Unit - 8

ENERGY SOURCES AND TRANSFER OF ENERGY

Energy is the most important physical concept which is studied in all sciences. work is closely related with energy which provides a link between force and energy. Work, energy and power have special meaning in physics.

Students Learning Outcomes (SLOs)

After learning this unit students should be able to:

- Define work and its SI unit.
- Calculate work done using equation Work = force × distance moved in the direction of force
- Define kinetic energy and potential energy
- Use Kinetic Energy $E_k = \frac{1}{2} mv^2$ and potential energy $E_p = mgh$; to solve problems.
- Describe the processes by which energy is converted from one form to another with reference to fossil fuel energy, hydroelectric generation, solar energy, nuclear energy, geothermal energy, wind energy, biomass energy and tidal energy.
- Differentiate energy sources as non renewable and renewable energy sources with examples of each.
- Define efficiency of a working system and calculate the efficiency of an energy
- conversion using the formula efficiency = energy converted into the required form / total energy input
- Explain why a system cannot have an efficiency of 100%.
- Define power and calculate power from the formula Power = work done / time taken
- Define the unit of power "watt" in SI and its conversion with horse power.

Do You Know!

Force is an agent which tends to change the state of an object.

What source of energy is more beneficent ? Why we face the shortage of petroleum and gas in our country? Why the people are replacing electric energy by solar energy? Why government is focusing its attention on the use of tidal, solar and wind energy? Why the waste material should be buried in Earth?

After learning this unit you will be able to answer these questions and some other similar questions.

8.1 WORK

Generally, work refers to perform some task or job. But in physics work has different meaning.

For example: A tailor stitching a suit, a shopkeeper selling fruits at his shop, a women cooking in her kitchen are all considered as "doing work" in daily life but in physics work has a proper meaning i.e. "work is done only when a force makes something to move; Fig 8.1(a,b)". Thus work can be define as

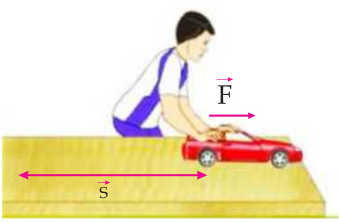


Fig 8.1 (a)
Demonstration of work done

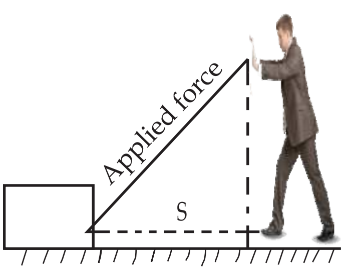


Fig 8.1 (b)
Demonstration of work done

The amount of work is the product of force and the distance moved in the direction of force.

Units of Work

The S.I unit of work is Joule other units of work can be Foot, Pound, Erg.

$$1 \text{ Joule} = 1\text{Nm}$$

Suppose a constant force "F" acts on a body and motion takes place in a straight line in the direction of force then work done is equal to the product of magnitude of force "F" and the distance "d" through which the body moves.

$$W = Fd\cos\theta \quad \text{.......................(8.2)}$$

The force "F" however may not act in the direction of motion of the body instead it makes some angle "θ" with it; Fig 8.2. In that case, we define the work by the force as the product of the component of the force along the line of motion and the distance "d"; the body moves along that line, i.e.

Suppose a constant force "F" acts on a body

$$\text{Work} = (\text{component of force}) \cdot (\text{distance})$$

$$W = (F\cos\theta)\, d$$

or $$W = (F\cos\theta)\, d$$

If $$\theta = 0 \Rightarrow \cos\theta = 1$$

then $$\text{Work} = W = Fd$$

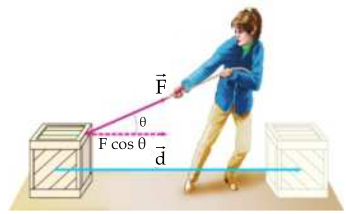


Fig 8.2 (a)
Force making some angle θ with the direction of motion

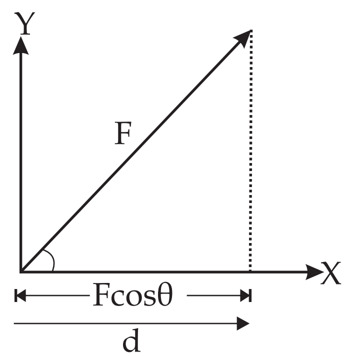


Fig 8.2 (b)
Force making some angle θ with the direction of motion

Worked Example 1

Find the work done when a force of 50N is applied to move a trolley at a shopping mall through a distance of 200m? Assume the angle to be of 0° between the force and the distance the trolley moved.

Solution

Step 1: Write down known quantities and quantities to be found.

$F = 50N$
$d = 200m$
$\theta = 0^\circ$
$W = ??$

Step 2: Write down formula and rearrange if necessary

$W = F \cdot d$
$W = Fd\cos\theta$

Step 3: Put the values in formula and calculate:

$W = 50N \times 200m \times \cos 0^\circ$
$W = 10000J$

Hence, the work done is 10000 Joules.

Self Assessment Questions:

Q1: Write down the names of any three units of work

Q2: According to the definition of work in physics, Urwa did not perform any work if she made and assignment on her laptop in three hours. Why?

Q3: At what angle between force and displacement the work done by a body will be maximum?

Energy

Energy is define as

The ability to do work.

the S.I unit of energy is joule (J). There are many forms of energy. Some of them are discussed below:

8.2 Energy Forms

Kinetic Energy

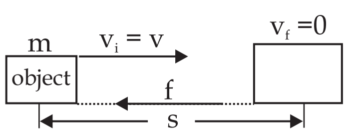
Kinetic energy of a body defined as:

Energy possessed by an object due to its motion is called kinetic energy.

The S.I unit of kinetic energy is joule.

It is also defined as "The work required to accelerate a body of a given mass from rest to its stated velocity". A moving body maintains its kinetic energy unless its speed changes.

Mathematically kinetic energy is given as:



$$\mathbf{K.E} = \frac{1}{2}\mathbf{mv}^2 \quad \text{..................}(8.3)$$

As we know that kinetic energy is due to the motion of object. Therefore for an object of mass m moving with speed v kinetic energy depends upon:

- the mass m of the object- the greater the mass, the greater its K.E
- the speed v of the object- the greater the speed, the greater the K.E

Do You Know!

Sailing boat, moving air, driving car, running and walking are example of kinetic Energy.

Worked Example 2

A ball of mass 400 gram, strikes the wall of velocity 4m/sec. How much is the kinetic energy of the ball at the time it strikes the wall?

Solution

Step 1: Write down known quantities and quantities to be found.

$$m = 400\text{ gram} = \frac{400}{1000}\text{ kg} = 0.4\text{ kg}$$

$$v = 4ms^{-1}$$

$$K.E = ?$$

Step 2: Write down formula and rearrange if necessary

$$K.E = \frac{1}{2}mv^2$$

Step 3: Put the values in formula and calculate

$$K.E = \frac{1}{2} \times 0.4kg \times (4ms^{-1})^2$$

$$K.E = 3.2J$$

Hence, Kinetic Energy is possessed by the ball 3.2 joules.

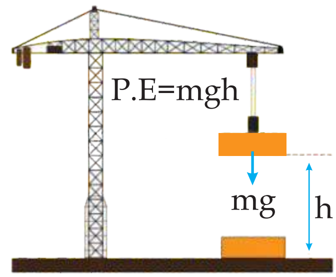


Fig 8.4 (a)
Gravitational Potential Energy

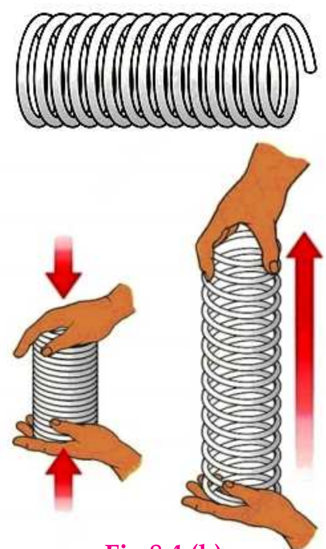


Fig 8.4 (b)
Elastic Potential Energy

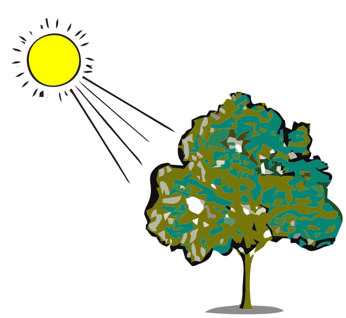


Fig 8.4 (c)
Chemical Potential Energy

Potential Energy

Potential energy of a body is defined as:

The energy that a body possesses by virtue of its position, shape or state of a system.

