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

**[2 marks]**

1 _____

_____

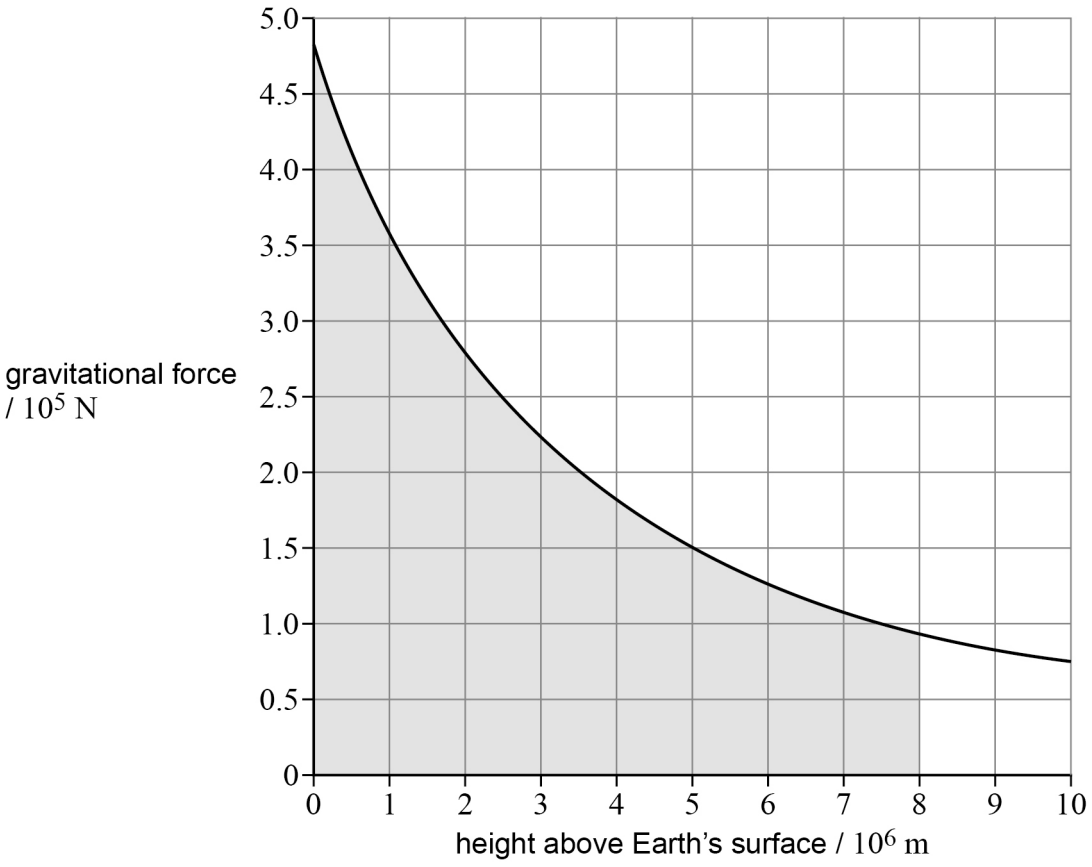
2 _____

_____

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]**

_____

_____

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 = $1.50 \times 10^{11}$ m

**[2 marks]**

$\frac{g_S}{g_E}$ = _____

**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]**

_____

_____

_____

**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 $4.9 \times 10^4$ kg.

Calculate the mass of **X**.

**[4 marks]**

mass of **X** = _____ kg

10

**1 0** Two protons are separated by a distance of $1 \times 10^{-9}$ m.

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

**[1 mark]**

**A** $10^{18}$ ⬭

**B** $10^{28}$ ⬭

**C** $10^{36}$ ⬭

**D** $10^{45}$ ⬭

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

The data show that $u$ is directly proportional to

**[1 mark]**

**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** $\frac{\sqrt{GM}}{(R+h)}$ ⬭

**B** $\sqrt{\frac{GM}{(R+h)}}$ ⬭

**C** $\frac{GM}{\sqrt{R+h}}$ ⬭

**D** $\frac{GM}{(R+h)}$ ⬭

**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. ⬭

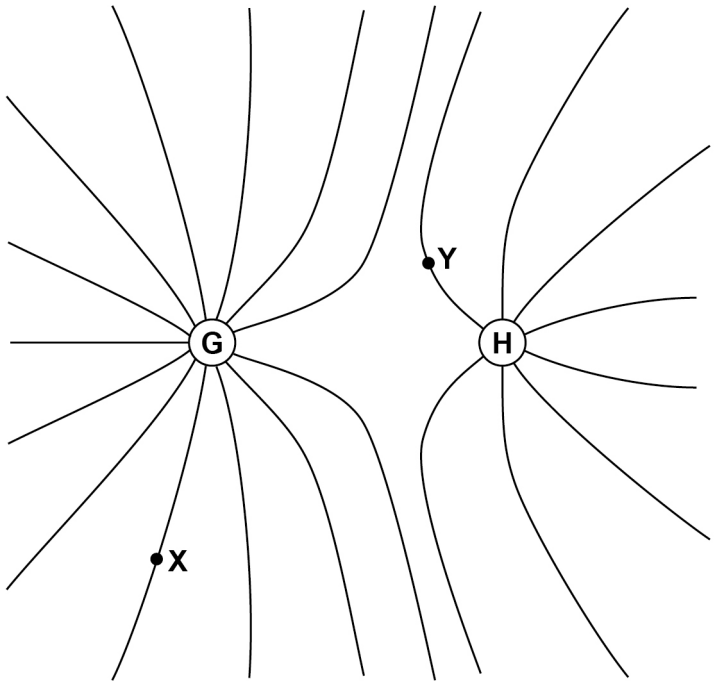
**B** The satellite has the same angular velocity as a point on the Earth's surface. ⬭

