

NCERT Class 9: Work, Energy, and Simple Machines - Ultimate Question Bank

This document contains a structured repository of questions tailored for NCERT Class 9 (Science/Physics) covering the concepts of Work, Kinetic and Potential Energy, Conservation of Energy, Power, and Simple Machines (Levers, Pulleys, Inclined Planes, Mechanical Advantage, Velocity Ratio, and Efficiency). The questions strictly adhere to the Class 9 conceptual framework while scaling up in critical thinking and analytical depth.

1. Easy Level Segment

Multiple Choice Questions (20 Items)

1. When a force of 1 N moves a body through a distance of 1 m in its own direction, the work done is: (a) 1 Watt, (b) 1 Joule, (c) 1 Newton, (d) 1 Pascal
2. Which of the following is not a unit of energy? (a) Joule, (b) Newton-meter, (c) Kilowatt-hour, (d) Kilowatt
3. An object of mass 2 kg is lifted vertically through a height of 5 m. Taking $g = 10 \text{ m/s}^2$, the potential energy gained is: (a) 10 J, (b) 50 J, (c) 100 J, (d) 20 J
4. Kinetic energy of a body depends on: (a) Mass only, (b) Velocity only, (c) Both mass and velocity, (d) Height above the ground
5. A machine reduces the effort required to lift a load by changing the: (a) Total work input, (b) Direction or magnitude of force, (c) Energy conservation laws, (d) Total mass of the load
6. In a class 1 lever, the fulcrum is located: (a) At one end, (b) Between the effort and the load, (c) At the exact midpoint always, (d) On the load itself
7. The work done by a conservative force on an object moving in a complete circular path is: (a) Positive, (b) Negative, (c) Zero, (d) Infinite
8. Power is defined as the: (a) Capacity of doing work, (b) Rate of doing work, (c) Force applied per unit time, (d) Product of force and distance
9. If the speed of a car is doubled, its kinetic energy becomes: (a) 2 times, (b) 4 times, (c) Half, (d) Remains unchanged
10. The energy stored in a compressed spring is: (a) Kinetic energy, (b) Elastic potential energy, (c) Chemical energy, (d) Gravitational potential energy
11. Mechanical Advantage (MA) of a simple machine is mathematically expressed as: (a) Effort / Load, (b) Load $\times$ Effort, (c) Load / Effort, (d) Work Input / Work Output
12. The Velocity Ratio (VR) of an ideal machine is: (a) Always less than MA, (b) Distance moved by effort / Distance moved by load, (c) Distance moved by load / Distance moved by effort, (d) Always equal to efficiency
13. When a force acts at an angle of 90 degrees to the direction of motion, the work done is: (a) Maximum, (b) Minimum, (c) Zero, (d) Negative
14. Commercial unit of electrical energy, 1 kWh, is equal to: (a) $3.6 \times 10^3 \text{ J}$, (b) $3.6 \times 10^5 \text{ J}$, (c)

$3.6 \times 10^6 \text{ J}$, (d) 36 J

15. A body is falling freely under gravity. Its total mechanical energy at any point during the fall: (a) Increases, (b) Decreases, (c) Remains constant, (d) First decreases then increases
16. Which of the following simple machines is essentially a modified inclined plane wrapped around a cylinder? (a) Lever, (b) Pulley, (c) Screw, (d) Wheel and axle
17. If a boy pushes a heavy rock with all his force for 10 minutes but fails to move it, the work done by him is: (a) Positive, (b) Negative, (c) Zero, (d) Equal to his metabolic energy expenditure
18. The work done against gravity depends only on the: (a) Path taken, (b) Initial and final positions, (c) Time taken to lift the body, (d) Velocity of lifting
19. A single fixed pulley changes only the: (a) Direction of the effort force, (b) Magnitude of the load, (c) Velocity ratio to a value greater than 2, (d) Efficiency of the system
20. The efficiency of a real machine is always: (a) Equal to 100%, (b) Greater than 100%, (c) Less than 100%, (d) Zero

Answer Key (Easy MCQs): 1-(b), 2-(d), 3-(c), 4-(c), 5-(b), 6-(b), 7-(c), 8-(b), 9-(4), 10-(b), 11-(c), 12-(b), 13-(c), 14-(c), 15-(c), 16-(c), 17-(c), 18-(b), 19-(a), 20-(c)

Subjective Questions (20 Items)

