HOLY CROSS COLLEGE

Life to the Full

Western Australian Certificate of Education
ATAR course examination, 2020

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Evaluation - Gravitation

Student Number: In figures

In words ______________________

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Mark: $\overline{}$ 30

Time allowed for this paper

Reading time before commencing work: five minutes
Working time for paper: fifty 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.

The table below describes the orbital paths of a number of natural and man-made satellites orbiting the Earth.

Name	Mass (kg)	Orbital Radius ($\times 10^7$ m)	Period ($\times 10^4$ s)	Acceleration (ms^{-2})	$\frac{1}{r^2}$ (1) (Units: $\times 10^{14}\ m^{-2}$) (1)
Shuttle	2.95×10^4	0.671	0.541	9.05	2.22
Tiros	1405	0.722	0.612	7.61	1.92
Itos	340	0.787	0.667	6.98	1.61
Lageos	411	1.23	1.35	2.66	0.661
Nato	310	4.22	8.64	0.223	5.62×10^{-2}
Moon	7.38×10^{22}	38.2	242	2.58×10^{-3}	6.85×10^{-5}

(1) (1) [sig. fig - 1 mark]

1. Using your knowledge of circular motion theory, show working to illustrate that the acceleration of each satellite is related to its orbital radius and its period by the expression:

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

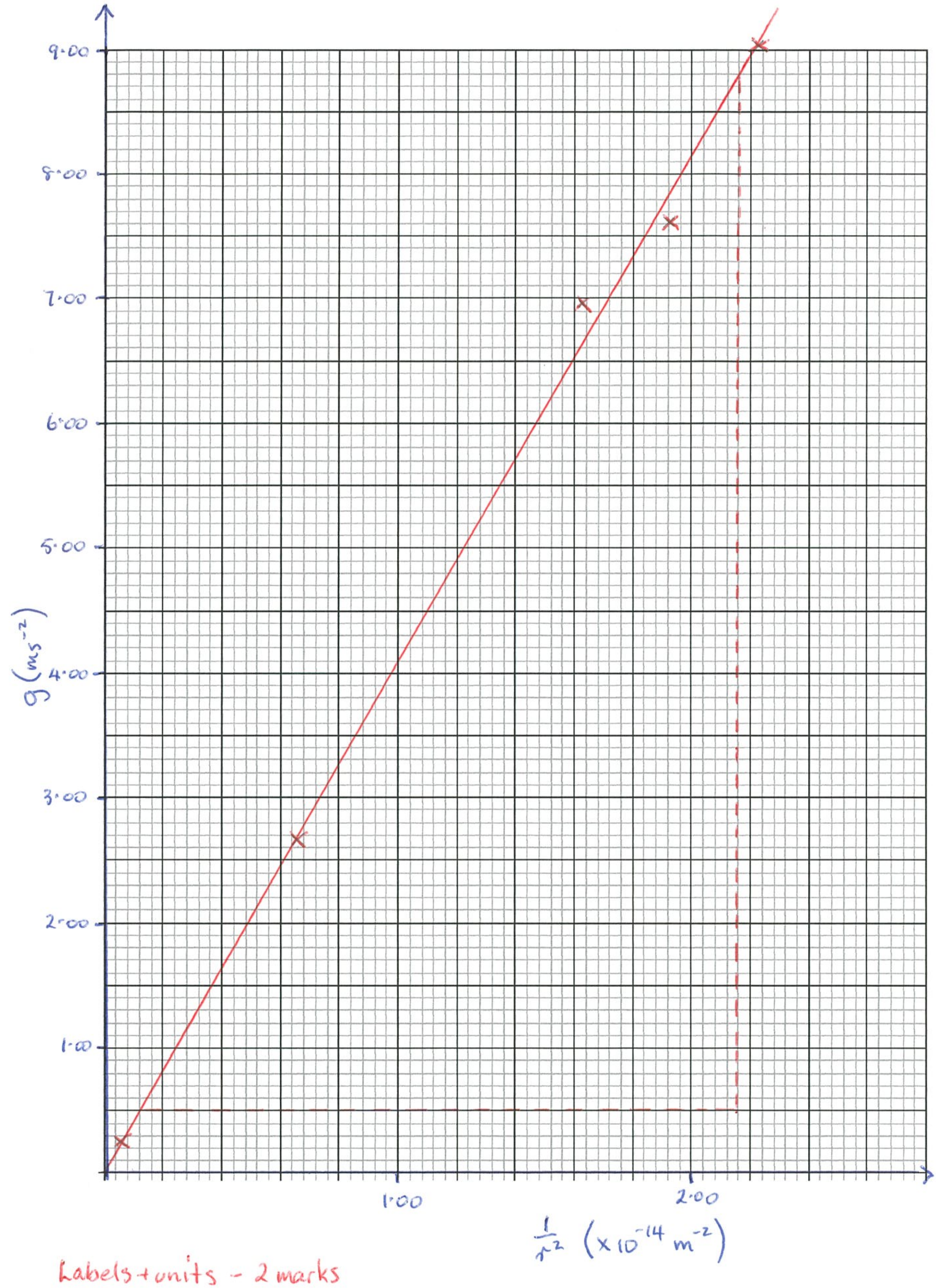
(4 marks)

