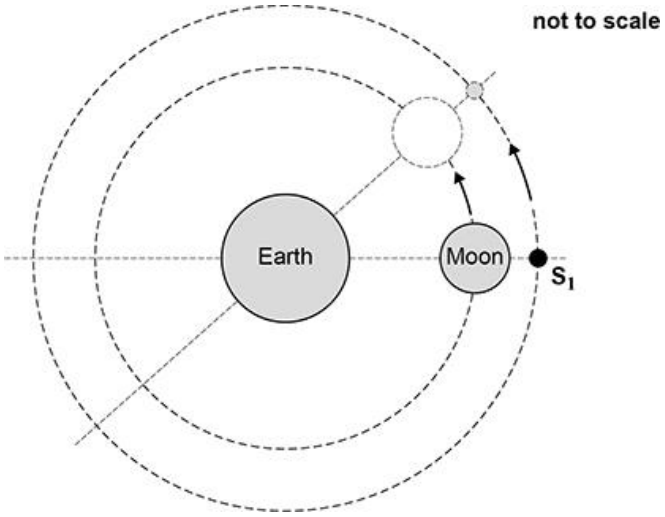
Q1.

A satellite **S_1** is placed in a circular orbit around the Earth so that observations of the far side of the Moon can be made continuously.

S_1 has the same angular speed as the Moon so that the centres of the Earth, the Moon and **S_1** are always in a straight line.

Figure 1 shows two positions of the Moon and **S_1** as they orbit the Earth.

Figure 1



(a) The resultant force on **S_1** is due to the gravitational forces from the Earth and the Moon.
The magnitude of the Earth's gravitational field strength at the orbital radius of **S_1** is 1.98×10^{-3} N kg^{-1}.
The magnitude of the Moon's gravitational field strength at the orbital radius of **S_1** is g_M.

Show that g_M is approximately 1.2×10^{-3} N kg^{-1}.

period of the Moon's orbit = 27.3 days
orbital radius of **S_1** = 4.489×10^5 km

(3)

(b) Calculate the distance from S_1 to the centre of the Moon.

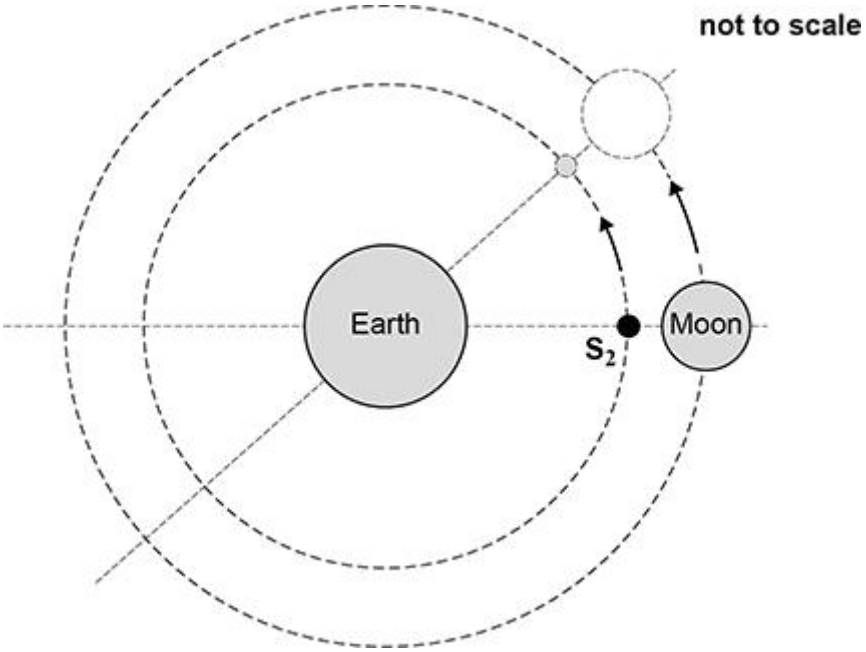
mass of the Moon = 7.35×10^{22} kg

distance = _____ m

(2)

(c) Another satellite S_2 is placed in a circular orbit between the Earth and the Moon.
S_2 always views the near side of the Moon.
S_2 also has the same angular speed as the Moon so that the centres of the Earth, the Moon and S_2 are always in a straight line.
Figure 2 shows two positions of the Moon and S_2 as they orbit the Earth.

