
PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 2017

MARK SCHEME

Maximum Mark: 100

Published

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Question	Answer	Marks
1(a)	gravitational force (of attraction between satellite and planet)	B1
	<u>provides / is</u> centripetal force (on satellite about the planet)	B1
1(b)	$M = (4/3) \times \pi R^3 \rho$	B1
	$\omega = 2\pi / T$ or $v = 2\pi nR / T$	B1
	$GM / (nR)^2 = nR\omega^2$ or v^2 / nR	M1
	substitution clear to give $\rho = 3\pi n^3 / GT^2$	A1
1(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2	C1
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	C1
	$\rho = 5.54 \times 10^3 \text{ kg m}^{-3}$	A1

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Question	Answer	Marks
2(a)	e.g. period = 3 / 2.5	C1
	frequency = 0.83 Hz	A1
2(b)	light (damping)	B1
2(c)	at 2.7 s, $A_0 = 1.5$ (cm)	B1
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	B1
	$= \frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$ $= 5.51 \times 10^{-4}$ (J)	C1
	at 7.5 s, $A_0 = 0.75$ (cm)	B1
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ or energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	C1
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	A1

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Question	Answer	Marks
3(a)(i)	signal consists of (a series of) 1s and 0s or offs and ons or highs and lows	B1
3(a)(ii)	component X: parallel-to-serial converter	B1
	component Y: DAC/digital-to-analogue converter	B1
3(a)(iii)	sample the (analogue) signal	M1
	at regular intervals and converts the analogue number to a digital number	A1
3(b)(i)	attenuation in fibre = 84×0.19 (= 16 dB)	C1
	ratio = 16 + 28 = 44 dB	A1
3(b)(ii)	ratio / dB = $10 \lg (P_2 / P_1)$	C1
	$44 = 10 \lg (\{9.7 \times 10^{-3}\} / P)$ or $-44 = 10 \lg (P / \{9.7 \times 10^{-3}\})$	C1
	power = $3.9 \times 10^{-7} \text{ W}$	A1

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Question	Answer	Marks
4(a)	random/haphazard	B1
	constant velocity or speed in a straight line between collisions or distribution of speeds/different directions	B1
4(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	M1
	moving haphazardly/randomly/jerky/in a zigzag fashion	A1
4(c)(i)	$pV = \frac{1}{3} Nm\langle c^2 \rangle$ $1.05 \times 10^5 \times 0.0240 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2 \rangle$	C1
	$\langle c^2 \rangle = 1.89 \times 10^6$	C1
	or	
	$\frac{1}{2} m\langle c^2 \rangle = (3/2) kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2 \rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	(C1)
	$\langle c^2 \rangle = 1.87 \times 10^6$	(C1)
	or	
	$nRT = \frac{1}{3} Nm\langle c^2 \rangle$ $1.00 \times 8.31 \times 300 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2 \rangle$	(C1)
	$\langle c^2 \rangle = 1.87 \times 10^6$	(C1)
	$c_{r.m.s.} = 1.37 \times 10^3 \text{ m s}^{-1}$	A1

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Question	Answer	Marks
4(c)(ii)	$\langle c^2 \rangle \propto T$	C1
	$\langle c^2 \rangle$ at 177 °C = $1.89 \times 10^6 \times (450 / 300)$	C1
	$c_{\text{r.m.s.}}$ at 177 °C = $1.68 \times 10^3 \text{ m s}^{-1}$	A1

Question	Answer	Marks
5(a)	(loss in) kinetic energy of α -particle = $Qq / 4\pi\epsilon_0 r$ or $7.7 \times 10^{-13} = Qq / 4\pi\epsilon_0 r$	C1
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	M1
	$r = 4.7 \times 10^{-14} \text{ m}$ r is closest distance of approach so radius less than this	A1
5(b)	force = $Qq / 4\pi\epsilon_0 r^2 = 4u \times a$	C1
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	C1
	$a = 2.5 \times 10^{27} \text{ m s}^{-2}$	A1
5(c)	so that single interactions between nucleus and α -particle can be studied or so that multiple deflections with nucleus do not occur	B1

