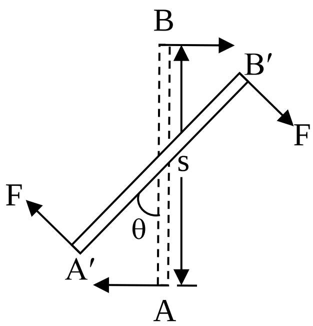
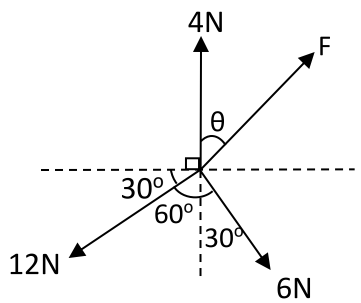
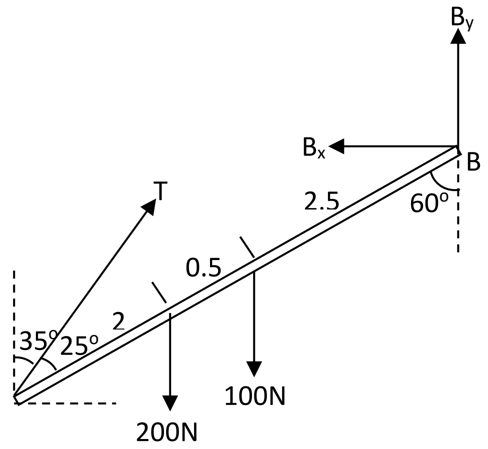
Qn	Answer	Marks
1 (a)	(i)…. two equal but unlike parallel forces whose lines of action are not the same.	1
	(ii) The moment of a force about a given point is the product of the force and the perpendicular distance from the point to the line of action of the force.	1
(b)	 Let the lines of action of the forces, F, be separated by a distance s. Suppose AB rotates through an angle θ, in radians, to position A′B′. The displacement of each of the forces, F, is $\frac{1}{2}s\theta$ The total work done by the two forces is $W = F.s\theta$ i.e. $W = T.\theta$ where T is the torque. ∴ **Work done by a couple = torque x angle of rotation**	1 1 1 1
(c)	 Let F be the additional force at an angle θ to the 4N force Then $F\sin\theta + 6\sin 30^\circ - 12\cos 30^\circ = 0$ ∴ $F\sin\theta = 12\cos 30^\circ - 6\sin 30^\circ$ $= 6\sqrt{3} - 3 = 7.39$ N and $F\cos\theta + 4 - 6\cos 30^\circ - 12\cos 60^\circ = 0$ ∴ $F\cos\theta = 6\cos 30^\circ + 12\cos 60^\circ - 4$ $= 3\sqrt{3} + 6 - 4 = 7.20$ N ∴ $F = \sqrt{7.39^2 + 7.20^2} = \sqrt{54.61 + 51.84}$ $=$ **10.32 N** Now $\tan\theta = \frac{F\sin\theta}{F\cos\theta} = \frac{7.39}{7.20} =$ **45.7°**	1 1 ½ 1 ½ 1 1

(c) (i)



Taking moments about the hinge, B

$T \times 5 \sin 25^o = 100 \times 2.5 \sin 60^o + 200 \times 3 \sin 60^o$ …. (1) — 1

$\therefore \quad T = \dfrac{216.5 + 519.6}{2.11} = \mathbf{348.9\ N}$ — 1

(ii) $B_x = T \sin 35^o = 348.9 \sin 35^o = 200$ N — 1½

and $B_y + T \cos 35^o = 200 + 100$ — 1

$\therefore \quad B_y = 300 - 348.9 \cos 35^o = 14.2$ N — ½

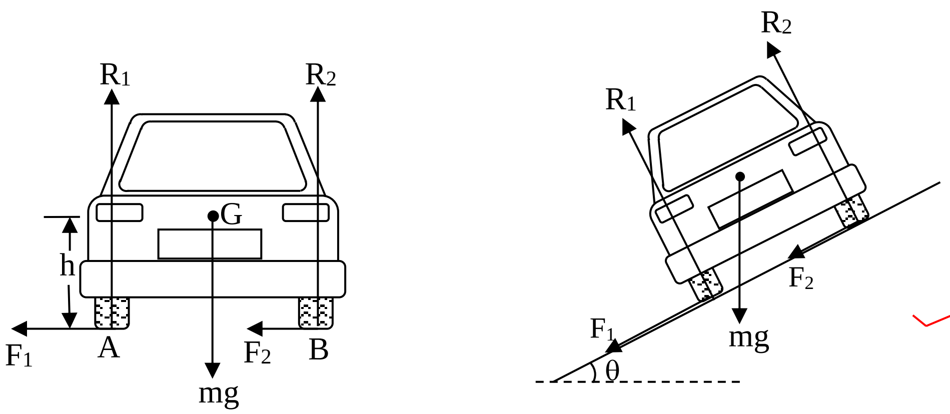
$\therefore$ Reaction at B $= \sqrt{200^2 + 14.2^2}$ — 1

