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STUDENT TEXTBOOK

GRADE 9

Federal Democratic Republic of Ethiopia
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GRADE 9

Module II

SIMPLE MACHINES, MECHANICAL OSCILLATION AND SOUND WAVES, TEMPERATURE AND THERMOMETRY

Federal Democratic Republic of Ethiopia
Ministry of Education

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Distance Education Material for High School Learners

Grade 9 Physics

Module 2

Simple Machines, Mechanical Oscillation and Sound waves, Temperature and Thermometry

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Introduction

Dear student! Module 1 has four units and you have learned about physics and human society, physical quantities, motion in a straight line, and force, work, energy and power. This module has three units and it deals with simple machines, mechanical oscillation and sound waves, and temperature and thermometry.

In the first unit of this module, you will learn about simple machine and their purposes, simple machines at home and work places, classification of simple machines and mechanical advantages of simple machines.

In the second unit of this module common characteristics of waves, string, pendulum and spring, propagation of waves and energy transmission, sound waves, superposition of waves and characteristics of sound waves will be discussed.

The third unit focuses on temperature and thermometry. The basic concept of temperature and our life, extreme temperature and safety, temperature changes and its effects, measuring temperature with different scales, types of thermometers and their use, conversion between temperature scales and thermal expansion of materials will be covered.

In each unit objectives, learning strategies, activities, self-test exercises, check lists, summary, self-assessment questions and written assignment are incorporated to follow the students' progress.

Symbols used in the module

This tells you there is an overview of the unit and what the unit is about.

? This tells you there is an in-text question to answer or think about in the text.

This tells you to take not of or to remember an important point.

This tells you there is a self-test for you to do

√ This tells you there is a checklist.

This tells you there is a written assignment

This tells you that this is the key to the answers for the self-tests.

This tells you there is a simulation which needs internet resources from a mobile data or a Wi-Fi connection.

Module Contents

Module Assessment Methods

To check your progress, various assessment techniques will be used in this module. These include self-test exercises, activities, end of unit self-assessment questions and written assignments. The written assignments in each unit can be used for formative assessment and will be converted to 15%. For summative assessment students will be evaluated by written examination from 35%. The percentage of evaluation for this module weighs 50%.

Unit 1 Simple machines

Introduction

Dear student! In unit 4 of module 1 you learned the basic concepts of force, work, energy and power which help you to understand this unit. This unit deals with the simple machines. In this unit, you are going to study important concepts of simple machines. You have observed that people in your local area use an axe to split wood into parts, use knives to cut and chop different items and use a pulley to lift water from a well. An axe, knife, and pulley are simple machines that help people to do work more easily. Humans have been making and using simple machines for a long time. We create these machines to help us to survive and do our work. We use these machines every day and in all aspects of our lives. In this unit, you will learn about different types of simple machines, the purpose of simple machines, and the mechanical advantages of simple machines.

After reading this unit, you should be able to:

- *know the types of simple machines;*
- *define the mechanical advantages and efficiency of a machine;*
- *solve problems related to simple machines;*
- *construct simple machines that are applicable to solve real problems in their local area.*

Unit Contents

Required study time

Dear student! You are expected to complete Section 1 in 4.5 hrs., Section 2 in 1.5 hrs., Section 3 in 1.5 hrs., Section 4 in 3 hrs., Section 5 in 15 hrs., and Section 6 in 3 hrs.

Learning Strategies

Dear student! In this unit, you are expected to use the following learning strategies:

- Follow the symbols in the module material that guides you to learn each section,
- Space out your study over time;
- After completing each subsection, do each activity and self-test exercises;
- For a difficult activities and self-test exercises in each subsection or section, go back and read it carefully until you understand the contents;
- Consult a physics teacher in your locality or a tutor for the contents you are unable to understand;
- Do end-of-unit self-assessment exercises to check whether you understand each section of the unit or not.

Section 1.1: Simple Machines and their purposes [4.5hrs]

Dear student! I hope you are using different types of simple machines in day-to-day activities. Try to answer the following brainstorming questions.

?
What are simple machines?

Which concepts do we need to understand simple machines?

What type of simple machines do you use in your home?

What is the purpose of using a simple machine?

After reading this section, you should be able to:

- *discuss simple machines;*
- *identify simple machines as force multipliers, distance multipliers or direction changers;*
- *list different simple machines in your locality.*

?
How can we change the direction of force?

Is it possible to multiply energy?

How can we multiply a force or a speed?

Dear student! Imagine trying to put a staple through a stack of paper with your bare hands! It is an almost impossible and dangerous task. A stapler gets the job done quickly, easily, and safely. A simple machine is a device, composed of only one or two parts, that requires a single force to do mechanical work. The stapler works by applying a single downward force at its open end. Like the stapler, the mechanisms of most physical systems are made of one or more simple machines that work alone or together to make physical tasks such as nailing, cutting, throwing, carrying, and chopping easier to do mechanical work.

☞ **A simple machine** is a device that requires a single effort to do work against a single force.

Activity 1.1

1. Make observations in your village for two to three days and note the types of simple machines the people in your village are using in their day-to-day activities.
2. Write about the purposes of these simple machines in the day-to-day activities of the people in your village.
3. List the number of activities in your village that are not supported by simple machines.
4. Suggest the type of simple machines that helps the villagers to do their mechanical work easily.

A simple machine is any device that helps us to do work easily. Simple machines are energy-transforming devices. Actually, machines do not create energy or change one form of energy into another. They simply transfer mechanical energy involving a small force into mechanical energy involving a large force.

Dear student!

The purpose of simple machines is to make mechanical work easier by:

- **Changing the direction of the force.**
  When you raise a flag on a flagpole, you pull down on a rope wrapped around a pulley to raise the flag up.
- **Changing the distance of force (to multiply speed or distance).**
  Imagine you need to move a heavy box up to the second floor of a building. It would be easier to carry it up an inclined plane (like a set of stairs) than to throw it straight up. But as you move the box up the stairs, it travels a longer distance than if you threw it straight up.
- **Changing the strength of a force (to multiply force).**
  A bottle opener is a lever. You can apply a weak force to pull the bottle opener up over a long distance, and it exerts a short distance but strong force on the bottle cap.

Simple machines make mechanical work easier, but they do not lessen the work done. While they can change a force, they do not add to it. There is always a tradeoff. If distance is gained, then the strength of the force lessens. If strength is gained, the distance a force must travel will be shorter.

Simple machines need energy or a power source to work. In many cases, you supply the energy to apply a force by pushing or pulling, but energy can come from gasoline or electricity, too. All of these are input forces. The machine's reaction or effect is the output. The input and output, or the total amount of energy, always remain the same.

Simple machines act as force or speed multipliers.

Self-Test Exercise 1.1

Part I: Give short answers to the following questions

1. What is the purpose of using a fixed single pulley to take water from a deep well?
2. What is the purpose of using an inclined plane to raise different objects in the truck?
3. What is the purpose of using a bicycle instead of walking or running on foot?

Dear student! While discussing self-test exercise 1.1, it is better to use the terms **effort** and **load.**

Effort (F): is the force exerted on a simple machine (a fixed pulley, an inclined plane, etc.) or a compound machine (e.g., a bicycle) by an external body like a human being. In order to do mechanical work, you need to move this effort over a distance.

$$Work\ input = effort\ \times distance\ moved\ by\ effort$$

Load (L): is a force exerted by a simple machine (a fixed pulley, an inclined plane, etc.) or a compound machine (e.g., a bicycle) on an object to be lifted or moved. A machine also provides work output; this may be used to move a load.

$$Work\ output = load\ \times distance\ moved\ by\ load$$

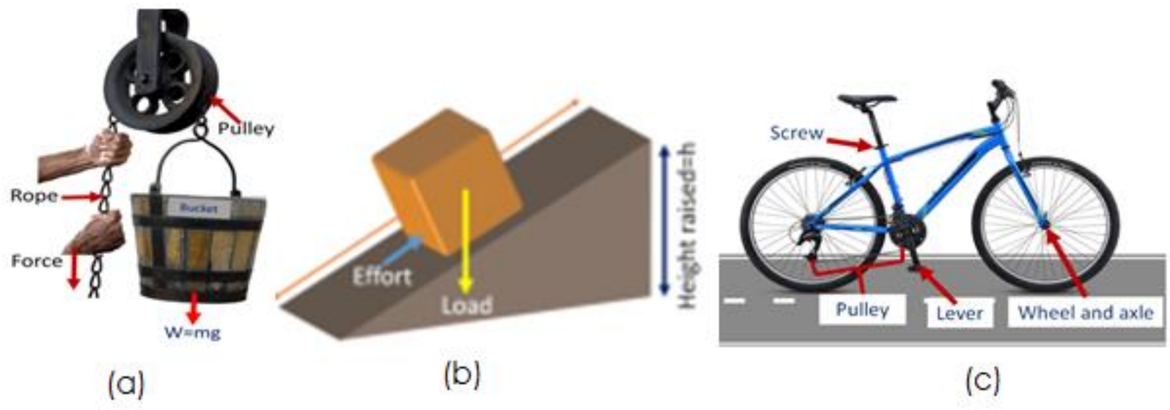


Figure 1.1: a fixed single pulley

Dear student! In your local area, people are using a fixed pulley to lift water from the well, an inclined plane to lift large loads, and a bicycle to travel a long distance easily.

Suppose in a fixed single pulley an effort moves 2 m in one second to lift a bucket of water from a well, and the bucket of water moves 2 m at the same time. The speed at which the effort moves would be 2 m/s, and that of the load is 2 m/s. Here, the speed of the effort is the same as the load. So, the purpose of the pulley is to change direction.

In an inclined plane, a small effort is used to lift the heavy load. Hence the inclined plane is used to multiply a force. It is a force multiplier.

On a bicycle, the small distance traveled by a person on a pedal is multiplied by the wheels of the bicycle, and a long distance is covered during the same time. Hence, a bicycle is called a speed multiplier or a distance multiplier.

☞ Machine: a device designed to do mechanical work easily.

Effort: the force applied to a machine or the force you exerted on a machine.

Load: the force exerted by the machine.

Self-Test Exercise 1.2

Part I: Write True if the statement is correct and False if it is incorrect.

1. Simple machines are used to create energy.
2. A fixed pulley is used to multiply force.
3. Some simple machines multiply speed and Force at the same time.

Part II: Choose the correct answer from the given alternatives.

1. The purpose of a simple machine is
   A. to change potential energy into kinetic energy
   B. to make work easier and use less force
   C. to produce energy
   D. to test force
2. The force exerted on a simple machine by an external body is
   A. load B. effort C. power D. energy
3. A force exerted by a simple machine on an object is
   A. load B. effort C. power D. energy

Part III: Give short answers to the following questions

1. Explain the purpose of using simple machines.
2. Is it possible to multiply energy using a simple machine? Explain.

√ Check List 1.1

Dear learner, now it is time to check your understanding of simple machines. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you define simple machines?	☐	☐
2. Can you identify some simple machines used as force multipliers, distance multipliers or direction changers?	☐	☐
3. Can you list different simple machines in your locality?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 1.2: Simple Machines at Home [1.5hrs]

Dear student! You are familiar with different types of simple machines (knives, axes, wedges, shovels, etc.) that are used at home. In this section, you will learn about simple machines used at home.

After reading this section, you should be able to:

- *list different simple machines used at home.*
- *write the purpose of the listed simple machines.*

Self-Test Exercise 1.3

Part I: Develop a list of simple machines at home.

No	Simple machines used at home	purpose of a simple machine
1		
2		
3		
4		
5		
6		

Most of the machines you encounter in everyday life are complex. However, break them down to their smallest parts, and you're left with simple machines: wheels, levers, wedges and screws. Simple machines magnify, spread out, or change the direction of force, making it easier to move, cut, and bind objects. *Figure 1.2* shows simple machines used in our day-to-day activities.

A simple machine is a device that helps to reduce the amount of force required to do work. They often change the direction or magnitude of a force and offer a mechanical advantage. Simple machines are seen as the building blocks of more complex machines.

Figure 1.2: Simple machines used at home and work

As we discussed in the previous section, the purpose of a simple machine is to:

- change direction,
- multiply a speed or distance,
- multiply a force

☞ Simple (compound) machines are said to be force multipliers when they enable us to lift big loads with little effort. The load is greater than the effort.

Simple (compound) machines are said to be distance (speed) multipliers when they enable people to lift a load over a large distance by moving the effort over a small distance.

Self-Test Exercise 1.4

Part I: Fill in the following table:

No.	A simple machine	Purpose
1	Hammer	
2	Knife	
3	Axe	
4	Shovel	

2. Does a machine multiply force and distance at the same time? Explain it.

√ **Check List 1.2**

Dear learner, now it is time to check your understanding simple machines at home. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you List different simple machines used at home?	☐	☐
2. Can you Write the purpose of simple machines used at home?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 1.3: Simple Machines at Workplace [1.5hrs]

Dear student! In the previous section, you have seen simple machines used at home to make work easier. In this section, you will learn about simple machines used at work.

After reading this section, you should be able to:

- *Describe the purpose of simple machines at the workplace according to their type.*

The development of the technology that created cars, airplanes, and other modern conveniences began with the invention of simple machines. A simple machine is an unpowered mechanical device that accomplishes a task with only one movement (such as a lever). A lever allows you to move a rock that weighs 10 times (or more) what you weigh.

Dear student! *Figure 1.3* describes a list of the simple machines used at home and workplace for different activities.

Figure 1.3: List of simple machines associated with different activities

Self-Test Exercise 1.5

Part I: Based on Figure 1.3, complete the following table:

No	Description of a simple machine	How it makes work easier
1		
2		
3		
4		
5		
6		
7		
8		

√ **Check List 1.3**

Dear learner, now it is time to check your understanding simple machines at workplace. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you describe the purpose of simple machines at home and workplace according to their type?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 1.4: Classification of Simple Machines

Dear student! In the previous section, you have seen different simple machines used at home and at the workplace to make work easier. In this section, you will learn about the classification of simple machines.

After reading this section, you should be able to:

- *list the types of simple machines;*
- *categorize simple machines at home and at the workplace according to their type;*
- *identify the six types of simple machines.*

Dear student! Many people think of machines as complicated devices such as cars, elevators, or computers. However, some machines are as simple as a hammer, shovel, or ramp. A simple machine does work only with one movement. A machine made up of a combination of simple machines is called a compound machine. The bicycle and wire cutter are familiar examples of compound machines. The wire cutters in *Figure 1.4* combine two levers and two wedges. Bicycles include wheels and axles, levers, screws, and pulleys. Cars and other vehicles are combinations of many machines.

Figure 1.4: Examples of compound machines

Dear student!

Simple machines are categorized into two groups and six types:

1. Inclined planes
    - Ramp or inclined plane
    - Wedge
    - Screw
2. Levers
    - Lever
    - Wheel and Axle
    - Pulley

Figure 1.5 shows the six different types of simple machines

Dear student! The six types of simple machines (lever, wedge, inclined plane, screw, pulley, and wheel) are demonstrated in *Figure 1.5*.

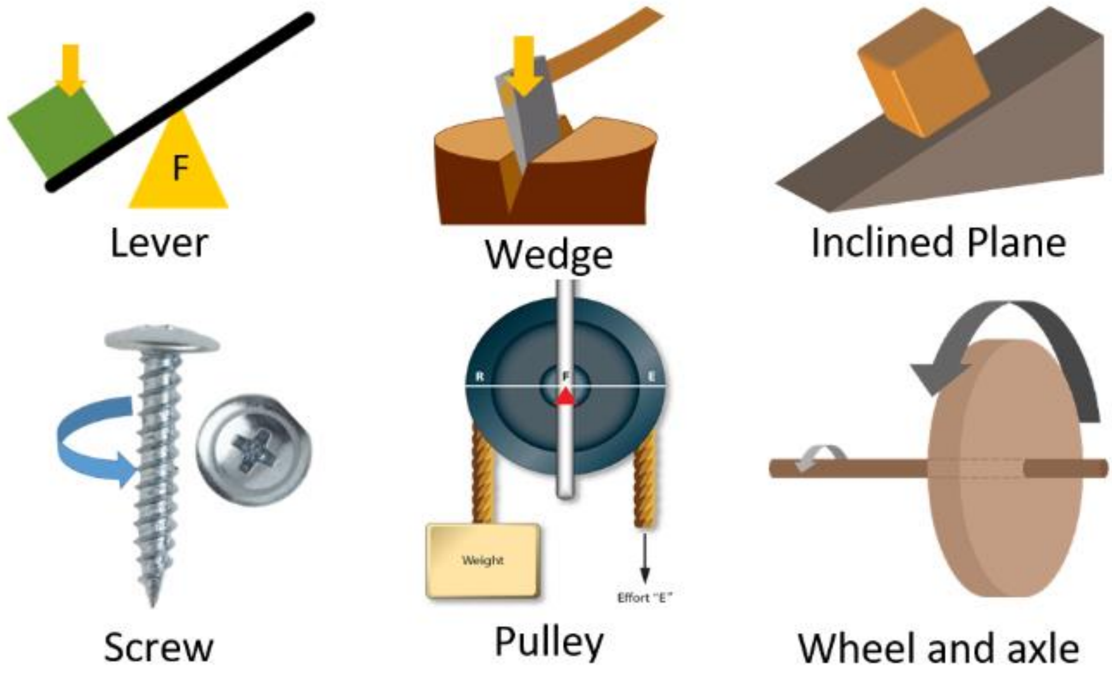


Figure 1.5: The six different types of simple machines

Dear student! No matter which type of simple machine we are dealing with, they will fit into one or more of the following categories:

Force multipliers: these are simple machines designed so that the load is greater than the effort. This is only possible if the load moves a smaller distance than the effort.

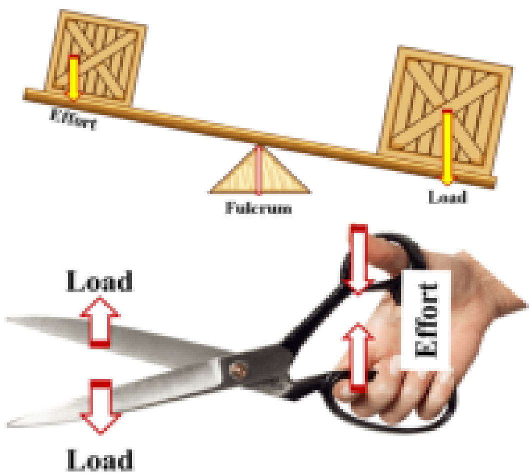


Figure 1.6: Schematic diagram of force multipliers

Speed multipliers: these are simple machines designed so that the distance moved by the load is greater than the distance moved by the effort at the same time.

Figure 1.7: Schematic diagram of speed multipliers

Direction changers: these are machines designed so that the load is moved in different directions to the effort.

☞ A simple machine is: a device that requires only a single force to do mechanical work; a device that has only one part for doing mechanical work; a device that uses a single effort to do mechanical work against a single load force.

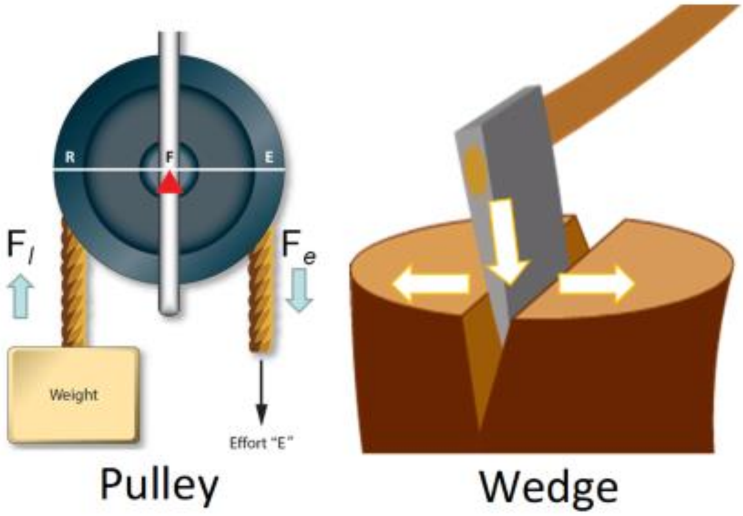


Figure 1.8: Schematic diagram of direction changers

Self-Test Exercise 1.6

Part I: Write True if the statement is correct and False if it is incorrect.

1. For speed multipliers, distance moved by the load is less than the distance moved by the effort.
2. A simple machine can multiply a force by moving a load over a long distance.

Part II: Choose the correct answer from the given alternatives.

1. A sloping surface that alters the force to move the load in a perpendicular direction.
   A. wedge B. inclined plane C. pulley D. screw
2. Which one of the following simple machines is a lever?
   A. hammer B. ramp C. Ladder D. knife
3. Which simple machine is used on a flagpole to help when the flag is raised?
   A. Lever B. inclined plane C. pulley D. wedge

Part III: Give short answers to the following questions

1. List six types of simple machines.
2. Define a simple machine.

√ Check List 1.4

Dear learner, now it is time to check your understanding about the classification of simple machines. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you list type of simple machines?	☐	☐
2. Can you categorize simple machines at home and workplace according to their type?	☐	☐
3. Can you Identify the six types of simple machines?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 1.5: Mechanical Advantage, Velocity ratio, and efficiency of Simple Machines

Dear student! In the previous section, you have learned about types of simple machines. In this section, you will learn about the mechanical advantage, velocity ratio, and efficiency of different types of simple machines.

After reading this section, you should be able to:

- *determine whether the machines are force multipliers, speed multipliers, or direction changers;*
- *define the terms work input, work output, effort, load, mechanical advantage (M.A), velocity ratio (V.R), and efficiency (η);*
- *derive the expression for efficiency;*
- *calculate the mechanical advantage and efficiency of simple machines.*

Dear student! In your day-to-day activities, you are familiar with different applications of simple machines. Take a few minutes and think of the following brainstorming questions:

?

1. Simple machines in the real world are not 100% efficient. Why?
2. Is it possible to transfer all input energy to output energy using simple machines?

Mechanical advantage (M.A)

Dear student! In this subsection, you deal with a general description of the mechanical advantage and velocity ratio of simple machines.

Dear student! Think of the following brainstorming questions: It helps you to follow this subsection.

1. What is the mechanical advantage of a simple machine?
2. What is the actual mechanical advantage?
3. What is the ideal mechanical advantage?

Dear student! Different simple machines may be used to accomplish the same work. For example, nails may be pulled out of a piece of wood with simple machines such as a pair of pliers or a claw hammer. The claw hammer does a job with less effort. Why? The hammer acts first-class lever that converts a small input force into a much larger output force. When a machine turns a small input force into a larger output force, we say that the machine gives us a mechanical advantage.

☞ $$Mechanical\ advantage\ (M.A) = \frac{Output\ force}{input\ force} = \frac{load}{effort}$$

Example: A load of 400 N is lifted by applying a force of 160 N on the lever. What is the mechanical advantage of the lever?

Given	Required	Solution
F_L= 400 N	M. A=?	$M.A = \frac{load}{effort} = \frac{F_L}{F_E} = \frac{400\ N}{160\ N}$ =2.5
F_E= 160 N		

Self-Test Exercise 1.7

Part I: Give short answers to the following questions

The hammer produces an output force 15 times greater than the force you apply to it (the input force). What is the mechanical advantage of a hammer?

