

CAMBRIDGE INTERNATIONAL EXAMINATIONS

Cambridge International Advanced Subsidiary and Advanced Level

MARK SCHEME for the May/June 2015 series

9702 PHYSICS

9702/41

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

This mark scheme is published as an aid to teachers and candidates, to indicate the requirements of the examination. It shows the basis on which Examiners were instructed to award marks. It does not indicate the details of the discussions that took place at an Examiners' meeting before marking began, which would have considered the acceptability of alternative answers.

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Section A

- 1 (a) (gravitational) force proportional to product of masses and inversely proportional to square of separation
reference to *either* point masses *or* particles *or* 'size' much less than separation
- M1
A1 [2]
- (b) gravitational force provides/is the centripetal force
 $GM_N m / r^2 = m r \omega^2$ (or $m v^2 / r$)
 $2\pi / T$ (or $v = 2\pi r / T$) leading to $GM_N = 4\pi^2 r^3 / T^2$
- B1
M1
A1 [3]
- (c) $M_N / M_U = (3.55 / 5.83)^3 \times (13.5 / 5.9)^2$
 x^3 factor correct
 T^2 factor correct
ratio = 1.18 (*allow 1.2*)
- C1
C1
A1
- alternative method:* mass of Neptune = 1.019×10^{26} kg
mass of Uranus = 8.621×10^{25} kg
ratio = 1.18
- (C1)
(C1)
(A1) [3]
- 2 (a) (sum of) potential energy and kinetic energy of molecules/atoms/particles
mention of random motion/distribution
- M1
A1 [2]
- (b) (i) $pV = nRT$
either at A, $1.2 \times 10^5 \times 4.0 \times 10^{-3} = n \times 8.31 \times 290$
or at B, $3.6 \times 10^5 \times 4.0 \times 10^{-3} = n \times 8.31 \times 870$
 $n = 0.20$ mol
- C1
A1 [2]
- (ii) $1.2 \times 10^5 \times 7.75 \times 10^{-3} = 0.20 \times 8.31 \times T$ or $T = (7.75 / 4.0) \times 290$
 $T = 560$ K
(*Allow tolerance from graph: $7.7-7.8 \times 10^{-3} \text{ m}^3$*)
- C1
A1 [2]
- (c) temperature changes/decreases so internal energy changes/decreases
volume changes (at constant pressure) so work is done
- B1
B1 [2]
- 3 (a) (numerically equal to) quantity of (thermal) energy/heat to change state/phase of unit mass
at constant temperature
(*allow 1/2 for definition restricted to fusion or vaporisation*)
- M1
A1 [2]
- (b) (i) at 70 W, $\text{mass s}^{-1} = 0.26 \text{ g s}^{-1}$
at 110 W, $\text{mass s}^{-1} = 0.38 \text{ g s}^{-1}$
- A1
A1 [2]

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	(ii) 1. $P + h = mL$ or substitution of one set of values (110 – 70) = (0.38 – 0.26)L $L = 330 \text{ J g}^{-1}$	C1 C1 A1	[3]
	2. <i>either</i> $70 + h = 0.26 \times 330$ <i>or</i> $110 + h = 0.38 \times 330$ $h = 17/16/15 \text{ W}$	C1 A1	[2]
4	(a) (i) frequency at which object is made to vibrate/oscillate	B1	[1]
	(ii) frequency at which object vibrates when free to do so	B1	[1]
	(iii) maximum amplitude of vibration of oscillating body when forced frequency equals natural frequency (of vibration)	B1 B1	[2]
	(b) e.g. vibration of quartz/piezoelectric crystal (<i>what is vibrating</i>) <i>either</i> for accurate timing <i>or</i> maximise amplitude of ultrasound waves (<i>why it is useful</i>)	M1 A1	[2]
	(c) e.g. vibrating metal panels (<i>what is vibrating</i>) <i>either</i> place strengthening struts across the panel <i>or</i> change shape/area of panel (<i>how it is reduced</i>)	M1 A1	[2]
5	(a) (magnitude of electric field strength is the potential gradient use of gradient at $x = 4.0 \text{ cm}$ gradient = $4.5 \times 10^4 \text{ N C}^{-1}$ (<i>allow</i> $\pm 0.3 \times 10^4$) <i>or</i> $V = \frac{Q}{4\pi\epsilon_0 x} \text{ and } E = \frac{Q}{4\pi\epsilon_0 x^2} \text{ leading to } E = \frac{V}{x}$ $E = 1.8 \times 10^3 / 0.04$ $= 4.5 \times 10^4 \text{ N C}^{-1}$	B1 M1 A1 (B1) (M1) (A1)	 [3]
	(b) (i) $3.6 \times 10^3 \text{ V}$	A1	[1]
	(ii) capacitance = Q/V $= (8.0 \times 10^{-9}) / (3.6 \times 10^3)$ $= 2.2 \times 10^{-12} \text{ F}$	C1 A1	[2]
	(a) (i) gravitational	B1	[1]
	(ii) gravitational and electric	B1	[1]
6	(iii) magnetic and one other field given magnetic, gravitational and electric	B1 B1	[2]

