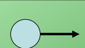
A 40.0 kg block is connected to an empty 2.00 kg bucket by a cord running over a pulley. The coefficient of static friction between the table and the block is .650 and the coefficient of kinetic friction between the table and the block is .380. Sand is gradually added to the bucket until the system just begins to move. Calculate the mass of the sand added to the bucket.

A clerk moves a box of cans down an aisle by pulling on a rope attached to the box. The clerk pulls with a force of 300.0 N at and angle of 25.0º with the horizontal. The box has a mass of 50.0 kg, the coefficient of static friction between the box and the floor is .400, and the coefficient of kinetic friction between the box and the floor is .380. If it started from rest, how far does the box go in 3.0 s?

Chapter 6 – Motion in Two Dimensions

Newton's 1^{st} Law of Motion (Law of Inertia)

An object at rest will remain at rest, and an object in motion will continue to move in a straight line with constant speed, if and only if the net force acting on that object is zero



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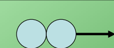

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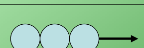

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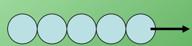

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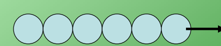

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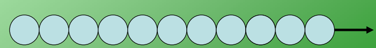

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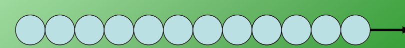

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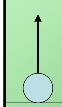
Free fall

the motion of a body when air resistance is negligible and the action can be considered due to gravity alone



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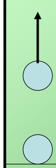

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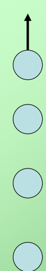

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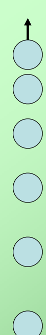

