Gravitational fields

Question Paper 1

Level	A Level
Subject	Physics
Exam Board	OCR
Topic	Newtonian world and astrophysics
Sub-Topic	Gravitational fields
Booklet	Question Paper 1

Time Allowed: **51 minutes**

Score: **/ 42**

Percentage: **/100**

Grade Boundaries:

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

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.

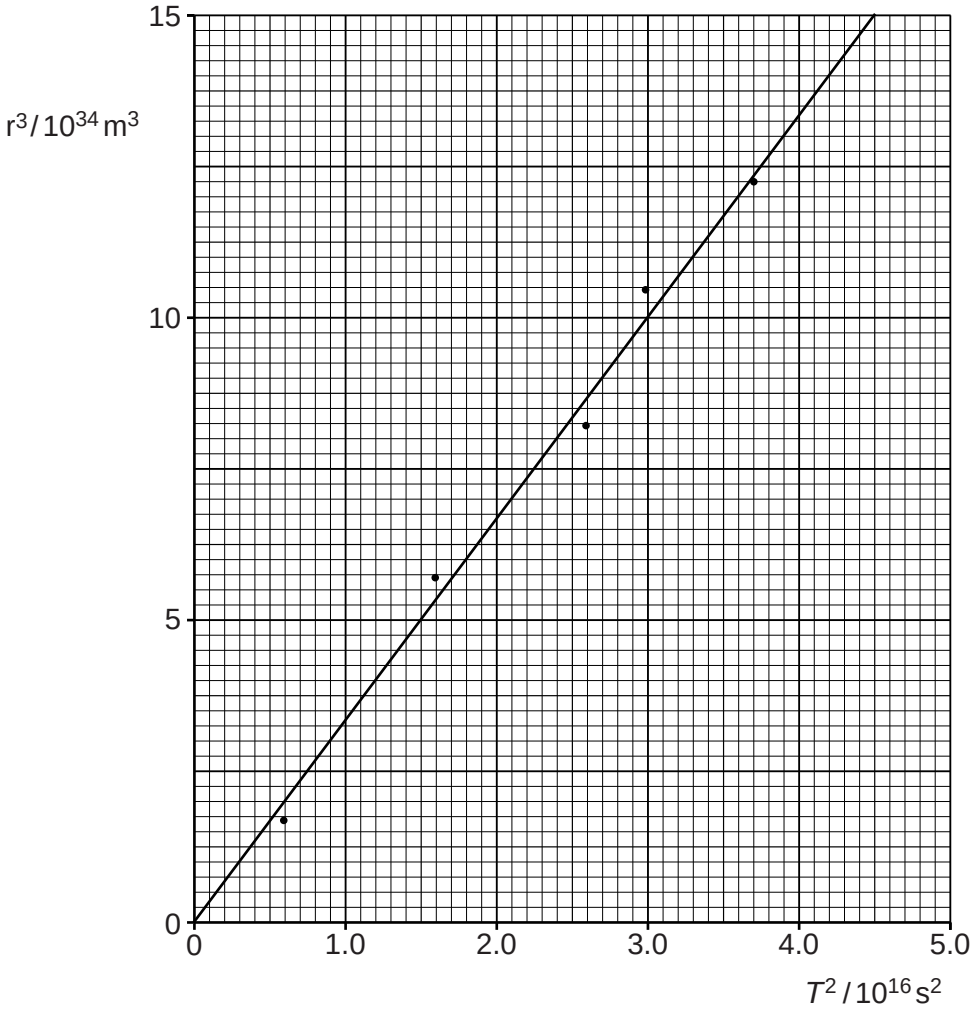

Fig. 4.1

(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 1.2×10^5 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 8.9×10^{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.

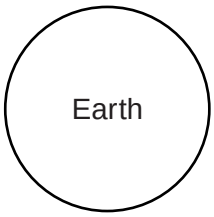

Fig. 2.1

(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 5.7×10^{26} kg and radius 6.0×10^{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 5.3×10^8 m and mass 2.3×10^{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 1.2×10^6 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 5×10^{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	6.4×10^3	9.8
Moon's orbit	3.8×10^5	2.7×10^{-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 6×10^{24} kg

[2]

(iii) determine the mean density of the Earth.

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

[Total: 8]