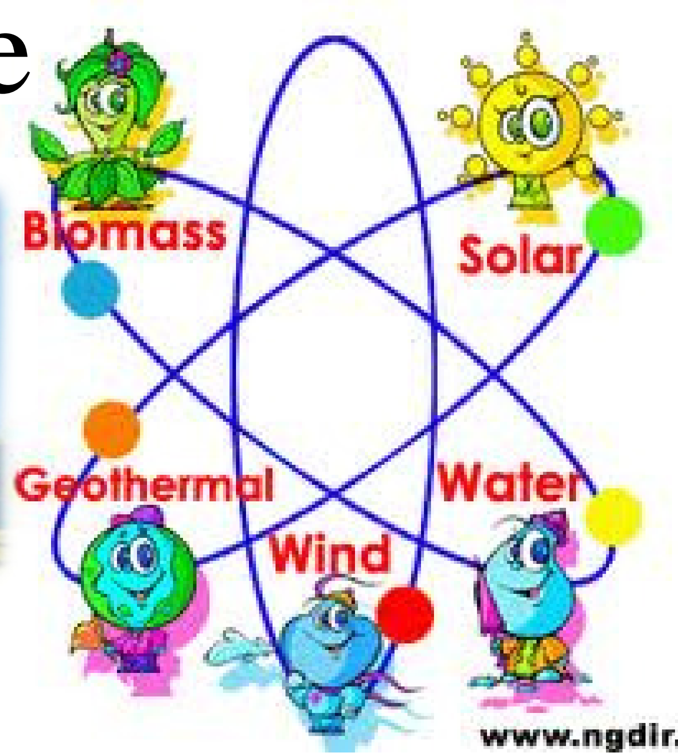
Main Ideas Today

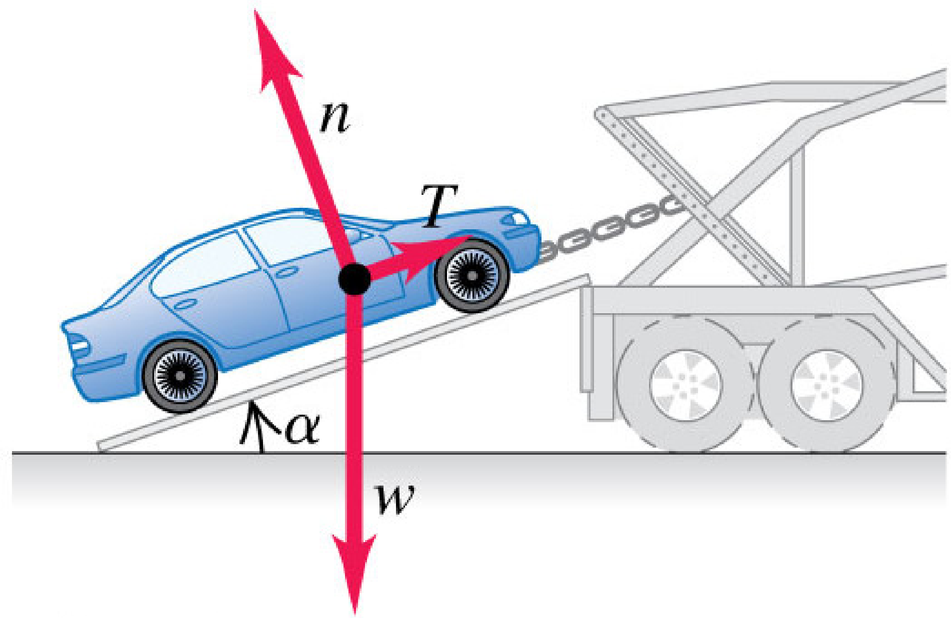
- Work Done by a Constant Force
- Work-Energy Principle
- Kinetic Energy

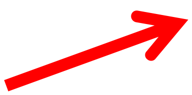


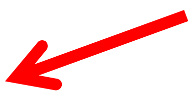
Extra Practice Problems: 5.1, 5.3, 5.5, 5.7, 5.9, 5.11, 5.13, 5.15, 5.17

A cable attached to a car **lowers the car down** the ramp (angle α).

Which direction should friction point?



A. 

B. 

C. 

