13. Gravitational Fields

13.2 Gravitational force between point masses

Paper 4

Marking Scheme

Q1.

(a)	(gravitational) force is (directly) proportional to product of masses	**B1**
	force (between point masses) is inversely proportional to the square of their separation	**B1**
(b)(i)	(gravitational) force acts perpendicular to direction of motion	**B1**
	gravitational force provides centripetal acceleration	**B1**
(b)(ii)	($F =$) $GMm / x^2 = mx\omega^2$ **and** $\omega = 2\pi / T$ **or** $GMm / x^2 = 4\pi^2 mx / T^2$	**M1**
	completion of algebra leading to $x^3 = GMT^2 / 4\pi^2$	**A1**
	clear indication that B = radius of planet **and** that A = mass (of planet)	**B1**
(b)(iii)	gradient = $\sqrt[3]{(4\pi^2 / GA)}$	**C1**
	e.g. $(1280 - 360) / (12 \times 10^6) = \sqrt[3]{(4\pi^2 / [6.67 \times 10^{-11} \times A])}$	**C1**
	$A = 1.3 \times 10^{24}$ kg	**A1**
	intercept = gradient × B	**C1**
	e.g. $360 = ((1280 - 360) \times B) / (12 \times 10^6)$ $B = 4.7 \times 10^6$ m	**A1**

Q2.

(a)	(gravitational) force is (directly) proportional to product of masses	**B1**
	force (between point masses) is inversely proportional to the square of their separation	**B1**
(b)	$GMm / R^2 = mR\omega^2$	**M1**
	$\omega = 2\pi / T$ and algebra leading to $4\pi^2 R^3 = GMT^2$	**A1**
	or	
	$GMm / R^2 = mv^2 / R$	**(M1)**
	$v = 2\pi R / T$ and algebra leading to $4\pi^2 R^3 = GMT^2$	**(A1)**
(c)	$4\pi^2 \times R^3 = 6.67 \times 10^{-11} \times 5.98 \times 10^{24} \times (24 \times 60 \times 60)^2$ ($R = 4.22 \times 10^7$ m)	**C1**
	$h = R - (6.37 \times 10^6)$	**C1**
	$h = (4.22 \times 10^7) - (6.37 \times 10^6)$ $= 3.6 \times 10^7$ m	**A1**
(d)(ii)	orbit is from east to west	**B1**
	orbit is not equatorial / orbit is polar	**B1**

Q3.

(a)(i)	(gravitational) force is (directly) proportional to product of masses	**B1**
	force (between point masses) is inversely proportional to the square of their separation	**B1**

Q4.

(a)	$F = (Gm_1m_2) / r^2$	**M1**
	where G is the gravitational constant	**A1**
(b)	gravitational force provides the centripetal force	**B1**
	$mR\omega^2 = GMm / R^2$ **and** $\omega = 2\pi / T$ **or** $mv^2 / R = GMm / R^2$ **and** $v = 2\pi R / T$ **or** $4\pi^2 mR / T^2 = GMm / R^2$	**M1**
	correct completion of algebra to get $T^2 = (4\pi^2 / GM)\ R^3$, with identification of $(4\pi^2 / GM)$ as k	**A1**
(c)(i)	$(24 \times 3600)^2 = (4\pi^2 \times R^3) / (6.67 \times 10^{-11} \times 6.0 \times 10^{24})$	**C1**
	$R = 4.2 \times 10^7$ m	**A1**
(c)(ii)	(orbit) must be above the Equator	**B1**
	(direction) must be from west to east	**B1**

Q5.

(b)(ii)	field lines show force (on satellite) is towards centre of planet **or** velocity of satellite is perpendicular to field lines	**B1**
	(gravitational) force perpendicular to velocity causes centripetal acceleration	**B1**

Q6.

(b)	$GMm / r^2 = mr\omega^2$ **and** $\omega = 2\pi/T$ **or** $GMm / r^2 = mv^2 / r$ **and** $v = 2\pi r / T$	**C1**
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (94 \times 60)]^2$	**C1**
	$r = 6.9 \times 10^6$ m	**A1**
(c)(i)	$r^3\omega^2$ = constant **or** r^3 / T^2 = constant	**C1**
	$r^3 / (6.9 \times 10^6)^3 = (150 / 94)^2$ so $r = 9.4 \times 10^6$ m	**A1**
	or	
	$GMT^2/4\pi^2 = r^3$ **and** clear that M is 6.0×10^{24}	**(C1)**
	$6.67 \times 10^{-11} \times 6.0 \times 10^{24} = r^3 \times [2\pi / (150 \times 60)]^2$ so $r = 9.4 \times 10^6$ m	**(A1)**

Q7.

