

Work, Energy and Power — Assignment 2

Class 11 Physics · Higher-difficulty challenge set + integrated problems · Answer key included · Narayan Gurukul Academy

Instructions: (1) Attempt all questions; start with the topic-wise challenge set, then attempt the integrated (multi-topic) problems.
(2) Give all answers with correct SI units. $g = 10 \text{ m/s}^2$ unless stated.
(3) A final answer key is provided at the end — try the full set before checking it.

Part A — Topic-wise challenge questions

Work

2 Mark Questions

1. Mountain roads rarely go straight up the slope but wind up gradually. Why?
2. Is it necessary that work done in the motion of a body over a closed loop is zero for every force in nature? Why?

3 Mark Questions

1. A body of mass 0.3 kg is taken up an inclined plane of length 10 m and height 5 m and then allowed to slide down to the bottom again. The coefficient of friction between the body and the plane is 0.15. Calculate (i) the work done by the gravitational force over the round trip, (ii) the work done by the applied force over the upward journey, (iii) the work done by the frictional force over the round trip, (iv) the kinetic energy of the body at the end of the trip. How is the answer to (iv) related to the first three answers?

Work Done by a Variable Force

2 Mark Questions

1. Find the work done when a particle moves from position $r_1 = (3\hat{i} + 2\hat{j} - 6\hat{k})$ to $r_2 = (14\hat{i} + 13\hat{j} - 9\hat{k})$ under a constant force $F = (4\hat{i} + \hat{j} + 3\hat{k}) \text{ N}$.

3 Mark Questions

1. A body is moving along the z-axis of a coordinate system under the effect of a constant force $F = (2\hat{i} + 3\hat{j} + \hat{k}) \text{ N}$. Find the work done by the force in moving the body a distance of 2 m along the z-axis.

Kinetic Energy and the Work–Energy Theorem

2 Mark Questions

1. A truck and a car moving with the same K.E. on a straight road. Their engines are simultaneously switched off which one will stop at a lesser distance?
2. How high must a body be lifted to gain an amount of potential energy equal to the kinetic energy it has when moving at a speed of $20 \text{ m}\cdot\text{s}^{-1}$? (Take $g = 9.8 \text{ m}\cdot\text{s}^{-2}$.)

3 Mark Questions

1. In lifting a 10 kg weight to a height of 2m, 230 J energy is spent. Calculate the acceleration with which it was raised?
2. A bullet of mass 0.02 kg is moving with a speed of 10 ms^{-1} . It can penetrate 10 cm of a wooden block, and comes to rest. If the thickness of the target would be 6 cm only, find the K.E. of the bullet when it comes out.

Conservation of Mechanical Energy

2 Mark Questions

1. A bob is pulled sideways so that string becomes parallel to horizontal and released. Length of the pendulum is 2 m. If due to air resistance loss of energy is 10%, what is the speed with which the bob arrived at the lowest point.
2. A ball at rest is dropped from a height of 12 m. It loses 25% of its kinetic energy in striking the ground, find the height to which it bounces. How do you account for the loss in kinetic energy?

3 Mark Questions

1. A ball bounces to 80% of its original height. Calculate the mechanical energy lost in each bounce.

Potential Energy of a Spring

2 Mark Questions

1. Two springs A and B are identical except that A is harder than B, so $K_A > K_B$. If both are stretched by the same force, on which spring is more work done?
2. Two springs A and B are identical except that A is harder than B, so $K_A > K_B$. If both are stretched by the same amount, on which spring is more work done?

3 Mark Questions

1. 20 J work is required to stretch a spring through 0.1 m. Find the force constant of the spring. If the spring is further stretched through 0.1 m. Calculate work done.

Power

2 Mark Questions

1. Which of the two kilowatt hour or electron volt is a bigger unit of energy and by what factor?

3 Mark Questions

1. A car of mass 2000 kg is lifted up a distance of 30 m by a crane in 1 min. A second crane does the same job in 2 min. Do the cranes consume the same or different amounts of fuel? What is the power supplied by each crane? Neglect Power dissipation against friction.
2. A man pulls a lawn roller through a distance of 20 m with a force of 20 kg weight. If he applies the force at an angle of 60° with the ground, calculate the power developed if he takes 1 min in doing so.

Collisions

3 Mark Questions

1. Prove that bodies of identical masses exchange their velocities after head-on elastic collision.
2. A bullet of mass 0.012 kg and horizontal speed 70 m/s strikes a block of wood of mass 0.4 kg and instantly comes to rest w.r.t. the block. The block is suspended from the ceiling by wire. Calculate the height to which the block rises. Also, estimate the amount of heat produced in the block.
3. A railway carriage of mass 9000 kg moving with a speed of $36 \text{ km}\cdot\text{h}^{-1}$ collides with a stationary carriage of the same mass. After the collision the carriages get coupled and move together. What is their common speed after the collision? What type of collision is this?

