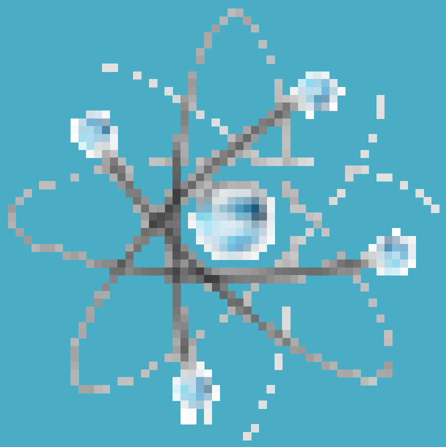
Teaching Some Selected Topics of

Based on National Physics Curriculum



Ethiopian Teachers Association (ETA)

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This Web-based Physics Teaching material is intended to support teachers who teach physics in the early years of secondary education.

The material is designed to help teachers to gain a better understanding of

physics, to use it as a reference besides the textbooks and allow them to experience for themselves the methods of teaching introduced and to develop greater confidence in their teaching of it.

It is also hoped that the material will help teachers in their continuing quest to develop new approaches to their teaching which will make physics more interesting and exciting for all their students.

The material contains facts, explanations, and sketches that will help to make the subject more interesting to student and teacher alike. This material is designed for lessons in which the primary emphasis is discovering rather than memorizing and in which teaching is by questioning rather than by telling.

The material deals with the following Units: vectors, pressure, heat and temperature, wave motion and sound. These contents are selected among the grade 9 physics textbook by expertise judgement which hinges on challenges and difficulties both for students and teachers pertinent to conceptual reasoning and understandings. Each content is divided into lessons.

Each lesson encompasses three sections:

- The starter activity relates the lesson with students daily life and experience, bringing together the overview of the chosen topic in a coherent, concise and engaging manner
- The main Activity highlights teaching and learning methods and attempts to make explicitly what students find ‘easy’ or 'difficult', clarify common students’ misconceptions . The teaching approaches provide proven teaching ideas and strategies designed to present the topic in an interesting and engaging manner
- The concluding activity includes the underlying concepts which need more attention, provide problems and exercises designed to develop the key skills and good problem solving habits.

Such materials have been chosen to address the key teaching and learning challenges; there will be no attempt to produce a complete resource material encompassing all the contents of grade 9 physics.

The primary goal in producing web-based physics supporting material for secondary school teachers can be: to produce a reference that is more focused and coherent, to provide special attention to concepts known to cause student difficulties and to support an active-learning environment

Aims

- To prompt teachers enthuse young students with the enjoyment and excitement of physics.
- To support the secondary school teachers particularly with concepts known challenging and difficult for students to learn and for teachers to teach..

The material includes several features designed to aid teacher comprehension. Each unit begins with a list of the objectives that should be achieved in that chapter. A great deal of quizzes included in each unit. These quizzes can serve as a useful self-test of comprehension. In addition, there are also end-of-chapter exercises.

It is our hope that using the web-based material will strengthen teachers' confidence and stimulate their enthusiasm for better engagement in teaching physics.

By the end of this lesson students will be able to:

Describe the difference between scalars and vectors,
Categorize physical quantities as scalars and vectors

Starter activity:

Begin the lesson recapping the core points about physical quantities. Remind students they studied in grades 7 & 8 that physics is an experimental science and experiments requires measurements, and we usually use numbers attached to units to describe the results of measurements. Any number that is attached to an appropriate units used to describe a physical phenomenon quantitatively is called a physical quantity. For example, among physical quantities that describe you are your weight and your height.

Any number or set of numbers with appropriate units attached, used for a quantitative description of a physical phenomenon is called a physical quantity.

The simplest kind of physical quantity is one that can be completely specified by its magnitude, a single number, together with the units in which it is measured. Such a quantity is called a scalar and examples include temperature, time and density.

But many other important quantities in physics have a direction associated with them and cannot be described by a single number and a unit.

A vector is a quantity that requires both a magnitude and a direction in space to specify it completely.

We may think of it as an arrow in space. A simple example is the motion of an airplane. To describe this motion completely, we must say not only how fast the plane is moving, but also in what direction. . A familiar example is force, which has a magnitude (strength) measured in Newton and a direction of application. Giving a complete description of a force means describing both how hard the force pushes or pulls on the body and the direction of the push or pull.

When a physical quantity is described by a single number, we call it a scalar quantity. In contrast, a vector quantity has both a magnitude (the "how much" or "how big" part) and a direction in space.

Main Activity:

To have a clear understanding more about vectors and how they combine, let us start with the simplest vector quantity, displacement. This involves two pieces of information –the distance between two points and also the direction of one point from the other. Displacement is simply a change in position of a point. (The point may represent a particle or any body.) In Fig below we represent the change of position from point PI to point P 2 by a line from PI to P 2, with an arrowhead at P 2 to represent the direction of motion. Displacement is a vector quantity because we must state not only how far the particle moves, but also in what direction.

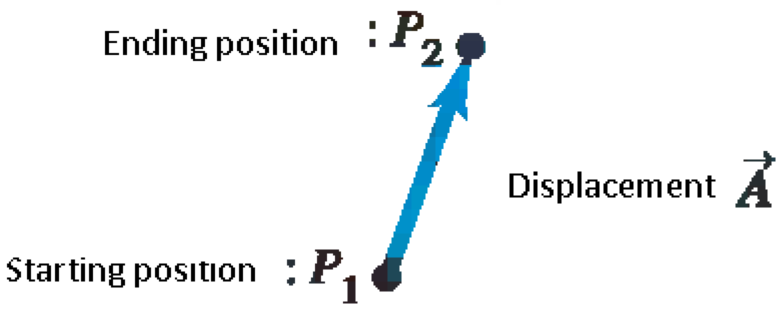


Figure 1.1: Vector notation

Analytically, we usually represent a vector quantity such as displacement by a bold type letter, such as **A** in Fig. 1.1 or by putting an arrow above them, the latter being much used in handwritten work. Keep students remind them that vector quantities have different properties from scalar quantities; the arrow is a reminder that vectors have direction. In handwriting, vector symbols are usually written with an arrow above them (see Fig. 1.1). When you write a symbol for a vector, always write it with an arrow on top.

A vector may be geometrically represented by an arrow with length proportional to the magnitude. The direction of the arrow indicates the direction of the vector, the positive sense of direction being indicated by the point.

If two vectors have the same direction, they are parallel (collinear). If they have the same magnitude and the same direction, they are equal, no matter where they are located in space.

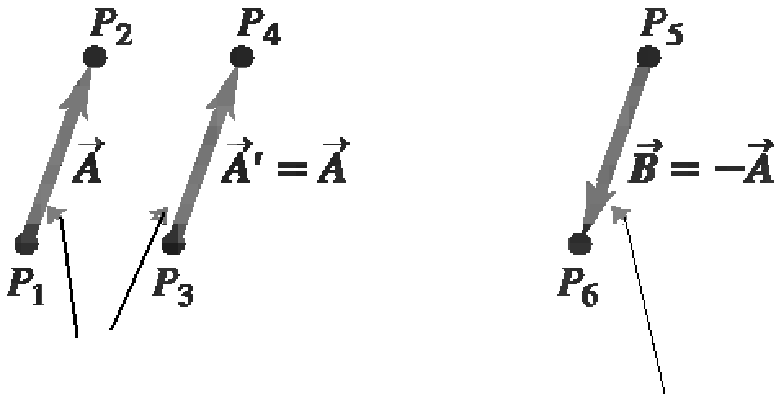


Figure1.2 Displacements

A and **A**' are equal because they have the same length and direction. But displacement **B** has the same magnitude as **A** but opposite direction, that is the negative of **A**.

If two vectors have the same direction, they are parallel. If they have the same magnitude and the same direction, they are equal, no matter where they are located in space. The vector **A'** from point P_3 to point P_4 in Fig. 1.2 has the same length and direction as the vector **A** from P_1 to P_2 . These two displacements are equal, even though they start at different points. We write this as **A'** = **A**.

Two vector quantities are equal only when they have the same magnitude and the same direction.

The vector **B** in Fig. 1.2, however, is not equal to **A** because its direction is opposite to that of **A**. We define the negative of a vector as a vector having the same magnitude as the original vector but the opposite direction. The negative of vector quantity **A** is denoted as -**A**, and we use a boldface minus sign to emphasize the vector nature of the quantities. When two vectors **A** and **B** have opposite directions, whether their magnitudes are the same or not, we say that they are anti-parallel.

We usually represent the magnitude of a vector quantity by the same letter used for the vector, but in light italic type with no arrow on top, rather than boldface italic with an arrow (which is reserved for vectors). An alternative notation is the vector symbol with vertical bars on both sides:

(Magnitude of A) =A = |A|.

Throughout this material we will represent a vector in diagrams as a line together with an arrowhead. We will make no distinction between an arrowhead at the end of the line and one along the line's length.

Concluding Activity:

A scalar is a quantity that is specified completely by a single number and a physical unit of measure. Scalars are quantities specified with units and are combined with the usual rules of arithmetic.

When the direction as well as the magnitude of a quantity must be quoted we are dealing with a vector quantity.

To represent a vector quantity diagrammatically, a line is drawn with length proportional to the magnitude of the vector quantity and with an arrow pointing in the same direction as the vector quantity. This allows geometry to be used to calculate the magnitude of unknown vector quantities, since the lengths of all lines in a vector diagram are proportional to the magnitudes of the vectors.

Stress the importance of getting in the habit of using the arrow symbols for vectors. If students often omit the vector arrow from the vector symbol they are more likely to be in confusion and mistakes.

After recapitulating the key ideas or concepts provide students with some carefully designed questions such as:

1. State the use of vectors in daily life.
2. You may often see F and V, representing the magnitudes of the vectors, without boldface or an arrow over the letters. Why?
3. Does it make any difference which of the two vectors is added first and which second?
4. The output voltage of a battery, the volume of a bottle, the clock time, and the mass of a body all has something in common. It is that they are represented by:

   A. One number
   B. More than one number

Support students in realizing that each is represented by only one number- the battery by 12V,the bottle by 1.5 Liter, the time by 2:35s and the weight by 67Kg ,and things described by a number with a unit are called scalars

Confirm that they come up the right answer as to supply travelling instructions and because it frequently useful to discuss the magnitude of the force or velocity without concerning ourselves with its directions to questions No 1 and 2 respectively.

add and subtract vectors graphically
Add and subtract vectors geometrically and algebraically

Starter Activity:

Start the lesson informing students that they use vectors frequently, even if they may not be familiar with the term.”Run 3km northeast” or “walk 4m north, 2m east” are both vector descriptions. The name vector means carrier. In Biology a mosquito is a malaria vector. In physics the vector measures where a thing is carried 3m forward, 4m to the right and 5m up.

Main Activity

Vectors can be added or subtracted. In this lesson, we show how to do these operations graphically. It may be helpful to consider that these two vectors represent displacement. A women walks along displacement vector **A** and then along displacement vector **B**. Her initial point is the tail of **A**, and she would end up at the point at the end of **A+B** vector .The sum represent the displacement vector from her initial to final position .

To be more specific about the addition of process: we start with two vectors **A** and **B**, both drawn at the common origin. To add them, we move the vector **B** so it starts at the head of **A**. The sum is a vector that starts at the tail of **A** and ends at the head of **B**.

$$\mathbf{C} = \mathbf{A} + \mathbf{B} \qquad (1.1)$$

Vector **C** is then represented by an arrow drawn from the tail of **A** to the tip point of **B**. This procedure, the triangle law of addition, assigns meaning to Eq. (1.1) and is illustrated in Fig. 1.3 bellow.

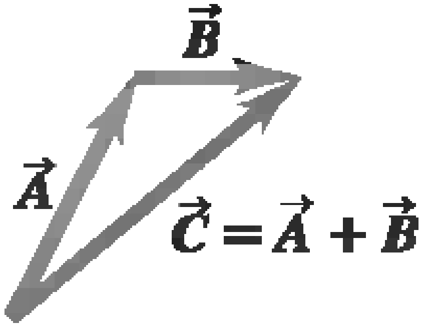


Figure1.3a: adding two vectors by placing those head to tail.

The sum **A+ B** of vectors **A** and **B** is defined as the vector directed from the initial point of **A** to the endpoint of **B** under the condition that **B** is applied at the endpoint of **A**. The rule for addition of vectors, which is contained in this definition, is called the triangle law of vector addition (see Fig. 1.3a.).

Subtraction is handled by defining the negative of a vector as a vector of the same magnitude but with reversed direction. Then

$$\mathbf{A} - \mathbf{B} = \mathbf{A} + (-\mathbf{B}) \qquad (1.2)$$

By completing the parallelogram (sketch it), we see that the sum **A + B** can also be found using the parallelogram law of vector addition- If vectors **A** and **B** are both drawn with their tails at the same point, vector **C** is the diagonal of a parallelogram constructed with A and B as two adjacent sides.

$$\mathbf{C} = \mathbf{A} + \mathbf{B} = \mathbf{B} + \mathbf{A}. \qquad (1.3)$$

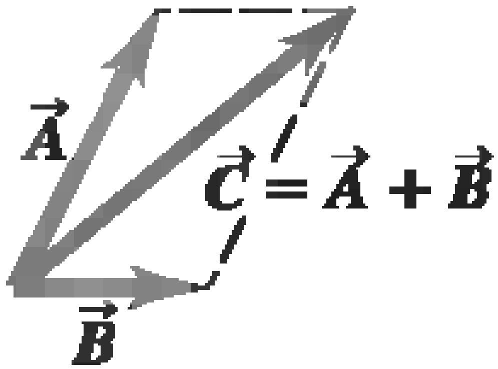


Figure 1.3b: adding two vectors by constructing a parallelogram.

Common misconception-Magnitudes in vector addition

It's a common error to conclude that if **C = A + B**, then the magnitude **C** should just equal the magnitude **A** plus the magnitude **B**. In general, this conclusion is wrong; for the vectors shown in Fig. 1.3b, you can see that C < A + B. The magnitude of **A + B** depends on the magnitudes of **A** and **B** and on the angle between A and B). Only in the special case in which A and B are parallel is the magnitude of **C = A + B** equal to the sum of the magnitudes of **A** and **B**. By contrast, when the vectors are anti parallel the magnitude of **C** equals the difference of the magnitudes of **A** and **B**. If you are careful about distinguishing between scalar and vector quantities, you'll avoid making errors about the magnitude of a vector sum.

Give strong emphasis to the fact that the addition of vectors only makes physical sense if they are of a like kind, for example if they are both forces acting in three dimensions.

When we need to add more than two vectors, we may first find the vector sum of any two; add this vector ally to the third, and so on. Figure 1.3c shows three vectors **A**, **B**, and **C**. In Fig 1.13c. We first add **A** and **B** to give a vector sum **D**; we then add vectors **C** and **D** by the same process to obtain the vector sum R:

$$\mathbf{R} = (\mathbf{A} + \mathbf{B}) + \mathbf{C} = \mathbf{D} + \mathbf{C}$$

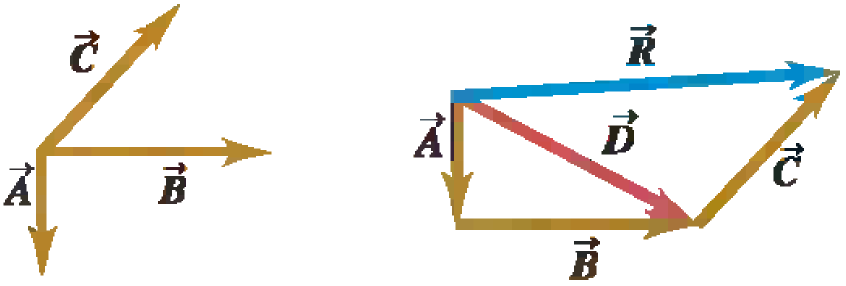


Figure 1.3c: How to add three vectors graphically

To Verify the Parallelogram Law, let students in group perform the following experiment

This experiment is carried out by applying three forces to a point and adjusting them until they are in equilibrium. When they are in equilibrium, their sum (as vectors) must be zero. The sum of any two of the vectors must then be equal and opposite to the third, to make the total sum of all three zero. We use the parallelogram law to find the resultant of two of the forces in the experiment, and show that this resultant is equal in magnitude and opposite in direction to the third force. This proves that the resultant found by the parallelogram law is the sum of the two vectors - especially when the experiment is repeated several times and a similar result is found each time

As shown in the figure below (Figure: 1.4), the investigation explores the concept of equilibrium using forces on springs. Try to keep the spring scales as parallel as possible. Attach three springs to the loops of string with the key ring in the middle. Have three people each pull a spring, keeping the ring motionless with all the springs in a line.

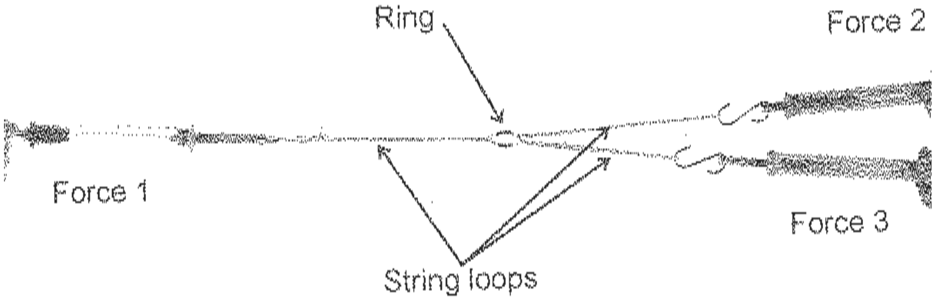


Figure: 1.4 concept of equilibrium

In the calculations, it is essential that the masses are converted to weights in Newton, What can you say about forces when nothing is moving? Notice that when nothing is moving it does not mean there are no forces acting. It means things are in equilibrium. In equilibrium the total (net) force is zero. What do your observations tell you about the relationship between the three forces acting on the ring? Let students draw a diagram showing the force vectors on the ring as arrows. Make the length of each arrow proportional to the strength of each force. For example,1 cm per 1N might be a reasonable length scale.

Concluding Activity:

Provide the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the quiz, let them reread their textbook, ask their teacher for help, or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

Q1. List four quantities that are represented by vectors.

Q2. A ship sails northeast at a speed of 100m/s. Its velocity is V. What direction and speed would a boat with a velocity vector –V have?

Q3. A minibus travels from Addis Ababa to Gondar through Dessie town. A bus travels from Addis Ababa to Gondar by taking the route through Bahirdar .Do these two journeys have equal displacement vectors?

Q4. If the total force acting on an object is zero, does the object has to be at rest?

Objectives:

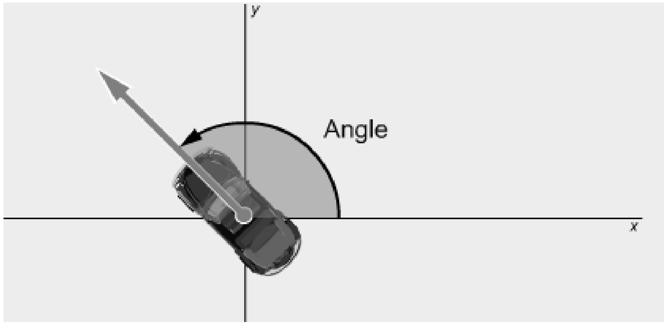
Represent vectors by its angle and magnitude.
Interpret a vector expressed by its angle and magnitude.

By defining a vector by its angle and magnitude, the magnitude and direction of the vector are stated separately. Three kilometers due north is an example. “Three kilometers” is the magnitude and “north” is the direction. The magnitude is always stated as a positive value. Instead of using “compass” or map directions, physicists use angles. Rather than saying “three kilometers north,” a physicist would likely say “three kilometers directed at 90 degrees.”

The angle is most conveniently measured by placing the vector’s starting point at the origin. The angle is then typically measured from the positive side of the x axis to the vector.

You see a car traveling northwest, with a vector indicating its velocity. Defining a vector by its angle and magnitude is one way to describe a vector. This notation states the two quantities (magnitude & direction) separately. Magnitude is the first part of this notation. In this case, it would be the speed of the car.

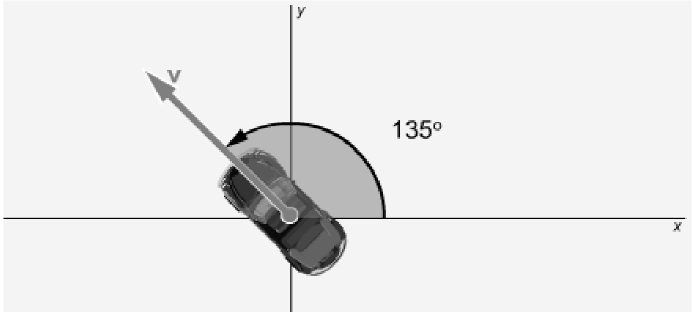
After magnitude, we need an angle to tell us which way to go. This gives us the direction of the vector, in this case the direction of the car’s velocity. In polar notation, the angle is measured from the positive x axis, as illustrated by the arc. An angle of 0° points directly to the right. Positive angles are in the counter-clockwise direction. Because the direction of the car is to the northwest (up and to the left), the value of the angle is between 90 and 180 degrees − to be precise, it is positive 135°.



For magnitude we use the letter v, since we are talking about velocity here. (For other quantities, other variables would be appropriate.) For angle, we use the Greek letter (theta). This is a common symbol for angles; you will see it often.

The way to write a vector in polar notation is (v,), in parentheses. First the magnitude (or length) of the vector is written, and then its direction

Let students attempt this question to express a velocity vector in polar notation.



- add or subtract vectors using the component method
- State what the components of a vector are, and how to use them in calculations.
- Identify Using components makes it relatively easy to do various calculations involving vectors.

Starter Activity:

In the preceding lessons we combined vectors graphically, but it is not an especially good way to find quantitative results. In this section we will introduce a coordinate description of vectors that will be the basis of an easier method of for doing vector calculations

We added vectors by using a scale diagram and by using properties of right triangles. Measuring a diagram offers only very limited accuracy, and calculations with right triangles work only when the two vectors are perpendicular. So we need a simple but general method for adding vectors. This is called the method of components.

To make the component method easy to understand, let us apply the analogy with a dance class, engaged with a preparation to win the Ethiopian Idol contest.. Ask the class if they have ever attended the dance class so that they may also help you.

If you were a dancer or a cheer leader you would easily understand the following choreography: “Take two steps forward, four steps to the right and one step back”. Note that these are vector instructions. If asked how far forward are after this dance move, you would say “one step”, which is two steps forward plus one step back Assist students to realize that their progress forward or back is unaffected by steps to the right or left. You correctly process left or right and forward or back separately.

Main Activity:

Frequently what we know, or want to know, about a particular vector is not its overall magnitude and direction, but how far it extends horizontally and vertically. On a graph, we represent the horizontal direction as x and the vertical direction as y. These are called Cartesian coordinates. The x component of a vector indicates its extent in the horizontal dimension and the y component its extent in the vertical dimension.

To define what we mean by the components of a vector A, we begin with a rectangular (Cartesian) coordinate system of axes (Fig1.5.). We then draw the vector with its tail at 0, the origin of the coordinate system. We can represent any vector lying in the xy-plane as the sum of a vector parallel to the x-axis and a vector parallel to the y-axis. These two vectors are labelled A_x and A_y" in Fig.; they are called the component vectors of vector A, and their vector sum is equal to A. In symbols,

$$\mathbf{A} = \mathbf{A_x} + \mathbf{A_y}$$

Since each component vector lies along a coordinate-axis direction, we need only a single number to describe each one. When the component vector A_x points in the positive x-direction, we define the number A_x to be equal to the magnitude of A_x When the component vector A_X points in the negative x-direction, we define the number A_X to be equal to the negative of that magnitude (the magnitude of a vector quantity is itself never negative). We define the number A_Y in the same way. The two numbers A_X and A_Y are called the components of A. (Fig.1.5)

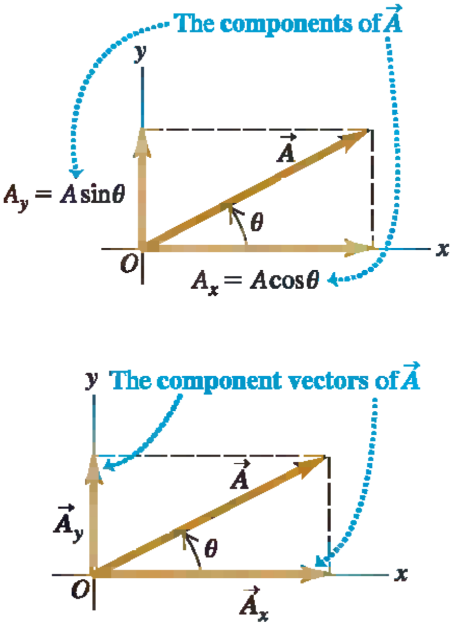


Figure: 1.5 Components of a vector

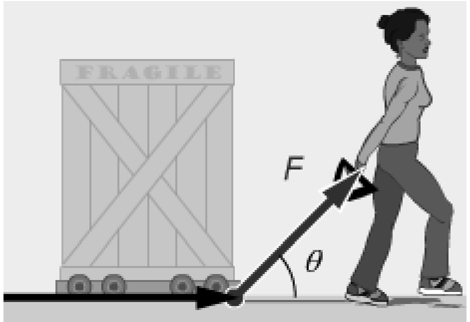
Common misconceptions: Components are not vectors

The components A_x and A_y of a vector **A** are not vectors themselves. This is why we print the symbols for components in light italic type with no arrow on top instead of the boldface italic with an arrow, which is reserved for vectors.