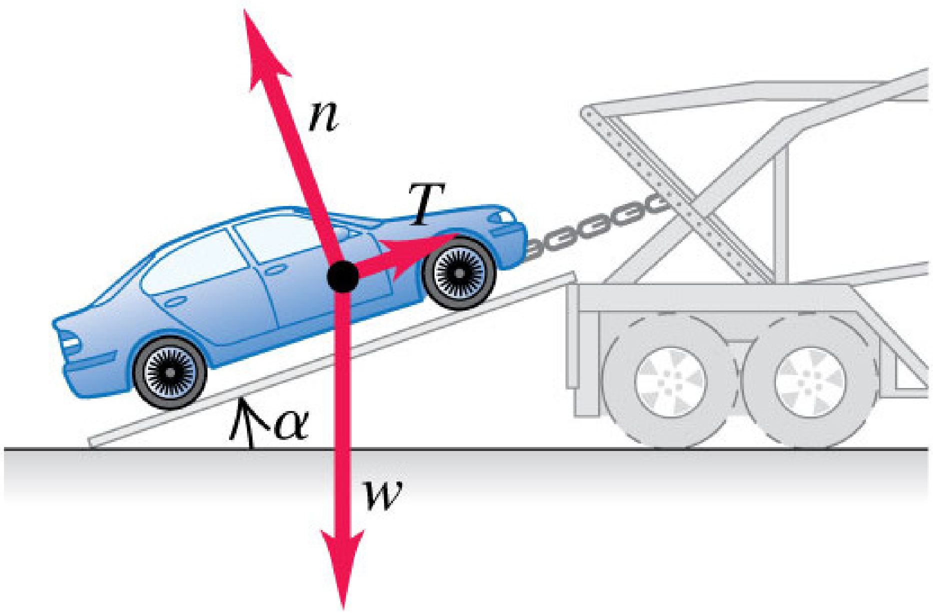
D. 

E. not enough information given to decide

Q49

Definition: Mechanical Work

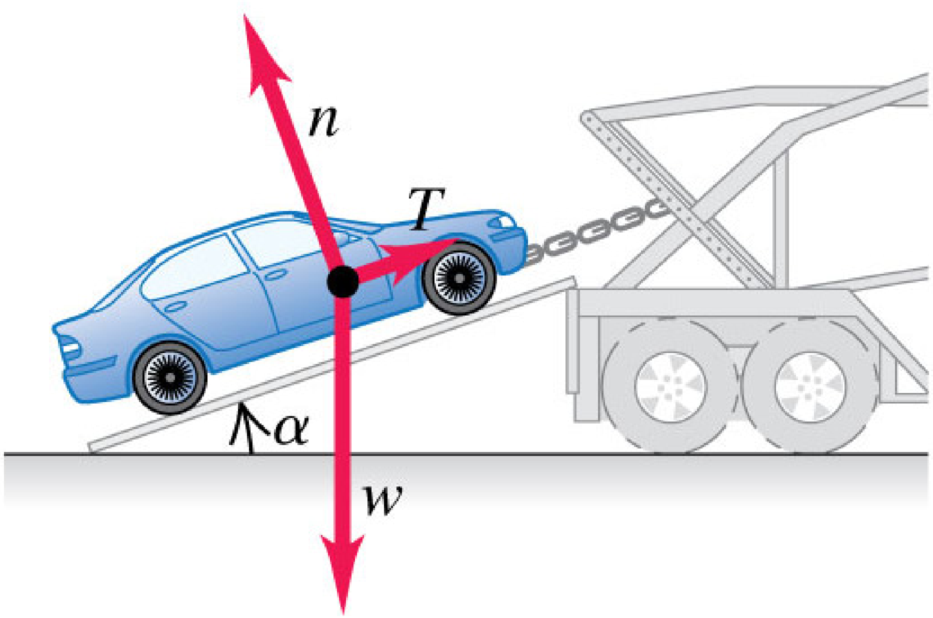
- Work is what is accomplished by a force acting on an object (i.e., movement in the direction of that particular force)
- Work is a **scalar** quantity - no direction
- It can, however, be either positive or negative. Positive if the object moves at least partly in the direction of the force. Negative if moves at least partly in the opposite direction.
- Zero if moves in direction perpendicular to the force.



Here we could discuss the work done by Tension, Friction, Gravity or the Normal Force.

