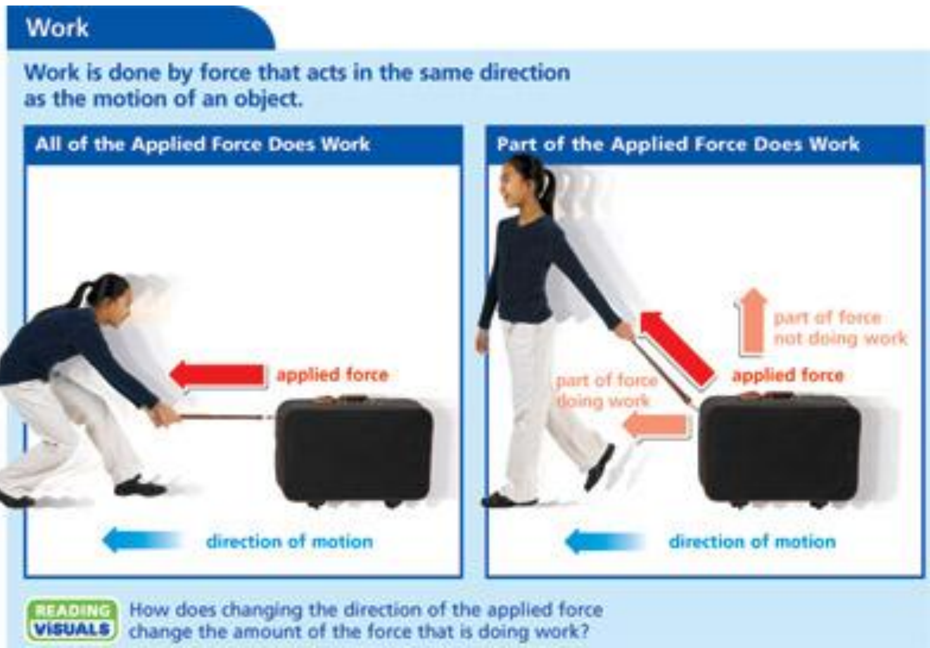
SECTION 1 (PP. 419-424): WORK IS THE USE OF FORCE TO MOVE AN OBJECT.

Georgia Standards: S8P3 – *Students will investigate the relationship between force, mass, and the motion of objects.*; S8CS3a – *Analyze scientific data by using, interpreting, and comparing numbers in several equivalent forms, such as integers, fractions, decimals, and percentages.*

1. **Force is necessary to do work.**
   To do **work** on an object, a force must be applied to the object, and the object must move in the direction of the force, as shown in the first diagram below. Work is done only by the component of the force that acts in the same direction as the movement of the object, as shown in the second diagram.

   Work is done by the force that acts in the same direction as the motion of an object.



Work can be calculated by multiplying the force applied to an object by the distance the object moves, while that force is being applied.

Work = Force • Distance
(W = F • d)

The standard unit of measurement of work is the ***newton-meter***, also called a **joule (J)**. A joule of work is done when a force of one newton moves an object one meter.

Calculating Work

Sample Problem

How much work is done if a person lifts a barbell weighing 450 N to a height of 2 m?

What do you know?	force needed to lift = 450 N, distance = 2 m
What do you want to find out?	Work
Write the formula:	$W = Fd$
Substitute into the formula:	$W = 450\ \text{N} \cdot 2\ \text{m}$
Calculate and simplify:	$W = 900\ \text{N}\cdot\text{m}$
Check that your units agree:	Unit is newton-meter (N·m). Unit of work is joule, which is N·m. Units agree.
Answer:	$W = 900\ \text{J}$

Click to enlarge

Practice the Math

1. If you push a cart with a force of 70 N for 2 m, how much work is done?
2. If you did 200 J of work pushing a box with a force of 40 N, how far did you push the box?

2. **Objects that are moving can do work.**
   Moving objects can do work.
   - The gravitational force of Earth does work on water and other natural materials.
   - People use moving objects to help them do work.

SECTION 2 (PP. 425-433): ENERGY IS TRANSFERRED WHEN WORK IS DONE.

