Year 12 PHYSICS ATAR 2017

Semester 1

Task 7: Test 2

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CATHOLIC COLLEGE

God is with us

TASK TYPE: Test

CONTENT: Gravity, circular motion and torque – 6%

	Possible Marks	Your Mark
Total	50	
Percentage	100%	

Student Name: Answer Key

Date:

Teacher: J. Wijaya

Instruction:

1. Answer all questions.
2. All numeric answers are to be corrected to three significant figures unless specified. Estimated answers are to be corrected to two significant figures.

1. Kepler's 3rd law of planetary motion is:

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

Derive this formula using at least two other equations from the supplied data sheet. Show ALL steps in your working.

[3]

$F_a = F_g$

$\frac{\cancel{m}v^2}{\cancel{r}} = \frac{G\cancel{m}M}{r^{\cancel{2}}}$ ①

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

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

$\therefore \left(\frac{2\pi r}{T}\right)^2 = \frac{GM}{r}$ ①

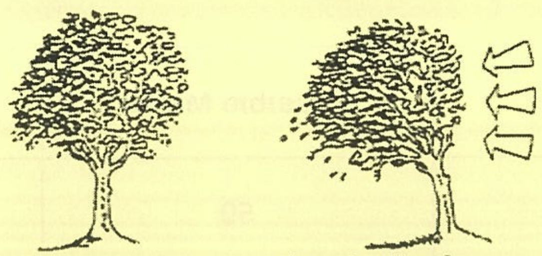
$\frac{4\pi^2 r^2}{T^2} = \frac{GM}{r}$ ①

$4\pi^2 r^3 = GMT^2$

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

2. Explain why very tall trees growing in a windy environment require a stronger and more extensive root system than similar, but shorter, trees to resist being blown over.

[4]



The trunk supports the branches and leaves.

The trunk and branches deflect (move) when resisting strong winds.

$\tau = F \times r$

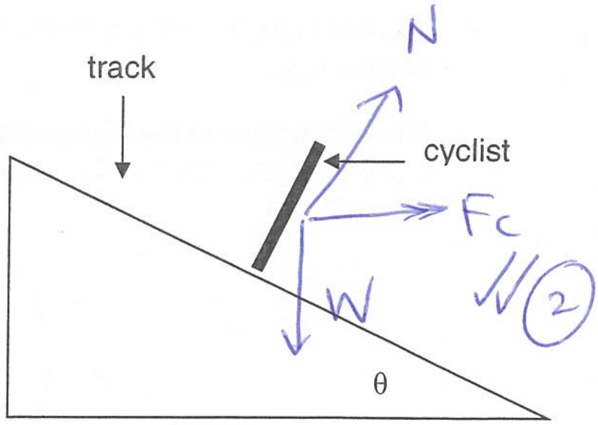
a tall tree has a greater r ✓✓ ②

$\tau \propto r$

$\therefore \tau$ is greater ✓ ①

$\therefore$ it requires counteract torque to balance the acting torque. ✓ ①

3. A velodrome is an oval-shaped cycle track, parts of which are steeply banked. The riders on this track are travelling at 15.0 m s^{-1}, the radius of curvature of the banked track is 35.0 m and there is no tendency for the bikes to slide up or down the slope.



a) On the diagram, label all forces including the net force. Then explain the benefits of banked curve using physics concepts you have learnt.

[4]

N provides an addition Force (the horizontal component to N) to the Fc.

greater Fc, ie $F_c \propto v^2$ } explanation (2)

∴ the rider can go faster.

b) Calculate the angle of the bank, θ.

[3]

$$\tan\theta = \frac{v^2}{rg}$$ ✓ (1)

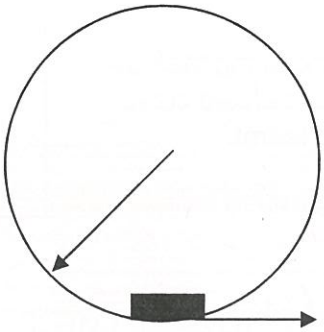
$$\tan\theta = \frac{15^2}{35 \times 9.8}$$ ✓ sub (1)

$$\tan\theta = 0.65598$$

$$\theta = \underline{33.3^\circ}$$ ✓ (1)

4. The photograph on the right shows a rollercoaster negotiating a vertical circular loop.

The dimensions of the loop and the rollercoaster's speed at the bottom of the loop are shown in the diagram below:



a) Describe the apparent weight of an occupant of mass 60.0kg when the rollercoaster is at the bottom of the circular loop. Support your answer with a calculation.

