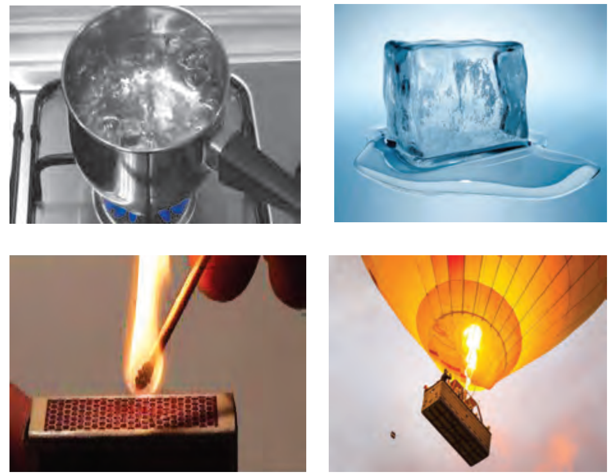
14. Measurement and Effects of Heat

Can you recall?

1. Which sources do we get heat from?
2. How is heat transferred?
3. Which effects of heat do you know?

Some effects of heat are shown in figure 14.1 What are they?



14.1 Various effects of heat

We have seen in previous standards that heat is a form of energy which flows from an object at high temperature to an object at low temperature. Temperature of an object tells us how hot or cold that object is. The temperature of a cold object is lower than the temperature of a hot object. Thus, the temperature of ice cream is less than the temperature of tea.

We have also seen that when we give heat to an object it expands and it contracts on cooling. Also, the state of matter changes due to heat.

The unit of heat in SI system is Joule while that in CGS units is calorie. One calorie is equivalent to 4.18 Joule. One calorie heat is the heat required to increase the temperature of 1 gm of water through 1^{0}C.

Solved examples

1. How much heat will be needed to raise the temperature of 1.5 kg of water from 15 ^{0}C to 45 ^{0}C ? Give the answer in calories as well as in Joule.

Given : mass of water = 1.5 kg = 1500 gm.
Change in temperature = 45 ^{0}C - 15 ^{0}C = 30 ^{0}C.
Heat required for temperature change = ?
Heat required for temperature change = mass of water (gm) x change in temperature (^{0}C) cal.
= 1500 × 30 cal = 45000 cal
= 45000 × 4.18 J = 188100 J

2. If the temperature of water changes by 10 ^{0}C on giving 300 cal of heat, what is the mass of water?

Given : Amount of heat given to water = 300 cal, change in temperature = 10 ^{0}C, mass of water = m = ?
Amount of heat given (cal) = mass of water (gm) x change in temperature (^{0}C)
300 = m × 10
m = 300 / 10 = 30 gm.

Sources of heat

1. Sun : The Sun is the biggest source of heat received by the earth. A large amount of heat is generated due to the nuclear fusion taking place in its centre. In this process hydrogen nuclei fuse together to form helium nuclei, generating heat in the process. Some of it reaches the earth in the form of light and heat.

2. Earth : As the temperature at the centre of the earth is high, the earth is also a source of heat. This heat is called geothermal energy.

3. Chemical energy : When fuels like wood, coal, petrol etc, burn, there is chemical reaction between the fuel and oxygen. Heat is generated in these reactions.

4. Electrical Energy : In your daily life, you have seen several equipments which produce heat with the help of electricity e.g. electric press, electric heater etc. Thus, electricity is a source of heat.

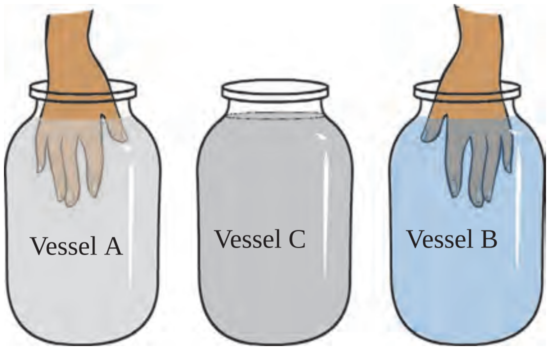
5. Atomic energy : A huge amount of heat is produced in a very short time when the nuclei of some elements like uranium, thorium etc undergo fission. This is used in atomic energy projects.

6. Air : A large amount of heat is present in the air around us.

Temperature : We can find out how hot or cold an object is by touching the object. However, our sense of 'hot' or 'cold' is relative. This can be understood from the following experiment.

Try this

1. Take three similar vessels. Let us call them 'A', 'B'and 'C'(see figure 14.2)
2. Fill A with hot water and B with cold water. Put some water from A and B in C.
3. Dip your right hand in A and left hand in B, and keep them immersed for 2 to 3 minutes.
4. Now dip both the hands in C. What do you feel?



14.2 Relative sensation

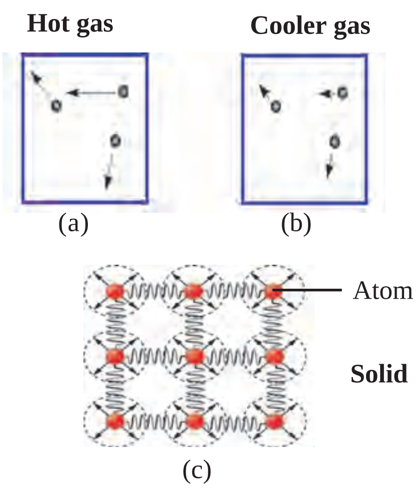
Even though, both the hands are dipped in water in the same vessel i.e. water at the same temperature, your right hand will find the water to be cold while the left hand will find it to be hot. What is the reason for this? Think about it.

