Mechanics
Springs
Air Resistance
Circular Motion

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Last time

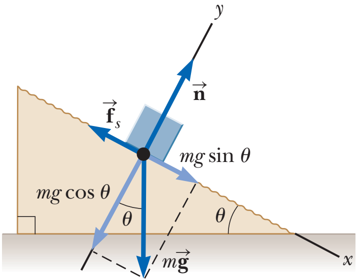
- finish Atwood machine
- friction

Overview

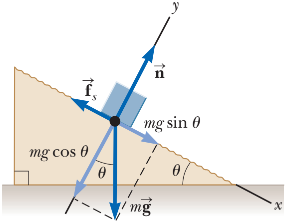
- another friction example
- springs and Hooke's law
- air resistance concepts
- circular motion and force

Incline with Friction

Given a block of mass $m = 1$ kg on an incline of $\theta = 30^\circ$ with a coefficient of static friction of $\mu_s = 0.3$, will the block slide?



Incline with Friction



If the net force is not zero, it will be downward parallel to the slope.
x-direction:

$$F_{\text{net},x} = mg \sin \theta - f_s$$

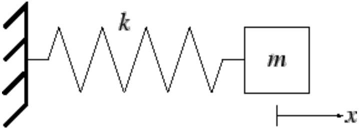
Block will slip if:

$$\begin{aligned}
mg \sin \theta - f_{s,\text{max}} &> 0 \\
mg \sin \theta - \mu_s (mg \cos \theta) &\stackrel{?}{>} 0 \\
(1 \text{ kg}) g (\frac{1}{2} - 0.3 \frac{\sqrt{3}}{2}) &\stackrel{?}{>} 0 \\
2.35 \text{ N, downward along the incline} &> 0 \Rightarrow \text{ Yes, it slides.}
\end{aligned}$$

Some types of forces

Elastic Forces

Springs exert forces as they are being compressed or extended. They have a natural length, at which they remain if there are no external forces acting.



Hooke's Law gives

$$\mathbf{F}_{\text{spring}} = -k\mathbf{x}$$

where k is a constant. $\mathbf{x}$ is the displacement of one end of a spring from it's natural length. (The amount of compression or extension.

[1]Figure from CCRMA Stanford Univ.

Elasticity

The force that the spring exerts to restore itself to its original length is proportional to how much it is compressed or stretched.

This is called Hooke's Law:

$$\mathbf{F}_{\text{spring}} = -k\mathbf{x}$$

where k is a constant that depends on the spring itself. (The "spring constant").

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If a very large force is put on the spring eventually it will break: it will not return to its original shape. The *elastic limit* is the maximum distance the spring can be stretched so that it still returns to its original shape.

Spring example

If a 2 kg painting is hung from a spring, the spring stretches 10 cm. What if instead a 4 kg painting is hung from the spring? How far will it stretch?

(A) 10 cm

(B) 20 cm

(C) 30 cm

(D) None of the above.

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We don't know the spring constant, but we can work it out from the information about the first 2 kg painting. The force on the spring is just the weight of the painting.

$$k = \frac{F_g}{x} = \frac{(2\text{ kg})g}{0.1\text{ m}} = 196.2\text{ N/m}$$

$$x = \frac{F}{k} = \frac{(4\text{ kg})g}{(196.2\text{ N/m})} = 0.2\text{ m}$$

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If you put on twice the force, you stretch the spring twice as far!

Spring example

If a 2 kg painting is hung from a spring, the spring stretches 10 cm.

Now suppose a 6 kg painting is hung from the same spring. How far does it stretch?

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Fluid Resistance (Concepts only)

Galileo predicted (correctly) that all objects at the Earth's surface accelerate at the same rate, g.

This was a revolutionary idea because it seems obvious that less massive objects should fall more slowly: consider a feather and a bowling ball.

What is happening there?

