UNIT 3

ENERGY IS CONSERVED AND ITS TRANSFORMATION AFFECTS LIVING THINGS AND THE ENVIRONMENT.

UNIT 3 OVERVIEW

Topic 3.1: What are the properties of energy?

Topic 3.2: How is energy transformed?

Topic 3.3: How does energy transformation affect global systems?

Topic 3.4: How does energy transformation affect humans?

SCIENCE CONNECTIONS 10: TOPIC 3.1

WHAT IS ENERGY?

TOPIC 3.1 OVERVIEW

- Energy can produce change in a system.
- There are different forms of energy.
- Energy can be transferred or transformed.
- Physical quantities contribute to different forms of energy.

WARM-UP

1. What is energy? What is *not* energy?
2. How do you know if something has energy?
3. Is energy infinite? Why or why not?
4. What are some misconceptions you have heard or seen about energy? Why do you think these misconceptions exist?

CONCEPT 1: ENERGY CAN PRODUCE CHANGE IN A SYSTEM

- There are different forms of energy that exist.
- These forms of energy can be transferred to an object or transformed into another form of energy.

ENERGY AND SYSTEMS

In physics (and all science, really) we need to define the system we are studying because it is impossible to study everything at once.

ENERGY AND SYSTEMS

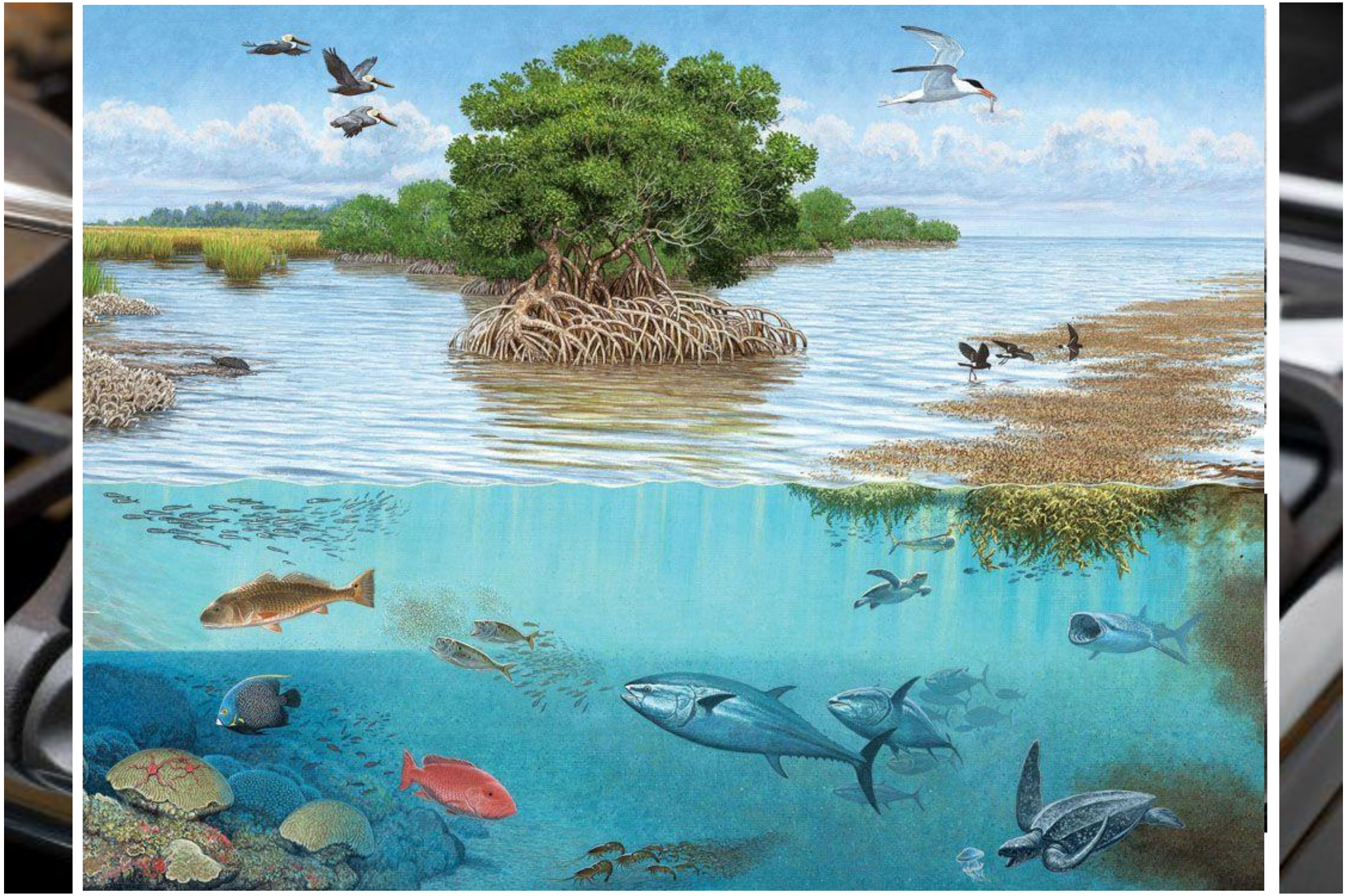
System: anything that is under observation; is defined by the observer

Surroundings: anything that is not part of a system

Universe = system + surroundings

PRACTICE

Identify the system and surroundings shown in each of the following:



DISCUSSION QUESTIONS

1. a) Why can it be a challenge to observe energy directly?

   b) How can this challenge be overcome?

2. a) Describe a system that could be applied to your classroom.

   b) What makes up the surroundings of the system you defined?

CONCEPT 2: THERE ARE DIFFERENT FORMS OF ENERGY.

REVIEW: SCIENCE 9 ELECTRICITY UNIT

1. What types of energy were discussed in grade 9 (or in past science studies)?
2. A basic circuit has different components, including: battery (source), wire, and load. How is energy associated with circuits and electricity?

CONCEPT 2: THERE ARE DIFFERENT FORMS OF ENERGY.

