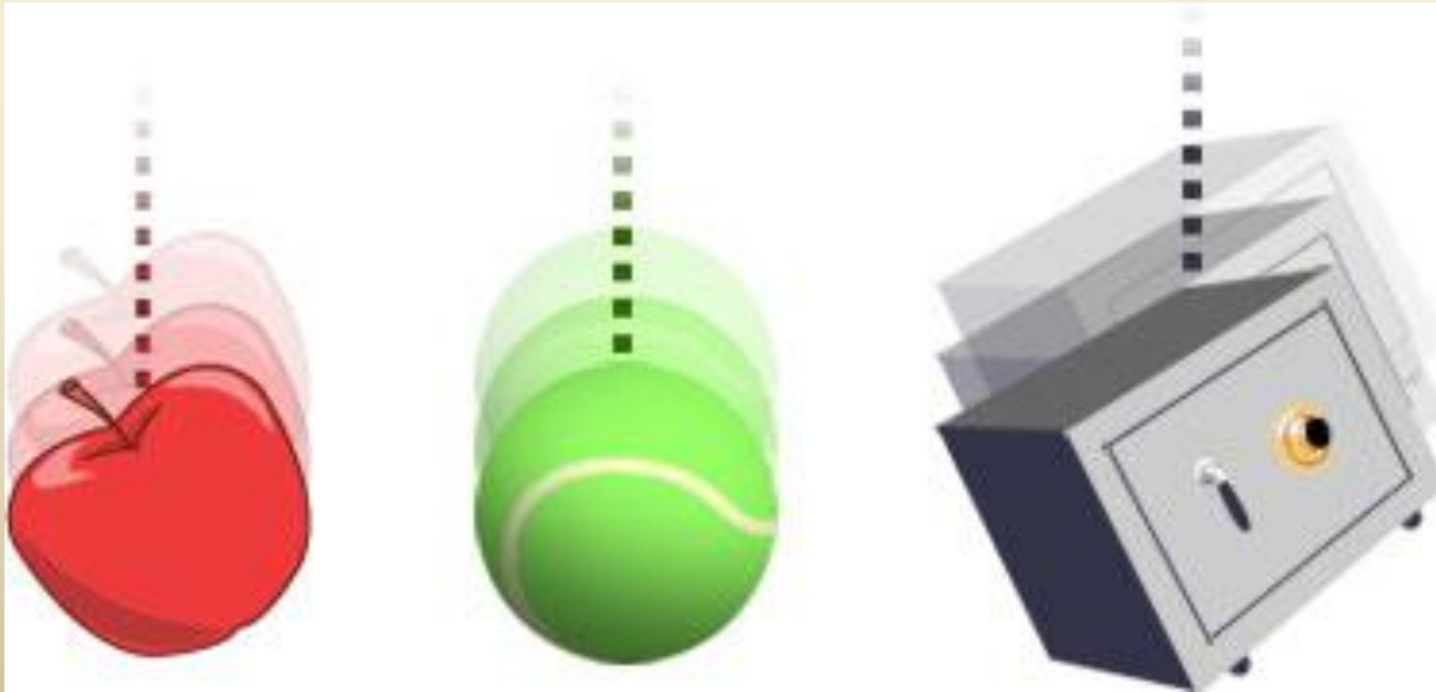
Work & Power

Chapter 14A



Name the major forms of energy.

Each form of energy has:

WARM-UP

Name the major forms of energy.

Chemical energy

Mechanical energy

Electrical energy

Light energy (electromagnetic **radiation**)

Sound energy

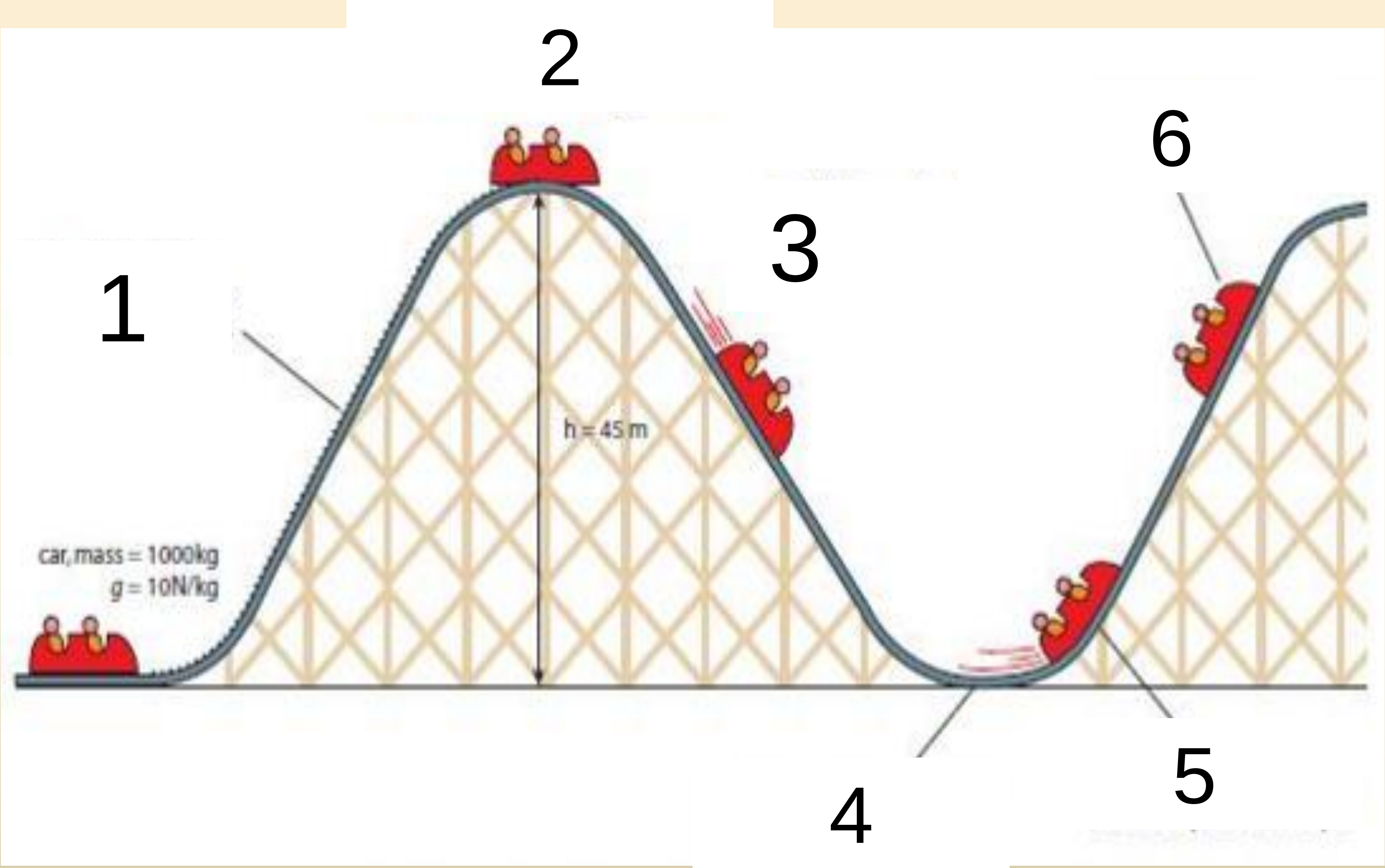
Magnetic energy

Heat energy

Nuclear Energy

Each form of energy has: PE & KE

Describe PE & KE at each point.