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- (b) (i) out of (plane of) paper/page (*not* “upwards”) B1 [1]
- (ii) $B = mv/qr$
 $= (3.32 \times 10^{-26} \times 7.6 \times 10^4)/(1.6 \times 10^{-19} \times 6.1 \times 10^{-2})$
 $= 0.26 \text{ T}$ C1
C1
A1 [3]
- (c) sketch: semicircle with diameter $< 12.2 \text{ cm}$ B1 [1]
- 7 (a) can change (output) voltage efficiently *or* to suit different consumers/appliances by using transformers B1
B1 [2]
- (b) for same power, current is smaller B1
- less heating in cables/wires
or thinner cables possible
or less voltage loss in cables B1 [2]
- 8 (a) (i) $p = h/\lambda$
 $= (6.63 \times 10^{-34})/(6.50 \times 10^{-12})$
 $= 1.02 \times 10^{-22} \text{ N s}$ C1
A1 [2]
- (ii) $E = hc/\lambda$ *or* $E = pc$
 $= (6.63 \times 10^{-34} \times 3.00 \times 10^8)/(6.50 \times 10^{-12})$
 $= 3.06 \times 10^{-14} \text{ J}$ C1
A1 [2]
- (b) (i) $0.34 \times 10^{-12} = (6.63 \times 10^{-34})/(9.11 \times 10^{-31} \times 3.0 \times 10^8) \times (1 - \cos \theta)$
 $\theta = 30.7^\circ$ C1
A1 [2]
- (ii) deflected electron has energy M1
this energy is derived from the incident photon A1
deflected photon has less energy, longer wavelength (so $\Delta\lambda$ always positive) B1 [3]
- 9 (a) nucleus/nuclei emits M1
spontaneously/randomly A1
 α -particles, β -particles, γ -ray photons A1 [3]
- (b) (i) $N - \Delta N$ A1 [1]
- (ii) $\Delta N/\Delta t$ A1 [1]
- (iii) $\Delta N/N$ A1 [1]
- (iv) $\Delta N/N\Delta t$ A1 [1]
- (c) graph: smooth curve in correct direction starting at (0,0) M1
n at $2t_{1/2}$ is 1.5 times that at $t_{1/2}$ ($\pm 2 \text{ mm}$) A1 [2]

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Section B

- 10 (a) (i)** (potential =) $1.2 / (1.2 + 4.2) \times 4.5 = +1.0 \text{ V}$ A1 [1]
- (ii)** (for $V_{\text{IN}} > 1.0 \text{ V}$) $V^+ > V^-$ B1
output (of op-amp) is +5 V or positive M1
diode conducts giving +5 V across R or V_{out} is +5 V A1
- (for $V_{\text{IN}} < 1.0 \text{ V}$) output of op-amp –5 V / negative so diode does not conduct, giving $V_{\text{out}} = 0$ or 0 V across R A1 [4]
- (b) (i)** square wave with maximum value +5 V and minimum value 0 M1
vertical sides in correct positions and correct phase A1 [2]
- (ii)** re-shaping (digital) signals/regenerator (amplifier) B1 [1]
- 11 (a)** change/increase/decrease anode/tube voltage B1
electrons striking anode have changed (kinetic) energy/speed B1
X-ray/photons/beam have different wavelength/frequency B1 [3]
- (b) (i)** $I = I_0 e^{-\mu x}$ B1 [1]
- (ii)** contrast is difference in degree of blackening (of regions of the image) B1
 μ (very) similar so similar absorption of radiation (for same thickness) so little contrast A1 [2]
- 12 (a) (i)** loudspeaker/doorbell/telephone etc. B1 [1]
- (ii)** television set/audio amplifier etc. B1 [1]
- (iii)** satellite/satellite dish/mobile phone etc. B1 [1]
- (b)** e.g. lower attenuation/fewer repeaters
more secure
less prone to noise/interference
physically smaller/less weight
lower cost
greater bandwidth
(any two sensible suggestions, 1 each) B2 [2]
- (c) (i)** ratio = $25 + (62 \times 0.21)$ C1
= 38 dB A1 [2]
- (ii)** ratio / dB = $10 \lg (P_2 / P_1)$ C1
 $38 = 10 \lg (P / \{9.2 \times 10^{-6}\})$
- $P = 58 \text{ mW}$ or $5.8 \times 10^{-2} \text{ W}$ A1 [2]
(allow 1/2 for missing 10 in equation)

