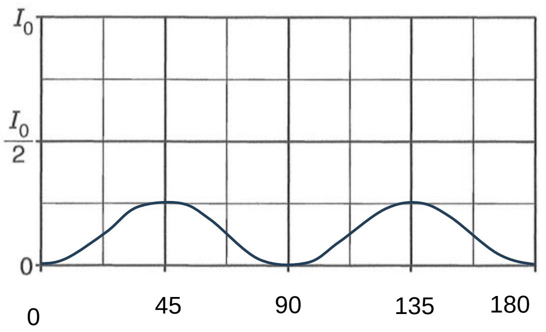
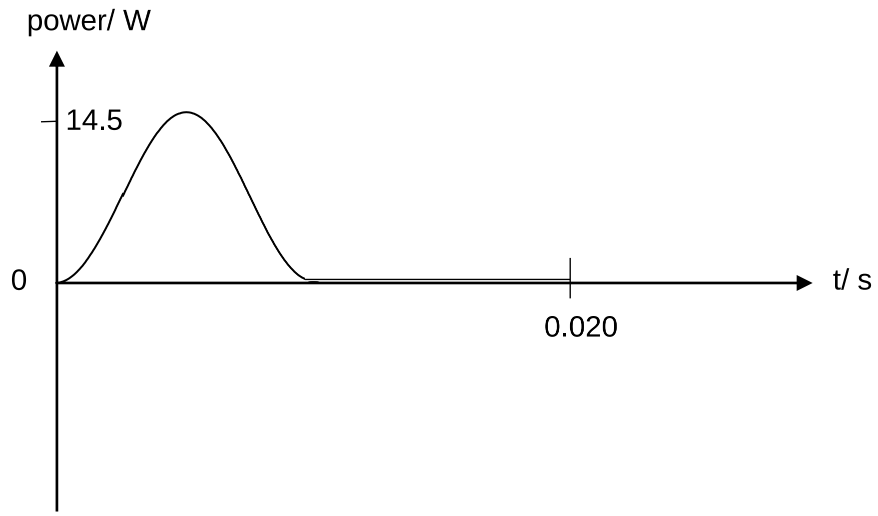
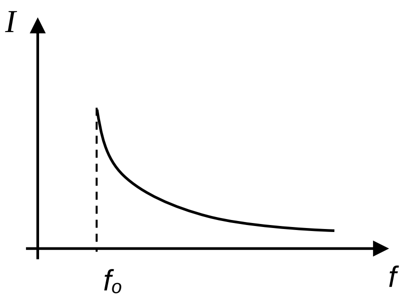
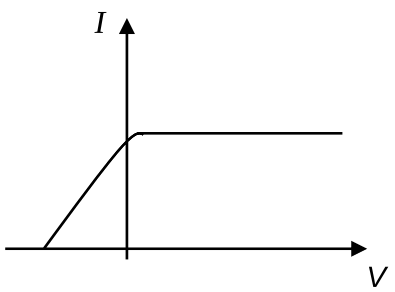
Paper 3 – Longer Structured

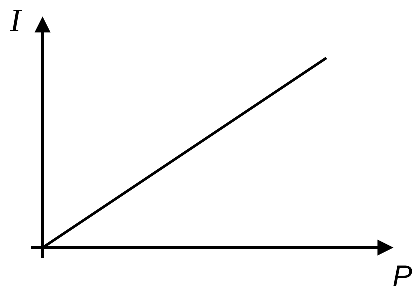
Qns	Answer	Marks
1a	 Correct positions of max and min intensities, and gradient at 0° and 180° should be approx zero [B1] Max intensity of $I_o/4$ [B1] Working: $I_o = I_o \cos^2\theta \cos^2(90-\theta)$ $= I_o \cos^2\theta \sin^2\theta$ $= I_o/4 \sin^2 2\theta$ [note: $\sin 2\theta = 2\sin\theta \cos\theta$]	
1bi	$d = 10\times10^{-6} \div 7$ $= 1.43 \times 10^{-6}$ m	M1 A1
1bii	For number of images on each side, $\sin\theta = 45°$ $n_{max} = d \sin 45°/\lambda$ $= 1.43 \times 10^{-6} \times \sin 45° / 600\times10^{-9}$ $= 1.68$ ≈ 1 Total number of images = 1 + 1 + 1 = 3	C1 A1
1biii	For the first order maxima, $d \sin\theta = \lambda$. <u>Most of the line spacing in the grating is uniform</u> such that the rays converge at α to give a bright image. <u>Some of the line spacing is smaller than the standard spacing</u>, giving rise to some part of the image being formed at a larger angle between α and β.	B1 B1