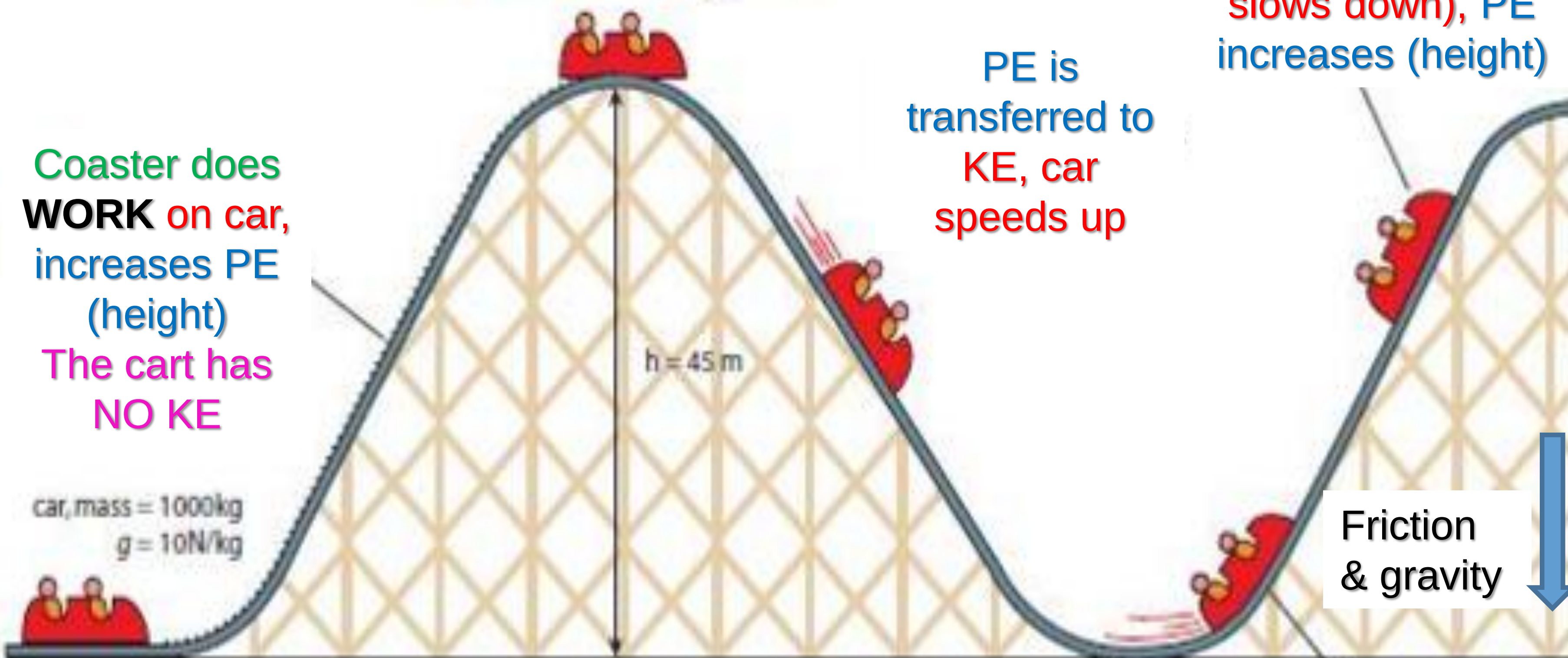
Describe PE & KE at each point.

Highest Point – Max PE, no KE (stopped)

KE decreases (car slows down), PE increases (height)

PE is transferred to KE, car speeds up

Coaster does **WORK** on car, increases PE (height)
The cart has NO KE



Friction & gravity

Max KE velocity, PE = 0 (lowest point)

KE “drives” car up slope

Work

What does the word "work" mean to you?

Is studying work? Is life guarding work? Do people "go to work"?

Focus Questions

1. Define and calculate Work as the force applied to an object over a specific distance (W = f d) in units of joules.
2. Understand how work relates to Potential Energy (mgh) and Kinetic Energy (½ mv^2).
3. Define and calculate Power as the amount of work done per unit of time (P = W/t) in units of Watts.
4. Define and calculate mechanical advantage for the six simple machines (discussed next session).

Work

What does the word "work" mean to you?

Is studying work? Is life guarding work? Do people "go to work"?

General Definition:

Activity involving mental or physical effort done in order to achieve a purpose or result.

Specialized Definition

Mental or physical activity as a means of earning income; employment.

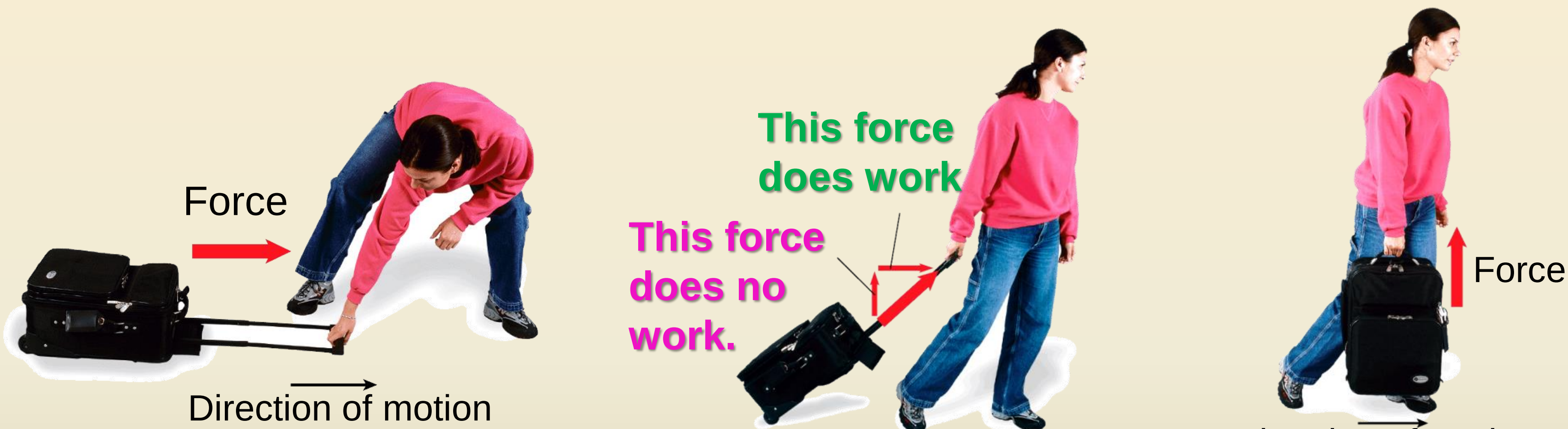
http://somup.com/cFX2bhniR8

(Physical Work Song 3:30)

Work

In science, **work** is the product of force and distance.

- The direction and motion of the force applied determines if work is done or not.



A Force and motion in the same direction
This force does work.

B Part of force in direction of motion

C Lifting force not in direction of motion
NO work is done by the upward force.

Work

$$W = f\ d$$

Work = force x distance

Joules Newton● meters

A force applied on an object and the distance that force operates.

Is Work Done when:

Picking up a book ?

Throwing a ball ?

Holding a barbell over your head ?

Work

$$W = f\ d$$

Work = force x distance

Joules Newton● meters

A force applied on an object and the distance that force operates.

Is Work Done When:

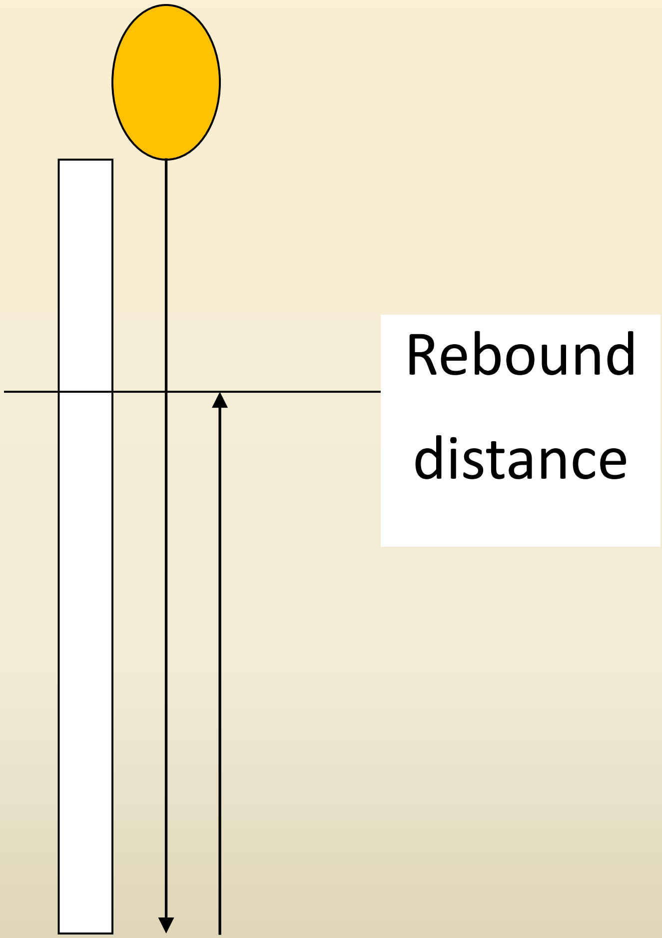
Picking up a book (f = *book's weight*; d = *height lifted*)

Throwing a ball (f = *ball's weight*; d = *distance thrown*)

Holding a barbell over your head yields NO WORK DONE … because no distance is covered by the weight (force).

Work Activity

- Drop a tennis ball from a height of **<u>three</u>** meters vertically.
- Allow it to rebound, and measure the <u>distance of rebound</u> to the nearest centimeter (2.1 m).
- Calculate the maximum amount of work done by the tennis ball when it dropped and when it rebounded.



