

How Forces Affect Motion - Question Bank

Class 9 Science (Exploration Edition) | Physics Chapter 5

Line Spacing: 1.15

Segment 1: Easy Level

1. Multiple Choice Questions (20 Questions)

1. Which of the following is a vector quantity?
A) Mass
B) Speed
C) Force
D) Distance
2. The SI unit of force is named after which scientist?
A) Galileo Galilei
B) Isaac Newton
C) Albert Einstein
D) Aristotle
3. If the net external force acting on a body is zero, the body:
A) Must be at rest
B) Must be moving with variable velocity
C) May be at rest or moving with a uniform velocity
D) Must be accelerating
4. Inertia of an object directly depends on its:
A) Velocity
B) Acceleration
C) Mass
D) Shape
5. When a carpet is beaten with a stick, dust particles come out of it due to:
A) Inertia of rest
B) Inertia of motion
C) Inertia of direction
D) Acceleration
6. Newton's first law of motion defines:
A) Force and Inertia
B) Momentum
C) Acceleration
D) Action and Reaction
7. A passenger in a moving bus tends to fall forward when the bus brakes suddenly. This is due to:
A) Inertia of rest
B) Inertia of motion
C) Centrifugal force
D) Friction
8. The mathematical formulation of Newton's second law of motion gives an expression for:

- A) Inertia
 - B) Momentum
 - C) Force
 - D) Velocity
9. The product of mass and velocity of a body is called:
- A) Force
 - B) Acceleration
 - C) Linear Momentum
 - D) Inertia
10. The SI unit of linear momentum is:
- A) $\text{kg} \cdot \text{m/s}^2$
 - B) $\text{kg} \cdot \text{m/s}$
 - C) N/s
 - D) $\text{kg} \cdot \text{s/m}$
11. When a force of 1 N acts on a mass of 1 kg, the acceleration produced is:
- A) 1 m/s^2
 - B) 9.8 m/s^2
 - C) 0.1 m/s^2
 - D) 10 m/s^2
12. Action and reaction forces mentioned in Newton's third law:
- A) Act on the same body
 - B) Act on different bodies in opposite directions
 - C) Act on different bodies in the same direction
 - D) Balance each other out inside a single object
13. A gun recoils after firing a bullet. This is an practical example of:
- A) Newton's First Law
 - B) Newton's Second Law
 - C) Newton's Third Law
 - D) Law of Conservation of Mass
14. A goalkeeper pulls his hands backwards while catching a fast-moving cricket ball to:
- A) Reduce the force exerted by the ball
 - B) Increase the force exerted by the ball
 - C) Reduce the change in momentum
 - D) Keep his hands steady
15. When a force is applied to a soft rubber ball, it changes its:
- A) Mass
 - B) Inertia
 - C) Shape
 - D) Momentum only
16. If a body is moving on a frictionless horizontal surface with a constant speed, the force required to keep it moving with the same speed is:
- A) Equal to its weight
 - B) Zero
 - C) Proportional to its mass
 - D) Infinitely high
17. A force of 5 N acts on a body of mass 2 kg. The acceleration of the body is:
- A) 10 m/s^2
 - B) 2.5 m/s^2
 - C) 0.4 m/s^2
 - D) 7 m/s^2
18. Rocket propulsion works on the principle of conservation of:

- A) Mass
- B) Kinetic Energy
- C) Linear Momentum
- D) Force

19. Balanced forces acting on an object can change its:

- A) State of rest
- B) State of motion
- C) Shape and size
- D) Velocity vector

20. Frictional force always acts in a direction:

- A) Parallel to the applied force
- B) Perpendicular to the surface of contact
- C) Opposite to the direction of motion of the object
- D) Vertically downwards

MCQ Answer Key (Easy): 1-C, 2-B, 3-C, 4-C, 5-A, 6-A, 7-B, 8-C, 9-C, 10-B, 11-A, 12-B, 13-C, 14-A, 15-C, 16-B, 17-B, 18-C, 19-C, 20-C

2. Subjective Questions (20 Questions)

1. State Newton's first law of motion.
2. Why is Newton's first law also known as the Law of Inertia?
3. Explain why a person sitting in a car leans sideways when the car takes a sharp turn at high speed.
4. Define linear momentum. Is it a scalar or a vector quantity?
5. State Newton's second law of motion and write its mathematical equation.
6. Define the SI unit of force (Newton).
7. State Newton's third law of motion.
8. Why do action and reaction forces not cancel each other out?
9. Explain why it is difficult to walk on an exceptionally slippery frozen lake surface.
10. A bullet fired from a rifle travels forward while the rifle moves backward. Compare the magnitudes of force acting on both.
11. State the Law of Conservation of Momentum.
12. Why do athletes jump on a sandbed or a thick cushion during a high-jump event?
13. Distinguish between balanced and unbalanced forces.
14. What happens to the linear momentum of an object if its mass is doubled and its velocity is halved?
15. Why is it dangerous to jump out of a rapidly moving train or bus even if you land on flat ground?
16. Explain how a swimmer propels themselves forward in water using Newton's third law.
17. An object experiences a net zero external unbalanced force. Is it possible for the object to be traveling with a non-zero velocity? Explain.
18. Name the physical quantity that corresponds to the rate of change of momentum.
19. Why does a heavy log require a larger force to set it in motion compared to a small wooden block?
20. Explain why water drops fly off tangentially when a wet umbrella is rotated rapidly.

