02

Work, Power and Energy

TREND ANALYSIS 3 YEARS

Average No. of Questions Across all Sets

Topic		Types of Questions	2023	2020	2019
TOPIC 01	Work	1 Mark	–	–	–
		2 Marks	–	–	–
		3 Marks	–	–	–
		4 Marks	–	–	–
TOPIC 02	Power and Energy	1 Mark	1	–	–
		2 Marks	2	–	1
		3 Marks	–	–	–
		4 Marks	1	–	–
TOPIC 03	Energy Sources and Conservation of Energy	1 Mark	1	–	–
		2 Marks	–	1	–
		3 Marks	–	–	1
		4 Marks	–	1	–
TOPIC 04	Machines	1 Mark	–	–	–
		2 Marks	–	1	–
		3 Marks	–	1	–
		4 Marks	–	–	1

TOPIC 1

Work

It is said to be done when a force produces displacement in the direction in which it acts. e.g. A man pulling a car, a horse pulling a cart, a cyclist while pedaling a bicycle, etc. *It is expressed as*

$$\mathbf{W = F \cdot s}$$

or $$\boxed{W = Fs\cos\theta}$$

where, F = Force applied on the body, s = Displacement produced and θ = Angle between direction of force and direction of displacement.

The SI unit of work is **joule** (J) and CGS unit is **erg**. It is a **scalar quantity**.

- 1 joule of work is said to be done when a force of 1 newton, displaces an object by 1 metre along with the direction of force.

- 1 erg of work is said to be done when a force of 1 dyne displaces an object by 1 centimetre along with the direction of force.

Different Cases

- If θ is 0°, then $\cos 0° = 1 \therefore W = Fs$
  Thus, work done is positive.
- If θ is 90°, then $\cos 90° = 0 \therefore W = 0$
  Thus, work done is zero.
- If θ is 180°, then $\cos 180° = -1 \therefore W = -Fs$
  Thus, work done is negative.

Bigger Units of Work

$$1\text{ kJ (kilo-joule)} = 10^3\text{ J}$$
$$1\text{ MJ (mega-joule)} = 10^6\text{ J}$$
$$1\text{ GJ (giga-joule)} = 10^9\text{ J}$$

Relation between Joule and Erg

$$1\text{ joule} = 1\text{ newton} \times 1\text{ metre}$$
$$\Rightarrow \quad 1\text{ joule} = 10^5\text{ dyne} \times 10^2\text{ centimetre}$$
$$\therefore \quad 1\text{ joule} = 10^7\text{ erg}$$

Different Formulae for Work Done

- Work done in terms of initial and final velocity,
$$W = F \cdot s = m\frac{v^2 - u^2}{2}$$
$$[\because v^2 = u^2 + 2as \text{ and } F = ma]$$
  where, u is the initial velocity and v is the final velocity.
- Work done by the force of gravity, i.e. $(F = mg)$ on a body, acting vertically downwards and the displacement is in the direction of the force, i.e. $(s = h)$ is expressed as $W = Fs = mgh$

PYQs Previous Years Questions

1 Mark Questions

1. 1 J = ... erg. **(ICSE 2022 Sem-I)**

(a) 10^9 (b) 10^7 (c) 10^5 (d) 10^6

2. A coolie raises a load upwards against the force of gravity, then the work done by the load is **(ICSE 2022 Sem-I)**

(a) zero
(b) positive work
(c) negative work
(d) None of the above

3. Work done by a body moving on a circular track is zero at every instant because **(ICSE SQP 2022 Sem-I)**

(a) displacement is zero
(b) displacement is perpendicular to the centripetal force
(c) there is no force acting
(d) reason is not mentioned in the other options

4. A coolie carrying a load on his head and moving on a frictionless horizontal platform does no work. Explain the reason, why? **(ICSE 2011)**

> **KEY idea**
> Always, remember that work is done when the displacement is in the direction of applied force.

5. How is work done related to the applied force? **(ICSE 2002)**

6. Define work. **(ICSE 2002)**

2 Marks Questions

7. What is the work done by a force when the force is
(i) normal to the displacement produced
(ii) in the same direction as the displacement produced **(ICSE SQP 2018)**

> **KEY idea**
> Always try to understand the angle between the force and the displacement.

8. Explain briefly, why the work done by a fielder when he takes a catch in a cricket match, is negative? **(ICSE 2015)**

9. How is work done by a force measured when the force
(i) is in the direction of displacement?
(ii) is at an angle θ to the direction of displacement? **(ICSE 2015)**

10. (i) When does a force do work?
(ii) What is the work done by the moon when it revolves around the earth? **(ICSE 2014)**

11. A man having a box on his head, climbs up a slope and another man having an identical box walks the same distance on a levelled road. Who does more work against the force of gravity and why? **(ICSE 2014)**

12. A force is applied on a body of mass 20 kg moving with a velocity of 40 ms^{-1}. The body attains a velocity of 50 ms^{-1} in 2 s. Calculate the work done by the body. **(ICSE 2013)**

13. A body is acted upon by a force. State two conditions under which the work done could be zero. **(ICSE 2010)**

14. State the amount of work done by an object when it moves in a circular path for one complete rotation. Give your reason to justify your answer. **(ICSE 2006)**

15. What should the angle between force and displacement be to get the
 (i) minimum work?
 (ii) maximum work? **(ICSE 2005)**

3 Marks Questions

16. (i) Derive a relationship between the SI and CGS unit of work.
 (ii) A force acts on a body and displaces it by a distance *s* in a direction at an angle θ with the direction of force. What should be the value of θ to get the maximum positive work? **(ICSE 2018)**

17. Define joule. Give the SI unit of work and establish a relationship between the SI and CGS unit of work. **(ICSE 2008)**

TOPIC 2
Power and Energy

Power

The rate of doing work or the rate of transfer of energy into work is called the power. The power of a source is measured as the amount of work done per second by the source or energy transfer per second.

If work W is done in time t, then power can be expressed as

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

It is a **scalar quantity**. The SI unit of power is **watt** (W) and CGS unit is **erg/s**.

The power depends on the two factors such as
 (i) the amount of work done and
 (ii) the time taken to perform that work.

