Gravitational Fields

Mark Scheme 5

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Gravitational Fields
Sub Topic	
Paper Type	Theory
Booklet	Mark Scheme 5

Time Allowed: **68 minutes**

Score: **/56**

Percentage: **/100**

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

1 (a) work done in bringing/moving unit mass M1
from infinity to the point..... ..... A1 [2]
(use of 1 kg in the definition – max 1/2)

(b) potential at infinity defined as being zero..... ..... B1
forces are always attractive..... B1
so work got out in moving to point..... ..... B1 [3]
(max potential is at infinity – allow 1/3)

(c) (i) $\varphi = -GM/R$
change = $6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (\{6.4 \times 10^{6}\}^{-1} - \{1.94 \times 10^{7}\}^{-1})$ C2
change = 4.19×10^{7} J kg^{-1} (ignore sign) A1

(ii) $\frac{1}{2}mv^2 = m\Delta\varphi$ C1
$v^2 = 2 \times 4.19 \times 10^{7} = 8.38 \times 10^{7}$
$v = 9150$ m s^{-1} ..... A1 [5]

(d) acceleration is not constant..... B1 [1]

2 (a) (i) $\frac{1}{2}mv^1 = GMm1R$ ..... BI
$v^1 = 2GMIR$ ..... AO
(ii) $g = GMIR^1$ ..... MI
clear algebra giving $v^2 = 2gR$ ..... A I [3]

(b) $\frac{1}{2}mv^2 = 3/2kT$
$v^2 = 3kTIm$ Cl
$3kT/m = 2gR$ Cl
$r = (2 \times 6.6 \times 10^{-27} \times 9.81 \times 6.4 \times 10^{6})$; $(1.38 \times 10^{-23} \times 3)$ c1
$T = 2.0 \times 10^{4}$ K ..... **Al** [4]

3 **(a** gravitational force provides the centripetal force B1
$GMm/r^2 = mr\omega^2$ (*must be in terms of* ω) B
$r^3\omega^2 = GM$ <u>and</u> GM is a constant B1 [3]

(b) (i) 1. for Phobos, $\omega = 2\pi/(7.65 \times 3600)$ C1
$= 2.28 \times 10^{-4}$ rad s^{-1}
$(9.39 \times 10^6)^3 \times (2.28 \times 10^{-4})^2 = 6.67 \times 10^{-11} \times M$ C1
$M = 6.46 \times 10^{23}$ kg A1 [3]

2. $(9.39 \times 10^6)^3 \times (2.28 \times 10^{-4})^2 = (1.99 \times 10^7)^3 \times \omega^2$ C1
$\omega = 7.30 \times 10^{-5}$ rad s^{-1} C1
$T = 2\pi/\omega = 2\pi/(7.30 \times 10^{-5})$
$= 8.6 \times 10^4$ s
$= 23.6$ hours A1 [3]

(ii) *either* almost 'geostationary'
or satellite would take a long time to cross the sky B1 [1]

4 **(a (i)** $pV = nRT$
$V = (8.31 \times 300)/(1.02 \times 10^5)$ C1
$= 0.0244$ m^3 (if uses Celsius, then 0/2) ..... A1 [2]

(ii) volume occupied by one atom = $0.0244 / (6.02 \times 10^{23}) = 4.06 \times 10^{-26}$ m^3 ..... M1
separation $\approx \sqrt[3]{(4.06 \times 10^{-26})}$ A1
$= 3.44 \times 10^{-9}$ m ..... A0 [2]

(b) (i) $F = GMm / r^2$ C1
$= (6.67 \times 10^{-11} \times \{4 \times 1.66 \times 10^{-27}\}^2) / (3.44 \times 10^{-9})^2$ C1
$= 2.49 \times 10^{-46}$ N ..... A1 [3]

(ii) ratio $= (4 \times 1.66 \times 10^{-27} \times 9.8) / 2.49 \times 10^{-46}$ C1
$= 2.6 \times 10^{20}$ ..... A1 [2]

(c) assumption that forces between atoms are negligible B1
comment e.g. ratio shows gravitational force to be very small
e.g. force is very much less than weig
e.g. if there are forces, they are not gravitational ..... B1 [2]

5	**(a)**	**(i)**	angular speed = $2\pi/T$	**C1**	
			$= 2\pi/(3.2 \times 10^7)$		
			$= 1.96 \times 10^{-7}$ rad s^{-1}	**A1**	**[2]**
		(ii)	force = $mr\omega^2$ <u>or</u> force = mv^2/r and $v = r\omega$	**C1**	
			$= 6.0 \times 10^{24} \times 1.5 \times 10^{11} \times (1.96 \times 10^{-7})^2$		
			$= 3.46 \times 10^{22}$ N	**A1**	**[2]**
	(b)	(i)	gravitation/gravity/gravitational field (strength)	**B1**	**[1]**
		(ii)	$F = GMm/x^2$ <u>or</u> $GM = r^3\omega^2$	**C1**	
			$3.46 \times 10^{22} = (6.67 \times 10^{-11} \times M \times 6.0 \times 10^{24})/(1.5 \times 10^{11})^2$	**C1**	
			$M = 1.95 \times 10^{30}$ kg	**A1**	**[**

6	(a)	(i)	grav. pot. energy = GM_1M_2/R	1	
			energy $= \{6.67 \times 10^{-11} \times 197 \times 4 \times (1.66 \times 10^{-27})^2\}/9.6 \times 10^{-15}$	1	
			$= 1.51 \times 10^{-47}$ J	1	**[3]**
		(ii)	elec. pot. energy = $Q_1Q_2/4\pi\varepsilon_0R$	1	
			energy $= \{79 \times 2 \times (1.6 \times 10^{-19})^2\}/4\pi \times 8.85 \times 10^{-12} \times 9.6 \times 10^{-15}$	1	
			$= 3.79 \times 10^{-12}$ J	1	**[3]**
			*(For the substitution, -1 each error or omission to max 2 in **(i)** and in **(ii)**)*		
	(b)		electric potential <u>energy</u> >> gravitational potential <u>energy</u>	1	**[1]**
	(c)		*either* 6 MeV = 9.6×10^{-13} J or 3.79×10^{-12} J = 24 MeV	1	
			not enough energy to get close to the nucleus	1	**[2]**

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