$= \mathbf{200.5\ N}$

at an angle $\theta = \tan^{-1}\left(\dfrac{200}{14.2}\right)$ to the vertical $= \mathbf{85.9^o}$ — 1

Total = 20

2 (a)

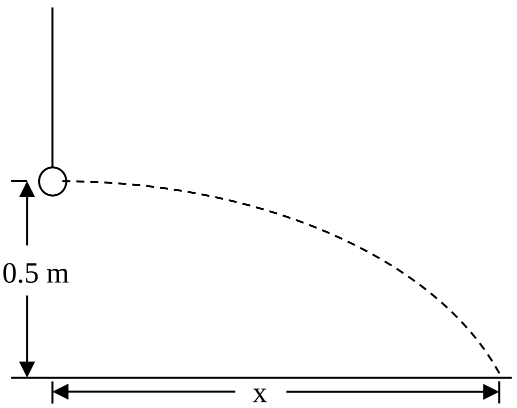
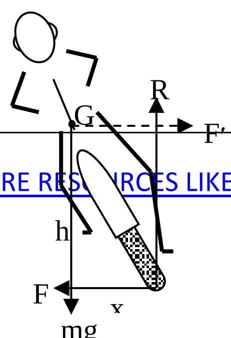


(i) Unbanked (ii) Banked — 1

On an unbanked track the only forces constituting the centripetal force are the frictional forces F_1 and F_2 at the tyres. — 1

If v_1 is the velocity when the car is on the point of sliding sideways, then

$$\frac{mv_1^2}{r} = F_1 + F_2 = \mu(R_1 + R_2) \quad \ldots\ldots\ldots\ldots (1)$$ — ½

	When the track is banked, the horizontal components of the normal forces R_1 and R_2 also contribute to the centripetal force. If v_2 is the velocity when the car is on the point of sliding outwards, then $\frac{mv_2^2}{r} = (F_1 + F_2)\cos\theta + \mu(R_1 + R_2)\sin\theta$ $= \mu(R_1 + R_2)\cos\theta + (R_1 + R_2)\sin\theta$ $= (R_1 + R_2)(\mu\cos\theta + \sin\theta)$ ………… (2) From (1) and (2) it is clear that $v_2 > v_1$	1 ½
(b)	 (i) It will break when the stone is in the lowest position because the tension at that point will be $T = mg + mr\omega^2$, where r is the length of the string and ω the angular speed	1 1
	(ii) $mg + mr\omega^2 = 20$ $g + r\omega^2 = \frac{20}{m}$ $\therefore\ 9.81 + 0.5\omega^2 = \frac{20}{0.5} = 40$ $\therefore\ \omega^2 = \frac{40 - 9.81}{0.5} = 60.4$ $\therefore\ \omega = \sqrt{60.4} =$ **7.77 radians**	1 ½ ½ 1
	(iii) The stone sets off with a speed $v = r\omega = 0.5 \times 7.77$ Let t be the time to hit the ground. Then, using $s = ut + \frac{1}{2}at^2$ $0.5 = 0 + \frac{1}{2} \times 9.81t^2$ $\therefore\ t = \sqrt{\frac{0.5}{4.905}}$ 0.319 s The stone lands at a distance x = vt away $= 0.5 \times 7.77 \times 0.319$ = **1.24 m**	½ ½ ½ ½ 1
(c)	 	

	The weight, mg, of the rider and his bicycle, is concentrated at the centre of gravity, G. For him to describe a circle, a force, F, must act on him towards the centre of the circle and this is provided by the frictional force at the road surface. Now, a horizontal centrifugal force, F' equal to F, acts on him through G. This produces a moment that would topple the rider outwards. So he leans inwards so as that his weight provides an equal counterbalancing moment. i.e Fh = mgx	½ ½ ½ ½ ½ ½
(d)	(i) …an orbit round a planet in which a satellite always remains positioned vertically above the same point on the planet's surface.	1
	(ii) Let m = mass of the satellite and ω = angular velocity in the orbit T = period Then $m(r+h)\omega^2 = \frac{GMm}{(r+h)^2}$ $\therefore\ m(r+h)\frac{4\pi^2}{T^2} = \frac{GMm}{(r+h)^2}$ But from equation at the earth's surface, $GM = gr^2$ Substituting for GM, we have $\frac{4\pi^2}{T^2} = \frac{gr^2}{(r+h)^3}$ $\therefore\ T = \sqrt{\frac{4\pi^2(r+h)^3}{gr^2}}$	1 ½ ½ 1
	(iii) Now $(r+h)^3 = \frac{gr^2T^2}{4\pi^2}$ $\therefore\ h = \sqrt[3]{\frac{gr^2T^2}{4\pi^2}} - r$ $= \sqrt[3]{\frac{9.81\times(6.4\times10^6)^2\times(24\times3.6\times10^3)^2}{4\pi^2}} - 6.4 \times 10^6$ $= 42.35 \times 10^6 - 6.4 \times 10^6$ $= \mathbf{3.6 \times 10^6\ m}$	½ ½ 1
	Total = 20	