WORK AND ENERGY

whenever a force makes a body move, then work is said to be done. For doing work, energy is required.

When work is done, an equal amount of energy is used up.

WORK

Work is done when a force produces motion.

For example,

1. when an engine moves a train along a railway line, it is said to be doing work;
2. a horse pulling the cart is also doing work;
3. a man climbing the stairs of a house is also doing work in moving himself against the force of gravity.

Note -

The work done by a force on a body depends on two factors -

(i) Magnitude of the force, and

(ii) Distance through which the body moves

(in the direction of force).

Work done in moving a body is equal to the product of force exerted on the body and the distance moved by the body in the direction of force.

$$\text{Work} = \text{Force} \times \text{Distance}$$

$$W = F \times s$$

Unit of Work

SI unit of work is joule which is denoted by the letter J.

Work is a scalar quantity.

note - No Displacement

A man standing still at a bus stop with heavy suitcases in his hands may get tired soon but he does no work in this situation.

Work Done Against Gravity

whenever work is done against gravity, the amount of work done is equal to the product of weight of the body and the vertical distance through which the body is lifted.

Work done in lifting a body
= Weight of body × Vertical distance
or $W = m \times g \times h$

Sample Problem 1. How much work is done by a force of 10 N in moving an object through a distance of 1 m in the direction of the force ?

F = 10 N   S = 1 m

work done = F × S

= 10 × 1

= 10 Joule

Sample Problem 2. Calculate the work done in lifting 200 kg of water through a vertical height of 6 metres (Assume g = 10 m/s2).

m = 200 kg   h = 6 m

work done = m × g × h

= 200 × 10 × 6

= 12000 Joule

Sample Problem 3. A car weighing 1000 kg and travelling at 30 m/s stops at a distance of 50 m decelerating uniformly. What is the force exerted on it by the brakes ? What is the work done by the brakes ?

m = 1000 kg

S = 50 m

u = 30 m/sec

v = 0

WORK DONE BY A FORCE ACTING OBLIQUELY

$$v^2 = u^2 + 2as$$

$$0 = (30)^2 + 2a \cdot 50$$

$$-100a = 900$$

$$a = -9$$ (retardation)

$$F = m \times a$$

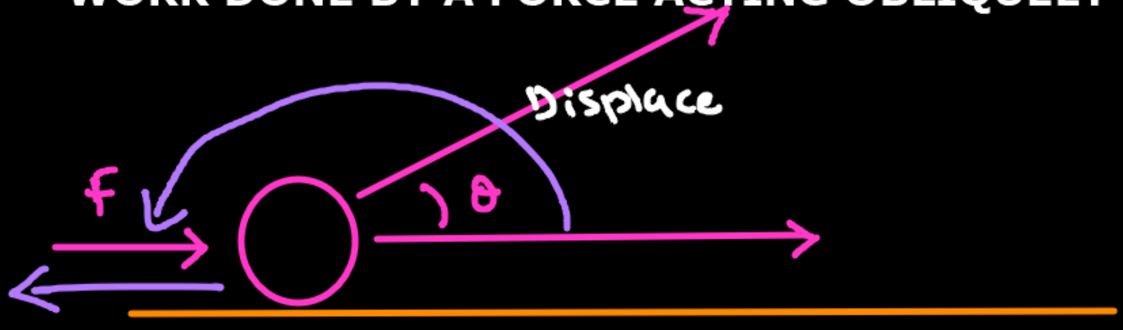
$$= 1000 \times (-9)$$

$$= -9000\ N$$

$$W = F \times S$$

$$= 9000 \times 50$$

$$= 450000 = \underline{\underline{450\ KJ}}$$



$$W = F \cos\theta \times s \text{ —— } (1)$$

$\cos 0 = 1$ $\cos 30^\circ = \frac{\sqrt{3}}{2}$ $\cos 45^\circ = \frac{1}{\sqrt{2}}$

$\cos 60^\circ = \frac{1}{2}$ $\cos 90 = 0$ $\cos 180^\circ = -1$

Note – θ is the angle between the direction of motion of body and the direction of force applied.

