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JUNIOR SECONDARY LEVEL

PHYSICS

Module 3: Energy

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JUNIOR SECONDARY LEVEL SCIENCE - PHYSICS

MODULE 1 – Measurement

MODULE 2 – Matter

➤ **MODULE 3 – Energy**

MODULE 4 – Sound, Waves and Light

MODULE 5 – Magnetism and Electricity

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MODULE 3

ENERGY

INTRODUCTION

In this Module we shall study "Energy". Our lives depend very much on energy. The daily activities we perform and also our comfort are related to energy. There are various forms of energy.

We make use of **heat** energy, **light** energy, **electrical** energy in everyday life. You need energy to do work. The rate of doing work/spending energy is termed **power**. **Machines** are important devices that help to facilitate our work. Levers, gears and pulleys are some examples of devices that help facilitate our work.

OBJECTIVES

After completing this Module, you should be able to:

- define energy, work done and power
- state the SI units for energy, work and power
- recognise the various forms of energy and describe their interconversions
- perform simple calculations on energy, work done and power
- recognise the use of levers, gears and pulleys to make work easier
- explain how levers, gears and pulleys make work easier and more convenient.

3.1 ENERGY: DEFINITION

In Physics, we define energy as 'the capacity for doing work'. We shall consider work done later in this Module. You need energy to do work. The food we eat gives us energy to do work. Another important source of energy is the sun. You will note that the sun provides us with energy in several forms. We get energy from the sun in the form of heat energy and light energy.

<u>Note</u>: You'll learn about heat energy and its importance in Chemistry - Module 3, Unit 1: 1.0

There are many other forms of energy. These include electrical energy, sound energy, chemical energy and mechanical energy. Energy can be converted from one form into another.

3.1.1 LAW OF CONSERVATION OF ENERGY

This law states that energy can neither be created nor destroyed, but it can be converted from one form to another.

When you switch on an electric bell, electrical energy is used to produce sound which is another form of energy. Here electrical energy is converted into sound energy.

Similarly when you switch on an electric bulb, electrical energy is converted into light energy and heat energy. (The bulb becomes hot!)

There are other examples of energy conversion.

<u>Note</u>: You'll look at more examples of energy conversion in Chemistry - Module 3, Unit 2: 2.1 to 2.2

✍ ***Before proceeding further, complete the following activity.***

ACTIVITY 1

(a) *Write down 5 forms of energy.*

…………………………………………………………………………………………………….
…………………………………………………………………………………………………….
…………………………………………………………………………………………………….
…………………………………………………………………………………………………….
…………………………………………………………………………………………………….

(b) *Describe the energy change that takes place when a television set is switched on.*

…………………………………………………………………………………………………….
…………………………………………………………………………………………………….
…………………………………………………………………………………………………….

You will find the answers at the end of the Module. .

3.1.2 UNIT(S) OF ENERGY

Energy is expressed in joules. It is abbreviated as J. Sometimes the Joule is too small a unit for energy. A bigger unit for energy is the kilojoule (KJ).

In fact, 1 KJ = 1000J

It is useful to note that the 'Joule' is named after the famous Scientist James Joule.

3.2 POTENTIAL ENERGY

Potential energy (P.E.) of a body means the energy it possesses by virtue of its position. It is the energy due to **position** i.e. height above the ground (in relation to ground level)

At ground level, the potential energy of an object/body is taken as zero. When the height of a body increases, the potential energy increases.

The amount of potential energy is given by

Potential Energy = Mass x Gravitational force per Kg x Height

Thus

P.E = mgh

m = mass (in Kg)

g = gravitational force per Kg (10N/Kg)

h = height (in m)

You will recall that

Mass x Gravitational force per Kg = Weight

Therefore P.E = Weight x height

✍ ***Before proceeding further, complete the following activity.***

Activity 2

A person of mass 36 Kg climbs up a vertical ladder a distance of 5 m.

(i) What is the potential energy of the person when 5 m above ground level?

You will find the following steps useful

Mass of person = __________________ *Kg*

Weight of person = _________________ *N*

Gain in height = _________________ *m*

Formula to be applied

……………………………………………………………………………………………

Now work out the formula. What do you have?

……………………………………………………………………………………………

(ii) *How much work does a person have to do when climbing the ladder?*

Work done = gain in potential energy

= ___________ J

You will find the answers at the end of the Module.

3.3 KINETIC ENERGY (K.E.)

Kinetic energy of a body means the energy the body possesses by reason of its motion, that is how fast or how slow it is moving. This is expressed in terms of velocity. Velocity of a body means the distance travelled in one second in a specific direction. It is measured in metres per second (m/s)

When a body moves faster, it has more K.E.

✍ ***Before proceeding further, complete the following activity.***

Activity 3

What is the kinetic energy of an object/a body which is at rest?

………………………………………………………………………………………
………………………………………………………………………………………

You will find the answer at the end of the Module.

The amount of kinetic energy of a body in motion depends on

(i) its mass (m Kg)

(ii) its velocity (v ms^{-1})

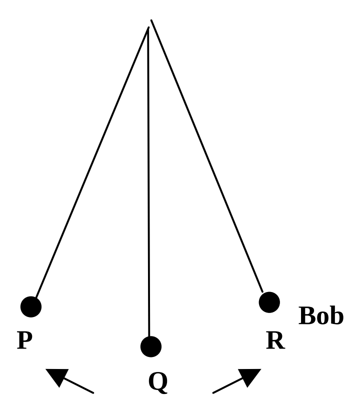
You will recall that velocity of a body means the distance it moves in 1 second in a specific direction. Velocity is measured in metre per second. This is denoted by m/s or ms^{-1}.

In fact the K.E of a body is calculated as

Kinetic Energy = $\frac{1}{2}mv^2$

Conversion of K.E into P.E and vice versa.

When a simple pendulum oscillates, kinetic energy is converted into potential energy. This happens when the height of the bob above the ground increases. This is the case when the bob moves from Q to P or from Q to R.



