**1** **(a)** Write a word equation which states Newton's law of gravitation.

.....

.....

..... **[1]**

**(b)** A planet of mass *m* moves in a circular orbit of radius *r* about a star of mass *M*. The planet has an orbital period *T*.

Use your knowledge of circular motion and Newton's law of gravitation to derive Kepler's third law.

**[4]**

**(c)** The star HD10180 in the constellation Hydrus is notable for its large planetary system. The period $T$ and the mean orbital radius $r$ for HD10180's planets have been deduced from recent observations. Fig. 4.1 has been constructed using these data.

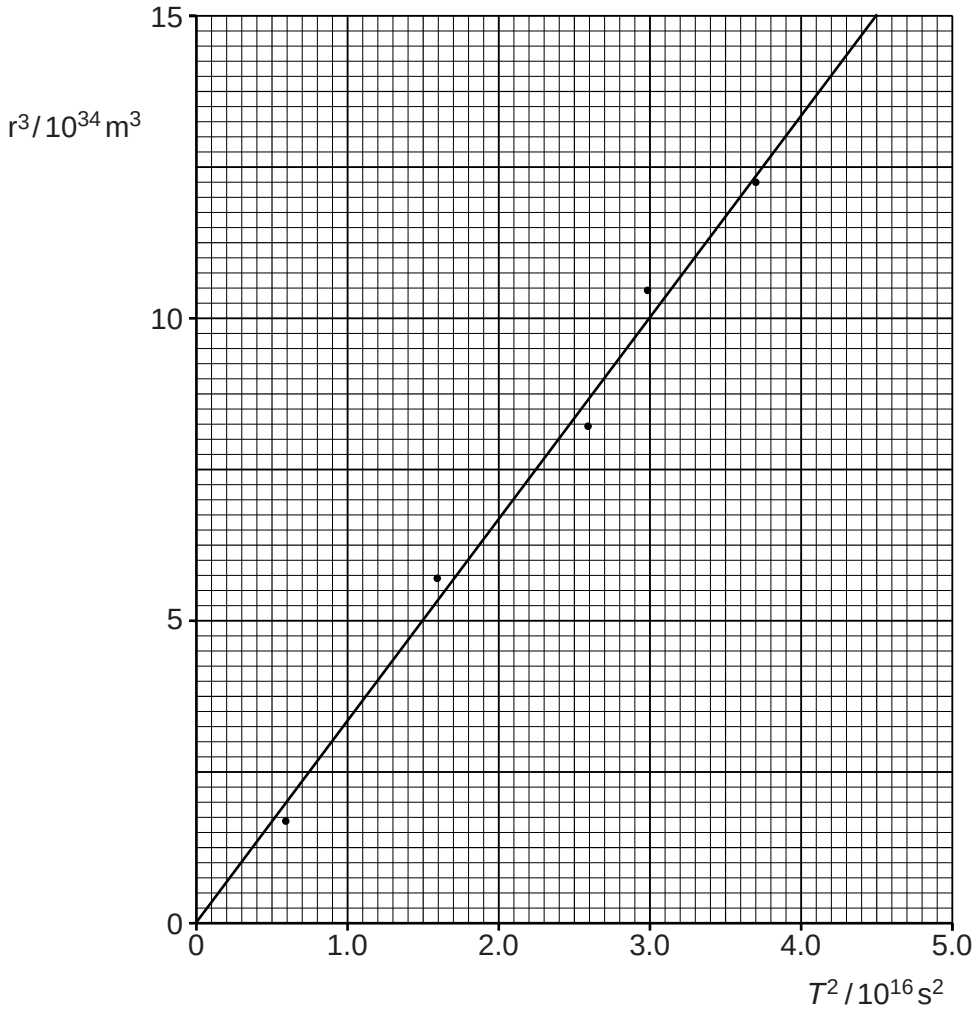


**Fig. 4.1**

**(i)** State what features of Fig. 4.1 support the view that Kepler's third law may be applied to this system.

.....

