac{mv^2}{r} = \frac{4\pi^2 rm}{T^2}$$

This centripetal force can be friction, tension, gravity...whatever.

Jan 20-12:04 PM



Read: Pg. 242-256.

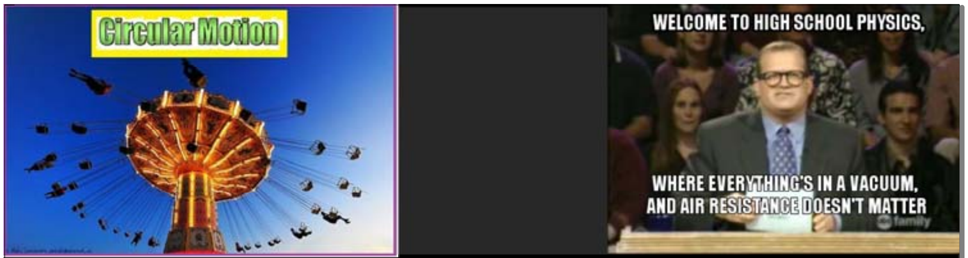
Crash Course Physics

https://www.youtube.com/watch?v=bpFK2VCRHUs

Khan Academy

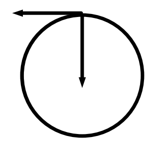
https://www.youtube.com/watch?v=FfNgm-w9Krw

Jan 20-2:05 PM

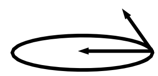


3.2 Vertical Circular Motion

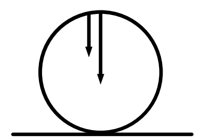
We have always drawn horizontal circular motion like this:



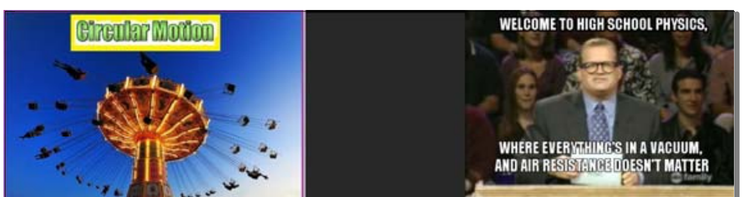
But it really should have been drawn like this:



Because now we look at vertical circular motion like this:
($\vec{Fg}$ is now at play)

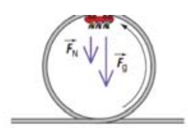


Jan 25-8:42 AM



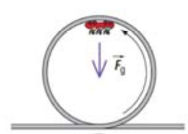
Analysis of Vertical Circular Motion: Why doesn't a roller coaster fall off the tracks when upside down?

▶ **Figure 5.28(a)** The first time through the loop, the speed is such that the roller coaster requires a centripetal force of 1500 N to keep it moving in a circular path. At the top of the loop, the roller coaster car will experience a centripetal force that is the sum of the force of gravity and the force exerted by the track, pushing the car inward to the centre of the circle. The centripetal force acts down, so it is −1500 N. The force of gravity is constant at 1000 N so the track pushes inward with 500 N to produce the required centripetal force. The car goes around the loop with no problem.

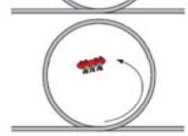


$\vec{F}_c = \vec{F}_g + \vec{F}_N$
$-1500\text{ N} = -1000\text{ N} + -500\text{ N}$

▶ **Figure 5.28(b)** Suppose the next time the car goes around the track, it is moving more slowly, so that the centripetal force required is only 1000 N. In this case, the force of gravity alone can provide the required centripetal force. Therefore, the track does not need to exert any force on the car to keep it moving on the track. There is no normal force, so the force of gravity alone is the centripetal force. The car goes around the loop again with no problem.



▶ **Figure 5.28(c)** Now suppose the last time the car goes around the track, it is moving very slowly. The required centripetal force is just 800 N, but the force of gravity is constant, so it is still 1000 N; that is, 200 N more than the centripetal force required to keep the car moving in a circular path with this radius. If the track could somehow pull upward by 200 N to balance the force of gravity, the car would stay on the track. This is something it can't do in our hypothetical case. Since the gravitational force cannot be balanced by the track's force, it pulls the car downward off the track.

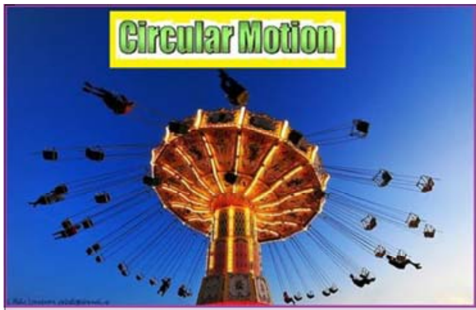


$\vec{F}_c = \vec{F}_g + \vec{F}_N$
$-800\text{ N} = -1000\text{ N} + 200\text{ N}$

Since the normal force cannot pull upward, it cannot generate +200 N. 200 N more is needed to keep the car on a track of this radius, so the car falls off.

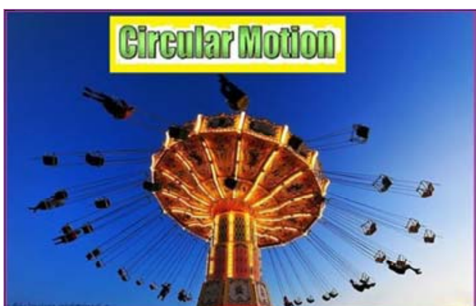
The centripetal force is supplied by the normal force and gravity at the top of the loop.

Jan 25-9:28 AM



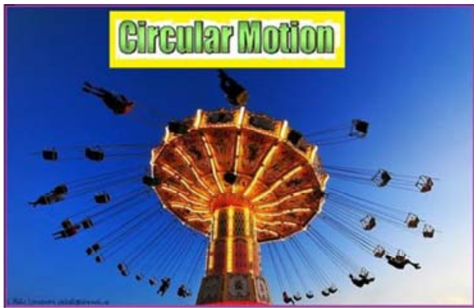
Ex.) Neglecting friction, what is the minimum speed a Hot Wheels car must go around a vertical loop of radius 15.0 cm to keep from falling off?

Jan 25-9:30 AM



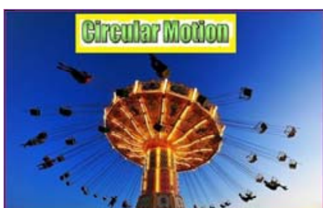
Ex.) What is the maximum radius a roller coaster loop can be if a cart with speed of 20.0 m/s is to go around safely?

