Published

This document consists of **18** printed pages.

Abbreviations

/	Alternative and acceptable answers for the same marking point.
( )	Bracketed content indicates words which do not need to be explicitly seen to gain credit but which indicate the **context** for an answer. The context does not need to be seen but if a context is given that is incorrect then the mark should not be awarded.
___	Underlined content must be present in answer to award the mark. This means either the exact word or another word that has the same technical meaning.

Mark categories

B marks	These are underlined independent marks, which do not depend on other marks. For a **B** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer.
M marks	These are method marks upon which **A** marks later depend. For an **M** mark to be awarded, the point to which it refers must be seen specifically in the candidate's answer. If a candidate is not awarded an **M** mark, then the later **A** mark cannot be awarded either.
C marks	These are compensatory marks which can be awarded even if the points to which they refer are not written down by the candidate, providing subsequent working gives evidence that they must have known them. For example, if an equation carries a **C** mark and the candidate does not write down the actual equation but does correct working which shows the candidate knew the equation, then the **C** mark is awarded. If a correct answer is given to a numerical question, all of the preceding **C** marks are awarded automatically. It is only necessary to consider each of the **C** marks in turn when the numerical answer is not correct.
A marks	These are answer marks. They may depend on an **M** mark or allow a **C** mark to be awarded by implication.

Annotations

✓	Indicates the point at which a mark has been awarded.
X	Indicates an incorrect answer or a point at which a decision is made not to award a mark.
XP	Indicates a physically incorrect equation ('incorrect physics'). No credit is given for substitution, or subsequent arithmetic, in a physically incorrect equation.

ECF	Indicates 'error carried forward'. Answers to later numerical questions can always be awarded up to full credit provided they are consistent with earlier incorrect answers. <u>Within</u> a section of a numerical question, ECF can be given after AE, TE and POT errors, but **not** after XP.
AE	Indicates an arithmetic error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
POT	Indicates a power of ten error. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
TE	Indicates incorrect transcription of the correct data from the question, a graph, data sheet or a previous answer. For example, the value of 1.6×10^{-19} has been written down as 6.1×10^{-19} or 1.6×10^{19}. Do not allow the mark where the error occurs. Then follow through the working/calculation giving full subsequent ECF if there are no further errors.
SF	Indicates that the correct answer is seen in the working but the final answer is incorrect as it is expressed to too few significant figures.
BOD	Indicates that a mark is awarded where the candidate provides an answer that is not totally satisfactory, but the examiner feels that sufficient work has been done ('benefit of doubt').
CON	Indicates that a response is contradictory.
I	Indicates parts of a response that have been seen but disregarded as irrelevant.
M0	Indicates where an A category mark has not been awarded due to the M category mark upon which it depends not having previously been awarded.
^	Indicates where more is needed for a mark to be awarded (what is written is not wrong, but not enough). May also be used to annotate a response space that has been left completely blank.
SEEN	Indicates that a page has been seen.

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 = $(r - R)$ = 2×10^4 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)**

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

Question	Answer	Marks
3(a)	acceleration (directly) proportional to displacement	**B1**
	acceleration in opposite <u>direction</u> to displacement **or** acceleration (directed) towards equilibrium position	**B1**
3(b)	$v = \omega(x_0^2 - x^2)^{\frac{1}{2}}$ **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**
	$f = 0.45\ \text{Hz}$	**A1**
3(c)	$1 / 0.45 = 2\pi \times (L / 9.81)^{\frac{1}{2}}$	**C1**
	$L = 1.2\ \text{m}$	**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 <u>and</u> 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 =) $8\,\mu F$	C1
	capacitance = 8 + 24 = $32\,\mu F$	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 $1000\,\Omega$	A1
7(b)(ii)	non-zero value less than $1000\,\Omega$	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)	$V_H = BI / ntq$	**C1**
	$= (4.6 \times 10^{-3} \times 6.3 \times 10^{-4}) / (1.3 \times 10^{29} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	
	$= 1.4 \times 10^{-12}$ 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**
A1	$p = (6.63 \times 10^{-34}) / (544 \times 10^{-9})$ $= 1.22 \times 10^{-27}$ N s	**A1**
11(b)(ii)	energy $= hc / \lambda$	**C1**
A1	$= 6.63 \times 10^{-34} \times 3.00 \times 10^8 \times (540^{-1} - 544^{-1}) \times 10^9$ $= 2.7 \times 10^{-21}$ 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**
12(c)	$t = 1.2 \times 10^{6}\,\text{s}$	**C1**
	$= 14$ days	**A1**