Expressions of Power

When a constant force F acts on a body and it moves the body through a distance d along the direction of applied force in time t, then power (P) is given by

$$P = \frac{W}{t} = \frac{Fd}{t} \qquad [\because W = Fd]$$

If $\frac{d}{t} = v$, where v is the average speed of the body.

So, power $\quad P = F\,v$

If in case displacement (s) and force has some angle θ, then power,

$$P = \frac{Fs\cos\theta}{t} = F\,v\cos\theta = \mathbf{F}\cdot\mathbf{v} \qquad \left[\because v = \frac{s}{t}\right]$$

Multiple Units of Power

$$1\text{ kW (kilo-watt)} = 10^3\text{ W}$$
$$1\text{ MW (mega-watt)} = 10^6\text{ W}$$
$$1\text{ GW (giga-watt)} = 10^9\text{ W}$$

Sub-multiple Units of Power

$$1\text{ mW (milli-watt)} = 10^{-3}\text{ W}$$
$$1\ \mu\text{W (micro-watt)} = 10^{-6}\text{ W}$$

Relationship between SI and CGS Unit

$$1\text{ W} = 1\text{ J/s} = 10^7\text{ erg/s}$$

NOTE Horse power is a common unit of power; 1 HP = 746 W = 0.746 kW

Energy

The energy of a body is its ability to do work. A body capable of doing work is said to possess energy. Work and energy are directly related to each other. The SI unit of energy is **joule** (J) and in CGS unit is **erg**. It is a **scalar quantity**.

The larger units of energy are watt hour (Wh) and kilowatt hour (kWh)

$$1\text{ Wh} = 3600\text{ J}$$
$$\Rightarrow \quad 1\text{ kWh} = 3.6 \times 10^6\text{ J}$$

Other unit of energy are calories and eV.

$$1\text{cal} = 4.18\text{J}$$
$$1\text{eV} = 1.6 \times 10^{-19}\text{ J}$$

The energy possessed by a body due to its position and state of motion is called **mechanical energy**.

It has two types

(i) Kinetic energy and

(ii) Potential energy

The total mechanical energy of a body is equal to the sum of its kinetic energy and potential energy.

Kinetic Energy

It is defined as the energy possessed by a body by virtue of its state of motion.

e.g. A swinging pendulum, a roaring rocket, running water, moving air, etc. It is generally denoted by KE. It is expressed as

$$\boxed{\text{KE} = \frac{1}{2}mv^2}$$

where, m = mass of the body, v = speed of the body.

- Kinetic energy K and momentum $p\,(= mv)$ are related as $K = p^2/2m$.
- **Work-Energy Theorem** If initial speed (velocity) of a body is u and final speed (velocity) of a body is v, then according to work-energy theorem,

  Work done by all the forces acting on the body (ΔW)

  = Change in kinetic energy of the body

  $$(\Delta K) = \frac{1}{2}mv^2 - \frac{1}{2}mu^2$$

Forms of Kinetic Energy

A moving body can have three types of motions namely the translational, rotational and vibrational.

There are three forms of kinetic energy as mentioned below

(i) **Translational Kinetic Energy** This energy comes in act when a force applied on a body causes a displacement in a straight line in its own direction. e.g. A car moving in a straight path, freely falling body, molecule of a monoatomic gas, etc.

(ii) **Rotational Kinetic Energy** If a body rotates about an axis, the motion is called rotational motion and the energy possessed due to rotational motion is called rotational kinetic energy. e.g. A rotating wheel, a spinning top, etc.

(iii) **Vibrational Kinetic Energy** This energy comes in act when a body vibrates to and fro about its mean position. e.g. A wire clamped at both ends when plucked at the middle vibrates.

Potential Energy

The energy possessed by a body by virtue of its specific position (configuration) is called the potential energy. e.g. A body placed at a height above the ground, a wound up watch spring. It is usually denoted by the symbol U.

Forms of Potential Energy

Mainly there are two types of potential energy such as

(i) **Gravitational Potential Energy** It is the amount of work done in raising a body from the ground to a point at height h, against gravity.

It is expressed by

$$\boxed{U = mgh}$$

where, m is the mass of the object, g is acceleration due to gravity and h is the height through which the object is raised.

(ii) **Elastic Potential Energy** The energy possessed by a body in the deformed state due to change in its shape and size is called elastic potential energy. e.g. Energy possessed by a compressed spring.

Different Forms of Energy

We get energy in various forms. Some of these forms are

(i) **Chemical energy** It is the energy possessed by fossil fuels such as coal, petroleum and natural gases. A battery has chemical energy in it.

(ii) **Mechanical energy** It is the energy possessed by a body due to its position and state of motion. A moving ball, a body at rest, etc., have mechanical energy.

(iii) **Heat energy** The energy released on burning fuels such as coal, oil, gas, etc., is called heat energy.

(iv) **Electrical energy** The energy the possessed by a charged body due to movement of free electrons is called electrical energy.

(v) **Nuclear energy** It is the energy released during the process of nuclear fission and fusion. We use nuclear energy in nuclear reactor to produce electrical energy.

(vi) **Sound energy** The energy possessed by a vibrating body producing sound is called sound energy. Sound energy is sensed by our ears.

(vii) **Light energy** A form of energy in presence of which we can see the object around us is called light energy. Sun is the natural source of light energy.

PYQs Previous Years Questions

1 Mark Questions

1. When the speed of a moving object is doubled, then its kinetic energy **(ICSE 2023)**

(a) remains the same
(b) decreases
(c) is doubled
(d) becomes four times

2. Which of the following is the correct expression for gain in kinetic energy, if initial velocity is not zero? **(ICSE SQP 2023)**

(a) $K = \frac{1}{2}mv^2$ (b) $K = \frac{mv^2}{4}$

(c) $K = \frac{mv^2}{2t}$ (d) $K = \frac{1}{2}m(v^2 - u^2)$

3. The usable form of mechanical energy is **(ICSE SQP 2022 Sem-I)**

(a) elastic potential energy
(b) kinetic energy
(c) gravitational potential energy
(d) none of the given options

4. The conversion of part of the energy into an undesirable form is called? **(ICSE 2014)**

5. What is nuclear energy? **(ICSE 2014)**

6. A body is thrown vertically upwards, its velocity keeps on decreasing. What happens to its KE, as its velocity becomes zero? **(ICSE 2014)**

7. By what factor, does the kinetic energy of a moving body change when its speed is reduced to half? **(ICSE 2002)**

8. What do kilowatt hour measure? **(ICSE 2002, 01)**

2 Marks Questions

9. Calculate the power spent by a crane, while lifting a load of mass 2000 kg, at velocity of 1.5 ms^{-1}. (Take, $g = 10 ms^{-2}$) **(ICSE 2023)**

> **KEY idea**
> In this case, power can be calculated by using $p = F \cdot v$, where F is force and v is the velocity of the object.