There are different types of potential energy. Like gravitational potential energy, elastic potential energy and chemical potential energy; Fig 8.4 (a, b, c).

For Example:

- A body raised to a height "h" above the ground has gravitational potential energy.
- A stretched spring has elastic potential energy due to its stretched position (condition).

- The energy stored in the plants that we eat is chemical potential energy.

S.I. unit of potential energy is Joule (**J**).

It is also defined as the work done stored in a body in lifting it to a height "h". The potential energy changes only when its position relative to ground changes; otherwise it remains same.

Mathematically potential energy is given as

$$\textbf{P.E = mgh} \quad .... (8.4)$$

Derivation of Gravitational Potential Energy P.E=mgh

To derive the expression for gravitational potential energy, let us consider an object of mass "m" which is raised up through height "h" from the ground; Fig 8.5. The work done in lifting it to height "h" is stored in it as its gravitational potential energy "P.E", i.e.

$P.E = \text{Work done}$

$P.E = W$ As $W = F.d$

$P.E = F.d$ where $d = h$ (height)

$P.E = (mg) \cdot h$ $F = mg$ (weight)

Therefore equation becomes:

$$\textbf{P.E = mgh} \quad .... (8.4)$$

Do You Know!

A book lying on the table and the water stored in a dam have potential energies.

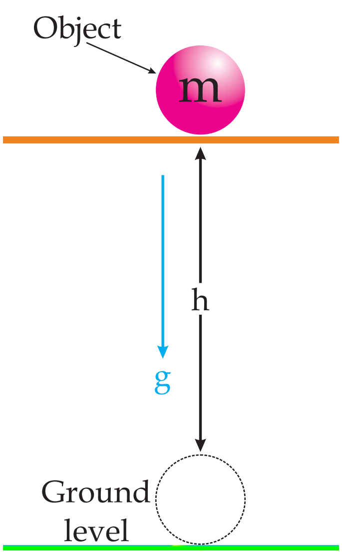


Fig 8.5
An object of mass 'm' raised to height 'h'.

Worked Example 3

A ball of mass 50 gram is raised to a height of 7m from the ground. Calculate its gravitational potential energy?

Solution

Step 1: Write down known quantities and quantities to be found.

$$m = 50gm = \frac{50}{1000}kg = 0.05kg$$

$h = 7m$

$g = 10ms^{-2}$

$P.E = ??$

Step 2: Write down formula and rearrange if necessary

$P.E = mgh$

Step 3: Put values in formula and calculate

$P.E = 0.05kg \times 10ms^{-2} \times 7m$

$P.E = 3.5 \text{ Joule}$

Hence, gravitational potential energy of the ball is 3.5 Joules.

Self Assessment Questions:

Q4: A car of mass 50kg moving with velocity $10ms^{-1}$ in the direction of force. Calculate its Kinetic energy.

Q5: A body of mass 10kg is dropped from a height of 20m on the ground. What will be its potential energy, if $g=9.8 \text{ m/sec}^2$?

Q6: Give the energy changes when a ball is dropped from a height of 7m to the ground.

8.3 CONVERSION OF ENERGY

Energy neither be created nor it can be destroyed but it can be converted from one form to other form. This is called law of conservation of energy.

Conversion of Energy from one form to another

i. Fossil Fuel Energy

Fossil fuel energy is formed from decayed plants and animals that have been converted to crud oil, coal, natural gases or heavy oils by exposure to heat and pressure in the Earth's crust over hundreds of millions of years; Fig 8.6.

Fig 8.6
Fossil fuel energy

Fig 8.7
Burning charcoal

Fossils fuels have stored chemical energy. This energy is converted by oxidation through burning. Thus on burning a fossil fuel like charcoal, produce heat energy and light energy; Fig 8.7.

ii. Hydroelectric Energy

Fig 8.8
Hydroelectric energy

Hydro electricity is the term referring to electricity generated by hydro power by using gravitational force of falling or flowing water; Fig 8.8.

Most common type of hydro electric power plants uses a dam on a river to store water in a reservoir. Water releases from the reservoir flows through a turbine, spinning it, which in turn runs a generator to produce electricity.

iii. Solar Energy

Fig 8.9 (a)
Solar energy (Solar Panel)

The energy radiated from the sun is known as solar energy. This is the most available source of energy throughout Pakistan. There are many devices which are capable of absorbing solar energy, which is then converted into electrical energy or heat energy. These devices may be photovoltaic solar panels and solar cells. Which convert the sun rays into electricity for different uses; Fig 8.9(a). Also solar heaters are used to convert solar energy "sun rays" into heat energy to heat water tanks and indoor spaces; Fig 8.9(b).

Fig 8.9 (b)
Solar energy (Solar heater)

iv. Nuclear Energy

The energy released during a nuclear reaction such as fission or fusion reaction. All radioactive materials store nuclear energy. For example Uranium, Radium etc. It is released from the nucleus in the form of radiation in addition to heat and light. A nuclear power plant utilize nuclear energy to produce steam to turn a turbine and generate electricity; Fig 8.10.

Fig 8.10
Nuclear energy

v. Geothermal Energy

Geothermal energy is stored in the Earth as its natural heat. Deep in the Earth, there is hot molten part called magma. Water close to magma changes to steam due to high temperature. This thermal energy is conducted to the surface of Earth. This energy is called geothermal energy; Fig 8.11(a).

Fig 8.11(a)
Geothermal energy

A geothermal power plant utilizes geothermal energy to drive an electrical generator; Fig 8.11 (b). Geothermal well can be built by drilling deep near hot rocks at different places, where hot molten or magma is very close, water is then pushed down into the well. The rocks quickly heat the water and change it into steam. The steam is used for heating purpose or to generate electricity.

Fig 8.11(b)
Geothermal power plant

vi. Wind Energy

The energy obtained by the wind is called wind energy. It is generated by wind mills (Fig 8.12). A wind mill consists of a turbine which rotates due to wind. Kinetic energy is produced due to the motion of turbine. Wind turbines convert this kinetic energy into the mechanical power. A generator converts that mechanical power into electricity.

Fig 8.12
Wind energy

Application

- It is being used as source of energy for sailing ships in oceans.
- It is being used by wind mills to pump water.

Fig 8.13(a)
Biomass energy (Wood)

Fig 8.13(b)
Biomass energy (Organic materials)

Fig 8.13(c)
Biomass energy (Garbage)

Fig 8.14
Tidal energy

- It is being used by wind mills to grind grain.
- It is used to turn wind turbines to produce electricity.

ii. Biomass Energy

Biomass is the organic material that comes from plants and animals. Biomass consists of stored energy from Sun, garbage, wastes, sugarcane etc. Solid biomass, such as wood, organic material and garbage, can be burned directly to produce heat; Fig 8.13 (a, b, c). Biomass can also converted into gas called biogas and into liquid biofuels such as ethanol and biodiesel.

viii. Tidal Energy

It is a form of hydro power that converts the energy obtained from tides into useful form of power; mainly electricity as the Earth uses the gravitational forces of both the moon and the sun every day to move vast quantities of water around the oceans and seas producing tides and in this way energy is produced called tidal energy; Fig 8.14.

Self Assessment Questions:

Q7: What is biomass?

Q8: Write down the name of fossil fuel?

Q9: Which type of energy is stored deep in the Earth?

8.4 RENEWABLE AND NON-RENEWABLE ENERGY SOURCE

Renewable Energy Source

The renewable sources can be consumed and used again and again. Solar energy, wind energy, tidal energy and geothermal energy are renewable sources.

Since very earlier age, people have tried to consume renewable sources of energy for their survival. Such as wind and water for milling grain and solar for lighting.

Non-Renewable Sources

Non-renewable resources are limited and will finish once used. Coal, petroleum and natural gases are nonrenewable sources. About 150 years ago scientists invented new technology to extract energy from the ancient fossilized remains of plants and animals. These super-rich but limited sources of energy (coal, oil and natural gas) replaced wood, wind and water as the main sources of fuel. They are being used at a faster rate than they can be restored again and, therefore cannot be renewed.

Self Assessment Questions:

Q10: Write down the names of any three renewable energy sources?

