0 3 . 1 Describe **two** properties of a radial gravitational field.

[2 marks]

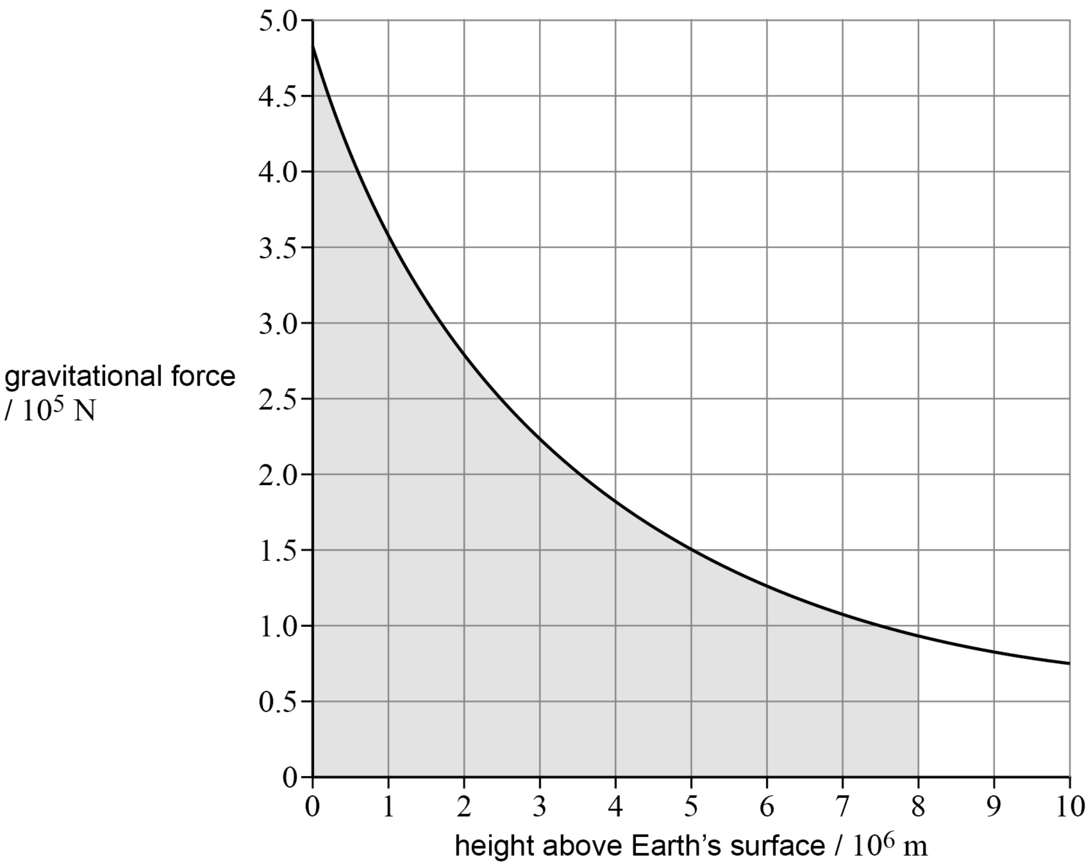
1 it is attractive

2 follows 1/r^2

A space probe is launched from the Earth's surface.

Figure 3 shows how the gravitational force acting on the space probe varies with height above the Earth's surface.

Figure 3



0 3 . 2 State the physical significance of the shaded area in **Figure 3**.

[1 mark]

change in GPE to move probe from surface to 8x10^6m

At the Earth's surface,

- the gravitational field strength of the Sun is g_S
- the gravitational field strength of the Earth is g_E.