[3]

$N = F + W$

$= \frac{mv^2}{r} + mg$ ✓✓ 2

$= \frac{60 \times 21^2}{10} + 60 \times 9.8$ ∴ heavier. ✓ 1

$= 3234 N$

compare to
$W = mg = 60 \times 9.8$
$= 588 N$

b) Calculate the minimum speed **at the bottom** of the circular loop so that the rollercoaster is **just** in contact to the top of the loop.

[5]

$v = \sqrt{rg}$ (top)

$= \sqrt{10 \times 9.8}$ ✓ 2

$= 9.8995 \text{ ms}^{-1}$ ✓

using $\underbrace{E_K + E_p}_{top} = \underbrace{E_K + \cancel{E_p}}_{bottom}$ ✓ 1

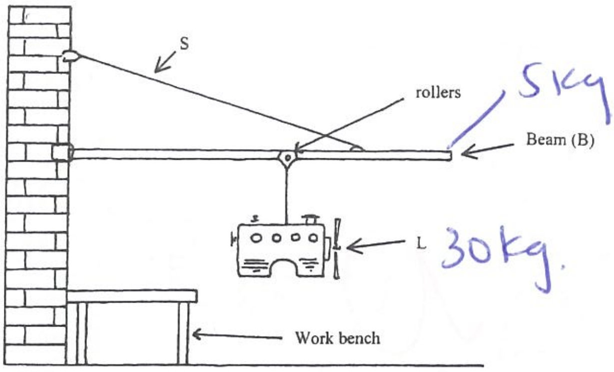
$\frac{1}{2}\cancel{m}v^2 + \cancel{m}gh = \frac{1}{2}\cancel{m}v^2$

$\frac{1}{2}(9.8995)^2 + 9.8 \times 20 = \frac{1}{2}v^2$ ✓ 1

$v^2 = 490$

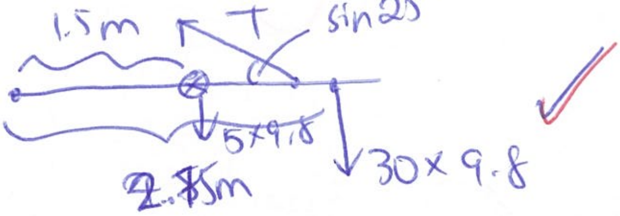
∴ $v = 22.1 \text{ ms}^{-1}$ ✓ 1

5. The wall crane is designed to lift motors from cars and transfer them to a workbench. It uses rollers to allow the operator to shift the load from one end of the beam to the other as shown in the diagram. The beam (B) is 3.0 m long and the support wire (S) is attached 0.5 m from the outer end at 25.0° to the beam. That is, the angle between S and B is 25.0°.



a) Calculate the tension S. When the load is 0.25 m from the right end.

[5]



$\tau_{cw} = \tau_{ACW}$

$5 \times 9.8 \times 1.5 + 30 \times 9.8 \times 2.75 = T \times 2.5 \times \sin 25°$

$T = 835$ N (along the line.)

b) What would happen to the tension S if the load was gradually being moved toward the end of beam (away from the wall)? Explain your answer.

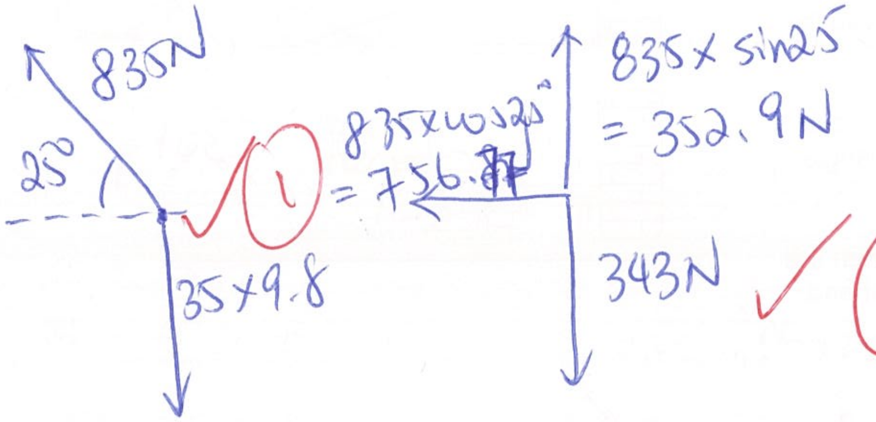
[3]

greater tension 1

this is due to the fact that τ_{cw} will be greater when $r_{\perp}$ is greater. ie a greater counteract τ required. 2