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- 13 (a) (i)** to align nuclei/protons B1
to cause Larmor/precessional frequency to be in r.f. region B1 [2]
- (ii)** Larmor/precessional frequency depends on (applied magnetic) field strength B1
knowing field strength enables (region of precessing) nuclei to be located M1
by knowing the frequency A1 [3]
- (b)** $E = 2.82 \times 10^{-26} \times B$
 $6.63 \times 10^{-34} \times 42 \times 10^6 = 2.82 \times 10^{-26} \times B$ C1
 $B = 0.99 \text{ T}$ A1 [2]

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- 1 (a) (i) 1. $F = Gm_1m_2/x^2$
 $= (6.67 \times 10^{-11} \times 2.50 \times 5.98 \times 10^{24}) / (6.37 \times 10^6)^2$
 $= 24.6 \text{ N (accept 2 s.f. or more)}$ M1
A1 [2]
2. $F = mx\omega^2$ or $F = mv^2/x$ and $v = \omega x$ (accept x or r for distance)
 $= 2.50 \times 6.37 \times 10^6 \times (2\pi/24 \times 3600)^2$
 $= 0.0842 \text{ N (accept 2 s.f. or more)}$ C1
A1 [2]
- (ii) reading $= 24.575 - 0.0842$ B1
 $= 24.5 \text{ N (accept only 3 s.f.)}$ A1 [2]
- (b) gravitational force provides the centripetal force M1
gravitational force is 'equal' to the centripetal force
(accept $Gm_1m_2/x^2 = mx\omega^2$ or $F_C = F_G$) M1
'weight'/sensation of weight/contact force/reaction force is difference between F_G
and F_C which is zero A1 [3]
- 2 (a) mean speed $= 1.44 \times 10^3 \text{ m s}^{-1}$ A1 [1]
- (b) evidence of summing of individual squared speeds C1
mean square speed $= 2.09 \times 10^6 \text{ m}^2 \text{ s}^{-2}$ A1 [2]
- (c) root-mean-square speed $= 1.45 \times 10^3 \text{ m s}^{-1}$ A1 [1]
(allow ECF from (b) but only if arithmetic error)
- 3 (a) (numerically equal to) quantity of heat/(thermal) energy to change state/phase of unit mass M1
at constant temperature A1 [2]
(allow 1/2 for definition restricted to fusion or vaporisation)
- (b) (i) constant gradient/straight line (allow linear/constant slope) B1 [1]
- (ii) $Pt = mL$ or power $= \text{gradient} \times L$ C1
use of gradient of graph
(or two points separated by at least 3.5 minutes) M1
 $110 \times 60 = L \times (372 - 325) \times 10^{-3} / 7.0$
 $L = 9.80 \times 10^5 \text{ J kg}^{-1}$ (accept 2 s.f.) (allow 9.8 to 9.9 rounded to 2 s.f.) A1 [3]
- (iii) some energy/heat is lost to the surroundings or vapour condenses on sides M1
so value is an overestimate A1 [2]
- 4 (a) displacement (directly) proportional to acceleration/force M1
either displacement and acceleration in opposite directions
or acceleration (always) towards a (fixed) point A1 [2]