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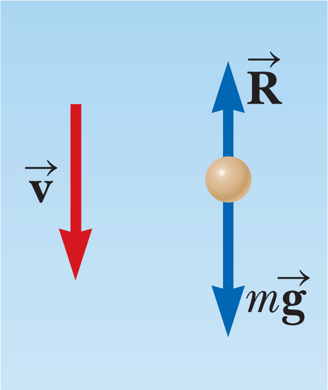
What is happening there?

Air resistance can play a big role in determining an object's motion.

Fluid Resistance

Resistive forces act on an object when it moves through a fluid medium, like a liquid or gas.

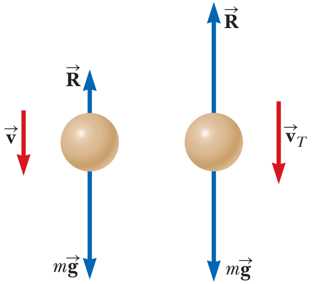
Is this object accelerating?



Fluid Resistance

Air resistance increases with speed.

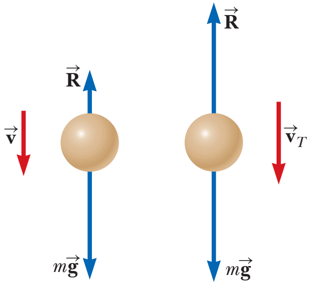
Will the object continue to increase it's velocity without bound?



Fluid Resistance

Air resistance increases with speed.

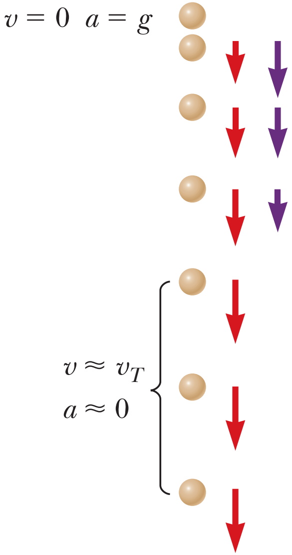
Will the object continue to increase it's velocity without bound?
No.



The velocity will not exceed some terminal value.

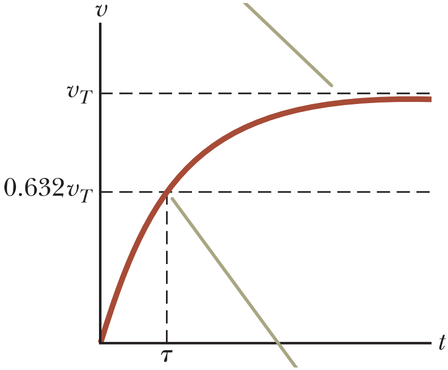
Resistive Forces

What is happening to the acceleration vector?



Velocity against Time with Fluid Resistance

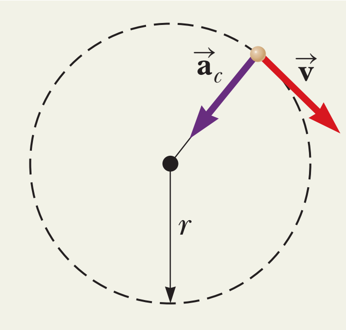
For an object dropped from rest:



The at first the velocity increases with time, but eventually it converges to a maximum constant value, v_T , the terminal velocity.

Reminder: Uniform Circular Motion

The velocity vector points along a tangent to the circle



For uniform circular motion:

- the radius is constant
- the speed is constant
- the *magnitude* of the acceleration is constant, $a = \frac{v^2}{r}$, and directed toward the center

Force and Circular motion

Newton's first law tells us that an object in motion will continue with a constant velocity unless acted upon by a net force.

What does that tell us about an object moving in a uniform circle?

Force and Circular motion

Newton's first law tells us that an object in motion will continue with a constant velocity unless acted upon by a net force.

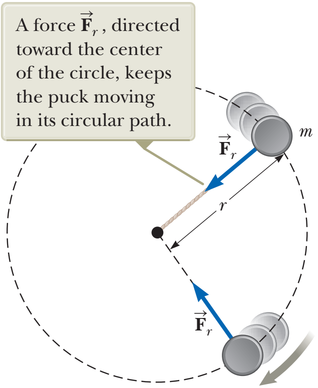
What does that tell us about an object moving in a uniform circle?

