

Name _____

Date _____

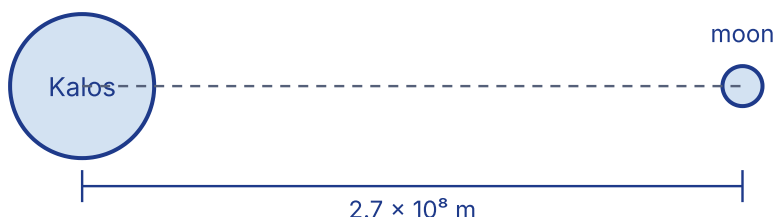
Score: _____ / 43

73 minutes · 43 marks · calculator and data booklet allowed

- Answer all the questions in the spaces provided.
- Show all your working. Marks are given for correct method.
- The marks for each part are shown in brackets [].
- Take $g = 9.8 \text{ m s}^{-2}$.

1. A planet and its moon [10 marks]

The planet Kalos has mass $4.8 \times 10^{24} \text{ kg}$ and radius $5.0 \times 10^6 \text{ m}$. Its moon has mass $6.0 \times 10^{22} \text{ kg}$. The distance between their centres is $2.7 \times 10^8 \text{ m}$.



- (a) **Define** gravitational field strength. [2]

- (b) **Show that** the gravitational field strength at the surface of Kalos is about 13 N kg^{-1} . [2]

- (c) **Calculate** the gravitational field strength of Kalos at the position of the moon. [1]

- (d) **Determine** the distance from the centre of Kalos, on the line joining the two centres, at which the net gravitational field is zero. [3]

- (e) **State** two assumptions made when the moon and the planet are treated as point masses. [2]

2. Orbits around Kalos [11 marks]

Satellites orbit Kalos (mass 4.8×10^{24} kg, radius 5.0×10^6 m) in circular orbits.

- (a) **Show that** the period T of a satellite in a circular orbit of radius r is given by $T^2 = 4\pi^2 r^3 / (GM)$, where M is the mass of Kalos. [2]

- (b) A satellite orbits 1.0×10^6 m above the surface. **Calculate** its orbital speed. [2]

- (c) **Calculate** the period of this satellite. [1]

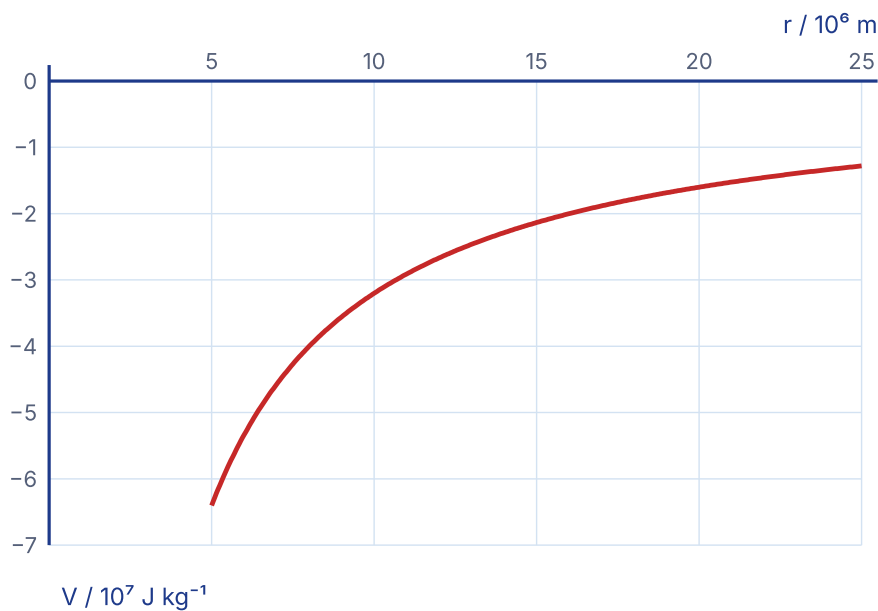
- (d) Kalos rotates once every 20 hours. A satellite is to stay above the same point on its equator. **Calculate** the radius of its orbit. [2]

- (e) **Calculate**, in days, the orbital period of the moon of Kalos (orbit radius 2.7×10^8 m). [2]

- (f) An astronaut in the satellite of (b) feels weightless. **Explain** why. [2]

3. The potential of Kalos [10 marks]

The graph shows how the gravitational potential V varies with the distance r from the centre of Kalos, from its surface outwards.



(a) **Define** gravitational potential at a point. [2]

(b) **Explain** why the gravitational potential is negative. [2]

(c) **Determine**, using the graph, the work done to move a 500 kg probe from the surface to $r = 2.0 \times 10^7 \text{ m}$. [2]

(d) **Determine**, using the graph, the gravitational field strength at $r = 1.0 \times 10^7 \text{ m}$. [2]

- (e) A graph of V against distance along the line from Kalos to its moon has a maximum between them. **State and explain** the value of the net gravitational field strength at the maximum. [2]

4. Energy and escape [12 marks]

This question is about the energy of bodies near Kalos (mass 4.8×10^{24} kg, radius 5.0×10^6 m). Ignore the atmosphere of Kalos except in (e).

- (a) **Show that** the escape speed from the surface of Kalos is given by $v = \sqrt{2GM/R}$. [2]

- (b) **Calculate** the escape speed from the surface of Kalos. [1]

- (c) A 900 kg satellite moves in a circular orbit of radius 8.0×10^6 m. **Show that** its total energy is about -1.8×10^{10} J. [2]

- (d) **Calculate** the minimum energy needed to move this satellite to a circular orbit of radius 1.6×10^7 m. [2]

- (e) A satellite in a low orbit meets a small drag force from the upper atmosphere. **Outline** the effect of the drag on the radius of the orbit and on the speed of the satellite. [3]

- (f) A probe is launched vertically from the surface with a speed of $0.80 \times$ the escape speed. **Determine** the greatest distance of the probe from the centre of Kalos. [2]