1. Define work in the context of scientific terminology and state its SI unit.
2. A force of 15 N causes a displacement of 4 m in an object along the line of action of the force. Calculate the work performed.
3. Differentiate between positive work and negative work with one example of each.
4. State the Law of Conservation of Energy in plain terms.
5. What is meant by the term 'Kinetic Energy'? Provide its standard formula for a moving object.
6. An object of mass 10 kg moves with a uniform velocity of 4 m/s. Find its kinetic energy.
7. Define gravitational potential energy and write down the variables that dictate its value.
8. Explain why the mechanical advantage of a single fixed pulley is equal to 1 under ideal conditions.
9. What is a simple machine? Name three distinct types of simple machines.
10. Define 'Power' and calculate the power of an engine that performs 12,000 Joules of work in 1 minute.
11. A pair of bullocks exerts a force of 140 N while plowing a field. The field being plowed is 15 m long. How much work is done in plowing the length of the field?
12. Define the terms Mechanical Advantage (MA) and Velocity Ratio (VR).
13. Why can the efficiency of a machine never reach 100% in practical scenarios?
14. Identify the positions of the Fulcrum, Effort, and Load in a pair of common scissors.
15. A light body and a heavy body possess identical kinetic energies. Which one will be moving faster? Explain briefly.
16. What happens to the potential energy of an object when its height above the earth's surface is tripled?
17. Define 1 Watt of power in terms of Joules and seconds.
18. How is a crowbar classified as a machine, and how does it make our work easier?
19. An electric bulb of 60 W is used for 6 hours per day. Calculate the 'units' of energy consumed in one day by the bulb.
20. Give an example where an object possesses both kinetic energy and potential energy simultaneously.

2. Moderate Level Segment

Multiple Choice Questions (20 Items)

1. An object is thrown vertically upwards with a velocity 'v'. At a height where its kinetic energy is reduced to half its initial value, its height will be: (a) $v^2/2g$, (b) $v^2/4g$, (c) v^2/g , (d) $2v^2/g$
2. A machine has a mechanical advantage of 4 and an efficiency of 80%. Its velocity ratio must be: (a) 5, (b) 3.2, (c) 0.2, (d) 4.5
3. Two masses of 1 kg and 4 kg are moving with equal linear momenta. The ratio of their kinetic energies is: (a) 4:1, (b) 1:4, (c) 1:2, (d) 2:1
4. A force $F = (2i + 3j)$ N acts on a particle and displaces it from origin to a point $r = (3i + 2j)$ m. The work done by the force is: (a) 5 J, (b) 12 J, (c) 13 J, (d) 6 J
5. When a force retards the motion of a body, the angle between the force and the displacement is: (a) 0° , (b) 90° , (c) 180° , (d) 45°
6. In a block and tackle pulley system consisting of 5 pulleys, an effort of 200 N is needed to lift a load of 800 N. The efficiency of this system is: (a) 80%, (b) 100%, (c) 75%, (d) 60%
7. A steady stream of water falls from a height of 20 m at a rate of 10 kg/s to run a turbine. The power delivered to the turbine is ($g = 10 \text{ m/s}^2$): (a) 2 kW, (b) 200 W, (c) 20 kW, (d) 100 W
8. An inclined plane of length 5 m is used to lift a load to a vertical platform of height 1 m. The ideal velocity ratio of this inclined plane is: (a) 1, (b) 5, (c) 0.2, (d) 2.5
9. A body of mass m is moving in a circle of radius r with a constant speed v . The work done by the centripetal force during three-quarters of a revolution is: (a) $(mv^2/r) \times (3\pi r/2)$, (b) Zero, (c) mv^2 , (d) None of these
10. If the mass of a body is reduced to half and its velocity is doubled, its kinetic energy will change by a factor of: (a) 1, (b) 2, (c) 4, (d) $1/2$
11. A machine lifts a load of 1200 N through a vertical height of 2 m in 4 seconds. If the power input to the machine is 800 W, its efficiency is: (a) 60%, (b) 75%, (c) 50%, (d) 80%
12. A uniform class 1 lever of length 2 m has its fulcrum placed at 0.5 m from the load end. To lift a load of 600 N, the minimum effort required at the other end is: (a) 200 N, (b) 300 N, (c) 150 N, (d) 1200 N
13. The linear momentum of a body is increased by 50%. The percentage increase in its kinetic energy is: (a) 50%, (b) 100%, (c) 125%, (d) 25%
14. A water pump lifts 30 kg of water per minute from a well 10 m deep and ejects it with a speed of 10 m/s. The total power of the pump is ($g = 10 \text{ m/s}^2$): (a) 50 W, (b) 75 W, (c) 100 W, (d) 25 W
15. A simple machine with a velocity ratio of 10 cannot lift a load greater than: (a) 10 times the effort, (b) The effort itself, (c) 5 times the effort, (d) Depends on the structural mass
16. An object undergoes a displacement of 10 m under a force that varies linearly with distance, starting from 0 N up to 20 N. The total work done is: (a) 200 J, (b) 100 J, (c) 50 J, (d) 0 J
17. A weighing machine or a physical balance with equal arms is an example of a: (a) Class 1 lever with $MA < 1$, (b) Class 2 lever with $MA > 1$, (c) Class 1 lever with $MA = 1$, (d) Class 3 lever with $MA < 1$
18. When the velocity of an object increases from 2 m/s to 6 m/s, the work done on it is equal to: (a) 16 times its mass, (b) 8 times its mass, (c) 32 times its mass, (d) 4 times its mass
19. A wheelbarrow is an application of a: (a) First-class lever, (b) Second-class lever, (c) Third-class lever, (d) Compound pulley
20. An engine pumps out 40,000 liters of water from a depth of 10 m in 5 minutes. The power

of the engine is (Take 1 liter = 1 kg, $g = 10 \text{ m/s}^2$): (a) 13.33 kW, (b) 1.33 kW, (c) 40 kW, (d) 8 kW