There are two main types of energy:

1) **Kinetic energy:** the energy of motion
2) **Potential energy:** the stored energy of an object as a result of its condition or its position

TYPES OF KINETIC ENERGY

1) Mechanical kinetic energy: energy of an object that is in motion

2) Radiant energy: energy of electromagnetic waves from an energy source

3) Thermal energy: energy of random motion of particles in a substance

CONCEPT 2: THERE ARE DIFFERENT FORMS OF ENERGY.

p. 203 Kinetic energy

TYPES OF KINETIC ENERGY

4) Sound energy:

energy of vibrations of particles

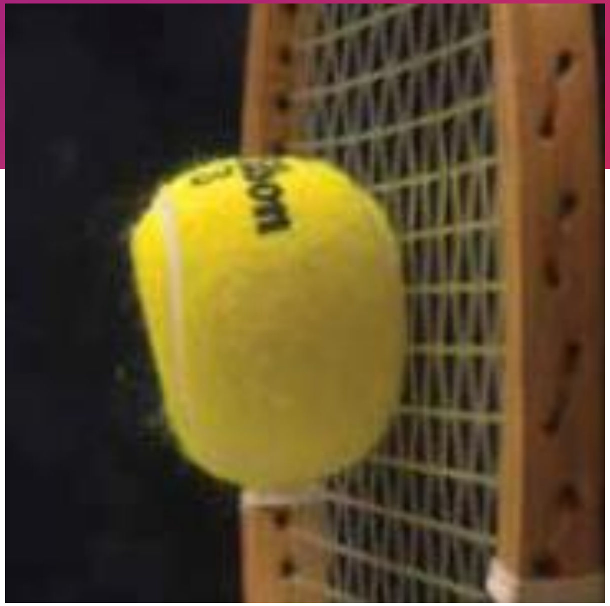
5) Electrical kinetic energy:

energy of electrons moving along a wire

CONCEPT 2: THERE ARE DIFFERENT FORMS OF ENERGY.

p. 203 Kinetic energy

TYPES OF POTENTIAL ENERGY



1) Elastic potential energy: energy stored in a stretched or compressed object

2) Chemical potential energy: energy stored in chemical bonds

3) Gravitational potential energy: energy due to the position of an object

p. 204 Potential energy

TYPES OF POTENTIAL ENERGY

4) Nuclear energy: energy stored in the nucleus of an atom

5) Electrical potential energy: energy is stored by a separation of positive and negative charges

6) Magnetic potential energy: energy stored in a magnetic field

https://circuitdigest.com/article/different-types-of-batteries

DISCUSSION QUESTIONS

1. Use a Venn diagram to compare kinetic and potential energy.

2. Give one example of each of the following:

   a) a form of kinetic energy

   b) a form of potential energy

   c) a form of energy that has both kinetic and potential energy

CONCEPT 3: ENERGY CAN BE TRANSFERRED OR TRANSFORMED.

Law of conservation of energy:

- Energy cannot be created or destroyed
- Energy can be **transformed** from one form to another, or **transferred** from one object to another

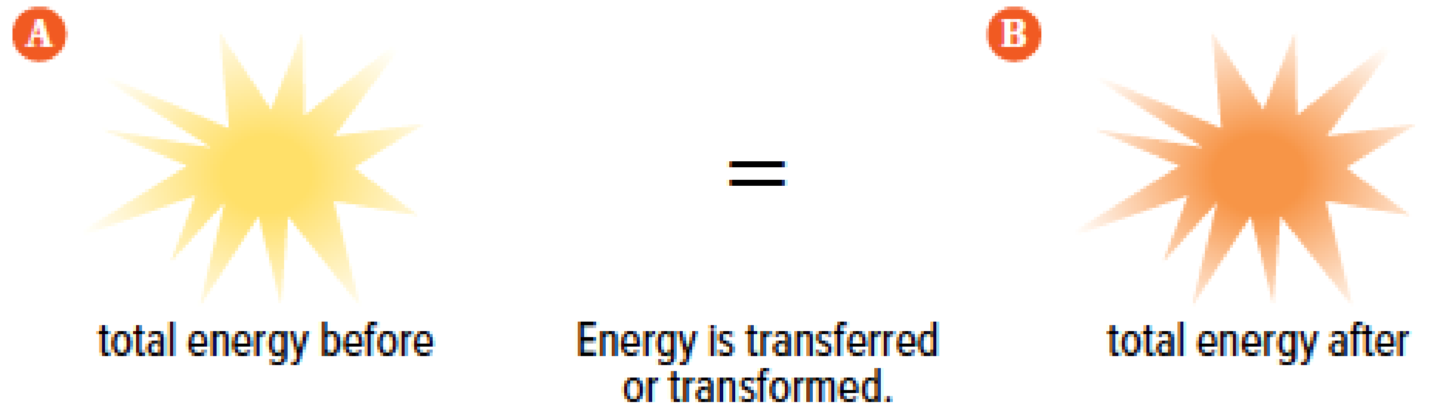
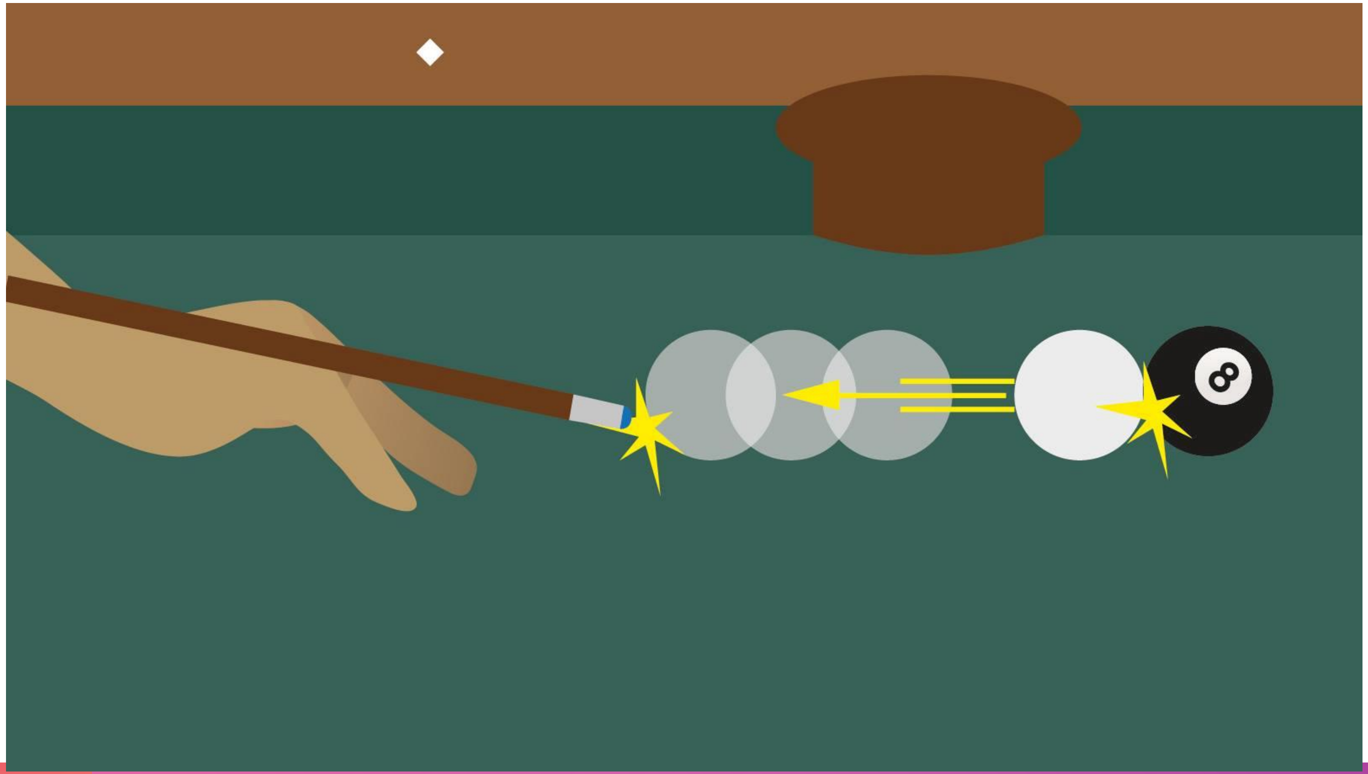