Part B — Integrated problems (multi-topic)

1. A 2 kg block is pushed against a spring of force constant 1250 N/m, compressing it by 0.2 m, and released on a frictionless track. Find (i) the speed of the block when the spring returns to its natural length and (ii) the maximum height reached if the block then slides up a frictionless incline.
2. A pump lifts 2000 kg of water through a height of 10 m in 50 s. Find (i) the work done by the pump and (ii) its minimum power output. Take $g = 10 \text{ m/s}^2$.
3. A 2 kg ball moving at 4 m/s makes a head-on elastic collision with (a) an identical ball at rest and then (b) a stationary 4 kg ball. Find the velocities of both balls after each collision.
4. A 1000 kg car accelerates uniformly from rest to 20 m/s in 10 s on a level road. Find (i) the work done on the car, (ii) the average power developed, and (iii) the gain in kinetic energy.
5. A 1 kg bob is released from rest with the string horizontal (length 1 m). At the lowest point it strikes a horizontal spring of force constant 2500 N/m. Find the maximum compression of the spring ($g = 10 \text{ m/s}^2$).

Answer Key**Work**

3M(0): (i) 0 — equal and opposite work over the round trip; (ii) $\approx 18.9 \text{ J}$ ($mgh + \mu mg \cos\theta \cdot l = 15 + 3.9$); (iii) -7.8 J ($-2 \cdot \mu mg \cos\theta \cdot l$); (iv) 11.1 J — equals the applied work minus the total friction work ($18.9 - 7.8$). 2M(0): a gentler slope reduces the component of weight down the slope ($mg \sin\theta$), so a smaller force is needed and less work is done against friction for the same vertical rise. 2M(1): No — only for conservative forces; friction is non-conservative, so its closed-loop work is not zero.

Work Done by a Variable Force

2M(0): $W = F \cdot \Delta r = 4(11) + 1(11) + 3(-3) = 46 \text{ J}$. 3M(0): only the z-component moves: $W = F_z \times 2 = 1 \times 2 = 2 \text{ J}$.

Kinetic Energy and the Work–Energy Theorem

2M(1): the truck — for equal K.E. the stopping distance $s = K.E./(\mu mg)$ is smaller for the heavier truck. 2M(3): $h = v^2/2g = 400/(2 \times 9.8) \approx 20.4 \text{ m}$. 3M(0): extra work $30 \text{ J} = (ma)h \rightarrow a = 30/(2 \times 10) = 1.5 \text{ m/s}^2$. 3M(1): retarding force $F = \frac{1}{2}mv^2/d = 1/0.1 = 10 \text{ N}$; K.E. out = $1 - 10 \times 0.06 = 0.4 \text{ J}$.

Conservation of Mechanical Energy

2M(0): K.E. at lowest = $0.9 mgl \rightarrow v = \sqrt{1.8 \times 10 \times 2} = 6 \text{ m/s}$. 2M(1): $h' = 0.75 \times 12 = 9 \text{ m}$; the 25% is lost as heat and sound (and in deforming the ground). 3M(0): 20% of the energy at impact is lost each bounce.

Potential Energy of a Spring

2M(0): B (the softer spring) — same force $\Delta W = F^2/2k$, so the smaller k does more work. 2M(1): A (the harder spring) — same stretch $\Delta W = \frac{1}{2}kx^2$, so the larger k does more work. 3M(1): $k = 2W/x^2 = 2 \times 20/0.01 = 4000 \text{ N/m}$; further stretch $\Delta W = \frac{1}{2}k(0.04 - 0.01) = 60 \text{ J}$.

Power

2M(0): the kilowatt hour — $1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$ and $1 \text{ eV} = 1.6 \times 10^{-19} \text{ J}$, so kWh is larger by 2.25×10^{25} . 3M(0): energy $6 \times 10^5 \text{ J}$ each; crane 1 $\rightarrow 10 \text{ kW}$, crane 2 $\rightarrow 5 \text{ kW}$; same fuel (same energy) but different power. 3M(3): $W = 200 \times \cos 60^\circ \times 20 = 2000 \text{ J}$; $P = 2000/60 \approx 33.3 \text{ W}$.

Collisions

3M(0): for $m_1 = m_2$, $v_1' = u_2$ and $v_2' = u_1$ — identical masses exchange velocities. 3M(1): $v = 0.84/0.412 \approx 2.04$ m/s; $h = v^2/2g \approx 0.21$ m; heat $\approx 29.4 - 0.86 \approx 28.5$ J. 3M(5): common speed = $10/2 = 5$ m/s; perfectly inelastic (masses couple).

Integrated problems

1: 5 m/s and 1.25 m ($v = x\sqrt{(k/m)}$, $h = v^2/2g$). 2: $W = mgh = 2 \times 10^5$ J; $P = 2 \times 10^5/50 = 4 \times 10^3$ W = 4 kW. 3: (a) first ball stops, second takes 4 m/s; (b) $v_1' = (2 - 4)/(2 + 4) \times 4 = -4/3$ m/s, $v_2' = 16/6 = 8/3$ m/s (≈ 2.67 m/s). 4: $W = \frac{1}{2}mv^2 = 2 \times 10^5$ J; $P = 2 \times 10^4$ W = 20 kW. 5: $mgl = \frac{1}{2}kx^2 \rightarrow x = \sqrt{(20/2500)} = 0.089$ m ≈ 9 cm.