You must have understood from the above activity that we cannot determine the temperature of an object accurately by simply touching it. Also you may hurt yourself by touching very hot or cold objects. So we feel the need of some device for measuring temperature. Thermometer is a device for measuring temperature. You have read about thermometer in the previous class. In this lesson you are going to learn about the construction of a thermometer.

Can you recall? What are potential and kinetic energies?

Heat and Temperature : What is the difference between heat and temperature? We know that a substance is made of atoms. The atoms in a substance are always in motion. The total kinetic energy of the atoms in a substance is a measure of the heat contained in that substance, while the temperature of a substance is related to the average kinetic energy of atoms. If the average kinetic energy of atoms in two objects is equal then their temperatures will also be equal.

Figure 14.3 'a'and 'b' show the velocities of atoms in a gas at high and low temperature, respectively. The direction and the length of the arrows attached to the atoms show the direction and magnitude of the velocity of the atoms. The velocity of atoms in the gas at higher temperature is larger than the velocity of atoms in the gas at lower temperature.



14.3 Motion of atoms in gas and solid

The velocities of atoms in a solid object are shown by arrows in figure 14.3(c). The atoms in a solid object are tied to one another because of the forces acting between them. So they cannot be displaced from their places. Because of heat, they oscillate around their fixed position. Higher the temperature of the solid, faster is their velocity of oscillation.

Suppose A and B are two objects made from the same substance. The mass of A is twice the mass of B which means that the number of atoms in A is twice the number of atoms in B. Even if the temperatures of A and B are equal, i.e. the average kinetic energy of atoms in A is same as that in B, the total kinetic energy of atoms in A is twice that in B. Thus, the heat content of A is twice that of B even though, they both have the same temperature.

Try this

1. Take two steel vessels A and B of the same size.

2. Fill some water in A and double that amount in B. Make sure that the water in both vessels are at the same temperature.

3. Raise the temperatures of water in both vessels by 10 ^{0}C using a spirit lamp. Did it take the same time to increase the temperature in the two vessels?

You must have required more time to raise the temperature of water in B. This means that for the same increase in temperature, you had to give more amount of heat to B. Thus, even though the water in A and B have the same temperature, the amount of heat in B is more than that in A.

Temperature is measured in units of Celsius (^{0}C), Fahrenheit (^{0}F) and Kelvin (K). Kelvin is used in scientific experiments, while the other two are used in daily life. The relation between the three units is shown by the following formulae.

$$\frac{(F-32)}{9} = \frac{C}{5} \quad \text{--------(1)}$$

$$K = C + 273.15 \quad \text{-------(2)}$$

Some specific temperatures are given in the three scales in the following table. Verify that they satisfy the above relations and fill appropriate numbers in the blanks.

Description	^{0}F	^{0}C	K
Boiling point of water	212	100	373.15
Freezing point of water	32	0	273
Room temperature	72	23	296
Boiling point of mercury		356.7	
Freezing point of mercury		-38.8	

Sloved examples

1. How much will the temperature of 68 ^{0}F be in Celsius and Kelvin?

Given : Temperature in Fahrenheit = F = 68, Temperature in Celsius = C= ?,
Temperature in Kelvin = K = ?

According to formula (1), $\frac{(F-32)}{9} = \frac{C}{5}$

$$\frac{(68-32)}{9} = \frac{C}{5}$$

$C = 5 \times \frac{36}{9} = 20\ ^0C$ According to formula (2)

K = C + 273.15 = 20 + 273.15 = 293.15

Thus, the temperature in Celsius = 20 ^{0}C and in Kelvin = 293.15 K

2. At what temperature will its value be same in Celsius and in Fahrenheit?

Given : If the temperature in Celsius is C, then the temperature in Fahrenheit (F) will be same, i.e. F= C.

Using formula (1), $\frac{(F-32)}{9} = \frac{C}{5}$

or, $\frac{(C-32)}{9} = \frac{C}{5}$

$(C-32) \times 5 = C \times 9$

$5C - 160 = 9\ C$

$4\ C = -\ 160$

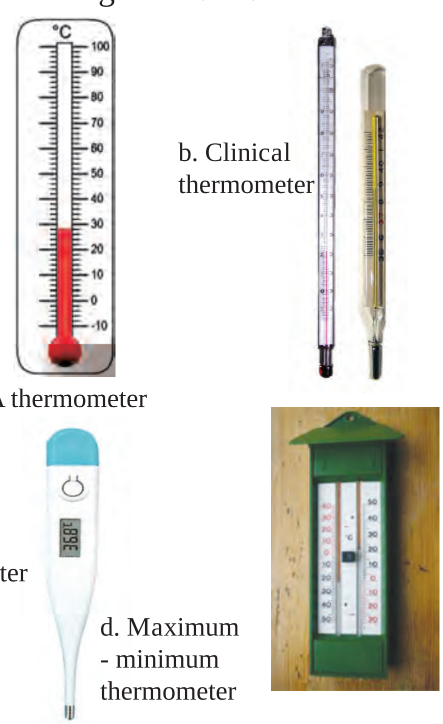
$C = F = -\ 40$ The temperatures in Celsius and in Fahrenheit will be same at $-\ 40^{0}$

Thermometer : You must have seen the thermometer that is used when someone at home has fever. That thermometer is called clinical thermometer. Different thermometers are used for different purposes. Let us first learn about the working of a thermometer.

