

MARK SCHEME for the May/June 2013 series

9702 PHYSICS

9702/41

Paper 4 (A2 Structured Questions), maximum raw mark 100

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	GCE AS/A LEVEL – May/June 2013	9702	41

Section A

- 1 (a) region of space area / volume
where a mass experiences a force B1
B1 [2]
- (b) (i) force proportional to product of two masses M1
force inversely proportional to the square of their separation M1
either reference to point masses *or* separation $\gg$ 'size' of masses A1 [3]
- (ii) field strength = GM / x^2 **or** field strength $\propto 1 / x^2$ C1
ratio = $(7.78 \times 10^8)^2 / (1.5 \times 10^8)^2$ C1
= 27 A1 [3]
- (c) (i) *either* centripetal force = $mR\omega^2$ and $\omega = 2\pi / T$
or centripetal force = mv^2 / R and $v = 2\pi R / T$ B1
gravitational force provides the centripetal force B1
either $GMm / R^2 = mR\omega^2$ *or* $GMm / R^2 = mv^2 / R$ M1
 $M = 4\pi^2 R^3 / GT^2$ A0 [3]
(allow working to be given in terms of acceleration)
- (ii) $M = \{4\pi^2 \times (1.5 \times 10^{11})^3\} / \{6.67 \times 10^{-11} \times (3.16 \times 10^7)^2\}$ C1
= 2.0×10^{30} kg A1 [2]
- 2 (a) obeys the equation $pV = \text{constant} \times T$ *or* $pV = nRT$ M1
 p , V and T explained A1
at all values of p , V and T /fixed mass/ n is constant A1 [3]
- (b) (i) $3.4 \times 10^5 \times 2.5 \times 10^3 \times 10^{-6} = n \times 8.31 \times 300$ M1
 $n = 0.34$ mol A0 [1]
- (ii) for total mass/amount of gas
 $3.9 \times 10^5 \times (2.5 + 1.6) \times 10^3 \times 10^{-6} = (0.34 + 0.20) \times 8.31 \times T$ C1
 $T = 360$ K A1 [2]
- (c) when tap opened
gas passed (from cylinder B) to cylinder A B1
work done on gas in cylinder A (and no heating) M1
so internal energy and hence temperature increase A1 [3]

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- 3 (a) (i) 1. amplitude = 1.7 cm A1 [1]
2. period = 0.36 cm C1
frequency = $1/0.36$
= 2.8 Hz A1 [2]
- (ii) $a = (-)\omega^2 x$ and $\omega = 2\pi/T$ C1
acceleration = $(2\pi/0.36)^2 \times 1.7 \times 10^{-2}$ M1
= 5.2 ms^{-2} A0 [2]
- (b) graph: straight line, through origin, with negative gradient M1
from $(-1.7 \times 10^{-2}, 5.2)$ to $(1.7 \times 10^{-2}, -5.2)$ A1 [2]
(if scale not reasonable, do not allow second mark)
- (c) either kinetic energy = $\frac{1}{2}m\omega^2(x_0^2 - x^2)$
or potential energy = $\frac{1}{2}m\omega^2 x^2$ and potential energy = kinetic energy B1
 $\frac{1}{2}m\omega^2(x_0^2 - x^2) = \frac{1}{2} \times \frac{1}{2}m\omega^2 x_0^2$ or $\frac{1}{2}m\omega^2 x^2 = \frac{1}{2} \times \frac{1}{2}m\omega^2 x_0^2$ C1
 $x_0^2 = 2x^2$
 $x = x_0 / \sqrt{2} = 1.7 / \sqrt{2}$
= 1.2 cm A1 [3]
- 4 (a) work done moving unit positive charge from infinity (to the point) M1
A1 [2]
- (b) (gain in) kinetic energy = change in potential energy B1
 $\frac{1}{2}mv^2 = qV$ leading to $v = (2Vq/m)^{1/2}$ B1 [2]
- (c) either $(2.5 \times 10^5)^2 = 2 \times V \times 9.58 \times 10^7$ C1
 $V = 330 \text{ V}$ M1
this is less than 470 V and so 'no' A1 [3]
- or $v = (2 \times 470 \times 9.58 \times 10^7)$ (C1)
 $v = 3.0 \times 10^5 \text{ ms}^{-1}$ (M1)
this is greater than $2.5 \times 10^5 \text{ ms}^{-1}$ and so 'no' (A1)
- or $(2.5 \times 10^5)^2 = 2 \times 470 \times (q/m)$ (C1)
 $(q/m) = 6.6 \times 10^7 \text{ C kg}^{-1}$ (M1)
this is less than $9.58 \times 10^7 \text{ C kg}^{-1}$ and so 'no' (A1)