When the bob moves from P to Q or from R to Q, the height above ground decreases. But the velocity increases. Thus potential energy changes into kinetic energy.

✍ ***Before proceeding further, complete the following activity.***

Activity 4

A bullet of mass 400g is fired vertically up (from ground level) at 80 ms^{-1}

(i) Calculate the initial kinetic energy of the bullet.

You will find the following steps useful:

Mass = ………………… Kg

Velocity = ……………………ms^{-1}

Initial kinetic energy = ……………………

……………………..

(ii) Calculate the maximum height to which it rises.

At maximum height, the bullet has greatest potential energy. This is derived from initial kinetic energy. (In fact the initial kinetic energy is converted into potential energy at the top of the flight of the bullet)

P.E = K.E

Weight x height = ½ mv^2

Substituting and working out, we have

………………………………………………………………………………………………

………………………………………………………………………………………………

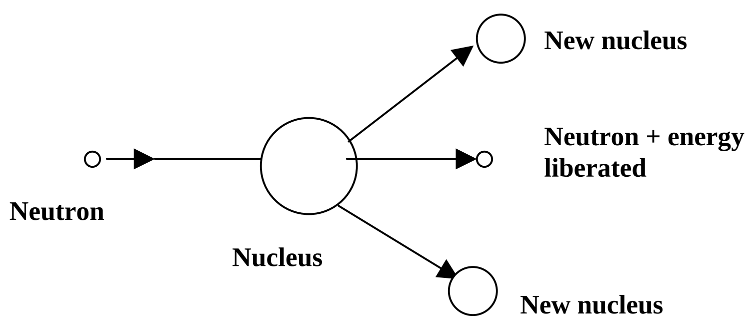
You will find the answers at the end of the Module.

3.4 NUCLEAR ENERGY

You will recall in Module 2, we looked at the nuclear model of an atom.

The nuclei of certain atoms are unstable. These nuclei disintegrate or decay. They are said to undergo nuclear reactions producing new nuclei. Nuclear reactions liberate large amount of energy, referred to as nuclear energy.

Nuclear reactions can be brought about by bombarding certain nuclei with fast moving neutrons. In this case, the neutron is absorbed by the nucleus, thus becoming unstable. The unstable nucleus then disintegrates into two smaller nuclei. This reaction is called **nuclear fission**. Other neutrons are also emitted. These neutrons may bombard the other new nuclei leading to further fission. Large amount of energy is liberated. Nuclear fission can be illustrated as follows:

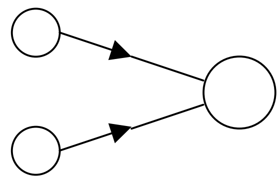


In fact controlled nuclear fission is used in many countries to generate nuclear energy in nuclear power stations. Large amount of energy is produced. However, the waste products from nuclear fission represent a danger to the environment because they are very harmful.

Another type of nuclear reaction which is quite different from nuclear fission is **nuclear fusion**. Here two small nuclei combine together to form a bigger nucleus. A very high temperature is required for nuclear fusion to take place.

In this case also nuclear energy is released. Such a nuclear reaction takes place in the sun. It is believed that nuclear fusion is the source of the sun's energy.

Nuclear fusion can be illustrated as follows:



3.5 WORK DONE

Work is said to be done when a force acts on a body and the body moves in the direction of the force.

We calculate work done as follows:

Work done in joules	=	Force in newtons	x	Distance moved in metres

You should note that work is done when

- a force acts on a body
- the body moves in the direction of the force.

If you push a wall, the wall does not move. Are you doing work?

If you push a car alone and the car does not move, you are not doing work. But if five persons push the car and the car moves then work is done.

Work can be done against force of friction or against force of gravity. If a body is moved on the ground horizontally work is done against friction. I'm sure you still recall what friction is! If not, quickly refer back to Module 1.

✍ ***Before proceeding further, complete the following activity.***

Activity 5

A boy applies a force of 80N to move a trolley over a horizontal distance of 12m. Calculate the work done

…………………………………………………………………………………………………
…………………………………………………………………………………………………
…………………………………………………………………………………………………

You will find the answer at the end of the Module.

When a body is moved vertically upwards, the force is the same as the weight of the body.

If a body is raised vertically upwards, work is done against gravity or against gravitational force. Here you can think of a man raising a brick vertically upwards. The work done appears as the potential energy of the brick.

✍ ***Before proceeding further, complete the following activity.***

Activity 6

A stone of mass 5 Kg is raised vertically upwards through a height of 15m. Given g = 10N/Kg, complete the following:

(1) Weight of stone = ………………….. N

(2) Work done = ……………… x …………………..

= ……………………………………

You will find the answers at the end of the Module.

3.6 POWER

Power means the rate of transfer of energy. It also means the rate of doing work.

Power is expressed in watts (W).

A power of 1W is the same as 1Joule per second.

We calculate power as:

$$\text{Power} = \frac{\text{Energy transferred}}{\text{Time taken}}$$

where energy is expressed in Joules(J) and time taken is expressed in seconds (s)

✍ ***Before proceeding further, complete the following activity.***

Activity 7

(a) State the unit of energy.

……………………………………………………………………………………………

(b) State the unit of time.

…………………………………………………………………………………………..

(c) Hence deduce the unit of power i.e. $\frac{\textit{unit of energy}}{\textit{unit of time}}$

……………………………………………………………………………………….
………………………………………………………………………………………

(This is also the watt, symbol W)

(d) In case of large values of power, we can use the kW.

1 kW = ……………………………..W

You will find the answers at the end of the Module.

Power is also calculated as

$$\text{Power} = \frac{\text{Work done}}{\text{Time taken}}$$

✍ ***Before proceeding further, complete the following activity.***

Activity 8

A crane lifts a mass of 500 Kg through a vertical distance of 60m in 30 seconds.

