Gravitational Fields

Mark Scheme 2

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Gravitational Fields
Sub Topic	
Paper Type	Theory
Booklet	Mark Scheme 2

Time Allowed: **78 minutes**

Score: **/65**

Percentage: **/100**

A*	A	B	C	D	E	U
>85%	'77.5%	70%	62.5%	57.5%	45%	<45%

1	**(a**	region of space area / volume	B1	
		where a mass experiences a force	B1	[2]
	(b)	**(i)** force proportional to product of two masses	M1	
		force inversely proportional to the square of their separation	M1	
		either reference to point masses *or* separation >> 'size' of masses	A1	[3]
		(ii) field strength $= GM / x^2$ **or** field strength $\propto 1 / x^2$	C1	
		ratio $= (7.78 \times 10^8)^2 / (1.5 \times 10^8)^2$	C1	
		$= 27$	A1	[3]
	(c)	**(** *either* centripetal force $= mR\omega^2$ and $\omega = 2\pi / T$		
		or centripetal force $= mv^2 / R$ and $v = 2\pi R / T$	B1	
		gravitational force provides the centripetal force	B1	
		either $GMm / R^2 = mR\omega^2$ *or* $GMm / R^2 = mv^2 / R$	M1	
		$M = 4\pi^2 R^3 / GT^2$	A0	[3]
		(allow working to be given in terms of acceleration)		
		(ii) $M = \{4\pi^2 \times (1.5 \times 10^{11})^3\} / \{6.67 \times 10^{-11} \times (3.16 \times 10^7)^2\}$	C	
		$= 2.0 \times 10^{30}$ kg		[2]

2	**(a**	equatorial orbit / above equator	B1	
		satellite moves from west to east / same direction as Earth spins	B1	
		period is 24 hours / same period as spinning of Earth	B1	[3]
		(allow 1 mark for 'appears to be stationary/overhead' if none of above marks scored)		
	(b)	gravitational force provides/is the centripetal force	B1	
		$GMm/R^2 = mR\omega^2$ or $GMm/R^2 = mv^2/R$	M1	
		$\omega = 2\pi / T$ or $v = 2\pi R / T$ or clear substitution	M1	
		clear working to give $R^3 = (GMT^2 / 4\pi^2)$	A	[4]
	(c)	$R^3 = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (24 \times 3600)^2 / 4\pi^2$	C1	
		$= 7.57 \times 10^{22}$	C1	
		$R = 4.2 \times 10^7$ m	A1	[3]
		(missing out 3600 gives 1.8×10^5 m and scores 2/3 marks)		
3	**(a**	force is proportional to the product of the masses and inversely proportional to the square of the separation	M1	
		either point masses *or* separation >> size of masses	A1	[2]
	(b) (i)	gravitational force provides the centripetal force	B1	
		$mv^2/r = GMm/r^2$ and $E_K = ½mv^2$	M1	
		hence $E_K = GMm/2r$	A0	[2]
	(ii)	$\Delta E_K = ½ \times 4.00 \times 10^{14} \times 620 \times (\{7.30 \times 10^6\}^{-1} - \{7.34 \times 10^6\}^{-1})$	C	
		$= 9.26 \times 10^7$ J (*ignore any sign in answer*)	A	[2]
		(*allow* 1.0×10^8 J *if evidence that* E_K *evaluated separately for each r*)		
	2.	$\Delta E_P = 4.00 \times 10^{14} \times 620 \times (\{7.30 \times 10^6\}^{-1} - \{7.34 \times 10^6\}^{-1})$	C	
		$= 1.85 \times 10^8$ J (*ignore any sign in answer*)	A	[2]
		(*allow* 1.8 or 1.9×10^8 J)		
	(iii)	*either* $(7.30 \times 10^6)^{-1} - (7.34 \times 10^6)^{-1}$ *or* ΔE_K is positive / E_K increased		
		speed has increased	A1	[2]