Mechanical advantage has no units; it is simply a comparison or ratio. When the input and output forces are the same, the mechanical advantage is 1. Machines with a mechanical advantage greater than 1 are force multipliers (as the load is greater than the effort).

☞ There are two kinds of mechanical advantages.

- Actual mechanical advantage (AMA)
- Ideal mechanical advantage (IMA)

Actual mechanical advantage compares the force you get out (load) with what you put in (effort).

Ideal mechanical advantage is the mechanical advantage if there were no energy losses (e.g., no losses due to friction, etc.)

Dear student! For most of our calculations and examples in this unit, we will consider that there are no energy losses. That is, AMA = IMA = MA. However, in the real-world IMA is always greater than AMA. Why? Think of it.

Self-Test Exercise 1.8

Part I: Complete the following table based on the definition of mechanical advantage.

Load (N)	M.A	Effort (N)
	3	600
40		160
	0.5	480
900	0.3	
2000		500

Dear student! In the previous subsection, you learned about mechanical advantage. In this subsection, you are going to learn about the velocity ratio.

Velocity ratio (V.R)

The term "**velocity ratio**" describes the ratio of the distance moved by the effort to the distance moved by the load.

$$Velocity\ ratio\ (V.R) = \frac{distance\ moved\ by\ the\ effort}{distance\ moved\ by\ the\ load}$$

The velocity ratio has no units. If the V.R is 3, then the effort has to move three times as far as the load. Similarly, if the V.R. is 0.5, then the effort moves half as far as the load (or the load moves twice as far as the effort).

Example: A load of 200 N is lifted by applying a force of 80 N on the lever. If the load is 10 cm from the fulcrum and the effort is 40 cm from the fulcrum, calculate:

a) The V.R of the lever

Given

d_L = 10 cm

d_E = 40 cm

Required

V.R =?

Solution

V.R = $\frac{d_E}{d_L} = \frac{40\ cm}{10\ cm} = 4$

☞ **Mechanical advantage:** the ratio of the load to the effort.

Velocity ratio: the ratio of the distance moved by the effort to the distance moved by the load.

Actual mechanical advantage: the ratio of the load and the effort, considering energy losses due to friction in real world.

Ideal mechanical advantage: the ratio of the load to the effort without considering energy losses due to friction.

Self-Test Exercise 1.9

1. **Part I:** Complete the following table based on the definition of velocity ratio:

Distance moved by effort	V.R	Distance moved by the load
0.2	4	
0.8		2
6	0.6	
	0.3	6
12	2	

2. What is the purpose of a machine if:

   1. $V.R < 1$?
   2. $V.R > 1$?

Dear student! In the previous subsection, you learned about the velocity ratio. In this subsection, you are going to learn about the efficiency of machines.

Efficiency of machines

Efficiency describes how good a machine is at transferring input energy into useful output energy. It can also be defined in terms of power. As power is energy utilization, efficiency can also be expressed as the ratio of power output to power input. Machines waste energy due to friction between their moving parts. As a result, the efficiency of a machine is less than one. When a machine provides an increase in force, there must always be a decrease in the distance the force moves. Is the reverse true? Yes, the reverse is also true. When a machine provides a decrease in force, there must always be an increase in the distance the force moves.

? Is it possible for a machine to increase both the magnitude and the distance of a force at the same time?

Dear student I hope that your response is no. You are right. It is not possible for a machine to increase both the magnitude and distance of a force at the same time. When a machine provides an increase in force, there must always be a decrease in the distance the force moves and vice versa

Dear student! There is no machine that can produce more work than the amount of work that is put into it. In physics, efficiency (η) is the ratio of work output to work input. It is often multiplied by 100 to give a percentage.

$$Effeciency\ (\eta) = \frac{work\ output}{work\ input}$$

Similar to M.A. and V.R. efficiency has no units since it is a ratio.

☞ In a real simple machine, not all of the input work is available as output work.

Some of the energy transferred by the work may be lost as thermal energy.

Self-Test Exercise 1.10

Part I: Give short answers to the following questions

The efficiency of a machine is 0.75 (or 75%). What is the physical meaning of this statement?

Efficiency can also be expressed in terms of M.A and V.R.

$$\eta = \frac{work\ output}{work\ input} = \frac{load \times distance\ moved\ by\ load}{effort \times distance\ moved\ by\ effort},$$

But $\frac{load}{effort} = M.A$ and $\frac{distance\ moved\ by\ load}{distance\ moved\ by\ effort} = \frac{1}{V.R}$

☞ $$\eta = \frac{M.A}{V.R}$$

Self-Test Exercise 1.11

Give short answers to the following questions

1. What is the efficiency of a machine with M.A = 3 and V.R = 6?
2. What do you conclude if M.A = V.R? Write your conclusion on a piece of paper and read it to the whole class.

Example 1.1: A simple machine provides a work output of 80 J for every 400 J of work input.

a) What is the efficiency of a simple machine?
b) What will be the work output of this simple machine if 2000 J of work go to it?

a) **Given** **Required**

work output = 80 J $\eta = ?$

work input = 400 J

Solution

$$\eta = \frac{work\ output}{work\ input} = \frac{80\ J}{400\ J} = 0.2\ (20\%)$$

b) Given **Required**

Work input 2000 J work output =?

From solution of a) $\eta = 0.2$

Solution

$$work\ output = \ \eta \times work\ input = 0.2\ \times 2000\,J = 400\,J$$

Levers

Dear student! In the previous subsections, you learned about the mechanical advantage, velocity ratio, and efficiency of simple machines. In this subsection, you are going to learn about different classes of levers, their mechanical advantage, velocity ratio, and efficiency.

Dear student! The term lever originates in France, where 'levier' means 'to raise'. A lever is a rigid bar of wood or metal that is free to turn about the supporting point, which is called a fulcrum (F). A lever also consists of an effort point (E), load point (L), and a fulcrum (F).

☞ Archimedes (282 – 212 BC): Give me a place to stand and, I shall move the Earth with a lever.

Self-Test Exercise 1.12

Give short answers to the following questions

1. Name the different parts of a lever,
2. List some examples of the levers that are used by people in your local area.
3. Is a lever a speed multiplier or a force multiplier?

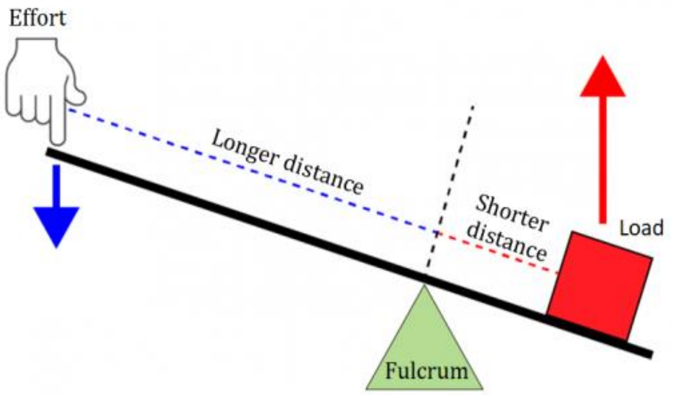


Figure 1.9: Feature of the lever

A lever consists of three parts namely: effort point (E), load point (L), and fulcrum (F).

Fulcrum: the pivot point of a lever.

Load arm: the part of the lever that extends from the fulcrum to the mass being moved.

Effort arm: the part of the lever that extends from the fulcrum to where the force is applied.

Different classes of levers

Dear student! You are familiar with the definition of the lever and its parts. Now you are going to learn about different classes of levers.

There are three different classes of levers, depending on the relative position of the fulcrum.

- The fulcrum is always located between the load and the effort.
- Examples: seesaw, scissors, a crowbar.
- IMA can be greater than one, equal to one, or less than one.

First-Class lever:

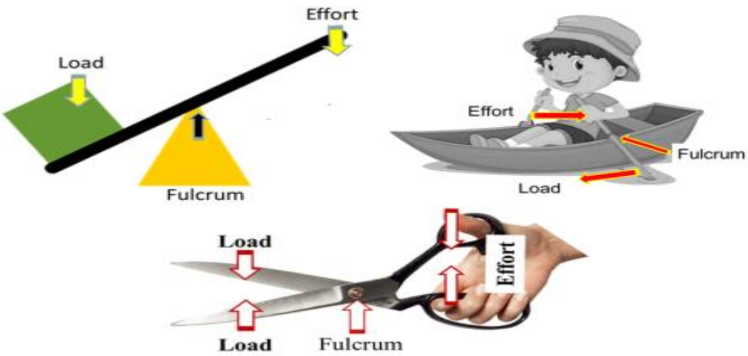


Figure 1.10: First-class levers

Second-Class lever:

- The lever has the load in the middle, between the effort and the fulcrum. In a second-class lever, the fulcrum is usually closer to the load, which reduces the force needed to accomplish the work.
- Example: wheelbarrow. The axle of the wheel acts as the fulcrum, the handles are the force arm, and the load is carried between the two in the bucket part of the wheelbarrow. Other second-class levers include a pair of nutcrackers and a bottle opener.
- The IMA is always greater than one.

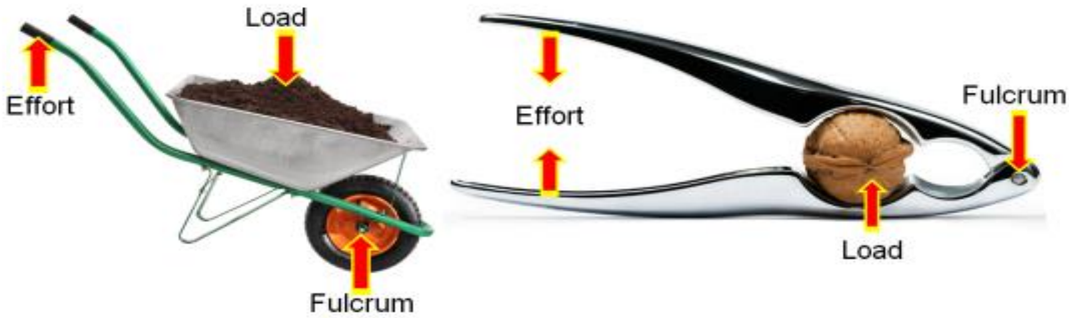


Figure 1.11: Second class levers

Third-Class lever:

- The lever has the effort in the middle, between the load and the fulcrum. This arrangement requires a large force to move the load. But this arrangement facilitates movement of the load over a long distance with a relatively small movement of the force arm.

- Examples of third-class levers are a fishing pole, a pair of tweezers, an arm lifting a weight, a pair of calipers, a person using a broom, a hockey stick, a tennis racket, a spade, or a shovel.
- IMA is always less than one.

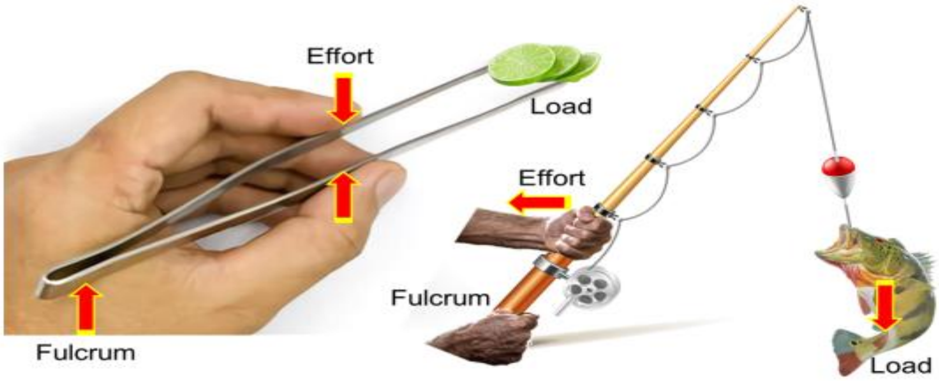
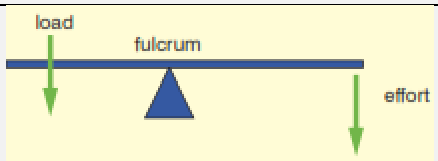
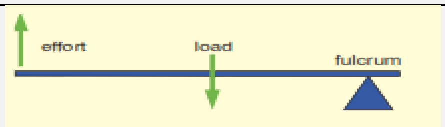
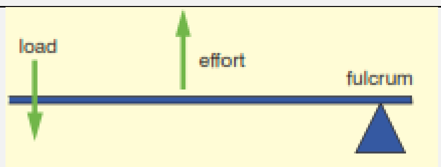


Figure 1.12: Third class levers

Self-Test Exercise 1.13

Write the description and examples of three different classes of levers in the following table.

Class	Diagram	Description	Examples
1st			1.________ 2.________ 3.________ 4.________
2nd			1.________ 2.________ 3.________
3rd			1.________ 2.________ 3.________

☞ First-order lever: the fulcrum is located between the effort and the load.

Second-order lever: the load is placed between the fulcrum and the effort.

Third-order lever: the effort is applied between the fulcrum and the load.

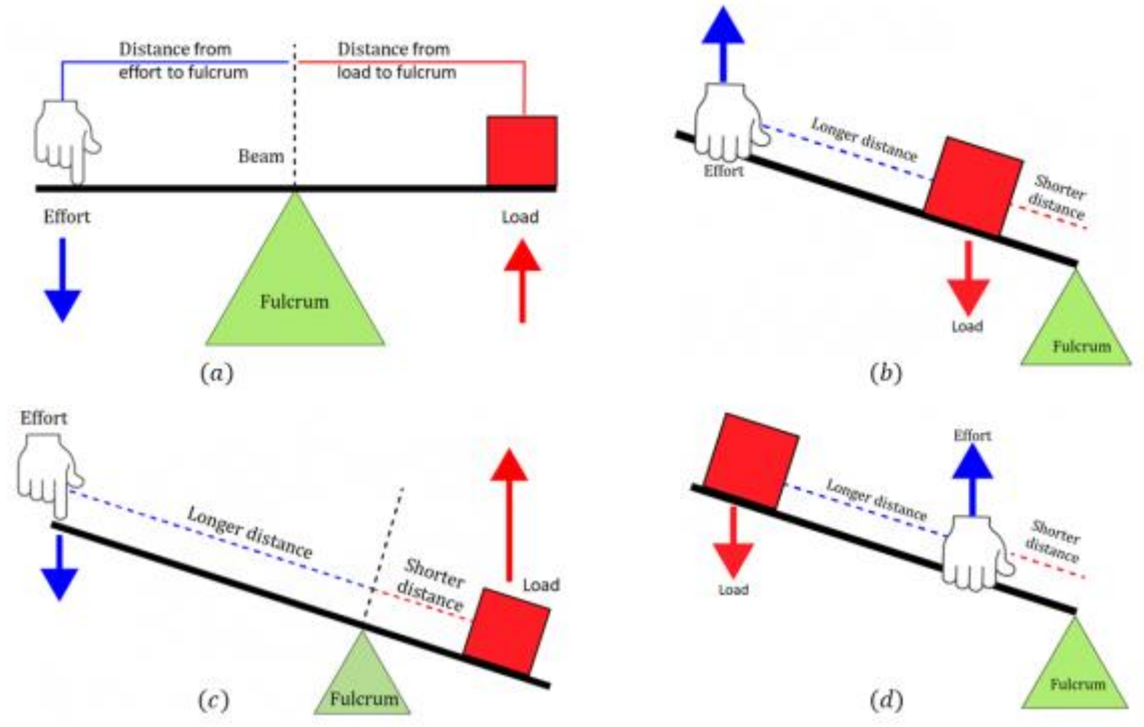


Figure 1.13: Different classes of levers

M.A, V.R, and efficiency of levers

Dear student! In the previous sub section, you learned about the three classes of levers. Now you are going to learn the mechanical advantage, velocity ratio and efficiency of levers.

The mechanical advantage of a lever is the ratio of load to effort.

$$M.A = \frac{load}{effort} = \frac{F_L}{F_E}$$

When dealing with levers, the forces are turning rather than moving. Hence, the equation for V.R. is somehow different. As a system is rotating, we do not use the distance moved by the force.

The V.R. can be determined as the ratio between the distance from the effort to the fulcrum and the distance from the load to the fulcrum.

$$V.R = \frac{distance\ from\ the\ effort\ to\ the\ fulcrum}{distance\ from\ the\ load\ to\ the\ fulcrum} = \frac{d_E}{d_L}$$

If there are no energy losses, the ideal mechanical advantage is equal to the velocity ratio.

$$IMA = V.R = \frac{d_E}{d_L}$$

Example 1.2: A load of 200 N is lifted by applying a force of 80 N on the lever. If the load is 10 cm from the fulcrum and the effort is 40 cm from the fulcrum, calculate:

b) The V.R of the lever b) The M.A of the lever c) Efficiency

Given	Required	Solution
L = 200 N	V.R = ?	V.R = $\frac{d_E}{d_L} = \frac{40\ cm}{10\ cm} = 4$
E = 80 N	M. A = ?	M.A = $\frac{L}{E} = \frac{L}{E} = \frac{200\ N}{80\ N} = 2.5$
d_L = 10 cm	ɳ = ?	ɳ = $\frac{M.A}{V.R} = \frac{2.5}{4} = 0.625\ (62.5\ \%)$
d_E = 40 cm		

Self-Test Exercise 1.14

Part I: Choose the correct answer from the given alternatives.

1. A lever is a rigid bar of wood or metal that is free to turn about a point. What is a point called?
   A. Effort B. Fulcrum C. Load D. Load arm
2. Suppose you apply a force on a machine; the machine also exerts a force on a body. Which of the following forces is exerted by the machine on the body?
   A. Effort B. Load C. Mass D. Power
3. Which one of the following statements is correct about effort, load, or fulcrum?
   A. A load is a force exerted on a lever.
   B. Effort is the force exerted on a machine.
   C. A fulcrum is a point at which force is exerted by a lever.
   D. Load is energy put into the machine.

4. A load of 200 N is lifted by applying a force of 80 N on the lever. The load is 10 cm, and the effort is 40 cm from the fulcrum. What will be the efficiency of the lever?

   A. 62.5% B. 72.5% C. 82.5% D. 92.5%

5. What should you do to reduce the amount of effort needed to lift something using a first-class lever?

   A. Move the fulcrum to the middle of the lever

   B. Move the fulcrum closer to the effort

   C. Move the fulcrum closer to the load

   D. None

Inclined plane, wedge, and screw

Dear student! In the previous sub-sub section, you learned about the mechanical advantage, velocity ratio, and efficiency of levers. Now you are going to learn about the inclined plane, wedge, and screw.

The inclined plane

The inclined plane is the simplest machine of all the machines. It is a sloping surface that connects two points together. An inclined plane is another name for a ramp. A screw and a wedge are made up of two inclined planes. The longer the ramp, the easier it is to do the work. However, it takes a much longer time to do the work. An inclined plane is another name for a ramp. The object is lifted to a height h by sliding it up the length of the slope l.

?

1. For what purpose do people use an inclined plane in your local area? Discuss your observation in the class.
2. Why is it easier to push a heavy object up an inclined plane than lift it?
3. How can you make your inclined plane have a large velocity ratio?

Figure 1.14: An inclined plane

$$M.A = \frac{Load}{Effort} = \frac{L}{E}$$

$$V.R = \frac{distance\ moved\ by\ effort}{distance\ moved\ by\ load} = \frac{length\ of\ inclined\ surface}{height\ of\ inclined\ plane} = \frac{l}{h}$$

Self-Test Exercise 1.15

Part I: Give short answers to the following questions

1. Calculate the velocity ratio (V.R) of:
   a) A slope of length 30 m that raises an object to a height of 5 m?
   b) A slope of an angle 37° to the horizontal and raises an object to a height of 60 m?
2. A slope of length 40 m raises an object to a height of 8 m above the ground. An effort of 80 N is needed to push a 240 N object up the inclined plane. Calculate:
   a) M.A b) V.R c) Efficiency

The wedge

Wedges are used to separate two objects or split objects apart. Examples of wedges include knives, nails, axes, and spears.

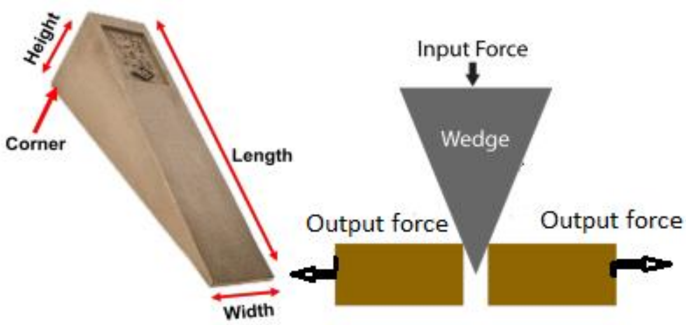


Figure 1.15: The wedge

Self-Test Exercise 1.16

Part I: Give short answers to the following questions

1. What is a wedge?
2. For what purpose do people use wedge in your community? Discuss.
3. List examples of wedges used in your surroundings.
4. What is the difference between an inclined plane and a wedge?

For wedges the load is the force exerted on the object being split and the effort would be the force applied to the top of the wedge.

$$M.A = \frac{Load}{Effort} = \frac{L}{E}$$

The velocity ratio of a wedge is the ratio of the penetration length (l) of a wedge and the thickness of the wedge (t).

$$V.R = \frac{penetration\ length}{thickness} = \frac{l}{t}$$

The efficiency of a wedge can be determined by:

$$\eta = \frac{M.A}{V.R} = \frac{L \times t}{E \times l}$$

The narrower the wedge, the greater the ratio of the penetration length of its slope to its thickness.

The screw

Dear student! The term screw refers to any cylinder with a helical thread around it. It includes nuts and bolts. It is used to hold objects together, dig into the ground, and bore through rocks.

In one turn of the screw, it penetrates and moves into the material at a distance equal to the separation between the threads. This is referred to as the pitch (p) of the screw. The length of the slope should be the same as the circumference of the screw shaft ($2\pi r = \pi d$). The movement of the screw tip into the material provides the load, whereas the force used to turn the screw is the effort.

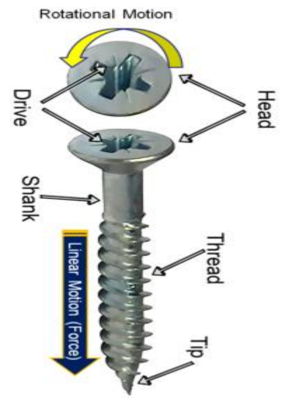


Figure 1.16: The screw

The mechanical advantage of the screw is given by:

$$M.A = \frac{\pi d}{p} = \frac{2\pi r}{p}, \qquad \text{diameter } (d) = 2\times \text{ radius } (r)$$

d = the mean diameter of the screw, and p = the pitch of screw in m.

Self-Test Exercise 1.17

Part I: Choose the correct answer from the given alternatives.

1. A device that is thick at one end and tapers to a thin edge at the other end is
   A. Screw B. wedge C. Inclined plane D. lever
2. Which of these is an example of a wedge?
   A. an axe B. a sea saw C. a ramp D. a can opener
3. Which simple machine is an inclined plane wound up on?
   A. screw B. wedge C. lever D. wheel and axle
4. Which simple machine is like two inclined planes put together?
   A. screw B. wedge C. lever D. wheel and axle
5. The length around the threads of a screw is the same as the
   A. height of an inclined plane B. width of an inclined plane
   C. Length of an inclined plane D. None of the above

The wheel and axle

Dear student! In the previous sub-sub section, you learned about the inclined plane, wedge, and screw and their mechanical advantages. Now you are going to learn about wheels and axles.

