Module 13
Transit Energies: Heat and Work

What this module is about

In everyday life, temperature and heat are usually used interchangeably. Temperature is associated with hotness or coldness of a thing. In Physics, are these terms really the same? What are the effects of heat? What do you mean by heat and temperature in molecular level?

In this module, you will be able to answer these and many other questions that may be bothering you. Concepts like internal energy, average kinetic energy of atoms and molecules, transfer of heat, and expansion are discussed in the following lessons:

- **Lesson 1 – Heat and Temperature**
- **Lesson 2 – Consequences of Heat**

What you are expected to learn

After going through this module, you are expected to:

1. differentiate heat from temperature;
2. differentiate thermal energy from internal energy;
3. define temperature in molecular level;
4. compare the commonly used temperature scales;
5. explain how heat transfers;
6. calculate the heat given off or added to an object during a change in temperature; and,
7. calculate the heat given off or absorbed during a change of phase.

How to learn from this module

In order to achieve the objectives of this module, here are some tips for you:

1. Read and follow instructions carefully in each lesson.
2. Take note and record points for clarification.
3. Do the activities to fully understand each lesson.
4. Answer the self check to monitor what you already learned in each lesson
5. Answer the posttest.
6. Check your answer in the posttest against the key to correction

Familiarity with the following terms will help you get the most from this module:

Term	Definition
Internal energy	Grand total of all energies inside a substance
Thermal energy	Energy resulting from heat flow
Thermometer	An instrument used to measure temperature
Temperature	The measure of the average kinetic energy of molecule of a substance.
Heat	Energy in transit from a body of high temperature to a body of low temperature
Calorie	Energy needed to raise the temperature of 1 g of water by 1 Celsius degree.
Joule	SI unit of heat
Specific heat	Energy required to change the temperature of a unit mass of substance by 1 degree.
Melting	Change from solid to gas
Melting temperature	The temperature at which melting of a substance takes place
Latent heat of fusion	Energy required to melt a unit mass of solid at its melting point.
Freezing	Change from liquid to solid
Coefficient of linear expansion	Increase in length

What to do before (Pretest)

Directions: Select the letter of the option that correctly answers the question or completes the statement.

1. If the absolute temperature of a gas is doubled, the average kinetic energy of its molecules
   a) remains the same. c) increases four times.
   b) increases two times. d) decreases to ½ of its original value.

2. Decrease in temperature of a substance indicates that
   a) the number of particles in it decreases.
   b) the average velocity of its particles increases.
   c) the average potential energy of particles decreases.
   d) the average kinetic energy of its particles decreases.

3. The normal body temperature is 37 ^{o}C. What is this in Fahrenheit?
   a) 32 ºF b) 98.6 °F c) 212 ºF d) 373 ºF

4. Which of the following happens when ice changes into a liquid?
   a) The molecules move slower than before.
   b) The temperature of the substance increases.
   c) The potential energy of the molecules increases.
   d) The average movement of the molecules increases.

5. The boiling point of water is 100 ^{o}C. What is this in K?
   a) 173 b) 212 c) 373 d) 512

6. The natural direction of heat flow between two reservoirs depends on
   a) their temperature. c) their internal energy contents.
   b) their pressure. d) whether they are in liquid, solid or gaseous state.

7. When you accidentally put your hand near the kettle's spout, you cried "ouch". But when you moved your hand a few inches away, you found that the steam was cool. Why?
   a) The steam cooled as it expanded.
   b) The steam condensed into liquid.
   c) The steam absorbed energy from the surrounding air.
   d) Energy transferred to your skin was greater when it was near the kettle's spout.

8. Which of the following substances of equal mass warms faster?
   a) aluminum b) brick c) copper d) water

9. The greater the rate of evaporation from the surface of seawater is,
   a) the hotter the surface of the seawater becomes.
   b) the cooler the surface of the seawater becomes.
   c) the more massive the surface of seawater becomes.
   d) the greater the energy absorbed by the surface of the seawater.

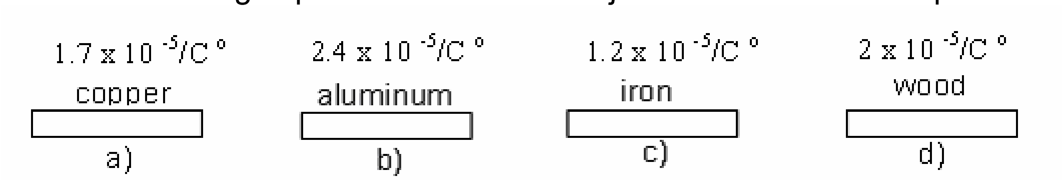
10. During warm days, you cool yourself by damping your skin with wet towel. Which of the following takes place?
   a) Your skin absorbs the coldness of the water.
   b) Your skin releases energy when water from your skin evaporates.
   c) The temperature of water on your skin decreases as it evaporates
   d) The temperature of your skin increases as water evaporates from your skin.

11. How may calories of heat is required to melt 10 g of ice at 0 ^{o}C?
   a) 80 b) 800 c) 540 d) 5400

12. How many calories of heat are required to change the temperature of 100 g of water at 5 C^0?
   a) 100 b) 250 c) 500 d) 5400

13. Contraction of a solid indicates that
   a) the number of particles decreases.
   b) the space between particles decreases.
   c) the average velocity of particles increases.
   d) there is a decrease in the average kinetic energy of particles.

14. Which of the following expands more when subjected to the same temperature change?



15. The average kinetic energy of the molecules of a body is a measure of the body's
   a. heat
   b. mass
   c. temperature
   d. volume

Key to answers on page 32

Lesson 1 Heat and Temperature

You encounter heat everyday. When cooking food, you burn fuel such as liquefied petroleum gas (LPG). You also see many people burn butane in cigarette lighter. When fuels are burned, heat is generated. Heat is often associated with temperature. In this lesson, you will learn more about heat and temperature.

Have you ever wondered why your body is hot even if you are at rest? Let's first have a short recall of past lessons. Do the activity that follows to find out if you still remember some concepts you will need to understand why your body is warm even if you are at rest.

What you will do

Self-Test 1.1

Fill in the blank with word or words to complete the following statements:

1. __________ energy is associated with moving objects.
2. The energy an object possesses due to its position is _________ energy.
3. If an object is raised 5 m above the ground its _________ potential energy increases.
4. A stretched spring has _________potential energy.
5. As an object freely falls its _________ energy is transformed into ________ energy.

Key to answers on page 32

In the previous modules, you have learned about the kinetic energy possessed by big moving objects such as a rolling ball or a running person, and the potential energy possessed by big bodies such as that of a raised hammer or a stretched spring. In this lesson the focus will be on energy of molecules and the atoms that make up these molecules. Let's call these atoms and molecules simply as particles.

Temperature

Have you ever experienced having a fever? Do you feel your forehead or your neck to determine whether you have fever or not? When you feel you are warm, you often say you have high temperature. Temperature is commonly associated with coldness or hotness of a body. When a body is hot, we say its temperature is high, and when it is cold, we say its temperature is low. How do we quantify this difference in hotness or coldness of a body? You might have seen how doctors and nurses measure temperature. Have you seen a small glass tube put in the underarm or under the tongue to determine temperature? This instrument is called a **thermometer.**

Thermometers usually apply physical properties of matter which change with temperature. An example of this property is the volume expansion of a liquid like mercury, which is most commonly used in thermometers. To establish a temperature scale, a process that occurs without a change in temperature is used as a fixed point on a temperature scale. To understand how temperature scale is established and what fixed points are, do Activity 1.1.