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Question	Answer	Marks
6(a)(i)	lamp needs 'high' power/'large' current/'large' voltage	B1
	op-amp can deliver only a small current/small voltage	B1
6(a)(ii)	correct symbol for relay coil connected between output and earth	B1
	switch between mains supply and lamp	B1
6(b)(i)	vary light intensity at which lamp is switched on/off	B1
6(b)(ii)	so that relay operates for only one current/voltage direction or so that relay/lamp operates for either dark or light conditions	B1
6(c)	when light level increases, LDR resistance decreases	B1
	(R_{LDR} low,) so $V^- > V^+$, so V_{OUT} negative/–5 V (must be consistent with B1 mark)	M1
	or	
	when light level decreases, LDR resistance increases	(B1)
	(R_{LDR} high,) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)	(M1)
	lamp comes on as light level decreases or lamp goes off as light level increases	A1

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Question	Answer	Marks
7(a)	(magnetic) force (always) normal to velocity/direction of motion	M1
	(magnitude of magnetic) force constant or speed is constant/kinetic energy is constant	M1
	so provides the centripetal force	A1
7(b)	increase in KE = loss in PE or $\frac{1}{2}mv^2 = qV$	M1
	$p = mv$ with algebra leading to $p = \sqrt{(2mqV)}$	A1
7(c)	$Bqv = mv^2 / r$ $mv = Bqr$ or $p = Bqr$	C1
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$	C1
	$B = 5.0 \times 10^{-4} \text{ T}$	A1
7(d)	greater momentum	M1
	($p = Bqr$ and) so r increased	A1

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Question	Answer	Marks
8	strong (uniform) magnetic field	B1
	* <u>nuclei</u> precess/rotate about field (direction)	
	radio frequency pulse/RF pulse (applied)	B1
	* RF or pulse is at Larmor frequency / frequency of precession	
	causes resonance / excitation (of nuclei)/nuclei to absorb energy	B1
	on relaxation/de-excitation, nuclei emit RF/pulse	B1
	* (emitted) RF/pulse detected and processed	
	non-uniform field (superposed on uniform field)	B1
	allows positions of (resonating) <u>nuclei</u> to be determined	B1
	* allows for position of detection to be changed/different slices to be studied	
	<i>max. 2 of additional detail points marked *</i>	B2

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Question	Answer	Marks
9(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage	B1
9(a)(ii)	reduces (size of eddy) currents in core	B1
	(so that) heating of core is reduced	B1
9(b)	alternating voltage gives rise to changing magnetic flux in core	M1
	(changing) flux links the secondary coil	A1
	induced e.m.f. (in secondary) only when flux is changing/cut	B1

Question	Answer	Marks
10(a)(i)	penetration of beam	M1
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy	A1
10(a)(ii)	greater accelerating potential difference or greater p.d. between anode and cathode	B1
10(b)	$I = I_0 \exp(-\mu x)$ ratio = $(\exp \{-1.5 \times 2.9\}) / (\exp \{-4.0 \times 0.95\}) (= \exp \{-0.55\})$	C1
	= 0.58	A1

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Question	Answer	Marks
11(a)	electrons (in gas atoms/molecules) interact with photons	B1
	photon energy causes electron to move to higher energy level/to be excited	B1
	photon energy = difference in energy of (electron) energy levels	B1
	when electrons de-excite, photons emitted in all directions (so dark line)	B1
11(b)(i)	photon energy $\propto 1 / \lambda$	C1
	energy = 1.68 eV	A1
	or	
	$E = hc / \lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19} \text{ J}$	(C1)
	energy = 1.68 eV	(A1)
11(b)(ii)	3.4 eV $\rightarrow$ 1.5 eV 3.4 eV $\rightarrow$ 0.85 eV 3.4 eV $\rightarrow$ 0.54 eV <i>all correct and none incorrect 2/2</i> <i>2 correct and 1 incorrect or only 2 correctly drawn 1/2</i>	B2

