

Note : Answers given below are intended only as a reference for the questions asked in board examinations. These answers are NOT an attempt at a detailed discussion related to the question.

VSAQs

1. (a) Define work.
(b) What are the conditions for doing work?
(c) State the mathematical expression for work?
(d) Does work have direction?

Refer to class notes ([click here for PDF](#))

2. In which of the following cases is work done? Explain.
 - (a) A man pushing a wall
 - (b) A girl climbing a stair case
 - (c) A body swimming in a tank
 - (d) A man standing at a place and holding a suitcase in hand.
 - (e) A lady cooking food
 - (f) A porter carrying a load on his head and walking on a level road
 - (g) A porter carrying a load and climbing upstairs

Refer to class notes ([click here for PDF](#))

3. State the sign of work done by a force in the following
 - (a) Work done by a man in lifting a bucket out of a well by means of a rope tied to the bucket.
 - (b) Work done by gravitational force in the above case
 - (a) Positive. This is because force applied by the person (through tension in the string) and the displacement of the bucket are both in upwards direction and therefore $\cos(0) = 1$
 - (b) Negative. This is because gravitational force on the bucket is downwards and displacement of the bucket is in upwards direction and therefore $\cos(180^\circ) = -1$
4. State the sign of work done by a force in the following cases
 - (a) Work done by friction on a body sliding on a on inclined plane
 - (b) Work done by gravitational force on a freely falling body
 - (a) Negative. This is because frictional force acts along the plane in the upwards direction whereas the body is sliding down along the plane and therefore $\cos(180^\circ) = -1$
 - (b) Positive. This is because a component of gravitational force i.e. $mg\sin(\theta)$, acts along the direction of downward displacement of the body and therefore $\cos(0^\circ) = 1$
5. State the sign of work done by a force in the following cases

- (a) Work done by applied force on a body moving on a rough horizontal plane with uniform velocity
- (b) Work done by resistive force of air on a vibrating pendulum in bringing it to rest

- (a) Positive. This is because applied force and the displacement of the body are along the same direction and hence $\cos(0^\circ) = 1$
- (b) Negative. This is because Resistive force acts opposite to the instantaneous direction of motion of the pendulum therefore $\cos(180^\circ) = -1$

6. State the conditions under which a force does no work.

Work done by a force on a body may be zero if

- (a) Net displacement of the body is zero
- (b) Angle between force and displacement is 90° , because $\cos(90^\circ)$ is zero

7. A man climbs a slope and another walks the same distance on a horizontal road. Who does more work and why?

Work done by the man climbing the slope is more as there is gain in his potential energy.

8. (a) State the CGS and SI units of work

(b) How is joule related to erg?

CGS unit of work is erg and SI unit is joule (J)

$$1 \text{ erg} = 10^{-6} \text{ J}$$

9. State the expression for work done by a force when the object experiencing the force is displaced opposite to the force.

$$W = |F| |S| \cos(\theta)$$

When force and displacement are in opposite directions then $\cos(\theta) = \cos(180^\circ)$ therefore

$$W = |F| |S| (-1)$$

$$W = -F S$$

10. Give an example where the displacement of a particle is in a direction perpendicular to the force acting on this particle.

- (a) For a body moving along a horizontal surface, normal reaction (N) and gravitational force (mg) are perpendicular to the direction of motion
- (b) For a body in uniform circular motion centripetal force is always perpendicular to the instantaneous displacement of the body

11. The displacement of a particle makes an angle θ w.r.t. the force acting on it. For what value of θ is the work maximum? For what value of θ is the work done minimum?

Work done is given by $W = |F||S| \cos(\theta)$

Therefore, work done is the maximum when θ is zero (because $\cos(0^\circ) = 1$) and work done is the minimum when θ is 180° (because $\cos(180^\circ) = -1$)

12. (a) What is energy? State define SI unit of energy.

(b) Define potential energy. Give two examples of potential energy

(c) Define kinetic energy. Give four examples of kinetic energy

Energy is defined as the capacity or ability of a body or a system to do work.

Its SI unit is joule (J).

It is a scalar quantity.

(a) Potential energy : It is the energy possessed by a system by the virtue of its position or state or configuration.

Examples

1. Energy stored in a compressed spring (elastic potential energy)
2. Projectile during its flight at a certain height from the ground (gravitational potential energy)

(b) Kinetic energy : It is the energy possessed by a body by the virtue of its motion.