Jan 25-9:33 AM



Ex.) What is the force the roller coaster track is providing to a 102 kg cart traveling at 15.0 m/s around a 7.0 m radius loop?

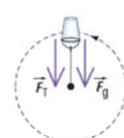
Jan 25-9:34 AM



Recall the bucket of water scenario. If we now twirl the bucket of water vertically what is keeping the water in the bucket?

▶ **Figure 5.30(a)** The bucket is at the top of the circle. In this position, two forces are acting on the bucket: the force of gravity and the tension of the rope. Both are producing the centripetal force and are acting downward. The equation to represent this situation is: $\vec{F}_c = \vec{F}_g + \vec{F}_T$

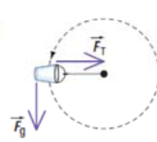
(a)



$\vec{F}_c = \vec{F}_g + \vec{F}_T$

▶ **Figure 5.30(b)** When the bucket has moved to the position where the rope is parallel to the ground, the force of gravity is perpendicular to the tension. It does not contribute to the centripetal force. The tension alone is the centripetal force. We can write this mathematically as: $\vec{F}_c = \vec{F}_T$

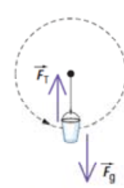
(b)



$\vec{F}_c = \vec{F}_T$

▶ **Figure 5.30(c)** As the bucket moves through the bottom of the circle, it must have a centripetal force that overcomes gravity. The tension is the greatest here because gravity is acting opposite to the centripetal force. The equation is the same as in (a) above, but tension is acting upward, so when the values are placed into the equation this time, $\vec{F}_T$ is positive and $\vec{F}_g$ is negative. The effect is demonstrated in Example 5.7.

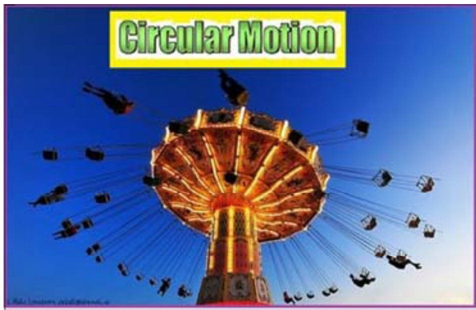
(c)



Here, gravity and tension work to supply the centripetal force.

$\vec{F}_c = \vec{F}_g + \vec{F}_T$

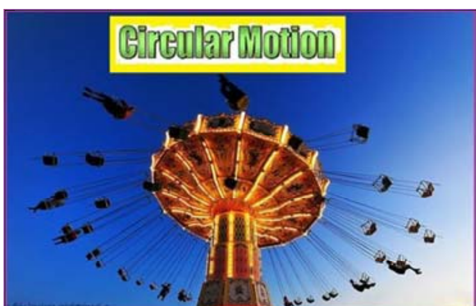
Jan 25-9:35 AM



It would seem like the force acting on the water must be acting outward to keep the water in the bucket, but it is not. The centripetal force is pointed towards the centre of the circle. And this force keeps things in a circular pattern, not a pattern where the water will fall.

Some people will refer to the "force" keeping the water in the bucket as "centrifugal force." But we know this isn't a real force. Physicists will refer to these "made up" forces as phantom forces or fictitious forces.

Jan 25-9:38 AM



Ex.) A string can hold a force of 135 N before breaking. If a 2.00 kg object is tied to the end of this string (L = 1.10 m), how fast can I spin it vertically before the string breaks?

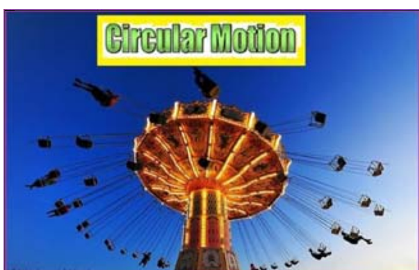
Jan 25-9:47 AM

[redacted]

[redacted] vertical circle with r = 0.75 m. What is the
[redacted] of the swing to maintain uniform circular

Questions: Pg. 268 # 6-13.

Jan 25-9:48 AM



Unit 3: Circular Motion, Work and Energy

3.3 Satellite Motion

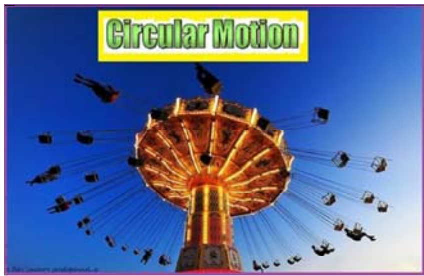
Satellite - any object that orbits around a central object (usually a planet)

Artificial Satellites - communications satellites, Space Shuttle, Hubble, ISS, space junk

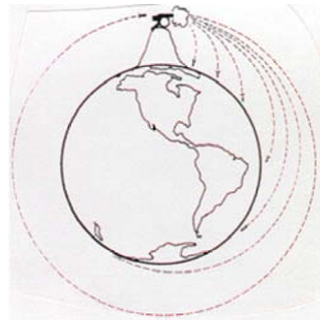
Natural Satellites - moons of planets, planets orbiting the Sun

Geosynchronous Satellite - a satellite that orbits Earth once per day

Jan 26-7:48 AM



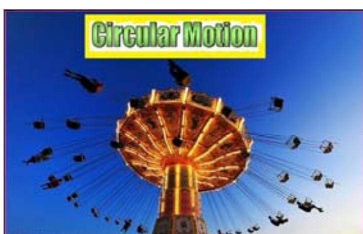
For the projectile problems we worked with there was an unstated assumption that the Earth was flat. However, we know that the Earth is in fact spherical, although not perfectly so. With this in mind, Sir Isaac Newton reasoned that some strange things would happen if one could horizontally project an object at high speeds.



At low speeds, a horizontal projectile will fall toward and hit the ground in a short time. As the speed of the horizontal projectile is increased, it will land further and further away from the starting point. For a *flat Earth* the projectile would always hit the ground; no matter how fast the projectile went, gravity would pull it down to the ground.

However, since the Earth is round, the curvature of the Earth affects where the projectile lands. As the diagram indicates, the greater the horizontal speed of the projectile, the more the Earth's curvature comes into play. Eventually, a critical speed is reached where, even though **the projectile is in constant freefall**, it would not hit the Earth, rather, it would become a **satellite** in **orbit** around the Earth.