Let students beware of the confusing terminology A_x and A_y component vectors, where as A_x and A_y simply components. Make sure that you do not put arrow symbols over the components.

Concluding activity:

It is often convenient to replace a single vector by two component vectors .For example we may imagine a cupboard on a road being pulled by a woman using a rope inclined at an angle θ to the road and exerting a force F as shown below in the figure



We may resolve the force F into two components at right angles to each other, F_X along the Road and F_Y perpendicular to the road. We see at once if the law of vector addition is applied,

$$\mathbf{F}=\mathbf{F}_X+\mathbf{F}_Y$$

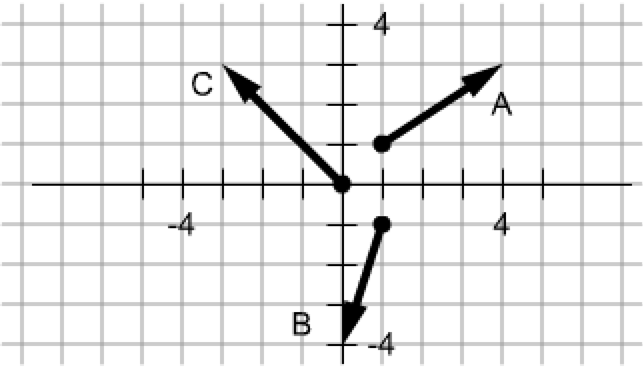
ACTIVITY:

a) Two vectors **A** and **B** can be added together using a scale diagram .Draw lines from the same point O in the correct directions and with the correct lengths according to the scale chosen .Put arrow heads on the lines representing the vectors.

b) Complete the parallelogram and draw the diagonal from O.The diagonal represents the vector sum (Resultant) ; it is a vector which has the same effect as **A** and **B** acting together

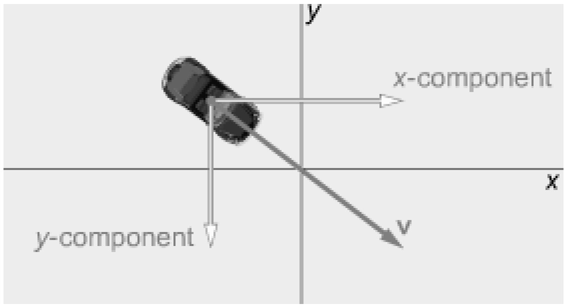
Let the teacher provide students with following simple questions and confirm their understanding

Q1. Write the vectors labeled **A**, **B** and **C** with rectangular coordinates.



Q2. Write the vectors labeled **V** with rectangular coordinates

Give students a reading assignment on the application of vectors so that before coming to class, students are required to read related articles on reference materials as well as corresponding sections in the textbook.



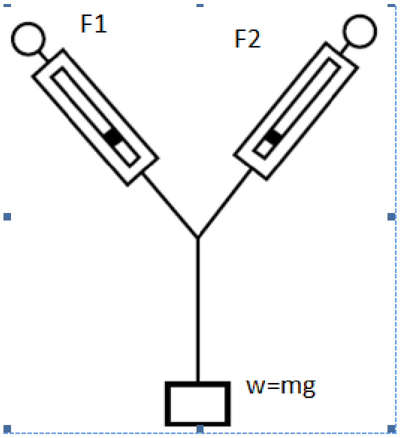
Describe the composition and resolution of vectors and some of their practical applications.
Identify the condition of equilibrium.

Starter Activity: Having previously assigned the reading of the chapter as homework, initiate the class work by a discussion of the problem. Follow this with a consideration of force vectors acting at 0^0 and 180^0 .Emphasize the definitions of components, resultant and equilibrant; then continue by the discussion and demonstrations listed below.

Main Activity Demonstration to verify the parallelogram law

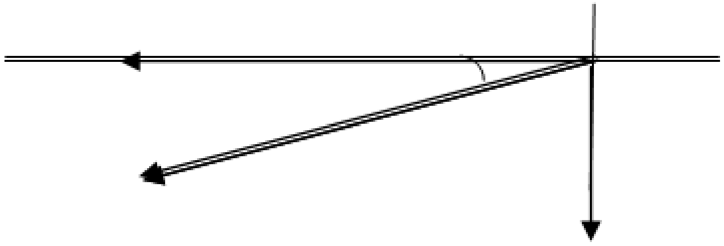
This experiment is carried out by applying three forces to a point and adjusting them until they are in equilibrium. When they are in equilibrium, their sum (as vectors) must be zero. The sum of any two of the vectors must then be equal and opposite to the third, to make the total sum of all three zero.

We use the parallelogram law to find the resultant of two of the forces in the experiment, and show that this resultant is equal in magnitude and opposite in direction to the third force. This proves that the resultant found by the parallelogram law is the sum of the two vectors - especially when the experiment is repeated several times and a similar result is found each time.



Worked Example:

Find the x-and y-components of vector A =6 units shown in the figure below. Assume that vector a makes 30^0 with the X-axis



First decompose vector A into components parallel to the axes. The vector A=6 units ,30^0 below the negative x-axis, points to the left (negative x-direction)and down(negative y-direction).So the components A_x and A_y are both negative.

A_x =-Acos 30^0=-(6 units) cos 30^0=-5.2 units
A_y =-Asin30^0 =-(6 units) sin 30^0 =-3 units

Vectors are also useful and helpful in describing navigation. For example, an aircraft pilot makes use of the displacement vector when he states his position, and velocity vectors and laws of vector addition when deciding upon the direction to head the aircraft in order to arrive at a given destination

Note to the teacher on vectors: Vectors as things to be added by geometrical and analytical means seem clear, useful and helpful things to matured and motivated students. The students who first meet vectors at an early stage in physics may find them odd and difficult; and almost impossible to understand. Since the sense of difficulty disappears completely as time goes on, we urge teachers not to press any discussion on vectors beyond what seems sensible to their students at each age.

Define the term pressure.
Use a wide variety of units for measuring pressure.

Starter Activity:

Elicit students' idea about pressure. It is a word they all know and use. They might have a commonsense idea of what pressure is. Let students state the difference between pressure and force. You can also use the following example as a starter:

It matters which way up a thumb tack (a drawing pin) is when you sit on it. In this section we see how the effect of a force depends on the area over which it is applied. The effect of sitting on a thumb tack is much greater in figure 2.1a than it is in figure 2.1b.In each case the force is the same, but the area of contact is much smaller in figure 2.1a than it is in figure 2.1 b.

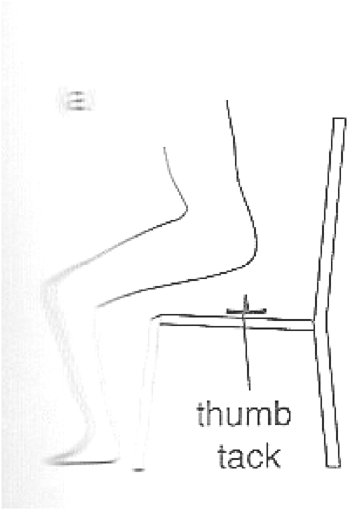


Figure: 2.1a

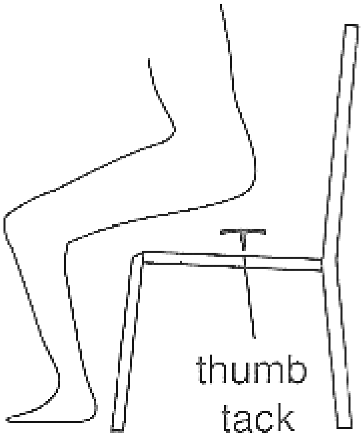


Figure: 2.1b

Relate this example with tractors having wide tyres of large diameter to prevent the wheels from sinking far into soft ground. The wide tyres spread the weight of the tractor over as large an area as possible.

Main Activity:

Let students in groups try this activity: A flat, square piece of wood of area 1cm^2 is placed on damp sand and a force of 10 N is applied to the top of it. This creates an indent (mark in the surface of something) in the sand .Then take another square wooden piece of area 4 cm^2, and a force of 10N is applied. This time, the indent is less deep .If the force is increased to 40N; the dents are about the same. That is a force of 40N spread over an area of 4 cm^2 has the same effect as the force of 10N spread over 1cm^2.

A special name is given to the force acting on unit area. It is called the pressure: Perpendicular contact force divided by the surface area over which the force acts.

$$\text{Pressure} = \frac{\text{force}}{\text{area}}$$

P = F/A
P = pressure
F=force
A=surface area

Units: Pascal (Pa), Newton/meter^2

The Pascal is an SI unit for pressure; one Pascal equals one Newton per square meter.

A pressure of 1 Pa is a small pressure. It is the weight of about 100g spread over the area of 1m^2 .Sometimes a larger unit, N/ cm^2 is used. Because there are 10000 cm^2 in 1m^2.

1Pa=1N/m^2
1N/cm^2 =10 000Pa

Stress the fact that pressure is a scalar, not a vector. Make a clear distinction between force and pressure. There is no direction associated with pressure, but the direction of the force associated with the pressure is perpendicular to the surface upon which it is acting. Thus it is incorrect to say, for example, that the pressure at the bottom of a beaker of water acts downwards on the bottom of the beaker or that pressure in a fluid acts in all directions. It is the force which is associated with the pressure which is the vector quantity and acts in a particular direction. Thus the water exerts a downward force on the bottom of the beaker as a result of the force of gravity acting on the water; at a particular point in a fluid the forces exerted by the water is the same in all directions, i.e. the resultant force is zero.

As an illustration of the distinction between pressure and force, let students in groups try this simple activity: consider the two blocks in Figure below. The blocks are identical, but one stands on its end and the other on its side. Assume the two blocks stand on a mattress, so that you can observe the amount of distortions produced. Both blocks are of equal weight and therefore exert the same force on the surface, but the upright block exerts a greater pressure against the surface. If the block were tipped up so contact is on a single corner, the pressure would be greater still.

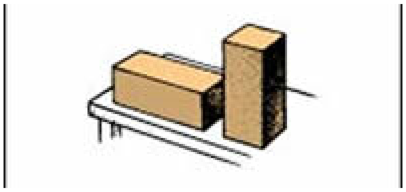


Figure: 2.2: Although the weight of both blocks is the same, the upright block exerts greater pressure against the table.

Invite students for discussion and elicit their arguments on this question: Suppose you are standing directly behind a young lady who steps back and accidentally stamps on your foot with the heel on one shoe. Would you feel better of the person if that person were:

- A large professional basketball player wearing sneakers
- A small and thin woman wearing high-heeled shoes

Assist and support students in releasing that spike-heeled shoes concentrate almost all the weight of the lady over a very small surface area, and can exert a pressure large enough to damage or cause pain.

Concluding Activity: Recapitulating the core points of the lesson provide the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the quiz, let them reread their textbook, ask their teacher for help, or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

Q1. Stand on a weigh scale and read your weight. When you lift one foot off so you're standing on one foot, does the reading change? Does a scale read force or pressure?

Q2. You know that a sharp knife cuts well than a dull knife. Do you know why this is so?

Q3.A thumb tack is squeezed between the finger and the thumb as shown in the figure. Figure. Which experience the greater pressure, the thumb or the finger? Be careful not to hut yourself!

Confirm students' understanding by comparing their replies with the following correct answers:

1. The weigh scale measures force, not pressure and is calibrated to read your weight. That is why your weight on the scale is the same whether you stand on one foot or both.
2. A sharp knife cuts well than a dull knife because it has a thinner cutting area which results in more cutting pressure for a given force.

Describe how liquids exert pressure.
State the factors on which liquid pressure depend**.**

Starter Activity: Begin this lesson with a revision on previous lesson and students' common experience in swimming.

A liquid contained in a vessel exerts forces against the walls of the vessel. To discuss the interaction between the liquid and the walls, it is convenient to apply the concept of pressure.

You experience pressure when you swim. If you dive deep under the water, you can feel the water pushing against you with more pressure, more force per square meter of your body. The deeper you swim, the greater the pressure. What causes this pressure? It is simply the weight of the fluids directly above you—water plus air—pushing against you. As you swim deeper, there is more water above you. Therefore there's more pressure. If you swim twice as deep, there is twice the weight of water above you, so the water's contribution to the pressure you feel is doubled. Because air pressure near the Earth's surface is nearly constant, the pressure you feel under water depends only on how deep you are.

Main Activity: Students have a common misconception that liquid pressure depends on surface area. Remove this misconception using an investigation experiment approach.

Let students observe water squirting out from a container through holes at different depths. Students need to make inferences, propose a hypothesis and plan an experiment to verify the hypothesis. First let the teacher show the demonstration and then assign students to carry out the activity in groups.

Use a hammer and a nail to make three holes of the same size in the side of the can .Hold a piece of wood inside the can where you are making the holes. This helps you to make the holes lie in a vertical line but at different distances from the bottom

Fill the can with water, and watch the water flow out of the holes.

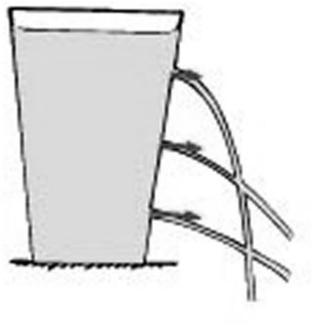


Figure: 2.3 Water pressure acts perpendicular to the sides of a container, and increases with increasing depth.

Demonstrate also the following simple activity to show the direction of the pressure:

Use a plastic bag without any holes in it. Fill it with water and tie up the opening so that water cannot get out.

Stick a pin through the bag, and gently squeeze the bag .The pressure causes the water to flow out and it comes out at right angles to the surface even if the hole is on the top surface of the bag. Put in more holes in different positions and observe.

Notice that when liquid presses against a surface, there is a net force directed perpendicular to the surface. Although pressure doesn't have a specific direction, force does.

Concluding Activity:

Provide assistance and guide students to arrive at the following concluding remarks:

The pressure pushes the water out of the holes. The water comes out fastest from the lowest hole, where the depth of water is greatest. This implies the pressure is greatest where the depth of water is greatest. Notice also that the water comes out of the holes at right angles to the surface of the can before gravity pulls it downwards. It curves downward due to gravity

Derive the equation of the pressure at a depth in a liquid
Calculate the actual /total pressure at a point in a liquid

Starter Activity: We use the concept of forces in equilibrium to derive the equation for pressure in a liquid. The liquid is assumed to have a uniform density , no matter what its depth.

Main Activity: The figure2.3 below shows a liquid in a container. The column of water extends from the surface of the liquid down to the depth where the pressure is to be determined. It has height h and its bottom surface has area A. The mass of the liquid in the column is m.

In a container of liquid, the pressure at any point results from the weight of the liquid above that point and the weight of the atmosphere, assuming that the container is open to the atmosphere. The pressure resulting from the weight of the liquid alone is known as the gauge pressure. So the actual pressure at a particular point in a liquid is equal to the gauge pressure plus the atmospheric pressure. In practice, even though it may not be explicitly stated, it is the gauge pressure which is normally in question.

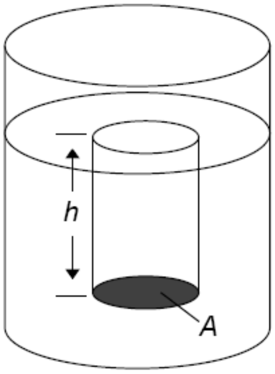


Figure: 2.4 pressure at a depth in a liquid

Two forces act on the column. The pressure P of the liquid below the column presses up on its bottom surface with a force PA. Gravity acting on its mass pulls it down; the magnitude of this force is the column’s weight, mg. We assume that the liquid is static, so we know that the column is not accelerating in any direction.

Variables:

mass of column	m
acceleration of gravity	g
pressure on bottom surface	P
area of bottom surface	A
density of liquid	
height of column	h

Strategy:

Since the column is not accelerating, the net force acting on it must be zero. This means the forces acting on it must sum to zero.

Use the definitions of density, weight and volume to rearrange and simplify the equation that sums the forces to zero.

Physics principles and equations: The pressure P on the area A is due to the weight of the liquid above it.

Newton’s second law

$$\mathbf{F} = m\mathbf{a}$$

The definitions of pressure and weight

$P = \mathbf{F}/A$ weight $= mg$

The definition of density

$= m/V$

The volume of the column equals the area of its base times its height

$V=Ah$

Step-by-step derivation

Since the column of liquid is not accelerating, Newton's second law implies that the upward and downward forces on it are equal

1. $\mathbf{F} = m\mathbf{a} = 0$	Newton's 2nd law; column not accelerating
$PA + (-mg) = 0$	definitions of pressure and weight
$PA = mg$	rearrange
$PA = (\rho Ah)g$	definition of density
$P = \rho gh$	gauge pressure
$P_{actual} = P_{gauge} + P_{atm} = \rho gh + P_{atm}$	

It is important to note that only the depth below the surface of the liquid of density is involved; the shape of the vessel and the area of the liquid surface are not involved in the pressure at all. Therefore, the factors on which pressure in a liquid at rest depends on are density of the liquid, acceleration due to gravity, and depth of the liquid.

Concluding Activity: A few words on the units of pressure are in order. We have stated that the units of pressure are N/m2. This combination of units is given a name. It is called the Pascal, abbreviated Pa.

$$\mathbf{1\ Pa = 1N/m^2}$$

Pressures are often quoted in terms of the non-SI unit of pressure, the atmosphere, abbreviated atm and defined such that, on the average, the pressure of the earth's atmosphere at sea level is 1 atm. In terms of the Pascals,

$$\mathbf{1\ atm = 1.013\times10^5\ Pa}$$

The big mistake that students make in applying equation ($P = P_0 + \rho gd$) is to ignore the units. They'll use 1 atm for P_0 and without converting that to Pascals; they'll add the product ρgh to it. Of course, if one uses SI units for ρ, g, and h, the product ρgh comes out in N/m2 which is a Pascal which is definitely not an atmosphere (but rather, about a hundred-thousandth of an atmosphere). Of course one can't add a value in Pascals to a value in atmospheres. The way to go is to convert the value of P_0 that was given to you in units of atmospheres, to Pascals, and then add the product ρgh (in SI units) to your result so that your final answer comes out in Pascals.

To confirm whether students distinguish the difference between gauge pressure and absolute pressure; let them solve the following problem in 5 minutes.

What is the gauge pressure inside the bottom of the tank due to the weight of the water alone? What is the absolute pressure, including atmospheric pressure, pressing down inside the bottom?

State the Pascal’s principle
Perform an activity to demonstrate Pascal’s principle

Starter Activity:

Start the lesson with a short summary of the previous lesson as-the hydrostatic pressure in a liquid depends only on the depth and the pressure at the surface .We see some important implications of this observation. The equation:

$$\mathbf{P_{actual} = P_{gauge} + P_{atm} = gh + P_{atm}}$$

Implies that, if the pressure on a liquid is increased, perhaps by fitting a piston and pressing it down, the pressure at any depth in the liquid will increase by the same amount. This is the basis of Pascal’s principle.

Main Activity: An enclosed fluid transmits pressure unchanged. Here you see two blocks of differing masses. The same fluid supports both masses in a state of equilibrium. Why? Because the pressure is the same underneath both masses. The more massive block exerts more downward force than its counterpart, but it exerts it over a proportionally greater area. This means the pressure is the same on both sides

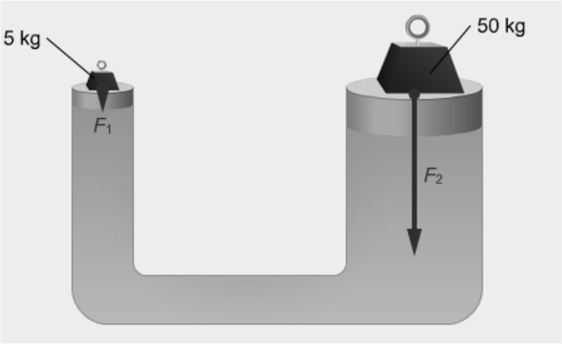


Figure: 2.5 An enclosed fluid transmits pressure unchanged

Fluids transmit pressure uniformly in all directions. Since the system is in equilibrium, the downward pressure exerted on the fluid by the small block equals the upward pressure exerted by the fluid on the large block. The fluid also exerts pressure on the sides of the hydraulic system.

Concluding Activity: We can draw a conclusion from the hydrostatic pressure equation-

$$P=P_0+\ gd$$

Where:

P is the absolute pressure,
P_0 is atmospheric pressure
$P_{g\,=}$ gd is the gauge pressure, and

If we change the pressure P_0 at the surface to P_1, the pressure at depth d becomes

$$P^{'}=P_0+\ gd$$

The change in pressure $\Delta P = p_1 - p_0$ is the same at all points in the fluid, independent of the size or shape of the container? This idea, that a change in pressure at one point in an incompressible fluid appears undiminished at all points in the fluid, and is called ***Pascal's principle.***

This is the basis of many hydraulic devices. For example, braking systems of cars; in fork-lift trucks; in tractor systems; in car jacks; in lifts, etc. Essentially a small force applied over a small area of a piston can generate a larger force elsewhere in the system utilizing a larger area.

A connected liquid in hydrostatic equilibrium rises to the same height in all open regions of the container.

The pressure is the same at all points on a horizontal line through a connected liquid in hydrostatic equilibrium.

Demonstration: The figure below shows two connected tubes .It is certainly true that the larger volume of the liquid in the wide tube weighs more than the liquid in the narrow tube. Students might think that this extra weight would push the liquid in the narrow tube higher than in the wide tube .But it doesn't .If d_1 were larger than d_2, then according to the hydrostatic equation, the pressure at the bottom of the narrow tube would be higher than the pressure at the bottom of the wide tube. This pressure difference would cause the liquid to flow from the right to the left until the heights are equal.

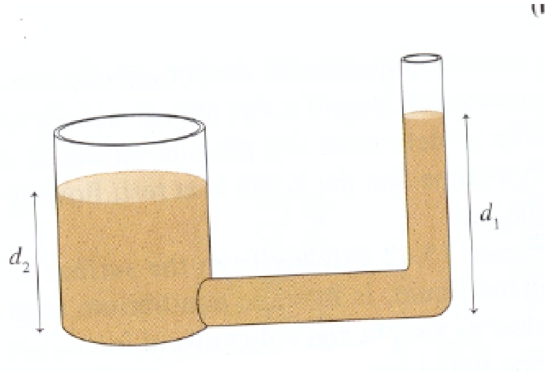


Figure: 2.6

We suggest that the teacher should give a demonstration of Pascal's principle and then ask students to experiment in groups to feel the pressure of a liquid.

You need a small and a large syringe that are joined by a plastic or rubber tube. Remove the pistons from the syringes and fill the tube and barrel with water. Put back the large piston, and push it fully into the barrel. Then insert the small piston into its barrel. The system should now be full of water.

Press on one of the syringes while holding your thumb on the piston of the other to stop it moving. What do you notice about the forces?

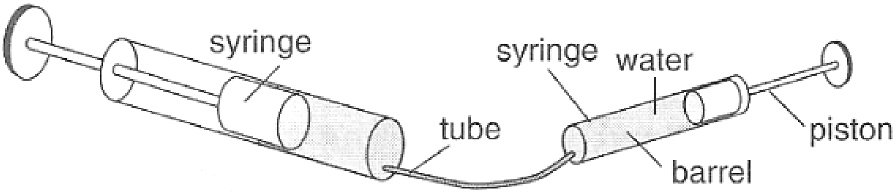


Figure: 2.7

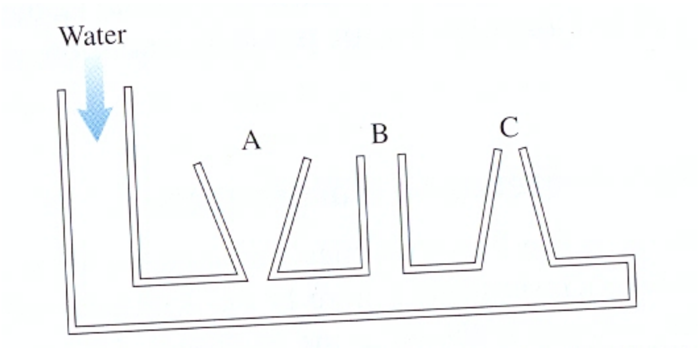
Try it also the other way round.

Elaborate to the class that the braking system of the car is like the syringe experiment. Of course oil is used instead of water .The oil is called hydraulic fluid. A brake cylinder has a large area; a pedal cylinder has a small area. This implies that the force on the brake is much larger than the force needed to press the pedal cylinder.

After this demonstration and thorough discussion of pressure due to liquids; let students proceed to attempt to give the correct answer to the following concept test question. Confirm their understanding and give support and assistance if there are any confusions or ambiguity.

Q. Water is slowly poured into the container until the water level has risen into the tubes A, B, and C. The water does not overflow from any of the tubes. How do the water depths in the three columns compare to each other?

