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| **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) | s  F  F  B  A  B′  A′  θ  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  sθ  The total work done by the two forces is  W = F.sθ  i.e. W = T.θ  where T is the torque.  ∴**Work done by a couple = torque x angle of rotation** | 1  1  1  1 |
| (c) | 4N  30o  12N  6N  60o  30o  F  θ  Let F be the additional force at an angle θ to the 4N force  Then F sinθ + 6 sin 30o – 12 cos 30o = 0  ∴ F sinθ = 12 cos 30o - 6 sin 30o  = 6- 3 = 7.39 N  and F cosθ + 4 - 6 cos 30o – 12 cos 60o = 0  ∴ F cosθ = 6 cos 30o + 12 cos 60o – 4  = 3 + 6 – 4 = 7.20 N  ∴ F =  =  = **10.32 N**  Now tan θ =  = **45.7o** | 1  1  ½  1  ½  1  1 |
| (c) | (i)  0.5  2.5  2  T  By  Bx  100N  200N  60o  35o  25o  B  Taking moments about the hinge, B  T x 5 sin 25o = 100 x 2.5 sin 60o + 200 x 3 sin 60o …. (1)  ∴ T =  = **348.9 N** | 1  1  1 |
| (ii) Bx = T sin 35o = 348.9 sin 35o = 200 N  and By + T cos 35o = 200 + 100  ∴ By = 300 – 348.9 cos 35o = 14.2 N  ∴ Reaction at B =  = **200.5 N**  at an angle θ = tan-1 to the vertical = **85.9o** | 1½  1  ½  1  1 |
| ***Total = 20*** | | |
| 2 (a) | R2  R1  mg  θ  F1  F2  R1  R2  h  G  F1  F2  A  B  mg  R1  R2  h  G  F1  F2  A  B  mg  R1  R2  h  G  F1  F2  A  B  mg    (i) Unbanked (ii) Banked  On an unbanked track the only forces constituting the centripetal force are the frictional forces F1 and F2 at the tyres.  If v1 is the velocity when the car is on the point of sliding sideways, then  = F1 + F2 = μ(R1 + R2) ………… (1)  When the track is banked, the horizontal components of the normal forces R1 and R2 also contribute to the centripetal force.  If v2 is the velocity when the car is on the point of sliding outwards, then  = (F1 + F2) cos θ + μ(R1 + R2) sin θ  = μ(R1 + R2) cos θ + (R1 + R2) sin θ  = (R1 + R2)(μcos θ + sin θ) …………. (2)  From (1) and (2) it is clear that v2 > v1 | 1  1  ½  1  ½ |
| (b) | 0.5 m  x  (i) It will break when the stone is in the lowest position  because the tension at that point will be T = mg + mrω2 ,  where r is the length of the string and ω the angular speed | 1  1 |
| (ii) mg + mrω2 = 20  g + rω2 =  ∴ 9.81 + 0.5ω2 =  = 40  ∴ ω2 =  = 60.4  ∴ ω =  = **7.77 radians** | 1  ½  ½  1 |
| (iii) The stone sets off with a speed v = rω = 0.5 x 7.77  Let t be the time to hit the ground.  Then, using s = ut + at2  0.5 = 0 + x 9.81t2  ∴ t =  0.319 s  The stone lands at a distance x = vt away  = 0.5 x 7.77 x 0.319  = **1.24 m** | ½  ½  ½  ½  1 |
| (c) | G  R  F  mg  F׳  x  h    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, Fꞌ 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)ω2 =  ∴ m(r + h) =  But from equation at the earth’s surface, GM = gr2  Substituting for GM, we have  =  ∴ T = | 1  ½  ½  1 |
| (iii) Now (r + h)3 =  ∴ h =  - r  =  - 6.4 x 106  = 42.35 x 106 - 6.4 x 106  = **3.6 x 106 m** | ½  ½  1 |
| ***Total = 20*** | | |