
PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 2018

MARK SCHEME

Maximum Mark: 100

Published

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PUBLISHED**Generic Marking Principles**

These general marking principles must be applied by all examiners when marking candidate answers. They should be applied alongside the specific content of the mark scheme or generic level descriptors for a question. Each question paper and mark scheme will also comply with these marking principles.

GENERIC MARKING PRINCIPLE 1:

Marks must be awarded in line with:

- the specific content of the mark scheme or the generic level descriptors for the question
- the specific skills defined in the mark scheme or in the generic level descriptors for the question
- the standard of response required by a candidate as exemplified by the standardisation scripts.

GENERIC MARKING PRINCIPLE 2:

Marks awarded are always **whole marks** (not half marks, or other fractions).

GENERIC MARKING PRINCIPLE 3:

Marks must be awarded **positively**:

- marks are awarded for correct/valid answers, as defined in the mark scheme. However, credit is given for valid answers which go beyond the scope of the syllabus and mark scheme, referring to your Team Leader as appropriate
- marks are awarded when candidates clearly demonstrate what they know and can do
- marks are not deducted for errors
- marks are not deducted for omissions
- answers should only be judged on the quality of spelling, punctuation and grammar when these features are specifically assessed by the question as indicated by the mark scheme. The meaning, however, should be unambiguous.

GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
1(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	B1
1(b)(ii)1.	gravitational force equals/is centripetal force	C1
	$GMm/R^2 = mR\omega^2$ and $\omega = 2\pi/T$ or $Gm/R^2 = mv^2/R$ and $v = 2\pi r/T$ or $GMm/R^2 = mR(2\pi/T)^2$	M1
	convincing algebra leading to $k = GM/4\pi^2$	A1
1(b)(ii)2.	correct use of R^3/T^2 for one planet (c gives 3.54×10^{21} ; e and g both give 3.56×10^{21})	C1
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$ $M = 2.1 \times 10^{33} \text{ kg}$	A1
	two or three values of R^3/T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	B1

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Question	Answer	Marks
2(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
2(a)(ii)	$a = -\omega^2 y$ and $\omega = 2\pi f$	C1
	$4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ (or other valid read-off)	
	$f = 3.8$ Hz	A1
2(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
2(b)(ii)	(just leaves plate when) acceleration = 9.81 ms^{-2}	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ or $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

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Question	Answer	Marks
3(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
3(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
3(b)	$pV = NkT$	C1
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	C1
	or	
	$pV = nRT$ and $N = n \times N_A$	(C1)
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.8 \times 10^{25}$	A1

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Question	Answer	Marks
4(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	B1
4(b)	<u>pulses</u> (of ultrasound)	B1
	reflected at boundaries (between media)	B1
	(reflected pulses) detected by (ultrasound) generator	B1
	Any three from: - time delay (between transmission and receipt) gives information about depth (of boundary) - intensity of reflected pulse gives information about (nature of) <u>boundary</u> - gel used to minimise reflection at skin/maximise transmission into skin - degree of reflection depends upon impedances of two media (at boundary)	B3

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Question	Answer	Marks
5(a)(i)	west to east	B1
5(a)(ii)	above the Equator	B1
5(a)(iii)	value in range $(1-300) \times 10^9$ Hz	A1
5(b)(i)	gain/dB = $10 \lg(P_2/P_1)$	C1
	$-195 = 10 \lg(P/3000)$ or $195 = 10 \lg(3000/P)$	C1
	power = 9.5×10^{-17} W	A1
5(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) or down-link signal must be (greatly) amplified (before transmission back to Earth) or up-link has (much) smaller intensity/power than down-link	B1
	(different frequency) prevents down-link (signal) swamping up-link (signal)	B1

Question	Answer	Marks
6(a)	force per unit charge	B1
6(b)	$E = Q/(4\pi\epsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q/(4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	A1
6(c)	charge (= $Q [52/26]^2$) = $4Q$	C1
	additional charge = $3Q$	A1