Figure 3.4: According to the law of conservation of energy, energy present before energy transfer or transformation (A) is equal to energy present afterward (B). The form of energy may change (the shapes differ in colour), but the amount of energy remains equal (the size of the shape is the same).

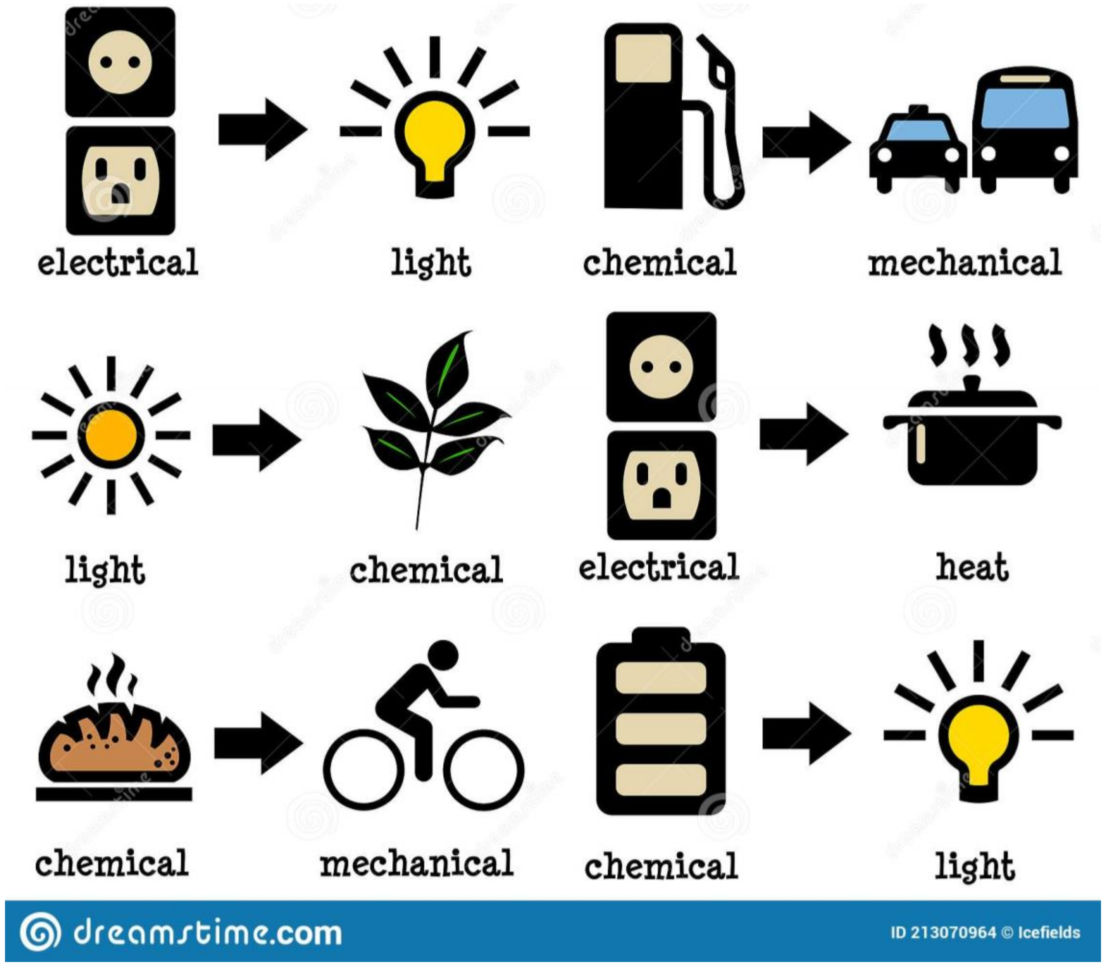
ENERGY TRANSFER

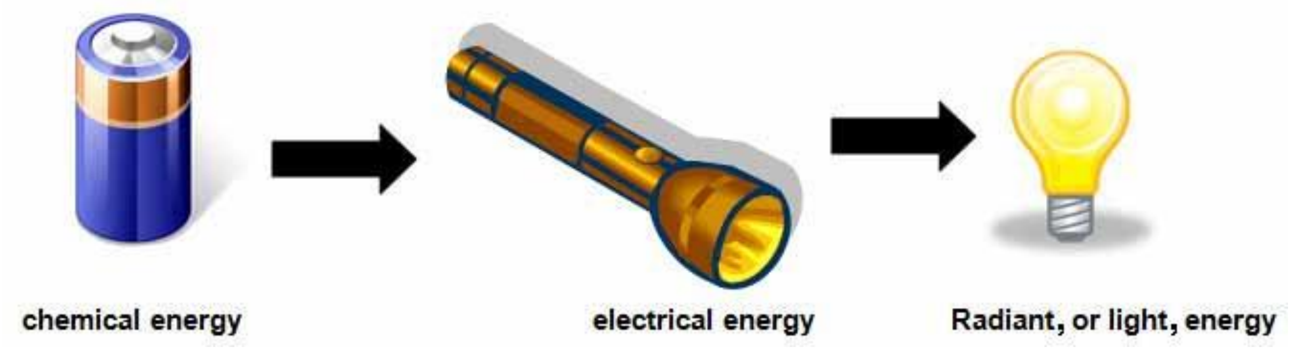
- When energy is *transferred*, it stays in the same form.
  - Example: mechanical kinetic energy transferred from the stick to the ball



