Physics ATAR - Year 12

Gravity and Motion
Test 2
2016

Name: SOLUTIONS

Mark: / 57

= %

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 **(13 marks)**

A 1450 kg telecommunications satellite is placed into a geostationary orbit around the Earth.

(a) Explain why geostationary orbits are used for ground based communications.

(3 marks)

- Geostationary orbits have the same period of revolution as the rotation of the Earth
- Satellite remains in same position above the equator.
- To maintain communication with base station / station does not need to track the satellite.

(b) Calculate the distance it must be placed above the surface of the Earth, showing all derivations from know formulae.

(6 marks)

$Fg = Fc$ 0.5

$\frac{m_S v^2}{r} = \frac{G m_S M_E}{r^2}$ 0.5

$\frac{m_S 4\pi^2 r}{T^2} = \frac{G m_S M_E}{r^2}$ 0.5

$\frac{r^3}{T^2} = \frac{GM_E}{4\pi^2}$ 0.5

T = 24 x 60 x 60
= 86,400 s 1

$r_o = \sqrt[3]{\frac{GM_E T^2}{4\pi^2}}$ 0.5

0.5

$= \sqrt[3]{\frac{(6.67\times10^{-11})(5.97\times10^{24})(86400^2)}{4\pi^2}}$

$= 4.22 \times 10^7$ m 0.5

0.5

Alt = $r_o - R_E$
$= 4.22 \times 10^7 - 6.38 \times 10^6$
$= 3.58 \times 10^7$ m 1

(c) Calculate the gravitational force the Earth exerts on the Satellite. (if you could not answer 1(b), use $r_o = 4.82 \times 10^7$ m.

(3 marks)

$F_g = \frac{G m_s M_E}{r^2}$ 1

$= \frac{(6.67\times10^{-11})(5.97\times10^{24})(1450)}{(4.22\times10^7)^2}$ 1

$= 327\ N\ towards\ Earth$ 1

If student uses whole values, F = 324 N

(d) Calculate the orbital speed of the satellite. (3 marks)

$v = \frac{2\pi r}{T}$ 1

$= \frac{2\pi(4.22\times10^{7})}{86{,}400}$ 1

$= 3.07\times10^{3} m/s$ 1

OR

$Fg = Fc$ 0.5

$\frac{m_S v^2}{r} = \frac{G m_S m_E}{r^2}$ 0.5

$v^2 = \frac{G m_E}{r}$ 0.5

$v = \sqrt{\frac{(6.77\times10^{-11})(5.97\times10^{24})}{4.22\times10^{7}}}$ 0.5

$= 3.07\times10^{3} m/s$ 1

OR

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

$v = \sqrt{\frac{F_C\, r}{m}}$

$= \sqrt{\frac{324(4.22x10^{7})}{1450}}$

$= 3.07\times10^{3} m/s$

If $r_o = 4.82 \times 10^7$ m is used in part 1c)

then v = 2.87×10^3 m/s

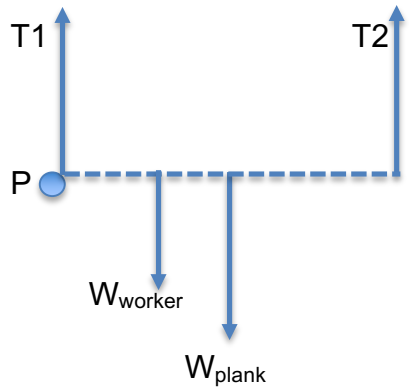
Question 2 **(3 marks)**

An astronaut aboard the Russian Soyuz spacecraft has just docked with the International Space Station that orbits the Earth at an altitude of 400 km. The astronaut comments that he is weightless while floating in the spacecraft. Explain whether the astronaut's statement is correct.

- No
- Weight still acts on astronaut as astronaut is still within the Earth's gravitational field.
- Apparent weight is zero as there is no Normal force exerted on the astronaut as both he and the ISS are accelerating at the same rate

Question 3 **(5 marks)**

An irregular 5.00 m long horizontal platform of mass 100 kg is suspended by a cable at each end. When an 80.0 kg worker stands 2.00 metres from the left cable, the tension in each cable is equal. Calculate the location of the centre of mass of the platform.