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Question	Answer	Marks
7(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
7(b)(i)	$4.5 \times 10^{-6} \text{ C}$	A1
7(b)(ii)	$9.0 \times 10^{-8} \text{ C}$	A1
7(b)(iii)	capacitance = $(9.0 \times 10^{-8}) / 120$	C1
	$= 7.5 \times 10^{-10} \text{ F}$	A1
7(c)	total capacitance is halved	B1
	current is halved	B1

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Question	Answer	Marks
8(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) subtracted/deducted from input	A1
8(a)(ii)	any two valid points e.g.: • greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth • smaller gain	B2
8(b)(i)	gain = $(-)\frac{9600}{800}$	C1
	= -12	A1
8(b)(ii)	1. 1.2V	B1
	2. -6V	B1
8(b)(iii)	replace the 9600Ω resistor with an LDR	B1

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Question	Answer	Marks
9(a)	using Fleming's left-hand rule force on wire is upwards	B1
	by Newton's third law, force on magnet is downwards	B1
9(b)(i)	$F = BIL$	C1
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$	A1
	$= 1.6 \times 10^{-3} \text{ N}$	
9(b)(ii)	$F = 1.6 \times 10^{-3} \text{ N}$	A1
9(c)	sketch: sinusoidal wave with two cycles	B1
	amplitude $2.3 \times 10^{-3} \text{ N}$	B1
	period 0.05 s	B1

Question	Answer	Marks
10(a)	induced <u>e.m.f.</u> proportional to rate	M1
	of <u>change</u> of (magnetic) <u>flux</u> (linkage) or of <u>cutting</u> (magnetic) <u>flux</u>	A1
10(b)	current in coil produces flux	B1
	(by Faraday's law) changing flux induces e.m.f. in ring	B1
	current in ring causes field (around ring)	B1
	(by Lenz's law) field around ring opposes field around coil	B1

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Question	Answer	Marks
11(a)(i)	packet/quantum/discrete amount of <u>energy</u>	M1
	of electromagnetic radiation	A1
11(a)(ii)	(maximum) energy of emitted electrons is independent of intensity or no emission of electrons below the threshold frequency regardless of intensity or no emission of electrons when photon energy is less than work function (energy) regardless of intensity	B1
11(b)	in darkness: conduction band empty so high resistance	B1
	in daylight: electrons in valence band absorb photons	B1
	in daylight: electrons ‘jump’ to conduction band	B1
	this leaves holes in valence band	B1
	more charge carriers in daylight so resistance decreases	B1

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Question	Answer	Marks
12(a)(i)	$I = I_0 e^{-\mu x}$	C1
	$= I_0 \exp(-0.90 \times 2.8)$	A1
	$= 0.080 I_0$	
12(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	C1
	$= I_0 (0.259 \times 0.20)$	A1
	$= 0.0052 I_0$	
12(b)(i)	difference in degrees of blackening	M1
	between structures	A1
12(b)(ii)	large difference in intensities so good contrast	B1

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Question	Answer	Marks
13(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
13(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60) \text{ (s}^{-1}\text{)}$	C1
	N at 14 minutes = 4.4×10^7 and $A = \lambda N$	C1
	activity = $4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ = $3.6 \times 10^4 \text{ Bq}$	A1
	or	
	correct tangent drawn at time $t = 14$ minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity = $3.6 \times 10^4 \text{ Bq}$	(A1)
13(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ or $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4} \text{ s}^{-1}$	A1