ENERGY TRANSFORMATION

- When energy is *transformed*, it changes into another form of energy





ENERGY TRANSFORMATION

- Energy transformation is not 100% efficient. Some of the energy is converted into a form that is not useful (e.g. heat, sound) and it is considered to be "lost."

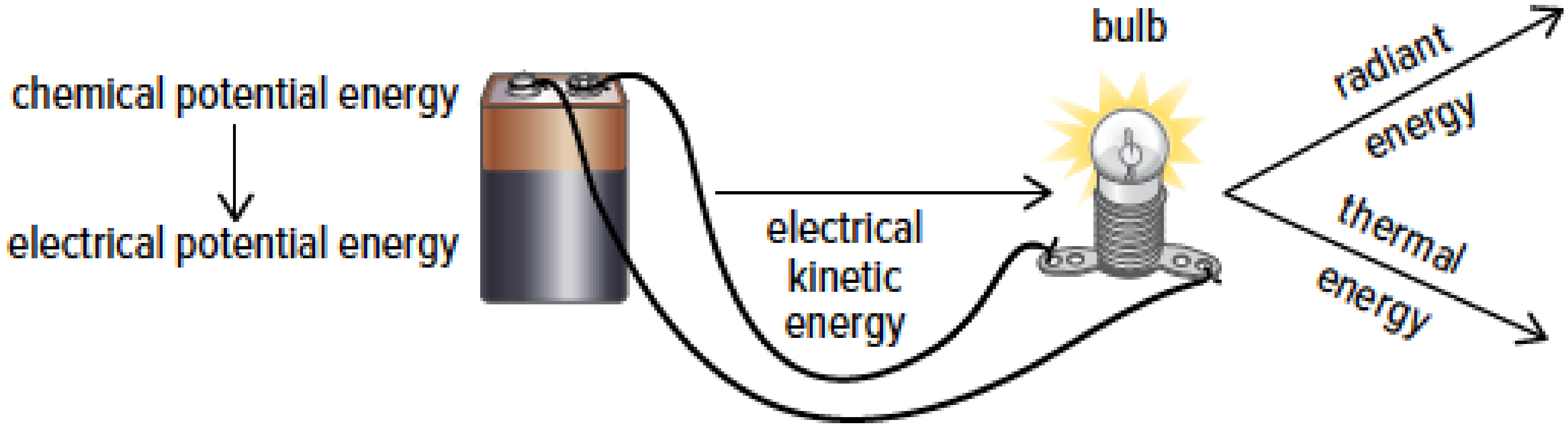
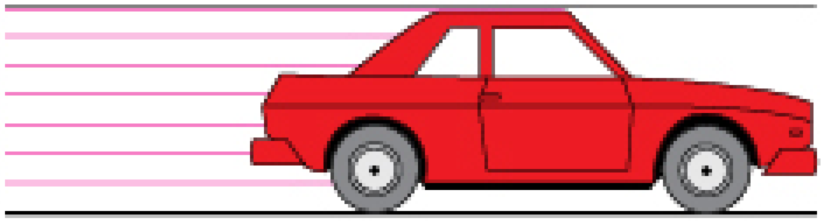
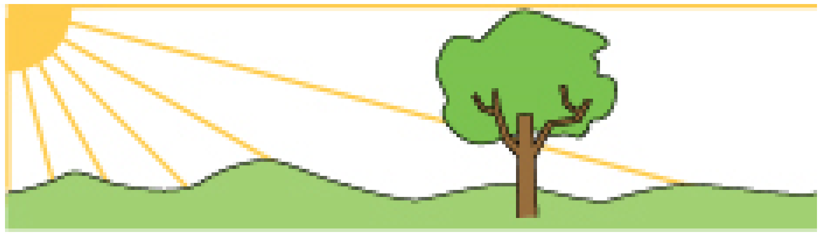


Figure 3.5: Energy is both transformed and transferred in this image, but it is never destroyed. The result is that a useful task is carried out.

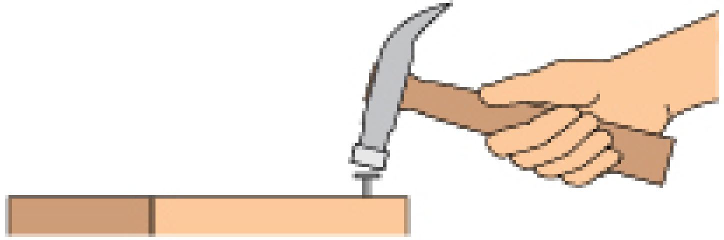
Changing forms of energy



An automobile engine changes chemical energy to mechanical and heat energy.

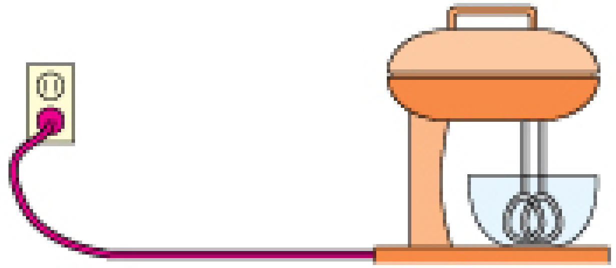


A tree changes radiant energy to chemical energy.