Q11: Write down the names of any three non-renewable energy sources.

Q12: What is the difference between renewable and non-renewable energy sources?

8.5 EFFICIENCY

Every machine needs some energy to perform work. Whatever energy given to a machine is called input and the work done by the machine is called output.

For example: We give electric energy as input to the electric motor in washing machines and in drilling machines.

Do You Know!

- Wind energy is clean fuel source.
- It does not pollute the air.
- Wind turbines does not produce atmospheric emission that causes greenhouse gasses.

Do You Know!

The costal belt of Pakistan is about 1045 km long with best resources for utilizing and producing tidal energy.

A system in which some energy 'E_1' is supplied to it as 'input' and the system returns back some energy 'E_2' as output has some efficiency. This efficiency is defined as

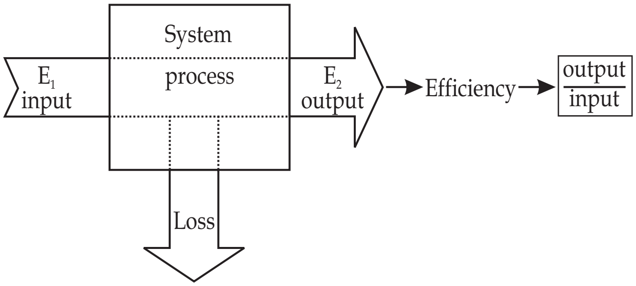
The ratio of output to the input is called Efficiency.

Efficiency is denoted by "η". As it is the ratio of two energies therefore it has no unit. No machine is 100% efficient because some energy is always wasted in the form of heat, sound or light etc.

$$\text{Efficiency} = \frac{\text{Energy as output}\,(E_2)}{\text{Energy as input}\,(E_1)}$$

$$\therefore \qquad \eta = \frac{E_2}{E_1} \times 100$$

$$\text{Efficiency} = \frac{\text{output}}{\text{input}} \times 100 \quad \text{.........................(8.5)}$$



Do You Know!

We get

- Chemical energy from fuel, gas and battery
- Thermal energy from heat
- Nuclear energy from nuclear Fission and fusion
- Electrical energy from movement of electrons in atom
- Mechanical energy from walking, running
- Sound energy from sound waves

8.6 POWER

When you run up and cover distance in 5 seconds or take slow walk up the same distance in 20 seconds. You are doing the same amount of work, However, you are doing it at different rate. When you run up, you are working much faster and you have a higher power then when you walk up.

This quantity that tells us the rate of doing work. Thus, power is defined as:

The rate of doing work. or
The amount of energy transferred per unit time.

Mathematically,

$$\text{Power} = P = \frac{\text{work done}}{\text{time taken}}$$

$$\therefore \quad P = \frac{w}{t} \quad \text{.......................(8.6)}$$

Since work and time are scalar quantities. Therefore, power is also a scalar quantity.

Unit of Power

In SI system unit of power is $\frac{\text{Joule}}{\text{sec}}$ = Watt

Thus SI unit of power is watt which is defined as:

The power of a body is said to be one watt if it does work at the rate of one Joule per second.

Worked Example 5

Calculate the power of a machine. If the machine performs 900 joules of work in 30 minutes.

Solution

Step 1: Write down known quantities and quantities to be found.

$$W = 900J$$

$$t = 30min = 30 \times 60s = 1800\,s$$

$$P = ??$$

Step 2: Write down formula and rearrange if necessary

$$P = \frac{W}{t}$$

Step 3: Put values in formula and calculate

$$P = \frac{900J}{1800s}$$

$$P = 0.5\,W$$

Hence, power of the machine is 0.5 Watt.

Do You Know!

1kg of 4% enriched fuel grade uranium releases energy equivalent to the combustion of nearly 100 tons of high grade coal or 60 tons of oil.

Do You Know!

Larger units of power are
Kilo watt (kW),
Mega watt (MW),
Horse Power (hp) etc.
$1kW = 1000W = 10^3$ watt
$1MW = 1000000W = 10^6$ Watt
1 hp = 746 Watt

Self Assessment Questions:

Q13: A man pushes a car 18m with a force of 2N in 4 second. Calculate the power of the man.

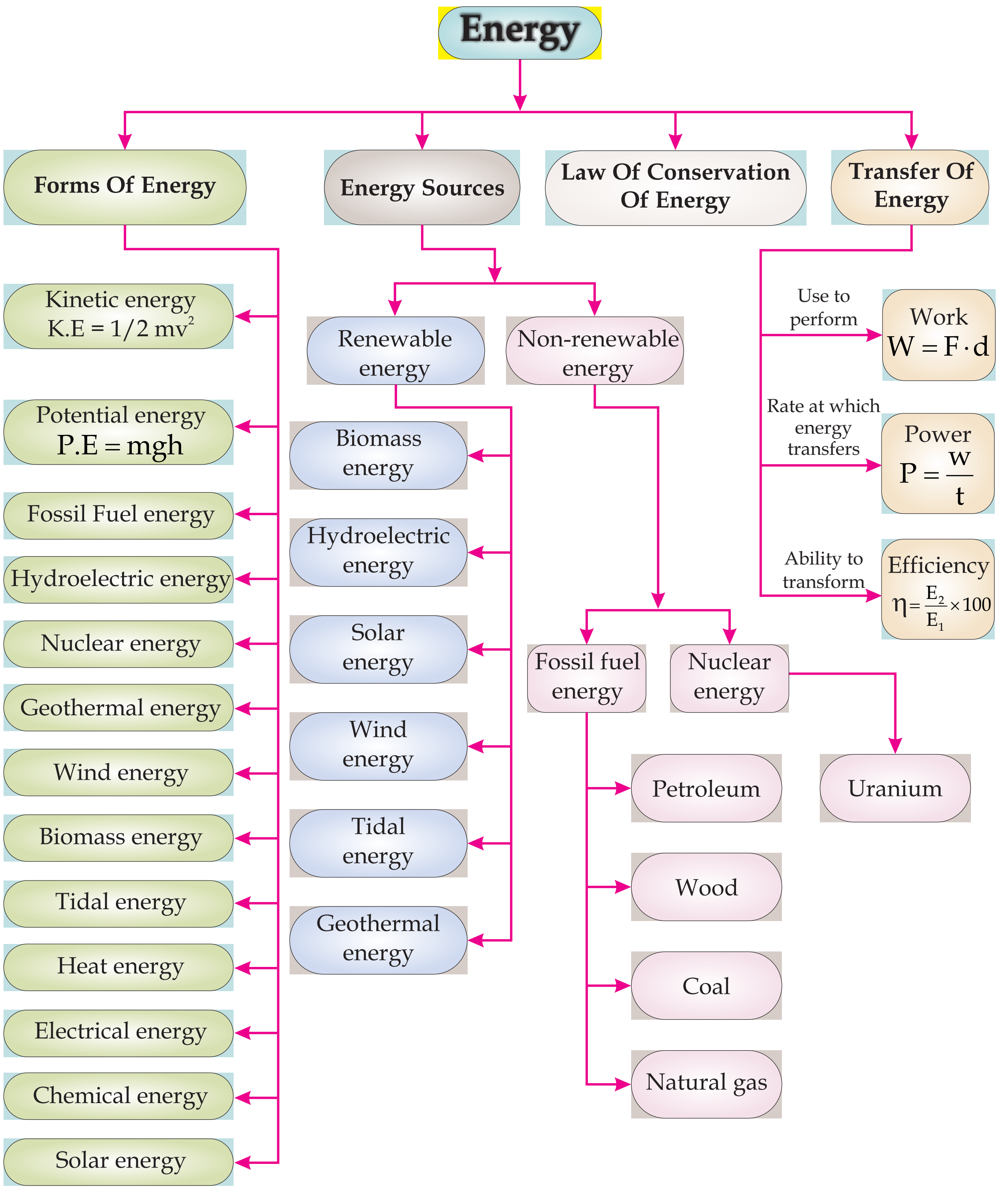
Q14: Why power is a scalar quantity?

Q15: Name the physical quantity which gives the rate of doing work.