Jan 26-7:52 AM



Newton was able to calculate the speed required to put an object into an orbit which would just skim the surface of a smooth Earth. Newton realized that a satellite orbiting the Sun, the Earth, or some other body is simply a case of uniform circular motion. He reasoned that the **gravitational force would act as the centripetal force for a circular orbit**.

$$F_c = F_g$$

$$\frac{mv^2}{r} = \frac{GMm}{r^2}$$ (the mass of the satellite cancels, and one r cancels as well)

$$v^2 = \frac{GM}{r}$$

$$v = \sqrt{\frac{GM}{r}}$$

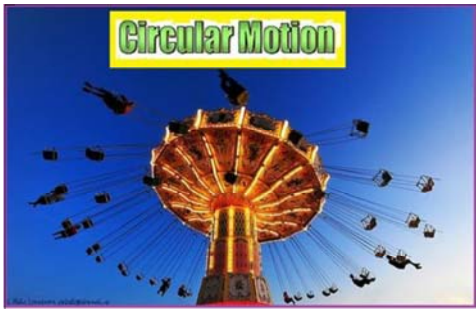
where:
M mass of body being orbited
r distance from the center of M to the satellite

Note:

1. The orbit does not depend on the mass of the satellite as long as the mass of the planet or star around which the satellite is orbiting is much, much larger than the mass of the satellite.

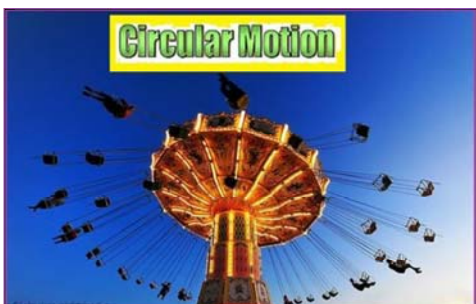
2. The treatment of orbits that we shall work with is quite limited. For example, to calculate the escape velocities of satellites requires that we account for gravitational potential energy. In addition, we will limit ourselves to circular and not elliptical orbits.

Jan 26-8:07 AM



Ex.) What is the speed of orbit for a satellite orbiting Saturn if the radius of orbit is 6.43×10^7 m?

Jan 26-8:12 AM



Recall that the derivation of the formula we used came from the idea that the force of gravity is supplying the centripetal force. We have more choices for these equations depending on the unknown in the problem:

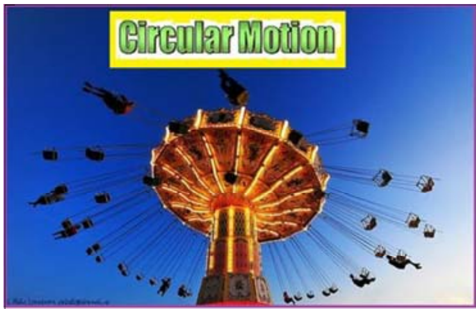
$$\vec{F}_g = mg$$

$$\vec{F}_g = \frac{Gm_1m_2}{r^2}$$

$$F_c = \frac{mv^2}{r} = \frac{4\pi^2 rm}{T^2}$$

In the following examples you need to choose the appropriate formulas to use based on the variables given and the unknown.

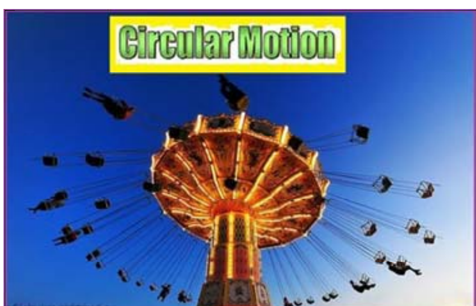
Jan 26-8:13 AM



Ex.) Galileo discovered 4 moons of Jupiter, listed below. Also listed are their periods of revolution and their orbital radii (centre to centre). From this data, determine the mass of Jupiter.

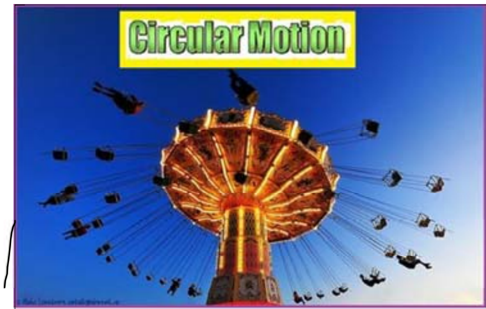
moon	period (days)	distance (10^6 m)
Io	1.769137786	422
Europa	3.551181041	671
Ganymede	7.154552960	1070
Callisto	16.68901840	1883

Jan 26-8:20 AM



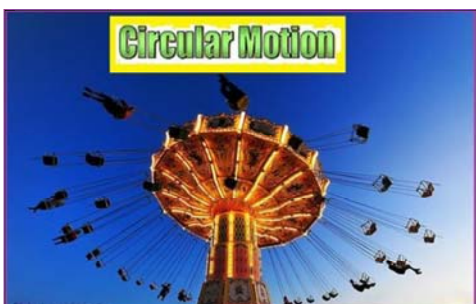
Ex.) What is the speed of the moon Io based on the information from the previous slide?

Jan 26-8:26 AM



Ex.) The average distance from the centre of the Earth to the centre of the Moon is 3.85×10^{8} m? What is the period of orbit of the Moon around the Earth?

Jan 26-8:26 AM

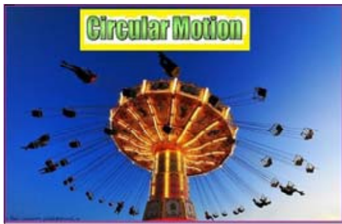


Ex.) Determine the height from the surface of the Earth of a geo-sync satellite.

Read: Pg. 276 - 286

Questions: Pg. 286 # 9-13.