Page 4	Mark Scheme	Syllabus	Paper
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- 5 (a) (uniform magnetic) flux normal to long (straight) wire carrying a current of 1 A
(creates) force per unit length of 1 N m^{-1} M1
A1 [2]
- (b) (i) flux density $= 4\pi \times 10^{-7} \times 1.5 \times 10^3 \times 3.5$ C1
 $= 6.6 \times 10^{-3} \text{ T}$ A1 [2]
- (ii) flux linkage $= 6.6 \times 10^{-3} \times 28 \times 10^{-4} \times 160$ C1
 $= 3.0 \times 10^{-3} \text{ Wb}$ A1 [2]
- (c) (i) (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage) M1
A1 [2]
- (ii) e.m.f. $= (2 \times 3.0 \times 10^{-3}) / 0.80$ C1
 $= 7.4 \times 10^{-3} \text{ V}$ A1 [2]
- 6 (a) (i) to reduce power loss in the core due to eddy currents/induced currents B1
B1 [2]
- (ii) *either* no power loss in transformer
or input power = output power B1 [1]
- (b) *either* r.m.s. voltage across load $= 9.0 \times (8100 / 300)$ C1
peak voltage across load $= \sqrt{2} \times 243$
 $= 340 \text{ V}$ A1 [2]
or peak voltage across primary coil $= 9.0 \times \sqrt{2}$ (C1)
peak voltage across load $= 12.7 \times (8100/300)$
 $= 340 \text{ V}$ (A1)
- 7 (a) (i) lowest frequency of e.m. radiation giving rise to emission of electrons (from the surface) M1
A1 [2]
- (ii) $E = hf$ C1
threshold frequency $= (9.0 \times 10^{-19}) / (6.63 \times 10^{-34})$
 $= 1.4 \times 10^{15} \text{ Hz}$ A1 [2]
- (b) *either* $300 \text{ nm} \equiv 10 \times 10^{15} \text{ Hz}$ (and $600 \text{ nm} \equiv 5.0 \times 10^{14} \text{ Hz}$)
or $300 \text{ nm} \equiv 6.6 \times 10^{-19} \text{ J}$ (and $600 \text{ nm} \equiv 3.3 \times 10^{-19} \text{ J}$)
or zinc $\lambda_0 = 340 \text{ nm}$, platinum $\lambda_0 = 220 \text{ nm}$ (and sodium $\lambda_0 = 520 \text{ nm}$)
emission from sodium and zinc M1
A1 [2]
- (c) each photon has larger energy M1
fewer photons per unit time M1
fewer electrons emitted per unit time A1 [3]

Page 5	Mark Scheme	Syllabus	Paper
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- 8 (a) two (light) nuclei combine to form a more massive nucleus M1 A1 [2]
- (b) (i) $\Delta m = (2.01410 \text{ u} + 1.00728 \text{ u}) - 3.01605 \text{ u}$
 $= 5.33 \times 10^{-3} \text{ u}$
energy $= c^2 \times \Delta m$
 $= 5.33 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$
 $= 8.0 \times 10^{-13} \text{ J}$ C1 C1 A1 [3]
- (ii) speed/kinetic energy of proton and deuterium must be very large so that the nuclei can overcome electrostatic repulsion B1 B1 [2]