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Question	Answer	Marks
12(a)	$x = 7$	A1
12(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10} \text{ J}$	C1
	division by 1.6×10^{-13} clear to give 934 MeV	A1
12(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ or $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053 \text{ u}$	C1
	energy $= 0.21053 \times 934$ $= 197 \text{ MeV}$	A1
12(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ -ray photon energy	B1

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Question	Answer	Marks
1(a)	force per unit mass	B1
1(b)(i)	$g = GM/r^2$ $= (6.67 \times 10^{-11} \times 1.0 \times 10^{13}) / (3.6 \times 10^3)^2$	C1
	$= 5.1 \times 10^{-5} \text{ N kg}^{-1}$	A1
1(b)(ii)	mass = $(960 / 9.81) \text{ kg}$ weight on comet = $(960 / 9.81) \times 5.1 \times 10^{-5}$	C1
	$= 5.0 \times 10^{-3} \text{ N}$	A1
1(c)	similarity: e.g. both attractive/pointed towards the comet e.g. same order of magnitude	B1
	difference: e.g. radial/non-radial e.g. same (over surface)/varies (over surface)	B1

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Question	Answer	Marks
2(a)(i)	mean/average square speed/velocity	B1
2(a)(ii)	$pV = NkT$ or $pV = nRT$	B1
	$\rho = Nm / V$ or $\rho = nN_A m / V$ and $k = nR / N$	B1
	$E_K = \frac{1}{2} m \langle c^2 \rangle$ with algebra to $(3/2)kT$	B1
2(b)(i)	no (external) work done or $\Delta U = q$ or $w = 0$	B1
	$q = N_A \times (3/2)k \times 1.0$	M1
	$N_A k = R$ so $q = (3/2)R$	A1
2(b)(ii)	specific heat capacity = $\{(3/2) \times R\} / 0.028$	C1
	= $450 \text{ J kg}^{-1} \text{ K}^{-1}$	A1

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Question	Answer	Marks
3(a)(i)	e.g. period = $6 / 2.5$	C1
	frequency = 0.42 Hz	A1
3(a)(ii)	energy = $\frac{1}{2} m \times 4\pi^2 f^2 y_0^2$	C1
	$= \frac{1}{2} \times 0.25 \times 4\pi^2 \times 0.42^2 \times (1.5 \times 10^{-2})^2$	C1
	$= 2.0 \times 10^{-4} \text{ J}$	A1
3(b)(i)	(induced) e.m.f. proportional to rate of	M1
	change of magnetic flux (linkage) or cutting of magnetic flux	A1
3(b)(ii)	coil cuts flux/field (of moving magnet) <u>inducing</u> e.m.f. in coil	B1
	(induced) current in resistor causes heating (effect)	M1
	thermal energy/heat derived from energy of oscillations (of magnet)	A1

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Question	Answer	Marks
4(a)	pulse (of ultrasound)	B1
	* produced by quartz crystal/piezo-electric crystal	
	* gel/coupling medium (on skin) used to reduce reflection at skin	
	reflected from boundaries (between media)	B1
	reflected pulse/wave detected by (ultrasound) transmitter	B1
	reflected wave processed and displayed	B1
	* intensity of reflected pulse/wave gives information about boundary	
	* time delay gives information about depth of boundary	
	<i>max. 2 of additional detail points marked *</i>	B2
4(b)	$I_T = I_0 \exp(-\mu x)$	C1
	$2.9 = \exp(4.6\mu)$	C1
	$\mu = 0.23 \text{ cm}^{-1}$	A1

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Question	Answer	Marks
5(a)	any two reasonable suggestions e.g. • signal can be regenerated/noise removed (not “no noise”) • circuits more reliable • circuits cheaper to produce • multiplexing (is possible) • error correction/checking • easier encryption/better security	B2
5(b)(i)	samples the analogue signal	M1
	at regular intervals and converts it (to a digital number)	A1
5(b)(ii)	1. smaller step depth	B1
	2. smaller step height	B1