Answer Key (Moderate MCQs): 1-(b), 2-(a), 3-(a), 4-(b), 5-(c), 6-(a), 7-(a), 8-(b), 9-(b), 10-(b), 11-(b), 12-(a), 13-(c), 14-(b), 15-(a), 16-(b), 17-(c), 18-(a), 19-(b), 20-(a)

Subjective Questions (20 Items)

1. A box of mass 20 kg is pulled up a rough inclined plane of length 10 m and height 3 m. If the work done against friction is 200 J, find the total work done in pulling the box up the incline. ($g = 10 \text{ m/s}^2$)
2. Show that the kinetic energy of an object can be expressed as $P^2/2m$, where P represents linear momentum and m is the mass of the object.
3. A machine is used to lift a load of 450 N through a height of 2 m. The effort applied is 150 N, and the effort point moves through a distance of 8 m. Calculate the mechanical advantage, velocity ratio, and efficiency of the machine.
4. A bullet of mass 20 g moving with a speed of 500 m/s strikes a wooden block and penetrates 10 cm before coming to rest. Calculate the average resistive force exerted by the block.
5. Explain why a third-class lever always has a mechanical advantage of less than one. What is the benefit of using such a lever?
6. A crane lifts a cargo container of mass 2000 kg to a height of 30 meters in 1.5 minutes. Calculate the useful power output of the crane.
7. Derive an expression for the kinetic energy of an object of mass 'm' moving with a uniform velocity 'v' using the equations of motion and the basic definition of work.
8. A system of pulleys has a velocity ratio of 4. If its efficiency is 75%, calculate the maximum load that can be lifted by applying an effort of 250 N.
9. A car of mass 1000 kg is climbing up an incline rising 1 in 20 (meaning 1 meter vertical rise for every 20 meters along the incline). If the car moves at a constant speed of 10 m/s, find the power developed by the engine, neglecting friction. ($g = 10 \text{ m/s}^2$)
10. A ball is dropped from a height of 10 m. It bounces back from the ground to a height of 7 m. What fraction of its mechanical energy is lost during the collision with the floor?
11. A sugar tongs is an example of which class of lever? Draw a neat labeled schematic diagram indicating the positions of the load, effort, and fulcrum for sugar tongs.
12. An electric motor of power 2 kW operates a water pump. How much water can it raise per minute to a water tank situated at a height of 15 m? ($g = 10 \text{ m/s}^2$)
13. If a force acting on a body is doubled while the time for which it acts is halved, what will be the change in the momentum and kinetic energy of the body assuming it started from rest?
14. A body of mass 5 kg is sliding down an inclined plane making an angle of 30 degrees with the horizontal. Calculate the work done by gravity when the body slides a distance of 4 m along the incline. ($g = 10 \text{ m/s}^2$, $\sin 30^\circ = 0.5$)
15. Distinguish between a single fixed pulley and a single movable pulley based on mechanical advantage, velocity ratio, and specific practical utility.
16. An object is projected horizontally from the top of a tower 80 m high with a velocity of 20 m/s. Calculate its kinetic energy 3 seconds after projection if its mass is 2 kg. ($g = 10 \text{ m/s}^2$)
17. A person consumes 2500 kcal of food energy in a day. If all this energy were converted into lifting 50 kg weights, how high could the person theoretically lift the weight? (1 kcal = 4184 J, $g = 10 \text{ m/s}^2$)
18. Explain the mechanism of a wheel and axle as a simple machine. How can its velocity ratio be increased?

19. A porter lifts a suitcase of 15 kg from the ground and puts it on his head 1.5 m above the ground. He then walks a distance of 50 m on a horizontal platform. Calculate the work done by the porter against gravity (i) during lifting, and (ii) during walking.
20. A machine requires an input of 500 J of work to lift a 40 kg mass through a vertical distance of 1 m. Calculate the energy wasted due to friction and moving parts.

3. Difficult Level Segment

Multiple Choice Questions (20 Items)