$$F_g = F_c \quad (1)$$

$$\Rightarrow \cancel{m}g = \frac{\cancel{m}v^2}{r} \quad (1)$$

$$\Rightarrow g = a_c = \frac{4\pi^2 r^2}{\cancel{r}\, T^2} \quad (1)$$

$$\Rightarrow a_c = \frac{4\pi^2 r}{T^2} \quad (1)$$



Labels + units - 2 marks

Accuracy - 1 mark

Appropriate scales - 1 mark

Line of best fit - 1 mark

2. (a) Using the expression from Question 1, calculate and fill in the values for the **fifth column in the table above**. Ensure you display the values to the correct number of significant figures. (2 marks)

(b) Show workings for the calculation you performed to determine the acceleration of Lageos. (2 mark)

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

$$= \frac{4\pi^2(1.23\times10^7)}{(1.35\times10^4)^2} \quad (1)$$

$$= \underline{2.66\ ms^{-2} \text{ towards Earth}} \quad (1)$$

3. (a) Fill in the values of uncertainty associated with Lageos in the table below. (4 marks)

Quantity		Absolute Uncertainty	Percentage Uncertainty (%)
Orbital Radius (x 10^7 m)	1.23	$\pm 0.005\times10^7$	0.407
Period (s)	1.35 x 10^4	$\pm 0.005\times10^4$	0.370

[1 mark each]

(b) Using this information, calculate the percentage uncertainty (%) and absolute uncertainty for the acceleration of Lageos. (3 marks)

$$\%\text{ uncertainty} = 0.407 + 2(0.370) \quad (1)$$

$$= \pm 1.15\%$$

$$= \pm 0.031\ ms^{-2}$$

Ans: % Uncertainty acceleration: $\pm 1.15\%$ (1)

Ans: Absolute Uncertainty acceleration: $\pm 0.031\ ms^{-2}$ (1)

4. Complete the **sixth column of the table** on page 1 by calculating the values of **inverse of radius squared**. Clearly show the power of 10 and units by writing them at the top of that column.

(3 marks)

5. Plot a graph of gravitational field strength (**g**) against inverse of the radius squared ($^1/_{r^2}$) on the grid on page 3. Include a line of best fit.
(A spare grid is on page 6.)

(5 marks)

6. It is known that gravitational field strength due to the Earth can be calculated using the formula:

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

Use your graph to determine the mass of the Earth. Show all working. (7 marks)

$$\text{gradient} = \frac{\Delta g}{\frac{1}{r^2}} = \frac{(8.80 - 0.50)}{(2.16 - 0.12) \times 10^{-14}} \quad (1)$$

$$= 4.07 \times 10^{14} \; m^3 s^{-2}$$
(1) (1)

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

$$\Rightarrow \quad M_E = \frac{gr^2}{G}$$

$$= \frac{\text{gradient}}{G} \quad (1)$$

$$= \frac{4.07 \times 10^{14}}{6.67 \times 10^{-11}}$$

$$= \underline{6.10 \times 10^{24} \text{ kg}} \quad (1)$$

[2 non-data points used - 1 mark]

Spare grid