Work Activity

TRY IT

Mass of the tennis ball: **59 g**

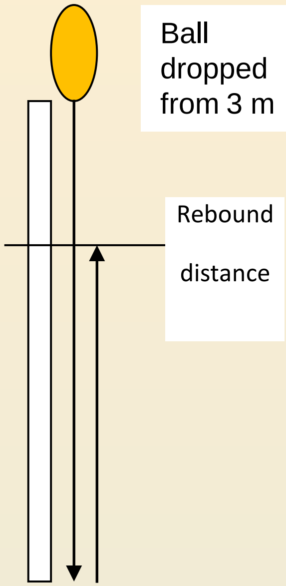
Mass of the tennis ball in kg: ______ **kg**

(g x 1 kg / 1000 g = kg)

Force applied by the super ball in Newtons: ______ **N**

(f = Weight = mg → mass x gravity)

Average Distance the ball rebounded: 2.1 m



$W = f \times d$

Work done when dropped: _____ joules

Work done on rebound: ______ joules

Work Activity

TRY IT

Mass of the tennis ball: **59 g**

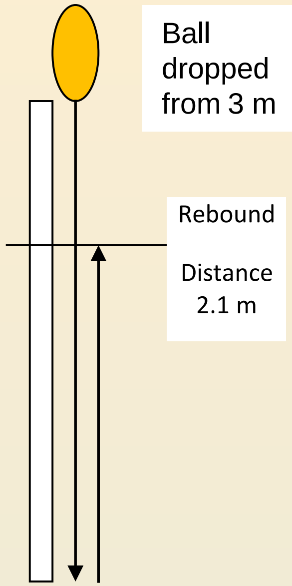
Mass of the tennis ball in kg: **0.059 kg**

(g x 1 kg / 1000 g = kg)

Force applied by the tennis ball in Newtons: **0.59 N**

(f = Weight = mg → mass x gravity)

Average Distance the ball rebounded: 2.1 m



$$W = f \times d$$

Work done when dropped: **1.8** joules

W = 0.59 N x 3.0 m

Work done on rebound: **1.2** joules

W = 0.59 N x 2.1 m

Work Activity

TRY IT

How does the rebound height compare with the original height of the tennis ball?

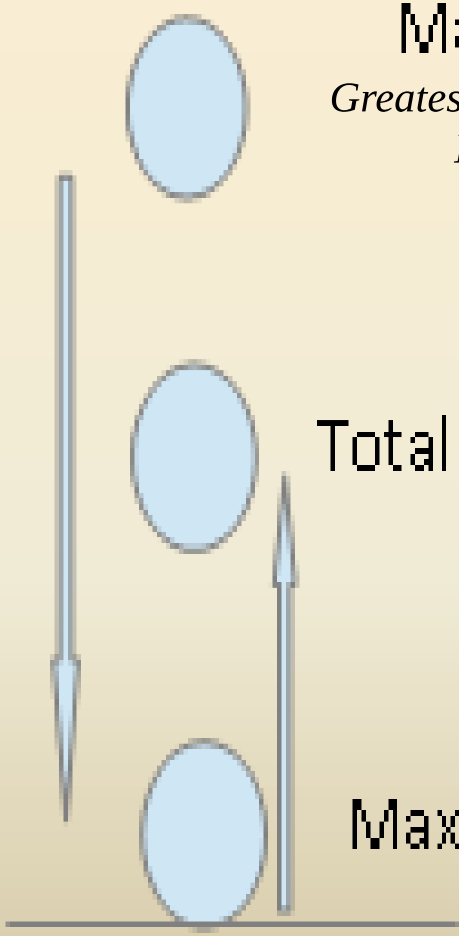
Make a sketch of the tennis ball at its highest point before dropping it, to the point it rebounds off the floor and then to the highest point it rebounded. Label the Maximum PE, the Maximum KE, and where PE = KE.

Work Activity

How does the rebound height compare with the original height of the tennis ball?

It does not bounce back to the original height because of friction.

Make a sketch of the tennis ball at its highest point before dropping it, to the point it rebounds off the floor and then to the highest point it rebounded. Label the Maximum PE, the Maximum KE, and where PE = KE.



POWER

If we do physical work over time, we call this POWER.

Compare a car that does 0 to 60 (mph) in 5 seconds versus 0 to 60 (mph) in 10 seconds. Which is more powerful?

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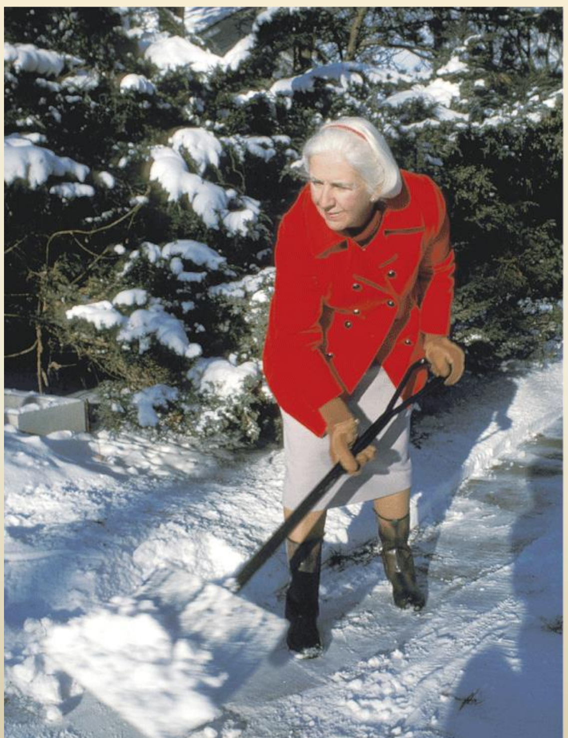
POWER

Because the snow blower can remove more snow in less time, it requires more power than hand shoveling does.



POWER

If we do physical work over time, we call this POWER.

Compare a car that does 0 to 60 (mph) in 5 seconds versus 0 to 60 (mph) in 10 seconds. Which is more powerful?

- *The car that does the most work in the least amount of time. (So, the car that does 0 to 60 mph in 5 seconds)*

Power = Work / time

P = f x d / t

Horsepower (foot pounds per second) … English units

Watts (joules per second) … metric units

POWER

A small motor does 4000 joules of work in 20 seconds. What is the power of the motor in watts?

A

G

E

S

POWER

QUICK CHECK

A small motor does 4,000 joules of work in 20 seconds. What is the power of the motor in watts?

A power (P)

G W = 4,000 j; t = 20 s

E **P = W / t**

S **P = 4000 j / 20 s** **P = 200 watts**

POWER

QUICK CHECK

A 900 N mountain climber scales a 100 m cliff. How much work is done by the mountain climber?

A

G

E

S

How powerful is the mountain climber if he took 3 hours (10,800 s) to climb the mountain?

A

G

E

S

POWER

QUICK CHECK

A 900 N mountain climber scales a 100 m cliff. How much work is done by the mountain climber?

A W (j)

G f = 90 N; d = 100 m

E **W = f x d**

S **W = 900 N x 100 m … W = 90,000 joules**

How powerful is the mountain climber if he took 3 hours (10,800 s) to climb the mountain?

A P (watts)

G W = 90,000 j; t = 10,800 s

E **P = W / t**

S **P = 90,000 j / 10,800 s = 8.3 Watts**

POWER

QUICK CHECK

A person exerts a vertical force of 72 newtons to lift a box to a height of 1.0 meter in a time of 2.0 seconds. How much power is used to lift the box?

A

G

E

S

POWER

QUICK CHECK

A person exerts a vertical force of 72 newtons to lift a box to a height of 1.0 meter in a time of 2.0 seconds. How much power is used to lift the box?

A Power (P in watts)

G f = 72 N; d = 1.0 m; t = 2.0 s

E **P = W / t W = f x d …. P = f x d / t**

S **P = 72 N x 1.0 m / 2.0 s = 36 j/s = 36 watts**

Does the answer make sense?

36 watts is not a lot of power, which seems reasonable considering the box was lifted slowly, through a height of only 1 meter.