**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]**

**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]**

**Question 4 continues on the next page**

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

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

Calculate the radius $R$ of **P**.

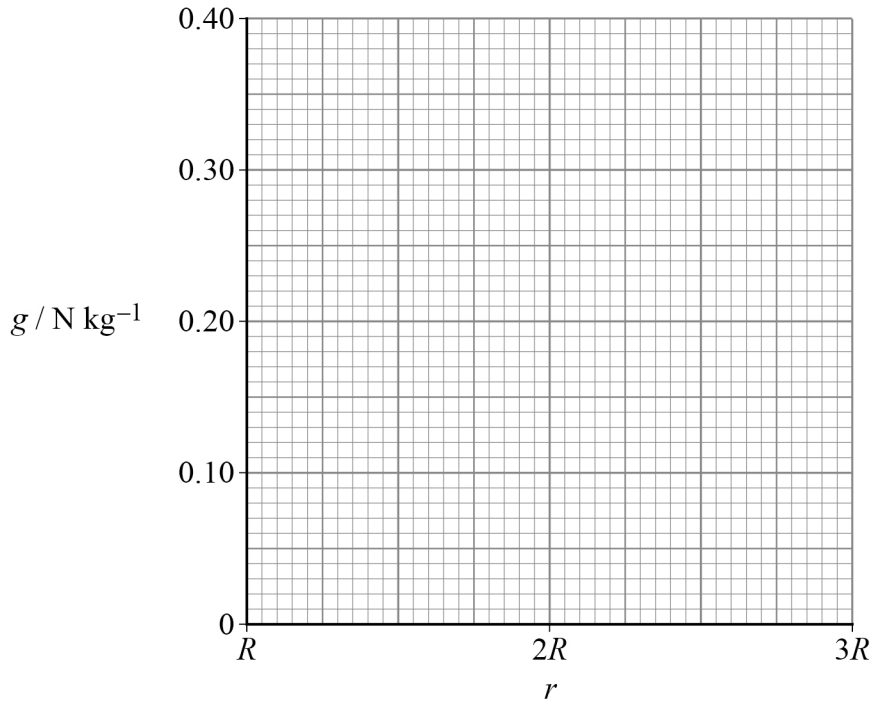
**[1 mark]**

$R =$ _____ 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**



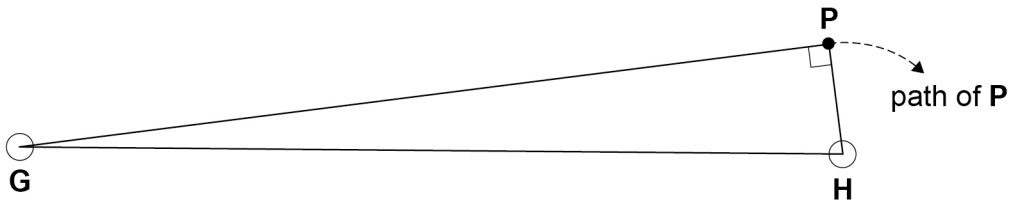

**0 4 . 5** Explain what is represented by the area under the graph between $r = R$ and $r = 2R$ on **Figure 5**.

**[2 marks]**

**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**.

**Figure 6**




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

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

**[4 marks]**

magnitude of acceleration = _____ m $s^{-2}$

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

**[1 mark]**

12

**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** | $2R$ | $2M$ | ⬭ |
| **B** | $R\sqrt{2}$ | $\frac{M}{2}$ | ⬭ |
| **C** | $\frac{R}{\sqrt{2}}$ | $\frac{M}{2}$ | ⬭ |
| **D** | $\frac{R}{\sqrt{2}}$ | $2M$ | ⬭ |

**1 0** The Moon orbits the Earth in 27 days.

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

**[1 mark]**

**A** $4.3 \times 10^{-7}$ rad s$^{-1}$ ⬭

**B** $2.7 \times 10^{-6}$ rad s$^{-1}$ ⬭

**C** $3.7 \times 10^{-2}$ rad s$^{-1}$ ⬭

**D** $2.3 \times 10^{-1}$ rad s$^{-1}$ ⬭

**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** $\sqrt{\frac{2gR}{m}}$ ⬭

**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?

**[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** $2\pi\sqrt{\frac{GM}{R^3}}$ ⬭

**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**?

**[1 mark]**

**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 ⬭