Jan 26-9:57 AM



Unit 3: Circular Motion, Work and Energy

3.4 Kepler's Laws of Planetary Motion

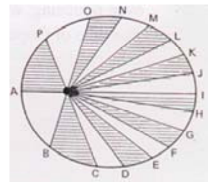
An astronomical observer named Tycho Brahe (1546-1601) spent more than 20 years making careful measurements and observations of the heavens. His measurements were accurate to 1/1000th of a degree. Johannes Kepler, an assistant to Brahe, wanted to use Brahe's data to plot the orbit of Mars. For years Brahe kept promising the data to Kepler. Finally, Kepler stole Brahe's data after Brahe died in 1601. Kepler spent 16 years working on and plotting the orbit of Mars, producing 900 pages of calculations. Fortunately for Kepler, Mars' orbit is just enough of an ellipse that Brahe's data could not be forced to conform to a circular orbit. Kepler discovered three laws of planetary motion:

1. Planets orbit the sun in *elliptical* orbits with the sun at one focus of the ellipse.

2. A straight line joining the sun to a planet sweeps out equal areas in equal times.

3. The cube of a planet's mean distance (r) from the sun is proportional to the square of the period of revolution (T) of a planet.

$$\frac{r^3}{T^2} = k$$



Kepler's *Law of Areas.* A planet moves along its orbit at a rate such that the line from the sun to the planet sweeps over areas which are proportional to the time-intervals. The time taken to cover *AB* is the same as that for *BC*, *CD*, and so on.

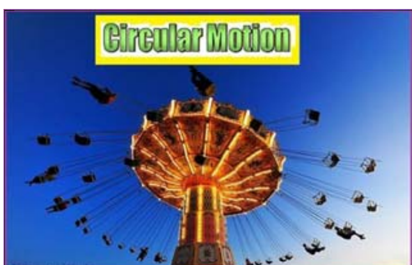
Random Scientist Facts

- Kepler's mother was accused of witchcraft.

- Kepler devised the eyeglass for nearsightedness and farsightedness

- Tycho Brahe liked to drink and get in fights...his nose was cut off so he had a bronze nose made and obsessively rubbed it with oil. He had a gold nose for special occasions.

Jan 26-9:24 AM



Kepler gave no explanation of why planets go around the sun. His laws are only descriptive. However, Sir Isaac Newton provided the explanation for why the moon, Earth, Sun, planets and stars moved and behaved as they did. Newton was able to explain Kepler's three laws of planetary motion. He reasoned that if we make the approximation that a planet's orbit is circular, than the gravitational attraction between the planet and the Sun provides the centripetal force to maintain the planet's orbit around the Sun.

$$F_c = F_g$$

$$\frac{4\pi^2 mr}{T^2} = G\frac{Mm}{r^2}$$

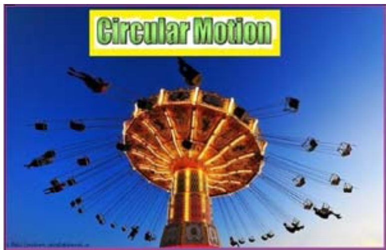
$$\frac{r^3}{T^2} = \frac{GM}{4\pi^2}$$

or

$$\frac{r^3}{T^2} = k \qquad \text{where } k = \frac{GM}{4\pi^2} = 3.35\times10^{18}\ \mathrm{m^3/s^2} \text{ for the Sun}$$

This is Kepler's third law.

Jan 26-9:27 AM

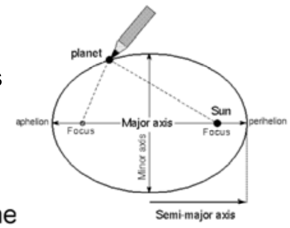


Kepler's First Law: planets move in ellipses, with the Sun at one focus

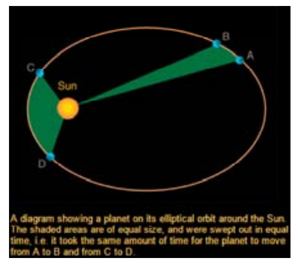
Kepler's Second Law: planets sweep out equal areas in equal times (ie. their orbital speed is not fixed)

Kepler's Third Law: the square of the period of a plane orbit divided by the cube of its orbital radius is a constant

$$\frac{r^3}{T^2} = k$$



Drawing an **ellipse**: loop string around thumb tacks at each **focus** and stretch string tight with a pencil while moving the pencil around the tacks. The Sun is at one focus.



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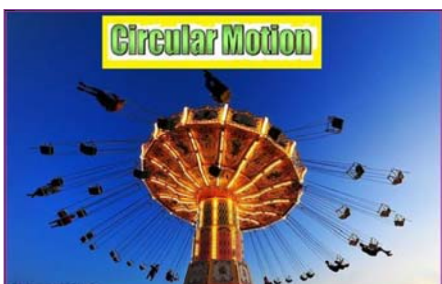
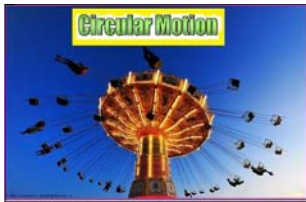


Kepler's Third Law was "proven" with data that Tycho Brahe had collected. Years later, Newton determined that gravity keeps planets in their orbits and that centripetal force is supplied by gravity proving Kepler's Third Law.

Homework: Unit Assignment

Jan 26-9:46 AM

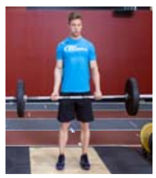


Unit 3: Circular Motion, Work and Energy

3.5 Work

Which person is doing more work?

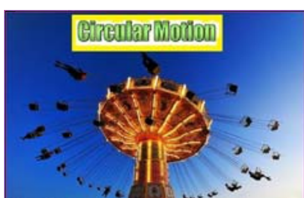
or



or

weight lifter on the Moon or weight lifter on the Earth

Jan 26-9:59 AM



$$W = \Delta E$$

Work is a change in energy...but this is saying a lot more than it seems.

From the previous slide, we can deduce that:

work is proportional to mass

$$W \propto m$$

work is proportional to displacement

$$W \propto \vec{d}$$

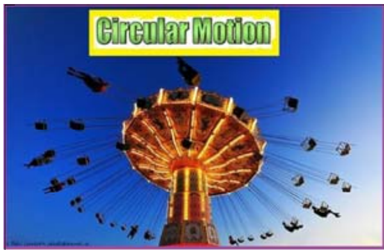
work is proportional to acceleration (ie. gravity)

$$W \propto \vec{a}$$

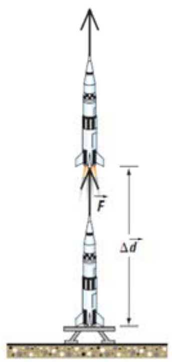
So...

$$W = \vec{F} \cdot \vec{d}$$

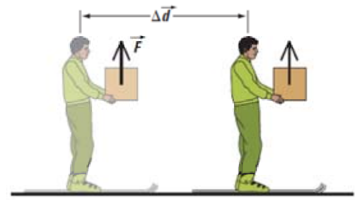
Jan 26-10:10 AM



Work is scalar (only a magnitude). However, force and displacement must be in the same direction for work to have been done!!