1. Energy of an arrow shot from a bow
2. Energy of a cricket ball in motion
3. Energy of an aeroplane in flight
4. Projectile during its flight

13. What kind of energy is possessed by the body in the following cases?

(a) A cocked up spring and an air gun

Elastic potential energy

(b) A shooting arrow

Elastic potential energy (above the ground) and kinetic energy (due to its motion)

(c) A stone lying on the top of a house

Gravitational potential energy

(d) Water stored in a dam

Gravitational potential energy

(e) An electron spinning around the nucleus

Electrostatic potential energy due to interaction with the nucleus and kinetic energy due to its motion

(f) A fish moving in water

Gravitational potential energy due to its position and kinetic energy due to its motion

14. Give two examples of elastic potential energy.

- (a) Potential energy stored in the spring when it is compressed or elongated
- (b) Potential energy in a bow that is pulled to release an arrow

15. State the law of conservation of energy.

If internal forces are conservative in nature and external forces do no work on the system then total energy of the system remains constant.

16. Define work, power and energy. State their SI units.

Work : Work done by a force acting on a body is defined as the as the product of component of force in the direction of displacement and the magnitude of displacement of the body.

$$dW = \mathbf{F} \cdot d\mathbf{s}$$

SI unit of work is joule (J)

Power : It is defined as the rate at which work is done on a body

$$P = \frac{dW}{dt}$$

SI unit of power is watt (W)

Energy : It is the capacity to do work

SI unit of energy is joule (J)

17. State the relation between kinetic energy and momentum of a body

Kinetic energy of a body is given by $KE = \frac{1}{2}mv^2$

Multiplying and dividing by m we get

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

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

Using the relation $p = mv$ we get

$$KE = \frac{p^2}{2m}$$

18. State the expression for kinetic energy of a body of mass m moving at a speed v .

Kinetic energy of a body is give by $KE = \frac{1}{2}mv^2$

19. Does the kinetic energy of a body depend on the direction of its motion?

No, kinetic energy is a scalar quantity. Its value does not depend on the direction of motion of the body.

- 20.** By what factor does the kinetic energy of a particle increase if its speed is increased by a factor of 3?

Kinetic energy of a body is given by $KE = \frac{1}{2}mv^2$

Therefore when velocity increases by 3 times the kinetic energy increases by 9 times.

- 21.** What is the relation between the work done by external forces acting on a body and its energy?

Work done by an external conservative force leads to a change in kinetic energy or potential energy of the system. Work done by an external non-conservative force is dissipated from the system.

- 22.** What is mechanical energy?

The sum of kinetic energy and potential energy of the system is called mechanical energy.

- 23.** Can matter be converted into energy?

Yes. Under suitable conditions matter may be converted to energy.

Example : In nuclear fusion & fission reactions the loss of mass is liberated in the form of energy.

- 24.** Write the energy conversions in the following

- (a) Total energy of a system is always constant no matter what internal and external forces are present on the body
- (b) The work done by the earth's gravitational force in keeping the moon in its orbit for one complete revolution is zero

No answer. Inconsistent question !

- 25.** Define kilowatt hour and convert it into joule.

One kilowatt hour is the energy equivalent of a power of 1000 watts consumed for a time interval of 1 hour.

$$\begin{aligned} 1\text{kWhr} &= 1000 \times 60 \times 60 \text{ J} \\ &= 3600000 \text{ J} \end{aligned}$$

- 26.** Define electron volt and express it in joule

One electron volt is the amount of energy gained by an electron as it is allowed to move through a potential difference of 1 volt.

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

- 27.** Define power and write its units.

- (a) State the absolute unit of power in SI unit.

(b) What is horse power? What is its magnitude in SI unit?

SI unit of power is watt (W).

A horse power is one of the earlier units power intended as a comparison between the output of horse to that of a steam engine.

One mechanical horsepower equals about 746 watts.

28. Which physical quantity remains constant in an (a) elastic collision (b) inelastic collision

(a) Elastic collision : total linear momentum and total kinetic energy of the system of colliding particles

(b) Inelastic collision : total linear momentum of the system of colliding particles (part of kinetic energy is dissipated into other forms of energy such as light, heat, sound etc.)

29. Define power. Write the relation between force, velocity and power.

It is the rate at which work is done on a body or a system.

$$P = F \cdot v$$

SAQs

1. In which of the following cases is the work done positive, negative or zero?

(a) Work done a porter on a suitcase in lifting it from the platform on to his head.

(b) Work done by the force of gravity on the suitcase as the suitcase falls down from the porter's head.