A thermometer is shown in figure 14.4 a. It has a narrow glass tube which has a bulb at one end. The bulb and part of the tube is filled with a liquid. Earlier, mercury was used but, as it is harmful for us, it has been replaced with alcohol. The rest of the volume of the tube has vacuum and its other end is closed. The bulb is kept in contact with the object whose temperature is to be measured so that its temperature becomes same as that of the object. Because of the increased temperature the alcohol inside it expands and its level in the tube rises. Using the properties of the expansion of alcohol (to be discussed below), the temperature can be obtained from the level of the alcohol. The tube of the thermometer is marked accordingly.

Figure 14.4 (b) shows a clinical thermometer. As the body temperature of a healthy person is 37 ^{0}C, clinical thermometers are designed to measure temperatures between 35 ^{0}C and 42 ^{0}C. These days, instead of the above type, digital thermometers are used for clinical puroses. One such thermometer is shown in figure 14.4 c. This does not use the expansion of liquid due to heat. Instead, it has a sensor which can measure the heat coming out from the body directly and from that can measure the temperature of the body.

The thermometers used in laboratory are similar to the one shown in figure 14.4 a except that the range of temperatures that it can measure is large spanning 40 ^{0}C to 110 ^{0}C or even larger. A special type of thermometer is used to measure the minimum and maximum temperatures in a day. It is called the maximum minimum thermometer. It is shown in figure 14.4 d.



a. A thermometer

b. Clinical thermometer

c. Digital thermometer

d. Maximum - minimum thermometer

14.4 : Different thermometers

When a hot object is kept in contact with a cold object they both exchange heat. The hot object gives away heat while the cold object absorbs heat. Thus, temperature of the hot object decreases, while that of the cold object increases. This means that the kinetic energy of atoms in the cold object goes on incresing while that in the hot object goes on decreasing. A time comes when the average kinetic energies of atoms in both objects become equal, which means that the temperatures of both objects become equal.

Specific heat : The specific heat of an object is the amount of heat required to increase the temperature of unit mass of that substance through one degree. This is represented by the symbol 'c'. Its unit in SI is Joule /(kg ^{0}C) and in CGS is cal/(gm ^{0}C). Suppose Q amount of heat is required to increase the temperature of an object of mass m and specific heat c, from T_i to T_f This amount depends on the mass and specific heat of the object as well as on the increase in temperature and can be written as.

$Q = m \times c \times (T_f - T_i)$...................... (3)

Different substances have different specific heats. We are going to learn more about it in future classes. The specific heats of a few substance are given in the following table.

Substances	Specific heat cal/(gm ^{0}C)	Substance	Specific heat cal/(gm ^{0}C)
Aluminium	0.21	Iron	0.11
Alcohol	0.58	Copper	0.09
Gold	0.03	Mercury	0.03
Hydrogen	3.42	Water	1.0

Calorimeter : We have seen that a thermometer is used to measure the temperature of an object. A calorimeter is used to measure the heat content of an object. Using this equipment, we can measure the heat produced or absorbed in a physical or chemical process.

A calorimeter is shown in figure 14.5 Similar to a thermosflask, a calorimeter has two vessels, an inner and an outer one. This way, no heat can be transferred from the inner to the outer vessel or from the outer to the inner vessel. Thus, the inner vessel is thermally isolated from the surroundings. The inner vessel is made of copper. A thermometer for measuring the temperature and a stirrer for stirring the liquid in the calorimeter are fitted in it.

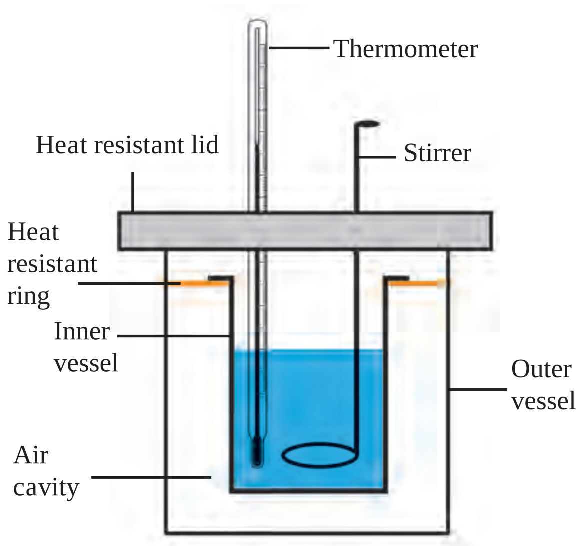
Use your brain power

1. Why does your mother put folded cloth strips soaked in cold water on your forehead when you have high fever?
2. Why is the calorimeter made of copper?

Water at a fixed temperature is placed inside the calorimeter. This means that the temperature of the inner vessel and that of the water in it are the same. When a hot object is placed in water, heat is exchanged between the hot object, water and the calorimeter and all three reach the same temperature. As the calorimeter is thermally isolated from the surroundings, the total heat lost by the hot object is equal to the total heat absorbed by the calorimeter and water inside it.