10. (i) What should be the angle between the direction of force and the direction of displacement, for work to be negative?
(ii) Name the physical quantity obtained using the formula $\frac{U}{h}$, where U is the potential energy and h is the height. **(ICSE 2023)**

11. If kinetic energy of a moving body is 40 J, then what will be its kinetic energy when its velocity is doubled? **(ICSE SQP 2023)**

12. A light body A and a heavy body B have the same momentum. **(ICSE 2022 Sem-I)**
(i) Choose a correct statement from the given options.
(a) Kinetic energy of body A and body B will be the same.
(b) Kinetic energy of body A is greater than kinetic energy of body B.
(c) Kinetic energy of body B is greater than kinetic energy of body A.
(d) Unless we know the velocity, we cannot find which body has greater kinetic energy.
(ii) If the ratio of kinetic energies of A and B is 5 : 2, then which one of the following gives the mass ratio of the bodies respectively?
(a) 5 : 2 (b) 25 : 4
(c) 2 : 5 (d) 4 : 24

13. A body has kinetic energy 2500 J. If the mass of the body is 500 g, **(ICSE SQP 2022 Sem-I)**
(i) the velocity of the body is
(a) $\sqrt{10}$ m/s
(b) 10 m/s
(c) 20 m/s
(d) 100 m/s
(ii) the momentum of the body will be
(a) 10 kg-m/s
(b) $500\sqrt{10}$ kg-m/s
(c) 50 kg-m/s
(d) 4. 5 kg-m/s

14. Two bodies A and B have masses in the ratio 5 : 1 and their kinetic energies are in the ratio 125 : 9. Find the ratio of their velocities. **(ICSE 2019)**

15. (i) State and define the SI unit of power.
(ii) How is the unit horse power related to the SI unit of power? **(ICSE 2018)**

16. State the energy changes in the following cases while in use
(i) an electric iron.
(ii) a ceiling fan. **(ICSE 2018)**

17. Name the unit of physical quantity obtained by the formula $\frac{2K}{v^2}$, where K is kinetic energy and v is linear velocity. **(ICSE 2018)**

18. A metal ball of mass 60 g falls on a concrete floor from a vertical height of 2.8 m and rebounds to a height of 1.3 m. Find the change in KE in SI units. **(ICSE SQP 2018)**

19. If the power of a motor be 100 kW, at what speed can it raise a load of 50000 N? **(ICSE 2017)**

20. A boy weighing 40 kgf climbs up a stair of 30 steps each 20 cm high in 4 min and a girl weighing 30 kgf does the same in 3 min. Compare
(i) the work done by them.
(ii) the power developed by them. **(ICSE 2016)**

21. State the energy changes in the following while in use
(i) burning of a candle.
(ii) a steam engine. **(ICSE 2015)**

22. Rajan exerts a force of 150 N in pulling a cart at a constant speed of 10 m/s. Calculate the power exerted. **(ICSE 2015)**

23. Calculate the change in the kinetic energy of a moving body, if its velocity is reduced to 1/3rd of the initial velocity. **(ICSE 2014)**

24. A girl of mass 35 kg climbs up from the first floor of a building at a height 4 m above the ground to the third floor at a height 12 m above the ground. What will be the increase in her gravitational potential energy? (Take, $g = 10\ ms^{-2}$) **(ICSE 2013)**

25. A ball is placed on a compressed spring. When the spring is released, the ball is observed to fly away.
(i) What form of energy does the compressed spring possess?
(ii) Why does the ball fly away? **(ICSE 2012)**

26. A body of mass 0.2 kg falls from a height of 10 m to a height of 6 m above the ground. Find the loss in potential energy taking place in the body. (Take, $g = 10\ ms^{-2}$) **(ICSE 2012)**

27 A moving body weighing 400 N possesses 500 J of KE. Calculate the velocity with which the body is moving. (Take, $g = 10\ m/s^2$) **(ICSE 2012)**

> **KEY Idea**
> Here, velocity of moving body is determine by
> $$v = \sqrt{\frac{KE \times 2 \times g}{w}}$$

28 A body of mass 5 kg is moving with a velocity of $10\ ms^{-1}$. What will be the ratio of its initial kinetic energy and final kinetic energy, if the mass of the body is doubled and its velocity is halved? **(ICSE 2009)**

29 What is the SI unit of energy? How is the electron volt (eV) related to it? **(ICSE 2009, 05)**

30 Two bodies A and B of equal mass are kept at heights 20 m and 30 m, respectively. Calculate the ratio of their potential energies. **(ICSE 2007)**

31 The work done by the heart is 1 joule per beat. Calculate the power of the heart, if it beats 72 times in one minute. **(ICSE 2005)**

32 If the power of a motor is 40 kW, at what speed does it raises a load of 20000 N? **(ICSE 2003)**

33 A machine raises a load of 750 N through a height of 16 m in 5 s. Calculate the power at which the machine works. **(ICSE 2002)**

34 A body P has a mass of 20 kg and is moving with a velocity of 5 m/s. Another body Q has a mass of 5 kg and is moving with a velocity of 20 m/s. Calculate
(i) the ratio of the momentum of P and Q.
(ii) the kinetic energy of P in SI unit. **(ICSE 2000)**

> **KEY idea**
> Apply the formula of momentum for both the bodies ($p = mv$) and then to calculate kinetic energy, apply formula $\left(KE = \frac{p^2}{2m}\right)$.