$\Sigma F = 0$ 0.5

$T1 + T2 - W_{Worker} - W_{Plank} = 0$ 0.5

T1 = T2 0.5

2T = W + W

2T = (80x9.8) + (100 x 9.8) 0.5

T = 882 N 0.5

$\Sigma\tau = 0$ 0.5

$\tau = r\,Fsin\theta$ 0.5

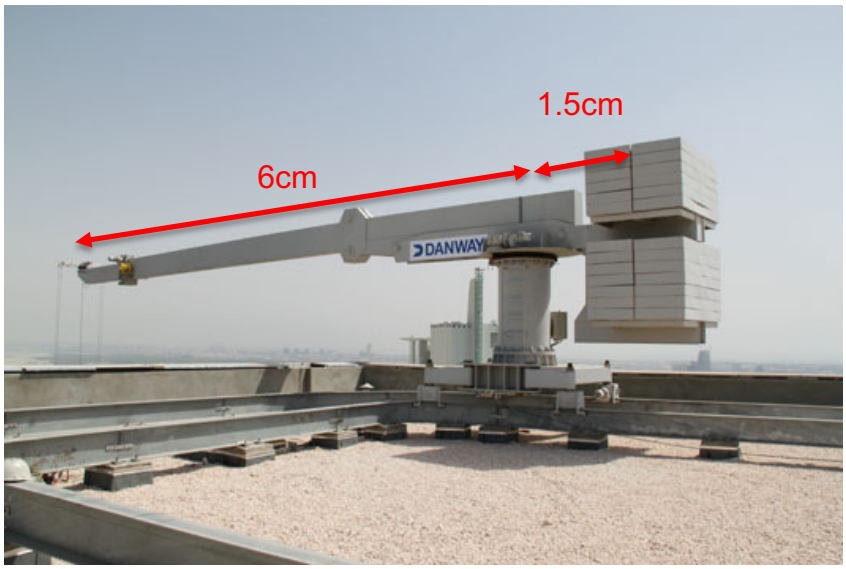
$2(80\times9.8) + r(100\times9.8) = 5(882)$ 0.5

$980r = 2842$

$r = 2.90\ from\ the\ left\ cable$ 1

Question 4 **(7 marks)**

A tall building's window cleaning platform has a large cantilever made of concrete slabs (shown in image), on the roof to support the platform and the workmen.



(a) Explain why the concrete slabs must be present.

(3 marks)

- Platform and workers produce an anticlockwise torque about cantilever base.
- Cantilever produces a clockwise torque
- To keep system in rotational equilibrium

(b) Use the diagram to calculate the mass of concrete slabs required if the cantilever is used to support the platform and workmen of combined mass of 2.00 x10^3 kg. Provide your measurements on the diagram.

(4 marks)

$r_2 = 4r_1$ 0.5

$\Sigma\tau = 0$ 0.5

$\tau = r\,F\sin\theta$ 0.5

$r_2 W = r_1 W_{Cantilever}$ 0.5

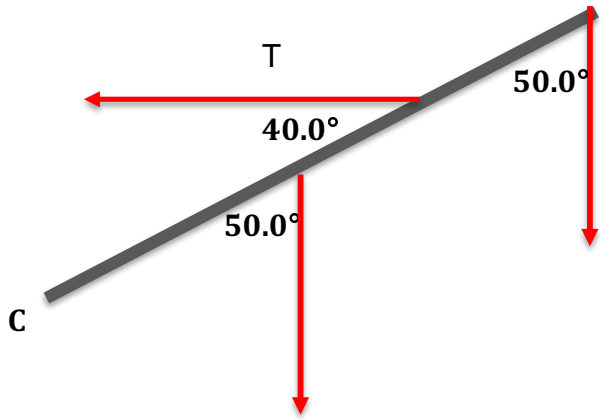
$4r_1(mg) = r_1(m_C g)$ 0.5

$m_{Cantilever} = 4m$ 0.5

= 8.00 x 10^3 kg 1

Question 5 **(16 marks)**

A 50.0 kg storefront sign is hung from a wall by a 3.00 m long rigid beam of uniform mass 30.0 kg and a cable as shown in the diagram below. The cable is attached 1.80 m from C along the beam.



(a) Calculate the tension in the cable. (4 marks)

$\Sigma\tau = 0$ 0.5

$\tau = r\,F sin\theta$ 0.5

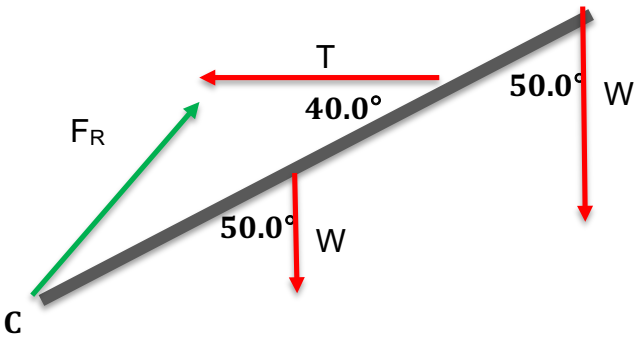
$1.5(30\times9.8)sin50 + 3(50\times9.8)sin50 = 1.8Tsin40$ 2

$$T = \frac{1.5(30\times9.8)sin50 + 3(50\times9.8)sin50}{1.8sin40}$$

$T = 1.27\times10^{3}\ N$ 1

(b) Calculate the the force exerted on the beam by the wall, at point C

(4 marks)