Wheel and axle: are comprised of a large wheel secured to a smaller wheel, which is called an axle. The wheel and axle can be used in two ways. In some devices, the input force is used to turn the wheel, and the output force is exerted by the axle. Because the wheel is larger than the axle, the mechanical advantage is greater than one. So, the output force is greater than the input force. Hence,

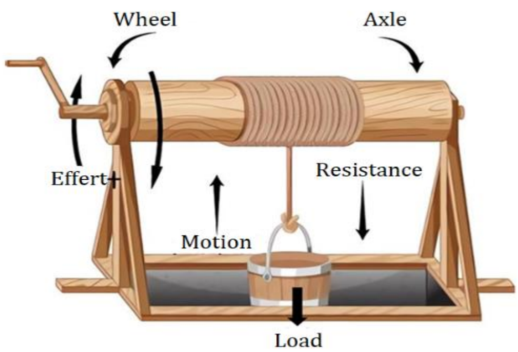
- A wheel with a rod through its center, called an axle, lifts or moves loads.
- The axle is a rod that goes through the wheel. This lets the wheel turn.
- The wheel and axle can be used as a tool to multiply the force you apply or the distance traveled.
- A lever is able to rotate through a complete circle (360°).
- The circle turned by the wheel is much larger than the circle turned by the axle.
- The increased distance over which the force is applied as the wheel turns results in a more powerful force on the axle, which moves a shorter distance.
- The larger the diameter of the wheel, the less effort you need to turn it, but you have to move the wheel a greater distance to get the same work done.

There are two basic types of wheel-and-axle simple machines.

1. A machine where the force is applied to the axle.

   Applying a large force to the axle makes the wheel go faster. The mechanical advantage is less than one, and the output force is less than the input force. Everyday examples of this type of wheel and axle include:

   - Bicycle
   - Car tires
   - Electric fan



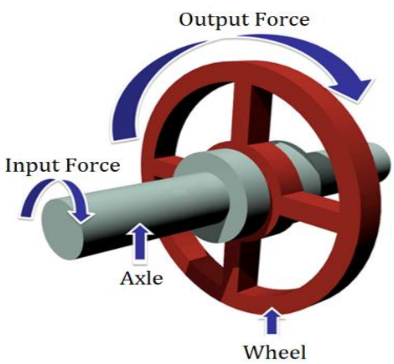


Figure 1.17: Arrangement of wheel and axle (input force is used to turn the wheel)

2. A machine where the force is applied to the wheel.

When you apply a small force to the wheel, it travels a longer distance and creates a stronger force on the axle. In this method, the effort (input force) has to move a long distance, whereas the load (output force) moves a short distance. This is because the circumference of the wheel is much larger than the circumference of the axle. This is helpful for lifting large loads.-Everyday examples of this type of wheel and axle include:

- Screwdriver
- Drill
- Windmill
- Water wheel
- Doorknob
- skateboard

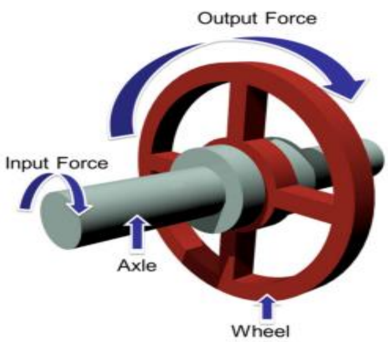


Figure 1.18: Arrangement of wheel and axle (input force is used to turn the axle)

Dear student! The mechanical advantage of the wheel and axle is given by:

$$AMA = \frac{L}{E}$$

The velocity ratio (V.R) of the wheel and axle is the ratio of the radius of the wheel to the radius of the axle. If R is the radius of the wheel and, r is the radius of the axle, then as a wheel covers a distance of $2\pi R$, the axle travels a distance of $2\pi r$.

$$V.R = \frac{distance\ moved\ by\ the\ effort}{distance\ moved\ by\ the\ load} = \frac{2\pi R}{2\pi r} = \frac{R}{r}$$

If there are no energy losses, $V.R = M.A = IMA = \frac{R}{r}$

Self-Test Exercise 1.18

Part I: Write True if the statement is correct and False if it is incorrect.

1. The wheel and axle in a car tire are used as force multipliers.
2. A doorknob is an example of a wheel and axle.
3. Wheels and axles can be used as force and speed multipliers.

Part II: Give short answers to the following questions

1. The diameter of the wheel is 20 times greater than the diameter of the axle. What is the velocity ratio of this wheel and axle system?

The pulley system

Dear student! In the previous sub-sub section, you learned about the wheel and axle and their mechanical advantages. Now you are going to learn about the pulley system.

Dear student! Try to answer the following brainstorming questions.

1. What is a pulley?
2. List different types of pulleys.
3. What is the purpose of using fixed and movable pulleys?

A pulley is a circular body (wheel) with a grooved surface that is free to rotate about its center.

There are different kinds of pulleys. They are:

1. Fixed pulley 2. Movable pulley 3. Compound pulley

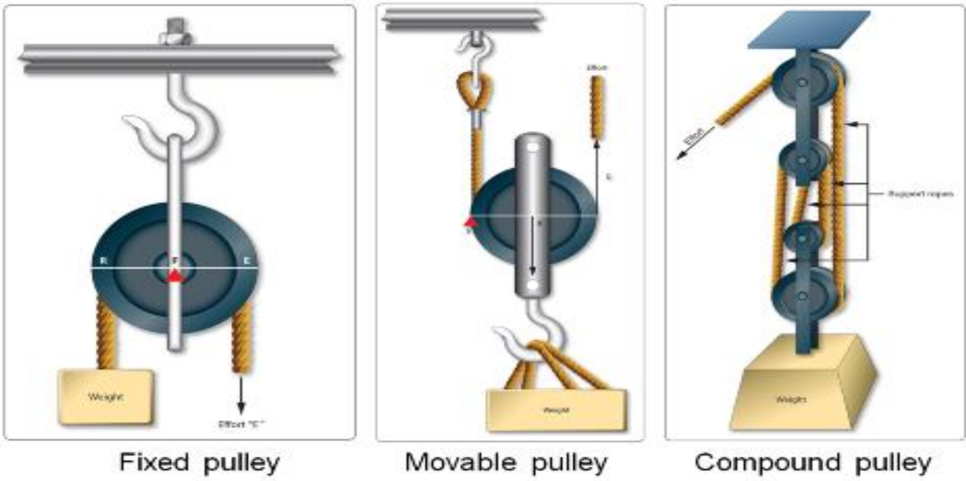


Figure 1.19: A fixed pulley, a movable pulley and a compound pulley

A fixed pulley: comprises a fixed axle with the rope looped over the top. A fixed pulley is used to change the direction of the force. A fixed pulley is the only pulley that, when used individually, uses more effort than the load to lift from the ground. The fixed pulley, when attached to an immovable object, e.g., a ceiling or wall, acts as a first-class lever with the fulcrum located at the axis, but with a minor change, the bar becomes a rope. The advantage of the fixed pulley is that you do not have to pull or push the pulley up and down. The disadvantage is that you have to apply more effort than the load.

A movable pulley: In this type of pulley, the axle is free to move up and down. For a movable pulley, if one end of the rope is fixed, applying an effort to the other end of the rope will effectively provide about twice the force. A movable pulley has a V.R = 2. That is, in order to lift the load 1m, you would have to pull 2 m of the rope through the pulley. The main disadvantage of a movable pulley is that you have to pull or push the pulley up or down. The main advantage of a movable pulley is that it requires effort to pull the load.

For both a fixed and a movable pulley, there are energy losses due to friction. As a result, mechanical advantage (M.A) is always less than the velocity ratio (V.R).

A compound pulley: is the combination of a fixed and a movable pulley. This is sometimes called a block and tackle. A combined pulley makes life easier as the effort needed to lift the load is less than half the weight of the load. The main advantage of this pulley is that the amount of effort is less than half of the load. The main disadvantage is that it travels a very long distance. Figure 5.15 shows different pulley types.

Self-Test Exercise 1.19

Part I: Choose the correct answer from the given alternatives.

1. The velocity ratio of a fixed pulley is
   A. 1 B. 2 c. 3 D. 0.5
2. The velocity ratio of a single movable pulley is
   A. 1 B. 2 C, 3 D. 0,5
3. The velocity ratio of a compound pulley in Figure 1.19 is
   A. 4 B. 2 C. 3 D. 1

Part II: Give short answers to the following questions

1. In a compound pulley what are the purposes of a fixed pulley and a movable pulley?
2. Construct or design pulley systems with:
   A. V.R = 3 B. V.R =4 C. V.R =5 D. V.R =6

√ Check List 1.5

Dear learner, now it is time to check your understanding about the mechanical advantage, velocity ratio, and efficiency of different types of simple machines. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you determine whether the machines are force multipliers, speed multipliers, or direction changers?	☐	☐
2. Can you define the terms work input, work output, effort, load, mechanical advantage (M.A), velocity ratio (V.R), and efficiency (ɳ)?	☐	☐
3. Can you derive the expression for efficiency?	☐	☐
4. Can you calculate the mechanical advantage and efficiency of simple machines?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 1.6: Designing the best model of a Simple Machines

Dear student! In the previous section, you learned about the mechanical advantage and efficiency of simple machines. In this section, you will learn how to construct simple machines in your local area.

Dear student! You are familiar with six kinds of simple machines and their mechanical advantages. Moreover, you have observed the working conditions of people in your community. There are many activities that require simple machines to make work easier. For example, people in your community are lifting a bucket of water from a deep well without using simple machines; they are carrying big loads without the help of simple machines, and so on. Therefore, you are required to:

1. List activities that need simple machines in your community.
2. Prioritize and select one activity in a group.
3. Collect materials.
4. Design a machine that includes at least two simple machines.

Unit summary

- A simple machine (compound machine) is a device that makes it easier to do mechanical work.
- Machines can be classified as direction changers, force multipliers, and speed or distance multipliers.
- There are six different types of simple machines (inclined plane, wedge, screw, lever, wheel and axle, and pulley).
- The force put into a machine is called the effort.
- Work input to a machine = effort × distance moved by the effort.
- Work output from a machine = load × distance moved by the load.
- AMA= load/effort.
- V.R=distance moved by effort/distance moved by the load.
- Efficiency (ɳ)= M.A/V.R.
- If there are no energy losses, AMA= IMA=V.R.
- There are three classes of levers depending on the relative position of the load, fulcrum and effort.
- For a lever the AMA=load/effort and V.R = $d_E\,/d_L$.
- For an inclined plane AMA=load/effort.
- If we assume there are no energy losses in an inclined plane then V.R=IMA =length of the slope (l)/height of the slope (h)
- For a wedge AMA= the force applied to the object being split apart/the force applied to the top surface of the wedge.
- If we assume there are no energy losses on the wedge, V.R=IMA=penetration length (l)/wedge thickness (t).
- For screw IMA= $\pi d/p$, where $d$is the average diameter of the screw and p is the peach.
- For wheel and axle, AMA=load/effort and V.R=radius of the wheel/radius of the axle.
- There are three different kinds of pulley systems: fixed, movable and compound.
- For a pulley, AMA=load/effort and V.R = IMA= N (number of sections of ropes used to lift the load)

Self-assessment questions

Part I: Choose the correct answer from the given alternatives.

1. Which one is **NOT** correct about simple machines?
   A. Machines help us to do work easier
   B. Machines create energy to help us
   C. Machines act as force multipliers
   D. Machines act as speed multipliers
2. Which one of the following is the purpose of a simple machine?
   A. Increasing volume C. multiplying energy
   B. Changing mass D. multiplying force
3. If a machine raises a load to a height of 8 m when effort is moved by 2m, which of the following is true about this machine?
   A. Distance multiplier C. Both force and speed multiplier
   B. Force multiplier D. direction changer
4. An effort of 30 N is applied to a machine to raise a load of 150 N. By how much does the machine multiply the force?
   A. 3 B. 5 C. 7 D. 0.25
5. A machine used 50 N of effort through a distance of 8 m in order to lift a load of 100 N through a distance of 4 m. What is the efficiency of the machine?
   1. 70% B. 80% C. 90% D. 100%

Part II: Write True if the statement is correct and False if it is incorrect.

1. In the real world, there is a machine, which is 100% efficient.
2. A fixed pulley is used to multiply a force.
3. A wedge is a double-inclined plane.
4. The separation between each thread in the screw is known as a pitch.

Part III: Work out

1. A simple wheel and axle are used to lift the bucket of water out of a well. The radii of the wheel and axle are 30 cm and 5 cm, respectively. Determine:
   a) The velocity ratio
   b) The effort required to lift a load of 40 N assuming no energy losses.
   c) The efficiency of the actual effort required is 20 N.

2. A block of weight 6000 N is pushed up the slope by a force of 300 N. Assume there are no energy losses. Determine:
   a) The actual mechanical advantage
   b) The velocity ratio
   c) The length of the slope if the height of the slope is 10 m.
3. A 12 cm long and a 3 cm wide wooden wedge is pushed into a soft wood block. Calculate:
   a) The velocity ratio of the wedge.
   b) The load on the soft wood if the effort applied is 20 N (assuming there are no energy losses).
4. What is the mechanical advantage of a lever that can lift 100 N load with an input force of 20 N?
5. A single movable pulley is being used to move a 140 N load. The pulley is a little dirty, so it adds another 5 N of frictional force.
   a) Can this load be moved with a 75 N input force? Explain your answer.
   b) Would a single fixed pulley work? Explain your answer

Part IV: Give short answers to the following questions

1. In order to displace 50 N of wood sideways a wedge of length 40 cm and thickness 8 cm is used. If MA of the machine is 4, then what is:
   a) the velocity ratio? B. the efficiency?
2. The pitch of the screw is 0.5 cm and effort applied at the end of the jack screw makes a circle of radius 10 cm. Calculate the velocity ratio of the screw,
3. A lever with the fulcrum at one end and the effort at the other is 3 m long. A load of 600 N is 60 cm from the fulcrum and is raised by the effort of 200 N. Calculate the efficiency of the lever.
4. An inclined plane is used to lift an object that weighs 360 N by using 60 N effort along a slope of length 20 m and at 60^0 with the horizontal. What is the velocity ratio of this machine?
5. A force of 80 N is needed to raise a 240 N load with pulley system. The load goes up 2 m for every 10 m of the rope pulled through the pulleys. What is the efficiency of the pulley system?

Written Assignment

Part I: Choose the correct answer from the given alternatives.

1. A block of weight 4000 N is pushed up a slope by a force of 400 N. The velocity ratio assuming there is no friction is
   A. 5 B. 10 C. 15 D. 20
2. Which one of the following quantities cannot be increased by any machines?
   A. distance B. speed C. force D. energy
3. Three of the following simple machines are basically the same. Choose the one that does not belong to the group.
   A. Pulley B. wedge C. lever D. wheel and axle
4. An inclined plane has a velocity ratio of 4. An effort of 5 N is needed to lift a 10 N load using the inclined plane. What is the efficiency of an inclined plane?
   A. 40% B. 20% C. 80% D. 50%
5. A simple wheel and axle is used to lift a bucket of water out of the well. The radii of the wheel and axle are 20 cm and 4 cm, respectively. What is the theoretical effort required to lift a load of 300 N when it is applied to the wheel?
   A. 600 N B. 150 N C. 30 N D. 60 N

Part II: Write True if the statement is correct and False if it is incorrect.

1. Efficiency is the ratio of work input to work output.
2. A pulley can be considered a special kind of lever,
3. knife is an example of a wedge.
4. The wheel and axle act as a force multiplier when effort is applied on the axle.
5. A spade is a second class of lever.

Part III: Work out

1. In order to displace 50 N of wood sideways a wedge of length 40 cm and thickness 8 cm is used. If MA of the machine is 4, then what is:
   b) the velocity ratio? B. the efficiency?
2. The pitch of the screw is 0.5 cm and effort applied at the end of the jack screw makes a circle of radius 10 cm. Calculate the velocity ratio of the screw,

3. A lever with the fulcrum at one end and the effort at the other is 3 m long. A load of 600 N is 60 cm from the fulcrum and is raised by the effort of 200 N. Calculate the efficiency of the lever.
4. An inclined plane is used to lift an object that weighs 360 N by using 60 N effort along a slope of length 20 m and at 60^0 with the horizontal. What is the velocity ratio of this machine?
5. A force of 80 N is needed to raise a 240 N load with pulley system. The load goes up 2 m for every 10 m of the rope pulled through the pulleys. What is the efficiency of the pulley system?

Part IV: Give short answers to the following questions

1. Explain the causes for a simple machine to be
   i) Force multiplier ii) speed multiplier iii) direction changer
2. Explain three classes of lever with example.

Answer Key for Self-assessment questions

Self-Test Exercise 1.1:

1. To change direction. 2. To multiply a force. 3. To multiply a speed.

Self-Test Exercise 1.2:

1. False 2. False 3. False
1. B 2. B 3. B
1. Simple machines are used i) to change the direction of force ii) to multiply a distance or speed iii) to multiply a force.
2. No, energy can neither be created nor destroyed but is transferred from one form to another. So, it is impossible to multiply energy.

Self-Test Exercise 1.3:

Develop a list of simple machines at home and show it to your tutor.

Self-Test Exercise 1.4:

No.	A simple machine	Purpose
1	hammer	Used to multiply a force
2	Knife	Used to multiply a force
3	Axe	Used to multiply a force
4	Shovel	Used as a distance or speed multiplier

Self-Test Exercise 1.5:

No	Description of a simple machine	How it makes work easier
1	Lever	Multiplying force
2	Wheel and axle	Multiplying force
3	Lever	Multiplying force
4	Pulley	Changing direction
5	Wedge	Multiplying force
6	Screw	Multiplying force
7	Wheel and axle	Multiplying speed
8	Wheel and axle	Multiplying speed
9	Inclined plane	Multiplying force
10	Wedge	Multiplying force
11	Wedge and wheel and axle	Multiplying force
12	Inclined plane	Multiplying force
13	Lever	Multiplying force
14	Lever	Multiplying distance/speed
15	Wheel and axle	Multiplying force
16	Inclined plane	Multiplying force
17	Lever	Multiplying distance/speed
18	Wheel and axle	Multiplying force
19	Wedge and lever	Multiplying force
20	Lever	Multiplying force

Self-Test Exercise 1.6:

1. False 2. False
1. B 2. A 3. C
1. See section 1.4 in this unit
2. See section 1.4 in this unit

Self-Test Exercise 1.7:

1. 15

Self-Test Exercise 1.8:

Load (N)	M.A	Effort (N)
1800	3	600
40	0.25	160
240	0.5	480
900	0.3	3000
2000	4	500

If $V.R < 1$, the distance moved by the load is greater than the distance moved by the effort. So, the simple machine is a distance multiplier or a speed multiplier.

If $V.R > 1$, the distance moved by the load is less than the distance moved by the effort. So, the simple machine is a force multiplier.

Self-Test Exercise 1.9:

Distance moved by effort	V.R	Distance moved by the load
0.2	4	0.05
0.8	0.4	2
6	0.6	10
1.8	0.3	6
12	2	6

Self-Test Exercise 1.10:

1. $\eta = 75\%$ means, 75% of the work input to the machine is obtained as a useful work output. The remaining 25% of the work input has been lost in overcoming the friction.

Self-Test Exercise 1.11:

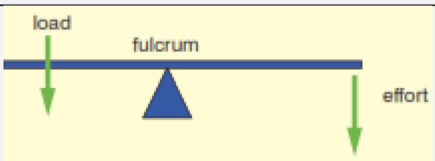
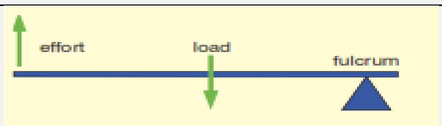
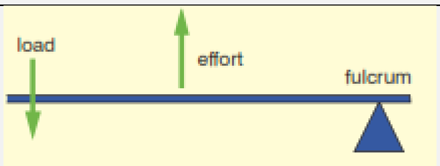
1. $\eta = \frac{M.A}{V.R} = \frac{3}{6} = 0.5$ or $\eta = \frac{M.A}{V.R} \times 100\% = \frac{3}{6} \times 100\% = 50\%$

2. If $M.A = V.R$, then $\eta = 1$ and the machine 100% efficient. That is 100% of the work input to the machine is obtained as a useful work output. There is no loss in energy due to friction.

Self-Test Exercise 1.12:

1. The different parts of lever are load, fulcrum and effort.
2. Guide the students to discuss in group and list some examples of lever that people are using in the local area.
3. Levers can be used as force multipliers or speed multipliers. Levers can be force multipliers, when they increase the force that is put in (the effort). They can be distance or speed multipliers if they make the load move further than the effort. The amount of the force or the distance is multiplied depends on the distance between the load and the fulcrum and the effort and the fulcrum.

Self-Test Exercise 1.13:

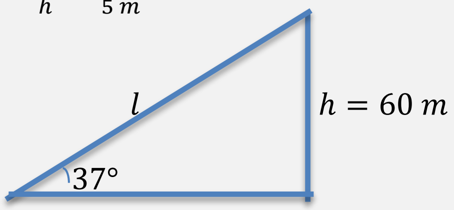
Class	Diagram	Description	Examples
1st		Fulcrum is between the load and effort	1.Scissors 2.See-saw 3.Crow bar 4.Bottle opener
2nd		The load is between the effort and load	1.Wheel barrow 2.Paper cutter 3.Nut crackers
3rd		The effort is between the load and fulcrum	1.Spade 2.Charcoal tongs 3.Tweezers

Self-Test Exercise 1.14:

1. B 2. B 3. B 4. A 5. C

Self-Test Exercise 1.15:

1. $V.R = \frac{l}{h} = \frac{30\ m}{5\ m} = 6$
2.



$\sin 37° = \frac{h}{l} \Longrightarrow l = \frac{h}{\sin 37°} = \frac{60\ m}{0.6}$

$l = 100\ m$

$V.R = \frac{l}{h} = \frac{100\ m}{60\ m} = 1.67$

Given	Required	Solution
$l = 40\ m$	$M.A = ?$	$M.A = \frac{Load}{effort} = \frac{F_L}{F_E} = \frac{240\ N}{80\ N} = 3$
$h = 8\ m$	$V.R = ?$	$V.R = \frac{l}{h} = \frac{40m}{8\ m} = 5$
$F_E = 80\ N$	$\eta = ?$	$\eta = \frac{M.A}{V.R} = \frac{3}{5} = 0.6$ or 60%
$F_L = 240\ N$		

Self-Test Exercise 1.16:

1. Wedges are two inclined planes joined back-to-back. Wedges are used to split or hold objects together.
2. Tell students discuss in group the purpose of using wedges in their local area. In most cases they use wedges as force multipliers.
3. Ask students to list examples of wedges used in their village. Some common examples are: knives, axe blade, nails, and spears and so on.
4. An inclined plane stays in one place and something moves up and down the slope. However, the wedge moves to do its work. Inclined planes are used to lift heavy objects to some height, whereas wedges are used to split objects into two parts.