0 3 . 3 Calculate $\frac{g_S}{g_E}$.

distance from the Earth to the Sun = 1.50×10^{11} m

[2 marks]

$g_S = \frac{GM_S}{(1.5\times10^{11})^2}$ $\quad$ $g_E = \frac{GM_E}{(6.37\times10^{6})^2}$

$\frac{g_S}{g_E} = \frac{\cancel{G}M_S}{(1.5\times10^{11})^2} \times \frac{(6.37\times10^{6})^2}{\cancel{G}M_E}$

$\frac{g_S}{g_E}$ = 6×10^{-4}

0 3 . 4 Explain why g_S is more important than g_E in predicting the motion of the space probe as it escapes from the Solar System.

[1 mark]

because the mass of the sun is many factors bigger than the earth the force from the sun is bigger than the force of the earth at the the edge of the solar system (and at that distance the distance of the probe to the sun and to the earth are approx the same)

Question 3 continues on the next page

0 3 . 5 The space probe eventually reaches a point where the gravitational influence of the Solar System is negligible.
The probe is unpowered as it approaches an isolated interstellar body **X**.
The gravitational field of **X** changes the kinetic energy of the space probe.

Table 2 shows the distance of the space probe from the centre of mass of **X** and the speed for two positions **A** and **B** of the space probe.

Table 2

	Distance of space probe from centre of mass of X / 10^6 m	Speed of space probe / 10^3 m s^{-1}
A	6.0	1.1
B	0.17	1.3

The space probe has a mass of 4.9×10^4 kg.

Calculate the mass of **X**.

[4 marks]

$$\Delta E_K = \Delta E_p$$

$$\frac{1}{2}\cancel{m_p}(v_B^2 - v_A^2) = G M_x \cancel{m_p}\left(\frac{1}{r_B} - \frac{1}{r_A}\right)$$

$$\frac{(v_B^2 - v_A^2)}{2G\left(\frac{1}{r_B} - \frac{1}{r_A}\right)} = M_x$$

mass of **X** = 6.3×10^{20} kg

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1 0 Two protons are separated by a distance of 1×10^{-9} m.

Which is an estimate of $\dfrac{\text{electric repulsion force}}{\text{gravitational attraction force}}$ for these two protons?

[1 mark]

$\frac{F_E}{F_G} = \frac{KQ_1Q_2}{\cancel{r^2}} \times \frac{\cancel{r^2}}{GMM} = \frac{KQ^2}{GM^2}$

$\frac{K}{G} \times \frac{(1.6\times10^{-19})^2}{(1.7\times10^{-27})^2} = \frac{K}{G} \times 8.9\times10^{15}$

A 10^{18}

B 10^{28}

C 10^{36}

D 10^{45}

this is very approx calculation. Or you might even know it from strong force work.

1 1 Data are collected for the mass M, radius R and escape velocity u for each planet in the Solar System.

Ek is equal to the EPE at the surface

The data show that u is directly proportional to

[1 mark]

$\frac{1}{2}\cancel{m}v^2 = \frac{GM\cancel{m}}{r}$

$v^2 = \frac{2GM}{r} \Rightarrow v = \sqrt{\frac{2GM}{r}}$

for us $v = u$ & $R = r$

so $u = \sqrt{\frac{2GM}{R}} \Rightarrow u \propto \sqrt{\frac{M}{R}}$

A $\left(\frac{M}{R}\right)^{-\frac{1}{2}}$

B $\left(\frac{M}{R}\right)^{\frac{1}{2}}$

C $\frac{M}{R}$

D $\left(\frac{M}{R}\right)^{2}$

Turn over for the next question

1 2 A satellite is in a circular orbit at a height h above the surface of a planet of mass M and radius R.

What is the linear speed of the satellite?

[1 mark]

A $\dfrac{\sqrt{GM}}{(R+h)}$ ○

B $\sqrt{\dfrac{GM}{(R+h)}}$ ○

C $\dfrac{GM}{\sqrt{R+h}}$ ○

D $\dfrac{GM}{(R+h)}$ ○

$$\frac{GM\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$$

$$v^2 = \frac{GM}{r} \qquad r = R+h$$

$$\therefore\ v = \sqrt{\frac{GM}{R+h}}$$

1 3 Which statement is **not** true for a satellite in a geostationary orbit?

