Western Australian Certificate of Education
ATAR course examination, 2018

Question/Answer Booklet

12 PHYSICS

Name SOLUTIONS

Practical Test - Gravity Investigation

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

Mark: $\overline{\quad}$ 48

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.

1. How many metres are there in one light-year? **[3 marks]**

$$1.00 \text{ l.y.} = (3.00\times10^{8})(3.60\times10^{3})(24.0)(365.25) \quad (1) \quad (1)$$

$$= \underline{9.47\times10^{15} \text{ m}} \quad (1)$$

2. How close is Ross128b to our solar system? **[1 mark]**

11 light years (1)

3. Briefly explain how Ross128b was discovered. **[2 marks]**

- ESO's High Accuracy Radial Velocity Planet Searcher (HARPS).
- Examination of years of HARPS data.

4. Why is Ross128b of much great interest to astronomers? **[2 marks]**

- Earth-like planet.
- Possibly inside habitable zone.

On 22 February 2017, astronomers announced that the planetary system of this star is composed of seven temperate terrestrial planets, of which five (*b, c, e, f* and *g*) are similar in size to Earth, and two (*d* and *h*) are intermediate in size between Mars and Earth. Three of the planets (*e, f* and *g*) orbit within the habitable zone.

5. To which planetary system is this statement referring? **[2 marks]**

- Trappist - 1. (2)
- seven planets in orbit.

6. What is meant by the term, 'habitable zone'? **[2 marks]**

- Range of orbits around a star that can support liquid water.
  (1) (1)

7. What type of stars do these planets orbit? **[2 marks]**

- Trappist - 1 is an ultra - cool red dwarf star.
  (1) (1)

8. What telescope will take the place of the Hubble Space Telescope and where will it be positioned? **[2 marks]**

- James Webb telescope. (1)
- Second Lagrange (L2) point. (1)

Johannes Kepler brought the power of mathematics to bear on the observations of the solar system by his mentor Tycho Brahe. By 1619 Kepler had stated three laws:

i. Planets follow plane elliptical paths with the sun at one focus.

ii. A radial line between the sun and a planet will sweep out equal areas of the ellipse in equal times.

iii. The square of the period of a planet varies directly as the cube of the radius (the semi-major axis). The constant $k = r^3/T^2$ is the same for all planets.

9. Show, by using the principles of horizontal motion and Newton's universal law of gravity, that the ratio $\boldsymbol{r^3/T^2}$ is a constant for all planets. **[5 marks]**

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

$$\Rightarrow \frac{GM_1m_2}{r^2} = \frac{m_2v^2}{r} \quad (1)$$

$$\Rightarrow \frac{GM_1m_2}{r^2} = \frac{4\pi^2 m_2 r}{T^2} \quad (1)$$

$$\Rightarrow r^3 = \frac{GM_1T^2}{4\pi^2} \quad (1)$$

$$\Rightarrow \frac{r^3}{T^2} = k \quad \text{where } k = \frac{GM_1}{4\pi^2} \quad (1)$$

10. Using data you collected during your research, calculate the mass of the exoplanet Ross128b. **[5 marks]**

$$r^3 = \frac{GMT^2}{4\pi^2} \quad (1)$$

$$\Rightarrow M = \frac{4\pi^2 r^3}{GT^2} \quad (1)$$

$$= \frac{4\pi^2(7.42\times10^9)^3}{(6.67\times10^{-11})(9.9\times24.0\times3.60\times10^3)^2} \quad (1) \quad (1)$$

$$= \underline{3.30\times10^{29}\text{ kg}} \quad (1)$$

Planet	Neptune	Jupiter	Earth	Mercury
Mass (m)	17.23	317.893	1.00	0.0558
Radius (r)	4496.6	778.3	149.6	57.9
Period (T)	60189	4332.589	365.256	87.969

Where: Mass = (5.976×10^{24} kg) [mass of the earth]
Radius = (1.00×10^{6} km) [orbital radius around the sun]
Period = (23 h 56 m 04.098 s) [sidereal day]

