^	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)	work done per unit mass	**B1**
	(work done to) move mass from infinity (to the point)	**B1**
1(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**
1(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**
	= 1.8×10^{10} J	**A1**
1(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)**

Question	Answer	Marks
2(a)	ρ: Nm / V	B1
	⅓: molecules move in three dimensions (not one) so ⅓ in any (one) direction	B1
	$<c^2>$: molecules have different speeds so take average	M1
	of (speed)^2	A1
2(b)	$pV = NkT$	C1
	$N = (3.0 \times 10^5 \times 6.0 \times 10^{-3}) / (1.38 \times 10^{-23} \times 290)$	C1
	$= 4.5 \times 10^{23}$	C1
	mass $= 20.7 / (4.5 \times 10^{23})$ $= 4.6 \times 10^{-23}$ g	A1

Question	Answer	Marks
3(a)	(little/no volume change so) little/no external work done	B1
	thermal energy supplied to provide latent heat	M1
	internal energy increases	A1
3(b)	(rapid) increase in volume	B1
	gas does work against the atmosphere	M1
	internal energy decreases	A1

Question	Answer	Marks
4(a)	($\omega = 2\pi / T$ and $T = 2.2$ s so) $\omega = 2\pi / 2.2 = 2.9$ rad s^{-1}	**A1**
4(b)(i)	$\omega^2 = g / R$	**C1**
	$R = 9.81 / 2.86^2$ $= 1.2$ m	**A1**
4(b)(ii)	$v_0 = \omega x_0$	**C1**
	$= 2.9 \times 3.0 \times 10^{-2}$ $= 0.087$ m s^{-1}	**A1**
4(c)	smooth wave starting at 3.0 cm when $t = 0$	**B1**
	positions of peaks and troughs show same period (or slightly longer)	**B1**
	each peak and trough at lower amplitude than the previous one	**B1**

Question	Answer	Marks
5(a)	pulses of ultrasound	**B1**
	ultrasound incident on quartz crystal	**B1**
	waves make crystal oscillate	**B1**
	oscillations (of crystal) generates an e.m.f. (across the crystal)	**B1**
5(b)	specific acoustic impedances of air and skin are very different	**B1**
	intensity reflection coefficient depends on difference between acoustic impedance	**B1**
	most ultrasound reflected so little transmission	**B1**

Question	Answer	Marks
6(a)	• greater bandwidth • less noise • less attenuation **or** fewer repeaters • less crosslinking **or** greater security *Any three points, 1 mark each*	**B3**
6(b)(i)	ratio / dB = 10 lg(P_1 / P_2)	**C1**
	21 = 10 lg [(6.3 × 10^{-17}) / P] P = 5.0 × 10^{-19} W	**A1**
6(b)(ii)	attenuation per unit length = (1 / 4.5 × 10^{3}) × 10 lg [(9.8 × 10^{-3}) / (6.3 × 10^{-17})]	**C1**
	= 0.032 dB km^{-1}	**A1**

Question	Answer	Marks
7(a)	force per unit charge	**M1**
	(force on) positive charge	**A1**
7(b)(i)	no electric field inside a conductor	**B1**
	R = 4.5 cm	**A1**
7(b)(ii)	$E = Q / (4\pi\varepsilon_0 x^2)$	**C1**
	clear correct read-off of a pair of values of E and x	**C1**
	e.g. $Q = 18 \times 10^5 \times 4\pi \times 8.85 \times 10^{-12} \times (4.5 \times 10^{-2})^2$ $= 4.0 \times 10^{-7}$ C **or** 4.1×10^{-7} C	**A1**
7(c)	At 8.0 cm, $E = 5.75 \times 10^5$ V m^{-1}	**C1**
	$F = Eq$ **and** $a = F / m$	**C1**
	$F = (5.75 \times 10^5 \times 2 \times 1.6 \times 10^{-19}) / (4 \times 1.66 \times 10^{-27})$ $= 2.8 \times 10^{13}$ m s^{-2}	**A1**

