

Question	Answer	Marks
1(a)(i)	region (of space)	**B1**
	where a particle experiences a force	**B1**
1(a)(ii)	force per unit mass	**B1**
1(b)	$g = GM / R^2$	**C1**
	$= (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (3.39 \times 10^{6})^2$	**C1**
	$= 3.73\ \text{N kg}^{-1}$	**A1**

Question	Answer	Marks
1(c)	$0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / r^2$	**C1**
	$r = 3.41 \times 10^6$ (m)	**C1**
	height = $(r - R)$ $= 2 \times 10^4$ m	**A1**
	or	
	$0.99 \times 3.73 = (6.67 \times 10^{-11} \times 6.42 \times 10^{23}) / (R + h)^2$ $(R + h)^2 = 1.1596 \times 10^{13}$	**(C1)**
	$R + h = 3.41 \times 10^6$ (m)	**(C1)**
	$h = 2 \times 10^4$ m	**(A1)**
	or	
	$0.99 = (3.39 \times 10^6)^2 / r^2$	**(C1)**
	$r = 3.41 \times 10^6$ (m)	**(C1)**
	height = 2×10^4 m	**(A1)**

<table>
<tr><th>Question</th><th>Answer</th><th>Marks</th></tr>
<tr><td rowspan="2">2(a)</td><td>+q: thermal energy transfer to system</td><td>B1</td></tr>
<tr><td>+w: work done on system</td><td>B1</td></tr>
<tr><td>2(b)(i)</td><td>(W =) $2.6 \times 10^5 \times (3.8 - 2.3) \times 10^{-3}$ = 390 J</td><td>A1</td></tr>
<tr><td rowspan="2">2(b)(ii)</td><td>no (total) change (in internal energy)</td><td>B1</td></tr>
<tr><td>gas returns to its original temperature</td><td>B1</td></tr>
<tr><td rowspan="4">2(c)</td><td>A to B row all correct (1370, – 390, 980)</td><td>B1</td></tr>
<tr><td>B to C row all correct (0, 550, 550)</td><td>B1</td></tr>
<tr><td>C to A row: ΔU adds to the other two ΔU values to give zero</td><td>B1</td></tr>
<tr><td>C to A row: w = 0 and q adds to w to give ΔU value

complete correct answer:

<table>
<tr><th>change</th><th>q / J</th><th>w / J</th><th>ΔU / J</th></tr>
<tr><td>A to B
B to C
C to A</td><td>(+)1370
0
–1530</td><td>–390
(+)550
0</td><td>(+)980
(+)550
–1530</td></tr>
</table>
</td><td>B1</td></tr>
</table>

Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration in opposite direction to displacement **or** acceleration (directed) towards equilibrium position	**B1**
3(b)	$v = \omega(x_0^2 - x^2)^{½}$ **and** $\omega = 2\pi f$ **or** $v_0 = x_0\omega$ **and** $\omega = 2\pi f$	**C1**
	substitution of any correct point from graph, e.g. for $x = 0$: $0.25 = 2\pi f \times 8.8 \times 10^{-2}$	**C1**
	$f = 0.45$ Hz	**A1**
3(c)	$1 / 0.45 = 2\pi \times (L / 9.81)^{½}$	**C1**
	$L = 1.2$ m	**A1**
3(d)	ellipse about the origin with same intercepts on x-axis	**B1**
	ellipse about the origin crossing v-axis inside original loop	**B1**

Question	Answer	Marks
4(a)	quartz crystal	**B1**
	alternating p.d. across crystal causes it to vibrate	**B1**
	resonance occurs when frequency of p.d. matches natural frequency of crystal	**B1**
	natural frequency of crystal is in ultrasound range	**B1**
4(b)	$I = I_0 e^{-\mu x}$	**C1**
	$I / I_0 = e^{-1.2 \times 3.5}$ $= 0.015$	**C1**
	ratio / dB $= -10 \lg (1 / 0.015)$ **or** $10 \lg (0.015)$	**C1**
	$= -18$ dB	**A1**

Question	Answer	Marks
5(a)	work done per unit charge	**B1**
	(work done on charge) moving positive charge from infinity	**B1**
5(b)(i)	$(2.0 \times 10^{-9}) / 4\pi\varepsilon_0(4.0 \times 10^{-2}) + Q / 4\pi\varepsilon_0(8.0 \times 10^{-2}) = 0$	**C1**
	$Q = 4.0 \times 10^{-9}$ C	**A1**
	Q given with negative sign	**B1**
5(b)(ii)	change = 1200 V	**A1**
5(c)	$\frac{1}{2}mv^2 = qV$	**C1**
	$\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times v^2 = 2 \times 1.60 \times 10^{-19} \times 1200$	**C1**
	$v = 3.4 \times 10^5$ m s^{-1}	**A1**