Continue Question 5

c) Calculate the reaction force applied on the beam from the wall. [5]



$\therefore$ net ↑ 9.886 1 $\therefore$ Reaction

756.77 756.77N 9.886

$\tan\theta = \frac{9.886}{756.77}$ 1 $R = \sqrt{756.77^2 + 9.886^2}$

$\theta = 0.748°$ below $= 757N$ 1

6. Neptune has several moons, two of which are Triton and Nereid. Use the following data to answer Parts (a) to (d) where necessary.

QUANTITY	DATA
Mass of Triton	2.14×10^{23} kg
Radius of Triton	1.35×10^{6} m
Mass of Neptune	1.02×10^{26} kg
Period of Triton's orbit	5.08×10^{5} s
Radius of Nereid's orbit around Neptune	5.51×10^{9} m

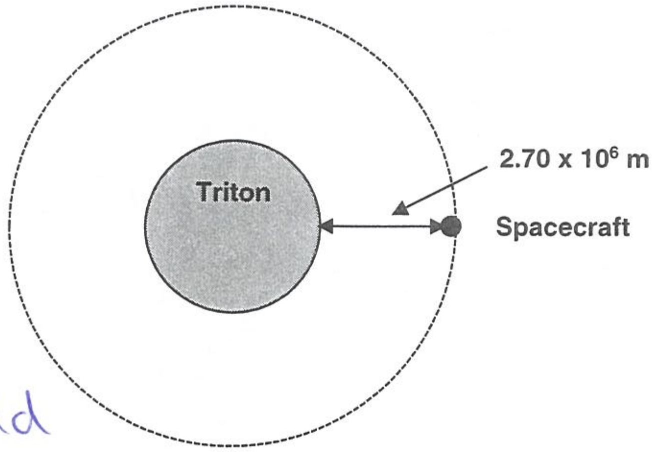
a) A spacecraft is at rest on Triton's surface. One of the experiments on board involves a 10.0 kg mass hanging at rest from a spring balance. The scale of the spring balance is correctly calibrated in Newtons. What is the reading on the spring balance? Show your working. [2]

$$F_W = \frac{GMm}{r^2}$$

$$= \frac{6.67\times10^{-11} \times 2.14\times10^{23} \times 10}{(1.35\times10^{6})^2} = 78.3N$$

Continue Question 6

In parts b), c) and d), the spacecraft (mass **2.00 x 10^3 kg**) is in a circular orbit with its engines off at **an altitude of 2.70 x 10^6 m** above Triton, as shown in the diagram.



b) In physics terms, describe what is meant by being in 'orbit'? [2]

* the object travels at the same g-field at all time (2)

OR. $F_g = F_a$

c) Calculate the gravitational field strength at this altitude due to Triton. [3]

$$g = \frac{GM}{r^2} = \frac{6.67\times10^{-11} \times 2.14\times10^{23}}{(2.7\times10^6 + 1.35\times10^6)^2}$$

$$= 0.870\ \text{Nkg}^{-1}$$ (to the centre of Triton)

d) The 10.0 kg mass is still attached to the spring balance as before. What is the reading on the spring balance now? Give reasons for your answer. [3]

0.N (1)

The object is freely falling as it is on its orbit. (2)

Continue Question 6

The orbital period of Nereid around Neptune is approximately the same as that of the Earth around the Sun (that is 365.25 earth days).

e) Calculate the average orbital speed of Nereid around Neptune.

[2]

$$V = \frac{2\pi r}{T} = \frac{2\pi \times 5.51 \times 10^{9}}{365.25 \times 60 \times 60 \times 24}$$

$$= 1097 = 1.10 \times 10^{3}\ ms^{-1}$$

1

1

f) The length of one day on Neptune is 16 hours, 6 minutes and 36 seconds. Calculate the altitude of a geosynchronous orbit around Neptune. Show all working.

[3]

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

1

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

$$r^3 = \frac{(16 \times 60 \times 60 + 6 \times 60 + 36)^2 \times 6.67 \times 10^{-11} \times 1.02 \times 10^{26}}{4\pi^2}$$

1

$$r^3 = 5.796 \times 10^{23}$$

End of the test

$$r = 83378508\ m$$

1

$$\therefore \text{altitude} = 83378508 - \ldots$$

$$8.34 \times 10^{7} m$$