HOLY CROSS COLLEGE
Life to the Full

Western Australian Certificate of Education
ATAR course examination, 2018

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Test 3 - Moments and Equilibrium

Student Number: In figures | | | | | | | | | |

Mark: ___/55

In words _____

_____

Time allowed for this paper
Reading time before commencing work: five minutes
Working time for paper: sixty minutes

Materials required/recommended for this paper
To be provided by the supervisor
This Question/Answer Booklet
Formulae and Data Booklet

To be provided by the candidate
Standard items: pens, (blue/black preferred), pencils (including coloured), sharpener, correction fluid/tape, eraser, ruler, highlighters

Special items: non-programmable calculators satisfying the conditions set by the School Curriculum and Standards Authority for this course

Important note to candidates
No other items may be taken into the examination room. It is **your** responsibility to ensure that you do not have any unauthorised notes or other items of a non-personal nature in the examination room. If you have any unauthorised material with you, hand it to the supervisor **before** reading any further.

Structure of this paper

Section	Number of questions available	Number of questions to be answered	Suggested working time (minutes)	Marks available	Percentage of exam
Section One: Short Answers	-	-	-		
Section Two: Problem-solving	11	11	60	55	100
Section Three: Comprehension	-	-	-	-	-
				Total	100

Instructions to candidates

1. The rules for the conduct of examinations at Holy Cross College are detailed in the College Examination Policy. Sitting this examination implies that you agree to abide by these rules.

2. Write your answers in this Question/Answer Booklet.

3. Working or reasoning should be clearly shown when calculating or estimating answers.

4. You must be careful to confine your responses to the specific questions asked and to follow any instructions that are specific to a particular question.

5. Spare pages are included at the end of this booklet. They can be used for planning your responses and/or as additional space if required to continue an answer.

   - Planning: If you use the spare pages for planning, indicate this clearly at the top of the page.
   - Continuing an answer: If you need to use the space to continue an answer, indicate in the original answer space where the answer is continued, i.e. give the page number. Fill in the number of the question(s) that you are continuing to answer at the top of the page.

6. Answers to questions involving calculations should be ***evaluated and given in decimal form.*** It is suggested that you quote all answers to ***three significant figures***, with the exception of questions for which estimates are required. Despite an incorrect final result, credit may be obtained for method and working, providing these are ***clearly and legibly set out***.

7. Questions containing the instruction "estimate" may give insufficient numerical data for their solution. Students should provide appropriate figures to enable an approximate solution to be obtained. Give final answers to a maximum of two significant figures and include appropriate units where applicable.

8. Note that when an answer is a vector quantity, it must be given with magnitude and direction.

9. In all calculations, units must be consistent throughout your working.

1. Explain why it is not possible for you to get up from your seat without first leaning forward. You may use diagrams to illustrate your answer. [3 marks]

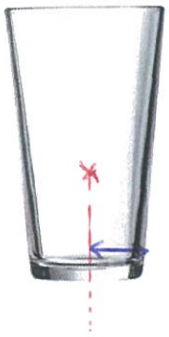
TRYING TO GET STRAIGHT UP

- F_W is to the left of the pivot of the feet, so torque pulls the person onto the seat. (1)

MOVING FORWARDS

- Centre of gravity moves forwards over the feet. (1)
- Legs can exert an upward force to lift the centre of mass. (1)

2. (a) Explain whether a water glass that tapers down to a narrow base is easier to tip over than one with straight sides. [2 marks]

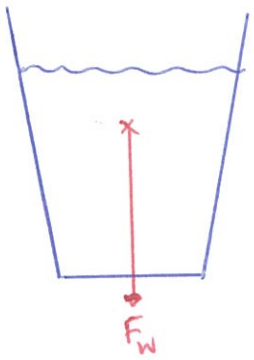


- Narrow base glass is easier to tip. (1)
- Centre of mass in the narrow base moves through a smaller angle before the weight force acts outside of the base. (1)

(Assumes the centres of mass are similar.)