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- (b) (i) $\frac{1}{3}\pi$ rad or 1.05 rad (*allow 60° if unit clear*) A1 [1]
- (ii) $a_0 = -\omega^2 x_0$
 $= (-) (2\pi/1.2)^2 \times 0.030$ C1
 $= (-) 0.82 \text{ m s}^{-2}$ A1 [2]
(special case: using oscillator P gives $x_0 = 1.7 \text{ cm}$ and $a_0 = 0.47 \text{ m s}^{-1}$ for 1/2)
- (iii) max. energy $\propto x_0^2$
ratio $= 3.0^2/1.7^2$ C1
 $= 3.1$ (*at least 2 s.f.*) A1 [2]
(if has inverse ratio but has stated max. energy $\propto x_0^2$ then allow 1/2)
- (c) graph: straight line through (0,0) with negative gradient M1
correct end-points (−3.0, +0.82) and (+3.0, −0.82) A1 [2]
- 5 (a) work done bringing/moving per unit positive charge from infinity (to the point) M1
A1 [2]
- (b) (i) slope/gradient (of the line/graph/tangent) B1 [1]
*(allow dV/dx , but **not** $\Delta V/\Delta x$ or V/x)*
(allow potential gradient)
(negative sign not required)
- (ii) maximum at surface of sphere A or at $x = 0$ (cm) B1
zero at $x = 6$ (cm) B1
then increases but in opposite direction B1 [3]
(any mention of attraction max. 2/3)
- (c) (i) M shown between $x = 5.5 \text{ cm}$ and $x = 6.5 \text{ cm}$ B1 [1]
- (ii) 1. $\Delta V = (570 - 230) = 340 \text{ V}$ (*allow 330 V to 340 V*) A1 [1]
2. $q(\Delta)V = \frac{1}{2}mv^2$ **or** change/loss in PE = change/gain in KE **or** $\Delta E_K = \Delta E_P$ B1
- $4.8 \times 10^7 \times 340 = \frac{1}{2}v^2$ C1
 $v^2 = 3.26 \times 10^{10}$
 $v = 1.8 \times 10^5 \text{ m s}^{-1}$ (*not 1 s.f.*) A1 [3]
- 6 (a) packet/quantum/discrete amount of energy of electromagnetic energy/radiation/waves M1
A1 [2]
- (b) (i) arrow below axis and pointing to right B1 [1]

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- (ii) 1. $E = hc/\lambda$
 $= (6.63 \times 10^{-34} \times 3.0 \times 10^8)/(6.80 \times 10^{-12})$
 $= 2.93 \times 10^{-14} \text{ J (accept 2 s.f.)}$ C1
A1 [2]
2. energy of electron $= (3.06 - 2.93) \times 10^{-14}$
 $= 1.3 \times 10^{-15} \text{ J}$ C1
speed $= \sqrt{(2E/m)}$ C1
 $= 5.4 \times 10^7 \text{ m s}^{-1}$ A1 [3]
- (c) momentum is a vector quantity B1
either must consider momentum in two directions
or direction changes so cannot just consider magnitude B1 [2]
- 7 (a) moving magnet gives rise to/causes/induces e.m.f./current in solenoid/coil B1
(induced current) creates field/flux in solenoid that opposes (motion of) magnet B1
work is done/energy is needed to move magnet (into solenoid) B1
(induced) current gives heating effect (in resistor) which comes from the work done B1 [4]
- (b) current in primary coil give rise to (magnetic) flux/field B1
(magnetic) flux/field (in core) is in phase with current (in primary coil) B1
(magnetic) flux threads/links/cuts secondary coil inducing e.m.f. in secondary coil B1
(there **must** be a mention of secondary coil)
e.m.f. induced proportional to rate of change/cutting of flux/field so not in phase B1 [4]
- 8 (a) (i) energy $= 5.75 \times 1.6 \times 10^{-13}$
 $= 9.2 \times 10^{-13} \text{ J}$ A1 [1]
- (ii) number $= 1900/(9.2 \times 10^{-13} \times 0.24)$ C1
 $= 8.6 \times 10^{15} \text{ s}^{-1}$ A1 [2]
- (b) (i) decay constant $= 0.693/(2.8 \times 365 \times 24 \times 3600)$ C1
 $= 7.85 \times 10^{-9} \text{ s}^{-1}$ (allow 7.8 or 7.9 to 2 s.f.) A1 [2]
- (ii) $A = \lambda N$
 $8.6 \times 10^{15} = 7.85 \times 10^{-9} \times N$ C1
 $N = 1.096 \times 10^{24}$ C1
mass $= (1.096 \times 10^{24} \times 236)/(6.02 \times 10^{23})$ M1
 $= 430 \text{ g}$ A1 [4]
- (c) $0.84 = 1.9 \exp(-7.85 \times 10^{-9} t)$ C1
 $t = 1.04 \times 10^8 \text{ s}$
 $= 3.3 \text{ years}$ A1 [2]