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Question	Answer	Marks
6(a)	force proportional to product of charges and inversely proportional to the square of the separation	M1
	reference to point charges	A1
6(b)(i)	(near to each sphere,) fields are in opposite directions or point (between spheres) where fields are equal and opposite or point (between spheres) where field strength is zero	M1
	so same (sign of charge)	A1
6(b)(ii)	(at $x = 5.0 \text{ cm}$,) $E = 3.0 \times 10^3 \text{ V m}^{-1}$ and $a = qE / m$	C1
	$E = (1.60 \times 10^{-19} \times 3.0 \times 10^3) / (1.67 \times 10^{-27})$	C1
	$= 2.9 \times 10^{11} \text{ m s}^{-2}$	A1
6(c)	field strength or E is potential gradient or field strength is rate of change of (electric) potential	M1
	(field strength) maximum at $x = 6 \text{ cm}$	A1

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Question	Answer	Marks
7(a)	equal and opposite charges on the plates so no resultant charge	B1
	+ve and –ve charges separated so energy stored	B1
7(b)	charge / potential difference	M1
	reference to charge on one plate and p.d. between plates	A1
7(c)	energy = $\frac{1}{2} CV^2$ or energy = $\frac{1}{2} QV$ and $C = Q / V$	C1
	$(1 / 16) \times \frac{1}{2} CV_0^2 = \frac{1}{2} CV^2$ $V = \frac{1}{4} V_0$	A1

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Question	Answer	Marks
8(a)(i)	circle around both diodes	B1
8(a)(ii)	indicates (whether) temperature	M1
	(is) above or below a set value	A1
8(b)(i)	(when resistance of C > R_V ,) $V^- > V^+$ or $V^+ < 3V$ or p.d. across $R_V <$ p.d. across $R/Y/3V$ or p.d. across C > p.d. across $R/X/3V$	M1
	op-amp output is negative	M1
	(only) green	A1
8(b)(ii)	resistance of C becomes less than R_V or $V^- < V^+$	B1
	green (LED) goes out	A1
	blue (LED) comes on	A1
8(c)	changes/determines <u>temperature</u> at which LEDs switch	B1

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Question	Answer	Marks
9(a)(i)	Hall voltage depends on thickness of slice	C1
	thinner slice, larger Hall voltage	A1
9(a)(ii)	Hall voltage depends on current in slice	B1
9(b)	sinusoidal wave, one cycle	B1
	at $\theta = 0$ and at $\theta = 360^\circ$, $V_H = V_{MAX}$	B1
	at $\theta = 180^\circ$, $V_H = -V_{MAX}$	B1

Question	Answer	Marks
10(a)	two from: • frequency below which electrons not ejected • <u>maximum</u> energy of electron depends on frequency • <u>maximum</u> energy of electrons does not depend on intensity • instantaneous emission of electrons	B2
10(b)(i)	(λ_0 is the) threshold wavelength or wavelength corresponding to threshold frequency or maximum wavelength for emission of electrons	B1
10(b)(ii)1.	intercept = $1/\lambda_0 = 2.2 \times 10^6 \text{ m}^{-1}$ $\lambda_0 = 4.5 \times 10^{-7} \text{ m}$ or 450 nm	A1
10(b)(ii)2.	gradient = hc	C1
	gradient = 2.0×10^{-25} or correct substitution into gradient formula	C1
	$h = (2.0 \times 10^{-25}) / (3.0 \times 10^8) = 6.7 \times 10^{-34} \text{ J s}$	A1
10(c)	line: same gradient	B1
	straight line, positive gradient, intercept at greater than 2.2×10^6 when candidate's line extrapolated	B1