1. A particle moves under the action of a position-dependent force given by $F = (3x^2 - 2x + 5)$ N. The work done by this force in displacing the particle from $x = 0$ to $x = 2$ m is: (a) 14 J, (b) 18 J, (c) 10 J, (d) 16 J
2. A machine driven by a constant power source moves a body of mass m along a straight line. If the body starts from rest, its velocity at time t is proportional to: (a) t , (b) t^2 , (c) $t^{1/2}$, (d) $t^{3/2}$
3. In a block and tackle system with 4 pulleys and an efficiency of 60%, a load W is lifted by an effort E . If the friction in the bearings is suddenly eliminated, making the system ideal, the new effort required to lift the same load will decrease by a factor of: (a) 0.6, (b) 0.4, (c) 1.67, (d) 2.5
4. An elastic spring of stiffness constant k is compressed by an amount x . It is then compressed further by an amount y . The additional work done during the second compression is: (a) $0.5 k y^2$, (b) $0.5 k (x + y)^2$, (c) $0.5 k y (2x + y)$, (d) $0.5 k x (2y + x)$
5. A block of mass m is suspended from a ceiling through two identical pulleys configured as a system. If the string is pulled with a constant speed v , the rate at which work is done on the block when it rises vertically with speed $v/2$ is: (a) mgv , (b) $mgv/2$, (c) $mgv/4$, (d) $2mgv$
6. A water reservoir is shaped like an inverted right circular cone of base radius R and height H . The work done in pumping out all the water from the top of the completely filled reservoir is proportional to: (a) H , (b) H^2 , (c) H^3 , (d) H^4
7. A force $F = -k/x^2$ (where k is a positive constant) acts on a particle moving along the x -axis. The work done by this force in moving the particle from $x = d$ to $x = 2d$ is: (a) $-k/2d$, (b) $k/2d$, (c) $-3k/2d$, (d) $3k/2d$
8. A heavy uniform chain of length L and mass M is held on a smooth horizontal table with one-third of its length hanging over the edge. The work done to pull the hanging part back onto the table is: (a) $MgL/6$, (b) $MgL/9$, (c) $MgL/18$, (d) $MgL/2$
9. A 2 kg mass is attached to a string and whirled in a vertical circle of radius 1 m. The difference in kinetic energy of the mass between the lowest point and the highest point of its trajectory is: (a) 20 J, (b) 40 J, (c) 10 J, (d) 0 J
10. A non-ideal lever has an efficiency of 70%. The distance from the fulcrum to the effort is 1.5 m, and from the fulcrum to the load is 0.3 m. To lift a load of 1050 N, the effort that must be applied is: (a) 210 N, (b) 300 N, (c) 147 N, (d) 450 N
11. A constant force acts on a 5 kg object initially at rest. The power delivered by the force varies with time. If the velocity of the object at $t = 2$ s is 4 m/s, the instantaneous power at $t = 3$ s is: (a) 24 W, (b) 40 W, (c) 30 W, (d) 12 W
12. An object of mass m dropped from a high tower experiences an air resistance force proportional to its speed, $F_{\text{air}} = -bv$. After falling a long distance, the rate at which gravity does work on the body reaches a constant value equal to: (a) m^2g^2/b , (b) mg/b , (c) m^2g/b^2 , (d) zero
13. A conveyor belt moves horizontally at a constant speed of 2 m/s. Material is dropped

vertically onto the belt at a steady rate of 5 kg/s. The extra power required from the motor to maintain the belt's constant speed is: (a) 10 W, (b) 20 W, (c) 5 W, (d) 40 W

14. A particle of mass m is moving under a conservative force field where its potential energy varies as $U(x) = ax^2 - bx$. The particle will be in stable equilibrium at a position x equal to: (a) b/a , (b) $b/2a$, (c) $2b/a$, (d) a/b
15. A complex machine consists of two simple machines in series. The first machine has an efficiency of 80% and a velocity ratio of 5. The second machine has an efficiency of 60% and a velocity ratio of 3. The overall mechanical advantage of the combined system is: (a) 7.2, (b) 15, (c) 9.0, (d) 12
16. A bullet loses $1/20$ th of its velocity after penetrating a distance of 3 cm into a uniform wooden plank. How many more identical planks will it be able to penetrate before coming completely to rest, assuming constant resistance? (a) 19, (b) 10, (c) 9, (d) 11
17. A dynamic system requires a variable force $F = kt$ (where $k = 2 \text{ N/s}$) to accelerate a 1 kg mass along a straight path. The work done by this force during the interval from $t = 0$ to $t = 2$ seconds, assuming the mass starts from rest, is: (a) 4 J, (b) 2 J, (c) 8 J, (d) 1.33 J
18. A class 2 lever of length L is loaded at a distance of $L/4$ from the fulcrum. Due to structural bending, 20% of the input work is lost. The actual mechanical advantage of this lever is: (a) 4.0, (b) 3.2, (c) 5.0, (d) 2.5
19. A body is moved along a rough horizontal surfaces by a force acting at an angle θ above the horizontal. The work done by the normal reaction force during a horizontal displacement ' s ' is: (a) mgs , (b) $s \cdot F \sin\theta$, (c) Zero, (d) $s \cdot (mg - F \sin\theta)$
20. A pump is used to empty a rectangular swimming pool of dimensions $10\text{m} \times 5\text{m} \times 2\text{m}$. If the pool is full of water, the work done in pumping all the water out over the top edge of the pool is: (a) 10^6 J , (b) $5 \times 10^5 \text{ J}$, (c) $2 \times 10^6 \text{ J}$, (d) $1.5 \times 10^6 \text{ J}$

Answer Key (Difficult MCQs): 1-(a), 2-(c), 3-(a), 4-(c), 5-(b), 6-(d), 7-(a), 8-(c), 9-(b), 10-(b), 11-(a), 12-(a), 13-(b), 14-(b), 15-(a), 16-(c), 17-(b), 18-(b), 19-(c), 20-(a)

Subjective Questions (20 Items)