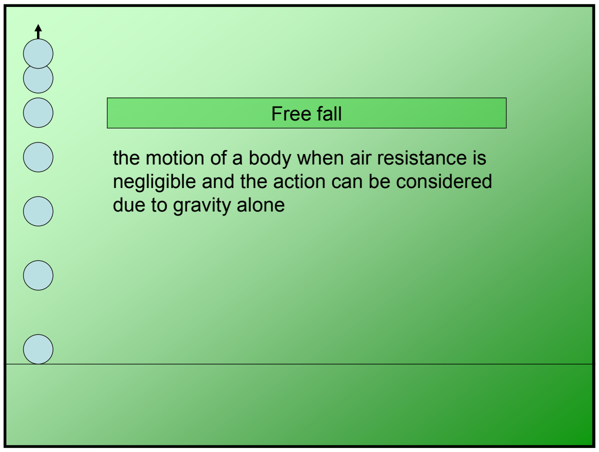
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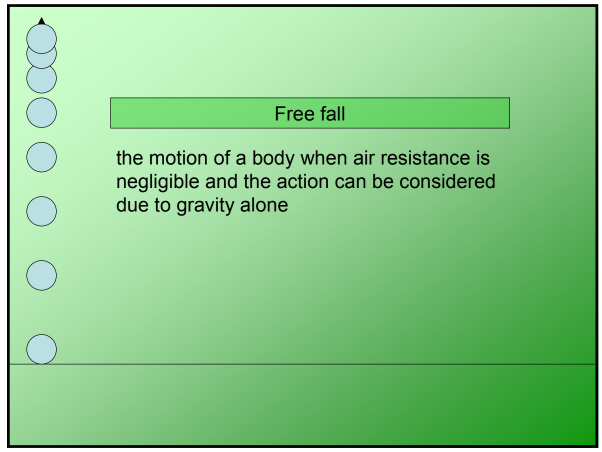
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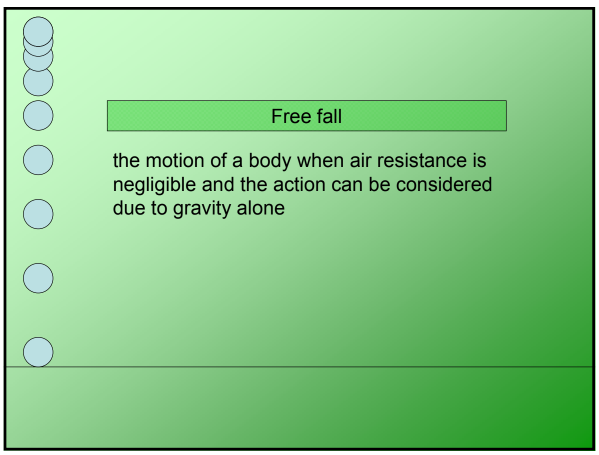
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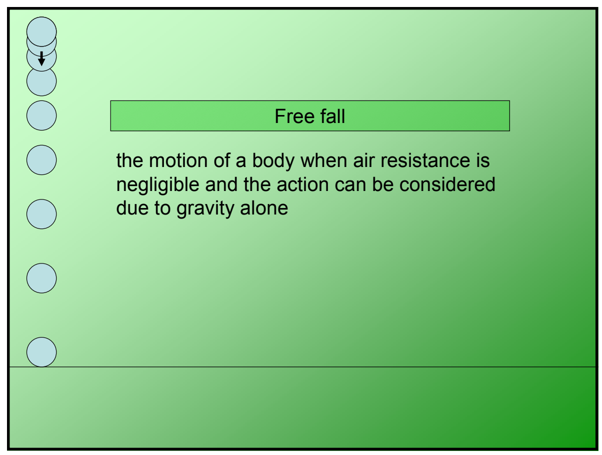
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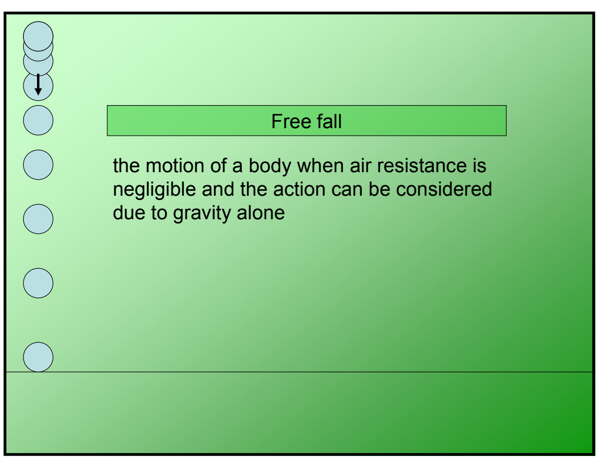
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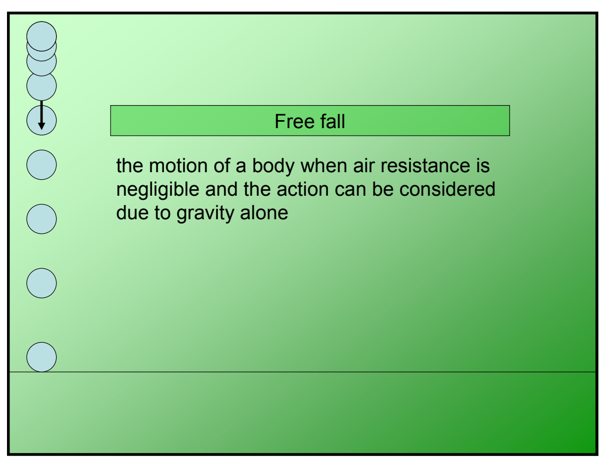
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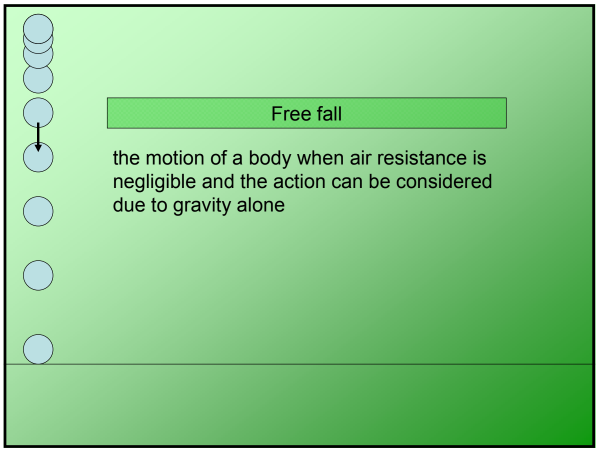
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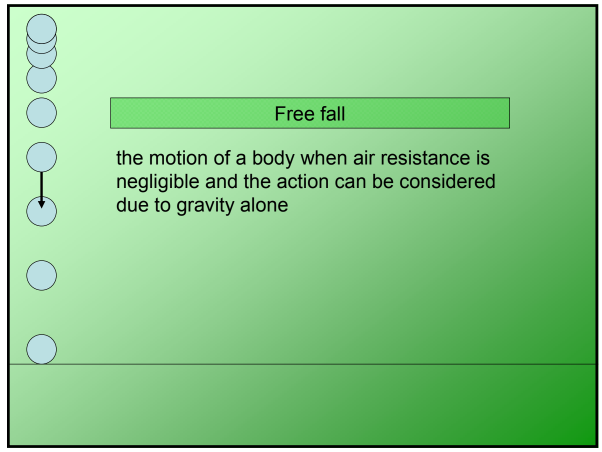
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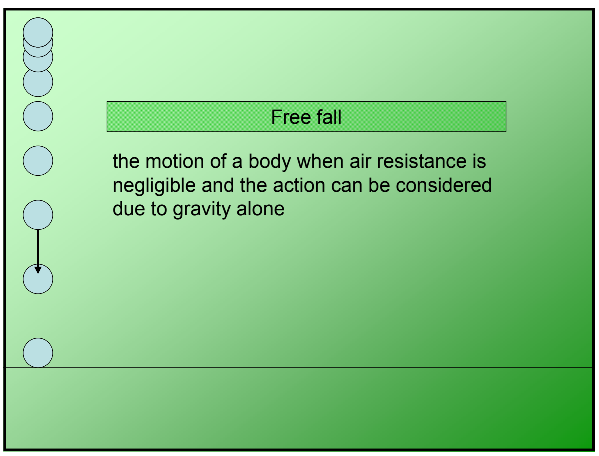
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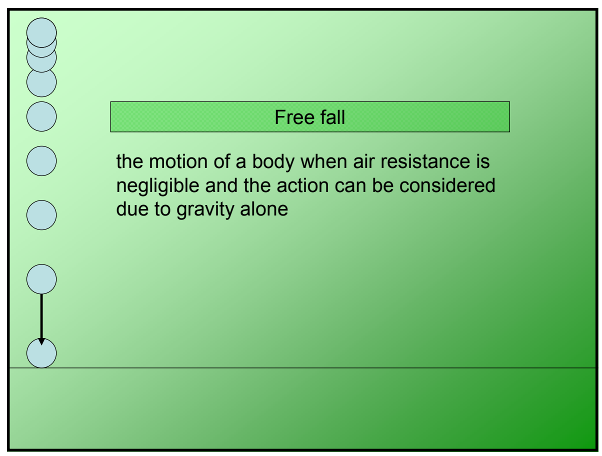
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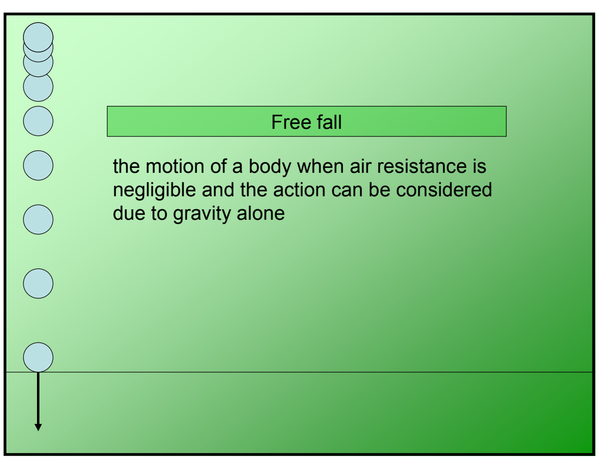
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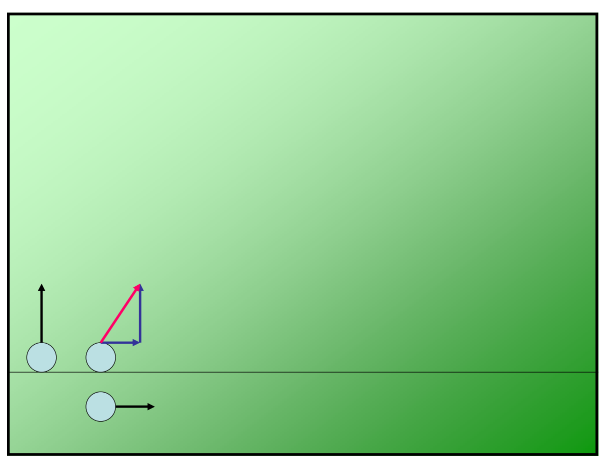
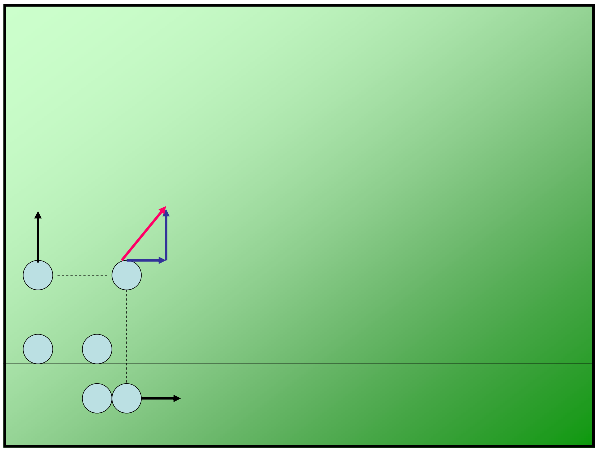
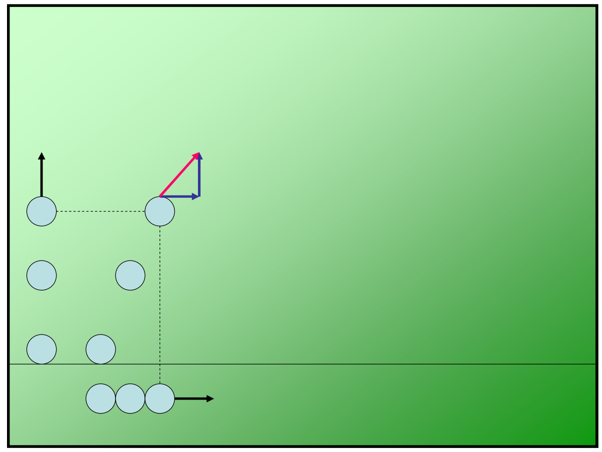
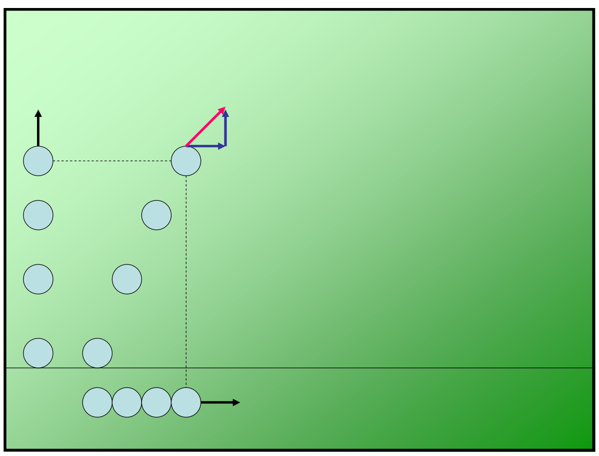
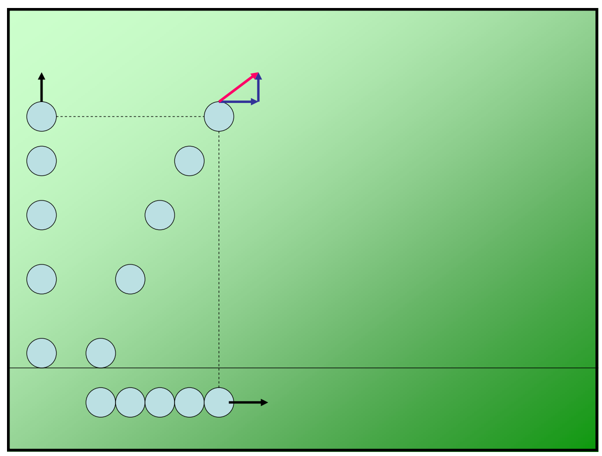
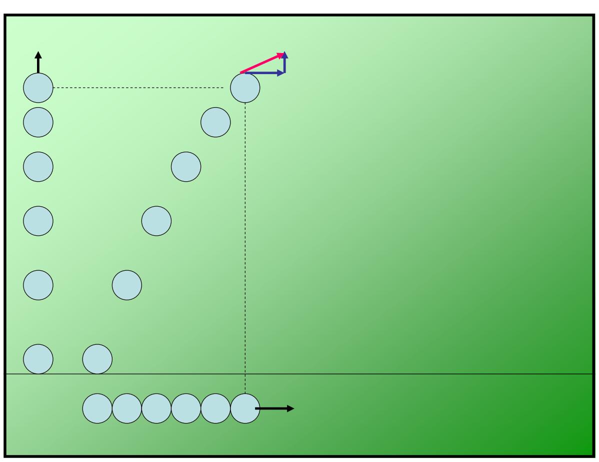