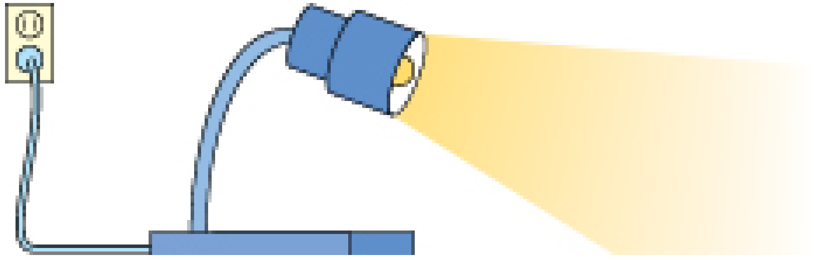


Hammering a nail changes mechanical energy to deformation and heat energy.

A thermonuclear reaction changes nuclear energy to radiant and heat energy.

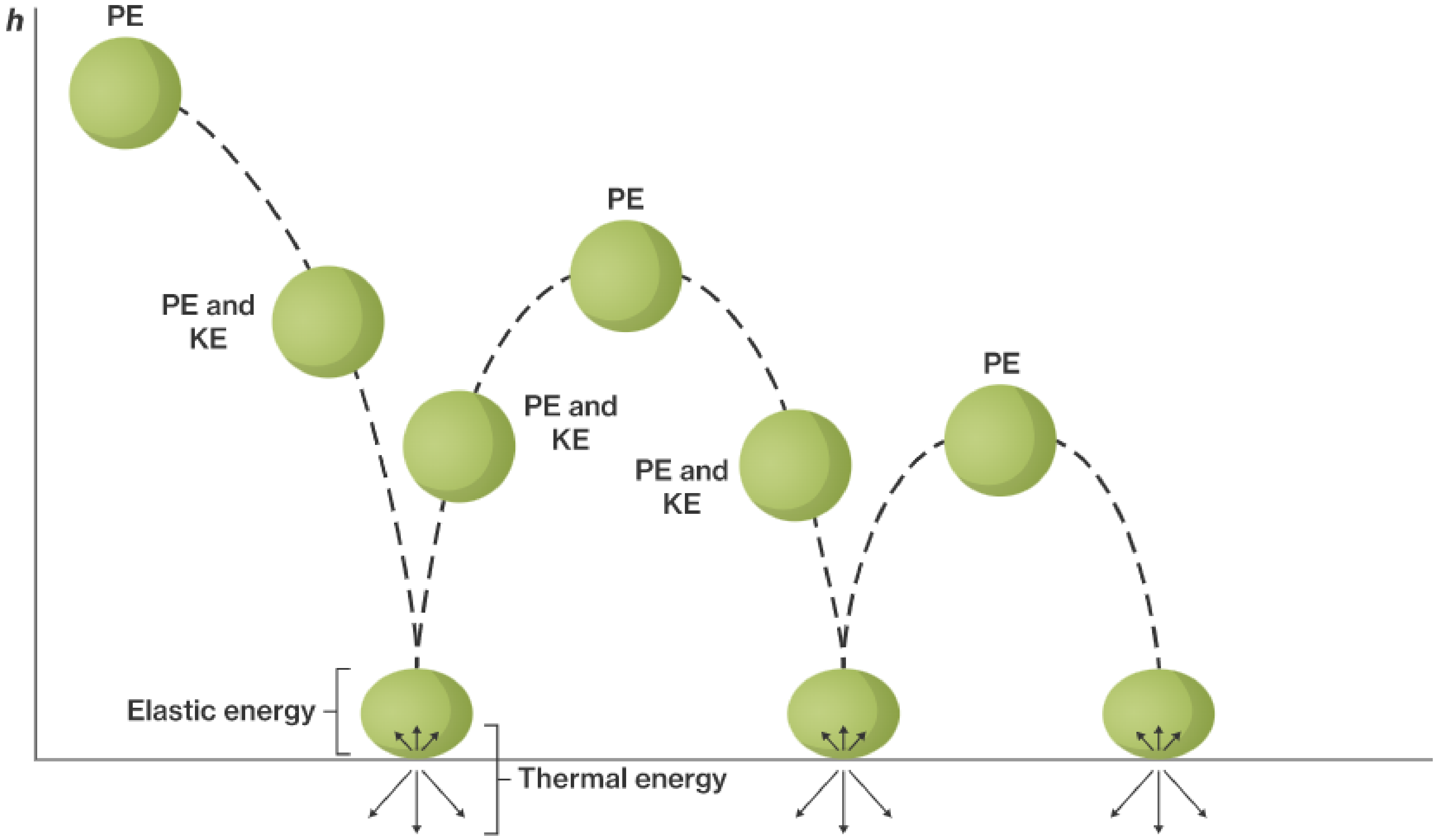


An electric mixer changes electrical energy to mechanical and heat energy.



A lamp changes electrical energy to radiant and heat energy.