Self-Test Exercise 1.17:

1. B 2. A 3. A 4. B 5. C

Self-Test Exercise 1.18:

1. False 2. True 3. True

1. Given Required

$d_{wheel} = 20d_{axel}$ $M.A = ?$

$M.A = \frac{R_{wheel}}{r_{axle}} = \frac{d_{wheel}}{d_{axle}} = 20$

Self-Test Exercise 1.19:

1. A B. B C. A
2. In a compound pulley, the purpose of using a fixed pulley is to change the direction of force. However, the purpose of using a movable pulley is to multiply force.
3. Discuss with your tutor and draw the system of pulleys.

1. B 2. D 3. A 4. B 5. D

1. False 2. False 3. False 4. True 5. True

1. a) Given Required

$r_{wheel} = 30\ cm$ $V.R = ?$ $V.R = \frac{r_{wheel}}{r_{axle}} = \frac{30\ cm}{5\ cm} = 6$

$r_{axel} = 5\ cm$

b) $F_L = 40\ N$ $F_E = ?$ If there are no energy losses, $M.A = VR$

$\frac{F_L}{F_E} = 6 \implies F_E = \frac{40\ N}{6} = 6.67\ N$

c) $F_E = 20\ N \implies M.A = \frac{F_L}{F_E} = \frac{40\ N}{20\ N} = 2$ $\eta = \frac{M.A}{V.R} = \frac{2}{6} = 0.33 = 33.3\%$

2. a) Given Required

$F_L = 6000\ N$ $AMA = ?$ $AMA = \frac{F_L}{F_E} = \frac{6000\ N}{300\ N} = 20$

$F_E = 300\ N$

No energy losses

b) If there are no energy losses, $AMA = V.R = 20$

c) $h = 10\ m$ $l = ?$ $V.R = \frac{l}{h}] \implies 20 = \frac{l}{10\ m} \implies l = 200\ m$

3. Given Required

$l = 12\ cm$ a) $V.R = ?$ $V.R = \frac{l}{t} = \frac{12\ cm}{3\ cm} = 4$

$t = 3\ cm$ b) What is F_L? if F_E=20 N.

If there is are no energy loses, $M.A = V.R \implies \frac{F_L}{F_E} = 4 \implies F_L = 4F_E = 80\ N$

4. Given Required

$F_L = 100\ N$ $M.A = ?$ $M.A = \frac{F_L}{F_E} = \frac{100\ N}{20\ N} = 5$

$F_E = 20\ N$

5. Given

The total load= $140\ N\ (Actual\ weight) + 5\ N\ (dirt\ on\ pulley) \Longrightarrow F_L = 145\ N$

$F_E = 75\ N$

a) Yes, the load can be moved by a movable pulley. This is because the movable pulley multiplies the applied force twice. That is, 150 N is more than enough to move a 145 N load.

b) No, the fixed pulley only changes the direction, and it is impossible to lift a 145 N load by applying a 75 N force.

1. See your module.
2. See your module.
3. $AMA < IMA$ because, there are energy losses due to friction in real application of simple machines.
4. See your module.
5. See your module.

Unit 2

Mechanical Oscillation and Sound wave

Introduction

Many systems oscillate, that is, they move back and forth about a fixed point. All oscillations involve force and energy. For example, you push a child in a swing to get the motion started. You put energy into a guitar string when you pluck it. Some oscillations create waves. A wave is a disturbance that moves from its source accompanied by a transfer of energy. A guitar creates sound waves, and you can make water waves in a swimming pool by slapping the water with your hand. Some, such as water waves, are visible. Some, such as sound waves, are not. Oscillation is also known as periodic motion. Periodic motion is a motion that repeats itself. A small object oscillating at the end of a spring, a swinging pendulum, etc. are examples of periodic motion.

After reading this unit, you should be able to:

- *understand the oscillation of strings, a pendulum, and a spring-mass system;*
- *know the propagation of different types of waves;*
- *distinguish between different types of waves;*
- *estimate the speed of a sound in different media and at different temperatures*

Unit Contents

The Required Study Time: The time allotted for this section is 15 hours.

Learning Strategies:

- Use search engines for online resources and virtual labs to study the common characteristics of waves.
- Use necessary materials to investigate the vibration of string, pendulum, and spring-mass systems. Try to understand the concepts of amplitude, wavelength, period, and frequency.
- Collect data about pendulum and spring oscillations; let you propose and implement ways of making accurate measurements of length, mass, and time.
- Organize and analyze the data so that you arrive at the formula for the periods of pendulum and spring oscillation.
- Use a spring-mass system to trace the waveform of a simple harmonic oscillator. Re-construct the wave form by comparing the trace with sinusoidal wave forms and using it investigate wave characteristics such as frequency, period, wavelength, amplitude, phase, and wave speed.
- Determine wave speed in different mediums at different temperatures.
- Encourage yourself to read about such concepts as wave propagation, reflection, and standing waves.
- Make observations at home and in the surrounding area to identify bodies producing sound, record a brief description of how sound is produced in each case, and determine whether the sound from these sources is comfortable or disturbing.

- Propose solutions to the problems you identified from your observation of the surrounding area.

Section 2.1: Common Characteristics of Waves

Dear student! In this section, you will learn about the characteristics that all waves have in common. Can you list some common characteristics of waves?

After reading this section, you should be able to:

- *define the common characteristics of waves such as period, frequency, wavelength, and amplitude;*
- *describe terms like crest, trough, and wave speed;*
- *relate wave frequency, period, wavelength, and velocity;*
- *solve problems involving wave properties.*

There are common terms such as period, frequency, amplitude, wave speed, and wavelength that are used to explain periodic motion. These are common characteristics that all waves share and are discussed below.

Rest position: Rest position is the undisturbed position of particles when they are not vibrating. **Displacement**: Displacement is the distance that a certain point in the medium has moved from its rest position.

Trough: Trough is the lowest point below the rest position. **Crest**: Crest is the highest point above the rest position.

Period (T): Period, denoted by symbol T, is the time for one complete cycle of the periodic motion. It is also defined as the time taken for one complete wave to pass a given point.

Frequency (f): Frequency, denoted by symbol f, of a wave is defined as the number of complete waves passing a given point per unit time. The higher the frequency, the greater the number of waves per second. A common unit for frequency is one cycle per second. This is defined as one Hertz (Hz).

$$1\text{Hz} = 1\ \text{cycle/s}.$$

Amplitude (A): Amplitude is defined as the maximum displacement from equilibrium position. Amplitude is denoted by the symbol A and measured in meters(m).

Wave speed (v): Wave speed is defined as the distance the wave travels in one second. It is denoted by the symbol v and like all speeds, it is measured in meters per second.

Wavelength (λ): Wavelength is defined as the distance between identical points on adjacent waves. For example, the distance between two adjacent crests or troughs of a wave is one wavelength. Wavelength is denoted by the Greek letter λ (lambda).

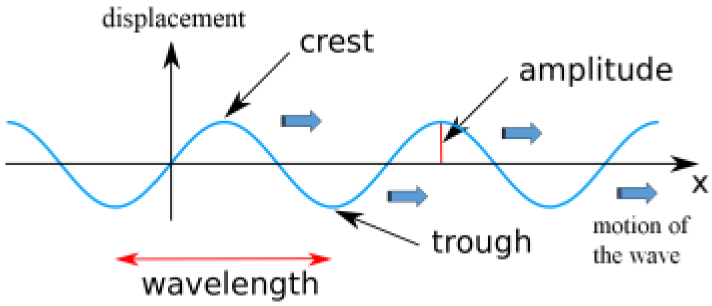


Figure 2.1: Characteristics of wave

Next, we illustrate the relation between period, frequency, wavelength, and wave speed. We begin with a simple question. What does it mean by a wave of frequency 1Hz, 2Hz, 3Hz, etc.? If you consider a wave with a frequency of 2 Hz, this would mean two waves passing one point per second. This implies that each wave would take 0.5 seconds to pass the point. Therefore, the period of the wave is 0.5 seconds. Hence, the period is the reciprocal of the frequency.

$$f = \frac{1}{T} \quad or \;\; T = \frac{1}{f}$$

In terms of wavelength and frequency, wave speed can be written as,

$$wave\ speed = \ frequecy\ \times\ wavelength$$

$$v = f \times \lambda$$

☞ Period, Frequency, Amplitude, Waves peed, and Wavelength are common characteristics of all waves.

√ **Check List 2.1**

Dear learner, now it is time to check your understanding about the common characteristics of waves. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you define the common characteristics of waves such as period, frequency, wavelength and amplitude?	☐	☐
2. Can you describe terms like crest, trough, and wave speed?	☐	☐
3. Can you relate wave frequency, period, wavelength, and velocity?	☐	☐
4. Can you solve problems involving wave properties?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 2.2: String, Pendulum, and Spring

Dear student! In this section, you will learn about string, pendulum, and spring. Have you ever played a swing? What do you think will happen if you stretch or compress a mass attached to spring? Try to practically observe such phenomena.

After reading this section, you should be able to:

- *calculate the period of a simple pendulum of a given length;*
- *compute the period of oscillation of a spring mass system on a smooth horizontal surface;*
- *define Hooke's law;*
- *practically measure the periods of a simple pendulum of a given length and spring mass system in a laboratory or class;*
- *calculate the value of the acceleration due to gravity in your locality*

If you flick the string once, either up or down, a single traveling disturbance is created. This single disturbance's propagation is called a pulse. The pulse moves horizontally along the string while the particles of the string move up and down at right angles to the horizontal motion of the pulse. A wave is comprised of a series or train of pulses traveling in a medium.

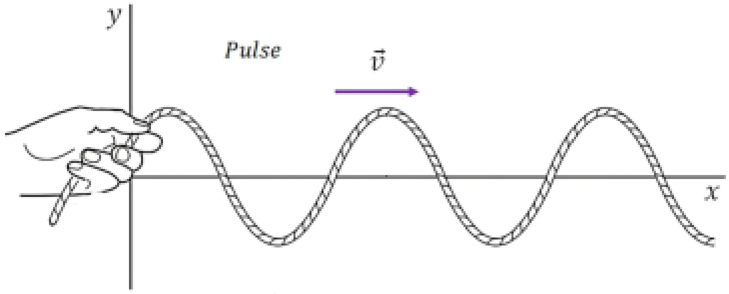


Figure 2.2: Pulsed string wave

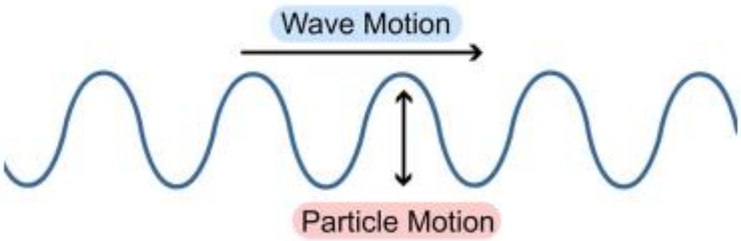


Figure 2.3: Particle and wave motion

Periodic motion

A to-and-fro movement that repeats itself over and over in a fixed time interval is referred to as periodic motion. The beating of your heart, the ticking of a clock, and the movement of a child on a swing are familiar examples. One of the key characteristics of a periodic system is the time required for the completion of one cycle of its repetitive motion. A simple swinging pendulum is another example of periodic motion. A simple pendulum consists of a point mass (the bob) suspended by a massless, non-stretchable string.

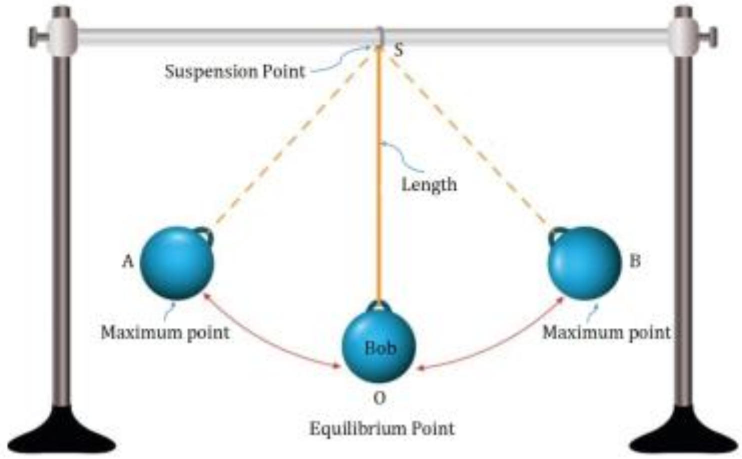


Figure 2.4: Schematics of simple pendulum

If the pendulum is displaced from equilibrium, it swings back and forth, and its motion is periodic.

A simple pendulum is defined to have an object that has a small mass, also known as the pendulum bob, that is suspended from a light wire or string, such as that shown in *Figure 2.4*.

The period of a simple pendulum is given by

$$T = 2\pi\sqrt{\frac{L}{g}}$$

where L is the length of the simple pendulum, and g is the acceleration due to gravity. This result is interesting because of its simplicity. The only parameters that affect the period of a simple pendulum are its length and the acceleration due to gravity. The period is completely independent of other factors, such as mass. If the length of a pendulum is precisely known, it can actually be used to measure the acceleration due to gravity.

Example 2.1: What is the period of a simple pendulum with length 50 cm? Use the acceleration due to gravity $g = 9.8\ \mathrm{m}/\mathrm{s}^2$

Given: $L = 50\ \mathrm{cm} = 0.5\ \mathrm{m},\ g = 9.8\ \mathrm{m}/\mathrm{s}^2$

Required: The period T

Solution: The period of a simple pendulum is given by

$$T = 2\pi\sqrt{\frac{L}{g}},$$

Substituting the values of L and g and using $\pi = 3.14$ we have,

$$T = 2\pi\sqrt{\frac{0.5\ \mathrm{m}}{9.8\ \mathrm{m}/_{s^2}}} = 1.42\ s$$

Example 2.2: A simple pendulum has a length of 100 cm and oscillates periodically with a period of $0.65\pi\ s$ at a certain place. What is the size of the acceleration due to gravity at that place?

Given: $L = 100\ \mathrm{cm} = 1\ \mathrm{m} T\ = 0.65\pi\ \mathrm{s}$

Required: The acceleration due to gravity g.

Solution: From the expression of the period of a simple pendulum,

$$T = 2\pi\sqrt{\frac{L}{g}},$$

The acceleration due to gravity at that place is given by

$$g\ = \left(\frac{2\pi}{T}\right)^2 L = \left(\frac{2\pi}{0.65\pi\ s}\right)^2\ 1\mathrm{m}$$

$$=\ 9.47\ m/s^2$$

☞ The period of a simple pendulum depends only on its length and the acceleration due to gravity. It does not depend on the mass of the bob.

Activity 2.1

- Poke a stick into water contained in a dish. What do you observe? Instead of poking the stick into the water once, continuously move it in and out. Now what do you observe? Discuss the phenomenon with your friends and your teacher.

Activity 2.2

- Use a simple pendulum to determine the acceleration due to gravity g in your locality. Cut a piece of string that is about 1m long and attach a metal ball (or any small object of high density) to the end of the string. Starting at an angle of less than 10o, allow the pendulum to swing. Using a stopwatch, measure the period of the simple pendulum for 10 complete oscillations and calculate g. How accurate is this measurement? How might it be improved?

The simple spring

We are all familiar with a spring. Suppose an object of mass m is attached to one end of the spring, while the other end is held fixed. The object has an equilibrium position, call it x = 0, and this is the position where the spring is neither stretched nor compressed. If the object is displaced away from x = 0 (either stretched or compressed) and released, it will undergo a to–and-fro motion about x = 0. This is another example of periodic motion. In this case, x is the distance by which the spring is either stretched or compressed and is measured from the equilibrium position.

If the object is displaced form x = 0, the spring pulls (or pushes) it back to the equilibrium position (x = 0). Thus, the spring produces a restoring force denoted by F_{res}. The restoring force is related to the extension of the spring by Hook’s law. Thus, Hook’s law is stated as, ’The restoring force (or the force exerted by the spring) is directly proportional to the displacement of the object from the equilibrium position x. Mathematically,

$$F_{res} = -kx \,,$$

where k is a proportionality constant called the spring constant (or stiffness) of the spring. Its SI unit is N/m (newton per meter). The negative sign indicates that the restoring force always acts opposite to the direction of motion or displacement of the spring-mass system. The restoring force F_{res} is equal in magnitude and opposite in direction to the applied force that causes the displacement. That is,

$$F_{app} = -F_{res} = -(-kx) \,,$$

$$F_{app} = kx \,,$$

where, F_{app} is now the applied force on the spring.

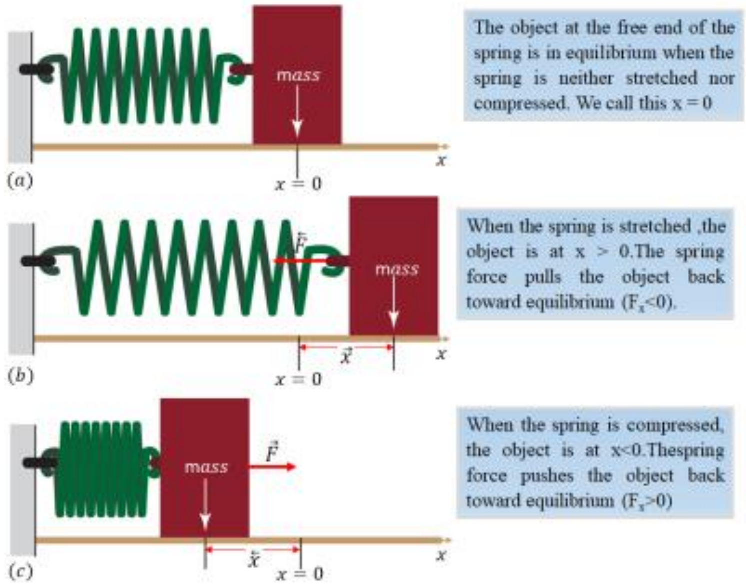


Figure 2.5: Demonstration of Hooke's law using displacement of a spring

The force exerted by the spring is a restoring force. No matter which way the object is displaced from equilibrium, the spring force always acts to return the object to equilibrium. If k is large, then the spring is stiff and produces a lot of force for a small displacement. If k is small, then the spring is said to be loose and doesn't pull back with much force. The spring constant k can be measured by applying a force (F_{app}) and measuring how much the spring stretches (x). Then $k = \frac{F_{app}}{x}$ and has units of force/distance (N/m).

An oscillating object moves repeatedly one way and then in the opposite direction through its equilibrium position. The displacement of the object (i.e., distance and direction) from equilibrium continually changes during the motion. In one full cycle after being released from a non-equilibrium position, the displacement of the object:

- decreases as it returns to equilibrium;
- reverses and increases as it moves away from equilibrium in the opposite direction;
- decreases as it returns to equilibrium;
- increases as it moves away from equilibrium towards its starting position.

Activity 2.3

- Discuss different examples of spring by bringing them to class. Which springs are stiffer, and which ones are loose?

The force exerted by the spring is a restoring force. No matter which way the object is displaced from equilibrium, the spring force always acts to return the object to equilibrium

Now, suppose the cart is released from rest at the location x = A. As indicated in Figure 2.6, the spring exerts a force on the cart to the left, causing the cart to accelerate toward the equilibrium position. When the cart reaches x = 0, the net force acting on it is zero. Its speed is not zero at this point, however, and so it continues to move to the left. As the cart compresses the spring, it experiences a force to the right, causing it to decelerate, and finally comes to rest at x = -A. The spring continues to exert a force to the right; thus, the cart immediately begins to move to the right until it comes to rest again at x = A, completing one oscillation in the time T.

From *Figure 2.6*:

a) The mass is in its resting position and at its maximum positive value of x. Its velocity is zero, and the force on it points to the left with maximum magnitude.
b) The mass is at the equilibrium position of the spring. Here the speed has its maximum value, and the force exerted by the spring is zero.
c) The mass is at its maximum displacement in the negative x direction. The velocity is zero here, and the force points to the right with maximum magnitude.
d) The mass is at the equilibrium position of the spring, with zero force acting on it and maximum speed.
e) The mass has completed one cycle of its oscillation about x = 0.

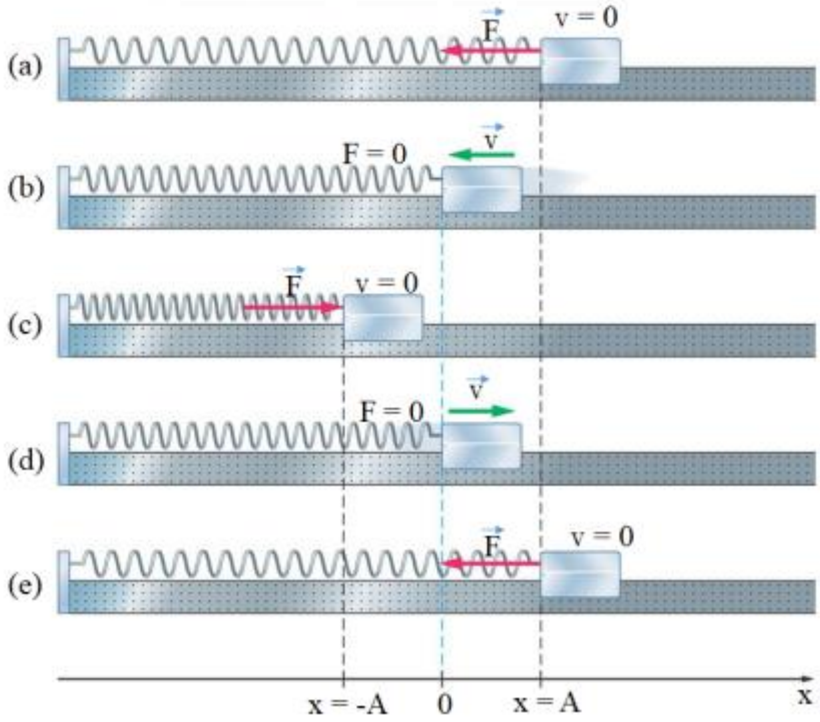


Figure 2.6: mass attached to a spring undergoes periodic motion about x = 0

The period of an object of mass m attached to a spring of spring constant k is given by

$$T = 2\pi\sqrt{\frac{m}{k}}$$

where, m is the mass of the object and k is the spring constant of the spring. It can be seen that the period only depends on the mass and the spring constant (or stiffness) of the spring.

Example 2.3: A block of mass 2 kg is connected to the free end of a spring with a spring constant of 200 N/m. Compute the period of the block.

Given: $m = 2\text{ kg}, \quad k = 200\frac{\text{N}}{\text{m}},$

Required: The period *T*

Solution:

$$T = 2\pi\sqrt{\frac{m}{k}}$$

$$T = 2\pi\sqrt{\frac{2\text{ kg}}{200\text{N/m}}} = 2\pi\sqrt{\frac{1}{100}}\text{ s} = \frac{2\pi}{10}\text{ s} = \frac{\pi}{5}\text{s}$$

Self-Test Exercise 2.1

Give short answers to the following questions

A block of mass 4kg is connected to the free end of a spring and undergoes periodic motion with a period of 10 s. Compute the spring constant of the spring in N/m.