Machines

QUICK CHECK

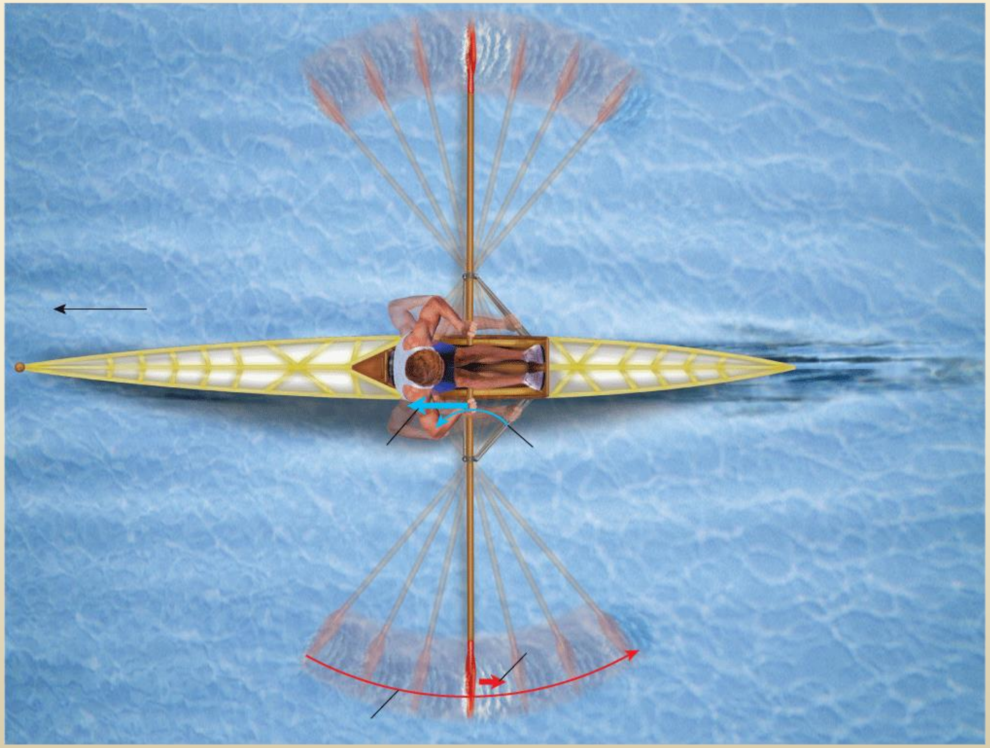
Machines make work easier to do, by changing the size of a force needed, the direction of a force, or the distance over which a force acts.

The man only applies a small force but exerts it over a large distance, becoming a large force (to lift the car) a short distance.

Machines

QUICK CHECK

Machines make work easier to do, by changing the size of a force needed, the direction of a force, or the distance over which a force acts.



The oars of the boat act as machines that increase the distance over which the force acts. Note that the oarsman pulls and the oar pushes (opposite direction).

Machines

There are 6 Simple Machines that can act alone or be combined as a compound machine. They help us do work, making work "easier".

- The actual <u>work output</u> DOES NOT change

You can dig a hole by hand, with a shovel, with a back hoe … same work.

The only way to increase the work output is to increase the amount of work you put into the machine. **You cannot get more work out of a machine than you put into it!**

Machines

Work OUTPUT = F_o x d_o

"resistance" *output force x output distance*

(the work that needs to be done)

Work INPUT = F_i x d_i

"effort" *(what I do)* *input force x input distance*

In which of the following cases is work being done on an object?

a. pushing against a locked door
b. suspending a heavy weight with a strong chain
c. pulling a trailer up a hill
d. carrying a box down a corridor

What is the output distance of a machine that requires 2 newtons of force exerted over 6 meters and whose output force is 4 newtons?

A

G

E

S

QUICK CHECK

In which of the following cases is work being done on an object?

a. pushing against a locked door (no motion)
b. suspending a heavy weight with a strong chain (no motion)
c. **pulling a trailer up a hill**
d. carrying a box down a corridor (force & motion in different directions)

What is the output distance of a machine that requires 2 newtons of force exerted over 6 meters and whose output force is 4 newtons?

A output distance ()

G $f_i = 2$ N; $d_i = 6$ m; $f_O = 4$ N

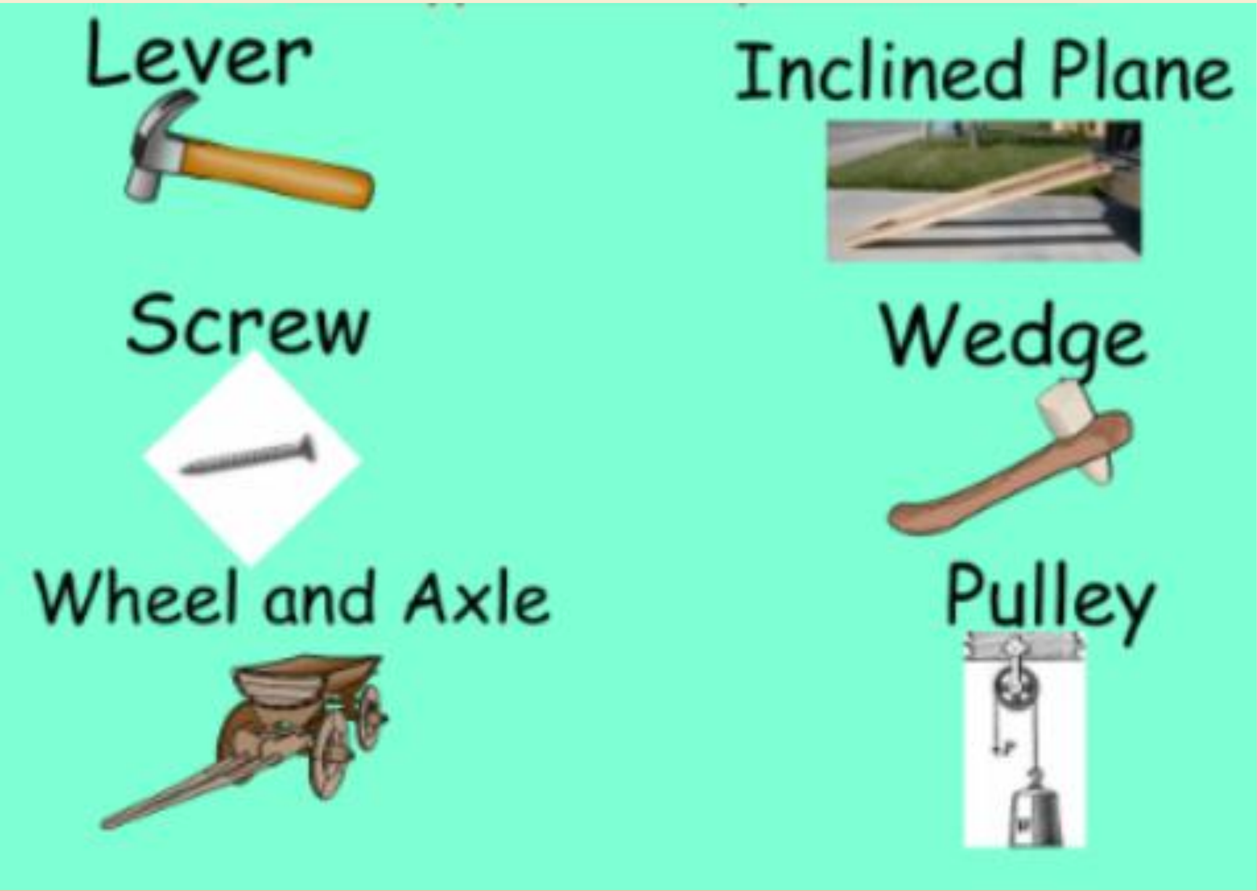
E $W_O = W_i \rightarrow f_i \times d_i = f_O \times d_O$ … solve for d_O

S $d_O = f_i \times d_i / f_O = 2 \text{ N} \times 6 \text{ m} / 4 \text{ N} =$ **3 m**

Simple Machines

6 Simple Machines:

http://somup.com/cFX2qNniWH (3:02)



Simple Machines

Force and distance are inversely proportional, meaning as one increases, the other decreases. For instance, if the force of doing the work is decreased, the distance must increase.

(e.g. wheel chair ramp is much "easier", but much "farther")

Remember: **Work = force x DISTANCE**

Simple Machines

Force and distance are inversely proportional, meaning as one increases, the other decreases. For instance, if the force of doing the work is decreased, the distance must increase.