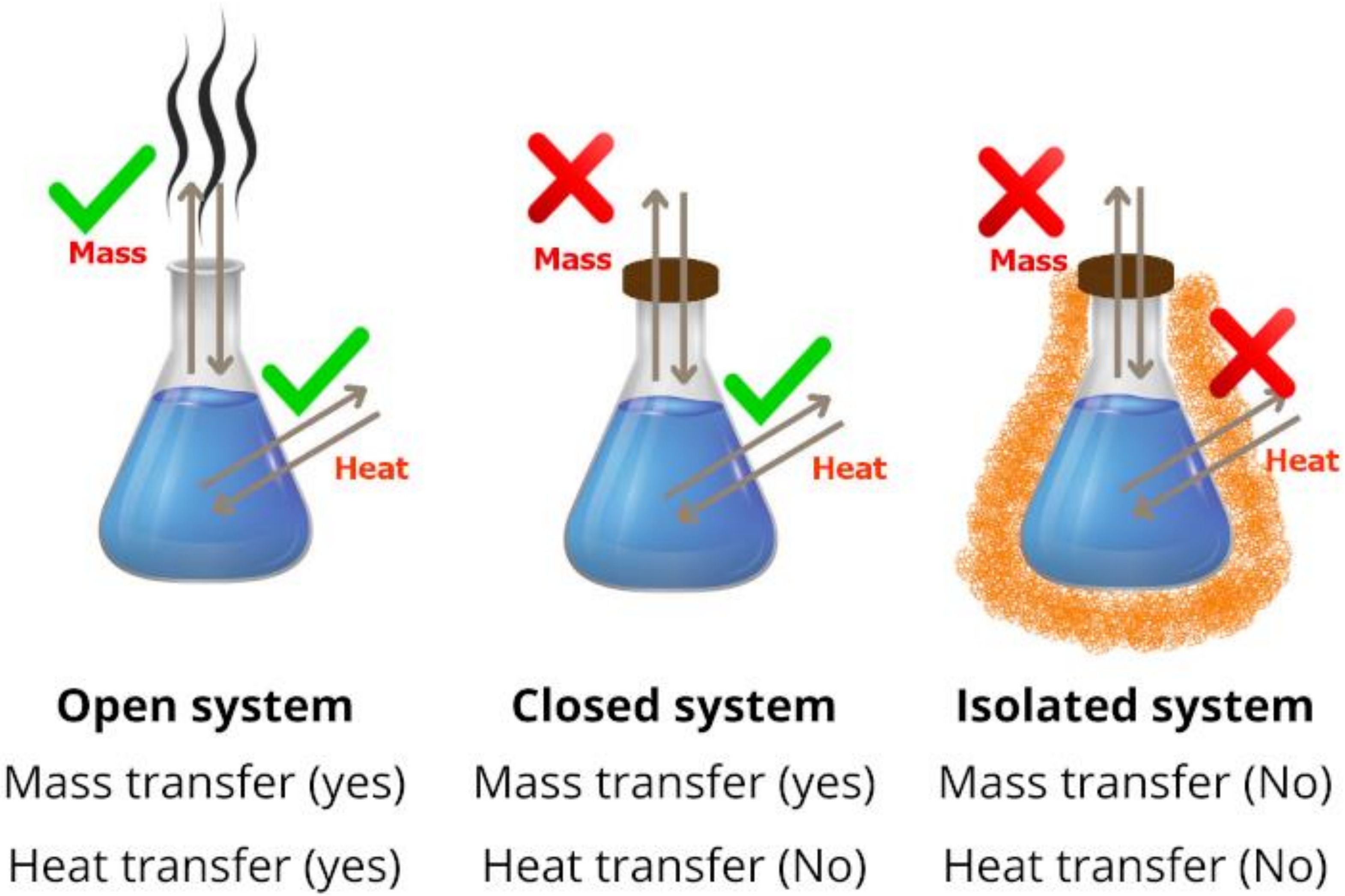
https://www.coursehero.com/sg/general-chemistry/energy/



A ball released from a height, *h*, will convert potential energy to kinetic energy as it falls toward Earth. At the point of impact, most of the kinetic energy is converted to elastic energy, which causes the ball to bounce back up, but some kinetic energy is converted to thermal energy.

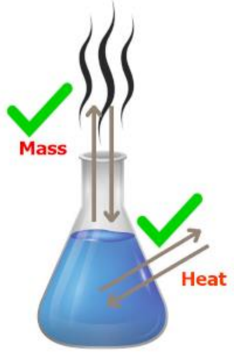
WHAT ENERGY TRANSFORMATIONS DO YOU OBSERVE?

TYPES OF SYSTEMS

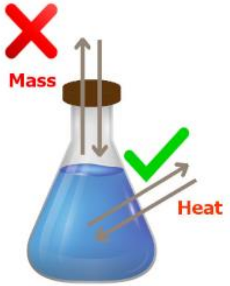


TYPES OF SYSTEMS

1) <u>**Open system**</u>: a system that can exchange both **energy and matter** with its surroundings



2) <u>**Closed system**</u>: a system that can exchange **only energy but not matter** with its surroundings



3) <u>**Isolated system**</u>: a system that **cannot exchange energy nor matter** with its surroundings

