Lesson #5

Day 1

1. A force can cause an object to stop. List three other ways a force can affect an object.

____

2. Match each unit with what is measured.

_______	liter	A) mass
_______	meter	B) volume of a liquid
_______	gram	C) volume of a solid
_______	cubic meter	D) length/distance

3. Which two factors do all forces have?

   direction   distance   magnitude   resistance

4. Which two factors affect the strength of a magnetic field?

   direction   distance   magnitude   resistance

5. Which of these is evidence that a field exists?

   A) Mold grows on a rotten orange.
   B) A frozen pond begins to melt.
   C) A compass needle turns away from the flow of electric current.
   D) all of these

6. Ostriches often travel in pairs or in small flocks. To escape predators, they run very fast or use their strong legs to deliver a powerful kick. This description is _____________.

   qualitative   quantitative

   The egg of an ostrich averages 150 mm in length and 125 mm in diameter. It has a mass of about 1.35 kg. This description is _____________.

   qualitative   quantitative

7. Hypothesis: Hollyhock stems growing in full sun will grow taller than hollyhock stems growing in shade. Identify the *independent variable* (**I**) and the *dependent variable* (**D**).

   _______ amount of sunlight the plants receive

   _______ height of hollyhock stems

8. Fill in the blanks.

A) magnetic B) flow C) buildup D) electric

Electric forces are all around us. One type is current electricity, which is a(n) _______ of negatively charged particles that produce a(n) _______ field. Another type is static electricity, which is a(n) _______ of negatively charged particles that produce a(n) _______ field.

9. How are magnetism and electricity similar?

A) They are created by charged particles.
B) The strength of their fields is related to magnitude and proximity.
C) They are forces that attract or repel.
D) all of these

10. The electricity a generator produces can be increased by strengthening the magnetic field. List three ways this can be done.

____

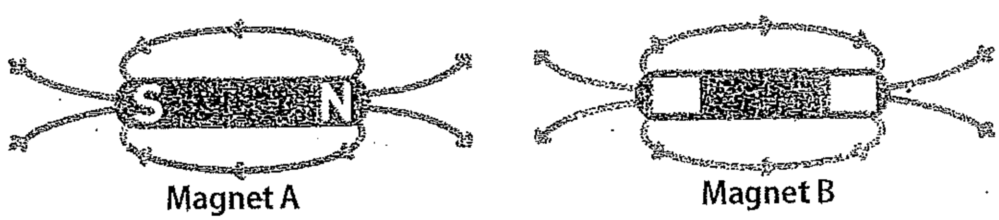
____

11. Two magnets are placed end to end. We observe that the magnets push away from each other. What can we conclude?

A) The opposite poles of the magnets are interacting.
B) The like poles of the magnets are interacting.
C) The magnets will eventually be touching each other.
D) An increase in distance will increase the magnetic field.

12. A generator is a machine that uses changing ____________________ fields to produce electricity.

13. The diagram shows two magnets that are repelling each other. Label the poles of magnet B.



What will happen if we change the orientation of magnet B?

____

Lesson #6

Day 2

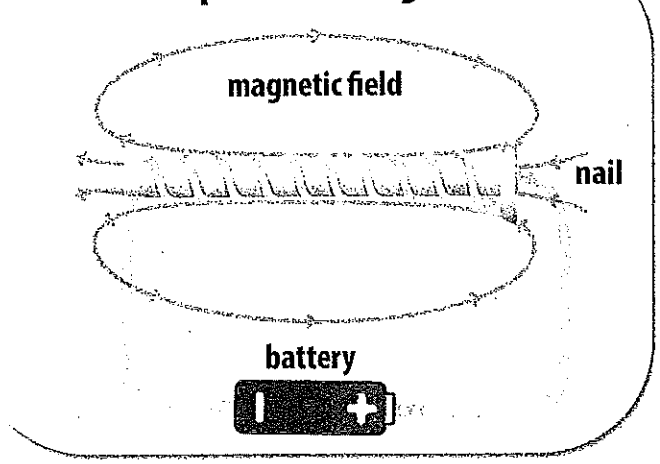
Electromagnets

Just as magnets can be used to generate electricity, electricity can be used to create magnets. Remember, electric current flowing through a wire generates a magnetic field around the wire. This is how an **electromagnet** is made.

A permanent magnet has its magnetism all the time. However, an electromagnet attracts or repels only while a current is passed through it. It can also be turned on and off by starting or stopping the current. And the magnetic field around an electromagnet can be reversed. This is done by reversing the flow of the current.

You can make a simple electromagnet. Moving charges always produce a magnetic field; therefore connecting the ends of a wire to the terminals of a battery will produce a weak magnetic field. If you wrap the wire in coils, or loops, you increase the amount of wire and current in a given area. An iron nail placed through the coils acts as a core and strengthens the magnetic field even more. Put all these parts together, and you have an electromagnet.

Simple Electromagnet



Remember, increasing the loops means more wire and more current in the same amount of area. The more loops there are, the stronger the electromagnet will be. A larger battery with more electric charge will also strengthen the magnetic field.

What happens if you remove the wire from one of the battery terminals? This stops the current. Without the current, there is no magnetic field.

The properties of electromagnets make them useful in countless ways. They are used in heating, lighting, and household appliances. Medical devices, communication equipment, and transportation systems all use electromagnets.

Electromagnets are used in high-speed vehicles called magnetic levitation (maglev) trains. A maglev train does not have an engine. Instead, there are large magnets on the underside of the train and magnetized coils on its iron rails. The current flowing through the coils creates a magnetic field that powers the train. Interactions between magnetic fields cause the train to levitate, or float, about a centimeter above the track. Floating eliminates friction. Maglev train technology has been successful in China and other Asian countries for many years. The trains travel at hundreds of kilometers per hour. They are safe, energy efficient, and less noisy than engine-driven trains.