SUMMARY

- Work is the product of force and the distance $W = F \cdot S$
- The ability to do work is called energy. SI unit of energy is Joule (**J**).
- Energy possessed by an object due to its motion is called as Kinetic Energy $K \cdot E = 1/2\, mv^2$
- Energy due to position of an object is called Potential Energy $P \cdot E = mgh$.
- Energy exists in many different forms such as nuclear energy, heat energy, electrical energy, chemical energy, light energy, etc.
- Solar energy, wind energy, tidal energy, geothermal energy, biomass energy and hydroelectric energy are the examples of renewable sources of energy.
- Wood, coal, petroleum, natural gas and Uranium are examples of nonrenewable sources of energy.
- The ratio of output to the input is called efficiency.
- The work done in unit time is called power. SI unit of work is Watt.

CONCEPT MAP


Energy
Forms Of Energy
Energy Sources
Law Of Conservation Of Energy
Transfer Of Energy
Kinetic energy $K.E = 1/2\ mv^2$
Potential energy $P.E = mgh$
Fossil Fuel energy
Hydroelectric energy
Nuclear energy
Geothermal energy
Wind energy
Biomass energy
Tidal energy
Heat energy
Electrical energy
Chemical energy
Solar energy
Renewable energy
Non-renewable energy
Biomass energy
Hydroelectric energy
Solar energy
Wind energy
Tidal energy
Geothermal energy
Fossil fuel energy
Nuclear energy
Petroleum
Wood
Coal
Natural gas
Uranium
Use to perform
Work $W = F \cdot d$
Rate at which energy transfers
Power $P = \frac{w}{t}$
Ability to transform
Efficiency $\eta = \frac{E_2}{E_1} \times 100$

End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

1. If force of 6N displaces an object 2m in the direction of force, then work done will be__________.
   - a) 0
   - b) 12 Joule
   - c) 3 Joule
   - d) Both b and c
2. If a body of mass 1 kg is moving with velocity of 1m/sec then K.E of the body will be ___________.
   - a) Joules
   - b) Joules
   - c) Joules
   - d) 1 Joule
3. If a machine performs 20J of work in 10sec then its power is ________.
   - a) 200 watt
   - b) 20 watt
   - c. 2watt
   - d) 0.2 watt
4. A body of mass 1kg is lifted through a height of 1m . The energy possessed in the body will be_______. (consider $g = 10ms^{-2}$)
   - a) 1J
   - b) 10 Joule
   - c) 100 Joule
   - d) 1000 Joule
5. The energy released during fission or fusion reaction is called ____________.
   - a) Solar energy
   - b) Geothermal energy
   - c) Tidal energy
   - d) Nuclear energy
6. Which is the renewable source of energy
   - a) Solar and wind
   - b) Coal
   - c) Natural gas
   - d) Petrolium
7. The ratio of output to input is called
   - a) Energy
   - b) Work
   - c) Power
   - d) Efficiency

8. Work done per unit time is called __________.

a) Efficiency b) Energy
c) Power d) Force

9. Coal, gas and oil are all examples of_________.

a) Tidal energy b) Nuclear energy
c) Fossil fuel energy d) Biomass energy

10. ____________ is not a renewable source of energy.

a) Solar energy b) Coal
c) Wind energy d) Geothermal energy

Section (B) Structured Questions

Work

1. a) Define work?
   b) Derive the equation; work = Fd cosθ.
2. How much work is needed to move horizontally a body 20m by a force of 30N, the angle between the body and the horizontal surface is 60^{o}?
3. How much work is done, if a crate is moved at a distance of 50m, when a force of 30N is applied along the surface.
4. What is the work done by Usman? If a bar of weight 100 N is brought by him from A to B, then brought back to A.

Energy Forms

5. a) Define Kinetic energy
   b) Derive the equation.
6. What will be the Kinetic energy of a boy of mass 50kg driving a bike with velocity of $2ms^{-1}$.
7. a) Define Potential Energy
   b) Derive the equation. PE = mgh

8. a) If LED screen of mass 10kg is lifted up and kept it on a cupboard of height 2m. Calculate the potential energy stored in the LED screen.
   b) Calculate the potential energy of 3kg water raised to the tank at the roof of a home 4m high. (assume $g=10ms^{-2}$)

Conversion of Energy

9. a) Why fossil fuel energy is called non-renewable source?
   b) Define solar energy and its importance in Pakistan?
10. Write notes on Tidal energy and Geothermal energy.
11. a) What is wing energy?
    b) Write any three applications of wind energy ?
12. a) Write the name of any one radioactive element which is used as source of nuclear energy.
    b) Write the names of any one device that can convert solar energy into heat energy.
    c) Write the names of any two devices that can convert solar energy into electrical energy.

Renewable and Non-renewable Energy Sources

13. Write a note on renewable energy sources?
14. Write a note on non-renewable energy sources?
15. What is the difference between renewable of non-renewable energy sources?
16. Make a table of renewable and non-renewable energy sources from the following:

    Uranium, Solar, Coal, Wind, Natural gas, Tidal, Biomass, Hydroelectricity.

Efficiency

17. Calculate the efficiency of a machine which consumes 200 J of energy and performs 50J of work.
18. Write a note on efficiency.
19. If the efficiency of a machine is 70% and its output is 100 J then calculate its input.
20. Which machine is more efficient, machine "A" which has an output of 200J after consuming 400J of energy or machine "B" which has an output of 300J after consuming 450J of energy?

Power

21. a) Define power.
    b) The energy of 600J dissipated by a bulb in 50 minutes. Find the power of the bulb.
22. a) Convert 20watt into horse power.
    b) Calculate the power of a machine, if it does 40 Joules of work in 10 sec.
23. a) Define Watt.
    b) A student of weight 400N takes 5 sec to climb up an obstacle of height 2m. Calculate the power consumed ?
24. a) Write down the names of any two larger units of power.
    b) If a machine consumes 250J of energy per hour then what will be its power?

Unit - 9

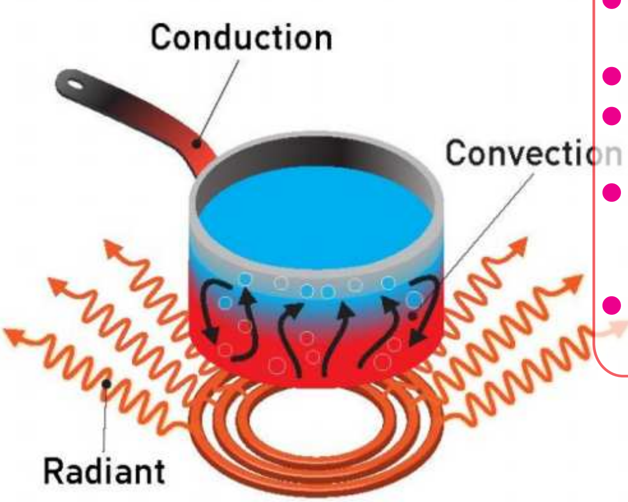
THERMAL PROPERTIES OF MATTER

The properties of matter which change with the change in temperature are called "Thermal properties". Materials change their states due to change in their temperature, cause by the addition or removal of heat. Like for example, water changes from liquid to gas 'steam' due to addition of heat or to solid 'ice' due to removal of heat. The process of evaporation, boiling, freezing, thermal expansion (liner and volumetric) are all happens due to the change in temperature of the substance. Thus changes in temperature caused by the addition or removal of heat play very important role in our daily life.

Students Learning Outcomes (SLOs)

After learning this unit students should be able to:

- Differentiate between heat and temperature
- Define the terms heat capacity and specific heat capacity with SI unit
- Describe one everyday effect due to relatively large specific heat of water
- Describe heat of fusion and heat of vaporization (as energy transfer without a change of temperature for change of state)
- Describe experiments to determine heat of fusion and heat of vaporization of ice and water respectively by sketching temperature-time graph on heating ice.
- Explain the process of evaporation and the difference between boiling and evaporation.
- Explain that evaporation causes cooling
- List the factors which influence surface evaporation
- Define thermal expansion
- Describe qualitatively the thermal expansion of solids (linear and volumetric expansion)
- List and explain some of the everyday applications and consequences of thermal expansion
- Explain the thermal expansion of liquids (real and apparent expansion)



The objective of this unit is to create critical logical thinking among the students, so that they can observe and analyze the physical quantities and changes taking place in their surroundings.

- How does water in our surrounding helps us to maintain the temperature of environment?
- Why different liquids heat up in different manner at same time an same temperature?
- What is the importance of specific heat in everyday life?
- How evaporation takes place and its affects on the surroundings?
- What happen when temperature of solids and liquids increases?
- How does physical state of matter changes from one state to other?
- Why wet clothes take more time to dry out in cloudy day?
- What is the role of thermal expansion in our daily life?