Similarly if we put a cold object in the calorimeter, the cold object will receive heat from the water and its temperature will increase, while water and calorimeter will lose heat and their temperature will decrease.

Suppose the mass of the inner vessel in the calorimeter is 'm_c' and its initial temperature is 'T_i'and the mass of the water in the calorimeter is 'm_w'. The temperature of water will also be 'T_i' . Suppose we place an object of mass 'm_O' and temperature 'T_o' in the calorimeter. If 'T_o' is higher than T_i the object will give away heat to the calorimeter and water. Soon the temperature of all three will become the same.



14.5 Caloriemeter

Let us call this final temperature 'T_f' . The total heat given away by the object ('Q_o') will be equal to the sum of the heat gained by the calorimeter ('Q_c') and by water ('Q_w'). We can write this as.

$Q_o = Q_C + Q_W$ .... (4)

As seen above Q_o, Q_c and Q_w depend on mass, specific heat and change in temperature ΔT. If the specific heats of the material of calorimeter, water and the object are c_c , c_w and c_o respectively, we can write using formula (3),

$$Q_O = m_O \times \Delta T_O \times C_O, \qquad \Delta T_O = T_O - T_f$$
$$Q_W = m_W \times \Delta T_W \times C_W, \qquad \Delta T_W = T_f - T_i$$
$$Q_C = m_C \times \Delta T_C \times C_C, \qquad \Delta T_C = T_f - T_i = \Delta T_W$$

Using (4), $m_o \times \Delta T_o \times c_o = m_w \times \Delta T_w \times c_w + m_c \times \Delta T_c \times c_c$ .... (5)

We can measure all the masses and temperatures. If we know the specific heats of the material of the calorimeter i.e. copper and that of water, we can calculate the value of the specific heat of the object using formula (5). We will learn about this in more details in higher standards.

Solved Examples

1. Suppose the masses of the calorimeter, the water in it and the hot object made up of copper which is put in the calorimeter are the same. The initial temperature of the calorimeter and water is 30 ^{0}C and that of the hot object is 60 ^{0}C. The specific heats of copper and water are 0.09 cal / (gm ^{0}C) and 1 cal / (gm ^{0}C) respectively. What will be the final temperature of water?

Given : $m_w = m_o = m_c = m$, $T_i = 30\ ^oC$, $T_o = 60\ ^oC$ $T_i = ?$

Using formula (5), $m \times (60 - T_f) \times 0.09 = m \times (T_f - 30) \times 1 + m \times (T_f - 30) \times 0.09$

$(60 - T_f) \times 0.09 = (T_f - 30) \times 1.09$

$60 \times 0.9 + 30 \times 1.09 = (0.09 + 1.09)\ T_i$

$T_1 = 32.29\ ^0C$

The final temperature of water wil be 32.29 ^{0}C.

Effects of heat

In previous standards, we have studied two effects of heat on matter : 1. expansion and contraction and 2. change of state. In this lesson, we are going to learn more about expansion. You will learn about change of state of matter in higher standards.

Expansion

When heat is given to any substance, its temperature increases and it expands. Its expansion depends on the increase in its temperature. Solids, liquids and gases, all expand on receiving heat.

Expansion of solids

Linear expansion : The linear expansion of a solid is the increase in length of a wire or a rod of a solid due to increase in its temperature.

When we increase the temperature of a rod of length l_1 from T_1 to T_2, its length becomes l_2. The change in length is proportional to the original length and the increase in temperature, ($\Delta T = T_2 - T_1$). So we can write the change in length as follows.

Change in length α original length x change in temperature

$l_2 - l_1 \; \alpha \; l_1 \times \Delta T$

$l_2 - l_1 = \lambda \times l_1 \times \Delta T$ .... (6)

$l_2 = l_1 (1 + \lambda \Delta T)$ .... (7)

Here λ (lambda) is the constant of proportionality and it is called the coefficient of linear expansion of the solid substance.

The expansion coefficients of different substances are different. From the above formula we can see that if we take two rods of different substances, both having the same length, and increase their temperatures by the same amount, the rod of the substance having higher expansion coefficient will expand more. Thus, the increase in its length will be larger.

From formula (6), we can write the expansion coefficient as

$\lambda = (l_2 - l_1) / (l_1 \Delta T)$ .... (8)

Thus, the expansion coefficient is the change in length of a rod of unit length when its temperature is increased by 1 degree. From formula (8) we can see that the unit of expansion coefficient is the inverse of the unit of temperature, i.e. $1/^0C$. The expansion coefficients of some substances are given in the following table.

Solid	Coefficient of linear expansion x 10^6 ($1/^0C$)	Liquid	Coefficient of volume expansion x 10^3 ($1/^0C$)	Gas	Expansion coefficient x 10^3 ($1/^0C$)
Copper	17	Alcohol	1.0	Hydrogen	3.66
Aluminium	23.1	Water	0.2	Helium	3.66
Iron	11.5	Mercury	0.2	Nitrogen	3.67
Silver	18	Chloroform	1.3	Sulphur dioxide	3.90

14.6 : Coefficient of expansion of some substances

Solved Examples

Example : What will be the increase in length of a steel rod of length 0.5 m, when its temperature is increased by 60 ^0C? The coefficient of linear expansion of steel is 0.000013 ($1/^0C$).