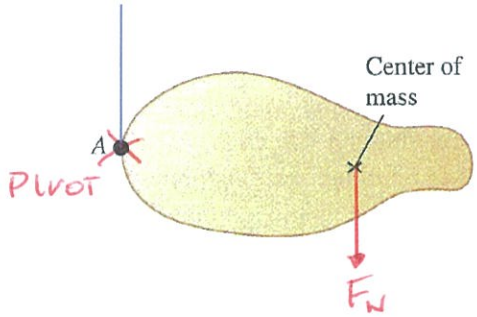
This distance is greater
⇒ more stable.

(b) Discuss the difference between a full tapered glass and an empty tapered glass. You may need to use drawings to support your answer. [2 marks]



- less stable when full. (1)
- centre of gravity is higher so it tips when moved through a smaller angle. (1)

3. The irregular object shown in the figure below is hung on a string. Its centre of mass is as shown. The object rotates back and forth till it reaches a final position.



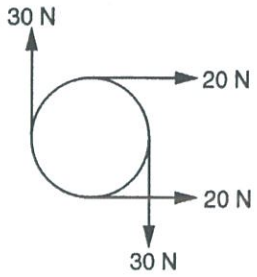
(a) Explain why the object rotates back and forth. [2 marks]

- Weight force is away from the pivot A. (1)
- Clockwise torque moves the centre of mass beyond A. (½)
- Anticlockwise torque pulls it back. (½)

(b) Friction acts to eventually stop the object from rotating. State the position of the centre of mass in the object's final position. [1 mark]

- Vertically below point A. (1)

4. The diagram shows four forces applied to a circular object. The radius of the object is *r*.
[4 marks]



(a) Which of the following describes the resultant force and resultant torque on the object? Circle correct letter.

	Resultant force	Resultant torque
A	zero	zero
B	zero	non-zero
C	non-zero	zero
D	non-zero	non-zero

(1)

(b) Justify your answer by calculating the resultant torque (in terms of *r*) and the resultant force.

Resultant τ = $\tau_{CM} - \tau_{ACM}$

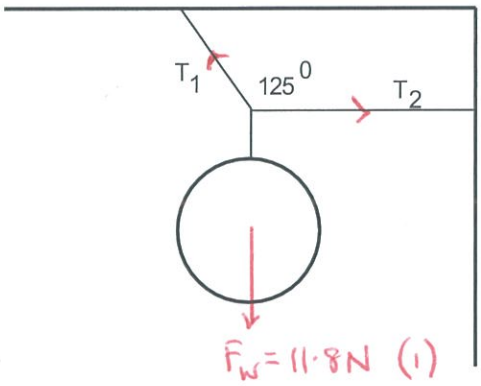
= $30r + 20r + 30r - 20r$ (1)

= $60r$ clockwise (1)

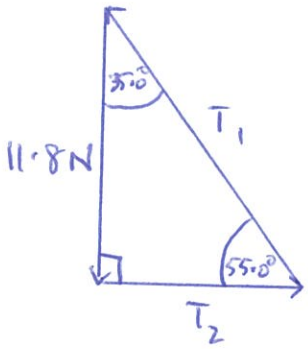
$\Sigma F = 20 + 20$

= 40 N right (1)

5. A globe is strung up in a classroom as shown in the diagram below. Note that the roof and T_2 are both horizontal.:



If the mass of the globe is 1.20 kg, determine the tension T_1 and T_2. The one cable is horizontal to the ground. [4 marks]