(e.g. wheel chair ramp is much "easier", but much "farther")

Work = Force x distance

There are TWO forces involved in work:

Input Force, f_i, force needed to do the work on an object (effort force)

Output Force, f_O, the force of the object itself (resistance force) … usually the object's **weight.**

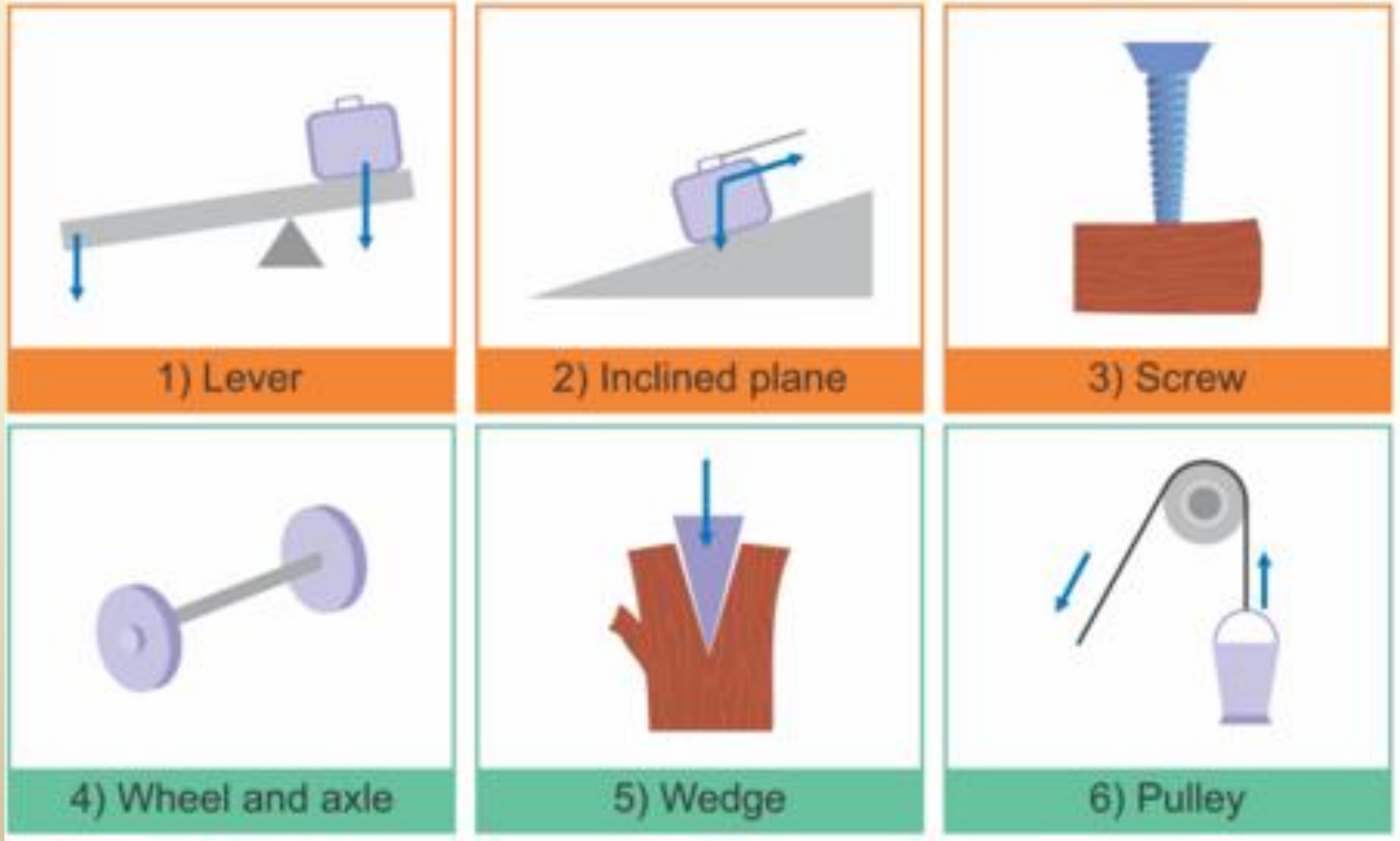
Therefore, there is:

***Input distance**, d_i ,(the distance we apply our effort) and*

***Output distance**, d_O ,(how far the resistance moves)*

Types of Simple Machines

Simple Machines normally DECREASE the effort (input) force or angle … Therefore, they INCREASE the effort (input) distance. But the actual **work DONE or work OUTPUT does NOT change**.



Types of Simple Machines

INCLINED PLANES

– a slanted surface which decreases the effort force

Inclined planes are the most used simple machines.

Examples?

Specialized Planes:

WEDGE – ***an inclined plane that moves … the longer the wedge the less effort force***

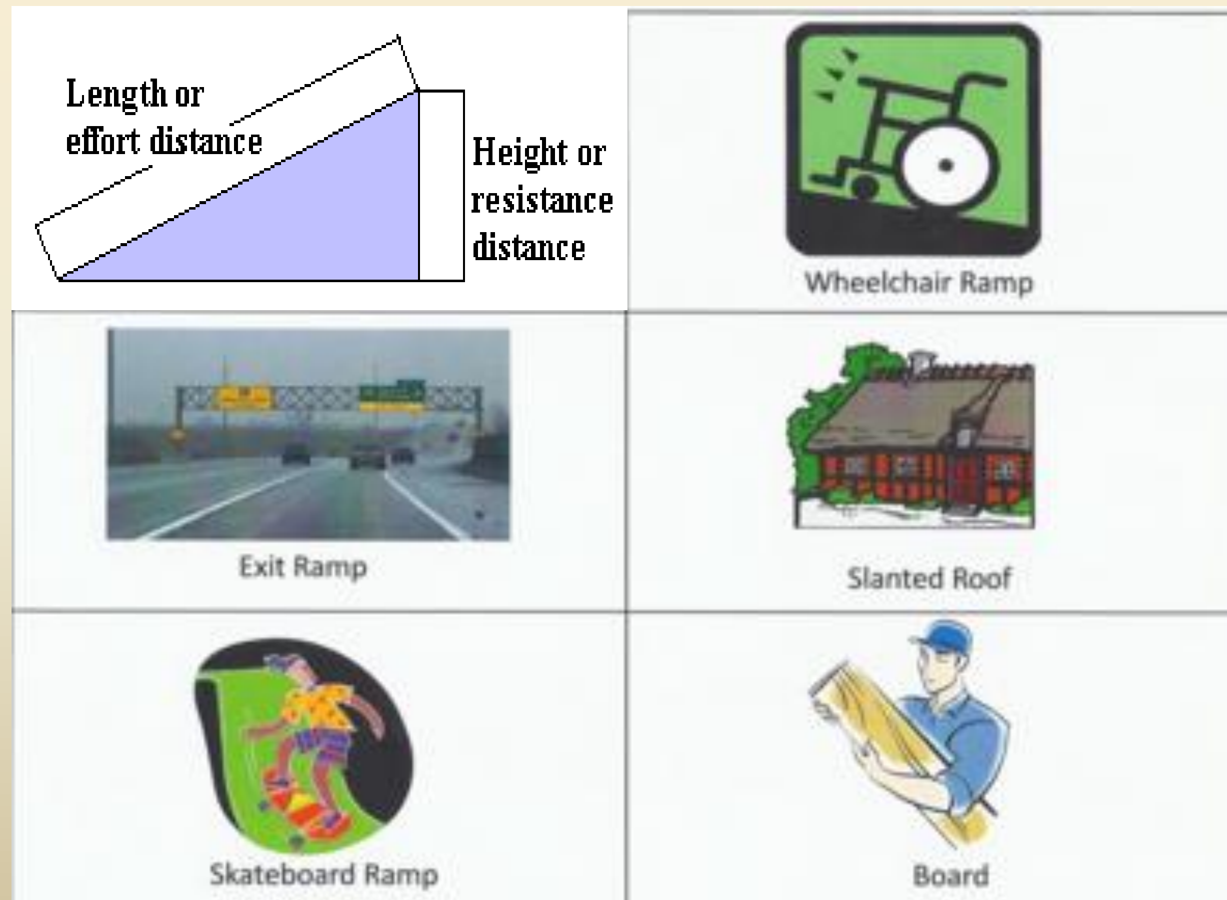
SCREWS – ***an inclined plane wrapped around a cylinder***

Types of Simple Machines

INCLINED PLANES

– a slanted surface which decreases the effort force

Inclined planes are the most used simple machines.



