## Main Ideas Today



Sola

Wate

Biomass

Geotherm

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



Money Isn't All You're Saving

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  $\alpha$ ).

Which direction should friction point?

B.

**C**.





## 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 Negativ
- Normal force
- Friction N





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*. The sign of the work done by gravity depends on if the object moves up or down.
D. none of these



36.9°

## Work Done by a Constant (or Average) Force

• Force **F** acting on an object causes the object to move a distance  $\Delta x$  does work W

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

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

- $\Delta x$  displacement of object
- $F_{||}$  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?

Δx

Λx

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.

<complex-block>



• Energy is always **conserved** - neither increased nor decreased.

However, it can be converted to heat. (in Ch.11)

- Energy can be derived from  $W = F_{\parallel} \Delta x$  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.



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

$$v^{2} = v_{o}^{2} + 2a\Delta x \implies a = \frac{v^{2} - v_{o}^{2}}{2\Delta x}$$
$$\Rightarrow F_{net} = ma = m \left(\frac{v^{2} - v_{o}^{2}}{2\Delta x}\right)$$
$$W_{net} = F_{\parallel}\Delta x \implies W_{net} = \frac{1}{2}mv^{2} - \frac{1}{2}mv_{o}^{2}$$

## **The Work-Energy Principle**

The work done on an object by a net force is

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

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

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



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



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

Examples: billard balls and football players



What is the kinetic energy of the system of vehicles?

Can KE(system) ever be negative? Ever zero? A) 0 B) <sup>1</sup>/<sub>2</sub> mv<sup>2</sup> C) mv<sup>2</sup> D) 2mv<sup>2</sup> E) 3mv<sup>2</sup>

![](_page_12_Picture_4.jpeg)

![](_page_13_Picture_0.jpeg)

## 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.

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

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.

![](_page_14_Picture_1.jpeg)

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

$$\begin{split} & \text{KE} = \frac{1}{2} \ (70 \ \text{kg}) \ (3,000,000 \ \text{m/s})^2 \\ = & 315 \ \text{trillion} \ \text{kg} \ \text{m}^2/\text{s}^2 \ (\text{J}) = & 75 \ \text{billion} \ \text{Calories} \\ & (0.00024 \ \text{Calories} = & 1 \ \text{kg} \ \text{m}^2/\text{s}^2 \ ) \end{split}$$

#### 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.

![](_page_15_Picture_3.jpeg)

![](_page_15_Picture_4.jpeg)

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

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

Two iceboats (one of mass m, one of mass 2m) 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.

![](_page_17_Picture_1.jpeg)

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

![](_page_18_Picture_5.jpeg)

Two iceboats (one of mass m, one of mass 2m) 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.

![](_page_19_Picture_1.jpeg)

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

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

![](_page_20_Figure_2.jpeg)

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