Segment 2: Moderate Level

1. Multiple Choice Questions (20 Questions)

1. A constant force acts on an object of mass 5 kg for a duration of 2 seconds. It increases the object's velocity from 3 m/s to 7 m/s. The magnitude of the applied force is:
A) 5 N
B) 10 N
C) 20 N
D) 15 N
2. A body of mass 2 kg moving with a uniform velocity of 10 m/s hits a wall and stops in 0.1 s. The average force exerted by the wall on the body is:
A) 20 N
B) 200 N
C) 2 N
D) 100 N
3. An object of mass 100 g moves along a straight line with a constant acceleration of 5 m/s². The magnitude of change in its momentum in 4 seconds is:
A) 2 kg·m/s
B) 20 kg·m/s
C) 0.2 kg·m/s
D) 0.5 kg·m/s
4. Two bodies have masses in the ratio 2:3. If they experience equal forces, the ratio of their accelerations will be:
A) 2:3
B) 3:2
C) 4:9
D) 1:1
5. A bullet of mass 20 g is horizontally fired from a pistol of mass 2 kg with a velocity of 150 m/s. The recoil velocity of the pistol is:
A) -1.5 m/s
B) -15 m/s
C) -0.15 m/s
D) -3.0 m/s
6. A dynamic system consists of an object pulled over a rough surface. If the force of friction is 5 N and the applied pulling force is 12 N, the net unbalanced force causing acceleration is:
A) 17 N
B) 7 N
C) 60 N
D) 0 N
7. A hammer of mass 500 g, moving at 50 m/s, strikes a nail. The nail stops the hammer in a very short time of 0.01 s. The force of the nail on the hammer is:
A) 2500 N
B) 500 N
C) 250 N
D) 1000 N
8. Two identical blocks A and B are placed on a table. Block A is pushed with a force F. The inertia of block A compared to block B is:
A) Greater
B) Smaller
C) Exactly the same
D) Dependent on the force F
9. A force of 10 N gives a mass m_1 an acceleration of 10 m/s² and a mass m_2 an acceleration of 20 m/s². If both masses are tied together, the acceleration produced by the

same force would be:

- A) 30 m/s^2
 - B) 15 m/s^2
 - C) 6.67 m/s^2
 - D) 5 m/s^2
10. The velocity-time graph of a ball of mass 20 g moving along a straight line on a long table is a straight line sloping down from a velocity of 20 cm/s to 0 in 10 s. The frictional force exerted by the table is:
- A) $-4 \times 10^{-4} \text{ N}$
 - B) -4 N
 - C) -0.04 N
 - D) -40 N
11. A passenger standing in a lift feels lighter when the lift accelerates:
- A) Upwards
 - B) Downwards
 - C) With uniform speed upwards
 - D) With uniform speed downwards
12. The momentum of a particle varies with time as $p = 2 + 3t^2$. The force acting on the particle at $t = 2 \text{ s}$ is:
- A) 12 N
 - B) 14 N
 - C) 6 N
 - D) 8 N
13. A vehicle of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is brought to rest in 5 s by a constant braking force. The acceleration is:
- A) -5 m/s^2
 - B) -18 m/s^2
 - C) -4.5 m/s^2
 - D) -6 m/s^2
14. In the previous question, the magnitude of the braking force is:
- A) 6000 N
 - B) 21600 N
 - C) 5400 N
 - D) 1200 N
15. A dynamic balance contains two masses of 3 kg and 5 kg connected by a light string passing over a frictionless pulley. The acceleration of the system when released is ($g = 10 \text{ m/s}^2$):
- A) 2.5 m/s^2
 - B) 4 m/s^2
 - C) 2 m/s^2
 - D) 5 m/s^2
16. A cracker of mass 100 g explodes into two pieces of masses 40 g and 60 g. If the 40 g piece flies off with a velocity of 12 m/s, the velocity of the 60 g piece is:
- A) -8 m/s
 - B) -12 m/s
 - C) -6 m/s
 - D) -18 m/s
17. A man weighing 60 kg runs up a stationary escalator in 20 seconds. If the force he exerts vertically downwards on the steps is equal to his weight, the reaction force of the steps on him is ($g = 10 \text{ m/s}^2$):
- A) 600 N vertically upwards

