1 As part of the Apollo space missions to the Moon, astronauts were required to measure the mass of collected lunar rock samples using a spring balance.

The spring balance was calibrated to measure mass in the non-SI unit of the pound. The gravitational field strength on the Moon is 1/6th of that on Earth.

(a) A sample of lunar rock was observed to have a mass of 35 pounds.

Calculate the weight of the sample on the Moon.

1 pound = 0.45 kg

(3)

Weight of sample on the Moon =

(b) The sample measured in part (a) was brought to Earth.

Suggest how the measurements could be scaled so that the same spring balance could be used to measure the mass of the sample on Earth.

(1)

(c) Instead of rescaling the spring balance for use on Earth, the spring could be replaced.

Suggest, with a reason, a difference between springs selected for use in spring balances on Earth and those for use on the Moon.

(2)

(Total for Question = 6 marks)

2 In a science fiction television programme the gravitational field strength on the Moon becomes equal to that of the Earth. The radius of the Moon stays constant.

(a) Calculate the mass of the Moon that would be required for the gravitational field strength at its surface to equal the gravitational field strength at the surface of the Earth.

radius of the Moon = 1.74×10^6 m

(2)

Mass of Moon required =

(b) Explain why a more massive Moon would have no effect on the time taken for the Moon to orbit the Earth.

(2)

(c) Suggest what effect a more massive Moon would have at the Earth's surface.

(1)

(Total for Question = 5 marks)

3 The Moon has an orbit around the Earth of radius 3.86×10^8 m, with a time period of 2.36×10^6 s.

(a) (i) Using the data provided, show that the product GM is about 4.1×10^{14} m^3 s^{-2}, where M is the mass of the Earth.

(3)

(ii) At the surface of the Earth g is measured to be 9.81 N kg^{-1}.

Calculate a value for the radius of the Earth.

(2)

Radius of the Earth =

(b) It has been estimated that, at any one time, there may be about a thousand small asteroids orbiting the Earth. These asteroids orbit at between five to ten times the distance of the Moon from the Earth. Most make no more than one orbit before being pulled out of this orbit by the Sun.

Suggest why these asteroids do not remain in a stable orbit around the Earth.

(2)

(Total for Question = 7 marks)

4 Mars is our nearest neighbour in the solar system. In August 2003 the distance between Mars and the Earth was the closest in recorded history at 5.6×10^{10} m.

mass of Mars = 6.4×10^{23} kg

mass of Earth = 6.0×10^{24} kg

Calculate the gravitational force between Mars and the Earth when they were at this distance.

(2)

Gravitational force =

(Total for Question = 2 marks)

5 (a) Derive an expression for the gravitational field strength g at a distance r from the centre of a mass M. Use the list of equations at the end of this question paper.

(2)

(b) Use your expression to calculate g at the surface of the Earth.

mass of Earth $M_E = 5.97 \times 10^{24}$ kg
radius of Earth $r_E = 6.38 \times 10^6$ m

(1)

g =

(Total for Question = 3 marks)

6 Communications satellites were first proposed in 1945 by the science fiction author Arthur C. Clarke. In an article published in the magazine 'Wireless World' he asked whether rocket stations could give worldwide radio coverage.

In the article Clarke states:

"There are an infinite number of possible stable orbits, circular and elliptical, in which only one rocket would remain if the initial conditions were correct. A velocity of 8 km s^{-1} applies only to the closest possible orbit, one just outside the atmosphere, and the period of revolution would be about 90 minutes. As the radius of the orbit increases the velocity decreases, since gravity is diminishing and less centrifugal force is needed to balance it."

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(a) (i) Explain what is meant in the article by the phrase "gravity is diminishing", and criticise the statement that "less centrifugal force is needed to balance (the satellite)".

(3)

(b) (i) Deriving an appropriate equation, show that the orbital speed of the satellite decreases as the radius of orbit increases.

(3)

(ii) Deriving an appropriate equation, show that the orbital period of a satellite increases as the orbital speed decreases.

(2)

(c) The period T of a satellite in a circular orbit is given by the equation

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

where r is the radius of orbit and M is the mass of the Earth.

Calculate the period of a satellite in an orbit 4.0×10^6 m above the surface of the Earth.

mass of the Earth 5.98×10^{24} kg

radius of the Earth 6.36×10^6 m

(2)

Period of satellite =

(d) After time the radius of the satellite's orbit will start to decrease due to the resistive forces acting on the satellite from the atmosphere. As this happens the satellite speeds up.

Describe the energy changes occurring as the radius of the orbit decreases.

(2)

(Total for Question 12 marks)