Gravitational Fields

Mark Scheme 1

Level	International A Level
Subject	Physics
Exam Board	CIE
Topic	Gravitational Fields
Sub Topic	
Paper Type	Theory
Booklet	Mark Scheme 1

Time Allowed:	**66 minutes**
Score:	**/55**
Percentage:	**/100**

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

1 **(a)** (gravitational) force proportional to product of masses and inversely proportional to square of separation — M1

reference to *either* point masses *or* particles *or* 'size' much less than separation — A1 [2]

(b) gravitational force provides/is the centripetal force — B1

$GM_N m / r^2 = mr\omega^2$ (or mv^2/r) — M

$2\pi/T$ (*or* $v = 2\pi r/T$) leading to $GM_N = 4\pi^2 r^3/T^2$ — A1 [3]

(c) $M_N/M_U = (3.55/5.83)^3 \times (13.5/5.9)^2$

x^3 factor correct — C1

T^2 factor correct — C1

ratio = 1.18 (*allow 1.2*) — A1

alternative method: mass of Neptune = 1.019×10^{26} kg — (C1)

mass of Uranus = 8.621×10^{25} kg — (C1)

ratio = 1.18 — (A1) [3]

2 **(a)** (**1.** $F = Gm_1m_2/x^2$

$= (6.67 \times 10^{-11} \times 2.50 \times 5.98 \times 10^{24})/(6.37 \times 10^6)^2$ — M1

$= 24.6$ N (*accept 2 s.f. or more*) — A [2]

2. $F = mx\omega^2$ **or** $F = mv^2/x$ **and** $v = \omega x$ *(accept x or r for distance)* — C1

$= 2.50 \times 6.37 \times 10^6 \times (2\pi/24 \times 3600)^2$

$= 0.0842$ N (*accept 2 s.f. or more*) — A [2]

(ii) reading = 24.575 – 0.0842 — B1

= 24.5 N (*accept only 3 s.f.*) — A [2]

(b) gravitational force provides the centripetal force — M1

gravitational force is 'equal' to the centripetal force (*accept* $Gm_1m_2/x^2 = mx\omega^2$ **or** $F_C = F_G$) — M

'weight'/sensation of weight/contact force/reaction force is difference between F_G and F_C which is zero — A1 [3]

3 **(a)** $g = GM/R^2$ C1

$= (6.67 \times 10^{-11} \times 6.4 \times 10^{23})/(3.4 \times 10^6)^2 = 3.7\,\text{N kg}^{-1}$ A1 [2]

(b) $\Delta E_P = mg\Delta h$

because $\Delta h \ll R$ (or $1800\,\text{m} \ll 3.4 \times 10^6\,\text{m}$) g is constant B1

$\Delta E_P = 2.4 \times 3.7 \times 1800$ C1

$= 1.6 \times 10^4\,\text{J}$ A [3]

(*use of g = 9.8 m s*$^{-2}$ *max. 1 for explanation*)

(c) gravitational potential <u>energy</u> = (–)GMm/x C1

$v^2 = 2GM/x$ C1

$x = 4D = 4 \times 6.8 \times 10^6$ C1

$v^2 = (2 \times 6.67 \times 10^{-11} \times 6.4 \times 10^{23})/(4 \times 6.8 \times 10^6)$

$= 3.14 \times 10^6$

$v = 1.8 \times 10^3\,\text{m s}^{-1}$ A1 [4]

(*use of 3.5D giving 1.9* $\times 10^3\,\text{m s}^{-1}$*, allow max. 3*)

4 **(a)** work done bringing unit mass M1

from infinity (to the point) A1 [2]

(b) $E_P = -m\phi$ B1 [1

(c) $\phi \propto 1/x$ C1

either at $6R$ from centre, potential is $(6.3 \times 10^7)/6$ (= $1.05 \times 10^7\,\text{J kg}^{-1}$)

<u>and</u> at $5R$ from centre, potential is $(6.3 \times 10^7)/5$ (= $1.26 \times 10^7\,\text{J kg}^{-1}$) C1

change in energy = $(1.26 - 1.05) \times 10^7 \times 1.3$ C1

$= 2.7 \times 10^6\,\text{J}$ A1

or change in potential = $(1/5 - 1/6) \times (6.3 \times 10^7)$ (C1)

change in energy = $(1/5 - 1/6) \times (6.3 \times 10^7) \times 1.3$ (C1)

$= 2.7 \times 10^6\,\text{J}$ (A1) [4]

5 **(a**	gravitational force provides/is the centripetal force	B1	
	$GMm / r^2 = mv^2 / r$	M1	
	$v = \sqrt{(GM / r)}$	A	[2]
	allow gravitational field strength provides/is the centripetal acceleration	(B1)	
	$GM / r^2 = v^2 / r$	(M1)	
(b) (i)	kinetic energy increase/change = loss / change in (gravitational) potential energy	B1	
	$½mV_0^2 = GMm / x$	C1	
	$V_0^2 = 2GM / x$		
	$V_0 = \sqrt{(2GM / x)}$	A	[3]
	(max. 2 for use of r not x)		
(ii)	V_0 is (always) <u>greater than v</u> (for $x = r$)	M	
	so stone could not enter into orbit	A1	[2]
	(*expressions in **(a)** and **(b)(i)** must be dimensionally correct)*		

6 **(a**	work done in moving unit mass	M1	
	from infinity (to the point)	A1	[2]
(b) (	gravitational potential energy = GMm / x		
	energy = $(6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times 4.5) / (1.74 \times 10^6)$	M	
	energy = 1.27×10^7 J	A0	[1]
(ii)	<u>change in</u> grav. potential energy = <u>change in</u> kinetic energy	B1	
	$½ \times 4.5 \times v^2 = 1.27 \times 10^7$		
	$v = 2.4 \times 10^3\ \mathrm{m\,s^{-1}}$	A1	[2]
(c)	Earth would attract the rock / potential at Earth('s surface) not zero / <0 / at Earth, potential due to Moon not zero	M1	
	escape speed would be lower	A1	[2]

7 **(a** force proportional to product of the two masses and inversely proportional to the square of their separation M1
either reference to point masses *or* separation >> 'size' of masses A1 [2]

(b) gravitational force provides the centripetal force B1
$GMm / R^2 = mR\omega^2$ M1
where *m is* the mass of the planet A1
$GM = R^3\omega^2$ A0 [3]

(c) $\omega = 2\pi / T$ C1
either $M_{star} / M_{Sun} = (R_{star} / R_{Sun})^3 \times (T_{Sun} / T_{star})^2$
$M_{star} = 4^3 \times (½)^2 \times 2.0 \times 10^{30}$ C1
$= 3.2 \times 10^{31}$ kg A1 [3]
or $M_{star} = (2\pi)^2 R_{star}{}^3 / GT^2$ (C1)
$= \{(2\pi)^2 \times (6.0 \times 10^{11})^3\} / \{6.67 \times 10^{-11} \times (2 \times 365 \times 24 \times 3600)^2\}$ (C1)
$= 3.2 \times 10^{31}$ kg (A1)