## Chapter 10 and Chapter 11 – Energy, Work, Energy Conservation, and Simple Machines

### 10.1 Energy and Work

Is work being done?

Pushing wall
NO

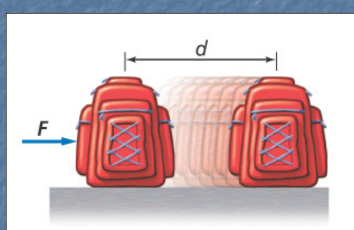
Holding garbage can
NO

Book falling
YES

Carrying fuel can at constant speed
NO

### 10.1 Energy and Work

Work – the product of force and an object's displacement




### 10.1 Energy and Work

Can you come up with an equation to calculate the work done on an object?

$$W = Fd$$

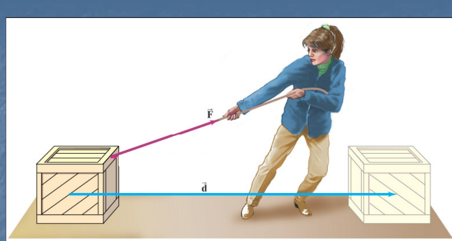
What are the units on the quantity work?

$$W = F \cdot d$$

Newton (N) meter (m)

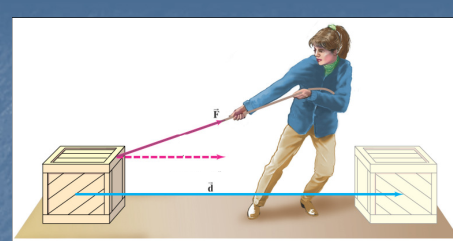
1 N·m = 1 Joule (J)

### 10.1 Energy and Work




Not all of the force applied to the crate is used to move it

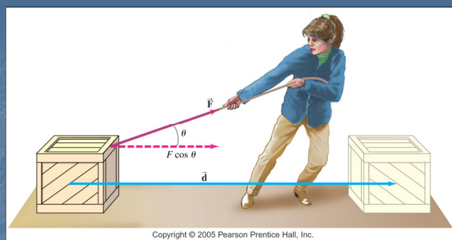
### 10.1 Energy and Work




Not all of the force applied to the crate is used to move it

Only the force applied in the direction of the motion of the object is used to calculate the work done on the object

## 10.1 Energy and Work




Can you come up with a more specific equation to calculate the work done on an object?

$$W = Fd\cos\theta$$

## 10.1 Energy and Work

Is work being done?

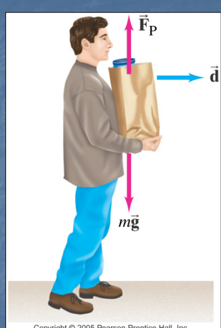
Pushing wall
NO

Holding garbage can
NO

Book falling
YES

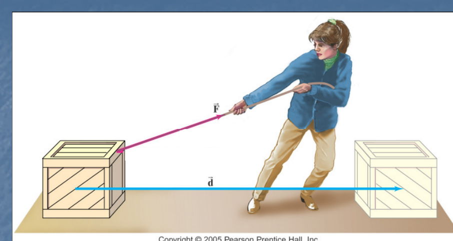
Carrying fuel can at constant speed
NO

## 10.1 Energy and Work




No work is done because the force is perpendicular to the displacement

## 10.1 Energy and Work



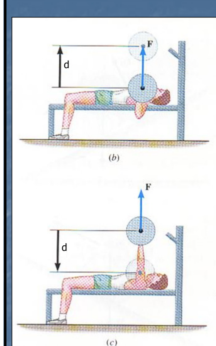

The rope in the above picture has a tension of 45.0 N and is angled 30.0º to the floor. Find the work done by the force in pulling the crate a distance of 75.0 m.

## 10.1 Energy and Work

A 25.0 kg box that was pushed to slide across a level floor comes to rest in a distance of 5.5 m after the initial force was removed. Find the work done by the force of kinetic friction in bringing the box to rest. $\mu_k = .320$

Work can be positive or negative

## 10.1 Energy and Work

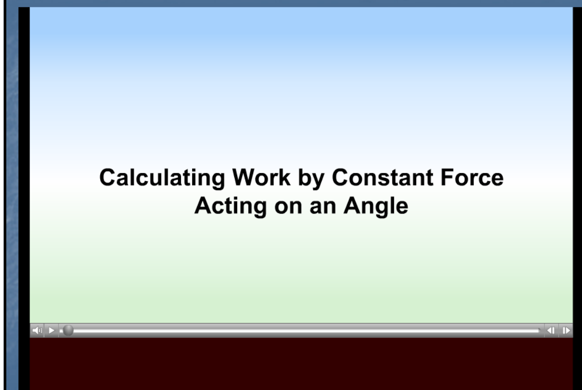



The weight lifter is benching 72.4 kg. In the top figure he raises the barbell 0.65 m above his chest, and in the lower figure he lowers it the same distance. The weight is raised and lowered at a constant velocity. Determine the work done by the lifter on the barbell during the

a) Lifting phase

b) Lowering phase

## 10.1 Energy and Work




## 10.1 Energy and Work

If a constant force of 10 N is applied perpendicular to the direction of motion of a ball, moving at a constant speed of 2 m/s, what will be the work done on the ball?

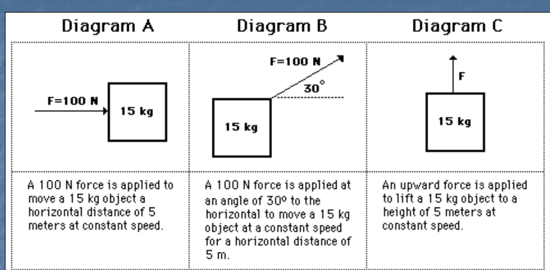
A. 20 J

B. 0 J

C. 10 J

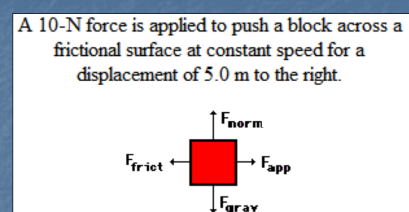
D. Data insufficient

## 10.1 Energy and Work




Determine the work done in each of the above scenarios

## 10.1 Energy and Work




Which forces do work on the block?

## 10.1 Energy and Work 11.1 The Many Forms of Energy

What is meant by kinetic energy?

Applying a force to an object through some distance sets that object into motion

An object in motion can apply a force to something and in turn do work to that object (it has energy – the ability to do work)

The *moving* bowling ball can do work on the pins

Kinetic energy – energy an object has because it is in motion

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

The unit of KE is the Joule

## 10.1 Energy and Work 11.1 The Many Forms of Energy

What is Newton's 2nd Law? $F = ma$

What kinematics equation relates the final velocity of an object to its initial velocity, acceleration, and displacement?

$$v_f^2 = v_i^2 + 2a\Delta d$$

Solve for a: $a = \frac{v_f^2 - v_i^2}{2\Delta d}$

Substitute a into 2nd Law: $F = m\left(\frac{v_f^2 - v_i^2}{2\Delta d}\right)$

Multiply both sides by d: $Fd = m\left(\frac{v_f^2 - v_i^2}{2}\right)$

Rearrange:

$$Fd = \frac{1}{2}mv_f^2 - \frac{1}{2}mv_i^2$$

Work

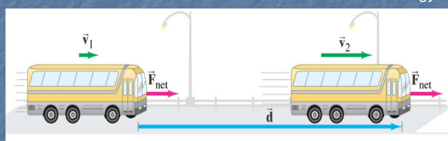
Kinetic Energy

## 10.1 Energy and Work 11.1 The Many Forms of Energy

$$Fd = \frac{1}{2}mv_f^{\,2} - \frac{1}{2}mv_i^{\,2}$$

Work

Kinetic Energy



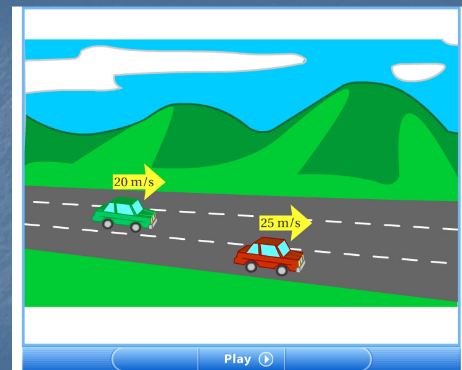

By applying a force over a distance the kinetic energy of the bus is changed

Work – Energy Theorem

Work done by the net force!