Do You Know!

Heat transfers in three ways
i. Conduction
ii. Convection
iii. Radiation

9.1 HEAT AND TEMPERATURE

Heat

Mostly we think that heat and temperature are the same, however, this is not true, they are related with each other, but are different concepts; Fig 9.1(a, b).
Heat is a form of energgy. Where as temperature is flow of heat.
For Example: A hot cup of tea is placed on table, after some time the tea in the cup becomes cold because surrounding temperature is lower than that of the hot tea. Hence heat flows from hot cup to the surrounding. Therefore heat and temperature can be stated as:

Fig 9.1 (a)
Heat

Fig 9.1 (b)
Temperature

Heat	Temperature
It is the form of energy which transfers from hot body to cold body as a result of difference of temperature between them. As heat is form of energy. Therefore its SI unit is joule. Its other unit is calorie.	It is a degree of hotness of a body. It determines the direction of flow of heat from one body to the other body. SI unit of temperature is Kelvin. Its other units are Celsius and Fahrenheit.

Thermometer

Thermometer is a device, used to measure temperature.

For example;

A clinical thermometer is used to measure the temperature of human body (Fig 9.2).

Fig 9.2
Clinical thermometer

Thermometers have different scales to measure temperature.

There are three scales of temperature (Fig 9.3).

1. Celsius scale (Mostly used for environmental measurements)
2. Fahrenheit scale (Mostly used for clinical measurements)
3. Kelvin scale (Mostly used for industrial measurements)

These three scales of temperature are interconvertible. Therefore temperature measured in Celsius scale can be converted into Kelvin and Fahrenheit scales as follows:

Conversion of temperature from Celsius scale to Kelvin scale

$$K = {}^{\circ}C + 273$$

Conversion of temperature from Celsius scale to Fahrenheit scale

$$^{\circ}F = 1.8^{\circ}C + 32$$

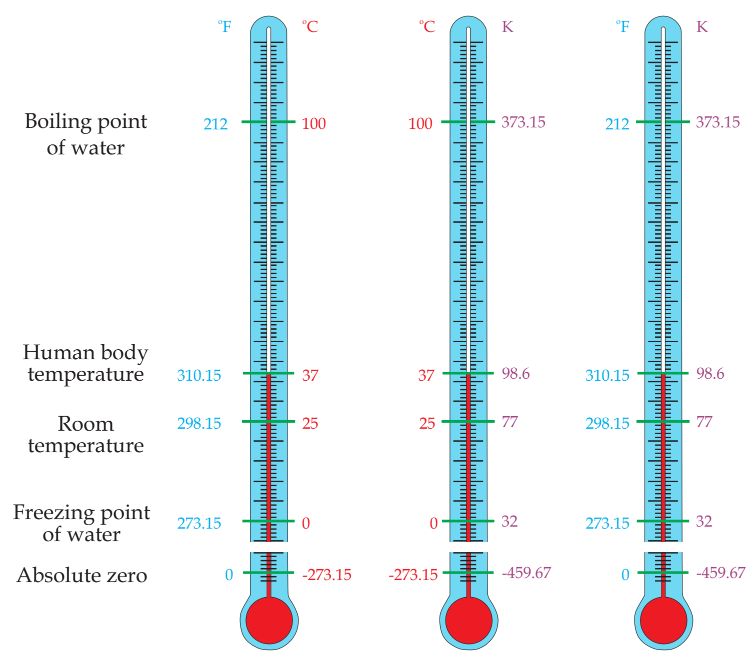


Fig 9.3
The three scales of thermometer

Do You Know!

The temperature of a small cup of tea might be the same as the temperature of a large cup of tea , but the large cup of tea gas more amount of heat because it has more tea has amount of thus more total thermal energy.

Do You Know!

Specific heat of water is 4200 $Jkg^{-1} K^{-1}$.
Boiling point of water is 100°C

Worked Example 1

The temperature of Hyderabad on a hot day is 45 degree Celsius (45°C). What will be its equivalent temperature on Fahrenheit Scale?

Step 1: Write down known quantities and quantities to be found.

$$°C = 45°$$

$$°F = ??$$

Step 2: Write down formula and rearrange if necessary

$°F = 1.8°C + 32$

Step 3: Put values in formula and calculate

$°F = 1.8 \times 45 + 32$

$°F = 113°$

Hence, the equivalent temperature in Fahrenheit scale is 113°F.

Self Assessment Questions:

Q1: Differentiate between heat and temperature.

Q2: Why we can not tell temperature of a body by teaching it?

Q3: Explain different scales used in thermometers to measure the temperature

9.2 SPECIFIC HEAT CAPACITY

Heat Capacity

Heat capacity is a term in physics that describe how much heat is added to a substance to raise its temperature by 1°C.

Mathematically $C = \frac{Q}{\Delta T}$ where Q = amount of heat absorbed and ΔT is change in temperature.

Heat capacity depends upon the nature of material. For example Two beakers contain equal masses of water and oil are heated by the same gas burner for three

Substance	Specific heat capacity (J/(kg·°C))
Water	4.18×10^3
Ethyl alcohol	2.46×10^3
Ice	2.1×10^3
Aluminum	9.2×10^2
Glass	8.4×10^2
Iron	4.5×10^2
Copper	3.8×10^2
Sliver	2.4×10^2
Lead	1.3×10^2

Table 9.1
Specific Heat Capacity of different substances.

Do You Know!

Water has very high specific heat, while the sand has relatively low specific heat, therefore the sand heats up very quickly with little energy.

minutes. Then it is observed that the temperature of oil may rise twice than water.

Specific Heat Capacity

When comparing the heat capacity of different substances, we are actually talking about their specific heat capacity.

Hence specific heat capacity can be defined as:

Amount of heat required to raise the temperature of 1 kg of a substance through 1 °C is called specific heat capacity of that substance.

Equation of specific heat capacity 'c' is as under:

$$c = \frac{C}{m} = \frac{1}{m}\left(\frac{Q}{\Delta T}\right)$$

$$c = \frac{\Delta Q}{m\Delta T} \quad ....(9.1)$$

Where "c" is constant which depends upon the nature of material of the body. This constant is called as specific heat capacity or specific heat. Its SI unit is joule per kilogram per Kelvin (**$Jkg^{-1}K^{-1}$**).

Table 9.1 shows the specific heat capacity of different substances of common use.

Effects due to large specific heat of water

We know that water has a large specific heat, due to this quality it plays an important role in everyday life.

- The large amount of water in oceans and lakes help to maintain the temperature ranges in their surroundings.
- Water with coolant is used to reduce the temperature of engine through radiator of vehicle.
- Water also help to maintain our body temperature.

Worked Example 2

The thermal energy required to raise the temperature of 50g of water from 40°C to 70°C is 6300 Joules. Calculate the specific heat capacity of water.

Step 1: Write down known quantities and quantities to be found.

$T_1 = 40°C$

$T_2 = 70°C$

$\Delta T = T_2 - T_1 = 70°C - 40°C = 30°C = 30K$

$\Delta Q = 6300J$

$m = 50g = 0.05\,kg$

$c = ?$

Step 2: Write down formula and rearrange if necessary

$$c = \frac{\Delta Q}{m\Delta T}$$

Step 3: Put values in formula and calculate

$$c = \frac{6300J}{0.05kg \times 30K}$$

$$c = 4200Jkg^{-1}K^{-1}$$

Hence, specific heat of water is $c = 4200Jkg^{-1}K^{-1}$.

Do You Know!

Soil has specific heat capacity of 810 $Jkg^{-1}K^{-1}$, which is about 5 times less than that of water.

Self Assessment Questions:

Q4: Define specific heat capacity.

Q5: Write down the factors on which specific heat capacity depends.

Q6: Write examples of specific heat capacity from daily life experience.

9.3 Heat of fusion and heat of vaporization

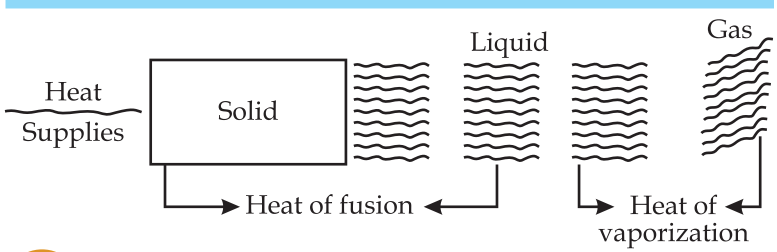
Heat of fusion

The heat absorbed by a unit mass of a solid at its melting point in order to convert solid into liquid without change of temperature is called "heat of fusion".