(c) Work done by a person on a book held in his hand while walking with uniform speed on a horizontal road.

2. Why does a person standing for a long time get tired even when he does not appear to do any work?

3. What do you understand by potential energy? Explain with two examples.

Refer to class notes ([click here for PDF](#))

4. How can you justify that a body kept at a greater height has larger energy?

Gravitational potential energy is given by

$$PE = m g h$$

Therefore as the height of the body from the ground increases its potential energy also increases.

5. What is potential energy? Derive an expression for gravitational potential energy.

It is the energy possessed by a system by the virtue of its position or state or configuration.

Refer to class notes ([click here for PDF](#))

6. A lorry and a car moving with the same momentum are brought to rest by application of brakes which provide equal retarding forces. Which one of them will come to rest in shorter time? Which one of them will come to rest in lesser distance?

Let the momentum of both the car and the lorry be denoted by p .

As acceleration is constant, using the relation

$$v = u + at, \text{ multiplying by } m \text{ of both sides we get}$$

$$mv = mu + mat$$

as the final velocity and therefore momentum is zero and $F = ma$ is negative we get

$$0 = p - Ft$$

$$t = \frac{p}{F}$$

From the above equation it is observed that as p and F are same of both car and truck, they will come to rest in the same interval of time.

As acceleration is constant, using the relation

$$v^2 - u^2 = 2aS, \text{ multiplying by } m^2 \text{ of both sides we get}$$

$$m^2v^2 - m^2u^2 = 2m^2aS$$

as the final velocity and therefore momentum is zero and acceleration is negative we get

$$0 - p^2 = -2m^2aS$$

$$S = \frac{p^2}{2m^2a}$$

Using $F = ma$ we get

$$S = \frac{p^2}{2Fm}$$

As p and F are same for both the bodies, from the above equation it is observed that, due to its greater mass, truck comes to rest in a shorter distance than the car.

7. Distinguish between conservative and non conservative forces with one example each.

Refer to class notes ([click here for PDF](#))

8. Work done by a force F_1 is larger than the work done by another force F_2 . Is it necessary that the power delivered by F_1 is also greater than the power delivered by F_2 ?

Refer to class notes ([click here for PDF](#))

9. Derive an expression for the height attained by a freely falling body after n number of rebounds from the floor.

Let the initial height from which the body is dropped be H .

Coefficient of restitution (in terms of heights) is given by

$$e = \sqrt{\frac{h_2}{h_1}}$$

$$h_2 = e^2 h_1$$

After the first rebound the height reached is

$$h_2 = e^2 H$$

After the second rebound the height reached is

$$h_3 = e^2 h_2$$

$$\Rightarrow h_3 = e^2 \times e^2 H$$

$$\Rightarrow h_3 = e^4 H$$

Similarly after the n^{th} rebound the height reached is

$$h = e^{2n} H$$

10. Explain the law of conservation of energy.

Law of conservation of energy : Total energy of a system remains constant if external forces acting on the system do no work and the internal forces are conservative in nature.

Total work done on a system may consist of

W_{ext} : work done by external forces

W_{ic} : work done by conservative internal forces

W_{nic} : work done by non-conservative internal forces

The net work done on a system leads to change in its kinetic energy. Therefore

$$W_{\text{ext}} + W_{\text{ic}} + W_{\text{inc}} = \Delta KE$$

When work done by external forces is zero and internal forces are conservative then we get

$$W_{\text{ic}} = \Delta KE$$

Work done by internal conservative forces is equal to $-\Delta PE$, therefore

$$-\Delta PE = \Delta KE$$

$$PE_i - PE_f = KE_f - KE_i$$

$$PE_i + KE_i = KE_f + PE_f$$

Therefore total energy is conserved.

- 11.** What is the total displacement of a freely falling body after successive rebounds from the same place of the ground before it comes to stop? Assume that e is the coefficient of restitution between the body and the ground.

As the body starts from a height and eventually stops on the ground its total displacement is equal to the height from which it is dropped (and in the downward direction) .

LAQs

- 1.** Develop the notion of work and energy and show that it leads to the work-energy theorem

Work done is said to be done on a body if the applied force causes a displacement of the body in the direction of the applied force.

Work may be done on a system due to external forces, internal conservative forces and internal non-conservative forces. Work done by internal non-conservative forces is dissipated from the system (in the form of heat energy etc.). Work done by internal conservative forces is stored as potential energy in the system. Therefore the net work done on the system leads to a change in kinetic energy.

