CHAPTER 12

SOUND AND ELECTROMAGNETIC ENERGY

- ***THE PHYSICAL SETTING: KEY IDEA 4***
  Energy exists in many forms and when these forms change energy is conserved

Waves

Waves are disturbances that transfer energy from place to place. If you throw a stone into a pond, circular waves move along the surface. When the stone hits the pond, it has kinetic energy. Some of the kinetic energy of the moving stone is transferred to the water, causing the water to move.

The substance through which some waves travel is a **medium**. This can be a solid, liquid, or gas. Air is usually the medium for sound waves. Light does not need a medium to travel through, it can travel through empty space (**vacuum**).

There are two types of waves. Transverse waves are waves in which the particles move up and down at right angles to the direction of the wave motion. Compressional waves are waves in which the particles move back and forth, in the direction of wave motion.

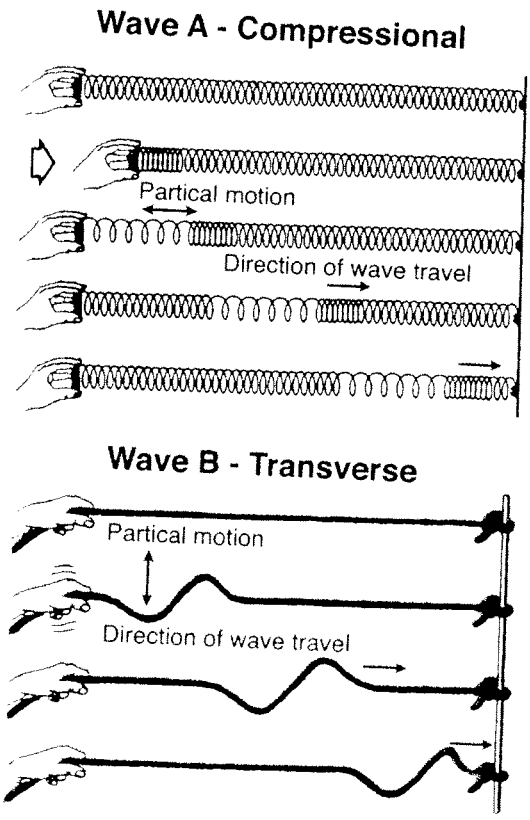


FIGURE 1. TRANSVERSE & COMPRESSIONAL WAVES

Transverse waves have a number of features. These include the crest, trough, and wavelength. The crest is the top of the wave. The trough is the bottom of the wave. The distance between two adjacent crests or troughs is known as the **wavelength**. The number of waves that pass a specific location in one second is the frequency.

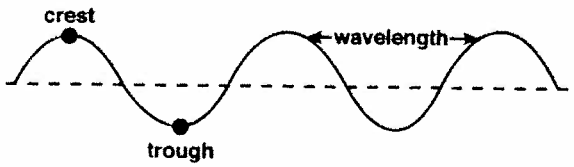


FIGURE 2. PARTS OF A TRANSVERSE WAVE

Waves can be reflected, refracted, or diffracted. **Reflection** is the bouncing back of a wave after striking a barrier or surface. Light waves are reflected off a mirror, so we see our image. An echo is reflected sound waves.

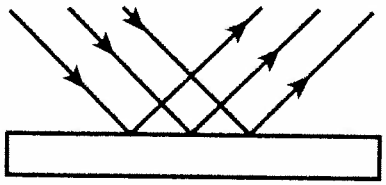


FIGURE 3. REFLECTION

Refraction is the bending of waves as they move from one medium to another. Light is refracted when it goes through a prism. When light moves from the air to the glass , the light wave will bend.

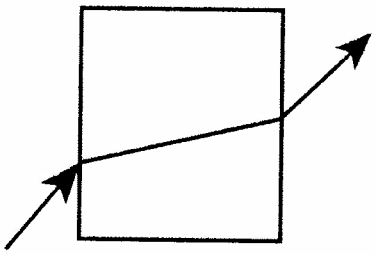


FIGURE 4. REFRACTION

Diffraction is the bending of waves around a barrier. This is why you can hear noise from around a corner.

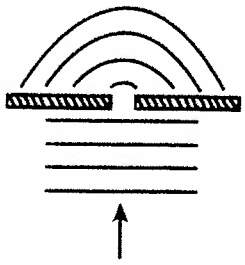
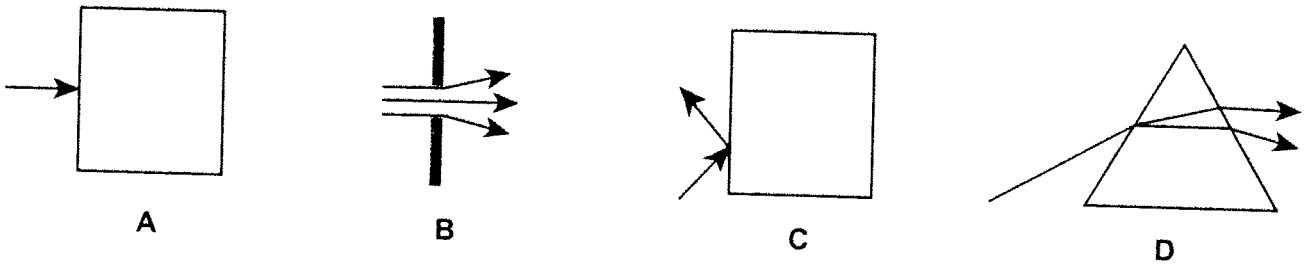