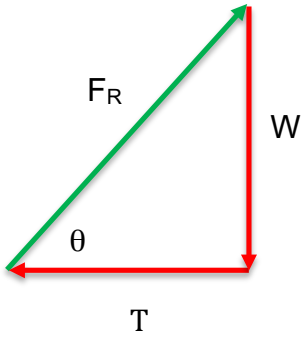


$\Sigma F = 0$ 0.5

$F_R + W_{beam} + W_{sign} + T = 0$ 0.5

$F_R = \sqrt{1265.25^2 + 784^2}$

$= 1.49 \times 10^3$ 1



$\theta = tan^{-1}\left(\frac{784}{1265.25}\right)$ 1

$= 31.8°$

$F_R = 1.49 \times 10^3$ N 31.8° above horizontal 1

OR

$\Sigma Fx = 0$ 0.5

$F_{RX} + T = 0$

$F_{RX} = 1265.25$ N →

$\Sigma Fy = 0$

$F_{RY} - W_{beam} - W_{sign} = 0$ 0.5

$F_{RY} = W + W$

$F_{Ry} = 784$N ↑

$F_R = \sqrt{1265.25^2 + 784^2}$ 1

$= 1.49 \times 10^3$

$\theta = tan^{-1}\left(\frac{784}{1265.25}\right)$

$= 31.8°$ 1

$F_R = 1.49 \times 10^3$ N 31.8° above horizontal to the right 1

(c) Calculate the maximum mass the sign could be if the cable is attached at point B and can withstand a maximum tension of 2.00 kN before breaking.

(4 marks)

$\Sigma\tau = 0$ 0.5

$\tau = r\,F sin\theta$ 0.5

$1.5(30\times9.8)sin50 + 3(M\times9.8)sin50 = 1.8(2.00\times10^3)sin40$ 2

$3(M\times9.8)sin50 = 1.8(2.00\times10^3)sin40 - 1.5(30\times9.8)sin50$

$$M = \frac{1.8(2.00\times10^3)sin40 - 1.5(30\times9.8)sin50}{3(9.8)sin50}$$

$M = 87.7\ kg$ 1

(d) The owner of store wants to mount the cable at point A, instead of B. State the effect this would have on the tension in the cable and explain your reasoning.

(4 marks)

As the system is still in rotational equilibrium 0.5

The c.w.τ must equal the a.c.w.τ 0.5

Since τ = r F sinθ 1

For the same torque, if r$\perp$ increases then F (tension) must decrease 1

OR

For the same torque, if θ approaches 90, sinθ increases,
then F (tension must decrease) 1

Question 6 **(7 marks)**

People often say that an easy way to lose "weight" is to stand in a position where the moon is directly overhead. A 60.0 kg person stands on Earth and waits until the moon is directly overhead. The gravitational force exerted by the Earth on the person is 586.962 N

(a) Calculate the net force acting on the person due to the positions of the Earth and the Moon, when the Moon is directly overhead. Give your answer to **6 significant figures.**

(4 marks)

0.5

$\Sigma F = F_E + F_M$ 0.5

$= -586.962 + \frac{Gm_pM_m}{r^2}$

$= -586.962 + \frac{6.67\times10^{-11}\times60\times7.35\times10^{22}}{(3.84\times10^8 - 6.38\times10^6)^2}$ 1

$= -586.926 + 0.00206738$ 0.5 0.5

$= -586.960\ N$

$= 586.960\ N\ \downarrow$ 1

(b) Use the values calculated in (a) to determine how many apparent grams of mass would the person feel they have lost when standing in this position.

(3 marks)

$mass_{apparent} = mass_{actual}\left(1 - \frac{\Sigma F}{F_E}\right)$ 1

OR award marks if student shows suitable logic in working out.

$= 60\left(1 - \frac{586.960}{586.962}\right)$ 1

$= 0.000204443\ kg$

$= 0.204443\ grams$ 1

Students need to use value given in question (586.962)
-1 mark if g = 9.8 m/s/s is used

Question 7 **(4 marks)**

A large construction crane, shown below, has extendable stabiliser legs that can allow the crane arm to lift a heavier load. Explain how the stabiliser legs allow the crane to do this.

- Stability requires the center of mass to be above the base
- of the crane.
- Lifting a large load at the end of the crane arm moves the center of mass towards the load.
- The stabilizer legs increase the length of the base of the crane
- Allowing the center of mass to remain within the base and maintain stability.

END OF TEST