PHYSICS – CLASS XI

Chapter 4 : Laws of Motion

SOLUTIONS AND MARKING SCHEME (Step-by-Step)

Marks for each step are shown in brackets. Alternative correct methods carry full marks.

Quick answer key – Section A

Q	1	2	3	4	5	6	7	8
Ans	(b)	(c)	(b)	(a)	(b)	10 N s	4 N	(a)

SECTION A

1. **Ans: (b) 2 m s⁻².** **(1)**

Net force = $\sqrt{(8^2 + 6^2)}$ = 10 N. $a = F/m = 10/5 =$ **2 m s⁻²**.

2. **Ans: (c) 10 kg m s⁻¹.** **(1)**

$\Delta p = m(-v) - m(v) = -2mv$, so $|\Delta p| = 2 \times 0.5 \times 10 =$ **10 kg m s⁻¹**.

3. **Ans: (b) 6 N.** **(1)**

Common acceleration $a = 10/(2 + 3) = 2$ m s⁻². Contact force on the 3 kg block = $3 \times 2 =$ **6 N**.

4. **Ans: (a).** **(1)**

Action and reaction are equal and opposite but act on different bodies, so they cannot cancel each other. R correctly explains A.

5. **Ans: (b) 15 N.** **(1)**

$(f_s)_{max} = \mu_s mg = 0.4 \times 50 = 20$ N. The applied force (15 N) is less than 20 N, so the block does not move and static friction equals the applied force: **15 N**.

6. **Ans: 10 N s; 10 kg m s⁻¹.** **(1)**

Impulse = area under the F–t graph = $20 \times 0.5 =$ **10 N s** (½). Change in momentum = impulse = **10 kg m s⁻¹**. (½)

7. **Ans: 4 N.** **(1)**

Tension supplies the centripetal force: $T = mv^2/R = 0.5 \times 16/2 =$ **4 N**.

8. **Ans: (a) 1/√3.** **(1)**

At the point of sliding, $\tan\theta = \mu_s$, so $\mu_s = \tan 30° =$ **1/√3**.

SECTION B

9. **(2)**

Treat the two blocks as a system: $a = F/(m_1 + m_2) = 50/10 =$ **5 m s⁻²**. (1)

The string alone accelerates the 4 kg block: $T = 4 \times 5 =$ **20 N**. (Check: $50 - T = 6 \times 5 \rightarrow T = 20$ N.) (1)

10. **(2)**

(i) $N = mg = 100$ N, so $f_k = \mu_k N = 0.3 \times 100 =$ **30 N**. (1)

(ii) $F - f_k = ma \rightarrow 50 - 30 = 10a \rightarrow a =$ **2 m s⁻²**. (1)

11. Let the (equal) contact time be Δt. By the second law, the force on A by B: $\mathbf{F}_{AB}\Delta t = \mathbf{p}'_A - \mathbf{p}_A$, and on B by A: $\mathbf{F}_{BA}\Delta t = \mathbf{p}'_B - \mathbf{p}_B$. (1) **(2)**
By the third law $\mathbf{F}_{AB} = -\mathbf{F}_{BA}$, so $\mathbf{p}'_A - \mathbf{p}_A = -(\mathbf{p}'_B - \mathbf{p}_B)$, i.e. $\mathbf{p}'_A + \mathbf{p}'_B = \mathbf{p}_A + \mathbf{p}_B$. Total momentum is conserved. (1)

OR

Initially both are at rest, so total momentum = 0. After firing: $m_b v_b + m_g v_g = 0$. (1)
$v_g = m_b v_b / m_g = 0.025 \times 400/5 = \mathbf{2\ m\ s^{-1}}$, opposite to the bullet. (1)

12. Equilibrium of the 6 kg mass: vertically $T\cos 37° = mg = 60$ N; horizontally $T\sin 37° = F$. (1) **(2)**
$T = 60/0.8 = \mathbf{75\ N}$; $F = mg\tan 37° = 60 \times 3/4 = \mathbf{45\ N}$. (1)

SECTION C

13. Scale reading N is the normal reaction; take $mg = 600$ N. **(3)**
(i) Upward acceleration: $N - mg = ma \rightarrow N = 60(10 + 2) = \mathbf{720\ N}$. (1)
(ii) Downward acceleration: $mg - N = ma \rightarrow N = 60(10 - 2) = \mathbf{480\ N}$. (1)
(iii) Free fall, $a = g$: $N = m(g - g) = \mathbf{0}$ (apparent weightlessness). (1)

