

1)

(a) State, in words, Newton's law of gravitation.

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

(b) Fig. 3.1 shows the circular orbits of two of Jupiter's moons: Adrastea, **A**, and Megaclite, **M**.

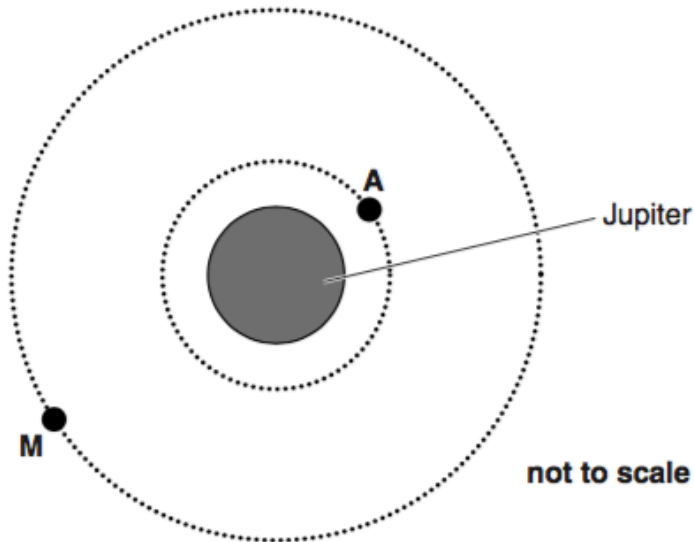


Fig. 3.1

Use the following data in the calculations below.

- orbital radius of **A** = 1.3×10^8 m
- orbital period of **A** = 7.2 hours
- gravitational field strength at orbit of **A** = 7.5 N kg^{-1}
- orbital radius of **M** = 2.4×10^{10} m

Calculate

(i) the mass of Jupiter

mass = kg [3]

(ii) the gravitational field strength at the orbit of **M**

gravitational field strength = N kg^{-1} [2]

(iii) the orbital period of **M**.

orbital period = hours [3]

[Total: 9]

2)

(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]

3)

(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]

4)

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

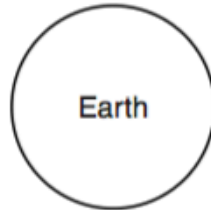


Fig. 2.1

- (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.

$g_s = \dots\dots\dots \text{N kg}^{-1}$ [2]

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

1 its orbital speed v

$v = \dots\dots\dots \text{ m s}^{-1}$ [3]

2 its kinetic energy.

kinetic energy = $\dots\dots\dots \text{ J}$ [1]

[Total: 9]

5)

(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]

6)

(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.