(i) Calculate the energy transferred

You will find the following steps useful

Work is done against gravity. The mass gains Potential Energy.

Gain in Potential Energy

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

Hence, energy transferred

………………………………………………………………………………………

………………………………………………………………………………………

(ii) Calculate the power developed by the crane

$$\textit{Power developed} = \frac{\textit{energy transferred}}{\textit{time taken}}$$

Substituting, we have

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

You will find the answers at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

Activity 9

(a) *A staircase has 18 steps, each of which is 0.2 m high. A person of mass 60 Kg takes 10 seconds to walk up the staircase. Calculate the average power.*

You will find the following steps useful

Vertical height risen

……………………………………………………………………………………

……………………………………………………………………………………..

Potential energy gained

……………………………………………………………………………………

……………………………………………………………………………………

$$\textit{Power} = \frac{\textit{Gain in Potential Energy}}{\textit{Time Taken}}$$

= ……………………………..

(b) *If the person were to run up the staircase in 4 seconds what would be the average power in this case?*

Gain in Potential Energy is the same as in (a)
i.e. ……………………………………………..

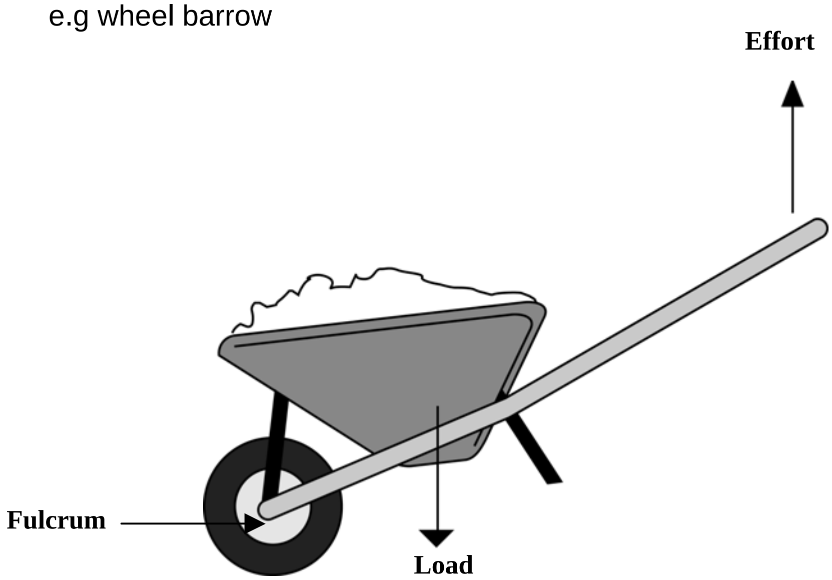
$$\textit{Power} = \frac{\textit{Gain in Potential Energy}}{\textit{Time Taken}}$$

You will find the answers at the end of the Module.

3.7 MACHINES

We are familiar with tools such as levers, gears, screw jack and pulleys. These are machines. In each case, we apply an **effort** to overcome a **load**.

e.g wheel barrow



They help us to do work.

Definition

A machine is a device which makes forces more convenient to use. We shall consider some examples of these machines in the following sections.

3.7.1 THE CROWBAR

The crowbar is a common example of a lever. Levers are devices used to make work more convenient. Instances of levers include: pliers, tin openers, bottle cap openers.

✍ ***Before proceeding further complete the following activity.***

Activity 10

Draw the sketch of a crowbar.

Mark on it the following items.

- *Load*
- *Fulcrum (support)*
- *Effort*

You will find the answers at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

Activity 11

Consider each statement below concerning the crowbar. Write True OR False in the space provided.

(a) *The fulcrum (support) is nearer to the point of application of the effort (force) than to the load.*

Answer: ……………………………………………………

(b) *The effort is less than the load.*

Answer: …………………………………………………

(c) *A small effort can match a large load.*

Answer: ………………………………………………

(d) *The effort moves through smaller distance than the load.*

Answer: …………………………………………………

(e) *It is very convenient to apply the effort downward to cause the load to be lifted up.*

Answer: ………………………………………………..

You will find the answers at the end of the Module.

3.7.2 GEARS

In the bicycle, gears are used in the driving wheel and pedal. We are familiar with the pedal being larger than the driving wheel.

✍ ***Before proceeding further, complete the following activity.***

Activity 12

(a) Consider 2 cog-wheel (A, B) of equal diameter having equal number of teeth (say 10 each).