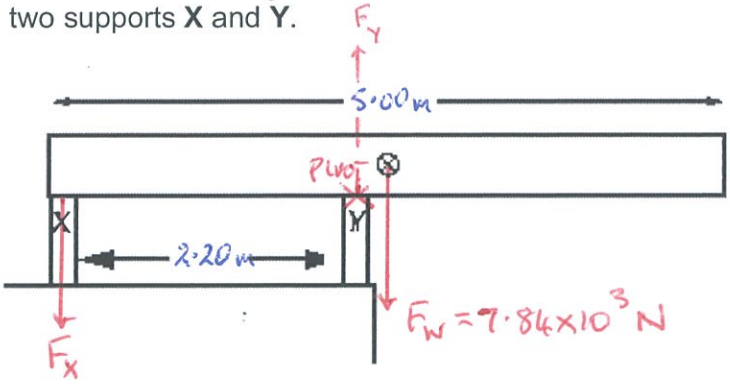


$$\frac{T_1}{\sin 90.0^\circ} = \frac{T_2}{\sin 35.0^\circ} = \frac{11.8}{\sin 55.0^\circ} \quad (1)$$

$$\Rightarrow T_1 = 14.4\,N \quad (1)$$

$$\Rightarrow T_2 = 8.26\,N \quad (1)$$

6. A uniform cantilever 5.00 m long is shown below. It has a mass of 8.00 x 10^2 kg and is held up by two supports **X** and **Y**.



(a) State the direction of the force exerted by support **X** on the cantilever.

[1 mark]

- Down (1)

(b) Determine the force that each of the supports exerts on the cantilever.

[4 marks]

Take Y as pivot

$\Sigma CM = \Sigma ACM$

$\Rightarrow (7.84 \times 10^3)(0.300) = F_x(2.20)$ (1)

$\Rightarrow F_x = 1.07 \times 10^3$ N (1)

$\Sigma F_v = 0$

$\Rightarrow F_y = 1.07 \times 10^3 + 7.84 \times 10^3$ (1)

$= 8.91 \times 10^3$ N (1)

7. Sumo wrestling is a sport with a simple objective: push your opponent so they topple over. The Sumo wrestler is often a very large person with a lot of weight. When they begin, the wrestlers move their feet apart on the floor and crouch down low to the floor.

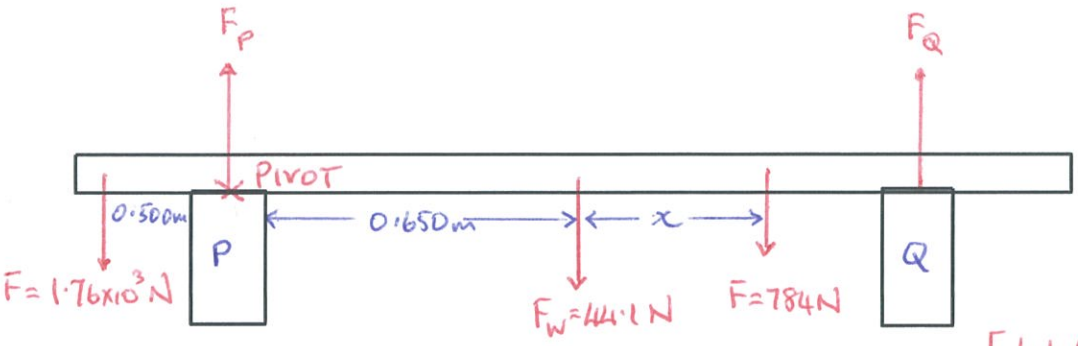
(a) Explain why Sumo wrestlers stand in this way. [2 marks]

- lowers their centre of gravity. ($\frac{1}{2}$)
- widen their base. ($\frac{1}{2}$)
- This increases their stability. (1)

(b) A 1.80 x 10^2 kg Sumo wrestler goes to sit 10.0 cm from the left end of a 2.50 m long bench. The bench has a mass of 4.50 kg.

(i) How far from the other end of the bench should an 80.0 kg spectator sit to just stop the bench from tipping, if the legs of the bench are 60.0 cm from each end?