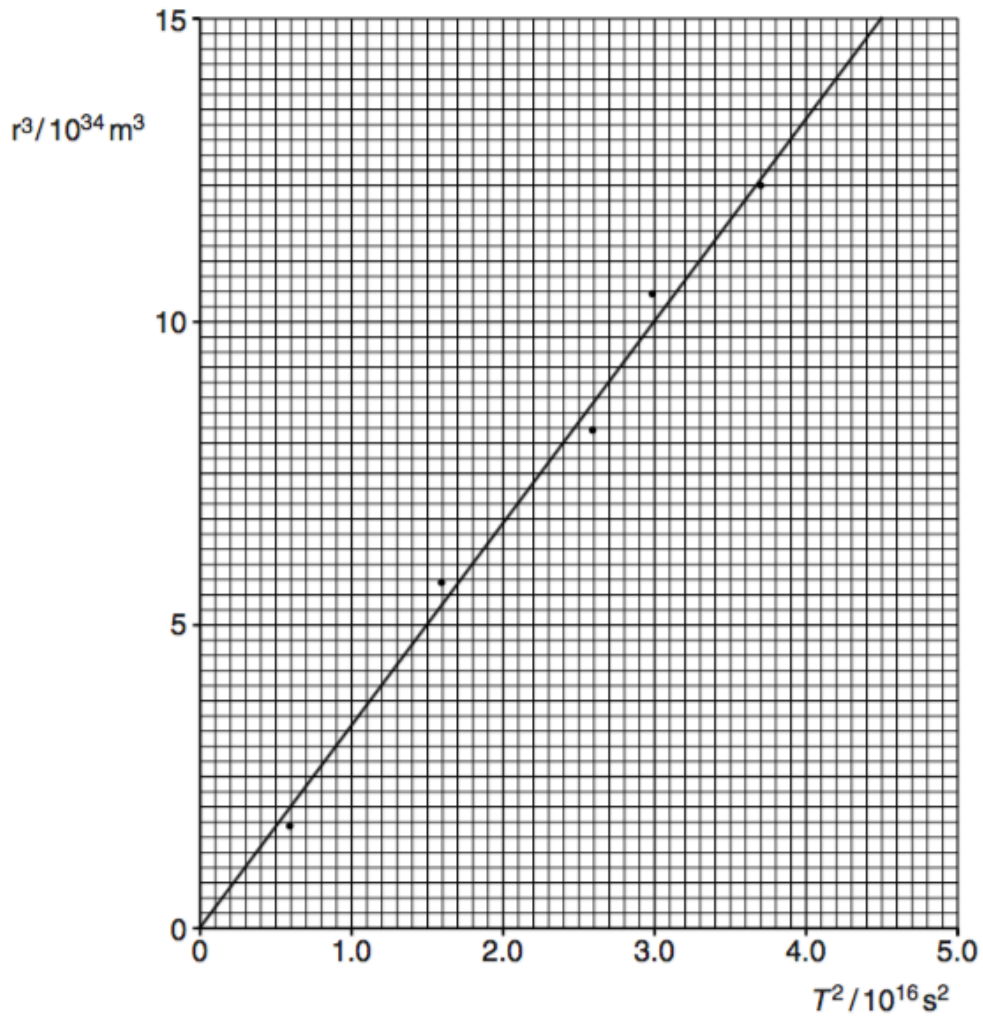


Fig. 4.1

- (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]**

7)

- (a) Fig. 2.1 shows an aeroplane flying in a horizontal circle at constant speed. The weight of the aeroplane is W and L is the lift force acting at right angles to the wings.



Fig. 2.1

- (i) Explain how the lift force L maintains the aeroplane flying in a **horizontal** circle.

.....

 [2]

- (ii) The aeroplane of mass $1.2 \times 10^5 \text{ kg}$ is flying in a horizontal circle of radius 2.0 km .

The centripetal force acting on the aeroplane is $1.8 \times 10^6 \text{ N}$. Calculate the speed of the aeroplane.

speed = ms^{-1} [2]

- (b) Fig. 2.2 shows a satellite orbiting the Earth at a constant speed v . The radius of the orbit is r .

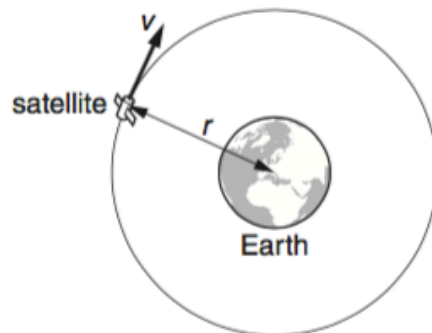


Fig. 2.2

Show that the orbital period T of the satellite is given by the equation

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

where M is the mass of the Earth and G is the gravitational constant.

[3]

- (c) The satellites used in television communication systems are usually placed in geostationary orbits.



In your answer, you should use appropriate technical words spelled correctly.

- (i) State two features of geostationary orbits.

1.
.....
2.
..... [2]

- (ii) Calculate the radius of orbit of a geostationary satellite.

The mass of the Earth is 6.0×10^{24} kg.

radius = m [3]

[Total: 12]

8)

- (a) (i) State, in terms of force, the conditions necessary for an object to move in a circular path at constant speed.

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

- (ii) Explain why this object is accelerating. State the direction of the acceleration.

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

- (b) A satellite moves in a circular orbit around the Earth at a constant speed of 3700 ms^{-1} .

The mass M of the Earth is $6.0 \times 10^{24} \text{ kg}$.

Calculate the radius of this orbit.

radius = m [4]

- (c) In order to move the satellite in (b) into a new smaller orbit, a decelerating force is applied for a brief period of time.

- (i) Suggest how the decelerating force could be applied.

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

- (ii) The radius of this new orbit is $2.0 \times 10^7 \text{ m}$. Calculate the speed of the satellite in this orbit.

speed = ms^{-1} [2]

[Total: 10]

9)

- (a) (i) State the name given to satellites that orbit the Earth, with a period of 1 day, above the equator.



You should use the appropriate technical term spelled correctly.

..... [1]

- (ii) Explain why these satellites orbit above the equator.

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

- (iii) For companies who provide a satellite TV service, suggest the main advantage of using this type of satellite.

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

- (iv) The mass of the Earth is 6.0×10^{24} kg. Show that the radius of the orbit of a satellite with an orbital period of 1 day is about 4×10^7 m.

[3]

- (b) (i) State Kepler's third law.

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

- (ii) The Moon orbits the Earth with a period of 27.3 days. Use the information given in (a)(iv) to calculate the following ratio:

$$\frac{\text{distance of the Moon from the Earth's centre}}{\text{distance of the satellite from the Earth's centre}}$$

ratio = [2]

[Total: 9]

10)

A satellite orbits the Earth in a circular path 800 km above the Earth's **surface**. At the orbit of the satellite the gravitational field strength is 7.7 N kg^{-1} . The radius of the Earth is 6400 km.

(a) Calculate

(i) the orbital speed of the satellite

orbital speed = ms^{-1} **[3]**

(ii) the period of the orbit of the satellite.

period = s **[2]**

(b) The orbit of the satellite passes over the Earth's poles.

(i) Show that the satellite makes about 14 orbits around the Earth in 24 hours.

[1]

(ii) The cameras on board the satellite continually photograph a strip of the Earth's surface, of width 3000 km, directly below the satellite. Determine, with an appropriate calculation, whether the satellite can photograph the whole of the Earth's surface in 24 hours. State your conclusion.

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

(c) Suggest a practical use of such a satellite.

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

[Total: 10]