What you will do

Activity 1.1

1. Look at the data below obtained in an experiment where 200 ml of pure water is heated and boiled.
2. Observe what happens to the temperature as water is being heated.

Time (min)	Temperature (^{o}C)	Time (min	Temperature (^{o}C
0	30	16	66
1	32	17	69
2	34	18	74
3	35	19	76
4	38	20	79
5	41	21	80
6	44	22	83
7	46	23	86
8	48	24	88
9	51	25	90
10	53	26	94
11	55	27	96
12	58	28	98
13	60	29	100 water boils
14	62	30	100
15	64	31	100

3. Answer the following questions:

a. What happens to the temperature of water as time passes?
b. What is the temperature of water when it begins to boil?
c. What happens to the temperature of water while it is boiling?

Key to answers on page 32

Have you noticed that the temperature increases as water is being heated? But, when water is already boiling, no change in temperature occurs. When a substance changes phase from liquid to gas its temperature remains the same.

> **Remember This!**
> Temperature of a substance increases as it is heated. Temperature of a substance remains the same while it is undergoing a change of phase

This constant temperature is used as a fixed point in a temperature scale. For example, the two fixed points used are the freezing point of ice and the boiling point of water.

What you will do

Activity 1.2

1. Figure 1.1 shows thermometers in different temperature scales.

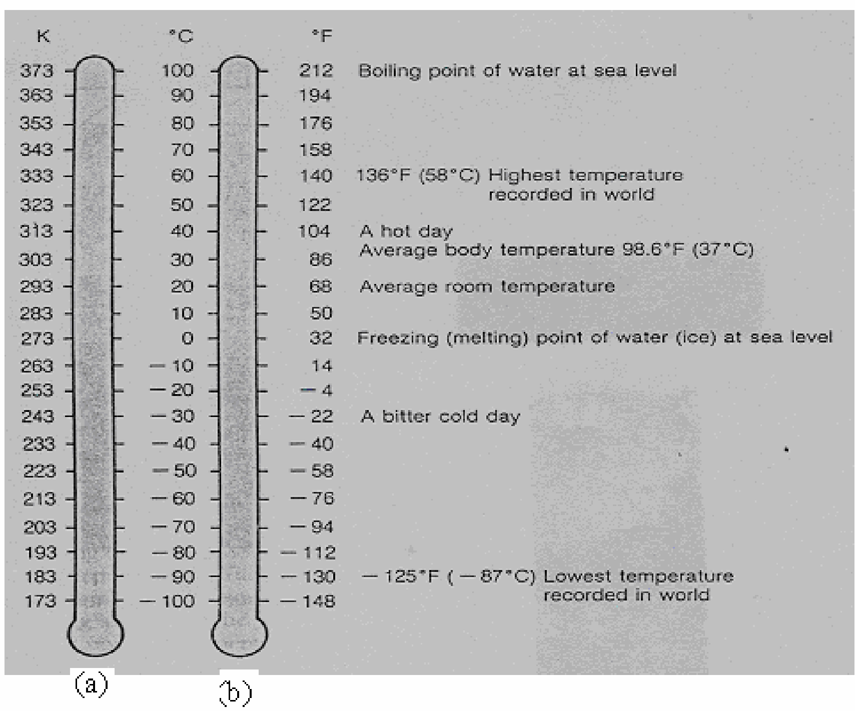


Fig. 1.1 a) Thermometer calibrated in Kelvin, b) Thermometer calibrated in Celsius and Fahrenheit scales

2. Answer the following questions:

   a. What are the temperature scales used in measuring temperature?
   b. What is the freezing point of water in degrees Celsius? In degrees Fahrenheit? In Kelvin?
   c. At what temperature does water boil in degrees Celsius? in degrees Fahrenheit? in Kelvin?
   d. What is the temperature difference between the freezing point and the boiling point of water in each of the three temperature scales?
   e. Derive an equation to change the temperature from Celsius to Fahrenheit, from Fahrenheit to Celsius, from Celsius to Kelvin, and from Kelvin to Celsius.

Key to answers on page 32

Did you notice that the freezing point of water in the Celsius scale is 0^0 while in the Fahrenheit scale, it is $32\ ^0$. Did you also notice that the difference between the freezing point and the boiling point of water in the Celsius scale is 100^0? In the Fahrenheit scale, the difference between the two fixed points is $180\ ^0$. To change the temperature from Celsius scale to Fahrenheit scale, always remember that 0^0 is equivalent to 32^0 and that a range of $180\ ^0$ on the Fahrenheit scale is equivalent to 100^0 on the Celsius scale. One Celsius degree is equivalent to 180/100, or 9/5, of one Fahrenheit degree. The equation would be

$T_F = 180/100\ T_C + 32$, or
$T_F = 9/5\ T_C + 32$

Example Problem 1

Change the normal body temperature which is $37\ ^0C$ to Fahrenheit.

Solution

1. The equation to be used is
   $T_F = 9/5\ T_C + 32$
2. Substitute the given value into the equation,
   $T_F = 9/5\ (37) + 32$
   $= 98.6\ ^0F$

Example Problem 2

A newscaster reports that the temperature in Korea is -15 ^{0}C. What is this temperature in Fahrenheit?

Solution

1. The equation to be used is
   $T_F = 9/5\ T_C + 32$

2. Substitute the given value into the equation,
   $T_F = 9/5\ (-15) + 32$
   $= 5\ °F$

Can you derive the equation that will convert a temperature in the Fahrenheit scale to Celsius scale? Rearranging equation 14.1, we have
   $T_C = 5/9\ (T_F - 32)$.

3. The temperature of the room is 108 °F. What is this temperature in ^{0}C?

Solution

1. The equation to be used is
   $T_C = 5/9\ (T_F - 32)$.

2. Substitute the given value into the equation,
   $T_C = 5/9\ (T_F - 32)$.

   $= 5/9\ (108 - 32)$
   $= 42.2\ ^0C$

What you will do
Self-Test 1.2

Get a clean sheet of paper and solve the following problems.

1. A nurse gets the temperature of a child using a mercury thermometer. The thermometer reads 40 ^{0}C. What is this temperature in the Fahrenheit scale?
2. Hydrochloric acid has a boiling point of -84°C. What is this temperature in Fahrenheit scale? in Kelvin scale?
3. Tungsten, a material used as filaments in electric incandescent bulbs, has a melting point of 6152 °F. What is this temperature in degrees Celsius?
4. What is the reading of a thermometer in Celsius scale when the temperature of the air around us is 80 ^{0}F? What is the temperature in the Kelvin scale?

Key to answers on page 33

Temperature and Kinetic Energy

Even if your body as a whole, when at rest, has zero kinetic energy, the molecules which it is made of are moving. The particles move from one place to another. They rotate or vibrate, hence, they possess kinetic energy. Temperature is associated with this translational motion of molecules. It is proportional to the average kinetic energy of the molecule of a substance. This means that if the temperature is high, the average kinetic energy of the molecules is greater, or the average movement of the molecules is fast. The temperature, however, is not directly affected by the rotational or vibrational motion of the molecules.