FIGURE 5. DIFFRACTION

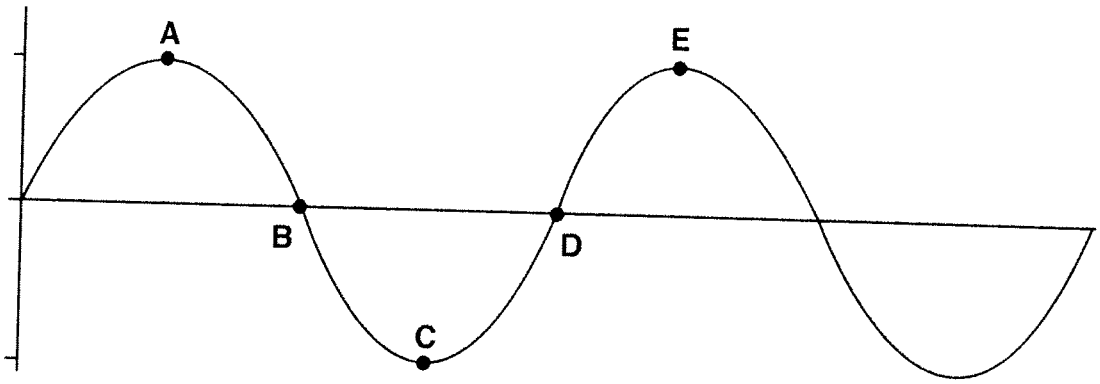
Review Questions

1. Waves are disturbances that transfer _____.
2. The material that a wave travels through is called a _____.
3. Light can travel through a _____.
4. The distance from a crest to the next crest is the _____.
5. Select the diagram that illustrates:



a. reflection _____ b. refraction _____ c. diffraction _____

6. In the diagram below, the wavelength is between letters _____ and _____.



Sound

Sound is a form of energy that travels as a compressional wave. Sound cannot travel through a vacuum, it needs a medium (substance) to travel through. **Sound** travels through the medium by vibrating the particles of that substance. When sound travels through air it vibrates the air molecules. As sound travels into your ear, it vibrates the bones and tissues of your inner ear.

Sound travels much slower than light. This is why you see lightning before you hear thunder. Sound travels at different speeds through different mediums. It travels slowest through gases and fastest through solids. The speed of sound also depends on the temperature. As temperature increases, molecules move faster and there are more collisions, so sound travels faster. On a cold winter day sound will travel slower.

The intensity of sound is the amount of energy it has. Sound is measured in decibels (dB). A whisper is 10 dB but a jet plane is 170 dB. Continuous exposure to loud sounds can cause health problems such as increase in blood pressure and a loss of hearing.

Review Questions

7. Sound cannot travel though a _____.
8. Sound is caused by the _____ of particles.
9. The speed of light is _____ than the speed of sound.
10. Sound travels fastest through _____ materials.
11. Sound travels faster when the temperature is _____.
12. Constant exposure to sounds of more than 90 dB can cause _____ loss.

Electromagnetic Energy

Electromagnetic energies can travel through a medium (material) or through a vacuum (empty space). All electromagnetic energies travel at the speed of light which is more than a million times faster than sound. Electromagnetic energy includes microwave, infrared (heat), visible light, ultraviolet, x-rays, and gamma rays. These energies travel as transverse waves. Each type has a different wavelength. The shorter the wavelength, the more dangerous the electromagnetic energy.

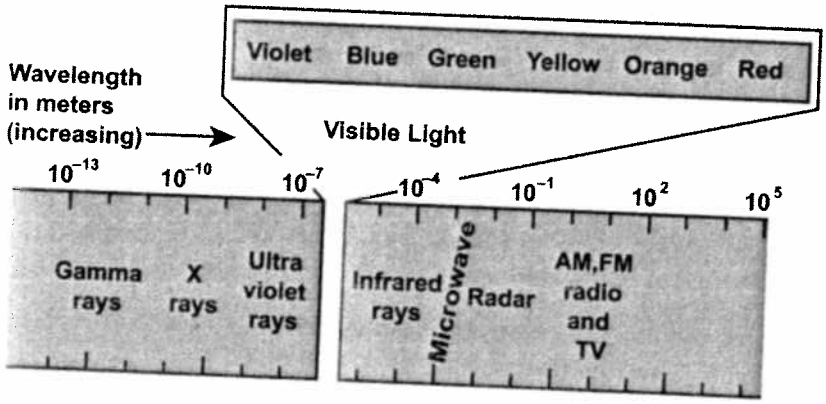


FIGURE 6. ELECTROMAGNETIC SPECTRUM

Gamma rays have the shortest wavelength. They are very dangerous and are used to destroy cancer cells. They are given off by radioactive elements and nuclear explosions. X-rays have great penetrating power and are used to examine bones, teeth, and luggage.

Ultraviolet radiation (UV) is found in light from the Sun. It causes sunburn and skin cancers. Ultraviolet radiation can damage the immune system, cause damage and cataracts in the eye, and stunt plant growth. Ozone in the stratosphere blocks out most of the UV radiation from the Sun.

Visible light is the only electromagnetic energy we can see. Each color we see has a different wavelength. Red is the longest, and blue the shortest wavelength.

Infrared radiation produces heat energy. Earth receives infrared radiation from the Sun. All objects give off heat or infrared radiation. Earth radiates heat to space, our bodies radiate heat to a room.

Microwave radiation is used in communications, cell phones, satellites, and in cooking. It is absorbed by food, which causes the food to heat up.

Radio waves have the longest wavelength. They are used to transmit radio and TV signals. Reflected radio waves can give us ground images in the dark or through clouds.

Review Questions

13. Electromagnetic waves can travel through a medium or through a _____.
14. Each type of electromagnetic energy has a different _____.
15. Cancer cells are destroyed by _____.
16. The only electromagnetic energy that we can see is _____.
17. Ozone blocks out _____ rays.
18. Heat is _____ radiation.
19. Name the type of energy used or given off.

a. a warm kitten _____
b. image of a broken arm _____
c. sunburn _____
d. a television antenna _____
e. cooks food quickly _____
f. the colors we see _____

Light Energy

Light waves travel as transverse waves. Light does not need a medium or a material to travel through, it can travel through a vacuum. The speed of light is 300,000 km/sec.

Light is the only energy we can see. Some objects are luminous and give off light such as the Sun or a lamp. Other objects reflect light. We see the Moon and each other because of reflected light.

Light can be reflected, or bounced back unchanged. Reflection is best off a smooth, light-colored surface. Light can be absorbed, or taken into an object and then changed to heat energy. Dark, rough objects absorb light energy the best and therefore become warm very quickly.

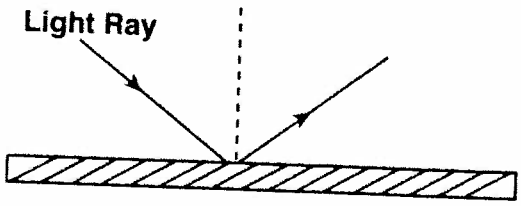


FIGURE 7. REFLECTION OF LIGHT

Refraction occurs when light enters a new medium causing its speed and direction to change. Refraction results in the bending of light rays. We see rainbows because of the refraction of sunlight as it passes through ice crystals and water droplets in the atmosphere. Objects appear bent when they are viewed in water. A pencil in a cup will appear to bend at the point that the water and air meet.