1. How is an electromagnet created? Underline your answer in the first paragraph.

2. You can make a simple electromagnet with a wire wrapped around a nail and attached to a battery. How can you make the magnetic field stronger?

   A) wrap the wire many more times
   B) use a bigger battery
   C) add another battery
   D) all of these

3. How is an electromagnet different from a permanent magnet?

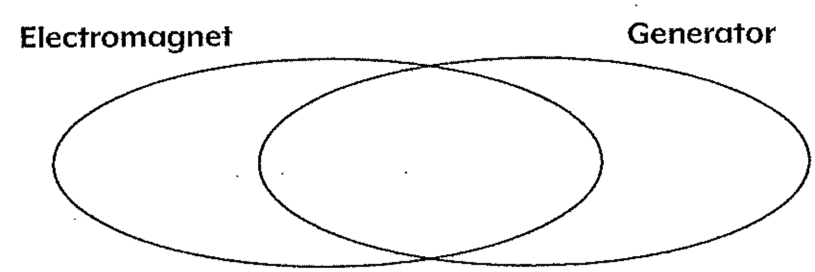
   A) An electromagnet is stronger than a permanent magnet.
   B) An electromagnet only has one pole.
   C) An electromagnet can be turned on and off.

4. There are countless uses for electromagnets. List four ways they are being used today.

____

____

5. Complete the Venn diagram for generators and electromagnets.



   A) generates a magnetic field
   B) generates an electric current
   C) uses magnets
   D) uses a battery
   E) uses coiled wire
   F) is strengthened by making more coils

6. A generator requires either a moving ______________ or a moving ______________.

7. Which of these will increase the amount of electricity produced by a generator?

   A) increasing the number of coils around the magnet
   B) using a stronger magnet
   C) either A or B

Lesson #7

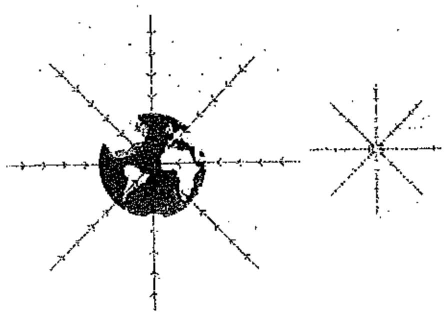
Day 3

Gravitational Fields

All objects exert a force of attraction on each other; this force is **gravity**. Anything that has mass has a gravitational field around it. Like a magnetic field or electric field, a **gravitational field** attracts objects even when the objects are not touching. Unlike electromagnetic fields, a gravitational field only attracts; it does not repel. The strength of an object's gravitational field depends on two things: the mass of each object and the distance between them.

The larger an object's mass, the stronger its gravitational field. For example, a pencil and a paper clip exert a gravitational force on each other. However, these objects have very little mass, so the gravitational force they exert on each other is very small. The gravitational force of everyday objects is too weak to be noticed. Objects such as the moon, Earth, and the sun are very massive, so they each exert a strong gravitational force.

Gravitational Fields



The strength of the gravitational field is also related to distance. The closer two objects are to each other, the stronger the gravitational force between them. The farther the objects are from each other, the weaker the gravitational force between them. As an object moves away from Earth's massive core, Earth's gravitational field weakens. An object at the top of Mount Everest would experience the pull of gravity a tiny bit less than it does at sea level.

Earth's gravitational field extends into outer space. It pulls on satellites in the atmosphere and keeps the moon in its orbit. But the strength of this field decreases the farther away an object is. The International Space Station orbiting Earth is 400 km away. At this distance, the space station experiences 90% of Earth's gravity. If a person traveled to the outer edges of our atmosphere—10,000 km away—the force of gravity would be just 2% of what it is on Earth's surface.

1. What objects have gravity? Underline your answer in the text.

2. Gravitational forces ______________.

   attract   repel   both attract and repel

3. The strength of a gravitational field depends on two factors. What are they?

_______ the mass of an object _______ the density of the object

_______ the amount of charge _______ the distance from the object

4. How are gravity, electricity, and magnetism alike? Choose all that apply.

_______ All these forces occur through fields.

_______ All these forces can attract and repel.

_______ All are electromagnetic forces.

_______ All are noncontact forces.

5. How does gravitational force differ from other noncontact forces, like electricity and magnetism?

A) Electricity and magnetism attract and repel, but gravity only attracts.
B) All objects with mass exert gravitational force; this is not true of other forces.
C) The force of gravity acts through a field, but the other forces do not.
D) both A and B

6. Which objects listed below exert a gravitational force? Choose all that apply.

Earth the sun an apple a person the moon a car

7. Which object listed above exerts the strongest gravitational force? _______________

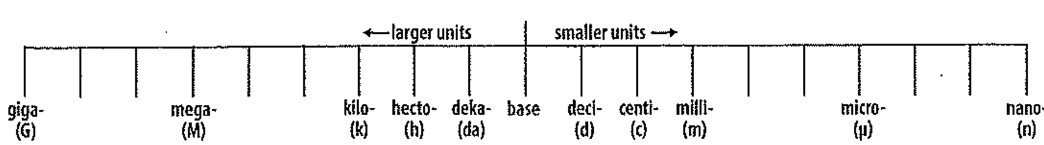
Which object exerts the weakest gravitational force? _______________

8. True or False?

_______ All objects exert a force of attraction on one another; this force is gravity.

_______ Anything that has mass has a gravitational field around it.

9. The metric system is based on multiples of ten. The diagram shows common metric prefixes. Rank these units in order from smallest (**1**) to largest (**4**).



______ kiloliter ______ liter ______ centiliter ______ milliliter

Lesson #8

Day 4

Gravity on the Moon

Historic video of humans walking on the moon can be comical. The astronauts appear to bounce, hop, and jump as they move their legs across the lunar surface. In a video clip from December 1972, Apollo astronauts Eugene Cernan and Harrison Schmitt sing and laugh as they hop along.