Section B

- 9 (a) (i) light-dependent resistor/LDR B1 [1]
- (ii) strain gauge B1 [1]
- (iii) quartz/piezo-electric crystal B1 [1]
- (b) (i) resistance of thermistor decreases as temperature increases M1
either $V_{\text{OUT}} = V \times R / (R + R_T)$
or current increases and $V_{\text{OUT}} = I R$
 V_{OUT} increases A1 A1 [3]
- (ii) *either* change in R_T with temperature is non-linear
or V_{OUT} is not proportional to R_T / change in V_{OUT} with R_T is non-linear
so change is non-linear M1 A1 [2]
- 10 (a) sharpness: how well the edges (of structures) are defined B1
contrast: difference in (degree of) blackening between structures B1 [2]
- (b) e.g. scattering of photos in tissue/no use of a collimator/no use of lead grid
large penumbra on shadow/large area anode/wide beam
large pixel size
(any two sensible suggestions, 1 each) B2 [2]
- (c) (i) $I = I_0 e^{-\mu x}$ C1
ratio $= \exp(-2.85 \times 3.5) / \exp(-0.95 \times 8.0)$ C1
 $= (4.65 \times 10^{-5}) / (5.00 \times 10^{-4})$
 $= 0.093$ A1 [3]
- (ii) *either* large difference (in intensities)
or ratio much less than 1.0
so good contrast M1 A1 [2]
- (answer given in (c)(ii) must be consistent with ratio given in (c)(i))

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- 11 (a) (i) amplitude of the carrier wave varies (in synchrony) with the displacement of the information signal M1 A1 [2]
- (ii) e.g. more than one radio station can operate in same region/less interference enables shorter aerial increased range/less power required/less attenuation less distortion
(any two sensible answers, 1 each) B2 [2]
- (b) (i) frequency = 909 kHz C1
wavelength = $(3.0 \times 10^8) / (909 \times 10^3)$
= 330 m A1 [2]
- (ii) bandwidth = 18 kHz A1 [1]
- (iii) frequency = 9000 Hz A1 [1]
- 12 (a) for received signal, $28 = 10 \lg(P / \{0.36 \times 10^{-6}\})$ C1
 $P = 2.3 \times 10^{-4} \text{ W}$ A1 [2]
- (b) loss in fibre = $10 \lg(\{9.8 \times 10^{-3}\} / \{2.27 \times 10^{-4}\})$ C1
= 16 dB A1 [2]
- (c) attenuation per unit length = $16 / 85$
= 0.19 dB km^{-1} A1 [1]

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Section A

- 1 (a) equatorial orbit / above equator B1
satellite moves from west to east / same direction as Earth spins B1
period is 24 hours / same period as spinning of Earth B1 [3]
(allow 1 mark for 'appears to be stationary/overhead' if none of above marks scored)
- (b) gravitational force provides/is the centripetal force B1
 $GMm/R^2 = mR\omega^2$ or $GMm/R^2 = mv^2/R$ M1
 $\omega = 2\pi / T$ or $v = 2\pi R / T$ or clear substitution M1
clear working to give $R^3 = (GMT^2 / 4\pi^2)$ A1 [4]
- (c) $R^3 = 6.67 \times 10^{-11} \times 6.0 \times 10^{24} \times (24 \times 3600)^2 / 4\pi^2$ C1
 $= 7.57 \times 10^{22}$ C1
 $R = 4.2 \times 10^7 \text{ m}$ A1 [3]
(missing out 3600 gives $1.8 \times 10^5 \text{ m}$ and scores 2/3 marks)
- 2 (a) (i) 1. $pV = nRT$
 $1.80 \times 10^{-3} \times 2.60 \times 10^5 = n \times 8.31 \times 297$ C1
 $n = 0.19 \text{ mol}$ A1 [2]
2. $\Delta q = mc\Delta T$
 $95.0 = 0.190 \times 12.5 \times \Delta T$ B1
 $\Delta T = 40 \text{ K}$ A1 [2]
(allow 2 marks for correct answer with clear logic shown)
- (ii) $p/T = \text{constant}$
 $(2.6 \times 10^5) / 297 = p / (297 + 40)$ M1
 $p = 2.95 \times 10^5 \text{ Pa}$ A0 [1]
- (b) change in internal energy is 120 J / 25 J B1
internal energy decreases / ΔU is negative / kinetic energy of molecules decreases M1
so temperature lower A1 [3]