Heat

Some objects are hot, others are cold. The flame of the candle is hot while ice is cold. What makes some object hot and other objects cold?

Heat Transfer

If you get out of your house during cold days, you feel cold. This is because energy passes out from your skin into the air. If you touch a piece of ice, energy passes out of your hand into the ice. If, however, you touch the flame of a candle, energy passes out from the candle into your hand.

When something hot is placed next to something cold, energy transfers from the hot object to the cold object until both eventually come to the same temperature. In the system of air and your skin, the warmer body is your skin. Energy transfer is from your skin to the cooler air. In the ice and hand system, the direction of energy transfer is from the warmer hand to the cooler air. In the flame and hand system, the direction of energy transfer is from the hot flame to your hand. Generally, energy transfers naturally from a body of high temperature to a body of lower temperature (Fig. 1.2). The energy transferred from one body to another because of a temperature difference is called **heat**. **Heat**, therefore, is energy in transit from a body of higher temperature to a body of lower temperature. Once transferred, it can no longer be called heat. It becomes the **internal energy** of the body. Transfer of energy from hot objects to cool object stops when the two attain the same temperature. The objects are said to be in thermal equilibrium.

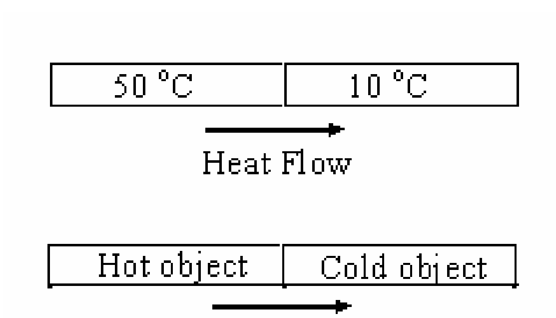


Fig 1.2 Direction of Heat Flow

Remember This!

Energy transfers naturally from a body of higher temperature to a body of lower temperature.

The energy transferred from one body to another because of a temperature difference is called **heat.**

What you will do

Activity 1.3

I. Study figure 1.3 showing two objects of different temperature. The white circles represent particles in a hot object while the dark circles represent particles in a cold object. The arrows indicate the movement of the particles.

II. Answer the following questions

1. Compare the movement of particles in hot and cold objects.
2. Compare the temperatures of the two objects.
3. When the two were placed in contact, what happened to their temperatures?
4. After sometime (Fig. 1.3 (c)) what happened to the temperature of the two objects?

Key to answers on page 34

In molecular level how does transfer of energy happen from a hot body to a cold body? If you could view what happens in the area of interaction between the two objects, you would see fast moving molecules in the hot object and slow-moving molecules in the cold object (Fig. 1.3 a). The faster molecules in a hot object collide with the slow-moving molecules in the cold object (Fig. 1.3 b). The collisions would cause the faster molecules to slow down and the slow-moving ones to move faster than before.

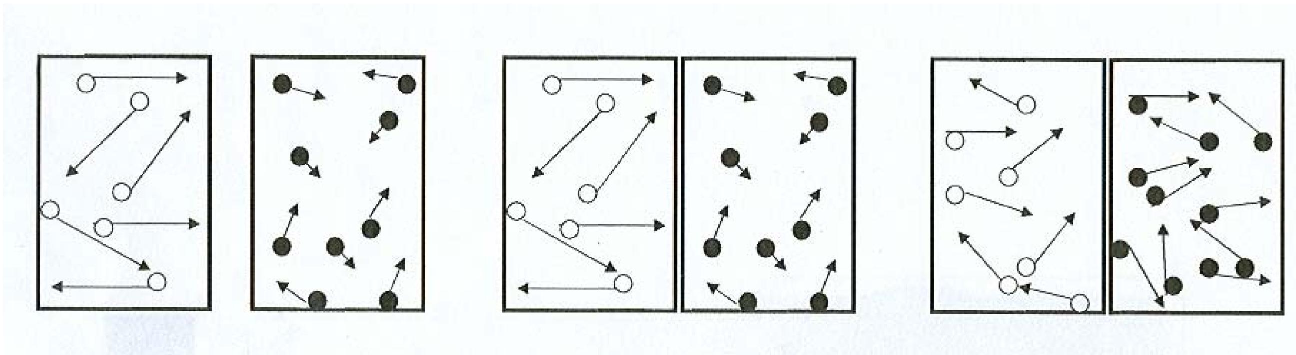


Fig. 1.3 (a) The particles in a hot object move faster than the particles in the colder object. (b) The two objects come in contact. When the two objects are in contact, fast-moving molecules collide with slow-moving molecules causing the slow-moving molecules to speed up and the fast-moving one to slow down.
(c) Heat flows from hotter to colder object causing the particles in the hot object to slow down and the particles in the colder object to speed up. The molecules move at the same speed, a state of thermal equilibrium.

Think about this!

What happens to the kinetic energy of the fast-moving molecule that collides with the slow-moving molecule?

Do you realize that the kinetic energy of the fast-moving molecule decreases when it collides with the slow-moving molecule, thus increasing the kinetic energy of the slow-moving molecule? So there is a transfer of energy from the fast-moving molecule to the slow moving molecule. After sometime, the molecules in the two objects move with the same average kinetic energy (Fig. 1.3c), thus, their temperatures are the same. No heat flows between the two objects. The two objects are said to be in thermal equilibrium.

What you will do
Self-Test 1.3

1. Which is warmer, a person's skin or the air around you during cold days?
2. Which is warmer, your hand or the piece of ice?
3. Which is warmer, the flame of the candle or your hand?
4. What is the general direction of heat flow between the person's skin and the cold air around it? between your hand and the piece of ice? between the flame of the candle and your hand?
5. Suppose two objects are placed in contact with one another in an insulated container.

$T = 30\ ^{0}C$	$T = 75\ ^{0}C$
Object A	Object B

Fig 2.3

   a) Draw an arrow to show the direction of energy transfer between the two objects.
   b) Before the objects are placed in contact, which has greater kinetic energy, the molecules in object A or the molecules in object B?
   c) What happens to the temperature of the two objects after sometime?
6. In molecular level, explain the transfer of energy from a hot object to a cold object.
7. What effect does transfer of energy have on an object?

Key to answers on page 34

Thermal energy and internal energy

Atoms in molecules also move, so they also possess kinetic energy. The atomic and molecular energy of a substance is called **internal energy**. Internal energy consists of thermal energy, which is the random kinetic energy of the atoms and molecules, and the potential energy of these tiny particles resulting from their bonds and interaction with each other. **Internal energy** is, therefore, the total of all the energy in a body.

In the previous section of this module, you learned that temperature is the measure of the average kinetic energy of molecules. Heat is a process whereby energy is transferred from one body to another of different temperatures. During a heat transfer, fast-moving molecules in a hot object collide with slow-moving molecules in a cold object. Thermal equilibrium is reached when the average kinetic energies of the molecules in both objects are the same. The kinetic energy of a slow-moving molecule increases upon collision with a fast-moving molecule. Since the average kinetic energy of the molecules in the formerly cold object increases, its temperature increases. On the other hand, the temperature of the formerly hot object decreases due to a decrease in the average kinetic energy of the molecules. Since there is an increase in the kinetic energy of the molecules in the formerly cold object, the sum of the energies of this object increases, or its internal energy increases. Since the kinetic energy of the molecules in the formerly hot object decreases, the internal energy of the object decreases.