4	**(a**	work done in bringing unit mass from infinity (to the point)	B1	[1]
	(b)	gravitational <u>force</u> is (always) attractive	B1	
		either as r decreases, object/mass/body does work		
		or work is done by masses as they come together	B1	[2]
	(c)	*either* force on mass = mg (where g is the acceleration of free fall /gravitational field strength)	B1	
		$g = GM/r^2$	B1	
		if r @ h, g is constant	B1	
		ΔE_P = force × distance moved	M1	
		$= mgh$	A0	
		or $\Delta E_P = m\Delta\phi$	(C1)	
		$= GMm(1/r_1 - 1/r_2) = GMm(r_2 - r_1)/r_1r_2$	(B1)	
		if $r_2 \approx r_1$, then $(r_2 - r_1) = h$ and $r_1r_2 = r^2$	(B1)	
		$g = GM/r^2$	(B1)	
		$\Delta E_P = mgh$	(A0)	[4]
	(d)	$\frac{1}{2}mv^2 = m\Delta\phi$		
		$v^2 = 2 \times GM/r$	C1	
		$= (2 \times 4.3 \times 10^{13}) / (3.4 \times 10^6)$	C1	
		$v = 5.0 \times 10^3\ \mathrm{m\,s^{-1}}$	A1	[3]
		(Use of diameter instead of radius to give $v = 3.6 \times 10^3\ \mathrm{m\,s^{-1}}$ scores 2 marks)		

5	**(a)**	force proportional to product of masses and inversely proportional to square of separation (*do not allow square of distance/radius*)	M	
		either point masses *or* separation @ size of masses	A1	[2]
	(b) (	$\omega = 2\pi / (27.3 \times 24 \times 3600)$ or $2\pi / (2.36 \times 10^6)$	M1	
		$= 2.66 \times 10^{-6}$ rad s^{-1}	A0	[1]
	(ii)	$GM = r^3\omega^2$ or $GM = v^2r$	C1	
		$M = (3.84 \times 10^5 \times 10^3)^3 \times (2.66 \times 10^{-6})^2 / (6.67 \times 10^{-11})$	M1	
		$= 6.0 \times 10^{24}$ kg	A0	[2]
		(special case: uses $g = GM/r^2$ with $g = 9.81$, $r = 6.4 \times 10^6$ scores max 1 mark)		
	(c) (	grav. force $= (6.0 \times 10^{24}) \times (7.4 \times 10^{22}) \times (6.67 \times 10^{-11})/(3.84 \times 10^8)^2$	C1	
		$= 2.0 \times 10^{20}$ N (*allow 1 SF*)	A1	[2]
	(ii) *either*	$\Delta E_P = Fx$ because F constant as x ! radius of orbit	B1	
		$\Delta E_P = 2.0 \times 10^{20} \times 4.0 \times 10^{-2}$	C1	
		$= 8.0 \times 10^{18}$ J (*allow 1 SF*)	A1	[3]
	or	$\Delta E_P = GMm/r_1 - GMm/r_2$	C1	
		Correct substitution	B1	
		8.0×10^{18} J	A1	
		($\Delta E_P = GMm/r_1 + GMm/r_2$ is incorrect physics so 0/3)		
6	(a **(i)**	weight $= GMm/r^2$	C1	
		$= (6.67 \times 10^{-11} \times 6.42 \times 10^{23} \times 1.40)/(½ \times 6.79 \times 10^6)^2$	C1	
		$= 5.20$ N	A1	[3]
	(ii)	potential energy $= -GMm/r$	C1	
		$= -(6.67 \times 10^{-11} \times 6.42 \times 10^{23} \times 1.40)/(½ \times 6.79 \times 10^6)$	M1	
		$= -1.77 \times 10^7$ J	A0	[2]
	(b) *either*	$½mv^2 = 1.77 \times 10^7$	C1	
		$v^2 = (1.77 \times 10^7 \times 2)/1.40$	C1	
		$v = 5.03 \times 10^3$ m s^{-1}	A1	
	or	$½mv^2 = GMm/r$	(C1)	
		$v^2 = (2 \times 6.67 \times 10^{-11} \times 6.42 \times 10^{23})/(6.79 \times 10^6/2)$	(	
		$v = 5.02 \times 10^3$ m s^{-1}	(A1)	[3]
	(c) **(i)**	$½ \times 2 \times 1.66 \times 10^{-27} \times (5.03 \times 10^3)^2 = \frac{3}{2} \times 1.38 \times 10^{-23} \times T$	C1	
		$T = 2030$ K	A1	[2]
	(ii) *either*	because there is a range of speeds	M1	
		some molecules have a higher speed	A1	
	or	some escape from point above planet surface	(M1)	
		so initial potential energy is higher	(A1)	[2]