1. A heavy box of mass 50 kg is pushed across a horizontal floor. The coefficient of friction implies that a resistive force of 150 N acts against motion. If the box is pushed by an effort of 200 N over a distance of 6 m, calculate: (i) work done by the applied force, (ii) work done by friction, and (iii) net change in the kinetic energy of the box.
2. A uniform rod of length 3 meters and mass 12 kg is lying flat on a horizontal ground. Calculate the minimum work required to tip the rod up so that it stands vertically on one of its ends.
3. A non-uniform lever of length 2 m is balanced horizontally on a fulcrum placed at its geometric center when a mass of 5 kg is placed at one end and a mass of 3 kg is placed at the other end along with the rod's own weight distribution. If the center of gravity of the rod itself is located at 0.2 m from the geometric center towards the lighter end, calculate the total mass of the rod.
4. An engine of a car develops a constant power P . The car starts from rest and moves along a straight horizontal track. Derive an expression for the distance covered by the car as a function of time ' t ', mass ' m ', and power ' P '.
5. A system of Pulleys has 3 movable pulleys and 1 fixed pulley (a standard Weston differential or a distinct system where each movable pulley is suspended by a separate string). Derive its ideal velocity ratio, and calculate the effort needed to lift a load of 1600 N if the efficiency is 80%.
6. A variable force $F = (7 - 2x + 3x^2) \text{ N}$ acts on a particle of mass 2 kg. If the particle's initial velocity at $x = 0$ is 2 m/s, determine its velocity when it reaches the position $x = 5 \text{ m}$.
7. A bullet of mass 10 g traveling horizontally at 400 m/s embeds itself into a block of wood

- of mass 990 g suspended by a long light cord of length 2 m. Find the maximum vertical height to which the combined block-bullet system will rise after the impact. ($g = 10 \text{ m/s}^2$)
8. A solid block of iron of volume 0.01 m^3 and density 7800 kg/m^3 is totally immersed in water inside a deep tank. It is raised slowly through a vertical height of 5 m inside the water. Calculate the work done by the lifting tension force. (Density of water = 1000 kg/m^3 , $g = 10 \text{ m/s}^2$)
 9. A composite machine is constructed by connecting an inclined plane (angle 30 degrees to the horizontal) to a pulley system of VR = 2 at the top of the incline. A load of mass 100 kg is pulled up along the 10 m long incline using this arrangement. If the overall efficiency of this combined setup is 60%, find the effort required.
 10. A particle moves along a trajectory where its kinetic energy K depends on the distance traveled ' s ' as $K = as^2$, where ' a ' is a positive constant. Determine the magnitude of the net force acting on the particle as a function of ' s '.
 11. A water tank of cross-sectional area A is filled with water up to a height H . A small hole is opened at the bottom, and water flows out. Prove that the work done by gravity in completely emptying the tank is equivalent to assuming the entire mass of water was initially concentrated at its center of mass.
 12. An ideal class 3 lever has a length of 1.2 m. The effort is applied at a point 30 cm away from the fulcrum. If a load of 40 N is placed at the far end, calculate the force required at the effort point and explain why this machine acts as a speed multiplier rather than a force multiplier.
 13. A 60 kg stuntman jumps from a platform 5 m high onto a safety mattress. The mattress deforms by 0.5 m as it brings the stuntman to rest. Calculate the average force experienced by the stuntman during the deceleration phase.
 14. A sleek wind turbine captures wind energy. The power P available from the wind is proportional to the air density ρ , the area of the blades A , and the cube of the wind speed v ($P = k \cdot \rho \cdot A \cdot v^3$). If the wind speed increases by 30%, calculate the percentage increase in the available power.
 15. A massive bead of mass m slides without friction along a vertical circular wire loop of radius R . If it is released from rest at the top-most point of the loop, calculate its speed and its kinetic energy when it reaches the lowest point of the loop.
 16. A planetary exploration rover uses a screw jack (which is an inclined plane wrapped around a cylinder) to lift a heavy structural module. The pitch of the screw is 5 mm, and the length of the handle used to turn the screw is 40 cm. Find the ideal velocity ratio of this machine.
 17. An object of mass 4 kg is dropped from a height of 20 m onto a vertical elastic spring fixed on the ground. The spring constant is $k = 2000 \text{ N/m}$. Calculate the maximum compression suffered by the spring. ($g = 10 \text{ m/s}^2$)
 18. A man cycles up a hill with a slope of 1 in 10 at a speed of 7.2 km/h. The combined mass of the man and the cycle is 100 kg. If the efficiency of the man's muscles in converting metabolic energy to mechanical work is 25%, find the rate at which he burns food energy (metabolic power).
 19. A block of mass 2 kg is pulled at a constant velocity up an inclined plane of angle 45° by a force parallel to the incline. If the work done by the pulling force during a displacement of 5 m along the incline is 100 J, find the work done against friction during this motion.
 20. A custom compound lever system consists of two levers connected such that the output of the first acts as the input to the second. The first lever has an arm ratio (Effort arm/Load arm) of 4:1, and the second has an arm ratio of 5:1. If the overall efficiency of the assembly is 75%, calculate the actual load lifted by an effort of 50 N.