1ci	The stationary wave is formed when the incident wave is reflected at the sea wall such that the incident and reflected waves are of the same type, amplitude, frequency, wavelength and speed the incident and reflected wave travelling in opposite directions then overlap and superpose.	**B1** **B1**
1cii	For the increase in amplitude at wall, the incident and reflected waves must have amplitudes of the same sign / crest meets with crest. OR Constructive interference The reflected wave must have the same phase as the incident wave, hence no phase change occurred during reflection.	**M1** **A1**
1ciii	$1.75\lambda = 0.78$ $\lambda = 0.78/1.75$ $v = f\lambda$ $= 720 \times 0.78/1.75$ $= 321$	**C1** **A1**

Qns	Answer	Marks
2(ai)	The <u>increase in internal energy</u> of a system is the sum of <u>external work done on</u> the system and the <u>heat supplied</u> to the system.	B1 B1
2(aii)	When roasting, heat is supplied to the potato, thus Q_{to} is positive. W_{on} is negligible since there is little change in volume of the potato) / W_{on} is positive since cooked potato becomes smaller in volume Therefore, $\Delta U_{increase}$ is positive. OR W_{on} is negative but magnitude of Q is larger than magnitude of W Therefore, $\Delta U_{increase}$ is positive. $\Delta U = \Delta KE + \Delta PE$ ΔPE is negligible as there is no change in state of the potato, therefore, ΔKE is positive. **<u>OR</u>** ΔPE is positive as water from the potato is changed to gaseous state but ΔKE is also positive. Since KE is directly proportional to (thermodynamic) temperature, the temperature of the potato increases.	B1 B1 B1
2(b)(i)	$\Delta U = Q + W$ Constant volume, therefore W = 0 J $\Delta U = Q$ $= -55$ J	 B1 A1
2(b)(ii)	Process A to B takes place at constant temperature, therefore $U_A = U_B$ => $\Delta U_{AB} = 0$ For cyclic process, $\Delta U_{ABCA} = 0$ $\Delta U_{AB} + \Delta U_{BC} + \Delta U_{CA} = 0$ $\Delta U_{CA} = 55$ Process C to A is an adiabatic process, therefore $Q_{to} = 0$ J $\Delta U_{CA} = W_{on} = 55$ $W_{by} = -55$	B1 B1 A1

Qns	Answer	Marks
3(a)	r.m.s. value of an alternating current is the value of a steady direct current that will dissipate thermal energy at the same average rate as the a.c. in a given resistor	**A1**
3(b)	peak voltage = $6.0\sqrt{2}$ peak voltage = 8.5 V	 **A1**
3(c)	$k = \omega = 2\pi f = 2\pi(50) = 310$ Unit: radian per second, rad s^{-1} (or s^{-1})	**A1** **A1**
3(d)	8.5 V	**A1**
3(e)	zero because either no current in circuit (and V = IR) or all p.d. across diode	**A1**
3(f)	 $P_{max} = \frac{V_o^2}{R} = \frac{8.5^2}{5.0} = 14.5$ W $T = \frac{1}{f} = \frac{1}{50} = 0.020$ s Shape and showing one complete cycle Labelling max power as 14.5 W Labelling period as 0.020 s	 **M1** **A1** **A1**

Qns	Answer	Marks
4(a)(i)	A beam of white light consists of photons of all wavelengths (λ) in the visible spectrum. The photons interact with electrons in the gas atoms OR The photons will be absorbed by the electrons **(Option 1)** Photon energy causes electron to move to higher energy level (or to be excited) The photon energy (of certain wavelengths (E = hf = hc/λ)) is equal to the energy difference between the energy levels of the gas atoms When electrons de-excite, photons are re-emitted in all directions **(Option 2)** This results in fewer photons of these wavelengths/photons with much less intensity in the direction of the incident light/original direction of travel. Hence, there will be dark lines corresponding to these wavelengths in the diffraction pattern.	 **B1** **B1** **B1** **B1** **B1**
4(a)(ii)	Transitions –3.40eV to –0.85eV and –3.40eV to –1.51eV	**B1**
4(b)(i)	f increases, so energy carried by each photon (= hf) increases. P is constant, so the total incident energy per unit time is constant. Hence, the number of photons per unit time must decrease. The number of photoelectrons must also decrease.  $\text{quantum yield} = \dfrac{\text{no. of photoelectrons emitted}}{\text{no. of incident photon}}$ is a fixed value for a given wavelength and type of metal. Correct shape – **B1** Indication of f_o – **B1**	
4(b)(ii)	Negative potential diffrence slows down the electrons, so fewer electrons can reach the collector, photocurrent decreases, to 0 if electrons with max KE cannot reach collector. Positive potential difference accelerates the electrons towards the collector, so all electrons reach the collector, saturation current is reached. 	**B1**