"Boy, is this a neat way to travel!" one exclaims.

"Isn't it great?" answers the other.

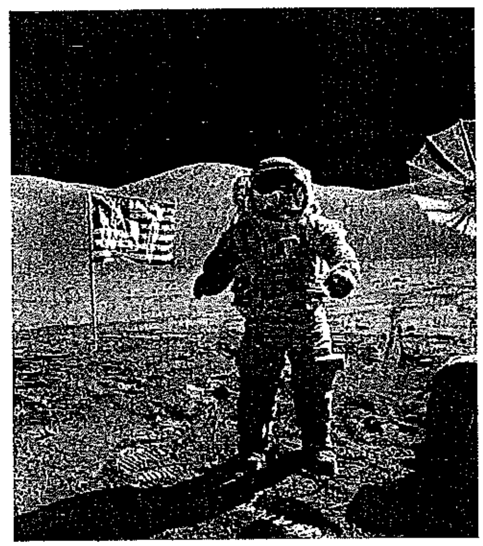
"I like to skip along."

"Skip?"

"Well, whatever you call it. I can't get my left leg in front of me!"

The astronauts were used to walking in Earth's gravity, so they used their legs the same way they did on Earth. But the men weighed less on the moon, so they were walking with more force than they needed. And that caused them to bounce with every step.

Why did the astronauts weigh less on the moon? **Weight** is related to two factors: mass and gravity. Mass does not change from location to location. So the men had the same mass on the moon as on Earth. But the moon's gravitational force is weaker than Earth's gravitational force. So the men weighed less on the moon.



Eugene Cernan on the moon in 1972

1. For the Apollo crew, moon walking was much different from walking on Earth. Why?

   A) The moon's gravitational force is much weaker than Earth's.

   B) The men weighed less on the moon than on Earth.

   C) The astronauts pushed with more energy than needed during the moonwalk.

   D) all of these

2. An object's weight is ____________. Choose all that apply.

   _______ always constant

   _______ dependent on the force of gravity acting on the object

   _______ greater on the moon than on Earth

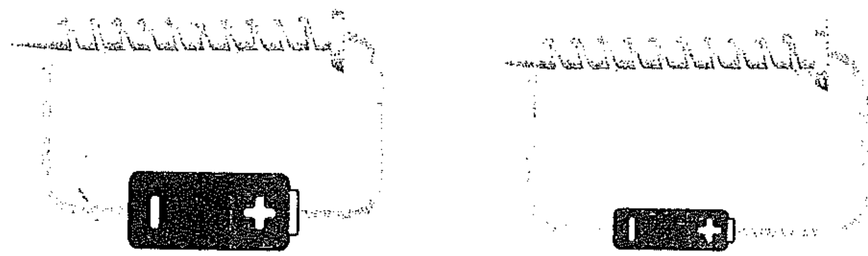
   _______ always the same as its mass

   _______ less on the moon than on Earth

3. True or False?

_______ Mass is the amount of matter an object has, and mass is a constant, which means it never changes.

4. Which electromagnet will produce a stronger magnetic field?



A B

5. How are gravity, electricity, and magnetism alike? List two ways.

____

6. Gravitational force differs from other noncontact forces, such as electricity and magnetism. List at least one difference.

____

____

7. True or False?

_______ Weight is the amount of matter an object has, and it is a constant, which means weight never changes.

_______ Static electricity produces an electric field.

8. Read each description. Write **A** for *quantitative* or **B** for *qualitative.*

_______ describes qualities or characteristics; Example: Gold is a dense, yellow metal that is soft and malleable. It is a pure substance.

_______ involves measurements or numbers; Example: Fort Knox houses 4,580 metric tons of gold bullion. Each gold bar weighs 31 grams and is 99% pure.

Lesson #9

Day 5

Kinetic and Potential Energy

Energy is the ability to cause change. We observe energy when we see light or motion, when we feel heat or vibrations, and when we hear sounds. These are just a few examples. Energy is all around us, and it is in everything.

Although we observe energy in a variety of phenomena, it is all the same energy. No matter how we observe it, energy is always energy—it just presents itself in different ways. Some energy is in motion, and some is stored in fields.

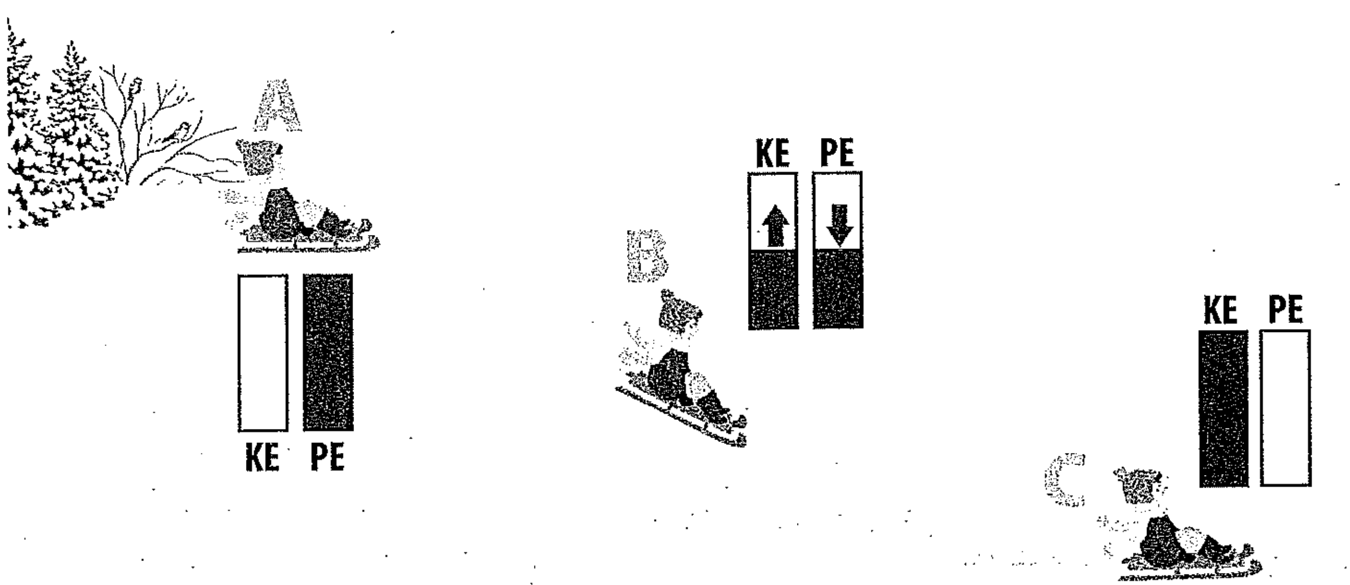
Energy of motion is called **kinetic energy**. Motion is movement—a robot marching, a bird flying, or the wind blowing. The particles of matter are also in motion even though these particles are too small to see. All the particles that make up matter have kinetic energy because these particles are always moving.