Lesson 2 Consequences of Heat

Measurement of Heat

Suppose you have 1 g of water at 28 ^{0}C and you want to heat it to a temperature of 29 ^{0}C. How much heat is needed? The unit of heat more commonly used is calorie. A calorie is defined as the heat needed to raise the temperature of 1 g of water by 1^0 C degree. A bigger unit is the kilocalorie. A kilocalorie is equivalent to 1000 calories.

Remember this!

1 kcal = 1000 cal

Are you aware that the fuel value of food is also measured? The heat unit used to label foods is actually the kilocalorie. Nutritionists and dieticians call this the big calorie or Calorie (because this is written with a capital letter C). One Calorie is, therefore, one kilocalorie or 1000 calories.

In the SI, the unit of energy is the joule. One calorie is equivalent to 4.18 joules. One kilocalorie is equivalent to 4180 joules.

Remember this!

1 cal = 4.18 J
1 kcal = 4180 J

What you will do
Self-Test 2.1

Answer the following questions.

1. Nowadays, people are fond of doing aerobic exercises. Aerobic exercises are believed to burn Calories from the food intake. A 150 – lb person playing volleyball, for example, uses 34 Calories per 10 minutes from the food intake. Express this energy in calories, in kilocalories, and in joules.
2. Most food energy goes into running your body and keeping it warm. The basal metabolic rate, or the average energy used by the body just lying quietly in bed is about 1400 Calories per day for women and 1600 Calories per day for men. What are these in kilocalories/day? in calories/day?

Key to answers on page 34

Specific Heat Capacity

The sand in the beach heats faster than the water, but it also cools faster. At noontime, especially during summer, the sand becomes so hot, it is difficult to step on it barefooted, but you can immerse your body in seawater without being burned. In late afternoon, however, the land cools faster than the seawater. Why? To understand why this happens, do the activity that follows.

What you will do
Activity 2.1

A.

1. Ask your teacher to lend you three pieces of different metals of the same mass, probably aluminum, iron and copper.
2. Place the metals in boiling water for about 10 minutes.
3. With metal tongs remove the metals from boiling water and place them on a tray of paraffin. (Be careful in handling hot metals.)
4. Allow the metals to stay on the paraffin until they cool.

B. Answer the following questions and write your answer on a clean sheet of paper:

1. Which metal melted the most paraffin?
2. Which metal has the most energy? Explain your answer.
3. Compare the temperature of the three metals before they were transferred to the paraffin.

Key to answers on page 35

Did you notice that among the three metals, aluminum melted the most paraffin and copper melted the least amount of paraffin? Since heat is required to melt paraffin, what is the source of this heat? The source of this heat is the metal. The metals got hot when immersed in boiling water, and attained the same temperature as the boiling water. When the hot metals were transferred to the paraffin, energy flowed from the hot metal to the cooler paraffin. The energy they got from the water was transferred to the paraffin because of temperature difference. Since aluminum absorbed the most energy, it also gave up the most energy. Copper absorbed the least energy, so it gave up the least energy.

From the above discussion, it is clear that different metals of the same amount absorb different amounts of energy .

What you will do

Activity 2.2

A.
1. Place a cup of tap water in the kettle and heat it until it boils.
2. Fill another kettle with tap water up to the brim and heat it also until it boils.
3. Get a timer or a watch and record the time it takes for the two samples to boil.

B. Answer the following questions:
1. Which takes a longer time to boil, a cup of water or a kettleful of water?
2. In which set up is the energy transfer greater?
3. Which has greater mass, a cup of water or a kettleful of water?
4. At constant temperature, how is the amount of energy transferred to a substance related to the mass?

Key to answers on page 35

If you urgently need to drink hot coffee, and there is no available hot water, what do you usually do? Do you boil a cup of water or a kettle of water? Of course, you boil just a cup of water because it takes a shorter time. If the time it takes to boil a cup of water is short, the energy transferred from the flame to the water is less. This indicates that mass is a factor in determining the amount of energy transferred from one body to another. Results of experiments show that the energy required to change the temperature of a substance by one degree is directly proportional to the mass of the substance, or

$$Q \,\alpha\, m$$

The equation indicates that for the same change in temperature, if mass is doubled, the energy required to have that change in temperature is also doubled. If mass is tripled, the energy required to change the temperature is also tripled, and so on.

What you will do

Self-Test 2.2

1. Which takes a longer time to boil, a cup of tap water or a kettleful of tap water?
2. If it takes a longer time to heat a given substance, what does that indicate about the amount of energy transferred to the substance?
3. Compare the change in temperature of the boiled cup of water with that of the kettleful of water.
4. At constant change in temperature, what possible relationship exists between amount of energy transferred to a substance and its change in mass?

Key to answers on page 35

Which takes more time: boiling 1 cup of water or warming the same amount of water if the two samples have the same initial temperature? Based on experience, boiling water takes more time than just warming the same amount of water if the samples have the same initial temperature. Since the samples are at the same initial temperature, the change in temperature of the boiled water is greater than the change in temperature of the warm water. This clearly shows that temperature is another factor to take into consideration in determining the amount of energy needed to have a change in temperature. Results of experiments show that the energy required in changing the temperature, t, of a given mass of a substance is directly proportional to the change in temperature. The greater the change in temperature of a given mass of substance is, the greater is the amount of energy needed, or

$$Q \propto \Delta t$$

Combining the two equations, we have

$$Q \propto m\Delta t$$

If we change the proportionality sign to an equal sign, we have

$$Q = k\, m\, \Delta t,$$

where k is a constant of proportionality which depends on the kind of substance. This constant of proportionality is given a symbol c. If we rewrite the equation, we have,

$$Q = m\, c\, \Delta t.$$

Equation 1.4 may be used to determine the energy added to a substance to increase its temperature. The same equation may also be used to determine the energy that is lost from a substance.

Solving for c in equation 1.4, we have

$$c = \frac{Q}{m\Delta t} .$$

The equation shows that the energy added or removed per unit mass and unit change in temperature of substance is constant. The value c is constant only for a specific substance, so it is called **specific heat.**

Example Problem 2.1

What quantity of heat must be added to 50 grams of water at 10°C to increase its temperature to 50°C?

Solution:

1. The given quantities are:
   Mass of substance, m= 50 g
   specific heat of water, c= 1 cal/gC°
   Initial temperature of water, t_i= 10°C
   Final temperature of water, t_f= 50°C
   Required:
   Energy needed, Q

2. The equation that relates the given quantities with the unknown quantity is
   $Q= mc\Delta t$

3. Substitute the given quantity into the working equation. The working equation is the basic equation for Q,

$$Q= mc\Delta t$$
$$= 50g(1cal/gC^o)\ (50\text{-}10)C^o$$
$$= 50\ cal\ (40)$$
$$Q= 2\ 000\ cal$$

Example Problem 2.2

How much heat must be added to boil a cup of water at 20 ^{o}C for coffee? One cup of water has a mass of about 220 g.