A. $d_A > d_B > d_C$
B. $d_A < d_B < d_C$
C. $d_A = d_B = d_C$
D. $d_A = d_B > d_C$



state Archimedes’ principle
describe what is meant by the buoyant force

Starter Activity: start the lesson asking students what will happen to objects submerged into the liquid. Let them predict.

If you take an object in your hand and let submerge the object in still water, and release the object from rest, one of three things will happen: The object will experience an upward acceleration and bob to the surface, the object will remain at rest, or the object will experience a downward acceleration and sink.

Or you may prefer to listen to their experience in lifting heavy submerged objects.

Anyone who has ever lifted a submerged object out of water is familiar with buoyancy, the apparent loss of weight experienced by objects submerged in a liquid. For example, lifting a large rock off the bottom of a riverbed is a relatively easy task as long as the rock is below the surface. When it is lifted above the surface, however, the force required to lift it is increased considerably. This is because when the rock is submerged, the water exerts an upward force on it that is exactly opposite to the direction of gravity's pull. This upward force is called the ***buoyant force*** and is a consequence of pressure increasing with depth.

Main activity: What causes buoyancy? – Figure 2.8 shows why the buoyant force acts upward. Forces due to water pressures are exerted everywhere against the object in a direction perpendicular to its surface—as shown by the vectors. Force vectors against the sides at equal depths cancel one another—so there is no horizontal buoyant force. Force vectors in the vertical direction, however, don't cancel. Pressure is greater against the bottom of the rock because the bottom is deeper. So upward forces against the bottom are greater than downward forces against the top, producing a net force upward—the buoyant force.

As shown in the figure2.8a below; a rock floats on water. The water exerts pressure forces round the rock .The total or net effect of all these forces is a force upward on the rock, the up thrust/buoyant force. The rock floats at a depth where the buoyant force balances the weight.

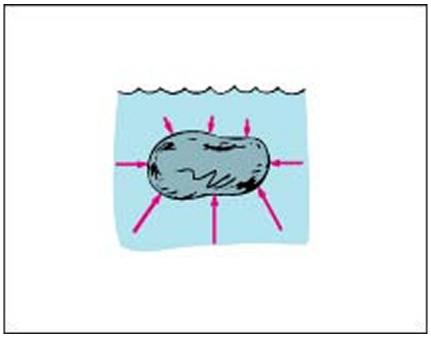


Figure 2.8a: Buoyant force on a body immersed in a liquid

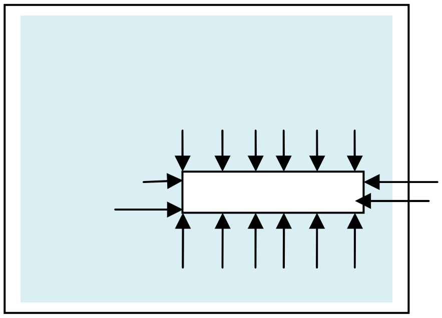


Figure 2.8b

The net pressure-times-area force (are on which a force acts) on an object submerged in a fluid is upward because of the fact that pressure increases with depth. The upward pressure times-area force on the bottom of an object is greater than the downward pressure-times-area force on the top of the object. The result is a net upward force on any object that is either partly or totally submerged in a fluid. The force is called the buoyant force on the object. The agent of the buoyant force is the fluid.

A piece of iron in water also has pressure forces round it. There is an upthrust because the pressure forces under the block are greater than those on the top. (Figure)But the upthrust is less than the weight of the iron and the iron sinks. For it to float the density of the object must be less than the density of the liquid.

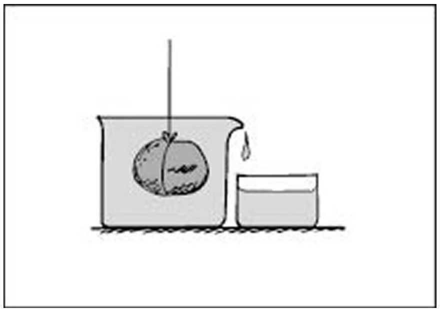


Figure: 2.9

Emphasize that the buoyant force is always upward. So why on earth would the object ever sink? The reason is, of course, that after you release the object, the buoyant force is not the only force acting on the object. The gravitational force still acts on the object when the object is submerged.

Recall that the earth's gravitational field permeates everything. The key question is whether the object (released from rest in the fluid) sinks, stays put, or bobs to the surface, is determined by how the magnitude of the buoyant force compares with that of the gravitational force. If the buoyant force is greater, the net force is upward and the object bobs toward the surface. If the buoyant force and the gravitational force are equal in magnitude, the object stays put. And if the gravitational force is greater, the object sinks.

You can also demonstrate the Cartesian diver experiment to show the equilibrium condition for a body immersed in a fluid. The test tube is placed in a long glass vessel filled with water whose opening is covered with an elastic membrane. The test tube is partly filled with water and its remaining part contains some air. When the elastic membrane is pressed the air pressure above the water in the vessel and, together with it, the pressure in the water itself increases. The air in the test tube is compressed, the volume of the water displaced by the test tube decreases and the test tube moves downwards to the bottom. When the pressure on the membrane is decreased the test tube moves backwards. The pressure on the membrane can be regulated so that the test tube is made to move in any upward or downward direction or to occupy any intermediate position between the bottom and the membrane.

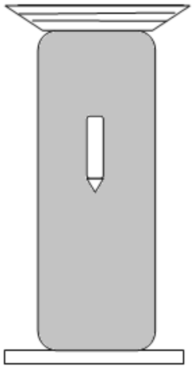


Figure 2.10: A Cartesian diver

Concluding Activity: Buoyancy is a familiar phenomenon: A body immersed in water seems to weigh less than when it is in air. When the body is less dense than the fluid, it floats. The human body usually floats in water, and a helium-filled balloon floats in air. Archimedes's principle states: When a body is completely or partially immersed in a fluid, the fluid exerts an upward force on the body equal to the weight of the fluid displaced by the body.

Keep reminding students that Archimedes’ principle can also be applied to gases and cite example as:

When a balloon floats in equilibrium in air, its weight (including the gas inside it) must be the same as the weight of the air displaced by the balloon. . A fish's flesh is denser than water, yet a fish can float while submerged because it has a gas-filled cavity within its body. This makes the fish's average density the same as water, so its net weight is the same as the weight of the water it displaces.

% & ' % $

Use the Archimedes’ principle to solve problems**.**
Develop the problem solving skills.

Example: This piece of wood weighs 43 N, and it displaces 0.0030 m^3 of water. What is the buoyant force on it?

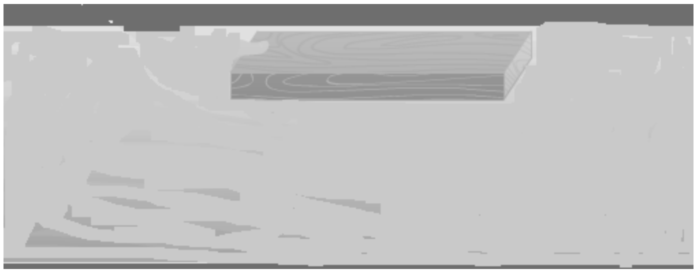


Figure 2.11: a floating block of wood

First let us find the weight of the displaced water.

Then we multiply the density of the displaced water by its volume to determine its mass, and then by *g* to determine its weight. This is the magnitude of the buoyant force, which is directed up. Since the buoyant force is less than the weight of this chunk of extremely dense wood, it will sink.

$m = \quad V$
$m = (1000\ \text{kg/m}^3)(0.0030\ \text{m}^3)$
$m = 3.0\ \text{kg}$
$mg = (3.0\ \text{kg})(9.80\ \text{m/s}^2) = 29\ \text{N}$
$F = 29$ N, directed up

Concluding Activity:

After you make a summary of the lesson, have students come up with the solution of the following problems on buoyancy**.** If students have trouble with the problems, motivate them to take more practice on solving problems, ask their teacher for assistance and guidance, or discuss the material with a fellow student.

1) What is the buoyant force acting on a stone having a mass of 3 Kg and submerged in water if the density of the stone is 2.4X 10^3 Kg/m^3?
2) An ice cube floats in a glass filled with water. What will be the change in the level of water after the ice has melted?

#

Identify gases exert pressure
Show the strength of atmospheric pressure with some demonstrations

Starter Activity: Let us have a peek on gases, measure pressures and speculate about the mechanism of gas pressures. Ask students what makes air press on things, or how air press on things, and leave the question unanswered until further study of air pressure. Remind students that gases do press on things strongly and do move easily.

Let students perform the following simple activity: shut your mouth and puff off your cheeks and feel your cheeks with your fingers .Feel the lightly compressed air in your chest driving out through your mouth and nose when you breathe out .Or they might have heard carbon dioxide bursting out from a bottle of soda water. Gases can make a considerable pressure on anything that holds them.

Main Activity: Let the teacher demonstrate these experiments to show that the atmosphere exerts a pressure.

1. Fill a glass to the brim with water .Slide a card over the top so that there are no air bubbles in the glass. Turn the glass upside-down, using your finger to keep the card pressed against the glass Figure). Then takes your finger away. The liquid does not fall out. The pressure of the atmosphere is large enough to keep the card in place.

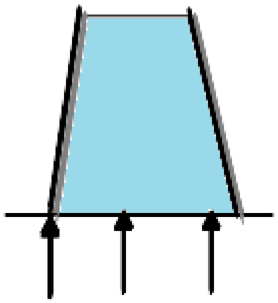


Figure 2.12:

2. You need a rubber sucker as shown in the figure2.13. Wet the sucker, and press it against a hard, flat, polished surface. Pressing the sucker pushes out the air between the sucker and the surface. The air now presses mainly on the outside of the sucker. Attach a string to the sucker if possible. Use a spring balance to measure the force to pull the sucker from the wall. If you measure the area of the sucker, you will be able to work out a value for the atmospheric pressure.

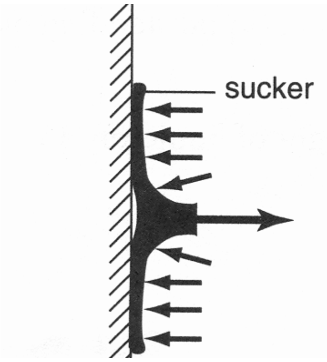


Figure 2:13: A rubber sucker

3. Put some water in a can and heat it as strongly as possible (Figure2.14).Keep it boiling quickly for a few minutes so that the steam pushes out most of the air inside. Take the source of heat away and cork the can firmly. Let the can cool .As it cools, the steam inside turn back into liquid. Air cannot get into the can and there is less air inside than before, the air pressure inside is less than the air pressure outside. The can will collapse under the atmospheric pressure as the steam inside condenses. The condensation can be speeded up by pouring cold water over the can.

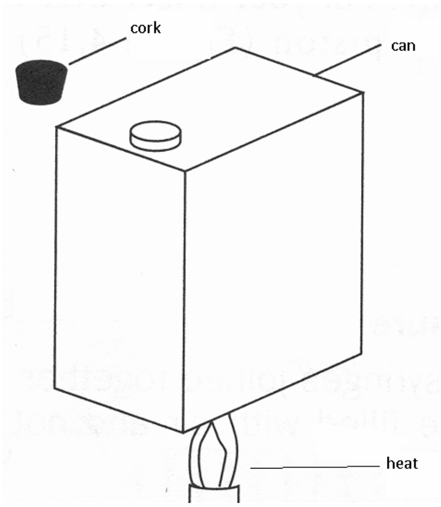


Figure 2.14: collapsing can

4. A hardboiled, peeled, egg can be forced into a milk bottle by the force from atmospheric pressure. Burn a bundle of paper in the bottle. When the flame is established strongly, quickly place the egg in the bottle's mouth. It helps to moisten the egg first. As the air inside is heated it expands, forcing air out around the egg. Then as the air cools inside, the pressure drops inside the bottle, and the egg is pushed inside by the greater air pressure outside. The egg can be removed by turning the bottle upside down so the egg blocks the neck. Then close your lips around the bottle's mouth and blow into it, creating enough pressure to force the egg out. It pops out surprisingly quickly, so be ready to catch it. **Note:** Avoid any explanation you may have seen in books which involves the flame "using up oxygen" in the bottle, for such processes have negligible effect on the pressure in the bottle.

Note to the teacher: If students wish to try the third activity as a home experiment; they should be warned that most cylindrical cans withstand atmospheric pressure, so that a rectangular can should be used.

Concluding Activity: Provide the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the quiz, let them reread their textbook, ask their teacher for help, or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

Explain in terms of pressure, how you are able to drink Mango juice by using a straw?-

( )

Acquaint themselves with pressure gauges and their functions
Measure gas pressure using a manometer

Starter Activity: Begin the lesson introducing what is meant by a manometer. An *open-tube manometer*, a device for measuring the gauge pressure of a gas confined in a vessel. The vessel that contains the gas is connected to a U-shaped tube partially filled with mercury and open to the atmosphere at its far end. This apparatus allows physicists to accurately determine the gauge pressure of the gas.

Main Activity: Discuss thoroughly how it operates and function using fine illustrations.. This is a device called an open-tube manometer. For a given pressure in the spherical vessel, the height of the column of mercury on the right rises or falls until, with the help of atmospheric pressure, it balances the vessel pressure. The total pressure exerted on the right is the pressure exerted by the column of extra mercury, plus the pressure of the atmosphere on top of it. This total pressure balances the pressure inside the vessel

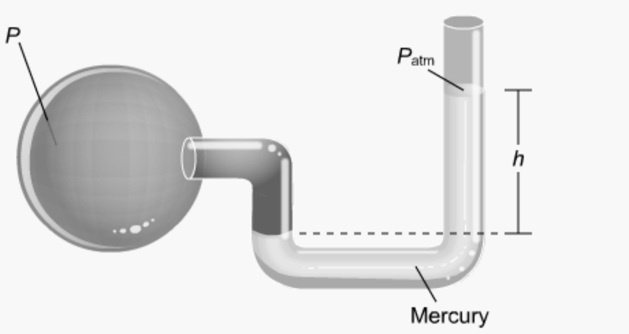


Figure 2.15: A manometer

In this illustration you see the quantities associated with a manometer. The equation states that the pressure P inside the vessel equals the atmospheric pressure P_{atm} plus the pressure gh exerted by the extra mercury on the right. The pressure inside the vessel is the **absolute pressure.** The pressure exerted by the extra mercury on the right is the **gauge pressure.** If the pressure of the gas in the vessel falls below atmospheric pressure, then the mercury column on the right will be shorter than the one on the left, *h* will be negative, and the equation will still hold.

Group the students in the class and let them do the following activity to measure the pressure of the gas supply.

1. You need a U-tube (manometer) with sides 30cm long. The U-tube manometer can be made of transparent plastic, secured to a board. Attach a rubber tube to one side .Half fill the manometer with water (colored with dyes) and hold it so that the sides are vertical.
2. Connect it to the gas supply, possibly to your mouth, using the rubber tube and the difference in levels in the manometers is measured.
3. Let students measure their lung pressure by blowing on this manometer

   For the sake of hygiene, each student should fit his own rubber tubing to the manometer.

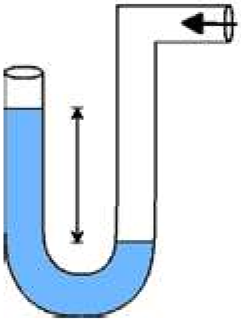


Figure 2.16: A U-tube manometer

Note that water can be used in manometers, but it is not much use for large pressures. Since water is not a very dense liquid like mercury, h becomes very big. Mercury is a good liquid to use for greater pressures.

Concluding Activity: This activity is intended to extend the students' experience of pressure and in particular to give opportunities to measure and compare pressures. Stress the point that the pressure difference is proportional to the depth of a fluid to measure unknown pressures. Ask students about the pressure in the automobile tire. Check their understanding. If the do not give the correct answer provide them with immediate correction as-The pressure we measure in the automobile tyre is gauge pressure. When the tyre is completely flat, the gauge pressure is zero. The absolute pressure P is obtained from the gauge pressure by adding atmospheric pressure to it.

$$P = P_{gauge} + P_{atm}$$

*   +

State what is meant by a barometer
Describe how a barometer measures atmospheric pressure

Starter Activity: Start the lesson asking this question –"Well, if the air does press on everything, could we use the U-tube and mercury to measure the atmospheric pressure?"

If students do not know what to suggest, point out that the U-tube pressure-gauges had two pressures, one on each side, the lung pressure on one side and the atmosphere on the other side-assuming for the moment that the atmosphere is with us and does press on things.

Main Activity:

Instruments used for measuring the pressure of the atmosphere are called **barometers**. You can make a simple barometer using a thick glass tube longer than 76 cm closed at one end as illustrated in Figure .It has to be filled with mercury, so you must wear gloves, as mercury is poisonous. Fill the tube with mercury, holding it over the tray (you can pour mercury using the funnel) until it is nearly full at the open end. Tap it gently to get rid of air bubbles, and add more mercury it is completely full. Close that end with a finger so that there is no air in the tube and air cannot enter it.. Hold a finger on the top and invert into the trough. Do not remove the finger until the end of the tube is below the surface. The mercury level falls to the height "h".No air has entered the tube, and so the space above the mercury in the closed tube is a good vacuum. Hold the tube in a clamp and measure the height. The height h therefore measures the atmospheric pressure. Now you have a barometer which measures atmospheric pressure in cm /mm of mercury.

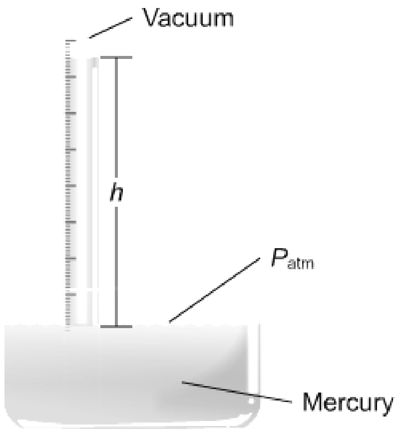


Figure2.17: A mercury barometer

The barometer is calibrated in millimeters. The height *h* of the column of mercury is typically about 760 mm at sea level. By definition, the pressure exerted by 760 mm of mercury, also called 760 torr, equals one standard atmosphere of pressure.

In practice, pressure is often measured in millimeters of mercury (mmHg),a unit called the **torr.**The various units of pressure are related as follows:

$$\mathbf{1\ atm=760mmHg=760torr=1.01X10^{5}\ Pa}$$

Other units commonly used on weather maps are the **bar** and the **millibar**, which are defined as

$$\mathbf{1\ bar=1000millibar=10^{5}\ Pa}$$

Concluding Activity

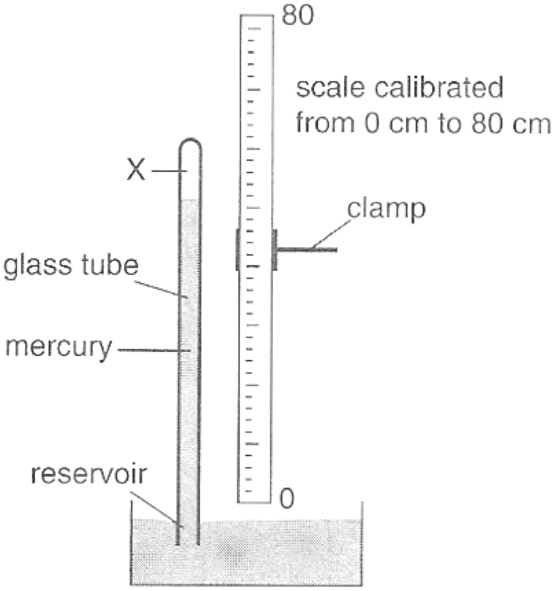
A barometer works by having the pressure of a column of a fluid, often mercury, balance the pressure of the atmosphere at the surface of a reservoir

Provide students with appropriate questions to check their understanding as:

1. The figure below shows a simple mercury barometer.

    i) What occupies the space labelled X? and

ii) Copy the diagram and show on it the distance which could be measured to find the atmospheric pressure.



2. The average (gauge) pressure in the aorta is about 100mmHg.Convert this average blood pressure to Pascals.

Define the term temperature
Distinguish between the terms temperature and heat

Starter Activity: Open the discussion by pointing out that everybody is familiar with idea of temperature. Elicit students' background knowledge about temperature. You hear the word used every day. Then use the following analogies to make learning easy: Mass is a measure of the amount of substance in a system. Velocity is a measure of how fast a system moves .Acceleration is a measure of how fast velocity is changing. But just what is a temperature a measure of ?

Temperature is an indication of the hotness of something. We can tell by touching an object whether it is hot or cold. However, this is a subjective judgment, and is not very reliable. Let us use a simple experiment to demonstrate this. Take three basins of water, each holding the same quantity of liquid, but one containing hot water, a second containing lukewarm water, and the third one cold water. Place one hand in the hot water, and the other in the cold water. Leave them for a few seconds. Now, put both hands together into the basin of lukewarm water, and notice that both hands give different messages. The hand that came from the hot water now feels cold, whereas the hand taken out of the cold water feels warm.

We cannot rely on our skin as an accurate way of measuring temperature. The physiological sensations registered by receptors in our skin depend largely on their immediate past experience, as the experiment illustrates. So, we need thermometers with suitably defined scales for the reliable measurement of temperature.

Rub two sticks together and you will notice that the temperature of each increases. You did work on the sticks and their temperature increased. Doing work is transferring energy. So you transferred energy to the sticks and their temperature increased. This means that an increase in the temperature of a system is an indication of an increase in the internal energy (or thermal energy) of the system.

Another way of increasing the temperature of a pair of sticks is to bring them into contact with something hotter than the sticks are. When you do that, the temperature of the sticks gradually increases—you don't have to do any work on them. Again, the increase in the temperature of either stick indicates an increase in the internal energy of that stick. Where did that energy come from? It must have come from the hotter object. You may also notice that the hotter object's temperature decreased when you brought it into contact with the sticks. The decrease in temperature of the hotter object is an indication that the amount of internal energy in the hotter object decreased. You brought the hotter object in contact with the sticks and energy was automatically transferred from the hotter object to the sticks. The energy transfer in this case is referred to as the flow of heat. Heat is energy that is transferred from a hotter object to a cooler object when you bring the two objects in contact with each other. Heat is not something that a system has but rather energy that is transferred or is being transferred. Once it gets to the system to which it is transferred we call it internal energy. The idea is to distinguish between what is being done to a system, "Work is done on the system and/or heat is caused to flow into it", with how the system changes as a result of what was done to it, "The internal energy of the system increases."

The fact that an increase in the temperature of an object is an indication of energy transferred to that object might suggest that anytime you transfer energy to an object its temperature increases. But this is not the case. Try putting a hot spoon in a glass of ice water. (Here we consider a case for which there is enough ice so that not all of the ice melts.) The spoon gets as cold as the ice water and some of the ice melts, but the temperature of the ice water remains the same (0 °C).The cooling of the spoon indicates that energy was transferred from it, and since the spoon was in contact with the ice water the energy must have been transferred to the ice water. Indeed the ice does undergo an observable change; some of it melts. The presence of more liquid water and less ice is an indication that there is more energy in the ice water. Again there has been a transfer of energy from the spoon to the ice water. This transfer is an automatic flow of heat that takes place when the two systems are brought into contact with one another. Evidently, heat flow does not always result in a temperature increase

Concluding Activity: After recapping the core ideas of the lesson, let students attempt to solve the following questions so that you can confirm their level of understandings.

1. An object has a high temperature when:

   A. The molecules of the object get hot
   B. The molecules of the object move at high speed.
   C. The molecules move at low speeds
   D. The molecules are at rest

2. Suggest two reasons why the human body is not a suitable device to measure temperature.

+

Show how thermometers are calibrated and how Fahrenheit readings are converted to Celsius readings, and vice versa

Starter Activity: Initiate the class by pointing out that whenever you measure something, you are really just comparing that something with an arbitrarily-established standard. For instance, when you measure the length of a table with a meter stick, you are comparing the length of the table with the standard meter. In the case of temperature, a standard, now called the "degree Celsius" was established as follows: At 1 atmosphere of pressure, the temperature at which water freezes was defined to be 0 °C and the temperature at which water boils was defined to be 100 °C. Then a substance with a temperature-dependent measurable characteristic, such as the length of a column of liquid mercury, was used to interpolate and extrapolate the temperature range. (Mark the position of the end of the column of mercury on the tube containing that mercury when it is at the temperature of freezing water and again when it is at the temperature of boiling water. Divide the interval between the two marks into a hundred parts. Use the same length of each of those parts to extend the scale in both directions and call it a temperature scale.) Materials whose property significantly and noticeably changes, when heated are referred to have temperature –dependent measurable characteristics. Any property which varies continuously as a substance gets hotter can be used to measure temperature. But to devise an effective method of providing a temperature scale some fixed reference points must be agreed. One such temperature-dependent property is the length of a mercury column contained in a glass envelope.

Main Activity: Suppose you have a mercury thermometer without any degree marks on its stem. To use it to measure a temperature on the Celsius scale, you need to have these two temperatures, called fixed points.

To measure an unknown temperature, we first place the bulb in melting ice, and measure the length of the mercury column. Call this reading L_0 .The bulb should then be placed in the steam from boiling water and the length measured again. Call this L_{100} .We mark these points on the graph, and draw a straight line between them. Once we have marked the fixed points on the stem, we can divide the interval between the two marks into 100 equal lengths. Each length can also be added below the 0 °C mark and above the 100°C mark to measure temperature outside these points. This provides the basis of the ‘mercury –in-glass’ temperature scale.