Specialized Planes:

WEDGE – ***an inclined plane that moves … the longer the wedge the less effort force***

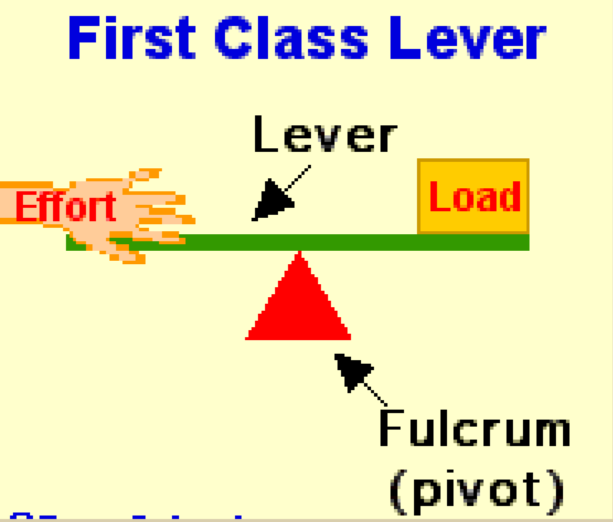
SCREWS – ***an inclined plane wrapped around a cylinder***

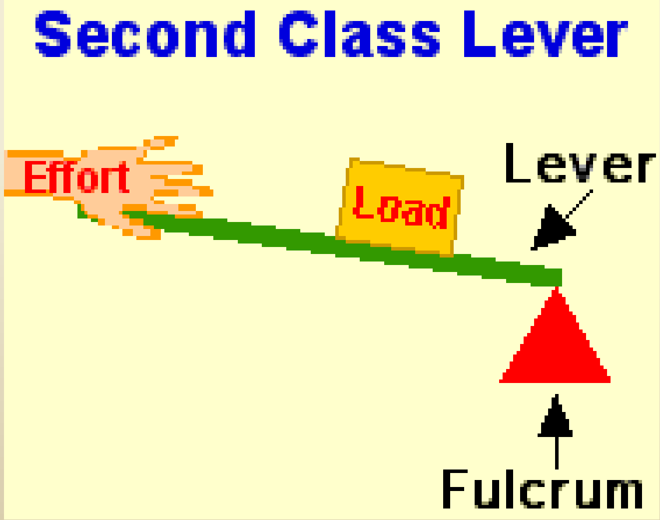
Types of Simple Machines

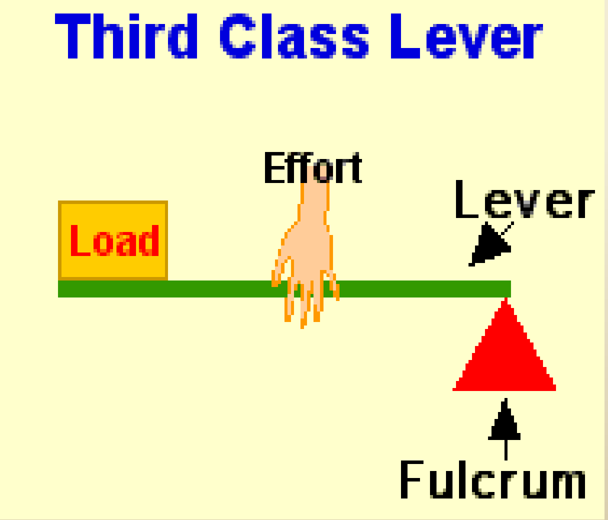
LEVERS

– a rigid bar that is free to pivot, or move about, a fixed point (fulcrum). Second most used simple machine.

There are THREE classes of Levers:

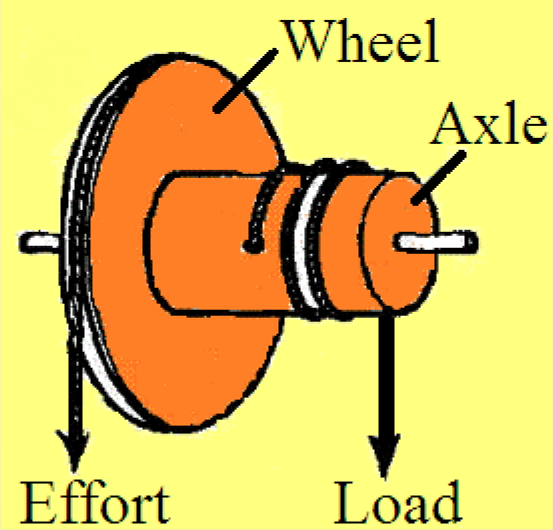






WHEEL AND AXLE

– two circular objects of different sizes (wheel = the largest object; axle = the smaller object)

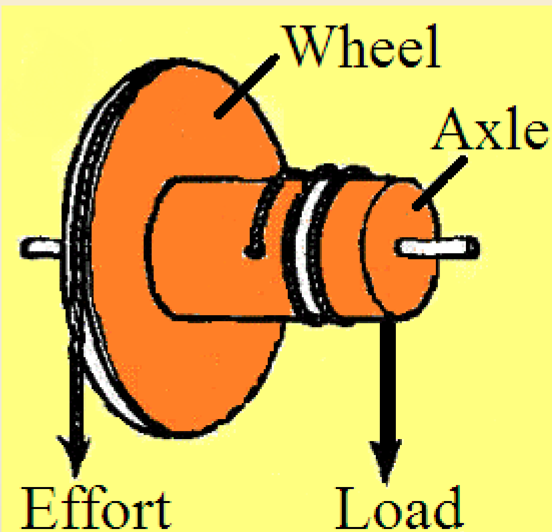


Examples?

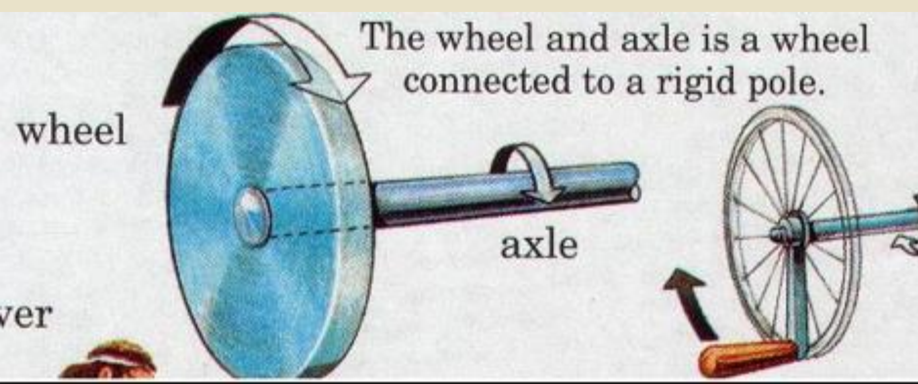
Types of Simple Machines

WHEEL AND AXLE

– two circular objects of different sizes (wheel = the largest object; axle = the smaller object)