Question	Answer	Marks
6(a)(i)	charge per unit potential (difference)	**M1**
	charge on one plate and potential difference across the plates	**A1**
6(a)(ii)	any three points from: • smoothing • timing/(time) delay • tuning • oscillator • blocking d.c. • surge protection • temporary power supply	**B3**
6(b)	(capacitors in series have combined capacitance =) 8 μF	**C1**
	capacitance = 8 + 24 = 32 μF	**A1**

Question	Answer	Marks
7(a)	two resistors connected in series between earth and positive of battery and no extra connections	**B1**
	one resistor and thermistor connected in series between earth and positive of battery and no extra connections	**B1**
	midpoints of the two potential dividers connected, one each, to the op-amp input terminals	**B1**
	thermistor in correct place in potential divider circuit (either the upper part of the potential divider leading to V^+ or the lower part of the potential divider leading to V^-)	**B1**
7(b)(i)	value greater than 1000 Ω	**A1**
7(b)(ii)	non-zero value less than 1000 Ω	**A1**

Question	Answer	Marks
8(a)(i)	downwards	**B1**
8(a)(ii)	PQRS and JKLM	**B1**
8(b)	(as charge separates) an electric field is created (between opposite faces)	**B1**
	(maximum value is reached when) electric force (on electron) is equal and opposite to magnetic force (on electron)	**B1**
8(c)	$V_H = BI / ntq$ $= (4.6 \times 10^{-3} \times 6.3 \times 10^{-4}) / (1.3 \times 10^{29} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	**C1**
	$= 1.4 \times 10^{-12}$ V	**A1**
8(d)	semiconductors have a (much) smaller value for n	**B1**
	V_H for semiconductors is (much) larger so more easily measured	**B1**

Question	Answer	Marks
9(a)	flux density × area	**M1**
	where flux is normal to area	**A1**
	or	
	flux density × area × sin θ	**(M1)**
	where θ is angle between flux direction and (plane of) area	**(A1)**
9(b)(i)	(alternating) current creates changing (magnetic) flux	**B1**
	core links (magnetic) flux with secondary coil	**B1**
	changing flux (in secondary) causes induced e.m.f.	**B1**
9(b)(ii)	rate of change of flux is not constant	**B1**
	(induced) e.m.f. is proportional to rate of change of flux	**B1**
9(c)	reduces induced currents in core	**B1**
	hence reduces energy losses (in core)	**B1**

Question	Answer	Marks
10(a)	X-rays are used	**B1**
	section (of object) is scanned	**B1**
	scans/images taken at many angles/directions **or** images of each section are 2-dimensional	**B1**
	(images of (many)) sections are combined	**B1**
	(to give) 3-dimensional image of (whole) structure	**B1**
10(b)	K = 6 L = 7 M = 2 N = 9 3 marks: all four correct 2 marks: three correct and one incorrect **or** all correct with two numbers transposed 1 mark: two correct and two incorrect	**B3**

Question	Answer	Marks
11(a)(i)	quantum of energy	**M1**
	of electromagnetic radiation	**A1**
11(a)(ii)	arrow (on Fig. 11.1) pointing upwards and to the right	**B1**
11(b)(i)	$\lambda = h / p$	**C1**
	$p = (6.63 \times 10^{-34}) / (544 \times 10^{-9})$ $= 1.22 \times 10^{-27}$ N s	**A1**
11(b)(ii)	energy $= hc / \lambda$	**C1**
	$= 6.63 \times 10^{-34} \times 3.00 \times 10^{8} \times (540^{-1} - 544^{-1}) \times 10^{9}$ $= 2.7 \times 10^{-21}$ J	**A1**
11(c)	(smaller wavelength corresponds to) greater photon energy	**B1**
	any one point from: • (deflected) photon loses energy (so not possible) • (deflected) photon would need to gain energy (so not possible) • electron would need to lose energy (so not possible) • initially electron energy is zero (so not possible)	**B1**

Question	Answer	Marks
12(a)(i)	unstable nucleus	**B1**
	emits ionising radiation **or** decays spontaneously	**B1**
12(a)(ii)	probability of decay (of a nucleus)	**M1**
	per unit time	**A1**
12(b)	$A = \lambda N$	**C1**
	$560 = 9.9 \times 10^{-7} \times N$ $N = 5.7 \times 10^{8}$	**A1**
12(c)	$A = A_0\, e^{-\lambda t}$ $170 = 560 \exp(-9.9 \times 10^{-7} \times t)$	**C1**
	$t = 1.2 \times 10^{6}$ s	**C1**
	= 14 days	**A1**