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Question	Answer	Marks
1(a)(i)	direction of force on a (small test) <u>mass</u> or path in which a (small test) <u>mass</u> will move	B1
1(a)(ii)	(at surface,) lines (of force) are radial	B1
	Earth has large radius/height above surface is small so lines are (approximately) parallel	B1
	parallel lines → constant field strength	B1
1(b)	(change in) KE of rock = (change in) PE or $\frac{1}{2}mv^2 = GMm/R$	C1
	$(m)v^2 = (m)(2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / (1.7 \times 10^3 \times 10^3)$	C1
	$v = 2.4 \times 10^3 \text{ m s}^{-1}$	A1
	correct conclusion based on <u>comparison</u> of v with 2.8 km s^{-1}	B1
	or	
	(change in) KE of rock = (change in) PE	(C1)
	(at infinity) $E_P = (6.67 \times 10^{-11} \times 7.4 \times 10^{22} \times m) / (1.7 \times 10^3 \times 10^3)$ $= 2.9 \times 10^6 m$	(C1)
	$E_K \text{ of rock} = \frac{1}{2} \times m \times (2.8 \times 10^3)^2 = 3.9 \times 10^6 m$	(A1)
	correct conclusion based on <u>comparison</u> of E_K and E_P values	(B1)
	or	

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Question	Answer	Marks
	(change in) KE of rock = (change in) PE or $\frac{1}{2}mv^2 = GMm/R$	(C1)
	$(m) (2800)^2 = (m) (2 \times 6.67 \times 10^{-11} \times 7.4 \times 10^{22}) / R$	(C1)
	$R = 1.3 \times 10^3 \text{ km}$	(A1)
	correct conclusion based on <u>comparison</u> of R with $1.7 \times 10^3 \text{ km}$	(B1)
	or	
	(change in) KE of rock = (change in) PE or $\frac{1}{2}mv^2 = GMm/R$	(C1)
	$(m) (2800)^2 = (m) (2 \times 6.67 \times 10^{-11} \times M) / (1.7 \times 10^6)$	(C1)
	$M = 1.0 \times 10^{23} \text{ kg}$	(A1)
	correct conclusion based on <u>comparison</u> of M with $7.4 \times 10^{22} \text{ kg}$	(B1)

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Question	Answer	Marks
2(a)	no intermolecular forces (so no potential energy)	B1
2(b)(i)	mean square speed (of molecule(s))	B1
2(b)(ii)	kelvin/thermodynamic/absolute <u>temperature</u>	B1
2(c)(i)1.	$pV = NkT$	C1
	$4.7 \times 10^{-2} \times 2.6 \times 10^5 = N \times 1.38 \times 10^{-23} \times 446$	C1
	or	
	$pV = nRT$ and $N = nN_A$ $4.7 \times 10^{-2} \times 2.6 \times 10^5 = n \times 8.31 \times 446$ $n = 3.3$ (mol)	(C1)
	$N = 3.3 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.0 \times 10^{24}$	A1
2(c)(i)2.	average increase = $2900 / (2.0 \times 10^{24})$ $= 1.5 \times 10^{-21}$ J	A1
2(c)(ii)	$\Delta E_K = (3/2)k(\Delta)T$ $1.5 \times 10^{-21} = (3/2) \times 1.38 \times 10^{-23} \times (\Delta)T$	C1
	$(\Delta)T$ in range 70–72 K	C1
	$T = 173 + 273 + 70$ $= 520$ K	A1

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Question	Answer	Marks
3(a)	(during melting,) bonds between atoms/molecules are broken	B1
	potential energy of atoms/molecules is increased	B1
	no/little work done so required input of energy is thermal	B1
3(b)(i)	$(\Delta Q =) mc\Delta\theta$	C1
	$\text{loss} = (160 \times 0.910 \times 15) + (330 \times 4.18 \times 15)$ $= 2.3 \times 10^4 \text{ J}$	A1
3(b)(ii)	$2.3 \times 10^4 = (48 \times 2.10 \times 18) + 48L + (48 \times 4.18 \times 23)$	C1
	$48L = 1.66 \times 10^4$ $L = 350 \text{ J g}^{-1}$	A1