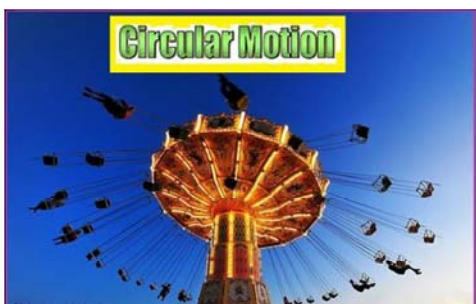


▲ Figure 6.6



▲ Figure 6.7

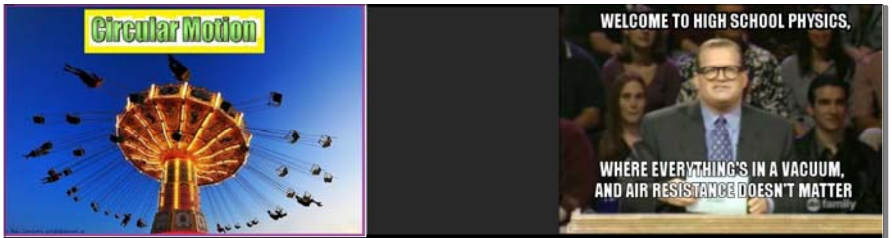
Jan 26-10:14 AM



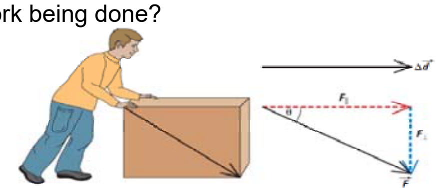
Ex.) How much work is done in lifting a 25 kg box to a height of 5.0 m?

Ex.) How much work is needed, after lifting the box to carry it horizontally 250 m?

Jan 26-10:19 AM



What about this fella...there are two dimensions to the force he is applying to the box so is work being done?

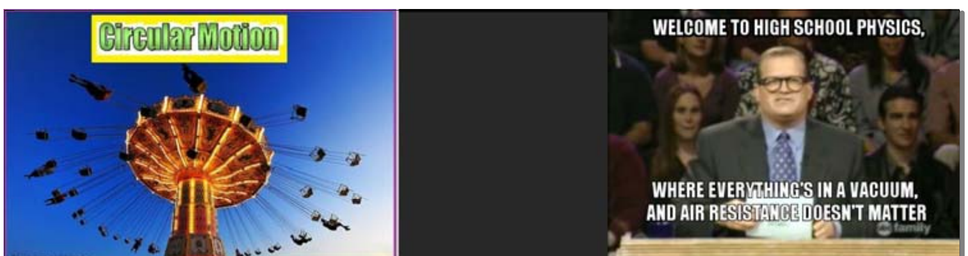


▲ **Figure 6.5** When a force acts on an object, resulting in a displacement, only the component of the force that acts parallel to the displacement does work. If the box moves horizontally, only the horizontal component, $\vec{F}_{\parallel}$, does work.

The answer is yes...sort of. When force is being applied at an angle, θ, we can break the force down into parallel and perpendicular components. Therefore, if one component of the force is acting in the same direction as the displacement, some work is being done. We can find it using our old pal, Trigonometry.

$$W = \left|\vec{F}\right|\left|\vec{d}\right|\cos\theta$$

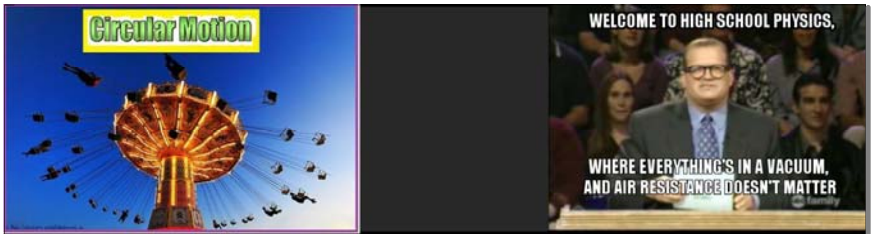
Jan 26-10:20 AM



Ex.) Ryan is shoveling the walk. A force of 150 N is applied down the shovel handle, which makes an angle of 35.0° with the horizontal. Ryan pushes the shovel 10.0 m. How much work is being done on the shovel?

**units for work are Joules

Jan 26-10:25 AM



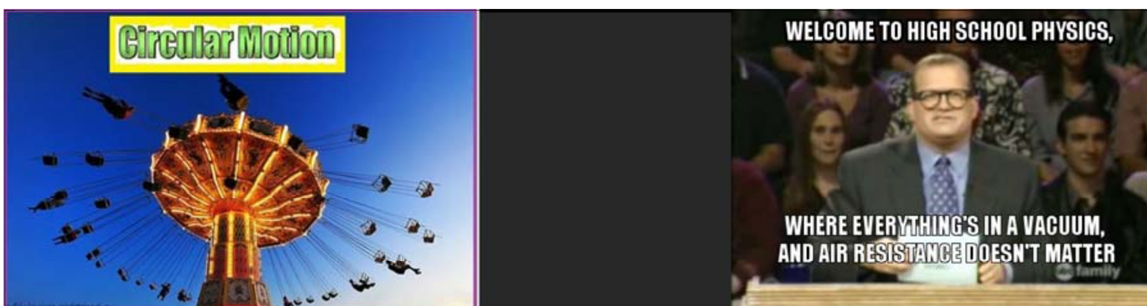
Ex.) A 7.00 kg crate is pushed up a hill with an incline of 11.0° for 3.00 m. A 90.0 N horizontal force, parallel to the ground, is applied to the crate. The coefficient due to friction is 0.200.

a) How much work is done?

b) How much work is done by gravity against the crate?

c) How much work is done by friction against the crate?

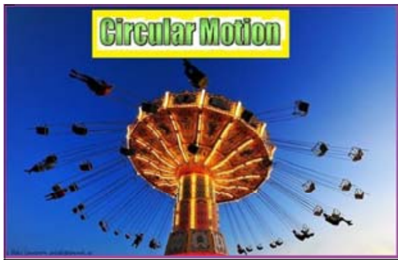
Jan 26-10:27 AM



Read: Pg. 293-294.

Questions: Pg. 294 Practice Problems.

