Class -09
WORK, ENERGY AND SIMPLE MACHINES

Note: Calculations use the value of g stated in each question. Where no value is stated, g = 10 m/s² is used unless the question's numbers indicate g = 9.8 m/s².

Very Short Answer Type (2 Marks)

1. The casing of a rocket in flight becomes hot due to friction. At whose expense is this heat energy obtained?

The heat is produced mainly by the conversion of the rocket's kinetic energy and the energy of the surrounding air into thermal energy.

2. A gas molecule hits a horizontal wall at 200 m/s, making an angle of 30° with the normal, and rebounds at the same speed. Is momentum conserved? Is the collision elastic or inelastic?

The molecule's momentum alone changes because its velocity component perpendicular to the wall reverses. Momentum of the complete molecule–wall system is conserved. Since the molecule rebounds with the same speed, its kinetic energy is unchanged; the collision is elastic.

3. Name two types of potential energy.

Gravitational potential energy and elastic (strain) potential energy.

4. Can an object have zero acceleration even when several forces act on it? Explain.

Yes. If the forces balance and their vector sum is zero, the net force is zero. By Newton's second law, acceleration is then zero.

5. Convert 1 kWh into joules.

1 kWh = 1000 W × 3600 s = 3.6×10^6 J.

6. What is gravitational potential energy?

It is the energy an object has because of its position or height in a gravitational field. Near Earth's surface, relative to a chosen reference level, PE = mgh.

7. In tug-of-war, one team wins and the other loses. Which team does positive work and which does negative work?

The winning team does positive work on the losing team if it pulls the losing team in the direction of its force and causes displacement. The losing team's opposing force does negative work on the winning team. Work depends on the force and the displacement of the object being considered.

8. A man does 60 J of work in 6 s. Calculate his power.

Power = work/time = 60/6 = 10 W.

9. What is the commercial unit of energy? Define it.

The commercial unit is the kilowatt-hour (kWh). One kWh is the energy used by a 1 kW appliance operating for 1 hour; it equals 3.6×10^6 J.

10. When an arrow is released from a stretched bow, where does it get its kinetic energy?

The elastic potential energy stored in the stretched bow is converted into the kinetic energy of the arrow.

11. A body has kinetic energy 10 J. What is its new kinetic energy if its speed doubles?

Kinetic energy is proportional to speed squared. New KE = $10 \times 2^2 = 40$ J

12. Draw/describe a graph showing kinetic energy, potential energy and total energy during the free fall of a body.

Taking the ground as zero potential energy and neglecting air resistance: as the body falls, PE decreases linearly with height, while KE increases by the same amount. Total mechanical energy (PE + KE) remains constant. On a graph against time, the exact KE and PE curves are not straight lines; total energy is a horizontal line.

13. Mention a situation in which an object is displaced in the absence of a force acting on it.

An object already moving in a straight line at constant speed in deep space, far from significant forces, continues to move with no net force acting on it.

14. How is energy transferred when (A) a rubber band is stretched and (B) a stretched rubber band is released?

(A) Work done by the hand is stored as elastic potential energy in the rubber band. (B) The stored elastic potential energy changes mainly into kinetic energy of the band or the object it launches, with some energy dissipated as sound and heat.

15. A boy and a girl do the same work in 5 minutes and 10 minutes respectively. Who has more power, and why?

The boy has more power. For the same work, power = work/time; the boy takes half as long, so his power is twice the girl's.

16. What is the mechanical advantage of a machine?

Mechanical advantage (MA) is the ratio of load to effort: MA = load force / effort force.

17. What is the velocity ratio of a single movable pulley?

For an ideal single movable pulley, the velocity ratio is 2.

Short Answer Type (3 Marks)

1. The mass of body A is less than that of body B. Both have equal momentum. Which has more kinetic energy?

KE = $p^2/(2m)$. For the same momentum, kinetic energy is inversely proportional to mass. Therefore, body A (the lighter body) has greater kinetic energy.

2. A force acts on a 10 kg body and its speed changes from 5 m/s to 3 m/s. Find the work done by the force.

Work done = change in KE = $\frac{1}{2}m(v^2 - u^2) = \frac{1}{2} \times 10 \times (3^2 - 5^2) = 5 \times (9 - 25) = -80$ J. The negative sign means the force removes kinetic energy.