Question	Answer	Marks
4(a)	acceleration proportional to displacement	B1
	acceleration <u>directed</u> towards fixed point or displacement and acceleration in opposite <u>directions</u>	B1
4(b)(i)	1. amplitude decreases gradually so light damping or oscillations continue so light damping	B1
	2. loss of energy	B1
	due to friction in wheels or due to friction between wheels and surface (during slipping) or due to air resistance (on trolley)	B1
4(b)(ii)1.	$\omega^2 = 2k/m$	C1
	$= (2 \times 230) / 0.950$	C1
	$\omega = 22 \text{ rad s}^{-1}$	A1
4(b)(ii)2.	$T = 2\pi / \omega$	C1
	$T = (2\pi / 22) = 0.286 \text{ s}$	A1
	time $= 1.5T$ $= 0.43 \text{ s}$	

Question	Answer	Marks
5(a)(i)	range of frequencies (of signal)	B1
5(a)(ii)	advantage: e.g. better quality (of reproduction) greater rate of transfer of data less distortion	B1
	disadvantage: e.g. fewer stations (in any frequency range)	B1
5(b)(i)	5.0 V	A1
5(b)(ii)	maximum: 674 kHz	A1
	minimum: 626 kHz	A1
5(b)(iii)	$T = 1 / (10 \times 10^3) = 1.0 \times 10^{-4} \text{ s}$ minimum time = $T / 2$ $= 5.0 \times 10^{-5} \text{ s}$	A1

Question	Answer	Marks
6(a)	capacitance = charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
6(b)(i)	two in series, in parallel with the other (correct symbols)	A1
6(b)(ii)	two in parallel connected to one in series (correct symbols)	A1
6(c)(i)	capacitance = $1.2 \mu\text{F}$	A1
6(c)(ii)	1. $Q = CV$	C1
	$= 1.2 \times 8.0$ $= 9.6 \mu\text{C}$	A1
	2. $E = \frac{1}{2}QV$ and $V = Q/C$ or $E = \frac{1}{2}CV^2$ and $V = Q/C$ or $E = \frac{1}{2}Q^2/C$	C1
	$E = \frac{1}{2} (9.6 \times 10^{-6})^2 / (3.0 \times 10^{-6})$ $= 1.5 \times 10^{-5} \text{ J}$	A1

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Question	Answer	Marks
7(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) <u>subtracted/deducted</u> from input	A1
7(a)(ii)	Any two valid points e.g. • greater bandwidth/gain constant over a larger range of frequencies • smaller gain	B2
7(b)(i)	gain = $1 + (6400 / 800)$ = 9.0	A1
7(b)(ii)	1. (+)5.4 V	A1
	2. –9.0 V	A1
7(b)(iii)	replace the 6400Ω resistor with a thermistor	B1

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Question	Answer	Marks
8(a)	electric and magnetic fields at right-angles to one another (<i>may be shown on a clearly labelled diagram</i>)	B1
	particle enters fields (with velocity) normal to the (two) fields (<i>may be shown on a clearly labelled diagram</i>)	B1
	no deviation for particles with selected velocity	B1
8(b)	magnetic force equals/is the centripetal force	C1
	$Bqv = mv^2/r$	C1
	$M = Bqr/v$ $= (94 \times 10^{-3} \times 1.6 \times 10^{-19} \times 0.075) / (3.4 \times 10^4)$	M1
	<u>division</u> by 1.66×10^{-27} shown, to give $m = 20 \text{ u}$	A1
8(c)	sketch: semicircle clear (in same direction)	B1
	with larger radius	B1

Question	Answer	Marks
9(a)	(magnetic) flux density $\times$ area	B1
	magnetic flux density normal to area or reference to cross-sectional area or $\times \sin$ (angle between B and A)	B1
	$\times$ number of turns on coil	B1
9(b)	e.m.f. = BAN/t or e.m.f. = rate of change of flux <u>linkage</u>	C1
	$= (7.5 \times 10^{-3} \times \pi \times \{1.2 \times 10^{-2}\}^2 \times 160) / 0.15$ $= 3.6 \times 10^{-3} \text{ V}$	A1
9(c)	sketch: zero for 0–0.10 s, 0.25–0.35 s, and 0.425–0.55 s, and non-zero outside these ranges	B1
	two horizontal steps, with zero voltage either side	B1
	with same polarity	B1
	correct values (1st step 3.6 mV and 2nd step 7.2 mV)	B1