Sample Problem. A child pulls a toy car through a distance of 10 metres on a smooth, horizontal floor. The string held in child's hand makes an angle of 60° with the horizontal surface. If the force applied by the child be 5 N, calculate the work done by the child in pulling the toy car.

$$w = F \cos\theta \times s$$

$$= 5 \times \cos 60^\circ \times 10 = 25J$$

Work Done When the Force Acts at Right Angles to the Direction of Motion

If the force acts at right angles to the direction of motion of a body, then the angle θ between the direction of motion and direction of force is 90°. Now, cos 90° = 0,

$$W = F \cos 90^\circ \times s$$
$$= F \times 0 \times s$$
$$\text{Work done, } W = 0$$

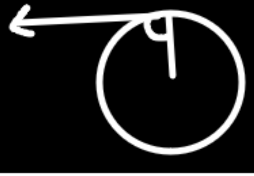
when the displacement of the body is perpendicular (at 90°) to the direction of force, no work is done.

(1)

For example, if a man carries a suitcase strictly horizontally, he does no work with respect to gravity because the force of gravity acts vertically downwards and the angle between the displacement of the suitcase.

(2)

the work done in the case of earth moving round the sun is zero, and the work done in the case of a satellite moving round the earth is also zero.



Work Done When the Force Acts Opposite to the Direction of Motion

If the force acts opposite to the direction of motion of a body, then the angle θ between the direction of motion and the direction of force is 180°.

$$\cos 180^\circ = -1$$

$$\boxed{W = - F \times s}$$

Positive, Negative and Zero Work

The work done by a force can be positive, negative or zero.

1. Work done is positive when a force acts in the direction of motion of the body.
2. Work done is negative when a force acts opposite to the direction of motion of the body.
3. Work done is zero when a force acts at right angles to the direction of motion of the body.

ENERGY

energy is the ability to do work.

↓

The amount of energy possessed by a body is equal to the amount of work it can do when its energy is released.

note - Energy is a scalar quantity.

Unit of Energy

the SI unit of energy is joule (which is denoted by the letter J).

The energy required to do 1 joule of work is called 1 joule energy.

1 kJ = 1000 J

Different Forms of Energy

1. Kinetic energy
2. Potential energy
3. Chemical energy
4. Heat energy
5. Light energy
6. Sound energy
7. Electrical energy
8. Nuclear energy

KINETIC ENERGY

The energy of a body due to its motion is called kinetic energy.

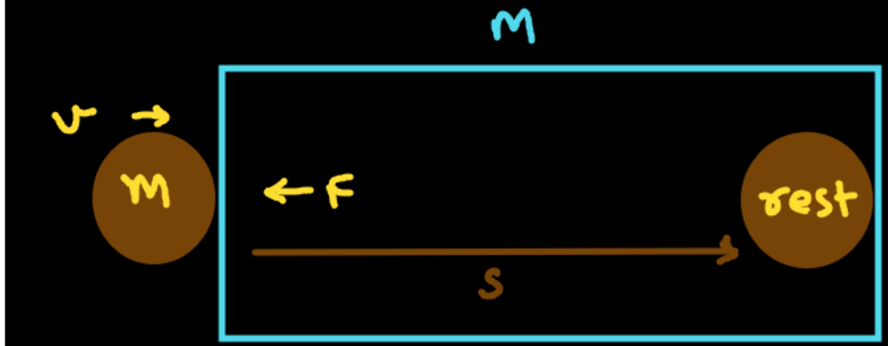
Formula for Kinetic Energy

$$KE = \frac{1}{2} m v^2$$

m = mass

v = velocity

The kinetic energy of a moving body is measured by the amount of work it can do before coming to rest.