3 Marks Questions

35. A body of mass 50 kg has a momentum of $3000\ kg\text{-}ms^{-1}$. Calculate
(i) the kinetic energy of the body.
(ii) the velocity of the body. **(ICSE 2010)**

36. 6.4 kJ of energy causes a displacement of 64 m in a body in the direction of force in 2.5 s. Calculate (i) the force applied (ii) power in horse power (HP). (Take, 1 HP = 746 W) **(ICSE 2009)**

37. (i) Define one kilowatt hour. How is it related to the joule?
(ii) How can the work done be measured when force is applied at an angle to the direction of displacement? **(ICSE 2007)**

38. Define power and energy. **(ICSE 2002)**

39. An engine can pump 30000 L of water to a vertical height of 45 m in 10 min. Calculate the work done by the machine and its power. (Take, $g = 9.8\ m/s^2$, density of water $= 10^3\ kg/m^3, 1000\ L = 1\ m^3$) **(ICSE 2000)**

4 Marks Question

40. A car of mass 120 kg is moving at a speed 18 km/h and it accelerates to attain a speed of 54 km/h in 5 s. Calculate **(ICSE 2023)**
(i) the work done by the engine.
(ii) the power of the engine.

TOPIC 3
Energy Sources and Conservation of Energy

Conversion of Energy from One Form to Another

The process of the conversion of energy from one form to the other form is known as **transformation of energy**. In our daily life, we require energy in various forms.

Production of electricity from different forms of energy are illustrated as below

Production of Electricity from Solar Energy

The sun is the most vast and direct source of energy. The energy obtained from the sun is called **solar energy**. The two devices **solar cell** and **solar power plant** are used for generating electricity.

Solar Cell

Solar cells are usually made from semiconductors like silicon and gallium. At ordinary temperature, a semiconductor has a very low conductivity but its conductivity increases either with the rise in temperature or when some impurities are added to it.

If the sunlight is made to incident on an impurity added semiconductor, a potential difference is produced between its surfaces.

Due to this potential difference, a current flows in the circuit connected between the opposite faces of the semiconductor. Thus, electricity is produced.

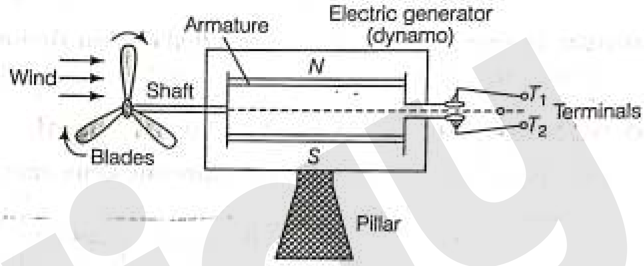
Solar Power Plant

It consists of a number of concave reflectors, at the focus of which, there are black painted water pipes.

The reflectors concentrate the heat energy of the sun rays on the pipes due to which water inside the pipes starts boiling and produces steam. The produced steam is used to rotate a steam turbine which drives a generator to produce electricity.

Production of Electricity from Wind Energy

Wind energy is used in a wind generator to produce the electricity by making use of two drive and a wind generator. In wind generator, a small electric generator (or dynamo) is placed at the top of a pillar. The armatue of the connected is connected to the shaft attached with the blades of a wind mill.



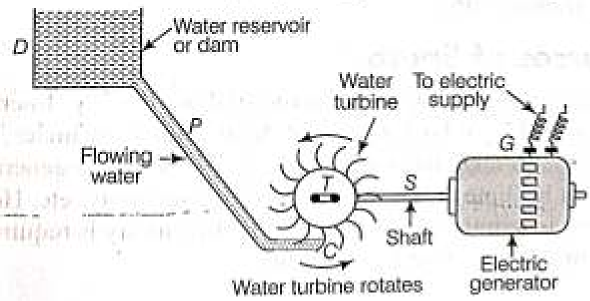
When the blowing wind strikes the blades of the wind mill, the translational KE of wind changes into rotational KE of the blades. The rotation of blades of the turbine rotates the armature of the dynamo. Due to rotation of the armature, the magnetic flux linked with it changes between the poles N and S of a strong magnet, an emf is produced between the terminals T_1 and T_2, which leads to the production of electricity.

Production of Electricity from Water or Hydro Energy

The kinetic energy possessed by the flowing water is called the water (or hydro) energy. A high rise dam is constructed on the river to obstruct the flow of water and thereby collect water in large reservoirs.

Due to rise in water level, the kinetic energy of flowing water gets converted into potential energy. The water from the high level is carried through the pipe to turbine located near the bottom of the dam, which is connected to the electric generator.

When the water turbine rotates, then the armature of the generator also rotates rapidly and produce electricity.



Nuclear Power Plant

The most important use of nuclear energy is generation of electricity. This is done by using a s et up called nuclear power plant.

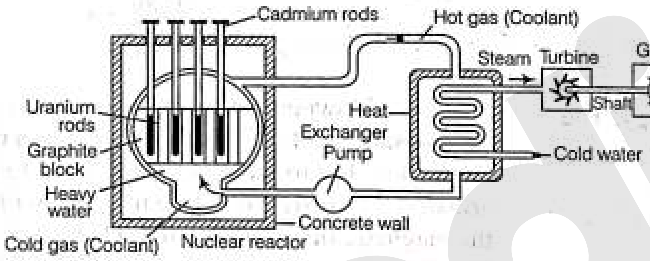
Nuclear energy of U^{235} → Heat energy of steam → Kinetic energy of turbine → Electrical energy

Connection of nuclear effects into electrical energy

Principle The heat produced in a controlled nuclear fission reaction is utilised for producing steam. This steam is used to run turbines connected to the generators and electricity is generated.

Components of a Nuclear Power Plant

A nuclear power plant consists of the following components



A schematic view of nuclear power plant

(i) **Nuclear Reactor** Here, a controlled nuclear fission of a fissionable fuel such as $_{92}U^{235}$ is carried out.

(ii) **Heat Exchanger** The reactor is connected to a heat exchanger. Here, the heat produced in the reactor is transferred to water by circulating a **coolant** through a coiled pipe. The water gets converted into steam. The coolant is pumped back to the reactor.

(iii) **Steam Turbine** The steam generated in the heat exchanger is used to run the steam turbine. The spent steam is sent back as hot water to the **heat exchanger.**

(iv) **Electric Generator** (or dynamo) The shaft of the steam turbine is connected to an electric generator (or dynamo) electricity, so produced is sent for transmission.