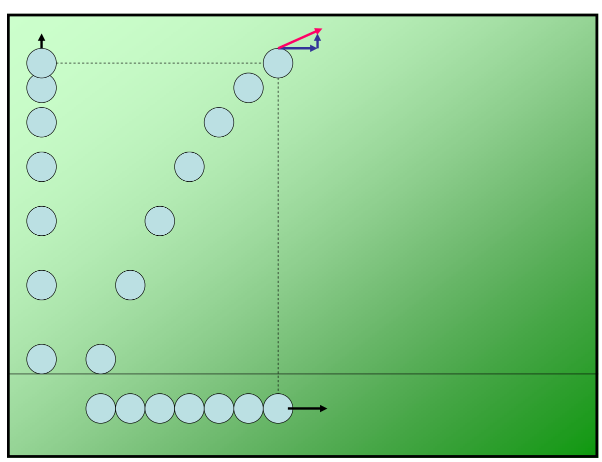


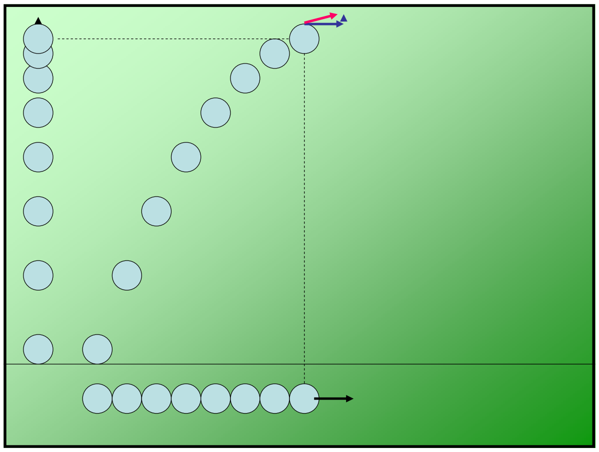
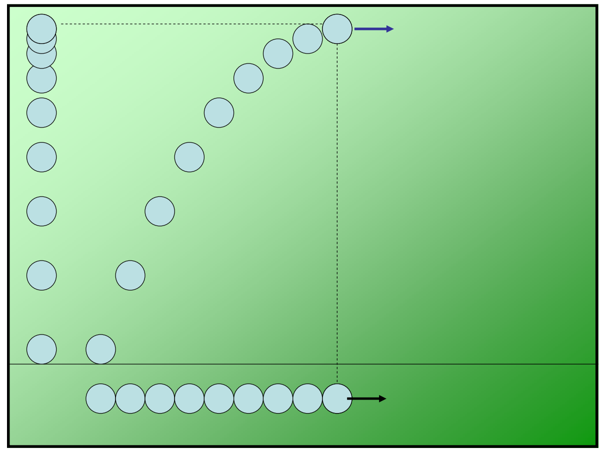
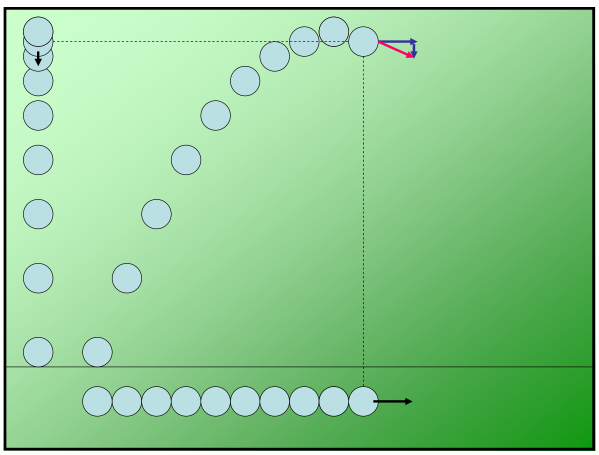
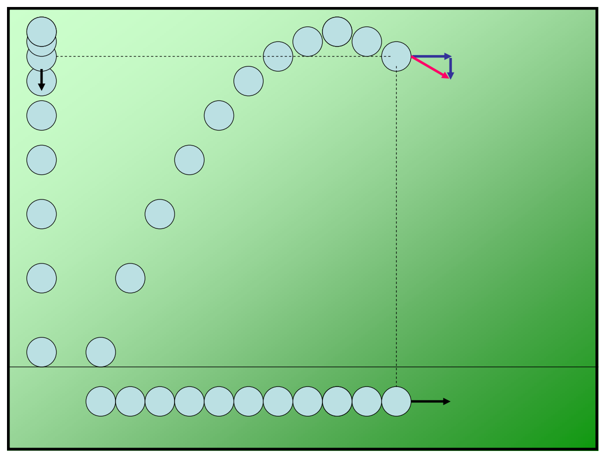
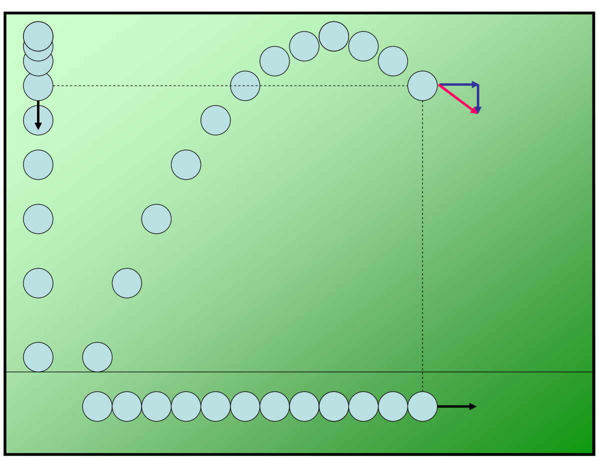
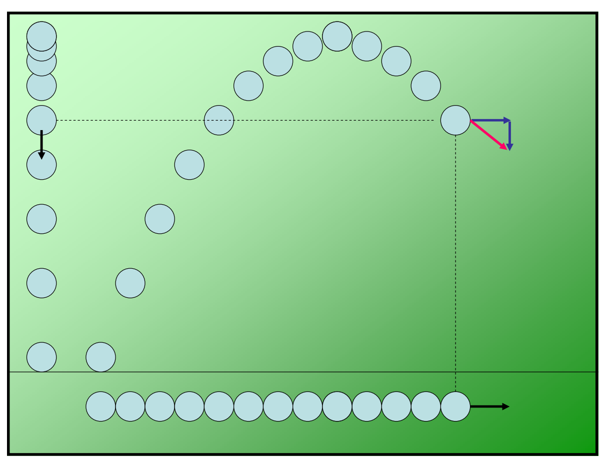