4. Olympiad Level Segment

Multiple Choice Questions (20 Items)

1. A particle moves in a conservative force field where the potential energy function is given by $U(x, y) = 3x^2y - 5xy^2 + 2$. The component of the force acting along the x-direction, F_x , at the point (1, 2) is: (a) -2 N, (b) 8 N, (c) -8 N, (d) 4 N
2. A system of variable masses involves a rocket ejecting gases at a constant rate $dm/dt = r$ with a relative exhaust velocity u . The instantaneous power delivered by the thrust force to the rocket when its velocity is v is given by: (a) ruv , (b) $0.5 ru^2$, (c) $ruv - 0.5 rv^2$, (d) $ru^2 + rv^2$
3. A flexible heavy rope of uniform mass per unit length λ and total length L lies coiled on a smooth floor. A person lifts one end vertically upward with a constant speed v . The total work done by the person during the time interval it takes to fully lift the rope completely off the floor is: (a) $0.5 \lambda g L^2 + \lambda L v^2$, (b) $0.5 \lambda g L^2 + 0.5 \lambda L v^2$, (c) $\lambda g L^2$, (d) $0.5 \lambda g L^2$
4. A modified wedge with an angle α sits on a smooth table. A block of mass m is placed on its incline. The wedge is pushed horizontally with an acceleration 'a' such that the block does not slide up or down the incline. The work done by the normal contact force on the block as the system moves a horizontal distance 'd' is: (a) $mg d \tan \alpha$, (b) $m d (g + a \tan \alpha)$, (c) $m d (g \tan \alpha + a)$, (d) $m a d$
5. A non-ideal variable-ratio pulley system exhibits a load-dependent efficiency function given by $\eta = L / (L + k)$, where k is a constant and L is the load weight. If the ideal velocity ratio is V , the effort E required to lift a load L is expressed by: (a) $(L + k) / V$, (b) $L(L+k)/V$, (c) L / V , (d) $k L / V$
6. A particle of mass m is attached to a spring of constant k and is oscillating horizontally on a surface with a friction force of constant magnitude f . Every time the particle passes through the equilibrium position, its kinetic energy compared to the previous pass decreases by exactly: (a) $2 f \cdot A$, (b) $4 f \cdot A$, (c) $f \cdot A$, (d) $0.5 f \cdot A$ (where A is the amplitude)
7. A heavy hemispherical bowl of radius R is fixed on a table. A small particle of mass m is released from the lip of the bowl and slides down its smooth internal surface. The rate at which the normal force does work on the particle when it has descended through a vertical distance of $R/2$ is: (a) $mg\sqrt{gR}$, (b) Zero, (c) $0.5 mg\sqrt{gR}$, (d) $1.5 mg\sqrt{gR}$
8. An innovative simple machine has an efficiency that drops linearly with the distance traveled by the effort, $\eta(s) = 1 - \alpha s$. If the velocity ratio is V , the total work output obtained when the effort moves from $s = 0$ to $s = D$ under a constant effort force E is: (a) $E \cdot V \cdot D(1 - 0.5\alpha D)$, (b) $E \cdot V \cdot D(1 - \alpha D)$, (c) $E \cdot D(1 - 0.5\alpha D)/V$, (d) $E \cdot V \cdot D^2(1 - \alpha D)$
9. A power plant uses a thermodynamic cycle where the input rate of energy is constant, but the dissipation rate depends on the operating speed ω as $P_{\text{loss}} = c\omega^2$. The maximum useful power output is achieved when the operating speed ω is equal to: (a) $\sqrt{(P_{\text{in}} / 3c)}$, (b) $\sqrt{(P_{\text{in}} / c)}$, (c) $0.5 \sqrt{(P_{\text{in}} / c)}$, (d) $P_{\text{in}} / 2c$
10. A block of mass M is connected to a light spring of constant k and placed on a smooth horizontal floor. A bullet of mass m moving with speed u hits the block horizontally and gets embedded in it. The maximum compression of the spring is: (a) $u \cdot \sqrt{(m / k)}$, (b) $u \cdot m / \sqrt{((M+m)k)}$, (c) $u \cdot \sqrt{((m^2)/((M+m)k))}$, (d) $u \cdot M / \sqrt{((M+m)k)}$
11. A unique class 1 lever has a non-uniform mass distribution such that its own gravitational potential energy shifts when it rotates. To tip the lever from horizontal to an angle θ requires work W_{lever} . If an ideal load L at distance d_1 is raised simultaneously by an effort E at distance d_2 , the work equation is governed by: (a) $E \cdot d_2 \cdot \theta = L \cdot d_1 \cdot \theta + W_{\text{lever}}$, (b) $E \cdot d_2 = L \cdot d_1$, (c) $E \cdot d_2 \cdot \sin \theta = L \cdot d_1 \cdot \sin \theta$, (d) $E \cdot d_2 \cdot \theta = L \cdot d_1 \cdot \theta - W_{\text{lever}}$
12. The potential energy of a particle moving along the x-axis is given by $U = -A/x + B/x^2$,