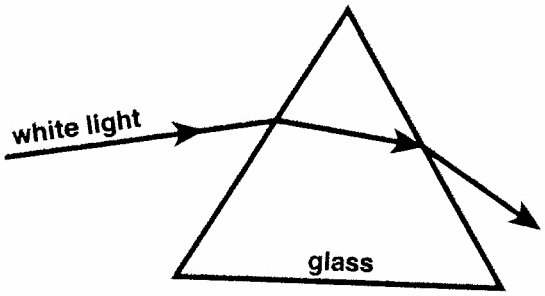


FIGURE 8. REFRACTION OF LIGHT

Light can be transmitted or passed through a material. Window glass allows light to be transmitted.

Review Questions

20. Light can travel through a medium like glass or through a _____.
21. We see objects because the objects _____ light.
22. The bending of light is _____.
23. A light colored, smooth surface will _____ light more than a dark, rough surface.
24. A black shirt will tend to _____ light energy.
25. Clear glass will _____ light.

Heat Energy

Another form of electromagnetic energy is infrared radiation, also known as **heat.** Matter is made up of tiny particles. These particles are always in motion. Heat or thermal energy makes the particles of matter move faster. The particles move faster and further apart as heat is added. Most substances **expand** when heated. When heat energy is removed from a material, the particles will move slower and closer together. Most materials will **contract** when cooled. Water is the exception, it expands as it cools and changes to ice.

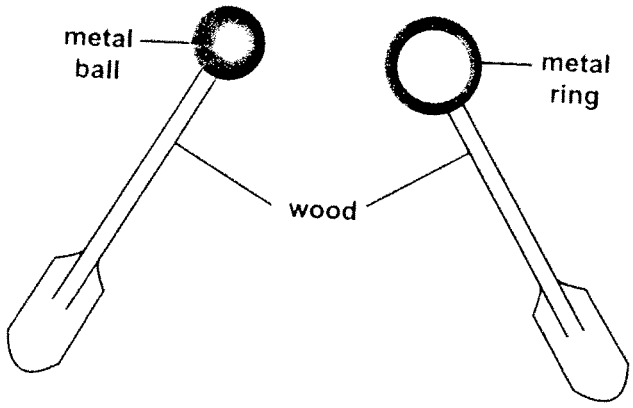


FIGURE 9. WHEN THE BALL IS COOL IT WILL PASS THROUGH THE RING. WHEN THE BALL IS HEATED, IT EXPANDS, AND WILL NOT FIT THROUGH THE RING.

Heat is a form of kinetic energy. Heat and temperature are not the same. **Temperature** indicates that heat energy is present. Heat affects the temperature of a substance. When heat is added, the temperature usually increases. When heat is removed, the temperature usually decreases. Heat moves in a predictable way. It flows from warm objects to cooler ones, until both reach the same temperature.

The unit of heat is the calorie. It takes one calorie of heat to raise the temperature of one gram of water by 1 degree Celsius. You may be familiar with food Calories. Food Calories are equal to 1000 calories.

Substances will heat faster or slower, depending on their color, texture, and type of material. Dark colors absorb energy faster than light colors. Black asphalt will heat faster than sand. Rough textures will absorb faster than smooth surfaces which reflect energy. Soil will heat faster than water.

Review Questions

26. Heat is a form of electromagnetic energy known as _____ radiation.

27. Most substances will _____ when heated.

28. When a material is cooled, the substance will usually _____.

29. When heat is removed, the temperature _____.

30. For each statement select the process that is occurring.

	Description	Reflection	Absorption
a.	A shiny, smooth surface		
b.	We see the Moon at night		
c.	A dark shirt becomes very warm		
d.	We see our face in a mirror		

Changes in the Phases of Matter

Matter can change state or phase when heat is absorbed or released. This is a physical change, there is no chemical change in the substance. When heat is added, molecules gain energy from the environment. As heat is added to water, the molecules move faster and further apart. They finally move fast enough to escape from their container as vapor. Energy is absorbed when a solid changes to a liquid (melting), or when a liquid changes to a gas (**evaporation**). When heat is removed, the particles of matter lose energy. Heat is removed when gases change to a liquid (**condensation**), or a liquid changes to a solid (**freezing**).

A substance's **freezing point** is the temperature at which its liquid form changes to a solid. Liquid water changes to ice at 32°F or 0°C. Every liquid has its own freezing point. Alcohol freezes at −117°C, and ocean water at −1°C. The melting point is the same as the freezing point. Melting will occur when heat is added, freezing will occur when heat is removed.

A substance's **boiling point** is the temperature when it evaporates, or changes from a liquid to a gas. Alcohol boils at 78°C; water boils at 100°C. Water vapor will condense at 100°C when heat is removed.

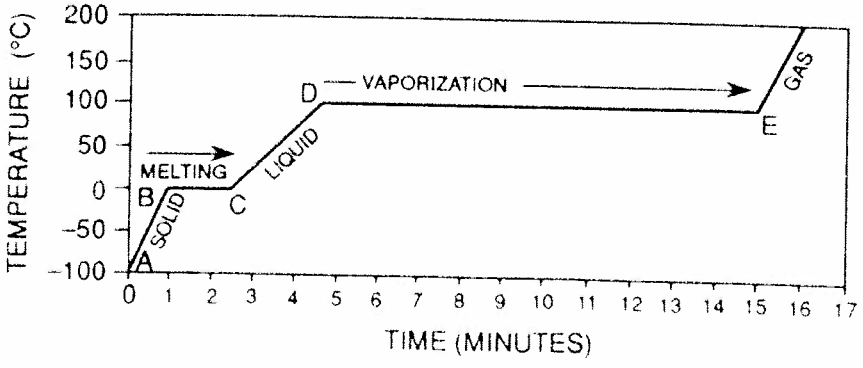


FIGURE 10. PHASE CHANGE

Review Questions

31. The phase change from solid to liquid is _____.

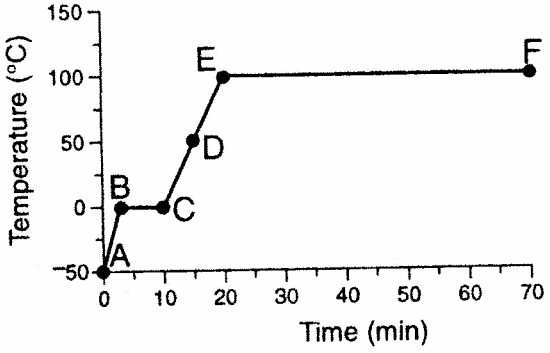
32. During melting, heat is _____.