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- 3 (a) (i) $\omega = 2\pi / T$
 $= 2\pi / 0.69$
 $= 9.1 \text{ rad s}^{-1}$
(allow use of $f = 1.5 \text{ Hz}$ to give $\omega = 9.4 \text{ rad s}^{-1}$)
C1
A1 [2]
- (ii) 1. $x = 2.1 \cos 9.1t$
2.1 and 9.1 numerical values
use of cos
B1
B1 [2]
2. $v_0 = 2.1 \times 10^{-2} \times 9.1$ (allow ecf of value of x_0 from (ii)1.)
 $= 0.19 \text{ m s}^{-1}$
 $v = v_0 \sin 9.1t$ (allow $\cos 9.1t$ if $\sin$ used in (ii)1.)
B1
B1 [2]
- (b) energy = either $\frac{1}{2} m v_0^2$ or $\frac{1}{2} m \omega^2 x_0^2$
= either $\frac{1}{2} \times 0.078 \times 0.19^2$ or $\frac{1}{2} \times 0.078 \times 9.1^2 \times (2.1 \times 10^{-2})^2$
 $= 1.4 \times 10^{-3} \text{ J}$
C1
A1 [2]
- 4 (a) (i) $V = q / 4\pi\epsilon_0 R$
B1 [1]
- (ii) (capacitance is) ratio of charge and potential or q/V
 $C = q/V = 4\pi\epsilon_0 R$
M1
A0 [1]
- (b) (i) $C = 4\pi \times 8.85 \times 10^{-12} \times 0.45$
 $= 50 \text{ pF}$
C1
A1 [2]
- (ii) either energy = $\frac{1}{2} C V^2$ or energy = $\frac{1}{2} Q V$ and $Q = C V$
energy of spark = $\frac{1}{2} \times 50 \times 10^{-12} \{(9.0 \times 10^5)^2 - (3.6 \times 10^5)^2\}$
 $= 17 \text{ J}$
C1
C1
A1 [3]
- 5 (a) (uniform magnetic) flux normal to long (straight) wire carrying a current of 1 A
(creates) force per unit length of 1 N m^{-1}
M1
A1 [2]
- (b) (i) sketch: concentric circles
increasing separation (*must show more than 3 circles*)
correct direction (anticlockwise, looking down)
M1
A1
B1 [3]
- (ii) $B = (4\pi \times 10^{-7} \times 6.3) / (2\pi \times 4.5 \times 10^{-2})$
 $= 2.8 \times 10^{-5} \text{ T}$
C1
A1 [2]
- (iii) $F = BIL (\sin \theta)$
 $= 2.8 \times 10^{-5} \times 9.3 \times 1$
 $F/L = 2.6 \times 10^{-4} \text{ N m}^{-1}$
C1
A1 [2]
- (c) force per unit length depends on product $I_X I_Y$ / by Newton's third law / action and reaction are equal and opposite
so same for both
M1
A1 [2]

