Physics ATAR - Year 12

Gravity and Motion
Test 2
2018

Name:	Mark: / 51 = %

Time Allowed: 50 Minutes

Notes to Students:

1. You must include **all** working to be awarded full marks for a question.
2. Marks will be deducted for incorrect or absent units and answers stated to an incorrect number of significant figures.
3. **No** graphics calculators are permitted – scientific calculators only.

Question 1 **(3 marks)**

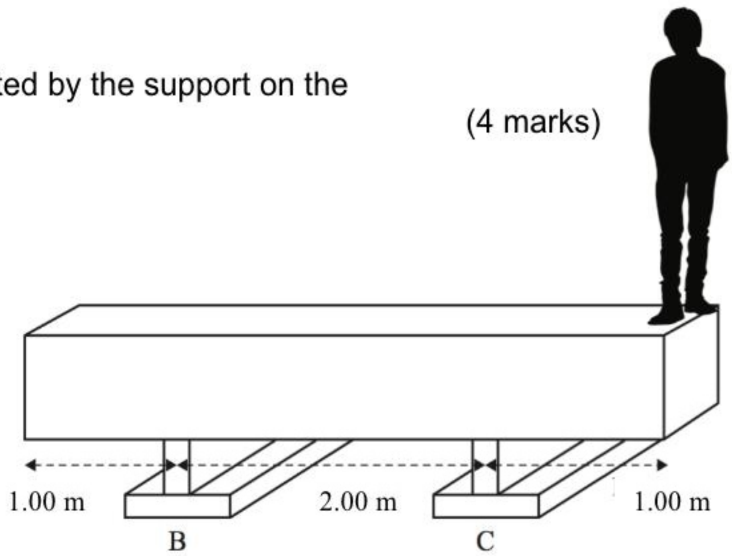
Roger states that there are a number of situations on or near Earth's surface where a person may 'feel weightless'. Mark states that this is impossible. It is only possible to feel weightless in deep space where there is no, or infinitely little, gravitational force on a person. State who is correct with an explanation to support your answer.

- Roger is correct
- Apparent Weightlessness occurs when there is no normal force acting
  Or
- A persons Apparent Weight is determined by the normal force acting on the person
- This can occur when an object is in freefall or falling at the same rate as the surface

Question 2 **(7 marks)**

A 70.0 kg man stands on the end of a 125 kg park bench of uniform mass, as shown in the diagram below. The supports B and C are not rigidly connected to the ground and is held in place by its weight.

(a) Calculate the magnitude of the force exerted by the support on the bench at point C. (4 marks)



$\Sigma\tau = 0$ $\tau = rFsin\theta$ (1)

$cwm = acwm$

Taking Pivot about B

$1.00(125 \times 9.8) + 3.00(70 \times 9.8) = 2(F_C)$ (2)

$F_C = \frac{3283}{2}$

$F_C = 1640$ N (3.s.f) (1)

(b) Using an appropriate calculation to support your answer, determine if the bench will topple if the person stands at this point. (3 marks)

C.O.M from B

$x_{cm} = \frac{m1x_1 + m2x_2}{m1 + m2}$ (1)

$= \frac{125(1) + 70(3)}{125 + 70}$ (1)

= 1.72 m from B (Hence stable) (1)

OR

Reaction force at F_B

$\Sigma Fy = 0 = W_{person} + W_{bench} + F_B + F_C$ (1)

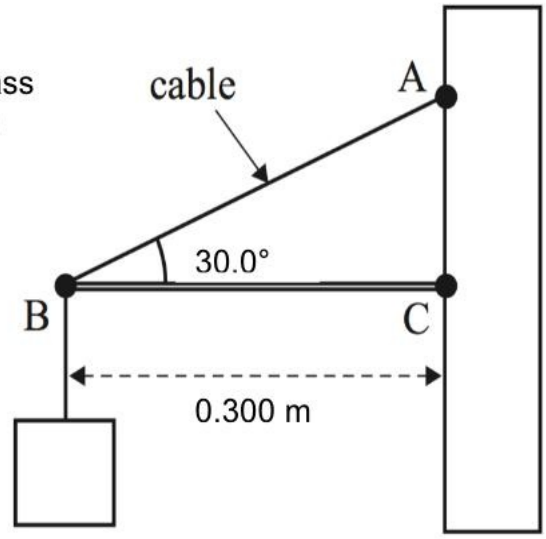
$F_B = - F_C - W_{person} - W_{bench}$ (1)

$= -(1640) - (70 \times -9.8) - (125 \times -9.8)$

= 271 N Upwards. (Hence stable) (1)

Question 3 **(9 marks)**

A horizontal beam, C is attached to a wall, as shown below. The mass of the beam is 0.200 kg and there is a hanging mass at point B. Point C is a hinge and the cable is attached an angle of 30.0° to the beam.