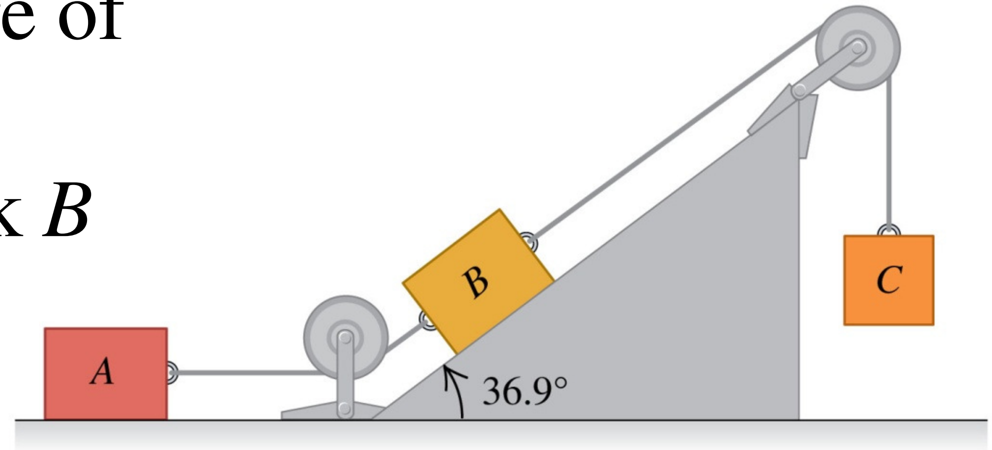
What is the sign of the work of each force?

	Car Going Up the Ramp	Car Going Down
• Tension	Positive	
• Gravity	Negative	
• Normal force	Zero	
• Friction	Negative	



The work done by kinetic friction is always negative, since it always points in the direction opposite of motion.

Three blocks are connected as shown. The ropes and pulleys are of negligible mass. When released, block *C* moves downward, block *B* moves up the ramp, and block *A* moves to the right.



After each block has moved a distance *d*, the force of gravity has done

A. positive work on *A*, *B*, and *C*.

B. zero work on *A*, positive work on *B*, and negative work on *C*.

C. zero work on *A*, negative work on *B*, and positive work on *C*.

D. none of these

The sign of the work done by gravity depends on if the object moves up or down.

Q54

Work Done by a Constant (or Average) Force

- Force **F** acting on an object causes the object to move a distance Δx does work *W*

$$W = F_{\parallel} \Delta x$$

Or equivalently: Only concerned with movement in the direction of the force

Δx displacement of object

$F_{\parallel}$ component of force parallel to displacement of object

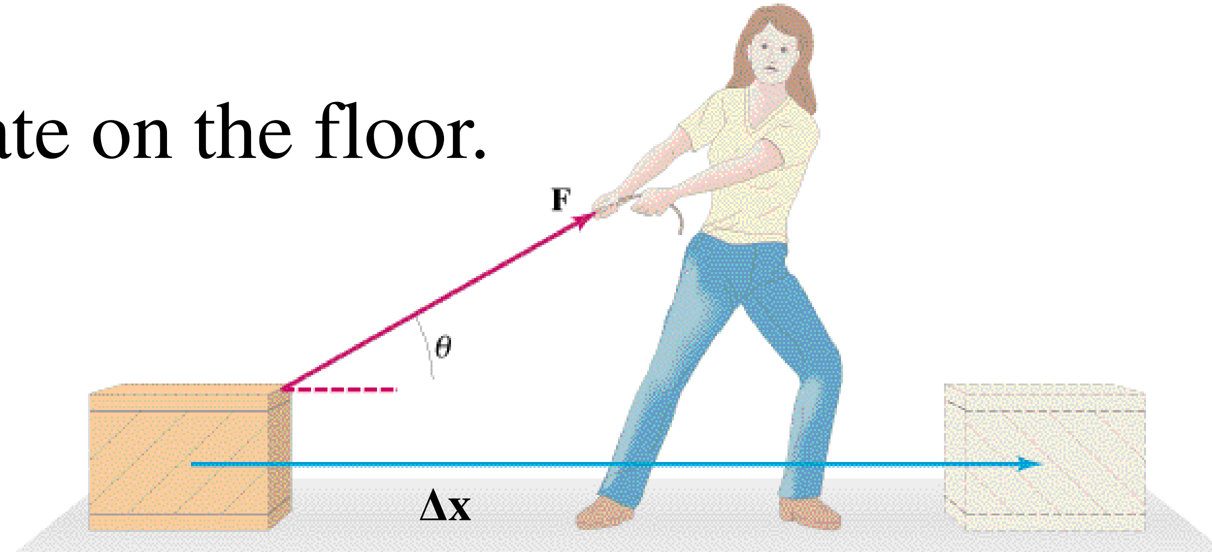
Units: N m = Joule (J)