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- 6 (a) (induced) e.m.f. proportional to rate
of change of (magnetic) flux (linkage) M1
A1 [2]
- (b) (i) positive terminal identified (upper connection to load) B1 [1]
- (ii) $V_P = \sqrt{2} \times V_{RMS}$
ratio = $240 \sqrt{2} / 9$
= 38 C1
C1
A1 [3]
($V_P = V_{RMS} / \sqrt{2}$ gives ratio = 18.9 and scores 1/3)
(ratio = $240 / 9 = 26.7$ scores 1/3)
(ratio = $9 / (240 / \sqrt{2}) = 0.0265$ is inverted ratio and scores 1/3)
- (c) (i) e.g. (output) p.d. / voltage / current does not fall to zero
e.g. range of (output) p.d. / voltage / current is reduced (*any sensible answer*) B1 [1]
- (ii) sketch: same peak value at start of discharge M1
correct shape between one peak and the next A1 [2]
- 7 (a) each wavelength is associated with a discrete change in energy M1
discrete energy change / difference implies discrete levels A1 [2]
- (b) (i) 1. arrow from -0.54 eV to -0.85 eV, labelled L B1 [1]
2. arrow from -0.54 eV to -3.4 eV, labelled S B1 [1]
(two correct arrows, but only one label – allow 2 marks)
(two correct arrows, but no labels – allow 1 mark)
- (ii) $E = hc / \lambda$ C1
 $(3.4 - 0.54) \times 1.6 \times 10^{-19} = (6.63 \times 10^{-34} \times 3.0 \times 10^8) / \lambda$ C1
 $\lambda = 4.35 \times 10^{-7}$ m A1 [3]
- (c) $-1.50 \rightarrow -3.4 = 1.9$ eV
 $-0.85 \rightarrow -3.4 = 2.55$ eV (allow 2.6 eV)
 $-0.54 \rightarrow -3.4 = 2.86$ eV (allow 2.9 eV)
3 correct, 2 marks with –1 mark for each additional energy
2 correct, 1 mark but no marks if any additional energy differences B2 [2]

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- 8 (a) energy is given out / released on formation of the α -particle (or reverse argument) M1
either $E = mc^2$ so mass is less
or reference to mass-energy equivalence A1 [2]
- (b) (i) mass change = $18.00567 \text{ u} - 18.00641 \text{ u}$ C1
= $7.4 \times 10^{-4} \text{ u}$ (*sign not required*) A1 [2]
- (ii) energy = $c^2 \Delta m$
= $(3.0 \times 10^8)^2 \times 7.4 \times 10^{-4} \times 1.66 \times 10^{-27}$ C1
= $1.1 \times 10^{-13} \text{ J}$ A1 [2]
(*allow use of $u = 1.67 \times 10^{-27} \text{ kg}$*)
(*allow method based on 1u equivalent to 930 MeV to 933 MeV*)
- (iii) *either* mass of products greater than mass of reactants M1
this mass/energy provided as kinetic energy of the helium-4 nucleus A1
or both nuclei positively charged (M1)
energy required to overcome electrostatic repulsion (A1) [2]

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Section B

- 9 (a) 30 litres → 54 litres (*allow ± 4 litres on both limits*) A1 [1]
- (b) (i) only 0.1 V change in reading for 10 litre consumption (*or similar numbers*) B1
above about 60 litres gradient is small compared to the gradient at about 40 litres B1 [2]
- (ii) voltmeter reading (nearly) zero when fuel is left C1
voltmeter reads only about 0.1 V when 10 litres of fuel left in tank A1 [2]
(*“voltmeter reads zero when about 4 litres of fuel left in tank” scores 2 marks*)
- 10 (a) product of density and speed of sound / wave M1
(density of medium and) speed of sound / wave in medium A1 [2]
- (b) if $(Z_1 - Z_2)$ is small, mostly transmission M1
if $(Z_1 - Z_2)$ is large, mostly reflection M1
(*if ‘mostly’ not stated allow 1/2 marks for these first two marks*)
either reflection / transmission also depends on $(Z_1 + Z_2)$
or intensity reflection coefficient = $(Z_1 - Z_2)^2 / (Z_1 + Z_2)^2$ A1 [3]
- (c) e.g. smaller structures can be distinguished B1
because better resolution at shorter wavelength / higher frequency B1 [2]
- 11 (a) changing voltage changes energy / speed of electrons M1
changing electron energy changes maximum X-ray photon energy A1 [2]
- (b) (i) 1. loss of power / energy / intensity B1 [1]
2. intensity changes when beam not parallel C1
decreases when beam is divergent A1 [2]
- (ii) ratio = $(\exp \{-2.9 \times 2.5\}) / (\exp \{-0.95 \times 6.0\})$ C1
= 0.21 (*min. 2 sig. fig.*) A1 [2]
(*values of both lengths incorrect by factor of 10^{-2} to give ratio of 0.985 scores 1 mark*)

