inkPhysics

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

NAVY SCREEN 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.
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} [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.
$G = 6.67 \times 10^{-11}$ N m^2 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.
$G = 6.67 \times 10^{-11}$ N m^2 kg^{-2} [3]

B4 Near a certain point in the field, the gravitational potential changes by 1.0×10^6 J kg^{-1} over a radial distance of 1.0×10^5 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 2.1×10^6 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 -6.25×10^{7} 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 $r = 7.0 \times 10^{6}$ m to a higher orbit at $r = 1.4 \times 10^{7}$ 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 -6.25×10^{7} J kg^{-1}. Its launch vehicle can transfer at most 2.0×10^{10} J to the satellite. The table gives the gravitational potential at three possible operating orbits.
orbit A: -5.00×10^{7} J kg^{-1}
orbit B: -4.50×10^{7} J kg^{-1}
orbit C: -5.50×10^{7} 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 -3.0×10^{7} 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 -2.8×10^{6} J kg^{-1}. Show that the escape velocity from its surface is about 2.4 km s^{-1}. [3]