Energy stored in fields is called **potential energy**. It is in Earth's gravitational field and in the magnetic field around a magnet, for example. Potential energy is related to the position of an object in a force field. When a child is sitting at the top of a slide, there is potential energy. When a paper clip is near a magnet, there is potential energy. When there is a buildup of static electricity, there is potential energy.

An object can have kinetic energy, potential energy, or both. The model shows a sled at the top of a hill (Point A). In this position, the sled has potential energy but not kinetic energy.

The sled begins to move. Now, it has both potential energy and kinetic energy. Halfway down the hill (Point B), half of the potential energy has changed to kinetic energy.

Once the sled is on flat ground (Point C), it has no more potential energy. However, it is still sliding very fast. At this point, the sled has only kinetic energy.



1. Gravitational potential energy is related to the ________________________ of an object within a force field.

2. Match.

_______ potential A) energy of motion

_______ kinetic B) energy stored in fields

3. Write **K** for *kinetic energy*, **P** for *potential energy*, or **B** for *both.*

_______ energy in a speeding car and in a gently blowing breeze

_______ energy based on position within a force field

_______ energy that can transfer into or out of a system

4. True or False?

_______ Objects can have either kinetic energy or potential energy, but not both.

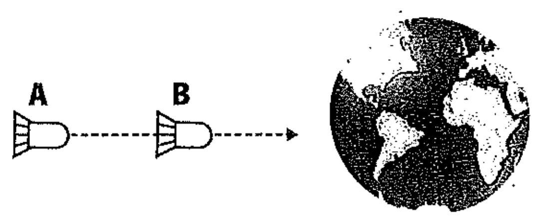
5. All forces have two factors. What are they?

____

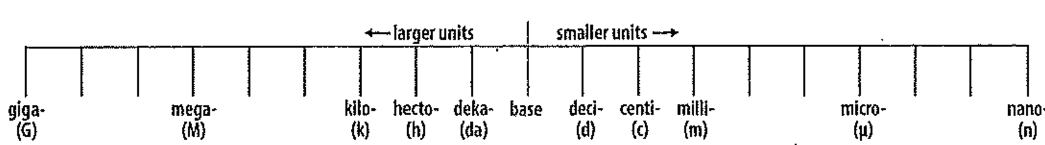
6. The strength of a magnetic force depends upon two factors. List them here.

____

7. A spacecraft approaches Earth. In what position is Earth's gravitational pull stronger?



8. The metric system is based on multiples of ten. The diagram shows common metric prefixes. Rank these units in order from smallest (**1**) to largest (**4**).

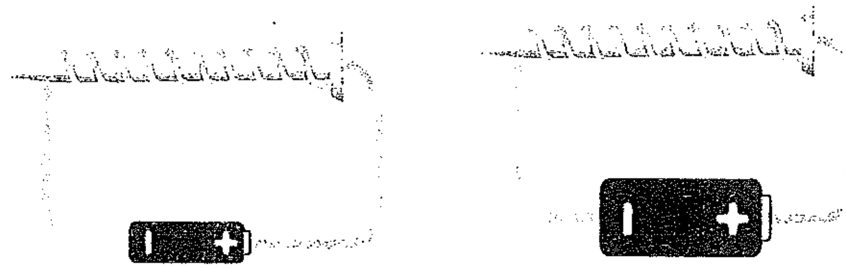


_____ meter _____ kilometer _____ millimeter _____ centimeter

Lesson #10

Day 6

1. Which electromagnet will produce a stronger magnetic field?



A B

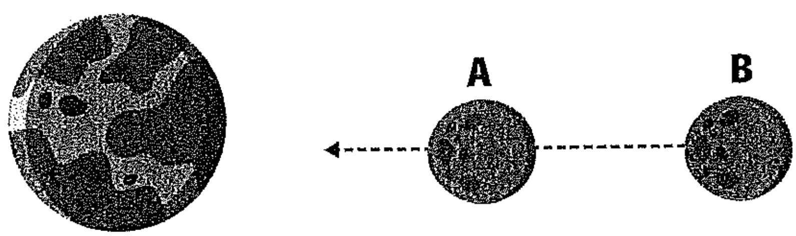
2. What are two ways to increase the strength of a magnetic field?

____

3. What are two ways to decrease the strength of a magnetic field?

____

4. An asteroid is approaching Mars. In which position is Mars' gravitational field stronger?



Explain your answer.