Sources of Energy

We require energy in every activity of our life. e.g. Energy is required to light homes, to cook food, to move vehicles, to run TV, etc. To meet these requirements the energy is generally needed in some of the forms like heat, electricity, etc. Heat energy is required for cooking food. Electricity is required for running electric motors, fans, etc.

A source of energy provides adequate amount of useful energy at a steady rate over a longer period of time. From the availability point of view, the energy sources are divided into following two groups

(a) Renewable sources of energy

(b) Non-renewable sources of energy

Law of Conservation of Energy

According to this law, energy can neither be created nor be destroyed, it can only be transferred from one form to another form.

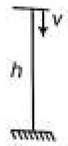
Conservation of Mechanical Energy

The total mechanical energy of a system remains constant, if the internal forces involved are non-dissipative (not frictional) and the external forces do not work. This is called the **principle of conservation of energy.**

If kinetic energy of the system is K and potential energy is U, then from conservation of mechanical energy,

$$\text{Mechanical energy} = K + U = \text{constant}$$

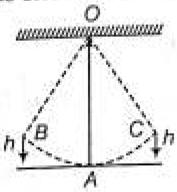
Example of conservation of mechanical energy is a free falling body, as it falling the potential energy gets converted to kinetic energy such that



$$mgh+\frac{1}{2}mv^2=\text{constant}$$

where, h is height and v is speed of the body.

- The law of conservation of energy can also be applied to a simple pendulum as shown in the figure.



- The particle is having mass m when it goes from A to B or B to C. We can apply conservation of mechanical energy as $(KE)_A=(PE)_C$ or $\frac{1}{2}mv^2=mgh$

PYQs Previous Years Questions

1 Mark Questions

1. The energy conversion in washing machine is from **(ICSE 2023)**
   (a) magnetic to electrical
   (b) electrical to mechanical
   (c) electrical to magnetic
   (d) magnetic to electrical

2. The energy conversion, when an oscillating pendulum moves from mean to extreme position is **(ICSE SQP 2023)**
   (a) kinetic to potential
   (b) potential to kinetic
   (c) potential to kinetic to potential
   (d) kinetic to potential to kinetic

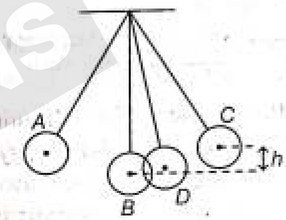
3. The energy change during photosynthesis in plants is **(ICSE 2022 Sem-I)**
   (a) heat to chemical
   (b) light to chemical
   (c) chemical to light
   (d) chemical to heat

4. In an electric cell while in use, the change in energy is from **(ICSE SQP 2022 Sem-I)**
   (a) chemical to mechanical
   (b) chemical to electrical
   (c) electrical to mechanical
   (d) electrical to chemical

5. Name the process used for producing electricity using nuclear energy. **(ICSE 2014)**

2 Marks Questions

6. The diagram below shows a pendulum having a bob of mass 80 g. A and C are extreme positions and B is the mean position. The bob has velocity 5 m/s at position B. [Take, $g=10\,\text{N/kg}$] **(ICSE SQP 2022 Sem-I)**



   (i) Which one of the following statements is correct?
   (a) At point A, the bob has only kinetic energy.
   (b) At point B, the bob will have only potential energy.
   (c) At point B, the bob will have maximum kinetic energy.
   (d) At point D, the bob will have more potential and less kinetic energy.

   (ii) The height h is
   (a) 1.25 cm (b) 125 m
   (c) 1.25 m (d) 0.125 m

7. Give one example of each, when **(ICSE 2020)**
   (i) chemical energy changes into electrical energy.
   (ii) electrical energy changes into sound energy.

8. Write the energy conversions in the following. (ICSE SQP 2018)
   (i) Microphone
   (ii) Lighted candle

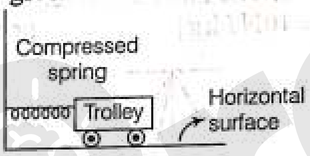
9. State the energy changes in the following devices while in use
   (i) a loudspeaker (ii) a glowing electric bulb. (ICSE 2014)

10. State one important advantage and disadvantage each of using nuclear energy for producing electricity. (ICSE 2014)

11. (i) State the energy conversion taking place in a solar cell.
   (ii) Give one disadvantage of using a solar cell. (ICSE 2012, 02)

12. A ball of mass 200 g falls from a height of 5 m. What will be its kinetic energy when it just reaches the ground? (Take, $g = 9.8\ m/s^2$) (ICSE 2011)

13. A spring is kept compressed by a small trolley of mass 0.5 kg lying on a smooth horizontal surface as shown in the figure given below.



When the trolley is released, it is found to move at a speed of $2\ ms^{-1}$, what potential energy did the spring possess when compressed? (ICSE 2010)

> **KEY Idea**
> Apply conservation of energy, i.e. PE of spring is equal to KE imparted to the trolley.

14. State the energy changes that takes place in the following when they are in use
   (i) a photovoltaic cell.
   (ii) an electromagnet. (ICSE 2009)

15. When an arrow is shot from a bow, it has a kinetic energy in it. Explain briefly from where does it get its kinetic energy? (ICSE 2008)

16. What energy conversions take place in the following when they are working
   (i) Electric toaster?
   (ii) Microphone? (ICSE 2008)

17. What is the main energy transformation that occurs in
   (i) photosynthesis in greenhouse?
   (ii) charging of a battery? (ICSE 2007)

18. A ball of mass 0.20 kg is thrown vertically upwards with an initial velocity of 20 m/s. Calculate the maximum potential energy it gains as it goes up. (ICSE 2004)

3 Marks Questions

19. A body of mass 10 kg is kept at a height of 5 m. It is allowed to fall and reach the ground. (ICSE 2019)
   (i) What is the total mechanical energy possessed by the body at the height of 2 m assuming it is a frictionless medium?
   (ii) What is the kinetic energy possessed by the body just before hitting the ground? (Take, $g = 10\ m/s^2$)

20. Draw a diagram to show the energy changes in an oscillating simple pendulum. Indicate in your diagram how the total mechanical energy in it remains constant during the oscillation. (ICSE 2011)