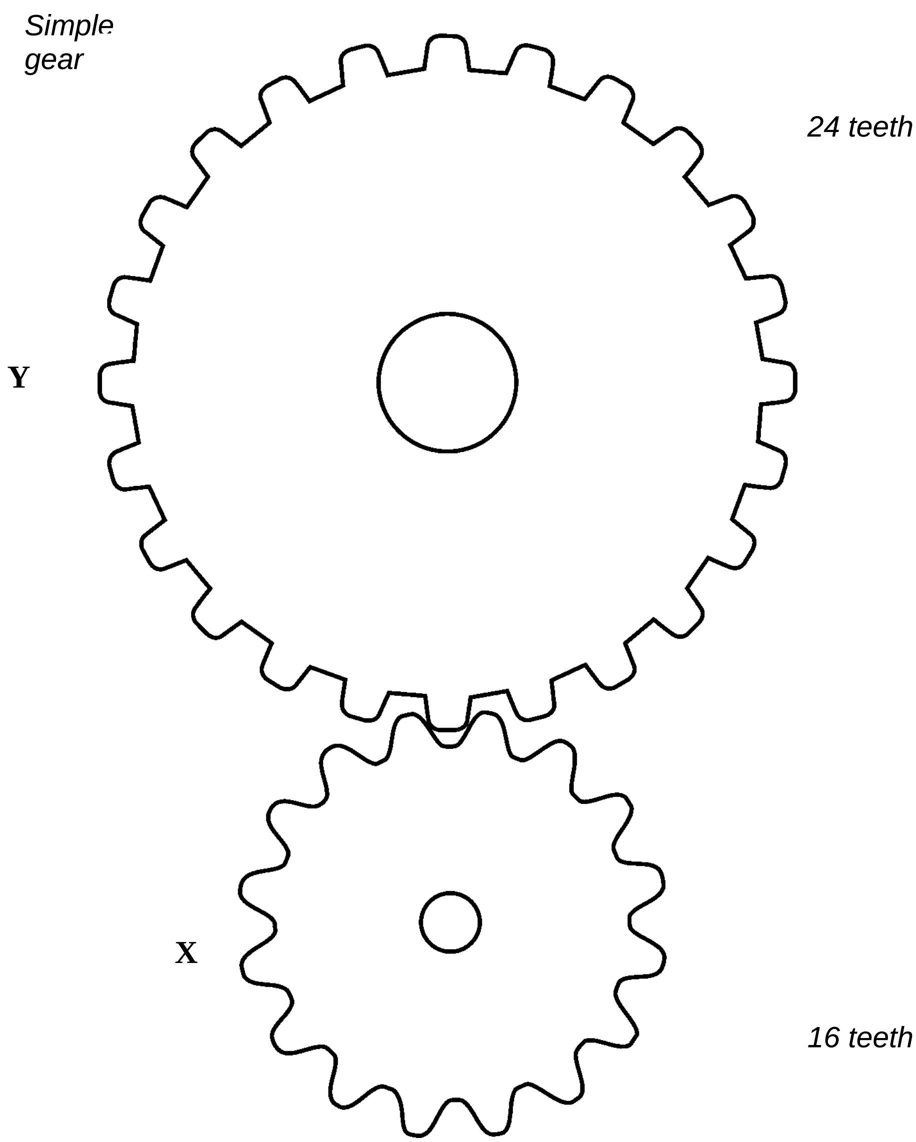
(i) When 1 of them (A) rotates through 1 revolution, it will cause B to make ……………………………………………….. revolution.

(ii) Which rotates faster? ………………………………….

(iii) Does it provide any advantage? ………………………………….

Activity 12 (ctd)

(b) Now consider 2 cog-wheels (X, Y) such that X is smaller of the two and has 16 teeth. Y has 24 teeth. Please see diagram.



Activity 12 (ctd)

When Y makes 2 revolutions, it will cause X to make

……………………………………. revolutions.

(i) Which rotates faster? ……………………………………

(ii) Does it provide any advantage? Why?

…………………………………………………………………

You will find the answers at the end of the Module.

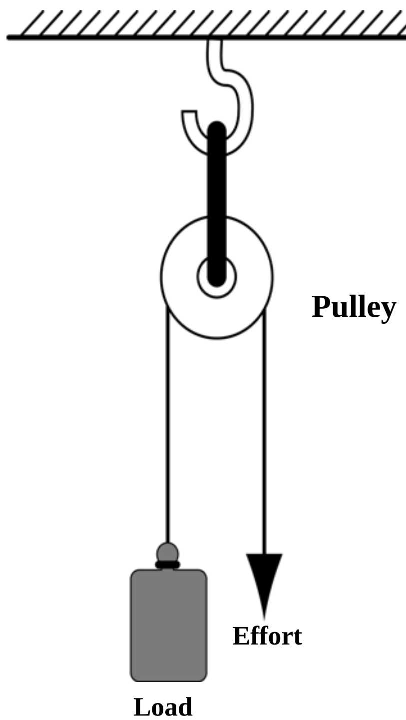
3.7.3 PULLEYS

Pulleys are devices which are used to raise loads by applying forces in a downward direction.

✍ ***Before proceeding further, complete the following activity.***

Activity 13

Consider the single pulley shown in this diagram



(a) Is the effort less than the load?

…………………………………………………………………………

(b) What is an advantage of using the single pulley?

…………………………………………………………………………
…………………………………………………………………………
…………………………………………………………………………

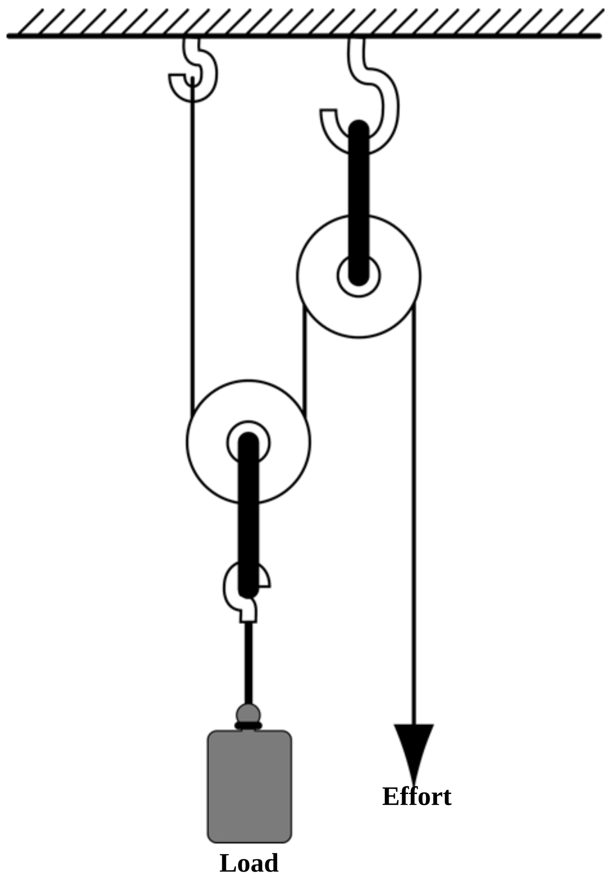
You will find the answers at the end of the Module.

Instead of a single pulley, at times a combination of pulleys is used.

✍ ***Before proceeding further, complete the following activity.***

Activity 14

Consider a combination of pulleys shown in this figure.



Give 2 advantages when using the above combination.