Draw and label all forces and measurements on the diagram below.
[6 marks]



[Labelling - 1 mark]

[$F_Q = 0$ - 1 mark]

Take P as pivot

$\Sigma CM = \Sigma ACM$

$\Rightarrow (44.1)(0.650) + (784)(0.650 + x) = (1.76 \times 10^3)(0.500)$ (2)

$\Rightarrow \quad x = 0.436\,m$ (1)

$\therefore$ Must sit 0.814m from the other end. (1)

(ii) Each leg of the bench can only withstand a maximum force of 2.50 x 10^3 N. Will the bench break with the Sumo wrestler and the spectator seated as above? Show your working out. [3 marks]

$\Sigma F_V = 0$

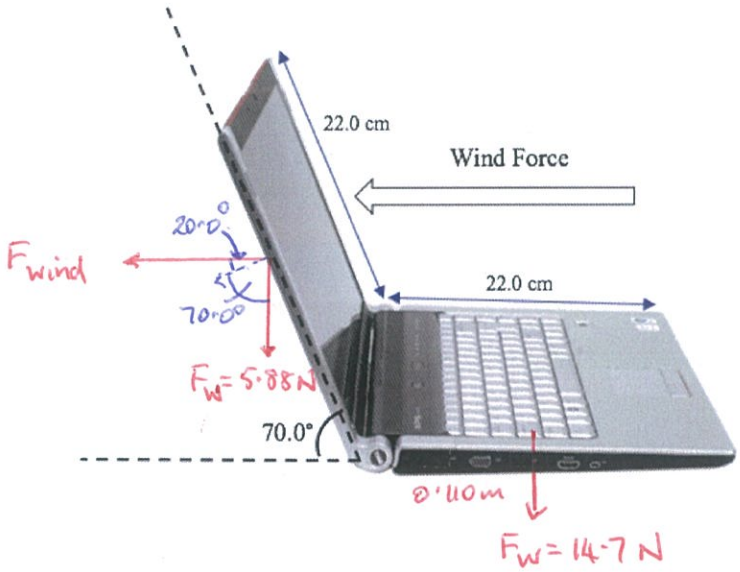
Since $F_Q = 0$: $F_P = 1.76 \times 10^3 + 44.1 + 784$ (1)

$= 2.59 \times 10^3\,N > 2.50 \times 10^3\,N$ (1)

$\therefore$ Leg breaks. (1)

8. The diagram below shows a side view of a laptop computer resting on an outdoor table. The mass of the base of the laptop is 1.50 kg and the mass of the screen is 0.600 kg. They are both 22.0 cm long. There is an angle of 70.0° between the horizontal and the screen. The computer is blown over by wind.

Assume that the base and screen both have a uniform mass distribution.



Calculate the minimum single equivalent wind force on the centre of the screen needed to tip the laptop over. [4 marks]

$$\Sigma CM = \Sigma ACM$$

$$\Rightarrow (14.7)(0.110) = (F_{wind}\cos 20.0^\circ)(0.110) + (5.88\cos 70.0^\circ)(0.110)$$

(1) (1) (1)