Heat of vaporization

When a beaker filled with water placed on a burner to boil, the temperature of water gradually raises until it reaches 100°C. At this temperature it starts to boil, that is to say that bubbles of vapor formed at the bottom and start to raise to the surface and then escape in the form of steam. At this stage the temperature of water (liquid) and of water vapors (gas) is same. Thus the heat energy which is required to convert water from liquid to vapor state is know as "heat of vaporization". Therefore heat of vaporization is defined as:

The amount of heat energy required to change the state of a substance from liquid to vapor form, without changing its temperature is called "heat of vaporization".



Do You Know!

- The heat of fusion for water at 0°C is approximately 334 Joules per gram.
- The heat of vaporization for water at 100°C is about 2230 Joules per gram.

Activity

Encourage students to take solid ice pieces in a container and supply heat through burner, and observe the process of heat of fusion in class/lab.

Experiments given below determine latent heat of fusion and latent heat of vaporization of ice and water respectively by sketching temperature-time graph of heating ice. This experiment has two parts

(i) Conversion of ice into water.

(ii) Conversion of water into steam.

(i) Convert Ice (Solid) into Water liquid

Experiment

Take a container and place it on a stand as shown in; Fig 9.4. Put small pieces of ice in the container. Suspend a thermometer in the container to measure the temperature. Take a stop watch to measure accurate time at different stages. Now place the container on the burner. The ice will start melting after absorbing heat. The temperature will remain same up to 0°C until all the ice melts. Note the time t_1 and t_2, which the ice takes to melt completely into water at 0°C. Supply heat continuously to water at 0°C, again note the time, Its temperature will start to increase. Note the time, which water in container takes to reach its boiling point at 100°C from 0°C. Draw a temperature-time graph as shown in graph 9.1. Calculate the heat of fusion of ice from the data using the graph.

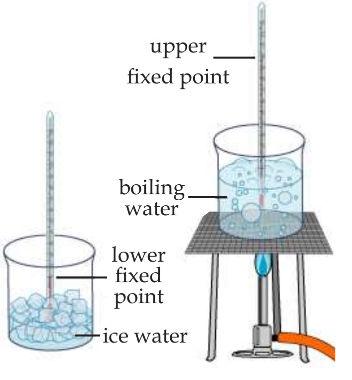
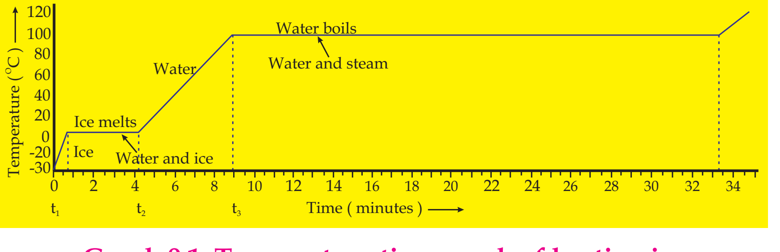


Fig 9.4
Heating ice experiment



Graph 9.1. Temperature-time graph of heating ice

Experiment
(ii)Convert Water (Liquid) into steam (Gas)

It is continuity of previous experiment; Fig 9.5. The container now contains boiling water we continue to supply heat to water, till all the water convert into steam. Note the time during which water in container completely changed into steam at its boiling point, using the temperature-time graph no 9.1 calculate the heat of vaporization of water.

Table 9.2 shows heat of fusion and vaporization of different elements.

Self Assessment Questions:

Q7: Why does the temperature not increase when ice is heated at $0^{\circ}C$?

Q8: Why does the temperature not increase when water is heated at $100^{\circ}C$? Explain.

9.4 EVAPORATION PROCESS

It is our common observation that wet clothes dry in sun due to the evaporation. The water in the wet cloth takes heat energy from sun and get evaporated. Similarly the water taken from the sea is kept under the sun for a long period of time leading to the evaporation of the water molecules and as a result the common salt is formed, which is left as remnants in this whole process. We mostly notice that water placed in a pot, disappear slowly. It is because of evaporation process

The process in which the water changes from liquid to gas or vapor form is known as "evaporation".

Difference between boiling point and evaporation

Evaporation	Boiling
1. It takes place without supply having external heat source.	1. It only takes place without on supply external heat source.
2. It occurs at any temperature below boiling point.	2. It occurs only at certain temperature called "Boiling point".
3. It causes cooling.	3. It do not causes cooling.
4. It is relatively slow.	4. It is relatively fast.
5. It takes place only at the liquid surface.	5. It takes place throughout the liquid.
6. No formation of bubbles.	6. Bubbles are formed.

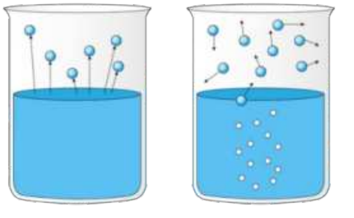


Fig 9.5
Difference between evaporation and boiling

Figure 9.5 demonstrates the difference between evaporation and boiling. The table 9.3; shows the freezing and boiling points of some important solvents.

Solvent	Freezing point (°C)	Boiling Point (°C)
Water	0.0	100
Acetic acid	17.0	118.1
Benzene	5.5	80.2
Chloroform	-63.5	61.2
Ethanol	-114.7	78.4

Table 9.3 Freezing and boiling points of different solvents

Evaporation causes cooling

When evaporation occurs, the molecules of water with greater Kinetic energy escape from its surface. So the molecules of water with lower Kinetic energy are left behind. This results in a decrease in the temperature of water. Hence, evaporation causes cooling.

You feel cold when come out directly under a heavy wind after taking bath. This is due to the reason

Fig 9.6
Evaporation causes cooling

that water molecules with greater Kinetic energy escape from your skin surface, while the molecules with lower Kinetic energy are left behind. This lowers the temperature of water at your skin and you feel cold.

Some liquids have low boiling point due to which they change from liquid to vapor very easily at ordinary temperature, these liquids are called 'volatile liquids'.

For Example methylated ether has low boiling point. If little amount of methylated spirit is taken on our hand it evaporates rapidly and our hand feel instantly cold. To change spirit from liquid to vapor it requires latent heat which is obtained from our hand thus our hand losses heat and we feel cool.

Water also causes the hand to become cold but it is not felt as spirit. The water has high boiling point then spirit so it evaporates slowly at the temperature of our hand and hence it does not cause the cooling effect.

Factors which Influencing Surface Evaporation

a. **Temperature:** With the increase in temperature the rate of evaporation also increases.

b. **Wind Speed:** Rate of evaporation also increases with the increase in wind speed.

c. **Surface area of liquid:** Rate of evaporation increases with the increase in surface area of liquid.

d. **Humidity:** The rate of evaporation decreases with increase in humidity.

e. **Nature of liquid:** Nature of liquid also effect the rate of evaporation. Liquid with lower boiling point have grater vapor pressure and evaporate more rapidly.

f. **Solute Concentration:** Salty water evaporates more slowly than pure water.

Self Assessment Questions:

Q9: Define evaporation and factors influencing evaporation process.

Q10: Differentiate between boiling and evaporation.

Q11: What is the freezing point of ethanol in Celsius scale?

9.5 THERMAL EXPANSION

Most solid materials expand on heating and squeeze on cooling because on heating the kinetic energy of their molecules increases. Therefore changes take place in shape, area and volume of the substances with the change in temperature. This is called "thermal expansion", defined as:

The expansion of substance on heating is called thermal expansion.

Examples of thermal expansion

- Expansion in railway tracks in summer; Fig 9.7(a).
- Expansion in electric wires in summer; Fig 9.7(b).
- Expansion in bridges in summer; Fig 9.7(c), etc.

Fig 9.7 (a)
Thermal expansion

Fig 9.7 (b)
Thermal expansion

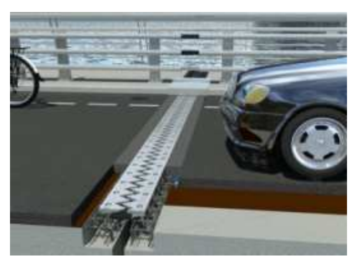


Fig 9.7 (c)
Thermal expansion

Expansion of Solid

The molecules of solid materials vibrate at their mean positions. So, when a solid is heated, its molecules vibrate with greater amplitudes due to increase in their kinetic energy. As a result the solid expands its length and volume.