Work = Force × Distance

W = F × s ———————— (1)

If a body has an initial velocity ‘v’, final velocity ‘V’, acceleration ‘a’ and travels a distance ‘s’,

$$\boxed{V^2 = u^2 + 2as}$$

$u = v$ $\quad$ acc $= -a$

$V = 0$ $\quad$ Distance $= s$

$$0 = v^2 - 2as$$

$$v^2 = 2as \Rightarrow a = \frac{v^2}{2s}$$

Now acc to Newtons 2nd law

$$F = m \cdot a$$

$$= m \frac{v^2}{2s}$$

$$F.s = \frac{m v^2}{2}$$

from eqn (1)

$$W = \frac{1}{2} m v^2$$

↳

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

$$KE = \frac{1}{2} m . v^2$$

(i) the kinetic energy of a body is directly proportional to the mass of the body,

(ii) the kinetic energy of a body is directly proportional to the square of velocity of the body (or square of the speed of the body).

note -

1. if the mass of a body is doubled, its kinetic energy also gets doubled and if the mass of a body is halved, its kinetic energy also gets halved.

2. if the velocity of a body is doubled, its kinetic energy becomes four times, and if the velocity of a body is halved, then its kinetic energy becomes one-fourth.

Sample Problem 1. Calculate the kinetic energy of a body of mass 2 kg moving with a velocity of 0.1 metre per second.

$m = 2\,kg$ $\qquad v = 0.1\ m/sec$

$$KE = \frac{1}{\cancel{2}} \times \cancel{2} \times 0.1 \times 0.1$$

$$= 0.01\,J$$

Sample Problem 2. Two bodies of equal masses move with uniform velocities v and 3v respectively. Find the ratio of their kinetic energies.

I		II
m	mass	m
v	velocity	3v

$$KE_1 = \frac{1}{2} m v^2 \qquad KE_2 = \frac{1}{2} m (3v)^2$$

$$= \frac{1}{2} m v^2 . 9$$

$$\frac{KE_1}{KE_2} = \frac{\cancel{\frac{1}{2} m v^2}}{\cancel{\frac{1}{2} m v^2} . 9}$$

$$= \frac{1}{9} \Rightarrow \underline{\underline{1 : 9}}$$

Sample Problem 3. How much work should be done on a bicycle of mass 20 kg to increase its speed from 2 m/s to 5 m/s ?

$m = 20$ $\qquad$ $m = 20$

$v = 2\,m/sec \longrightarrow v = 5\,m/sec$

$KE = \frac{1}{2} mv^2$ $\qquad$ $KE = \frac{1}{2} mv^2$

$= \frac{1}{2} 20 \times 2 \times 2$ $\qquad$ $= \frac{1}{\cancel{2}} \times \cancel{20}^{10} \times 5 \times 5$

$= 40\,J$ $\qquad$ $= 250\,J$

change in K.E. $= 250 - 40$

work done $= \underline{\underline{210\,J}}$

POTENTIAL ENERGY

The energy of a body due to its position or change in shape is known as potential energy.

1. the energy of a body due to its position above the ground is called gravitational potential energy and
2. the energy of a body due to a change in its shape and size is called elastic potential energy.

note - The gravitational potential energy as well as elastic potential energy are commonly known as just potential energy.

Note –

The sum of the potential and kinetic energies of a body is called its mechanical energy.

POWER

power is defined as the rate of doing work.

Power = Work done / Time taken

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

power is the work done per unit time →

or

(when work is done, an equal amount of energy is consumed.)

power is also defined as the rate at which energy is consumed

Power = Energy consumed / Time taken

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

Power is the rate at which work is done or energy is consumed. ✓

note - 1. Power is a scalar quantity

Units of Power

the SI unit of power is watt.

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

$W = 1$ Joule $\quad t = 1$ sec

$$P = \frac{1}{1} = 1 \text{ watt}$$

1 watt is the power amount of work done at the rate of 1 joule per second

Now $P = \frac{E}{t}$

$E = 1$ Joule $\quad t = 1$sec

1 watt is the power of an appliance which consumes energy at the rate of 1 joule per second

$1\ kw = 1000\ w$

$1\ mw = 10^6\ w$

Note — $1\ HP = 746$ watt

Sample Problem 1. A body does 20 joules of work in 5 seconds. What is its power ?