[1 mark]

A The satellite orbits in the plane of the Earth's equator. ○

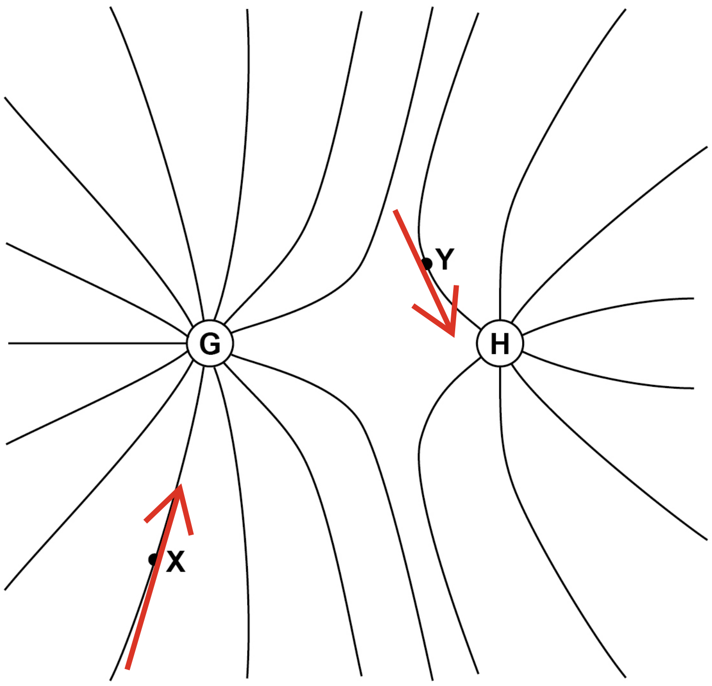
B The satellite has the same angular velocity as a point on the Earth's surface. ○

C The satellite takes 24 hours to orbit the Earth. ○

D Signals from the satellite can be sent to any point on the Earth's surface during one orbit. ○

0 4 The lines in **Figure 4** show the shape of the gravitational field around two stars **G** and **H**.

Figure 4



0 4 . 1 Compare, with reference to **Figure 4**, the masses of **G** and **H**.

[2 marks]

G is more massive as the lines are closer together and the null ppoint is closer to H.

0 4 . 2 **X** and **Y** are two points in the field.

Annotate **Figure 4** to show the field direction at **X** and the field direction at **Y**.

[1 mark]

tangent

Question 4 continues on the next page

0 4 . 3 A spherical asteroid **P** has a mass of 2.0×10^{20} kg.

The gravitational field strength at its surface is $0.40\ \mathrm{N\ kg^{-1}}$.

Calculate the radius R of **P**.

[1 mark]