√ Check List 2.2

Dear learner, now it is time to check your understanding about string, pendulum, and spring. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you calculate the period of a simple pendulum of a given length?	☐	☐
2. Can you compute the period of oscillation of a spring mass system on a smooth horizontal surface?	☐	☐
3. Can you define Hooke's law?	☐	☐
4. Are you able to practically measure the periods of a simple pendulum of a given length and spring mass system in a laboratory or class?	☐	☐
5. Are you able to calculate the value of the acceleration due to gravity in your locality?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 2.3: Propagation of Waves and Energy Transmission

Dear students! In this section, you will learn about the propagation of waves and energy transmission. Do you think waves carry energy? If your answer is yes, how can you proof it?

After reading this section, you should be able to:

- *differentiate between mechanical, electromagnetic, longitudinal, and transverse waves;*
- *give examples of mechanical, electromagnetic, longitudinal, and transverse waves;*
- *describe the propagation of waves practically using string and water.*

A wave is a disturbance propagating in space or in matter. A musician's instrument creates waves that carry sound to your ears. Dialing a cell phone to call a friend sends microwaves from the cell phone antenna; the microwaves carry the signal containing your voice to your friend. Similarly, when you throw a stone into a pond, the energy of the falling stone creates waves in the water that carry the energy to the edge of the pond. Do you think waves require a material medium for their propagation? In this section, we see that some waves need a material medium for their propagation, while others do not. Waves that require a material medium for their propagation are called mechanical waves. Other types of waves, known as electromagnetic waves, do not need a material medium for their propagation.

Mechanical waves travel through a material as a result of the vibration of the particles of the material (water, wood, air, etc.). It is these vibrations that form the wave. All mechanical waves require a medium to travel through. Examples of mechanical waves include sound waves, water waves, waves in strings, etc.

Electromagnetic waves do not require a medium to travel through. They are composed of vibrating electric and magnetic fields, and there are no particle vibrations at all. This means electromagnetic waves are able to travel through a vacuum. Examples of electromagnetic waves include light, radio waves, x-rays etc.

The above discussion of wave propagation is dependent on whether the waves require a material medium for their propagation or not. It is also possible to explain wave propagation depending on the relation between the direction of propagation of the wave and the direction of vibrations of the particles in the medium. On this basis, waves can be classified as transverse and longitudinal.

Transverse and Longitudinal Waves

A transverse wave is a wave where the direction of propagation of the wave is perpendicular to the direction of vibrations of particles in the medium. In other words, in transverse waves, the directions of the particles' vibrations are at right angles to the direction of energy transfer (wave movement). Examples of transverse waves include all electromagnetic waves, waves on strings, etc. *Figure 2.7* shows a transverse wave on the string. To generate such a wave, start by tying one end of a long string or rope to a wall. Pull on the free end with your hand, producing tension in the string, and then move your hand up and down. Note that the wave travels in the horizontal direction, even though your hand oscillates vertically about one spot. The displacement of particles in a string is at right angles to the direction of propagation of the wave.

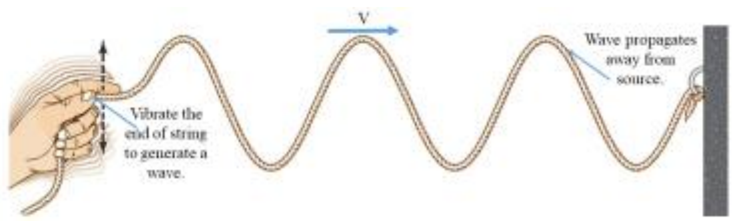


Figure 2.7: Example of a transverse wave on a string

In longitudinal waves, the direction of propagation of the wave (the direction of energy transfer) is parallel to (in the same direction as) the direction of vibrations of particles in the medium. This means, the vibrations are going forward and backward along the wave. Examples of longitudinal waves include sound waves, pressure waves, etc. Propagation of longitudinal waves results in areas of compression and rarefaction. Compressions refer to regions where the particles are pushed together, whereas rarefactions refer to regions where the particles move apart (see *Figure 2.8*). Compressions and rarefactions can be considered the longitudinal versions of a crest and a trough, respectively. Moreover, if the medium of propagation is gas, compressions and rarefactions can be thought of as regions of high and low pressure, respectively.

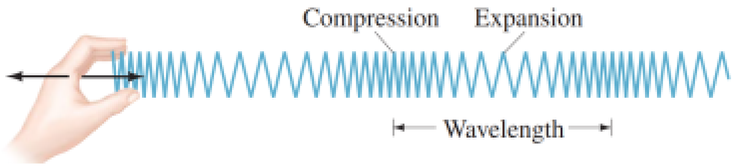


Figure 2.8: Illustration of longitudinal wave

☞ All mechanical waves require a medium to travel through. Electromagnetic waves do not require a medium to travel through.

In a transverse wave, the displacement of individual particles is at right angles to the direction of propagation of the wave.

A transverse wave is a wave where the direction of propagation of the wave is perpendicular to the direction of vibrations of particles in the medium. In longitudinal waves, the direction of propagation of the wave is parallel to the direction of vibrations of particles in the medium.

√ Check List 2.3

Dear learner, now it is time to check your understanding about the propagation of waves and energy transmission. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you differentiate between mechanical, electromagnetic, longitudinal, and transverse waves?	☐	☐
2. Can you give examples of mechanical, electromagnetic longitudinal, and transverse waves?	☐	☐
3. Can you practically describe the propagation of waves using string and water?	☐	☐

Is there any question for which you marked “no’ in the box under it? If so, please go back to your text and read about it.

Section 2.4: Sound Waves

Dear student! In this section, you will learn about sound waves. Can you list some sources of sound? During thunderstorm, you see the flash light before you hear the sound. What do you think is the reason?

After reading this section, you should be able to:

- *identify sources of sound waves and explain how sound is produced;*
- *compare the speed of sound in different materials;*
- *determine the speed of sound in air at a given temperature;*
- *explain reflection, refraction, diffraction, and interference of sound waves.*

Have you ever tried to play a "guitar" or "kirar"? When you strike each string, it starts to vibrate, and as a result, you hear a musical sound. When a tuning fork is struck against a hard object, the prongs vibrate (move backward and forward). The vibrations travel away from the tuning fork as a wave called a sound wave.

Sound is one of the most common phenomena in nature. You hear different sounds throughout the day. The sound of cars, the barking of dogs, friends chatting, a teacher talking, and music are some examples of sounds. All the above-mentioned sounds stimulate your ears and make you recognize the sources of sound and the messages sent through sound. In this topic, we explain what a sound is, the production and propagation of sound, the speed of sound in different media, and the reflection of sound (echo).

Sound carries energy and loses it as it travels. Our ears are designed by nature to pick up sound transmitted through different materials. Like other waves, sound has the properties of frequency, wavelength, amplitude, and speed.

Production and Propagation of Sound

Sound waves are the most common example of longitudinal waves. They travel through any material medium at a speed that depends on the properties of the medium. As the wave travels through air, the elements of air vibrate, producing changes in density and pressure along the direction of the wave's motion. Sound is generated by the series of vibrations of an object. Every source of sound is in a state of vibration.

When you touch the pith ball with a tuning fork, nothing happens to the pith ball. Now strike the tuning fork by the hammer on the prong while holding on to its stem. Then touch the pith ball with the fork; you can see the pith ball will fling away. This shows that the energy on the prong is transferred to the pith ball, and the pith ball starts to vibrate.

All the sounds you hear are produced by a vibrating object. The air near the vibrating object is set in motion in all directions. The produced sound travels in every direction in the form of energy and reaches your ear.

The material through which the sound travels and reaches your ear is called a medium. Sound needs a material medium for its transmission. For example, being in a classroom, you hear the school bell ringing, a student shouting in a field, or an ambulance siren. All these sounds travel and reach your ear using air as a medium.

Activity 2.4

- Take different materials such as a whistle, a ruler, a tuning fork, etc. from your locality and produce a sound using them. Explain how each material produces a sound. How does the sound reach your ears? Explain and confirm that sounds are produced by vibrating objects.

Activity 2.5

- Tie a pith ball with a thread and suspend it from any height. Bring a tuning fork and touch the pith ball with it. What do you observe? Strike the tuning fork with a rubber hammer or on a table edge, and touch the pith ball. What do you observe? What does this show?

Activity 2.6

- This activity shows the transmission of sound through solids. Two students sitting at the two ends of a table will do this activity. Let one student from one end scratch the table with his/her finger nail slightly while you are sitting on the other end of the table and listening. Have you heard the scratch or not? Now let the other student who is sitting place his/her ear against the table while you are scratching. Ask the student who has placed his/ her ear against the table, what he/she has heard. Can you tell the difference? What do you conclude from this activity?

Speed of Sound

Have you ever compared the speed of sound and light? Exercise 6.2 helps you compare the two.

The speed of sound waves in a medium depends on the compressibility and density of the medium. This means that sound has different speeds in different media. The speed of sound in air is about 331 m/s at 0 °C. The speed of sound in air (v) at any temperature T can be calculated as

$$v = (331\mathrm{m/s})\sqrt{1+\frac{T_c}{273°\mathrm{C}}}$$

where 331m/s is the speed of sound at $0\,°\mathrm{C}$ and T_c is the air temperature in degrees Celsius. The speed of sound in liquids and solids is not significantly affected by the change in temperature but is affected by their body structure.

Example 2.4: What is the speed of sound in air at $20\ °\mathrm{C}$?

Given: $T_c = 20\ °\mathrm{C}$

Required: The speed of sound v

Solution: The speed of sound at temperature T_c is given by:

$$v = (331\mathrm{m/s})\sqrt{1+\frac{T_c}{273°\mathrm{C}}}$$

$$v = (331 m/s)\sqrt{1 + \frac{20℃}{273℃}} \approx 343 m/s$$

The difference in speed of sound in different materials can be easily understood from the structure of molecules in the substance. The transmission of sound in different substances depends on the structure of the particles in those substances. Since the particles in solids are close together, they easily pass the sound to the next particles by collision, and the sound moves faster. The particles in liquids are close together but not bound. However, in gases, the particles are far apart and collision between them takes place rarely. This is why sound travels slower in liquids than in solids and faster in liquids than in gases. The speed of sound in different materials is given in *Table 2.1*.

Table 2.1: The speed of sound in various materials

S. No	Material	Speed of sound in m/s
1	Air (0^oC)	331
2	Air (0^oC)	343
3	Sea water (25^oC)	1533
4	Water (25^oC)	1493
5	Iron	5950
6	Lead	1960
7	Rubber	1600

☞ Sound is generated by a series of vibrations of particles. Every source of sound is in a state of vibration.

Sound travels slower in liquids than in solids and faster in liquids than in gases. The speed of sound in liquids and solids is not significantly affected by the change in temperature, but is affected by their body structure.

Self-Test Exercise 2.2

Give short answers to the following questions

During a thunderstorm, you may see a distant lightning flash some seconds before you hear the thunder. What do you think is the reason?

Self-Test Exercise 2.3

Give short answers to the following questions

During rainy season, it is common to hear thunderstorms. Can you estimate the distance to the thunderstorm? Hint: Count the number of seconds between seeing the flash of lightning and hearing the thunder and use the air temperature to be approximately 20 °C.

Reflection, Refraction, Diffraction, and Interference of Sound

Echo is used in SONAR (Sound Navigation and Ranging) to find the depth of the sea or the distance of submarines. The principle used here is the fact that the time taken for the sound to reach the obstacle from the source is equal to the time taken for it to return.

When you shout in an empty hall or in a forest, the sound will bounce back from the wall or forest and comes towards you. We call this the reflection of sound. The reflection of sound from hard surfaces is called an "echo".

Hard substances such as walls, rocks, hills, metals, wood, buildings, etc., are good reflectors of sound since they are polished and hard. But when sound strikes soft surfaces such as wool, cloth, etc., most of the sound energy is absorbed. When you shout or whistle while you are some distance away from a tall building or a mountain, you may be able to hear the original sound and the reflected sound as two separate sounds.

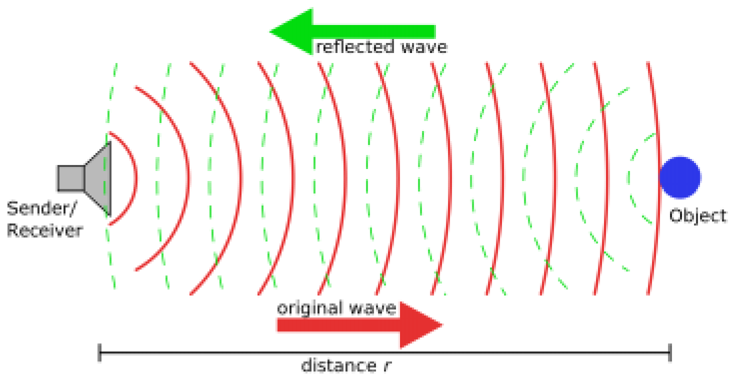


Figure 2.9: Reflection of sound from an object

Sound bends (changes its direction) when parts of the wave fronts travel at different speeds. This occurs, for example, in uneven winds or when sound is travelling through an air of uneven temperature. Such a bending or a change in the direction of a sound wave due to change in its speed is called refraction. During a day, the air near the ground is warmer than the rest of the air. This means that the speed of sound near the ground increases, making them bend away from the ground. However, during the night, the air near the ground is colder than the rest of the air, and the speed of sound near the ground decreases. This makes sound waves bend towards the ground.

Figure 2.10: Demonstration of reflection of sound (echo)

☞ The reflection of sound from hard surfaces is called an echo.

A sound wave also changes its direction or spreads out. Such a change in the direction or spreading out of a sound wave as it passes through an opening or around a barrier in its path is known as diffraction. Diffraction is a phenomenon that we experience in our day to-day-lives. It is because of the diffraction of sound waves that we can hear others who are speaking to us from adjacent rooms. Diffraction is more pronounced with waves of longer wavelengths. It means that we will be able to hear low frequencies around obstacles better than those that are higher. The long wavelength waves can bend around obstacles and reach our ears from sources situated in distant places. This principle is also used when soundproofing a room. A superior quality soundproofing means that there are no openings present, as even a small aperture can let the sound spread in the whole area and cause disturbance by the process of diffraction.

Figure 2.11: Reflection of sound during the day and night

Self-Test Exercise 2.4

Give short answers to the following questions

Discuss with your friends the following questions. What do you hear if you shout in a big empty hall or in a forest? Have you ever used a whip to scare birds or animals? What is the sound that you hear back?

Self-Test Exercise 2.5

Give short answers to the following questions

When do we hear sounds clearly? Is it during the day or at night? Discuss this phenomenon in groups.

√ Check List 2.4

Dear learner, now it is time to check your understanding about the superposition of waves. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you identify the sources of sound wave and explain how sound is produced?	☐	☐
2. Can you compare the speed of sound in different materials?	☐	☐

3. Can you determine the speed of sound in air at a given temperature? ☐ ☐

4. Can you explain reflection, refraction, diffraction, and interference of sound waves. ☐ ☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 2.5: Superposition of Waves

Dear student! In this section, you will learn about the superposition of waves. What do you think is superposition?

After reading this section, you should be able to:

- *define the superposition principle;*
- *explain how standing waves are formed;*
- *define the interference of waves*

When two or more waves pass through a single point at the same time the resultant instantaneous displacement at that point is the sum of the displacements that would be created separately by each wave, taking signs in to account. This principle is said to be the superposition principle.

Superposition is also known as Interference. Interference can be either constructive or destructive depending on the phase between the interfering waves. Two waves are said to be in phase when corresponding points of each wave reach maximum or minimum displacements at the same time. When two periodic waves with the same frequency and wavelength travel in the same direction in phase, their resultant wave is more amplified, and we can say that the two waves interfere constructively. If two periodic waves with the same frequency and wavelength travel in the same direction but are out of phase, the resulting wave is diminished (or may be zero) in amplitude. In such a case, the two waves interfere destructively.

Standing Waves

The superposition of two identical waves travelling in opposite directions in the same medium gives a standing (stationary) wave. If you have ever plucked a guitar string or blown across the mouth of a pop bottle to create a tone, you have generated standing waves. In general, a standing wave is one that oscillates with time but remains fixed in its location. It is in this sense that the wave is said to be "standing."

The positions in the medium at which maximum displacement occurs are called antinodes (A) and those positions with zero displacement are called nodes (N). Note that:

- The distance between adjacent antinodes is equal to $\frac{\lambda}{2}$.
- The distance between adjacent nodes is equal to $\frac{\lambda}{2}$.
- The distance between a node and an adjacent antinode is $\frac{\lambda}{4}$.

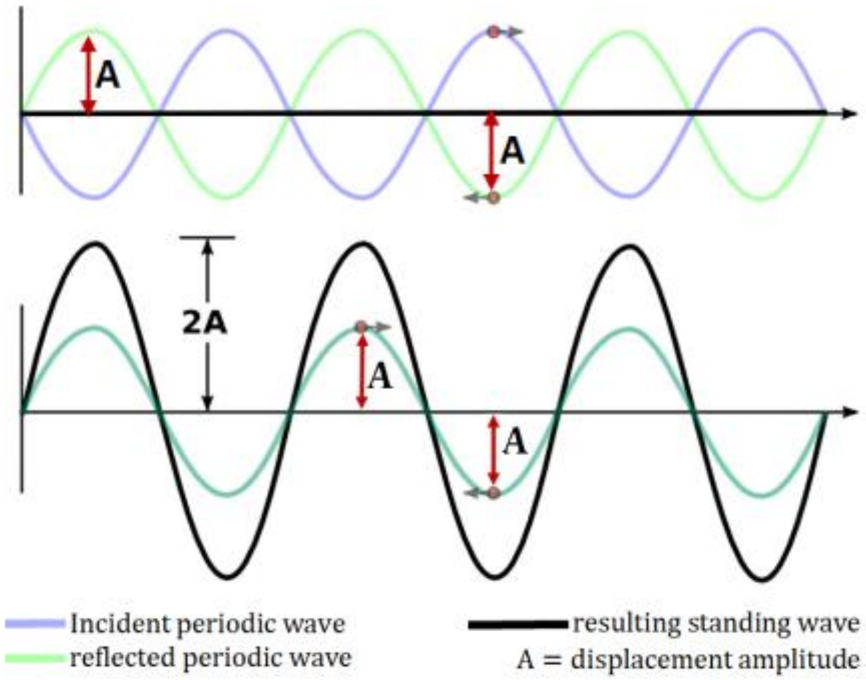


Figure 2.12: Superposition of two identical waves resulting in a standing wave

> Superposition occurs when two or more waves pass through a single point at the same time.
>
> The superposition of two identical waves travelling in opposite directions in the same medium gives a standing (stationary) wave.

√ Check List 2.5

Dear learner, now it is time to check your understanding about the superposition of waves. Read each question and put a mark ("X") in the box that corresponds to your answer.

	Yes	No
1. Can you define the superposition principle?	☐	☐
2. Can you explain how standing waves are formed?	☐	☐
3. Can you define interference in waves?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 2.6: Characteristics of Sound Waves

Dear student! In this section, you will learn about the characteristics of sound waves. Have you ever played musical instruments? You might have observed that the same note played on different instruments sounds distinctly different. What do you think is the reason? If you are at home, you can still hear sounds from outside sources. Can you explain why?

After reading this section, you should be able to:

- *define terms like loudness, pitch, and timbre (quality);*
- *identify sound pollution issues in the surrounding area and justify problems identified in relation to sound standards.*

Sound cannot travel through a vacuum. The movement of molecules in a medium is essential for the propagation of sound waves. The characteristics of sound are:

Pitch: The pitch of a sound depends on the frequency of the sound wave. The higher the frequency of the sound waves, the higher their pitch. In higher-pitched sounds, the particles vibrate more often past their equilibrium position per second.

Loudness: The loudness of a sound depends on the amplitude of the sound wave. If the amplitude is greater, the sound is louder. In louder sounds, the particles move further from their equilibrium position. The loudness of a sound is measured in decibels (dB). Exposure to elevated sound that may lead to adverse effects in humans or other living organisms is called sound pollution. Some of the adverse effects include hypertension, hearing loss, sleep disturbances, etc. A noise becomes harmful when it exceeds 75 dB and painful above 120 dB.

Timbre (quality): The same note played on different instruments sounds distinctly different. Timber or quality is the property of tone that distinguishes it from another tone of the same pitch and intensity but produced by different sources. Quality does not mean good or bad, it just refers to the difference in sound.

☞ Pitch refers to the highness or lowness of a sound. Loudness or intensity describes your perception of the energy of the sound. The loudness of a sound is measured in decibels (dB). Timbre is a general term for the distinguishable characteristics of a tone.

Self-Test Exercise 2.6

Give short answers to the following questions

What is the difference between louder and quieter sounds, or higher pitch and lower pitch sounds? Why does the same note sound different from a violin to a piano? Discuss in groups and with your teacher.

Activity 2.7

- What do you think are the causes of sound pollution in your locality? Discuss in groups and suggest possible solutions to avoid some of them.

√ **Check List 2.6**

Dear learner, now it is time to check your understanding about the characteristics of sound waves. Read each question and put a mark (“X”) in the box that corresponds to your answer.

	Yes	No
1. Can you define terms like loudness, pitch, and timbre (quality)?	☐	☐
2. Can you identify sound pollution issues in the surrounding and justify problems identified in relation to sound standards.	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Unit summary

- Oscillation, also known as periodic motion is a to-and-fro motion about a fixed point called equilibrium position.
- A wave is a disturbance that propagates from source carrying energy. mechanical waves are those that require a material medium for their propagation, whereas electromagnetic waves are those that do not require a medium for their propagation are known as.
- Transverse waves are waves in which the direction of their propagation is perpendicular to the direction of the vibrations of the particles in the medium. However, the direction of movement of some waves is parallel to the direction of vibration of particles in the medium. Such waves are called longitudinal waves.
- Sound waves are the most common example of longitudinal waves. They travel through any material medium with a speed that depends on the properties (density) of the medium.
- When two or more waves pass through a single point at the same time, the resultant instantaneous displacement at that point is the sum of the displacements that would be created separately by each wave, taking signs into account. This principle is said to be the superposition principle. The superposition of two identical waves travelling in opposite directions in the same medium gives a standing (stationary) wave.

Self-assessment questions

Part I: Conceptual Questions and Workout Problems.

1. Calculate the period of a simple pendulum of length 4m.
2. An object of mass 2 kg is attached to one end of a spring with a spring constant 800 N/m. If the object is undergoing periodic motion on a smooth horizontal surface, what is the period of oscillation?
3. Explain the difference in the speed of sound:
    a) between solids, liquids and gases
    b) between warm air and cold air
4. In which type of wave are the vibrations parallel to the direction of wave propagation? Give at least two examples for such type of wave.
5. An electromagnetic wave has a wavelength of 10 nm. Calculate its frequency.
6. Draw diagrams to illustrate the difference between constructive and destructive interference.
7. Two identical waves of amplitude 4cm meet. What will be the amplitude of the combined wave at a point where:
    a) they interfere constructively?
    b) They interfere destructively?
8. Imagine you are sitting in a room, and someone is playing kirar outside and next to your room. You may be able to hear the sound of the kirar through the open doorway, though you cannot see the kirarist. Explain why?
9. Sound travels along a steel rod of length 4m in a time of 0.0008 s. What is the speed of sound in the steel?
10. Calculate the speed of sound in air at 30℃
11. Suppose a man stands at a distance from a cliff and claps his hands. He receives an echo from the cliff after 2 seconds. Calculate the distance between the man and the cliff. Take the speed of sound to be 343 m/s.
12. A ship is sailing in a part of the sea where seabed is 500 m below the ship. The ship uses sonar to detect the seabed. How long will it take a pulse of sound to travel to the seabed and return to the ship. Use speed of sound in sea water to be 1500 m/s.

