13. Gravitational Fields

13.4 Gravitational potential

Paper 4

Marking Scheme

Q1.

(a)	work done per unit mass	**B1**
	work done moving mass from infinity (to the point)	**B1**
(b)(i)	potential is zero at infinity	**B1**
	work is done **by** (two) masses in moving them **closer** together **or** work is done **on** (two) masses in moving them **apart**	**B1**
(b)(ii)	magnitude of potential shown as 4Φ	**B1**
	potential negative **and** shown as a multiple of $-\Phi$ [potential = -4Φ if fully correct]	**B1**

Q2.

(b)(ii)	$E_P = -GMm / x$ $= -(6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 2.63) / (1.47 \times 10^{11})$	**C1**
	$= -2.37 \times 10^{9}$ J	**A1**

Q3.

(a)(iii)	similarity: • inversely proportional to distance (from point) • points of equal potential lie on concentric spheres • zero at infinite distance *Any point, 1 mark*	**B1**
	difference: • gravitational potential is (always) negative • electric potential can be positive or negative *Any point, 1 mark*	**B1**

Q4.

(a)(i)	work done per unit mass	**B1**
	work (done) moving mass from infinity (to the point)	**B1**
(a)(ii)	$\phi = -GM / r$ $= -(6.67 \times 10^{-11} \times 7.3 \times 10^{22}) / (1.7 \times 10^{6})$	**C1**
	$= -2.9 \times 10^{6}$ J kg^{-1}	**A1**
(b)(i)	$E_P = m\phi$	**B1**
(b)(ii)	$\frac{1}{2}mv^2 + m\phi = 0$	**M1**
	correct algebra leading to $v = \sqrt{(-2\phi)}$	**A1**
(c)	speed $= \sqrt{(2 \times 2.9 \times 10^{6})}$ $= 2400$ m s^{-1}	**A1**

Q5.

(a)(i)	work (done) per unit mass	**B1**
	work (done on mass) in moving mass from infinity (to the point)	**B1**
(a)(ii)	$E_P = \phi m$ $E_P = (-GM/r) \times m = -GMm/r$ **or** $\phi = -GM/r$ **and** $E_P = \phi m = -GMm/r$	**B1**
(b)(i)	$\Delta E_P = 6.67 \times 10^{-11} \times 1.99 \times 10^{30} \times 2.20 \times 10^{14} \times [1/(6.38 \times 10^{10}) - 1/(8.44 \times 10^{11})]$	**C1**
	$= 4.23 \times 10^{23}$ J	**A1**
(b)(ii)	(gravitational) force is attractive so decrease **or** (gravitational) force does work so decrease	**B1**
(b)(iii)	$\Delta E_P = \frac{1}{2}m(v_2^2 - v_1^2)$	**C1**
	$4.23 \times 10^{23} = \frac{1}{2} \times 2.20 \times 10^{14} \times (v^2 - 34\,100^2)$	**C1**
	v (= 70 800 m s^{-1}) = 70.8 km s^{-1}	**A1**
(c)	both PE and KE equations include m, so path is unchanged	**B1**

Q6.

(c)(ii)	separation increases so (potential energy) increases **or** movement is against gravitational force so (potential energy) increases	**B1**
(c)(iii)	potential energy = $(-)GMm/r$	**C1**
	$\Delta E_P = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 1200 \times [(6.9 \times 10^6)^{-1} - (9.4 \times 10^6)^{-1}]$	**C1**
	$= 1.9 \times 10^{10}$ J	**A1**

Q7.

(a)	work done per unit mass	**B1**
	(work done in) moving mass from infinity	**B1**
(b)(iii)	ϕ (Earth) = $(-)6.67 \times 10^{-11} \times (5.98 \times 10^{24} / 3.5 \times 10^8)$ **and** ϕ (Moon) = $(-)6.67 \times 10^{-11} \times (7.35 \times 10^{22} / 0.38 \times 10^8)$	**C1**
	$\phi = (-)6.67 \times 10^{-11} \times [(5.98 \times 10^{24} / 3.5 \times 10^8) + (7.35 \times 10^{22} / 0.38 \times 10^8)]$	**C1**
	$= -1.3 \times 10^6$ J kg^{-1}	**A1**

Q8.

(a)	(gravitational) field strength equals (gravitational) potential gradient	**M1**
	reference to minus sign	**A1**
(b)(i)	potential is zero at infinity	**B1**
	(gravitational) force is attractive	**B1**
	(test) mass getting closer (from infinity) loses potential energy	**B1**
(b)(ii)	• potential at (surface of) planet is smaller than at (surface of) moon • potential gradient at (surface of) planet is smaller than at (surface of) moon • magnitude of potential varies inversely with distance from centre near the spheres • (point of) maximum potential is nearer to moon than planet *Any two points, 1 mark each*	**B2**

Q9.