We can now find an unknown temperature T°C by measuring L and using the graph. **Concluding Activity:** Liquid-in-glass thermometers have the advantage that they can be used to read the temperature directly. Once the fixed points have been marked on the stem, the space between them can be divided into 100 equal lengths and numbered. We can find an unknown temperature by seeing how long the length ***L*** is when the bulb of the thermometer is at the unknown temperature.

Have students practice using thermometers as an assignment. You may want to review this topic by posing some questions .Have some students in one group use a thermometer to measure the temperature outside during different hours, such as the morning, afternoon, and late afternoon. Ask them how the does the temperatures change? Why do they think it changed? Then have another group use thermometers to measure the temperature of a cup of water. Add ice cubes and measure the temperature again

Convert Celsius readings to Kelvin and Fahrenheit readings.
Derive the expressions used for conversion.

Starter Activity: in this lesson you see thermometers representing three temperature scales. You may be most familiar with the Celsius scale, but the Fahrenheit and Kelvin scales are also used in the sciences. This demands a need to switch from one temperature scale to another. As the thermometers show, temperature values are different on each scale. For example, an average indoor room temperature is 68 degrees on the Fahrenheit scale, which equals 20 degrees Celsius or 293.15 Kelvin.

Main Activity: The temperature at which water freezes is 0° on the Celsius scale. The comparable temperatures are shown on the other scales. There are 100 degrees between the freezing and boiling points of water on the Celsius scale, and 100 kelvins between freezing and boiling on the Kelvin scale. This means the units of these two scales are equal. Since the Celsius and Kelvin scales have the same number of units between the freezing and boiling points of water, it takes just one step to convert between the two systems, as shown in the first conversion formula below.

Since the Celsius and Kelvin systems differ only in their zero points, converting between the two scales is a matter of addition or subtraction. To convert from degrees Celsius to Kelvin, you add 273.15 degrees. To convert from Kelvin to degrees Celsius, you subtract the same value.

$$T_K = T_C + 273.15$$

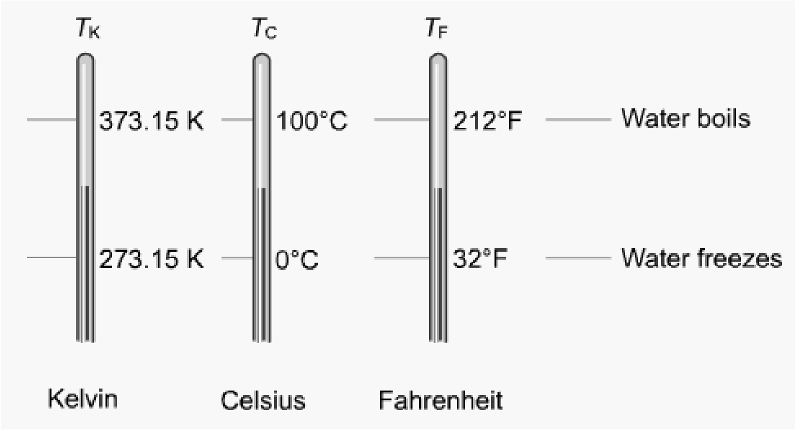


Figure 3.1 temperature scales

The following equation helps you to convert from degrees Fahrenheit to degrees Celsius.

$$T_C = (5/9)\,(T_F -–32)$$
$$T_{F=}\ (9/5)\ TC\ +32$$
$$T_{K\,=}\ T_C + 273.16$$

Where

T_K=Kelvin temperature
T_C=Celsius temperature
T_F = Fahrenheit temperature

Another important concept shown in the illustration is: ***absolute zero***. At this temperature, molecules (in essence) cease moving. Reaching this temperature is not theoretically possible, but temperatures quite close to this are being achieved. Absolute zero is 0 K, or −273.15°C.

Concluding Activity: Confirm students understanding by providing the class with a quiz and have quick check to see if they have understood the conversions introduced in the lesson. If students have trouble with the conversion, let them reread their textbook, do more practice on conversion problems ; ask their teacher for assistance and guidance , or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

1. The temperature of a glass of water increases from 20 ^{0} C to 30 ^{0} C .What is ΔT ?

A. 10 K
B. 273K
C. 293K
D. 300K

2. An iron rod is heated from 66.0°F to 280°F. Express the increase in temperature in Celsius.
Convert each of the following temperatures to the indicated scale:

A. 100 K to the Celsius scale;
B. 100K to the Fahrenheit scale;
C. 72°F to the Celsius scale; and
D. −273.15°C to the Fahrenheit scale.

,

Identify heat as a form of energy
State commonly used units of heat
Identify heat and work are equivalent terms

Starter Activity: Initiate the lesson asking students to state some differences between heat and temperature, and then inform them that we will discuss experiments that led us to the abandonment of the caloric theory of heat and its replacement by an energy interpretation of it. Ask them whether they have heard of 18th century scientists thought-that heat was an invisible, fluid substance called caloric or not.

If they are unfamiliar with this idea, you may wish to start this lesson with the introduction of the caloric theory. In the caloric theory heat was thought as a substance with fluid-like properties. If you place a hot object and a cold object together, they evolve toward a common final temperature. Commonsense suggests that “something” flows from the hot object to the cold until equilibrium is achieved. This “heat fluid” was called caloric and every object contained caloric. This theory was proven wrong by Benjamin Thomson. He believed that, if caloric existed, any object being heated or cooled should change mass as the caloric flowed into it or out of it. He designed experiments to test this idea and his findings showed the mass of an object did not change in any way when it was heated. He concluded that caloric did not exist and heat was not a fluid.

Main Activity: Careful experiments conducted by Joule found that we can raise the temperature of a beaker of water by two entirely different means:

1. Heating it with a flame
2. Doing work on it a rapidly spinning paddle wheel

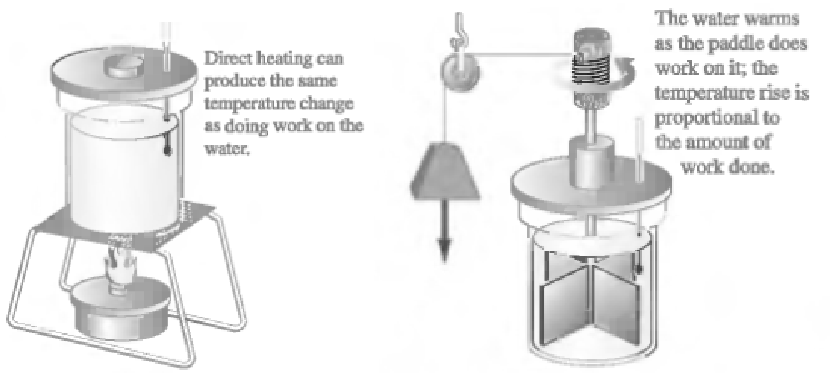


Figure 3.2 Joule's experiment

The final state of the water is exactly the same in both cases. This implies that ***heat and work are basically equivalent to each other.*** In other words, heat is not a substance. Instead ***heat is the energy that is transferred from a hotter object to a colder object as a consequence of temperature difference between them.***

Physicists do **not** say an object has heat. Heat refers solely to the flow of energy due to temperature differences. Heat transfers *thermal energy* that is internal to objects, related to the random motion of the atoms making up the objects.

Heat is like work: It changes the energy of an object or system. It does not make sense to say ***"how much work a system has",*** nor does it make sense to say ***"how much heat the system has".*** Just as work is done by a system or on a system, heat as thermal energy can enter a system or leave a system. Having said that heat is measured in joules, we will backtrack a little in order to explain some other commonly used units.

Historically, before the connection between heat and work had been recognized, a unit for measuring heat, the calorie had been defined as :

1 calorie=1 cal=the quantity of heat needed to change the temperature of 1g of water by 1 ^{0}C

Once Joule established that heat is energy, it is apparent that the calorie is really a unit of energy. In today's SI unit the conversion is

1 cal= 4.186J

The calorie you may be familiar with in relation to food in biology lesson; is not the same as the heat calorie, abbreviated Cal with a capital C, is

1 food calorie= 1Cal=1000cal=4186J

The calories you see labeled on the back of food packages − –is actually a kilocalorie Food calories measure how much heat will be released when an object is burned

Concluding Activity: After recapping the core points of the lesson you may want to emphasize that it is especially important not to associate an observed temperature increase with heat. Of course, heating a system is one way of changing the temperature of the system, but Joule showed it is not the only way, since you can also change the system's temperature by dong work on the system.

Give also emphasis to significance of pointing out that matter does not *contain* heat. Matter contains molecular kinetic energy and possibly potential energy, *not heat*. Heat is *energy in transit* from a body of higher temperature to one of lower temperature. Once transferred, the energy ceases to be heat. As an analogy, work is also energy in transit. A body does not *contain* work. It *does* work or has work done on it.)You may wish to test students understanding by posing such questions:

1. Which one of the following processes involves heat?

    A. The brakes in your bike get hot when you stop.
    B. A steel block is held over a candle flame.
    C. You push a block across a frictionless surface

(% -

Explain why solids, liquids and gases are expanding

Starter Activity: You can start the lesson asking students “what happens to materials when their temperature changes?’ Pose these questions to elicit students’ experience-Have you ever realized that telephone wires become longer and sag more on a hot summer day than they do on a cold winter day? Have you ever noticed that steel roofs likely produce a cracking sound on hot days? Have you experienced that if one part of a piece of glass is heated or cooled more rapidly than adjacent parts, the resulting expansion or contraction may break the glass, especially if the glass is thick? Then state that in this lesson we see about expansion, its effects and the uses we can make of it.

Main Activity: Precede the lesson stating that when an object absorbs heat energy, various changes in the physical properties of the object may occur. To name some the temperature of the object may rise, accompanied by an expansion or contraction of the object, or the object may liquefy or vaporize during which the temperature remains constant.

Heating things causes’ expansion due to the increase in the energy of the particles in the substances .The expansion of solids is small and not usually great enough to be measured with a ruler. Let the teacher demonstrate this simple activity to illustrate expansion of a metal rod.

1. You need a metal rod, a needle, and a drinking straw, two weights, two wooden blocks, a microscope slide and a source of heat. Arrange the apparatus as in the figure.

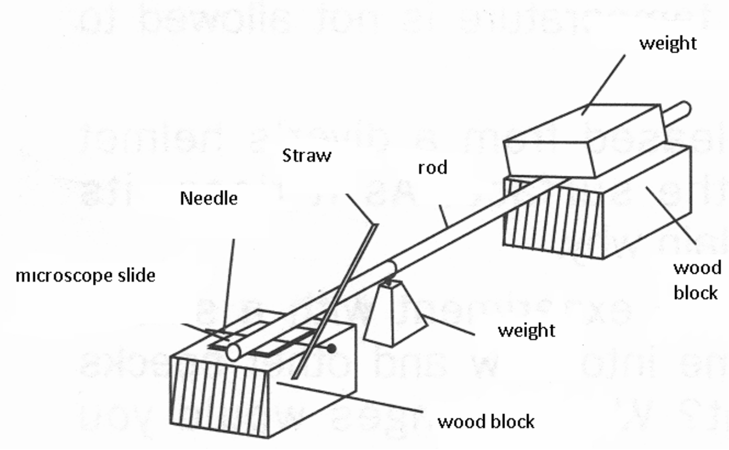


Figure 3.3: expansion of a metal rod

2. One end of the rod is held fixed by a large weight such as a brick. The other end rests on the needle on the microscope slide so that it can roll the needle when it expands. The needle is pushed through a straw which acts as a pointer. A smaller weight is hung on the rod to keep the rod pressed against the needle.
3. Heat the rod strongly .As the rod expands, its free end rolls on the needle. The straw shows the angle that the needle has turned through.

We can show the expansion of metal solids in other ways. Divide the class into smaller groups and assign them to carry out the following hands-on activities:

I. The bar and gauge experiment-In this experiment the bar fits the gauge at room temperature. But when the bar is heated, it expands and it is then too big fit the gauge. Notice that it fits the gauge again when it has got cooled.

II. The ball and ring experiment-a metal ball just passes through a metal ring at room temperature. When the ball is heated, it will not pass through. Ask students what happens ‘if instead of the ball being heated, the ring is cooled?’Lead those to the correct answer by pointing out that the ring shrinks, and the ball will not pass through it until the ring has warmed up again.

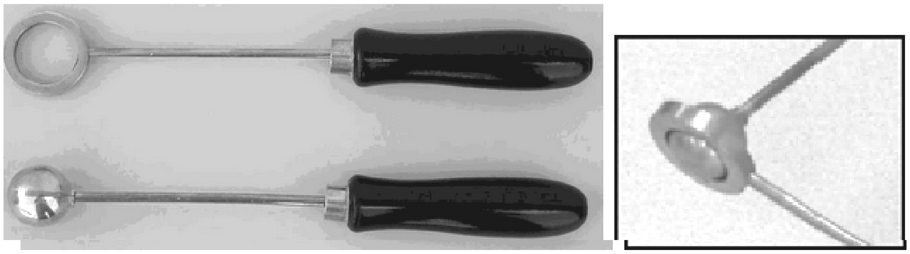


Figure 3.4: ball and ring

Common misconception: Students usually believe that when the metal surrounding a hole is heated then the hole will get small when it actually should increase in size. This is a good demonstration because it highlights the misconceptions students develop. They like to think that the hole gets smaller. Students find this demonstration very helpful. If a metal plate containing a hole is heated then the whole plate will expand including the hole.
Imagine a circle drawn on the plate with no hole.

Concluding Activity: Recapitulate the key points in concise and clear statements as:

Most solids, like metals expand equally in all directions as they are heated. In the ball and ring experiment, the ball has a bigger radius and thus a bigger volume. Any expansion of the ring would result in the hole having a bigger radius, and thus a bigger area. However guide students by stressing the point that not all solids expand equally in all directions .Finally check students understanding by posing the following questions:

Q1. A steel block is heated so that the length of each side increases 1%. What happens to its mass?

A. It increase by 1 %
B. It increase by 3 %
C. It does not change

Q2**.** Explain why a thick glass vessel often crack if placed in very hot water.

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Demonstrate liquids also expand when heated
Demonstrate gases expand when heated

Starter Activity: Begin this lesson revising what they learnt in the previous lesson about expansion of solids. Remind students that when solids are heated, its particles gain energy and so vibrate with greater speeds; their average distance of separation between atoms increases and this leads to an overall increase in size. We will see the expansion of liquids and gases in this lesson.

Main Activity: Since students are not familiar with the kinetic molecular theory of gases**, it** is appropriate to support this lesson with experiments to illustrate the basic ideas behind**.**

Activity on expansion of liquids

1. You need a flask with a bung and delivery tube as shown figure3.15 Fill the flask with water .Make sure that there is no air in the flask and that there is some water in the tubing.

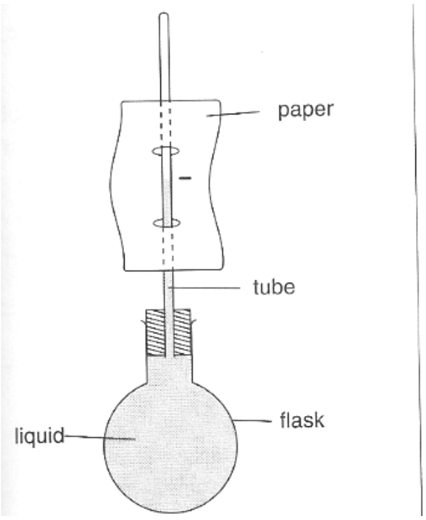


Figure 3.5: expansion of a liquid

2. Make two holes in a sheet of paper and slip it over the tube as shown. Mark the level of the water.

3. Gently warm the flask and note what happens to the water level.
4. Try using a different liquid in the flask such as kerosene.

The water level rises as you warm the flask, showing that the liquid is expanding. The amount of expansion increases as the water gets hotter. You can take it as a large model of a thermometer, though water would not be used as a thermometric substance in a thermometer.

Keep reminding students that the flask is also expanding as you warm it. It can therefore hold more liquid. Notice that the water level dropped as you started warming the flask. The heat first warms the flask and it expands. Because it can hold more liquid, the liquid level in the tube drops. However, as the heat reaches the water and because the water expands more than the glass, the liquid level soon rises. The actual expansion of the liquid is more than it appears to be.

Activity on expansion of gases-Use the flask used above, but without any water in it. Hold the flask between your hands so that the end of the tube just dips below the surface of water in a beaker, as shown in the figure .The warmth of your hands causes the air to expand, and it bubbles out through the water.

In this experiment, the volume of the gas increases because of the rise in temperature.

You can also try the following simple activity: Take an empty bottle of course; the bottle is not really empty for it is filled with air. Attach a balloon to its neck. Now heat some water in a vessel on a heater or stove. When the water starts boiling, gently place the bottle in boiling water. Look at the balloon. It is inflated. Why is the balloon inflated? The reason is that the air in the balloon expands when its temperature rises. Take the bottle out of the boiling water and allow it to cool. When the air in the bottle is cooled, the balloon is deflated and collapses. The air has contracted on cooling.

Or you can proceed as follows: When the air expands then air cools. There is a demonstration for you all to try right there at your seats. Are you ready? Let everyone have a hand. Put your hands in front of your mouth and with your mouth open the air does not expand. Now bring your mouth down really tight so the air expands as it comes down .Now feel the temperature of the air.

Thermal Expansion of Water

Heating does not always lead to expansion. Water, in the temperature range from 0 ^{0}C to 4°C, decreases in volume with increasing temperature. Above 4°C, water expands when heated. Hence water has its greatest density at 4°C. Water also expands when it freezes, which is why ice humps up in the middle of the compartments in an ice cube tray. By contrast, most materials contract when they freeze.

This abnormal behavior of water has an important effect on plant and animal life in lakes. A lake cools from the surface down; above 4°C, the cooled water at the surface flows to the bottom because of its greater density. But when the surface temperature drops below 4°C, the water near the surface is less dense than the warmer water below. Hence the downward flow ceases, and the water near the surface remains colder than that at the bottom. As the surface freezes, the ice floats because it is less dense than water. The water at the bottom remains at 4°C until nearly the entire lake is frozen. If water behaved like most substances, contracting continuously on cooling and freezing, lakes would freeze from the bottom up. Circulation due to density differences would continuously carry warmer water to the surface for efficient cooling, and lakes would freeze solid much more easily. This would destroy all plant and animal life that cannot withstand freezing. If water did not have this special property, the evolution of life would have taken a very different course.

Concluding Activity: After you make a concise, clear concluding remark on the lesson, you can provide them with ample questions and problems to check their understanding.

1. Why do soft drinks cans burst when left in a refrigerator too long? Assist students to arrive at the correct answer by giving them a tip on the abnormal expansion of water.

\# . (%

Describe the pros and cons of consequences of expansion of materials.

Cite examples of the advantages and disadvantages of the consequences

Starter Activity: Ask the students to cite examples of the usefulness of expansion and contraction**.** Have them also cite cases in which there are disadvantages. Some examples of the advantages are: thermometers, expansion and contraction of gases in refrigerator, etc. Examples of the latter are: in railroad rails, the laying of sidewalks in bridges, in the construction of buildings

Main Activity: To open a glass container with a very tight lid, you might hold the glass container under hot tap water. When the temperature increases, the metal lid and the glass container both expand.

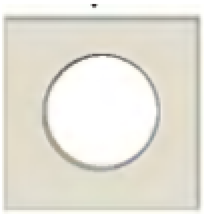
The expansion of materials due to a temperature change can be useful sometimes, as the jar-opening example demonstrates. Sometimes, it poses challenging engineering problems. For example, when nuclear waste is stored in a rock mass, heat can flow from the waste to the rock, raising the rock’s temperature and causing it to expand and crack. This could allow the dangerous waste to leak out. Knowing the exact rate of expansion can help engineers design storage intended to prevent cracking.

Good engineering practice takes expansion into account. For instance, bridges are built with expansion joints, which have room for expansion as the temperature increases. Gaps must be left between the lengths of railway tracks to allow for the expansion of the steel rails in the hot season.

Metal tyres can be securely fixed round wheels by means of expansion. The tyre is made a little smaller than the wheel which it is to fit. It is then heated so that it expands enough to be slipped onto the wheel when it is hot. As it cools, it contracts and grips the wheel tightly.

Concluding Activity: You can conclude this lesson by emphasizing the point that the expansion of materials is often a nuisance. If a solid or liquid is prevented from expanding, very large forces are exerted. The effects of expansion must be remembered when designs are made. Pose the questions below to confirm student's conceptual understandings.

1. Consider electricity cables that have been put up between their poles on a day when the air is quite hot. Why do you think the cables have been left slack?
2. Explain why an inflexible screw lid on a jar can often be unscrewed after being warmed in hot water.
3. A metal disc with a hole in it is heated until the iron expands some percent. The diameter of the hole will



   A. Not change
   B. Increase.
   C. Decreases.

Nut is very tight on a screw. Which of the following is most likely to free it?

4. Cooling it.

   A. Heating it.
   B. Either
   C. Neither

(%

Describe the linear expansion of materials.
Determine the change in length during expansion.

Starter Activity: Start the lesson providing students with a review questions to enable them remind the key ideas on expansion of solids. Elicit their responses and gear it towards applying the previous knowledge to today's lesson. Then proceed the lesson pointing out the fact that most objects expand with increased temperature; how much they expand varies by material. In this lesson, we discuss how much they expand in one dimension, along a line. Their expansion is measured as a fraction of their initial length.

Main Activity:

When heated, the rod expands. Here, we concentrate on its increase in length. We call this linear expansion, the change in length measured along one dimension.

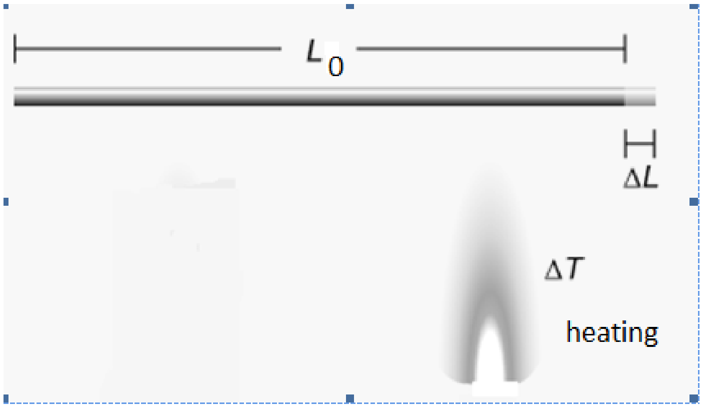


Figure 3.16: Linear expansion of a rod

Consider two rods made of the same material but of different lengths. When the rods expand, the length of the expansion is proportional to the initial length L_0 of the rod. These rods are made from the same material, but one is twice as long as the other. Their temperature increases by the same amount, but the longer rod increases in length twice as much.

However, the two rods expand the same **percentage** of their original length, L_0 and the ratio of their lengths remains the same.

Imagine also the bimetallic strip made up of two different materials. Their temperatures increase with heat by the same amount, but they expand by different amounts, making the strip curl. A constant called the coefficient of linear expansion specifies how much a given material expands with a change in temperature. The Greek letter (alpha) represents the coefficient of linear expansion of the material.

The amount that an object's length changes when it is heated is the product of its initial length, the coefficient of linear expansion for the material of the object and the change in temperature. It is important to remember that this equation calculates the **change** in length, not the new length.

$$L = L_0 \quad T$$

L_0 = ***original length***
= coefficient of linear expansion
T ***= change in temperature***

Coefficients of linear expansion for materials are based on Celsius or Kelvin temperatures. The change in either scale is the same, since their units are equal. As far as the length goes, any unit of length will work since the equation expresses a proportional change in length.

Materials	Coefficient of linear expansion at 25 ^{0}C
Steel	$1.17X\ 10^{-5}$
Iron	$1.18X\ 10^{-5}$
Copper	$1.65X\ 10^{-5}$
Silver	$1.89X10^{-5}$
Aluminum	$2.31X\ 10^{-5}$
Magnesium	$2.48X\ 10^{-5}$
Lead	$2.89X\ 10^{-5}$

Worked example:

The copper rod is heated from 20°C to 100°C. What will its increase in length be?

You are asked to measure the change in length when the temperature of the rod increases. We start with the equation for linear expansion. The change in temperature is 80 C°.

$$L = L_0 \quad T$$

$T = 100°\text{C} - 20°\text{C} = 80\ \text{C}°$
$L = (0.5\ \text{m})(1.65\times10^{-5}\ 1/\text{C}°)(80\ \text{C}°)$
$L = 6.6\times10^{-4}\ \text{m}$

In the second step we substitute the values for length, the coefficient of linear expansion for copper, and the change in temperature. The calculation shows that the change in length is less than a millimeter.

Concluding Activity: : Confirm students understanding by providing the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the expansion equation, let them reread their textbook, prompt them to do more practice on problem solving ; ask their teacher for assistance and guidance on topics of difficulties , or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

1) A hot water running through a pipe causes the temperature of a lead pipe, which is now considered hazardous; to increase from 20 ^{0}C to 40^0 C. If the pipe is initially 4m in length, calculate the change in the length of the pipe.
2) A metal rod is 2.67m long at 23^0 C. When its temperature is increased to 168 ^{0}C, the length of the rod is 2.68m.What is the metal's coefficient of expansion?