Figure 2



Explain how the resultant force on $\mathbf{S_2}$ due to the gravitational fields of the Earth and the Moon causes $\mathbf{S_2}$ to orbit with the same angular speed as the Moon.
No calculations are required.

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(3)

(Total 8 marks)

Q2.

(a) Describe **two** properties of a radial gravitational field.

1 _____

_____

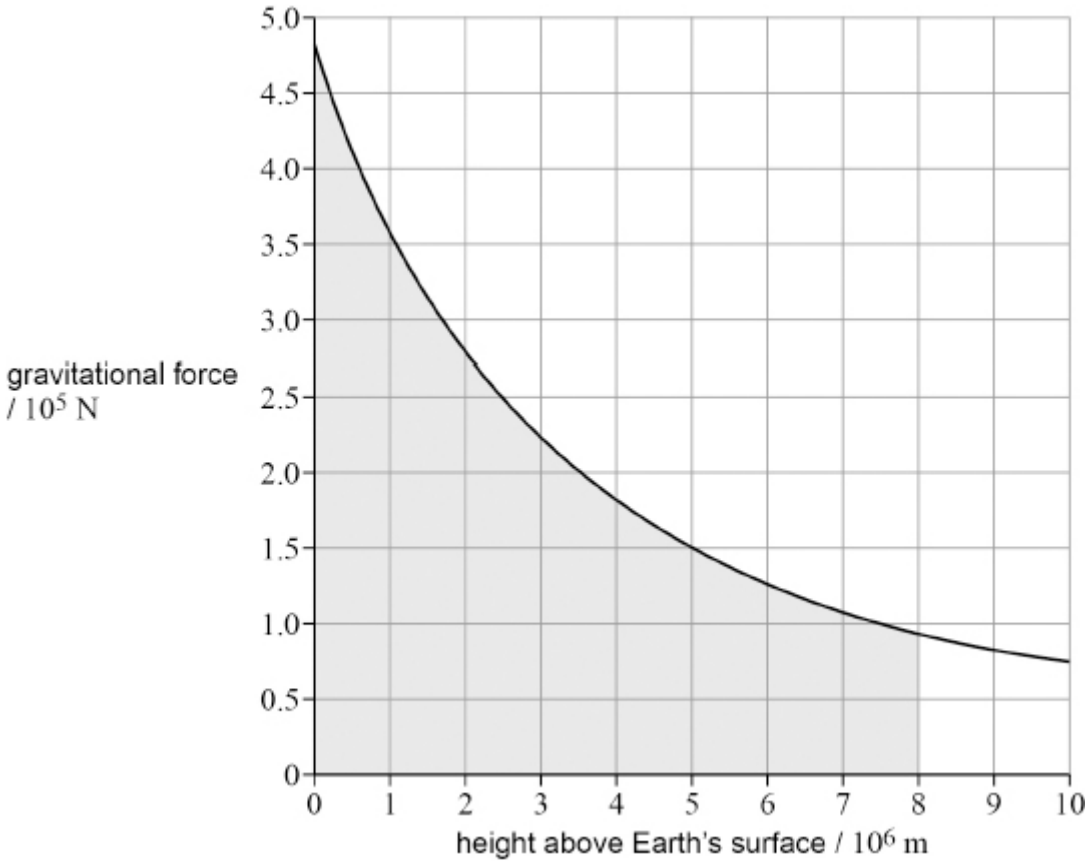
2 _____

_____

(2)

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

The figure below shows how the gravitational force acting on the space probe varies with height above the Earth's surface.



(b) State the physical significance of the shaded area in the figure above.

_____

_____

(1)

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.

(c) Calculate $\frac{g_S}{g_E}$.

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

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

(2)

(d) 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)

(e) 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.

The table below 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.

	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**.

mass of **X** = _____ kg

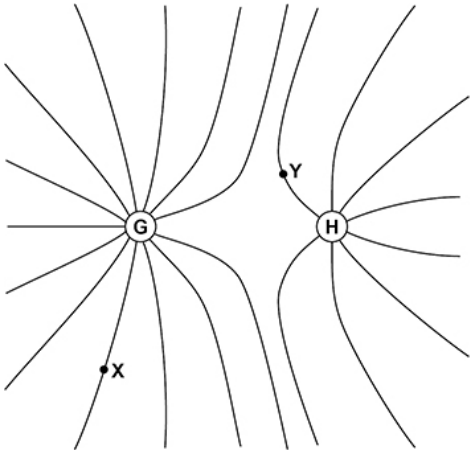
(4)

(Total 10 marks)

Q3.

