A Level · OCR · Physics

29 mins 3 questions

Structured Questions

Gravitational Potential & Energy

Gravitational Potential / Calculating Gravitational Potential / Force-Distance Graph / Gravitational Potential Energy / Escape Velocity

Medium (1 question)	/7
Hard (2 questions)	/22
Total Marks	**/29**

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Medium Questions

1 (a) Write an expression for the gravitational potential V_g at the surface of a planet of mass M and radius r.

[1]

....

(1 mark)

(b) The table below shows some data for Mercury and Pluto.

	Mass / kg	**Radius / m**	**Mean distance from Sun / m**
Mercury	3.30×10^{23}	2.44×10^{6}	57.9×10^{9}
Pluto	0.131×10^{23}	1.19×10^{6}	5910×10^{9}

i) Show that the escape velocity v of a gas molecule on the surface of Pluto is given by the equation

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

where M is the mass of Pluto and r is its radius.

[2]

ii) Calculate the escape velocity v of gas molecules on the surface of Pluto.

v = ... m s^{-1} **[1]**

iii) Explain why Mercury has no atmosphere whilst Pluto still has a thin atmosphere. Use data from the table to support your explanation.

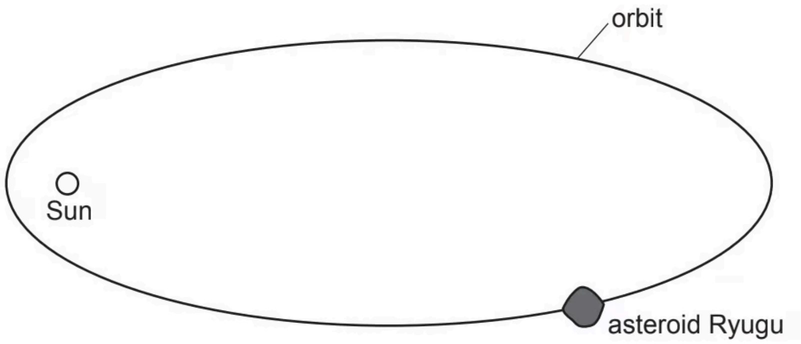
[3]

(6 marks)

Hard Questions

1 (a) In June 2018, the spacecraft Hayabusa2 arrived at an asteroid called Ryugu.

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)**.

[2]

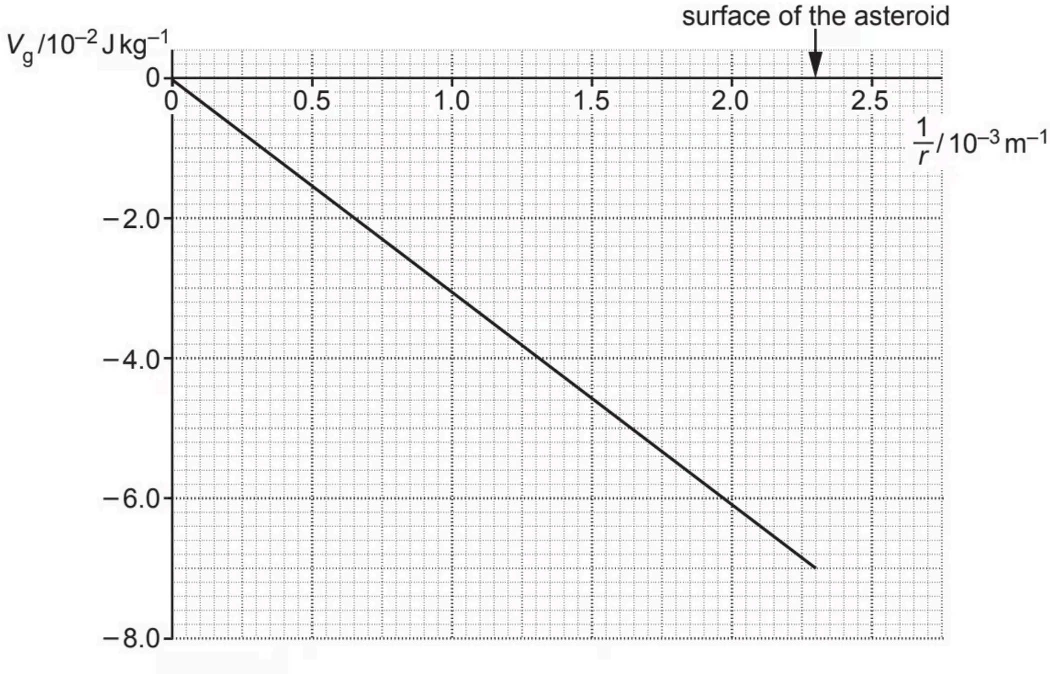
....

....

....

(3 marks)

(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**.

[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]**

....

....

....

....

(4 marks)

(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]**

....

....

....

(3 marks)

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

Define the **gravitational potential** of an object at a point in a gravitational field.

[1]

....

(1 mark)

(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]**

....

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....

....

(5 marks)

(c) The power source for the instrumentation on board the space probe is plutonium-238, which provides 470 W initially.

Plutonium-238 decays by α-particle emission with a half-life of 88 years. The kinetic energy of each α-particle is 8.8×10^{-13} J.

i) Calculate the number *N* of plutonium-238 nuclei needed to provide the power of 470 W.

N = ... **[3]**

ii) Calculate the power *P* still available from the plutonium-238 source 100 years later.

P = ... W **[3]**

(6 marks)