Question	Answer	Marks
10(a)	emission of electron	B1
	when electromagnetic radiation incident (on surface)	B1
10(b)(i)	packet/quantum/discrete amount of <u>energy</u>	M1
	of electromagnetic radiation	A1
10(b)(ii)	$E = hc/\lambda$	C1
	$= (6.63 \times 10^{-34} \times 3.00 \times 10^8) / (420 \times 10^{-9})$	A1
	$= 4.7 \times 10^{-19} \text{ J}$	
10(b)(iii)	sodium: yes zinc: no	B1

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Question	Answer	Marks
11(a)	<u>X-ray</u> image(s) taken of <u>one slice</u>	M1
	(many images) taken from <u>different angles</u>	A1
	(computer) produces 2D image <u>of slice</u>	B1
	(this is) repeated for (many) <u>slices</u>	M1
	to build up a 3D image (of structure)	A1
11(b)(i)	combining of <u>images</u> involves (very) large number of calculations	B1
11(b)(ii)	CT scan consists of (very) many (single X-ray) images	B1

Question	Answer	Marks
12(a)	emission of particles/radiation by <u>unstable nucleus</u>	B1
	spontaneous emission	B1
12(b)(i)	P – the curve that starts with a high number D – the curve with the peak S – the curve that increases from zero throughout <i>(one correct 1 mark, all three correct 2 marks)</i>	B2
12(b)(ii)	$\lambda t_{1/2} = 0.693$ $\lambda = 0.693 / (60.0 \times 60)$	C1
	$= 1.93 \times 10^{-4} \text{ s}^{-1}$	A1
12(c)	half-life of F is much shorter than half-life of E	B1
	<u>nuclei</u> of F decay (almost) as soon as they are produced	B1

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GENERIC MARKING PRINCIPLE 4:

Rules must be applied consistently e.g. in situations where candidates have not followed instructions or in the application of generic level descriptors.

GENERIC MARKING PRINCIPLE 5:

Marks should be awarded using the full range of marks defined in the mark scheme for the question (however; the use of the full mark range may be limited according to the quality of the candidate responses seen).

GENERIC MARKING PRINCIPLE 6:

Marks awarded are based solely on the requirements as defined in the mark scheme. Marks should not be awarded with grade thresholds or grade descriptors in mind.

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Question	Answer	Marks
1(a)	force proportional to product of masses and inversely proportional to square of separation	B1
	idea of force between point masses	B1
1(b)(i)	velocity changes/direction of motion changes/there is an acceleration/there is a resultant force so not in equilibrium	B1
1(b)(ii)1.	gravitational force equals/is centripetal force	C1
	$GMm/R^2 = mR\omega^2$ and $\omega = 2\pi/T$ or $Gm/R^2 = mv^2/R$ and $v = 2\pi r/T$ or $GMm/R^2 = mR(2\pi/T)^2$	M1
	convincing algebra leading to $k = GM/4\pi^2$	A1
1(b)(ii)2.	correct use of R^3/T^2 for one planet (c gives 3.54×10^{21} ; e and g both give 3.56×10^{21})	C1
	$3.5(5) \times 10^{21} = (6.67 \times 10^{-11} \times M) / 4\pi^2$ $M = 2.1 \times 10^{33} \text{ kg}$	A1
	two or three values of R^3/T^2 correctly calculated and used in a valid way to find a value for M based on more than one k	B1