Jan 26-10:41 AM



Unit 3: Circular Motion, Work and Energy

3.6 Energy

Energy - the capacity to do work, can be converted from one form to another, change in energy is called work

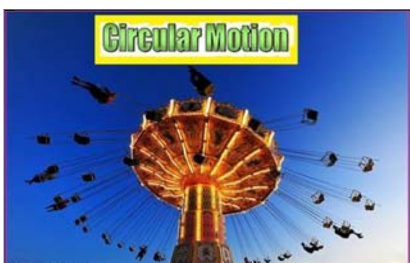
Gravitational Potential Energy

$$E_p = mgh$$

Kinetic Energy

$$E_k = \frac{1}{2}mv^2$$

Jan 26-10:43 AM



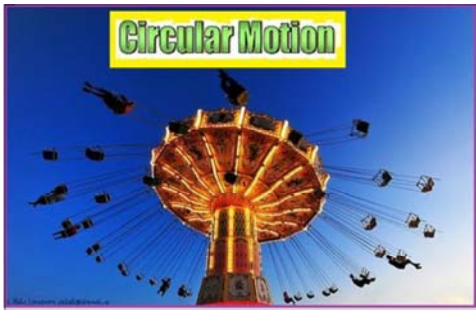
Ex.) A 70 kg person climbed a 12 m ladder. Calculate the potential energy with respect to:

a) The ground.

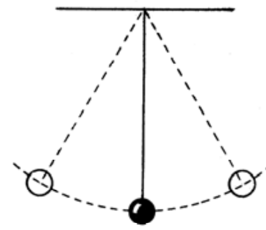
b) The roof (11 m above the ground).

c) A tree, 7.0 m below the top of the ladder.

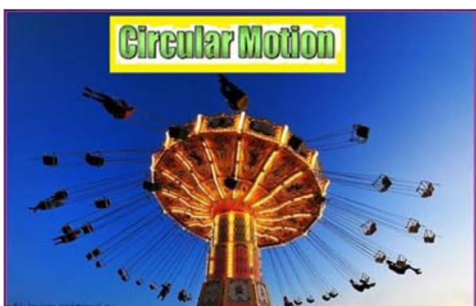
Jan 26-11:36 AM



Ex.) A pendulum bob of mass of 2.00 kg is fixed from the ceiling by a string of length 1.00 m. If the bob is pulled 0.750 m to one side, what is its potential energy with respect to its equilibrium position?

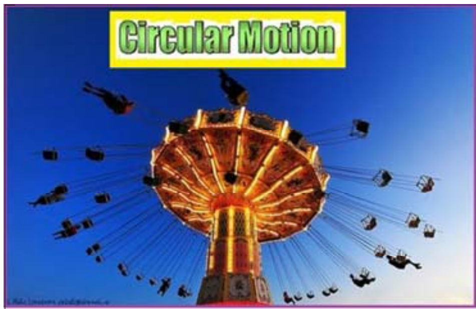


Jan 26-11:38 AM



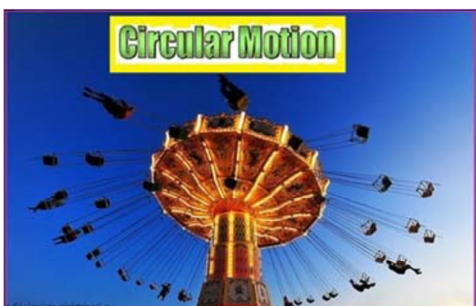
Ex.) A 10.0 N ball is accelerated uniformly from rest at a rate of 2.50 m/s^2. What is the kinetic energy of this object after it has accelerated a distance of 15.0 m?

Jan 26-11:41 AM



Ex.) An 8.0 kg rock is dropped from a height of 7.0 m. What is the kinetic energy of the rock as it hits the ground?

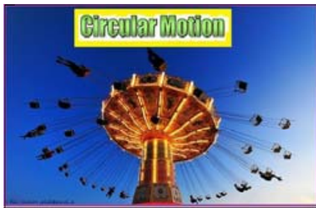
Jan 26-1:41 PM



Ex.) By what factor must the kinetic energy increase to cause the speed to triple?

Pg. 305 # 2, 3, 6, 7, 9.

Jan 26-1:42 PM



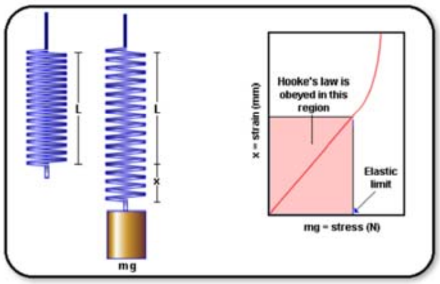
Unit 3: Circular Motion, Work and Energy

3.7 Hooke's Law and Elastic Energy

In 1676, Robert Hooke devised a relationship between the amount of stretch in a spring and the weight suspended by that spring.

Random Scientist Fact

This is not Robert Hooke... No one really liked him because as the years went on he became grumpy. So no one bothered to keep paintings of him in tact and we have no real likeness of him to this day.



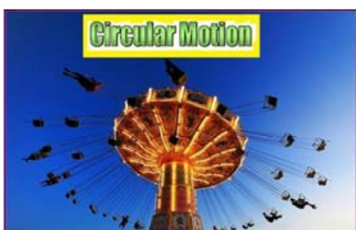
$$F_s = kx$$

F = force applied to the spring (N)

x = displacement from equilibrium (stretch or compress) of spring (m)

k = spring constant (slope) (N/m)

Jan 26-1:43 PM



Note: You will notice there are two very similar formulas on your formula sheet for Hooke's Law. One with a negative and one without. This is because as you stretch a spring, you can decided which direction you want to be positive or negative and adapt the formula accordingly.

If you find the area under a weight vs. stretch graph, you are finding work (and therefore energy).