$$\Rightarrow F_{wind} = 13.5 \text{ N horizontally} \quad (1)$$

9. A ball is placed on different surfaces as shown in the diagrams below.

Fig. a

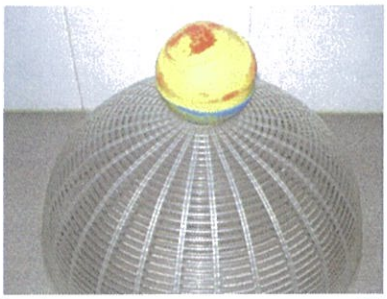


Fig. b

Fig. c

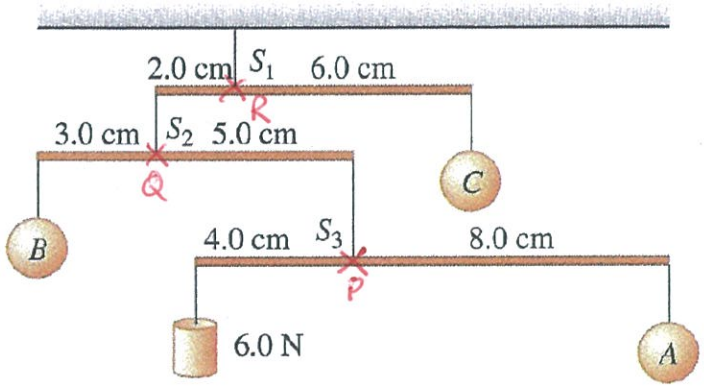
State whether the ball is in a state of stable equilibrium, unstable equilibrium or neutral equilibrium and explain your answer in each case. [3 marks]

Fig. a: Stable - returns to its original position after a push. (1)

Fig. b: Unstable - does not return to its original position. (1)

Fig. c: Neutral - centre of mass does not rise or fall. (1)

10. A decorative mobile contains three unknown weights A, B and C. The strings and rods have negligible weight and the rods are to hang horizontally. Find the weights of the balls A, B and C. [4 marks]



Take P as pivot

$\Sigma CM = \Sigma ACM$

$\Rightarrow A(0.080) = (6.0)(0.040)$

$\Rightarrow A = 3.0\,N$ (1)

Take Q as pivot

$\Sigma CM = \Sigma ACM$

$\Rightarrow (9.0)(0.050) = B(0.030)$ ($\frac{1}{2}$)

$\Rightarrow B = 15.0\,N$ (1)

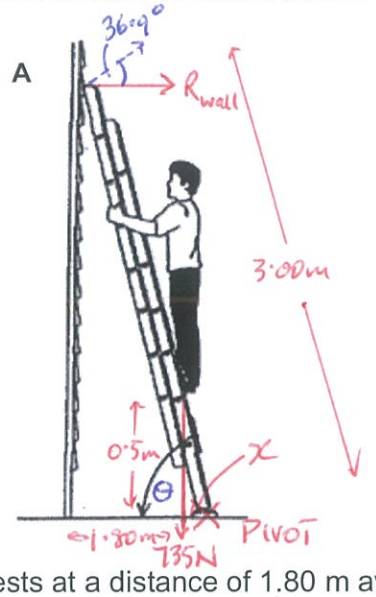
Take R as pivot

$\Sigma CM = \Sigma ACM$

$\Rightarrow C(0.060) = (24.0)(0.020)$ ($\frac{1}{2}$)

$\Rightarrow C = 8.0\,N$ (1)

11. A person climbs a ladder that leans on wall as shown below.



The ladder is 3.00 m long and rests at a distance of 1.80 m away from a wall. The man stands with his feet 0.500 m above the ground. The ladder has a negligible mass and the man has a mass of 75.0 kg.

(a) Determine the angle the ladder makes with the ground. [1 mark]

$\cos\theta = \frac{1.80}{3.00}$

$\Rightarrow \theta = 53.1^\circ$ (1)

(b) Calculate the force that the wall exerts on the ladder at position **A**. Assume that the force acts at right angles to the wall. [6 marks]

$\tan 53.1^\circ = \frac{0.500}{x}$ (1)

$\Rightarrow x = 0.375\,m$ (1)

Take bottom of the ladder as pivot.

$\Sigma CM = \Sigma ACM$

$\Rightarrow (R_{wall}\cos 36.9^\circ)(3.00) = (735)(0.375)$ (2)

(1)

$\Rightarrow R_{wall} = 115\ N$ away from the wall (1)

(c) If the person climbs higher up the ladder, explain qualitatively how the force exerted on the ladder by the wall changes. [3 marks]

- By inspection, $R_{wall} \propto$ horizontal distance of the person from the pivot. (1)
- Climbing higher increases the horizontal distance. (1)
- R_{wall} increases. (1)