33. Energy is _____ when a gas changes to a liquid.

34. Energy is released when a liquid changes to a _____.

35. Molecules of a _____ have the most heat energy.

36. The graph shows the heating of a solid material until it becomes a gas.



a. Temperature when the solid melts is _____

b. Letter at which all the material is a liquid _____

c. Letter where the material has the least energy _____

d. Letter where the material begins to boil _____

Methods of Energy Transfer

All types of energy can be transferred between locations, objects, or through matter in three ways: conduction, convection, and radiation. Energy is transferred through empty space by **radiation**. During radiation energy moves from one object to another without direct contact or matter in between. This is how electromagnetic radiation from the Sun reaches Earth.

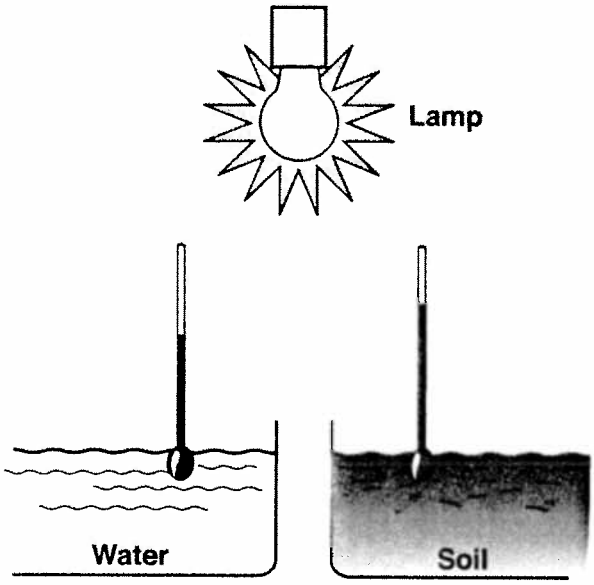


FIGURE 11. RADIATION

Conduction is the flow of energy through a solid by the collisions of its atoms or molecules. Energy is transferred by direct contact. The handle of a pot on the stove may get hot, even though the flame is not near it. Conductors are materials that allow energy to move through easily. This is why metal pots are used in cooking. Poor conductors are called insulators. They keep heat in and prevent heat from moving from place to place. This is why pot handles are often made of wood or plastic.

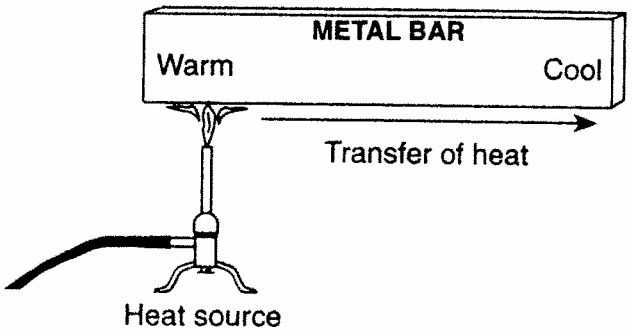


FIGURE 12. CONDUCTION

Convection is the flow of energy within a gas or a liquid. It is caused by density differences. Cold, dense air and water will sink causing the less dense, warm air or water to rise. This circulation of energy causes **convection currents**. This is why you are instructed to drop to the floor in a fire. The cooler air is at the bottom of the room.

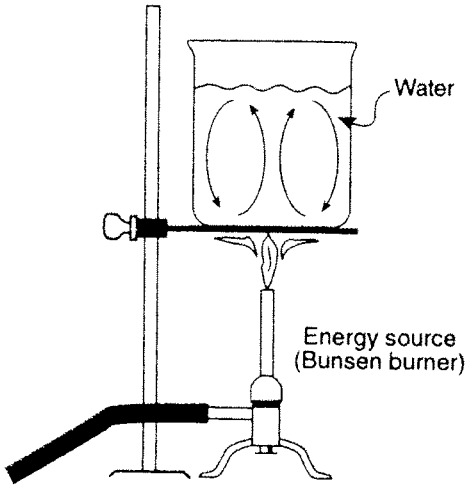


FIGURE 13. CONVECTION

Review Questions

37. Energy is transferred by direct contact during _____.

38. Hot air is _____ dense than cold air.

39. Heat circulates through the air in a classroom by _____.

40. Place an "**X**" in the column for the method of energy transfer described.

	Description	Radiation	Conduction	Convection
a.	Radio waves travel through space			
b.	Heat travels through a metal spoon			
c.	Electricity travels through an electric cord			
d.	Food is warmed in a microwave			
e.	Ocean water circulates by currents			
f.	Sunlight passes through a window			

CHAPTER REVIEW

1. An echo is an example of
   (1) reflection (2) refraction (3) diffraction (4) absorption

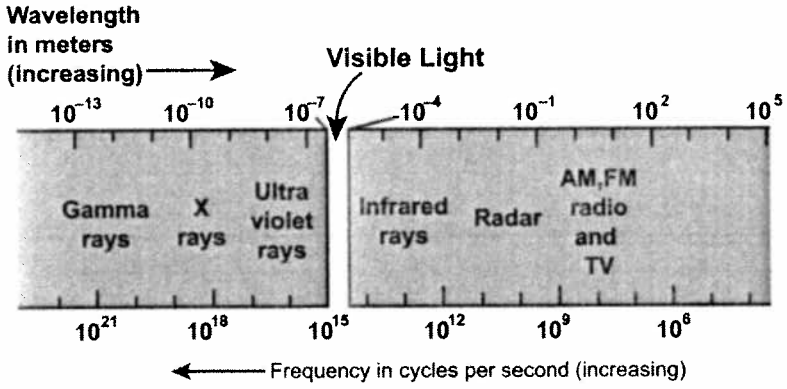
2. When you sit in a room you can hear noises in the hallway because sound is
   (1) reflected (2) refracted (3) diffracted (4) absorbed

3. Sound is produced when particles of matter
   (1) vibrate (2) change phase (3) evaporate (4) chemically react

4. Through which material will sound travel the fastest?
   (1) cold solid (2) hot solid (3) hot gas (4) cold gas

5. Which of the following is true about sound?
   (1) Sound will travel slower in a vacuum.
   (2) Sound will travel faster in a vacuum.
   (3) Sound will not travel through a vacuum.