Work Done by a Constant Force

Ex: Person pulling a crate on the floor.

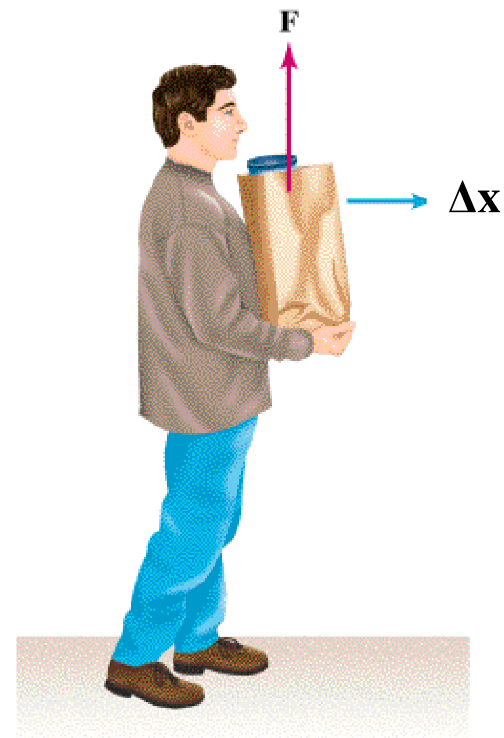
$$F_{\parallel} = F\cos\theta$$

$$W = (F\cos\theta)\Delta x$$



What is the component of the force along the direction of motion?

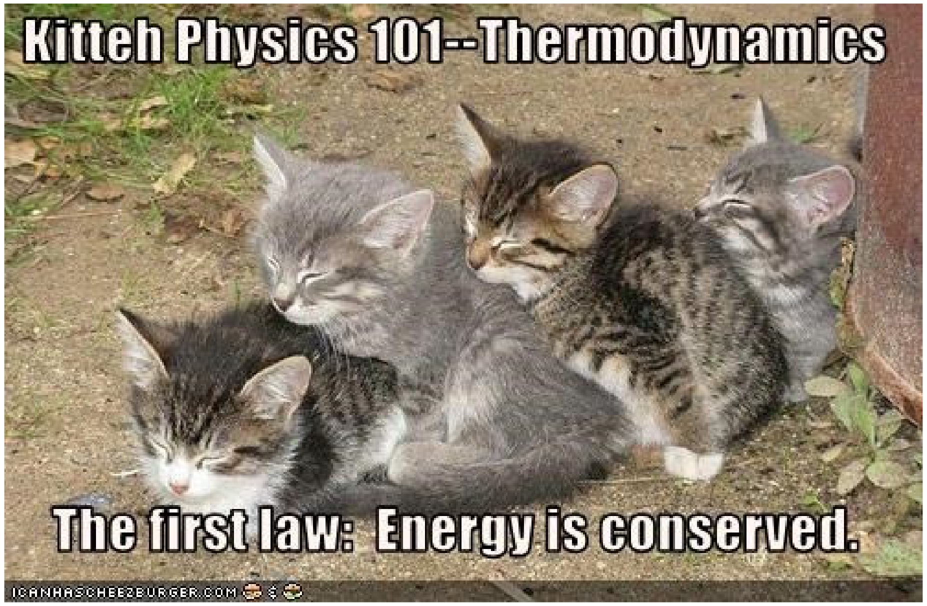
Ex: Person carrying bag of groceries at constant speed



$$F_{\parallel} = 0$$

$$W = F_{\parallel}\Delta x = 0$$

A person lifts a bag of groceries that weighs 15 N from the ground to a height of 1.5 m above the ground at a constant velocity. Calculate the work done by the person on the bag and the work done by gravity.



