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AQA, Edexcel

A Level

A Level Physics

Gravitational Fields 2 (Answers)

Name:

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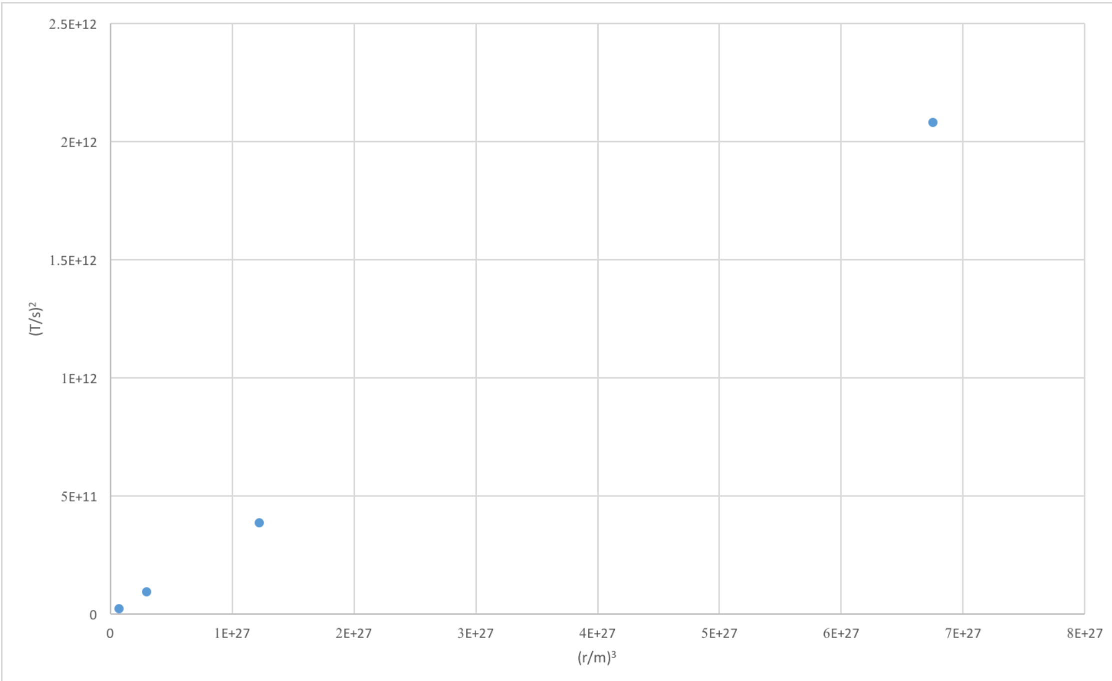
Total Marks: /30

1. The graph below shows the variation of the orbital period squared with the radius cubed for Jupiter's moons.

Total for Question 1: 10



(a) Define a gravitational field. [1]

Solution: A region where a mass experiences a force.

(b) By equating the centripetal force and the gravitational force on a planet, show that $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$. [4]

Solution: $\frac{mv^2}{r} = \frac{GmM}{r^2} \rightarrow v^2 = \frac{GM}{r}$
Since the planet is assumed to be moving in a circle, $v = \frac{2\pi r}{T}$
Combining gives: $T^2 = \left(\frac{4\pi^2}{GM}\right)r^3$

(c) Use the result from the previous part and the graph above to calculate Jupiter's mass. [3]

Solution: 1.9×10^{27} kg

(d) Kepler's second law states that a line segment joining a planet and the sun sweeps out equal areas during equal intervals of time. Use this to explain why we rarely see great comets, whose orbits are highly elliptical. [2]

Solution: Orbits are highly elliptical; when close to the sun the comets travel much faster than elsewhere. Therefore, they spend much less time near the sun (where we can see them) than they do far away.

2. Satellites can also be analysed using the various laws of gravitation and circular motion. For this question, assume that Earth's mass is 6.0×10^{24} kg and that it has a radius of 6400 km.

Total for Question 2: 10

(a) By equating gravitational and centripetal forces, show that the mass of a satellite in orbit does not affect its speed. [2]

Solution: $\frac{mv^2}{r} = -GmM/r^2 \rightarrow v = \sqrt{\frac{GM}{r}}$

(b) Calculate the speed at which a satellite must be released into orbit if it is to maintain a height of 100 km above Earth's surface. [2]

Solution: 7.8 kms^{-1}

(c) Define a geostationary orbit. [3]

Solution: 1/ directly above the equator
2/ rotates in same direction as earth
3/ period of orbit is 24hrs.

(d) Calculate the altitude of a geostationary orbit. [3]

Solution: 3600 km

3. All vector fields have an associated scalar potential. For this question, assume Earth has a radius of 6400 km and a mass of 6.0×10^{24} kg.

Total for Question 3: 10

(a) Define, in words, the gravitational potential. [1]

Solution: At a point, the energy required, per unit mass, to bring a body from infinity to that point.

(b) Given that the gravitational potential, V_g, is 63 $\mathrm{MJkg^{-1}}$ at Earth's surface, calculate the following:

i. V_g at infinity. [1]

Solution: Zero

ii. V_g at an altitude equal to Earth's radius. [1]

Solution: 31.5 $\mathrm{MJkg^{-1}}$

(c) Calculate the gravitational potential energy of a 10 kg ball at an altitude equal to three times Earth's radius. [2]

Solution: 210 MJ

(d) Sketch a graph to show how the magnitude of the gravitational force varies with the distance from the centre of the spherical object creating the field. What is represented by the area underneath the graph? [1]

> **Solution:** Should take form of $y \propto 1/x$
> Work done.

(e) The average kinetic energy of an H_2 molecule is given by the equation $\frac{1}{2}m\bar{c^2} = \frac{3}{2}kT$, where m is the mass of the molecule, c is the r.m.s. speed, k is the Boltzmann constant and T is temperature. By calculating the r.m.s. speed and the escape velocity, determine whether or not a helium molecule at 300 K can escape Earth's atmosphere. The mass of one atom of helium is 6.6×10^{-27} kg. [4]

> **Solution:** In theory it cannot: r.m.s. speed is 970 ms^{-1} and escape velocity is 11.2 kms^{-1}.