OCR Physics Unit 4

Topic Questions from Papers

Gravitational Fields

3 Fig. 3.1 represents the planet Jupiter. The centre of the planet is labelled as **O**.

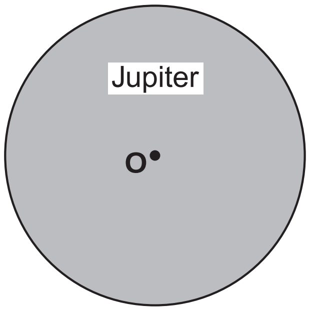

Fig. 3.1

(a) Draw gravitational field lines on Fig. 3.1 to represent Jupiter's gravitational field. **[2]**

(b) Jupiter has a radius of 7.14×10^7 m and the gravitational field strength at its surface is $24.9\,\mathrm{N\,kg^{-1}}$.

(i) Show that the mass of Jupiter is about 2×10^{27} kg.

[3]

(ii) Calculate the average density of Jupiter.

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

[Total: 7]

2 **(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 1.2×10^5 kg is flying in a horizontal circle of radius 2.0 km.

The centripetal force acting on the aeroplane is 1.8×10^6 N. Calculate the speed of the aeroplane.

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

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

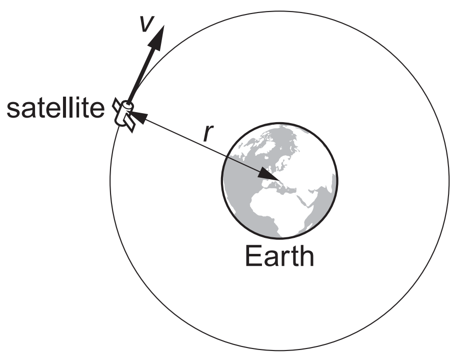

Fig. 2.2

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]

3 **(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 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]

6 (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]

END OF QUESTION PAPER

2 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 = ... m s^{-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]

3 **(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**.

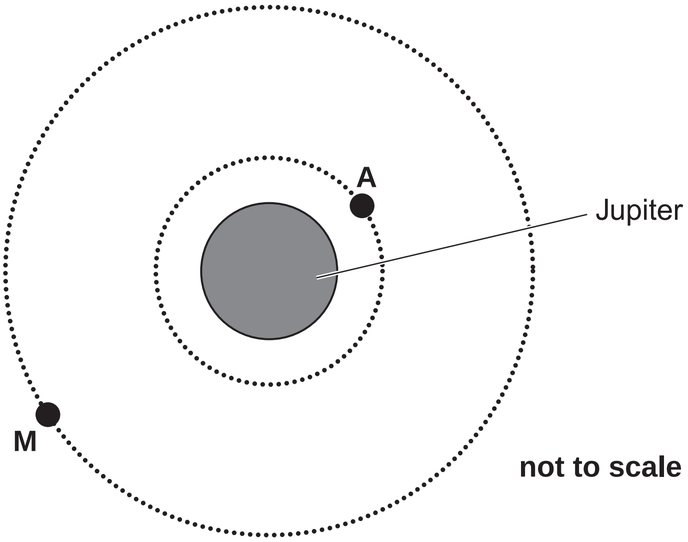

Fig. 3.1

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]

Data

Values are given to three significant figures, except where more are useful.

speed of light in a vacuum	c	3.00×10^{8} m s^{-1}
permittivity of free space	ε_0	8.85×10^{-12} C^2 N^{-1} m^{-2} (F m^{-1})
elementary charge	e	1.60×10^{-19} C
Planck constant	h	6.63×10^{-34} J s
gravitational constant	G	6.67×10^{-11} N m^2 kg^{-2}
Avogadro constant	N_A	6.02×10^{23} mol^{-1}
molar gas constant	R	8.31 J mol^{-1} K^{-1}
Boltzmann constant	k	1.38×10^{-23} J K^{-1}
electron rest mass	m_e	9.11×10^{-31} kg
proton rest mass	m_p	1.673×10^{-27} kg
neutron rest mass	m_n	1.675×10^{-27} kg
alpha particle rest mass	m_α	6.646×10^{-27} kg
acceleration of free fall	g	9.81 m s^{-2}

Conversion factors

unified atomic mass unit	$1\ \text{u} = 1.661 \times 10^{-27}$ kg
electron-volt	$1\ \text{eV} = 1.60 \times 10^{-19}$ J
	1 day $= 8.64 \times 10^{4}$ s
	1 year $\approx 3.16 \times 10^{7}$ s
	1 light year $\approx 9.5 \times 10^{15}$ m