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Question	Answer	Marks
2(a)(i)	straight line through origin indicates acceleration $\propto$ displacement	B1
	negative gradient shows acceleration and displacement are in opposite directions	B1
2(a)(ii)	$a = -\omega^2 y$ and $\omega = 2\pi f$	C1
	$4.5 = (2\pi \times f)^2 \times 8.0 \times 10^{-3}$ (or other valid read-off)	
	$f = 3.8$ Hz	A1
2(b)(i)	maximum displacement upwards/above rest/above the equilibrium position	B1
2(b)(ii)	(just leaves plate when) acceleration = 9.81 ms^{-2}	C1
	$9.81 = (2\pi \times 3.8)^2 \times y_0$ or $9.81 = 563 \times y_0$	C1
	amplitude = 17 mm	A1

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Question	Answer	Marks
3(a)(i)	sum of potential and kinetic energies (of molecules/atoms/particles)	B1
	(energy of) molecules/atoms/particles in random motion	B1
3(a)(ii)	(in ideal gas) no intermolecular forces so no potential energy	B1
	internal energy is (solely) kinetic energy (of particles)	B1
	(mean) kinetic energy (of particles) proportional to (thermodynamic) temperature of gas	B1
3(b)	$pV = NkT$	C1
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 298$	C1
	or	
	$pV = nRT$ and $N = n \times N_A$	(C1)
	$6.4 \times 10^6 \times 1.8 \times 10^4 \times 10^{-6} = n \times 8.31 \times 298$ $n = 46.5$ (mol) $N = 46.5 \times 6.02 \times 10^{23}$	(C1)
	$N = 2.8 \times 10^{25}$	A1

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Question	Answer	Marks
4(a)	e.g. microphone weighing scales/pressure sensor lighters/spark generation watches/clocks/regulation of time	B1
4(b)	<u>pulses</u> (of ultrasound)	B1
	reflected at boundaries (between media)	B1
	(reflected pulses) detected by (ultrasound) generator	B1
	Any three from: - time delay (between transmission and receipt) gives information about depth (of boundary) - intensity of reflected pulse gives information about (nature of) <u>boundary</u> - gel used to minimise reflection at skin/maximise transmission into skin - degree of reflection depends upon impedances of two media (at boundary)	B3

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Question	Answer	Marks
5(a)(i)	west to east	B1
5(a)(ii)	above the Equator	B1
5(a)(iii)	value in range $(1-300) \times 10^9$ Hz	A1
5(b)(i)	gain/dB = $10 \lg(P_2/P_1)$	C1
	$-195 = 10 \lg(P/3000)$ or $195 = 10 \lg(3000/P)$	C1
	power = 9.5×10^{-17} W	A1
5(b)(ii)	up-link has been (greatly) attenuated (before reaching satellite) or down-link signal must be (greatly) amplified (before transmission back to Earth) or up-link has (much) smaller intensity/power than down-link	B1
	(different frequency) prevents down-link (signal) swamping up-link (signal)	B1

Question	Answer	Marks
6(a)	force per unit charge	B1
6(b)	$E = Q/(4\pi\epsilon_0 r^2)$	C1
	$2.0 \times 10^4 = Q/(4\pi \times 8.85 \times 10^{-12} \times 0.26^2)$ charge = 1.5×10^{-7} C	A1
6(c)	charge (= $Q [52/26]^2$) = $4Q$	C1
	additional charge = $3Q$	A1

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Question	Answer	Marks
7(a)	(capacitance =) charge / potential	M1
	charge is (numerically equal to) charge on one plate	A1
	potential is potential difference between plates	A1
7(b)(i)	$4.5 \times 10^{-6} \text{ C}$	A1
7(b)(ii)	$9.0 \times 10^{-8} \text{ C}$	A1
7(b)(iii)	capacitance = $(9.0 \times 10^{-8}) / 120$	C1
	$= 7.5 \times 10^{-10} \text{ F}$	A1
7(c)	total capacitance is halved	B1
	current is halved	B1