Question	Answer	Marks
8(a)(i)	constant gain for all frequencies	**B1**
8(a)(ii)	unchanged	**B1**
8(b)(i)	(open loop) gain of op-amp is infinite	**B1**
	feedback loop ensures $V^+ \approx V^-$ **or** any difference between V^+ and V^- results in saturated output	**B1**
	non-inverting input is 0 V so inverting input also at 0 V	**B1**
8(b)(ii)	input = $(40 \times 1.5) / (40 + 110)$	**C1**
	= 0.40 V	**A1**
8(b)(iii)	gain = (–) (100 + 230) / 150 **or** feedback current = $0.40 / (150 \times 10^3)$ (A)	**C1**
	p.d. = [(100 + 230) / 150] × 0.40 = 0.88 V	**A1**
8(c)	(magnitude of) gain decreases	**M1**
	voltmeter reading decreases	**A1**

Question	Answer	Marks
9(a)(i)	force is downwards/down the page **or** current is (right) to left	**B1**
	by left-hand rule, field is into plane of paper	**B1**
9(a)(ii)	magnetic force provides the centripetal force	**C1**
	$Bqv = mv^2 / r$	**C1**
	$v = Bqr / m$ $= (8.0 \times 10^{-4} \times 1.60 \times 10^{-19} \times 6.4 \times 10^{-2}) / (9.11 \times 10^{-31})$ $= 9.0 \times 10^{6}$ m s^{-1}	**A1**
9(b)(i)	arrow showing field direction down the page	**B1**
9(b)(ii)	$Bqv = Eq$ **or** $v = E / B$	**C1**
	$E = 9.0 \times 10^{6} \times 8.0 \times 10^{-4}$ $= 7.2 \times 10^{3}$ N C^{-1}	**A1**
9(c)	straight line/undeviated	**B1**
	condition for no deflection depends only on v **or** condition for no deflection does not depend on m or q	**B1**

Question	Answer	Marks
10(a)	(induced) electromotive force is proportional to rate	**M1**
	of change of (magnetic) flux (linkage)	**A1**
10(b)(i)	to change magnitude of potential difference	**B1**
10(b)(ii)	magnitude of e.m.f. varies as rate of change of flux changes	**B1**
	direction of e.m.f. changes when direction of change of flux reverses/when flux changes from increasing to decreasing	**B1**
	flux is continuously increasing and decreasing, so polarity of e.m.f. is continuously switching	**B1**
10(b)(iii)	to reduce energy/power losses **or** to reduce eddy currents	**B1**

Question	Answer	Marks
11(a)	conduction band and valence band overlap	**B1**
	number (density) of charge carriers does not vary	**B1**
	increase in temperature gives rise to <u>increased</u> lattice vibrations	**B1**
	(lattice) vibrations hinder movement of charge carriers so resistance increases	**B1**
11(b)	$mv = h / \lambda$	**C1**
	$v = (6.63 \times 10^{-34}) / [(2.6 \times 10^{-11}) \times (9.11 \times 10^{-31})]$ $(= 2.80 \times 10^{7}\ \text{m s}^{-1})$	**C1**
	$qV = ½mv^2$	**C1**
	$V = [9.11 \times 10^{-31} \times (2.80 \times 10^{7})^2] / [2 \times 1.60 \times 10^{-19}]$ $= 2.2 \times 10^{3}\ \text{V}$	**A1**

Question	Answer	Marks
12(a)	difference between mass of nucleus and mass of (constituent) nucleons	**M1**
	where nucleons are separated to infinity	**A1**
12(b)(i)	$E = mc^2$	**C1**
	$= 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2 / (1.60 \times 10^{-13}) = 934$ MeV	**A1**
12(b)(ii)	mass defect = $2 \times (1.007276 + 1.008665) - 4.001506$ $(= 0.030376)$	**B1**
	binding energy per nucleon = $(0.030376 \times 934) / 4 = 7.09$ MeV	**A1**
12(c)	binding energy per nucleon is much greater	**M1**
	so would require a large amount of energy to separate the nucleons in helium	**A1**
	or	
	amount of energy released in forming hydrogen isotopes	**(M1)**
	is less than energy required to break apart helium nucleus	**(A1)**