Mathematical equations

arc length $= r\theta$

circumference of circle $= 2\pi r$

area of circle $= \pi r^2$

curved surface area of cylinder $= 2\pi rh$

volume of cylinder $= \pi r^2 h$

surface area of sphere $= 4\pi r^2$

volume of sphere $= \frac{4}{3}\pi r^3$

Pythagoras' theorem: $a^2 = b^2 + c^2$

For small angle $\theta \Rightarrow \sin\theta \approx \tan\theta \approx \theta$ and $\cos\theta \approx 1$

$\lg(AB) = \lg(A) + \lg(B)$

$\lg(\frac{A}{B}) = \lg(A) - \lg(B)$

$\ln(x^n) = n\ln(x)$

$\ln(\mathrm{e}^{kx}) = kx$

Formulae and relationships

Unit 1 – Mechanics

$F_x = F\cos\theta$
$F_y = F\sin\theta$

$a = \dfrac{\Delta v}{\Delta t}$

$v = u + at$

$s = \dfrac{1}{2}(u + v)t$

$s = ut + \dfrac{1}{2}at^2$

$v^2 = u^2 + 2as$

$F = ma$

$W = mg$

moment = Fx

torque = Fd

$\rho = \dfrac{m}{V}$

$p = \dfrac{F}{A}$

$W = Fx\cos\theta$

$E_k = \dfrac{1}{2}mv^2$

$E_p = mgh$

efficiency = $\dfrac{\text{useful energy output}}{\text{total energy input}} \times 100\%$

$F = kx$

$E = \dfrac{1}{2}Fx \qquad E = \dfrac{1}{2}kx^2$

stress = $\dfrac{F}{A}$

strain = $\dfrac{x}{L}$

Young modulus = $\dfrac{\text{stress}}{\text{strain}}$

Unit 2 – Electrons, Waves and Photons

$\Delta Q = I\Delta t$

$I = Anev$

$W = VQ$

$V = IR$

$R = \dfrac{\rho L}{A}$

$P = VI \qquad P = I^2R \qquad P = \dfrac{V^2}{R}$

$W = VIt$

e.m.f. = $V + Ir$

$V_{out} = \dfrac{R_2}{R_1 + R_2} \times V_{in}$

$v = f\lambda$

$\lambda = \dfrac{ax}{D}$

$d\sin\theta = n\lambda$

$E = hf \qquad E = \dfrac{hc}{\lambda}$

$hf = \phi + KE_{max}$

$\lambda = \dfrac{h}{mv}$

$R = R_1 + R_2 + \dots$

$\dfrac{1}{R} = \dfrac{1}{R_1} + \dfrac{1}{R_2} + \dots$

Unit 4 – Newtonian World

$F = \frac{\Delta p}{\Delta t}$

$v = \frac{2\pi r}{T}$

$a = \frac{v^2}{r}$

$F = \frac{mv^2}{r}$

$F = -\frac{GMm}{r^2}$

$g = \frac{F}{m}$

$g = -\frac{GM}{r^2}$

$T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

$f = \frac{1}{T}$

$\omega = \frac{2\pi}{T} = 2\pi f$

$a = -(2\pi f)^2 x$

$x = A\cos(2\pi ft)$

$v_{max} = (2\pi f)A$

$E = mc\Delta\theta$

$pV = NkT$

$pV = nRT$

$E = \frac{3}{2}kT$

Unit 5 – Fields, Particles and Frontiers of Physics

$E = \frac{F}{Q}$

$F = \frac{Qq}{4\pi\varepsilon_0 r^2}$

$E = \frac{Q}{4\pi\varepsilon_0 r^2}$

$E = \frac{V}{d}$

$F = BIL\sin\theta$

$F = BQv$

$\phi = BA\cos\theta$

induced e.m.f. = – rate of change of magnetic flux linkage

$\frac{V_s}{V_p} = \frac{n_s}{n_p}$

$Q = VC$

$W = \frac{1}{2}QV$ $\quad W = \frac{1}{2}CV^2$

time constant = *CR*

$x = x_0 e^{-\frac{t}{CR}}$

$C = C_1 + C_2 + \ldots$

$\frac{1}{C} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$

$A = \lambda N$

$A = A_0 e^{-\lambda t}$

$N = N_0 e^{-\lambda t}$

$\lambda t_{½} = 0.693$

$\Delta E = \Delta mc^2$

$I = I_0 e^{-\mu x}$