____

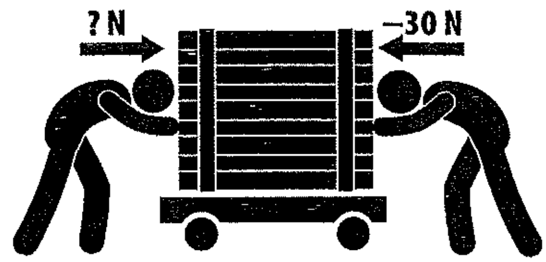
____

5. Do all objects have gravity? yes no answer unknown

6. Why don't we observe gravity between two everyday objects, such as a cup and a spoon?
   A) These small objects do not have gravity; only space objects have gravity.
   B) Gravitational force is not something that can be observed.
   C) The gravitational force of a cup or spoon is very small—too small to be noticed.
   D) both A and B

7. The magnitude of a force is measured in Newtons. Study the image. If the net force is 10 N, what is the force on the left? (Think: –30 + ___ = 10)

____



Net Force = 10 N

8. True or False?

_______ Mass is a constant, which means the mass of an object does not change.

_______ Weight is a measure of the gravitational force acting on an object. Weight can change if the gravitational force changes.

9. A generator _____________.

A) creates an electric current

B) creates an electromagnet

C) converts coal into steam

D) all of these

10. Potential energy is energy of (motion / position).

11. A magnet and a paper clip are sitting on a table. You bring the magnet closer to the paper clip and the paper clip moves. What is this evidence of?

_______ The magnet is surrounded by a field.

_______ Energy is stored in fields.

_______ The field is stronger closer to the magnet.

_______ The paperclip is affected by gravity.

12. The table lists several known objects in order by mass.

Venus has (more / less) mass than Vesta.

An object on Vesta would weigh (more / less) than on Venus.

An object on Neptune would weigh (more / less) than on Earth.

An object on Ceres would weigh (more / less) than on Pluto.

An object on the moon would weigh (more / less) than on Juno.

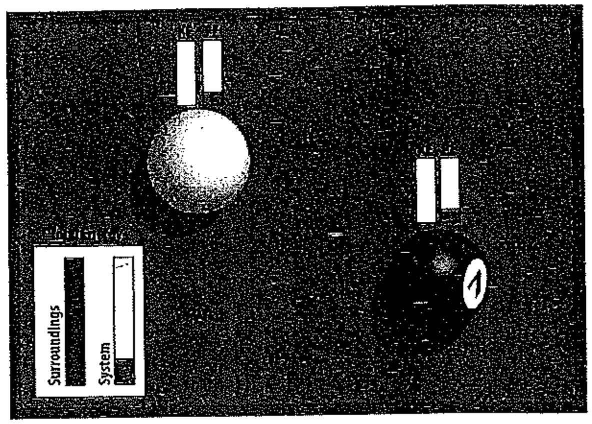
An object on Mars would weigh (more / less) than on Neptune.

Object	
the sun	↑ Increasing mass
Neptune	
Earth	
Venus	
Mercury	
Mars	
Earth's moon	
Pluto	
Eris	
Ceres	
Vesta	
Juno	

Lesson #11

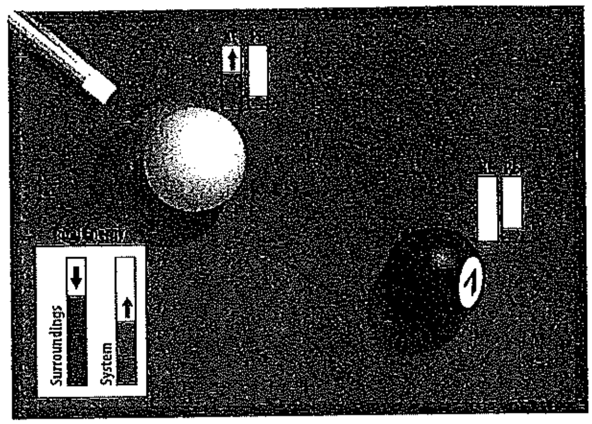
Day 7

Energy Transfers: Conservation of Energy



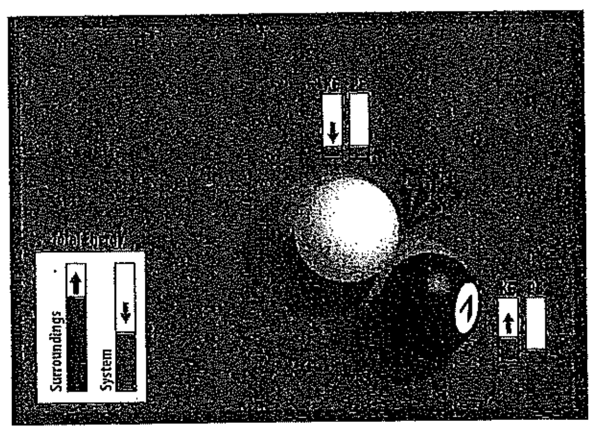
The **law of conservation of energy** states that energy cannot be created or destroyed. This means a certain amount of energy exists in the universe, and this amount never increases or decreases.

Although the total energy of the universe is constant, energy can move in and out of a system. It can transfer from one object to another and change from one form to another.

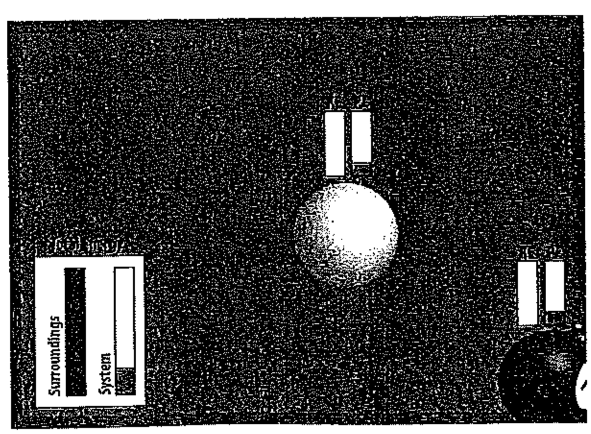


Billiard balls on a pool table can demonstrate the law of conservation of energy. Observe the total energy in the model. The billiard balls represent a system. In the beginning, the billiard balls are not moving. They have no kinetic energy. They are the same distance from the ground, so they have equal amounts of potential energy.