- B) 600 N vertically downwards
 - C) 30 N vertically upwards
 - D) Zero
18. A block of mass M is pulled along a smooth horizontal surface by a rope of mass m . If a force F is applied at the free end of the rope, the force exerted by the rope on the block is:
- A) F
 - B) $F \cdot M / (M+m)$
 - C) $F \cdot m / (M+m)$
 - D) $F \cdot M / m$
19. When a horse pulls a cart, the force that helps the horse to move forward is exerted by:
- A) The cart on the horse
 - B) The ground on the horse
 - C) The horse on the ground
 - D) The horse on the cart
20. A body under the action of a constant force F acquires an acceleration ' a '. If its mass is reduced to one-third, the new acceleration under the same force will be:
- A) $a/3$
 - B) $3a$
 - C) $9a$
 - D) a

MCQ Answer Key (Moderate): 1-B, 2-B, 3-A, 4-B, 5-A, 6-B, 7-A, 8-C, 9-C, 10-A, 11-B, 12-A, 13-A, 14-A, 15-A, 16-A, 17-A, 18-B, 19-B, 20-B

2. Subjective Questions (20 Questions)

1. Derive the mathematical formula $F = ma$ from Newton's second law of motion.
2. A motorcar of mass 1200 kg is moving along a straight line with a uniform velocity of 90 km/h. Its velocity is slowed down to 18 km/h in 4 seconds by an external unbalanced force. Calculate the acceleration and change in momentum.
3. A bullet of mass 10 g traveling horizontally with a velocity of 150 m/s strikes a stationary wooden block and comes to rest in 0.03 s. Calculate the distance of penetration of the bullet into the block and the magnitude of the force exerted by the wooden block on the bullet.
4. An object of mass 1 kg traveling in a straight line with a velocity of 10 m/s collides with, and sticks to, a stationary wooden block of mass 5 kg. Then they both move off together in the same straight line. Calculate the total momentum just before the impact and just after the impact, and the velocity of the combined object.
5. Two objects of masses 100 g and 200 g are moving along the same line and direction with velocities of 2 m/s and 1 m/s, respectively. They collide and after the collision, the first object moves at a velocity of 1.67 m/s. Determine the velocity of the second object.
6. Explain why it is easier to pull a lawn roller than to push it, focusing on the resolution of vertical forces qualitatively.
7. A truck starts from rest and rolls down a hill with a constant acceleration. It travels a distance of 400 m in 20 s. Find its acceleration. Find the force acting on it if its mass is 7 metric tonnes (1 metric tonne = 1000 kg).
8. Using a position-time graph showing a straight line with a non-zero slope, prove that the net force acting on the body is zero.
9. A certain force applied to a body of mass m_1 gives it an acceleration of 5 m/s^2 . The same force applied to a body of mass m_2 gives it an acceleration of 15 m/s^2 . What acceleration would it give if both masses were joined together?
10. Why does an industrial machine firmly bolted to a heavy concrete floor shake less during

- operation than if it were placed on a light wooden platform?
11. Explain how a jet plane works on the basis of Newton's third law of motion.
 12. Describe a simple classroom experiment to demonstrate the law of conservation of linear momentum using two marbles or toy carts.
 13. A force of 5 N produces an acceleration of 8 m/s^2 on a mass m_1 and an acceleration of 24 m/s^2 on a mass m_2 . What acceleration would the same force provide if both masses are tied together?
 14. Can a body have momentum without having kinetic energy? Explain your answer clearly.
 15. A dynamic cable is used to tow a car of mass 1500 kg up a ramp. If the car accelerates at 2 m/s^2 and frictional resistance is 500 N, calculate the tension force in the cable.
 16. How does a safety seatbelt prevent injuries during a sudden motorcar accident? Explain with reference to inertia and time of impact.
 17. A stone of mass 1 kg is thrown with a velocity of 20 m/s across the frozen surface of a lake and comes to rest after traveling a distance of 50 m. What is the force of friction between the stone and the ice?
 18. What is the momentum of an object of mass m , moving with a velocity v ? Show how force is related to the rate of change of this momentum.
 19. Why do big luxury cars provide a smoother ride on bumpy roads compared to small hatchbacks? Explain in terms of mass and acceleration.
 20. A block of mass 2 kg is pulled on a frictionless table by a constant horizontal force. If it covers 10 m in the first 2 seconds from rest, find the magnitude of the applied force.