Solution:

1. The given quantities are;
   mass of water, m= 220g
   initial temperature of water, t_i= 20 °C
   final temperature of water, t_f = 100 °C
   Required:
   Heat needed, Q

2. The working equation to be used is the basic equation,
   $Q= mc\Delta t$

3. Substitute the given quantities into the working equation,

$Q = 220g\ (1\ cal/gC^o)\ (100 - 20)C^o$
$= 220\ cal\ (80)$
$= 17,600\ cal$

Change of Phase

Another consequence of heat transfer is change of phase. Surely, you have seen what happens to ice when it is taken out of the freezer. To understand what takes place when ice water melts, do activity 2.3

Melting

What you will do
Activity 2.3

1. Borrow a laboratory thermometer from your teacher.
2. After taking out the ice cubes from the freezer immediately put them in a container. Gently push the thermometer into the ice cubes. The mercury should be covered with ice.
3. Take the initial temperature of the ice, and record it in your data table (see table 2.1)

Table 2.1

Time (min)	Temperature (°C)
0	
1	
2	
3	
4	
5	
6	

7	
8	
9	
10	

4. Record the temperature every minute thereafter, until you observe that most of the ice has melted.
5. Plot a graph of temperature against time. Describe the graph.

Did you observe that the initial temperature of ice was below 0 ^oC. The temperature of ice from a larger time before taking out of the freezer is usually below 0 ^oC. When left outside the freezer, the temperature increased until it reached 0^o C. At this temperature, the ice started to melt. While it was melting, did you observe that its temperature remained the same?

Does the graph of the temperature against time that you plotted the same as the one next page (Figure 2.1)? The first part of the graph is a straight slanting line while the second part is a straight horizontal line.

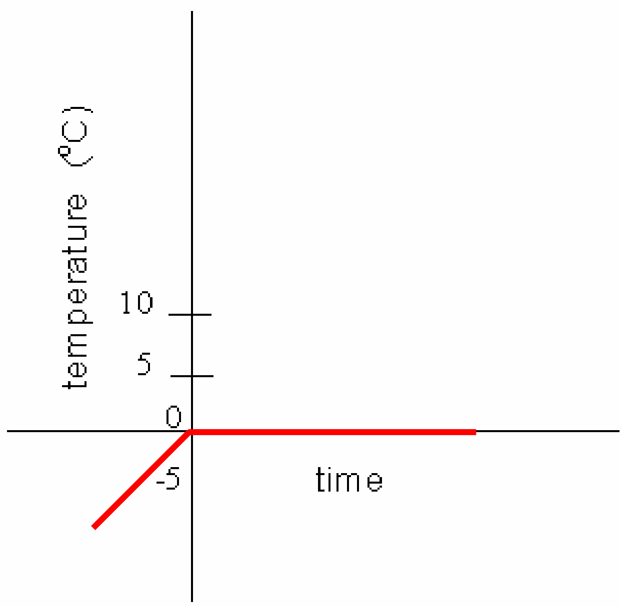


Fig. 2.1 Graph of temperature versus time for melting ice

What happens to the particles when a solid melts? The atoms in a solid are usually bonded to each other in a well-defined structure. They can vibrate about an equilibrium position but they cannot rotate or move to new positions. If heat is added to a solid such as ice, the temperature increases to 0^oC. While the temperature is increasing, the particles vibrate with greater amplitude. At 0^oC, further heating will cause the particles to break away from those near them and move about more freely. Melting occurs, or the solid changes to liquid. The temperature at which this change from solid to liquid happens is called the **melting temperature**.

What you will do

Activity 2.4

1. Study Table 2.2 which shows the melting and boiling temperatures of some substances.

Substance	Melting		Boiling	
	Melting Temperature (^oC)	Heat of Fusion (J/kg)	Boiling Temperature (^oC)	Heat of Vaporization (J/kg)
Hydrogen	-259.31	58.6×10^3	-252.89	452×10^3
Nitrogen	-209.97	25.5×10^3	-195.8	201×10^3
Oxygen	-218.79	13.8×10^3	-183.0	213×10^3
Ethanol	-114	104.2×10^3	78	854×10^3
Mercury	-39	11.8×10^3	357	272×10^3
Water	0.00	334×10^3	100.00	2256×10^3
Sulfur	119	38.1×10^3	444.6	326×10^3
Lead	327.3	24.5×10^3	1750	871×10^3
Antimony	630.50	165×10^3	1440	561×10^3
Silver	960.80	88.3×10^3	2193	2336×10^3
Gold	1063.00	64.5×10^3	2660	1578×10^3
Copper	1083	134×10^3	1187	5069×10^3

2. Compare the melting temperatures of the different substances.

Did you observe that the melting temperatures of the substances differ? Melting temperature is one of the identifying properties of a substance.

The amount of energy required to change the phase from solid to liquid also varies for different substances. The measure of the energy required to melt a solid is called the **latent heat of fusions, h_f**. The heat of fusion of a solid is defined as the energy needed to melt a unit mass of solid at the melting temperature. If you look at Table 2.2, you will find that the heat of fusion of ice is 334×10^3 J/kg or 80 cal/g. This means that 1 kg of ice needs 334×10^3 joules or 1 g of ice needs 80 cal to melt it at its melting temperature.

How much heat is needed to melt a mass **m** of solid? In general, the heat, **Q**, needed to melt a mass of solid is

$$Q = mh_f$$

The value, Q, is always a positive number because energy must be added to the substance to melt it.

Freezing of Liquids

In the previous sections of this module, you learned about melting and the energy needed to melt a given mass of substance. What do you think happens when liquid freezes or changes to solid? Freezing is the opposite of melting. When a liquid freezes, energy is given off.

> **Think about this!**
>
> What happens to the random motion of the particles of matter when water freezes?

When a liquid freezes, the random motion of the particles slows down. Particles begin to fuse or bond. The liquid changes to a solid. This change from the liquid to the solid state is called **freezing**. This occurs at the melting temperature.

The same amount of energy is involved is freezing as that in melting.

Energy absorbed to melt a substance	=	Energy released to freez the substance

The energy **Q** released when a mass **m**, of liquid changes from liquid to solid or when a liquid freezes is

$$\mathbf{Q = - mh_f}$$

The negative sign indicates that energy is given off when the liquid freezes.

Always remember that during a change of phase, the temperature of the substance remains the same. Thus, when ice melts, temperature remains the same until all the ice was totally melted. Similarly, the temperature remains the same until all the liquid has totally frozen.

What you will do
Activity 2.5

Try solving the following problems using the equations you have learned.

1. How much heat must be added to 200 g of ice at O^{o} C to totally melt it at the same temperature?
2. 100 g of water in an ice tray at 30^{o} C was placed in the freezer of a refrigerator. After sometime, it froze. How much heat was removed from the water when all of it was frozen at 0^{o} C?

Key to answers on page 36

Thermal Expansion

Have you observed what happens to an inflated balloon when left under the sun? What happens to the dried skin of pork or beef made into “chicharon”?

When left under the sun, an inflated balloon expands. It gets bigger. The dried pork or beef skin also expands when placed in hot oil. Recall that whenever the thermometer is placed in a glass of hot water, the level of mercury inside the thermometer tube rises. Solids, liquids and gases expand when they are heated

What happens to the molecules when matter expands? Do activity 2.6 to find out.