(a)	force acting between two masses **or** force on mass due to another mass **or** force on mass in a gravitational field	**B1**
(c)(iii)	$x = 0.4d$	**C1**
	$6.67 \times 10^{-11} \times M_1 = (1.0 - 0.4) \times (1.8 \times 10^{12})^3 \times (4.5 \times 10^{-9})^2$	**C1**
	$M_1 = 1.1 \times 10^{30}$ kg	**A1**

Q8.

(b)(ii)	$GMm / r^2 = mv^2 / r$	**C1**
	$v^2 = GM / r$ $= (6.67 \times 10^{-11} \times 6.0 \times 10^{24}) / (1.2 \times 10^7)$	**C1**
	$v = 5800\ \text{m s}^{-1}$	**A1**
(c)	any one point from: • smaller gain in energy required if orbit is west to east • smaller change in velocity if orbit is west to east • smaller gain in energy if orbit is in same direction as Earth's rotation • smaller change in velocity if orbit is in same direction as Earth's rotation • satellite already moving west to east at launch • Earth's rotation is from west to east	**B1**

Q9.

(a)	($F =$) GMm / x^2, where G is the (universal) gravitational constant	**B1**
(b)(i)	$GMm / x^2 = mv^2 / x$ **or** $v^2 = GM / x$	**C1**
	$v^2 = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) / (3.4 \times 10^6 + 240 \times 10^3)$ so $v = 3.7 \times 10^3\ \text{m s}^{-1}$	**A1**

Q10.

(a)	($F =$) GMm / x^2, where G is the (universal) gravitational constant	**B1**
(b)(ii)	torque $= 1.5 \times 10^{-2} \times 9.3 \times 10^{-10}$ $= 1.4 \times 10^{-11}\ \text{N m}$	**A1**
(c)(i)	force $\times\ 8.0 \times 10^{-2} = 1.4 \times 10^{-11}$	**C1**
	$(G \times 1.3 \times 7.5 \times 10^{-3} \times 8.0 \times 10^{-2}) / (6.0 \times 10^{-2})^2 = 1.4 \times 10^{-11}$	**C1**
	$G = 6.4 \times 10^{-11}\ \text{N m}^2\ \text{kg}^{-2}$	**A1**
(c)(ii)	Any one from: • law applies only to point masses/spheres are not point masses • radii of spheres not small compared with separation • spheres may not be uniform • the masses are not isolated • force between L and rod • spheres may be charged/may be electrostatic force (between spheres)	**B1**

Q11.

(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of (gravitational) force between point masses	**B1**
(b)(i)	above the equator	**B1**
	from west to east	**B1**
(b)(ii)	gravitational force provides/is the centripetal force	**B1**
	$GM / r^2 = r(2\pi / T)^2$	**C1**
	$(6.67 \times 10^{-11} \times M) = \{(4.23 \times 10^7)^3 \times 4\pi^2\} / (24 \times 3600)^2$	**C1**
	$M = 6.0 \times 10^{24}\ \text{kg}$	**A1**

Q12.

(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of (gravitational) force between point masses	**B1**
(b)	gravitational force provides/is the centripetal force	**B1**
	$GM / R^2 = R\omega^2$ **or** $GM / R^2 = v^2 / R$	**M1**
	$\omega = 2\pi / T$ **or** $v = 2\pi R / T$	**M1**
	algebra leading to $R^3/T^2 = GM / 4\pi^2$	**A1**
(c)	$(6.67 \times 10^{-11} \times M) / 4\pi^2 = (4.38 \times 10^6)^3 / (2.44 \times 3600)^2$	**C1**
	$M = 6.45 \times 10^{23}$ kg	**A1**

Q13.

(a)	force proportional to product of masses and inversely proportional to square of separation	**B1**
	idea of force between point masses	**B1**
(b)(ii)1.	gravitational force equals/is centripetal force	**C1**
	$GMm / R^2 = mR\omega^2$ **and** $\omega = 2\pi / T$ **or** $Gm / R^2 = mv^2 / R$ **and** $v = 2\pi r / T$ **or** $GMm / R^2 = mR\,(2\pi / T)^2$	**M1**
	convincing algebra leading to $k = GM / 4\pi^2$	**A1**
(b)(ii)2.	correct use of R^3 / T^2 for one planet (c gives 3.54×10^{21}; e and g both give 3.56×10^{21})	**C1**
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$ $M = 2.1 \times 10^{33}$ kg	**A1**
	two or three values of R^3 / T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	**B1**