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- 12 (a) takes all the simultaneous digits for one number
and 'sends' them one after another (along the transmission line) B1
B1 [2]

- (b) (i) 0111 A1 [1]

- (ii) 0110 A1 [1]

- (c) levels shown

t	0	0.2	0.4	0.6	0.8	1.0	1.2
	0	8	7	15	6	5	8

(–1 for each error or omission)

correct basic shape of graph i.e. series of steps
with levels staying constant during correct time intervals
(vertical lines in steps do not need to be shown)

A2
M1
A1 [4]

- (d) increasing number of bits reduces step height
increasing sampling frequency reduces step depth / width
reproduction of signal is more exact

M1
M1
A1 [3]

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Section A

- 1 (a) region of space area / volume where a mass experiences a force B1 B1 [2]
- (b) (i) force proportional to product of two masses M1
force inversely proportional to the square of their separation M1
either reference to point masses *or* separation $\gg$ 'size' of masses A1 [3]
- (ii) field strength = GM / x^2 **or** field strength $\propto 1 / x^2$ C1
ratio = $(7.78 \times 10^8)^2 / (1.5 \times 10^8)^2$ C1
= 27 A1 [3]
- (c) (i) *either* centripetal force = $mR\omega^2$ and $\omega = 2\pi / T$
or centripetal force = mv^2 / R and $v = 2\pi R / T$ B1
gravitational force provides the centripetal force B1
either $GMm / R^2 = mR\omega^2$ *or* $GMm / R^2 = mv^2 / R$ M1
 $M = 4\pi^2 R^3 / GT^2$ A0 [3]
(allow working to be given in terms of acceleration)
- (ii) $M = \{4\pi^2 \times (1.5 \times 10^{11})^3\} / \{6.67 \times 10^{-11} \times (3.16 \times 10^7)^2\}$ C1
= 2.0×10^{30} kg A1 [2]
- 2 (a) obeys the equation $pV = \text{constant} \times T$ *or* $pV = nRT$ M1
 p , V and T explained A1
at all values of p , V and T /fixed mass/ n is constant A1 [3]
- (b) (i) $3.4 \times 10^5 \times 2.5 \times 10^3 \times 10^{-6} = n \times 8.31 \times 300$ M1
 $n = 0.34$ mol A0 [1]
- (ii) for total mass/amount of gas
 $3.9 \times 10^5 \times (2.5 + 1.6) \times 10^3 \times 10^{-6} = (0.34 + 0.20) \times 8.31 \times T$ C1
 $T = 360$ K A1 [2]
- (c) when tap opened
gas passed (from cylinder B) to cylinder A B1
work done on gas in cylinder A (and no heating) M1
so internal energy and hence temperature increase A1 [3]