Segment 3: Difficult Level

1. Multiple Choice Questions (20 Questions)

1. A machine gun fires 360 bullets per minute, each of mass 20 g with a velocity of 500 m/s. The average force required to hold the gun steady in place is:
 - A) 60 N
 - B) 36 N
 - C) 120 N
 - D) 18 N
2. A body of mass M collides elastically with another stationary body of mass m . If the first body stops dead after the collision, the ratio of their masses (M/m) must be:
 - A) 1
 - B) 2
 - C) 0.5
 - D) Infinite
3. A stream of water flowing horizontally at speed v hits a vertical wall normally and drops down vertically without bouncing. If the cross-sectional area of the stream is A and density of water is ρ , the force exerted on the wall is:
 - A) ρv^2
 - B) $2\rho v^2$
 - C) $0.5\rho v^2$
 - D) ρv
4. A helicopter of mass 2000 kg ascends with a vertical acceleration of 5 m/s^2 . The mass of the crew and passengers is 500 kg. The force exerted by the crew on the floor of the helicopter is ($g = 10 \text{ m/s}^2$):
 - A) 7500 N

- B) 5000 N
C) 25000 N
D) 12500 N
5. In the previous question, the action force of the rotor blades on the surrounding air is:
A) 37500 N downwards
B) 37500 N upwards
C) 25000 N downwards
D) 30000 N upwards
6. A block of mass m is placed on a smooth wedge of inclination θ . The wedge is given a horizontal acceleration ' a ' towards the left so that the block remains stationary relative to the wedge. The value of ' a ' is:
A) $g \sin \theta$
B) $g \cos \theta$
C) $g \tan \theta$
D) $g/\tan \theta$
7. A force vector acts on a mass of 2 kg such that its position varies with time as $x = 2t + 5t^2 + t^3$. The net force acting on the body at $t = 2$ s is:
A) 44 N
B) 22 N
C) 32 N
D) 12 N
8. A mass of 3 kg experience a force that varies with time according to the graph where force rises from 0 to 6 N linearly in 3 seconds, then drops to 0 in another 3 seconds. The total change in momentum of the body is:
A) 18 kg·m/s
B) 9 kg·m/s
C) 36 kg·m/s
D) 6 kg·m/s
9. A block of mass 5 kg is pressed against a vertical rough wall with a horizontal force of 100 N. If the coefficient of static friction is 0.4, the frictional force acting on the block to prevent it from sliding down under gravity is ($g = 10 \text{ m/s}^2$):
A) 40 N
B) 50 N
C) 100 N
D) 20 N
10. Two masses 4 kg and 6 kg are attached to the ends of a light inextensible string that passes over a frictionless pulley fixed at the top of an inclined plane of angle 30° . If the 6 kg mass hangs vertically and the 4 kg mass sits on the smooth incline, the acceleration of the system is ($g = 10 \text{ m/s}^2$):
A) 4 m/s^2
B) 2 m/s^2
C) 5 m/s^2
D) 1 m/s^2
11. A ball of mass 0.15 kg is dropped from a height of 10 m and rebounds from the floor to a height of 5 m. If the ball was in contact with the floor for 0.05 s, the average force exerted by the floor on the ball is ($g = 10 \text{ m/s}^2$):
A) 72.3 N
B) 18.2 N
C) 54.6 N
D) 90.4 N
12. A heavy rope of mass m and length L is hung vertically from a ceiling. The tension in the

rope at a distance x from the lower free end is:

- A) $m \cdot g$
 - B) $m \cdot g \cdot (x/L)$
 - C) $m \cdot g \cdot (1 - x/L)$
 - D) $m \cdot g \cdot (x^2/L^2)$
13. A dynamic system consists of three blocks of masses 1 kg, 2 kg, and 3 kg connected adjacent to each other on a smooth horizontal table. If a force of 12 N is applied horizontally on the 1 kg block to push the system forward, the contact force between the 2 kg and 3 kg block is:
- A) 6 N
 - B) 4 N
 - C) 2 N
 - D) 8 N
14. A monkey of mass 40 kg climbs up a light rope which can stand a maximum tension of 600 N. In which of the following cases will the rope snap? ($g = 10 \text{ m/s}^2$):
- A) Monkey climbs up with an acceleration of 6 m/s^2
 - B) Monkey climbs down with an acceleration of 4 m/s^2
 - C) Monkey climbs up with a uniform speed of 5 m/s
 - D) Monkey falls down the rope nearly freely under gravity
15. A body of mass 5 kg is exploded into three fragments of masses in the ratio 1:1:3. The two fragments of equal masses fly off perpendicular to each other with a speed of 21 m/s each. The speed of the heavier fragment is:
- A) 7 m/s
 - B) $7\sqrt{2} \text{ m/s}$
 - C) 14 m/s
 - D) 21 m/s
16. A continuous conveyor belt moves horizontally at a constant speed v . Sand is dropped vertically onto the belt at a constant rate of $dm/dt = R \text{ kg/s}$. The extra power required to keep the conveyor belt moving at the same speed is:
- A) $R \cdot v^2$
 - B) $0.5R \cdot v^2$
 - C) $2R \cdot v^2$
 - D) $R \cdot v$
17. A block of mass m slides down a rough inclined plane of inclination angle θ with a constant velocity. The net force exerted by the inclined plane surface on the block is:
- A) $m \cdot g \sin \theta$
 - B) $m \cdot g \cos \theta$
 - C) $m \cdot g$
 - D) Zero
18. A string breaks if its tension exceeds 100 N. A stone of mass 250 g tied to this string of length 1 m is rotated in a horizontal circle over a frictionless table. The maximum speed with which the stone can be rotated is:
- A) 20 m/s
 - B) 10 m/s
 - C) 40 m/s
 - D) 5 m/s
19. A dynamic cart of mass M holds a vertical pipe. A small ball of mass m is dropped into the pipe while the cart is accelerating horizontally with acceleration ' a '. The apparent acceleration of the ball relative to the pipe frame is:
- A) g
 - B) $\sqrt{(g^2 + a^2)}$

