Gravitational Fields 1

Have a go at the following exam questions.

OCR, G484, JUNE 2011

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

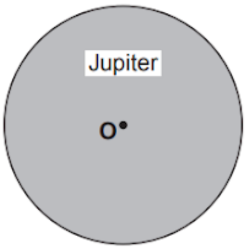


Fig. 3.1

(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 $24.9\,\text{N kg}^{-1}$.

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

[3]

(ii) Calculate the average density of Jupiter.

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

[Total: 7]

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]

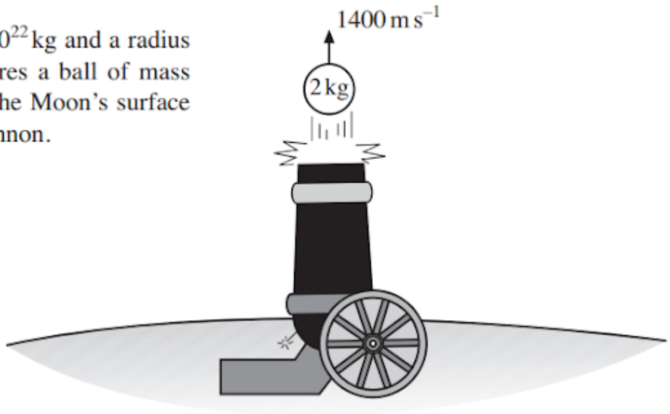
(c) Rhea is another moon of Saturn with a smaller orbital radius than Titan.
Determine the ratio

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

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

[Total: 10]

5. The moon has a mass of $7{\cdot}35 \times 10^{22}$ kg and a radius of $1{\cdot}74 \times 10^{6}$ m. An astronaut fires a ball of mass 2·00 kg vertically upwards from the Moon's surface at a speed of $1400\,\mathrm{m\,s^{-1}}$ from a cannon.



(a) (i) Calculate the gravitational field strength at the surface of the Moon. [2]

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(ii) Calculate the weight of the cannon ball on the Moon's surface. [2]

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(b) (i) Calculate the initial kinetic energy of the cannon ball. [1]

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....

(ii) Show that the initial gravitational potential energy of the cannon ball is –5·6 MJ. [2]

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(iii) Apply the principle of conservation of energy to the cannon ball and calculate the greatest height that the cannon ball reaches above the surface of the Moon. [4]

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4. The first step in deriving the relationship between the height of a satellite above the Earth's surface, h, and the period of its orbit around the Earth is to note that the centripetal force is provided by the gravitational force:

$$\frac{Gm_1m_2}{r^2} = m_2\omega^2 r$$

(a) Explain briefly the meaning of each term in the equation. [4]

m_1 ....

m_2 ....

r ....

ω ....

(b) Use the above equation to derive the relationship between the height, h, of a satellite above the Earth's surface and its orbital period, T, [4]

$$h + R_E = \sqrt[3]{\frac{Gm_1T^2}{4\pi^2}}$$

where R_E is the radius of the Earth.

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(c) The mass of the Earth is 6.0×10^{24} kg and its radius is 6.4×10^6 m. Calculate the height of a geostationary satellite above the Earth's surface. [2]

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(d) The mass of the satellite is 850 kg. Calculate the increase in its potential energy when it was initially moved from the Earth's surface to the geostationary orbit. [3]

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