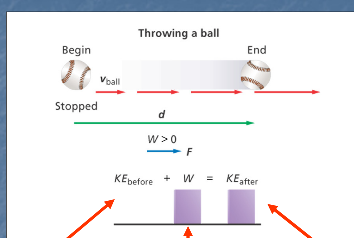
$$W_{net} = \frac{1}{2}mv_f^{\,2} - \frac{1}{2}mv_i^{\,2}$$

## 10.1 Energy and Work 11.1 The Many Forms of Energy




## 10.1 Energy and Work 11.1 The Many Forms of Energy

What do I have to do to throw a baseball?




Beforehand: KE = 0

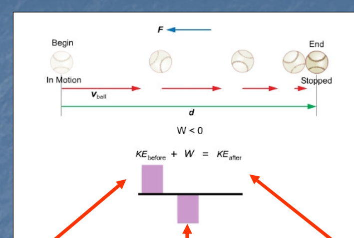
Do positive work

Afterward: KE > 0

The positive work done on the ball gave the ball kinetic energy

## 10.1 Energy and Work 11.1 The Many Forms of Energy

What do I have to do to catch a baseball?



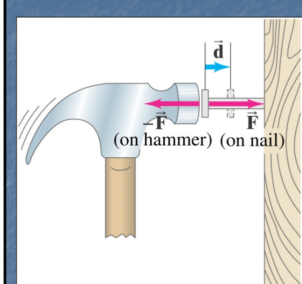

Beforehand: KE > 0

Do negative work

Afterward: KE = 0

The negative work done on the ball took the ball's kinetic energy

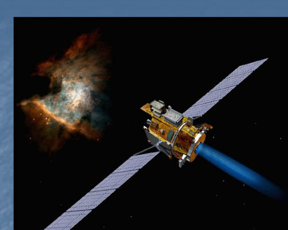
## 10.1 Energy and Work 11.1 The Many Forms of Energy




The kinetic energy of the nail is increased because positive work is done on it.

The kinetic energy of the hammer is decreased because negative work is done on it.

## 10.1 Energy and Work 11.1 The Many Forms of Energy



A space probe of mass $5.00 \times 10^4$ kg is traveling at $1.10 \times 10^4$ m/s through deep space. The engine exerts a constant force of $4.00 \times 10^5$ N, directed parallel to the displacement. The engine fires continuously while the probe move in a straight line for a displacement of $2.50 \times 10^6$ m.

What is the final speed of the space probe?

## 10.1 Energy and Work 11.1 The Many Forms of Energy

On a frozen pond, a person kicks a 10.0 kg sled, giving it an initial speed of 2.2 m/s. How far does the sled move if the coefficient of kinetic friction between the sled and the ice is 0.10?

## 10.1 Energy and Work

1. What speed would a fly with a mass of .55 g need in order to have the same kinetic energy as a 1200 kg car traveling at 20 m/s?

29,542 m/s

2. A 0.075 kg arrow is fired horizontally. The bowstring exerts an average force of 80 N on the arrow over a distance of .80 m. With what speed does the arrow leave the bow?

41.3 m/s

## 10.1 Energy and Work

**Worksheet 1 #3 a) 1800 J b) -1200 J**

1. Assuming the refrigerator started from rest, how much KE does it have after it has slid 8.00 m?

2. What is the speed of the refrigerator at 8.00 m?

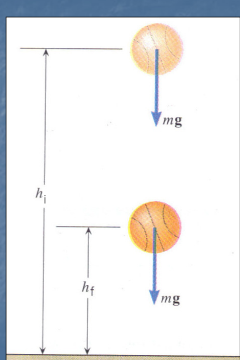
3. If after 8.00 m the pullling force is removed, how much work would have to be done by the frictional force to bring the refrigerator to rest?

4. If after 8.00 m the pulling force is removed, how far does the fridge slide until is stops?

## 10.1 Energy and Work 11.1 The Many Forms of Energy

A 58.0 kg skier is coasting down a 25° slope. A sliding friction force of 70. N opposes his motion. Near the top of the slope his speed is 3.6 m/s. Determine the speed at a point 57 m down hill.

## 10.1 Energy and Work 11.1 The Many Forms of Energy



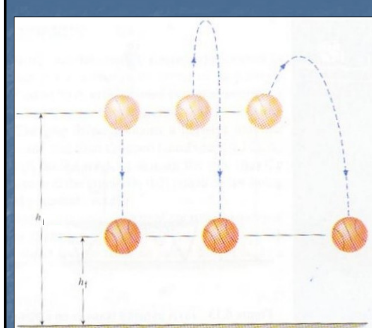

The work done by gravity to bring this ball from a height of $h_i$ to a height $h_f$ is:

$$W = F \cdot d \cdot \cos\theta$$

mg $\quad (h_f - h_i) \quad$ 1

$$W_{gravity} = mg\,(h_f - h_i)$$

## 11.1 The Many Forms of Energy

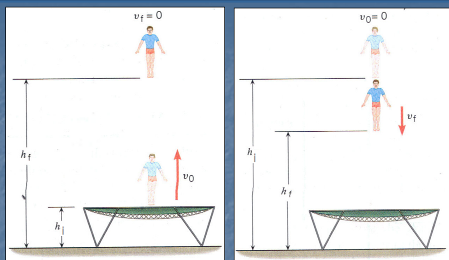


The work done by the gravitational force is the same in all three cases.

The vertical distance is the same.

$$W_{gravity} = mg\,(h_i - h_f)$$

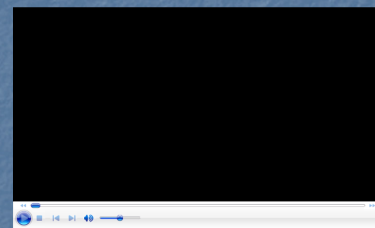
## 10.1 Energy and Work    11.1 The Many Forms of Energy




A gymnast springs vertically upward from a trampoline. The gymnast leaves the trampoline at a height of 1.20 m and reaches a max height of 4.80 meters before falling back down.

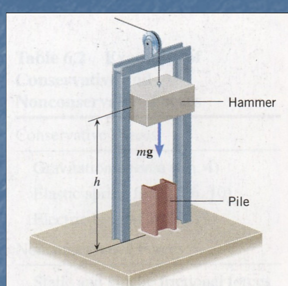
a) Determine the initial speed with which the gymnast leaves the trampoline.
b) The speed of the gymnast after falling back to a height of 3.50 m.

## 11.1 The Many Forms of Energy



## 11.1 The Many Forms of Energy

Positive work must be done to raise the hammer from the ground.