4(b)(iii)	With energy per photon (= h*f*) constant, the number of incident photons increases linearly with power. Hence, the number of photoelectrons also increases linearly with power. 	**B1**
4(c)(i)	no. of electrons $= 6^{10} = 6.05 \times 10^{7}$	**B1**
4(c)(ii)	no. of electrons per unit time from 10th dynode $= \dfrac{9.2 \times 10^{-6}}{1.6 \times 10^{-19}} = 5.75 \times 10^{13}$ no. of electrons per unit time from cathode $= \dfrac{5.75 \times 10^{13}}{6.05 \times 10^{7}} = 9.50 \times 10^{5}$	**M1** **A1**
4(c)(iii)	no. of incident photons per unit time $= 9.50 \times 10^{5} \times 3 = 2.85 \times 10^{6}$ power of incident light $= n\dfrac{hc}{\lambda}$ $= 2.85 \times 10^{6} \times \dfrac{6.63 \times 10^{-34} \times 3.0 \times 10^{8}}{361 \times 10^{-9}} = 1.57 \times 10^{-12}$ W	**M1** **A1**
4(c)(iv)	kinetic energy of an electron $= qV = 1.6 \times 10^{-19} \times 50 = 8.0 \times 10^{-18}$ J $E = \dfrac{p^{2}}{2m} = 8.0 \times 10^{-18}$ J $\Rightarrow p = \sqrt{2mE} = \sqrt{2 \times 9.11 \times 10^{-31} \times 8.0 \times 10^{-18}} = 3.82 \times 10^{-24}$ N s $\lambda = \dfrac{h}{p} = \dfrac{6.63 \times 10^{-34}}{3.82 \times 10^{-24}} = 1.74 \times 10^{-10}$ m	**M1** **M1** **A1**

<table>
<tr><th>Qns</th><th>Answer</th><th>Marks</th></tr>
<tr><td>5ai</td><td>
Binding energy of Mo = $95 \times 8.09 = 768.55$ MeV
Binding energy of La = $139 \times 7.92 = 1100.88$ MeV

Energy released
= Binding energy of Mo + Binding energy of La – Binding energy of U

Therefore
182 = 768.55 + 1100.88 - Binding energy of U

Binding energy of U = 1687.43 MeV = 1690 MeV
</td><td>
C1
(either one)

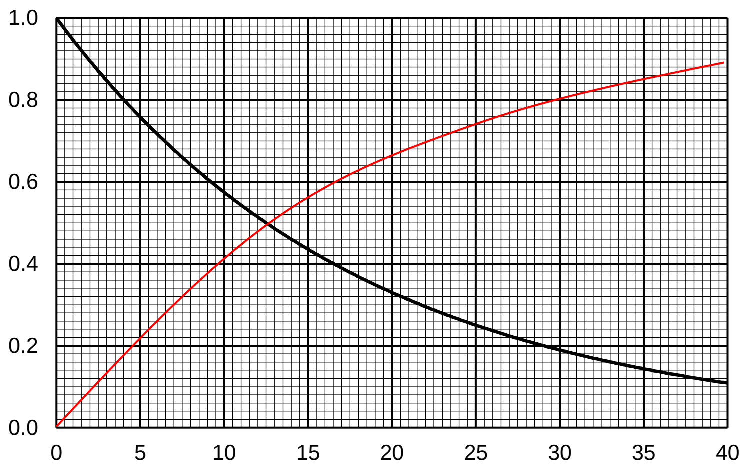
M1

A1
</td></tr>
<tr><td>5aii</td><td>
Binding energy = $\Delta m\, c^2$

$\Delta m = \dfrac{1687.43 \times 10^{6} \times 1.6 \times 10^{-19}}{\left(3.0 \times 10^{8}\right)^{2}}$
$= 3.00 \times 10^{-27}$ kg
</td><td>
C1

