MOMENTUM

IB Physics HL

Gravitation and astronomy - Set 1 - Markscheme

D.1 | First assessment 2025 | Higher Level

Independent examination-style practice material

10 original problems

Task 01 - A gravitational field at two radii

Paper 1A style | IB code D.1 | Total [1]

Part	Marking guidance	Marks
Answer	A. Gravitational force is proportional to 1/r^2, so doubling r reduces the force by a factor of four.	**1**

Task 02 - The neutral point between two bodies

Paper 2 style | IB code D.1 | Total [6]

Part	Marking guidance	Marks
(a)	Sets GM_E/x^2 = GM_M/(d-x)^2.	**2**
(b)	Uses M_E/M_M = 81.3 to obtain x/(d-x) = sqrt(81.3), hence x = 3.46e8 m from Earth.	**3**
(c)	Earth is much more massive, so equal field magnitudes occur much closer to the Moon.	**1**

Task 03 - A satellite in low Earth orbit

Paper 2 style | IB code D.1 | Total [7]

Part	Marking guidance	Marks
(a)	Uses v = sqrt(GM/r) with r = 6.771e6 m, giving v = 7.67 km s^{-1}.	**3**
(b)	Uses T = 2 pi r/v, giving T = 5.55e3 s or 92.4 min.	**2**
(c)	The satellite and its contents have the same free-fall acceleration, so there is no supporting normal force.	**2**

Task 04 - The geostationary orbit

Paper 2 style | IB code D.1 | Total [6]

Part	Marking guidance	Marks
(a)	Circular orbit in the equatorial plane and in the same direction as Earth's rotation.	**2**
(b)	Uses r^3 = GMT^2/(4 pi^2), giving r = 4.216e7 m.	**3**
(c)	Altitude = r - R_E = 3.579e7 m or about 35 800 km.	**1**

Task 05 - Energy of an orbiting satellite

Paper 2 style | IB code D.1 | Total [6]

Part	Marking guidance	Marks
(a)	For a circular orbit K = GMm/(2r) = 2.29e10 J.	**2**
(b)	U = -GMm/r = -4.57e10 J.	**2**
(c)	Total energy is -GMm/(2r), so 2.29e10 J must be added to reach zero total energy.	**2**

Task 06 - Speeds at perigee and apogee

Paper 2 style | IB code D.1 | Total [7]

Part	Marking guidance	Marks
(a)	a = (r_p+r_a)/2 = 1.05e7 m.	**1**
(b)	Uses v^2 = GM(2/r - 1/a), giving v_p = 8.71 km s^{-1}.	**3**
(c)	Gives v_a = 4.36 km s^{-1} and verifies r_p v_p = r_a v_a.	**3**

Task 07 - Escape from a planet

Paper 2 style | IB code D.1 | Total [5]

Part	Marking guidance	Marks
(a)	Equates mv^2/2 to GMm/R and uses GM = gR^2 to obtain v_e = sqrt(2gR).	**2**
(b)	v_e = sqrt(2(12.0)(8.00e6)) = 1.39e4 m s^{-1}.	**2**
(c)	The object's mass cancels from the energy equation.	**1**

Task 08 - Kepler's second and third laws

Paper 2 style | IB code D.1 | Total [5]

Part	Marking guidance	Marks
(a)	Uses T^2 = a^3 in years and AU, giving T = 8.00 years.	**2**
(b)	Equal areas are swept in equal times; time is 20.0(1.50/6.00) = 5.00 days.	**2**
(c)	Fastest at perihelion.	**1**

Task 09 - Mass of a binary-star system

Paper 2 style | IB code D.1 | Total [6]

Part	Marking guidance	Marks
(a)	Combines mutual gravitation with circular motion to obtain M_total = 4 pi^2 r^3/(GT^2), where r is the separation.	**3**
(b)	Substitution gives M_total = 6.34e27 kg.	**2**
(c)	Each star has mass 3.17e27 kg.	**1**

Task 10 - An exoplanet observed in transit

Paper 2 style | IB code D.1 | Total [7]

Part	Marking guidance	Marks
(a)	Uses depth = (R_p/R_s)^2, so R_p = 0.100R_s = 6.96e7 m.	**3**
(b)	Uses rho = M/(4 pi R^3/3), giving approximately 1.35e3 kg m^-3.	**3**
(c)	The chord across the stellar disc is shorter.	**1**