(a) If the tension in the cable is 17.3 N, calculate the mass hanging at point B. (4 marks)

$\Sigma\tau = 0$ $\tau = rF\sin\theta$ (1)

$cwm = acwm$

Taking pivot about C

0.3(mx9.8) + 0.15(0.2x9.8) = 0.3(17.3)(sin30) (2)

2.94m + 0.294 = 2.595

m = $\frac{2.595-0.294}{2.94}$

= 0.783 kg (1)

(b) Calculate the reaction force the hinge exerts on the beam at Point C. (If you could not do (a), use m = 0.650 kg) (5 marks)

$\Sigma F_y = 0$ = W_{beam} + W_{mass} + Tsin30 + F_{RY} (½)

F_{RY} = - W_{beam} - W_{mass} - Tsin30

= -(0.2x-9.8) –(0.783x-9.8) – 17.3sin30 (1)

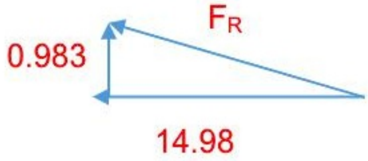
= + 0.983 N

$\Sigma F_x = 0$ = Tcos30 + F_{Rx} (½)

F_{RX} = - Tcos30

= 17.3cos30 (1)

= + 14.98 N



$F_R = \sqrt{14.98^2 + 0.983^2}$ $\theta = \tan^{-1}\left(\frac{0.983}{14.98}\right)$

= 15.0 N (½) = 3.76° (½)

F_R = 15.0 N @ 3.76° above horizontal (1)

Question 4 **(10 marks)**

A spacecraft is placed in orbit around Saturn so that it is Saturn-stationary (the Saturn equivalent of Geostationary: the spacecraft is always over the same point on Saturn's surface on the equator). The following information may be needed.

mass of Saturn: 5.68×10^{26} kg
mass of spacecraft: 2.00×10^{3} kg
period of rotation of Saturn: 10 hours 15 minutes
equatorial radius of Saturn: 6.03×10^{7} m

(a) Show the derivation of Kepler's 3rd Law

(3 marks)

$\Sigma F = F_c = F_g$ (½) $v = \frac{2\pi r}{T}$ (½)

$$\frac{mv^2}{r} = \frac{Gm1m2}{r^2}$$

$$\frac{m\frac{4\pi r^2}{T^2}}{r} = \frac{Gm1m2}{r^2}$$ (1)

$$\frac{4m2\pi r}{T^2} = \frac{Gm2}{r^2}$$

→ $$\frac{r^3}{T^2} = \frac{Gm2}{4\pi^2}$$ (1)

(b) Calculate the altitude of the space craft in this Saturn-stationary position.

(4 marks)

Set T = 10 hours x 60 x 60 +15 x 60

= 36,900s (1)

$$r_o = \sqrt[3]{\frac{GMT^2}{4\pi^2}} = \sqrt[3]{\frac{(6.67\times10^{-11})(5.68\times10^{26})(36900)^2}{4\pi^2}}$$ (½) (½)

$r_o = 1.09 \times 10^8$ (1)

Alt $= 1.09 \times 10^8 - 6.03 \times 10^7$

$= 4.90 \times 10^7$ m (1)

(c) Calculate the gravitational field strength 'g' at the position of the satellite.
(if you could not complete (b), use $r_o = 7.50 \times 10^8$ m)

(3 marks)

$$g = \frac{GM_S}{r_0^2}$$ (1)

$$g = \frac{(6.67\times10^{-11})(5.68\times10^{26})}{(1.09\times10^8)^2}$$ (1)

$= 3.19$ ms^{-2} towards centre of Saturn (1)

Question 5 **(3 marks)**

The diagram below shows a spacecraft S at a point between the Jupiter and Ganymede at which the pull of the Jupiter on it is equal in magnitude to the pull of the Ganymede on it. Use Newton's law of gravitation to express the mass of the Jupiter M_J as a ratio of the mass of Ganymede M_G.

$F_{gJ} = F_{gG}$ ½

$$\frac{Gmsm_J}{(9d)^2} = \frac{Gmsm_G}{d^2}$$ ½

$$\frac{m_J}{81d^2} = \frac{m_G}{d^2}$$ 1

$$\frac{m_J}{m_G} = 81$$ 1

Question 6 **(13 marks)**

A 15.0 kg ladder of uniform density rests against a window (no friction exists between the ladder and the window) as shown in the diagram below. A 50.0 kg painter stands 1.20 m from the bottom of the ladder.