- C) $g - a$
D) $g + a$

20. A force $F = k \cdot t$ acts on a particle of mass m initially at rest at $t=0$. The distance traveled by the particle in time T is:
A) $k \cdot T^3 / (6m)$
B) $k \cdot T^2 / (2m)$
C) $k \cdot T^3 / (3m)$
D) $k \cdot T^4 / (12m)$

MCQ Answer Key (Difficult): 1-A, 2-A, 3-A, 4-A, 5-A, 6-C, 7-A, 8-B, 9-B, 10-A, 11-A, 12-B, 13-A, 14-A, 15-B, 16-A, 17-C, 18-A, 19-B, 20-A

2. Subjective Questions (20 Questions)

1. A machine gun fires 240 bullets per minute, each of mass 25 g with a velocity of 600 m/s. Calculate the average force required to hold the gun steady in position. If the hunter can exert a maximum force of 200 N, what is the maximum number of bullets he can fire safely per second?
2. A truck of mass 5 metric tonnes moving at 18 km/h collides elastically with a stationary car of mass 1000 kg. If the collision is perfectly head-on along a straight track, calculate the individual velocities of both vehicles after the impact.
3. A jet of water from a pipe of cross-sectional area 10 cm^2 strikes a wall normally with a speed of 20 m/s and does not rebound. Calculate the force exerted on the wall. If the water bounces back elastically with the same speed, what will be the new force?
4. A lift cabin along with its passengers has a total mass of 800 kg. It is suspended by steel cables. Calculate the tension in the cables when the lift is: (i) ascending with an acceleration of 2 m/s^2 , (ii) descending with a deceleration of 1.5 m/s^2 . (Take $g = 10 \text{ m/s}^2$).
5. A heavy block of mass 20 kg is pulled along a rough horizontal path by a rope of mass 2 kg. A force of 110 N is applied at the free end of the rope. If the coefficient of friction between the block and the floor is 0.2, calculate the acceleration of the system and the tension at the midpoint of the rope.
6. A wedge with a frictionless inclined surface of angle α is accelerated horizontally with an acceleration 'a'. Find the mathematical relationship between 'a' and angle α such that a small block placed on it does not slide up or down.
7. The linear momentum of a body moving in a single direction changes with time according to the equation $p = a + b \cdot t^2$, where a and b are constants. Find the expression for the force acting on it. How does the force vary with time?
8. A context-dependent variable force acts on a 500 g particle such that the force increases from 0 to 10 N in 4 seconds and then drops linearly to 0 in another 2 seconds. Plot this force-time graph qualitatively and calculate the total change in velocity of the particle.
9. A box of mass 10 kg is pushed against a vertical accent wall with a horizontal force P . If the coefficient of static friction between the box and the wall is 0.5, find the minimum value of P required to hold the box stationary against gravity ($g = 10 \text{ m/s}^2$).
10. Two blocks of masses 7 kg and 3 kg are connected by a light string over a frictionless pulley at the peak of a double incline (one side 30° , other side 60°). If the surfaces are completely smooth, find the acceleration of the blocks when released from rest.
11. A tennis ball of mass 60 g moving at 30 m/s strikes a wall at an angle of 30° to the wall surface and rebounds with the same speed at the same angle. If the contact lasted 0.02 seconds, calculate the average force experienced by the wall.
12. Explain the conceptual variation of tension along a thick canvas rope of mass M and length L hanging from a high crane hook when a load W is tied to its lowest end.
13. Three blocks of masses 4 kg, 2 kg, and 1 kg are placed in contact with each other on a

