NCERT Chapter 4: Laws of Motion - Exercise Answer Key

Medium Detail Solutions for JEE/NEET Preparation

4.1 Give the magnitude and direction of the net force acting on:

(a) A drop of rain falling down with a constant speed

Answer: Net force = 0 N **Explanation:** Constant speed means zero acceleration. By Newton's first law, net force must be zero. Weight (downward) is balanced by air resistance (upward).

(b) A cork of mass 10 g floating on water

Answer: Net force = 0 N **Explanation:** Cork is in equilibrium. Weight ($0.01 \times 10 = 0.1$ N downward) is balanced by buoyant force (0.1 N upward).

(c) A kite skillfully held stationary in the sky

Answer: Net force = 0 N **Explanation:** Kite is at rest, so acceleration = 0. All forces (weight, air pressure, string tension) balance to give zero net force.

(d) A car moving with constant velocity of 30 km/h on rough road

Answer: Net force = 0 N **Explanation:** Constant velocity means zero acceleration. Engine force balances friction and air resistance.

(e) A high-speed electron in space far from all material objects

Answer: Net force = 0 N **Explanation:** No external forces acting (gravity, electric, magnetic fields absent). By Newton's first law, electron continues with constant velocity.

4.2 A pebble of mass 0.05 kg is thrown vertically upwards:

(a) During upward motion

Answer: Net force = 0.5 N downward **Explanation:** Only gravity acts on pebble. $F = mg = 0.05 \times 10 = 0.5$ N (taking $g = 10$ m/s²)

(b) During downward motion

Answer: Net force = 0.5 N downward **Explanation:** Same as upward motion - only gravity acts. Force is independent of direction of motion.

(c) At highest point where momentarily at rest

Answer: Net force = 0.5 N downward **Explanation:** Zero velocity ≠ zero force. Gravity still acts even when pebble is momentarily at rest.

For 45° angle: Answers remain same. Gravitational force is always vertically downward regardless of throwing angle.

4.3 Net force on stone of mass 0.1 kg:

(a) Just after dropped from stationary train

Answer: 1.0 N vertically downward **Explanation:** Only gravity acts. $F = mg = 0.1 \times 10 = 1.0$ N

(b) Just after dropped from train at constant 36 km/h

Answer: 1.0 N vertically downward **Explanation:** Same as (a). Stone's horizontal velocity doesn't affect gravitational force. No horizontal force once released.

(c) Just after dropped from train accelerating at 1 m/s²

Answer: 1.0 N vertically downward **Explanation:** Once released, stone has no connection to train.

Only gravity acts.

(d) Lying on floor of accelerating train (1 m/s^2)

Answer: $\sqrt{(1.01)} \approx 1.005$ N **Explanation:** Two forces: Weight (1.0 N down) and friction (0.1 N horizontal to accelerate with train). Net force = $\sqrt{(1^2 + 0.1^2)} = \sqrt{1.01}$ N

4.4 Circular motion force question

Answer: (i) T

Explanation: For circular motion, centripetal force = mv^2/l directed toward center. This is provided entirely by string tension T. The mv^2/l is not an additional force but describes what the tension must equal.

4.5 Retarding force problem

Given: F = 50 N, m = 20 kg, u = 15 m/s, v = 0

Solution: Using Newton's second law: a = F/m = -50/20 = -2.5 m/s^2 Using v = u + at: 0 = 15 + (-2.5)t **Answer:** t = 6 s

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4.6 Force calculation

Given: m = 3.0 kg, u = 2.0 m/s, v = 3.5 m/s, t = 25 s

Solution: Acceleration: a = (v-u)/t = (3.5-2.0)/25 = 0.06 m/s^2 Force: F = ma = 3.0 × 0.06 = 0.18 N **Answer:** 0.18 N in direction of motion

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4.7 Perpendicular forces

Given: $m = 5$ kg, $F_1 = 8$ N, $F_2 = 6$ N (perpendicular)

Solution: Net force: $F = \sqrt{(8^2 + 6^2)} = \sqrt{(64 + 36)} = 10$ N Acceleration: $a = F/m = 10/5 = 2\ m/s^2$ Direction: $\tan^{-1}(6/8) = 36.87°$ from 8 N force **Answer:** $2\ m/s^2$ at 36.87° from the 8 N force