Part II: Choose the correct answer from the given alternatives.

1. With reference to waves, a disturbance is:
   A. an oscillation produced by some energy that creates a wave.
   B. the resistance produced by some particles of a material.
   C. the number of oscillations per unit time
   D. the constructive or destructive interference of waves.
2. What is the period of a wave with a frequency of 2 Hz?
   A. 1 s B. 4 s C. 0.5 s D. 2 s
3. 15. What kind of interference occurs between two identical waves moving in opposite directions?
   A. Constructive interference
   B. Destructive interference
   C. Both constructive and destructive interference
   D. Neither constructive nor destructive interference
4. Diffraction is
   A. The constructive interference of two waves of the same frequency travelling in the same direction
   B. The change in direction of waves as they pass through an opening or around a barrier in their path
   C. The change in the direction of waves as they pass from one medium to another
   D. The change in the direction of waves when they bounce off a barrier
5. A closed organ pipe has
   A. a node at the closed end and an antinode at the open end
   B. an antinode at the closed end and a node at the open end
   C. a node at each end
   D. an antinode at each end
6. The loudness (or intensity) of a sound wave is related to its
   A. Frequency B. wavelength C. amplitude D. period

Answer Key for Self-assessment questions

Answer to Exercise 2.1:

1600 N/m

Answer to Exercise 2.2

Light travels much faster than sound.

Answer to Exercise 2.3

Encourage the students to perform the activity and estimate the distance to the thunderstorm. To estimate the distance to the thunderstorm, they should count the number of seconds between seeing the flash of lightning and hearing the thunder using a stopwatch. If you multiply the time measured by the speed of sound at 20°C, it gives the estimated distance to the thunder.

Answer to Exercise 2.4

The sound that you hear back is called an echo.

Answer to Exercise 2.5

During a day, the air near the ground is warmer than the rest of the air. This means that the speed of sound near the ground increases, making them bend away from the ground. However, during the night, the air near the ground is colder than the rest of the air, and the speed of sound near the ground decreases. This makes sound waves bend towards the ground allowing us to hear clear sound at night.

Answer to Exercise 2.6

Two notes of the same pitch and loudness played on different instruments do not sound the same because of the difference in quality or tone of the sounds.

Answer to Self-assessment questions

Part I

1. 3.97 s (Using $g = 10 m/s^2$)

2. 0.314 s

3. (a) The speed of sound in solids > the speed of sound in liquids > the speed of sound in gases.

(b) The speed of sound in warm air is greater than that in cold air.

4. Longitudinal waves. Examples of longitudinal waves include sound waves and pressure waves, but they are not limited to these two.

5. 3×10^{16} per second.

6. Refer to the textbook

7. (a) 8 cm (for complete constructive interference)

(b) 0 (for complete destructive interference)

8. All the sounds you hear are produced by a vibrating object. The air near the vibrating kirar is set in motion in all directions. Even though you cannot see the player, the produced sound travels in all directions in the form of energy and reaches your ear.

9. 5000 m/s

10. 348.71 m/s

11. 343 m

12. 0.67 s

Part II

13. A

14. C

15. B

16. B

17. A

18. C

Unit 3 Temperature and Thermometry

Introduction

Dear student! In unit 2, you learned about the basic concepts of mechanical oscillation and sound waves. In this unit, you are going to learn important concepts like temperature and thermometry.

You are familiar with the word temperature. The water in the shower or bucket feels hot, cold, or warm. The weather outside is chilly or steamy. You certainly have a good sense of how one temperature is qualitatively different from another. You may not always agree on whether the temperature in the room is too hot, too cold, or just right. But you will likely all agree that you possess built-in thermometers for making qualitative judgments about relative temperatures. In this unit, you will learn about temperature and its effects, different temperature measuring scales, different types of thermometers, the conversion of temperature from one scale to another, and the linear expansion of solids.

After reading this unit, you should be able to:

- *understand temperature,*
- *explain different temperature scales;*
- *construct your own temperature scale;*
- *develop experience using different thermometers.*

Unit Contents

The required study times

Dear student! You are expected to complete Section 1 in 1.5 hrs., Section 2 in 1.5 hrs., Section 3 in 3 hrs., Section 4 in 6 hrs., Section 5 in 4.5 hrs., Section 6 in 9 hrs., and Section 7 in 6 hrs.

Learning Strategies

Dear student! In this unit you are expected to use the following learning strategies:

- Follow the symbols in the module material that guide you to learn each section,
- Space out your study over time;
- After completing each subsection, do each activity and the self-test exercises;
- For a difficult activities and self-test exercises in each subsection or section, go back and read it carefully until you understand the contents;
- Consult a physics teacher in your locality or a tutor for the contents you are unable to understand;
- Do end-of-unit self-assessment exercises to check whether you understand each section of the unit or not.

Section 3.1: Temperature and our life

Dear student! You are familiar with temperature in your day-to-day activities. Try to answer the following brainstorming questions:

What is temperature? How do you feel your environment? Is it hot or cold? Do you feel the difference between hot and warm, cold and cool? Are these words accurate to describe the temperature of an object? How is temperature related to our lives?

After reading this section, you should be able to:

- *define temperature;*
- *describe the effect of temperature in your daily life;*
- *discuss the range of temperature differences from the equator to the polar region of the Earth.*

The concept of temperature has evolved from the common concepts of hot and cold. Human perception of what feels hot or cold is a relative one.

Dear student! The following activity helps you to observe your sense of feeling about temperature.

Activity 3.1

1. a) Prepare three cups with hot, warm and cold water;
   b) Place your left hand in hot water and the right hand in cold water and automatically put both hands in warm water. What do you feel on your left and right hands? Explain.
2. If you touch a wood and a metal plate in the morning the wood feels warmer than the metal plate. Why?
3. Is testing the hotness and coldness of a body by your hands (feeling) reliable?

From Activity 3.1, you have learned that testing the hotness or coldness of a body by feeling is not reliable. This is because the warm water feels cool to the hand that was in the hot water and warm to the one that was in the cold water. Thus, you cannot conclude that the warm water is hot or cold using your hand.

> ☞ Temperature is defined as the measure of the average kinetic energy of the particles in a sample of matter expressed in terms of units or degrees designated on a standard scale.

Dear student, click on the following link to see the motion of water and gas particles. (https://phet.colorado.edu/en/simulations/gas-properties) Describe the motion of water and gas particles and their average kinetic energy as the temperature increases or decreases gradually.

A key feature of our environment is the combination of temperature and humidity that determines the heat balance of human beings. Human beings are comfortable with temperature between 18 °C and 22 °C, particularly referred to as room temperature. Temperature affects human life in different ways. Mankind's clothing, eating habit, health and even economy is affected by temperature of the environment.

> ☞ Temperature is the degree of hotness or coldness of a body.
>
> Temperature is the average kinetic energy of the particles on a body.

(a) Cold weather (b) Moderate weather (c) Hot weather

Figure 3.1: Different living styles due to variation of temperature

> ? How does temperature affect mankind's clothing, eating habit, health and economy?
>
> What do you feel when the temperature is below or above the room temperature?

On our planet Earth, temperature varies from one place to another. For example, polar regions are very cold, temperate regions have a moderate temperature, and tropical regions are hot. The temperature difference from the pole to the equator depends on the Sun's energy and the energy retained in Earth's system. The equator receives the most direct sunlight and therefore the most solar energy. The polar energy, on the other hand, receives less amount of the Sun's energy and has a lower overall temperature. The yearly average temperature of tropical rainforest climates is between 21 °C to 31 °C. The average temperature of temperate climates is between -3 °C and 18 °C. During summer, the average temperature in the polar zone is -14 °C. However, in winter, the average temperature is -50 °C.

Figure 3.2: Temperature of the tropics, temperate, and polar zones

Self-Test Exercise 3.1

Give short answers to the following questions

1. How do human beings and other living creatures adapt to the temperature of tropic, temperate and polar regions? Explain.
2. Identify bodies with extremely high and extremely low temperatures and very low in your surrounding and in nature.

In nature, the Sun and other stars have high temperatures. The average temperature of the Sun's outer surface is about 5600 K (≅ 5327 °C). In your surroundings, there are also bodies with high temperatures, for example: fire from biomass (wood), electric heaters, electric stoves, a candle's flame, and so on. There are also materials that have a low temperature. Some examples are solid water or ice (below 0 °C), solid carbon dioxide (-78 °C), liquid nitrogen (-196 °C) and so on.

Self-Test Exercise 3.2

Part I: Write True if the statement is correct and False if it is incorrect.

1. It is possible to measure the exact temperature of a body by using our hands.
2. The average kinetic energy of particles in a body increases by decreasing its temperature.
3. The temperature of the environment determines the living style of human beings.

Part II: Choose the correct answer from the given alternatives.

1. Which one of the following bodies has a very high temperature?
   A. Moon B. Sun C. Candle D. Fire
2. Which one of the following bodies has a very low temperature?
   A. Water ice B. Solid carbon dioxide C. Liquid nitrogen D. None
3. The average temperature of zones in increasing order is
   A. Polar, tropical, temperate C. Tropical, temperate, polar
   B. Polar, temperate, tropical D. Tropical, polar, temperate

√ Check List 3.1

Dear learner, now it is time to check your understanding about familiar with temperature. Read each question and put a mark ("X") in the box that is appropriate choice to you.

	Yes	No
1. Can you define temperature?	☐	☐
2. Can you describe the effect of temperature in your daily life?	☐	☐
3. Can you discuss the range of temperature difference from equator to polar region of the Earth?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 3.2: Extreme temperature safety

Dear student! In the previous section, you learned about temperature and our lives. In this section, you will learn about extreme temperatures and their safety.

After reading this section, you should be able to:

- *describe the comfortable environmental temperature for human beings,*
- *explain some safety precautions for extreme temperatures.*

? What is an extreme temperature? Which temperature is comfortable for human beings?

The human body has a normal temperature between 97 °F (36.56 °C) and 99 °F (37.2 °C), but on average, a normal body temperature is 98.6 °F (37 °C). To maintain this temperature without the help of warming or cooling devices, the surrounding environment needs to be at about 82 °F (28 °C). In reality, the temperature of the surrounding environment is not 28 °C. It varies from time to time.

? How can you stay healthy when the temperature of the surrounding is very cold or very hot? Explain.

High environmental temperatures can be dangerous to your body. In the range of 90 °F and 105 °F (32 °C and 40 °C), you can experience heat cramps and exhaustion. Between 105 °F and 130 °F (40 °C and 54 °C), heat exhaustion is more likely. You should limit your activities in this range. An environmental temperature over 130 °F (54 °C) often leads to heatstroke.

? How can you protect yourselves from exposure to very high or very low temperatures?

☞ **Safety precautions**

1. Stay well-hydrated to best avoid heat-related illness. Drink enough fluids. Don't rely solely on thirst as a guide to how

much liquid you should be drinking.

2. Wear clothing that is appropriate to your environment. Clothing that is too thick or too warm can quickly cause overheating. If you feel yourself getting too hot, loosen your clothing or remove excess clothing until you feel cool enough. Clothing that is too thick or too warm can quickly cause overheating.
3. Wear sunscreen, when possible, to avoid sunburn which makes it harder for your body to get rid of excess heat.
4. Try to avoid places that can get extremely hot.

Self-Test Exercise 3.3

Part I: Write True if the statement is correct and False if it is incorrect.

1. Drinking enough water avoids heat-related illness.
2. Heat cramps and exhaustion can be experienced at a temperature of 82 ^oF.

Part II: Choose the correct answer from the given alternatives.

1. The environmental temperature that is used to maintain the body temperature of humans without the help of warming or cooling devices is

   A. 82 ^oF B. 28 ^oC C. 37 ^oC D. A and B
2. On average, the body temperature of human body is

   A. 97 ^oF B. 99 ^oF C. 98.6 ^oF D. 82 ^oF
3. Heat stroke can be induced when the human body is exposed to a temperature of

   A. over 130 ^oF B. 104 ^oF C. 90 ^oF D. None

√ Check List 3.2

Dear learner, now it is time to check your understanding about temperature and our lives. Read each question and put a mark (“X”) in the box that is appropriate choice to you.

	Yes	No
1. Can you describe the comfortable environmental temperature	☐	☐

for human beings?

2. Can explain some safety precautions of extreme temperature? ☐ ☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 3.3: Temperature Change and its Effects

Dear student! In the previous section, you learned about extreme temperatures and their safety. In this section, you will learn about temperature change and its effects.

After reading this section, you should be able to:

- *describe the average change in global temperature;*
- *explain the major effects of higher temperatures in our community and environment;*
- *list the causes for the temperature increment in our environment;*
- *list greenhouse gases that cause a rise in temperature.*

? Have you observed a change in temperature from year to year? What are the causes of change in temperature? How can this problem be resolved?

One of the most immediate and obvious effects of global warming is the increase in temperature around the world. The average global temperature has increased by about 1.4 degrees Fahrenheit (0.8 degrees Celsius) over the past 100 years, according to the National Oceanic and Atmospheric Administration (NOAA). Since record keeping began in 1895, the hottest year on record worldwide was 2016, according to NOAA and NASA data. That year, Earth's surface temperature was 1.78 degrees Fahrenheit (0.99 degrees Celsius) higher than the 20th century average.

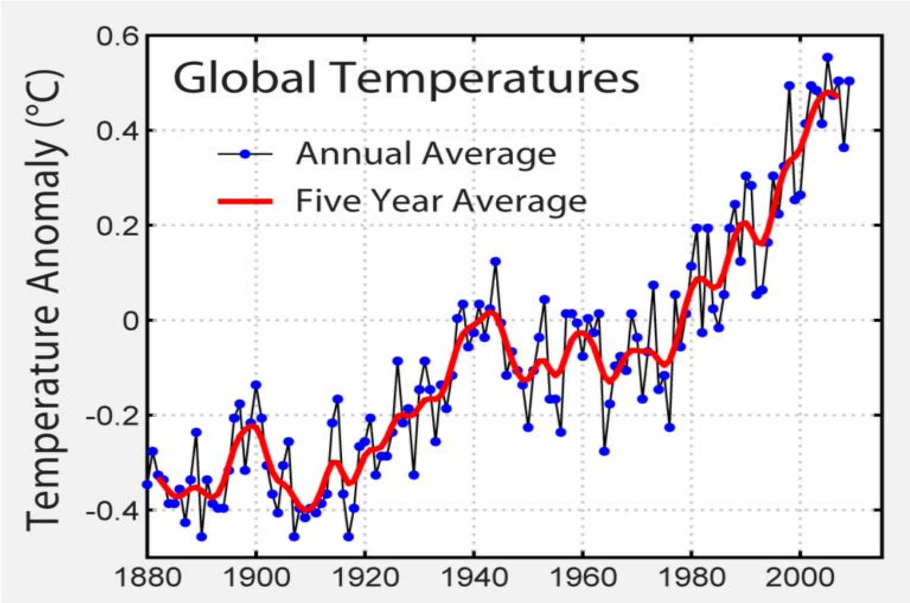


Figure 3.3: Yearly average global temperature increment for the last 120 years

Self-Test Exercise 3.4

Part I: Search from different sources and write a report on the following questions.

1. What are the causes for the continuous rise in temperature on our planet Earth?
2. How do you think this problem can be solved to improve the lives of the future generation?
3. What is the greenhouse effect?
4. The communities in different regions of Ethiopia have indigenous knowledge practices of caring for natural resources like forests. Have you observed

The choices we make now and in the next few decades will determine how much the planet's temperature will rise.

- If people keep adding greenhouse gases into the atmosphere at the current rate, the average temperature around the world could increase by about 4 to 12 °F.
- If we make big changes, like using more renewable resources instead of fossil fuels, the increase will be less than 2 to 5 °F.

Higher temperatures mean that heat waves are likely to happen more often and last longer, too. Heat waves can be dangerous, causing illnesses such as heat cramps and heat stroke, or even death. Warmer temperatures can also lead to a chain reaction of other changes around the world. That's because increasing air temperature also affects the oceans, weather patterns, snow and ice, and plants and animals. The warmer it gets, the more severe the impacts on people and the environment will be

Activity 3.2

Discuss the major effects that higher temperatures have on people and the environment with respect to:

1. Agriculture
2. Energy
3. Water supply
4. Health
5. Plants, animals and ecosystems
6. Forests

Greenhouse gases are the causes of global warming.

A higher temperature affects agriculture, energy, water supply, health, and ecosystems.

Greenhouse gases are carbon dioxide, methane, nitrous, oxide and fluorinated gases.

A body having particles with small kinetic energy has a low temperature.

A body having particles with high kinetic energy has high temperature.

Self-Test Exercise 3.5

Part I: Write True if the statement is correct and False if it is incorrect.

1. Ozone is categorized under greenhouse gases.
2. Most places on Earth are warmer than they were 100 years ago.

Part II: Choose the correct answer from the given alternatives.

1. What is the greenhouse effect?
   A. Certain gases in the atmosphere trap heat and warm the Earth.
   B. Life on Earth exhales gases that warm up the atmosphere.

C. The tilt of the Earth changes the amount of solar energy the Earth receives.
D. The sun is putting out more radiant energy over time.

2. Which activities are the contributors or sources of greenhouse gases?
A. Deforestation B. Industry C. Transportation D. All are answers
3. The increment in the average global temperature for the past century is
A. 1.4 °F B. 0.8 °C C.1.4 °C D. A and B are answers
4. Which of the following gases does not trap heat?
A. Carbon dioxide B. Nitrogen C. Water vapors D. Methane

√ **Check List 3.3**

Dear learner, now it is time to check your understanding about extreme temperatures and their safety. Read each question and put a mark ("X") in the box that is appropriate choice to you.

		Yes	No
1.	Can you describe the average change in global temperature?	☐	☐
2.	Can you explain the major effects of higher temperature in our community and environment?	☐	☐
3.	Can you list the causes for the temperature increment in our environment?	☐	☐
4.	Can you list greenhouse gases that cause rise in temperature?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 3.4: Measuring with Different Thermometric Scales

Dear student! In the previous section, you learned about temperature changes and their effects. In this section, you will learn about measuring with different thermometric scales.

After reading this section, you should be able to:

- *define thermometer;*
- *explain how a thermometer works;*
- *describe different temperature scales;*
- *design a temperature scale using local materials.*

Dear student! I hope, you are familiar and visit a physician to check your body temperature. Try to answer the following brainstorming questions:

? Which temperature scales do you come across in your life? Which scale do physicians use to measure your body temperature?

You did a simple experiment and concluded in the previous section that it is impossible to accurately measure the temperature of a body by touching or using our senses. To measure the temperature of a body accurately, we need a special instrument called a thermometer.

A thermometer is a device used to measure the temperature of a body. It measures temperature in degrees.

? How does a thermometer work? Try to explain it.

Many thermometers make use of the fact that materials usually expand with increasing temperature. A thermometer consists of a tube of uniform thin bore with a small bulb at its bottom. The tube is commonly filled with mercury or alcohol to a certain height. It operates by a contraction and expansion of the mercury or alcohol in the bulb. Figure 3.5 shows parts of a mercury thermometer.

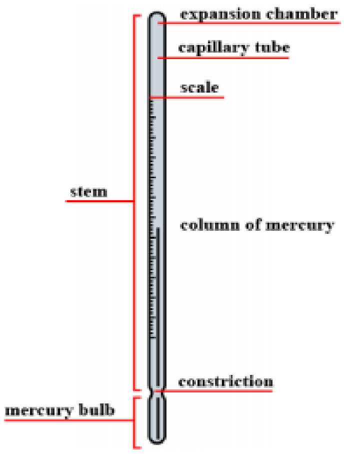


Figure 3.4: Mercury thermometer

Self-Test Exercise 3.6

Give short answers to the following questions

1. Which temperature scales do you know? List them.
2. In what temperature scale do medical doctors measure the body's temperature?
3. What is the human body temperature in Celsius and Fahrenheit?
4. Which temperature scale is commonly used in your local area?

Dear student! There are three different temperature scales. These are:

- Centigrade (Celsius) scale
- Fahrenheit scale
- Kelvin scale

In designing a thermometer, two temperatures of a body are marked on it as fixed points. These are the **lower fixed point** (melting point of ice) and the **upper fixed point** (boiling point of water) at sea level.

Activity 3.3

1. What is the temperature of the melting point of ice?
2. What is the temperature of the boiling point of water at sea level?

Dear student! Already, you have learned the three different temperature scales. Now you are going to learn each scale in depth.

3.4.1 The Celsius scale

The Celsius scale, or centigrade scale, was devised by the Swedish astronomer, Anders Celsius (1701-1744). He assigned the value 0 °C (0 degree Celsius) to the ice point of water and 100 °C (100 degree Celsius) to the steam point or boiling point of water. By dividing the space between the two fixed points into 100 equal parts, a Celsius scale is determined. Each unit or division is called a degree (°). Each division in Figure 3.5 represents 1 °C

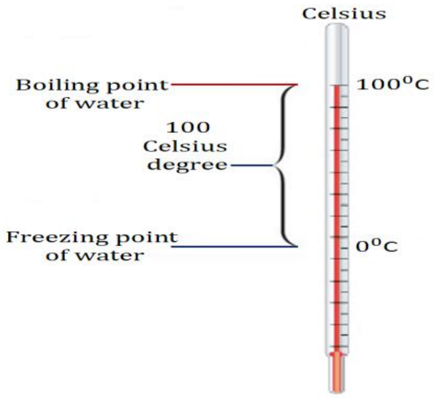


Figure 3.5: The Celsius temperature scale

3.4.2 The Fahrenheit scale

The Fahrenheit scale was designed by the German scientist Daniel Fahrenheit. He assigned 32 °F (32 degrees Fahrenheit) to the ice point of water and 212 °F (212 degrees Fahrenheit) to the steam point or boiling point of water. Since the difference between the ice point and boiling point is 180, one can obtain the Fahrenheit scale by dividing the space between the two fixed points into 180 equal parts. Temperature in Fahrenheit scale is denoted by °F, read as degrees Fahrenheit.