Base your answers to **questions 6-9** on the diagram below which shows the types of electromagnetic energies.



6. Based on the diagram which statement is true?
   (1) X-rays have a shorter wavelength than visible light.
   (2) Visible light has a shorter wavelength than gamma rays.
   (3) Infrared radiation has a shorter wavelength than gamma rays.
   (4) Radio waves have a shorter wavelength than infrared radiation.

7. What is the difference between ultraviolet, visible, and infrared radiation?
   (1) temperature (2) wavelength (3) speed of travel (4) density

8. Which energy is not classified as electromagnetic?
   (1) radar (2) sound (3) television (4) heat

9. The electromagnetic energy that allows us to see objects is
   (1) gamma rays (3) ultraviolet radiation
   (2) x-ray radiation (4) visible light

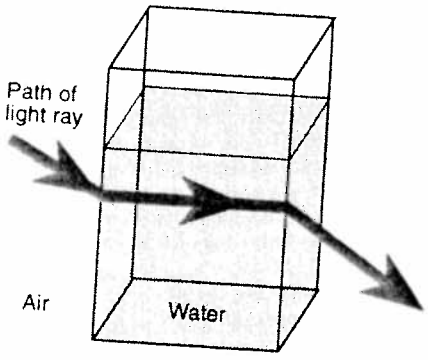
10. A surface reflects 90 percent of the light that hits it. This surface is most likely:
(1) dark colored and rough textured
(2) dark colored and smooth textured
(3) light colored and smooth textured
(4) light colored and rough textured

11. Compared to a dull and rough surface, a shiny and smooth surface will most likely cause sunlight to be
(1) reflected (2) refracted (3) scattered (4) absorbed

12. Changing the color of the roof of a house from light to dark would probably increase the amount of solar energy that is
(1) reflected (2) created (3) refracted (4) absorbed

13. On a sunny day changing your shirt from a light color to a dark color would make you feel
(1) cooler due to reflection
(2) cooler due to absorption
(3) warmer due to absorption
(4) warmer due to reflection

14. The diagram below shows the path of visible light as it travels from air through water. The light did not travel in a straight line because of

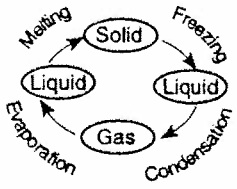


(1) reflection (2) refraction (3) diffraction (4) convection

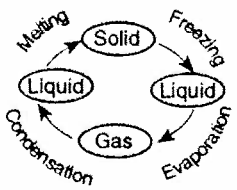
15. If you can not remove a metal cap from a glass jar, it might be helpful to place the cap under hot water. Which of the following supports this advice?
(1) Heating causes metal to contract faster than glass.
(2) Heating causes metal to expand faster than glass.
(3) Heating does not cause metals or glass to change.

16. Complete the statement: Cooling is to contracting, as heating is to
(1) vibrating (2) expanding (3) shortening (4) boiling

17. Which diagram correctly shows the processes that change the states of matter?



(1)



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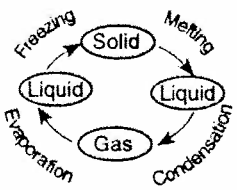

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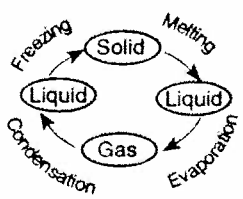


(4)

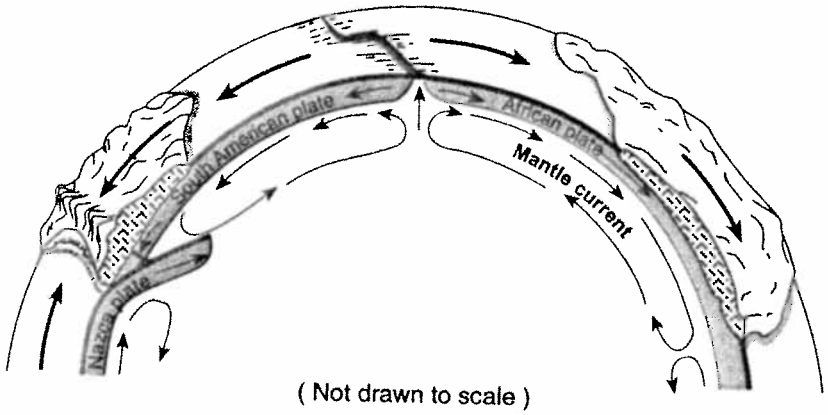
18. The change in phase from gas to liquid is called

(1) evaporation (2) condensation (3) precipitation (4) transpiration

19. Water releases energy when it changes phase from

(1) liquid to solid (2) solid to liquid (3) liquid to gas (4) solid to gas

20. The diagram below shows the movement of crustal plates. The arrows in the mantle indicate the flow of heat energy by:



(Not drawn to scale)

(1) conduction (2) convection (3) radiation (4) refraction

21. On a clear summer night the ground cools off by

(1) conduction (2) convection (3) radiation (4) refraction

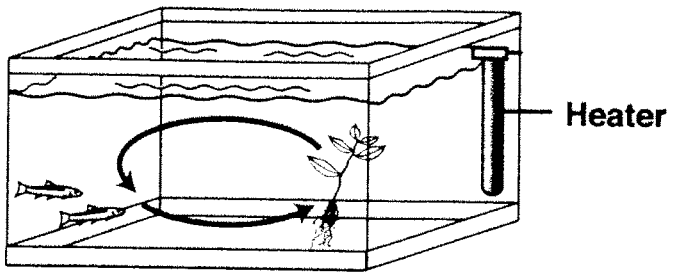
22. On Earth the movement of air by winds and currents is due to

(1) conduction (2) convection (3) radiation (4) refraction

23. Light from *Polaris*, the North Star, travels to Earth by

(1) conduction (2) convection (3) radiation (4) refraction

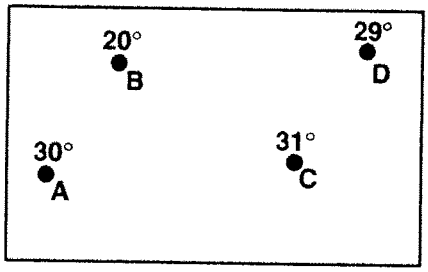
24. A piece of plant in a fish tank moved up and across the tank away from the water heater. When the plant reached the other side of the fish tank, it sank. What type of energy transfer does this movement show?