The lines in **Figure 1** show the shape of the gravitational field around two stars **G** and **H**.

Figure 1



(a) Compare, with reference to **Figure 1**, the masses of **G** and **H**.

_____

_____

_____

_____

(2)

(b) **X** and **Y** are two points in the field.

Annotate **Figure 1** to show the field direction at **X** and the field direction at **Y**.

(1)

(c) A spherical asteroid **P** has a mass of 2.0×10^{20} kg.

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

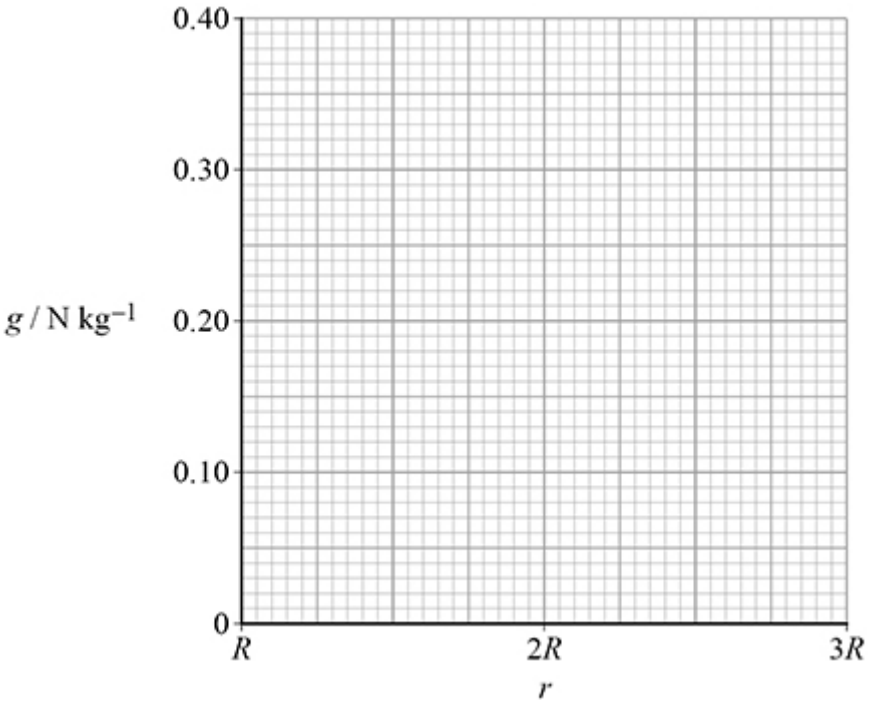
Calculate the radius R of **P**.

R = _____ m

(1)

(d) Sketch, on **Figure 2**, the variation of the gravitational field strength g with distance r.
The distance r is measured from the centre of **P**.

Figure 2



(1)

(e) Explain what is represented by the area under the graph between $r = R$ and $r = 2R$ on **Figure 2**.

_____

_____

_____

_____

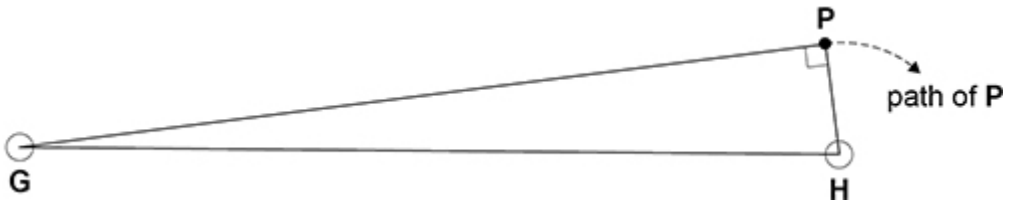
_____

_____

(2)

Asteroid **P** approaches the two stars **G** and **H**.
Figure 3 shows one position of **P** close to **H**.

Figure 3



(f) 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**.

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

(4)

(g) Explain why **P** cannot have a circular orbit around **H**.

_____

_____

_____

(1)

(Total 12 marks)