DISCUSSION QUESTIONS

1. Describe the law of conservation of energy.

2. How do energy transfer and transformation differ? How are they similar?

3. Use an example from your everyday life to show how you could change an open system to

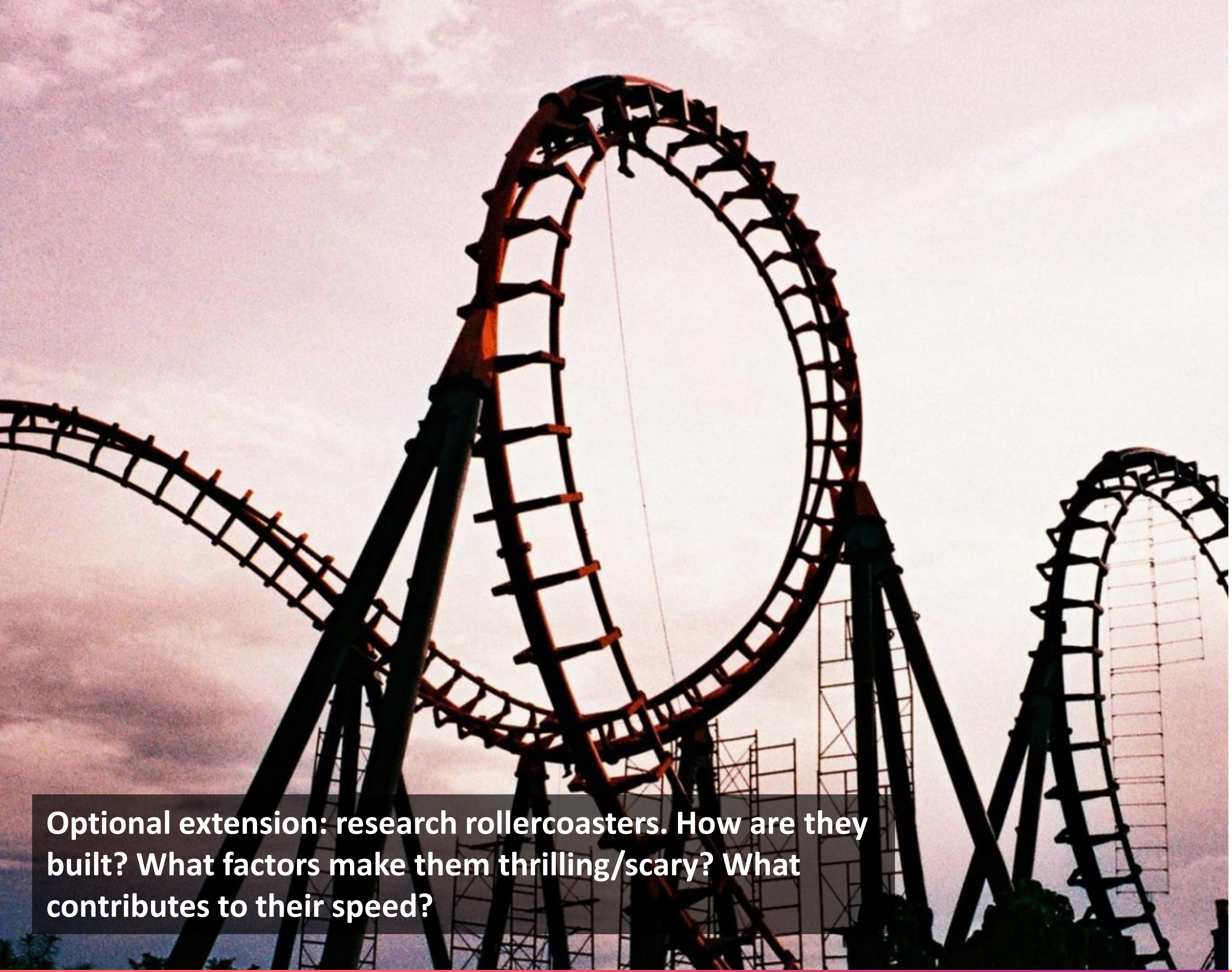
   a) a closed system

   b) an isolated system

ACTIVITY: COASTER DESIGN

- Design a rollercoaster on the piece of paper provided.
- **Goal: to make the fastest possible rollercoaster.**

https://www.inc.com/amy-vetter/how-to-get-off-emotional-roller-coaster-of-highs-lows-in-business.html



ACTIVITY: COASTER DESIGN

- Compare your rollercoaster to another group's. Which will go faster? How do you know?
- What elements increase the speed of a rollercoaster ride?

https://www.inc.com/amy-vetter/how-to-get-off-emotional-roller-coaster-of-highs-lows-in-business.html

CONCEPT 4: PHYSICAL QUANTITIES CONTRIBUTE TO DIFFERENT FORMS OF ENERGY.

- Physical quantities (e.g., height, mass, speed, etc.) can affect different forms of energy.
- For example, the higher the object is above the ground, the more gravitational potential energy it has.

A NOTE ON CALCULATIONS

To use these formulas, the **units must be correct**. The Joule is *defined* as $\frac{kg \cdot m^2}{s^2}$, so if your units are incorrect, your answer will be incorrect as well.

Tips:

- Always write units when you are showing your work. Keep rewriting the units the whole way through. Laziness = mistakes!
- Some unit conversions (e.g. from g to kg) may be necessary before you get your final answer.

UNIT CONVERSION TUTORIAL

Question: Convert 52 g to kg.	
1. Determine the conversion factor.	$1kg = 1000g$
2. Set up your multiplication. (Desired unit should be at the top of the fraction; unit you want to 'get rid of' is at the bottom.)	$52g = 52g \times \frac{1kg}{1000g}$
3. Calculate. Give your final answer with units.	$= 0.052kg$

So $\frac{1kg}{1000g} = 1$ and $\frac{1000g}{1kg} = 1$

(Dividing any number by itself equals 1.)

Multiplying by "1" is allowed because it does not change its value.

UNIT CONVERSION TUTORIAL

1. Convert 224.9 g to kg.
2. Convert 3420 cm to m.
3. Convert 3420 cm to km.
4. Convert 145 mm to m.
5. How many seconds in 3 hours?
6. Convert 15 km/h to m/s.

Prefix	Prefix Symbol	Multiplier
kilo-	k	10^3 (1000)
BASE UNIT	-	10^0 (1)
centi-	c	10^{-2} (0.01)
milli-	m	10^{-3} (0.001)

UNIT CONVERSION TUTORIAL

1. Convert 224.9 g to kg.	0.2249kg
2. Convert 3420 cm to m.	34.2m
3. Convert 3420 cm to km.	0.0342km
4. Convert 145 mm to m.	0.145m
5. How many seconds in 3 hours?	10800s
6. Convert 15 km/h to m/s.	4.16 m/s

UNIT CONVERSION TUTORIAL

6. Convert 15 km/h to m/s.

$$1km = 1000m$$

$$1h = 3600s$$

$$15\frac{km}{h} = 15\frac{km}{h} \times \frac{1000m}{1km} \times \frac{1h}{3600s}$$

$$= 4.16\frac{m}{s}$$

You can do multiple conversions in one step! Just make sure that after you have 'cancelled out' all the units, you are left with the units you desire.

UNIT CONVERSION TUTORIAL

6. Convert 15 km/h to m/s.

$1km = 1000m$

$1h = 60min$

$1min = 60s$

$$15\frac{km}{h} = 15\frac{km}{h} \times \frac{1000m}{1km} \times \frac{1h}{60min} \times \frac{1min}{60s}$$

$$= 4.16\frac{m}{s}$$

Another way…

WHAT TYPE OF ENERGY DOES A MOVING CAR DEMONSTRATE?

Answer: ***mechanical kinetic energy***

https://www.wired.com/story/sanfrancisco-smaller-firetrucks/ https://www.edmunds.com/mazda/3/

WHICH HAS MORE KINETIC ENERGY?

5 km/h

50 km/h

https://www.edmunds.com/mazda/3/

WHICH HAS MORE KINETIC ENERGY?

50 km/h

50 km/h

https://www.wired.com/story/sanfrancisco-smaller-firetrucks/ https://www.edmunds.com/mazda/3/

MECHANICAL KINETIC ENERGY EQUATION

Equation for mechanical kinetic energy (KE):

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

E_k mechanical kinetic energy (J, Joules)

m mass (kg, kilograms)

v velocity (m/s, meters per second)

Remember subscripts from chemistry? In physics and math, subscripts are often used to give more information about variables. Here, the "E" stands for energy; the "k" stands specifies that it is *kinetic* energy we are referring to.

Calculate the kinetic energy of a steak that weighs 0.8 kg and is headed towards your mouth at a speed of 3.2 m/s.	
1. Write out your knowns and unknowns. Do any conversions if necessary.	$m = 0.8kg$ $v = 3.2\frac{m}{s}$ $E_k = ?$
2. Write out your formula.	$E_k = \frac{1}{2}mv^2$
3. Plug in your values. (*Remember units*. Use unrounded values (e.g. from unit conversion))	$E_k = \frac{1}{2}(0.8kg)(3.2\frac{m}{s})^2$
4. Calculate. Give your final answer with units.	$= 4.096\ J$

Calculate the kinetic energy of a car that weighs 1500kg and is going at a speed of 50 km/h.

