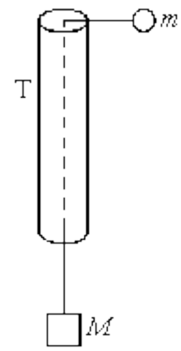
1



The figure shows a smooth thin tube T through which passes a string with masses *m* and *M* attached to its ends. Initially the tube is moved so that the mass, *m*, travels in a horizontal circle of constant radius *r*, at constant speed, *v*. Which one of the following expressions is equal to *M*?

A $\frac{mv^2}{2r}$

B mv^2rg

C $\frac{mv^2g}{r}$

D $\frac{mv^2}{rg}$

(Total 1 mark)

2 The Earth moves around the Sun in a circular orbit with a radius of 1.5×10^8 km. What is the Earth's approximate speed?

A $1.5 \times 10^3 ms^{-1}$

B $5.0 \times 10^3 ms^{-1}$

C $1.0 \times 10^4 ms^{-1}$

D $3.0 \times 10^4 ms^{-1}$

(Total 1 mark)

3 What is the value of the angular velocity of a point on the surface of the Earth?

A 1.2×10^{-5} rad s^{-1}

B 7.3×10^{-5} rad s^{-1}

C 2.6×10^{-1} rad s^{-1}

D 4.6×10^{2} rad s^{-1}

(Total 1 mark)

4 A planet of mass M and radius R rotates so rapidly that loose material at the equator just remains on the surface. What is the period of rotation of the planet?

G is the universal gravitational constant.

A $2\pi\sqrt{\frac{R}{GM}}$

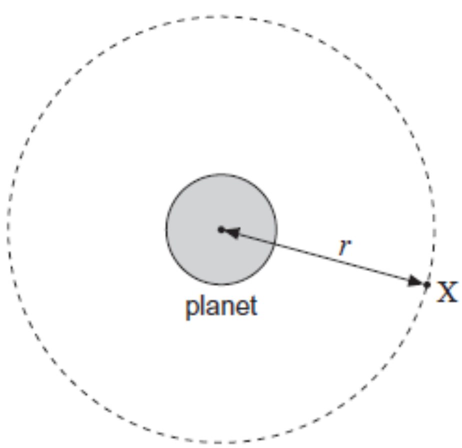
B $2\pi\sqrt{\frac{R^2}{GM}}$

C $2\pi\sqrt{\frac{GM}{R^3}}$

D $2\pi\sqrt{\frac{R^3}{GM}}$

(Total 1 mark)

5 A satellite X is in a circular orbit of radius r about the centre of a spherical planet of mass M.



Which line, **A** to **D**, in the table gives correct expressions for the centripetal acceleration a and the speed v of the satellite?

	Centripetal acceleration a	Speed v
A	$\frac{GM}{2r}$	$\sqrt{\frac{GM}{2r}}$
B	$\frac{GM}{2r}$	$\sqrt{\frac{GM}{r}}$
C	$\frac{GM}{r^2}$	$\sqrt{\frac{GM}{2r}}$
D	$\frac{GM}{r^2}$	$\sqrt{\frac{GM}{r}}$

(Total 1 mark)

6 What would the period of rotation of the Earth need to be if objects at the equator were to appear weightless?

radius of Earth = 6.4×10^6 m

A 4.5×10^{-2} hours

B 1.4 hours

C 24 hours

D 160 hours

(Total 1 mark)

7 As a comet orbits the Sun the distance between the comet and the Sun continually changes. As the comet moves towards the Sun this distance reaches a minimum value.
Which one of the following statements is **incorrect** as the comet approaches this minimum distance?

A The potential energy of the comet increases.

B The gravitational force acting on the comet increases.

C The direction of the gravitational force acting on the comet changes.

D The kinetic energy of the comet increases.

(Total 1 mark)

8 A satellite of mass *m* travels in a circular orbit of radius *r* around a planet of mass *M*. Which one of the following expressions gives the angular speed of the satellite?

A $\sqrt{GMr}$

B $\sqrt{Gmr}$

C $\sqrt{\frac{Gm}{r^3}}$

D $\sqrt{\frac{GM}{r^3}}$

(Total 1 mark)

9 The diagram shows two positions, **X** and **Y**, on the Earth's surface.

Which line, **A** to **D**, in the table gives correct comparisons at **X** and **Y** for gravitational potential and angular velocity?

	gravitational potential at X compared with Y	**angular velocity at X compared with Y**
A	greater	greater
B	greater	same
C	greater	smaller
D	same	same

(Total 1 mark)

10 A satellite is in orbit at a height h above the surface of a planet of mass M and radius R. What is the velocity of the satellite?