What you will do
Activity 2.6

Study figure 2.2, then answer the questions that follow. The figure shows a solid heated to increase the temperature from 20^{o} C to 50^{o} C

T= 20 ^{o} C   T= 50 ^{o} C

a   b

1. Describe the temperature of the solid in a and b.

2. If the small circles represent the molecules, estimate the number of molecules in the substance in a and b.
3. Compare the lengths of the two solids.
4. Compare the space between the molecules in solid **a** and solid **b**

Key to answers on page 36

At higher temperature, the atoms and molecules in a solid or liquid vibrate through a greater distance. They push each other apart slightly in all directions. This is called **thermal expansion**. Linear expansion is the increase in length while volume expansion is the increase in volume per unit length or volume per degree rise in temperature.

Most solid objects change length in direct proportion to a change in temperature. This means that for the same initial length of a solid, the greater the change in temperature, the greater is its increase in length.

Most solid objects also change length in direct proportion to their original lengths. So, for the same change in temperature, a short iron bar expands less than a longer one. But if we get the ratios of the change in length to the initial length of the two bars, they are the same. The equation

$$\Delta L \; \alpha \; L \; \Delta t$$

shows the relationship of increase in length with original length and change in temperature of the solid. If we change the proportionality sign to an equal sign, we introduce a constant of proportionality **k**. Thus we have

$$\Delta L = kL \, \Delta t$$

where Δ**L** is the increase in length, **k** is the proportionality constant, $\mathbf{L_o}$ is the original length and Δ**t** is the change in temperature of the solid. The constant k may be changed to α and is called the coefficient of linear expansion. How is this value obtained?
From the equation, $\Delta L = \alpha L_o \Delta t$, the α maybe solved;

$$\alpha = \frac{\Delta L}{L \, \Delta t}$$

This means that the ratio of the change in length to original length and unit change of temperature is constant. However, this is constant for a given substance only. For different substances, the value varies.

Table 2.3 Coefficient of Thermal Expansion at 20 °C

Substance	Linear Expansion α (/ C°)	Volume Expansion β (/ C°)
Aluminum	25 X 10^{-6}	72 X 10^{-6}
Steel and iron	12 X 10^{-6}	36 X 10^{-6}
Glass (Pyrex)	3 X 10^{-6}	9 X 10^{-6}
Ethanol	250 X 10^{-4}	750 X 10^{-6}
Gasoline	300 X 10^{-6}	900 X 10^{-6}
Air		3670 X 10^{-6}

Thermal expansion occurs in all three dimensions. A solid does not merely become longer, it also becomes wider and thicker. So, both the area and the volume of the solid increase.

The behavior of liquids is quite similar to that of solids. However, since liquids do not have definite shapes, the change in volume caused by expansion is determined

Think about this!

What do you think will happen to the level of liquid when its container is heated?

Since liquids expand more than solids, when a container holding a liquid is heated, the level of the liquid rises. This is because the increase in volume of the liquid is greater than the increase in the volume of the container. This principle is applied in liquid thermometers. When heated, the level of mercury in the mercury thermometer rises.

What you will do

Activity 2.7

Use the data in table 2.3 to answer the questions below:

1. Compare the thermal expansion of solids to that of liquids.
2. Compare the volume expansion of gases to that of solids and liquids.

The volume expansion of gases is greater than those of solids and liquids. Unlike solids and liquids, expansion of gases is uniform.

Example Problem 1

An iron rod is 20 cm in length at 30 ^oC. a) What is the increase in length of the rod when the temperature is increased to 60 ^oC? b) What is the length of the rod at 60 ^oC?

Solution

(a)

1. The given quantities are;

$L = 20$ cm

$T_1 = 30\ ^oC$

$T_2 = 60\ ^oC$

$\alpha_{iron} = 12 X 10^{-6}$

2. The working equation to be used is the basic equation

$$\Delta L = \alpha L\ \Delta t$$

3. Substitute the given quantities into the equation

$\Delta L = 12 X 10^{-6}/C^o X 20 cm X (60\text{-}30) C^o$

$= 7200 X 10^{-6}$ cm or

$\Delta L = 0.0072$ cm

(b)

1. The given quantities are

$L_1 = 20$ cm

$\Delta L = 0.0072$ cm

2. The basic equation to be used is

$\Delta L = L_2 - L_1$

3. Derive the equation for L_2 from the equation $\Delta L = L_2 - L_1$

$L_2 = \Delta L + L_1$

4. Substitute the given quantities into the equation

$L_2 = .0072$ cm + 20 cm

$= 20.0072$ cm

Example Problem 2

a) An aluminum rod is 1 m at 30 ^oC. What is the length of this rod at 60 ^oC? b) If the rod is cut in half, by how much does the length of each half increase for the same temperature change?

Solution
(a)

1. The given quantities are

$L = 1m$

$T_i = 30\ ^oC$

$T_f = 60\ ^oC$

$\Delta T = (60-30)\ C^o$

$= 30\ C^o$

2. The equation to be used is

$L_2 = \Delta L + L$, where $\Delta L = \alpha L \Delta t$

3. Substitute the given quantities in the 2nd equation

$\Delta L = \alpha L \Delta t$

$= 25 \text{ X } 10^{-6} / C^o \times 1m \times 30\ C^o$

$= 0.000750$ m

$L_2 = \Delta L + L$

$= 0.000750$ m $+1$ m

$L_2 = 1.00075$ m

Solution
(b)

1. The given quantities are

$L = 0.5$ m

$\Delta T = 30\ C^o$

Required : ΔL

2. The equation to be used is

$\Delta L = \alpha L \Delta t$

3. Substitute the given quantities into the equation

$\Delta L = \alpha L \Delta t$

$= 25 \text{ X } 10^{-6}/C^o \text{ X } 0.5 \text{ m} \times 30\ C^o$

$= 375.0 \text{ X } 10^{-6}$ m, or

$= .000375$ m

What you will do

Self-Test 2.7

Solve the following problems:

1. A piece of copper pipe is 6.0 meters long at 25 ^oC. a) If it is heated to 25 ^oC, what is the increase in its length? (α_{al} = 1.7 x 10^{-5} / C^o).

2. What is the length of the rod in no. 1 if it is heated at 75 ^oC?

Key to answers on page 37

Let's summarize

1. Temperature is the measure of the hotness or coldness of a body. In molecular level, temperature is defined as the measure of the average kinetic energy of the molecules.

2. Heat is energy in transit from a body of higher temperature to a body of lower temperature.

3. The energy resulting from heat flow is called thermal energy.

4. Internal energy is the total of all energies in a substance. It includes the translational kinetic energy of molecules, the rotational kinetic energy of molecules and kinetic energy due to movement of atoms in a molecule, and the potential energy due to the forces between molecules.

5. The commonly used temperature scales are the Celsius, Fahrenheit, and Kelvin scales. In the Celsius scale, 0 degree is assigned as the temperature at which water freezes, while 100 degrees is assigned as the boiling temperature of water. The difference between the freezing temperature and the boiling temperature is 100 degrees. In the Fahrenheit scale, 32 degrees is assigned as the freezing point of water while 212 degrees is assigned as the boiling temperature of water. There is a gap of 180 degrees between the freezing and the boiling temperatures of water. In the Kelvin scale, the freezing point of water is 273 kelvins, while the boiling point is 373 kelvins.