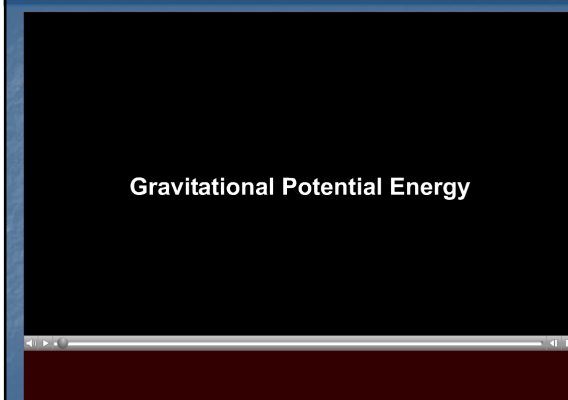

When raised to a height and dropped, gravity can do positive work on the hammer

As it falls, the hammer will gain kinetic energy, and be able to do work on the pile

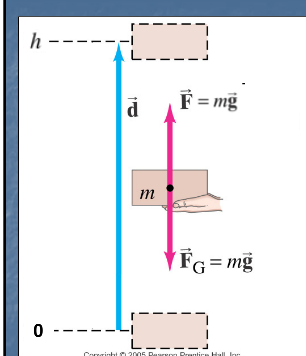
The hammer, when raised has the *potential* to do work

gravitational potential energy – The stored energy in a system resulting from the gravitational force between Earth and the object

## 11.1 The Many Forms of Energy




## 11.1 The Many Forms of Energy




In raising a mass, *m,* to a height, *h,* the work done by the force (the hand) is

W = F · d · cos θ

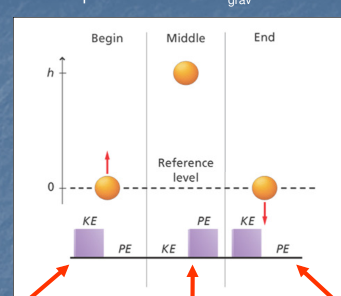
mg · h · 1

Gravitational Potential Energy

$$PE_{grav} = mgh$$

## 11.1 The Many Forms of Energy

reference level – The position where $PE_{grav}$ is defined to be zero.

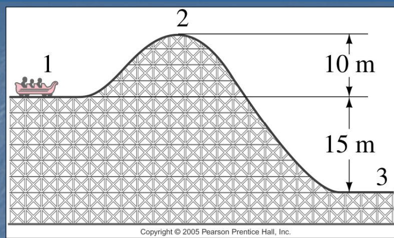



Juggler releases ball: KE > 0; PE = 0

Ball at max height: KE = 0; PE > 0

Returns to juggler: KE > 0; PE = 0

## 11.1 The Many Forms of Energy

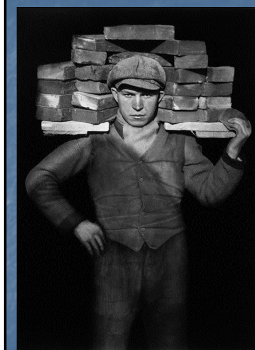



A 1000. kg roller coaster moves from point 1 to point 2 and then to point 3.

a) Find the gravitational PE at Point 2 and Point 3 relative to Point 1.

b) What is the change in gravitational PE when the coaster goes from Point 2 to Point 3?

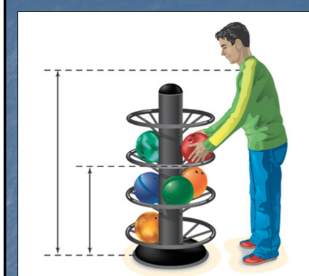
## 11.1 The Many Forms of Energy



How much work does a bricklayer do to carry 30.2 kg of bricks from the ground up to the third floor (height = 11.1 m) of a building under construction, at constant speed?

What is the potential energy of the bricks when the bricklayer reaches the third floor?

## 11.1 The Many Forms of Energy



You lift a 7.30 kg bowling ball from the storage rack and hold it up to your shoulder. The storage rack is 0.610 m above the floor and your shoulder is 1.12 m about the floor.

a) When the ball is at your shoulder, what is the the ball's gravitational potential energy relative to the floor?

b) When the ball is at your shoulder, what is the the ball's gravitational potential energy relative to the the storage rack

c) How much work was done by gravity as you lifted the ball from the rack to shoulder level?

## 11.1 The Many Forms of Energy

From what height would a car have to be dropped so that when it hits the ground it has the same kinetic energy as when it is being driven at 65 mi/h (29.1 m/s)?

## 11.1 The Many Forms of Energy

Do all these cliff jumpers have the same potential energy?

Will they all have the same kinetic energy when they hit the water?

Will they have the same velocity when they enter the water?

Will they each take the same amount of time to reach the water?

## 11.1 The Many Forms of Energy

A boy running on a track doubles his velocity. Which of the following statements about his kinetic energy is true?

A. Kinetic energy will be doubled.

B. Kinetic energy will reduce to half.

C. Kinetic energy will increase by four times.

D. Kinetic energy will decrease by four times.

## 11.1 The Many Forms of Energy

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## 11.1 The Many Forms of Energy

If an object moves away from the Earth, energy is stored in the system as the result of the force between the object and the Earth. What is this stored energy called?

A. Rotational kinetic energy

B. Gravitational potential energy

C. Elastic potential energy

D. Linear kinetic energy

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## 11.1 The Many Forms of Energy

Two girls, Sarah and Susan, having same masses are jumping on a floor. If Sarah jumps to a greater height, what can you say about the gain in their gravitational potential energy?

A. Since both have equal masses, they gain equal gravitational potential energy.

B. Gravitational potential energy of Sarah is greater than that of Susan.

C. Gravitational potential energy of Susan is greater than that of Sarah.

D. Neither Sarah nor Susan possesses gravitational potential energy.

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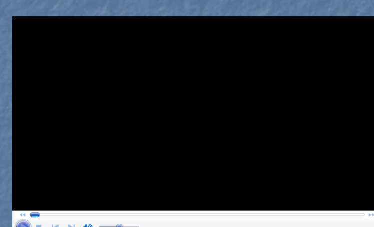
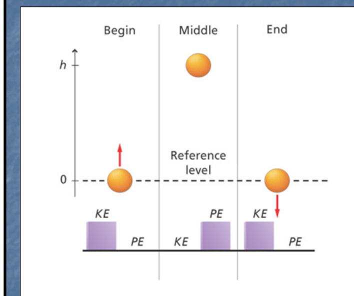
## 11.2 Conservation of Energy



## 11.2 Conservation of Energy

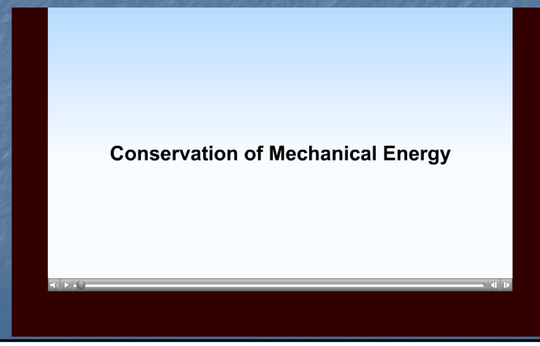



Recall that the sum of the gravitational potential energy and the kinetic energy for an object remains constant

Energy is converted from one form to another, but the quantity is conserved

## 11.2 Conservation of Energy

mechanical energy – the sum of the kinetic energy and gravitational potential energy of a system




## 11.2 Conservation of Energy

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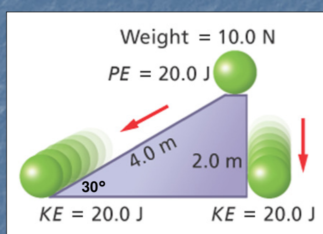
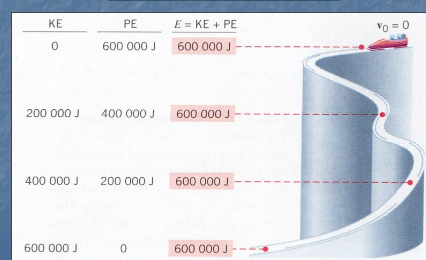



In the absence of friction and air resistance (nonconservative forces), this ball will have the same KE whether it rolls down the ramp or drops straight down. The path the ball takes does not matter.