Energy

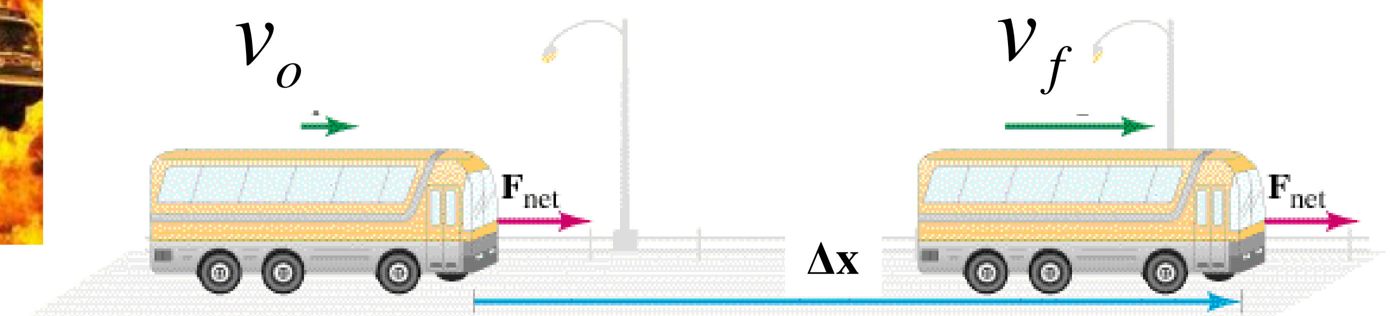
• Energy is always **conserved** - neither increased nor decreased. However, it can be converted to heat. (in Ch.11)

- Energy can be derived from W= $F_{||}\Delta x$ and one of our formulas from Chapter 2. (you don't need to derive)

- Let's do that. We start by finding the work done when we change the speed of an object.

The Work-Energy Principle

Relates net work done on an object to the change in its speed



Constant net force changes velocity from $\mathbf{v}_1$ to $\mathbf{v}_2$ over a distance Δx

$$v^2 = v_o^2 + 2a\Delta x \qquad \Rightarrow a = \frac{v^2 - v_o^2}{2\Delta x}$$

$$\Rightarrow F_{net} = ma = m\left(\frac{v^2 - v_o^2}{2\Delta x}\right)$$

$$\Rightarrow W_{net} = F_{\parallel}\Delta x \Rightarrow \boxed{W_{net} = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_o^2}$$

The Work-Energy Principle

The work done on an object by a net force is

$$W_{net} = \tfrac{1}{2}mv^2 - \tfrac{1}{2}mv_o^2$$

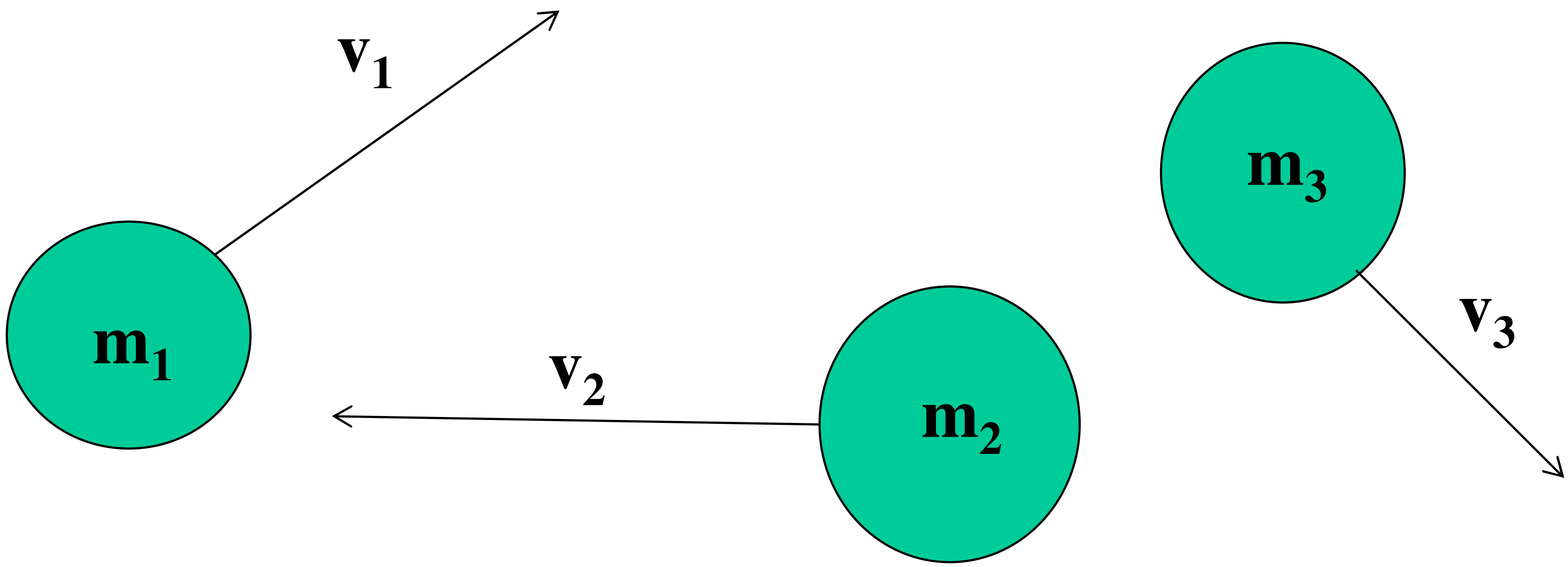
Translational kinetic energy (energy of motion) of an object:

$$KE = \tfrac{1}{2}mv^2$$

→ The net work done on an object is equal to the change in its kinetic energy

→ $$W_{net} = \Delta KE = KE_f - KE_o$$

A system of objects: Just add up their individual kinetic energies



$$KE_{system} = \tfrac{1}{2}m_1 {v_1}^2 + \tfrac{1}{2}m_2 {v_2}^2 + \tfrac{1}{2}m_3 {v_3}^2$$

We will do systems more in the next chapter when we discuss collisions!

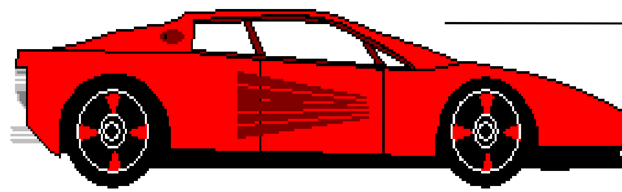
Examples: billard balls and football players

Kinetic Energy of a System

v ←

Mass 2m

2v →



Mass m

What is the kinetic energy of the system of vehicles?

Can KE(system) ever be negative? Ever zero?

A) 0
B) $\frac{1}{2} mv^2$
C) mv^2
D) $2mv^2$
E) $3mv^2$

Q55

Fun Example : The Flash

The Flash runs so fast that he can pluck bullets from the air (Flash's speed ≥ speed of bullets).

Where does all of this energy come from?

Food. The Flash eats for the same reason we do.

$$KE = \frac{1}{2} m v^2$$

The Flash's (and our) caloric intake requirements increase quadratically the faster we run. Twice as fast means four times the calories needed to fuel the running.

Let's estimate, like you should for your movie calculation.

Flash's weight ~155 pounds or 70 kg

Let's say he is running at 1% the speed of light (not his top speed) = 1860 miles/s or 3 million m/s

$$KE = \frac{1}{2} (70\ kg)\ (3{,}000{,}000\ m/s)^2$$

$=315$ trillion $kg\ m^2/s^2$ (J) = 75 billion Calories

(0.00024 Calories = 1 $kg\ m^2/s^2$)

That's **150 million burgers**!

And if he stops, he would need another 150 million burgers to speed up again!

Why does food give us energy?

It's not the kinetic energy of the atoms shaking. A hot meal has the same calories as a cold meal.

It's the potential energy locked in the chemical bonds. Remember that energy can never be created nor destroyed.

Bonds are treated like "springs“ (Ch. 13).