(a)	work done per unit mass	**B1**
	(work done to) move mass from infinity (to the point)	**B1**
(b)	curve from r to $4r$, with gradient of decreasing magnitude and starting at $(r, \pm\phi)$	**B1**
	line passing through $(2r, \pm 0.5\phi)$ and $(4r, \pm 0.25\phi)$	**B1**
	line showing potential is negative throughout	**B1**
(c)(i)	gravitational potential energy = $(-)\ GMm / R$	**C1**
	change $= (6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 3.4 \times 10^{3}) / (6.4 \times 10^{6}) \times [1/3 - 1/4]$	**C1**
	$= 1.8 \times 10^{10}$ J	**A1**
(c)(ii)	rock loses potential energy	**B1**
	(so) kinetic energy increases so speed increases	**B1**
	or	
	force is attractive	**(B1)**
	moves towards planet so speeds up	**(B1)**

Q10.

(a)	work done per unit mass	**B1**
	(work done) moving mass from infinity (to the point)	**B1**
(b)(i)	gravitational potential energy = $(-)GMm / r$	**C1**
	$\Delta E_P = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times 2.4 \times 10^{3} \times [(6.4 \times 10^{6})^{-1} - (1.2 \times 10^{7})^{-1}]$	**C1**
	or	
	$\Delta\phi = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times [(6.4 \times 10^{6})^{-1} - (1.2 \times 10^{7})^{-1}]$	**(C1)**
	$\Delta E_P = m\Delta\phi$	**(C1)**
	$\Delta E_P = 7.0 \times 10^{10}$ J	**A1**

Q11.

(b)(ii)	potential energy = $(-)GMm / x$	**C1**
	$E_A = (-)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (3.64 \times 10^{6})$ **or** $E_B = (-)(6.67 \times 10^{-11} \times 7.5 \times 10^{23} \times 650) / (5.00 \times 10^{7})$	**M1**
	correct substitution and subtraction $E_B - E_A$ shown, leading to $\Delta E_p = 8.3 \times 10^{9}$ J	**A1**
	or	
	$\phi = (-)GM / x$ **and** potential energy = $m\phi$	**(C1)**
	$\Delta\phi = (6.67 \times 10^{-11} \times 7.5 \times 10^{23}) \times [(1 / (3.64 \times 10^{6})) - (1 / (5.00 \times 10^{7}))]$ $(= 1.27 \times 10^{7}$ J kg$^{-1})$	**(M1)**
	$\Delta E_p = 1.27 \times 10^{7} \times 650$ $= 8.3 \times 10^{9}$ J	**(A1)**
(c)	kinetic energy <u>or</u> potential energy decreases	**B1**
	kinetic energy <u>and</u> potential energy decrease so total energy decreases	**B1**

Q12.

(b)	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**C1**
	$(m)v^2 = (m)(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (1.7 \times 10^3 \times 10^3)$	**C1**
	$v = 2.4 \times 10^3\,\text{m s}^{-1}$	**A1**
	correct conclusion based on <u>comparison</u> of v with $2.8\,\text{km s}^{-1}$	**B1**
	or	
	(change in) KE of rock = (change in) PE	**(C1)**
	(at infinity) $E_P = (6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times m) / (1.7 \times 10^3 \times 10^3)$ $= 2.9 \times 10^6\,m$	**(C1)**
	E_K of rock $= \frac{1}{2} \times m \times (2.8 \times 10^3)^2 = 3.9 \times 10^6\,m$	**(A1)**
	correct conclusion based on <u>comparison</u> of E_K and E_P values	**(B1)**
	or	
	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**(C1)**
	$(m)\,(2800)^2 = (m)\,(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / R$	**(C1)**
	$R = 1.3 \times 10^3\,\text{km}$	**(A1)**
	correct conclusion based on <u>comparison</u> of R with $1.7 \times 10^3\,\text{km}$	**(B1)**
	or	
	(change in) KE of rock = (change in) PE **or** $\frac{1}{2}mv^2 = GMm/R$	**(C1)**
	$(m)\,(2800)^2 = (m)\,(2 \times 6.67 \times 10^{-11} \times M) / (1.7 \times 10^6)$	**(C1)**
	$M = 1.0 \times 10^{23}\,\text{kg}$	**(A1)**
	correct conclusion based on <u>comparison</u> of M with $7.4 \times 10^{22}\,\text{kg}$	**(B1)**

Q13.

(a)(i)	work done per unit mass	**B1**
	work done moving mass from infinity (to the point)	**B1**
(a)(ii)	(near Earth's surface change in) height $\ll$ radius **or** height <u>much</u> less than radius	**B1**
	potential inversely proportional to radius **and** radius approximately constant (so potential approximately constant)	**B1**
(b)	initial kinetic energy = (–) potential energy (at surface) **or** $\frac{1}{2}mv^2 = GMm/r$	**B1**
	$v^2 = (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (0.5 \times 3.5 \times 10^6)$	**C1**
	$v = 2.4 \times 10^3\,\text{m s}^{-1}$	**A1**