* / %

Describe the volume expansion of materials.
Compute the change in volume using the equation.

Starter Activity: It is appropriate to begin this lesson summing up what students have learnt about linear expansion. You may pose some question just to let them recall the basic concepts of the previous lesson.

Main Activity:

The volume of most materials, including liquids, increases as their temperature increases. For example, the volume of the water in an automobile radiator increases as the engine gets hotter. Most radiators have an overflow tank to capture excess coolant when it expands to a volume greater than the radiator's capacity.

Every substance has a coefficient of volume expansion that determines the relative expansion in volume for that substance for a given temperature increase. The Greek letter γ (gamma) represents that coefficient. The radiator metal and the coolant have very different coefficients, which is why the fluid overflows the radiator.

Just as with linear thermal expansion, the expansion in volume is proportional to the initial dimensions, in this case the volume of the material.

You see the equation for volume expansion. The change in volume is equal to the initial volume times the coefficient of volume expansion times the **change** in temperature, measured in Kelvin or degrees Celsius.

$$V = V0\,\gamma \quad T$$

Where,

V_0 = original volume
γ = coefficient of volume expansion
T = change in temperature
Coefficient calibrated for K or °C

Notice that for a solid, the coefficient of volume expansion is about three times the coefficient of linear expansion, because the solid expands linearly in three dimensions.

$$\gamma \quad \mathbf{3}$$

Where

γ = coefficient of volume expansion
= coefficient of linear expansion

Worked Example:

The temperature of 2 L of water increases from 10.0° C to 30° C. How much does its volume increase?

You need to use the coefficient of volume expansion of water, which is shown

$$\boldsymbol{V = V_0 \gamma \quad T}$$

$T = 30°\text{C} - 10°\text{C} = 20\ \text{C}°$
$V = (2\ \text{L})\ (2.07\times10^{-4}\ 1/\text{C}°)(20\ \text{C}°)$
$V = 0.0083\ \text{L}$

In the first step, we write the equation for volume expansion. We calculate the change in temperature, and then enter the values for initial volume, coefficient of volume expansion, and the change in temperature. The volume increases by 0.0083 liters, which equals about half a tablespoon.

Concluding Activity:

Check students' understanding by providing the class with numerical problems, so that they can solve it in group discussion; and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the expansion equation, prompt to do more practice on solving problems, let them reread their textbook, ask their teacher for help, or discuss the material with a fellow student.

1. A ball made of lead has a volume of 100 cm^3 at 20.5 ^{0}C.What is the change in volume; in cm^3 when its temperature changes 24.5 ^{0}C?

2. A solid copper ball of radius 1.5 cm increase in temperature from 35^0 C to 106 ^{0}C. What is the change in its volume in Cm^3?
3. The density of mercury at 0 ^{0}C is 13.6Kg/m^3.What is its density at 100 ^{0}C, in kg/m^3?

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Describe what is meant by specific heat

Apply the law of heat exchange in the solution of problems involving

Explain some consequences of the high specific heat of water.

Starter Activity: Initiate the classes by asking some review questions on the relationship between heat and work which lead to discussion of measuring heat. Direct their answers to the point that, to be scientific in the study of heat, we must be able to measure the quantity of heat given off or absorbed by a given mass of a substance when it is cooled or heated through a given change in temperature and that some standard must be used for this measurement. Or you may begin the lesson providing common experiences in daily life as:

If you touch a hot stove, energy enters your hand because the stove is warmer than your hand. When you touch a piece of ice, on the other hand, energy passes out of your hand and into the colder ice. The direction of spontaneous energy transfer is always from a warmer thing to a neighboring cooler thing. The energy transferred from one thing to another because of a temperature difference between the things is called **heat**.

Main Activity:

How much heat flows depends not only on the temperature difference between substances but on the amount of material as well. For example, a barrelful of hot water will transfer more heat to a cooler substance than a cupful of water at the same temperature. This is because; there is more internal energy in the larger amount of water.

Different substances have different capacities for storing internal energy. In other words, different materials absorb or release energy in different ways. For example, if you wait a short while before eating a piece of hot roast beef and pieces of mashed potatoes, both initially at the same temperature, you'll find that the meat has cooled off more than the potatoes. Similarly, If we heat a beaker with water on a stove, we might find that it requires 15 minutes to raise it from room temperature to its boiling temperature. But if we put an equal mass of iron on the same flame, we would find that it would rise through the same temperature range in only about 2 minutes. This implies different materials require different amounts of heat to raise the temperature of a given mass of the material by a specified number of degrees.

Specific heat is a property of a material. It is a constant that tells how much the temperature of a mass of the material changes when a particular amount of heat is transferred.

Each matter has its own characteristics to absorb heat. It is the distinguishing property of matters.

A material’s specific heat is determined by how much heat is required to increase the temperature of one kilogram of the material by one Kelvin. A material with a greater specific heat requires more heat per kilogram to increase its temperature a given amount than one with a lesser specific heat. In spite of its name, specific heat is not an amount of heat, but a constant relating heat, mass, and temperature change.

$$Q = cm\ \ T$$

Where
Q = heat
c = specific heat (J/kg·K)
m = mass
T = temperature change in C° or K

This is an equation that uses specific heat. The heat transferred to or from an object equals the product of its material’s specific heat, the mass of the object and the change in temperature. Specific heat is measured in joules per kilogram Kelvin.

We can think of specific heat as thermal inertia. Recall that inertia is a term used in mechanics to signify the resistance of an object to a change in its state of motion. Specific heat is like a thermal inertia, since it signifies the resistance of a substance to a change in temperature.

Substances	Specific heat(J/Kg.K)
Lead	129
Silver	235
Copper	385
Iron	449
Carbon	709
Aluminum	897

Explain the point that the specific heat of water is considerably larger than that of the other substances. Its high specific heat means that for a given quantity of heat energy absorbed by water, its rise in temperature will be comparatively small. Thus water, because of its large specific heat, is used in many types of heat exchanger. Large bodies of water such as lakes, seas or oceans tend to moderate variations of temperature nearby since they can absorb or release large amounts of thermal energy while undergoing only very small changes in temperature. The specific heat of water is five times that of the earth or sand, and the water takes longer to heat up than the land. Hence we can say that the high specific heat of water affects the climate near the sea and large lakes.

Other familiar example is the use of water in the cooling system of a car. It removes much of the heat energy that would otherwise cause damage to the engine.

Because so much of our body is composed of water our muscles do not overheat. If we engage in exercise or strenuous physical work, the body temperature does not rise excessively because of the body’s high specific heat.

Concluding Activity: Confirm students understanding by providing the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the quiz, let them re-read their textbook, ask their teacher for help, or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

1. Which has a higher specific heat capacity, water or sand?
2. Suppose you apply a flame to 1 L of water for a certain time and its temperature rises by 2°C. If you apply the same flame for the same time to 2 L of water, by how much will its temperature rise?

3. An iron thumbtack and a big iron bolt are removed from a hot oven. They are red hot and have the same temperature. When dropped into identical containers of water of equal temperature, which one raises the water temperature more?
4. Imagine you have 1 kg each of iron, glass, and water and that all three samples are at 10 °C.Rank the samples from lowest to highest temperature after 100J of energy is added to each sample.

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Define phase change, heat of fusion and heat of vaporization
Identify phase change occurs at constant temperature
Describe the effect of pressure on boiling point of water

Starter Activity: Initiate this lesson by pointing out that the matter in our environment exists in three common phases (or states). Ice, for example, is the solid phase of H_2O. Add energy, and you add motion to the rigid molecular structure, which breaks down to form H_2O in the liquid phase, water. Add more energy, and the liquid changes to the gaseous phase.

Then in this lesson we see why a kettle of water can be boiled for hours without changing its temperature and that the sun in summer can shine for hours on a large ice without changing either the temperature of the ice or the temperature of the water that drips from it.

Main Activity: In everyday language, the three phases of matter are called ice, water, and steam. That is, the term water implies the liquid phase, ice the solid phase and steam the gas phase.

When ice which is at a temperature below 0 ^{0}C is allowed to warm up slowly, its temperature rises to 0 ^{0}C and then stays at that value while the ice melts. When all the ice has melted, the temperature will rise above 0 ^{0}C.The temperature at which the solid-to -liquid change occurs is called the ***melting point.*** That is, it takes energy to liberate the water molecules from the crystal structure of the ice and allow them to move freely at the same temperature through the liquid. This occurs as the ice melts, changing phase from a solid to a liquid. Phase changes between solid, liquid and gas do not change an object's temperature, but they do require heat transfer. ***Phase change*** *is a t*ransformation between solid and liquid, liquid and gas, or solid and gas. The phase of matter depends on its temperature and the pressure that is exerted on it. Changes of phase almost always require a transfer of energy.

If we cool a pure liquid, it changes to a solid at the same temperature as its melting point. This is called the **freezing point**. Impure solids and mixture melt over a range of temperatures; they do not have a definite melting point .A very good example of this behavior is wax.

When energy is supplied to water, its temperature rises and, if the rate of supply of energy large enough, the water boils. The temperature remains constant as the water boils. This temperature at which liquids changes to gas by boiling is referred to as **boiling point.**

Elaborate also that the boiling point depends on the atmospheric pressure. When water boils, bubbles of steam are formed in the liquid and rise to surface. The pressure of the vapor in the bubble has to be a little greater than the external pressure for the bubble to exist. At normal atmospheric pressure, this happens at 100^0C. Bubbles in the liquid can form only when the pressure of the vapor within the bubbles is great enough to resist the pressure of the surrounding liquid. Unless the vapor pressure is great enough, the surrounding pressure will collapse any bubbles that may form. At temperatures below the boiling point, the vapor pressure in bubbles is not great enough, so bubbles do not form until the boiling point is reached If the pressure is lower than the normal, bubbles can form at some temperature below 100^0C, so that the water boils at a lower temperature. Water boils at temperatures well below 100^0C at the top of high mountains, and cooking food becomes a problem. If the temperature of the boiling water is too low, food will not cook at all. It is important to note that it is the high temperature of the water that cooks the food, not the boiling process itself.

As water is changed into steam, the energy that we supply does not cause a rise of temperature. It supplies the energy necessary to enable molecules to escape from the liquid, and do work against forces biding them together as a liquid. This latent heat is known as the latent heat of vaporization.

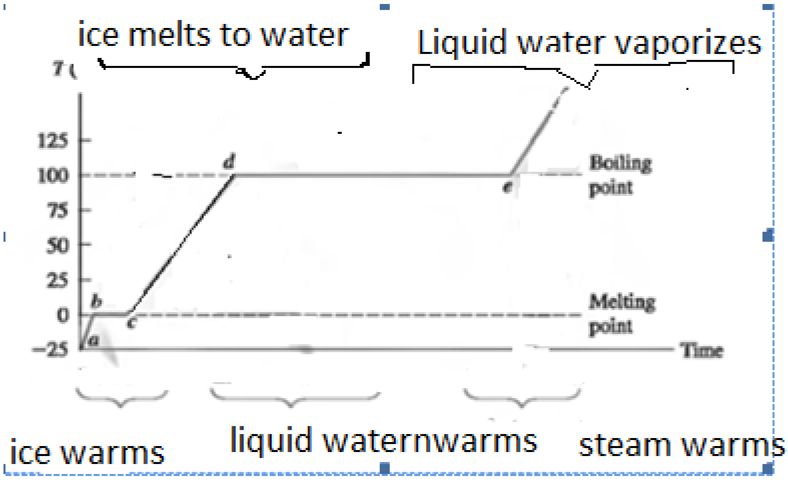

Figure 3.17: phase changes

To change a mass m of a material to a different phase at the same temperature (such as liquid to solid or liquid to vapour) requires the addition or subtraction of a quantity of heat. The amount of heat is equal to the product of m and L, the heat of fusion, vaporization, or sublimation.

$$Q= +mL$$

Where
Q=quantity of heat absorbed or released
m= mass of the body
L= latent of heat

Latent heat is energy used for loosening or breaking bonds between molecules and not for raising temperature. There are two forms, viz. latent heat of fusion, L_F, and latent heat of vaporization, L_V.

Common misconception: There is a tendency to believe that any time heat is flowing into ice, the ice is melting. **NOT SO**. When heat is flowing into ice, the ice will be melting only if the ice is already at the melting temperature. When heat is flowing into the ice that is below the melting temperature, the temperature of the ice is increasing.

Concluding Activity: After you make a short, concise , summary or concluding remarks which highlight the underlying concepts of the lesson make sure students’ conceptual understanding by providing such kind of concept test questions ;

1. Why does the temperature of an ice cube remains at 0 ^{0}C when it is absorbing heat and melting?
2. Why might you become chilled as water evaporates from your skin after a swim?
3. Does a pail of water in a cold room at -10 ^{0}C warm or cool the air around it as it freezes?
4. For each of the following processes: Does the temperature increase, decrease, or not change?

   A. You hit a nail with a hammer
   B. You compress the air in a bicycle pump by pushing down on the handle very rapidly
   C. A flame turns water into steam

Confirm that their answers agree with the following explanations:

1. The temperature remains constant because the energy added increase the potential energy of the particles weakening the ice crystals bond.
2. The molecules with highest kinetic energy evaporate (leaving the skin) so that the water molecules left behind have a lower kinetic energy, hence a lower temperature. In addition thermal energy is absorbed from the skin during the phase change.
3. It warms the air because freezing releases energy, heat of fusion.

Explain the process of boiling.
Identify that boiling is a cooling process.
Distinguish between evaporation and boiling.

Starter Activity: Start this lesson asking students' experience of boiling water. .You may wish to ask them questions such as: Have you ever observed that when water is coming to boil it starts to murmur? Why? Elicit their reply and continue with your detailed explanation.

Main Activity: Let us heat a glass vessel with cold water on a burner and watch the process. The bottom and the walls of the glass will soon be covered with small bubbles. These bubbles contain air and water vapour. Observing a bubble at a constant temperature implies that it retains its volume. This means that the internal pressure in the bubble is balanced by the external pressure on its surface. Since the bubble contains air whose amount should be considered, this equilibrium is stable.

When some bubbles rise to the surface, their volume is reduced .Why does this occur? Notice that these bubbles contain water vapour and a small amount of air. When a bubble arrives colder upper layer of water, a considerable amount of water vapour condenses, and the bubble contracts. This alternating increase and decrease in the volume of bubbles is accompanied by a noise: water coming to the boil starts to 'murmur'. Ultimately, the entire mass of water is heated. At this stage, the volume of rising bubble does not decrease any longer, and the bubbles burst at the surface ejecting steam to the surrounding space. The murmuring is now changes to a loud bubbling sound, and the water is said to boil.

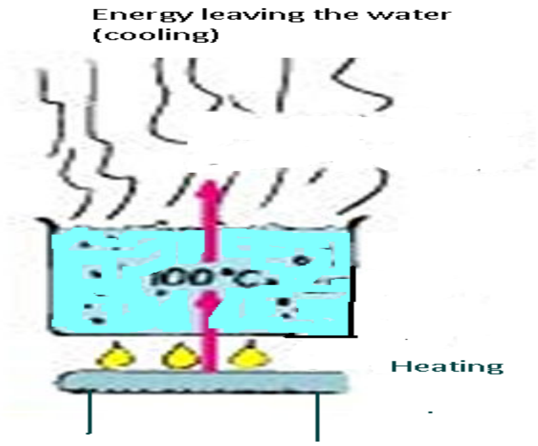

Figure3.18: boiling is a cooling process

Under the right conditions, evaporation can take place beneath the surface of a liquid, forming bubbles of vapor that are buoyed to the surface where they escape. This change of phase throughout a liquid rather than only at the surface is called **boiling**.

Evaporation is a cooling process. So is boiling. At first reflection, this may seem surprising perhaps because we usually associate boiling with heating. But heating water is one thing; boiling is another. When 100°C water at atmospheric pressure is boiling, its temperature remains constant. That means it cools as fast as it warms. If cooling didn't take place, continued input of energy to a pot of boiling water would result in a continued increase in temperature. The reason a pressure cooker reaches higher temperatures is because it prevents normal boiling, which in effect prevents cooling.

Concluding activity: After you recapitulate the underlying concepts of the lesson, provide these conceptual questions to confirm whether they meet the lesson objectives or not. Use the feedback for the better improvement of the lesson.

1) Why is a steam burn more damaging than a burn from boiling water of the same temperature?
2) Distinguish between evaporation and boiling.
3) Why is the boiling point of water lower at high altitude?
4) Is it the boiling of water, or higher temperature of water, that cooks food faster in a pressure cooker?

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Describe the mechanisms of heat transfer
Differentiate between thermal energy, temperature ,and heat

Starter Activity: Commence this lesson by mentioning the point that when the temperature drops outside, you put on your winter clothes. By wearing heavier, thicker clothing you are preventing your body from losing too much heat. Keeping thins cool by keeping heat out is often just as important as keeping heat in. You can cite example as: when you are out in the sun, you may wear a hat to keep your head cool. Or you prefer to use a heavy mug to keep your hot drink warm longer than a thin –walled china cup does. In this lesson we see the mechanisms of heat transfer and how to control of heat transfer.

Main Activity: Proceed with your exposition of heat transfer as –Imagine grabbing the steel handle bars of your bicycle after it has been sitting out in the sun on a hot summer day. Now imagine picking up a piece of wood that is about the same size as the handle bars and that has also been sitting out in the sun. Which do you think would feel hotter? Ask students to suggest reasons. The handle bars are hot because of the metals ability to transfer the heat to all parts of it.

Or you may elaborate it as-for example, if you hold one end of a long metal bar and insert the other end into a flame; you will find that the temperature of the metal in your hand soon increases. The energy reaches your hand by means of conduction. You can understand the process of conduction by examining what is happening to the microscopic particles in the metal. Initially, before the rod is inserted into the flame, the microscopic particles are vibrating about their equilibrium position. As the flame heats the rod, the particles near the flame begin to vibrate with greater and greater amplitudes. These particles in turn collide with their neighbours and transfer some of their energy in the collisions. Slowly, the amplitudes of vibrations of metal atoms and electrons farther and farther from the flame increase until, eventually, those in the metal near your hand are affected. This vibration is detected by an increase in the temperature of the metal and of your potentially burned hand. The transfer of heat by the collision of particles in the solid is called **conduction.** Conduction is the direct flow of thermal energy without a net motion of the materials involved.

How well a solid object conducts heat depends on the bonding within its atomic or molecular structure. Solids made of atoms that have one or more outer electrons conduct heat (and electricity) well. Metals have loosely bound outer electrons, which are free to carry energy by collisions throughout the metal. They are excellent conductors of heat and electricity for this reason. Silver is the best, copper is next, and, among the common metals, aluminum and then iron are next in order. Wool, wood, straw, paper, cork, and Styrofoam, on the other hand, are poor conductors of heat. The outer electrons in the atoms of these materials are tightly attached. Poor conductors are called *insulators*.

A cooking pan is a good example of an application of conduction. The pan itself is usually made of metal (a good conductor) so that the heat is rapidly applied to all contents to cook them evenly. However, we do not want the handle to be too hot. The handle should be made of a poor conductor, such as wood or plastic.

Let students in groups conduct activity on rate of heat conduction. Four students, each holding a rod of a different substance in a flame, will demonstrate the difference in conductivity of heat by their object from the flame. Use about the same sized rods of iron, aluminum, glass, and copper

Concluding Activity: Check students' understanding of heat transfer by providing concept tests which will lead to a better understanding of the concept.

A room has one wall made of concrete, one wall made of copper, and one wall made of steel. All of the walls are the same size and at the same temperature of 20°C. Which wall feels coldest to the touch? (i) the concrete wall; (ii) the copper wall; (ill) the steel wall; (iv) all three walls feel equally cold to the touch.

Check that their line of reasoning agrees with the following: Answer: (ii) when you touch one of the walls, heat flows from your hand to the lower-temperature wall. The more rapidly heat flows from your hand, the colder you will feel. Recall that the rate of heat flow is proportional to the thermal conductivity. Note also that, copper has a much higher thermal conductivity (385.0W/m'K) than steel (50.2W/m'K) or concrete (0.8 W/m. K), and so the copper wall feels the coldest to the touch.

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Describe what convection is meant by
State activities to illustrate convection as mechanisms of heat transfer.

Starter Activity: Commence this lesson by reviewing the previous lesson as: You have learned how heat transfer takes place in solids by conduction .But not all matter is solid. Liquid and gases are phases of matter in which the particles flow from place to place. They are called fluids, and they are poor heat conductors. Pose this question to the class - If liquids and gases do not conduct heat as well as solids do, how does heat transfer take place in fluids? Let students write their predictions on their notebook.

Main Activity: You may wish to proceed with your exposition as follows –Imagine about soup. How does the soup in a pot on the stove become hot enough to boil? To warm the soup more quickly, you can stir it with a spoon or a stick. As you stir a pot of soup on the stove with a spoon, you can feel the spoon become hot; heat being transferred by conduction along the spoon. As soup is heating, some parts of it, near the heat source, will be hotter than other parts. By stirring, you are mixing higher -temperature soup with lower -temperature soup. This also occurs naturally; because particles in liquids and gases can flow and move past each other. This movement is called convection. **Convection** is the transfer of heat by mass motion of a fluid from one region of space to another. It is heat transfer through a gas or liquid caused by movement of the fluid. Convection takes place only in fluids. It cannot take place in solids as the atoms/molecules are fixed in their positions relative to each other

You can also conduct the following hands-on activities to investigate how heat transfer by convection occurs in liquids and gases.

Convection in liquids:

1) Place a large glass beaker full of water on a tripod so that one side overlaps the edge as shown in the figure. Do not use a piece of gauze .Put food colouring or a crystal of potassium permanganate into the beaker at that edge.

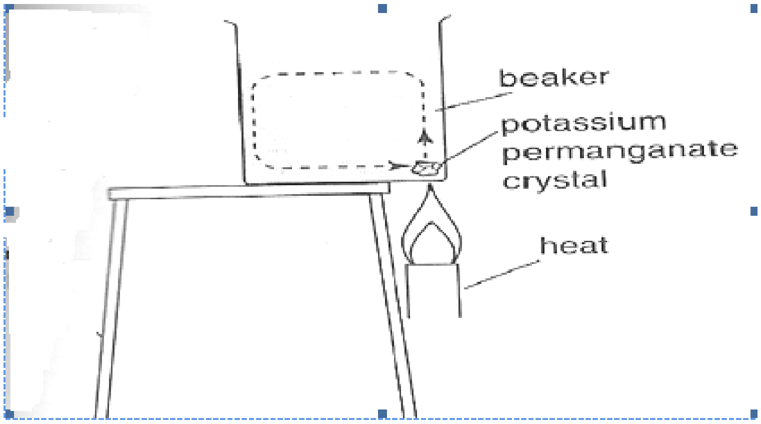


Figure 3.19: convection in liquids

2) Heat gently just under the potassium permanganate crystal. The potassium permanganate solution shows convection current in the water.

Convection in gases:

1) Using a chimney box similar to the one shown in the figure, a candle in the holder under one of the chimneys.

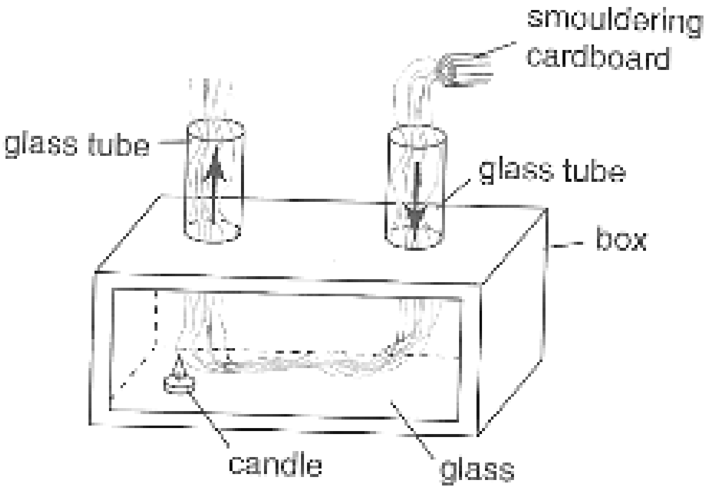


Figure 3.20: convection box

2) Hold a piece of smouldering cardboard (smoke paper) over the other tube. The smoke is drawn into the tube by the convection current, and it emerges from the tube over the candle.

3) If you try to do a similar experiment using one tube, with the other blocked by a cork, no convection current occurs. The candle may burn less strongly and go out for lack of ventilation.

Concluding Activity: You can recap this lesson by stressing on convection currents and noting the point that convection in liquids and in gases is very similar.

Discuss radiation as means of energy transfer
Cite examples of bodies that emit electromagnetic radiation

Starter Activity: You can begin this lesson by reviewing the previous lesson as-you have learned that heat transfer by conduction and convection depends on the motion of particles .In conduction the particles, move back and forth, colliding with each other. These collisions transfer energy from one particle to the next, but the particles themselves do not move very far. In convection, the particles move through a fluid, transferring energy as they collide with other particles. You know that the sun is the main source of Earth's energy. The space between the Earth and the sun contains almost no particles, so heat transfer by either of these two methods, conduction and convection, is impossible. Then pose the question 'how is the sun's energy transferred to the Earth?'