1. Write out your knowns and unknowns. Do any conversions if necessary.	$m = 1500kg$ $v = 50\frac{km}{h} = 13.\overline{8}\frac{m}{s}$ $E_k = ?$
2. Write out your formula.	$E_k = \frac{1}{2}mv^2$
3. Plug in your values. (*Remember units*. Use unrounded values (e.g. from unit conversion))	$E_k = \frac{1}{2}(1500kg)(13.9\frac{m}{s})^2$
4. Calculate. Give your final answer with units.	$= 145000J = 145kJ$

MECHANICAL KINETIC ENERGY EQUATION (CONT)

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

Can rearrange the equation in the following ways to find mass or speed

(Note: you will ***not*** be given these versions on the test; either memorize or learn to derive them)

$$m = \frac{2E_k}{v^2}$$

$$v = \sqrt{\frac{2E_k}{m}}$$

E_k	mechanical kinetic energy (J)
m	mass (kg)
v	velocity (m/s)

PRACTICE:

1. Determine the mass of an object that has 16.2 J of kinetic energy and is moving at a speed of 2.5 m/s.
2. Determine how fast Usain Bolt (94 kg) would have to run in order to have a kinetic energy of 5,000 J.

GRAVITATIONAL POTENTIAL ENERGY EQUATION

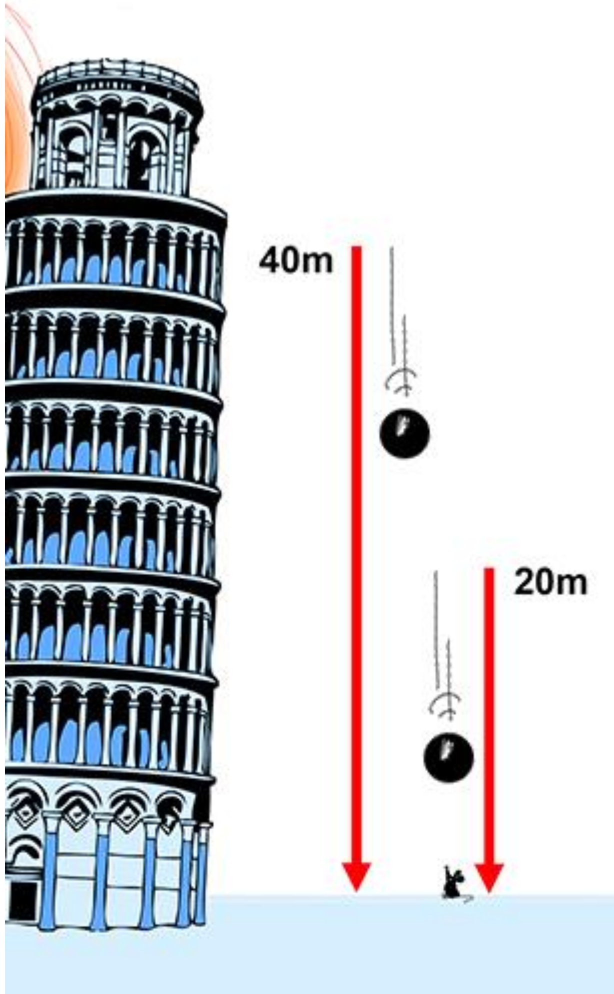
Equation for gravitational potential energy (GPE):

$$E_g = mg\Delta h$$

E_g	gravitational potential energy (J)
m	mass (kg)
g	acceleration due to gravity (m/s^2)
	(= **9.8 m/s^2** on Earth)
h	height (m)

Δh means "change in height".

What are you measuring the potential energy relative to? (If not specified, assume 'height above the ground' or 'distance it could fall before hitting something')



Calculate the gravitational potential energy of a basketball that weighs 0.62 kg and is 6.2m above the ground.	
1. Write out your knowns and unknowns. Do any conversions if necessary.	$m = 0.62\ kg$ $\text{g} = 9.8\frac{m}{s^2}$ $\Delta h = 6.2m$ $E_p = ?$
2. Write out your formula.	$E_p = mg\Delta h$
3. Plug in your values. (*Remember units*. Use unrounded values (e.g. from unit conversion))	$E_p = 0.62kg \times 9.8\frac{m}{s^2} \times 6.2m$
4. Calculate. Give your final answer with units.	$= 37.7\ J\ (rounded)$

Calculate the potential energy of a hummingbird that weighs 6.3g and is flying at a speed of 8m/s, 30m above the ground.	
1. Write out your knowns and unknowns. Do any conversions if necessary.	$m = 6.3g = 0.0063kg$ $\text{g} = 9.8\frac{m}{s^2}$ $\Delta h = 30m$ $E_p = ?$
2. Write out your formula.	$E_p = mg\Delta h$
3. Plug in your values. (*Remember units*. Use unrounded values (e.g. from unit conversion))	$E_p = 0.0063kg \times 9.8\frac{m}{s^2} \times 30m$
4. Calculate. Give your final answer with units.	$= 1.85J$

GRAVITATIONAL POTENTIAL ENERGY EQUATION (CONT)

$$E_g = mg\Delta h$$

Can rearrange the equation in the following ways to find other unknowns

(Note: you will ***not*** be given these versions on the test; either memorize or learn to derive them)

$$m = \frac{E_g}{g\Delta h}$$

$$\Delta h = \frac{E_g}{mg}$$

$$g = \frac{E_g}{m\Delta h}$$

to calculate gravity if you are not on Earth

E_g	gravitational potential energy (J)
m	mass (kg)
g	acceleration due to gravity (m/s^2) (= **9.8 m/s^2** on Earth)
h	height (m)

PRACTICE

1. Calculate the mass of an object held 2.3 km above the ground that has 2894 J of gravitational potential energy.
2. Determine the gravitational acceleration on the moon if a 10 kg block held 65 m above the ground has a gravitational potential energy of 1053 J.

DISCUSSION QUESTIONS

1. What physical quantities affect

   a) mechanical kinetic energy and

   b) gravitational potential energy?

2. Why might it appear that the law of conservation of energy does not apply to the sled in Figure 3.11?