ALL SAINTS' COLLEGE
Ewing Avenue, Bull Creek, Western Australia

12 Physics ATAR   Motion & Forces Test 2   March 2016

Time allowed: 50 minutes
Total marks available: 50
Show calculation answers to 3 significant figures

Student Name: ___________________________

1. Future Australian astronaut Gareth Spires is in a circular orbit around the Earth within a space station. The on-board gravitometer shows a field strength reading of 7.20 N kg^{-1}. Determine the altitude of Gareth above the Earth's surface.

(3)

g = 7.20   M = 5.97 x 10^{24} kg

$$g = \frac{GM}{r^2}$$

$$7.20 = \frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{r^2} \checkmark$$

r = 7 436 761.16779 m ✓

Altitude = r – r_{earth} = 7 436 761.16779 – 6.37 x 10^6 = 1.07 x 10^6 m ✓

2. Explain why distances between suns, planets and moons are, by default, given as the distance between their centres rather than from surface to surface.

(2)

The centre of mass of the planet is located at the centre of the sphere. ✓
The mass is conceptually and practically concentrated at this location for the action of the gravitational force. ✓ Or similar

3. Use other equations on your data sheet to derive the following equation:

(2)

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

$by\ substitution\ of\ v = \frac{2\pi r}{T}$ into $\frac{v^2}{r} = g = \frac{GM}{r^2}$
✓

Shows correct derivation ✓

4. The planet Ionas has a mass of 4.62×10^{25} kg and its moon Geogair a mass of 3.75×10^{23} kg. The gravitational force of attraction between the planet and the moon is 6.02×10^{19} N. Calculate the distance between the planet and the moon stating your answer in kilometres.

(3)

$$F = \frac{Gm_1m_2}{r^2}$$

$$6.02 \times 10^{19} = \frac{6.67 \times 10^{-11} \times 4.62 \times 10^{25} \times 3.75 \times 10^{23}}{r^2} \checkmark$$

$r = 4.38 \times 10^9$ m ✓

$r = 4.38 \times 10^6$ km ✓

5. A satellite of mass 950 kg is in a circular orbit at an altitude of 2500 km above the Earth's surface. Calculate the orbital speed of satellite.

(3)

$\frac{v^2}{r} = \frac{GM}{r^2}$ by derivation $v = \sqrt{\frac{GM}{r}}$

$r = 6.37 \times 10^6 + 2\,500\,000 = 8.87 \times 10^6$ ✓

$$v = \sqrt{\frac{6.67 \times 10^{-11} \times 5.97 \times 10^{24}}{8.87 \times 10^6}} \checkmark$$

$v = 6.70 \times 10^3$ m s^{-1} ✓

6. Artificial satellites are used for communication, navigation, remote-sensing and research.

a) Describe briefly two ways in which their orbits are classified.

(2)

By the altitude of their orbit – e.g. Low, medium, high Earth ✓
By their inclination – e.g. Polar, equatorial, sun synchronous. ✓
Or whether circular or elliptical. Any 2 good points

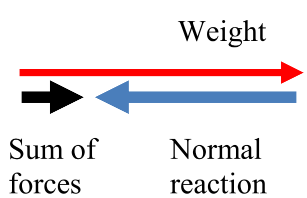
b) Give three specific examples of uses of artificial satellites. (The repetition of key words used in this question will not be awarded marks).

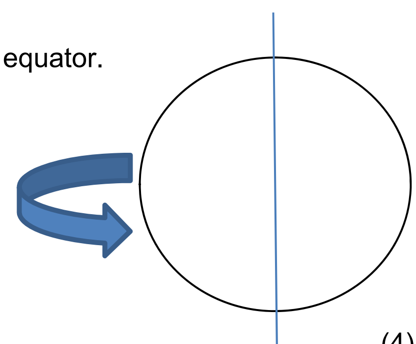
(3)

The GPS constellation for communication ✓
Television and telephone signals transmitted via satellite. ✓
Monitoring of population movement/biodiversity/Ocean Currents. ✓
Any 3 good points

7. The Earth rotates once per 24 hours about the axis through its poles. Assume a **perfectly spherical** Earth for this question.

For a person of mass 72.0 kg calculate their apparent weight on the equator. You must refer to a vector diagram in your response and indicate the sum of forces





(4)

$$At\ equatorial\ surface \quad v = \frac{2\pi r}{T} = \frac{2\times\pi\times 6.37\times 10^{6}}{24\times 60\times 60} =$$

v = 463.24 m s^{-1} ✓

From vector diagram N = W − ΣF ✓

$$N = mg - \frac{mv^2}{r}$$

$$N = 72 \times 9.8 - \frac{72\times 463.24^2}{6.37\times 10^6} \checkmark \quad N = 703\ N \checkmark$$

Continued on next page

8. The planet Gashprag is the largest planet in a soon to be discovered solar system. It has a radius of 34 220 km. The largest moon of Gashprag is Nalyd which has a mass of 4.12 x 10^{22} kg and a diameter of 2800 km. Nalyd has an orbital period of 6.77 Earth days and an orbital radius of 414 278 km.

a) Determine the mass of the planet Gashprag from this data.