Georgia Standards: S8P2a – *Explain energy in terms of the Law of Conservation of Energy;* S8P2b – *Explain the relationship between potential and kinetic energy.*

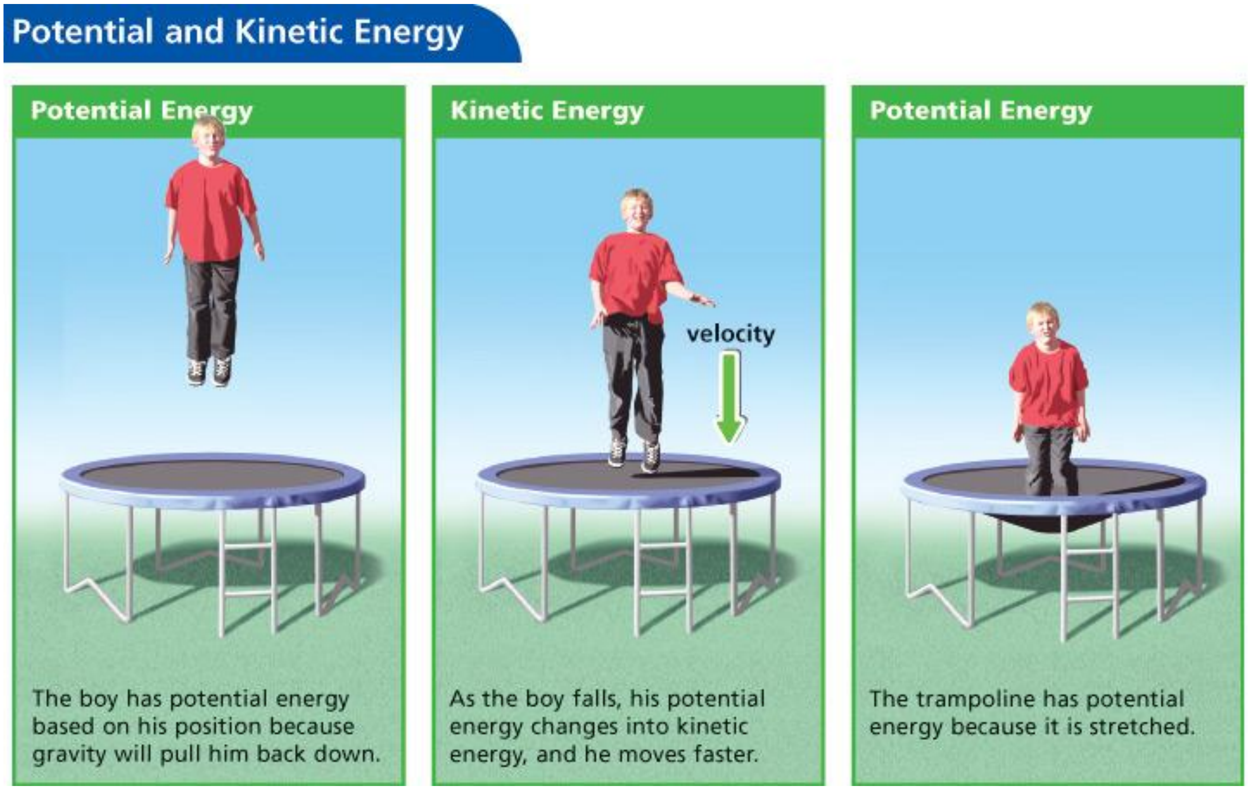
1. **Work transfers energy.**
   When work is done on an object, energy is transferred from whatever is exerting the force to the object.

THINK ABOUT

How is energy transferred?

School carnivals sometimes include dunk tanks. The goal is to hit a target with a ball, causing a person sitting over a tank of water to fall into the water. You do work on the ball as you throw with your arm. If your aim is good, the ball does work on the target. How do you transfer your energy to the ball?

2. **Work changes potential and kinetic energy.**
All forms of energy can be considered in terms of either potential energy or kinetic energy.



- An object has **potential energy** due to its position or shape. Potential energy due to gravity is called ***gravitational potential energy (GPE).*** The GPE of an object can be found by multiplying the object's mass by the acceleration due to Earth's gravity and by the object's height above the ground.

GPE = mass • gravity • height of object
(GPE = mGh)

Note: the acceleration due to Earth's gravity (G) is 9.8 m/s^2

Calculating Potential Energy

Sample Problem

What is the gravitational potential energy of a girl who has a mass of 40 kg and is standing on the edge of a diving board that is 5 m above the water?

