MOMENTUM

IB Physics HL

Gravitation and astronomy - Set 1

D.1 | First assessment 2025 | Higher Level

Independent examination-style practice material

10 original problems

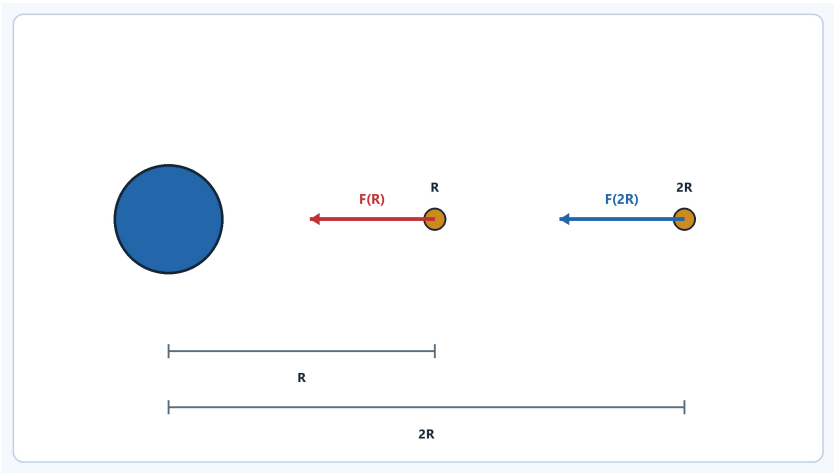
TASK 01

[1]

A gravitational field at two radii

Paper 1A style | IB code D.1

A 1200 kg satellite experiences a gravitational force of 12.0 kN at distance R from the centre of a planet.



What force acts at distance 2R? A. 3.00 kN B. 6.00 kN C. 12.0 kN D. 24.0 kN

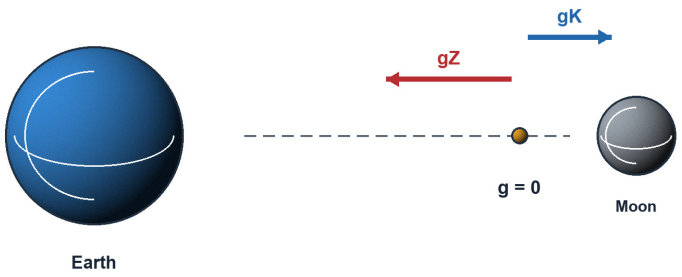
TASK 02

[6]

The neutral point between two bodies

Paper 2 style | IB code D.1

Earth and the Moon are 3.84e8 m apart. The mass of Earth is 81.3 times the mass of the Moon. Ignore the rotation of the system.



(a) Write an equation for the point on the line of centres where the resultant gravitational field is zero. [2]

(b) Determine its distance from the centre of Earth. [3]

(c) Explain why the point is not halfway between the bodies. [1]

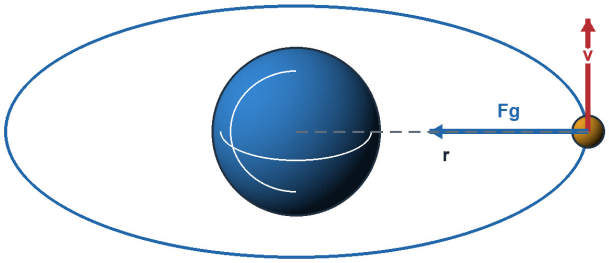
TASK 03

[7]

A satellite in low Earth orbit

Paper 2 style | IB code D.1

A satellite moves in a circular orbit 400 km above Earth. Use Earth radius 6.371e6 m and GM = 3.986e14 m^3 s^{-2}.