.....

..... **[1]**

**(ii)** Use Fig. 4.1 to determine the mass of the star HD10180.

mass = ..... kg **[3]**

**2** **(a)** State what is meant by the term *geostationary orbit*.

.....

.....

..... **[1]**

**(b)** In a science fiction movie, a spaceship approaches a planet called Benzar.
Benzar has a period of rotation of $1.2 \times 10^5$ s.
The captain of the spaceship orders the crew to "enter a stationary orbit over the South Pole of Benzar".

**(i)** Use your knowledge of physics to explain why it is impossible to follow these orders.

.....

.....

.....

.....

..... **[2]**

**(ii)** Benzar has mass $8.9 \times 10^{25}$ kg.
Calculate the radius of the possible stationary orbit for a spaceship circling Benzar.

radius = ..... m **[3]**

**[Total: 6]**

**3** **(a)** Fig. 2.1 shows the Earth in space.

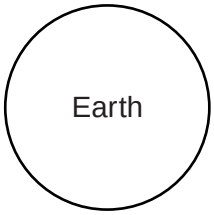


**Fig. 2.1**

**(i)** Draw lines on Fig. 2.1 to show the shape and direction of the gravitational field of the Earth. **[1]**

**(ii)** The gravitational field strength, $g$, is uniform close to the Earth's surface. Describe the pattern of gravitational field lines close to the surface of the Earth.

*In your answer you should use appropriate technical terms spelled correctly.*

.....

.....

.....

..... **[2]**

**(b)** The planet Saturn has mass $5.7 \times 10^{26}$ kg and radius $6.0 \times 10^{7}$ m.

**(i)** Calculate the gravitational field strength $g_s$ at Saturn's surface.

$g_s$ = ..... $N\,kg^{-1}$ **[2]**

**(ii)** Saturn's second-largest moon, Rhea, has orbital radius $5.3 \times 10^8$ m and mass $2.3 \times 10^{21}$ kg.
Calculate for Rhea

**1** its orbital speed $v$

$v$ = ..... $m\,s^{-1}$ **[3]**

**2** its kinetic energy.

kinetic energy = ..... J **[1]**

**[Total: 9]**

**4** **(a)** **(i)** State Newton's law of gravitation.

.....

.....

..... **[2]**

**(ii)** Define *gravitational field strength, g*.

.....

..... **[1]**

**(b)** Titan, a moon of Saturn, has a circular orbit of radius $1.2 \times 10^6$ km. The orbital period of Titan is 16 Earth days.

**(i)** Calculate the speed of Titan in its orbit.

speed = ..... m $s^{-1}$ **[2]**

**(ii)** Show that the mass of Saturn is about $5 \times 10^{26}$ kg.

**[3]**

**(c)** Rhea is another moon of Saturn with a smaller orbital radius than Titan.
Determine the ratio

$$\frac{\text{orbital period } T_R \text{ of Rhea}}{\text{orbital period } T_T \text{ of Titan}}$$ in terms of their orbital radii $r_R$ , and $r_T$ .

ratio = ..... **[2]**

**[Total: 10]**

**5** **(a)** Define *gravitational field strength*.

.....

..... **[1]**

**(b)** The table shows, in modern units, information that was known to physicists at the time of Isaac Newton.

| position | distance $r$ from centre of the Earth / km | gravitational field strength $g$ due to the Earth / N kg$^{-1}$ |
|---|---|---|
| surface of Earth | $6.4 \times 10^{3}$ | 9.8 |
| Moon's orbit | $3.8 \times 10^{5}$ | $2.7 \times 10^{-3}$ |

Use the information provided in the table to

**(i)** state a relationship between the gravitational field strength $g$ and the distance $r$ and verify this relationship

.....

..... **[3]**

**(ii)** show that the mass of the Earth is about $6 \times 10^{24}$ kg

**[2]**

**(iii)** determine the mean density of the Earth.

density = ..... kg m$^{-3}$ **[2]**