A = 1/2 bh

or

E = 1/2 Fx

E = 1/2(kx)x

which yields:

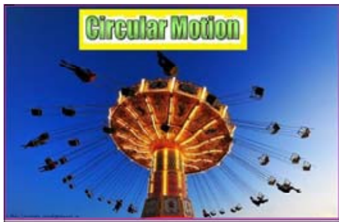
$$E_s = \frac{1}{2}kx^2$$

E_S = elastic potential energy (J)

k = spring constant (N/m)

x = displacement of spring (m)

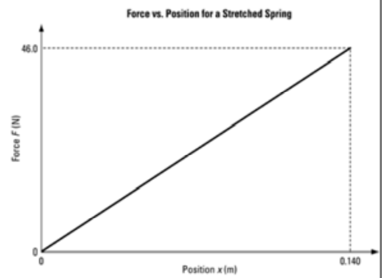
Jan 26-3:06 PM



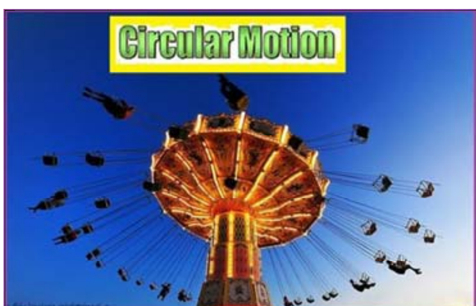
Ex.) The following graph shows how a force causes change in position as it stretches a spring.

a) Calculate the energy stored in the spring when the force is 36.0 N.

b) Compare the energy when the force is 46.0 N to the energy stored in the spring when the position is 7.00 cm.

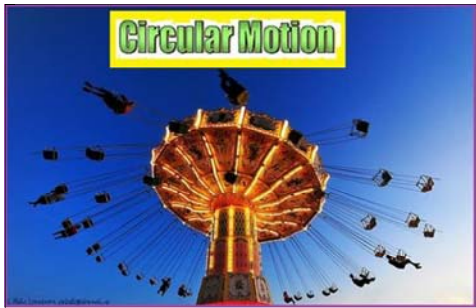


Jan 26-4:10 PM



Questions: Pg. 305 # 4, 8, 11.

Jan 26-4:15 PM



Unit 3: Circular Motion, Work and Energy

3.8 Mechanical Energy

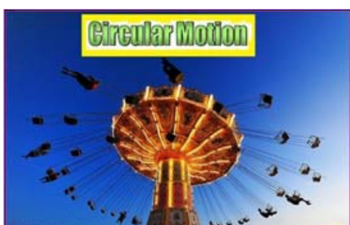
Mechanical Energy - the sum of all energies acting on a given system (ie. a skydiver has potential and kinetic energies at any given time in the air)

Since mechanical energy is the sum of all energies and work is the change in energy, we could say:

The Work-Energy Theorem

$$W = \Delta E_k + \Delta E_p$$

Jan 27-12:54 PM



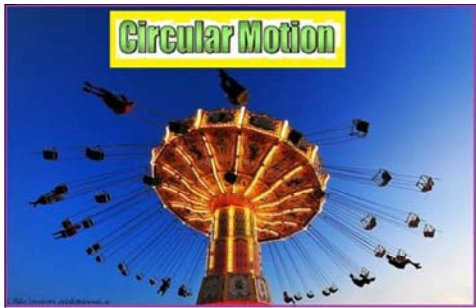
Ex.) A farmer is hauling feed and he lifts a 9.00 kg bucket up 5.00 m of rope. This takes a force of 150 N upwards.

a) What work does the farmer do on the feed?

b) What is the change in PE of the feed?

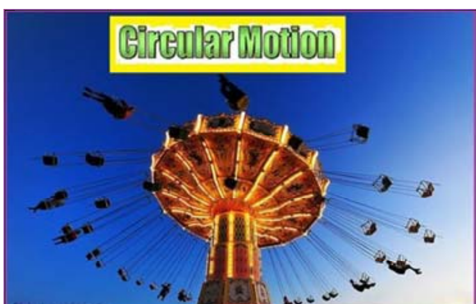
c) What is the change in KE of the feed?

Jan 27-12:58 PM



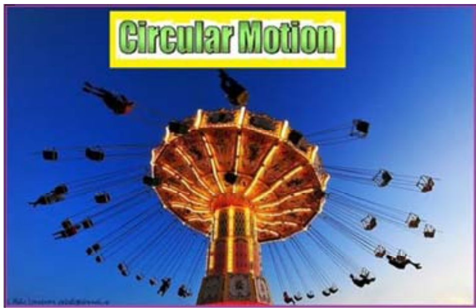
Ex.) A 150 kg sled and rider are pushed up a hill with a vertical height of 6.53 m. The initial velocity of the rider is 2.50 m/s and the final velocity of the rider is 5.80 m/s.What amount of work is needed to push the sled up the hill?

Jan 27-1:00 PM



Ex.) A 450 kg care package for soldiers is dropped from an airplane and reaches a velocity of 35 m/s at 350 m. What is the mechanical energy of the package? (Hint: pick appropriate units of energy)

Jan 27-1:10 PM



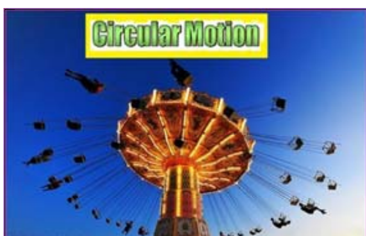
Why is mechanical energy important? Because of the big idea we have studied throughout this course...THE LAW OF CONSERVATION OF ENERGY!

In an isolated system, mechanical energy is conserved. Energy is not created or destroyed, only changed in form.

Isolated System - a system in which energy cannot enter or leave

Energy is Conserved - the total amount of energy is constant but may be in constant flux

Jan 27-1:11 PM



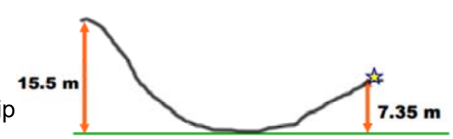
Ex.) A frictionless roller coaster car has a mass of 200 kg and travels along a path as shown:

Calculate the :

a) PE at the first hill

b) KE and speed at the bottom of the dip

c) speed at the top of the second hill



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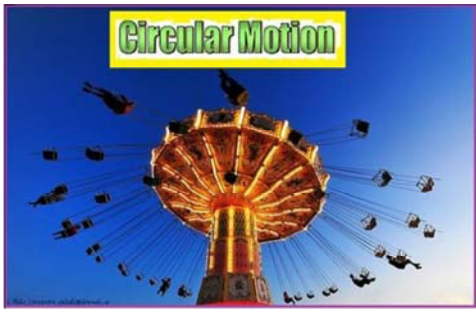
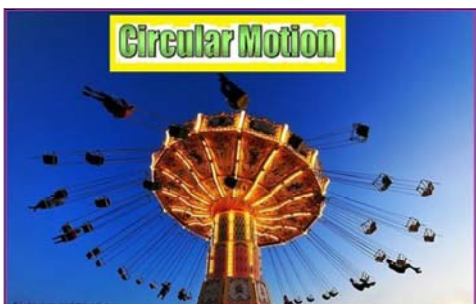


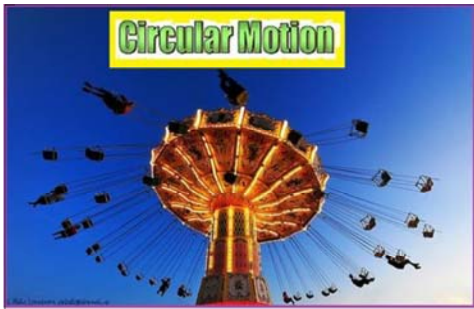
Ex.) Draw (on the same set of axes) an E_p vs. time graph and a E_k vs. time graph for an ideal pendulum swinging back and forth. Consider the starting point to be when the bob is pulled back to the side then released.