$w = 20\ J$ $t = 5$ sec

$$P = \frac{w}{t} = \frac{20}{5} = 4 \text{ watt}$$

Sample Problem 2. What is the power of a pump which takes 10 seconds to lift 100 kg of water to a water tank situated at a height of 20 m ? (g = 10 m/s2)

$t = 10$ sec $h = 20m$ $m = 100\ kg$

$$w = mgh$$

$$= 100 \times 10 \times 20$$

$$= 20000J$$

$$P = \frac{w}{t} = \frac{2000\cancel{0}}{1\cancel{0}} = 2000 \text{watt}$$

$$= \underline{\underline{2kw}}$$

Sample Problem 3. An electric bulb consumes 7.2 kJ of electrical energy in 2 minutes. What is the power of the electric bulb ?

$E = 7.2\ kJ$ $t = 2$ min

$= 7200\ J$ $= 2 \times 60$ sec

$$P = \frac{E}{t} = \frac{720\cancel{0}}{2 \times 6\cancel{0}} = \frac{720}{12}$$

$$= 60 \text{ watt}$$

COMMERCIAL UNIT OF ENERGY

The commercial unit (or trade unit) of energy is kilowatt-hour

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

$$E = P \times t$$

kilowatt

hour

1 kw.hr = 1 Unit

1 kw hr = 1000 watt × 60 × 60 sec

= 36 000 00 Joule

$= 3.6 \times 10^6$ Joule

1 kw hr $= 3.6 \times 10^6$ Joule

Sample Problem 1. A radio set of 60 watts runs for 50 hours. How many 'units' (kWh) of electrical energy are consumed ?

$P = 60$ watt $\quad t = 50$ hr

$= \frac{60}{1000}$ kw

$E = P \times t$

$$= \frac{6\cancel{0}}{\underset{2}{\cancel{100}}\cancel{0}} \times \overset{1}{\cancel{50}} = \frac{6}{2}$$

= 3 unit

Sample Problem 2. A family uses 250 units of electrical energy during a month. Calculate this electrical energy in joules.

1 Unit $= 1$ KWhr $= 3.6 \times 10^6$ Joule

250 unit $= 250 \times 3.6 \times 10^6$

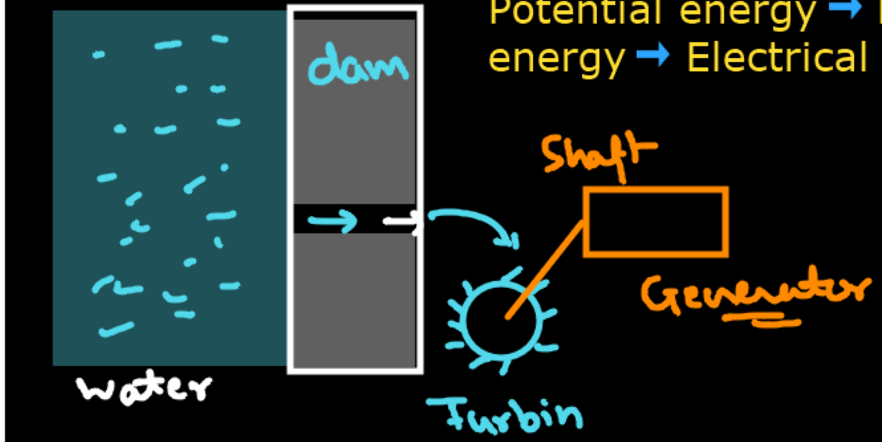
$= 9 \times 10^8$ Joule

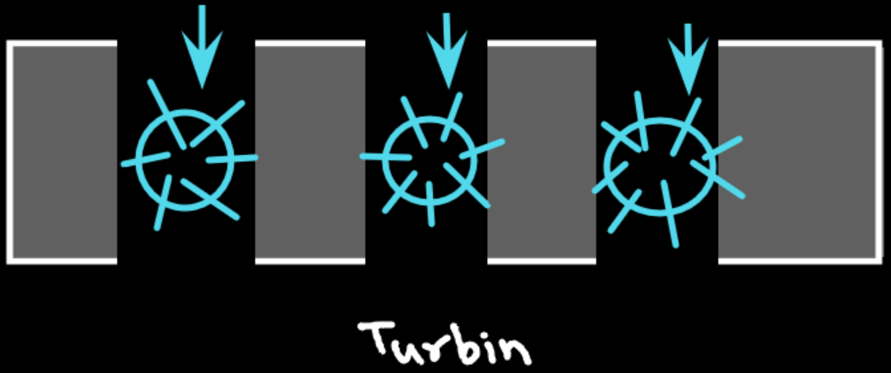
TRANSFORMATION OF ENERGY

The change of one form of energy into another form of energy is known as transformation of energy.