A1
</td></tr>
<tr><td>5bi</td><td>
${}^{42}_{19}\mathrm{K} \rightarrow {}^{42}_{20}\mathrm{Ca} + {}^{0}_{-1}e + \bar{\nu}$

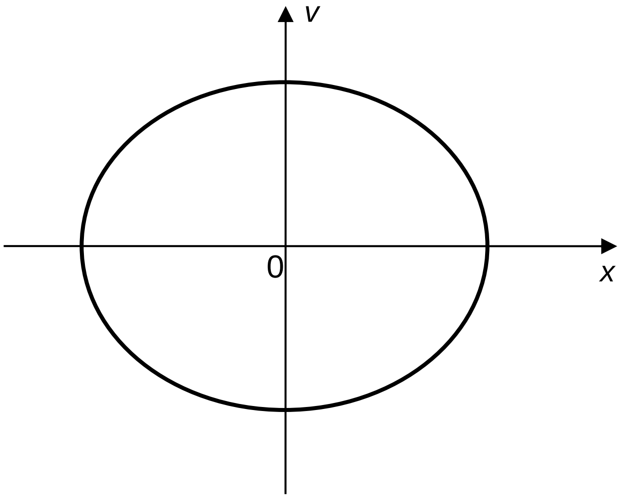
Also accept: “neutrino”, “anti-neutrino” and ν
</td><td>A1</td></tr>
<tr><td>5bii</td><td>
From Fig. 5.2,
time taken for number of nuclei to drop from N_0 to 0.25 N_0 is 25 hours.

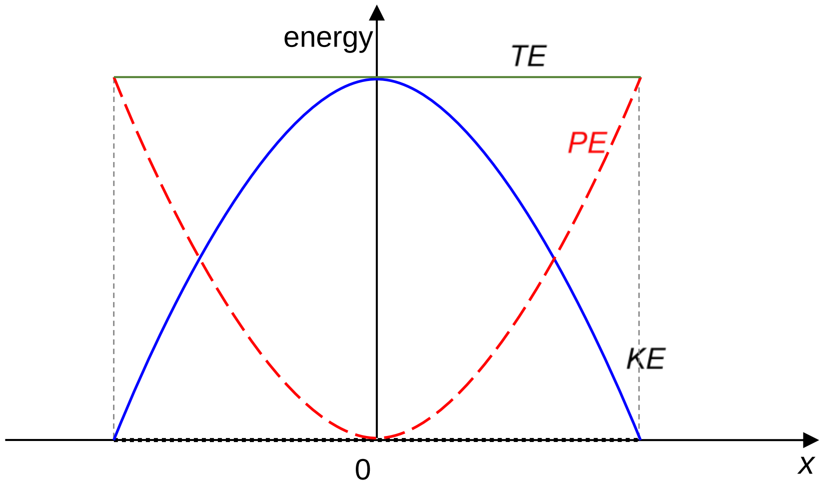
$2t_{1/2} = 25$
$t_{1/2} = 12.5$ hours
</td><td>A1</td></tr>
<tr><td>5biii</td><td>


Graph of Ca is a reflection of the graph for K in the N =0.5 N_0 line.
Graphs will intersect at N = 0.5 N_0
</td><td>P1</td></tr>
<tr><td>5biv</td><td>
When N (Ca) = 4 N (K),
N (K) = 0.2 N_0

