

1

Which of the following statements about Newton's law of gravitation is correct?

Newton's gravitational law explains

A the origin of gravitational forces.

☐

B why a falling satellite burns up when it enters the Earth's atmosphere.

☐

C why projectiles maintain a uniform horizontal speed.

☐

D how various factors affect the gravitational force between two particles.

☐

(Total 1 mark)

2

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(Total 1 mark)

3

(a) State Newton's law of gravitation.

(2)

- (b) In 1798 Cavendish investigated Newton's law by measuring the gravitational force between two unequal uniform lead spheres. The radius of the larger sphere was 100 mm and that of the smaller sphere was 25 mm.
- (i) The mass of the smaller sphere was 0.74 kg. Show that the mass of the larger sphere was about 47 kg.

$$\text{density of lead} = 11.3 \times 10^3 \text{ kg m}^{-3}$$

(2)

- (ii) Calculate the gravitational force between the spheres when their surfaces were in contact.

answer = _____ N

(2)

- (c) Modifications, such as increasing the size of each sphere to produce a greater force between them, were considered in order to improve the accuracy of Cavendish's experiment. Describe and explain the effect on the calculations in part (b) of doubling the radius of both spheres.

(4)

(Total 10 marks)

4

- (a) State, in words, Newton's law of gravitation.

(3)

- (b) By considering the centripetal force which acts on a planet in a circular orbit, show that $T^2 \propto R^3$, where T is the time taken for one orbit around the Sun and R is the radius of the orbit.

(3)

- (c) The Earth's orbit is of mean radius 1.50×10^{11} m and the Earth's year is 365 days long.

- (i) The mean radius of the orbit of Mercury is 5.79×10^{10} m. Calculate the length of Mercury's year.

- (ii) Neptune orbits the Sun once every 165 Earth years.

Calculate the ratio $\frac{\text{distance from Sun to Neptune}}{\text{distance from Sun to Earth}}$.

(4)

(Total 10 marks)

Mark schemes

1 D [1]

2 D [1]

3 (a) force of attraction between two point masses (or particles) (1)
 proportional to product of masses (1)
 inversely proportional to square of distance between them (1)

[alternatively

quoting an equation, $F = \frac{GM_1M_2}{r^2}$ with all terms defined (1)

reference to point masses (or particles) **or** r is distance between centres (1)

F identified as an attractive force (1)]

max 2

(b) (i) mass of larger sphere $M_L (= \frac{4}{3} \pi r^3 \rho) = \frac{4}{3} \pi \times (0.100)^3 \times 11.3 \times 10^3$ (1)
 $= 47(.3)$ (kg) (1)

[alternatively

use of $M \propto r^3$ gives $\frac{M_L}{0.74} = \left(\frac{100}{25}\right)^3$ (1) (= 64)

and $M_L = 64 \times 0.74 = 47(.4)$ (kg) (1)]

2

(ii) gravitational force $F \left(= \frac{GM_L M_S}{x^2} \right) = \frac{6.67 \times 10^{-11} \times 47.3 \times 0.74}{0.125^2}$ (1)

$= 1.5 \times 10^{-7}$ (N) (1)

2

- (c) for the spheres, mass $\propto$ volume (or $\propto r^3$, or $M = \frac{4}{3}\pi r^3 \rho$) (1)

mass of either sphere would be 8 $\times$ greater (378 kg, 5.91 kg) (1)

this would make the force 64 $\times$ greater (1)

but separation would be doubled causing force to be 4 $\times$ smaller (1)

net effect would be to make the force (64/4) = 16 $\times$ greater (1)

(ie 2.38×10^{-6} N)

max 4

[10]

4

- (a) attractive **force** between point masses (1)
proportional to (product of) the masses (1)
inversely proportional to square of separation/distance apart (1)

3

(b) $m\omega^2 R = (-)\frac{GMm}{R^2} \left(\text{or } = \frac{mv^2}{R} \right)$ (1)

(use of $T = \frac{2\pi}{\omega}$ gives) $\frac{4\pi^2}{T^2} = \frac{GM}{R^3}$ (1)

G and M are constants, hence $T^2 \propto R^3$ (1)

3

(c) (i) (use of $T^2 \propto R^3$ gives) $\frac{365^2}{(1.50 \times 10^{11})^3} = \frac{T_m^2}{(5.79 \times 10^{10})^3}$ (1)

$T_m = 87(.5)$ days (1)

(ii) $\frac{1^2}{(1.50 \times 10^{11})^3} = \frac{165^2}{R_N^3}$ (1) (gives $R_N = 4.52 \times 10^{12}$ m)

ratio = $\frac{4.51 \times 10^{12}}{1.50 \times 10^{11}} = 30(.1)$ (1)

4

[10]