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Question	Answer	Marks
11(a)	loss of (electric) potential energy = gain in kinetic energy or $qV = \frac{1}{2}mv^2$ or $E_k = p^2/2m = qV$	B1
	$p = mv$ with algebra leading to $p = \sqrt{2mqV}$	B1
11(b)(i)	particle/electron has a wavelength (associated with it)	B1
	dependent on its momentum or when/because particle is moving	B1
11(b)(ii)	$p = (2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2}$	C1
	$\lambda = (6.63 \times 10^{-34}) / (5.91 \times 10^{-24})$	C1
	$= 1.12 \times 10^{-10} \text{ m}$	A1
11(c)	wavelength is similar to separation of atoms	M1
	so diffraction observed	A1

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Question	Answer	Marks
12(a)	$7\text{}^0_{-1}\text{e}$	A1
12(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$	M1
	$= 1.494 \times 10^{-10} \text{ J}$ division by 1.60×10^{-13} clear to give 934 MeV	A1
12(b)(ii)	$\Delta m = (82 \times 1.00863\text{u}) + (57 \times 1.00728\text{u}) - 138.955\text{u}$ $= (-) 1.16762 \text{ (u)}$	C1
	energy = 1.16762×934	C1
	energy per nucleon = $(1.16762 \times 934) / 139$ $= 7.85 \text{ MeV}$	A1
12(c)	above $A = 56$, binding energy per nucleon decreases as A increases	B1
	U-235 has larger nucleon number	M1
	so less (binding energy per nucleon)	A1
	or	
	fission takes place with uranium	(B1)
	fission reaction releases energy	(M1)
	binding energy per nucleon less (for uranium than for products)	(A1)

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1(a)	gravitational force (of attraction between satellite and planet)	B1
	<u>provides / is</u> centripetal force (on satellite about the planet)	B1
1(b)	$M = (4/3) \times \pi R^3 \rho$	B1
	$\omega = 2\pi / T$ or $v = 2\pi nR / T$	B1
	$GM / (nR)^2 = nR\omega^2$ or v^2 / nR	M1
	substitution clear to give $\rho = 3\pi n^3 / GT^2$	A1
1(c)	$n = (3.84 \times 10^5) / (6.38 \times 10^3) = 60.19$ or 60.2	C1
	$\rho = 3\pi \times 60.19^3 / [(6.67 \times 10^{-11}) \times (27.3 \times 24 \times 3600)^2]$	C1
	$\rho = 5.54 \times 10^3 \text{ kg m}^{-3}$	A1

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Question	Answer	Marks
2(a)	e.g. period = 3 / 2.5	C1
	frequency = 0.83 Hz	A1
2(b)	light (damping)	B1
2(c)	at 2.7 s, $A_0 = 1.5$ (cm)	B1
	energy = $\frac{1}{2} m \times 4\pi^2 f^2 A_0^2$	B1
	$= \frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (1.5 \times 10^{-2})^2$	C1
	$= 5.51 \times 10^{-4}$ (J)	
	at 7.5 s, $A_0 = 0.75$ (cm)	B1
	energy = $\frac{1}{4} \times 5.51 \times 10^{-4}$ or energy = $\frac{1}{2} \times 0.18 \times 4\pi^2 \times 0.83^2 \times (0.75 \times 10^{-2})^2$	C1
	energy = 1.38×10^{-4} (J) change = $(5.51 \times 10^{-4} - 1.38 \times 10^{-4}) = 4.13$ J	A1

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Question	Answer	Marks
3(a)(i)	signal consists of (a series of) 1s and 0s or offs and ons or highs and lows	B1
3(a)(ii)	component X: parallel-to-serial converter	B1
	component Y: DAC/digital-to-analogue converter	B1
3(a)(iii)	sample the (analogue) signal	M1
	at regular intervals and converts the analogue number to a digital number	A1
3(b)(i)	attenuation in fibre = 84×0.19 (= 16 dB)	C1
	ratio = 16 + 28 = 44 dB	A1
3(b)(ii)	ratio / dB = $10 \lg (P_2 / P_1)$	C1
	$44 = 10 \lg (\{9.7 \times 10^{-3}\} / P)$ or $-44 = 10 \lg (P / \{9.7 \times 10^{-3}\})$	C1
	power = $3.9 \times 10^{-7} \text{ W}$	A1