Everyone has felt the warmth of the sun's radiation and the intense heat from a glowing coal in a fireplace. Most of the heat from these very hot bodies reaches you not by conduction or convection in the intervening air but by radiation.

Main Activity: The third means of energy transfer that we shall discuss is **radiation**. All objects radiate energy continuously in the form of electrometric waves (see the next chapter) produced by the thermal vibrations of the molecules. Mention that if you place your hand near a red-hot heating element and feel your hand warm up, you are experiencing thermal radiation: the transfer of energy by electromagnetic waves. You correctly think of objects like the heating element as radiating heat; in fact, every object with a temperature above absolute zero radiates energy. You are familiar with electromagnetic radiation in the form of orange glow from an electric stove burner, or the coil of a toaster. Radiation does not require particles to transfer energy. Energy transferred by radiation is referred to as radiant heat.

You can allow students in group try out this simple activity which enables them to discover some of the properties of radiant heat. Let them hold their hands briefly near the incandescent light source and record what they feel. Then let them hold their hands near the fluorescent light source and record their feeling. Finally pose this question to lead them to group discussion: which light source produce more radiant heat?

You can also give the class a project work to discover the **emitting radiation** as:

1. You need a copper plate polished on one side and dull black on the other, and a strong source of heats (several Bunsen burners).Heat the plate strongly until it is very hot.
2. Remove the burners, and turn the plate, holding it by the clamp, until its sides are vertical.
3. Carefully use the back of your hand or your cheek to detect the radiation sent out by each side of the plate.

Precede the discussion to draw the conclusion that a dull black surface is gives out or emits much more radiation than a polished surface at the same temperature. The best emitter is a dull black surface; silvery polished surface is the worst.

Let students also try the following hands-on activity to investigate **absorbing radiation-**

1. You need two aluminium plates about 10 cm square. One should be polished on its front surface, and the other painted dull black, and an electric fire.
2. At the centre of the back of each plate, melt a little wax and stick a small bearing in it before the wax hardens.
3. Place each plate in turn in front of an electric fire with the polished or black surface facing the fire.
4. Notice how long it takes for each ball bearing to fall off its plate.

Provide students guidance and support to arrive at a concluding remark that the dull black surface takes in or absorb energy much more quickly than the silvery surface. All surfaces absorb energy but the best absorber of radiation is a dull black surface; it absorbs all of the radiation falling on it if it is a truly black .The worst is a silvery polished or white surface, which is a good reflector of radiation. Stress the point that good emitters are good absorbers, and poor emitters' are poor absorbers.

Concluding Activity: After recapping the core points of the lesson confirm students' conceptual understanding posing the following conceptual questions.

1) What is the difference between the transfer of energy by conduction and convection?

2) How does the transfer of energy by conduction and convection differ from radiation?
3) What does it mean for a substance to be a good conductor of heat?

Check that their answer agree with the following short explanations or not.

1. In conduction energy is transferred from particle to particles; while in convection energy is transferred by currents in fluids.
2. Radiation transfers energy by electromagnetic waves and does not require matter.
3. It means that heat travels more rapidly through a good conductor.

Note for the teacher: Heat transfer by radiation is important in some practical applications, for example in a thermos flask the flask is a double-walled glass vessel which has been evacuated and sealed. The air is pumped out of the spaces between the walls; this eliminates nearly all heat transfer by conduction and convection. The silver coating on the walls reflects most of the radiation from the contents back into the container, and the wall itself is a very poor emitter. Thus a vacuum bottle can keep coffee or tea hot for several hours. The thermos flask is often used to keep liquids very cold; store very cold liquefied gases.

Describe what a wave is
State the characteristics of waves
Perform activities to demonstrate the properties of waves

Starter Activity: Introduce this chapter using water waves as a model to help conceptualize wave properties. A ripple tank would be most helpful in demonstrating the properties and behavior of water waves. One of the most difficult concepts for students to grasp involves the motion of the wave. Many students will think the water travels along the wave front. Raise questions like –have you ever watched waves in a pond/lake? Some students may recall their experience at the beach.

Energy can be sent from one place to another by means of waves. In every case, the waves travel from a source to a detector or a receiver. Waves are of many types. Sound, light and radio are common examples of waves. Sound waves can be received by the ears or by a microphone, light waves by the eyes a camera, and radio waves by an aerial attached to a radio receiver. You shall also consider waves which you can see: first waves on strings, and then waves or ripples on water.

Main Activity: A wave is a disturbance that repeats itself all points along the path that it follows. The ***medium*** of a wave is the substance through or along which the wave moves. For instance, the medium of water waves is the water; the medium of sound waves is the air. As a wave passes through a medium, the atoms that make up the medium (the particles of the medium) are displaced from their equilibrium position. This is a ***disturbance*** of the medium. Therefore, we can define wave as an ***organized*** motion of the particles of the medium, in contrast with the ***random*** molecular motion of thermal energy. We can distinguish two types of waves.

1. Mechanical Waves

Mechanical waves can travel only within a material medium, such as air or water. The ones you are very familiar with are water waves and sound waves. It also includes waves on a stretched string, seismic waves (i.e. shock waves produced either artificially from explosions used by geologists in explorations or naturally occurring due to earthquakes).

2. Electromagnetic Waves

These include visible light, radio waves, microwaves, infrared waves, light, ultraviolet rays, X-rays, and gamma rays which are a self-sustaining oscillations of the electromagnetic field. Electromagnetic waves require no material medium and can travel through a vacuum.

While ocean waves were always known to man, as was visible radiation, many parts of the electromagnetic spectrum were not discovered until the latter years of the 19th century and the beginning of the 20th century.

It is worth mentioning the point that a medium through or along which a wave passes must be elastic. Because a restoring force of some sort brings the medium back to equilibrium after it has been displaced or disturbed. As a wave passes through a medium, the atoms that make up the medium (or particles of the medium) are displaced from equilibrium. We call this a disturbance of the medium. Disturbance is the key word in wave motion. The water ripples are disturbances of the water surfaces as the pulse traveling down the stretched string is a disturbance. Note that the disturbance of a wave is an organized motion of particles in the medium, when compared, with the random molecular motion of thermal energy.

A wave disturbance is produced by a source. The source of the wave can be a stone thrown into water, a hand plucking a stretched string, or an oscillating loudspeaker cone pushing on the air. Once created, the disturbance travels outward through the medium at the wave speed v.

Lead the class to grasp the key point that as the disturbance propagates through the medium, a wave does transfer energy, but the medium as whole doe not move. Stress the fact that wave transfer energy, but it does not transfer any material outward from the source.

You can do the following activity to make a wave pulse:

Concluding Activity: After recapping the core points of the lesson, confirm students' conceptual understanding posing the following conceptual questions:

1. How is the motion of a wave pulse different from the motion of a moving object such as a car? (Hint: What is that moves in the case of a wave?)
2. What happens to the wave pulse when it hits the far end of the string? Does the pulse stay on the same side of the string or flip to the other side? Use the word 'reflect' in your answer.

Identify the two distinct types of wave motion
Distinguish between transverse and longitudinal waves
Do activities to demonstrate these wave motions

Starter Activity: Begin the lesson reviewing the previous lesson and ask students a leading question that enable them to recall that, the particles of a string vibrate up and down but do not move in the direction of a pulse traveling along the string.

Main Activity: We can classify two distinct types of wave motion- transverse and longitudinal by the relationship between their direction of travel, and the direction of the motion of the particles in the medium.

1. A **transverse wave pulse** is sent along the spring by moving your hand to the right or left at right angles to the spring and then back to the original position. The pulse travels along the spring and is reflected at the fixed end. To produce waves, the source has to vibrate .You can notice that the waves are close together if it vibrates swiftly; if it vibrates slowly, the waves are further apart.

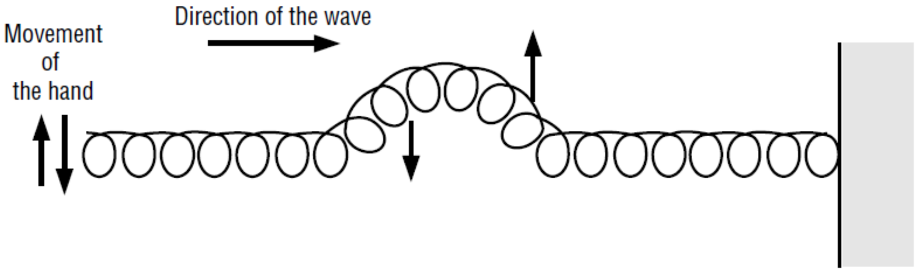


Figure 4.1: Transverse pulse on the slinky

Although the wave moves to the right, the particles that make up the medium move up and down. An individual particle of the Slinky and its movement is shown with the vertically directed arrows. The direction of the wave is **perpendicular** to the motion of the particles of the medium. This type of wave is called a ***transverse wave***

2. Now visualize that instead of shaking the Slinky up and down, you pulls the Slinky to the left and then pushes it to the right, as shown in the fig</ure below. This causes the spring to be stretched and then compressed. In this activity, the movement of the spring is in the direction in which the pulse is traveling. A **longitudinal pulse** is sent along the spring by a quick push forward followed by a pull back of the hand in line with the Slinky. Again, the pulse is seen to be reflected at the fixed end. The pulse travels with the same speed whether it is a short pulse or a long pulse.

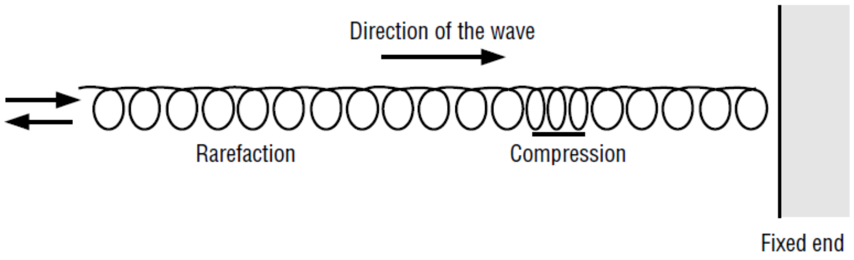


Figure 4.2: Longitudinal pulse on a slinky

3. To produce a transverse wave train the hand is moved at a constant rate, left then right, at right angles to the Slinky. The longer the Slinky the better as the crests and troughs can be seen travelling continuously down the spring. When the wave is reflected at the fixed end the reflected wave interferes with the incident wave, making the progress of the wave difficult to discern.

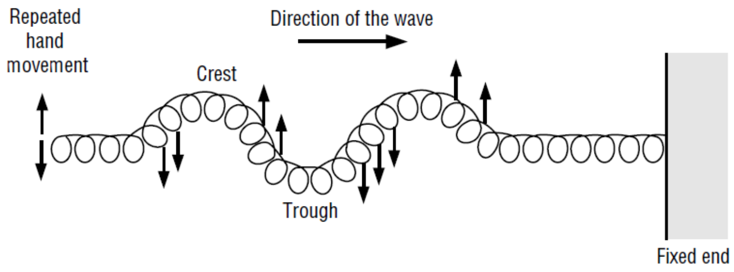


Figure 4.3: *Continuous transverse waves on the Slinky*

4. You can produce a longitudinal wavetrain by pushing your hand back and forth at a constant rate in line with the Slinky. If you move the end of the spring to and fro, it produces a bunching of the turns of the spring called **Compressions** (regions of high coil density) which moves along the spring; followed by the bunching of the spring where

the turns are further apart than usual called **rarefactions** (regions of low coil density) can be seen continuously travelling along the spring until the wave motion reaches the fixed end. This is called a longitudinal wave .Each part of the medium oscillates with the same frequency as the source (your hand, in this case).

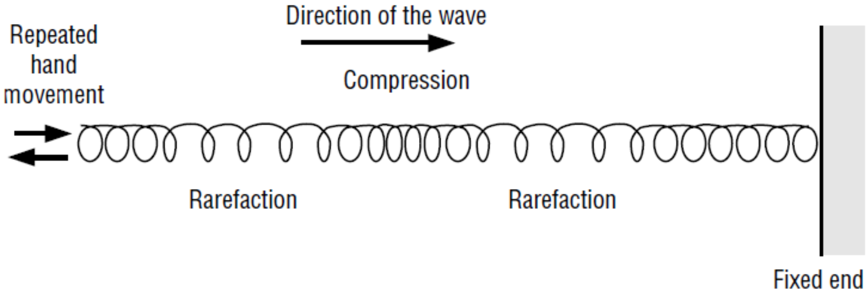


Figure 4.4: Continuous longitudinal waves on the Slinky

You will see the pulse traveling to the right. The direction in which the pulse travels is indicated by the arrow. This is how a longitudinal pulse is created in the spring. Notice that the coils vibrate back and forth in the direction in which the pulse travels. A longitudinal wave is generated by producing continuous pulses in the spring. This can be done by attaching the free end of the spring to a vibrating tuning fork.

As the end oscillates, a regular succession of compressions and rarefactions travels outwards. In this case, the wavelength of the wave is the distance from the centre of one compression to the center of the next, or from the centre of one rarefaction to the center of the next.

You can also use a line of students to demonstrate a longitudinal wave. The student should suddenly push the student in front of as soon as he or she feels the push from the student behind.

Concluding Activity: You can conclude this lesson stressing the point that in both transverse and longitudinal waves, the particles do move, but there is no net motion of the particles. A particle moves up and down, or back and forth, but it returns to its initial position. It oscillates like a mass attached to a spring.

Confirm students’ Understandings of types of wave motion, by providing concept tests that will lead to a better understanding of the concept.

1. Give an example of a wave, from your own experience, you know is a transverse wave. What observation or evidence tells you this is a transverse wave?
2. Give an example of a wave, from your own experience, you know is a longitudinal wave. What observation or evidence tells you this is a longitudinal wave?
3. Students are lined up at a flag ceremony stand. If the student at the back pushes the student in front of him, and she in turn pushes the student in front of her, and so on, will they create a transverse or longitudinal wave in the line? Explain.
4. When sports viewers do "the wave," are they making a transverse or longitudinal wave? Explain.

State the terms used to describe a periodic wave.
Describe how a wave travels through a medium
Distinguish between a pulse and a wave train

Starter Activity: The proper understanding of waves is essential to investigate communications, whether by speech, radio or television; how we see; how we hear; how musical instruments work. How is it that waves are so important and yet so uncommon in our day-to-day experiences? Then we shall see what set of properties are characterized by the wave motion

Main Activity: We say that the water and the string are disturbed as waves travel through them. The disturbances can be different sizes and can be different distances apart. In this lesson, we focus on waves in which the particles are vibrating in simple harmonic motion. This vibration will be caused by something (in this case, a hand) moving or vibrating in simple harmonic motion. The result is the type of sinusoidal wave you see to the right.

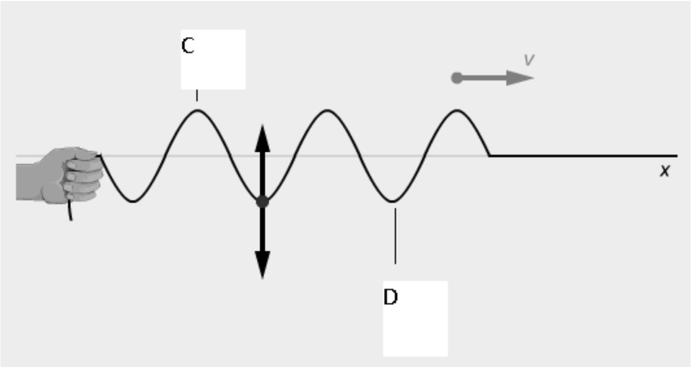


Figure 4.5: A sinusoidal wave

Here, the hand jerks the string up and then down, creating a disturbance that travels along the string. This single disturbance is called a ***wave pulse.*** When the handshakes the string in a repeating up and down motion, it creates a continuous wave that travels along the string. If the hand moves up and down in simple harmonic motion, the result is the ***sinusoidal wave*** you see here.

These waves are periodic because they are generated by a source (a hand in this case) whose motion is periodic. Thus a periodic wave is a continuous and regular disturbance which travels in a medium due to the periodic oscillatory motion of the particles of the medium.

The vertical arrows indicate the displacement of the particles of the string as the wave travels on it. Notice at points marked C the displacement has a maximum positive value. These points are called ***crests.*** On the other hand, at points marked D, the displacement has a maximum negative value. These points are called ***troughs.***

Thus, the crest of a transverse wave traveling in a medium is the point where the displacement has a maximum positive value and the trough is a point where the displacement has a maximum negative value.

The maximum displacement of a particle occurs at crests and troughs. The distance between the equilibrium or rest position of the particle and its maximum displacement is the ***amplitude*** of the wave. Another way to define amplitude is the height of a peak. The amplitude of a wave is always a positive value, so you can consider it the absolute value of the greatest displacement.

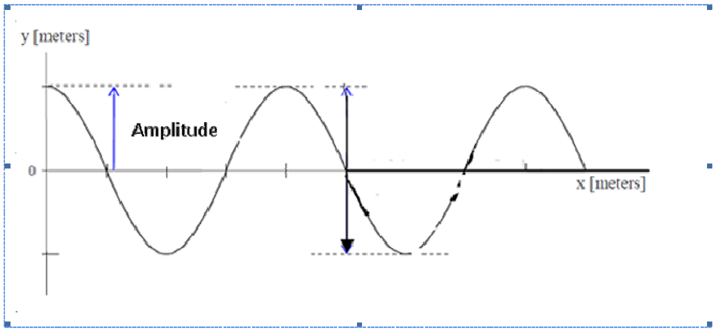


Figure 4.6:

The **wavelength** is the distance between two nearest identical /equivalent points in any wave. Usually, it is easiest to measure this distance between two adjacent crests or troughs.

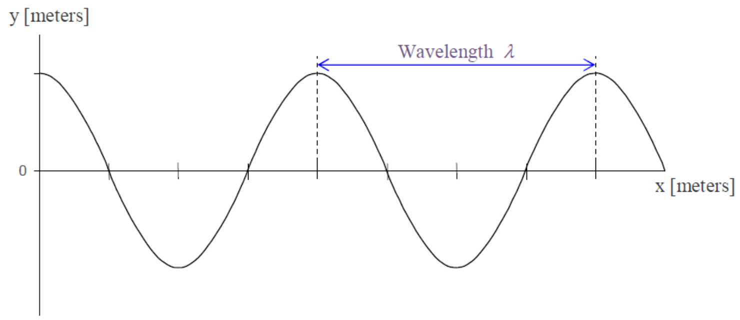


Figure 4.7:

Wavelength is the distance between two successive crests or troughs (in the case of a transverse wave) or between two successive compressions or rarefactions (in the case of a longitudinal wave).It is usually represented by λ and is measured in meters in the SI system.

It is clear that a crest is produced every time your hand moves up. Thus the time interval between two successive crests (or troughs) is equal to the time period of your hand. Hence wavelength may also be defined as the distance travelled by the wave in one time period of particle vibrations. Notice that the shape and size of a wave is described by its wavelength and amplitude.

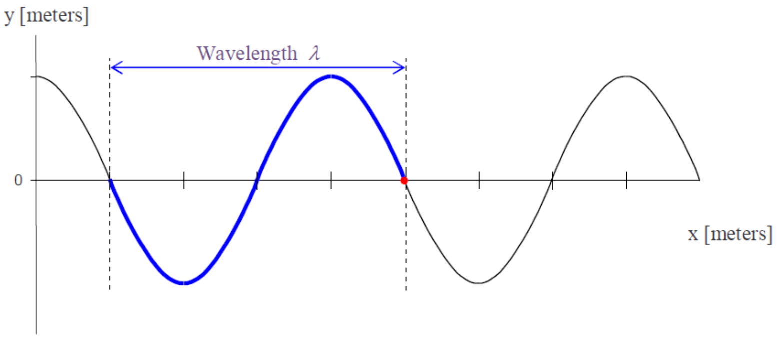


Figure 4.8

We can also say that the wavelength is the distance in which the disturbance at one instant of time repeats itself.

The period of a wave T is the time taken by any particle of the medium to complete on full oscillation or vibration. It is expressed in seconds. The period of a wave is the same as that of the vibrating source that produces the wave.

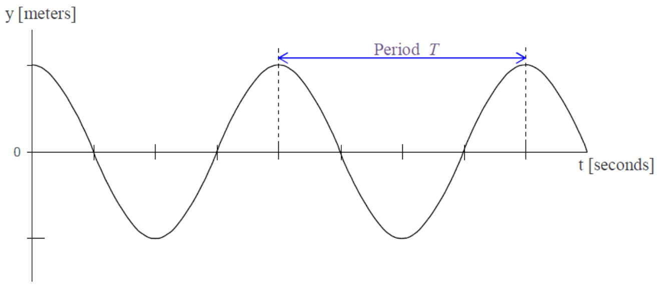


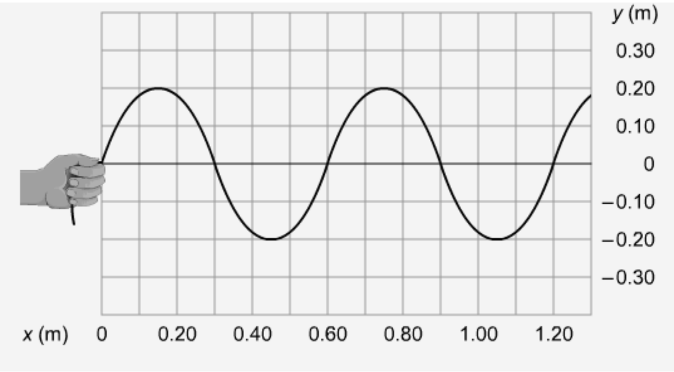
Figure 4.9:

The frequency of a wave is the number of oscillations done by any particle of the medium in one second .It is usually denoted by the letter ν and is expressed in hertz(Hz).The frequency of a wave is obviously equal to that of the vibrating source that produces the wave.

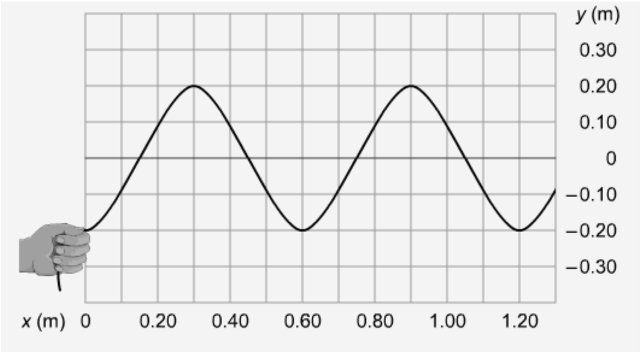
Concluding Activity: You can conclude this lesson by summing up the terms used to describe a periodic wave, which distinguish one wave from another. These are: Amplitude, period, wavelength, and frequency.

Check students' Understandings of characteristics of waves, by providing questions that will lead to a better understanding of the concept.

1. Determine the amplitude of the wave by looking at the graph below.



2. Measure the distance between two adjacent peaks.



3. In a transverse wave, a crest and the next trough are 5cm apart. What is the wavelength of the wave?
4. A wave is traveling through a particular medium. The wave source is then modified so that it now emits waves at a higher frequency. Then the wavelength, ,

   A. Increases
   B. decreases
   C. stay the same

&

Describe how the speed of wave is determined
Explain the speed of wave in different medium

Starter Activity: Initiate this lesson reminding students that the disturbance of a wave moves away from the source. This implies waves have speed**.** Ask students to name different types of waves which have different speeds. Let them compare the speed 300,000,000 m/s for light of light and 343 m/s for sound in air. Which one moves faster?

I*n this lesson we will have a look on the wave speed with which the disturbance travels in a medium. In the case of a transverse wave, it is the speed with which the crests or troughs travel. In the case of a longitudinal wave, the speed with which the compressions or rarefactions travel is the wave speed*

Main Activity: How fast a wave moves through a medium is known as its wave speed. The wave speed, the constant speed with which the wave propagates, can be expressed in terms of wavelength and frequency we have just discussed

Let us derive the relationship between wave speed, wavelength and frequency. If a wave travels a distance ***s*** in a time ***t***, its speed ***v*** is given by:

Wave speed=distance traveled/ time taken Or

$v=S/t$

By definition, the distance travelled by a wave in a time period T is its wave length λ, that is if t=T and s= λ

Then $v=\lambda/T$
But $1/T=\nu$
Where ν is the frequency?
Hence: $v=\nu\ \lambda$

i.e. *Wave speed=frequency wavelength*

Notice that this relation, called wave equation, holds true for both transverse and longitudinal waves.

The relation **$v=\nu\lambda$** can be easily understood using the analogy of the speed with which you walk, the number of steps you take in 1s and the length of each step.

Let $\nu=10$ the number of steps you take in 1s, that is, $\nu=5$ Hz is the frequency of your steps. Let $\lambda=100$cm length of each step. Then you walk with a speed $v=\nu\lambda=10X100=1000$cm/s. Similarly if wave source emits 10 waves per second, that is, its frequency $\nu=10$Hz and each wavelength is 100cm long, the wave must be traveling with a speed of $v=\nu\lambda=10X100=1000$cm/s.