3. Find the power needed to lift 90 metric tonnes of coal per hour from a mine 200 m deep.

Mass per second = 90,000 kg / 3600 s = 25 kg/s. Power = mass flow rate × gh = 25 × 10 × 200 = 50,000 W = 50 kW.

4. A 60 kgf skier moves from A (75 m high) to B (15 m high). (A) Find the change in gravitational potential energy. (B) If 75% of the lost energy becomes kinetic energy at B, find the speed at B.

(A) The height decreases by 75 − 15 = 60 m. The skier's mass is 60 kg, so $\Delta PE = mg(h_B - h_A) = 60 \times 10 \times (15 - 75) = -36{,}000$ J. The potential energy decreases by 36 kJ. (B) KE at B = 0.75 × 36,000 = 27,000 J. Using $\frac{1}{2}mv^2 = 27{,}000$: $v = \sqrt{(2 \times 27{,}000/60)} = 30$ m/s.

5. A constant force acts on a body moving with constant acceleration. Is the power constant? How must force vary with speed for constant power?

No. Instantaneous power P = Fv. With constant force, power increases as speed increases. For constant power, the force must vary inversely with speed: F = P/v.

6. A nail becomes warm when hammered into a plank. Explain.

The hammer's mechanical energy is converted into internal energy due to deformation and friction between the nail and wood. This raises their temperature.

7. Ram and Shyam each have a weight of 40 kgf and climb a 50 m hill in 60 s and 50 s respectively. Who is more powerful? (g = 10 m/s²)

Each has mass 40 kg. Work = mgh = 40 × 10 × 50 = 20,000 J. Ram's power = 20,000/60 ≈ 333 W. Shyam's power = 20,000/50 = 400 W. Shyam is more powerful.

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

W = mgh = 200 × 10 × 6 = 12,000 J.

9. A child pulls a toy car 10 m along a horizontal floor. The string makes an angle of 60° with the horizontal and the force is 10 N. Find the work done.

$W = Fs \cos\theta = 10 \times 10 \times \cos 60° = 100 \times 0.5 = 50$ J.

10. The position of a particle is $x = (t - 3)^2$, with x in metres and t in seconds. Find the work done by the force in the first 6 s.

$x = t^2 - 6t + 9$, so acceleration $a = d^2x/dt^2 = 2$ m/s² (constant). From t = 0 to t = 6 s, x changes from 9 m to 9 m, so net displacement is zero. For a constant force, net work = F × displacement = 0 J. (The mass is not specified, but the zero-displacement result makes the net work zero.)

11. A 1200 kg car travelling at 72 km/h stops in 80 m. Find the average braking force. What happens to its original kinetic energy?

Initial speed = 72 × 1000/3600 = 20 m/s. Initial KE = ½ × 1200 × 20² = 240,000 J. Work by braking force = −240,000 J = F × 80, so F = −3000 N. The average braking force has magnitude 3000 N opposite to motion. The kinetic energy is mainly converted into heat in the brakes/tyres and surroundings, with some sound.

12. A 100 W electric lamp is used for 5 hours per day. Find the energy consumed in one day in units.

Energy = 100 W × 5 h = 500 Wh = 0.5 kWh. Since 1 unit = 1 kWh, the lamp uses 0.5 unit per day.

13. A 10 kg body is released from a height of 10 m. When its kinetic energy becomes 450 J, what is its potential energy? (g = 10 m/s²)

Initial total energy = mgh = 10 × 10 × 10 = 1000 J. Neglecting air resistance, total energy stays constant. PE = 1000 − 450 = 550 J.

14. A pump lifts 1000 kg of water per minute from a well 12 m deep and ejects it at 20 m/s. Find the work done per minute and the power.

Work per minute = gain in PE + gain in KE = mgh + ½mv² = 1000 × 10 × 12 + ½ × 1000 × 20² = 120,000 + 200,000 = 320,000 J. Power = 320,000/60 ≈ 5333 W = 5.33 kW.

15. A pendulum rises 15 cm above its lowest point at the end of its swing. How fast is it moving at the lowest point?

At the lowest point, its kinetic energy changes into gravitational potential energy at the highest point: ½mv² = mgh. Thus $v = \sqrt{(2gh)} = \sqrt{(2 \times 9.8 \times 0.15)} \approx 1.71$ m/s (about 1.7 m/s).