Energy enters the system when the pool stick strikes the cue ball. This strike transfers energy from the surroundings to the system. The amount of energy in the surroundings decreases. The amount of energy in the system increases. Note that the total energy has not changed. The total energy is constant.



When the cue ball strikes the seven ball, energy from the cue ball is transferred to the seven ball. This energy is still a part of the system. Note, however, that a small amount of energy is transferred as sound. This energy goes into the environment. So the energy of the system goes down just a bit and the energy of the surroundings goes up by the same amount. Again, the total energy does not change.



In the end, both balls sit motionless. Their kinetic energy is gone. Where did it go? As the balls rolled across the table, the force of friction transferred energy from each ball to the table as heat. Energy leaves the system and goes into the surroundings.

Energy cannot be created, and it cannot be destroyed. Instead, it is constantly being transferred.

1. What is the law of conservation of energy? Underline your answer in the text.

2. Energy is never created or destroyed; however, it ____________.

   A) moves in and out of systems
   B) transfers from one object to another
   C) changes form
   D) all of these

3. In the first image, what is the kinetic energy of the cue ball? ____________________

   Explain. ____

4. In the second image, why has the kinetic energy of the cue ball changed?

   ____

   ____

5. In the third image, the seven ball is moving. Where does the seven ball get its kinetic energy?

   ____

6. What happened to the kinetic energy of the cue ball when it struck the seven ball?

   ____

7. In the fourth image, the bars show that neither ball has kinetic energy. What does that tell you?

   A) Energy has left the system.
   B) The balls are not moving.
   C) Energy was destroyed.
   D) both A and B

8. In the diagrams shown on the opposite page, the potential energy of the two billiard balls does not change. Why is this?

   ____

9. Examine the Total Energy bars in each diagram. How do they illustrate the conservation of energy?

   A) At times, the system gains energy. Other times, it loses energy.
   B) At times, the surroundings gain energy. Other times, the surroundings lose energy.
   C) The total energy of the system never changes.
   D) all of these

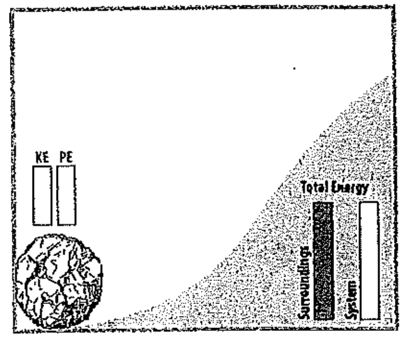
Lesson #12

Day 8

Gravity and Transfers of Energy

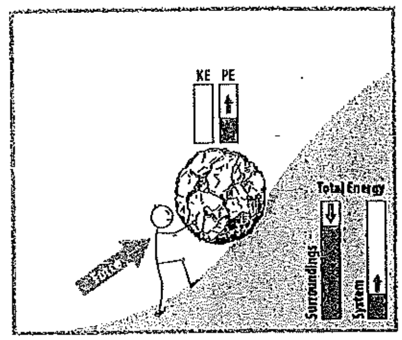
Energy can be transferred without contact. When an object changes its position within a field, the potential energy in the system changes. Sometimes, energy is transferred into the field. Other times, energy is transferred out of the field. Study the models.

A ball is sitting at the bottom of a hill. Earth's gravity is pulling downward on the ball. The ball, Earth, and the gravitational field make up a system.



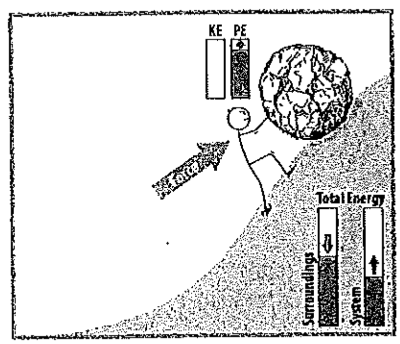
The system includes a ball, a hill, and gravity.

A person pushes the ball partway up the hill and stops. To do this, a force is needed to overcome the force of gravity. The force transfers energy from the person (the surroundings) to the system. This potential energy is now stored in the gravitational field.



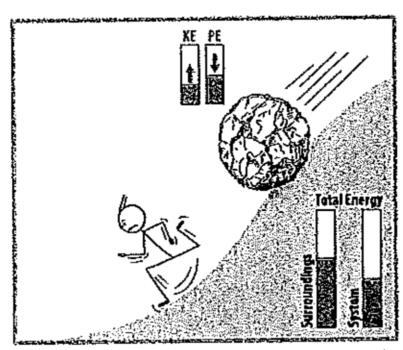
To raise the ball, a force is used. This force transfers energy to the gravitational field.

Again, the person pushes the ball upward and stops. As before, the energy used to move the ball has been transferred to the system. The potential energy in the gravitational field has increased. The more force that is applied to move the ball, the more energy there is stored in the gravitational field.



An additional force raises the ball higher. This action transfers more energy to the gravitational field.

The system changes again when the ball is released. When the outside force is removed, the ball begins to move downward. Potential energy from the gravitational field pulls on the ball. The energy in the field decreases. As the potential energy from the field is transferred to the ball, the ball's kinetic energy increases. The ball moves faster and faster. It reaches the bottom of the hill and rolls away.



As the ball rolls downhill, energy is transferred from the gravitational field to the ball.