A $\sqrt{\frac{GM(R+h)}{R}}$

B $\frac{\sqrt{GM(R+h)}}{R}$

C $\sqrt{\frac{GM}{(R+h)}}$

D $\frac{\sqrt{GM}}{(R+h)}$

(Total 1 mark)

11 Communications satellites are usually placed in a *geo-synchronous orbit*.

(a) State **two** features of a geo-synchronous orbit.

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(2)

(b) Given that the mass of the Earth is 6.00×10^{24} kg and its mean radius is 6.40×10^{6} m,

(i) show that the radius of a geo-synchronous orbit must be 4.23×10^{7} m,

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(ii) calculate the increase in potential energy of a satellite of mass 750 kg when it is raised from the Earth's surface into a geo-synchronous orbit.

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(6)
(Total 8 marks)

12 (a) (i) Define gravitational field strength and state whether it is a scalar or vector quantity.

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(2)

(ii) A mass m is at a height h above the surface of a planet of mass M and radius R. The gravitational field strength at height h is g. By considering the gravitational force acting on mass m, derive an equation from Newton's law of gravitation to express g in terms of M, R, h and the gravitational constant G.

(2)

(b) (i) A satellite of mass 2520 kg is at a height of 1.39×10^7 m above the surface of the Earth. Calculate the gravitational force of the Earth attracting the satellite.
Give your answer to an appropriate number of significant figures.

force attracting satellite .... N

(3)

(ii) The satellite in part (i) is in a circular polar orbit. Show that the satellite would travel around the Earth three times every 24 hours.

(5)

(c) State and explain **one** possible use for the satellite travelling in the orbit in part (ii).

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(2)
(Total 14 marks)

13 (a) The weight w of an object on the Earth can be represented either as $w = mg$ or $w = \frac{GMm}{r^2}$.

(i) Explain the meaning of g and G in these equations.

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(3)

(ii) Use the equations above to show that $M = \frac{gr^2}{G}$.

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(1)

(iii) Calculate the mass of the Earth to a precision consistent with the data below.

mean radius of the Earth, = 6.4×10^6 m

$G = 6.7 \times 10^{-11}$ N m^2 kg^{-2}

$g = 9.8$ N kg^{-1}

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mass of the Earth .... kg

(3)

(b) The figure below shows a satellite in a geostationary orbit around the Earth.

(i) State the time period for a geostationary satellite.

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(1)

(ii) The height of a geostationary satellite in orbit is approximately 36 000 km above the surface of the Earth.
Calculate the radius of a geostationary orbit.

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radius .... m

(1)

(iii) Calculate the speed, in km s^{-1}, of a satellite in a geostationary orbit.

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speed .... km s^{-1}

(3)

(iv) State a common use for a geostationary satellite.

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(1)

(v) Explain why a geostationary orbit is necessary for this use.

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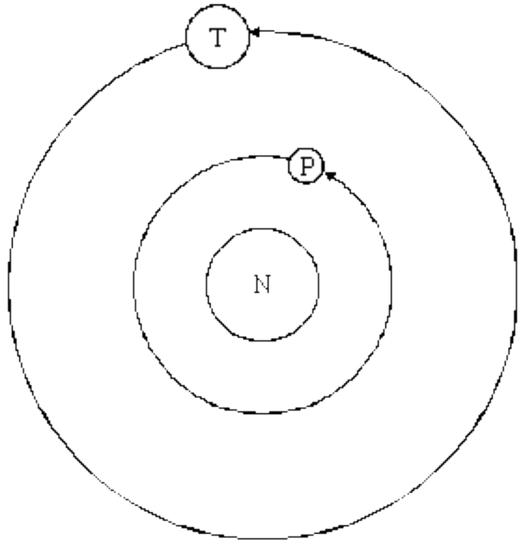
(1)
(Total 14 marks)

14 The diagram below (not to scale) shows the planet Neptune (N) with its two largest moons, Triton (**T**) and Proteus (**P**). Triton has an orbital radius of 3.55×10^8 m and that of Proteus is 1.18 $\times 10^8$ m. The orbits are assumed to be circular.



(a) Explain why the velocity of each moon varies whilst its orbital speed remains constant.

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(1)

(b) Write down an equation that shows how Neptune's gravitational attraction provides the centripetal force required to hold Triton in its orbit. Hence show that it is unnecessary to know the mass of Triton in order to find its angular speed.