Given : Initial length of the rod = 0.5 m, change in temperature = 60 ^0C, change in length = Δl = ?

Using formula (6), $\Delta l = \lambda \times l_1 \times \Delta T = 0.000013 \times 0.5 \times 60 = 0.00039$ m

Increase in length = 0.039 cm

Areal expansion of solids : Similar to linear expansion, the area of a sheet of a solid material also increaes on heating. This is called the areal expansion of solids. This is given by the following formula.

$A_2 = A_1 (1 + \sigma \Delta T)$ .... (9)

Here, ΔT is the change in temperature and A_1 and A_2 are the initial and final areas of the sheet. σ **is the coefficient of areal expansion of the solid**.

Volumetric expansion of solids : Similar to a sheet, a three dimensional piece of solid expands on all sides when heated and its volume increases. This is called the volumetric expansion of a solid. This is given by the following formula.

$V_2 = V_1 (1 + \beta \Delta T)$ .... (10) Here, ΔT is the change in temperature and and V_1 and V_2 are the initial and final volumes of the solid. β **is the volumetric expansion coefficient of the solid**.

Do you know?

Have you seen rails? They are not continuous. A small gap is kept between them at regular intervals. This is shown in the figure. This is kept to accommodate the change in the length of the rails with change in temperature. If this gap is not kept, then the rails will get distroted due to expansion in summer which may lead to accidents.

Similar to rails, the length of bridges can also increase due to expansion in summer. The length of the 18 km long great belt bridge in Denmark increases by 4.7 m in summer. Therefore, provision is made in the construction of the bridges to accommodate this expansion.

Expansion of liquids

A liquid does not have a definite shape but it has a definite volume. So we can define a volumetric expansion coefficient for a liquid as follows.

$V_2 = V_1 (1 + \beta \Delta T)$ .... (11)

Here, ΔT is the change in temperature and V_1 and V_2 are the initial and final volumes of the liquid. β is the volumetric expansion coefficient of the liquid.

Use your brain power

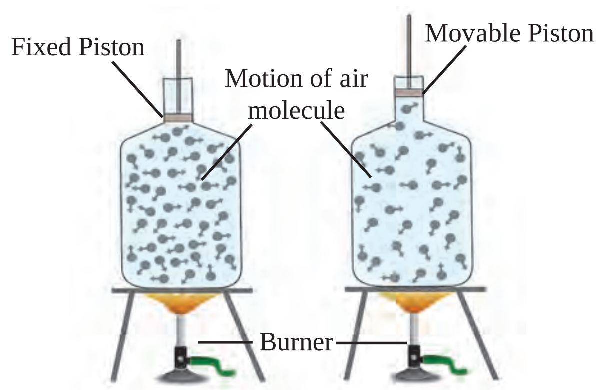
Which use of the expansion of liquids in daily life do you know?

The effect if heat on water is somewhat different from that for other liquids. This is called anomalous behaviour of water. We are going to learn about it in higher standard.

Expansion of gases

A gas does not even have a fixed volume. Gas expands on heating but if the gas is kept in a closed box, its volume cannot increase but its pressure increases. This is shown in figure 14.7

Observe figure 14.7 and find out answers to the questions.



14.7 Effect of heat on a gas

1. Using the formula density = mass / volume, explain what will be the effect of heat on the gas kept in a closed bottle.
2. If the bottle is not closed but has a movable piston attached to its open end (see the figure), what will be the effect of heating the gas in the bottle?

   Therefore, the expansion of a gas is measured by keeping its pressure constant. This volumetric expansion coeffcient is called the constant pressure expansion coefficient and is given by the following formula.

$V_2 = V_1 (1 + \beta \Delta T)$ .... (12)

Here, ΔT is the change in temperature and V_1 and V_2 are the initial and final volumes of the gas at costant pressure. β is the constant pressure expansion coefficient of the gas.

Use your brain power

The density of a gas decreases on heating. Which of the pictures in figure 14.1 makes use of this?

Exercises

1. A. Whom should I pair with?

Group A	Group B
a. Temperature of a healthy human body	i. 296 K
b. Boiling point of water	ii. 98.6 ^{0}F
c. Room temperature	iii. 0 ^{0}C
d. Freezing point of water	iv. 212 ^{0}F

B. Who is telling the truth?

a. The temperature of a substance is measured in Joules.
b. Heat flows from an object at higher temperature to an object at lower temperature.
c. Joule is the unit of heat.
d. Objects contract on heating.
e. Atoms of a solid are free.
f. The average kinetic energy of atoms in a hot object is less than the average kinetic energy of atoms in a cold object.

C. You will find if you search.

a. A thermometer is used to measure..........
b. The apparatus used to measure heat is called a ....
c Temperature is the measure of the .... kinetic energy of the atoms in a substance.
d. The heat contained in a substance is the measure of the .... kinetic energy of atoms in the substance.

2. Nishigandha kept a vessel containing all the ingredients for making tea in a solar cooker. Shivani kept a similar vessel on a stove. Whose tea will be ready first and why?