16. Why is the efficiency of a real inclined plane always less than 100%?

Some input work is used to overcome friction and is dissipated as heat and sound. Therefore, useful output work is less than input work, so efficiency is below 100%.

17. Why is a pair of scissors called a Class I lever?

In a Class I lever, the fulcrum lies between the effort and the load. In scissors, the pivot is between the handles (effort) and the blades (load).

Long Answer Type (5 Marks)

1. A 10 kg mass is released from 40 m above Earth's surface. Find its mechanical energy when it is 20 m above the surface. (g = 10 m/s²)

At release, total mechanical energy = mgh = 10 × 10 × 40 = 4000 J. At 20 m, PE = 10 × 10 × 20 = 2000 J, so KE = 4000 − 2000 = 2000 J. Total mechanical energy = PE + KE = 4000 J.

2. Bodies A (3 kg) and B (10 kg) are dropped simultaneously from a height of 14.9 m. Find (a) momentum, (b) potential energy and (c) kinetic energy when they are 10 m above the ground.

They have fallen 4.9 m. Taking g = 9.8 m/s², $v^2 = 2gh = 2 \times 9.8 \times 4.9 = 96.04$, so v = 9.8 m/s. (a) Momentum: A = 3 × 9.8 = 29.4 kg·m/s; B = 10 × 9.8 = 98 kg·m/s. (b) PE at 10 m: A = 3 × 9.8 × 10 = 294 J; B = 10 × 9.8 × 10 = 980 J. (c) KE gained during the 4.9 m fall: A = 3 × 9.8 × 4.9 = 144.06 J; B = 10 × 9.8 × 4.9 = 480.2 J.

3. A truck and a car have equal kinetic energies and are stopped by equal constant retarding forces. Compare the distances they travel before stopping.

The work done by the retarding force equals the initial kinetic energy: Fd = KE. Since both KE and the retarding force are equal, d = KE/F is equal. They travel the same distance before stopping.

4. A 100 W electric bulb is lit for 2 hours daily. Find the electrical energy used per day and the cost at Rs. 2 per unit.

Energy = 100 W × 2 h = 200 Wh = 0.2 kWh = 0.2 unit. Cost = 0.2 × Rs. 2 = Rs. 0.40 per day.

5. A running man has half the kinetic energy of a boy whose mass is half the man's mass. The man speeds up by 10 m/s and then has the same kinetic energy as the boy. Find their original speeds.

Let the man's mass be M, his speed u, and the boy's speed v. Initially, $\frac{1}{2}Mu^2 = \frac{1}{2}[\frac{1}{2}Mv^2] / 2$, so $u^2 = v^2/4$ and v = 2u. After the man speeds up, $\frac{1}{2}M(u + 10)^2 = \frac{1}{2}(M/2)v^2$. Substituting v = 2u gives $(u + 10)^2 = 2u^2$. Taking positive speeds, $u = 10/(\sqrt{2} - 1) \approx 24.14$ m/s and v = 2u ≈ 48.28 m/s.

6. A 20 kg block is pulled up a slope by a force equal to its weight component parallel to the slope. The slope is at 30° and the block moves 3 m. Find the work done and the increase in potential energy. Assume no friction and g = 10 m/s².

Force parallel to slope = mg sin 30° = 20 × 10 × 0.5 = 100 N. Work done = Fs = 100 × 3 = 300 J. Vertical rise = 3 sin 30° = 1.5 m. Increase in PE = mgh = 20 × 10 × 1.5 = 300 J.

7. A bullet moving at 300 m/s just pierces a 2 cm thick block of wood. What speed is needed to just pierce an 18 cm thick block of the same wood?

Assuming the resisting force of the wood is constant, the work needed to pierce the wood is proportional to thickness and equals the bullet's initial kinetic energy. Thus $v_2^2/v_1^2 = 18/2 = 9$, so $v_2 = 300\sqrt{9} = 900$ m/s.

8. The heart does 1.5 J of work per heartbeat. How many beats per minute does it make if its power is 2 W?

Power = work per beat × beats per second. Beats per second = 2/1.5 = 4/3. Beats per minute = (4/3) × 60 = 80 beats/min.