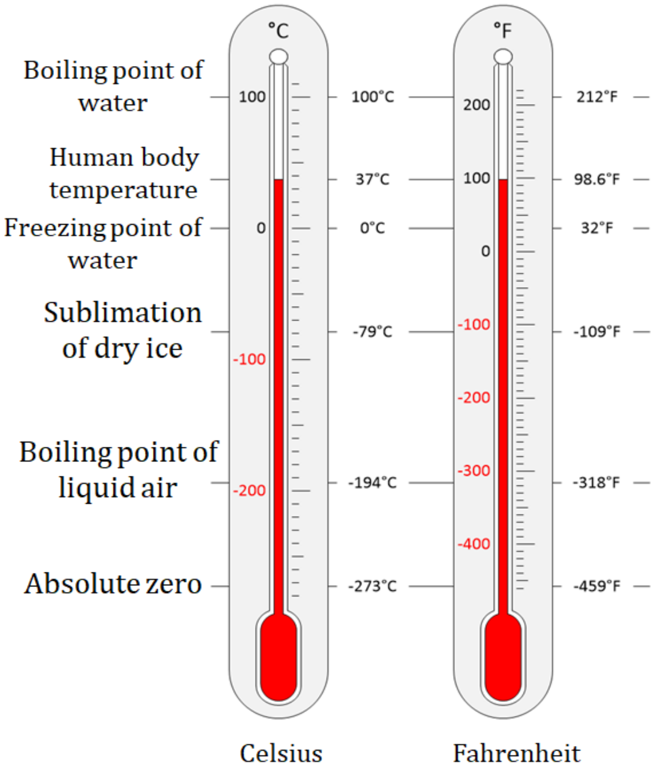


Figure 3.6: The Celsius and Fahrenheit temperature scales

3.4.3 The Kelvin scale

A third type of temperature scale is called the **Kelvin** scale. This scale was designed by Scottish physicist Lord Kelvin (1824–1907). He assigned 273.15 to the ice point and 373.15 to the boiling point. By dividing the space between the two fixed points into 100 equal parts, Kelvin scale is obtained. This scale is used frequently used in scientific publications. The SI unit for temperature is kelvin. Its symbol is K (Note that no degree sign is used with the unit kelvin). This scale is commonly used in scientific works and has greater scientific significance.

Experiments have shown that there exists a lowest possible temperature below which no substance can be cooled. This lowest temperature is defined to be the zero point on the Kelvin scale (0 K or -273.15 °C) and is referred to as **absolute zero.**

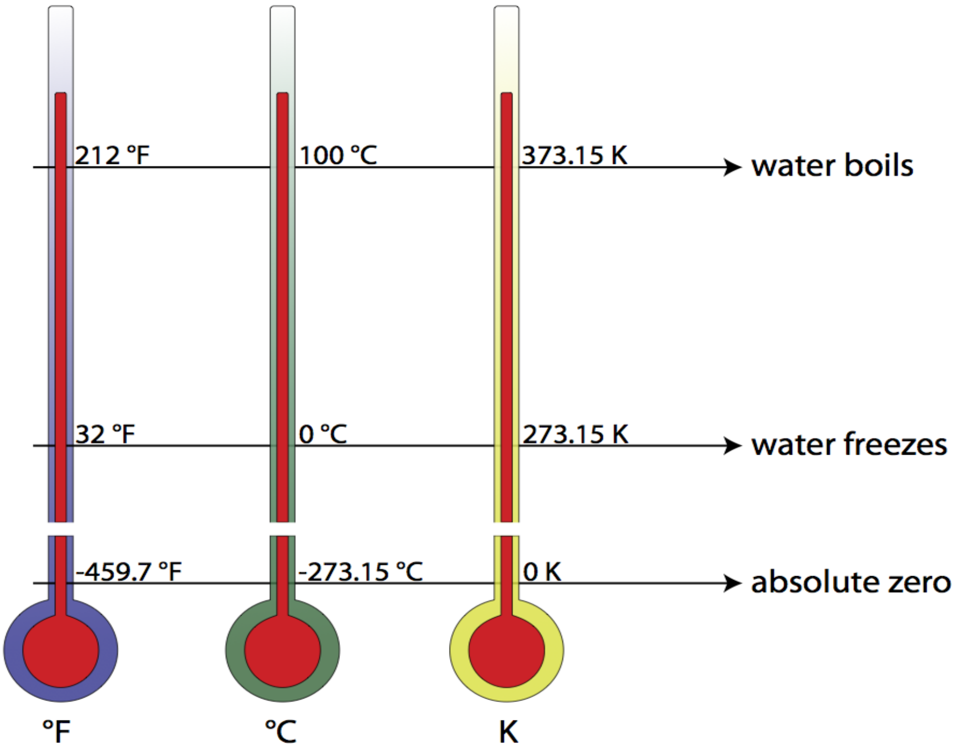


Figure 3.7: The Celsius, Fahrenheit and Kelvin temperature scales

☞ Celsius scale: a temperature scale where the freezing point of water is fixed at 0 degrees and the boiling point is at 100 degrees.

Fahrenheit scale: a temperature scale where the freezing point of water is fixed at 32 degrees and the boiling point is at 212 degrees.

Kelvin scale: a temperature scale that uses absolute zero as one of its fixed points.

Absolute zero: the temperature at which a substance has no thermal energy

3.4.5 Reading thermometer

When the temperature of a material rises, the volume of the mercury expands, causes= the mercury inside the tube to rise so that one can read out of the marked scale on the tube and know the temperature. In contrast to this when the temperature of the material falls, then the mercury inside the tube contracts. This causes the level of the mercury inside the tube to drop. The temperature can thus be read from the corresponding scale on the tube.

Self-Test Exercise 3.7

Part I: Write True if the statement is correct and False if it is incorrect.

1. The degrees in Fahrenheit are smaller than those in Celsius.
2. Temperature is really a measure of how fast the atoms and molecules.
3. Water freezes at 100 °C and boils at 0 °C.

Part II: Choose the correct answer from the given alternatives.

1. Which temperature scale has no negative temperatures?
   A. Celsius B. Fahrenheit C. Joule D. Kelvin
2. What instrument is usually used to measure temperature?
   A. Photometer B. Thermometer c. Barometer D. Celsius
3. How many commonly used temperature scales are there in the world today?
   A. 1 B. 2 C. 3 D. 4
4. What is the boiling and freezing points of water on the Celsius scale?
   A. 100 °C, 0 °C B. 0 °C, 100 °C C. 32 °C, 212 °C D. None
5. What happens at absolute zero?
   A. Objects start to melt C. Water freezes
   B. Water starts to boil D. All molecular motion stops

√ Check List 3.4

Dear learner, now it is time to check your understanding temperature changes and their effects. Read each question and put a mark ("X") in the box that is appropriate choice to you.

	Yes	No
1. Can you define thermometer?	☐	☐
2. Can you explain how thermometer works?	☐	☐
3. Can you describe different temperature scales?	☐	☐
4. Can you design temperature scale using local materials?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 3.5: Different thermometers and their use

Dear student! In the previous section, you learned about measuring with different thermometric scales. In this section, you will learn about different thermometers and their uses.

After reading this section, you should be able to:

- *List different types of thermometers;*
- *Explain the uses of different thermometers.*

Dear student! You came across different concepts on temperature and temperature scales in your previous section. Try to answer the following brainstorming question.

? What are the thermometric properties of mercury thermometer, alcohol thermometer, thermocouple, resistance thermometer and radiation thermometer?

All thermometers make use of the change in some physical property with temperature. A property that changes with temperature is called a ***thermometric property***. For example, the thermometric property of the mercury thermometer is the length of the mercury column, while in the constant-volume gas thermometer it is the pressure of the gas. Several important thermometers and their thermometric properties will now be discussed.

Self-Test Exercise 3.8

Give short answers to the following questions

1. What are the different temperature scales? What are fixed points in each scale?
2. What is the meaning of lowest and upper fixed points?
3. How many divisions are there between the lowest and upper fixed points, in each scale?
4. What is the SI unit of temperature?

3.5.1 Mercury thermometer

Dear student! In this subsection, you are going to learn about the working principles of mercury thermometer.

Mercury thermometers are used in households, laboratory experiments, and industrial applications. A mercury thermometer can measure temperatures ranging from -30 to 300 degrees Celsius.

In a mercury thermometer, a glass tube is filled with mercury, and a standard temperature scale is marked on the tube. With changes in temperature, the mercury expands, and contracts and the temperature can be read from the scale. Mercury thermometers can be used to determine body, liquid, and vapor temperature. Mercury thermometers are used in households, laboratory experiments, and industrial applications. A Mercury thermometer is suitable to measure temperatures ranging from -30 degree Celsius and 300 degrees Celsius.

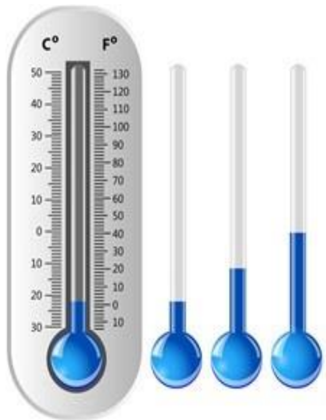


Figure 3.8: Mercury thermometer

3.5.2 Alcohol thermometers

Dear student! In the previous subsection, you learned about mercury thermometer and its working principle. Now you are going to learn about alcohol thermometers and their working principle.

An alcohol thermometer is a thermometer that utilizes the expansion and contraction of alcohol in response to temperature changes to measure the temperature. A number of different alcohols can be used, depending on the environment where the thermometer is being utilized, with ethanol being among the most common. This type of thermometer is very popular because it is nontoxic, unlike a mercury-in-glass thermometer, and the contents will not pose a threat to human health or the environment if the thermometer is broken. Alcohol thermometers are used to measure temperature from $-115\ ℃$ to $78.15\ ℃$.

Figure 3.9: Alcohol thermometer

3.5.3 Resistance thermometer

Dear student! In this subsection, you are going to learn about resistance thermometer and its working principle.

Most substances offer resistance to the flow of electricity, and this resistance changes with temperature. As a result, electrical resistance provides another thermometric property. *Electrical resistance thermometers* are often made from platinum wire because platinum has excellent mechanical and electrical properties in the temperature range from -270 °C to +700 °C. The resistance of platinum wire is known as a function of temperature. The material that is used in the construction of this thermometer has an accurate resistance and temperature relationship that is used in the measurement of temperature. Thus, the temperature of a substance can be determined by placing the resistance thermometer in thermal contact with the substance and measuring the resistance of the wire. The figure below shows the resistance thermometer.

Figure 3.10: Resistance thermometer

3.5.4 Thermocouple

Dear student! In this subsection, you are going to learn about thermocouple and its working principle.

The *thermocouple* is a type of thermometer used extensively in scientific laboratories. It consists of thin wires of different metals, welded together at the ends to form two junctions, as Figure 3.11 illustrates. Often the metals are copper and constantan (a copper–nickel alloy). One of the junctions, called the "hot" junction, is placed in thermal contact with the object whose temperature is being measured. The other junction, termed the "reference" junction, is kept at a known constant temperature (usually an ice–water mixture at 0 °C). The thermocouple generates a voltage that depends on the *difference in temperature* between the two junctions. This voltage is the thermometric property and is measured by a voltmeter, as the drawing indicates. With the aid of calibration tables, the temperature of the hot junction can be obtained from the voltage. Thermocouples are used to measure temperatures as high as 2300 °C or as low as -270 °C.

Figure 3.11: A thermocouple measuring circuit

3.5.5 Thermistor

Dear student! In this subsection, you are going to learn about thermocouple and its working principle.

A thermistor is a resistance thermometer, or a resistor whose resistance is dependent on temperature. The term is a combination of "thermal" and "resistor". It is made of metallic oxides, pressed into a bead, disk, or cylindrical shape, and then encapsulated with an impermeable material such as glass. There are two types of thermistors: those with a Negative Temperature Coefficient (NTC) and those with a Positive Temperature Coefficient (PTC). With an NTC thermistor, when the temperature increases, resistance decreases. Conversely, when temperature decreases, resistance increases. This type of thermistor is used the most. A PTC thermistor works a little differently. When the temperature increases, the resistance increases, and when the temperature decreases, the resistance decreases. This type of thermistor is generally used as a fuse. Typically, a thermistor achieves high precision within a limited temperature range of about 50 °C around the target temperature. This range is dependent on the base resistance.

Figure 3.12: A thermistor

3.5.6 Radiation Thermometers

Radiation thermometers are not based on any change in property with temperature but use the electromagnetic radiation from a body to be measured. As the body warms up, the total radiation it emits increases rapidly, and the spectral distribution shifts to shorter wavelengths. The temperature can thus be determined by measuring the radiation, and there is the clear advantage that all the detecting equipment is remote from the hot body. The application areas of radiation thermometer are quite extensive. They are frequently used in industrial processes, the professional sector and in particular to monitor main supply units or to measure the temperature of components in motors or machines. The Glass industries, and Electrical industries use many forms of radiation thermometers.

Figure 3.13: A radiation thermometer

Mercury thermometer uses the expansion of mercury due to change in temperature. It measures temperature between -30 degree Celsius and 300 degrees Celsius.

An alcohol thermometer uses the expansion of alcohol due to change in temperature. It is used to measure temperature from $-115\ ℃$ to$78.15\ ℃$.

The thermocouple uses voltage as the thermometric property. It measures temperatures as high as 2300 °C or as low as -270 °C.

Self-Test Exercise 3.9

Part I: Choose the correct answer from th given alternatives.

1. Which thermometer is suitable for measuring temperatures between $-30\ ℃$ and $300\ ℃$?
   A. Mercury thermometer C. Resistance thermometer
   B. Alcohol thermometer D. Thermocouple
2. Which of the following thermometers is not based on any change of property with temperature?
   A. Mercury thermometer C. Resistance thermometer
   Alcohol thermometer D. Radiation thermometer
3. Which of the following is a thermometric property of a thermocouple?
   A. Resistance B. Voltage C. Light D. Current

Part II: Give short answers to the following questions

1. List different types of thermometers.
2. Write the difference between mercury and alcohol thermometers.

3. Describe the measuring ranges of temperature for different types of thermometers.
4. Why do we need different types of thermometers? Discuss.

√ **Check List 3.5**

Dear learner, now it is time to check your understanding about measuring with different thermometric scales. Read each question and put a mark ("X") in the box that is appropriate choice to you.

	Yes	No
1. Can you list different types of thermometers?	☐	☐
2. Can you explain the uses of different thermometers?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 3.6: Conversion between Temperature Scales

Dear student! In the previous section, you learned about different thermometers and their use. In this section, you will learn about conversion between temperature scales.

After reading this section, you should be able to:

- *convert temperature in degree Celsius scale to temperature in Fahrenheit scale and vice versa;*
- *convert temperature in degree Celsius scale to temperature in Kelvin scale and vice versa;*
- *convert temperature in degree Fahrenheit scale to temperature in Kelvin scale and vice versa*

3.6.1 Temperature conversion between degree Celsius and Fahrenheit scale

Dear student! In this subsection, you are going to learn the conversion of temperature from degree Celsius scale to Fahrenheit scale and vice versa.

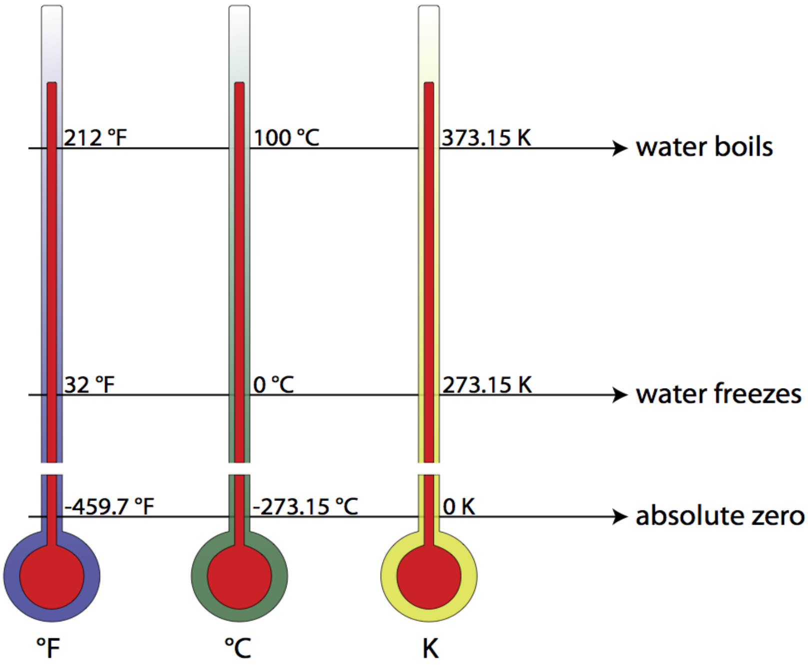


Figure 3.14: The fixed points of Fahrenheit, Celsius and Kelvin temperature scales

Dear student! The following two questions are basic to understand this subsection.

? Derive the formula for converting temperature in Celsius scale to Fahrenheit scale and vice versa.

Let us represent the Celsius temperature scale by T_C and the Fahrenheit temperature scale by T_F. Using the lower and upper fixed points of both scales;

$$\frac{T_C - ice\ point}{steam\ point - ice\ point} = \frac{T_F - ice\ point}{steam\ point - ice\ point}$$

$$\frac{T_C - 0}{100 - 0} = \frac{T_F - 32}{212 - 32} \quad \Longrightarrow \quad \frac{T_C}{100} = \frac{T_F - 32}{180}$$

☞

$$T_C = \frac{5}{9}(T_F - 32) = \frac{(T_F - 32)}{1.8}$$

$$T_F = \frac{9}{5}T_C + 32 \qquad T_F = 1.8T_C + 32$$

Example 1: What is the temperature in degree Celsius on a day when the it reaches 50 °F, ?

Given	Required	Solution
$T_F = 50\ °\mathrm{F}$	$T_C = ?$	$T_C = \frac{5}{9}(T_F - 32)$

Inserting the value of T_F, $T_C = \frac{5}{9}(50 - 32) = \frac{5}{9}(18) = 10\ °\mathrm{C}$

Example 2: The temperature of the room is $20\ °\mathrm{C}$. What is the temperature of the room in Fahrenheit scale?

Given	**Required**	**Solution**
$T_C = 20\ °\mathrm{C}$	$T_F = ?$	$T_F = \frac{9}{5}\ T_C + 32\ °\mathrm{F}$

Inserting the value of T_C, $T_F = \frac{9}{5}\ (20) + 32\ °\mathrm{F} = 36\ °\mathrm{F} + 32\ °\mathrm{F} = 68\ °\mathrm{F}$

3.6.2 Temperature conversion between degree Celsius and Kelvin scale

Dear student! In the previous subsection, you learned about the conversion of temperature from the Celsius scale to the Fahrenheit scale and vice versa. In this subsection, you are going to learn about temperature conversion between degree Celsius and Kelvin scale.

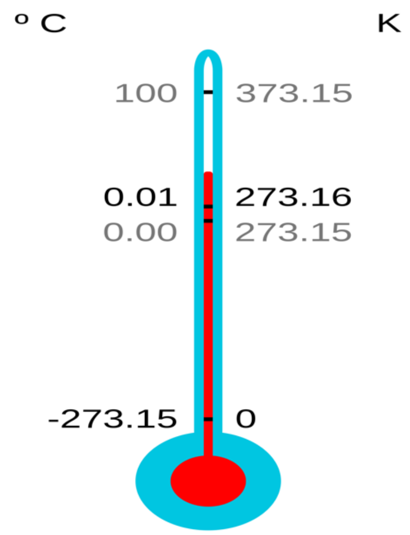


Figure 3.15: The fixed points of Celsius and Kelvin temperature scales

Denoting the Celsius temperature scale by T_C and the Kelvin temperature scale by T_K and using the ice and steam points of both scales;

$$\frac{T_C - ice\ point}{steam\ point - ice\ point} = \frac{T_K - ice\ point}{steam\ point - ice\ point}$$

$$\frac{T_C - 0}{100 - 0} = \frac{T_K - 273.15}{373.15 - 273.15} \quad \Longmapsto \quad \frac{T_C}{100} = \frac{T_K - 273.15}{100} \Longmapsto T_C = T_K - 273.15$$

☞ $T_C = T_K - 273.15$

$T_K = T_C + 273.15$

Example 3: Water is boiled to a temperature of 72 ℃. What does the Kelvin scale read for this value?

Given	**Required**	**Solution**
$T_C = 72\ ℃$	$T_K = ?$	$T_K = T_C + 273.15$

Inserting the value of T_C, $T_K = (72 + 273.15)$ K $\Longrightarrow T_K = 345.15$ K

Example 4: The temperature of a hot metal is 573.15 K. What is the value of this temperature in degree Celsius scale?

Given	**Required**	**Solution**
$T_K = 573.15$ K	$T_C = ?$	$T_C = T_K - 273.15$

Inserting the value of T_K, $T_C = (573.15 - 273.15)$ ℃ $\Longrightarrow T_C = 300$ ℃

Self-Test Exercise 3.10

Give short answers to the following questions

1. The size of one Kelvin is identical to that of one Celsius degree. Discuss and reason out.
2. The temperature difference of 5 ℃ is equal to the temperature difference of 5 K. Discuss.
3. What is the minimum possible temperature in nature?

3.6.3 Temperature conversion between degree Fahrenheit and Kelvin scale

Dear student! In the previous section, you learned about measuring with different thermometric scales. In this section, you will learn about different thermometers and their use.

Dear student! From the previous discussions, you learned how to derive a formula of conversion between the Celsius temperature scale and Fahrenheit temperature scale. Moreover, you came through how to determine the formula of conversion between the Celsius temperature scale and the Kelvin temperature scale.

Self-Test Exercise 3.11

Give short answers to the following questions

1. Employing the same procedure, derive the formula relating the Fahrenheit temperature scale and the Kelvin temperature scale.
2. The temperature of the environment in Fahrenheit scale is 82 °F . What is its reading in Kelvin scale?
3. Students designed their own thermometer and have a new temperature scale. On this temperature scale, the steam point is 312 °C and the ice point is 112 °C. What is the temperature on this scale that corresponds to 28 °C ?
4. Convert the following temperatures to degree Fahrenheit scale.

   a) 40 °C b)60 °C c) 30 °C
5. Convert the following temperatures to the degree Celsius scale.

   a) 98.6 °F b)50 °F c) 125 °F
6. Convert the following temperatures to the degree Kelvin scale.

   a)20 °C b)32 °F c) 100 °C

√ Check List 3.6

Dear learner, now it is time to check your understanding about different thermometers and their use. Read each question and put a mark ("X") in the box that is appropriate choice to you.

	Yes	No
1. Can you convert temperature in degree Celsius scale to temperature in Fahrenheit scale and vice versa?	☐	☐
2. Can you convert temperature in degree Celsius scale to temperature in Kelvin scale and vice versa?	☐	☐
3. Can you convert temperature in degree Fahrenheit scale to temperature in Kelvin scale and vice versa?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Section 3.7: Thermal Expansion of materials

Dear student! In the previous section you have learned about conversion of temperature scales. In this section, you will learn about thermal expansion of materials.

After reading this section, you should be able to:

- *define thermal expansion;*
- *describe the difference in expansion rates of materials;*
- *recommend materials based on their expansion rate;*
- *calculate the temperature dependent expansion of linear materials.*

Dear student! You are familiar with material heating and cooling. Try to answer the following brainstorming question.

? What happens to metals when they are heated or cooled? Does the wood expand or contract when it is heated or cooled?

Different materials expand or contract at different rates. In general, gases expand more than liquids, and liquids expand more than solids. Observation of thermal expansion in a solid object requires careful analysis. Understanding the expansion of metals is very crucial for using them in different technological applications. Have you ever found the metal lid on a glass jar too tight to open? One solution is to run hot water over the lid, which loosens because the metal expands more than the glass does. To varying extents, most materials expand when heated and contract when cooled.

Activity 3.4

- Dear student! The following practical activity helps you to understand that different materials expand differently.
- Materials needed: copper wire of 2 mm in diameter and 50 cm in length, aluminum wire of 2mm in diameter and 50 cm in length and

steel wire of 2 mm in diameter and 50 cm in length

Procedure:

- Fasten the three wires at one end and put on a surface or knife-edge near the other end,
- Heat the wires at the same time, (Please do not touch the wires in your hand. It is dangerous! Use holder.
- Observe the wires.