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Section B

- 9 (a) $V_B = 1000 \text{ mV}$ C1
when strained, $V_A = 2000 \times 121.5 / (121.5 + 120.0)$
 $= 1006.2 \text{ mV}$ M1
change = 6.2 mV (*allow 6 mV*) A1 [3]
- (b) (i) 1. resistor between V_{IN} and V^- and V^+ connected to earth B1
resistor between V^- and V_{OUT} B1 [2]
2. P/+ sign shown on earth side of voltmeter B1 [1]
- (ii) ratio of $R_F / R_{IN} = 40$ M1
 R_{IN} between 100Ω and $10 \text{ k}\Omega$ A1 [2]
(*any values must link to the correct resistors on the diagram*)
- 10 (a) product of density (of medium) and speed (of ultrasound) M1
in the medium A1 [2]
- (b) (i) $7.0 \times 10^6 = 1.7 \times 10^3 \times \text{speed}$ C1
speed = $4.12 \times 10^3 \text{ m s}^{-1}$
wavelength = $(4.12 \times 10^3) / (9.0 \times 10^5) \text{ m}$ C1
 $= 4.6 \text{ mm}$ (*2 s.f. minimum*) A1 [3]
- (ii) for air/tissue boundary, $I_R / I \approx 1$ M1
for air/tissue boundary, (almost) complete reflection/no transmission A1
for gel/tissue boundary, $I_R / I = 0.1^2 / 3.1^2$
 $= 1.04 \times 10^{-3}$ (*accept 1 s.f.*) M1
gel enables (almost) complete transmission (into the tissue) A1 [4]
- 11 (a) (i) metal (*allow specific example of a metal*) B1 [1]
- (ii) e.g. provides 'return' for the signal
shields inner core from interference/reduces cross-talk/reduces noise
increased security
(*any two sensible suggestions, 1 each*) B2 [2]
- (b) (i) (gradual) loss of power/intensity/amplitude B1 [1]
- (ii) dB is a log scale B1
either large (range of) numbers are easier to handle (on a log scale)
or compounding attenuations/amplifications is easier B1 [2]
- (c) attenuation = $190 \times 11 \times 10^{-3} = 2.09 \text{ dB}$ C1
 $-2.09 = 10 \lg(P_{OUT} / P_{IN})$ C1
ratio = 0.62 A1 [3]

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- 12 handset transmits (identification) signal to number of base stations B1
base stations transfers (signal) to cellular exchange B1
(idea of stations needed at least once in first two marking points)
- computer at cellular exchange selects base station with strongest signal B1
computer at cellular exchange selects a carrier frequency for mobile phone B1 [4]
(idea of computer needed at least once in these two marking points)