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Question	Answer	Marks
4(a)	random/haphazard	B1
	constant velocity or speed in a straight line between collisions or distribution of speeds/different directions	B1
4(b)	(small) specks of light/bright specks/pollen grains/dust particles/smoke particles	M1
	moving haphazardly/randomly/jerky/in a zigzag fashion	A1
4(c)(i)	$pV = \frac{1}{3} Nm\langle c^2 \rangle$ $1.05 \times 10^5 \times 0.0240 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2 \rangle$	C1
	$\langle c^2 \rangle = 1.89 \times 10^6$	C1
	or	
	$\frac{1}{2} m\langle c^2 \rangle = (3/2) kT$ $0.5 \times (4.00 \times 10^{-3} / 6.02 \times 10^{23}) \times \langle c^2 \rangle = 1.5 \times 1.38 \times 10^{-23} \times 300$	(C1)
	$\langle c^2 \rangle = 1.87 \times 10^6$	(C1)
	or	
	$nRT = \frac{1}{3} Nm\langle c^2 \rangle$ $1.00 \times 8.31 \times 300 = \frac{1}{3} \times 4.00 \times 10^{-3} \times \langle c^2 \rangle$	(C1)
	$\langle c^2 \rangle = 1.87 \times 10^6$	(C1)
	$c_{r.m.s.} = 1.37 \times 10^3 \text{ m s}^{-1}$	A1

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Question	Answer	Marks
4(c)(ii)	$\langle c^2 \rangle \propto T$	C1
	$\langle c^2 \rangle$ at 177 °C = $1.89 \times 10^6 \times (450 / 300)$	C1
	$c_{\text{r.m.s.}}$ at 177 °C = $1.68 \times 10^3 \text{ m s}^{-1}$	A1

Question	Answer	Marks
5(a)	(loss in) kinetic energy of α -particle = $Qq / 4\pi\epsilon_0 r$ or $7.7 \times 10^{-13} = Qq / 4\pi\epsilon_0 r$	C1
	$7.7 \times 10^{-13} = 8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / r$	M1
	$r = 4.7 \times 10^{-14} \text{ m}$ r is closest distance of approach so radius less than this	A1
5(b)	force = $Qq / 4\pi\epsilon_0 r^2 = 4u \times a$	C1
	$8.99 \times 10^9 \times 79 \times 2 \times (1.60 \times 10^{-19})^2 / (4.7 \times 10^{-14})^2 = 4 \times 1.66 \times 10^{-27} \times a$	C1
	$a = 2.5 \times 10^{27} \text{ m s}^{-2}$	A1
5(c)	so that single interactions between nucleus and α -particle can be studied or so that multiple deflections with nucleus do not occur	B1

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Question	Answer	Marks
6(a)(i)	lamp needs 'high' power/'large' current/'large' voltage	B1
	op-amp can deliver only a small current/small voltage	B1
6(a)(ii)	correct symbol for relay coil connected between output and earth	B1
	switch between mains supply and lamp	B1
6(b)(i)	vary light intensity at which lamp is switched on/off	B1
6(b)(ii)	so that relay operates for only one current/voltage direction or so that relay/lamp operates for either dark or light conditions	B1
6(c)	when light level increases, LDR resistance decreases	B1
	(R_{LDR} low,) so $V^- > V^+$, so V_{OUT} negative/–5 V (must be consistent with B1 mark)	M1
	or	
	when light level decreases, LDR resistance increases	(B1)
	(R_{LDR} high,) so $V^- < V^+$, so V_{OUT} is positive/+5 V (must be consistent with B1 mark)	(M1)
	lamp comes on as light level decreases or lamp goes off as light level increases	A1