1. In the first diagram, the ball has no kinetic energy because it is not ________________.

2. That ball has no potential energy because its position is ____________________.

3. In the second diagram, the system has energy. Where does the energy come from?

____

____

4. In the fourth diagram, the potential energy has decreased, and the kinetic energy has increased. Why is this?

____

____

5. What is the source of the potential energy we are studying in these diagrams?

   gravitational fields   magnetic fields   electric fields

6. In these diagrams, what does the system include?

   the ball   the person   Earth   the gravitational field

7. Based on the diagrams, which of these is true? (Hint: Study the bars.)

   _______ Energy can transfer from the surroundings to the system.

   _______ Energy can transfer from the system to the surroundings.

   _______ When energy is lost, the energy of the universe decreases.

   _______ The total energy (energy in the universe) never changes.

   _______ When energy enters a system, the energy of the universe increases.

8. The magnitude of a force is measured in SI units called ________________.

9. An electric generator produces an electric current. Which of these will strengthen the current?

   A) a smaller magnet
   B) turning the magnet faster
   C) decreasing the coils on a wire
   D) changing the orientation of the magnet

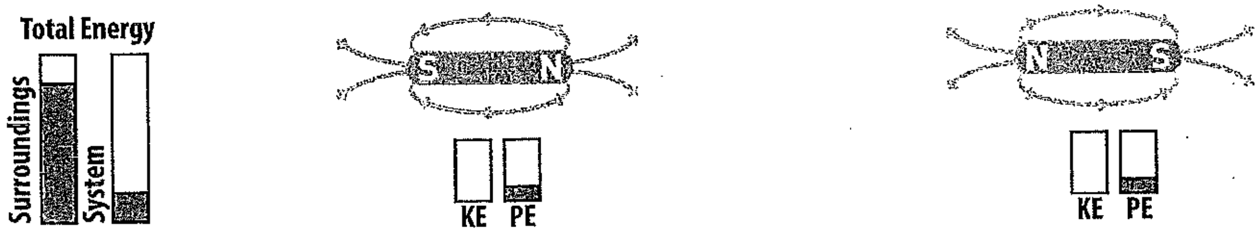
Lesson #13

Day 9

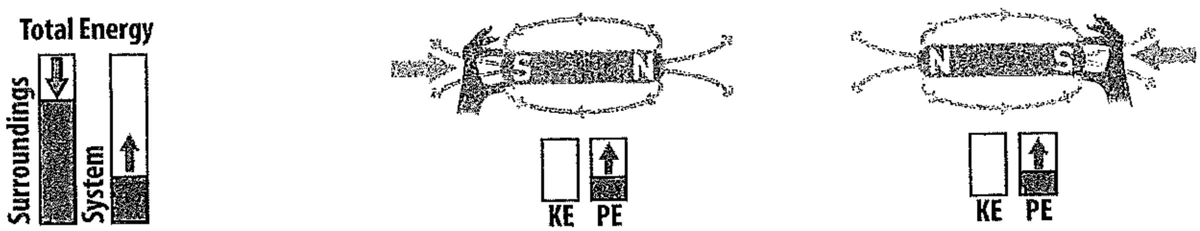
Magnets and Transfers of Energy, Part I

Magnetic fields are similar to gravitational fields. Magnetic fields can gain or lose energy. Also, the amount of energy is related to the position of the objects in the system.

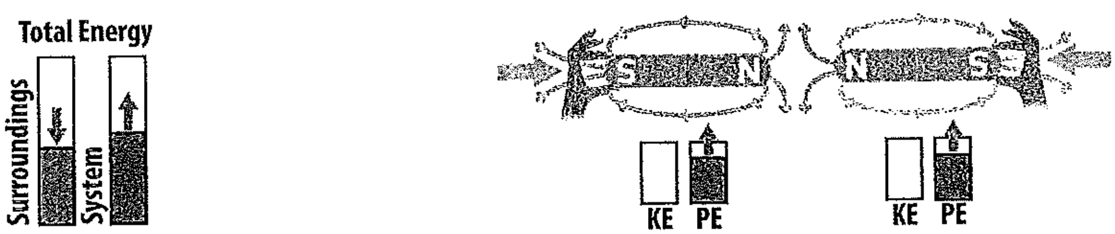
The model shows a system with two magnets. Because of their orientation, each magnetic field exerts a repelling force on the other.



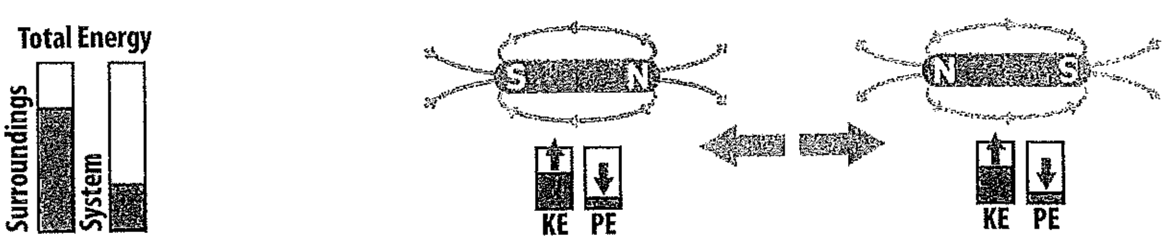
Imagine pushing the magnets toward each other. You must use energy to push against the repelling force. This outside force transfers energy into each magnet's magnetic field. The potential energy in each field increases.



An additional outside force is applied. The magnets are now even closer. The additional force has transferred more energy into the system—the potential energy in each magnetic field is increasing. The potential energy will continue to increase as the two magnets are moved closer and closer together. The more force that is applied, the more potential energy the magnetic fields will have.



What happens when the repelling magnets are released? When the outside forces are removed, the repelling force will push the magnets outward. Potential energy is transferred out of the magnetic fields, pushing the magnets apart. The potential energy in each field decreases. The kinetic energy of the magnets increases.



The magnetic field will continue to transfer energy to the magnets, moving them farther apart until the energy left in the field is not enough to move the magnets any farther.

1. Why is an external force needed to move the magnets together?
   - A) There is no energy in the surroundings.
   - B) The magnets have no charge.
   - C) The magnetic fields are exerting a repelling force.
   - D) The magnets are stuck.