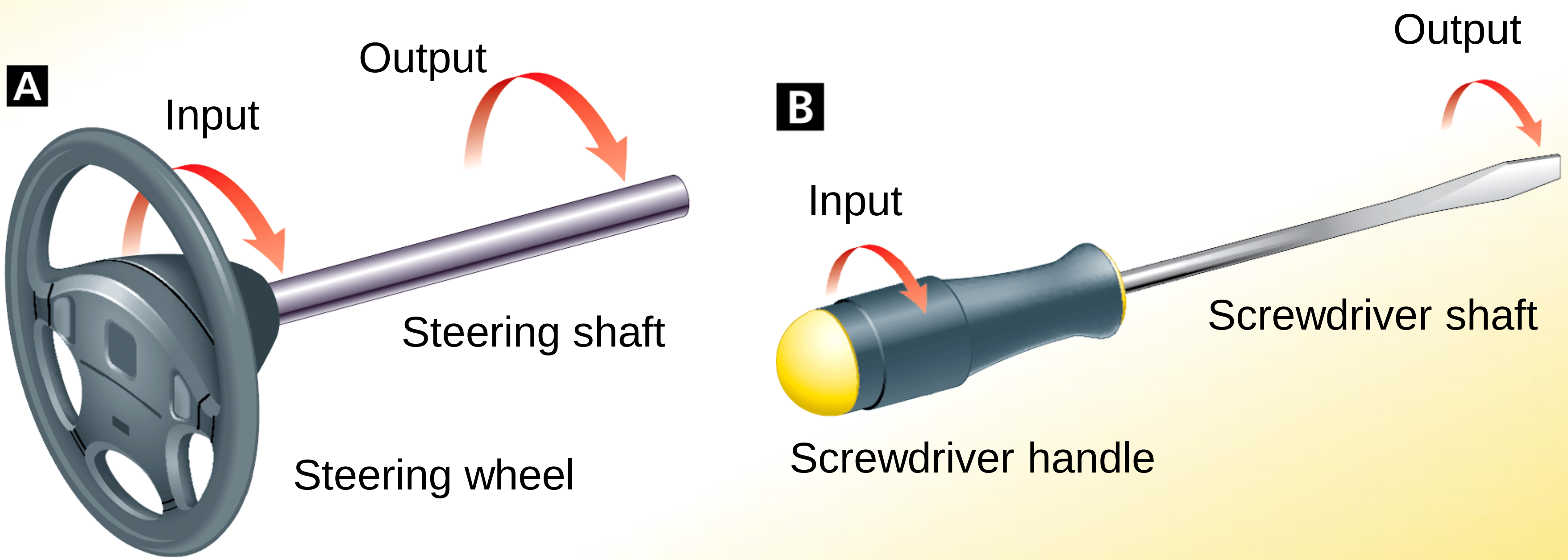


Screwdriver
Ferris wheel
Adjustable wrenches
Steering wheels



Wheel and Axle

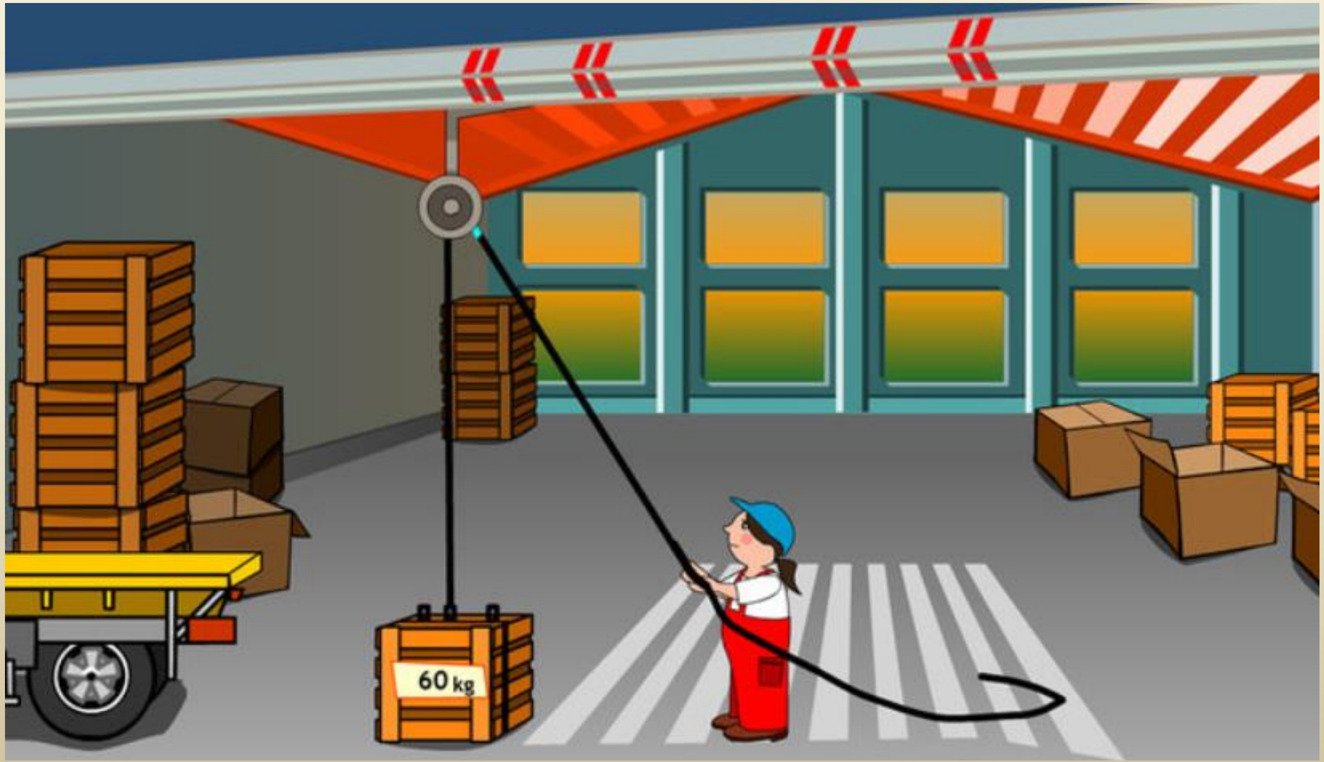
A wheel and axle is a type of simple machine consisting of two disks or cylinders with different radii.



Pulleys

A rope, belt, or chain wrapped around a grooved wheel which can change the direction of a force or the amount of effort force.

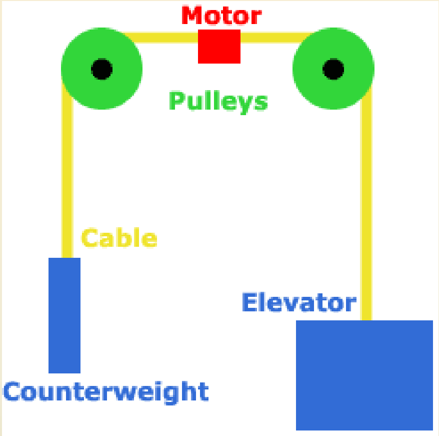
The example below shows a pulley with MA = 1. Why use it?

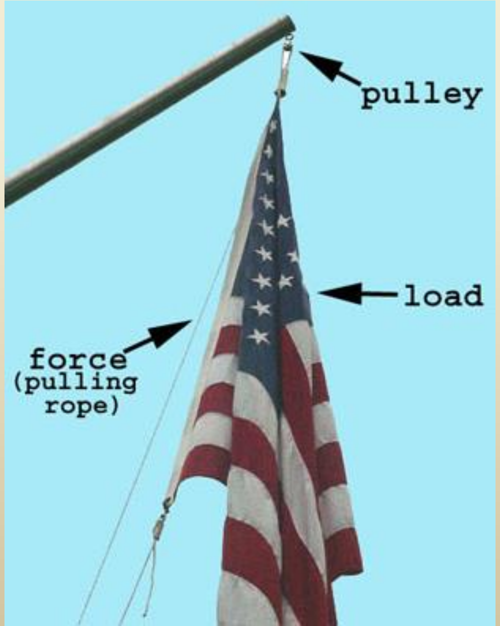


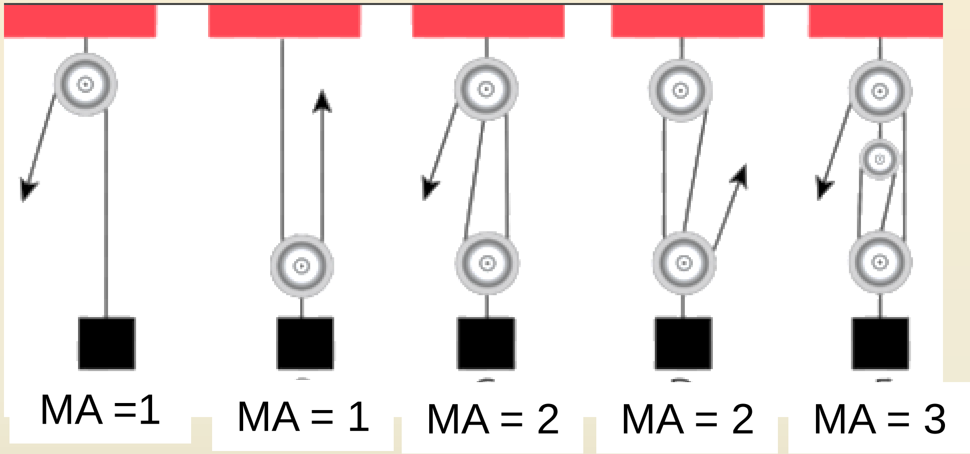
Types of Simple Machines

Pulleys

Mechanical Advantage is defined by # of ropes supporting the resistance.







Wheel & Axle & Pulleys (2:16)

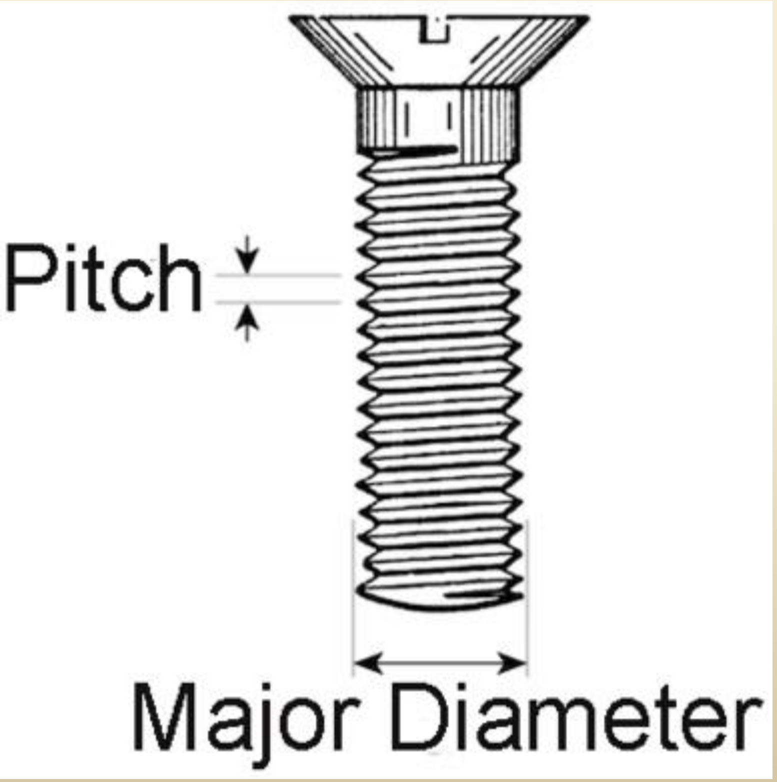
http://somup.com/cFX2qRniWs

Types of Simple Machines

Screw

– an inclined plane wrapped around a cylinder

Examples?