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Question	Answer	Marks
7(a)	(magnetic) force (always) normal to velocity/direction of motion	M1
	(magnitude of magnetic) force constant or speed is constant/kinetic energy is constant	M1
	so provides the centripetal force	A1
7(b)	increase in KE = loss in PE or $\frac{1}{2}mv^2 = qV$	M1
	$p = mv$ with algebra leading to $p = \sqrt{2mqV}$	A1
7(c)	$Bqv = mv^2 / r$ $mv = Bqr$ or $p = Bqr$	C1
	$(2 \times 9.11 \times 10^{-31} \times 1.60 \times 10^{-19} \times 120)^{1/2} = B \times 1.60 \times 10^{-19} \times 0.074$	C1
	$B = 5.0 \times 10^{-4} \text{ T}$	A1
7(d)	greater momentum	M1
	($p = Bqr$ and) so r increased	A1

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Question	Answer	Marks
8	strong (uniform) magnetic field	B1
	* <u>nuclei</u> precess/rotate about field (direction)	
	radio frequency pulse/RF pulse (applied)	B1
	* RF or pulse is at Larmor frequency / frequency of precession	
	causes resonance / excitation (of nuclei)/nuclei to absorb energy	B1
	on relaxation/de-excitation, nuclei emit RF/pulse	B1
	* (emitted) RF/pulse detected and processed	
	non-uniform field (superposed on uniform field)	B1
	allows positions of (resonating) <u>nuclei</u> to be determined	B1
	* allows for position of detection to be changed/different slices to be studied	
	<i>max. 2 of additional detail points marked *</i>	B2

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Question	Answer	Marks
9(a)(i)	core reduces loss of (magnetic) flux linkage/improves flux linkage	B1
9(a)(ii)	reduces (size of eddy) currents in core	B1
	(so that) heating of core is reduced	B1
9(b)	alternating voltage gives rise to changing magnetic flux in core	M1
	(changing) flux links the secondary coil	A1
	induced e.m.f. (in secondary) only when flux is changing/cut	B1

Question	Answer	Marks
10(a)(i)	penetration of beam	M1
	greater hardness means greater penetration/shorter wavelength/higher frequency/higher photon energy	A1
10(a)(ii)	greater accelerating potential difference or greater p.d. between anode and cathode	B1
10(b)	$I = I_0 \exp(-\mu x)$ ratio = $(\exp \{-1.5 \times 2.9\}) / (\exp \{-4.0 \times 0.95\}) (= \exp \{-0.55\})$	C1
	= 0.58	A1

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Question	Answer	Marks
11(a)	electrons (in gas atoms/molecules) interact with photons	B1
	photon energy causes electron to move to higher energy level/to be excited	B1
	photon energy = difference in energy of (electron) energy levels	B1
	when electrons de-excite, photons emitted in all directions (so dark line)	B1
11(b)(i)	photon energy $\propto 1 / \lambda$	C1
	energy = 1.68 eV	A1
	or	
	$E = hc / \lambda$ $E = 6.63 \times 10^{-34} \times 3.0 \times 10^8 / (740 \times 10^{-9})$ $= 2.688 \times 10^{-19} \text{ J}$	(C1)
	energy = 1.68 eV	(A1)
11(b)(ii)	3.4 eV $\rightarrow$ 1.5 eV 3.4 eV $\rightarrow$ 0.85 eV 3.4 eV $\rightarrow$ 0.54 eV <i>all correct and none incorrect 2/2</i> <i>2 correct and 1 incorrect or only 2 correctly drawn 1/2</i>	B2

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Question	Answer	Marks
12(a)	$x = 7$	A1
12(b)(i)	$E = mc^2$	C1
	$= 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ $= 1.494 \times 10^{-10} \text{ J}$	C1
	division by 1.6×10^{-13} clear to give 934 MeV	A1
12(b)(ii)	$\Delta m = (235.123 + 1.00863) - (94.945 + 138.955 + 2 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$ or $\Delta m = 235.123 - (94.945 + 138.955 + 1 \times 1.00863 + 7 \times 5.49 \times 10^{-4})$	C1
	$= 0.21053 \text{ u}$	C1
	energy $= 0.21053 \times 934$ $= 197 \text{ MeV}$	A1
12(c)	kinetic energy of nuclei/particles/products/fragments	B1
	γ -ray photon energy	B1