Expansion

Linear expansion | Volumetric expansion

Linear Expansion

Fig 9.8
Linear expansion

The expansion in length of a solid object on heating is called linear expansion.

It is one dimensional expansion as it occurs only along the length of the object; Fig 9.8.

Suppose a rod of some material with original length L, at initial temperature T, is heated through a certain temperature T′, then its length increase and becomes L′. Therefore

Change in temperature = $\Delta T = T' - T$ -------(i)

Change in length = $\Delta L = L' - L$ ---------------(ii)

It has been experimentally proved that change in length is directly proportional to the original length and change in temperature. Therefore

$$\Delta L = (\text{constant})\, L\, \Delta T \text{ -----------------------(iii)}$$

This constant is denoted by α, and is called coefficient of linear expansion. It depends upon the nature of the material.

Therefore equation (iii) can be written as

$$\Delta L = \alpha\, L\, \Delta T \text{----------------------(9.2)}$$

Do You Know!

The co-efficient of volume expansion of liquids greater than solids.

Volumetric Expansion

The expansion in volume of a solid object on heating is called volume expansion.

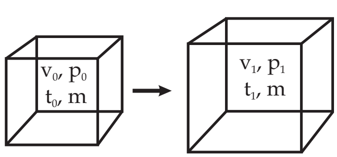


Fig 9.9
Volumetric expansion

It is three dimensional expansion as it occurs along the length, width and height of the object (Fig 9.9). Consider a solid body having volume V, at some initial temperature T. When the body is heated its temperature changes from T to T′ and its volume becomes V′.

Therefore

Change in temperature = $\Delta T = T' - T$ -------(i)

Change in volume = $\Delta V = V' - V$ ----------- (ii)

It has been experimentally proved that change in volume is directly proportional to the original volume and change in temperature.

ΔV = (constant) $V \Delta T$ ---------(iii)

This constant is denoted by "β" and is called coefficient of volume expansion. It depends upon the nature of material.

Therefore equation (iii) can be written as:

$$\Delta V = \beta V \Delta T \text{ .... } (9.3)$$

NOTE:

As linear expansion occurs in one dimension, where as volume expansion occurs in three dimensions. Hence, coefficient of volume expansion "β" is three times than coefficient of linear expansion "α":

Therefore:

$$\beta = 3\alpha \text{..........}(9.4)$$

Substance	Coefficient of expansion per degree centigrade
Aluminum	25×10^{-6}
Brass or Bronze	19×10^{-6}
Brick	9×10^{-6}
Copper	17×10^{-6}
Glass (Plate)	9×10^{-6}
Glass (Pyrex)	3×10^{-6}
Ice	51×10^{-6}
Iron or Steel	11×10^{-6}
Lead	29×10^{-6}
Quartz	0.4×10^{-6}
Silver	19×10^{-6}

Table 9.4

The coefficients of linear expansion of different substances.

Application and Consequences of thermal expansion

Thermal expansion of solids is useful in some situations of daily life and in some situations it creates problems:

Applications

Bimetal thermostat

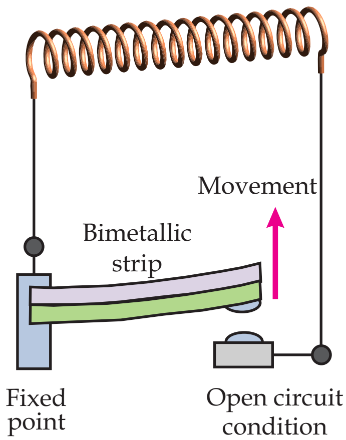


Fig 9.10
Bimetalic Thermostat

Bimetallic thermostat (Fig.9.10) is used to control temperature of ovens, irons water heaters, refrigerators, air conditioners and so on. It is designed to bend when it becomes hot. Two metals with different coefficient of linear expansion are joined firmly to make it . When it is heated, metal with large value of coefficient of linear expansion more than the other, causing the strip to bend. In this way, it cuts off the current supply. The current supply to the circuit is restored again when it cools down.

Rivets

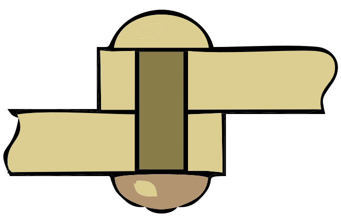


Fig 9.11 Rivet

Rivets(Fig.9.11) are used in shipbuilding and other industries to join metal plates. A red-hot rivet is passed through holes in two metal plates and hammered until ends are rounded. The rivet contracts on cooling and pulls the two plates tightly together.

A metal rim can be fixed on a wooden wheel(Fig.9.12) of a bull cart. The diameter of metal rim is set little bit smaller than the diameter of wooden wheel. The diameter of metal rim increases on heating and can easily be put over the wooden wheel. It contracts on cooling and holds wooden wheel tightly.


Fig 9.12
Wooden Wheel

i. Car Radiator Coolant

Engine coolant is used in car radiator in place of pure water because water has greater volume expansion it can expand enough to damage the engine or radiator.

ii. Mercury in Thermometer

Mercury expands on heating and contracts on cooling. It do not stick to the walls of thermometer. Therefore Mercury is placed in long sealed capillary tube in thermometer. Change in the temperature is measured by the position of mercury in capillary tube which has calibrated marks with °F, °C or K scale.

iv. Rail Tracks

The rail tracks are made up of metals and hence they expand in summer due to hot weather. Hence, small gaps are left at the joints of sections of tracks; Fig 9.13. This allows the tracks to expand safely. If these gaps are not left between the tracks, the tracks buckled and train would be de-tracked (derailed).

Fig 9.13
Gaps between Rail Tracks

Real and Apparent expansion of liquids

Consider a flask, filled with water up to level "a". The flask is placed on a burner, as shown below in; Fig 9.14.

Heat start to flow through the flask to water. So, the flask expand first. Due to expansion of flask, the level of water falls from point "a", level L_1 to point "b", level L_2. So, when water get heated, it start to expand from a point "b" beyond its original level.

Thus expansion of water appear from level "L_1" point "a" to level "L_3" point "c" is called "apparent expansion of water". But in real sense, the water on heating has expanded from level "L_2" point "b" to level "L_3" point "c" which is the "real expansion of water".

Real expansion = L_2 to L_3 i.e from point "b" to "c", as shown in; Fig 9.14.

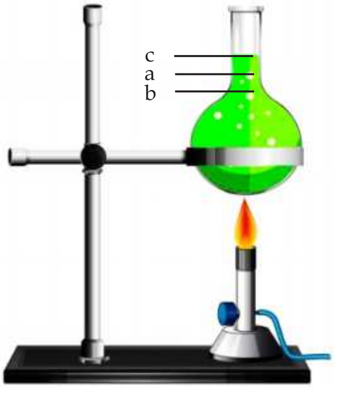


Fig 9.14
Real and Apparent expansion of liquids

Worked Example 3

A copper rod 15m long is heated, so that its temperature changes from 30°C to 85°C. Find the change in the length of the rod. The coefficient of linear expansion of copper is $17 \times 10^{-6}\,{}^{\circ}C^{-1}$.

Step 1: Write down known quantities and quantities to be found.

$$L = 15m$$

$$T = 30^{\circ}C$$

$$T' = 85^{\circ}C$$

$$\Delta T = T' - T = 85^{\circ}C - 30^{\circ}C = 55^{\circ}C$$

$$\alpha = 17 \times 10^{-6}\,{}^{\circ}C^{-1}$$

$$\Delta L = ?$$

Step 2: Write down formula and rearrange if necessary

$$\Delta L = \alpha L \Delta T$$

Step 3: Put values in formula and calculate

$$\Delta L = 17 \times 10^{-6}\,{}^{\circ}C^{-1} \times 15m \times 55\,{}^{\circ}C$$

$$\Delta L = 0.014m$$

Hence, the change in length of the copper rod is 0.014m.

Self Assessment Questions:

Q12: What is the reason for expansion of solids on heating?

Q13: Explain two types of thermal expansion.