What do you know?	mass = 40 kg, gravitational acceleration = 9.8 m/s^2, height = 5 m
What do you want to find out?	Gravitational Potential Energy
Write the formula:	$GPE = mgh$
Substitute into the formula:	$GPE = 40 \text{ kg} \cdot 9.8 \text{ m/s}^2 \cdot 5 \text{ m}$
Calculate and simplify:	$GPE = 1960 \text{ kg m}^2/\text{s}^2$
Check that your units agree:	$\text{kg m}^2/\text{s}^2 = \text{kg} \cdot \text{m/s}^2 \cdot \text{m} = \text{N}\cdot\text{m} = \text{J}$
	Unit of energy is J. Units agree.
Answer:	$GPE = 1960 \text{ J}$

Practice the Math

1. An apple with a mass of 0.1 kg is attached to a branch of an apple tree 4 m from the ground. How much gravitational potential energy does the apple have?
2. If you lift a 2 kg box of toys to the top shelf of a closet, which is 3 m high, how much gravitational potential energy will the box of toys have?

- An object has ***kinetic energy*** when it is moving. Kinetic energy can be calculated by the following formula:

$$\text{Kinetic Energy} = \frac{\text{mass} \cdot \text{velocity}^2}{2}$$

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

Calculating Kinetic Energy

Sample Problem

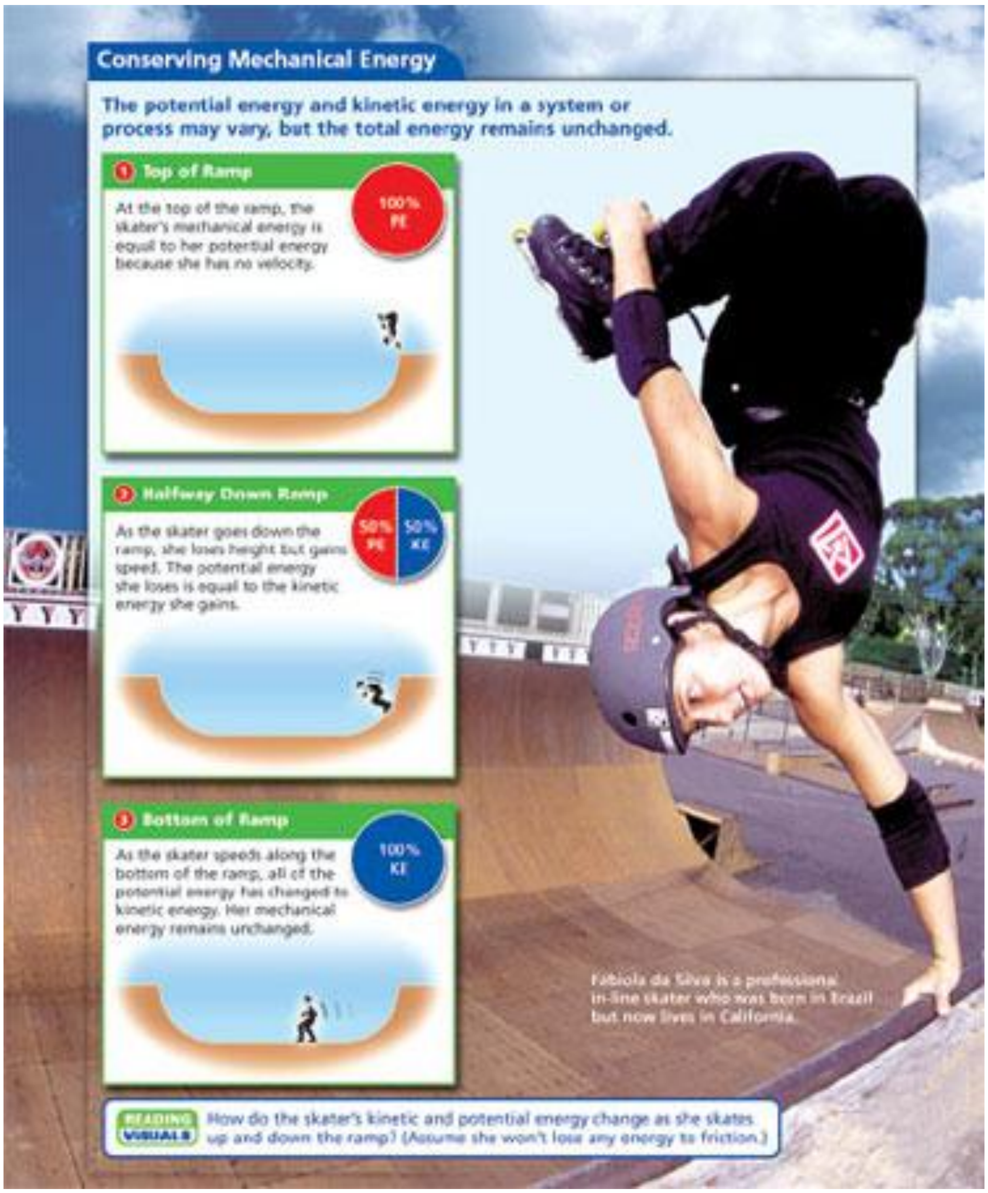
What is the kinetic energy of a girl who has a mass of 40 kg and a velocity of 3 m/s?