Note: The wave velocity is the speed and direction with which the wave pattern is traveling. It is not the speed with which the particles making up the string are traveling in their up and down motion. The direction part is clear-cut the wave propagates along the length of the string, away from the source (something oscillating) of the wave.

Worked Example:

Suppose the wavelength of visible light is $6x10^{-7}$ m. And the light completes 5 cycles in 10^{-14} second. Calculate the light's wave speed in m/s.

First compute the frequency of the light:

$\nu=5$ cycles/10^{-14} second=$5X10^{14}$ cycles /second=$5X10^{14}$ Hz

Then apply the wave equation: $v=\nu\lambda$

$V=(6X10^{-7})\,(5X10^{14}\text{ Hz})=$
$V=3X10^{8}$ m/s

Note: Light from a point source can also be represented as waves. Of course you cannot see the crests and troughs of these waves with your eyes because the wavelength is so short (and the speed of light is so large).Since the waves move outward from the point source in all directions (in three dimensions), they are spherical waves rather than circular ones (like the water waves in two dimensions).

Concluding Activity: After showing the derivation of the wave equation, let students apply the equation in solving both qualitative and quantitative problems. Confirm students' understandings of applying wave equation, by providing concept tests that will lead to a better understanding of the concept.

1. A wave has a wave speed of 240m/s and a wavelength of 3m.Calculate:

   A. The frequency
   B. The period of the wave

2. A girl produces surface water waves on a calm lake by rocking a boat. It is found that the boat performs 12 oscillations in 20 seconds and also that a given waves crest reaches the shore 20m away in 4 seconds, Find:

   A. The frequency
   B. The speed, and
   C. The wavelength of the waves.

3. A water strider (an insect walking on water) rests on a surface of a quite lake. A stone thrown into the lake creates a series of sinusoidal ripples that pass through the location where the strider sits, so that it rises and falls. The distance between its highest and lowest locations is 0.008 m. What is the amplitude of the wave?

   A. 0.003m
   B. 0.004m
   C. 0.002m
   D. 0.008m

! "

Explain the common properties of waves**.**
Define the term reflection
State the laws of reflection

Starter Activity: Start the lesson citing common experience in daily life such as: When you look at yourself in a mirror, you are seeing a reflection of yourself. When you look at the Moon at night, you are seeing sunlight reflecting off that distant body. Ask students if they have experienced the broken appearance of a spoon placed in a glass of water, the sparkling effect of we see on the street ahead of us on a very hot day; the deceptive shallowness of a body of water.

We will use the concepts of waves to explain all these effects.

Main Activity: In this lesson we discuss some common properties of waves. These are:

- Reflection
- Refraction
- Diffraction
- Interference

Now let us consider how a traveling wave is affected when it encounters a change in the medium. For example, imagine a pulse traveling on a string that is rigidly attached to a support at one end. When the pulse reaches the support, a severe change in the medium occurs, that is the string ends. The result of this change is that the pulse undergoes **reflection**-that is the pulse moves back along the string in the opposite direction. Notice that the reflected pulse is inverted.

Figure 4.10: wave pulse approaching a fixed end

Figure 4.11: wave after reflection

Now visualize another case this time, the pulse arrives at the end of the string that is tied to a ring of little mass free to slide vertically on a smooth post without friction. In this case, the pulse is reflected, but it is not inverted. When it reaches the post, the pulse exerts a force on the free end of the string, causing the ring to accelerate upward. This movement of the ring creates a reflected pulse that is not inverted and that has the same amplitude as the incoming pulse.

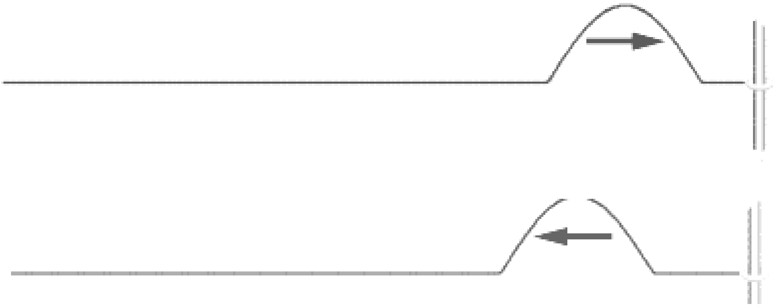


Figure 4.12:

Similarly when a surface wave in a ripple tank or lake encounters a barrier it is unrestrained (the medium is not attached to a barrier) and the reflected wave is consequently not inverted. When a surface wave in a lake (ripple tank) strikes a straight barrier, the wave is unrestrained the wave crest is reflected as a crest, and a trough is reflected as a trough.

You can demonstrate this by generating a single straight wave in the tank by gently pushing a ruler or other straight edge and observe the reflection of the wave from the opposite wall. The incident wave is unrestrained (the medium is not attached to a barrier) so the reflected wave is not inverted and a crest is reflected as a crest and a trough is reflected as a trough **.**If an incident wave is restrained, as was the case when you sent waves down the string tied securely to a wall, the incident wave is inverted and a crest is reflected as a trough while a trough is reflected as a crest. The reason can be explained as follows: when you send a transverse wave down a string that is tightly attached at one end the reflected wave is inverted. A wave traveling in a string will invert when it reaches a fixed end because the upward force exerted by the wave is accompanied by an opposite and equal reaction force, that causes the wave to invert. This downward force causes the pulse to invert upon reflection.

The reflection of water waves can be easily brought about by placing a barrier in the path of the incoming wave. You can see the reflection of a plane wave at a straight barrier. In the case of the plane wave, it is always found that the angle between the incident wave and the barrier is equal to the angle between the reflected wave and the barrier. But instead of drawing in the line of the wave fronts, it is more usual to draw in the direction in which the wave is traveling. Do not confuse the wave front with the direction in which it moves. The wave moves at right angles to the wave front. And instead of measuring the angles between the wave front and the reflecting surface, we measure angles between the direction of the wave travel and a perpendicular to the reflecting surface, called normal to the surface. The law of reflection states that the angle of incidence is equal to the angle of reflection.

Teaching note for the teacher: You may wish to relate the significance of reflection of waves with modern telecommunication systems using dish aerials to send messages over very long distances. It is worth noting that dish aerials are parabolic in shape and use **reflection** of waves while ordinary aerials send signals in all directions; so the signal gets weaker the further it travels. A dish aerial does not send energy in all directions. The signal starts out in the opposite direction to its final direction, and is *reflected* off the dish into a parallel beam. The receiver must face the dish and the dish must point towards the satellite or other source.

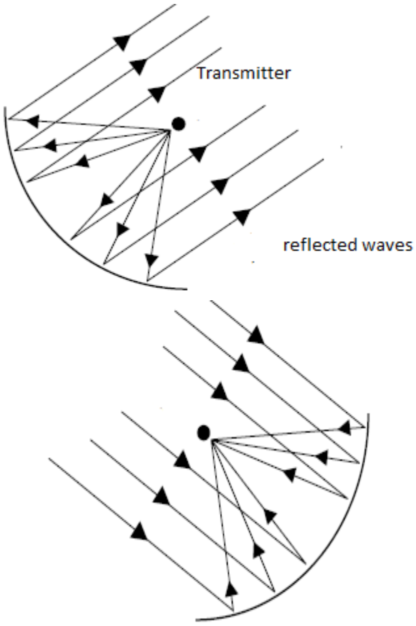


Figure 4.13: Dish areal transmitting and receiving a beam of energy

An antenna or aerial is used to radiate the energy from a transmitter into the space. The antennas used at the transmitting stations are called transmitters while the antenna used for receiving the radiated energy, near the receiver is called the receiver. An antenna is a conversion device which converts an electrical signal to electromagnetic energy when used as a transmitter and vice versa when used as a receiver.

Concluding Activity: You can provide the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the quiz, let them reread their textbook, ask their teacher for help , assistance or guidance in tackling both qualitative and quantitative problems, or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

1) When you send a transverse down a string that is firmly attached at one end the reflected pulse is inverted. Explain

% 2 "

Define what is meant by the term refraction.
State the laws of refraction

Starter Activity: Commence the lesson mentioning common experiences in students' encounter in their daily life. You may ask them if they have noticed when they stand at the edge of a pool and try to poke something underwater with a stick; they may misjudge the object's location. This is because the light from the object changes direction as it passes from the water to the air. You perceive the object to be closer to the surface than it actually is because you subconsciously assume that light travels in a straight line.

Main Activity: Refraction is the change in the direction of a wave at the interface between two materials. The interface is the boundary between two media, and the wave bends there. It is the surface between two media, such as air and water. Refraction is caused by a change in the speed of a wave as it crosses the interface.

In order to explain this refraction we can carry out an experiment in which plane waves are incident normally on a deeper /shallower water boundary. It is possible to change the speed of a wave in a ripple tank by changing the depth of the water. To obtain a significant change, the wave must move from a deep region to the shallower region. Put a glass plate in a ripple tank so that a very shallow layer of water lies on top of it. In the rest of the ripple tank the water will be much deeper. Use a single pulse or a plane wave generator to send waves along the tank and see if their speed changes when they reach the shallow water. Note the effects on the waves which pass over the plate. You can easily see the plane wave has slowed up as it passes over the shallow region.

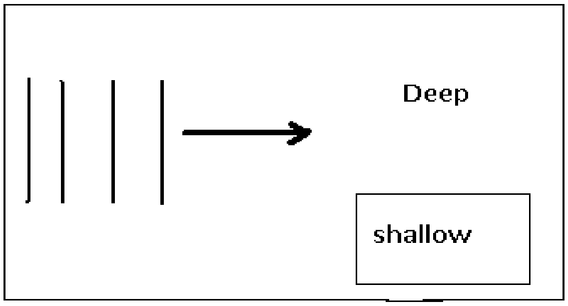


Figure 4.14: Refraction of water waves

When the waves meet the plate at an angel, you can observe a change of direction. The waves' direction of travel is bent towards the normal because of the change in speed. The end of the wavefront which meet the boundary first travels more slowly and not as far as the part of the wave front which has not yet reached the boundary.

Concluding Activity: You can conclude this lesson reinforcing the key point that refraction occurs when a wave travels obliquely (at an angel) from one medium to another. When the wave encounters a boundary at an angle, the part of the wave front striking the boundary changes speed before the other part of the wave front, causing the wave to bend toward or away from the normal and change direction.

Then confirm students understanding of the lesson with the help of the following questions**.**

1) What generally happens to the speed of water waves on the lake as they approach the shore?
2) When a wave moved from the deep water to the shallow water above the immersed plate of glass, did the frequency increase, or decrease? What happens to the wavelength and speed?

Make sure the reply given by the students and their line of reasoning should be in agreement with the following:

1) The water waves on the surface of the lake slow as they approach shallow waters near the shore.
2) Students will note that waves slow and wavelengths shortens as they move into the shallow water; however, the frequency does not change is dependent only upon the frequency of the source, not the media through which the wave travels.

 #   2

Define the term diffraction
Identify how waves diffract through narrow openings or slits.
Observe and explain the behavior of water waves when it interacts with material obstacles (diffraction)

Starter Activity: You can begin this lesson stating the point that the effects we are going to consider now are not quite common as those we have studied so far. Pose questions like- why you can hear sound through a doorway even when you are not standing directly in front of it.? Does light always travel in straight lines or can it bend around corners under certain conditions?

Main Activity: Simple objects like the hole in a button, or a wire can be used to observe diffraction. You can see water waves, after passing through an opening, spreads out to fill the space behind the opening**.** The ripple tank is a very convincing and easy way of displaying the spreading out of waves on passing through openings or around obstacles. This inevitable spreading of waves is the phenomena known as ***diffraction.***

1) Set up the ripple tank with a vibrating source to send out straight waves.
2) Place a long barrier parallel to the ripple with its vertical edge in the middle of the tank. Notice the diffraction or bending of the waves at different wave frequencies (varying motor speed)
3) Position the second barrier about 3 cm from the first one to form a slit. Investigate the effect on the resulting diffraction pattern of varying slit width for a fixed wavelength and of varying wavelength for a fixed slit width.

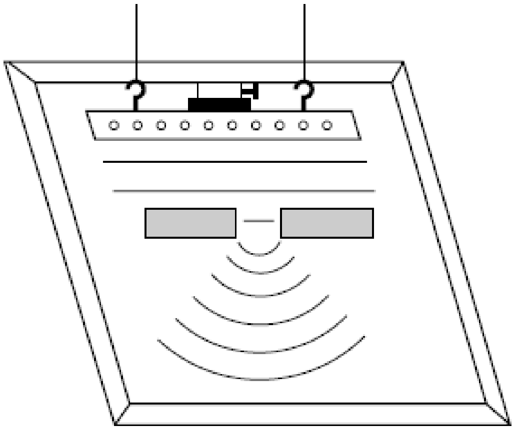


Figure 4.15: A spreading of waves occurs into the region behind the barriers (slit)

In the figure above, you can see, where plane waves approaching from left, spread out in circular arcs after passing through a hole in a barrier.

Demonstration: You can see effects which arise from the diffraction of light from a simple experiment which students can perform right at their seats. Let students held up their left hand at arm’s length, with the first two fingers close together, so that there is a narrow slit through which light can pass through them. Look through this slit at a bright source of light, such as a white cloud or a bright electric bulb. Then bring up your right hand just in front of your eye, again with two fingers close together. Ask students this question: can you see a series of vertical bands of light? Notice that the width of pattern is wider than the width of the second slit, and the light must be spreading out after passing through this slit. If the fingers close to your eye are opened out, the patterns disappear and the slit alone is seen. If the fingers are closed more, the pattern gets fainter and at the same time broadens out.

The spreading of waves is most noticeable in the case of sound waves as well. Note that the wavelength of sound waves can be in the range of a few centimeters to a few meters.But, the spreading is greater and that is why we are able to hear round corners even though we may not be in a direct line of the source.

Concluding Activity: After you recapitulate the basic underlying points of the lesson, let students practice in groups the activities which sows the diffraction waves.

Define the term interference
Distinguish between constructive and destructive interference.

Starter Activity: Start the lesson relating common experience observed to clarify the concept behind and make learning easy. Ask students if they have seen beautiful colors on the surface of the ground in wet streets where some petrol or oil has spilled? Highlight both of these effects can be explained by applying the concepts and behaviors of waves.

Main Activity:

It is evident that two balls cannot occupy the same point of space at the same time. Whereas a material object like a ball will not share its space with another ball, more than one vibration or wave can exist at the same time in the same space. If we drop two balls in water, the waves produced by each can overlap and form an **interference pattern.** Therefore, unlike particles, waves can pass directly through each other.

When two or more waves are simultaneously present at the same space at the same time, the displacements add at every point. This is the ***superposition principle***. So when the crest of one wave overlaps the crest of another, their individual effects add together to produce a wave of increased amplitude. This is called ***constructive interference***. When the crest of one wave overlaps the trough of another, their individual effects are reduced. The high part of one wave simply fills in the low part of another. This is called ***destructive interference***.

Figure 4.16: Interference of waves

To clarify the principle of superposition you can cite some common experiences such as-When waves on a lake hit the shore, a smaller reflected wave travels back to sea. When reflected waves meet incoming waves a short swell occurs in which the crest of the combined waves equals the sum of the heights of the two individual waves, causing the swimmer nearby to rise higher for a short period of time. It is clear from such observation that waves travel through the media independent of each other. This independence helps us to hear the sound of individual trumpet from the midst of the music band.

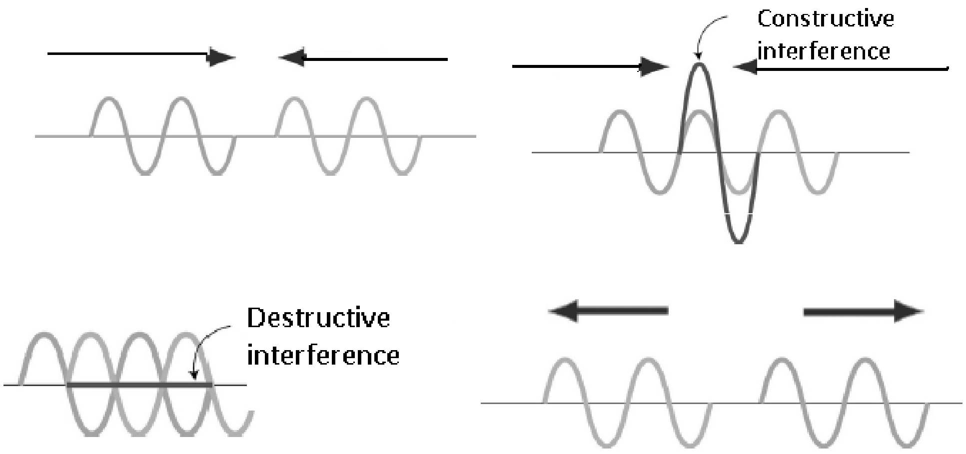


Figure 4.17: Constructive and destructive interference

Demonstration: You can demonstrate interference by putting two fingers close together, leaving a very small gap. Bring the fingers very close to one eye, closing the other eye, and an interference pattern of vertical lines can be seen in the gap between the fingers. The same effect can be achieved if two slits are cut in a piece of paper. Cut the paper with a sharp edge such as a scissor or a razor blade. The slits should be very close together and about the length of the index finger.

Concluding Activity:

Without a water wave apparatus that allows relatively high, uniform frequencies for the two point sources, it is not possible to observe interference between the waves. This activity still illustrates two things: 1) the analogy of two point sources for water waves, and how the waves from these two sources spread out as circles and 2) the fact that the two waves are not affected by each other except possibly at the points where they cross each other.

Fill the two eye droppers with water, and hold them about 3 cm apart and about 5 cm above the surface of the water in the trough. Squeeze the droppers so that drops fall from both at the same time at a fairly fast rate. Use observation sheet to sketch the wave pattern that you observed.

1. Describe the wave pattern you observed. Is there any evidence that the waves from one of the point sources are changed by the waves from the other point source when they cross each other's paths? Explain.
2. Why are you able to hear the sound of a guitar amidst the collection of sounds generated by the band?
3. Place the water trough on the overhead projector, and fill it with about 2-3 cm of water. Use an eyedropper or syringe held about 5 cm above the surface of the water to drip drops in the center of the trough at a steady rate, and watch the pattern on the wall or screen. Observe what happens with fewer drops per second and more drops per second.

    A. Describe the water wave pattern you observed, and compare it to your prediction. What is the shape of the observation with more drops/sec observation with fewer drops/sec water waves from a point source?
    B. What happens to the spacing between the water wave crests (and troughs) when the number of drops per second is increased? Decreased?

Note: The number of drops per second is called the *frequency*, and the spacing between the crests is called the *wavelength.*

Teaching note:

It takes a little practice to be able to produce drops at a constant rate, and to vary the rate. However, it is possible to get nice patterns of circles spreading out from the point where the drops hit the water. These patterns are clearly visible on a screen or wall using an overhead projector. Student observations should be in line with figure below.

Figure 4.18: Patterns of circles spreading out from a point

The waves are shaped like concentric circles with the point where the drops hit the water as the center. When the number of drops per second is increased, the spacing between the waves crests decreases. When the number per second is decreased, the spacing between the crests increases.

*   #

Explain how scientists use seismic waves to locate the epicenters of earthquakes.
Distinguish between P-waves and S-waves

Starter Activity: You can relate this lesson with prior concepts learnt about waves. Associate the parameters of wave to the surface waves on the earth. The magnitude of an earthquake is the energy released at the focus of the earthquake. It is measured with the help of an instrument called seismograph. The instrument's reading (amplitude of seismic waves) indicates the amount of strain energy released by an earthquake. The greater the wave amplitude, the greater the magnitude.

Main Activity: Earthquakes generate seismic waves that travel through the earth. The P-wave (primary wave) is a longitudinal or compression wave in which the particles vibrate parallel with the line of the wave’s propagation. The S-wave (secondary wave) is a transverse wave in which the displacement is at right angle to the direction of wave propagation. Since P-waves travel fastest, they arrive first at the seismograph, followed by S-waves. P-waves and S-waves, carry energy away from the focus of an earthquake .A seismograph is an instrument used to measure the strength of an earthquake. It is a sensitive instrument that measures and records seismic waves. When a seismic wave shakes the seismograph, the pen marks zigzag lines on a revolving paper roll. The lines are similar to this:

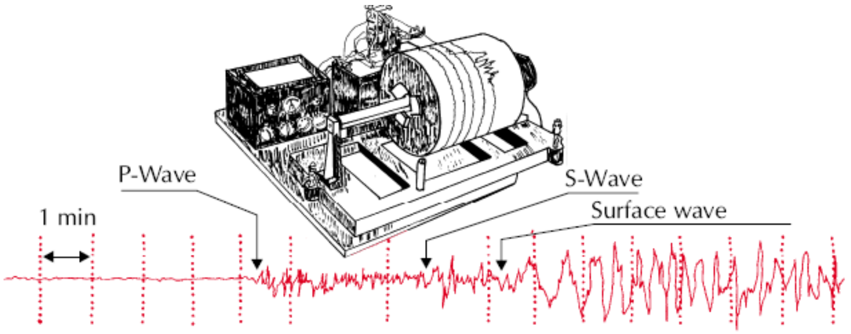


Figure4.19: seismograph and seismogram

By carefully timing the arrival of the P and S waves, seismologists are able to determine the epicenter of an earthquake and the size and orientation of the active fault. Scientists can calculate the distance to the epicenter of an earthquake by reading the seismogram and calculating the time difference between the arrival of the P-waves and the S-waves at the seismograph.

It takes readings from three seismograph stations to locate the epicenter of an earthquake as seen in the diagram

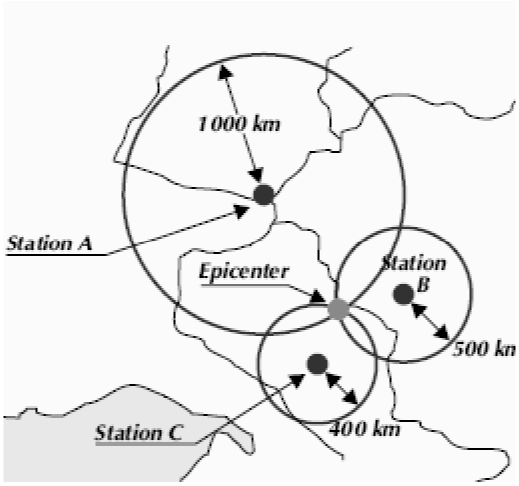


Figure4.20: Epicenter determination

Assume a scientist finds that the distance from Station A to the epicenter of an earthquake is 1,000 kilometers. The epicenter, therefore, might be at any point on a circle with a radius of 1,000 kilometers around station A on a map. The scientist draws this circle around Station A on a map. Assume that scientists at Station B and Station C have also read the charts and determined the distances to the epicenter to be 500 kilometers from Station B, and 400 kilometers from Station C. Scientists draw circles around their stations at B and C on maps, using the distance to the epicenter for the radius of each circle as before. The epicenter of the earthquake, shown on the previous diagram, is the point where the three circles intersect on a map.

!

Describe how sound waves are produced and propagated
State the properties of sound waves
Identify the factors that affect the speed of sound in air

Starter Activity: You may initiate this lesson by highlighting the significance of sound waves. There are several types of waves in nature, but two are particularly significant to us .These are sound waves and light waves which are the basis of hearing and seeing. These two waves are essential to our perception of the environment. The source of all sounds consists of vibrations of an object sending out waves through the medium in which it is placed. In this chapter we discuss the properties of sound waves, their propagation, transmission and their production by vibrating systems.

Main Activity: Sound waves travel through gases and they travel through liquids and solids as well. Every source of sound has a vibrating body. When drummer strikes the drum, you hear the sound of the drum and feel the vibrating membrane. The sound stops when the membrane stops vibrating. When you pluck the string of a kirar, or masinko you will not only hear the sound of the vibrating string but will also be able to see the vibrations of the string. Similarly, when you blow a whistle, it is the vibrations of the air in the whistle that produces the sound you hear. Your voice is also formed by the vibration of your vocal cords.

When the prongs of a tuning fork move forwards, the air in front of it is compressed; when it moves backwards the air in front of it is rarefied. If the prong oscillates continuously, successive regions of compressed and rarefied air are formed. The compressions and rarefactions move outwards from the source but the air itself does not move outwards. Compare this behavior with the water waves produced in a ripple tank or longitudinal waves produced in a spring.

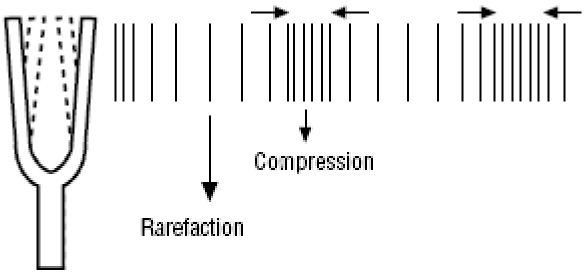


Figure 4.21: sound waves

In all the above case sounds were produced when solids such as metals, membranes, strings and air vibrated to and fro. The energy was then transmitted by longitudinal waves. Can you think of an example of sounds being produced by a moving liquid? In general sounds are not produced by vibrating liquids, although sound waves can travel through liquids very easily.

Most sounds that we hear are transmitted through the air. However, any elastic material whether solid, liquid or gas can transmit sound.