(a) Determine the orbital speed. [3]

(b) Determine the orbital period. [2]

(c) Explain why the satellite is weightless although the gravitational field is not zero. [2]

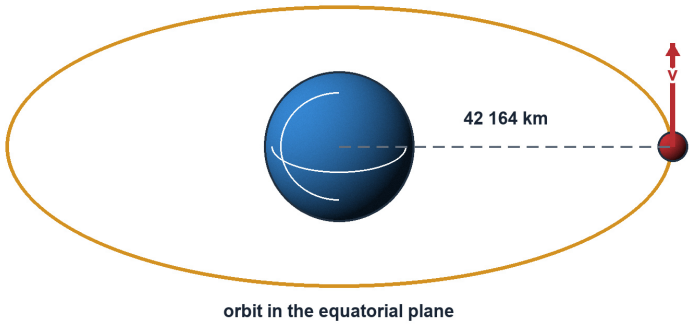
TASK 04

[6]

The geostationary orbit

Paper 2 style | IB code D.1

A satellite is to remain above one point on Earth's equator. Use Earth's sidereal period 86164 s, radius 6.371e6 m and GM = 3.986e14 m^3 s^{-2}.



orbit in the equatorial plane

(a) State two conditions, other than its period, required for a geostationary orbit. [2]

(b) Determine the orbital radius. [3]

(c) Determine the altitude above Earth's surface. [1]

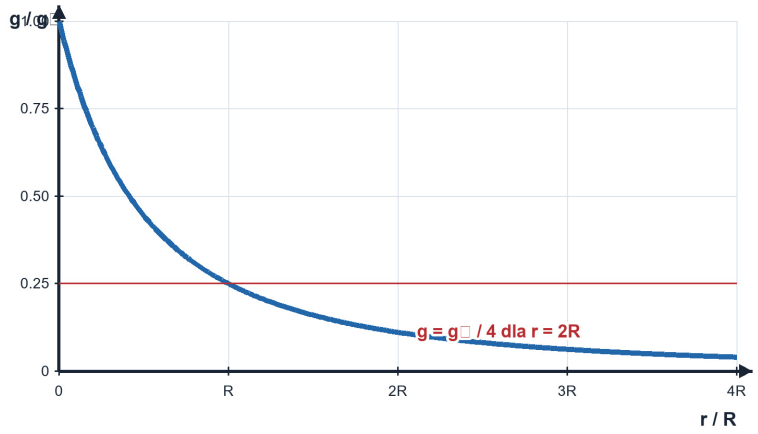
TASK 05

[6]

Energy of an orbiting satellite

Paper 2 style | IB code D.1

An 800 kg satellite moves in a circular Earth orbit of radius 7.00e6 m. Use GM = 4.00e14 m^3 s^{-2} and take gravitational potential energy as zero at infinity.



(a) Determine its kinetic energy. [2]

(b) Determine its gravitational potential energy. [2]

(c) Determine the minimum additional energy required for escape. [2]

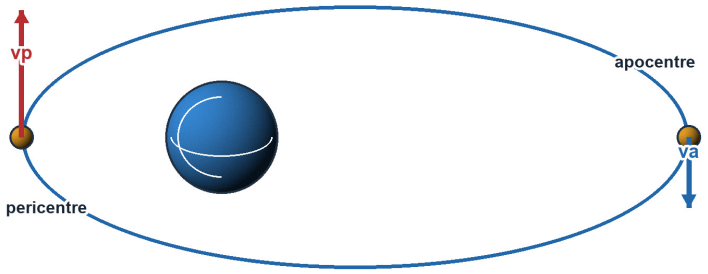
TASK 06

[7]

Speeds at perigee and apogee

Paper 2 style | IB code D.1

A satellite has perigee radius 7000 km and apogee radius 14000 km around Earth. Use GM = 3.986e14 m^3 s^{-2}.



(a) Determine the semi-major axis. [1]

(b) Determine the speed at perigee. [3]

(c) Determine the speed at apogee and verify angular momentum conservation. [3]

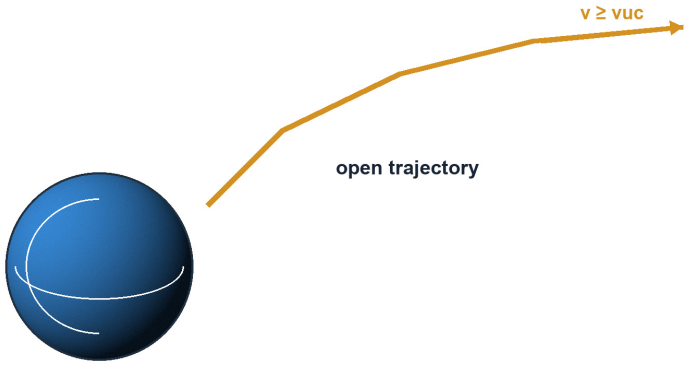
TASK 07

[5]

Escape from a planet

Paper 2 style | IB code D.1

A spherical planet has radius 8.00e6 m and surface gravitational field strength 12.0 N kg^{-1}. Atmospheric resistance and rotation are negligible.