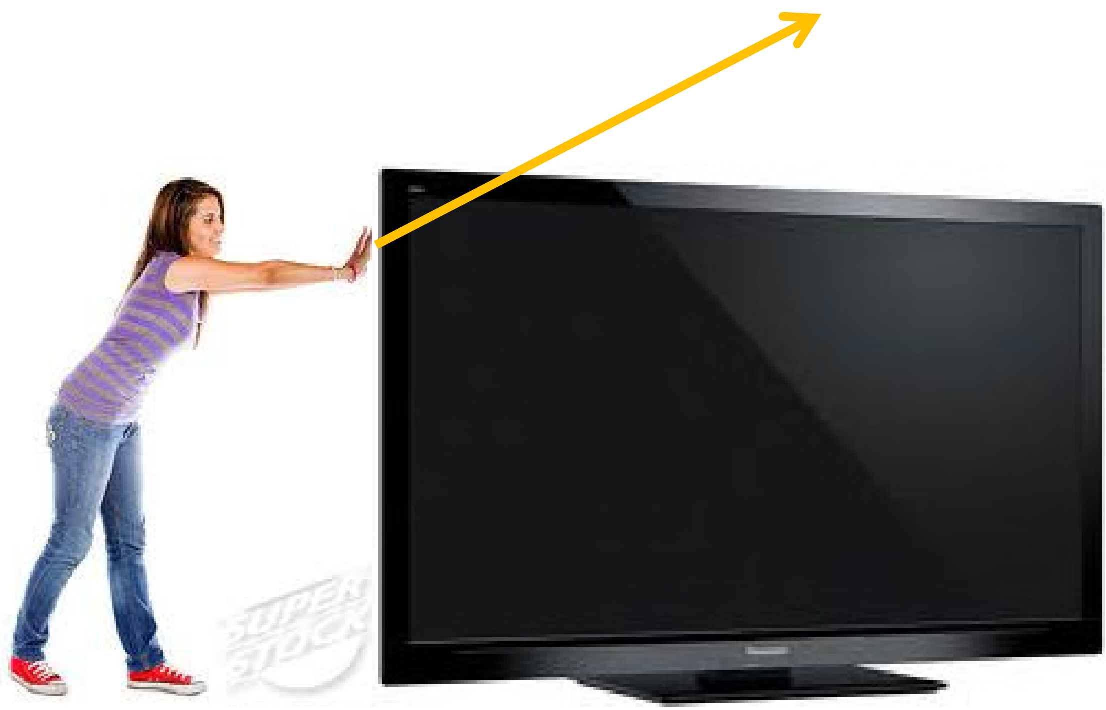
The chemical energy in our food can be used for other activities like moving and growing.

Cindy pushes her new 18 kg TV 20.0m at a constant speed and at an angle of 20 degrees from the rough carpet (μ_k=0.50).

A) What force does she apply?

B) How much work does she do on the TV?

C) What is the energy lost due to friction?

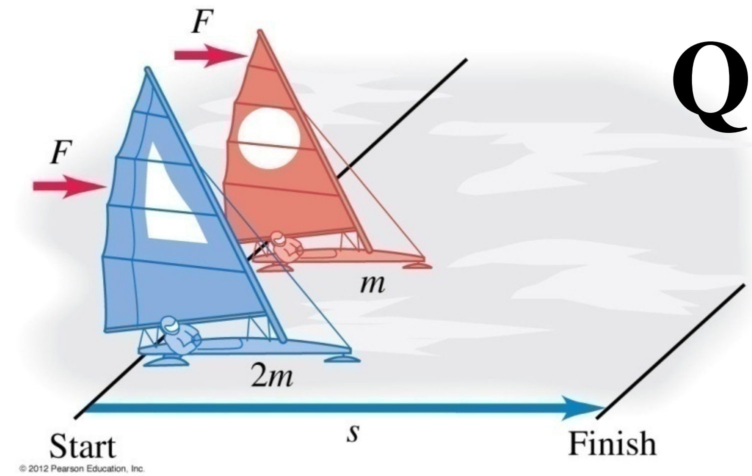


A cart on an air track is moving at 1.0 m/s when the air is suddenly turned off. The cart comes to rest after traveling 1 m. The experiment is repeated, but now the cart is moving at 2 m/s when the air is turned off. How far does the cart travel before coming to rest?

A) 1 m
B) 2 m
C) 3 m
D) 4 m
E) Impossible to determine

Q56

Two iceboats (one of mass *m*, one of mass 2*m*) hold a race on a **frictionless**, horizontal, frozen lake. Both iceboats start at rest, and the wind exerts the same constant force on both iceboats.