## 11.2 Conservation of Energy

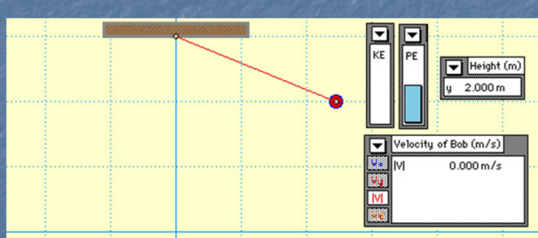
mechanical energy – the sum of the kinetic energy and the potential energy of a system

$$E = KE + PE$$




## 11.2 Conservation of Energy

A swinging pendulum illustrates the conservation of mechanical energy

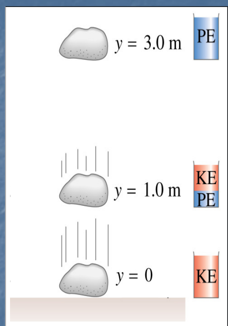



## 11.2 Conservation of Energy

conservation of mechanical energy – the total mechanical energy of an object remains constant in the absence of non-conservative forces such as friction and air resistance

$$\underbrace{\frac{1}{2}mv_i^2}_{KE_{initial}} + \underbrace{mgh_i}_{PE_{initial}} = \underbrace{\frac{1}{2}mv_f^2}_{KE_{final}} + \underbrace{mgh_f}_{PE_{final}}$$

## 11.2 Conservation of Energy

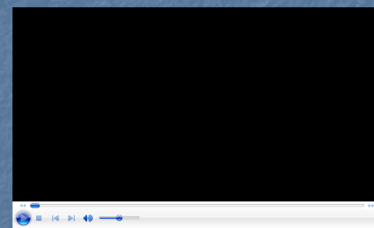



A stone is dropped from a height of 3.0 m. Calculate its speed

a) when it has fallen to a height 1.0 m above the ground.

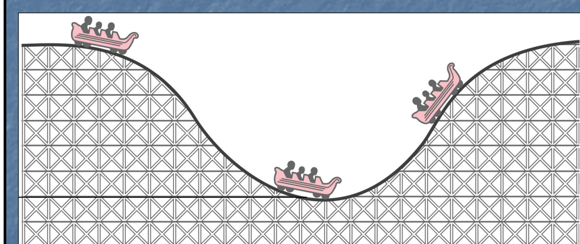
b) the instant before it hits the ground.

## 11.1 The Many Forms of Energy



## 11.2 Conservation of Energy

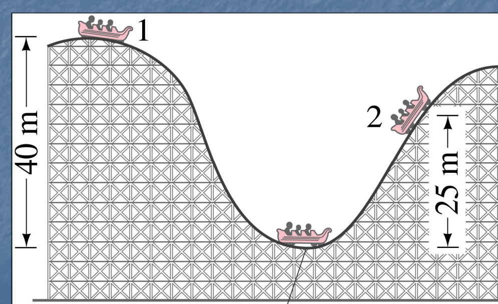
A roller-coaster car moving without friction illustrates the conservation of mechanical energy.



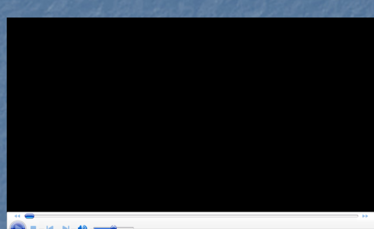


## 11.2 Conservation of Energy

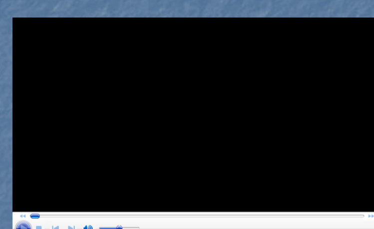
Because of friction, a roller coaster car does not reach the original height on the second hill.



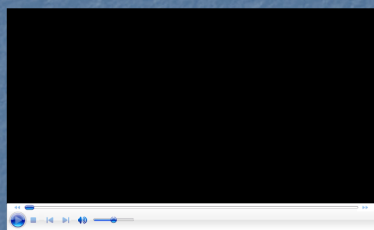

## 11.1 The Many Forms of Energy



## 11.1 The Many Forms of Energy



## 11.1 The Many Forms of Energy



## 11.2 Conservation of Energy

Pendulums stop, roller coasters require lower and lower hills, a bouncing ball doesn't reach the same height over and over again.

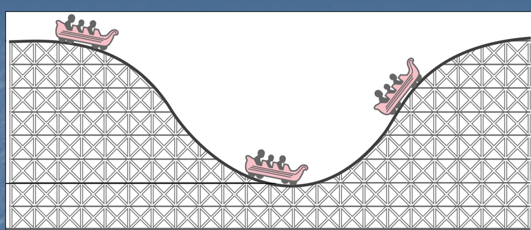
Where does the energy go?

1. air resistance

2. thermal energy – a measure of the internal motion of an object's particles (friction increases thermal energy)

law of conservation of energy – in a closed, isolated system, energy can neither be created nor destroyed; rather energy is conserved

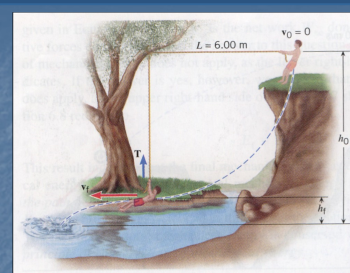
## 11.2 Conservation of Energy





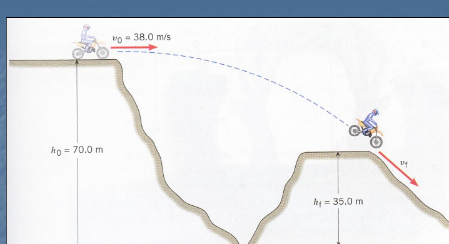
Assuming the height of the hill is 40.0 m and the roller coaster car starts from rest, calculate the speed at the bottom of the hill?

## 11.2 Conservation of Energy




A 6.00 m rope is tied to a tree limb and used as a swing. A person starts from rest with the rope held in a horizontal orientation. Ignoring friction and air resistance, how fast is the person moving at the lowest point in the circular arc of the swing?

## 11.2 Conservation of Energy



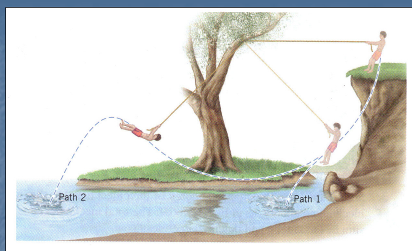

When the motorcyclist leaves the cliff, the cycle has a speed of 38.0 m/s. Ignoring air resistance what is the speed when the driver strikes the ground on the other side?

