Physics 12

Booklet #3

- Uniform Circular Motion
- Vertical Circles
- Universal Gravitation
- Gravity Fields
- Gravitational Potential Energy

Uniform Circular Motion

Example: A mass connected to a rope is being swung around in a circle at a constant speed. Determine the speed of the mass if the rope is 0.50 m long, and it completes two rotations per second.

Is the acceleration of the mass zero?

Terminology

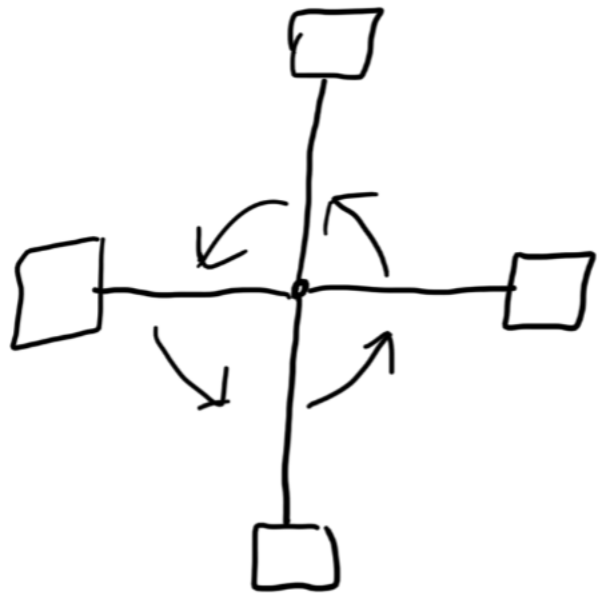
Circumference:

Period:

Frequency:

Since acceleration is a change in velocity, and velocity is a vector, even though the speed is constant, since the direction of the movement is changing the acceleration is NOT zero.

Consider the direction the mass is moving at various points as it goes around the circle:



Determine the acceleration of the mass as it moves from the southern most position to the easternmost position:

Determine the acceleration of the mass as it moves from the easternmost position to the northernmost position:

Note that the acceleration is always directed toward the centre of the circle.

This is called centripetal acceleration. For an object moving at uniform circular motion:

Using Newton's second law we can determine the centripetal FORCE that keeps the object moving.

Centripetal force is not a new type of force, it is whatever force is being used to accelerate an object in circular motion

A swinging weight, the centipedal force is provided by

In a car making a turn the centipedal force is provided by

When the moon orbits the earth the centipedal force is provided by

EXAMPLE: A 2.5 kg toy plane is moving in uniform circular motion, completing a revolution around a circle of radius 1.42m every 6.3 seconds.

What is the period of the plane?

What is the frequency of the plane?

What is the speed of the plane?

What is the velocity of the plane?

What is the acceleration of the plane?

What is the centripetal force acting on the plane?

EXAMPLE: A 1200 kg car goes around a curve of radius 76 m at 24 m/s. What is the magnitude of the centripetal force acting on the car?

What is the magnitude of the centripetal force if the car was moving at 35 m/s?

What is the minimum coefficient of friction between the car's tires and the road under each scenario?

What will happen if the coefficient of friction is less than this?

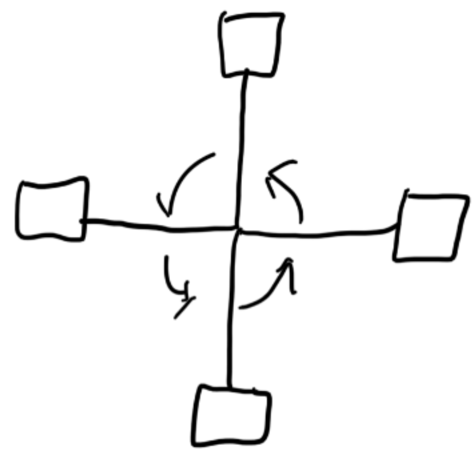
Vertical Circles

A 0.10 kg mass is connected to a rope and is swung in a vertical circle of radius 0.50 m, at 5.3 m/s.

Determine the centipedal force acting on the mass.

The mass is affected by both the tension in the rope and the force of gravity.

Draw tension and gravity forces on the block at the different places along the circle.



At the top of the circle, gravity is acting in the same direction as the centripetal force:

At the bottom of the circle, gravity is acting in the opposite direction as the centipedal force:

Determine the tension at the top of the circle and bottom of the circle:

PROBLEM: Determine the minimum speed of a mass in a vertical circle.

Consider what will occur if the centripetal force is less than the force of gravity:

EXAMPLE: What is the minimum speed a 2.5 kg object be swung in a vertical circle of radius 0.65 m at?

Apparent weight

A person standing on a floor is affected by two forces, gravity and the normal force. The force we feel is the normal force, as so we call that force the apparent weight of a person.

EXAMPLE: A person is on a Ferris wheel of radius 15m, which completes a revolution every 85 seconds. Determine their apparent weight at the top and bottom of the Ferris wheel.

EXAMPLE: A 5.0 kg ball is being swirled in a vertical circle of radius 1.3 m at the minimum speed to keep it in circular motion. What is the apparent weight of the ball at the top, bottom and middle of the circle?