6. Heat transfers naturally from a body of high temperature to a body of low temperature until the two bodies attain thermal equilibrium. In molecular level, during heat transfer, the kinetic energy of the fast-moving molecule decreases when it collides with a slow-moving molecule, so there is transfer of energy from the fast-moving molecule to slow-moving molecule. Thermal equilibrium is attained when the molecules have the same average velocity.

7. The heat given off or added to a substance is obtained using the equation

$$\mathbf{Q = mc\Delta t}$$

where **m** is the mass of the body, **c** is the specific heat, and Δ**t** is the change in temperature of the substance.

8. The heat given off during a change of phase from liquid to solid or absorbed during a change of phase from solid to liquid is given by the equation

$$\mathbf{Q = mh_f.}$$

It is positive if heat is absorbed and negative if heat is given off.

9. Solids expand when they are heated. The expansion is obtained using the equation

$$\mathbf{\Delta L\ \alpha\ L\ \Delta t}$$

Posttest

Directions: Select the letter of the option that correctly answers the given questions. Write your answer on a separate sheet of paper.

1. The Kelvin temperature of matter is directly proportional to the
   a) average kinetic energy of molecules and atoms.
   b) total kinetic energy of molecule and atoms.
   c) sum of kinetic energy and potential energy of molecules and atoms.
   d) average potential energy of molecules and atoms.

2. As an object's temperature increases
   a) the average kinetic energy of its particles increases.
   b) the average velocity of its particles decreases.
   c) the number of particles in it increases.
   d) the distance between its particles increases.

3. Oxygen boils at -183 ^oC. What is its equivalent in the Fahrenheit scale?
   a) -215 ^oF b) 297.4 ^oF c) -329 ^oF d) -361.4 ^oF

4. On the Celsius scale, the boiling point of water is 100 ^{o}. What is the boiling point in the Fahrenheit scale?
   a) 32 ºF b) 212 ºF c) 273 ºF d) 373 ºF

5. The human blood has a temperature of 37 ^{o}C. What is this in K?
   a) 273 K b) 310 K c) 346 K d) 373 K

6. Two bodies of different temperatures come in contact. Which of the following would NOT happen?
   a) Heat flows from a body of high temperature to a body of low temperature.
   b) The temperature of the hot body would increase.
   c) The two objects would have the same temperature after sometime.
   d) Particles in the colder object would move faster after sometime.

7. One gram of steam at 100 ^{o}C causes a more serious burn than one gram of water at 100 ^{o}C because the steam
   a) is less dense.
   b) strikes the skin with greater force.
   c) has a higher specific heat capacity.
   d) contains more internal energy.

8. A cup of hot coffee can be cooled by placing a cold spoon in it. Which of the following materials would be best for this purpose? Assume all spoons have the same mass.
   (Specific heat: Al = 910 J/kg.K ; Cu = 390 J/kg.K; Fe = 470 J/kg.K; Ag = 234 J/kg.K)
   a) aluminum b) copper c) iron d) silver

9. Evaporation cools a liquid because the
   a) slowest molecule tends to escape
   b) fastest molecules tend to escape
   c) pressure on the liquid decreases
   d) pressure on the liquid increases

10. When vapor condenses into a liquid
    a) it absorbs heat c) its temperature rises
    b) it evolves heat d) its temperature drops

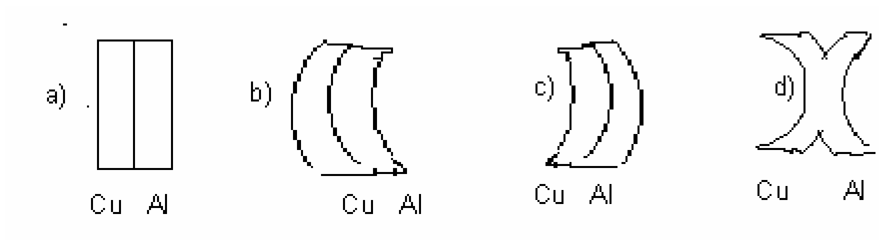
11. Fifty kJ of heat is added to a 20 kg block of ice at 0 ^{o}C. The amount of ice that melts is
    a) 0.093 kg b) 0.15 kg c) 0.83 kg d) 2.5 kg

12. If 10 kg of punch of specific heat 3.4 kJ/kg C^{o} absorbs 340 kJ of energy, the change in temperature of the punch is
    a) 6 C^{o} b) 8 C^{o} c) 10 C^{o} d) 12 C^{o}

13. Expansion of a solid indicates that
   a) the number of particles in it increases.
   b) the space between its particles increases.
   c) the average velocity of particles increases.
   d) there is an increase in the average kinetic energy of its particles.

14. A bimetallic strip consisting of copper and aluminum were subjected to a change in temperature and bent. Which figure shows the correct position of the bimetals? Refer to the table below.

Solid	**α (X 10^{-6}/ C^{o})**
Aluminum	25
Brass	19
Brick	9
Iron	12



15. Metals are good conductors of heat because
   a) they contain free electrons.
   b) their atoms are relatively far apart.
   c) their atoms collide frequently.
   d) their atoms are stable.

Key to answers on page 37

Key to Answers

Pre Test

1. b
2. d
3. b
4. c
5. c
6. a
7. b
8. c
9. b
10. b
11. b
12. c
13. b
14. b
15. c

Lesson 1

Self-Test 1.1

1. kinetic energy
2. potential energy
3. gravitational
4. elastic
5. gravitational potential, kinetic

Activity 1.1

3. a. The temperature of water increases as time passes.
   b. The temperature of water is 100 ^{o}C when it begins to boil.
   c. While the water is boiling, there is no change in the temperature.

Activity 1.2

2. a. The temperature scales used in measuring temperature are the Celsius, Fahrenheit, and Kelvin scales.
   b. The freezing point of water at sea level is 0 ^{o}C or 32 ^{o}F or 273 K.
   c. Water boils at sea level at a temperature of 100 ^{o}C or 212 ^{o}F or 373 K.
   d. The temperature difference between the freezing and boiling temperatures is 100 ^{o} in the Celsius scale, 180 ^{o} in the Fahrenheit and 100 in Kelvin scale.
   e. Changing temperature from Celsius to Fahrenheit

$$\text{Temperature in } ^{o}\text{F } (T_F) = 180/100\, T_C + 32 \text{ or}$$
$$= 9/5\, T_C + 32$$

Changing temperature from Fahrenheit to Celsius

Temperature in ^oC (T_C = 100/180 (T_F – 32) or

= 5/9 (T_F – 32)

Changing Temperature from Celsius to Kelvin

$T_K = T_C + 273$

Changing Temperature from Kelvin to Celsius

$T_C = T_K - 273$

Self – Test 1.2

1. Given: $T_C = 40\ ^oC$

   Find: T_F

   Solution:

   $T_F = 9/5\ T_C + 32$
   $= 9/5\ (40) + 32$
   $= 72 + 32$
   $= 104\ ^oF$

2. Given: $T_C = -84\ ^oC$

   Find: T_F

   Solution:

   $T_F = 9/5\ T_C + 32$
   $= 9/5\ (-84) + 32$
   $= -151.2 + 32$
   $= -119.2\ ^oF$

3. Given: $T_F = 6152\ ^oF$

   Find: T_C

   Solution:

   $T_C = 5/9\ (T_F – 32)$
   $= 5/9\ (6\ 152 – 32)$
   $= 5/9\ (6\ 120)$
   $= 3\ 400\ ^oC$

4. Given: $T_F = 80\ ^oF$

   Find: T_K

   Solution:

   a) Convert first the temperature from ^0F to ^0C

   $T_C = 5/9\ (T_F – 32)$
   $= 5/9\ (80 – 32)$
   $= 26.66\ ^oC$

   b) Convert temperature to Kelvin

   $T_K = T_C + 273$
   $= 26.66 + 273$
   $= 299.66\ K$

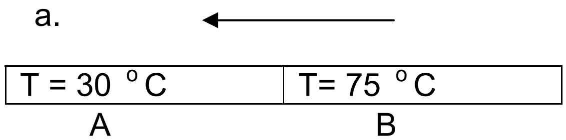
Activity 1.3

1. The movement of particles in hot object is faster than that in cold object.
2. The temperature of the hot object is higher than the temperature of the cold object.
3. When the two objects were placed in contact, the temperature of the hot object decreased while the temperature of the cold object increased.
4. After sometime, the temperature of the two objects were the same.