$$g = \frac{GM}{r^2} \Rightarrow r = \sqrt{\frac{GM}{g}}$$

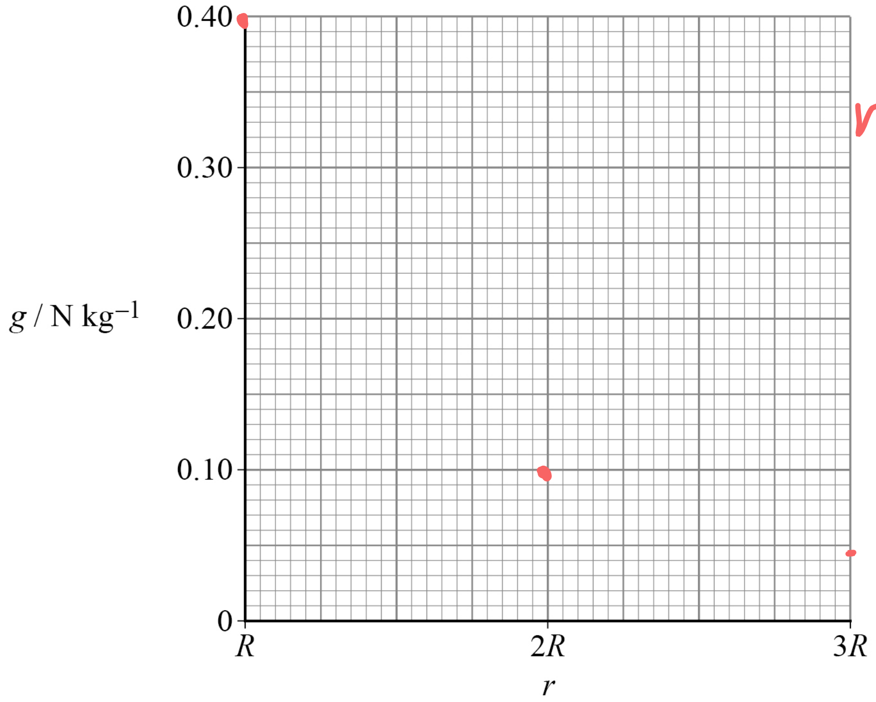
$$r = \sqrt{\left(\frac{6.67 \times 10^{-11} \times 2 \times 10^{20}}{0.4}\right)}$$

$R =$ 1.8×10^{5} m

0 4 . 4 Sketch, on **Figure 5**, the variation of the gravitational field strength g with distance r. The distance r is measured from the centre of **P**.

[1 mark]

Figure 5



nice curve

$\leftarrow g = \frac{0.4}{3^2}$

0 4 . 5 Explain what is represented by the area under the graph between $r = R$ and $r = 2R$ on **Figure 5**.

[2 marks]

area $= g \times r = \frac{GM}{r^2} \times r = \frac{GM}{r}$

so area is the change in grav pot (V) between R & 2R

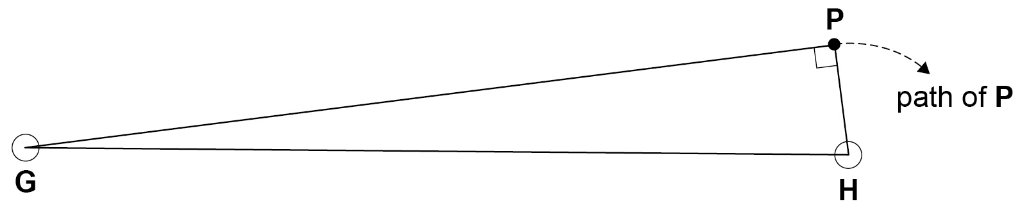
or work done per Kg in moving from R ro 2R

Question 4 continues on the next page

Asteroid **P** approaches the two stars **G** and **H**.
Figure 6 shows one position of **P** close to **H**.

$M_p = 2 \times 10^{20}$ kg

Figure 6



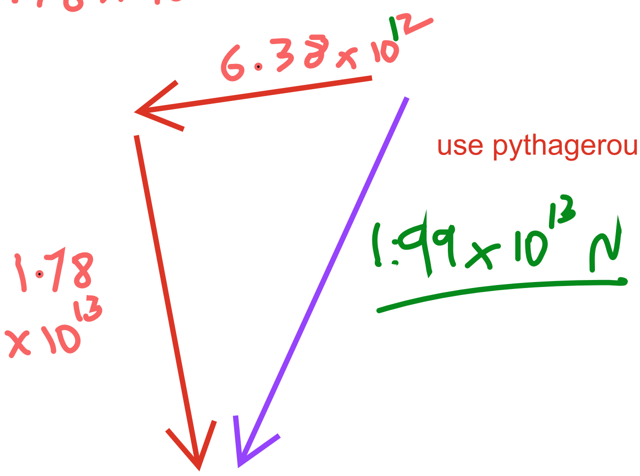
0 4 . 6 The gravitational force on **P** from **G** is 6.38×10^{12} N.
The mass of **H** is 3.00×10^{25} kg and the mass of **P** is 2.00×10^{20} kg.
The distance **HP** is 1.50×10^{11} m.