Jan 27-1:18 PM

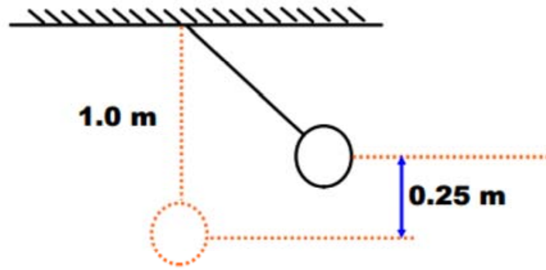


Ex.) Use two different methods to calculate the speed an object would hit the ground with if dropped from 12.0 m.

Jan 27-1:19 PM



Ex.) A pendulum is dropped from the position shown 0.25 m above equilibrium. What is the speed of the bob as it passes through the equilibrium position?



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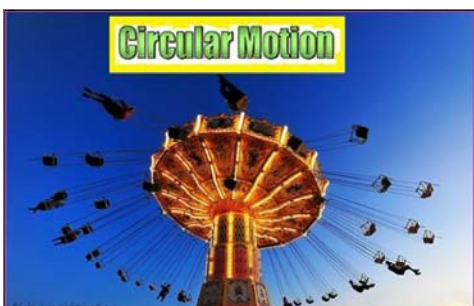
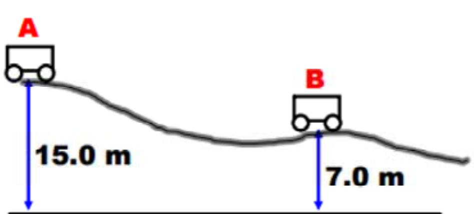


Ex.) A roller coaster traveling on a frictionless track is shown. If the speed of the car at A is 3.0 m/s, what is the speed at B?



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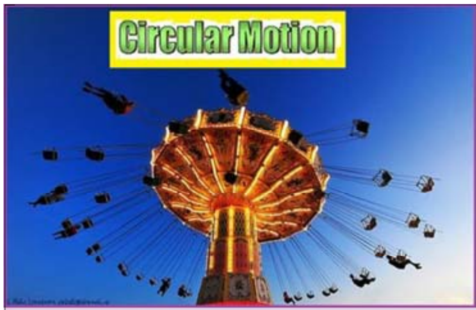
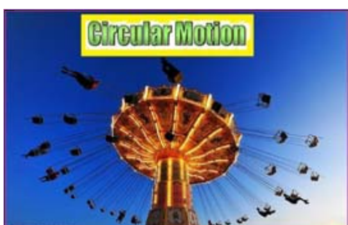


Questions: Pg. 310 # 6, 7, 8.

Pg. 315-316 # 1, 3, 4.

Read: Pg. 319-322.

Jan 27-1:23 PM



Unit 3: Circular Motion, Work and Energy

3.9 Work and Power

We know work is the change in energy but what is power?

Power - the rate of change of work

Recall from Math 10C that "rate of change" means slope.

Another way to describe power is "the amount of energy per second applied."

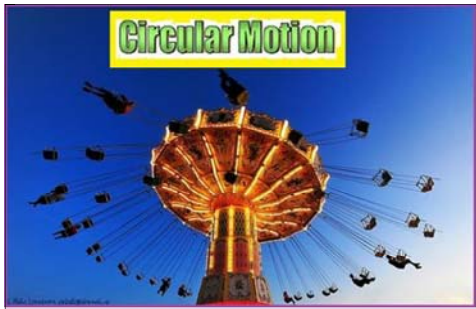
$$P = \frac{\Delta E}{\Delta t} = \frac{W}{\Delta t}$$

P = power (J/s = Watt(W))
W = work (J)
E = energy (J)
t = time (s)

Power was traditionally measure with the unit: horsepower (I'm sure you can imagine why) but this was cumbersome and thus replaced with the Watt.

1 hp = 746 W

Jan 27-1:24 PM



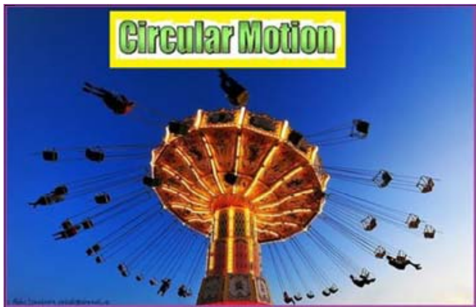
Note that when you are given the Power formula; P = W/Δt, you can derive different formulas not on the formulas sheet. This is because we have a couple formulas for work; W = Fd, W = mad. One useful derivation is shown:

$$P = \frac{W}{\Delta t}$$

$$P = \frac{\vec{F}\vec{d}}{\Delta t}$$

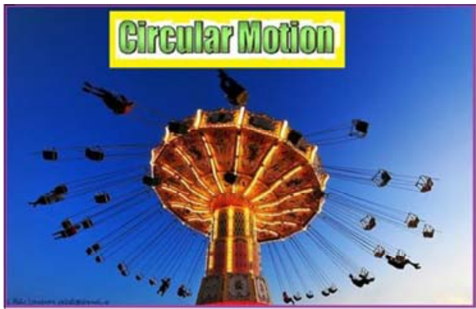
$$\boxed{P = \vec{F}\vec{v}}$$

Jan 27-1:29 PM



Ex.) You lift a 25.0 kg box to your waist (0.800 m) in 1.20 s. What is your power output?

Jan 27-1:34 PM



Ex.) A plane's engine exerts a thrust of 1.20×10^4 N to maintain a speed of 450 km/h. What power is the engine generating?

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