1st ……………………………………………………………………………

……………………………………………………………………………

2nd ……………………………………………………………………………

……………………………………………………………………………

You will find the answers at the end of the Module.

3.7.4 THE SCREW JACK

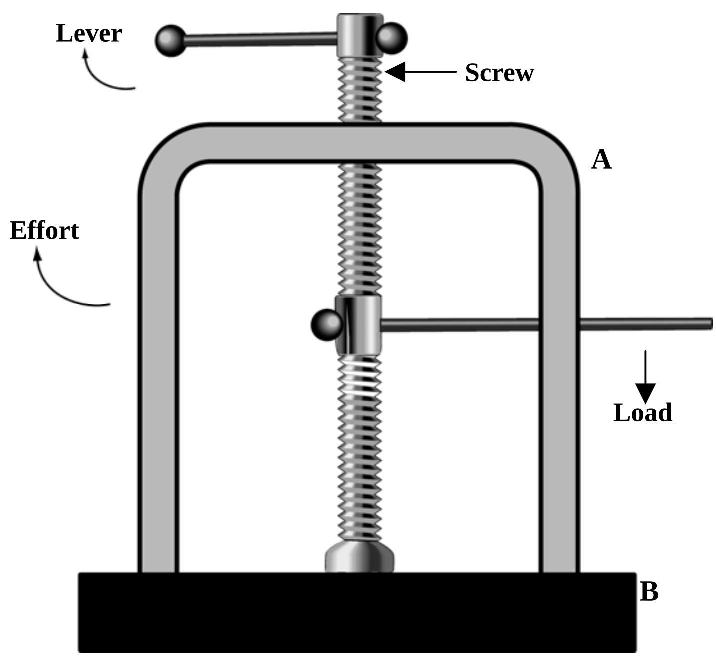
We might have observed car tyres getting punctured. For changing the wheel, the car has to be lifted up on one side. This is done using a screw jack.

✍ ***Before proceeding further, complete the following activity.***

Activity 15

Outline the steps used to construct a model screw jack.
You may assume that the following items are available

- *Blocks of wood*
- *Nails*
- *Threaded bolt*
- *Metal nut, metal washer, metal pipe spanner*



Steps

………………………………………………………………………………………

………………………………………………………………………………………

……………………………………………………………………………………….

You will find the answers at the end of the Module.

3.8 HEAT AND TEMPERATURE

You will recall we learnt about temperature in Module 2. At this stage it is useful to distinguish between **heat** and **temperature**. You will realise that heat is a form of energy. Temperature is the degree of hotness or coldness. We express heat energy in J or KJ. We express temperature in degrees **Celsius(^{o}C)** or **Kelvin (K).** To convert a temperature from degree Celsius to Kelvin, we simply add 273. You recall that, I'm sure!

$$1^{0}C = 273 + 1 = 274K$$

✍ ***Before proceeding further, complete the following activity.***

Activity 16

Complete the blanks in the table below.

	Temperature °C	**Corresponding temperature (K)**
Melting Ice		273
Boiling Water	100	
Body Temperature of Man	37	
Laboratory Temperature		298

You will find the answers at the end of the Module.

✍ ***Before proceeding further, complete the following activity.***

Activity 17

A *2 Kg mass of iron is initially at 18°C. It is heated to 35°C.*

Initial temperature of the iron = ……………….. K

Final temperature of the iron = ………………….. K

Change of temperature (on Celsius scale) …………………

Change of temperature (on Kelvin scale) …………………..

What do you conclude?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

You will find the answers at the end of the Module.

3.9 TRANSFER OF HEAT ENERGY

In this section, we shall look at the processes of heat transfer from a region of high temperature to a region of low temperature. Consider an iron rod which is heated at one end. After some time, the other end also becomes hot. Similarly if a beaker of water is heated at the base, soon all the water becomes heated uniformly. You will also agree that we rely a lot on energy we get from the sun.

All these above examples illustrate the transfer of heat energy. In fact, there are three processes of heat transfer as follows:

- Conduction
- Convection
- Radiation

Let's look at each briefly:

3.9.1 CONDUCTION

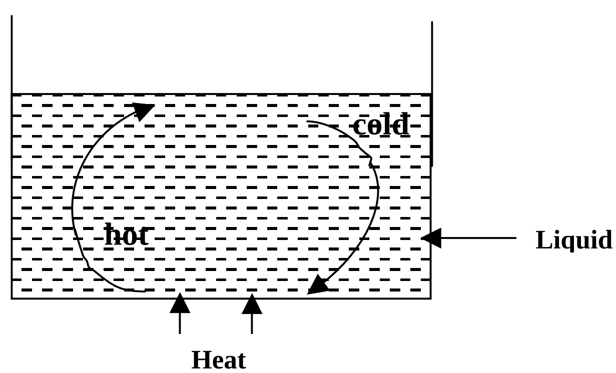
Conduction is a process of heat transfer during which heat flows through a material medium. However, the material medium does not flow, e.g. when a rod of copper is heated at one end, the heat flows through the copper rod so that the whole rod gets heated.

Copper allows the flow of heat through it readily. It is said to be a good conductor of heat. Metals are good conductors of heat. On the other hand wood, paper and glass are examples of bad conductors of heat.

3.9.2 CONVECTION

Convection is a process of heat transfer in fluids (gases or liquids) which occurs by means of currents in the fluid. Here heat is transferred by the movement of the fluid itself.

You will recall from Module 2 we looked at arrangement of particles in liquid and gases. When a liquid is heated, the particles get further apart. They occupy a bigger space or volume. The liquid is said to expand. When the liquid expands, its density (you will recall density = $\frac{mass}{volume}$) decreases. Thus the hot liquid is at the base of the container becomes less dense and moves up. The denser cold liquid from the top moves down. This movement of hot liquid and cold liquid constitute the convection currents. The whole liquid thus gets uniformly heated as a result of the movement of the liquid. We can illustrate this as follows.