- where A and B are positive constants. The minimum energy required to escape to infinity from the stable equilibrium state is: (a) $A^2/4B$, (b) $A^2/2B$, (c) $B^2/4A$, (d) A^2/B
13. A small water droplet of mass m falls through a dense mist. It accretes mass from the mist at a rate proportional to its cross-sectional area and speed, which translates to $dm/dt = kv$. If it reaches a terminal velocity v_t , the power dissipated by the drag/accretion mechanism at terminal velocity is: (a) $mg v_t$, (b) $0.5 mg v_t$, (c) $2 mg v_t$, (d) Zero
 14. A box of mass m is pulled up a rough hill of an arbitrary, curved profile from base to summit. The horizontal distance between base and summit is X , and the vertical height is Y . If the coefficient of friction is μ , the total work done against friction during the climb depends only on: (a) The exact profile path, (b) μ , m , g , and X , (c) μ , m , g , and Y , (d) μ , m , g , X , and Y
 15. A machine setup has a time-dependent mechanical advantage $MA(t) = \beta t$ and a constant velocity ratio V . If a constant load L is maintained, the effort force $E(t)$ required over time varies as: (a) $L / (\beta t)$, (b) $L \cdot \beta t / V$, (c) $L \cdot V / (\beta t)$, (d) $L / (V \cdot \beta t)$
 16. A dynamic system consists of two blocks of masses m_1 and m_2 connected by a spring of constant k . The blocks are pulled apart stretching the spring by x and then released from rest. The maximum kinetic energy of the mass m_1 during subsequent motion is: (a) $0.5 k x^2 \cdot [m_2 / (m_1 + m_2)]$, (b) $0.5 k x^2 \cdot [m_1 / (m_1 + m_2)]$, (c) $0.5 k x^2$, (d) $0.5 k x^2 \cdot [m_1 \cdot m_2 / (m_1 + m_2)]$
 17. A uniform disc of mass M and radius R is rigged as a pulley wheel. A light cord wrapped around it hoists a mass m . When the mass m falls a distance h from rest, the work done by gravity on the mass m is split between the kinetic energy of the falling mass and the kinetic energy of the rotating disc. The kinetic energy acquired by the falling mass is: (a) $mgh \cdot [m / (m + 0.5M)]$, (b) mgh , (c) $mgh \cdot [m / (m + M)]$, (d) $0.5 mgh$
 18. An object is subjected to a force field $F = -k \cdot r$, where r is the position vector from the origin. The work done in moving the object along an elliptical path from a point $(a, 0)$ to a point $(0, b)$ is: (a) $0.5 k(b^2 - a^2)$, (b) $0.5 k(a^2 - b^2)$, (c) $0.5 k(a^2 + b^2)$, (d) Zero
 19. A massive block is pulled across a floor by a rope with a tension T inclined at an angle θ to the horizontal. If the coefficient of friction is μ , the work done in moving the block a distance ' s ' is minimized when the angle θ satisfies: (a) $\tan\theta = \mu$, (b) $\sin\theta = \mu$, (c) $\cos\theta = \mu$, (d) $\theta = 0^\circ$
 20. A collection of N identical small blocks, each of mass m , lie spaced out on a horizontal line. The first block is given an initial kinetic energy K . It collides elastically with the second, which then collides with the third, and so on. If each collision loses a small fraction ϵ of kinetic energy due to internal non-ideal microscopic vibration, the kinetic energy of the N -th block will be: (a) $K \cdot (1 - \epsilon)^{(N-1)}$, (b) $K - N \cdot \epsilon$, (c) $K \cdot (1 - N \cdot \epsilon)$, (d) $K \cdot \epsilon^{(N-1)}$

Answer Key (Olympiad MCQs): 1-(c), 2-(c), 3-(a), 4-(c), 5-(a), 6-(a), 7-(b), 8-(a), 9-(a), 10-(c), 11-(a), 12-(a), 13-(a), 14-(b), 15-(a), 16-(a), 17-(a), 18-(b), 19-(a), 20-(a)

Subjective Questions (20 Items)

1. A flexible, uniform heavy chain of total length L and total mass M is placed coiled up on the edge of a tall smooth table. A small piece of the chain is nudged over the lip so that the chain begins to slide off the table under gravity. Using principles of work and mechanical energy conservation, calculate the speed of the chain at the precise moment the last link leaves the table surface.
2. An advanced mechanism uses a non-uniform lever arm whose mass per unit length increases linearly from the fulcrum towards the effort end according to $\lambda(x) = \alpha x$. The total length of the effort arm is L_e , and the load is an ideal point mass L hung at a distance L_l on the opposite side of the fulcrum. Derive the complete equation for the effort E required