(1) convection (2) conduction (3) refraction (4) radiation

25. The map shows four locations with the temperature of each given in Celsius. Heat will flow from:

(1) A to B
(2) A to C
(3) B to D
(4) D to C



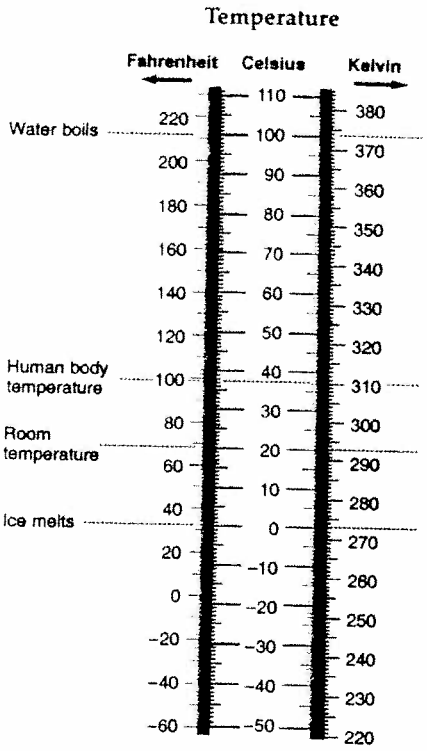
26. During a sunny afternoon it will become warmer because air molecules
(1) move faster (2) move slower (3) stop moving

27. Which action would help an air-conditioner use less energy on a hot, summer day?
(1) opening the curtains and blinds
(2) opening the windows
(3) turning on the lights and stove
(4) adding extra insulation in the walls and ceiling

Base your answers to **questions 28-29** on the diagram of temperature scales below.

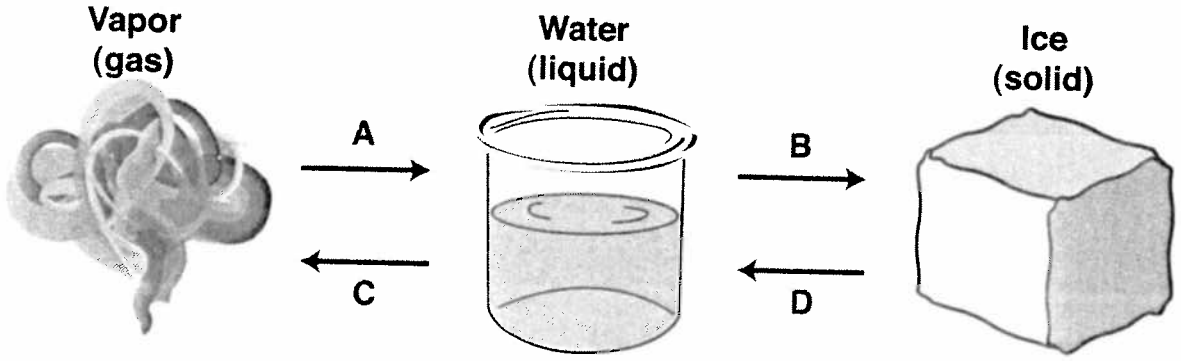
28. A temperature of 65°C is approximately equal to:
(1) 17°F
(2) 21°F
(3) 145°F
(4) 150°F

29. Average room temperature should be about:
(1) 68°C
(2) 68°F
(3) 98°C
(4) 270°K

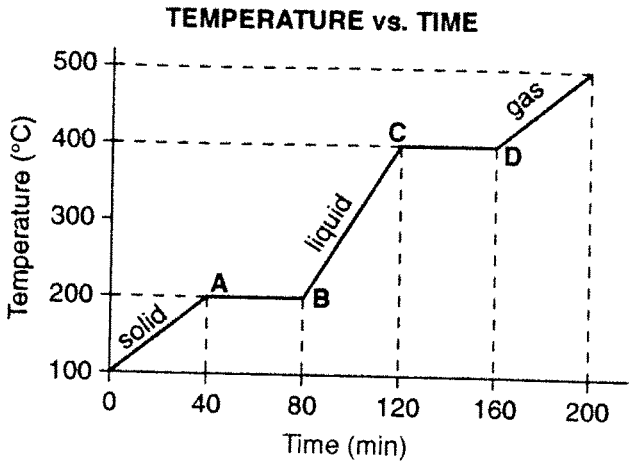


30. The diagram below represents the four processes that can occur when water changes phase. Which letter represents condensation?

(1) A (2) B (3) C (4) D



Base your answers to **questions 31-33 on** The graph below which shows the heating of a solid material for 200 minutes until it became a hot gas.



31. The temperature at which the material began to melt was

(1) 100°C (2) 200°C (3) 400°C (4) 500°C

32. Why did the temperature remain at 200° C for 40 minutes?

(1) no heat was being added during this time

(2) the particles began to release heat energy

(3) energy was used to change the particles' positions

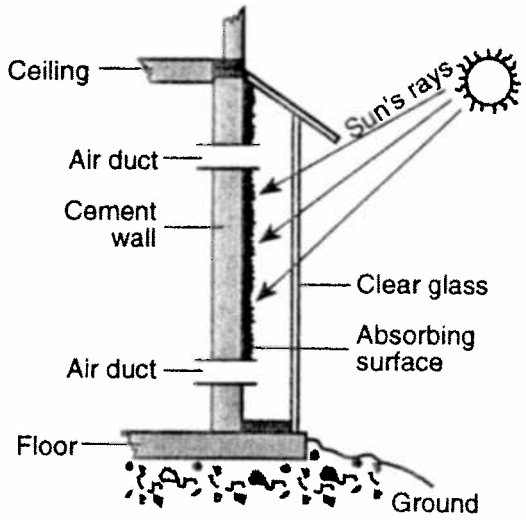
(4) energy was used to increase the kinetic energy

33. If heat energy was removed, then condensation would occur from letter

(1) A to B (2) C to B (3) C to D (4) D to C

EXTENDED RESPONSE

34. The diagram below shows a cross section of a solar collecting system in the wall of a house in New York. The table gives the house temperatures during a spring day. No other heat source is available for the house.



