Class 11 Physics · Chapter 4: Laws of Motion

Answer key and marking scheme · 20 marks · about 40 minutes · based on NCERT

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1. Which pair of quantities has the same SI unit? [1]

(a) impulse and force
(b) momentum and force
(c) force and rate of change of velocity
(d) impulse and momentum

Answer: (d) Impulse = force × time = change in momentum, so both are measured in N s = kg m s^{-1}, with dimensions [MLT^{-1}]. Force is in N, [MLT^{-2}].

2. For the action and reaction forces between two bodies, which statement is correct? [1]

(a) Action acts first and reaction follows it.
(b) They act on the same body and cancel each other.
(c) They act at the same instant, on different bodies.
(d) Reaction is smaller than action when one body is much heavier.

Answer: (c) The two mutual forces are simultaneous, equal and opposite, and act on different bodies; there is no cause and effect between them, and they cannot cancel because they do not act on the same body.

3. A hockey puck slides across a smooth, level sheet of ice in a straight line at a steady 4 m s^{-1}. [1] Neglecting air resistance, the net force on the puck is

(a) zero
(b) along its direction of motion
(c) opposite to its direction of motion
(d) equal to its weight, acting downward

Answer: (a) The puck moves with constant velocity, so its acceleration is zero; by the first law the net external force on it is zero. Its weight is cancelled by the normal force of the ice.

4. An artificial satellite moves round the earth in a circular orbit. The centripetal force on it is [1]

(a) a separate force produced by its circular motion
(b) the thrust of its engines
(c) the gravitational pull of the earth on it
(d) zero, since its speed is constant

Answer: (c) Centripetal force is not a new kind of force; it is the name for whatever material force gives the inward acceleration v^2/R. For a satellite that is the earth's gravitational pull, just as the sun's pull does for a planet.

5. A bar magnet lying on a table pulls a small iron nail held near it with a force of 0.2 N. The force [1] exerted by the nail on the magnet is

(a) 0.2 N, directed away from the nail
(b) 0.2 N, directed towards the nail
(c) less than 0.2 N, since the nail is lighter
(d) zero, since the nail is not a magnet

Answer: (b) Force on the magnet by the nail is equal and opposite to the force on the nail by the magnet. The magnet pulls the nail towards itself, so the nail pulls the magnet towards the nail with 0.2 N. The forces act at a distance; contact is not needed.

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6. A 0.1 kg ball, at rest, is struck by a stick. The force on the ball rises uniformly from zero to 600 N in 0.01 s and then falls uniformly to zero in the next 0.01 s. Find the speed of the ball just after the blow. [2]

Impulse = area under the force-time graph, a triangle: ½ × 600 × 0.02 = 6 N s. Impulse = change in momentum, so 0.1 v = 6, v = 60 m s^{-1}.

- impulse = area = 6 N s (1)
- v = 6/0.1 = 60 m s^{-1} (1)

7. Which two of the fundamental forces of nature are relevant in mechanics? What is the origin of contact forces such as friction and normal reaction? [2]

Only the gravitational and electrical forces are relevant in mechanics. Contact forces arise ultimately from the electrical forces between the charged constituents (nuclei and electrons) of the bodies in contact.

- gravitational and electrical (1)
- contact forces are electrical, between charged constituents (1)

8. A 50 kg girl stands on a weighing scale in a lift. While the lift is moving, the scale reads 400 N (g = 10 m s^{-2}). Find the magnitude and direction of the acceleration of the lift. [2]

Forces on the girl: weight 500 N down, normal force R = 400 N up (the scale reads R). Taking down as positive: 500 − 400 = 50a, a = 2 m s^{-2} downward. The lift is either speeding up going down or slowing down going up.

- mg − R = ma set up with R = 400 N (1)
- a = 2 m s^{-2}, downward (1)

9. A block is placed on a plank inclined at 37° to the horizontal (sin 37° = 0.6, cos 37° = 0.8). The coefficients of friction are μ_s = 0.5 and μ_k = 0.25 (g = 10 m s^{-2}). (a) Will the block start sliding from rest? (b) If it does, find its acceleration down the plank. [3]

(a) The block can stay at rest only if tan θ ≤ μ_s. Here tan 37° = 0.75 > 0.5, so static friction cannot hold it and it slides. (b) Down the plank: mg sin θ − μ_k mg cos θ = ma, so a = 10(0.6 − 0.25 × 0.8) = 10 × 0.4 = 4 m s^{-2}.

- compares tan 37° = 0.75 with μ_s = 0.5: it slides (1)
- net force mg sin θ − μ_k mg cos θ (1)
- a = 4 m s^{-2} (1)

10. Using the idea of impulse, explain why (a) a high jumper lands on a thick foam bed, and (b) cars are built with front parts that crumple in a collision. [3]

The change in momentum in stopping is fixed by the mass and the speed (impulse = F × Δt = Δp). (a) The foam bed takes a longer time to stop the jumper, so the average force on the body, Δp/Δt, is smaller and does not injure. (b) Crumpling lengthens the time in which the car and passengers are stopped, so the force on them is reduced.

- Δp fixed; F = Δp/Δt (1)
- foam bed lengthens stopping time, smaller force (1)
- crumple zone lengthens collision time, smaller force (1)

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11. A 4 kg trolley moving at 3 m s^{-1} on a smooth track runs into a 2 kg trolley at rest, and the two couple together. Find (a) their common velocity, (b) the impulse on each trolley during the coupling, and (c) show that these impulses agree with the third law. [3]

(a) Momentum is conserved: $4 \times 3 = (4 + 2)v$, $v = 2$ m s^{-1} in the original direction. (b) 2 kg trolley: $\Delta p = 2 \times 2 - 0 = +4$ N s. 4 kg trolley: $\Delta p = 4 \times 2 - 4 \times 3 = -4$ N s. (c) The impulses are equal and opposite. The two trolleys are in contact for the same time, so the forces on them, $F = \Delta p/\Delta t$, are equal and opposite, as the third law requires.

- common velocity 2 m s^{-1} (1)
- impulses +4 N s and −4 N s (1)
- equal and opposite impulses over the same time give equal and opposite forces (1)

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