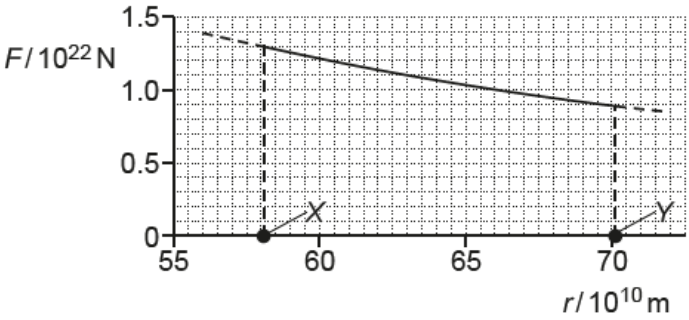
Gravitational fields – 2021/20 GCE Physics A Component 01

1. Nov/2021/Paper_H556_01/No.7

The planet Mercury has a highly elliptical orbit around the Sun.

The gravitational force F acting on Mercury due to the Sun varies with its distance r from the centre of the Sun. The graph of F against r for Mercury in its orbit is shown below.



Mercury is closest to the Sun when $r = X$ and furthest when $r = Y$.

What does the **area** under the graph between the distances X and Y represent?

A The centripetal force acting on Mercury.

B The change in the gravitational potential energy of Mercury.

C The impulse of the force acting on Mercury.

D The kinetic energy of Mercury.

Your answer ☐ **[1]**

2. Nov/2021/Paper_H556_01/No.11

Kepler-90 is a star with several planets orbiting it.
The two outermost planets are Kepler-90g and Kepler-90h.
Kepler-90g has an orbital period of 210 days and is 0.71 AU from the centre of Kepler-90.
Kepler-90h is 1.01 AU from the centre of Kepler-90.

Kepler's third law of planetary motion can be applied to the planets of Kepler-90.

What is the orbital period of Kepler-90h?

A 50 days

B 299 days

C 356 days

D 4350 days

Your answer ☐ **[1]**

3. Nov/2021/Paper_H556_01/No.20

(a) The diagram below shows the Earth in space.

(i) On the diagram above, draw a minimum of **four** gravitational field lines to map out the gravitational field pattern around the Earth. **[1]**

(ii) On the same diagram above, show **two** different points where the gravitational potential is the same. Label these points **X** and **Y**. **[1]**

(b)* A satellite is in a circular geostationary orbit around the centre of the Earth. The satellite has both kinetic energy and gravitational potential energy.

The mass of the satellite is 2500 kg and the radius of its circular orbit is 4.22×10^7 m.
The mass of the Earth is 5.97×10^{24} kg.

- Describe some of the features of a geostationary orbit.
- Calculate the **total** energy of the satellite in its geostationary orbit. **[6]**

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Additional answer space if required.

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4. Nov/2020/Paper_H556_01/No.5

The gravitational force between two point-mass objects **X** and **Y** is F_1.

The mass of **X** increases and the distance between **X** and **Y** is halved.

Which statement about the new gravitational force F_2 between these two objects is correct?

A $0 < F_2 < 0.25F_1$

B $F_2 > 4F_1$

C $F_2 = F_1$

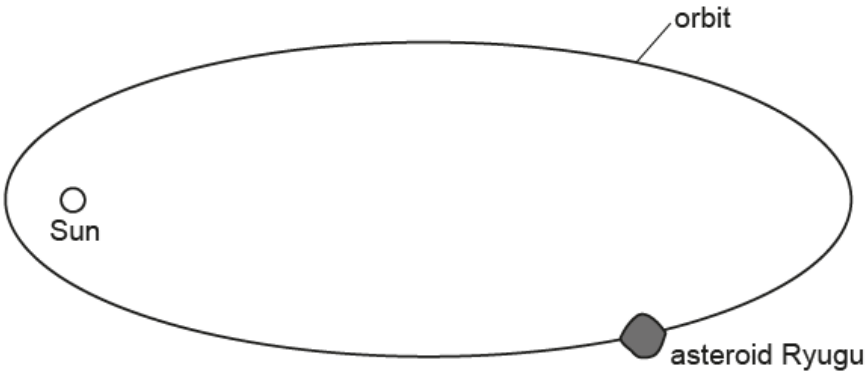
D $2F_1 < F_2 < 4F_1$

Your answer ☐ **[1]**

5. Nov/2020/Paper_H556_01/No.23

In June 2018, the spacecraft Hayabusa2 arrived at an asteroid called Ryugu.

(a) The asteroid orbits the Sun in an elliptical orbit as shown below.



The diagram is **not** drawn to scale.

(i) Indicate with a letter **X** on the orbit where the asteroid would be moving at maximum speed. **[1]**

(ii) Use Kepler's **second law** to explain your answer to **(a)(i)**.