Gravitation

The gravitational attraction between two objects depends on their ______________________________ and their _____________________________________.

$F_g =$ Where:

EXAMPLE: Calculate the force of gravity between two 75 kg students if their centers of mass are 0.95m apart.

EXAMPLE: Calculate the force of gravity between a 1.0 kg mass on the surface of our planet and the Earth. The mass of the Earth is 5.972×10^{24} kg and the radius of the Earth is 6,371 km.

EXAMPLE: Two objects have a gravitational attraction of 60.0 N.

What is their gravitational attraction if you double the weight of one of the objects?

What is their gravitation attraction if you double the distance between them?

What is their gravitational attraction if you triple the weight of one of the objects and triple the distance between them?

EXAMPLE: A 4500 kg Earth satellite has an orbital radius of 8.50×10^7m from the Earth's center. At what speed does it travel?

Gravity Fields

Contact forces are those in which two objects touch each other. These are the forces we are familiar with when you push a chair for example. However, forces like gravity affect objects at a distance, though empty space. Fields were invented as a way of talking about this.

Consider a fire, you could say the fire was surrounded by a "heat field"

As you get closer to the fire:

If the fire gets larger:

Gravity is a _______________ so a gravity field is a ___________________________________.

Since force is a ___________________, a gravity field has ______________________________.

One way of representing a gravity field is by drawing arrows showing the direction and strength of the force of gravity that would act on an object in that space.

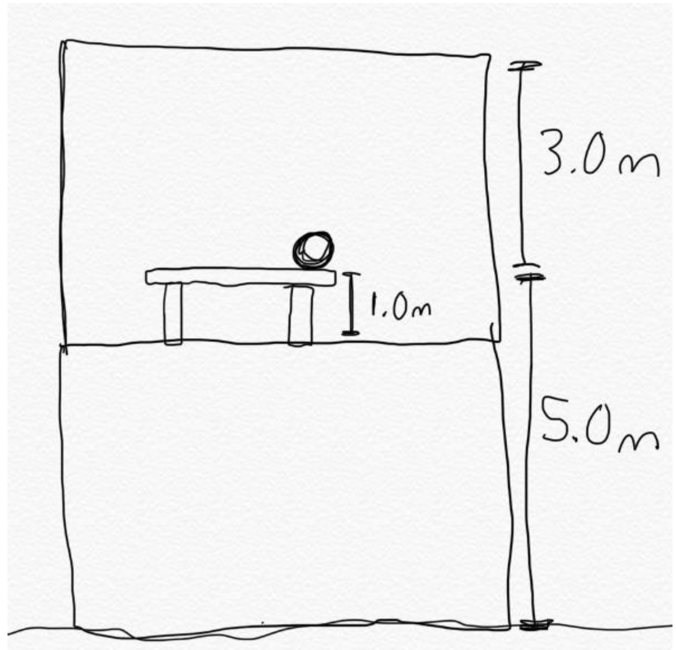
We have been using the idea of a gravitational field strength through the equation

Outside of Earth we can determine the strength of the gravitational field

What is the gravitational field strength on the surface of the moon?

Gravitational Potential Energy:

A 2.0 kg ball is placed on a table which is on the second floor of a building as shown.



What is the gravitational energy of the ball with respect to:

a) the floor of the room it is in?

b) the ground?

c)the roof?

Recall how we derived the potential energy formula. It is the ____________ needed to lift an object a certain height

Work =

This works when the force is constant. If an object is lifted a long ways from Earth the force required to lift it the first 1000 m will be ________________ than the force required to lift it the next 1000 m because the ____ decreases with distance. Since force is not constant, we will need to use a different formula.

Universal Gravitational Potential Energy

Where m_1 and m_2 are the masses

G is $6.674 \times 10^{-11} \frac{m^3}{kg \cdot s^2}$

r is the distance between the centers of the masses

Why is it negative?

We set the point where potential energy is zero to be when the objects are ________________________ far apart. This means the value we get will always be ________________. This turns out to be a reasonable choice for many problems.

Example: A 2500 kg satellite is in orbit 3.6×10^7 m above the Earth's surface. What is the gravitational potential energy of the satellite due to the gravitational field of Earth? (Earth has radius 6.38×10^6 m and mass 5.98×10^{24} kg.)

What is the gravitational potential energy of the satellite on the surface of Earth?

How much more potential energy does the satellite have when it is in orbit?

If the satellite were pulled directly into Earth, with no friction, how fast would it be moving when it hit the surface of the planet?

Escape Velocity

If you throw an object up it will come back down, unless you throw it ______________________ hard.

Escape velocity is the velocity which an object must be moving such that it will _______________ be pulled back by gravity.

As the object goes further from its launch site the gravitational pull will _________________but will never be fully eliminated so we must consider the velocity required to get the object ________________________ far from its starting point.

This is the point we set as the __________________ for our universal potential energy.

Recall energy is conserved so:

Example: What is escape velocity on Earth? (m =$5.98 \times 10^{24} kg$, r= $6.36 \times 10^{6} m$)