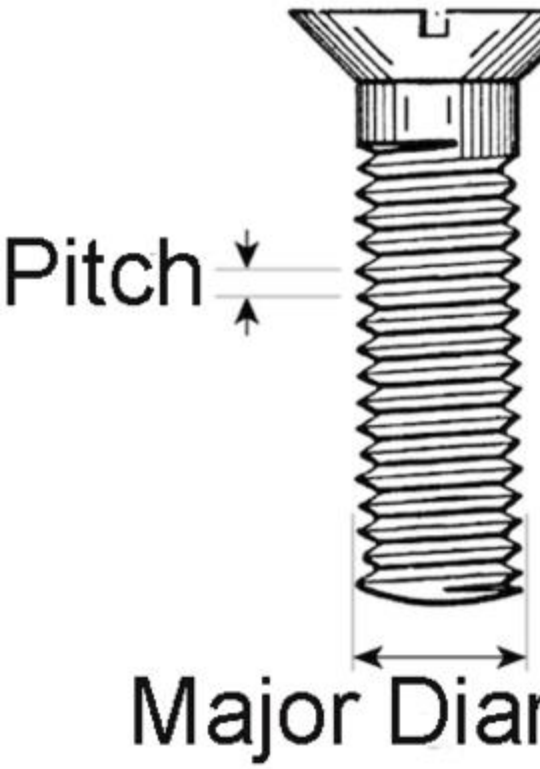
Mechanical Advantage of a screw:

Major Diameter / Pitch

Types of Simple Machines

Screw

– an inclined plane wrapped around a cylinder



Mechanical Advantage of a screw:

Major Diameter / Pitch

Wedge

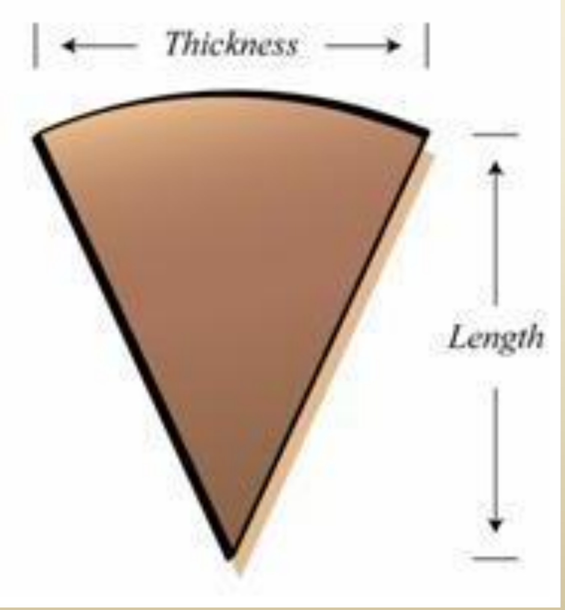
A double inclined plane that moves

… the longer the wedge the less effort force

Examples?

Mechanical Advantage of a wedge:

Length / thickness



Types of Simple Machines

Wedge

A double inclined plane that moves
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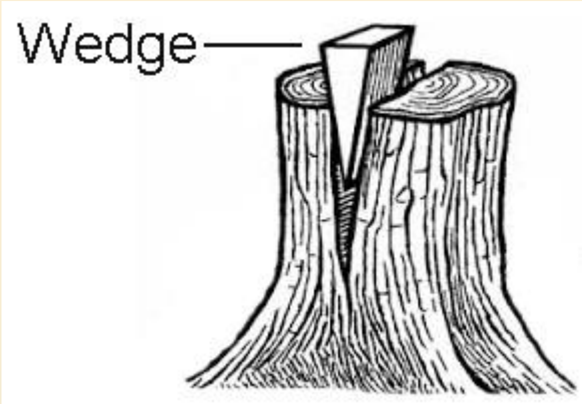
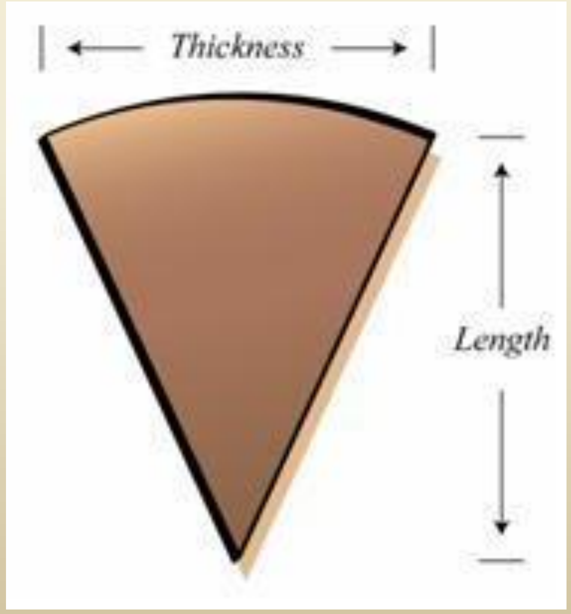


Mechanical Advantage of a wedge: **Length / thickness**



Calculating Power

Math Practice

1. Your family is moving to a new apartment. While lifting a box 1.5 m straight up to put it on a truck, you exert an upward force of 200 N for 1.0 s. How much power is required to do this?

Calculating Power

Math Practice

1. Your family is moving to a new apartment. While lifting a box 1.5 m straight up to put it on a truck, you exert an upward force of 200 N for 1.0 s. How much power is required to do this?

Work = Force × Distance =

200 N × 1.5 m = 300 J

Power = Work/Time = 300 J/1.0 s = 300 W

Calculating Power

Math Practice

2. You lift a book from the floor to a bookshelf 1.0 m above the ground. How much power is used if the upward force is 15.0 N and you do the work in 2.0 s?

Calculating Power

Math Practice

2. You lift a book from the floor to a bookshelf 1.0 m above the ground. How much power is used if the upward force is 15.0 N and you do the work in 2.0 s?

Work = Force × Distance =

15 N × 1.0 m = 15 J

Power = Work/Time = 15 J/2.0 s = 7.5 W

Calculating Power

Math Practice

3. You apply a horizontal force of 10.0 N to pull a wheeled suitcase at a constant speed of 0.5 m/s across flat ground. How much power is used? (*Hint:* The suitcase moves 0.5 m/s. Consider how much work the force does each second and how work is related to power.)

Calculating Power

Math Practice

3. You apply a horizontal force of 10.0 N to pull a wheeled suitcase at a constant speed of 0.5 m/s across flat ground. How much power is used? (*Hint:* The suitcase moves 0.5 m/s. Consider how much work the force does each second and how work is related to power.)

Work = Force × Distance =
10.0 N × 0.5 m = 5 J
Power = Work/Time = 5 J/1.0 s = 5 W

James Watt and Horsepower

Another common unit of power is the horsepower. One **horsepower** (hp) is equal to about 746 watts.

James Watt (1736-1819) was looking for a way to compare the power outputs of steam engines he had designed. Horses were a logical choice for comparison as they were the most commonly used source of power in the 1700s.

James Watt and Horsepower

The horse-drawn plow and the gasoline-powered engine are both capable of doing work at a rate of four horsepower.

Assessment Questions

1. In which of the following cases is work being done on an object?
   a. pushing against a locked door
   b. suspending a heavy weight with a strong chain
   c. pulling a trailer up a hill
   d. carrying a box down a corridor

Assessment Questions

1. In which of the following cases is work being done on an object?
   a. pushing against a locked door
   b. suspending a heavy weight with a strong chain
   c. pulling a trailer up a hill
   d. carrying a box down a corridor

   ANS: C

Assessment Questions

2. A tractor exerts a force of 20,000 newtons to move a trailer 8 meters. How much work was done on the trailer?
   a. 2,500 J
   b. 4,000 J
   c. 20,000 J
   d. 160,000 J

Assessment Questions

2. A tractor exerts a force of 20,000 newtons to move a trailer 8 meters. How much work was done on the trailer?
   a. 2,500 J
   b. 4,000 J
   c. 20,000 J
   d. 160,000 J

W = f x d
W = 20,000 N x 8 m … W = 160,000 joules

Assessment Questions

3. A car exerts a force of 500 newtons to pull a boat 100 meters in 10 seconds. How much power does the car use?
   a. 5000 W
   b. 6000 W
   c. 50 W
   d. 1000 W

Assessment Questions

3. A car exerts a force of 500 newtons to pull a boat 100 meters in 10 seconds. How much power does the car use?
   a. **5000 W**
   b. 6000 W
   c. 50 W
   d. 1000 W

W = f x d
W = 500 N x 100 m … W = 50,000 joules

P = W/t
P = 50,000 N / 10 s… P = 5,000 W