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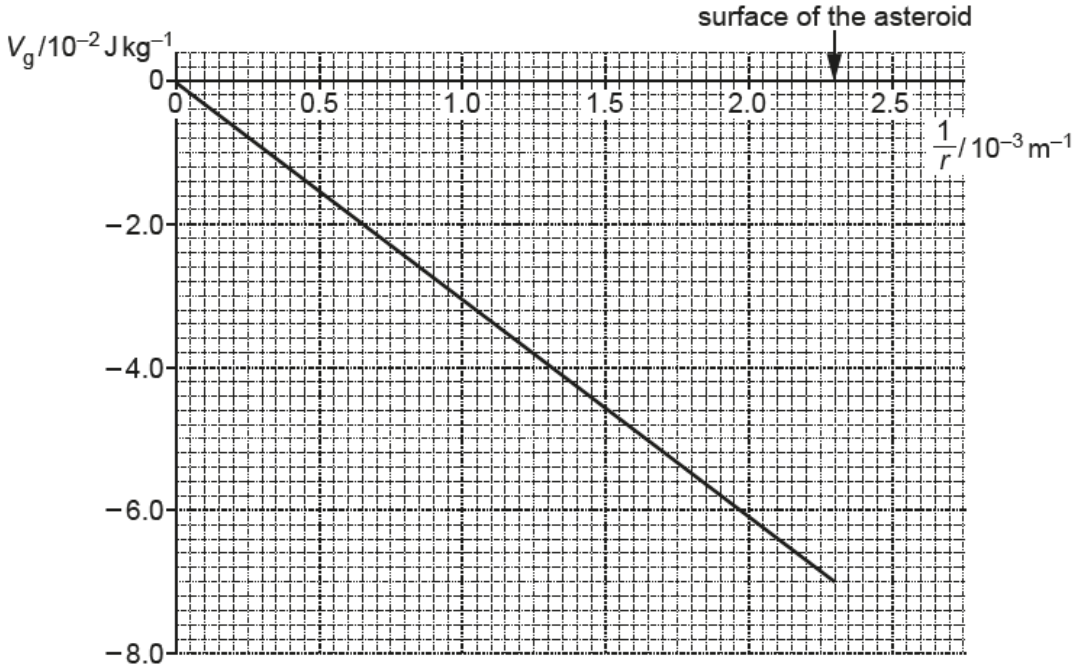
..... **[2]**

(b) The gravitational potential at a distance r from the centre of the asteroid Ryugu is V_g. The graph of V_g against $\frac{1}{r}$ for the asteroid is shown below.



(i) Define **gravitational potential**.

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..... **[1]**

(ii) Show that the magnitude of the gradient of the graph is equal to GM, where M is the mass of the asteroid and G is the gravitational constant.

[1]

(iii) Use the gradient of the graph to show that the mass M of the asteroid is about 4.6×10^{11} kg.

M = ... kg **[2]**

(c) In October 2018, the probe Mobile Asteroid Surface Scout (MASCOT) was released from **rest** from the Hayabusa2 spacecraft from a distance of 600 m from the centre of the asteroid.

Assume that the spacecraft was stationary relative to the asteroid when MASCOT was dropped.

Use information from **(b)** to calculate the speed of the impact v when MASCOT landed on the surface of the asteroid.

v = ... $m\,s^{-1}$ **[3]**

6. Nov/2021/Paper_H556_03/No.3(a, b)

This question is about a space probe which is in orbit around the Sun.

(a) Define **gravitational potential energy** of an object at a point in a gravitational field.

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..... **[1]**

(b) The space probe has mass 810 kg. The orbital radius of the space probe is 1.5×10^{11} m. The orbital period of the space probe around the Sun is 3.16×10^{7} s.
The mass of the Sun is 2.0×10^{30} kg.

(i) Show that the magnitude of the gravitational potential energy of the space probe is about 7×10^{11} J.

[2]

(ii) Show that the kinetic energy of the space probe is half the value of your answer to **(b)(i)**.

[3]

(iii) Calculate the total energy of the space probe.

total energy = ... J **[1]**

7. Nov/2020/Paper_H556_03/No.4(a, b)

The International Space Station (ISS) orbits the Earth at a height of 4.1×10^5 m **above** the Earth's surface.

The radius of the Earth is 6.37×10^6 m. The gravitational field strength g_0 at the Earth's surface is $9.81\,\text{N kg}^{-1}$.

(a) Both the ISS and the astronauts inside it are in free fall.

Explain why this makes the astronauts feel **weightless**.

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(b) **(i)** Calculate the value of the gravitational field strength g at the height of the ISS above the Earth.

g = ...N kg^{-1} **[3]**

(ii) The speed of the ISS in its orbit is $7.7\,\text{km}\,\text{s}^{-1}$. Show that the period of the ISS in its orbit is about 90 minutes.

[2]