3. Write brief answers.

a. Describe a clinical thermometer. How does it differ from the thermometer used in laboratory?
b. What is the difference between heat and temperature? What are their units?
c. Explain the construction of a calorimeter. Draw the necessary figure.
d. Explain why rails have gaps at specific distances.
e Explain with the help of formulae the expansion coefficients of liquid and gas.

4. Solve the following examples.

a. What must be the temperature in Fahrenheit so that it will be twice its value in Celsius?

(Ans. 320 ^{0}F)

b. A bridge is made from 20 m long iron rods. At temperature 18 ^{0}C, the distance between two rods is 0.4 cm. Up to what temperature will the bridge be in good shape?

(Ans. 35.4 ^{0}C)

c. At 15 ^{0}C the height of Eifel tower is 324 m. If it is made of iron, what will be the increase in length in cm, at 30 ^{0}C?

(Ans. 5.6 cm)

d. Two substances A and B have specific heats c and 2 c respectively. If A and B are given Q and 4Q amounts of heat respectively, the change in their temperatures is the same. If the mass of A is m, what is the mass of B?

(Ans. 2 m)

e. When a substance having mass 3 kg receives 600 cal of heat, its temperature increases by 10 ^{0}C. What is the specific heat of the substance?

(Ans.0.0033 cal /(gm ^{0}C))

Project :

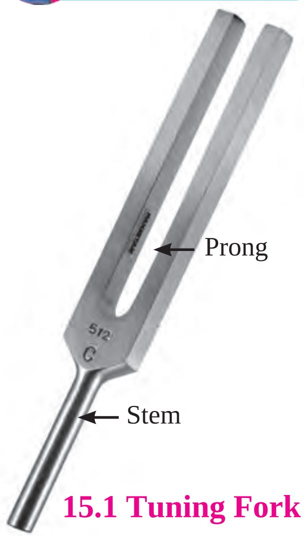
Collect information about bimetallic strips and discuss in your class how a fire alarm is made using it.

JHW1CH

15. Sound

Can you recall?

How is sound produced ?



15.1 Tuning Fork

Production of Sound

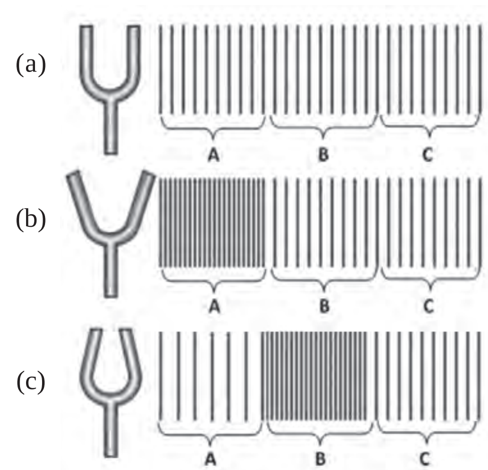
We have learnt that sound can be generated from a vibrating object.With an example of tuning fork, we will now learn about how a sound is produced due to such vibrations. A photograph of tuning fork is shown in Figure 15.1.

A tuning fork is made of two prongs and a stem. Keeping the stem steady, if the prongs are struck, they start vibrating.

Figure 15.2 (a) shows a stationary tuning fork. To show the state of air around the tuning fork, vertical lines are used. Here, the vertical lines are equally spaced. It indicates that the average distance between the air molecules is the same everywhere and the average air pressure in three regions 'A', 'B' and 'C' is also the same.

If the stem is kept steady and the prongs are struck, the prongs are set into vibrations. It means that they are set into periodic motion in forward and backward direction. We will see, step by step, the result of such a motion.

If during the vibration, the prongs of the tuning fork go away from each other, as shown in Figure 15.2 (b), the air outside the prongs is compressed and the pressure there increases. Such a state of high pressure is created in region A in the figure. The region in which air is at high pressure and high density is called compression. In the next step of vibration, the prongs of the fork come close to each other, as shown in Figure 15.2 (c). In this case, the air molecules near the prongs get more space to move away from each other. As a result, the air pressure in this region (Region A) decreases. Such region in which air is at low pressure and low density is called rarefaction.

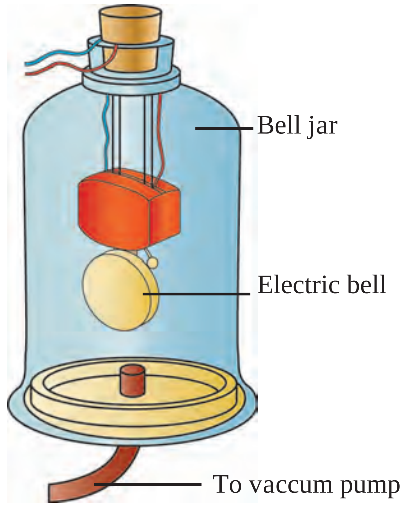


15.2 Production of sound by tuning fork

However, the air molecules in this region, which were in compressed state earlier (Figure 15.2 (b), region A) transfer their energy to the air molecules in the next region (region B). So, the air in that region goes to compressed state (See Figure 15.2 (c), region B). Such a periodic motion of the prongs creates compression and rarefaction in the air and these are propagated away from the prongs. These are nothing but the sound waves. When these waves reach our ear, the ear-drum vibrates. Accordingly, specific signals reach the brain and we get a sense of hearing a sound.