Time of Day	House Air Temperature (°C)
6 a.m.	12
8 a.m.	14
10 a.m.	16
noon	19
2 p.m.	22
4 p.m.	20

a. Describe the color and texture that the wall must be for maximum absorption of the sunlight. _____

b. State the time of day when the Sun is highest in the sky. _____

c. According to the data table, state the time when the house was the hottest.

_____

d. The homeowners are heating the home by using an energy resource which is (renewable) (non-renewable).

e. In New York this solar collecting wall should face the _____

35. On a trip to Florida, a student notices that most of the houses and buildings are painted very light colors. Explain a possible reason for this.

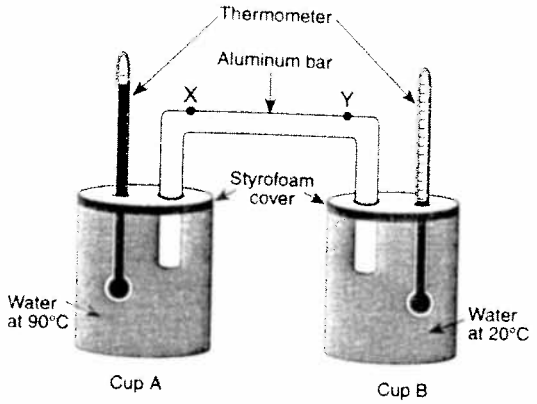
_____

_____

36. One summer night a student is awakened by a storm. While the student sits in a dark room he observes the lightning flashes before he hears the thunder. State the science concept that this observation proves.

_____

37. A hot cup of water and a cold cup of water are connected by metal bar.



	Temperature of Water (°C)	
Minute	Cup *A*	Cup *B*
0	90	20
1	88	20
2	86	20
3	85	21
4	83	21
5	82	22
6	81	22
7	80	22
8	79	22
9	78	23
10	77	23
11	76	23
12	75	23
13	74	23
14	73	23

a. State the method of heat transfer. _____

b. Graph data for the hot cup using a solid line. Label the line *HOT CUP*.

c. Graph data for the cold cup using a dashed line. Label the line *COLD CUP*.

d. State the responding (dependent) variable _____

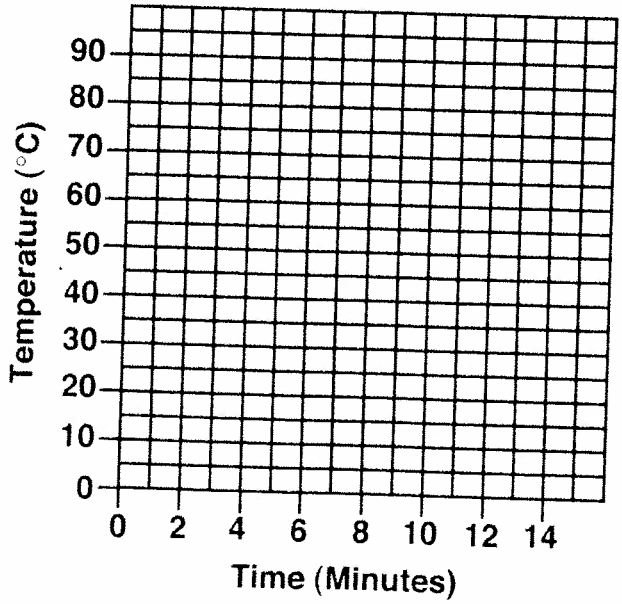
e. Name TWO constants during this experiment. (1) _____ (2) _____