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Question	Answer	Marks
8(a)(i)	(fraction of) output is combined with the input	M1
	output (fraction) subtracted/deducted from input	A1
8(a)(ii)	any two valid points e.g.: • greater bandwidth/gain constant over a larger range of frequencies/greater bandwidth • smaller gain	B2
8(b)(i)	gain = $(-)\frac{9600}{800}$	C1
	= -12	A1
8(b)(ii)	1. 1.2V	B1
	2. -6V	B1
8(b)(iii)	replace the 9600Ω resistor with an LDR	B1

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Question	Answer	Marks
9(a)	using Fleming's left-hand rule force on wire is upwards	B1
	by Newton's third law, force on magnet is downwards	B1
9(b)(i)	$F = BIL$	C1
	$= 3.7 \times 10^{-3} \times 5.1 \times 8.5 \times 10^{-2}$	A1
	$= 1.6 \times 10^{-3} \text{ N}$	
9(b)(ii)	$F = 1.6 \times 10^{-3} \text{ N}$	A1
9(c)	sketch: sinusoidal wave with two cycles	B1
	amplitude $2.3 \times 10^{-3} \text{ N}$	B1
	period 0.05 s	B1

Question	Answer	Marks
10(a)	induced <u>e.m.f.</u> proportional to rate	M1
	of <u>change</u> of (magnetic) <u>flux</u> (linkage) or of <u>cutting</u> (magnetic) <u>flux</u>	A1
10(b)	current in coil produces flux	B1
	(by Faraday's law) changing flux induces e.m.f. in ring	B1
	current in ring causes field (around ring)	B1
	(by Lenz's law) field around ring opposes field around coil	B1

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Question	Answer	Marks
11(a)(i)	packet/quantum/discrete amount of <u>energy</u>	M1
	of electromagnetic radiation	A1
11(a)(ii)	(maximum) energy of emitted electrons is independent of intensity or no emission of electrons below the threshold frequency regardless of intensity or no emission of electrons when photon energy is less than work function (energy) regardless of intensity	B1
11(b)	in darkness: conduction band empty so high resistance	B1
	in daylight: electrons in valence band absorb photons	B1
	in daylight: electrons ‘jump’ to conduction band	B1
	this leaves holes in valence band	B1
	more charge carriers in daylight so resistance decreases	B1

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Question	Answer	Marks
12(a)(i)	$I = I_0 e^{-\mu x}$	C1
	$= I_0 \exp(-0.90 \times 2.8)$	A1
	$= 0.080 I_0$	
12(a)(ii)	$I = I_0 \exp[(-0.90 \times 1.5) \times (-3.0 \times 1.3)]$	C1
	$= I_0 (0.259 \times 0.20)$	A1
	$= 0.0052 I_0$	
12(b)(i)	difference in degrees of blackening	M1
	between structures	A1
12(b)(ii)	large difference in intensities so good contrast	B1

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Question	Answer	Marks
13(a)	emission of particles/radiation by unstable nucleus	B1
	spontaneous emission	B1
13(b)(i)	use of graph to determine half-life = 14 minutes	B1
	hence $\lambda = \ln 2 / (14 \times 60) \text{ (s}^{-1}\text{)}$	C1
	N at 14 minutes = 4.4×10^7 and $A = \lambda N$	C1
	activity = $4.4 \times 10^7 \times \ln 2 / (14 \times 60)$ = $3.6 \times 10^4 \text{ Bq}$	A1
	or	
	correct tangent drawn at time $t = 14$ minutes	(B1)
	magnitude of gradient of tangent identified as activity	(C1)
	correct working for gradient leading to activity	(C1)
	activity = $3.6 \times 10^4 \text{ Bq}$	(A1)
13(b)(ii)	$3.6 \times 10^4 = \lambda \times 4.4 \times 10^7$ or $\lambda = \ln 2 / (14.0 \times 60)$	C1
	$\lambda = 8.2 \times 10^{-4} \text{ s}^{-1}$	A1