Calculate the magnitude of the acceleration of **P**.

[4 marks]

find the force on P from H. Then add to force grom G (given) then F=ma

$$F_{PH} = \frac{G M_P M_H}{r_{HP}^2} = 1.78 \times 10^{13} \text{ N}$$



$$\therefore a = \frac{F}{m} = \frac{1.99 \times 10^{13}}{2 \times 10^{20}}$$

$$\therefore a = 9.4 \times 10^{-8} \text{ m/s}^2$$

magnitude of acceleration = ______________________ m s^{-2}

0 4 . 7 Explain why **P** cannot have a circular orbit around **H**.

[1 mark]

because the radial field around H has been distorted by the addition of G meaning that the centripetal force (which is a resultant of the two fields) is not always pointing in the same direction or of the same size.

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Turn over for the next question

0 8 A fixed volume of an ideal gas is heated.

Which row gives quantities that double when the kelvin temperature of the gas doubles?

[1 mark]

A	rms speed of the molecules	pressure of the gas	⬭
B	density of the gas	rms speed of the molecules	⬭
C	internal energy of the gas	density of the gas	⬭
D	pressure of the gas	internal energy of the gas	⬭

0 9 A planet of radius R and mass M has a gravitational field strength of g at its surface.

Which row describes a planet with a gravitational field strength of $4g$ at its surface?

[1 mark]

	Radius of planet	Mass of planet		
A	$2R$	$2M$	⬭	$g/2$
B	$R\sqrt{2}$	$\frac{M}{2}$	⬭	$g/2$
C	$\frac{R}{\sqrt{2}}$	$\frac{M}{2}$	⬭	g
D	$\frac{R}{\sqrt{2}}$	$2M$	☒	$4g$

$g = \frac{GM}{r^2} \Rightarrow g \propto \frac{M}{r^2}$

1 0 The Moon orbits the Earth in 27 days.

What is the angular speed of the Moon's orbit?

[1 mark]

A 4.3×10^{-7} rad s^{-1}

B 2.7×10^{-6} rad s^{-1}

C 3.7×10^{-2} rad s^{-1}

D 2.3×10^{-1} rad s^{-1}

$\omega = \frac{2\pi}{T}$

$= \frac{2\pi}{27 \times 24 \times 60^2}$

1 1 The radius of the Earth is R and the acceleration due to gravity at the surface of the Earth is g.

What is the escape velocity for a mass m at the surface of the Earth?

[1 mark]

A $\sqrt{gR}$

B $\sqrt{2gR}$

C $\sqrt{2mgR}$

D $\sqrt{\frac{2gR}{m}}$

$g = \frac{GM}{r^2} \Rightarrow gr = V = \frac{GM}{r}$

$\frac{1}{2}mv^2 = \frac{GMm}{r}$

gr

$\frac{1}{2}\cancel{m}v^2 = gr\cancel{m}$

$v = \sqrt{2gr}$

1 2 A planet has a mass M and a radius R.
Loose material at the equator only just remains in contact with the surface of the planet.
This is because the speed at which the planet rotates is very large.

What is the period of rotation of the planet?

ie no frictional forces. Think of material as orbiting a R

[1 mark]

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

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

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

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

$\frac{GM\cancel{m}}{r^{\cancel{2}}} = \frac{\cancel{m}v^2}{\cancel{r}}$ $v = r\omega$

$v = r\frac{2\pi}{T}$

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

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

1 3 Satellites **N** and **F** have the same mass and move in circular orbits about the same planet.
The orbital radius of **N** is less than that of **F**.

Which is smaller for **N** than for **F**?

$R_N < R_F$

[1 mark]

v is bigger for N

A the gravitational force on the satellite

B the speed of the satellite

C the kinetic energy of the satellite

D the orbital period of the satellite

$T^2 \propto R^3$

going faster & also smaller R.