f. Write a conclusion based on the data _____

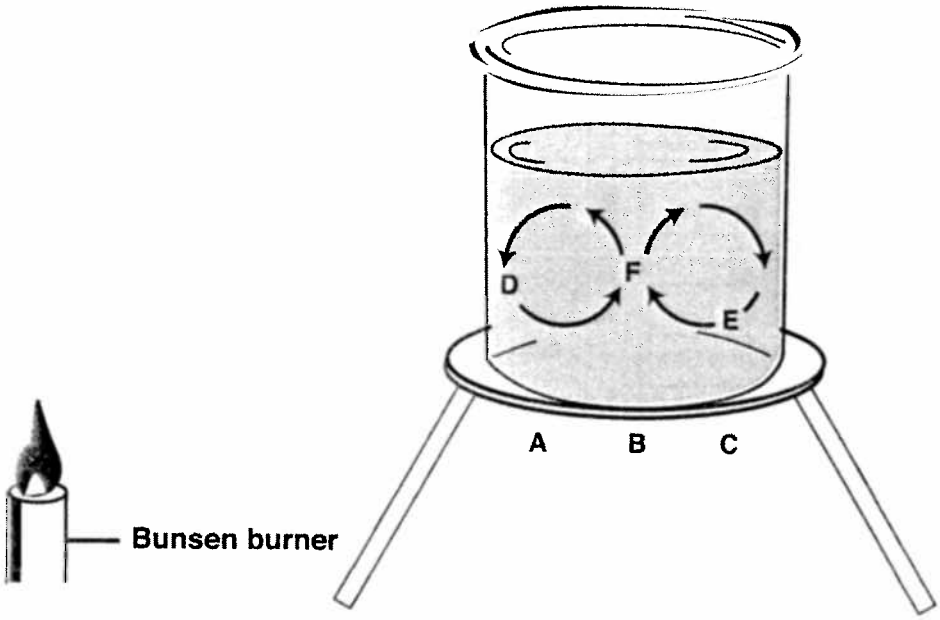
_____

g. Compare the amount of degrees that **A** went down and **B** went up. _____

_____



38. The diagram below shows the movement of water in a beaker which is being heated by a flame.

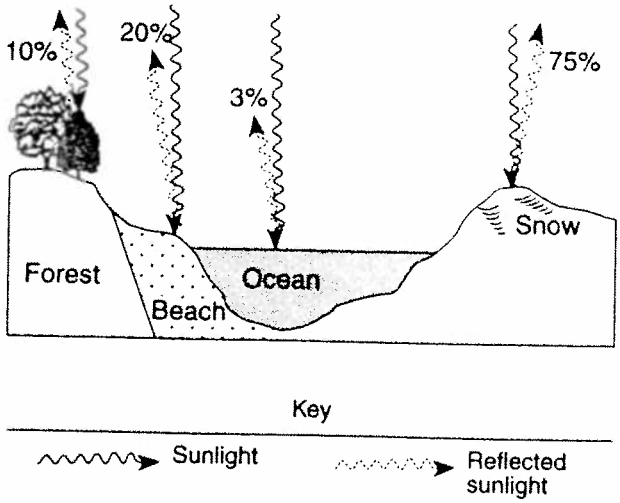


a. State the letter where the flame must be located. _____

b. State the letter where the water is the least dense. _____

c. Name the method of energy transfer occurring in the water. _____

39. The diagram below shows the percentage of sunlight reflected by different Earth surfaces when the Sun is overhead.



a. Name the surface that reflects the most light energy. _____

b. When light hits the surface of the ocean, very little of it is reflected. Explain why.

_____

_____

_____

c. Based on this data, explain why it is colder over a glacier than over the frozen tundra soil.

_____

_____

_____

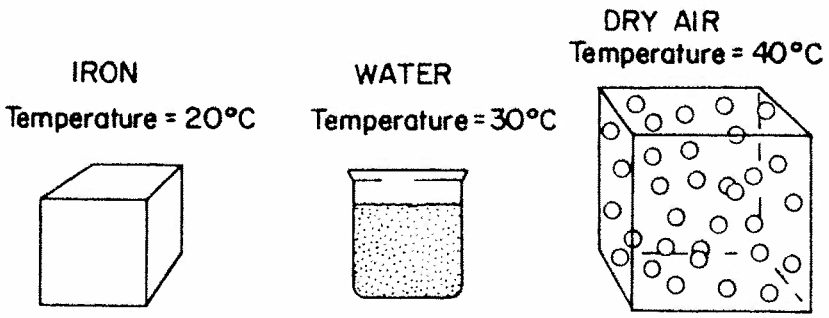
d. A forest reflects 10% of the sunlight and absorbs 90% of the sunlight. Explain what a forest does with the absorbed light energy.

_____

_____

_____

40. The diagram below shows three different materials representing the three states of matter.



a. Name the substance that has a definite shape and volume _____

b. Name the substance in which the particles have the most kinetic energy.

_____

c. Name the substance that can be produced by melting. _____

d. Name the substance that will have the same volume as the container it is in.

_____

e. Name the substance through which heat will travel by conduction. _____

41. A student wants to find out which brand of light bulbs lasts the longest. She designs a scientific experiment.

a. State the problem. _____

_____

b. State the manipulated (independent) variable. _____

c. State TWO factors that should remain *constant* during the experiment.

(1) _____ (2) _____

d. Describe the expected outcome. _____

_____

_____

42. Read the following passage:

> ***To Tan or Not To Tan***
>
> *Around 1870, scientists discovered that sunlight could kill bacteria. In 1903, Niels Finsen won the Nobel prize for the use of sunlight therapy to treat infectious diseases. Sunbathing came into wide use as a treatment for tuberculosis, Hodgkin's disease, and skin wounds. The discovery of vitamin D, the "sunshine vitamin", reinforced the healthful image of the Sun. At the time, the link between skin cancer and exposure to the Sun was not known.*
>
> *In the early 1900s people believed that a deep tan was a sign of good health. However, in the 1940s, the rate of skin cancer began to increase and reached large proportions in the 1970s. Scientists began to realize how damaging the Sun could be.*
>
> *Since then knowledge connecting the Sun to skin cancer has greatly increased. Many deaths due to this type of cancer can be prevented. The cure rate for skin cancer is almost 100% when treated early.*

a. State ONE known benefit of daily exposure to the Sun. _____

_____

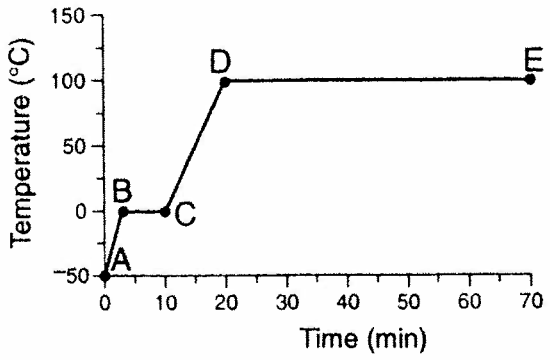
b. Explain ONE precaution that you can take to decrease your risk of skin cancer.

_____

c. In the first paragraph, the term "*infectious*" refers to diseases that are _____

_____

43. Refer to the phase change diagram of a solid material that is heated from **A** to **E**.



a. Explain what is happening to the substance between letters **B** and **C**.

_____

_____

b. State the phase(s) present between **C** and **D**. _____

c. At letter **A** the material has the least kinetic energy. Explain why. _____

_____

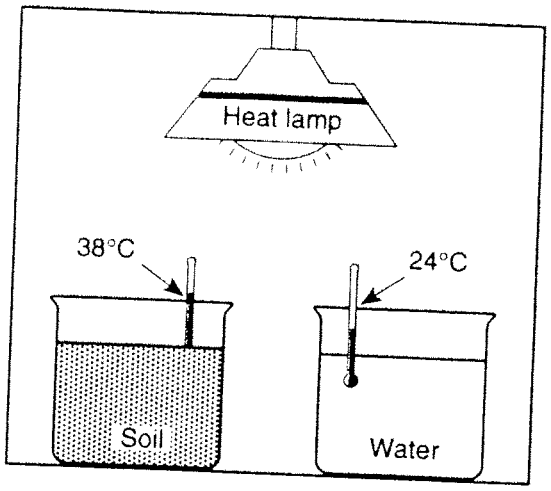
d. The starting temperature was _____

e. This substance is water. Explain how you know that this statement is true. _____

_____

_____

44. Diagram shows the heating of two containers which have equal amounts of soil and water.



a. Explain the characteristic that causes the soil to become hotter than the water.

b. Name the method of energy transfer that occurs between the lamp and the containers.