Air is a poor conductor of sound when compared to solids and liquids. Carry out the following activities and compare the loudness of the sound heard. You can hear the sound of a distant train more clearly if your ear is placed against the rail. Similarly, a watch placed on a table beyond hearing distance can be heard if you place your ear to the table. Or click some rocks together under water while your ear is submerged. You'll hear the clicking sound very clearly. If you've ever been diving under water in the presence of motorized boats, you probably noticed that you can hear the boats' motors much more clearly under water than above water. Liquids and solids are generally excellent conductors of sound much better than air. The speed of sound is generally greater in liquids than in gases and still greater in solids. Therefore, solids, liquids and gases transmit sound, but sound cannot travel in a vacuum, for the transmission of sound requires a medium. There can be no sound, if there is nothing to compress and expand.

Sound is a form of energy, but weak when compared to other forms with which we are familiar. While engineers and scientists are busy at work learning how to tap the energy of wind, sunlight, tides, and alternative fuels, no research is being done on harnessing the energy in sound because it is insignificant or weak.

Concluding Activity: You may wish to sum up this lesson by reinforcing the core point that any source of all sound has some part which is vibrating. Sound being mechanical waves needs a medium, solid, liquid or gas for its transmission.

Check whether students gain a clear knowledge and understanding of the production, transmission and propagation of sound waves, using the following discussion questions:

1. Give evidence to support the statement that sound is a form of energy.
2. Describe in short an experiment to verify that sound cannot travel through a vacuum
3. Describe an experiment which shows that sound cannot travel in a vacuum.

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Identify a normal audible frequency range.
Distinguish between infrasonic and ultrasonic frequencies.

Starter Activities: You may wish to start this lesson stating the point that **t**he human ear is sensitive to a wide range of frequencies, and then ask students to name some animals which can perceive frequencies that humans cannot. Discuss students' experience that when it comes to certain sounds, the ear is not the most sensitive part of the human body.

Main Activities: The sensation of hearing arises as the result of the action of mechanical vibrations of the human organs of hearing. A human ear can perceive vibrations of definite intensity; with frequency limits from 20Hz to 20,000Hz.This is the audible frequency range**.**

For a sound to be heard, the sound waves must reach the hearer's eardrum. When this happens, the eardrum is made to vibrate with the same frequency as the waves themselves.

Our ears are able to detect sinusoidal sound waves with frequencies in the audible range. Low frequencies are perceived as a 'low pitch' note while high frequencies are heard as a 'high pitch' note. Our high-frequency range of hearing deteriorate either with age or, as a result of exposure to loud sounds that damage the ear.

Sound waves exist at frequencies well above 20,000Hz, though humans cannot hear them. These are called ***ultrasonic*** frequencies, because they are above the normal hearing limit. And sound waves below 20Hz are called ***infrasonic*** frequencies, for they are below the normal hearing limit. Oscillators vibrating at frequencies of many MHz are able to generate ultrasonic waves used in ultrasound medical imaging. Notice that a frequency of 350 KHz corresponds to ultrasonic waves of wavelength 0.001m; and a frequency of 3MHz traveling through water, which is basically our body, at a speed of 1480m/s has a wavelength of 0.5mm.It is this very small wavelength that allows ultrasound to image very small objects.

Concluding Activity: After you make a short, concise concluding remarks emphasizing on the core points of the lesson. Form groups in a class and allow students to discuss and come up with short explanation on the following questions.

1. Can we hear sounds of all frequencies? What are ultrasonic?
2. Why is a man’s voice different from a woman’s voice?
3. Calculate the wavelength of ultrasound in water if its speed is 1400m/s and its frequency is 500 kHz

"

Define what is meant by the term echo
Determine the depth of a liquid using echo depth sounding method.

Starter Activity: Start the lesson by posing questions as :how do water waves reflect? After you hear their response you can proceed the lesson stating that like water waves, sound waves will be reflected when they meet an interface between media of different densities**.**

Main Activity: When sound waves meet the boundary between one medium and another, just like water waves, some energy is transmitted into the other medium, and some is reflected. The reflection of sound wave is referred to as an echo.

The proportion of energy carried by the reflected sound wave is large if the surface is hard and smooth like stones and less if the surface is soft and irregular. Sound energy not carried by the reflected sound wave is carried by the transmitted or absorbed wave.

Sound reflects from a smooth surface the same way that light does—the angle of incidence is equal to the angle of reflection. Sometimes when sound reflects from the walls, ceiling, and floor of a hall room, the reflecting surfaces are too reflective and the sound becomes distorted. This is due to multiple reflections called *reverberations*. On the other hand, if the reflective surfaces are too absorbent, the sound level would be low and the hall would sound dull and lifeless. This is mainly done in concert halls and studios or musical recording systems.

A simple activity to demonstrate the law of reflection of sound waves can be illustrated as: A ticking sound from a watch is sent out through the tube in a certain direction. The second tube, which is connected to the ear, is moved until the reflected sound of ticking is at maximum. Keep one ear close to the upper end of the other tube, and holds the tube at different angles until the ticking of the watch sounds louder. At that point, a large protractor is used to measure the angle between each of the tubes and a ruler held perpendicular to the wooden board where the tubes meet. When this is so, it is found that the angle of incidence and the reflection of sound at the reflecting board are nearly equal.

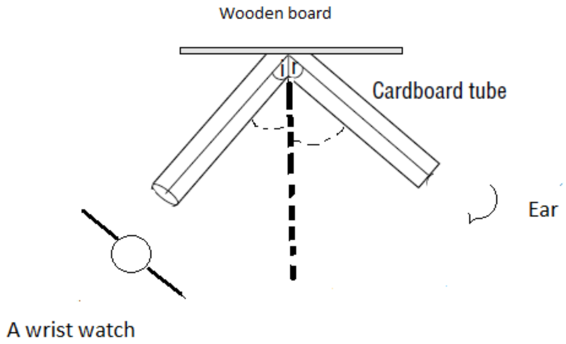

Figure 4.22: Law of reflection

An ultrasound source placed on a ship sends ultrasound pulse into the water which is propagated in a definite direction. When this pulse is arriving at the sea floor it is reflected and in some time the reflected wave reaches a receiver on a ship. The measurements of the time interval between the instances when the pulse is sent and received make it possible to determine the depth of the sea floor.

Concluding Activity: After you make a summary of the key ideas in the lesson, confirm whether students meet the expected objectives using practical activity as**:**

Measure the speed of sound using echoes. Let students in groups do this experiment outside of school time.

1. Find a big building with a large flat wall in a calm place.
2. Stand a long way away from the wall and clap hands or strike bang of two board's together .Listen for the echoes reflected from the wall.
3. Adjust the rate of clapping in such a way that a clap coincides with the return of the echo from the wall.
4. Measure the time taken from the first clap to hearing the echo of clap 11 at this particular rate > this is 10 clap intervals.
5. Repeat this observation and find a mean or average time for the two measurements.
6. Measure the distance from the position of the clapper to the wall.

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Determine the speed of sound in air.
Describe the factors that affect the speed of sound.

Starter Activity: You may start this lesson highlighting the fact that the speed of sound waves depends on the properties of the medium. A thermodynamic analysis of compressions and rarefactions shows that the wave speed in a gas depends on the temperature and on the molecular mass of the gas. For air at room temperature (20 ^{0}C) the speed of sound is 343m/s.

Main Activity: A distance as small as 100m is enough to notice a slight delay between when you see something such as hammering a nail, and when you hear it. If we watch a person at a distance chopping wood, we can easily see that the sound takes place an appreciable time before its sound reaches our ears. Thunder is heard after a flash of lightning is seen. These common experiences show that sound requires a recognizable time to travel from one place to another. The speed of sound depends on wind conditions, temperature, and humidity. It does not depend on the loudness or the frequency of the sound; all sounds travel at the same speed. The speed of sound in dry air at 0°C is about 330 meters per second.. Water vapor in the air increases this speed slightly. Sound travels faster through warm air than cold air. This is to be expected because the faster-moving molecules in warm air bump into each other more often and therefore can transmit a pulse in less time. For each degree rise in temperature above 0°C, the speed of sound in air increases by 0.6 meter per second. So in air at a normal room temperature of about 20°C, sound travels at about 340 meters per second.

As with other mechanical waves, the speed of a sound wave depends on the properties of the medium through which the wave travels. As you can see from the table, sound tends to travel faster in liquids than in gases, and faster in solids than in liquids.

	Substances (at 20 ^{0}C)	Speed (m/s)
Gases	Air	343
Liquids	Fresh water	1483
Solids	Glass	5640

Liquids and solids are less compressible than air, and that makes the speed of sound in liquids and solids higher than air.

The speed of sound in air depends on the air temperature. The equation shows that the speed of sound increases with air temperature.

$$\mathbf{V= V_0+ (0.6m/s/\ {}^0C)\ T\ {}^0C}$$

Where V_0 = 331m/s is the speed of sound in air at 0 ^{0}C.The speed of sound is a little bit lower at lower temperatures and a little higher at higher temperatures.

The simplest method that we use to measure the speed of a sound wave is to use a clock to measure the time between the light arriving and the sound being heard.

Another method is to use echo sounding. An echo is heard when the sound is reflected. You hear the echo after the initial sound because the wave has to travel out and back again.

$$\mathbf{Speed=distance/time= 2S/t}$$

Where s is the total distance traveled by the sound wave and t is the time taken.

The reflection of sound can be used for measuring the depth of a lake at a certain place. The device used for this purpose is called sonar which is carried in the ship. The device emits ultrasonic sound (high frequency) towards the bottom of the lake. The sound reflected from the bottom of the lake is received by the device .By measuring the time taken by the sound to return to the ship and knowing the speed of sound in water, we can find the depth of the lake at that particular place.

The speed of sound can also be used to determine distance from a thunderstorm. Seeing lightning before hearing the thunder is due to the relatively low speed of sound compared to that of light. By measuring the number of seconds between the flash of lightning being seen and the thunder being heard, the distance away of the storm may be estimated and by repeating the procedure it can be determined whether or not the storm is approaching or retreating.

Example: On a hot summer day of temperature 30 ^{0}C ,a hiker shouts into a cliff. He hears the echo 2 seconds later. How far away is the opposite side of the cliff?

Known variables:

Temperature T ^{0}C=30 ^{0}C
Time t=2s
Speed of sound=V

Distance to the other side of the cliff=S

The steps or strategy we need to follow to solve this problem is:

1. Determine the speed of sound in air at 30.0°C.
2. Use the speed of sound and the time for the sound to travel out and back to determine the distance to the other side of the cliff

The physics principles and equations we use to tackle this problem includes:

The equation for the speed of sound in air is,

$$\mathbf{V= V_0+ (0.6m/s/\ ^0C)\ T\ ^0C}$$
$$V=331m/s+ (0.6m/s/\ ^0C\ )\ (30\ ^0C\ )$$
$$V=331m/s+18\ m/s$$
$$V=349m/s$$

Now that we have determined the speed of sound, we can determine the distance to the other side of the cliff

$V= S/t$	Definition of speed
$V= 2S/t$	Total distance
$S=Vt/2$	Solve for S
$S= (349m/s)\ (2s)\ /2$	Substituting values
$S= 349m$	

Concluding Activity: You can provide the class with a quiz and have quick check to see if they have understood the concepts introduced in the lesson. If students have trouble with the quiz, let them reread their textbook, ask their teacher for study aids that will clarify concepts, or discuss the material with a fellow student. A simple and yet useful and helpful quiz may look like:

1) Calculate the speed of sound if a wave of wavelength 0.6m that has a frequency of 700Hz.
2) Why do the vibrations of a tuning fork rapidly die away?
3) An ultrasonic sound is sent from a ship towards the bottom of the lake .It is found that the time elapsed between the sending and receiving of sound is 3 seconds. If the speed of sound in water is 1483 m/s.Find the depth of the lake.
4) The time between a flash of lightning and crack of thunder is 4 seconds. How far away is the observer from the storm? Assume that the speed of sound in air is 331m/s? Why do you think that the thunder roars for sometime after the lighting flash?

Describe how sound waves refract.
Identify the frequency of a waves do not change as the wave moves from one medium to another.

Starter Activity: You may pose the following questions to let students remind what they had learnt about refraction in the previous lessons. How do water waves refract? What are the conditions necessary for refraction of water waves to occur? After you hear their responses, continue your lesson pointing out the fact that like water waves, sound waves are also able to refract.

Main Activity: It is not easy to show in a school laboratory that sound waves can be refracted .However; there is ample natural evidence that sound waves are refracted. Have you ever noticed that sounds produced at ground level can be more easily heard during the night than during the day? This is explained by refraction.

In order for refraction of sound to take place, the waves must be incident on the boundary between two media in which the speed of sound has different value.

The refraction and reflection of sound on the interface between the layers of the air having different temperatures makes the propagation of sound in the atmosphere complex**.** Echoes are common examples of the reflection of sound, but its refraction, which has been found to take place in the atmosphere when particularly loud sounds are transmitted over a large distance, is less common.

For example, at night the air near the ground is cooler than the air higher up. Thus the sound waves travel faster as they go higher and the separation between the wavefronts increases at greater heights as shown in the figure below (figure 4.23). The direction of travel of the sound energy is shown by the sound rays corresponding to these wavefronts; the sound waves are refracted downwards towards the ground.

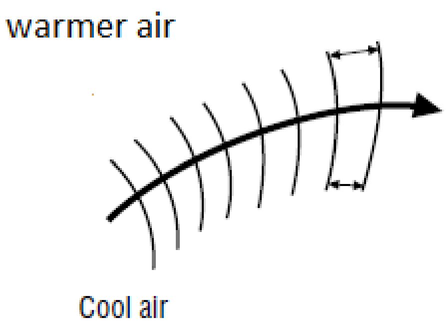

Figure 4.23

During the day the layers of air near the ground is warmer than the air higher up; so the wavefront is bent upwards over the head of the listener. Since the temperature falls with height, so does the speed of sound waves; they slow down.Therfore the sound waves bend towards the normal as they rise.

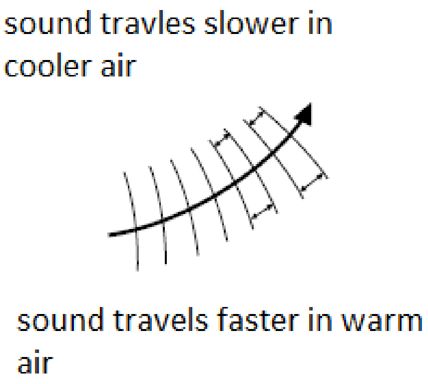

Figure 4.24

It is possible to observe during refraction velocity and wavelengths of waves change where as frequency of waves remain constant. Velocity and wavelength of wave coming from deep part of water tank to shallow part decrease. The diagram shown below (figure 4.25) shows this change in the velocity and wavelength of waves.

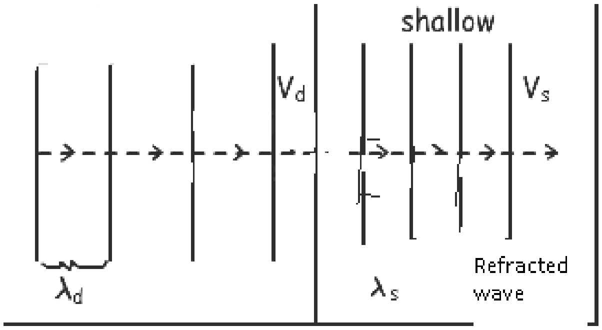

Figure 4.25

Concluding Activity: After you sum up the main ideas of the lesson .let students submit group report on the following conceptual questions.

1. Why does sound travel further on cool nights than on warm days?
2. How can relatively low sounds (e.g. normal conversation) travel long distances over water?

Cite evidence that sound waves undergo diffraction.
Describe an experiment to show that sound waves are diffracted.
State the right conditions for sound waves to be diffracted.

Starter Activity: You can initiate the class reviewing the past lessons as: Since sound is a wave motion, it will undergo diffraction given the right conditions. You can carry out the following demonstration as a starter activity.

Close all the widows and doors of a room Ask one of the students to speak normally in the room from a position directly behind the closed door, but a few meters away from it as shown in the figure 4.26. Ask someone else to listen at various positions A,B and C,outside the room and to report on whether he or she can hear what the person inside is saying.

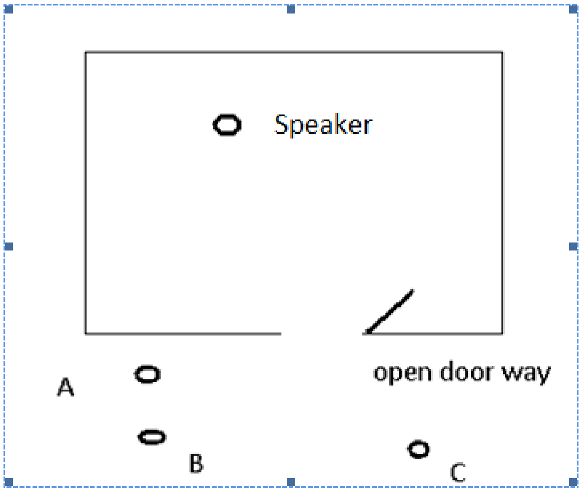

Figure 4.26

You will observe that not much is heard. Now repeat the experiment with door open. You should find that the speaker in the room is heard clearly from position C, and again from position B and possibly from position A.

The sound is heard at C because the waves pass straight through the open doorway. The sound is heard at B because the sound waves reach the listener after diffraction at the doorway. Similarly the sound is heard at A because of diffraction; the waves have been diffracted more than those reaching B.

Main Activity: Sound bends around corners and when it passes through an open door it doesn’t just remain in a narrow beam but spreads out in all directions. The wavelength of sound waves varies from about 20 cm to 10 m. The wavelengths which are similar in size to, or larger than, the aperture they are passing through are diffracted most.

Being able to hear round a corner is an everyday experience that indicates sound is easily diffracted.

The spreading of waves is greatest when the length of the wave is approximately the width of the opening. The wavelengths of humans’ speech are in the range 1-4 meter. Since the wavelength of human speech are comparable to the dimensions of doors and windows ,a substantial amount of diffraction occurs enabling us to hear people who are talking even though they may be standing around a corner or outside a door.

While the wavelength of visible light is so small compared to the dimensions of doors and windows ,little diffraction of light occurs ,making it impossible to see people if they are standing around a corner even though we may hear them speak.

Concluding Activity: After you sum up the basic underlying concepts of the lesson; give them an assignment to browse internet and share ideas among the students in class.

% 3

Describe the effects of interference of sound waves.
Distinguish between constructive and destructive interferences.

Starter Activity: You can begin the lesson reviewing the previous lessons on interference of water waves. Let student apply the concepts learnt to answer this question-What happens to the medium at a point where two sound waves traveling are present simultaneously?

Main Activity: one of the most basic characteristics of waves is the ability of two waves to combine into a single wave whose displacement is given by the principle of superposition. This superposition or combination of waved is referred to as interference.

When we combine two in-phase waves, using the principle of superposition, the net displacement at each point is twice the displacement of each individual wave. The superposition of two waves to create a wave with amplitude larger than either individual wave is called constructive interference. A superposition of two waves that creates a wave with amplitude smaller than either individual wave is called destructive interference.

Demonstration to illustrate constructive and destructive interference

Place the two speakers facing the same way, about 0.5 m to 1 m apart and use frequencies of around 3000 Hz. Walk slowly parallel to the speakers and a couple of meters from them, with no intervening objects alternate constructive and destructive interference.

Consider the two loudspeakers in the figure. The sound wave from loudspeaker 2 passes just to the side of loudspeaker 1, hence two overlapped sound waves travel to the right along the x-axis. We want to find out what happens when two overlapped waves travel in the same direction along the same axis.

The figure 4.27 shows a point on the axis where the overlapped waves are detected by your ear or by a microphone**.**

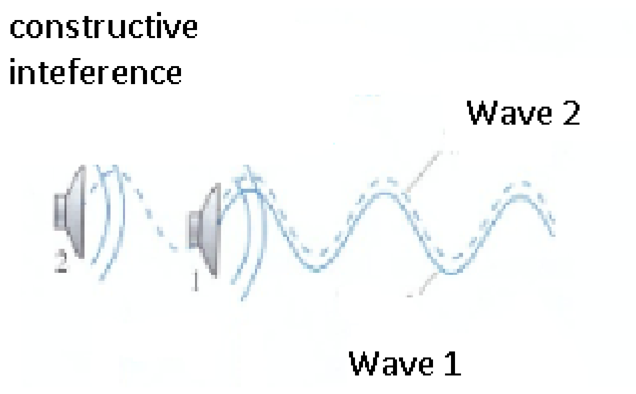

Figure 4.27

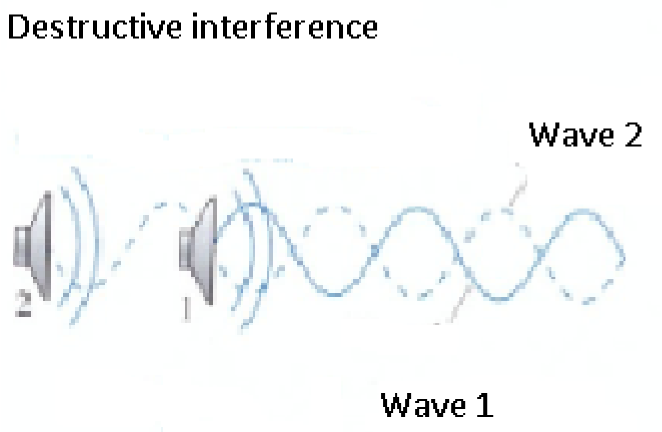

Figure 4.28

Concluding Activity: Recapitulate the underlying concept of the lesson highlighting the point that since sound is a wave motion sound waves superpose rather than collide when they meet, according to the principle of superposition. They pass through each other and the effects are additive. Assign students in group to state experiences which indicate the effects of interference of sound waves.

 #   3

Define what is meant by intensity of sound wave.
Apply the definition to determine the intensity of a wave.

Starter Activity: You may wish to initiate this lesson by reminding students the point that sound carries energy. It may be a small amount, as when someone whispers in your ear, or it may be much more, as when the thunder cracks. Sound intensity is used to characterize the power of sound. It is defined as the power of the sound passing perpendicularly through a surface area.

Main Activity:

The intensity of sound is the amount of sound power, the rate at which the energy being transported, in a wave as it passes perpendicularly through a surface area. Because sound waves spread as they travel, the intensity of sound weakens as you move farther away from a sound source. The power of the sound coming out of the horn has spread over a greater area for the second listener. From everyday experience we know that the intensity of sound decreases as we move further from the source. We hear a less intense sound.

Sound intensity equals power divided by the surface area. The power must pass perpendicularly through the area. The units are watts per meter squared.

When sound travels freely in every direction, its intensity diminishes with the square of the distance from the sound source.

$$I=P/4\ r^2$$

Where

P = power of sound source
r = distance from sound source

Note that The denominator of the expression for intensity is 4 r^2, the expression for the surface area of a sphere.

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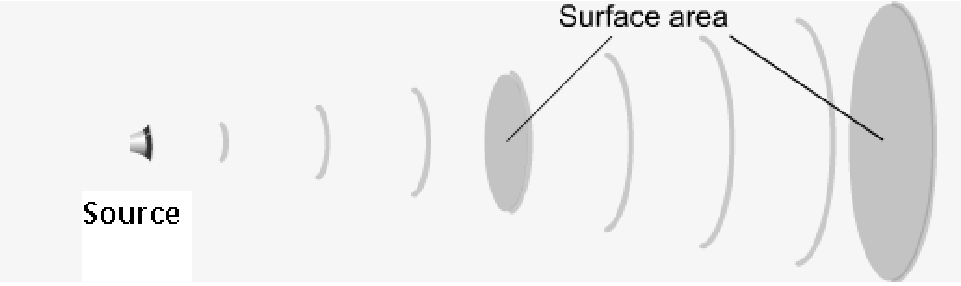

Figure 4.29

Worked Example:

A point source emits sound waves with an average power output of 80Watts.

A. Calculate the intensity 3m from the source.
B. Determine he distance at which the intensity of the sound is $1X10^{-8}$ W/m^2.

A point source emits energy in all directions, in the from of spherical waves and applying the equation,

$$\mathbf{I=P/4\ \ r^2}$$

$I= 80W/4\ \ \ (3m)^2$
$I=0.71m\ W/m^2$

Using the value we obtained for I in the equation, and solving for r gives:

$$\mathbf{r=}\sqrt{P/4\pi I}$$

Substituting the corresponding values,

$$\mathbf{r=2.5\ X10^4\ m.}$$

Concluding Activity:

After you make a summary of the lesson, have students come up with the solution of the following problems on the intensity of sound waves**.** If students have trouble with the problems, motivate them reread their textbook, ask their teacher to help them approach solving problems with confidence, or discuss the material with a fellow student.

1) You are standing 8m meters from a sound source that radiates equally in all directions, but it is too loud for you. How far away from the source should you stand to experience one third the intensity that you did at 8 meters?
2) 17 meters from a sound source that radiates freely in all directions, the intensity is 0.00460 W/m^2. What is the rate at which the source is emitting sound energy?
3) Sound spreads radially in all directions from a source with power 20 W. If the intensity you experience is 3.00×10^{-6} W/m^2, how far away are you from the source?

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