## 11.2 Conservation of Energy

Kelli weighs 420 N, and she is sitting on a playground swing that hangs 0.40 m above the ground. Her grandma pulls the swing back and releases it when the seat is 1.00 m above the ground.

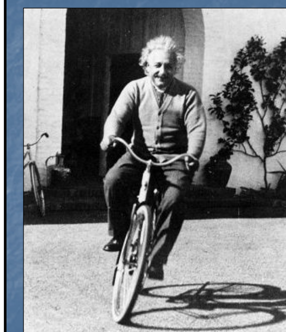
a) How fast is Kelli moving when the swing passes through its lowest position?

b) If Kelli moves through the lowest point at 2.0 m/s, how much work was done on the swing by friction?




This figure shows two possible paths by which a person, starting from rest at the top of a cliff, can enter the water below. Suppose that he enters the water at a speed of 13.0 m/s via path 1. How fast is he moving on path 2 when he releases the rope at a height of 5.20 m above the water?

11.2 Conservation of Energy



A happy cyclist approaches the bottom of a gradual hill at a speed of 11 m/s. This hill is 5.0 m high, and the cyclist is going fast enough to coast up and over it without peddling. Ignoring air resistance and friction, find the speed at which the cyclist crests the hill.

11.2 Conservation of Energy

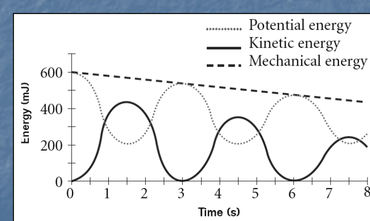
Two pole-vaulters just clear the bar at the same height. The first lands at a speed of 8.90 m/s, while the second lands at a speed of 9.00 m/s. The first vaulter clears the bar at a speed of 1.00 m/s. Determine the speed at which the second vaulter clears the bar.

11.2 Conservation of Energy

The graph shows the energy of a 75.0 g yo-yo at different times as the yo-yo moves up and down on its string.

By what amount does the mechanical energy of the yo-yo change after 6.0 s?

**A.** 500 mJ
**B.** 0 mJ
**C.** –100 mJ
**D.** –600 mJ

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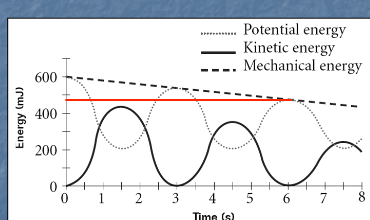
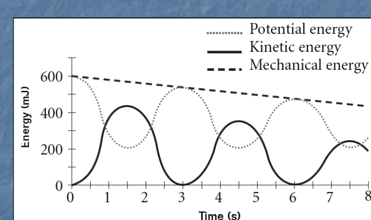



11.2 Conservation of Energy

The graph shows the energy of a 75.0 g yo-yo at different times as the yo-yo moves up and down on its string.

What is the speed of the yo-yo after 4.5 s?

**A.** 3.16 m/s
**B.** 1.00 m/s
**C.** 4.00 m/s
**D.** 3.05 m/s



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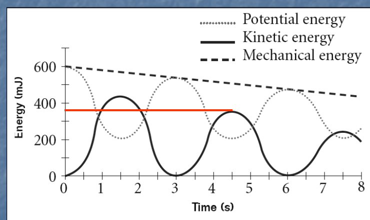
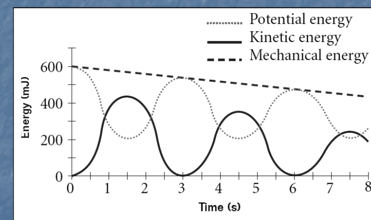



11.2 Conservation of Energy

The graph shows the energy of a 75.0 g yo-yo at different times as the yo-yo moves up and down on its string.

What is the maximum height of the yo-yo?

**A.** 0.27 m
**B.** 0.54 m
**C.** 0.75 m
**D.** 0.82 m

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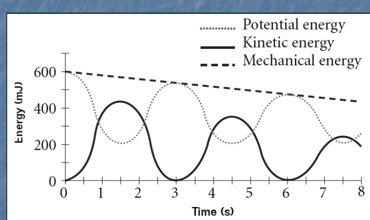
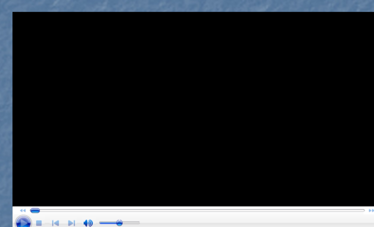


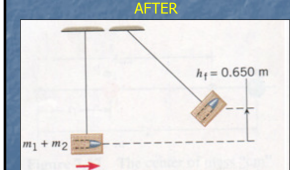

11.2 Conservation of Energy



11.2 Conservation of Energy

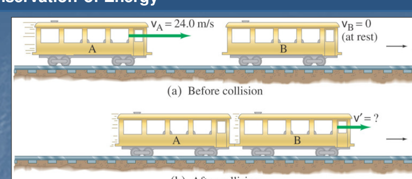
BEFORE


AFTER




A ballistic pendulum can be used to measure the speed of a bullet. It consists of a wood block (mass $m_2 = 2.50$ kg) suspended by a wire of negligible mass. A bullet (mass $m_1 = .0100$ kg) is fired with a speed $v_{01}$. Just after the bullet collides with it, the block (with the bullet in it) has a speed $v_f$ and then swings to a maximum height of 0.650 m above the initial position. Find the speed of the bullet.

11.2 Conservation of Energy



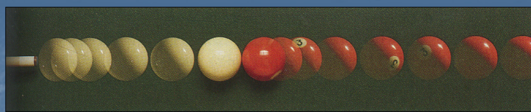

A 10,000 kg railroad car traveling at a speed of 24.0 m/s strikes an identical car at rest. If the cars lock together as a result of the collision, what is their common speed afterward? 12.0 m/s

What is the total kinetic energy before the collision?

What is the total kinetic energy after the collision?

What happened to the kinetic energy?

## 11.2 Conservation of Energy



A cue ball, with mass of 0.16 kg, rolling at 4.0 m/s, hit a stationary three-ball of the same mass. The cue ball comes to rest after striking the three-ball. What is the speed of the three-ball after the collision? 4.0 m/s

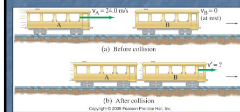
What is the total kinetic energy before the collision?

What is the total kinetic energy after the collision?

What happened to the kinetic energy?

## 11.2 Conservation of Energy

Collisions are classified according to whether or not the total KE changes during the collision.




Inelastic collision – one in which the total kinetic energy of the system is NOT the same before and after the collision.

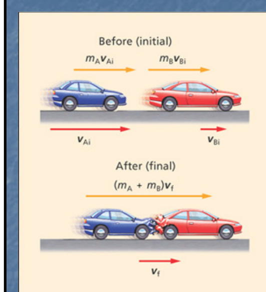
Elastic collision – one in which the total kinetic energy of the system after the collision is equal to the total kinetic energy before the collision.

The harder the objects, the less permanent distortion, the less KE that is lost

Momentum is always conserved

## 11.2 Conservation of Energy

## 11.2 Conservation of Energy




In an accident on a slippery road, a compact car with a mass of 575 kg moving at 15.0 m/s smashes into the rear end of a car with mass 1575 kg moving at 5.00 m/s in the same direction.

a) What is the final velocity of the cars if they lock together?

b) How much kinetic energy was lost during the collision?