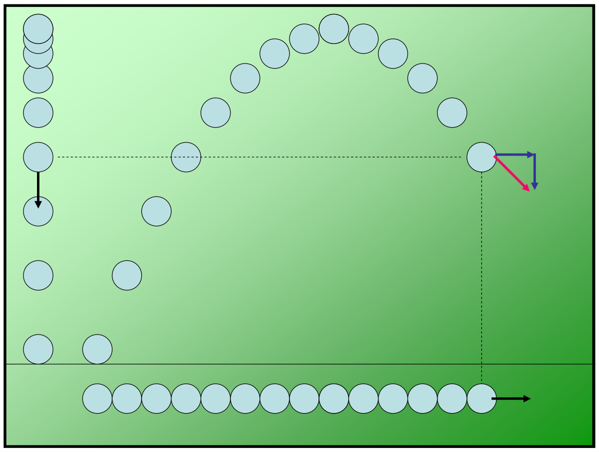


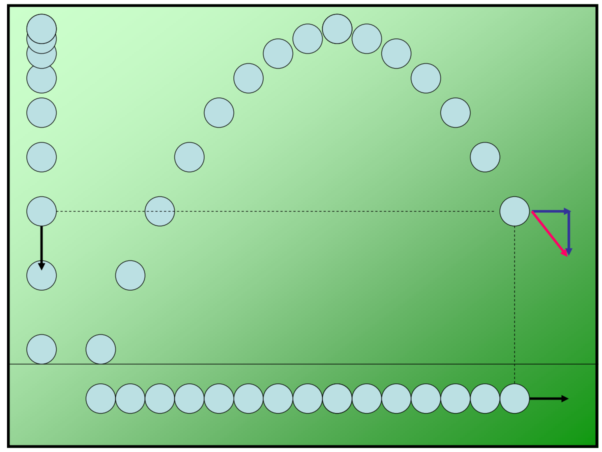


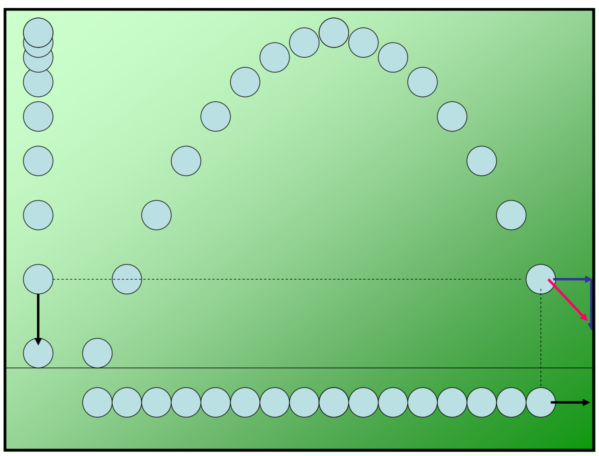


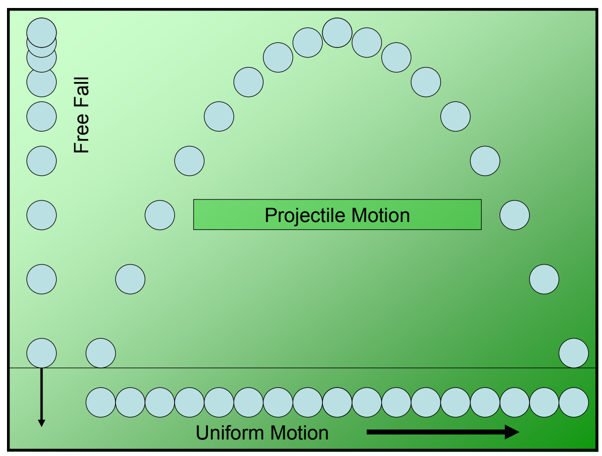






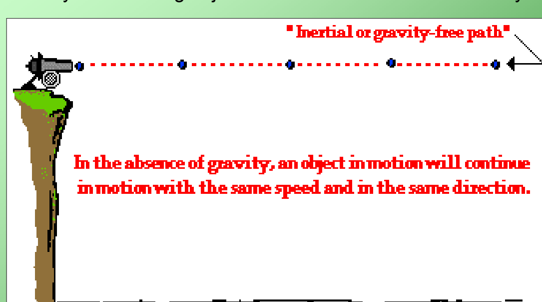




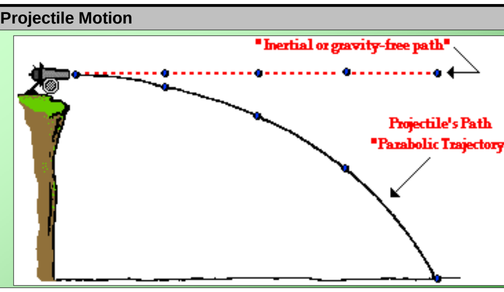
6.1 Projectile Motion

projectile motion – an object moving in two dimensions under the influence of gravity

basically a free falling object with an initial horizontal velocity



6.1 Projectile Motion



With gravity, a "projectile" will fall below its inertial path. Gravity acts downward to cause a downward acceleration. There are no horizontal forces needed to maintain the horizontal motion – consistent with the concept of inertia.

projectile – an object shot through the air

trajectory – a projectile's path through space (parabolic shape in the absence of air resistance)

6.1 Projectile Motion

the ball on the right was given an initial horizontal velocity

when considering projectile motion the horizontal and vertical components of the object's motion are treated separately

Notice:

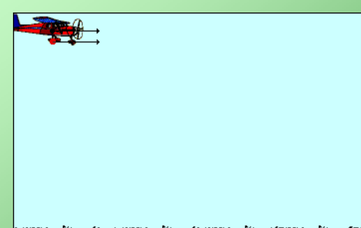
- equal horizontal spacing for the yellow sphere
- increasing, but equal vertical spacing for both the red and yellow spheres

6.1 Projectile Motion

6.1 Projectile Motion

6.1 Projectile Motion

To solve projectile motion problems all that is needed are the kinematics equations



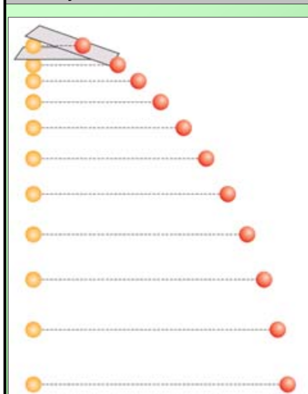
A plane traveling at 115 m/s East at an altitude of 1050. m is getting ready to drop a package of supplies to a target below. What is the time required for the package to hit the ground?

6.1 Projectile Motion

At what horizontal distance to the West of the target should the pilot release the package to ensure its hitting the target?

What is the velocity of the package when it hits the ground?

6.1 Projectile Motion



How do the vertical velocities of the two trajectories compare?

How does the acceleration of the two balls compare?

How does the red ball's horizontal motion affect its vertical motion?

How do you know that the vertical velocity of both balls is greater near the bottom of the figure than at the top?

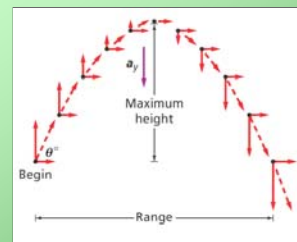
How do you know that the horizontal velocity of the red ball is constant from the top of its all to the bottom?

6.1 Projectile Motion

An unwise person jumps from a 30.0 m high building into a pool that is 5.0 m from the base of the building. What must be his horizontal velocity, v_x, to ensure he makes it into the water?