This movement of the currents can be seen by heating a flask containing water with a crystal of potassium permanganate at the bottom. Potassium permanganate is a dark purple solid.

Convection cannot take place in solids. Can you explain why?

3.9.3 RADIATION

Radiation is a process of heat transfer whereby heat energy is transferred in the form of waves. We shall learn about waves in Module 4. Radiation does not require any material medium. It can occur even in a vacuum. For example we get the energy from the sun is received on the earth by radiation.

3.10 HEAT ENERGY CHANGE

When a body is heated, it gains energy. Similarly when a body is cooled it gives out energy. Thus, assuming there is no change of state, we note that heating or cooling of a substance results in an energy change. This energy change depends upon

- the change in temperature
- the heat capacity of the substance (or thermal capacity)

3.10.1 HEAT CAPACITY (H)

The heat capacity of a substance means the amount of energy required to increase the temperature of the substance by 1 Kelvin (K). Heat capacity is expressed in Joules per kelvin (J/K or JK^{-1})

Heat energy change can be calculated using the relationship.

Heat energy change = Heat capacity x change in temperature

Heat energy change = $H\varphi$

where H = Heat capacity

φ = Change in temperature in Kelvin

✍ ***Before proceeding further, complete the following activity.***

Activity 18

(a) *A 2 Kg block of iron is at 20°C. Taking its heat capacity as 920JK^{-1}. Calculate the heat energy needed to raise its temperature to 30°C.*

You will find the following steps useful

(i) Rise in the temperature

……………………………………………………………………………………

(ii) Energy needed to raise the temperature of the block by 1 K =…J

Energy needed to raise the temperature of the block by …………K

(b) What happens to the energy absorbed?

……………………………………………………………………………………
……………………………………………………………………………………

You will find the answers at the end of the Module.

You will note that **thermal capacity** or heat capacity applies to the entire substance. When thermal capacity is specified for unit mass (1 Kg) of the substance, it becomes **SPECIFIC HEAT CAPACITY** (abbreviated as SHC)

For instance, the SHC of iron is 460 JKg^{-1}K^{-1}. It means that 460J of energy must be supplied to 1 Kg of iron to increase its temperature by 1K (say from 298K to 299K or from 323K to 324K).

✍ ***Before proceeding further, complete the following activity.***

Activity 19

A bucket of negligible heat capacity contains 2.5Kg of water at 20°C. How much energy is needed to raise the temperature to 25°C? Take the SHC of water as 4200 $JKg^{-1}K^{-1}$.

You will find the following steps useful:

(i) Rise in temperature = _______________ K

(ii) For temperature to rise by 1K

Energy needed by 1Kg of water = _____________J

Energy needed by 2.5Kg of water =

…………………………………………………………………………………………

…………………………………………………………………………………………

…………

(iii) *For temperature to rise by ………………………K*

Energy needed = ………………………………..

You will find the answers at the end of the Module.

Another method of calculation of heat energy involves the use of the formula:

Heat = Mass x SHC x Change in temperature

In the formula,

Energy change or heat is expressed in J

Mass is expressed in Kg

SHC is expressed in J/Kg/k

Change in temperature is normally expressed in Kelvin.

✍ ***Before proceeding further, complete the following activity.***

Activity 20

500J of energy is needed to raise the temperature of ½ Kg of paraffin from 298K to 298.5K.

(a) What is the SHC of paraffin?
(b) How much energy change takes place when 2Kg of paraffin cools from 308K to 298K?

Hint for (a)

Replace in the formula

Heat energy = Mass x SHC x change in temperature
…………………………………………………………………………………

…………………………………………………………………………………

…………………………………………………………………………………

Hint for (b)

As there is a fall in temperature by ……………..K there is decrease (loss) of energy by the paraffin.

Replace in Heat lost = Mass x SHC x fall in temperature
…………………………………………………………………………………

…………………………………………………………………………………

You will find the answers at the end of the Module.

3.10.2 HEAT ENERGY CHANGE DURING MELTING

Melting is also called **fusion**. It represents a change of state from solid to liquid. You will recall we pointed out in Module 2 that melting (fusion) takes place at the melting point of the solid. Heat change occurs whenever there is a change of state - although the temperature is constant. Energy is required to change the state of a substance from solid to liquid, even if the temperature does not change. The energy required is used to weaken the forces of attraction between the particles. Finally the solid collapses to form a liquid.

✍ ***Before proceeding further, complete the following activity.***

<u>Activity 21</u>

What happens to the energy supplied to a solid to just cause it to melt?

……………………………………………………………………………………

……………………………………………………………………………………

……………………………………………………………………………………

…………………………………………………………………………………..

You will find the answer at the end of the Module.

The energy needed to convert 1Kg of solid into liquid at a constant temperature is known as the **specific heat of fusion**. In fact it is specific **latent** heat of fusion (latent = ‘hidden’). The heat supplied is, as if, hidden as it does NOT cause the temperature to rise during melting. To convert 1 Kg of ice at 0^0C into 1 Kg of liquid water at 0^0C, we require 336000J. We say the specific latent heat of fusion of ice is 336000 J/Kg. In this case the energy change is calculated as

Energy required (for melting) = mass x L_F

where L_F is the specific latent heat of fusion

✍ ***Before proceeding further, complete the following activity.***

Activity 22

(a) A block of ice at 273K has a mass of 5Kg. How much heat is required just to melt the block at 273K?

You will find the following steps useful

- *Formula:* ……………………………………………………………………………
- *Replacing mass* ………………………………………

  L_F ………………………………………

- *Applying the formula*

  ……………………………………………………………………………

(b) What happens to the heat energy?
……………………………………………………………………………
……………………………………………………………………………
……………………………………………………………………………

You will find the answers at the end of the Module.