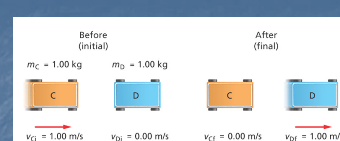
## 11.2 Conservation of Energy

A 25.0 kg bumper car moving to the right at 5.5 m/s overtakes and collides with a 35.0 kg bumper car moving to the right at 2.0 m/s. After the collision the 25.0 kg bumper car slows to 1.4 m/s to the right.

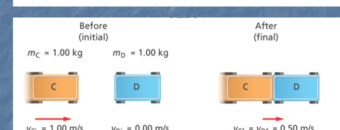
Was the collision elastic?

## 11.2 Conservation of Energy

A




B




In which case is both momentum and kinetic energy conserved?

## 11.2 Conservation of Energy

Two brothers, Jason and Jeff, of equal masses jump from a house 3-m high. If Jason jumps on the ground and Jeff jumps on a platform 2-m high, what can you say about their kinetic energy?

A. The kinetic energy of Jason when he reaches the ground is greater than the kinetic energy of Jeff when he lands on the platform.

B. The kinetic energy of Jason when he reaches the ground is less than the kinetic energy of Jeff when he lands on the platform.

C. The kinetic energy of Jason when he reaches the ground is equal to the kinetic energy of Jeff when he lands on the platform.

D. Neither Jason nor Jeff possesses kinetic energy.

## 11.2 Conservation of Energy

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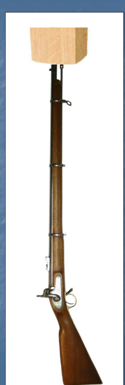
## 11.2 Conservation of Energy



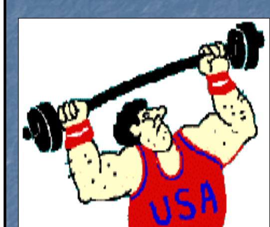
A 3.00 kg block of wood rests on the muzzle opening of a vertically oriented rifle, the stock of the rifle being firmly planted on the ground. When the rifle is fired, an 8.00 g bullet (velocity = 800. m/s, straight upward) becomes completely embedded in the block. Ignoring air resistance, determine how high the block / bullet system rises above the opening of the rifle.

## 10.1 Energy and Work

Power - the rate at which work is done

$$P = \frac{W}{t} \rightarrow 1\ \frac{\text{J}}{\text{s}} = 1\ \text{Watt (W)}$$

## 10.1 Energy and Work

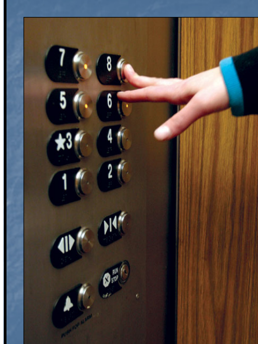



Two physics students, Will and Ben, are in the weightlifting room. Will lifts the 100-pound barbell over his head 10 times in one minute; Ben lifts the 100-pound barbell over his head 10 times in 10 seconds.

Which student does the most work?

Which student delivers the most power?

## 10.1 Energy and Work



An electric motor lifts an elevator 9.00 m in 15.0 s by exerting an upward force of $1.20 \times 10^4$N. What power does the motor produce in kW?

**10.1 Energy and Work**

The woman in the picture above lifts her 60.0 kg body a distance of 0.50 meters in 2 seconds. What is the power delivered by her biceps?

**10.1 Energy and Work**

Power - the rate at which work is done

$$P = \frac{W}{t} \rightarrow 1\ \frac{J}{s} = 1 \text{ Watt (W)}$$

Recall that W = F· d, so $P = \frac{W}{t} = \frac{Fd}{t} = F\frac{d}{t} = Fv$

$$P = Fv$$

**10.1 Energy and Work**

Three friends, Brian, Robert, and David, participated in a 200-m race. Brian exerted a force of 240 N and ran with an average velocity of 5.0 m/s, Robert exerted a force of 300 N and ran with an average velocity of 4.0 m/s, and David exerted a force of 200 N and ran with an average velocity of 6.0 m/s. Who amongst the three delivered more power?

A. Brian

B. Robert

C. David

D. All the three players delivered same power

**10.1 Energy and Work**

Now since the product of force and velocity in case of all the three participants is same:

Power delivered by Brian → P = (240 N) (5.0 m/s) = 1.2 kW

Power delivered by Robert → P = (300 N) (4.0 m/s) = 1.2 kW

Power delivered by David → P = (200 N) (6.0 m/s) = 1.2 kW

All the three players delivered same power.

**Chapter 10 and 11 Vocabulary**

work
reference level
kinetic energy
elastic potential energy
gravitational potential energy
watt
energy
joule
power
work-energy theorem
mechanical energy
elastic collision
inelastic collision
thermal energy
law of conservation of energy

Definition:

1. The transfer of energy by mechanical means; a constant force exerted on an object in the direction of motion, times the object's displacement.

**Chapter 10 and 11 Vocabulary**

work
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gravitational potential energy
watt
energy
joule
power
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law of conservation of energy

Definition:

2. A type of collision in which the kinetic energy after the collision is less than the kinetic energy before the collision

**Chapter 10 and 11 Vocabulary**

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reference level
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gravitational potential energy
watt
energy
joule
power
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elastic collision
inelastic collision
thermal energy
law of conservation of energy

Definition:

3. The ability of an object to do work

**Chapter 10 and 11 Vocabulary**

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elastic potential energy
gravitational potential energy
watt
energy
joule
power
work-energy theorem
mechanical energy
elastic collision
inelastic collision
thermal energy
law of conservation of energy

Definition:

4. The unit of energy

**Chapter 10 and 11 Vocabulary**

work
reference level
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elastic potential energy
gravitational potential energy
watt
energy
joule
power
work-energy theorem
mechanical energy
elastic collision
inelastic collision
thermal energy
law of conservation of energy

Definition:

5. A measure of the internal motion of an object's particles

**Chapter 10 and 11 Vocabulary**

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gravitational potential energy
watt
energy
joule
power
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law of conservation of energy

Definition:

6. The sum of the kinetic and gravitational potential energy of a system.

**Chapter 10 and 11 Vocabulary**

work
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gravitational potential energy
watt
energy
joule
power
work-energy theorem
mechanical energy
elastic collision
inelastic collision
thermal energy
law of conservation of energy

Definition:

7. The energy of an object resulting from its motion

**Chapter 10 and 11 Vocabulary**

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elastic potential energy
gravitational potential energy
watt
energy
joule
power
work-energy theorem
mechanical energy
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inelastic collision
thermal energy
law of conservation of energy

Definition:

8. The stored energy in a system resulting from the gravitational force between Earth and the object

**Chapter 10 and 11 Vocabulary**

- work
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- kinetic energy
- elastic potential energy
- gravitational potential energy
- watt
- energy
- joule
- power
- work-energy theorem
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- inelastic collision
- thermal energy
- law of conservation of energy

Definition:

9. Unit of power

**Chapter 10 and 11 Vocabulary**

- work
- reference level
- kinetic energy
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- gravitational potential energy
- watt
- energy
- joule
- power
- work-energy theorem
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- inelastic collision
- thermal energy
- law of conservation of energy

Definition:

10. States that when work is done on an object, a change in kinetic energy occurs

**Chapter 10 and 11 Vocabulary**

- work
- reference level
- kinetic energy
- elastic potential energy
- gravitational potential energy
- watt
- energy
- joule
- power
- work-energy theorem
- mechanical energy
- elastic collision
- inelastic collision
- thermal energy
- law of conservation of energy

Definition:

11. States than in a closed, isolated system, energy is not created or destroyed, but rather, conserved

**Chapter 10 and 11 Vocabulary**

- work
- reference level
- kinetic energy
- elastic potential energy
- gravitational potential energy
- watt
- energy
- joule
- power
- work-energy theorem
- mechanical energy
- elastic collision
- inelastic collision
- thermal energy
- law of conservation of energy

Definition:

12. A type of collision in which the kinetic energy before and after the collision remains the same

**Chapter 10 and 11 Vocabulary**

- work
- reference level
- kinetic energy
- elastic potential energy
- gravitational potential energy
- watt
- energy
- joule
- power
- work-energy theorem
- mechanical energy
- elastic collision
- inelastic collision
- thermal energy
- law of conservation of energy

Definition:

13. The work done, divided the time need to do the work

**Chapter 10 and 11 Vocabulary**

- work
- reference level
- kinetic energy
- elastic potential energy
- gravitational potential energy
- watt
- energy
- joule
- power
- work-energy theorem
- mechanical energy
- elastic collision
- inelastic collision
- thermal energy
- law of conservation of energy

Definition:

14. The potential energy that may be stored in an object as a result of change in shape

## Chapter 10 and 11 Vocabulary

work
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kinetic energy
elastic potential energy
gravitational potential energy
watt
energy
joule
power
work-energy theorem
mechanical energy
elastic collision
inelastic collision
thermal energy
law of conservation of energy

Definition:

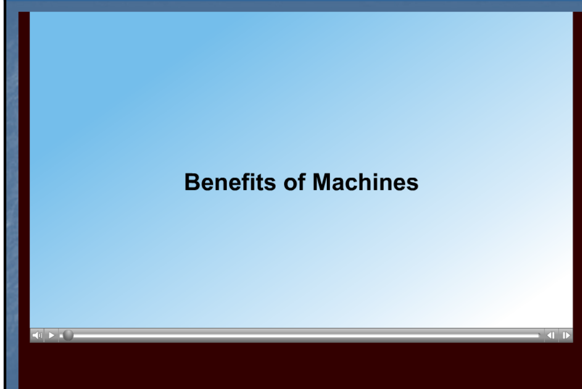
15. The position where gravitational potential energy is defined as zero.

## Chapter 10 and 11 Vocabulary

Answers:

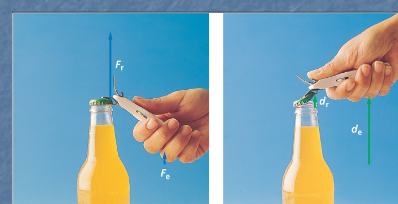
1. work
2. inelastic collision
3. energy
4. joule
5. thermal energy
6. mechanical energy
7. kinetic energy
8. gravitational potential energy
9. watt
10. work-energy theorem
11. law of conservation of energy
12. elastic collision
13. power
14. elastic potential energy
15. reference level

## 10.2 Machines




## 10.2 Machines

machine – a tool that makes work easier (but does not change the amount of work) by changing the magnitude or the direction of the force exerted to do the work.




Work is done on the opener, transferring energy to it (input work, $W_i$)

The opener does work on the bottle cap (output work, $W_o$)

## 10.2 Machines

The $W_o$ can never be greater than the $W_i$

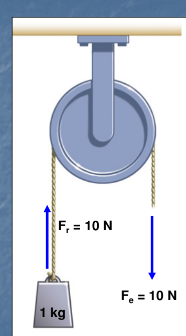

resistance force – force exerted by the machine

effort force – force exerted by a person on the machine

mechanical advantage – the ratio of the resistance force to the effort force

$$MA = \frac{F_r}{F_e}$$

## 10.2 Machines



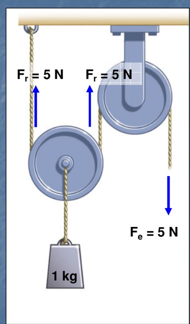

In a fixed pulley, such as the one shown here, the effort force and the resistance force are equal

$$MA = \frac{F_r}{F_e} = \frac{10\,N}{10\,N} = 1$$

Is this machine useful?

Yes, it changes the direction of the effort force

## 10.2 Machines

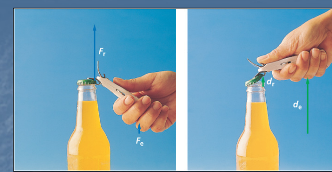



In a movable pulley, such as the one shown here, the effort force is ½ the resistance force

$$MA = \frac{F_r}{F_e} = \frac{10\,N}{5\,N} = 2$$

In this case both the direction and the magnitude of the effort force was changed

## 10.2 Machines



For a machine $W_o = W_i$, or, $F_r d_r = F_e d_e$

Rearrange to get $\frac{F_r}{F_e} = \frac{d_e}{d_r}$

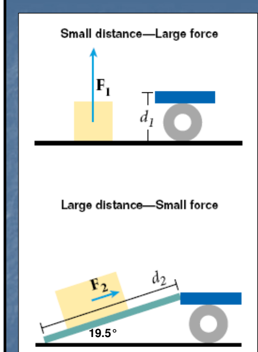
mechanical advantage

Ideal mechanical advantage – the displacement of the effort force divided by the displacement of the load.

The IMA is always greater than the MA because of the presence of friction

$$IMA = \frac{d_e}{d_r}$$

## 10.2 Machines



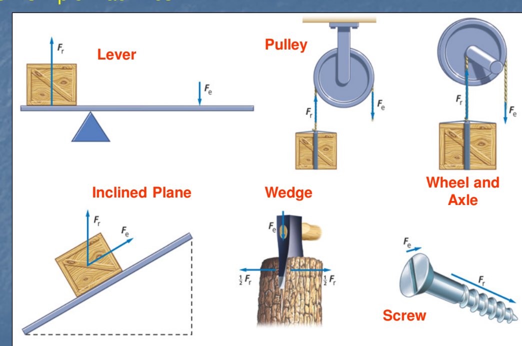

The diagram shows two examples of a 360. N trunk being loaded onto a truck 1.00 m high.

In the first example, a force (**F**$_1$) of 360 N moves the trunk through a distance ($d_1$) of 1.0 m. This requires 360 J of work.

In the second example, a lesser force (**F**$_2$) of only 120 N would be needed (ignoring friction), but the trunk must be pushed a greater distance ($d_2$) of 3.0 m. This also requires 360 J of work.

## 10.2 Machines

Six simple machines



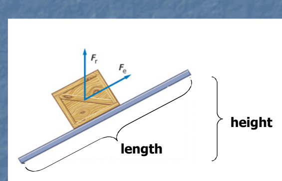

"Let People WAnder When the Party Starts"

## 10.2 Machines

Inclined Plane

Sloped surface used to make lifting easier

$$IMA = \frac{d_e}{d_r} = \frac{l}{h}$$




## 10.2 Machines

"Give me a place to stand and with a **lever** I will **move** the whole **world**."

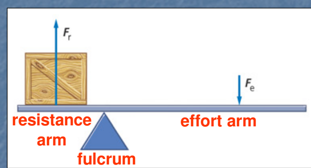
- Archimedes

## Lever

A bar free to move about a pivot point (fulcrum)

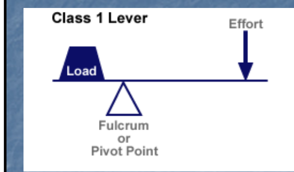
Parts to a lever:

1. effort arm
2. fulcrum
3. resistance arm






Levers are grouped into three classes

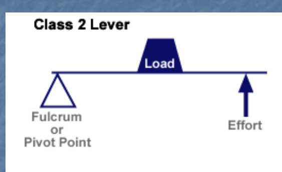



The fulcrum of a first class lever is always located between the effort force and the resistance force.