Development of work energy system

Consider a body of mass m having an initial velocity u . Under the action of a force let the body attain a final velocity v .

Consider change in kinetic energy of a body as a function of time

$$\frac{dKE}{dt} = \frac{d}{dt} \left(\frac{1}{2} m v^2 \right)$$

Assuming mass to be constant we get

$$\frac{dKE}{dt} = \frac{1}{2} m \frac{d}{dt} (v^2)$$

$$\frac{dKE}{dt} = \frac{1}{2} m 2v \frac{dv}{dt}$$

$$\frac{dKE}{dt} = m v \frac{dv}{dt}$$

Rate of change of velocity w.r.t. time is defined as acceleration, therefore

$$\frac{dKE}{dt} = m a v$$

$$dKE = F dx$$

To obtain total change in kinetic energy we integrate the above expression

$$\int_i^f dKE = \int F dx$$

$$KE_f - KE_i = W$$

$$W = \Delta KE$$

2. State and prove law of conservation of energy . Prove mathematically the law of conservation of energy in case of a freely falling body.

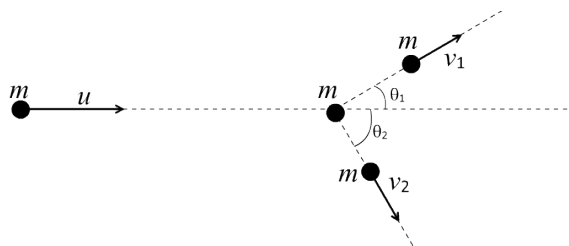
Refer to class notes ([click here for PDF](#))

3. What are collisions? Explain the types of collisions. Show that in case of one dimensional elastic collision, the relative velocity of approach of two colliding bodies before collision is equal to the relative velocity of separation after collision.

Refer to class notes ([click here for PDF](#))

4. Show that two equal masses undergoing oblique elastic collision will move at right angles after the collision, if the second body is initially at rest.

Let mass of each body be m and the initial velocity of the first body be u along the x -axis. Total initial momentum of the system is only along the x -direction therefore. Let the final velocities be v_1 and v_2 making angles θ_1 and θ_2 w.r.t. the x -axis respectively (as shown in the figure below)



Considering the law of conservation linear momentum we get

$$m\bar{u} = m\bar{v}_1 + m\bar{v}_2$$

$$\bar{u} = \bar{v}_1 + \bar{v}_2$$

Using parallelogram law of addition of vectors for magnitude of u , using v_1 and v_2 we get

$$u = \sqrt{v_1^2 + v_2^2 + 2v_1v_2\cos(\theta_1 + \theta_2)}$$

$$u^2 = v_1^2 + v_2^2 + 2v_1v_2\cos(\theta_1 + \theta_2) \quad \text{--- (i)}$$

From conservation of kinetic energy we get

$$\frac{1}{2}mu^2 = \frac{1}{2}mv_1^2 + \frac{1}{2}mv_2^2$$

$$u^2 = v_1^2 + v_2^2 \quad \text{--- (ii)}$$

Using this in equation (i) we get

$$v_1^2 + v_2^2 = v_1'^2 + v_2'^2 + 2v_1v_2\cos(\theta_1 + \theta_2)$$

$$2v_1v_2\cos(\theta_1 + \theta_2) = 0$$

Since v_1 and v_2 are not zero this implies

$$\cos(\theta_1 + \theta_2) = 0$$

$$\Rightarrow (\theta_1 + \theta_2) = 90^\circ$$

5. If the forces doing work are conservative show that the total mechanical energy of the system remains constant.

Refer to SAQ 10 or class notes ([click here for PDF](#))

6. Obtain expression for potential energy of a spring.

Refer to class notes ([click here for PDF](#))

7. State and prove work-energy theorem in case of a variable force.

Refer to class notes ([click here for PDF](#))

8. Define coefficient of restitution and obtain the expression for it.

A body falling from a certain height h , after striking a smooth floor, rebounds to a height $h/2$. What is the coefficient of restitution between the floor and the body?

Refer to class notes ([click here for PDF](#))

$$e = \sqrt{\frac{h_2}{h_1}}$$

$$e = \sqrt{\frac{h/2}{h}}$$

$$e = \sqrt{\frac{1}{2}}$$

9. An object is tied to a string and rotated in a vertical circle. Obtain expressions for the speeds of the object at the highest point and at the lowest points when the string becomes slack only at the highest point.

Refer to class notes ([click here for PDF](#))