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- 3 (a) (i) 1. amplitude = 1.7 cm A1 [1]
2. period = 0.36 cm C1
frequency = $1/0.36$
= 2.8 Hz A1 [2]
- (ii) $a = (-)\omega^2 x$ and $\omega = 2\pi/T$ C1
acceleration = $(2\pi/0.36)^2 \times 1.7 \times 10^{-2}$ M1
= 5.2 ms^{-2} A0 [2]
- (b) graph: straight line, through origin, with negative gradient M1
from $(-1.7 \times 10^{-2}, 5.2)$ to $(1.7 \times 10^{-2}, -5.2)$ A1 [2]
(if scale not reasonable, do not allow second mark)
- (c) either kinetic energy = $\frac{1}{2}m\omega^2(x_0^2 - x^2)$
or potential energy = $\frac{1}{2}m\omega^2 x^2$ and potential energy = kinetic energy B1
 $\frac{1}{2}m\omega^2(x_0^2 - x^2) = \frac{1}{2} \times \frac{1}{2}m\omega^2 x_0^2$ or $\frac{1}{2}m\omega^2 x^2 = \frac{1}{2} \times \frac{1}{2}m\omega^2 x_0^2$ C1
 $x_0^2 = 2x^2$
 $x = x_0 / \sqrt{2} = 1.7 / \sqrt{2}$
= 1.2 cm A1 [3]
- 4 (a) work done moving unit positive charge from infinity (to the point) M1
A1 [2]
- (b) (gain in) kinetic energy = change in potential energy B1
 $\frac{1}{2}mv^2 = qV$ leading to $v = (2Vq/m)^{1/2}$ B1 [2]
- (c) either $(2.5 \times 10^5)^2 = 2 \times V \times 9.58 \times 10^7$ C1
 $V = 330 \text{ V}$ M1
this is less than 470 V and so 'no' A1 [3]
- or $v = (2 \times 470 \times 9.58 \times 10^7)$ (C1)
 $v = 3.0 \times 10^5 \text{ ms}^{-1}$ (M1)
this is greater than $2.5 \times 10^5 \text{ ms}^{-1}$ and so 'no' (A1)
- or $(2.5 \times 10^5)^2 = 2 \times 470 \times (q/m)$ (C1)
 $(q/m) = 6.6 \times 10^7 \text{ C kg}^{-1}$ (M1)
this is less than $9.58 \times 10^7 \text{ C kg}^{-1}$ and so 'no' (A1)

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- 5 (a) (uniform magnetic) flux normal to long (straight) wire carrying a current of 1 A
(creates) force per unit length of 1 N m^{-1} M1
A1 [2]
- (b) (i) flux density $= 4\pi \times 10^{-7} \times 1.5 \times 10^3 \times 3.5$ C1
 $= 6.6 \times 10^{-3} \text{ T}$ A1 [2]
- (ii) flux linkage $= 6.6 \times 10^{-3} \times 28 \times 10^{-4} \times 160$ C1
 $= 3.0 \times 10^{-3} \text{ Wb}$ A1 [2]
- (c) (i) (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage) M1
A1 [2]
- (ii) e.m.f. $= (2 \times 3.0 \times 10^{-3}) / 0.80$ C1
 $= 7.4 \times 10^{-3} \text{ V}$ A1 [2]
- 6 (a) (i) to reduce power loss in the core due to eddy currents/induced currents B1
B1 [2]
- (ii) *either* no power loss in transformer
or input power = output power B1 [1]
- (b) *either* r.m.s. voltage across load $= 9.0 \times (8100 / 300)$ C1
peak voltage across load $= \sqrt{2} \times 243$
 $= 340 \text{ V}$ A1 [2]
or peak voltage across primary coil $= 9.0 \times \sqrt{2}$ (C1)
peak voltage across load $= 12.7 \times (8100/300)$
 $= 340 \text{ V}$ (A1)
- 7 (a) (i) lowest frequency of e.m. radiation giving rise to emission of electrons (from the surface) M1
A1 [2]
- (ii) $E = hf$ C1
threshold frequency $= (9.0 \times 10^{-19}) / (6.63 \times 10^{-34})$
 $= 1.4 \times 10^{15} \text{ Hz}$ A1 [2]
- (b) *either* $300 \text{ nm} \equiv 10 \times 10^{15} \text{ Hz}$ (and $600 \text{ nm} \equiv 5.0 \times 10^{14} \text{ Hz}$)
or $300 \text{ nm} \equiv 6.6 \times 10^{-19} \text{ J}$ (and $600 \text{ nm} \equiv 3.3 \times 10^{-19} \text{ J}$)
or zinc $\lambda_0 = 340 \text{ nm}$, platinum $\lambda_0 = 220 \text{ nm}$ (and sodium $\lambda_0 = 520 \text{ nm}$)
emission from sodium and zinc M1
A1 [2]
- (c) each photon has larger energy M1
fewer photons per unit time M1
fewer electrons emitted per unit time A1 [3]