(4)

$\frac{T^2}{R^3} = \frac{4\pi^2}{GM}$ R = 414 728 000 m ✓ T = 6.77 x 24 x 60 x 60 s

T = 584928 s ✓

$$M = \frac{4\pi^2 R^3}{GT^2}$$

$$M = \frac{4\pi^2 \times 414\,728\,000^{\,3}}{G \times 584928^2}$$ ✓

$$M = 1.23 \times 10^{26}\ kg$$ ✓

b) Calculate the acceleration of Nalyd relative to Gashprag.

(3)

$v = \frac{2\pi r}{T} = \frac{2\pi \times 414728000}{584928} =$ 4454.929 m s^{-1} ✓ into

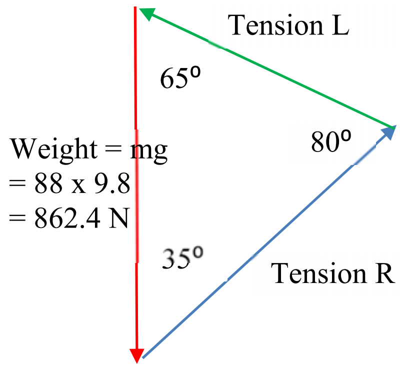
$$a = \frac{v^2}{r} = \frac{4454.299^2}{414728000}$$ ✓

$$a = 4.79 \times 10^{-2}\ m\ s^{-2}$$ ✓

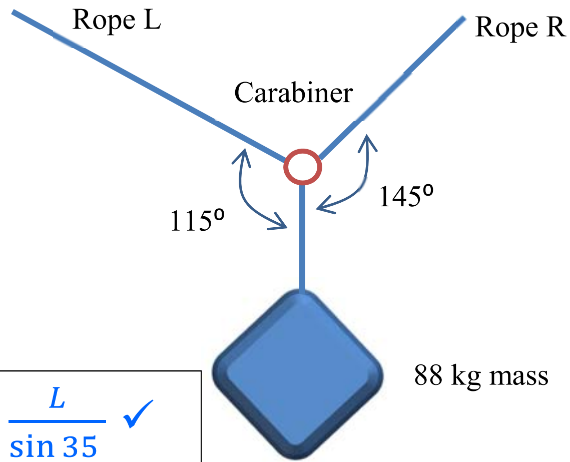
Or by using $g = \frac{GM}{r^2}$

9. An 88 kg mass is hanging from a carabiner suspended between 2 ropes. Relevant angles are shown on the diagram. Calculate the tension in Rope L and the tension in Rope R. You must refer to a vector diagram in your solution.

(4)



✓



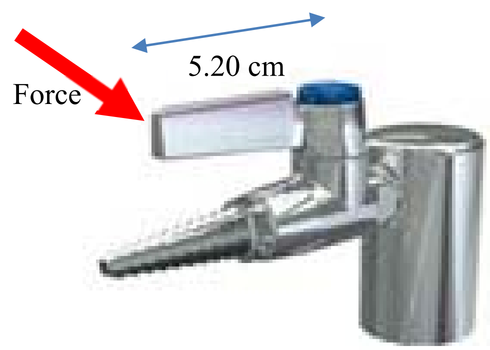
By the sine rule $\frac{W}{\sin 80} = \frac{L}{\sin 35}$ ✓

$L = \frac{\sin 35 \times 862.4}{\sin 80} = 502\ N$ ✓

By the sine rule $\frac{W}{\sin 80} = \frac{R}{\sin 65}$

$R = \frac{\sin 65 \times 862.4}{\sin 80} = 794\ N$ ✓

10. Amy is applying a force to turn a gas tap into the open position. She applies the force perpendicular to the gas tap handle and in the plane of rotation.



The gas tap handle has a length of 5.20 cm from the centre of rotation to the point where the force is applied.

a) Explain why it is easier to apply the force at the end of the gas tap handle rather than the middle.

(2)

T = r F sin θ ✓

If r is maximum then F is minimum to apply a given torque ✓

b) Amy applies a torque of 2.08 N m anticlockwise to the gas tap. Calculate the magnitude of her force.