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- 1 (a) (gravitational) force proportional to product of masses and inversely proportional to square of separation
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- M1
A1 [2]
- (b) gravitational force provides/is the centripetal force
 $GM_N m / r^2 = m r \omega^2$ (or $m v^2 / r$)
 $2\pi / T$ (or $v = 2\pi r / T$) leading to $GM_N = 4\pi^2 r^3 / T^2$
- B1
M1
A1 [3]
- (c) $M_N / M_U = (3.55 / 5.83)^3 \times (13.5 / 5.9)^2$
 x^3 factor correct
 T^2 factor correct
ratio = 1.18 (*allow* 1.2)
- C1
C1
A1
- alternative method:* mass of Neptune = 1.019×10^{26} kg
mass of Uranus = 8.621×10^{25} kg
ratio = 1.18
- (C1)
(C1)
(A1) [3]
- 2 (a) (sum of) potential energy and kinetic energy of molecules/atoms/particles
mention of random motion/distribution
- M1
A1 [2]
- (b) (i) $pV = nRT$
either at A, $1.2 \times 10^5 \times 4.0 \times 10^{-3} = n \times 8.31 \times 290$
or at B, $3.6 \times 10^5 \times 4.0 \times 10^{-3} = n \times 8.31 \times 870$
 $n = 0.20$ mol
- C1
A1 [2]
- (ii) $1.2 \times 10^5 \times 7.75 \times 10^{-3} = 0.20 \times 8.31 \times T$ or $T = (7.75 / 4.0) \times 290$
 $T = 560$ K
(*Allow tolerance from graph: $7.7\text{--}7.8 \times 10^{-3} \text{ m}^3$*)
- C1
A1 [2]
- (c) temperature changes/decreases so internal energy changes/decreases
volume changes (at constant pressure) so work is done
- B1
B1 [2]
- 3 (a) (numerically equal to) quantity of (thermal) energy/heat to change state/phase of unit mass
at constant temperature
(*allow* 1/2 for definition restricted to fusion or vaporisation)
- M1
A1 [2]
- (b) (i) at 70 W, $\text{mass s}^{-1} = 0.26 \text{ g s}^{-1}$
at 110 W, $\text{mass s}^{-1} = 0.38 \text{ g s}^{-1}$
- A1
A1 [2]

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- (ii) 1. $P + h = mL$ or substitution of one set of values
 $(110 - 70) = (0.38 - 0.26)L$
 $L = 330 \text{ J g}^{-1}$ C1
A1 [3]
2. *either* $70 + h = 0.26 \times 330$
or $110 + h = 0.38 \times 330$ C1
 $h = 17/16/15 \text{ W}$ A1 [2]
- 4 (a) (i) frequency at which object is made to vibrate/oscillate B1 [1]
- (ii) frequency at which object vibrates when free to do so B1 [1]
- (iii) maximum amplitude of vibration of oscillating body
when forced frequency equals natural frequency (of vibration) B1
B1 [2]
- (b) e.g. vibration of quartz/piezoelectric crystal (*what is vibrating*) M1
either for accurate timing
or maximise amplitude of ultrasound waves (*why it is useful*) A1 [2]
- (c) e.g. vibrating metal panels (*what is vibrating*) M1
either place strengthening struts across the panel
or change shape/area of panel (*how it is reduced*) A1 [2]
- 5 (a) (magnitude of electric field strength is the potential gradient
use of gradient at $x = 4.0 \text{ cm}$
gradient $= 4.5 \times 10^4 \text{ N C}^{-1}$ (*allow* $\pm 0.3 \times 10^4$) B1
M1
A1
- or*
- $$V = \frac{Q}{4\pi\epsilon_0 x} \text{ and } E = \frac{Q}{4\pi\epsilon_0 x^2} \text{ leading to } E = \frac{V}{x} \quad (\text{B1})$$
- $$E = 1.8 \times 10^3 / 0.04 \quad (\text{M1})$$

$$= 4.5 \times 10^4 \text{ N C}^{-1} \quad (\text{A1}) \quad [3]$$
- (b) (i) $3.6 \times 10^3 \text{ V}$ A1 [1]
- (ii) capacitance $= Q/V$ C1
 $= (8.0 \times 10^{-9}) / (3.6 \times 10^3)$
 $= 2.2 \times 10^{-12} \text{ F}$ A1 [2]
- 6 (a) (i) gravitational B1 [1]
- (ii) gravitational and electric B1 [1]
- (iii) magnetic and one other field given
magnetic, gravitational and electric B1
B1 [2]