14. **(i)** FBD of 15 kg block: weight 150 N down, normal reaction $N = 150$ N up, tension T towards the pulley, kinetic friction $f = 0.2 \times 150 = 30$ N opposite to motion. FBD of 5 kg block: weight 50 N down, tension T up. (1) **(3)**
(ii) For the 5 kg block: $50 - T = 5a$. For the 15 kg block: $T - 30 = 15a$. (½)
Adding: $20 = 20a \rightarrow a = \mathbf{1\ m\ s^{-2}}$. (1) Then $T = 30 + 15 \times 1 = \mathbf{45\ N}$. (½)

OR

(i) Static friction between the tyres and the road provides the centripetal force. (1)
(ii) Vertically $N = mg$. For no skidding, $mv^2/R \le \mu_s N = \mu_s mg$, so $v^2 \le \mu_s Rg$ and $\boldsymbol{v_{max} = \sqrt{(\mu_s Rg)}}$. (1)
(iii) $v_{max} = \sqrt{(0.45 \times 50 \times 10)} = \sqrt{225} = \mathbf{15\ m\ s^{-1}}$ (= 54 km h^{-1}). (1)

15. Forces on the block: weight $mg = 100$ N down, normal reaction N and friction f up the plane. Resolve along and perpendicular to the plane. **(3)**
(i) $N = mg\cos 37° = 100 \times 0.8 = \mathbf{80\ N}$. (1)
(ii) $f = mg\sin 37° = 100 \times 0.6 = \mathbf{60\ N}$ (up the plane). (1)
(iii) On the verge of sliding, $f = \mu_s N \rightarrow \mu_s = 60/80 = \mathbf{0.75}$ (= tan 37°). (1)

SECTION D

16. **(a)** $N_A = 40$ N, $N_B = 60$ N. $f_A = 0.2 \times 40 = \mathbf{8\ N}$; $f_B = 0.2 \times 60 = \mathbf{12\ N}$. (1) **(5)**
(b) System: $50 - (8 + 12) = (4 + 6)a \rightarrow a = 30/10 = \mathbf{3\ m\ s^{-2}}$. (1)
(c) For B alone: $N_{AB} - f_B = 6a$ (1) $\rightarrow N_{AB} = 6 \times 3 + 12 = \mathbf{30\ N}$. (Check for A: $50 - 30 - 8 = 12 = 4 \times 3$.) (1)
(d) Newton's third law: the force by B on A is equal and opposite, i.e. **30 N** directed backwards. (1)

OR

(a) If no external force acts on a system of particles, its total linear momentum remains constant (conserved). (1)
(b) $3 \times 4 + 0 = 3 \times 2 + 1 \times v_B \rightarrow v_B = \mathbf{6\ m\ s^{-1}}$ in the original direction. (1)
(c) Impulse = change in momentum. On B: $1 \times 6 - 0 = \mathbf{6\ N\ s}$ (forward). On A: $3 \times 2 - 3 \times 4 = \mathbf{-6\ N\ s}$ (backward). (2)
(d) F_{av} = impulse/time = $6/0.02 = \mathbf{300\ N}$. (1)

17. **(a)** The **tension in the string** (directed towards the centre). (1) **(5)**

(b) $T = mv^2/R = 0.4 \times 25/1.25 =$ **8 N**. (1)

(c) $T_{max} = mv_{max}^2/R \rightarrow v_{max}^2 = 50 \times 1.25/0.4 = 156.25$ (1) $\rightarrow v_{max} =$ **12.5 m s⁻¹**. (1)

(d) With no force towards the centre, by the first law the stone moves along the **tangent** to the circle at that point with its instantaneous speed (a straight line). (1)

OR

(a) FBD: weight mg vertically downwards and normal reaction N perpendicular to the track (tilted towards the centre by θ). (1)

(b) Vertical: $N \cos\theta = mg$. Horizontal (centripetal): $N \sin\theta = mv^2/R$. (1) Dividing: $\tan\theta = v^2/Rg \rightarrow$ **$v = \sqrt{(Rg \tan\theta)}$**. (1)

(c) $v = \sqrt{(90 \times 10 \times 1/4)} = \sqrt{225} =$ **15 m s⁻¹** $= 15 \times 18/5 =$ **54 km h⁻¹**. (1)

(d) At lower speed the car tends to slide down the slope, so friction acts **up the slope**. (1)

— END OF SOLUTIONS —