It must be experiencing a non-zero net force.

Which way must the net force be directed?

Force and Circular motion

Something must provide this net force:



It could be tension in a rope.

Force and Circular motion

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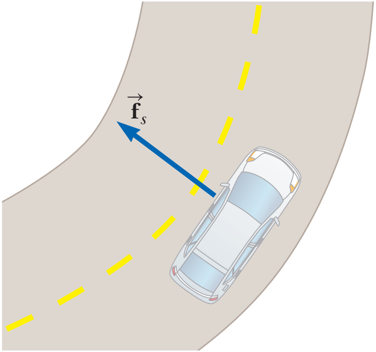


It could be friction.

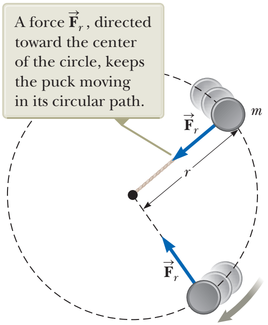
Force and Circular motion

Question. What will the puck do if the string breaks?

(A) Fly radially outward.

(B) Continue along the circle.

(C) Move tangentially to the circle.



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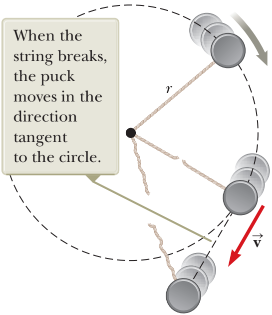
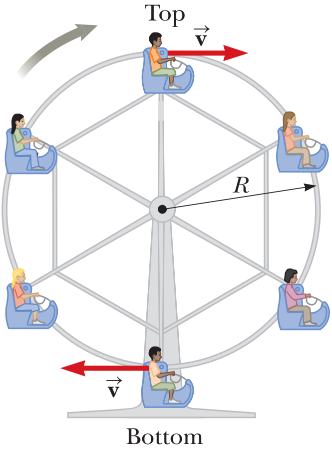


Ferris Wheel Forces

A Ferris wheel is a ride you tend to see at fairs and theme parks.



During the ride the speed, v, is constant.

Ferris Wheel Forces

Quick Quiz 6.1[1] You are riding on a Ferris wheel that is rotating with constant speed. The car in which you are riding always maintains its correct upward orientation; it does not invert.

(i) What is the direction of the normal force on you from the seat when you are at the top of the wheel?

(A) upward

(B) downward

(C) impossible to determine

[1] Page 153, Serway & Jewett

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Ferris Wheel Forces

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Ferris Wheel Forces

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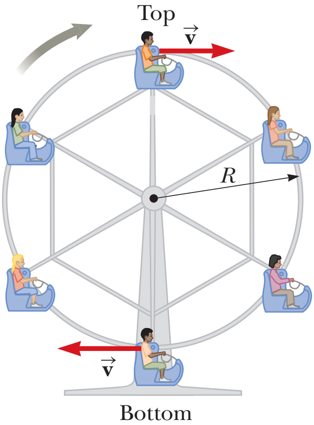
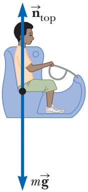
Ferris Wheel

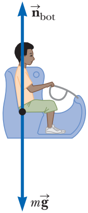
Assume the speed, v, is constant.



$n_{\text{top}} < mg$: $\mathbf{F}_{\text{net}}$ points down



$n_{\text{bot}} > mg$: $\mathbf{F}_{\text{net}}$ points up



Summary

- friction example
- springs and Hooke's law
- air resistance concepts
- circular motion and force

Quiz tomorrow.

Homework

- Ch 6 Prob: 25
- Ch 6 Probs: 41, 45, 49 (circular motion)
- Ch 7 Prob: 67 (springs)