- to lift the load, taking into account the weight of the lever itself.
3. A particle of mass m moves along the x -axis under the influence of a force field derived from the potential energy function $U(x) = U_0 \left[\left(\frac{x}{a} \right)^4 - 2 \left(\frac{x}{a} \right)^2 \right]$, where U_0 and ' a ' are positive constants. (i) Find the points of stable and unstable equilibrium. (ii) Calculate the minimum work required to move the particle from a stable equilibrium point to the unstable equilibrium point.
 4. A 3 kg block is placed on top of a 7 kg block which rests on a completely friction-free horizontal floor. The coefficient of friction between the 3 kg block and the 7 kg block is such that a force of 12 N is required to cause sliding between them. A horizontal pulling force F is applied to the upper 3 kg block. Calculate the total work done by the friction force on the lower 7 kg block during a displacement of 3 meters, assuming the applied force F is 10 N (so no relative slipping occurs).
 5. A variable-efficiency hydraulic jack satisfies the operational equation: $\text{Work Output} = [\text{Work Input}] - \beta \cdot (\text{Load})^2$, where β is a specific machine constant. If an operator can provide a maximum work input of W_{in} , derive an algebraic expression for the maximum load height ' h ' that can be achieved as a function of the load weight ' L '. Find the optimal load L for which the vertical height reached is maximized.
 6. A block of mass m is projected up an inclined plane of angle θ with an initial kinetic energy K . It travels up to a certain maximum distance along the incline, stops, and slides back down to the launching point. If its kinetic energy upon returning to the base is $K/3$, calculate the work done against friction during the upward journey in terms of K .
 7. A water fountain ejects water droplets vertically upwards from a nozzle of cross-sectional area A . The water stream reaches a maximum height H . Calculate the total mechanical power delivered by the fountain's pump mechanism solely to sustain this continuous vertical column of water.
 8. A heavy bead of mass m is threaded onto a smooth circular wire loop of radius R fixed in a vertical plane. The bead is connected to a spring of constant k whose other end is fixed at the highest point of the circular loop. The natural unstretched length of the spring is exactly equal to the radius R of the loop. If the bead is released from rest at a point level with the center of the loop (90 degrees away from the top), find its speed when it reaches the lowest point of the circular path.
 9. A multi-stage pulley system is rigged such that there are ' n ' movable pulleys, each suspended by an independent string anchored to the ceiling, with the effort pulled downwards over the final pulley. Each pulley wheel has a non-negligible mass ' m_p '. Derive the general expression for the actual mechanical advantage (MA) of this system when lifting a heavy load ' L ' with 100% ideal string efficiency, and show how the mass of the pulleys limits the MA as ' n ' becomes large.
 10. An architectural column of mass M and height H has a uniform cross-section. It stands vertically on the ground. Due to seismic activity, it topples over, pivoting about its base without sliding. By treating the column as a collection of small segments, calculate the total kinetic energy of the column at the instant it strikes the horizontal ground.
 11. A particle moves under a central force field where the force vector is $\mathbf{F} = -(k / r^3) \hat{r}$, where r is the distance from the origin. Calculate the work done by this force field in moving the particle from an initial radial distance $r = R$ to an infinite distance away.
 12. A heavy crate is dragged up a rough curved slope by a winch cable. The profile of the slope is given by the curve $y = c \cdot x^2$ from $x = 0$ to $x = X$. If the coefficient of sliding friction is μ , set up the conceptual work-energy balancing integral expression that represents the work done against friction, and demonstrate how it simplifies based on horizontal projection.
 13. An automated car of mass m starts from rest at $t = 0$, and its engine delivers a time-dependent power given by $P(t) = \alpha \cdot t$, where α is a known constant. Find the velocity

and displacement of the car as explicit functions of time 't'.

14. A compound machine consists of a first-class lever with an efficiency of 85% linked to a wheel-and-axle system with an efficiency of 90%. The lever has an effort arm of 80 cm and a load arm of 20 cm. The wheel-and-axle has a wheel radius of 30 cm and an axle radius of 5 cm. Calculate the total combined velocity ratio and the real-world effort required to hoist a 1530 N structural component.
15. A wedge of mass M with an inclined surface of angle θ sits on a smooth floor. A small block of mass m is placed at the top of the wedge incline at a vertical height h and released from rest. As the block slides down the incline, the wedge recoils horizontally. Using the absolute conservation of total mechanical energy and horizontal momentum, find the final speed of the wedge when the block reaches the floor.
16. A corporate testing laboratory measures a shock absorber spring whose force law is non-linear and obeys the equation $F(x) = -kx - \beta x^3$, where x is the compression distance. Find the total work required to compress this non-linear spring by a total distance D , and compute the maximum velocity a mass ' m ' will attain if launched by this compressed spring.
17. A worker uses an old inclined plane to roll barrels of oil up into a truck. The efficiency of the incline is poor, given by $\eta = \cos\theta$, where θ is the angle of the incline with the horizontal. The worker wants to minimize the total effort force required to push a barrel of weight W up to a fixed platform height H . Find the optimal angle θ that minimizes the required effort force.
18. A small particle of mass m is placed on the apex of a smooth solid sphere of radius R fixed firmly on a flat floor. The particle is given an infinitesimally small horizontal nudge and begins to slide down the curved surface. Find the vertical height below the apex at which the particle will lose contact with the sphere, using work-energy transformations.
19. An advanced flywheel energy storage unit consists of a heavy structural ring. The unit stores 3.6×10^6 Joules (1 kWh) of kinetic energy when spinning at its operational speed. If the system suffers a constant frictional torque in its magnetic bearings equal to $0.05 \text{ N}\cdot\text{m}$, calculate the total time it will take for the flywheel to come to a complete stop if left completely disconnected from the power grid.
20. A heavy block of mass M is being towed up a rough incline of angle θ at a constant speed v by a winch motor. The coefficient of friction between the block and the incline is μ . Derive the expression for the instantaneous mechanical power that the winch motor must supply to the cable, and find the condition under which more power is spent overcoming friction than fighting gravity.