- smooth horizontal floor. A horizontal force of 14 N is applied to the 4 kg block. Find the contact forces between the blocks.
14. A 50 kg gymnast climbs up a vertical rope. Calculate the tension in the rope if she: (i) climbs up with an acceleration of 1 m/s^2 , (ii) slides down with a uniform velocity of 2 m/s ($g = 10 \text{ m/s}^2$).
 15. An explosive shell of mass 6 kg traveling at 20 m/s breaks into two pieces of masses 2 kg and 4 kg. If the 2 kg piece stops immediately after explosion, find the velocity of the 4 kg piece.
 16. Sand drops vertically at a rate of 2 kg/s onto a long open cart of mass 100 kg moving initially at a constant speed of 5 m/s on a smooth horizontal track. Find the velocity of the cart after 10 seconds.
 17. A wooden crate of mass 50 kg rests on an inclined wooden ramp of slope 30° . If the crate remains perfectly stationary without sliding, deduce the magnitude and direction of the static frictional force and the normal reaction force acting on it.
 18. A stone of mass 0.5 kg tied to a string of length 80 cm is whirled in a vertical circle. At the lowest point of its path, its speed is 10 m/s . Find the tension in the string at this lowest point ($g = 10 \text{ m/s}^2$).
 19. A closed box containing a small bird is placed on a sensitive weighing scale. What happens to the scale reading when the bird: (i) hovers at a fixed height inside, (ii) accelerates vertically upwards inside? Explain.
 20. A particle of mass m starts from rest and experiences a force $F = F_0 \cdot e^{(-k \cdot t)}$. Derive a qualitative expression for its terminal velocity as time extends to infinity.

Segment 4: Olympiad Level

1. Multiple Choice Questions (20 Questions)

1. A flexible chain of length L and mass M is held on a smooth table with a fraction of its length hanging over the edge. If it is released from rest when a length ' h ' is hanging, the acceleration of the chain at the instant the entire chain leaves the table edge is:
 - A) g
 - B) $g \cdot \sqrt{1 - h^2/L^2}$
 - C) $g \cdot (1 + h/L)$
 - D) $g \cdot (1 - h/L)$
2. A small bead of mass m is threaded on a smooth circular wire ring of radius R fixed in a vertical plane. If the ring is rotated about its vertical diameter with a constant angular velocity w , the angle θ which the bead makes with the vertical downward direction at equilibrium satisfies:
 - A) $\cos\theta = g / (R \cdot w^2)$
 - B) $\sin\theta = g / (R \cdot w^2)$
 - C) $\cos\theta = R \cdot w^2 / g$
 - D) $\tan\theta = g / (R \cdot w^2)$
3. A block of mass m is connected to another block of mass M by a spring of spring constant k . The system is placed on a smooth horizontal table. If a constant force F pulls mass M , the acceleration of the center of mass of the system is:
 - A) $F / (M+m)$
 - B) F / M
 - C) F / m
 - D) zero

4. A system of two blocks of masses m_1 and m_2 connected by an inextensible string passing over a smooth pulley is suspended inside a lift. If the lift accelerates upwards with acceleration ' a ', the relative acceleration of m_1 with respect to the lift frame is:
 - A) $(m_1 - m_2)(g + a) / (m_1 + m_2)$
 - B) $(m_1 - m_2)g / (m_1 + m_2)$
 - C) $(m_1 - m_2)(g - a) / (m_1 + m_2)$
 - D) $m_1 \cdot a / (m_1 + m_2)$
5. A uniform rope of mass m and length L is pulled along a smooth horizontal surface by a force F applied at one end. The tension in the rope at a distance x from the end where force is applied is:
 - A) $F \cdot (1 - x/L)$
 - B) $F \cdot (x/L)$
 - C) F
 - D) $F \cdot (1 + x/L)$
6. A balloon of mass M is descending with an acceleration ' a ' ($a < g$). How much mass m should be removed from it so that it starts ascending with the same acceleration ' a '? (Neglect air density variations):
 - A) $2M \cdot a / (g + a)$
 - B) $2M \cdot a / (g - a)$
 - C) $M \cdot a / (g + a)$
 - D) $M \cdot a / (g - a)$
7. A heavy particle of mass m is dropped into a viscous fluid which exerts a drag force proportional to the square of its instantaneous velocity, $F_{\text{drag}} = -k \cdot v^2$. The terminal velocity attained by the particle is:
 - A) $\sqrt{(m \cdot g / k)}$
 - B) $m \cdot g / k$
 - C) $\sqrt{(k / m \cdot g)}$
 - D) $(m \cdot g / k)^2$
8. A disc of mass M and radius R rotated at angular velocity ω is dropped onto a rough horizontal floor. If the coefficient of friction is μ , the time taken for the disc to come to a complete stop is:
 - A) $3R \cdot \omega / (4\mu \cdot g)$
 - B) $R \cdot \omega / (2\mu \cdot g)$
 - C) $2R \cdot \omega / (3\mu \cdot g)$
 - D) $R \cdot \omega / (\mu \cdot g)$
9. A particle moves along a curve under the action of a central force. The quantity that remains strictly conserved is:
 - A) Linear Momentum
 - B) Kinetic Energy
 - C) Angular Momentum
 - D) Acceleration vector
10. A thread holds a block of mass m stationary on a smooth incline of angle θ inside a cart. If the cart accelerates horizontally to the right with acceleration $a = g \tan \theta$, the tension in the thread becomes:
 - A) $m \cdot g \sin \theta$
 - B) zero
 - C) $m \cdot g / \cos \theta$
 - D) $m \cdot g \cos \theta$
11. A sand-loaded cart of initial mass M_0 moves on a smooth horizontal track under a constant pulling force F . Sand leaks out from a hole in the bottom at a constant rate r kg/s relative to the cart frame. The acceleration of the cart at time t is:

- A) $F / (M_0 - r \cdot t)$
 B) F / M_0
 C) $(F - r \cdot v) / M_0$
 D) $F / (M_0 + r \cdot t)$
12. A particle of mass m is hitting a rough wall at an angle of incidence θ and rebounding elastically. If the coefficient of friction during the short impact is μ , the net impulse delivered along the wall surface is:
 A) $2\mu \cdot m \cdot v \cos\theta$
 B) $2m \cdot v \sin\theta$
 C) zero
 D) $2\mu \cdot m \cdot v \sin\theta$
13. A simple pendulum of mass m and length L is suspended from the ceiling of a cart moving horizontally with a constant acceleration ' a '. The equilibrium angle that the string makes with the vertical is:
 A) $\tan^{-1}(a/g)$
 B) $\sin^{-1}(a/g)$
 C) $\cos^{-1}(g/a)$
 D) $\tan^{-1}(g/a)$
14. For the pendulum in the previous question, the time period of small oscillations about its equilibrium position is:
 A) $2\pi \sqrt{L / \sqrt{(g^2 + a^2)}}$
 B) $2\pi \sqrt{L / g}$
 C) $2\pi \sqrt{L / (g + a)}$
 D) $2\pi \sqrt{L / (g - a)}$
15. A uniform block of mass m and dimensions length L , height H sits on a rough conveyor belt. As the belt's acceleration increases, the block will topple before sliding if:
 A) The coefficient of static friction $\mu_s > L/H$
 B) $\mu_s < L/H$
 C) $\mu_s > H/L$
 D) $\mu_s < H/L$
16. A block is supported on a smooth inclined plane of angle θ by a vertical wall. The force exerted by the inclined plane on the block is:
 A) $m \cdot g / \cos\theta$
 B) $m \cdot g \cos\theta$
 C) $m \cdot g \sin\theta$
 D) $m \cdot g / \sin\theta$
17. A flexible rope of mass M and length L lies coiled on a table. A student lifts one end vertically upwards with a constant velocity v . The force required to maintain this constant velocity at the instant a length x is off the table is:
 A) $M \cdot g \cdot x/L + M \cdot v^2/L$
 B) $M \cdot g \cdot x/L$
 C) $M \cdot v^2/L$
 D) $M \cdot g \cdot x/L + 2M \cdot v^2/L$
18. Two masses m_1 and m_2 are connected by a spring and placed on a smooth table. They are pulled apart and released. At any instant, their accelerations a_1 and a_2 are related as:
 A) $m_1 \cdot a_1 + m_2 \cdot a_2 = 0$
 B) $a_1 = a_2$
 C) $m_1 \cdot a_1 = m_2 \cdot a_2$
 D) $m_1 \cdot a_2 = m_2 \cdot a_1$
19. A spherical raindrop falling through air experiences a retarding force $F = -6\pi \cdot \eta \cdot r \cdot v$, where η is the viscosity coefficient, r is the radius, and v is velocity. If density of water is d , the

terminal speed of the drop varies with its radius r as:

- A) $v_t \propto r^2$
- B) $v_t \propto r$
- C) $v_t \propto 1/r$
- D) $v_t \propto r^3$

20. A heavy block of mass M is suspended by two identical light strings making an angle of θ with the horizontal ceiling. The tension in each string is:

- A) $M \cdot g / (2 \sin \theta)$
- B) $M \cdot g / \sin \theta$
- C) $M \cdot g \cos \theta$
- D) $M \cdot g / (2 \cos \theta)$

MCQ Answer Key (Olympiad): 1-A, 2-A, 3-A, 4-A, 5-A, 6-A, 7-A, 8-A, 9-C, 10-B, 11-A, 12-A, 13-A, 14-A, 15-A, 16-A, 17-A, 18-A, 19-A, 20-A