11. Calculate the gravitational force between Earth and Mercury when they are only a distance apart equal to the difference between their solar orbits. **[7 marks]**

$r_{Earth} = 149.6 \times 10^{9}$ m (1) $\quad r_{Mercury} = 57.9 \times 10^{9}$ m. (1)

$\therefore$ Orbit difference $= 9.17 \times 10^{10}$ m. (1) [conversion - 1 mark]

$$F = \frac{G M_E M_S}{r^2}$$

$$= \frac{(6.67 \times 10^{-11})(5.976 \times 10^{24})(3.335 \times 10^{23})}{(9.17 \times 10^{10})^2} \quad (1) \quad (1)$$

$$= \underline{1.58 \times 10^{16} \text{ N}} \quad (1)$$

12. Calculate the radius of Earth which will correspond with a gravitational force of 9.801 N acting on a mass of 1.00 kg on the surface. Give your answer to the nearest kilometre. **[4 marks]**

$$F = \frac{G M_E m}{r_E^2}$$

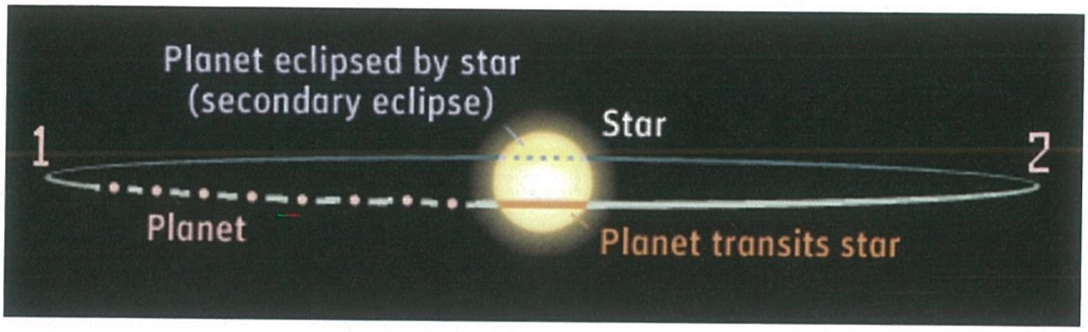
$$\Rightarrow r_E = \sqrt{\frac{G M_E m}{F}} \quad (1)$$

$$= \sqrt{\frac{(6.67 \times 10^{-11})(5.976 \times 10^{24})(1.00)}{9.801}} \quad (1)$$

$$= 6.377 \times 10^{6} \text{ m} \quad (1)$$

$$= \underline{6.377 \times 10^{3} \text{ km}} \quad (1)$$

13. Astrophysicists searching the cosmos for possible 'earth-like' planets have discovered a new exoplanet. Each night they take observational data and track the orbiting planet moving from position 1 to position 2 in 14.0 days. The central star diameter has been measured at 1.39×10^6 km.



(a) Calculate the mass of the star. **[7 marks]**

From diagram: diameter of star = 13 mm = 1.39×10^9 m. (1)

radius of orbit = 66 mm = 7.06×10^9 m. (1)

[Accuracy ~ 1 mark]

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

$$\Rightarrow M_s = \frac{4\pi^2 r^3}{G T^2} \quad (1)$$

$$= \frac{4\pi^2 (7.06 \times 10^9)^3}{(6.67 \times 10^{-11})(28.0 \times 24.0 \times 3.60 \times 10^3)^2} \quad (1)$$

(1)

$$= \underline{3.56 \times 10^{28} \text{ kg}} \quad (1)$$

(1)

(b) Find the gravitational field strength at the star's surface. **[4 marks]**

$$g = \frac{G M_s}{r_s^2} \quad (1)$$

$$= \frac{(6.67 \times 10^{-11})(3.56 \times 10^{28})}{(6.95 \times 10^8)^2} \quad (1)$$

$$= \underline{4.92 \text{ ms}^{-2}} \quad (1)$$

(1)