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- 8 (a) two (light) nuclei combine to form a more massive nucleus M1 A1 [2]
- (b) (i) $\Delta m = (2.01410 \text{ u} + 1.00728 \text{ u}) - 3.01605 \text{ u}$
 $= 5.33 \times 10^{-3} \text{ u}$
energy $= c^2 \times \Delta m$
 $= 5.33 \times 10^{-3} \times 1.66 \times 10^{-27} \times (3.00 \times 10^8)^2$
 $= 8.0 \times 10^{-13} \text{ J}$ C1 C1 A1 [3]
- (ii) speed/kinetic energy of proton and deuterium must be very large so that the nuclei can overcome electrostatic repulsion B1 B1 [2]

Section B

- 9 (a) (i) light-dependent resistor/LDR B1 [1]
- (ii) strain gauge B1 [1]
- (iii) quartz/piezo-electric crystal B1 [1]
- (b) (i) resistance of thermistor decreases as temperature increases M1
either $V_{\text{OUT}} = V \times R / (R + R_T)$
or current increases and $V_{\text{OUT}} = I R$
 V_{OUT} increases A1 A1 [3]
- (ii) *either* change in R_T with temperature is non-linear
or V_{OUT} is not proportional to R_T / change in V_{OUT} with R_T is non-linear
so change is non-linear M1 A1 [2]
- 10 (a) sharpness: how well the edges (of structures) are defined B1
contrast: difference in (degree of) blackening between structures B1 [2]
- (b) e.g. scattering of photos in tissue/no use of a collimator/no use of lead grid
large penumbra on shadow/large area anode/wide beam
large pixel size
(any two sensible suggestions, 1 each) B2 [2]
- (c) (i) $I = I_0 e^{-\mu x}$ C1
ratio $= \exp(-2.85 \times 3.5) / \exp(-0.95 \times 8.0)$ C1
 $= (4.65 \times 10^{-5}) / (5.00 \times 10^{-4})$
 $= 0.093$ A1 [3]
- (ii) *either* large difference (in intensities)
or ratio much less than 1.0
so good contrast M1 A1 [2]
- (answer given in (c)(ii) must be consistent with ratio given in (c)(i))*

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- 11 (a) (i)** amplitude of the carrier wave varies (in synchrony) with the displacement of the information signal M1 A1 [2]
- (ii)** e.g. more than one radio station can operate in same region/less interference
enables shorter aerial
increased range/less power required/less attenuation
less distortion
(any two sensible answers, 1 each) B2 [2]
- (b) (i)** frequency = 909 kHz C1
wavelength = $(3.0 \times 10^8) / (909 \times 10^3)$
= 330 m A1 [2]
- (ii)** bandwidth = 18 kHz A1 [1]
- (iii)** frequency = 9000 Hz A1 [1]
- 12 (a)** for received signal, $28 = 10 \lg(P / \{0.36 \times 10^{-6}\})$ C1
 $P = 2.3 \times 10^{-4} \text{ W}$ A1 [2]
- (b)** loss in fibre = $10 \lg(\{9.8 \times 10^{-3}\} / \{2.27 \times 10^{-4}\})$ C1
= 16 dB A1 [2]
- (c)** attenuation per unit length = $16 / 85$
= 0.19 dB km^{-1} A1 [1]