Q57

Which iceboat crosses the finish line with more kinetic energy (KE)?

A. The iceboat of mass *m*: it has twice as much KE as the other.

B. The iceboat of mass *m*: it has 4 times as much KE as the other.

C. The iceboat of mass 2*m*: it has twice as much KE as the other.

D. The iceboat of mass 2*m*: it has 4 times as much KE as the other.

E. They both cross the finish line with the same kinetic energy.

A satellite is moving around the Earth in a circular orbit. Over the course of an orbit, the Earth's gravitational force

A. does positive work on the satellite.

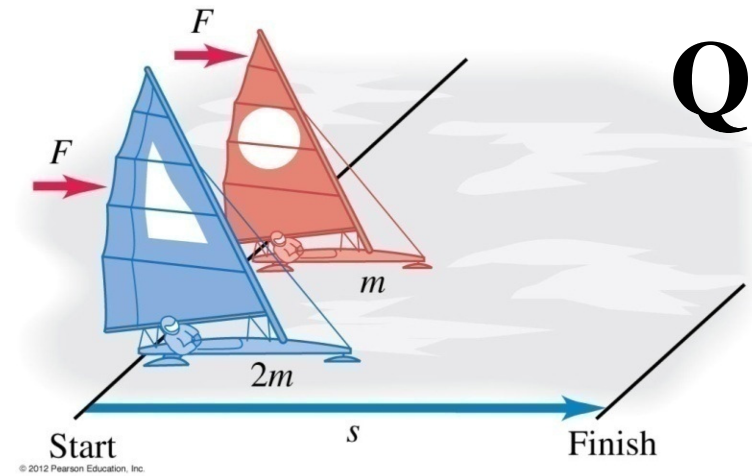
B. does negative work on the satellite.

C. does positive work on the satellite during part of the orbit and negative work on the satellite during the other part.

D. does zero work on the satellite at all points in the orbit.

Q58

Two iceboats (one of mass *m*, one of mass 2*m*) hold a race on a frictionless, horizontal, frozen lake. Both iceboats start at rest, and the wind exerts the same constant force on both iceboats.



Q59

Which iceboat crosses the finish line with more kinetic energy (KE)?

A. The iceboat of mass *m*: it has twice as much KE as the other.

B. The iceboat of mass *m*: it has 4 times as much KE as the other.

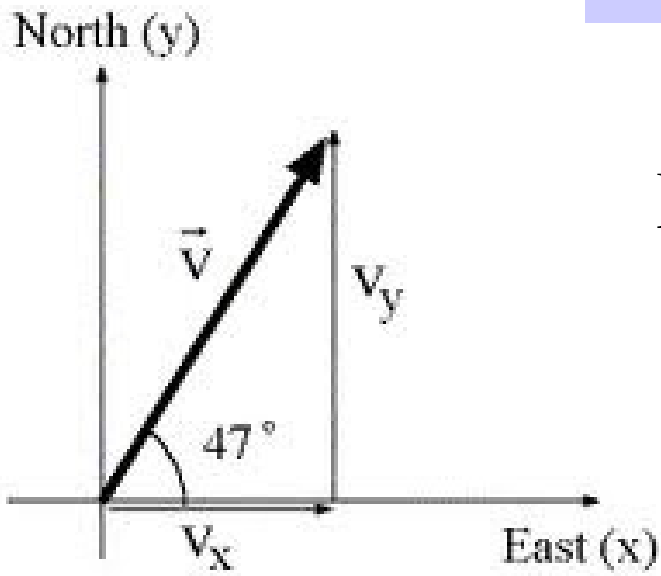
C. The iceboat of mass 2*m*: it has twice as much KE as the other.

D. The iceboat of mass 2*m*: it has 4 times as much KE as the other.

E. They both cross the finish line with the same kinetic energy.

Energy is a scalar, Velocity is not

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



In two dimensions

$$v^2 = v_x^2 + v_y^2$$

(pythagorean theorem)

In three dimensions

$$v^2 = v_x^2 + v_y^2 + v_z^2$$

I will not test you on three dimensions, but it could show up on the MCAT or DAT

Clicker Answers

Chapter/Section: Clicker #=Answer

54=C, 55=E, 56=D, 57=E, 58=D, 59=E