1. Which wire expands more?
2. Which wire expands less?
3. What are the factors that determine the linear expansion of solids?

Self-Test Exercise 3.12

Answers to the following questions

The lengths of solid bars of different materials can be measured at different temperatures using very precise equipment, as shown in Table 1.

Table 1: Expansion and contraction of solids

Material	Length in cm $(-100℃)$	Length in cm $(0\ ℃)$	Length in cm $(100\ ℃)$
Lead	99.71	100.00	100.29
Steel	99.89	100.00	100.11
Aluminum	99.77	100.00	100.23
Brass	99.81	100.00	100.19
Copper	99.83	100.00	100.17
Glass	99.91	100.00	100.09
Pyrex™ (glass)	99.97	100.00	100.03

1. What can you say about the change in length of the bars when they are cooled to the temperature of -100 °C or heated to the temperature of 100 °C ? Is it very small? While explaining, consider very long structures such as bridges.
2. What similarity do you see in how all the materials react as they warm?

3. In what way do the materials react differently as they warm?
4. Which material expands the most as it warms?
5. Which material expands the least as it warms?
6. What do you notice from your list when you examine how the materials cool and contract? Does the material that expands the most at a high temperature also contract the most at a low temperature?
7. Compare the changes in length of materials at $100\ ℃$ in the table and write them in an increasing order.
8. A builder asked you to select a metal that does not vary with temperature. Which best metal do you recommend from the list?

When a solid is heated, its particles move farther apart, and hence the solid expands. To varying extents, most materials expand when heated and contract when cooled. The increase in any one dimension of a solid is called **linear expansion**, and it is linear in the sense that the expansion occurs along a line. Figure 7.16 depicts the linear expansion of a rod of length is L_0 at temperature T_0. When the temperature increases from T_0 to $T_0 + \Delta T$, the length becomes $L_0 + \Delta L$ where ΔT and ΔL are the magnitude of the changes in temperature and length respectively. Conversely, when the temperature decreases to $T_0 - \Delta T$, the length decreases to $L_0 - \Delta L$.

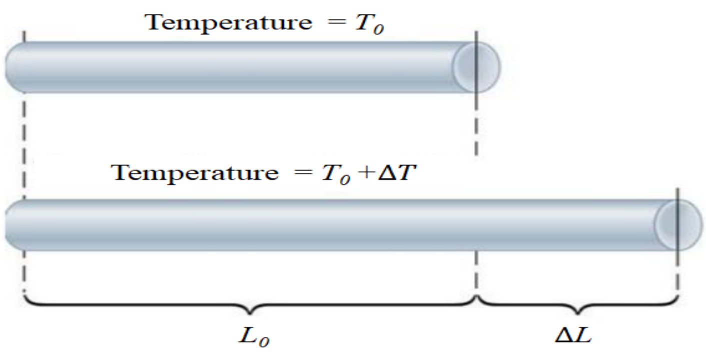


Figure 3.16: When the temperature of the rod raises by ΔT, the length of the rod increases by ΔL

For modest temperature changes, experiments show that the change in length (ΔL) is directly proportional to the change in temperature ΔT.

$$\Delta L \propto \Delta T$$

In addition, the change in length is proportional to the initial length of the rod.

$$\Delta L \propto L_{0.}$$

From the above two equations we conclude that,

$$\Delta L \propto L_0\, \Delta T.$$

By using the proportionality constant α,

☞ $$\Delta L = \alpha L_0\, \Delta T$$

where, α is the coefficient of linear expansion and its unit is $\frac{1}{℃}$.

☞ Linear expansion: the increase in length of a substance due to heating.

Coefficient of linear expansion: the increase in length of a 1 m road of a given substance when its temperature increases by 1 K.

Self-Test Exercise 3.13

Give short answers to the following questions

1. What happens to the change in length of the rod if the initial length of the rod is doubled?
2. Does the coefficient of linear expansion depend on the nature of material?
3. A **bimetallic strip** is made from two thin strips of metal that have *different* coefficients of linear expansion. Brass $\alpha = 19 \times 10^{-6}\ (℃)^{-1}$ and steel $\alpha = 12 \times 10^{-6}\ (℃)^{-1}$ are selected. The two pieces are weld together.
   a) What happens when the bimetallic strip is heated?
   b) What happens when the bimetallic strip is cooled?
   c) Discuss some technological applications of bimetallic strips.

The coefficients of linear expansion of solids are described in Table 3.

Substance	Coefficient of linear expansion (α) in $(℃)^{-1}$
Aluminum	2.6×10^{-5}
Brass	1.9×10^{-5}

Concrete	1.2×10^{-5}
Copper	1.7×10^{-5}
Glass (common)	8.5×10^{-6}
Glass (Pyrex)	3.3×10^{-6}
Gold	1.4×10^{-5}
Iron or steel	1.2×10^{-5}
Lead	2.9×10^{-5}
Nickel	1.3×10^{-5}
Quartz (fused)	0.5×10^{-6}
Silver	1.9×10^{-5}

An interesting example of linear expansion occurs when there is a hole in a piece of solid material. We know that the material itself expands when heated.

Activity 3.5

- What about the hole? Does it expand, contract, or remain the same? Explain it.

Example 1: A gold engagement ring has an inner diameter of $1.5 \times 10^{-2}\ m$ and a temperature of 27 °C. The ring falls into a sink of hot water, whose temperature is 49 °C. What is the change in the diameter of the hole in the ring?

Given **Required** **Solution**

$L_0 = 1.5 \times 10^{-2}\ m$ ΔL ? $\Delta L = \alpha L_0\ \Delta T$

$\alpha = 1.4 \times 10^{-5}\ (°\mathrm{C})^{-1}$ From Table 3 $\Delta L = 1.4 \times 10^{-5}\ (°\mathrm{C})^{-1} \times 1.5 \times 10^{-2}\ m$ (49 °C-27°C)

$T_0 = 27\ °\mathrm{C}$ $\Delta L = 1.4 \times 10^{-5}\ \cancel{(°\mathrm{C})^{-1}} \times 1.5 \times 10^{-2}\ m$ (22 $\cancel{°\mathrm{C}}$)

$T_0 = 49\ °\mathrm{C}$ $\Delta L = (1.4 \times 1.5 \times 22) \times 10^{-7}\ m = 4.62 \times 10^{-6}\ m$

Example 2: The initial length of a brass rod is 50 cm at a temperature of 35℃. What will be its final length when it is heated to a temperature of 80℃ ?

Given | Required | Solution

$L_0 = 50\ cm = 0.5\ m$ | $L_F = ?$ | $L_F = L_0 + \Delta L$

$T_0 = 25\ °C$ | $\Delta L = \alpha L_0\ \Delta T$

$T_F = 70\ °C$ | $\Delta L = 1.4 \times 10^{-5}\ (°C)^{-1} \times 50\ cm\ (80°C - 35°C)$

$\alpha = 1.4 \times 10^{-5}\ (°C)^{-1}$ | $\Delta L = (1.4 \times 0.5 \times 45) \times 10^{-5}\ m$

$\Delta L = 4.3 \times 10^{-4}\ m = 4.3 \times 10^{-2}\ cm = 0.043\ cm$

$L_F = 50\ cm + 0.043\ cm = 50.043\ cm$

Click on the following links to perform temperature-related experiments in a virtual laboratory under the guidance of your teacher. You can also copy and paste the links directly into your browser.

1. https://phet.colorado.edu/en/simultions/states-of-matter-basics
2. https://phet.colorado.edu/en/simulations/energy-forms-and-changes

√ Check List 3.6

Dear learner, now it is time to check your understanding about different thermometers and their use. Read each question and put a mark ("X") in the box that is appropriate choice to you.

	Yes	No
1. Can you define thermal expansion?	☐	☐
2. Can you describe the difference in expansion rate of materials?	☐	☐
3. Can you recommend materials based on their expansion rate?	☐	☐
4. Can you calculate temperature dependent expansion of linear materials?	☐	☐

Is there any question for which you marked "no' in the box under it? If so, please go back to your text and read about it.

Unit summary

- Temperature is the degree of hotness or coldness of a body or an environment or it is the measure of the average kinetic energy of the particles in a sample of matter.
- Temperature influences human clothing, eating habits, health, and economy.
- One of the most immediate and obvious effects of global warming is the increase in temperatures around the world due to greenhouse gases.
- An instrument that is used to measure the temperature of a body is called a thermometer.
- A thermometer can measure a temperature of a body in one of the three scales. These are the Celsius scale (℃), the Faherenheit scale (°F) and Kelvin scale (K).
- The S.I unit of temperature is Kelvin (K).
- The change in temperature between the Celsius and Kelvin scale is equal.
- The following formulae can be used to convert temperature from one scale to another scale.

  $T_C = \frac{(T_F - 32)}{1.8}$ ℃, $\quad T_F = 1.8T_C + 32$°F, $\quad T_K = T_C + 273.15,\ T_C = T_K - 273.15$

  $$T_F = 1.8(T_K - 273.15) + 32, \qquad T_K = \frac{T_F - 32}{1.8} + 273.15$$
- On heating, the particles of a substance move faster, and move further apart so that the substance expands.
- The increase in any one dimension of a solid is called **linear expansion.**
- For modest temperature changes, experiments show that the change in length (ΔL) is directly proportional to the change in temperature ΔT and the initial length of the rod L_0.

  $\Delta L = \alpha L_0\, \Delta T$, where α is coefficient of linear expansion.

Self-Assessment questions

Part I: Choose the correct answer from the given alternatives.

1. Which of the following best defines temperature? Temperature is:
   A. the degree of hotness or coldness of a body
   B. the measure of the average kinetic energy of a molecule in a body
   C. the measure of the total kinetic energy of a molecule in a body
   D. A and B E. A and C
2. Which one of the following instruments is used to measure the temperature of a body?
   A. Anemometer B. Barometer C. Hydrometer D. Thermometer
3. In constructing a thermometer, it is necessary to use a substance that:
   A. Expands with rising temperature
   B. Undergoes some changes when heated or cooled
   C. does not boil
   D. does not freeze
4. At what temperature do the Fahrenheit and Celsius scale read the same value?
   A. $40\ ℃, 40\ °F$ B $-40\ ℃,\ 40\ °F$ C. $-40\ ℃, -40\ °F$ D. $40\ ℃, -40°F$
5. Room temperature is about 20 degrees on the:
   A. Kelvin scale B. Celsius scale C. Fahrenheit scale D. Absolute scale

Part II: Give short answers to the following questions

1. What is temperature?
2. What are the causes for the rise of temperature in our environment?
3. Define absolute temperature.
4. What are the steam and ice points of water in Kelvin scale?

Part III: Workout

1. What is the temperature in Celsius scale if the reading in Fahrenheit scale is zero?
2. The temperature of an object is 310 K. What is this temperature in Fahrenheit scale?
3. The ice and the steam points of the newly designed thermometer are 25 °X and 125°X respectively. What value of temperature does this thermometer read for $62\ ℃$?
4. Calculate the increase in length of a 2m copper rod that is heated

from $0\ °C$ to $150\ °C$?

Written Assignment

Part I: Choose the correct answer from the given alternatives.

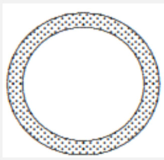
1. Thin strips of iron and zinc are weld together to form a bimetallic strip that bends when heated. The iron is on the inside of the bend because:

   A. It has a higher coefficient of linear expansion
   B. It has lower coefficient of linear expansion
   C. It has a higher specific heat
   D. It has lower specific heat

2. Which one of the following sets of temperatures are equivalent?

   A. $50\ °F, 10\ °C, 283.15$ K
   B. B. $68\ °F, 20\ °C, 341.15$ K
   C. C. $86\ °F, 30\ °C, 187.15$ K
   D. D. None

3. An annular thin ring of aluminum is cut from the aluminum sheet as shown. When the ring is heated:



   A. The aluminum expands outward and the hole remains the same
   B. The hole decreases in diameter
   C. The diameter of the hole expands the same percent as any length of the aluminum
   D. Linear expansion forces the shape of the hole to be elliptical.

4. The two metallic strips that constitute some thermostats must differ in:
   A. length B. thickness C. mass D. coefficient of linear expansion

5. Fahrenheit and Kelvin scales agree numerically at a reading of:

   B. A. -40 B. 273 C. 301 D. 574

Part II: Give short answers to the following questions

1. At which temperature do all molecules stop moving?
2. What is the working principle of a resistance thermometer?

3. What is the lowest possible temperature in nature?
4. Explain the difference between negative temperature coefficient thermistor and positive temperature coefficient thermistor.

Part III: Workout

1. 'Room temperature' is generally defined to be 25 ℃. What is the room temperature in: a) degree Fahrenheit, °F? b) Kelvin, K?
2. A ninth-grade student developed his own temperature scale called X scale. The difference between the freezing point and boiling point of water on X scale is 80 ^{0}X. If the outdoor temperature is 30 ℃ on the Celsius scale, what is it on the X scale?
3. The temperature varies from 25 ℃ to 38 ℃ yearly in the Afar region. A concrete side walk is constructed between two buildings when the temperature is 25 ℃. A sidewalk consists of one concrete slab of length 3m with negligible thickness. What amount of empty space should be provided to protect the concrete from bending?

Answer Key for Self-assessment questions

Self-test exercise 3.1

1. Human beings and other living creatures adapt to different temperature conditions in our planet, Earth. Particularly for human beings, this challenge creates room for innovation in temperature-related devices.
2. The sun and stars have high temperatures in nature. It is also possible to raise the temperature by burning wood, fuel and candle, electric heaters as well as using electric heaters and stoves. In contrast, there are bodies with lower temperature, such as water bodies with ice below0℃.

Self-test exercise 3.2

1. False 2. False 3. True

1. B 2. C 3. B

Self-test exercise 3.3

1. D 2. C 3. A

1. True 2. False

🛠 Self-test exercises 3.4

1. Greenhouse gases (carbon dioxide, methane, nitrous oxide and fluorinated gases) resulting from human activity are the causes for rising of temperature in our environment.
2. One of the strategies to mitigate this problem is reducing the concentration of greenhouse gases in the environment:
    - Using renewable energy sources such as solar energy, geothermal energy. wind energy, and energy from hydropower,
    - Conserving forest, planting trees. Bamboo and other plants can take Carbon dioxide from the air.
    - Reducing emissions from industry.
3. The greenhouse effect is the natural process that warms the Earth's surface.

🛠 Self-test exercises 3.5

1. A 2. D 3. D 4. B
2. False 2. True

🛠 Self-test exercises 3.6

1. You are expected to list at least one of the scales from the three scales. (Degree Celsius scale, degree Fahrenheit scale or Kelvin scale)
2. Degree Celsius
3. 37 ℃, 98.6 °F

🛠 Self-test exercises 3.7

1. D 2. B 3. C 4. A 5. D
1. False 2. True 3. False

🛠 Self-test exercises 3.8

1. The temperature scales are:
   Celsius temperature scale, Fahrenheit temperature scale, Kelvin scale; the fixed points are:
    - ice point (0℃) and steam point (100℃) for Celsius temperature scale
    - ice point (32 °F) and steam point (212°F) for Fahrenheit temperature scale

- ice point (273.15 K) and steam point (373.15K) for Kelvin temperature scale

2. The lower fixed point is the melting point of pure ice at normal atmospheric pressure, and the upper fixed point is the boiling point of pure water at normal at normal atmospheric pressure.
3. There are:
   - 100 divisions between the lower and upper fixed points of the degree Celsius scales;
   - 180 divisions between the lower and upper fixed points of the degree Celsius scales;
   - 100 divisions between the lower and upper fixed points of the degree Kelvin scales
4. The SI unit of temperature is Kelvin (K).

🛠 Self-test exercises 3.9

1. A 2. D 3. B

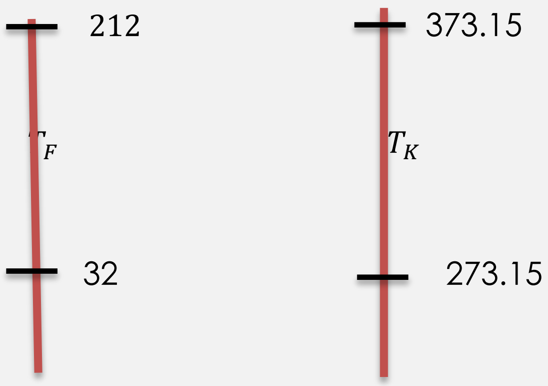
1. See section 3.5 in your module. Different types of thermometers and their importance have already been discussed.
2. The differences between alcohol and mercury thermometers are:
   - A mercury thermometer is a type of thermometer that uses a bulb filled with mercury as a temperature sensor, whereas an alcohol thermometer uses a bulb filled with alcohol as a temperature sensor
   - A mercury thermometer is more durable than an alcohol thermometer because mercury does not evaporate easily.
   - A mercury thermometer is used to measure high temperature,
   - whereas an alcohol thermometer is used to measure lower temperature;
   - A mercury thermometer has lower value of temperature coefficient of expansion than alcohol thermometer.
3. Different thermometers have different ranges of measuring temperature.
   - Alcohol thermometer measures temperature in the range of $-115\ ℃$ to $78.15\ ℃$.
   - A mercury thermometer measures temperature in the range of $-30\ ℃$ to $300\ ℃$.

- A thermocouple measures temperature in the range of $-270\ ^\circ\mathrm{C}$ to $2300\ ^\circ\mathrm{C}$.
- A resistance thermometer measures temperature in the range of $-270\ ^\circ\mathrm{C}$ to $700\ ^\circ\mathrm{C}$.
- Some radiation thermometers measure temperatures in the range of $400\ ^\circ\mathrm{C}$ to $1250\ ^\circ\mathrm{C}$.
- Thermistors measure temperature in the range of $0\ ^\circ\mathrm{C}$ to $100\ ^\circ\mathrm{C}$.

4. We need different thermometers. Because we have a very broad range of temperatures from the lowest possible temperature to a very high temperature, for example, temperatures of the sun or a star.

🛠 Self-test exercises 3.10

1.



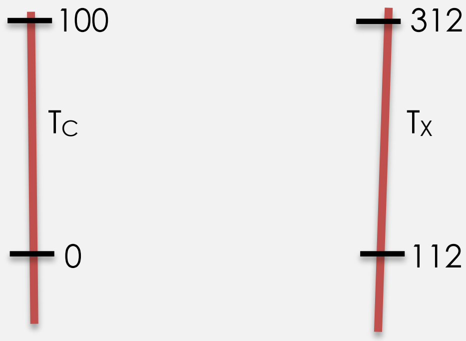
$$\frac{T_F - 32}{212 - 32} = \frac{T_K - 273.15}{373.15 - 273.15} \Longrightarrow \frac{T_F - 32}{180} = \frac{T_K - 273.15}{100}$$

$$T_F - 32 = 1.8(T_K - 273.15) \Longrightarrow T_F = 1.8(T_K - 273.15) + 32$$

$$\Longrightarrow T_K = \frac{T_F - 32}{1.8} + 273.15$$

2. 300.93 K

3.



$$\frac{T_C - 0}{100 - 0} = \frac{T_X - 112}{312 - 112} \Longrightarrow \frac{T_C}{100} = \frac{T_X - 112}{200}$$

$$T_X = 2T_C + 112 \quad \Longrightarrow \quad T_X = 2(28) + 112 = (56 + 112)^\circ X$$

$$T_X = 168\ ^\circ X$$

4.a) $104\ °F$ b) $140\ °F$ c) $86\ °F$

5.a) $37\ ℃$. b) $10\ ℃$ d) $51.7\ ℃$

6.a) 293.15 K b) 273.15 K c) 373.15 K

🛠 Self-test exercises 3.11

1. When the materials are heated at $100\ ℃$, the length of materials increases and when they are cooled at $-100℃$ the length of materials decrease. The change in length of materials is given in the following Table 1. If you double the length of the material, the change in length will double; if you triple the length of the material, its change in length will be tripled and so on. So, change in length for materials is not small, and affects in large constructions such as bridges if it is not considered.

Material	Change in length (ΔL) at $-100℃$	Change in length (ΔL) at $100℃$
lead	-0.29	0.29
steel	-0.11	0.11
aluminum	-0.23	0.23
brass	-0.19	0.19
copper	-0.17	0.17
glass	-0.09	0.09
Pyrex™ (glass)	-0.03	0.03

2. All materials expand when they are heated.
3. Different materials react differently when they are heated. The change in length of some materials is very small compared with other materials when they are exposed to the same temperature. For example, the change in length of lead is about ten times that of Pyrex.
4. Lead
5. Pyrex
6. The rates of expansion and contraction are the same. The material that expands the most at high temperature also contracts the most at low temperature. See the table.

7. Pyrex, glass, steel, copper, brass, aluminum, lead
8. Steel

🛠 Self-test exercises 3.12

1. The change in length can also be doubled.
2. Yes, the coefficient of linear expansion depends on the nature of the materials. It is different for different materials.
3. When the bimetallic strip is heated, the brass, having the larger value of α, expands more than the steel. Since the two metals are bonded together, the bimetallic strip bends into an arc as shown in part *b*, with the longer brass piece having a larger radius than the steel piece. When the strip is cooled, the bimetallic strip bends in the opposite direction, as in part c.

🛠 Self-test exercises 3.13

1. D
2. D
3. B
4. C
5. B

1. Temperature is the degree of hotness or coldness of a body or the measure of the average kinetic energy of the particles in a body.
2. Greenhouse gas emissions.
3. An absolute temperature is the possible minimum temperature, 0 K on the Kelvin scale or -273.5 ℃ in the Celsius scale.
4. 273.15 K (ice point), 373.15 (steam point)

1. -17.78
2. 98.33
3. 87 $°X$
4. 0.0051 m

Guide and answer to activity 3.1

1. Materials needed are: 3 cups, cold water, warm water and hot water. Make students in group to predict their idea before the experiment, and then tell them to do the experiment and finally reject or accept the idea based on the experiment.
2. The wood and the metal are in thermal equilibrium with the outside air and are thus the same temperature. They feel different because of the difference in the way that they conduct heat away from your skin. The metal conducts heat away from your body faster than the wood does. This is just one example demonstrating that the human sense of hot and cold is not determined by temperature alone.
3. Testing the hotness or coldness of a body by feeling is not reliable

Guide and answer to activity 3.2

High temperature has major effects on people and environment with respect to:

- Agriculture: the crops that we grow for food need specific conditions to thrive, including the right temperature and enough water,
- Energy: the rise in temperature could make it harder to produce certain types of electricity, such as hydropower. This results in power shortages and blackouts.
- Health: the rise in temperature affects the environment that provides us with clean air, food, water, and shelter. These threaten human health.
- Water supply: the rise in temperature reduces the amount of water in our local environment.
- Forest provides homes for many kinds of plants and animals. They also protect water quality, offer opportunity for recreation, and provide people with food. However, the rise in temperature results in wildfire that destructs the forest.
- Plants, animals and ecosystem: as the Earth gets warmer, plants and

animals that need to live in cold places like mountain might not have a suitable place to live. So, they become extinct.

Guide and answer to activity 3.3

1. 0 ℃ or 32 ℉ or 273.15 K
2. 100 ℃ or 212 ℉ or 373.15 K