(a) Calculate the reaction force of the window acting on the ladder to keep it stationary. (5 marks)

$l = \sqrt{1^2 + 3^2}$
$= 3.16$ m 1

$\theta = tan^{-1}(\frac{3}{1})$
$= 71.57°$

$\phi = 90 - 71.6$
$= 18.43°$

(angles not required if $r\perp$ is used)

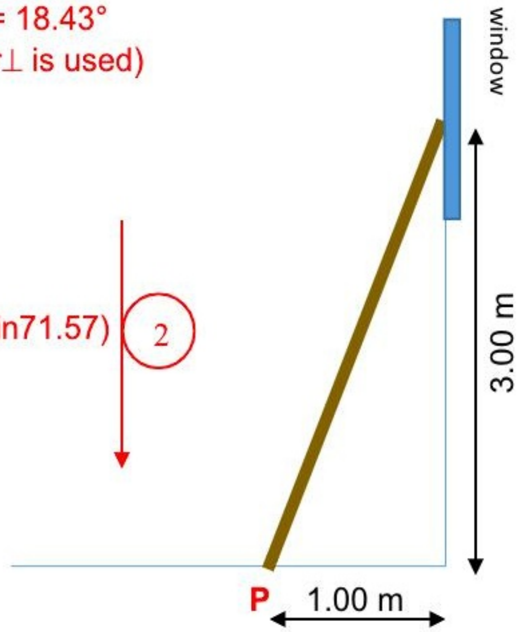
$\Sigma\tau = 0$ $\tau = rFsin\theta$
$cwm = acwm$ 1

Taking pivot about P

$(3.16/2)(15X9.8)(\sin 18.43) + 1.2(50x9.8)(\sin 18.43) = 3.16(F_R)(\sin 71.57)$ 2

$$F_R = \frac{259.3}{3.16\sin(71.57)}$$

$= 86.5$ N 1



(b) If the window can provide a reaction force of 150.0 N before breaking, determine, with the use of an appropriate calculation, whether the painter can climb to the top of the ladder.

(4 marks)

Set ACWM = rF$sin\theta$
= 3.16(150)sin71.57 (1)
= 450 Nm

With man at top
CWM = rFsinϕ + rFsinϕ
= (3.16/2)(15X9.8)(sin18.43) + 3.16(50x9.8)(sin18.43) (1)
= 562 Nm

Since the man would generate more torque than the maximum possible (1)

he cannot climb to the top (1)

Or, solving for r(max) using $\Sigma\tau = 0$
r = 2.43m
So cannot climb to the top.

Or Solving for F(max) using $\Sigma\tau = 0$
F = 187 N
So cannot climb to the top.

Ladders come with safety warnings, instructing users to not ascend to the top two steps as it may result in the bottom of the ladder slipping out when leaning against a wall

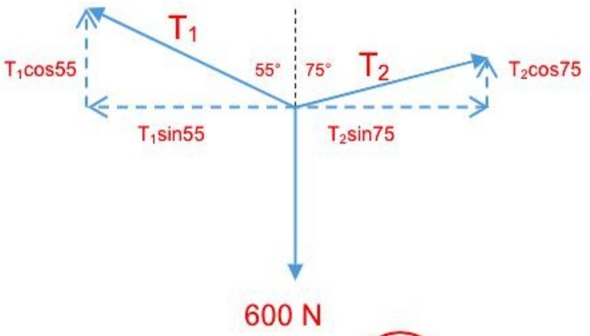
(c) Explain, using your knowledge of forces, torque and equilibrium how ascending the ladder increases the chances of the bottom of the ladder slipping out.

(4 marks)

- Ascending the ladder increased the torque as rF$sin\theta$
- To maintain rotational equilibrium, the counter torque must also increase
- This increases the reaction force of the wall and hence the required frictional force to maintain translational equilibrium
- Eventually the limit of static friction will be met and the ladder will begin to slip.

Question 7 **(6 marks)**

A gymnast of weight 6.00 x10^2 N is balancing in equilibrium on a slackline, producing a different tension force on either side of the gymnast. The angles of the two tensions to the vertical are shown below. Calculate the magnitude of both tension forces



$\Sigma Fx = 0$
$= T_2sin75 + T_1sin55$ (½) (1)

$\Sigma Fy = 0$
$= T_2cos75 + T_1cos 55 – 600$ (½) (1)

From ΣFx

$T_2 = \frac{T_1 sin55}{sin75}$ substitute in to ΣFy

$0 = \frac{T_1 sin55}{sin75}cos75 + T_1cos 55 – 600$ (2)

$0 = 0.219T_1 + 0.574T_1 - 600$

$0.7931T_1 = 600$

$T_1 = 757$ N

$T_2 = \frac{T_1 sin55}{sin75}$

$= \frac{757 sin55}{sin75}$ (1)

$= 642$ N

END OF TEST