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- (b) (i) out of (plane of) paper/page (*not* “upwards”) B1 [1]
- (ii) $B = mv/qr$
 $= (3.32 \times 10^{-26} \times 7.6 \times 10^4)/(1.6 \times 10^{-19} \times 6.1 \times 10^{-2})$
 $= 0.26 \text{ T}$ C1
C1
A1 [3]
- (c) sketch: semicircle with diameter $< 12.2 \text{ cm}$ B1 [1]
- 7 (a) can change (output) voltage efficiently *or* to suit different consumers/appliances by using transformers B1
B1 [2]
- (b) for same power, current is smaller B1
- less heating in cables/wires
or thinner cables possible
or less voltage loss in cables B1 [2]
- 8 (a) (i) $p = h/\lambda$
 $= (6.63 \times 10^{-34})/(6.50 \times 10^{-12})$
 $= 1.02 \times 10^{-22} \text{ N s}$ C1
A1 [2]
- (ii) $E = hc/\lambda$ *or* $E = pc$
 $= (6.63 \times 10^{-34} \times 3.00 \times 10^8)/(6.50 \times 10^{-12})$
 $= 3.06 \times 10^{-14} \text{ J}$ C1
A1 [2]
- (b) (i) $0.34 \times 10^{-12} = (6.63 \times 10^{-34})/(9.11 \times 10^{-31} \times 3.0 \times 10^8) \times (1 - \cos \theta)$
 $\theta = 30.7^\circ$ C1
A1 [2]
- (ii) deflected electron has energy M1
this energy is derived from the incident photon A1
deflected photon has less energy, longer wavelength (so $\Delta\lambda$ always positive) B1 [3]
- 9 (a) nucleus/nuclei emits M1
spontaneously/randomly A1
 α -particles, β -particles, γ -ray photons A1 [3]
- (b) (i) $N - \Delta N$ A1 [1]
- (ii) $\Delta N/\Delta t$ A1 [1]
- (iii) $\Delta N/N$ A1 [1]
- (iv) $\Delta N/N\Delta t$ A1 [1]
- (c) graph: smooth curve in correct direction starting at (0,0) M1
n at $2t_{1/2}$ is 1.5 times that at $t_{1/2}$ ($\pm 2 \text{ mm}$) A1 [2]

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Section B

- 10 (a) (i)** (potential =) $1.2 / (1.2 + 4.2) \times 4.5 = +1.0 \text{ V}$ A1 [1]
- (ii)** (for $V_{\text{IN}} > 1.0 \text{ V}$) $V^+ > V^-$ B1
output (of op-amp) is +5 V or positive M1
diode conducts giving +5 V across R or V_{out} is +5 V A1
- (for $V_{\text{IN}} < 1.0 \text{ V}$) output of op-amp –5 V / negative so diode does not conduct, giving $V_{\text{out}} = 0$ or 0 V across R A1 [4]
- (b) (i)** square wave with maximum value +5 V and minimum value 0 M1
vertical sides in correct positions and correct phase A1 [2]
- (ii)** re-shaping (digital) signals/regenerator (amplifier) B1 [1]
- 11 (a)** change/increase/decrease anode/tube voltage B1
electrons striking anode have changed (kinetic) energy/speed B1
X-ray/photons/beam have different wavelength/frequency B1 [3]
- (b) (i)** $I = I_0 e^{-\mu x}$ B1 [1]
- (ii)** contrast is difference in degree of blackening (of regions of the image) B1
 μ (very) similar so similar absorption of radiation (for same thickness) so little contrast A1 [2]
- 12 (a) (i)** loudspeaker/doorbell/telephone etc. B1 [1]
- (ii)** television set/audio amplifier etc. B1 [1]
- (iii)** satellite/satellite dish/mobile phone etc. B1 [1]
- (b)** e.g. lower attenuation/fewer repeaters
more secure
less prone to noise/interference
physically smaller/less weight
lower cost
greater bandwidth
(any two sensible suggestions, 1 each) B2 [2]
- (c) (i)** ratio = $25 + (62 \times 0.21)$ C1
= 38 dB A1 [2]
- (ii)** ratio / dB = $10 \lg (P_2 / P_1)$ C1
 $38 = 10 \lg (P / \{9.2 \times 10^{-6}\})$
- $P = 58 \text{ mW}$ or $5.8 \times 10^{-2} \text{ W}$ A1 [2]
(allow 1/2 for missing 10 in equation)

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- 13 (a) (i) to align nuclei/protons B1
to cause Larmor/precessional frequency to be in r.f. region B1 [2]
- (ii) Larmor/precessional frequency depends on (applied magnetic) field strength B1
knowing field strength enables (region of precessing) nuclei to be located M1
by knowing the frequency A1 [3]
- (b) $E = 2.82 \times 10^{-26} \times B$
 $6.63 \times 10^{-34} \times 42 \times 10^6 = 2.82 \times 10^{-26} \times B$ C1
 $B = 0.99 \text{ T}$ A1 [2]