2. Subjective Questions (20 Questions)

1. A uniform flexible chain of length L and mass M rests on a smooth horizontal table with a length ' h ' hanging over the edge. Derive an expression for the velocity of the chain at the exact instant the last link slides off the table edge, using energy and momentum principles adapted for Class 9 variables.
2. A smooth wire ring of radius R is fixed in a vertical plane. A small ring-bead of mass m can slide along it without friction. If the entire apparatus rotates about its vertical diameter with an angular velocity ω , set up the equilibrium equation to find the stable angular positions of the bead.
3. Two blocks of masses m and M are connected by a spring of stiffness k on a frictionless floor. A constant horizontal force F begins to pull mass M . Find the acceleration of each block at the instant the spring is stretched by an extension ' x '. Identify the motion of the center of mass.
4. An Atwood machine containing two masses m_1 and m_2 ($m_1 > m_2$) connected by a light string is suspended from the ceiling of an accelerating rocket cabin going up at ' a '. Derive the expression for the acceleration of m_1 relative to the cabin floor and the absolute tension in the string.
5. A thick hemp rope of mass M and length L is pulled along a smooth horizontal path by a constant force F . Derive the mathematical expression for the internal tension force at an arbitrary cross-section located at a distance ' y ' from the pulling end.
6. A hot air balloon of total mass M is descending vertically with a constant downward acceleration ' a '. To reverse its motion, the pilot drops a ballast sack of mass ' m '. Derive the mathematical formula for mass ' m ' in terms of M , a , and g such that the balloon starts ascending with the same acceleration ' a '.
7. An object of mass m is dropped from rest into a highly viscous medium where resistive drag is modeled as $F_{\text{drag}} = -b \cdot v$. Set up the dynamic equation of motion and find the terminal velocity. Explain how the net force approaches zero asymptotically.
8. A solid uniform disc of mass M and radius R spinning at an initial angular speed ω_0 is set gently onto a rough horizontal platform. If the coefficient of kinetic friction is μ , derive an expression for the time duration required for the disc to lose all its kinetic energy and come to a halt.
9. Define a 'central force field'. Prove conceptually why an object moving under a central force directed towards a fixed point must always move within a single, fixed two-dimensional plane, preserving its angular momentum.
10. A small block of mass m sits inside a cart on a smooth incline of angle θ . The block is secured by a light string parallel to the incline surface. If the cart accelerates horizontally

to the right with a critical acceleration $a = g \tan \theta$, determine the tension in the string and discuss the normal contact force.

11. A rocket-propelled test cart of mass M moves on a smooth track under a constant thruster force F . If water leaks out from a tank in its body vertically downwards at a constant rate of r kg/s relative to the cart, analyze if the loss of mass creates a reactive force along the direction of motion. Find its velocity as a function of time.
12. A steel ball of mass m strikes a heavy steel plate at an angle α to the normal and rebounds with the same speed at an identical angle. If the surface of the plate has a micro-roughness with a coefficient of friction μ , derive the expression for the net tangential and normal components of impulse delivered during the millisecond collision.
13. A simple pendulum is suspended from the roof of an omnibus that travels around a circular curve of radius R at a constant speed v . Find the expression for the angle θ that the pendulum string makes with the true vertical at steady state.
14. For the pendulum in the previous question, if the omnibus suddenly enters a straight track and accelerates forward with a constant acceleration ' a ', derive the expression for the new equilibrium position and the effective acceleration due to gravity acting on the bob.
15. A uniform rectangular crate of mass m , width W , and height H rests on a flat truck bed. The coefficient of static friction between the crate and the truck bed is μ . If the truck accelerates forward, determine the maximum acceleration possible before the crate either slips or topples over, and find the condition for toppling to occur first.
16. A heavy block of mass m is held stationary against a vertical wall by a smooth wedge of inclination angle θ . The wedge is pressed against the block by a horizontal force. Find the expression for the normal force exerted by the wedge on the block to keep it from falling.
17. A heavy flexible cable of mass M and length L lies in a heap on a warehouse floor. A crane hook lifts one end vertically upwards with a constant velocity v . Calculate the total upward force that the crane must exert as a function of the instantaneous height ' x ' of the lifted segment.
18. Two blocks of masses m_1 and m_2 are connected by an ideal spring on a smooth table. They are compressed together and released from rest. Prove that at any subsequent instant, the ratio of their accelerations is inversely proportional to the ratio of their masses, and explain how this relates to internal forces.
19. A tiny oil droplet of mass m and radius r falls through air. It experiences a Stokes' drag force given by $F = 6\pi\eta r \cdot v$. Derive the mathematical expression for its terminal velocity and show how it depends on the density of the oil and the radius of the droplet.
20. A heavy chandelier of mass M is suspended from a high ceiling by three identical chains of length L , attached symmetrically to form an equilateral cone with a semi-vertical angle α . Calculate the tension force developed in each individual supporting chain.