



QUESTION WORKBOOK

Gravitational potential

Gravitational fields · Year 13

AQA 3.7.2.3 · CIE 13.4.1, 13.4.2, 13.4.3 · OCR A 5.4.4(a), 5.4.4(b), 5.4.4(c), 5.4.4(d)

18 questions · 46 marks

PRINT EDITION

SECTION A · Warm-up

A1 Define the gravitational potential at a point in a gravitational field. [2]

A2 A planet has a mass of 6.0×10^{24} kg and a radius of 6.4×10^6 m. Calculate the gravitational potential at its surface. [2]
 $G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$

A3 Explain why gravitational potential always has a negative value. [2]

A4 A satellite moves along an equipotential surface of the Earth's gravitational field. State the work done against gravity during this motion and give a reason. [2]

A5 State the angle between an equipotential surface and the gravitational field lines that cross it. [1]

SECTION B · Standard

- B1** Calculate the gravitational potential at a distance of 1.0×10^7 m from the centre of a planet of mass 6.0×10^{24} kg.

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

[2]

- B2** A space vehicle of mass 500 kg is moved from the surface of the planet, at $r = 6.4 \times 10^6$ m, to a point at $r = 1.28 \times 10^7$ m from its centre. Calculate the work done against the gravitational field.

[4]

- B3** Calculate the escape velocity from the surface of the planet of mass 6.0×10^{24} kg and radius 6.4×10^6 m.

$$G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2}$$

[3]

- B4** Near a certain point in the field, the gravitational potential changes by $1.0 \times 10^6 \text{ J kg}^{-1}$ over a radial distance of $1.0 \times 10^5 \text{ m}$. Estimate the gravitational field strength at this point. [2]

- B5** The area under a graph of gravitational field strength against distance, between two distances from a planet's centre, is $2.1 \times 10^6 \text{ J kg}^{-1}$. State what this area represents, and calculate the energy needed to move an 800 kg probe between the two distances. [3]

- B6** Starting from the condition for a mass launched from the surface of a planet to just escape its gravitational field, show that the escape velocity does not depend on the mass of the escaping object. [2]

- B7** A probe falls freely from a high orbit towards a planet's surface. State the sign of ΔV for the fall, and describe the energy transfer taking place. [2]

SECTION C · Stretch

- C1** A spacecraft of mass 1000 kg is launched from the surface of the planet, where the gravitational potential is $-6.25 \times 10^7 \text{ J kg}^{-1}$. Determine the minimum energy needed for the spacecraft to escape from the planet's gravitational field. [3]

- C2** A satellite is boosted from an orbit at $r = 7.0 \times 10^6 \text{ m}$ to a higher orbit at $r = 1.4 \times 10^7 \text{ m}$. Calculate the change in gravitational potential between the two orbits. [3]

- C3** Describe how gravitational field strength and gravitational potential are related graphically for a radial field. [3]

- C4** A 1500 kg satellite sits on the surface of the planet, where the gravitational potential is $-6.25 \times 10^7 \text{ J kg}^{-1}$. Its launch vehicle can transfer at most $2.0 \times 10^{10} \text{ J}$ to the satellite. The table gives the gravitational potential at three possible operating orbits.

orbit A: $-5.00 \times 10^7 \text{ J kg}^{-1}$

orbit B: $-4.50 \times 10^7 \text{ J kg}^{-1}$

orbit C: $-5.50 \times 10^7 \text{ J kg}^{-1}$

Ignoring the kinetic energy of the satellite in orbit, deduce which of the orbits the launch vehicle can reach. [4]

- C5** At a distance r from the centre of a planet, the gravitational field strength is 6.0 N kg^{-1} and the gravitational potential is $-3.0 \times 10^7 \text{ J kg}^{-1}$. State the values of both quantities at a distance $2r$ from the centre, and explain why they change by different factors. [3]

- C6** The gravitational potential at the surface of an airless moon is $-2.8 \times 10^6 \text{ J kg}^{-1}$. Show that the escape velocity from its surface is about 2.4 km s^{-1} . [3]