From the graph, this occurs when t = 29 hours
</td><td>
M1

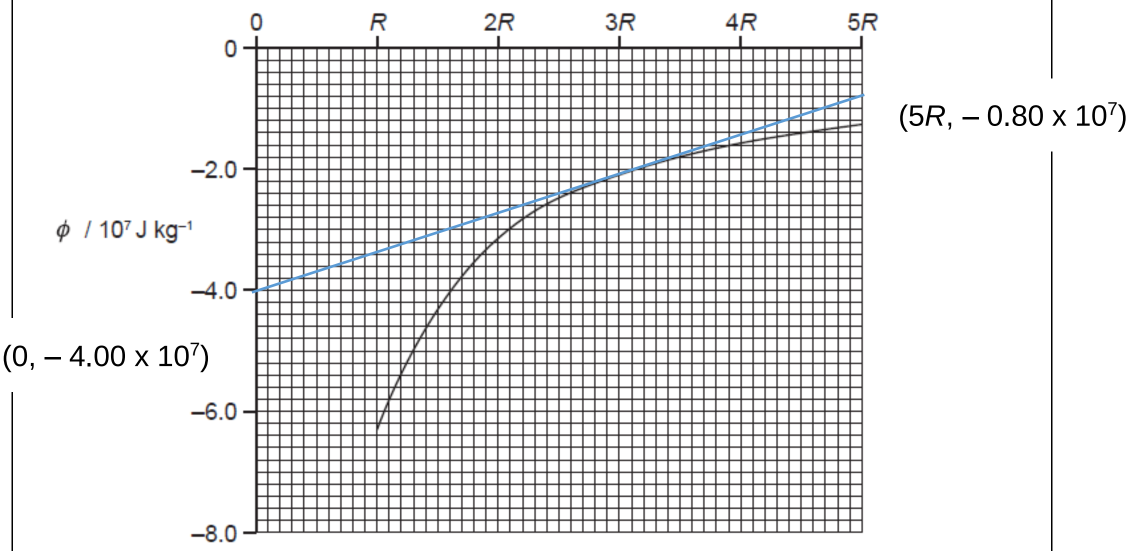
A1
</td></tr>
</table>

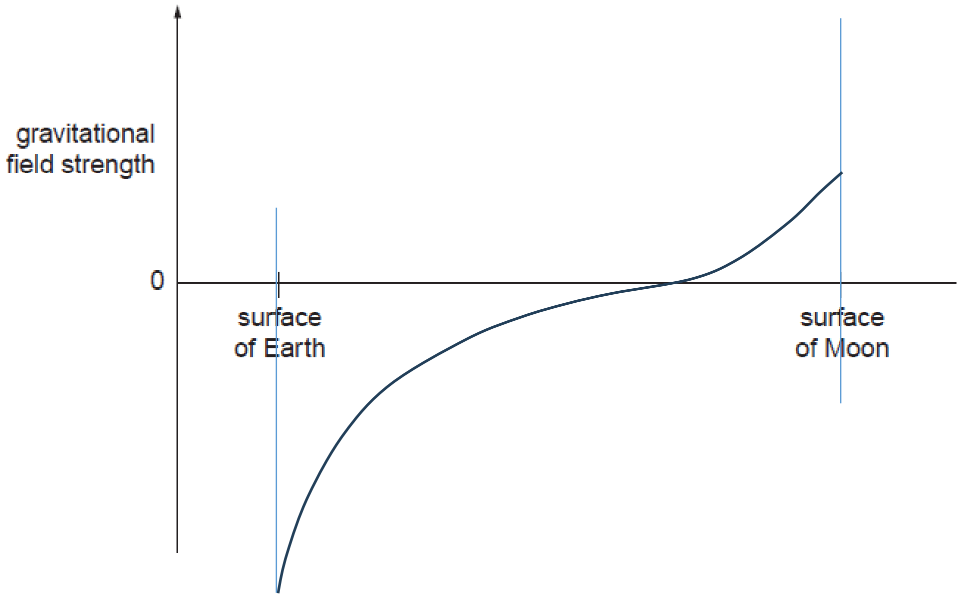
Qns	Answer	Marks
6(a)	acceleration proportional to displacement (from a fixed point) either acceleration and displacement in opposite directions or acceleration always directed towards a fixed point	**B1** **B1**
6(b)(i)	g and r are constant so a is proportional to x negative sign shows a and x are in opposite directions	**B1** **B1**
6(b)(ii)	$\omega^2 = \frac{g}{r}$ and $\omega = \frac{2\pi}{T}$ $\left(\frac{2\pi}{T}\right)^2 = \frac{9.81}{0.28}$ T = 1.06 s	**M1** **M1** **A0**
6(b)(iii)	$x = x_o \sin \omega t$ $1.5 = 2.0 \sin\left(\frac{2\pi}{1.1}t\right)$ $t = 0.15$ s (or 0.143 s)	 **M1** **A1**
6(b)(iv)	Correct shape  Correct maximum velocities Label units of v $v_o = \omega x_o$ $v_o = \left(\frac{2\pi}{T}\right)x_o$ $v_o = \left(\frac{2\pi}{1.1}\right)(0.020) = 0.11 \text{ m s}^{-1}$ (or 0.118 m s^{-1})	**B1** **B1** **B1**
6(b)(v)	Total energy = max KE $= \frac{1}{2}(0.100)(0.11)^2$ $= 0.61$ mJ (or 0.69 mJ)	**B1** **C1** **A1**