1. Energy Transformations at a Hydroelectric Power House

Potential energy → Kinetic energy → Electrical energy

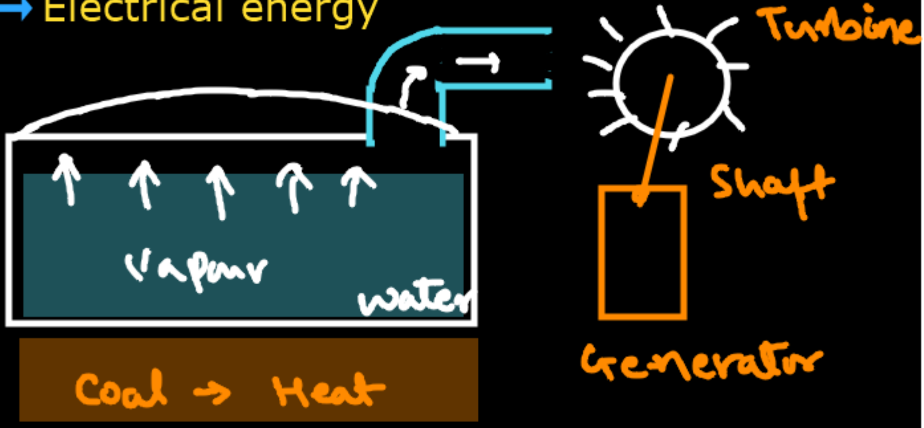




2. Energy Transformations at a Thermal Power House

at a thermal power house, chemical energy of coal is changed into heat energy, which is further converted into kinetic energy and electrical energy.

Chemical energy → Heat energy → Kinetic energy → Electrical energy



USING ENERGY CONVERTERS

In our everyday life we make use of many appliances (or machines) which convert (or transform) one form of energy into another form.

1. Electric Motor

A motor converts electrical energy into mechanical energy.

Electrical energy → Mechanical energy

2. Electric Iron

an electric iron converts electrical energy into heat energy.

Electrical energy → Heat energy

3. Electric Bulb

An electric bulb (or electric lamp) converts electrical energy into light energy

Electrical energy → Heat energy → Light energy

4. Radio

A radio converts electrical energy into sound energy.

Electrical energy → Kinetic energy → Sound energy

5. Steam Engine

steam engine converts heat energy into kinetic energy (or mechanical energy).

Heat energy → Kinetic energy

6. Car Engine

The car engine converts the chemical energy of petrol into heat energy and then into kinetic energy (or mechanical energy).

Chemical energy → Heat energy → Kinetic energy

7. Cell (or Battery)

a cell (or battery) converts chemical energy into electrical energy

Chemical energy → Electrical energy

8. Gas Stove

a gas stove converts the chemical energy of cooking gas into heat energy

Chemical energy → Heat energy

9. Solar Water

a solar water heater converts light energy into heat energy.

Light energy → Heat energy

10. Solar Cell

solar cell converts light energy into electrical energy.

Light energy → Electrical energy

LAW OF CONSERVATION OF ENERGY

Energy can neither be created nor destroyed

Whenever energy changes from one form to another, the total amount of energy remains constant

During the conversion of energy from one form to another, some energy may be wasted

Electric Bulb

Electricity $\xrightarrow[10\ \text{Jule}]{}$ = light + Heat

7 Jule 3 Jule

Free Fall

			Total
Top	KE=0	PE=50	50
	KE=10	PE=40	50
	KE=20	PE=30	50
	KE=30	PE=20	50
	KE=40	PE=10	50
Bottom	KE=50	PE=0	