Use your brain power

If sound waves are generated in air, what moves away from the source? Is it the air itself or the state of compression and rarefaction created in the air?



15.3 Medium is necessary for propogation of sound

Propagation of sound and Medium: We have learnt in the sixth standard that sound travels through some material medium like solid, liquid or gas and reaches us. But what if such medium does not exist between the source of sound and our ear?

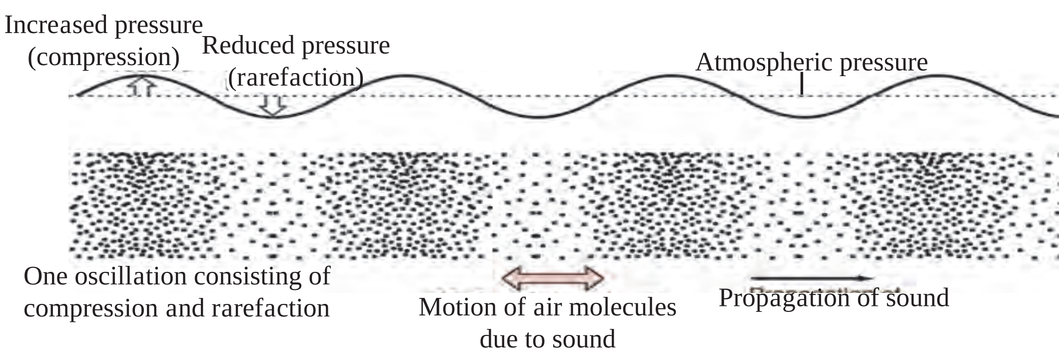
Sound generation and propagation needs medium like air. A simple experiment can prove this. The experimental arrangement is shown in Figure 15.3. In this experiment, a vaccum tight bell jar is placed on a smooth horizontal surface. The bell jar is connected to a vacuum pump via a tube. We can remove air inside the bell-jar, using the vacuum pump. As shown in the figure, the bell jar contains an electric bell, which is connected to the power supply through the lid of the bell jar.

At the start of experiment, the vacuum pump is off and the bell-jar contains air. If the key to electric bell is now switched on, the bell start ringing and the ringing can be heard from outside the bell jar. Now, if the vacuum pump is switched on, it starts removing the air from the bell jar. As the quantity of air inside the bell jar decreases, the level of ringing sound heard outside also decreases. If the pump is operated for sufficiently long period, the quantity of air like inside the bell jar will be low. At this point the level of ringing sound will also be very low. This experiment demonstrates that sound generation and propagation needs a medium. If the air inside the bell jar is totally removed, will we be able to hear the sound of ringing bell? Why?

Always remember

Two astronauts on the moon talking to each other directly, will be unable to listen to each other, even if they are very close to each other. The moon does not have atmosphere. Since there is no medium which is necessary for generation and propagation of sound, between the astronauts, direct sound propagation between them is not possible. Therefore, the astronauts use some technology like the one used in our cell-phones to communicate with each other. The waves used in cell-phone do not need any medium for propagation.

Frequency of Sound Waves : Using figure 15.2, we learnt about how the vibrations of tuning fork result in generation of compressions and rarefactions in air. More detail observation shows that, the actual variation in the air density and pressure are as shown in Figure 15.4. If any object vibrates in the air, such sound waves are produced in the air.



15.4 Cycles of compression and rarefaction in a sound wave and change in air pressure

As shown in the Figure 15.4, one compression and one rarefaction together forms one cycle of the wave. The number of cycles formed in the air in one second will be decided by the number of times the prongs of the tuning fork (or any other vibrating body) vibrates back and forth i.e. the number of vibrations of the tuning fork in one second.

Number of such cycles that are produced in the air (or other medium) per second is called as the frequency of the sound wave. The frequency is measured in Hertz. If one cycle is completed in one second, the frequency is said to be 1 Hz. For example, the tuning fork in Figure 15.1 shows its frequency to be 512 Hz. It means that the fork vibrates 512 times per second. These vibrations will set 512 cycles of compression and rarefaction in the air, per second. Thus, the sound generated by the fork will have a frequency of 512 Hz. The frequency of a tuning fork is decided by the dimensions of the prongs (length, thickness) and the material used for making the fork.

Try this

Take 6-7 glass cups. Arrange them in a line and fill them with water with gradually increasing water level from one end to other. Take a pencil and strike the cups sequentially. The sound generated by each cup will be different. Why it is so?

When a cup is struck, waves are set up in the air column above the water level in the cup. The frequency of the generated wave depends on the height of the air column inside the glass cup. Since the water level in each glass is different, the height of the air column in each glass is also different. Therefore, the frequency of sound generated by each glass cup will also be different. So, the sound generated is different.

An 'app' for measurement of sound frequency may be available on cell-phones. With the help of your teacher, use the app to measure the frequency of the sound generated from each glass cup. Do you observe any relation between the frequency of generated sound and the height of the air column in the glass-cup? This is your simple 'Jal-tarang'! Can this experiment be performed with stainless steel pots of different sizes?

Use of ICT

Download videos of Jaltarang from youtube and send them to your friends by email.

Sound and Music

From the above activity, it is clear that if the frequency of sound wave is changed, different sound is produced. Sound waves of different frequencies produce different sound notes. In the field of music, various musical instruments are used for creation of sound notes. This includes instruments like sitar, violin, guitar which use strings for production of sound and instruments like flute, shehnai which use air blown into pipes for the production of sound.