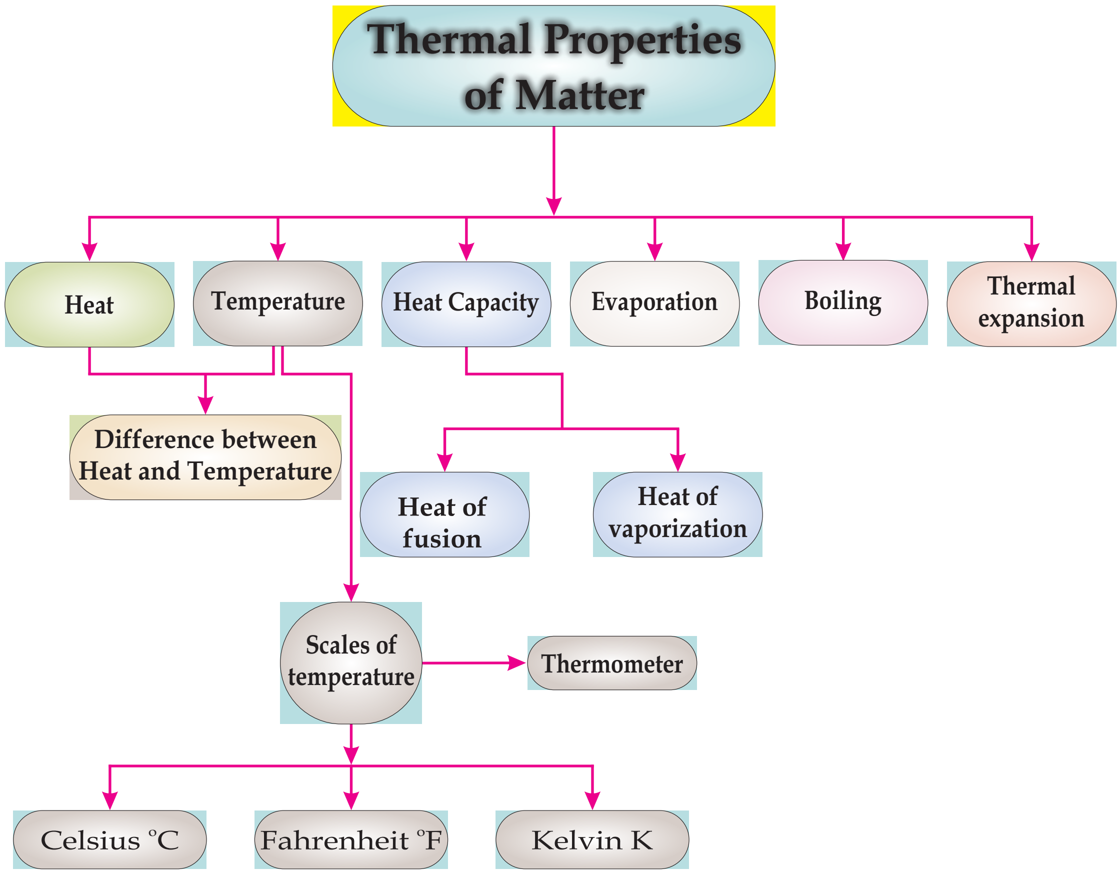
Q14: What is the relation between α and β?

SUMMARY

- Heat is the form of energy and its unit is Joule.
- Degree of hotness or coldness of a body is called as temperature.
- Temperature that determines the direction of transfer of thermal energy is called temperature..
- Three different scales, Celsius , Fahrenheit and are used for quantitative measurement of temperature.
- Temperature on Celsius scale is converted into Kelvin using $K = {}^{o}C + 273$.
- Temperature on Celsius scale is converted to Fahrenheit using: $F = 1.8{}^{o}C + 32$.
- Thermal energy transfer required per unit mass to raise the temperature by $1^{0}C$ or 1K is called specific heat capacity.
- The product of mass and specific heat capacity is called thermal capacity or heat capacity of an object.
- Thermal energy transfer required to change the state of a substance from solid to liquid without changing its temperature is called latent heat of fusion..
- Thermal energy transfer required to change the state of a substance from liquid into gas without changing its temperature is called heat of vaporization.
- The process in which liquid changes into gas without any external energy supply is called evaporation.
- Real expansion of water is the sum of apparent expansion of water and volume expansion of flask.

- Temperature, humidity, surface area of liquid, pressure, boiling point and moving air are the factors which affect the evaporation process of a liquid.
- Increase in length or size of a substance on heating is called thermal expansion.
- Increase in the length of a solid, when heated is called linear thermal expansion.
- Increase in volume of a solid, when heated is called volume thermal expansion.
- Volume thermal expansion of a solid depends upon increase in temperature, its original volume and properties of material.
- Increase in volume of a solid after heating is calculated by using $\Delta V = \beta V_0 \Delta T$.

CONCEPT MAP



Thermal Properties of Matter
Heat
Temperature
Heat Capacity
Evaporation
Boiling
Thermal expansion
Difference between Heat and Temperature
Heat of fusion
Heat of vaporization
Scales of temperature
Thermometer
Celsius °C
Fahrenheit °F
Kelvin K

End of Unit Questions

Section (A) Multiple Choice Questions (MCQs)

1. Heat is the form of __________
   a) Pressure   b) Weight
   c) Energy   d) All
2. Heat capacity is the product of mass and __________
   a) Boiling point   b) Freezing point
   c) Energy   d) Specific heat of material
3. The amount of heat needed to convert a substance from liquid to gas is called __________
   a) Heat of Vaporization   b) Specific heat
   c. latent heat of fusion   d) All
4. Thermal energy transfer required per unit mass to increase the temperature by 1^{0}C or 1 K is called ____
   a) Latent heat of Vaporization
   b) Specific heat capacity
   c) Latent heat of fusion
   d) Thermal capacity
5. A fixed temperature at which a pure liquid boils is called__________.
   a) melting point   b) freezing point
   c) boiling point   d) Both (a) and (b).
6. The melting point of ice at normal atmospheric pressure is __________.
   a) 0^{0}C   b) 0K
   c) 100^{0}C   d) Both (a) and (b)

7. Thermal energy transfer required to change a solid into liquid without changing its temperature is called __________.
   a) Latent heat of Fusion
   b) latent heat of vaporization
   c) latent heat of boiling
   d) specific heat capacity

8. Thermal energy transfer required to change a liquid into gas without changing its temperature is called
   a) latent heat of freezing
   b) latent heat of vaporization
   c) latent heat of boiling
   d) latent heat of melting

9. Evaporation can occur at __________
   a) freezing point   b) melting point
   c) boiling point   d) all temperatures

10. Rate of evaporation of a liquid can be increased by__________.
   a) increasing humidity
   b) decreasing temperature
   c) increasing its boiling point
   d) decreasing atmospheric pressure

11. Linear thermal expansion of a solid depends upon______________.
   a) increase in temperature
   b) original length
   c) properties of material
   d) all of these

Section (B) Structured Questions

Heat and Temperature

1. a) Define Heat and write its SI unit.
   b) Why does heat flows from hot body to cold body?
   c) Convert 30° C into Kelvin and Fahrenheit Scale.
2. a) Explain three different scales of temperature along with their main uses.
   b) Differentiate between heat and temperature.
   c) Convert 212°F into Celsius and Kelvin.

Specific Heat Capacity

3. a) Explain specific heat capacity.
   b) How would you find the specific heat of a solid?
   c) How much heat is required to boil 3 kg water which is initially 10° C ?
4. a) Explain the effects of large specific heat of water with examples from our daily life.
   b) 2kg of copper requires 2050J of heat to raise its temperature through 10°C. Calculate the heat capacity of the sample.

Heat of fusion and Heat of vaporization

5. Define heat of fusion with the help of an experiment.
6. Differentiate between heat of fusion and heat of vaporization
7. Demonstrate heat of fusion and heat of vaporization by the help of heating ice graph.

Evaluation Process

8. Explain in detail, why evaporation causes cooling?
9. Differentiate between evaporation and boiling.
10. Write any four factors that influence the surface evaporation.
11. Write down the freezing and boiling points of following
    i) Acetic acid ii) Benzene
    iii) Chloroform iv) Water

Thermal Expansion

12. Why solids increases in size on heating ? Explain.
13. An iron block of volume $3m^3$ is heated, so that its temperature changes from 25°C to 100°C. If the coefficient of linear expansion of iron is 11×10^{-6} °C^{-1}. What will be the new volume of the iron block after heating ?
14. a) Draw the diagram, showing real and apparent expansion of liquid. Label the diagram properly.
    b) Why small gaps are left at the joints of sections of railway tracks? Explain the phenomenon involved in it.