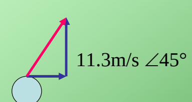
6.1 Projectile Motion

When a projectile is launched at an angle, the initial velocity has a vertical component, as well as a horizontal component

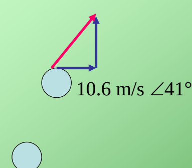


at the maximum height the vertical velocity is zero (only horizontal velocity)

range – the horizontal distance between launching and landing



The vector sum of v_x and v_y at each position points in the direction of the flight



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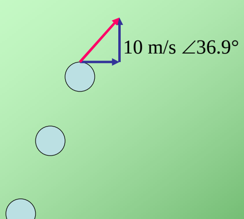

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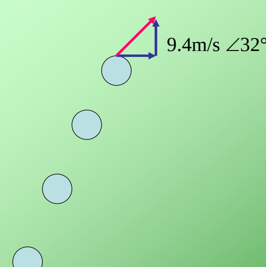

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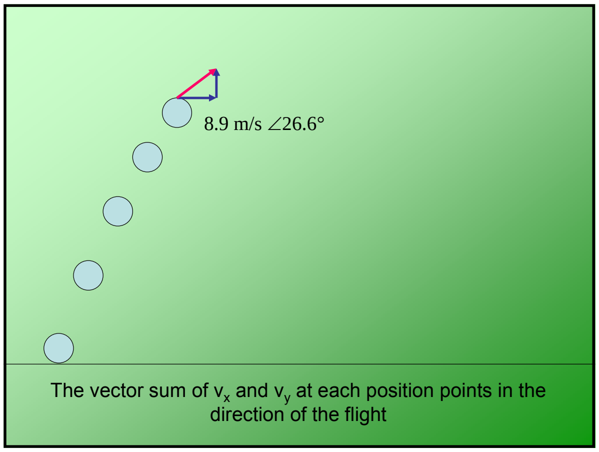
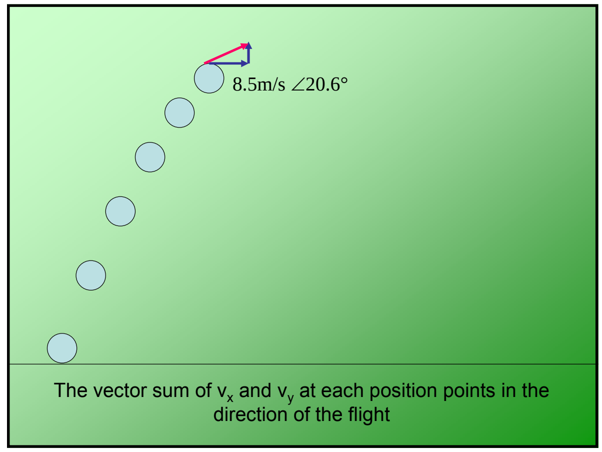
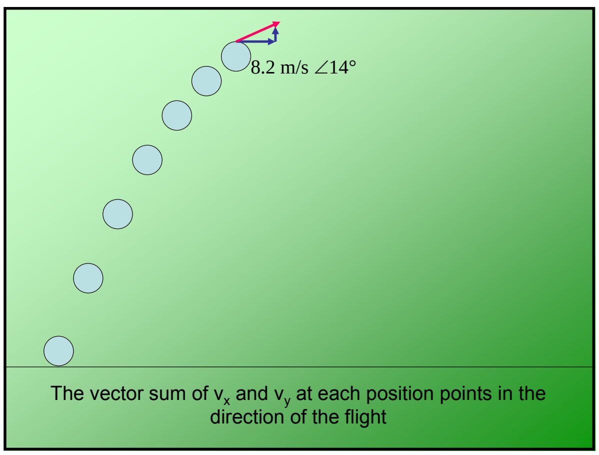
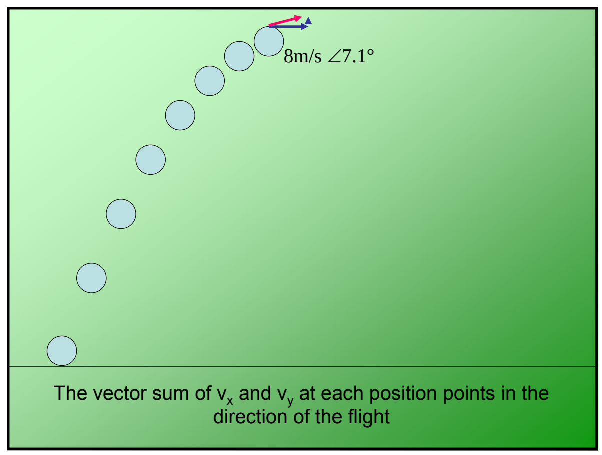
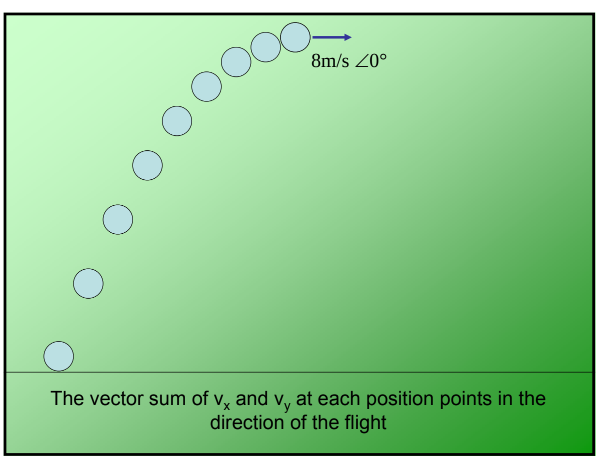

8.9 m/s ∠26.6°
The vector sum of v_x and v_y at each position points in the direction of the flight


8.5m/s ∠20.6°
The vector sum of v_x and v_y at each position points in the direction of the flight


8.2 m/s ∠14°
The vector sum of v_x and v_y at each position points in the direction of the flight