(a) Derive an expression for escape speed in terms of g and R. [2]

(b) Determine the escape speed. [2]

(c) State why the escaping object's mass does not affect the result. [1]

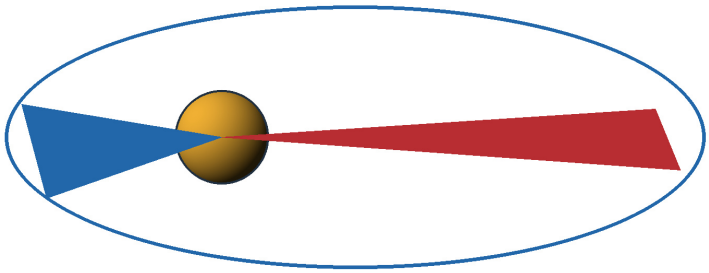
TASK 08

[5]

Kepler's second and third laws

Paper 2 style | IB code D.1

An asteroid orbits the Sun with semi-major axis 4.00 AU. During 20.0 days its radius vector sweeps an area of 6.00e15 km^2.



equal areas in equal times

(a) Determine the orbital period in Earth years. [2]

(b) Determine the time needed to sweep an area of 1.50e15 km^2 elsewhere on the orbit. [2]

(c) State where on the orbit the asteroid moves fastest. [1]

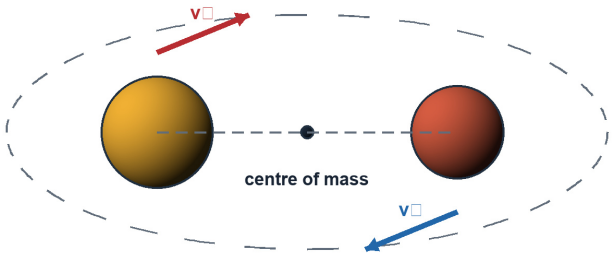
TASK 09

[6]

Mass of a binary-star system

Paper 2 style | IB code D.1

Two stars move in circular orbits about their common centre of mass. Their separation is 2.00e9 m and their period is 10.0 days.



(a) Derive the relation between total mass, separation and period. [3]

(b) Determine the total mass. [2]

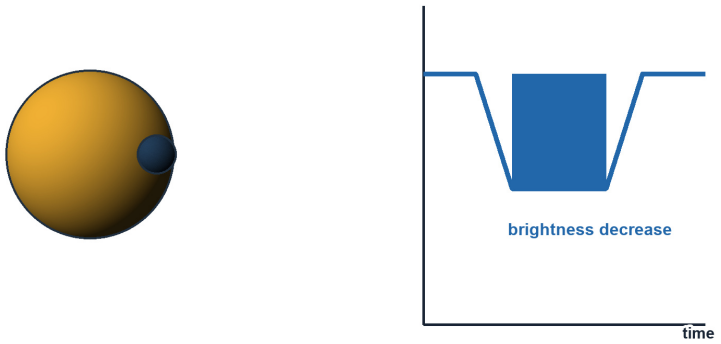
(c) Determine each mass if the stars are identical. [1]

TASK 10
[7]

An exoplanet observed in transit

Paper 2 style | IB code D.1

A central transit reduces a star's brightness by 1.00%. The star radius is 6.96e8 m. Limb darkening is neglected.



(a) Determine the planet radius. [3]

(b) The planet mass is 1.90e27 kg. Determine its mean density. [3]

(c) State one reason why a non-central transit lasts less time than a central transit. [1]