(3)

(c) Show that $\frac{\text{the orbital period of Triton}}{\text{the orbital period of Proteus}}$ is approximately 5.2.

(4)
(Total 8 marks)

15 **Figure 1** shows (not to scale) three students, each of mass 50.0 kg, standing at different points on the Earth's surface. Student **A** is standing at the North Pole and student **B** is standing at the equator.

Figure 1

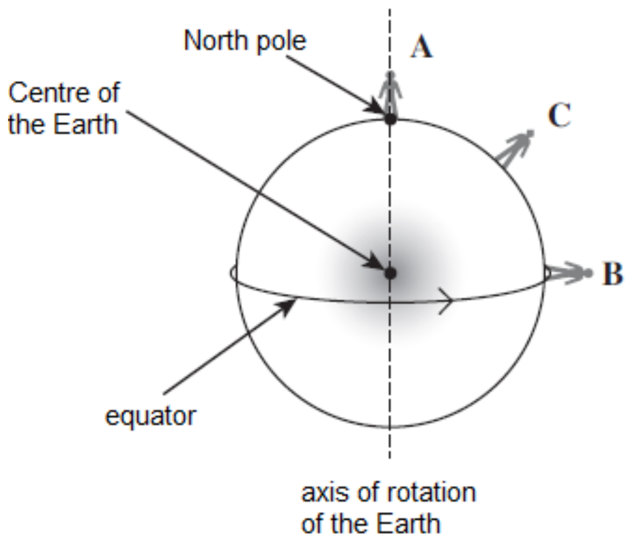
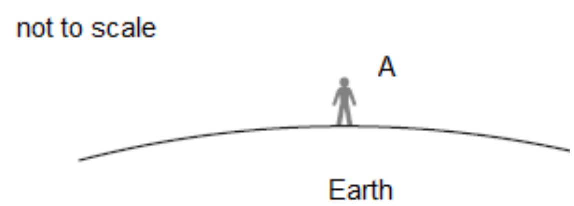


Figure 2



The radius of the Earth is 6370 km.
The mass of the Earth is 5.98×10^{22} kg.

In this question assume that the Earth is a perfect sphere.

(a) (i) Use Newton's gravitational law to calculate the gravitational force exerted by the Earth on a student.

force .... N

(3)

(ii) **Figure 2** shows a closer view of student **A**.
Draw, on **Figure 2**, vector arrows that represent the forces acting on student **A**.

(2)

(b) (i) Show that the linear speed of student **B** due to the rotation of the Earth is about 460 ms^{-1}.

(3)

(ii) Calculate the magnitude of the centripetal force required so that student **B** moves with the Earth at the rotational speed of 460 ms^{-1}.

magnitude of the force .... N

(2)

(iii) Show, on **Figure 1**, an arrow showing the direction of the centripetal force acting on student **C**.

(1)

(c) Student **B** stands on a bathroom scale calibrated to measure weight in newton (N). If the Earth were not rotating, the weight recorded would be equal to the force calculated in part (a)(i).

State and explain how the rotation of the Earth affects the reading on the bathroom scale for student **B**.

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(3)
(Total 14 marks)

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

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(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.

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(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.

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

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

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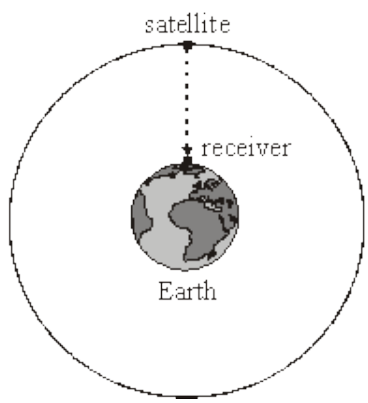
(4)
(Total 10 marks)

17 The Global Positioning System (GPS) is a system of satellites that transmit radio signals which can be used to locate the position of a receiver anywhere on Earth.



(a) A receiver at sea level detects a signal from a satellite in a circular orbit when it is passing directly overhead as shown in the diagram above.

(i) The microwave signal is received 68 ms after it was transmitted from the satellite. Calculate the height of the satellite.

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(ii) Show that the gravitational field strength of the Earth at the position of the satellite is 0.56 N kg^{-1}.

mass of the Earth = 6.0×10^{24} kg
mean radius of the Earth = 6400 km

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(4)

(b) For the satellite in this orbit, calculate

(i) its speed,

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(ii) its time period.

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(5)
(Total 9 marks)