3.10.3 HEAT ENERGY CHANGE DURING BOILING

We came across the term boiling in Module 2 - Section 2.2.2. Just as in the case of melting, heat energy is required to change a liquid into a vapour even if temperature does not change. At the boiling point, a liquid absorbs latent heat of vaporisation. The specific latent heat of vaporisation of a liquid (X) is 500000 J/Kg. This means that 500000J of energy is required to change one Kg of X from liquid to vapour at its boiling point.

✍ ***Before proceeding further, complete the following activity.***

Activity 23

(a) What is the temperature of boiling water?

Ans: …………………………… K

*(b) While boiling water is heated, the temperature does **not** rise. Why is it so?*

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

(c) Justify the word 'latent' in the term latent heat of vaporisation.

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

(d) Define specific latent heat of vaporisation of water.

………………………………………………………………………………………
………………………………………………………………………………………
………………………………………………………………………………………

You will find the answers at the end of the Module.

For water the specific latent heat of vaporisation is taken as 2 300 000 JKg^{-1} (at 373 K). What does this mean?

✍ ***Before proceeding further, complete the following activity.***

Activity 24

1 Kg of water is initially at 293 K. How much energy is required:

(i) to heat it to its boiling point (373 K)?
(ii) to just boil the water.

Use SHC of water 4200J/Kg/K and specific latent heat of vaporisation of water as 2300000J/Kg.

You will find the following steps useful

Mass of water = __________ Kg

SHC of water = 4200 $JKg^{-1}K^{-1}$.

Change of temperature = __________ K

Energy required = Mass x SHC x temperature change

……………………………………………………………………………………

……………………………………………………………………………………

Steps for (ii)

Formula to be used

……………………………………………………………………………………

Replacing in the formula, we have

……………………………………………………………………………………

……………………………………………………………………………………

You will find the answers at the end of the Module.

3.10.4 EVAPORATION

You will recall from Module 2 - Section 2.2.2 that boiling of a liquid occurs at a fixed temperature - that is at the boiling point of the liquid.

Now consider some water poured on the floor. Soon the wet floor turns dry. What has happened? Has the water boiled away? NO. The water has undergone evaporation.

How does evaporation differ from boiling?

Evaporation is a process during which a liquid changes into a vapour, at any temperature.

Moreover during evaporation no bubbles are formed in the liquid. The change from liquid to vapour state during evaporation requires latent heat. This is usually taken from the surroundings.

If you place some alcohol on your hand, the alcohol soon dries up. The alcohol evaporates. The latent heat required is taken from your hand - which feels cold.

Similarly when you are wearing wet clothes, you feel cold. The water from the wet clothes evaporates. The latent heat required is taken from your body.

Thus evaporation leads to a cooling effect.

3.11 AMOUNT OF ELECTRICAL ENERGY

We shall be learning about electricity in detail in Module 5. Here we just introduce you to electrical energy. Electrical energy occurs when work is done in 'driving' the electric current. We shall look at

- Electric charge (in coulombs)
- Potential difference (in volts)

At this stage it is useful to note that we calculate the amount of electrical energy by using the relationship:

Electrical energy =	Potential difference	x	charge
in (Joules)	in (Volts)		in (Coulombs)

✍ ***Before proceeding further, complete the following activity.***

Activity 25

How much electrical energy occurs when a charge of 1500 coulombs flows at 240 volts?

Steps (I) Formula:

…………………………………………………………………………………………

(ii) Replacing the values of charge and potential difference,

…………………………………………………………………………………………

You will find the answer at the end of the Module.

! POINTS TO REMEMBER

- Energy is the capacity for doing work.
- Energy exists in many forms such as electrical, heat, light.
- Energy is measured/expressed in unit of J (or kJ).
- There are three processes of heat transfer, namely
  - Conduction
  - Convection
  - Radiation
- Energy is needed to heat a substance. The amount of energy in this case is calculated as:

Heat = Mass x Specific heat capacity x rise in temperature

- During melting, the heat absorbed by a solid at its melting point. The heat energy required is given by.

Heat = Mass x Specific heat of fusion

- During boiling, heat is absorbed by a liquid at its boiling point. The heat energy required is given by:

Heat = Mass x Specific latent heat of vaporisation

- Evaporation of liquid leads to a cooling effect.
- Electrical energy can be measured as the product of coulombs and volts.
- Potential energy (P.E)is measured as the product of weight and height (above ground level).

- Kinetic energy (KE) is given by $KE = \frac{1}{2}mv^2$ (with usual notations).
- Nuclear energy is liberated during nuclear reactions.
- Power is calculated as $\frac{\text{Energy transferred}}{\text{Time taken}}$
- Power is calculated as $\frac{\text{work done}}{\text{Time taken}}$
- The unit of power is the watt
  1 Kilowatt = 1000 watts
- Machines help work to be done more conveniently.
- A lever is a simple machine.
- The crowbar is a common application of a lever.
- Gears involve cog wheels of different sizes with unequal number of teeth.
- Pulleys help to lift loads by more convenient application of efforts (forces).
- The screw jack can help to support or lift very large loads by applying small efforts.

ANSWERS TO ACTIVITIES

Activity 1

(a) Heat
Light
Sound
Electrical
Chemical

(b) Electrical energy → light + sound + heat

Activity 2

(i) Mass of person = 36 Kg
Weight of person = 360 N
Gain in height = 5 m

Formula:
Potential energy = weight x height
= 360 x 5
= 1800 J (or 1.8 KJ)

(ii) Work done = Gain in potential energy
= 1800 J (or 1.8 J)

Activity 3

Its velocity = 0
Its K.E = 0

Activity 4

(i) Mass = 0.4 Kg
Velocity = 80 ms^{-1}
Initial K.E = ½ x 0.4 x 80^2
= 1280 J

(ii) weight x height = 1280
4 x height = 1280
∴ height = $\frac{1280}{4}$
= 320m

Activity 5

Work done = Force applied x distance moved (in the direction of the force)
= 80 x 12
= 960 J