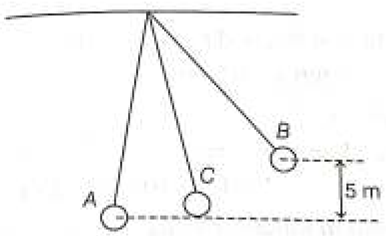
21. State the law of conservation of energy. (ICSE 2005)

22. A truck driver starts off with his loaded truck. What are the major energy changes that take place in setting the truck into motion? (ICSE 2001)

4 Marks Questions

23. A body of mass 200 g falls freely from a height of 15 m. (Take, $g = 10\ ms^{-2}$) (ICSE 2022 Sem-I)
   (i) When the body reaches 10 m above the ground, its potential energy will be
   (a) 20000 J (b) 10 J
   (c) 10000 J (d) 20 J
   (ii) The gain in kinetic energy of the body when it reaches 10 m above the ground is
   (a) 20 J (b) 10 J
   (c) 30 J (d) 25 J
   (iii) The total mechanical energy it will possess, when it is just about to strike the ground is
   (a) 30000 J (b) 20000 J
   (c) 30 J (d) 20 J
   (iv) The velocity in ms^{-1} with which the body will hit the ground is
   (a) 30 (b) 10
   (c) $10\sqrt{3}$ (d) $10\sqrt{2}$

24. The figure below shows a simple pendulum of mass 200 g. It is displaced from the mean position A to the extreme position B. The potential energy at the position A is zero. At the position B, the pendulum bob is raised by 5 m. (ICSE 2020)



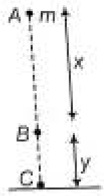
(i) What is the potential energy of the pendulum at the position B?

(ii) What is the total mechanical energy at point C?

(iii) What is the speed of the bob at the position A when released from B?

(Take $g = 10 \text{ ms}^{-2}$ and there is no loss of energy)

25. An object of mass m is allowed to fall freely from point A as shown in the figure. Calculate the total mechanical energy of the object at



(i) Point A

(ii) Point B

(iii) Point C

(iv) State the law which is verified by your calculations in parts (i), (ii) and (iii).

(ICSE 2009)

26. (i) A stone of mass 64.0 g is thrown vertically upward from the ground with an initial speed of 20.0 m/s. The gravitational potential energy at the ground level is considered to be zero. Apply the principle of conservation of energy and calculate the potential energy at the maximum height attained by the stone. (Take, $g = 10 \text{ ms}^{-2}$)

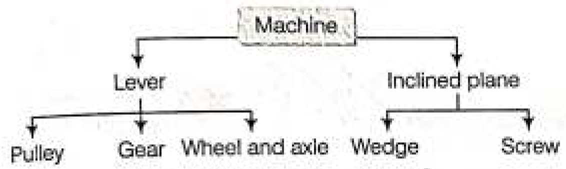
(ii) Using the same principle, state what will be the total energy of the body at its half-way point?

(ICSE 2008)

TOPIC 4

Machines

It is a device which helps us to do the work at one point and deliver it at another point with a view of accomplishing the work conveniently.



Classification of machine

Uses of Machines We use machines to
(i) multiply force
(ii) to change the direction of the force
(iii) to increase or decrease the speed

Terms Related to Machine

Load It is the resistive or opposing force against which the machine does the work. It is denoted by L.

Effort It is the force applied on the machine to overcome the load. It is denoted by E.

Mechanical Advantage (MA) It is the ratio of the load to the effort. It is denoted by MA. It is expressed as

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

Being a ratio, it has no unit.
If MA > 1, then it works as force multiplier.
If MA < 1, then it gains speed.
If MA = 1, then it changes the direction of effort.

Velocity Ratio (VR) It is the ratio of the distance moved by the effort d_E to the corresponding distance moved by the load d_L.

It is denoted by VR. It is expressed as

$$VR = \frac{\text{Velocity of effort } (v_E)}{\text{Velocity of load } (v_L)} = \frac{d_E}{d_L}$$

Efficiency (η) It is the ratio of the work done on the load by the machine to the work put into the machine by the effort. It is denoted by η.

It is expressed as

$$\eta = \frac{\text{Work done on the load}}{\text{Work done by the effort}} = \frac{W_{output}}{W_{input}}$$

It is expressed in percentage,

$$\eta = \frac{W_{output}}{W_{input}} \times 100$$

Relation between η, MA and VR If η is expressed as efficiency percentage, then

$$\boxed{\eta = \frac{MA}{VR} \times 100}$$

Ideal Machine For an ideal machine, η is 100%. For practical purpose, the efficiency of a machine is less than 100% that is because practical MA is always less than theoretical VR due to friction and the weight of the moving parts.

Lever

It is a rigid body capable of rotating about a fixed axis. It is one of the commonest and simplest of all machines.
According to principle of lever,
Movement of load about the fulcrum = Movement of effort about the fulcrum

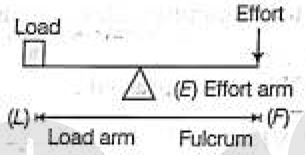
$$L \times d_L = E \times d_E$$

Kinds of Levers

There are following three types of levers
(i) Class I Lever
(ii) Class II Lever
(iii) Class III Lever

Class I Lever

In this type of lever, the effort (E) and the resistance load (L) are situated on either side of the fulcrum (F). e.g. A pair of scissors, handle of water pump, a catapult and the nodding of the human head, etc.



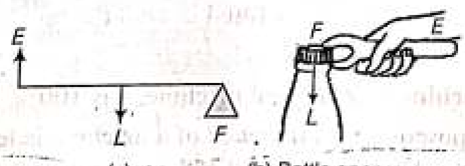
$$\text{MA of class I lever} = \frac{\text{Effort arm}}{\text{Load arm}},$$

$$\text{VR of class I lever} = \frac{d_E}{d_L}$$

If MA = 1, then load arm = effort arm
If MA > 1, then effort arm > load arm
If MA < 1, then effort arm < load arm

Class II Lever

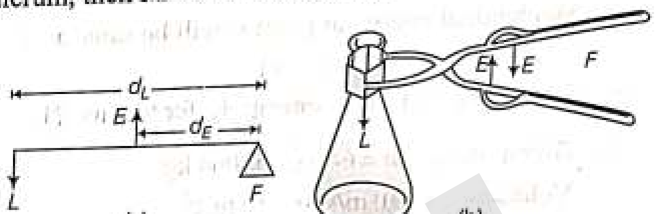
In this type of lever, the load is situated between fulcrum and effort. e.g. A bottle opener, a wheel barrow, a paper cutter, raising the weight of the human body on toes, etc. As effort arm is always greater than the load arm, then MA and VR are always more than 1.