8m/s ∠7.1°
The vector sum of v_x and v_y at each position points in the direction of the flight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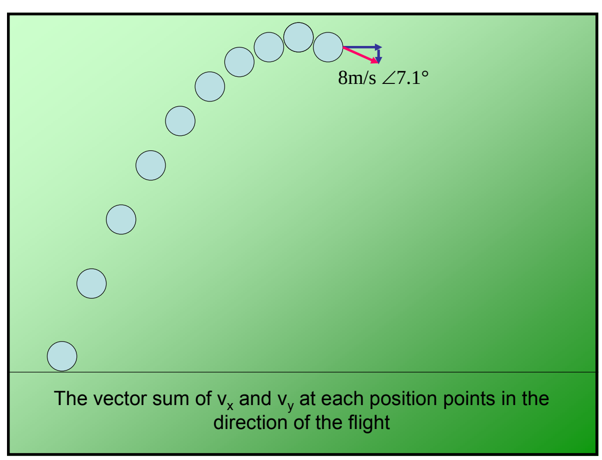
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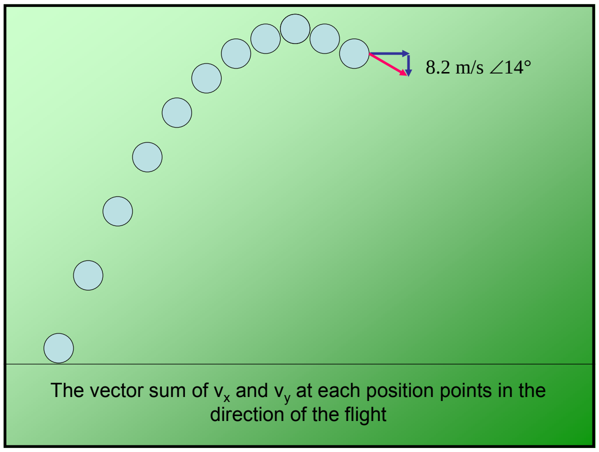
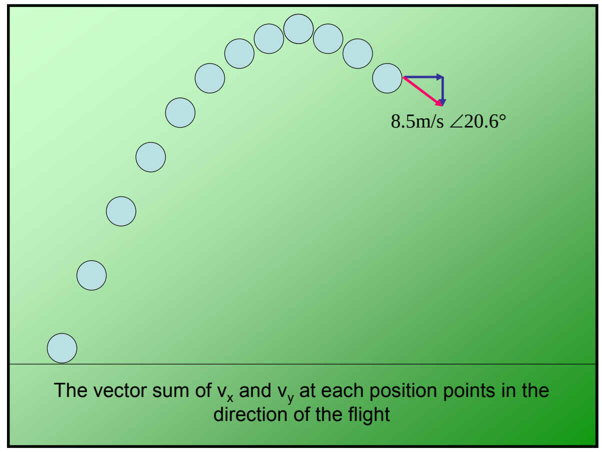
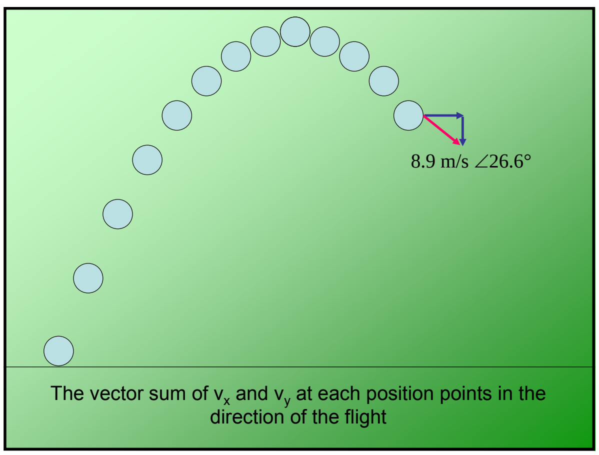
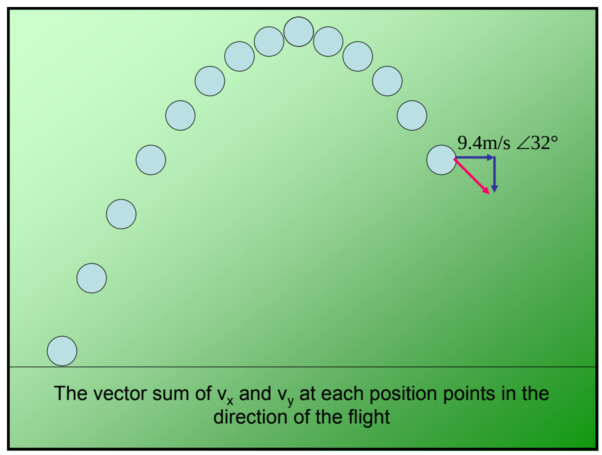
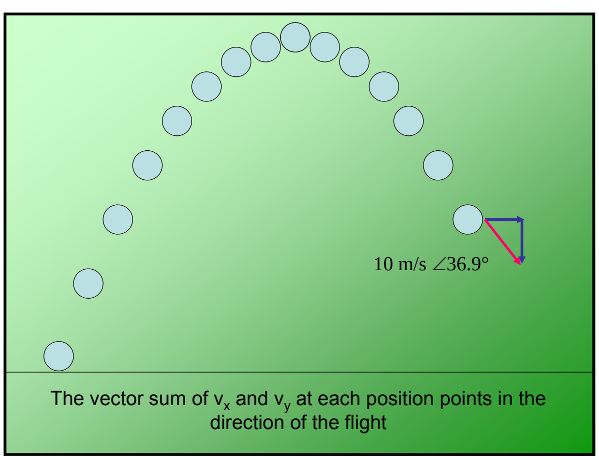
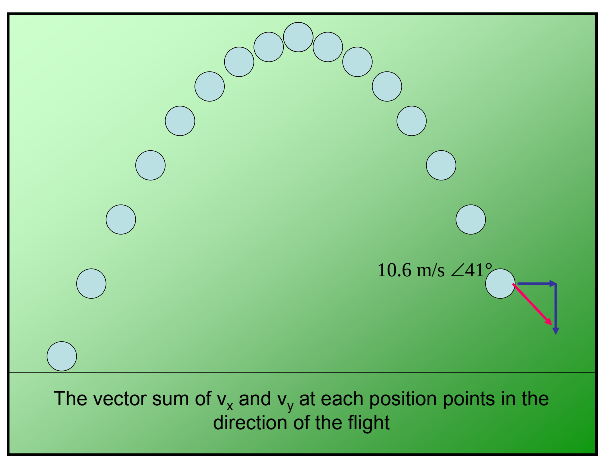

8.2 m/s ∠14°
The vector sum of v_x and v_y at each position points in the direction of the flight

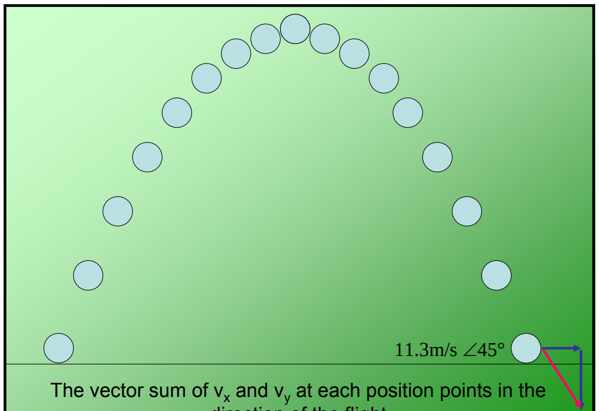

8.5m/s ∠20.6°
The vector sum of v_x and v_y at each position points in the direction of the flight


8.9 m/s ∠26.6°
The vector sum of v_x and v_y at each position points in the direction of the flight


9.4m/s ∠32°
The vector sum of v_x and v_y at each position points in the direction of the flight


10 m/s ∠36.9°
The vector sum of v_x and v_y at each position points in the direction of the flight


10.6 m/s ∠41°
The vector sum of v_x and v_y at each position points in the direction of the flight



The vector sum of v_x and v_y at each position points in the direction of the flight

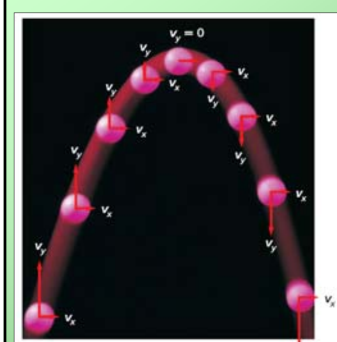
6.1 Projectile Motion

A placekicker kicks a football at an angle of 40.0° above the horizontal. The initial speed of the ball is 22 m/s. Ignore air resistance. What is the maximum height of the ball?

What is the hang time of the kick?

What is the football's range?

6.1 Projectile Motion



At what point is the magnitude of the ball's velocity vector the smallest?

What can be said about the relationship between the vertical component of the ball's velocity at the moment it leaves the ground and the moment it returns to the ground?

What can be said about the relationship between the horizontal component of the ball's velocity at the moment it leaves the ground and the moment it returns to the ground?

6.1 Projectile Motion

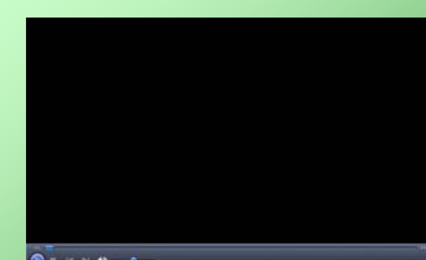
In the video clip above, Tom Brady throws a touchdown pass:

6.1 Projectile Motion

In the video clip above, Tom Brady throws a touchdown pass:

1. Watch the clip and determine the length of the pass.
2. Using a stopwatch determine the time the ball is in the air.
3. From this information, determine the horizontal velocity of the ball (v_x).
4. Determine the initial vertical velocity of the ball (v_{iy}).
5. Determine the maximum height of the ball.
6. Determine the initial velocity of the ball.