Activity 6

(1) Weight = 5 x 10
= 50 N

(2) Work done = Force x distance
= Weight x distance
= 50 x 15
= 750 J

Activity 7

(a) Joule
(b) Second
(c) Joule/second
(d) 1 KW = 1000 W

Activity 8

(i) Gain in P.E = weight x height
= 5000 x 60
= 300000 J
Hence, energy transferred = 300000 J

(ii) Power $= \frac{300000}{30}$
= 10000 W or 10 KW

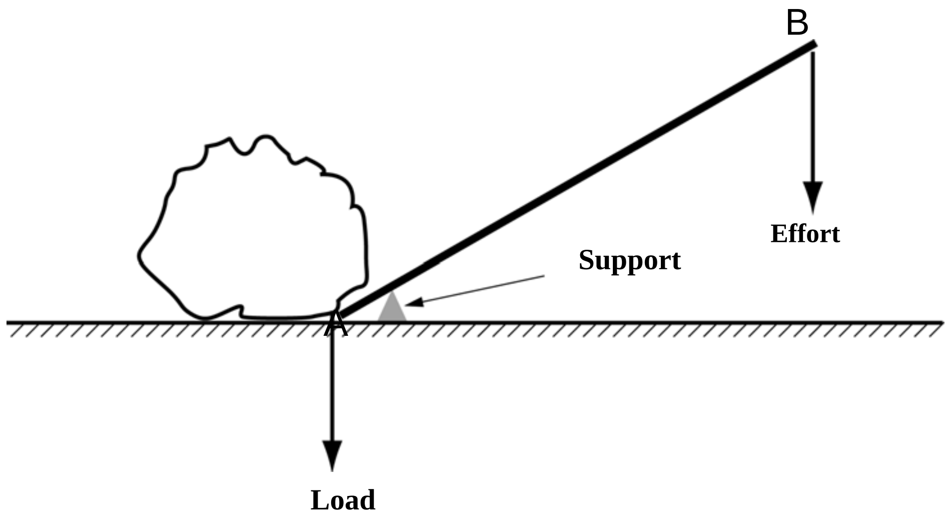
Activity 9

(a) Vertical height risen = 18 x 0.2
= 3.6 m
P.E gained = weight x height
= 600 x 3.6
= 2160 J
Power $= \frac{2160}{10}$
= 216 W

(b) Gain in PE = 2160 J
Power $= \frac{2160}{4}$
= 540 W

Activity 10

The crowbar



Activity 11

(a) False
(b) True
(c) True
(d) False
(e) True

Activity 12

(a) (i) One
(ii) None
(iii) No

(b) (i) three
(ii) X
(i) Yes - the larger rotates more slowly than the smaller one.

Activity 13

(a) No
(b) It is more convenient to apply the force downward in order to lift the load upward.

Activity 14

1. A smaller effort is sufficient to match a larger load.
2. It is quite convenient to apply the effort downward in an attempt to raise the load.

Activity 15

Steps

(i) Bore a hole in a block of wood **A**.
(ii) Select a long threaded bolt and sink the head into wood.
(iii) Fix a block **B** on block **A** and secure with nails.
(iv) Place upside down. Now fix a nut, a washer and a metal pipe.

(By turning the nut with a long spanner, the device serves as a powerful screw Jack).

Activity 16

	Temperature ^{0}c	**Corresponding temperature (K)**
Melting ice	0	273
Boiling water	100	373
Body temperature	37	310
Lab temperature	25	298

Activity 17

Initial temperature of the iron = (273 +18) K
= 291 K
Final temperature of the iron = (273 + 35) K
= 308 K
Change of temperature (on Celsius scale) = 35 - 18
= 17
Change of temperature (on Kelvin scale) = 308 - 291
=17
Conclusion: The change of temperature is <u>same</u> on both scales.

Activity 18

(a) (i) Rise in temperature = 10K
(ii) By 1K = 920 J
(iii) By 10K = 10 x 920
= 9200 J (or 9.2 kJ)

(b) It increases the energy of vibrations (vibrational energy) of the particles in iron.

Activity 19

(i) 5 K
(ii) Energy needed by 1 Kg of water = 4200 J
Energy needed by 2.5 Kg of water = 4200 x 2.5
= 10500 J (or 10.5 KJ)
(iii) For temperature to rise by 5 K,
Energy needed = 10.5 x 5 KJ
= 52.5 KJ

Activity 20

(a) 500 = ½ x SHC x 0.5
500 = ½ x SHC x ½

$$500 = \frac{SHC}{4}$$

500 x 4 = SHC
2000 = SHC (Answer in J/Kg/K))

(b) Fall in temperature = 10K
Energy change = 2 x 2000 x 10
= 40000 J
= 40 KJ

Activity 21

It is used up in overcoming the forces of attraction which hold together the particles in a solid.

Activity 22

(a)
- Formula:
  Energy required for melting = Mass x L_f
- Replacing, Mass = 5Kg
  L_f = 336000
- Applying the formula,
  Energy required = 5 x 336000 J
  = 1680000 J or 1680 KJ

(b) The heat energy is used up in overcoming the forces of attraction between the particles in ice.

Activity 23

(a) 373 K
(b) The heat energy supplied is used up in overcoming the forces of attraction between the molecules of water.
(c) ‘Latent’ means ‘hidden’. The heat supplied does NOT cause any increase in temperature.
(d) The specific latent heat of vaporisation of water is the energy required to convert 1 Kg of water at 373 K into water vapour at the same temperature i.e. at 373 K.

Activity 24

(i) Mass of water = 1 Kg
Change of temperature = 80 k
Energy required = 1 x 4200 x 80 J
= 336000 J or 336 KJ

(iii) Formula:
Energy needed for boiling = m x L_v
= 1 x 2300000
= 2300000 J or 2300 KJ

Activity 25

(ii) Formula
Electrical energy = Potential difference X Charge

(iii) Replacing, we have:
Energy = 240 x 1500
= 360000 J (or 360 KJ)