In string based instruments, the frequency of vibration of the string is changed by changing the tension on the string and/or by changing the vibrating length of the string using fingers. This results in generation of different notes.

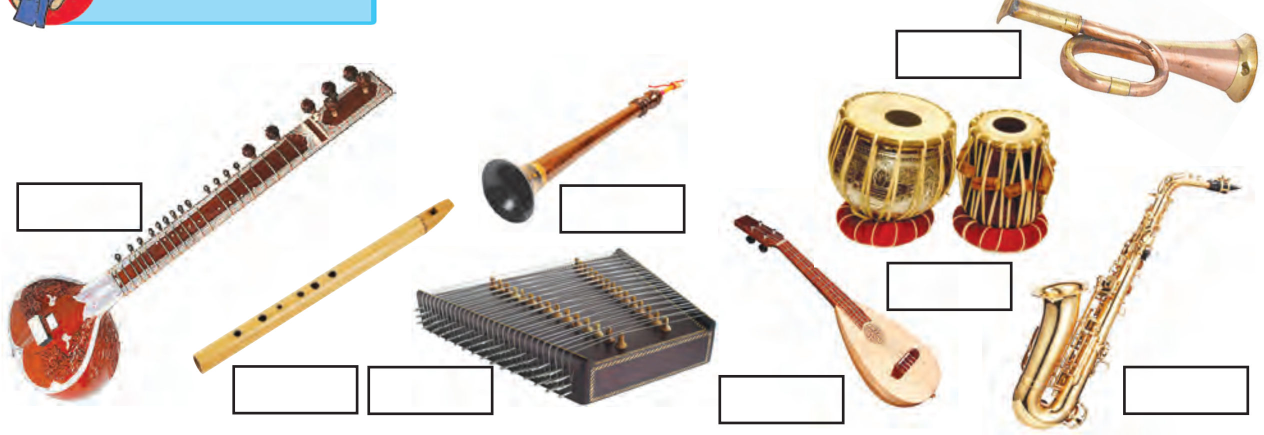
In musical instruments like flute, the holes on the flute are opened or closed to change the length of vibrating air column in the flute. The frequency of waves, therefore, changes and it results in the production of different notes. In flute, different notes can be generated by changing the way of air-blowing also.

Do you know?

What are the frequencies of musical notes 'sa', 're', 'ga', ma', 'pa', 'dha', 'ni' in the 'madhya saptak'?

Note	Frequency (Hz)
sa	256
re	280
ga	312
ma	346
pa	384
dha	426
ni	480

Observe and discuss. Identify the instruments and discuss sound production in them.



Try this 'Apps' for generation of different sound notes (sound note generator app) may be available on cell-phones. With the help of your teacher, using such an app, generate sound notes listed in the table.

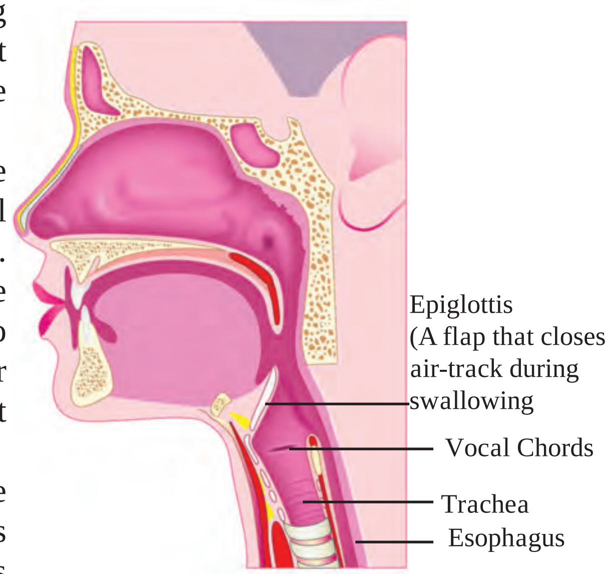
Sound Produced by Human

Either speak a little loudly or sing a song or produce humming sound like a bee and put your fingers on your throat. Do you feel some vibrations?

In the humans, sound is produced in the larynx. While swallowing food, we can feel with our finger a hard bump that seems to move. This is nothing but larynx. As shown in Figure 15.5, it is at the upper end of the windpipe. Two vocal cords, are stretched across the voice box or larynx in such a way that it leaves a narrow slit between them for the passage of air.

When the lungs force air through the slit, the vocal cords vibrate, producing sound. Muscles attached to the vocal cords can make the cords tight or loose. When the vocal cords are tight and thin, the type or quality of voice is different.

Take two rubber strips out of an unused bicycle tube. Place these two pieces one above the other and stretch them tight. Now blow air through the gap between them. As the air blows through the gap between the rubber strips, a sound is produced. Human larynx works in a similar way.



15.5 : Larynx in human

Vocal cords are 20 cm in length in male, about 15 cm in female and even smaller in children. Therefore the voice of male, female and children are different.

Try this Produce a sound 'bho…bho..' just like a dog-barking and 'meow.. meow..' just like a mewing cat. Carefully notice the tension on the vocal cords, when you produce these sounds. Do you feel that the tension on the vocal cords changes when you produce these two different sounds?