(a) (b) Bottle opener

Class III Lever

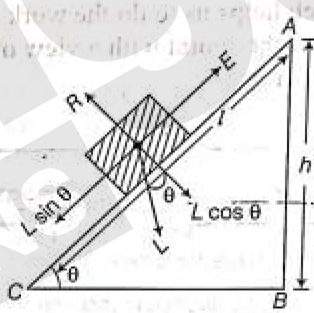
In this type of lever, effort is situated between the load and the fulcrum. e.g. Sugar tongs, the forearm used for lifting a load (**or action of the bicep muscle**), foot treadle, spade lifting a load. As effort is situated between the load and the fulcrum, then MA and VR is always less than 1.



(a) (b)

Inclined Plane

The inclined plane is a sloping surface that behaves like a simple machine whose mechanical advantage is always greater than 1.



$$\text{Mechanical Advantage (MA)} = \frac{\text{Load}(L)}{\text{Effort}(E)} = \frac{L}{L \sin\theta}$$

$$\because \quad \sin\theta = \frac{h}{l}$$

$$\therefore \quad MA = \frac{l}{h} = \frac{1}{\sin\theta}$$

The velocity ratio of an inclined plane

$$VR = \frac{d_E}{d_L} = \frac{AC}{BC} = \frac{l}{h}$$

Gears

A gear is a wheel with teeth around its rim. A gear wheel closer to the source of power is called the **driver** (or the **driving gear**), while the gear wheel which receives motion from the driver is called the **driven gear**.

Let r_A and r_B be the radii of the driver and driven wheels and N_A and N_B be the number of teeth in the driving gear and driven gear respectively.

The ratio of number of teeth in the driving wheel to the number of teeth in the driven wheel is called the **gear ratio**.

$$\text{Gear ratio} = \frac{N_A}{N_B}$$

The ratio of number of teeth in driven gear to the number of teeth in driving gear gives the gain in torque (or tunning effect).

$$\text{Gain in torque} = \frac{N_B}{N_A} = \frac{r_B}{r_A}$$

The gain in speed is equal to the ratio of speed rotation of driven wheel to the speed of rotation of the driving wheel.

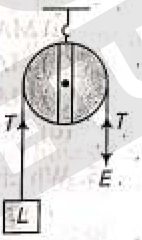
$$\text{Gain in speed} = \frac{n_B}{n_A} = \frac{N_A}{N_B}$$

Pulley

It is a wheel on an axle that is designed to support movement and change the direction of a cable or belt along its circumference.

A set of pulleys assembled, so that they rotate independently on the same axle to form a block is called **pulley system.**

Single Fixed Pulley



A pulley which has its axis of rotation fixed in position is called single fixed pulley.

Mechanical Advantage

$$(\text{MA}) = \frac{\text{Load}}{\text{Effort}} = \frac{T}{T} = 1$$

[$\because$ Load $L = T$, Effort $E = T$, if pulley is not rotating]

$$\text{Velocity Ratio (VR)} = \frac{d_E}{d_L} = \frac{d}{d} = 1$$

[$\because d_E = d$ and $d_L = d$]

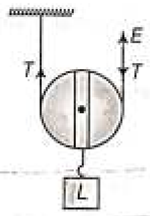
$$\text{Efficiency } (\eta) = \frac{\text{MA}}{\text{VR}} = 1 \text{ or } 100\%$$

Single Movable Pulley

A pulley whose axis of rotation is not fixed in position is called a movable pulley.

$$\text{Mechanical Advantage (MA)} = \frac{\text{Load}}{\text{Effort}} = \frac{2T}{T} = 2$$

[$\because L = T + T = 2T$ and $E = T$]



$$\text{Velocity Ratio (VR)} = \frac{d_E}{d_L} = \frac{2d}{d} = 2 \quad [\because d_E = 2d \text{ and } d_L = d]$$

$$\text{Efficiency } (\eta) = \frac{\text{MA}}{\text{VR}} \times 100 = \frac{2}{2} \times 100 = 100\% \text{ or } 1$$

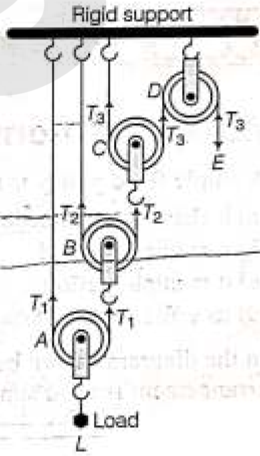
Combination of Pulleys

The combination can be made in two ways

(i) Using one fixed pulley and several movable pulleys.

(ii) Using several fixed pulleys in two blocks known as **block and tackle system.**

Using one fixed pulley and other movable pulley



If there are n movable pulleys with one fixed pulley, then the mechanical advantage of this system is $\text{MA} = 2^n$

So, mechanical advantage of system which has one fixed pulley and three movable pulleys $= 2^3 = 8$

If there are n movable pulleys connected to a fixed pulley, the velocity ratio of this system is $\text{VR} = 2^n$

So, velocity ratio of system which has one fixed pulley and three movable pulleys $= 2^3 = 8$

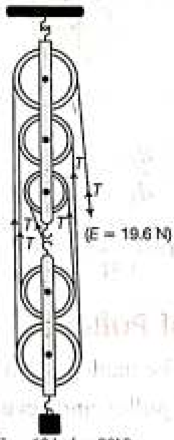
Using several fixed pulleys in two blocks (block and tackle system)

If the total number of pulleys used in both the blocks is n and the effort is being applied in the downward direction. In this case, Load $= nT$ and Effort $= T$

$$\text{Mechanical Advantage (MA)} = \frac{\text{Load}}{\text{Effort}} = n$$

Velocity ratio

In a block and tackle system, if the load moves up through a distance d, the effort end moves through a distance nd, because each section of the string supporting the load is loosened by a length d. i.e.