Self-Test 1.3

1. A person's skin is warmer than the air around it during cold days.
2. Our hand is warmer than the piece of ice.
3. The flame of the candle is warmer than our hand.
4. The general direction of heat flow between the person's skin and the cold air around it is from the person's skin to the cold air. The general direction of heat flow between the hand and the piece of ice is from the hand to the piece of ice. Between the flame and the candle, the direction of heat flow is from the flame to the hand.
5.

a.



b. Before the objects were placed in contact, the molecules in object B have greater kinetic energy than the molecules in object C.
c. The temperature of both objects after sometime will be the same.

6. Energy transfers from an object of high temperature to an object of low temperature. Since the formerly hot object loses energy its molecules move slower than before. The molecules in the formerly cold object now move faster than before.
7. Transfer of energy to an object will cause molecules in this object to have greater average kinetic energy, thus increasing its temperature.

Lesson 2

Self- Test 2.1

1. Given: Energy = 34 Calories
   Find: Energy in calories, in kilocalories, in joules
   a. To convert energy in Calories to calories, convert first Calorie to kilocalorie. Use the conversion factor

$$1 \text{ Calorie} = 1 \text{ kilocalorie}$$

$$\text{Energy in kcal} = 34 \text{ Cal} \times 1 \text{ kcal} / 1 \text{ Cal}$$
$$= 34 \text{ kcal}$$

b. To convert energy in kcal to cal, use the conversion factor

$$1 \text{ kcal} = 10^3 \text{ cal}$$

Energy in cal = 34 kcal x 10^3 cal / 1 kcal
= 34 x 10^3 cal or
= 3.4 x 10^4 cal

c. To convert energy to joules, use the conversion factor
1cal = 4.18 J

Energy in J = 3.4 x 10^4 cal x 4.18 J / 1 cal
= 14.212 x 10^4 J or
= 1.4212 x 10^5 J

2. Given: Basal metabolic rate for women = 1 400 Calories / day
Basal metabolic rate for men = 1 600 Calories / day

Find: Basal metabolic rate for women in kcal /day, in calories / day
Basal metabolic rate for men in kcal / day, in calories / day

Solution:
Basal metabolic rate for women in kcal /day = 1 400 Cal /day x 1 kcal / 1 Cal
= 1 400 kcal /day
Basal metabolic rate for women in cal / day = 1 400 kcal / day x 10^3 cal / 1kcal
= 1 400 x 10^3 cal
Basal metabolic rate for men in kcal / day = 1 600 Cal /day x 1 kcal / 1 Cal
= 1 600 kcal
Basal metabolic rate for men in cal / day = 1 600 kcal x 10^3 cal / 1 kcal
= 1 600 x 10^3 cal

Activity 2.1

B. 1. Aluminum melted the most paraffin.
2. Aluminum absorbed the most heat, so it has the most energy.
3. The temperatures of the three metals were the same before they were transferred to the paraffin.

Activity 2.2

B. 1. It takes longer time to boil a kettleful of water than a cupful of water.
2. Energy transferred is greater in the kettleful of water than in a cupful of water.
3. A kettleful of water has a greater mass than a cupful of water.
4. The greater the mass of a substance, the greater is the energy transferred to it.

Self – Test 2.2

1. It takes longer time to boil a kettleful of water than a cupful of water.
2. If it takes a longer time to heat a given substance, this indicates that the amount of energy transferred to the substance is greater.
3. The change in temperature of one cup of boiled water is equal to the change in temperature 1 kettle of boiled water.
4. The amount of energy transferred to a substance is directly proportional to its mass.

Activity 2.5

1. Given:

    $m = 200\ g$
    $t_i = 0\ ^oC$
    $t_f = 0\ ^oC$
    Required: Q
    Solution:

    $Q = mh_f$
    $= 200\ g \times 80\ cal/g$
    $Q = 16\ 000\ cal$

2. Given:

    $m = 100g$
    $t_i = 30\ ^oC$
    $t_f = 0\ ^oC$
    Required: Q
    Solution:

Since the initial temperature of water is 30 ^oC, you need to determine first the energy lost to change the temperature to freezing temperature which is 0 ^oC. Then determine the energy lost to completely freeze the water. Then add the two values to get the total energy lost.

a) Energy lost to change temperature from 30 ^oC to 0 ^oC

$Q_1 = mC\Delta t$
$= 100\ g \times 1\ cal/gC^o \times -30\ C^o$
$Q_1 = -3\ 000cal$

b) Energy lost to totally freeze the water

$Q_2 = -mh_f$
$= 100g\ (80\ cal/g)$
$Q_2 = -8\ 000\ cal$

c) Total energy lost

$Q = Q_1 + Q_2$
$= (-3\ 000\ cal) + (-8\ 000\ cal)$
$= -11\ 000\ cal$

Activity 2.6

1. The temperature of the solid in **b** is greater than the temperature of the solid in **a.**
2. The number of molecules in **a** is equal to the number of molecules in **b.**
3. The length of the solid in **b** is greater than the length of the solid in **a**.
4. The space between molecules in **b** is greater than the space between molecules in **a**.

Activity 2.7

1. The thermal expansion of liquids is greater than the expansion of solids.
2. The volume expansion of gas is greater than those of solids and liquids.

Self- Test 2.7

1. Given: $L = 6.0$ m
$T_1 = 25\,^{o}C$
$T_2 = 75\,^{o}C$
$\Delta t = 50\ C^{o}$
$\alpha = 1.7 \times 10^{-5} / C^{o}$

a) $\Delta L = \alpha L \Delta t$
$= 1.7 \times 10^{-5} / C^{o} \times 6.0\ m \times 50\ C^{o}$
$= 0.0051$ m

b) $L_2 = L_1 + \Delta L$
$= 6\ m + 0.0051\ m$
$= 6.0051$ m

Post Test

1. a
2. a
3. b
4. b
5. b
6. b
7. d
8. a
9. b
10. b
11. b
12. c
13. b
14. c
15. a

-End of Module-

References

Young, Hugh D. and R.G. Friedman. 2004, *University physics (11th ed).* Addison Wesley, San Francisco, CA: Pearson Education South Asia PTE Ltd.

Hewitt, Paul. 2002, *Conceptual physics: the high school physics program.* Upper Saddle River, New Jersey: Prentice – Hall, Inc.