Opening a paint can with a screwdriver is an example of using a class 1 lever



Levers are grouped into three classes



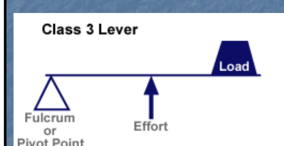

The output force of a second class lever is always located between the input force and the fulcrum.

The input distance is greater than the output distance

A wheel barrow is an example of a class 2 lever



Levers are grouped into three classes




The input force of a third class lever is always located between the fulcrum and the output force

The output distance is greater than the input distance

A broom is a class three lever



## Lever

A bar free to move about a pivot point (fulcrum)

Parts to a lever:

1. effort arm
2. fulcrum
3. resistance arm

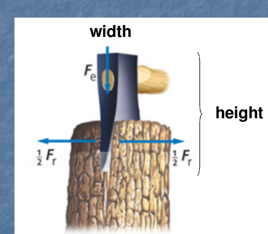

$$IMA = \frac{d_e}{d_r} = \frac{effort\ arm\ length}{resist\ arm\ length}$$



## Wedge

An inclined plane with two sloping surfaces

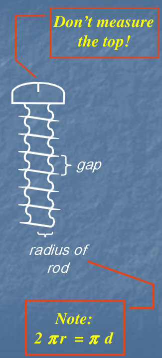
$$IMA = \frac{d_e}{d_r} = \frac{h}{w}$$



## Screw

An inclined plane wrapped around a rod

$$IMA = \frac{d_e}{d_r} = \frac{2\,\pi\, r_r}{l_g}$$



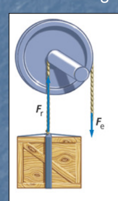

10.2 Machines

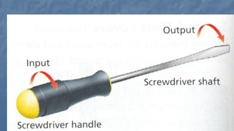
10.2 Machines

## Wheel and Axle

Two wheels of different sizes connected and move together

$$IMA = \frac{d_e}{d_r} = \frac{r_{wheel}}{r_{axle}}$$




Screwdriver is an example of a wheel and axle

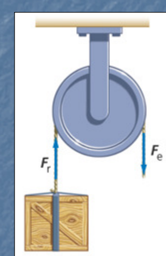
10.2 Machines

## Pulley

A rope that fits into a grooved wheel

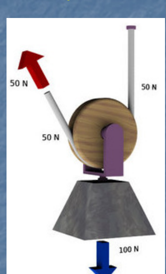
Produce an output force different in size, direction, or both, from that of the input force

The ideal mechanical advantage of a pulley or pulley system is equal to the number of rope sections supporting the load being lifted

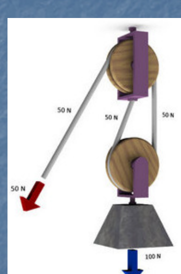



10.2 Machines

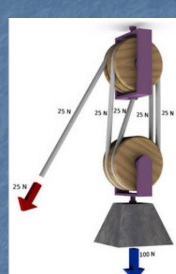
## Pulley




IMA = 2




IMA = 2




IMA = 4

10.2 Machines

In a real machine, not all of the input work is available as output work

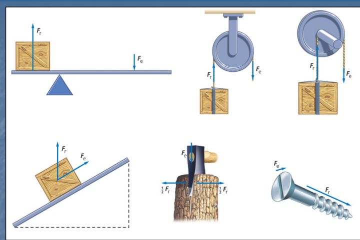
**Efficiency, $e$** – the ratio of the output work to the input work, multiplied by 100

$$e = \frac{W_o}{W_i} \times 100$$

$$\frac{W_o}{W_i} = \frac{F_r d_r}{F_e d_e} \quad \text{and} \quad MA = \frac{F_r}{F_e} \quad and \quad IMA = \frac{d_e}{d_r}$$

$$e = \frac{MA}{IMA} \times 100$$

## 10.2 Machines



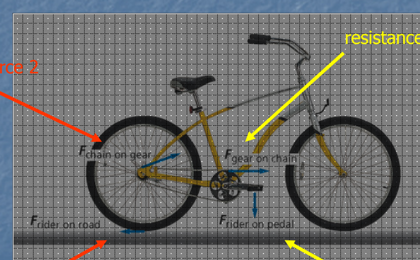
1. List the six simple machines from left to right, starting with the top row
2. What is $F_e$?
3. What is $F_r$?
4. For which of the machines is the output work greater than the input work?
5. After the effort force is exerted on the wedge, describe the direction of the load?
6. What equation would you use to determine the IMA of each machine?

## 10.2 Machines

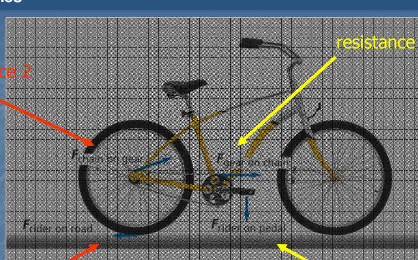
## 10.2 Machines

## 10.2 Machines

compound machine – two or more simple machines linked in such a way that the resistance force of one machine becomes the effort force of the second.




## 10.2 Machines




## 10.2 Machines

## 11.2 Conservation of Energy

From 1985 to 1995 a very popular comic strip was *Calvin and Hobbes*. In it a little boy named Calvin specializes in being bad. His best friend is a toy tiger named Hobbes, who only becomes alive when Calvin is present.

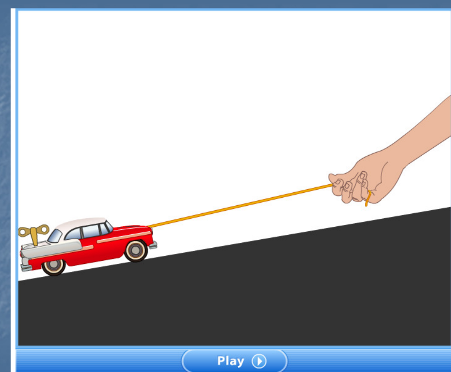
Let us imagine that Calvin has a collection of toy blocks, and every night after he goes to bed his parents pick up the blocks scattered all over the house and put them in the toy box. They notice that every night they end up with the same number of blocks. So they begin thinking about a concept of *conservation of blocks*.

One night after they have collected all the blocks they notice that they are 2 blocks short. But they look out the window and see 2 blocks in the back yard. So they now have 2 terms in their definition of the number of blocks:

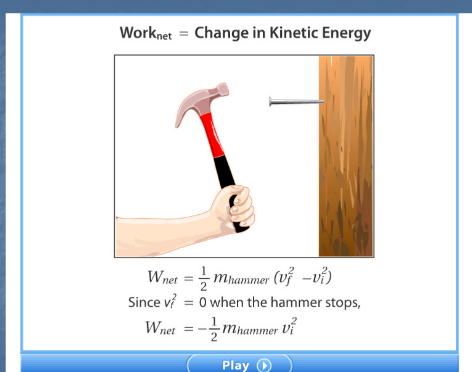
The principle, *conservation of blocks*, is preserved.

A couple of weeks later the number of blocks in the toy box plus the number in the back yard is one less than the previous night. But they notice that Hobbes' stomach is a little distended. Of course they can't cut Hobbes open and see if he has swallowed a block. But they are clever and weigh him. His weight has increased by the weight of one block. Again the principle, *conservation of blocks*, is still preserved

## 10.1 Energy and Work




## 10.1 Energy and Work 11.1 The Many Forms of Energy




## 11.1 The Many Forms of Energy

elastic potential energy – potential energy that may be stored in an object as a result of its change in shape