(2)

T = r F sin θ

2.08 = 0.052 x F ✓

F = 40.0 N ✓

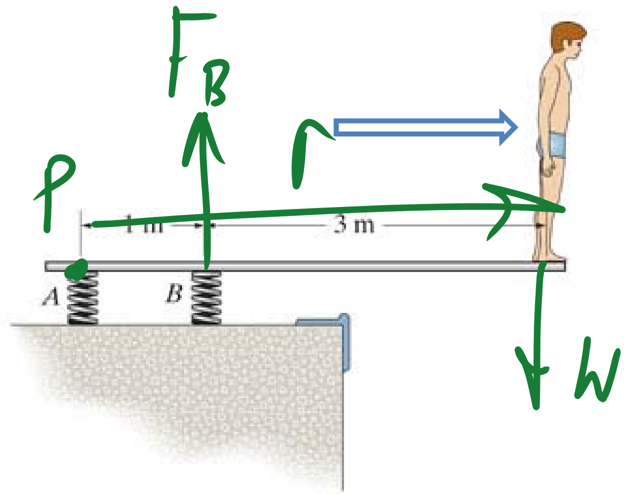
Continued on next page

11. A diver moves from the centre of a diving board to the right hand edge as shown in the diagram.

The board has a mass similar to that of the diver and is rigid. The board is attached to stiff springs A and B as shown. All forces acting on the board are in the vertical.

Explain what happens to the magnitude and direction of the forces acting on the board from A and B as the diver moves from the centre to the edge.

You must refer to the principles of translational and rotational equilibrium to give a reasoned and logical response.



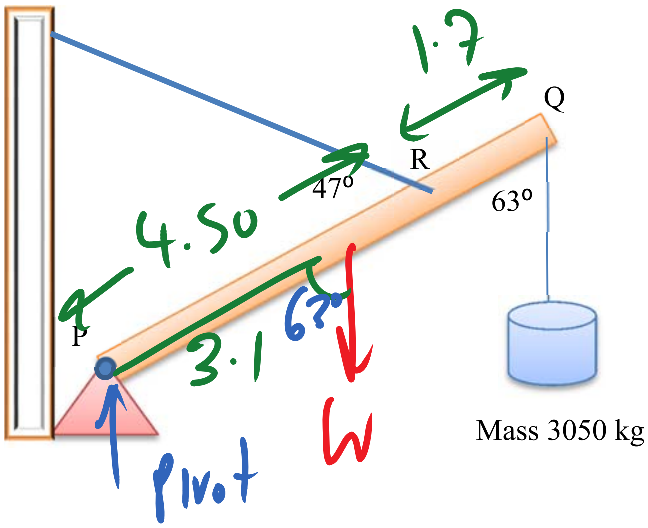
(4)

T = r F sin θ   Σacwm = Σcwm

Consider moments about point B acting on the diving board
As the boy walks right the cwm increases due to an increased lever arm at the action of his weight force. So the counter torque applied from A must increase to maintain equilibrium.
The force **from A** onto plank i**ncreases** in **downward** direction (tension increases) ✓ ✓

ΣF (up) = ΣF (down) consider the diving board as the object
Consider that sum of forces up must equal sum of forces down
As boy walks right all weights acting down are constant but force down from A increases, in order to maintain balance then the **force from B** must **increase upwards** (compression increases) ✓ ✓

12. The diagram below shows boom PQ which is part of a crane assembly. The crane is lifting a mass of 3050 kg from point Q. A steel wire is attached to the boom at point R. The boom is free to pivot at point P. Information about the set-up is shown on the diagram and in the table.



Length PQ	6.20 m
Length RQ	1.70 m
Mass of boom	5600 kg
Length PR	6.2 - 1.7 = 4.50 m ✓

a) Calculate the tension in the steel wire.

(4)

$T = r\,F\sin\theta$ $\quad \Sigma acwm = \Sigma cwm$

Consider moments about point P acting on the boom

$\Sigma acwm = \Sigma cwm$

$4.5 \times F_{tension} \times \sin 47$ ✓ $= (3.10 \times 5600 \times 9.8 \times \sin 63)$

$+ (6.20 \times 3050 \times 9.8 \times \sin 63)$ ✓

$4.5 \times F_{tension} \times \sin 47 = 316704.704$

$F_{tension} = 96230.8978\text{ N} = 9.62 \times 10^4\text{ N}$ ✓

FINAL QUESTION ON BACK PAGE

b) Determine the reaction force acting on the boom from the pivot at point P stating both magnitude and direction. If you could not solve part a) or if you are unsure of your solution then use a tension value of 96 230 N.

(5)

Sum of weights = (5600 + 3050) x 9.8 = 84770 N

$F_{tension}$ = 96230.8978 N = 9.62×10^4 N ✓

With reference to vector diagram ΣF on boom = 0

By cosine rule

$R^2 = W^2 + T^2 - 2WT \cos 70$

$R^2 = 84770^2 + 96230^2 - (2 * 84770 * 96230 * \cos 70)$ ✓

R = 104 240 N = 1.04×10^5 N ✓

By sine rule

$$\frac{R}{\sin 70} = \frac{T}{\sin\alpha}$$

$$\sin\alpha = \frac{T \sin 70}{R}$$

$$\sin\alpha = \frac{96230 \sin 70}{104240} \checkmark$$

$\alpha = 60.2^{o}$ ✓

R = 1.04×10^5 N at 60.2^{o} to the vertical