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0 2 The Global Positioning System (GPS) uses satellites to support navigation on Earth.

0 2 . 1 One GPS satellite is in a circular orbit at a height h above the surface of the Earth. The Earth has mass M and radius R.

Show that the angular speed ω of the satellite is given by

$$\omega = \sqrt{\frac{GM}{(R+h)^3}}$$

[2 marks]

0 2 . 2 Calculate the orbital period of the satellite when h equals 2.02×10^7 m.

[2 marks]

orbital period = _____ s

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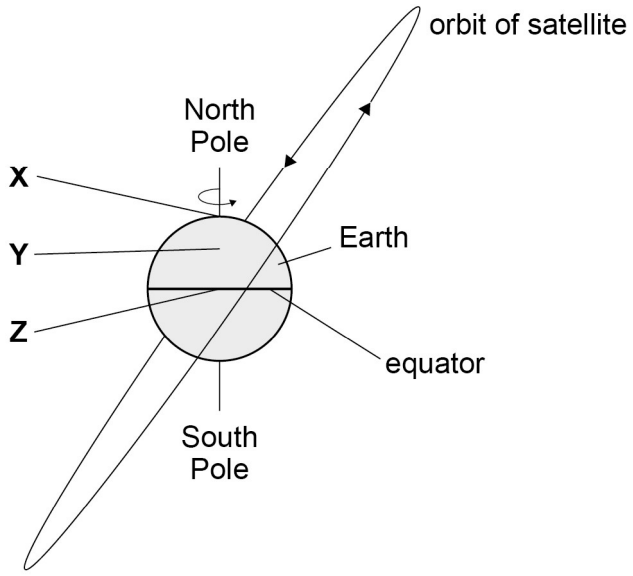
0 2 . 3 **Figure 3** shows the orbital plane of the satellite inclined at an angle to the equator. **X**, **Y** and **Z** are locations on the Earth.

X is at the North Pole, **Y** is on a high mountain and **Z** is on the equator.

Figure 3



The satellite is to be launched from one of the locations.

State and explain which launch site **X**, **Y** or **Z** minimises the amount of fuel required to send the satellite into its orbit.

[2 marks]

Question 2 continues on the next page

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0 2 . 4 The satellite has a mass of $1630\ \text{kg}$.

Calculate the gravitational potential energy of the satellite when in the orbit in Question **02.2**.

[2 marks]

gravitational potential energy = _____ J

0 2 . 5 A different satellite is in a higher circular orbit.

Explain how the linear speed of this satellite compares with the linear speed of the satellite in Question **02.1**.

[2 marks]

_____

_____

_____

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_____

10

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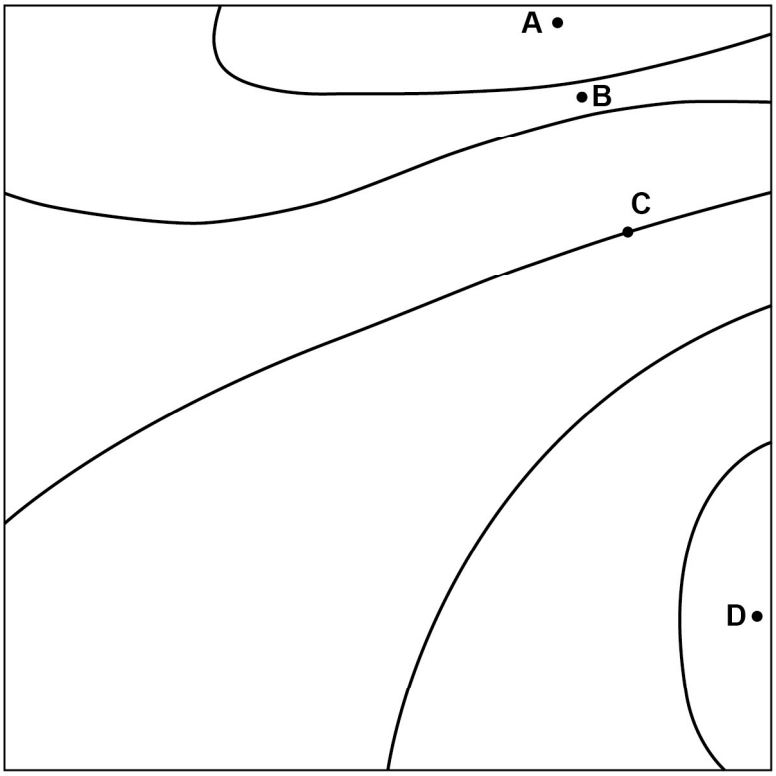
1 1 The diagram shows gravitational equipotentials. Adjacent equipotentials are separated by an equal gravitational potential difference V.



Which point has the greatest gravitational field strength?

[1 mark]

A ⬭

B ⬭

C ⬭

D ⬭

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1 2 A planet has radius R and density ρ. The gravitational field strength at the surface is g.

What is the gravitational field strength at the surface of a planet of radius $2R$ and density 2ρ?

[1 mark]

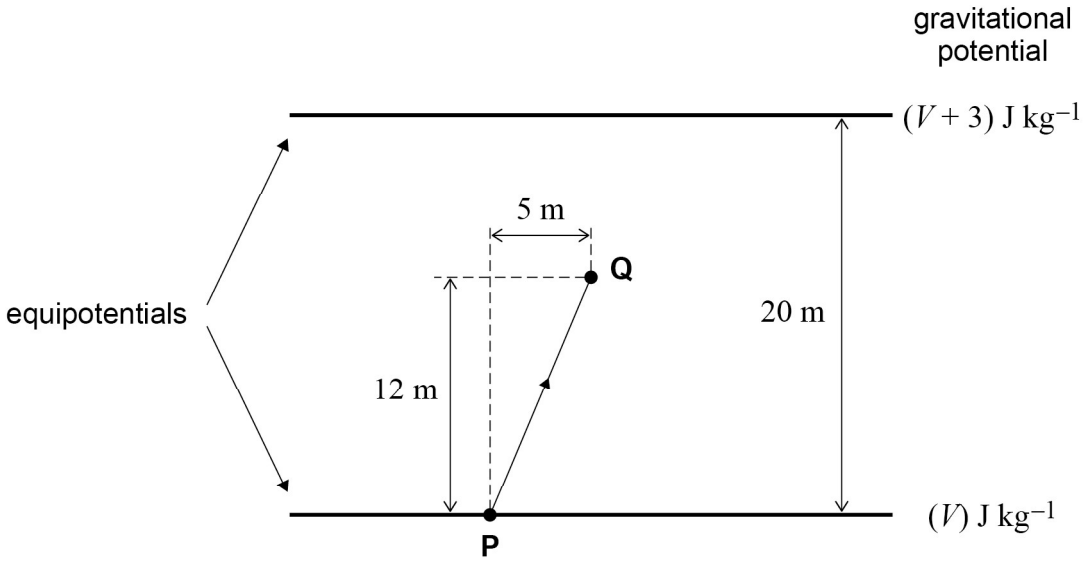
A $2g$ ⬭

B $4g$ ⬭

C $8g$ ⬭

D $16g$ ⬭

1 3 The diagram shows equipotential lines for a uniform gravitational field. The lines are separated by 20 m.



An object of mass 4 kg is moved from **P** to **Q**.

What is the work done against gravity to move the object?

[1 mark]

A 7.2 J ⬭

B 7.8 J ⬭

C 10.2 J ⬭

D 36 J ⬭