2. Compare the first three diagrams. Notice that the potential energy increases at each step. Where does the energy come from?

   ____

3. In the last diagram, why has potential energy decreased and kinetic energy increased?

   ____

   ____

4. What is the source of the potential energy we are studying in these diagrams?

   gravity fields　　magnetic fields　　electric fields

5. When the energy of a system increases, the energy of the surroundings ____________.

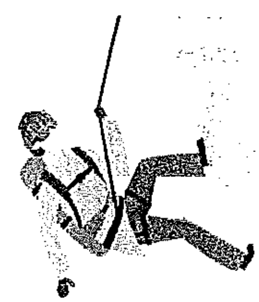
   increases　　decreases　　stays the same

6. In order to move upward, a rock climber must use ___________.

   gravity　　magnetism　　energy

   The energy the climber exerts becomes stored in the ___________ field.

   gravitational　　magnetic　　electric



7. Kinetic energy is related to speed. What is speed? (Check the Glossary if you're not sure.)

   ____

8. Look again at the diagrams in Lesson #12. How do we know that motion has occurred?
   - A) There is a change in position.
   - B) There is a change in velocity.
   - C) There is a change in direction.

Lesson #14

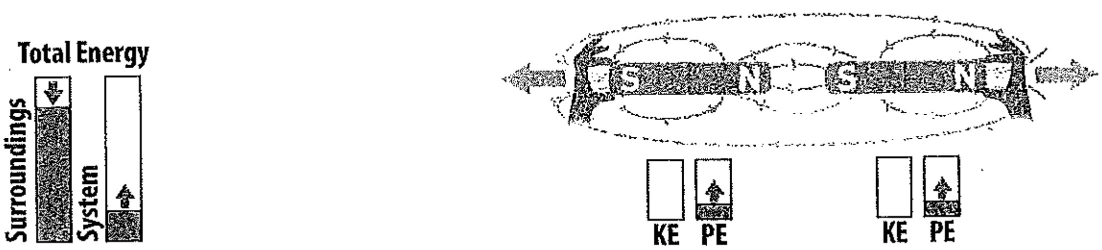
Day 10

Magnets and Transfers of Energy, Part II

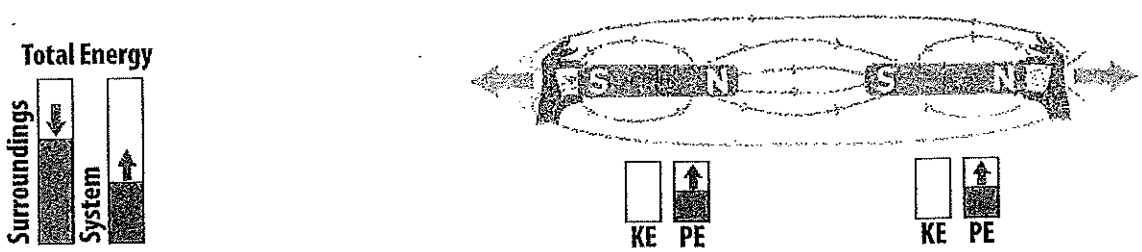
The interaction of two magnets depends on their orientation. In the previous lesson, the two magnets were turned with like poles facing each other. As a result, the magnets repelled each other. In this lesson, the magnets are turned with opposite poles facing each other. Now the magnets will be attracted to each other.

The north pole of one magnet is attracted to the south pole of the other magnet. The two magnets are touching. There is no potential energy stored in the system.

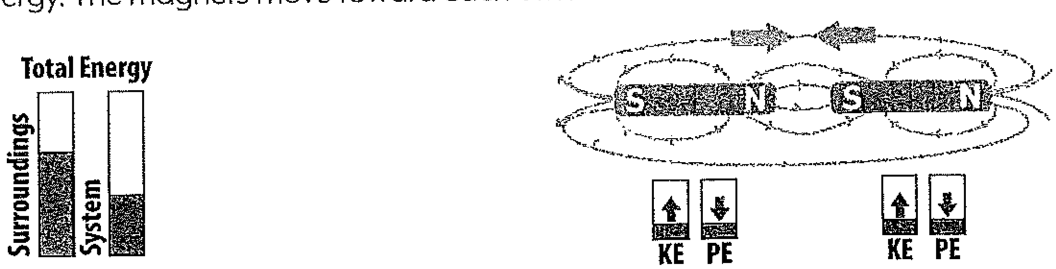
Imagine an outside force pulling the magnets away from each other. This force uses energy to pull the magnets apart. That energy is transferred to the magnetic field.



The magnets can be moved even farther apart by increasing the outside force. The larger force transfers more energy into the system. The magnetic field now has more potential energy.



What happens when the attracting magnets are released? The magnetic field pulls on the magnets. This force transfers energy out of the magnetic field and into the magnets as kinetic energy. The magnets move toward each other.



1. Why is an external force needed to pull the magnets apart?

____

____

2. Compare the first three diagrams. Notice that the potential energy increases at each step. Where does the energy come from?

____

____

3. In the end, why has potential energy decreased and kinetic energy increased?

____

____

4. What is the source of the potential energy we are studying in these diagrams?

   gravitational fields magnetic fields electric fields

5. Energy cannot be created or destroyed. This means ____________.

   A) the amount of energy in the universe never changes
   B) the energy within a system can never change
   C) if a system loses energy, the surroundings gain less than was lost
   D) both A and B

6. When the energy of a system decreases, the energy of the surroundings ____________.

   increases decreases stays the same

7. Which of these describe a gravitational field?

   _______ The strength of the field is related to mass.

   _______ The strength of the field is related to distance.

   _______ The closer two objects are, the weaker the field is.

   _______ The larger the mass, the stronger the field is.

   _______ All objects have a gravitational field.