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4.8 Three-wheeler braking

Given: $u = 36$ km/h = 10 m/s, $v = 0$, $t = 4$ s, total mass = 465 kg

Solution: Deceleration: $a = (0-10)/4 = -2.5\ m/s^2$ Retarding force: $F = ma = 465 \times 2.5 = 1162.5$ N **Answer:** 1163 N (approximately)

4.9 Rocket thrust

Given: $m = 20{,}000$ kg, $a = 5.0\ m/s^2$ upward

Solution: Forces on rocket: Thrust (up) - Weight (down) = ma Thrust - mg = ma Thrust = m(g + a) = 20,000(10 + 5) = 300,000 N **Answer:** 3.0×10^5 N

4.10 Body under constant force

Given: $m = 0.4$ kg, $u = 10$ m/s (north), $F = 8.0$ N (south), $t = 30$ s

Solution: Taking north as positive:

- $a = F/m = -8.0/0.4 = -20\ m/s^2$
- At $t = 0$: $x = 0$, $v = 10$ m/s

Using kinematic equations:

- **t = -5 s:** $x = -10(-5) + \frac{1}{2}(-20)(-5)^2 = 50 - 250 = -200$ m
- **t = 25 s:** $x = 10(25) + \frac{1}{2}(-20)(25)^2 = 250 - 6250 = -6000$ m
- **t = 100 s:** $x = 10(100) + \frac{1}{2}(-20)(100)^2 = 1000 - 100{,}000 = -99{,}000$ m

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4.11 Stone dropped from moving truck

Given: Truck acceleration = 2.0 m/s^2, t = 10 s when stone dropped

At t = 10 s: Truck velocity = $2.0 \times 10 = 20$ m/s

(a) Stone's velocity at t = 11 s

Horizontal component: 20 m/s (unchanged) **Vertical component:** $gt = 10 \times 1 = 10$ m/s
Resultant velocity: $\sqrt{(20^2 + 10^2)} = \sqrt{500} = 22.36$ m/s

(b) Stone's acceleration at t = 11 s

Answer: 10 m/s^2 vertically downward (only gravity acts)

4.12 Pendulum bob trajectories

Given: m = 0.1 kg, l = 2 m, v = 1 m/s at mean position

(a) String cut at extreme position

Answer: Straight vertical line downward **Explanation:** At extreme position, velocity = 0. Stone falls under gravity alone.

(b) String cut at mean position

Answer: Parabolic trajectory **Explanation:** Stone has horizontal velocity (1 m/s) and falls under gravity, creating projectile motion.

4.13 Man on weighing scale in lift

Given: m = 70 kg

(a) Upward with uniform speed 10 m/s

Answer: 700 N **Explanation:** No acceleration, so normal force = weight = mg

(b) Downward acceleration 5 m/s^2

Answer: 350 N **Explanation:** N = m(g - a) = 70(10 - 5) = 350 N

(c) Upward acceleration 5 m/s^2

Answer: 1050 N
Explanation: N = m(g + a) = 70(10 + 5) = 1050 N

(d) Free fall (lift mechanism failed)

Answer: 0 N **Explanation:** Both man and scale accelerate at g downward, no contact force.

4.14 Position-time graph analysis

Given: m = 4 kg, from graph: slopes change at t = 0 and t = 4 s

(a) Forces:

- **t < 0:** Constant slope = constant velocity, F = 0

- **0 < t < 4 s:** Parabolic curve suggests constant acceleration From graph: $a = 1\ m/s^2$, so $F = ma = 4\ N$
- **t > 4 s:** Constant slope again, $F = 0$

(b) Impulses:

- **At t = 0:** Velocity changes from 0 to 2 m/s, Impulse = 4 × 2 = 8 N·s
- **At t = 4 s:** Velocity changes from 6 to 4 m/s, Impulse = 4 × (-2) = -8 N·s

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4.15 Connected masses with applied force

Given: $m_1 = 10$ kg, $m_2 = 20$ kg, F = 600 N

(i) Force applied to A (10 kg)