Block and tackle for five pulleys

if $d_L = d$, then $d_E = nd$

$\therefore$ Velocity ratio $= \frac{nd}{d} = n$

But, if total weight of pulleys in the lower block be W,

$$L + w = nT$$

$$E = T$$

Mechanical Advantage (MA)

$$= n - \frac{w}{E},\ VR = n$$

Efficiency, $\eta = \frac{MA}{VR}$

$$= \frac{(n - W/E)}{n}$$

$$= 1 - \frac{W}{nE}$$

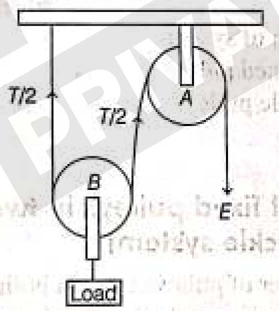
PYQs Previous Years Questions

1 Mark Questions

1. A single fixed pulley is used because **(ICSE 2022 Sem-I)**

(a) it changes the direction of applied effort conveniently
(b) it multiplies speed
(c) it multiplies effort
(d) its efficiency is 100%

2. In the diagram shown below, the velocity ratio of the arrangement is rigid support **(ICSE 2022 Sem-I)**



(a) 1 (b) 2 (c) 3 (d) 0

3. A woman draws water from a well using a fixed pulley. The mass of the bucket and the water together is 10 kg. The force applied by the woman is 200 N. The mechanical advantage is (Take $g = 10\ m/s^2$) **(ICSE 2022 Sem-I)**

(a) 2 (b) 20
(c) 0.05 (d) 0.5

4. Mechanical Advantage (MA), load (L) and effort (E) are related as **(ICSE SQP 2022 Sem-I)**

(a) $MA = L \times E$
(b) $MA = E/L$
(c) $MA \times E = L$
(d) $MA \times L = E$

5. Which one of the following statements is correct?

(a) A machine is used to have more output energy as compared to input energy. **(ICSE SQP 2022 Sem-I)**
(b) Mechanical advantage of a machine can never be greater than 1.
(c) If a machine gives convenience of direction, then its mechanical advantage should be greater than 1.
(d) For a given design of a machine, even if the mechanical advantage increases, the velocity ratio remains the same.

6. If a block and tackle system with convenient direction has 3 movable pulleys, then its velocity ratio **(ICSE SQP 2022 Sem-I)**

(a) is either 6 or 7
(b) should be 6
(c) should be 7
(d) is 3

7. A boy uses a single fixed pulley to lift a load of 50 kgf to some height. Another boy uses a single movable pulley to lift the same load to the same height. Compare the effort applied by them. Give a reason to support your answer. **(ICSE 2017)**

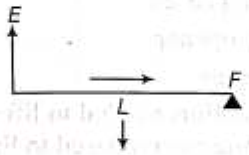
8. A scissor is a____multiplier. **(ICSE 2015)**

9. What is the principle of an ideal machine? **(ICSE 2014)**

2 Marks Questions

10. Crane A lifts a heavy load in 5s, whereas another crane B does the same work in 2s. Compare the power of crane A to that of crane B. **(ICSE 2020)**

11. The diagram below shows a lever in use **(ICSE 2018)**



(i) To which class of levers does it belong?

(ii) Without changing the dimensions of the lever, if the load is shifted towards the fulcrum, what happens to the mechanical advantage of the lever?

12. Explain why a single fixed pulley is used despite no gain in mechanical advantage. **(ICSE SQP 2018)**

13. Which class of lever will always have MA > 1 and why? **(ICSE 2017)**

14. With reference to the terms mechanical advantage, velocity ratio and efficiency of a machine, name and define the term that will not change for a machine of a given design. **(ICSE 2016)**

15. (i) Give an expression for mechanical advantage of an inclined plane in terms of the length of an inclined plane.

(ii) Name a common device, where a gear train is used. **(ICSE 2015)**

16. Draw a simplified diagram of a lemon crusher, indicating direction of load and effort. **(ICSE 2015)**

17. Draw a diagram to show how a single pulley can be used, so as to have its ideal MA = 2. **(ICSE 2014)**

18. A type of single pulley is very often used as a machine even though it does not give any gain in mechanical advantage

(i) Name the type of pulley used.

(ii) For what purpose is such a pulley used? **(ICSE 2013)**

19. Under what condition will a set of gears produce

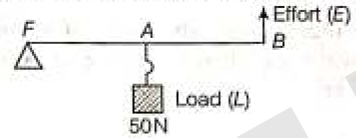
(i) a gain in speed?

(ii) a gain in torque? **(ICSE 2012)**

20. (i) What is meant by an ideal machine?

(ii) Write a relationship between the mechanical advantage (MA) and velocity ratio (VR) of an ideal machine? **(ICSE 2011)**

21. The diagram below shows a lever in use.



(i) To which class of lever does it belong?

(ii) If $FA = 40$ cm, $AB = 60$ cm, then find the mechanical advantage of the lever. **(ICSE 2011)**

22. Name a machine which can be used to

(i) multiply force.

(ii) change the direction of force applied. **(ICSE 2011)**

23. (i) Why is the mechanical advantage of a lever of the second order always greater than one?

(ii) Name the type of single pulley that has a mechanical advantage greater than one. **(ICSE 2010)**

24. (i) With reference to the terms mechanical advantage, velocity ratio and efficiency of a machine, name the term that will not change for a machine of a given design.

(ii) Define the term stated by you in part (i). **(ICSE 2009)**

25. Copy the diagram of the forearm given below, indicate the positions of load, effort and fulcrum.

(ICSE 2008)

26. Write an expression to show the relationship between mechanical advantage, velocity ratio and efficiency for a simple machine. **(ICSE 2007)**

27. Which class of levers has a mechanical advantage always greater than one? What change can be brought about in this lever to increase its mechanical advantage? **(ICSE 2007)**

28. A woman draws water from a well using a fixed pulley. The mass of the bucket and water together is 6.0 kg. The force applied by the woman is 70 N. Calculate the mechanical advantage. (Take, $g = 10$ m/s^2) **(ICSE 2004)**