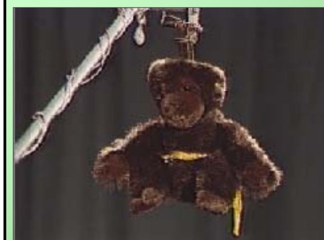
6.1 Projectile Motion



6.1 Projectile Motion

A stuntman jumps from the top on one building to the top of another 4.0 m away. With a running start, he leaps at an angle of 15.0° with respect to the flat roof he is on while traveling at 5.0 m/s. Will he make it to the other roof that is 2.5 m shorter than the building he jumps from?

6.1 Projectile Motion



A zookeeper finds an escaped monkey hanging from a tree. Aiming a tranquilizer gun at the monkey, the zookeeper stands 10.00 m from the tree, which is 5.00 m high. The tip of the gun is 1.00 m above the ground. The instant the zookeeper shoots, the monkey will let go of the tree. The dart travels at 50.0 m/s. If the zookeeper aims at the monkey, at what height above the ground will the monkey be hit?

6.1 Projectile Motion

6.1 Projectile Motion

A placekicker must kick a football from a point 36.0 m from the goalpost, and the ball must clear the crossbar, which is 3.05 m high. When kicked, the ball leaves the ground with a speed of 20.0 m/s at an angle of 53 degrees to the horizontal.

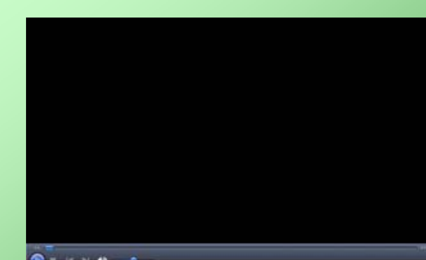
a) By how much does the ball clear or fall short of clearing the crossbar?

b) Does the ball approach the crossbar while still rising or while falling?

6.1 Projectile Motion

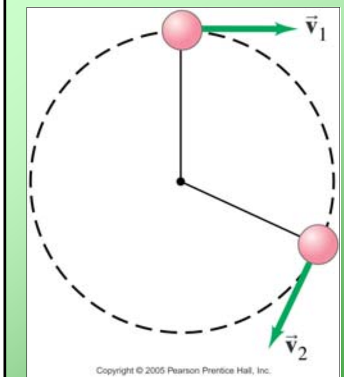
A car drives straight off the edge of a cliff that is 54 m high. Police at the scene of the accident note that the point of impact is 130 m from the base of the cliff. How fast was the car traveling when it went over the cliff?

6.1 Projectile Motion



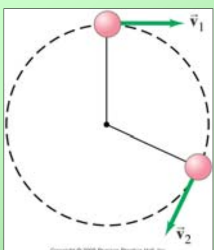
6.2 Circular Motion

6.2 Circular Motion



In circular motion the velocity of the object is tangent to its path

6.2 Circular Motion



The period (T) of the motion – the time required for one revolution (s / rev)

In the case of an object moving in a circle, the distance covered in one revolution is:

$$\Delta d = 2\pi r$$

For an object moving at a constant speed:

$$v = \frac{\Delta d}{\Delta t}$$

$$\Delta t = T \quad (in \quad s/rev)$$

speed of an object moving in a circle:

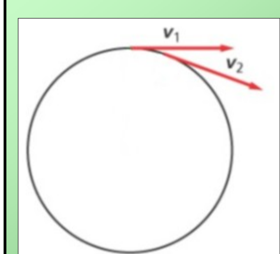
$$\boxed{v = \frac{2\pi r}{T}}$$

6.2 Circular Motion

The wheel of a car has a radius of 0.29 m and is being rotated at 830 revolutions per minute on a tire balancing machine. Determine the speed (in m/s) at which the outer edge of the wheel is moving.

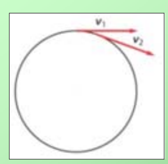
6.2 Circular Motion

Uniform circular motion – the movement of an object at a constant speed around a circle with a fixed radius

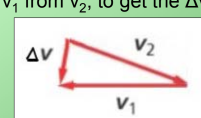


The magnitude of the velocity remains constant, but the direction is continually changing

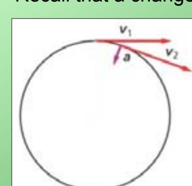
6.2 Circular Motion



Subtract the initial velocity v_1 from v_2, to get the Δv



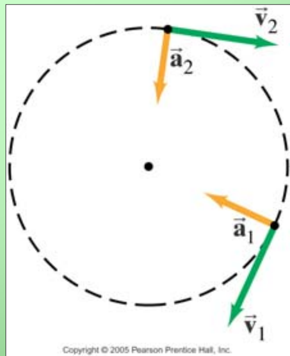
Recall that a change in velocity, Δv, is an acceleration



centripetal acceleration – the acceleration of an object for an object in uniform circular motion

centripetal means "center-seeking"

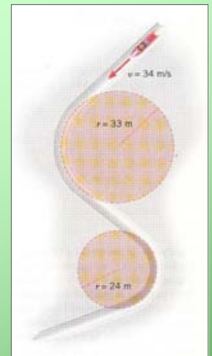
6.2 Circular Motion



centripetal acceleration

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

6.2 Circular Motion



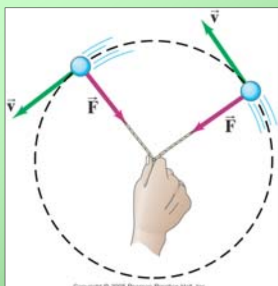
A bobsled travels at a constant speed around two different turns on a track. One turn has a radius with a radius of 33 m and the other with a radius of 24 m.

Which turn will require a greater centripetal acceleration?

Find the centripetal acceleration at each turn.

6.2 Circular Motion

What causes an acceleration?



centripetal force – the net force directed towards the center of the circle

A centripetal force can have different causes:

1. The tension in a string
2. Gravity
3. Friction

6.2 Circular Motion

What is the equation for Newton's 2nd Law?

$$\Sigma F = ma$$

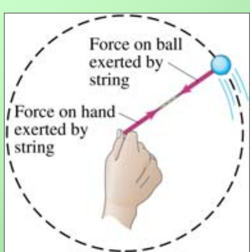
$$\Sigma F_c = ma_c$$

Remember, $a_c = \frac{v^2}{r}$

centripetal force

$$\Sigma F_c = \frac{mv^2}{r}$$

6.2 Circular Motion

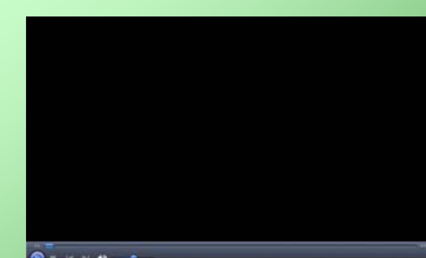


A ball has a mass of 0.90 kg and moves at a constant speed in a circle parallel to the ground.

Is the tension in the string greater when the ball has a speed of 19 m/s, or when the speed is 38 m/s?

Find the tension, T, in the guideline (length = 17 cm) for speeds of 19 m/s and 38 m/s.

6.2 Circular Motion



6.2 Circular Motion

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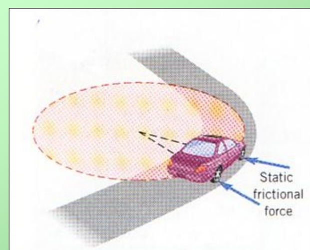
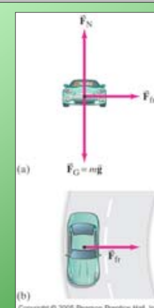




Compare the maximum speeds at which a 1150. kg car can safely negotiate an unbanked turn (radius = 50.0 m) in dry weather (μ_s = .900) and icy weather (μ_s = .100)

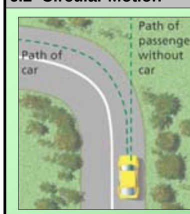
6.2 Circular Motion

In this commercial a 2400. kg Ford F150 truck is hung from a giant centrifuge and put into uniform circular motion in order to demonstrate the strength of its tow hooks.