What do you know?	mass = 40 kg, velocity = 3 m/s
What do you want to find out?	Kinetic Energy
Write the formula:	$KE = \frac{1}{2} mv^2$
Substitute into the formula:	$KE = \frac{1}{2} \cdot 40 \text{ kg} \cdot (3 \text{ m/s})^2$
Calculate and simplify:	$KE = \frac{1}{2} \cdot 40 \text{ kg} \cdot \frac{9 \text{ m}^2}{\text{s}^2}$
	$= \frac{360 \text{ kg} \cdot \text{m}^2}{2 \text{ s}^2}$
	$= 180 \text{ kg} \cdot \text{m}^2/\text{s}^2$
Check that your units agree:	$\frac{\text{kg} \cdot \text{m}^2}{\text{s}^2} = \frac{\text{kg} \cdot \text{m}}{\text{s}^2} \cdot \text{m} = \text{N}\cdot\text{m} = \text{J}$
	Unit of energy is J. Units agree.
Answer:	$KE = 180 \text{ J}$

Mechanical energy is an object's combined potential energy and kinetic energy. An object with mechanical energy can do work on another object.

3. **The total amount of energy is constant.**
   The law of conservation of energy states that energy is cannot be created or destroyed, although it can change into another form. Common forms of energy are mechanical, thermal, chemical, nuclear, and electromagnetic.

   As a ball rolls down a ramp, the amounts of potential and kinetic energy change. However, the total amount of energy remains the same.



SECTION 3 (PP. 434-441): POWER IS THE RATE AT WHICH WORK IS DONE.

Georgia Standards: S8P2a - *Explain energy in terms of the Law of Conservation of Energy;* S8CS3f – *Use ratios and proportions, including constant rates, in appropriate problems.*

1. **Power can be calculated from work and time.**
   Power is the rate at which work is done. When the power of an object increases, work is done faster. Power can be calculated from work and time:

$$\text{Power} = \frac{\text{Work}}{\text{time}} \qquad P = \frac{W}{t}$$

   - The unit of measurement for power is the **watt**, which is equal to one joule of work done in one second. **1 watt (W) = 1 joule/second (J/s).**
   - Another unit of power is **horsepower**, which is based on how much work a horse can do in one minute. It is used primarily to describe engines and motors. **One horsepower equals 745 watts.**

Calculating Power from Work

Sample Problem

An Antarctic explorer uses 6000 J of work to pull his sled for 60 s. What power does he need?

What do you know? Work = 6000 J, time = 60 s

What do you want to find out? Power

Write the formula: $P = \frac{W}{t}$

Substitute into the formula: $P = \frac{6000\ \text{J}}{60\ \text{s}}$

Calculate and simplify: $P = 100$ J/s = 100 W

Check that your units agree: $\frac{\text{J}}{\text{s}} = \text{W}$

Unit of power is W. Units agree.

Answer: $P = 100$ W

2. **Power can be calculated from energy and time.**
   Power can be thought of as the rate at which energy is transferred over a certain period of time. Power can be calculated from energy as well as work using the formula:

$$\text{Power} = \frac{\text{Energy}}{\text{time}} \qquad P = \frac{E}{t}$$