System acceleration: $a = F/(m_1 + m_2) = 600/30 = 20\ m/s^2$ For mass B: $T = m_2 a = 20 \times 20 = 400$ N **Answer:** Tension = 400 N

(ii) Force applied to B (20 kg)

Same system acceleration: $a = 20\ m/s^2$ For mass A: $T = m_1 a = 10 \times 20 = 200$ N **Answer:** Tension = 200 N

4.16 Atwood machine

Given: $m_1 = 8$ kg, $m_2 = 12$ kg

Solution: For 12 kg: $12g - T = 12a$ For 8 kg: $T - 8g = 8a$ Adding: $4g = 20a$, so $a = g/5 = 2\ m/s^2$ $T = 8g + 8a = 8(10 + 2) = 96$ N

Answer: Acceleration = $2\ m/s^2$, Tension = 96 N

4.17 Nuclear disintegration

Solution: Initially: Total momentum = 0 (nucleus at rest) After disintegration: $p_1 + p_2 = 0$ (momentum conservation) Therefore: $p_1 = -p_2$

This means the two products must have equal and opposite momenta, proving they move in opposite directions.

4.18 Billiard ball collision

Given: m = 0.05 kg each, u = 6 m/s each (opposite directions)

Solution: Taking positive direction for one ball: Initial momentum of one ball = 0.05 × 6 = 0.3 kg·m/s Final momentum of same ball = 0.05 × (-6) = -0.3 kg·m/s Change in momentum = -0.3 - 0.3 = -0.6 kg·m/s

Answer: Impulse on each ball = 0.6 N·s (opposite directions)

4.19 Gun recoil

Given: m_{shell} = 0.02 kg, M_{gun} = 100 kg, v_{shell} = 80 m/s

Solution: By momentum conservation: $M_{gun} \times v_{gun} + m_{shell} \times v_{shell} = 0$ $100 \times v_{gun} + 0.02 \times 80 = 0$ $v_{gun} = -1.6/100 = -0.016$ m/s

Answer: Recoil speed = 0.016 m/s (opposite to shell)

4.20 Ball deflection

Given: $m = 0.15$ kg, $v = 54$ km/h $= 15$ m/s, deflection = 45°

Solution: Initial momentum: $p_i = 0.15 \times 15 = 2.25$ kg·m/s Final momentum: same magnitude, 45° deflection Change in momentum magnitude $= p_i\sqrt{(2 - 2\cos 45°)} = 2.25\sqrt{(2 - \sqrt{2})} = 1.95$ kg·m/s

Answer: Impulse = 1.95 N·s

4.21 Stone in circular motion

Given: $m = 0.25$ kg, $r = 1.5$ m, $f = 40$ rev/min

Solution: $\omega = 2\pi \times 40/60 = 4.19$ rad/s $v = \omega r = 4.19 \times 1.5 = 6.28$ m/s Tension $= mv^2/r = 0.25 \times (6.28)^2/1.5 = 6.57$ N

For maximum tension (200 N):
$v_{max} = \sqrt{(T_{max} \times r/m)} = \sqrt{(200 \times 1.5/0.25)} = 34.6$ m/s

Answer: Tension = 6.57 N, Maximum speed = 34.6 m/s

4.22 String breaks suddenly

Answer: (b) The stone flies off tangentially from the instant the string breaks

Explanation: By Newton's first law, when string breaks, no centripetal force acts. Stone continues with whatever velocity it had at that instant, which is tangential to the circle.

4.23 Conceptual explanations:

(a) Horse cannot pull cart in empty space

Answer: No friction/reaction force available. Horse needs to push against something (ground) to generate forward force via Newton's third law.

(b) Passengers thrown forward when bus stops

Answer: Due to inertia. Passengers' bodies tend to continue moving forward while bus stops, causing relative forward motion.

(c) Easier to pull than push lawn mower

Answer: When pulling, normal force on wheels reduces, decreasing friction. When pushing, normal force increases, increasing friction.

(d) Cricketer moves hands backward while catching

Answer: Increases contact time, reducing average force needed to stop the ball (impulse-momentum theorem: $F \cdot \Delta t = \Delta p$).

Note: All solutions use $g = 10\ m/s^2$ as specified in the exercise introduction. For more precise calculations in competitive exams, use $g = 9.8\ m/s^2$.