The length of the centrifuge arm is 50.0 feet and the tow hooks are connected to the centrifuge with 3.00 feet of chain.

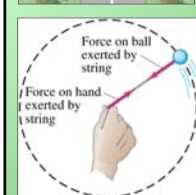
a) Determine the centripetal acceleration of the truck.
b) Determine the total force applied to the tow hooks.

6.2 Circular Motion

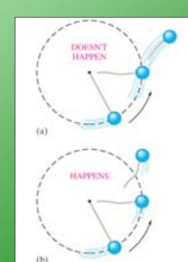


Centrifugal force (centrifugal means "center fleeing")

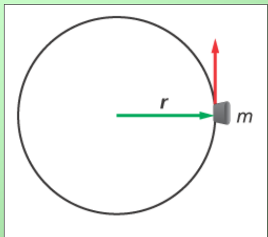
There is not a force pushing the person away from the center. Inertia causes that sensation.



There is a reaction force to the centripetal force. Is this the centrifugal force?



6.2 Circular Motion



A .013 kg rubber stopper is attached to a 0.93 m string. The stopper is swung in a horizontal circle, making one revolution in 1.18 s. Find the tension force exerted by the string on the stopper.

6.2 Circular Motion

A 20.0 kg child moves with a speed of 2.0 m/s when sitting 4.8 m from the center of a merry-go-round. Calculate the

a) The child's centripetal acceleration

b) The centripetal force acting on the child

A 1500 kg car rounds a circular turn of radius 25.0 m. If the road is flat and the coefficient of static friction between the tires and the road is 0.70, how fast can the car go without skidding?

6.2 Circular Motion

Can you go around a curve with the following:

a. Zero acceleration

b. Constant acceleration

6.2 Circular Motion

What is the direction of the velocity vector of an accelerating object moving in uniform circular motion?

A. Toward the center of the circle.

B. Away from the center of the circle.

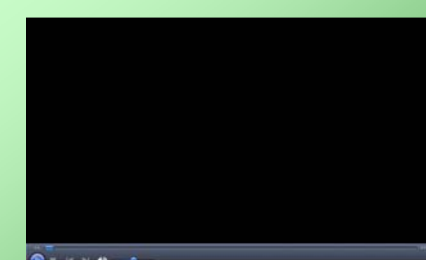
C. Along the circular path.

D. Tangent to the circular path.

6.2 Circular Motion

You swing a yo-yo around your head in a horizontal circle. Then you swing another yo-yo with twice the mass of the first one, but you don't change the length of the string or the period. How do the tensions in the string differ?

6.3 Relative Velocity

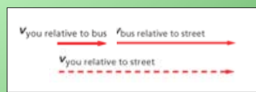


6.3 Relative Velocity

Suppose you are in a bus traveling at 8 m/s in the positive direction and you walk with a velocity of 1 m/s toward the front of the bus.

To an observer on the bus what is your velocity? 1 m/s

To an observer watching you from outside the bus what is your velocity? 9 m/s



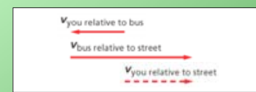
v_{yb}	+	v_{bs}	=	v_{ys}
velocity of you relative to the bus		**velocity of the bus relative to the street**		**velocity of you relative to the street**
1 m/s	+	8 m/s	=	9 m/s

6.3 Relative Velocity

Suppose you are in a bus traveling at 8 m/s in the positive direction and you walk with a velocity of 1 m/s toward the back of the bus.

To an observer on the bus what is your velocity? -1 m/s

To an observer watching you from outside the bus what is your velocity? 7 m/s



v_{yb}	+	v_{bs}	=	v_{ys}
velocity of you relative to the bus		**velocity of the bus relative to the street**		**velocity of you relative to the street**
-1 m/s	+	8 m/s	=	7 m/s

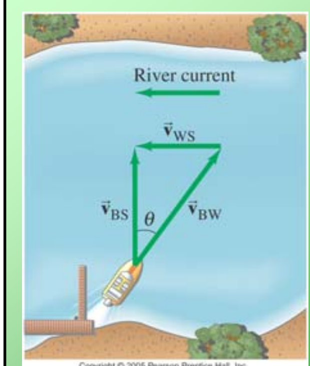
6.3 Relative Velocity

General form of relative velocity equation:

$$v_{ab} + v_{bc} = v_{ac}$$

the middle subscript drops out

6.3 Relative Velocity



To move directly across the river, the boat must head upstream at an angle θ

Pay attention to the subscripts:

$$v_{bw} + v_{ws} = v_{bs}$$

6.3 Relative Velocity

Ana and Sandra are riding on a ferry boat that is traveling east at a speed of 4.0 m/s. Sandra rolls a marble with a velocity of 0.75 m/s north, straight across the deck of the boat to Ana. What is the velocity of the marble relative to the water?

6.3 Relative Velocity

An airplane has a speed of 285 km/h relative to the air. There is a wind blowing at 95 km/h at 30.0º north of east relative to Earth. In which direction should the plane head to land at an airport due north of its present location?

What is the plane's speed relative to the ground?

6.3 Relative Velocity

Steven is walking on the roof of a bus with a velocity of 2 m/s toward the rear end of the bus. The bus is moving with a velocity of 10 m/s. What is the velocity of Steven with respect to Anudja sitting inside the bus and Mark standing on the street?

A. Velocity of Steven with respect to Anudja is 2 m/s and with respect to Mark is 12 m/s.

B. Velocity of Steven with respect to Anudja is 2 m/s and with respect to Mark is 8 m/s.

C. Velocity of Steven with respect to Anudja is 10 m/s and with respect to Mark is 12 m/s.

D. Velocity of Steven with respect to Anudja is 10 m/s and with respect to Mark is 8 m/s.

6.3 Relative Velocity

Which of the following formulas is the general form of relative velocity of objects a, b, and c?

A. $V_{ab} + V_{ac} = V_{bc}$

B. $V_{ab} - V_{bc} = V_{ac}$

C. $V_{ab} + V_{bc} = V_{ac}$

D. $V_{ab} - V_{ac} = V_{bc}$

6.3 Relative Velocity

An airplane flies due south at 100 km/hr relative to the air. Wind is blowing at 20 km/hr to the west relative to the ground. What is the plane's speed with respect to the ground?

A. $(100 + 20)$ km/hr

B. $(100 - 20)$ km/hr

C. $\sqrt{100^2 + 20^2}\ km/hr$

D. $\sqrt{100^2 - 20^2}\ km/hr$

Chapter 6 Vocabulary

Projectile

Trajectory

Maximum height

Range

Uniform circular motion

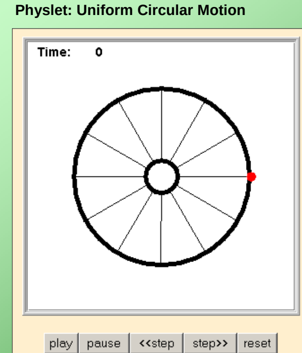
Centripetal acceleration

Centripetal force

6.3 Relative Velocity

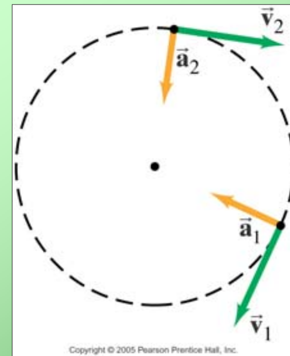
6.2 Circular Motion

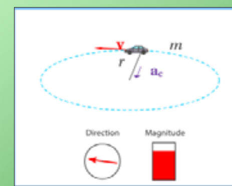
Physlet: Uniform Circular Motion



6.1 Projectile Motion

6.2 Circular Motion





centripetal acceleration

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

6.3 Relative Velocity