OCR

A Level

A Level Physics

Gravitational Fields 2

Name:

M M E

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Total Marks: /30

1. Kepler's laws were developed long before Newton's era and are based purely on empirical observation. From them it is possible to determine key orbit characteristics, especially if theoretical models are developed in accordance with observations.

Total for Question 1: 10

(a) State the following:

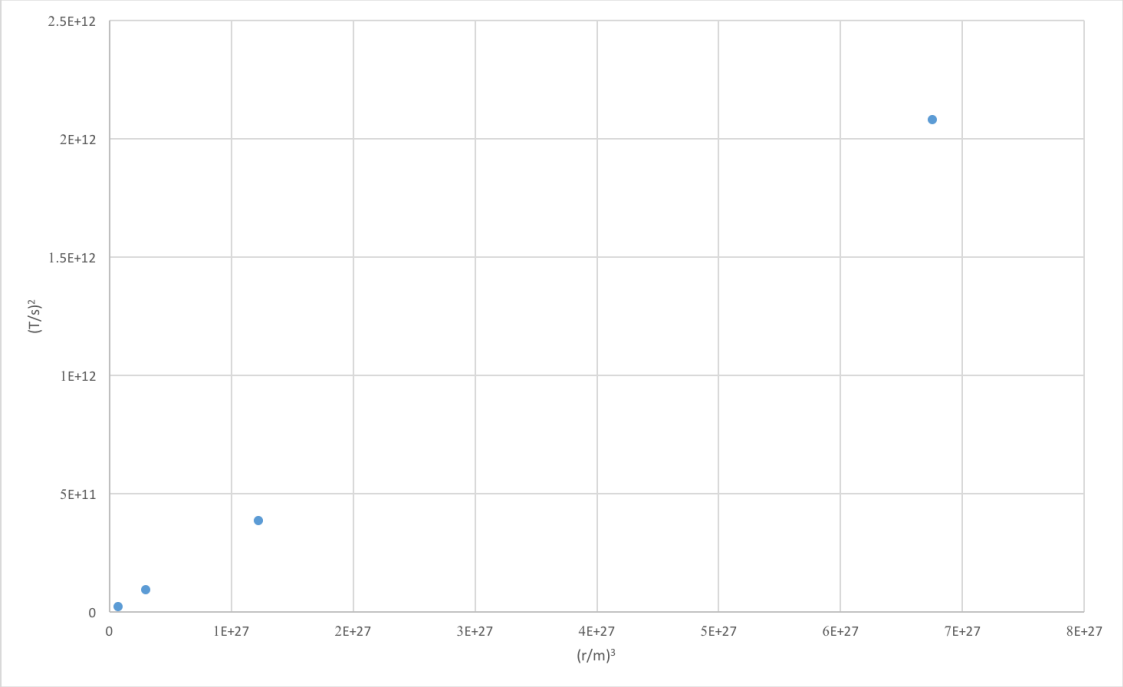
i. Kepler's first law. [1]

ii. Kepler's second law. [1]

iii. Kepler's third law. [1]

(b) What provides a planet's centripetal force? [1]

(c) Derive an expression that gives a theoretical justification for Kepler's third law. [3]



(d) The graph above shows the orbital properties of Jupiter's moons. Use it to calculate Jupiter's mass. [3]

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]

(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]

(c) Define a geostationary orbit. [3]

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

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]

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

i. V_g at infinity. [1]

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

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

(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]

(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]