6(b)(vi)	Correct shape of TE, KE and PE  Label TE value and unit on axis	**B1** **B1**

6(b)(vii)	**METHOD 1:** $N_{28}T_{28} = N_{29}T_{29}$ $N_{28}\sqrt{r_{28}} = N_{29}\sqrt{r_{28}}$ AND $(N+1)\sqrt{28} = N\sqrt{29}$ $N = 56.5$ $t = (56.5)(1.1)$ $= 62$ s or $t = (56.5)(1.06)$ $= 60$ s	**C1** **C1** **C1** **A1**
	METHOD 2: $N_{28}T_{28} = N_{29}T_{29}$ $N\sqrt{28} = (N-1)\sqrt{29}$ $N = 57.5$ $t = (57.5)(2\pi\sqrt{\frac{0.29}{9.81}})$ $= 62$ s	**C1** **C1** **C1** **A1**
	METHOD 3: $\Delta\phi = 2\pi$ $\phi - \phi' = 2\pi$ $\omega t - \omega' t = 2\pi$ $\left(\frac{2\pi}{T}\right)t - \left(\frac{2\pi}{T'}\right)t = 2\pi$ $\left(\frac{2\pi}{1.1}\right)t - \left(\frac{2\pi}{1.08}\right)t = 2\pi$ OR $\left(\frac{2\pi}{1.06}\right)t - \left(\frac{2\pi}{1.08}\right)t = 2\pi$ $t = 59$ s $t = 57$ s	**C1** **C1** **C1** **A1**

	METHOD 4: $\Delta\phi = 2\pi$ $\phi - \phi' = 2\pi$ $\omega t - \omega' t = 2\pi$ $\left(\sqrt{\frac{g}{r}}\right)t - \left(\sqrt{\frac{g}{r'}}\right)t = 2\pi$ $\left(\sqrt{\frac{9.81}{0.28}}\right)t - \left(\sqrt{\frac{9.81}{0.29}}\right)t = 2\pi$ $t = 61$ s **METHOD 5:** $\Delta T = 1.08 - 1.06 = 0.02$ s $\frac{1.06}{0.02} = 53$ $t = 53 \times 1.06$ $t = 56$ s	**C1** **C1** **C1** **A1** **C1** **C1** **C1** **A1**

Qns	Answer	Marks
7 (a)	work done per unit mass in bringing a small test mass from infinity to that point	**B1** **B1**
7(b)(i)	gravitational field strength of the electric field at a point is numerically equal to the potential gradient at that point.  field strength = $\dfrac{-0.80\times10^{7}-(-4.00\times10^{7})}{5R-0}$ $= \dfrac{3.2\times10^{7}}{5(6.4\times10^{6})}$ = 1.0 N kg^{-1} (accept 0.9 to 1.2 N kg^{-1})	**C1** **C1** **A1**
7(b)(ii)1	Point A. Since the total energy A intersects the potential energy graph at x = 2R, the space capsule would only possess gravitational potential energy and have zero kinetic energy.	**A1** **M1**
7(b)(ii)2	Point(s) B, C, D. Total energy is greater than GPE. KE is not zero	**A1** **M1** **M1**
7(b)(ii)3	Point D. As the total energy D value is equal to zero, the space capsule would have enough energy to travel to infinity where the potential energy is zero.	**A1** **M1**
7(b)(ii)4	Point B. For circular motion, $TE = -\dfrac{GMm}{2r} = = \dfrac{1}{2}\left(-\dfrac{GMm}{r}\right) = \dfrac{1}{2}(GPE)$	**A1** **M1**

7(c)(i)	 Shape g = 0 *at least* ⅔ distance to Moon $\lvert g_E \rvert > \lvert g_M \rvert$ at surface	 **M1** **B1** **B1**
7(c)(ii)	Minimum energy = m $\Delta\Phi$ = $(4.0)[-1.3 - (-62.3)] \times 10^6$ = 2.44×10^8 J	**C1** **C1** **A1**