

MARK SCHEME for the October/November 2012 series

9702 PHYSICS

9702/41

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

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Page 2	Mark Scheme	Syllabus	Paper
	GCE AS/A LEVEL – October/November 2012	9702	41

Section A

- 1 (a) force is proportional to the product of the masses and inversely proportional to the square of the separation
either point masses or separation $\gg$ size of masses M1 A1 [2]
- (b) (i) gravitational force provides the centripetal force
 $mv^2/r = GMm/r^2$ and $E_K = \frac{1}{2}mv^2$
hence $E_K = GMm/2r$ B1 M1 A0 [2]
- (ii) 1. $\Delta E_K = \frac{1}{2} \times 4.00 \times 10^{14} \times 620 \times (\{7.30 \times 10^6\}^{-1} - \{7.34 \times 10^6\}^{-1})$
 $= 9.26 \times 10^7 \text{ J}$ (*ignore any sign in answer*) C1 A1 [2]
(*allow $1.0 \times 10^8 \text{ J}$ if evidence that E_K evaluated separately for each r*)
2. $\Delta E_P = 4.00 \times 10^{14} \times 620 \times (\{7.30 \times 10^6\}^{-1} - \{7.34 \times 10^6\}^{-1})$
 $= 1.85 \times 10^8 \text{ J}$ (*ignore any sign in answer*) C1 A1 [2]
(*allow 1.8 or $1.9 \times 10^8 \text{ J}$*)
- (iii) *either $(7.30 \times 10^6)^{-1} - (7.34 \times 10^6)^{-1}$ or ΔE_K is positive / E_K increased*
speed has increased M1 A1 [2]
- 2 (a) (i) sum of potential energy and kinetic energy of atoms / molecules / particles
reference to random M1 A1 [2]
- (ii) no intermolecular forces B1
no potential energy B1
internal energy is kinetic energy (of random motion) of molecules B1 [3]
(*reference to random motion here then allow back credit to (i) if M1 scored*)
- (b) kinetic energy $\propto$ thermodynamic temperature B1
either temperature in Celsius, not kelvin so incorrect
or temperature in kelvin is not doubled B1 [2]
- 3 (a) temperature of the spheres is the same B1
no (net) transfer of energy between the spheres B1 [2]
- (b) (i) power = $m \times c \times \Delta\theta$ where m is mass per second C1
 $3800 = m \times 4.2 \times (42 - 18)$ C1
 $m = 38 \text{ g s}^{-1}$ A1 [3]
- (ii) some thermal energy is lost to the surroundings
so rate is an overestimate M1 A1 [2]
- 4 (a) straight line through origin M1
shows acceleration proportional to displacement A1
negative gradient M1
shows acceleration and displacement in opposite directions A1 [4]

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- (b) (i) 2.8 cm A1 [1]
- (ii) *either* gradient = ω^2 and $\omega = 2\pi f$ or $a = -\omega^2 x$ and $\omega = 2\pi f$ C1
 gradient = $13.5 / (2.8 \times 10^{-2}) = 482$
 $\omega = 22 \text{ rad s}^{-1}$ C1
 frequency = $(22/2\pi) = 3.5 \text{ Hz}$ A1 [3]
- (c) e.g. lower spring may not be extended
 e.g. upper spring may exceed limit of proportionality / elastic limit
 (any sensible suggestion) B1 [1]
- 5 (a) (i) ratio of charge and potential (difference) / voltage
 (ratio must be clear) B1 [1]
- (ii) capacitor has equal magnitudes of (+)ve and (-)ve charge B1
total charge on capacitor is zero (so does not store charge) B1
 (+)ve and (-)ve charges to be separated M1
 work done to achieve this so stores energy A1 [4]
- (b) (i) capacitance of Y and Z together is $24 \mu\text{F}$ C1
 $1/C = 1/24 + 1/12$
 $C = 8.0 \mu\text{F}$ (allow 1 s.f.) A1 [2]
- (ii) some discussion as to why all charge of one sign on one plate of X B1
 $Q = (CV) = 8.0 \times 10^{-6} \times 9.0$ M1
 $= 72 \mu\text{C}$ A0 [2]
- (iii) 1. $V = (72 \times 10^{-6}) / (12 \times 10^{-6})$
 $= 6.0 \text{ V}$ (allow 1 s.f.) (allow 72/12) A1 [1]
2. *either* $Q = 12 \times 10^{-6} \times 3.0$ or charge is shared between Y and Z C1
 charge = $36 \mu\text{C}$ A1 [2]
 Must have correct voltage in (iii)1 if just quote of $36 \mu\text{C}$ in (iii)2.
- 6 (a) (i) particle must be moving M1
 with component of velocity normal to magnetic field A1 [2]
- (ii) $F = Bqv \sin \theta$ M1
 q , v and θ explained A1 [2]
- (b) (i) face BCGF shaded A1 [1]
- (ii) between face BCGF and face ADHE A1 [1]
- (c) potential difference gives rise to an electric field M1
either $F_E = qE$ (no need to explain symbols)
 or electric field gives rise to force (on an electron) A1 [2]

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- 7 (a) induced e.m.f./current produces effects / acts in such a direction / tends to oppose the change causing it M1 A1 [2]
- (b) (i) 1. to reduce flux losses/increase flux linkage/easily magnetised and demagnetised B1 [1]
2. to reduce energy / heat losses (*do not allow 'to prevent energy losses'*) caused by eddy currents M1 A1 [2]
(*allow 1 mark for 'reduce eddy currents'*)
- (ii) alternating current / voltage B1
gives rise to (changing) flux in core B1
flux links the secondary coil M1
(by Faraday's law) changing flux induces e.m.f. (in secondary coil) A1 [4]
- 8 (a) discrete quantity / packet / quantum of energy of electromagnetic radiation B1
energy of photon = Planck constant $\times$ frequency B1 [2]
- (b) threshold frequency (1)
rate of emission is proportional to intensity (1)
max. kinetic energy of electron dependent on frequency (1)
max. kinetic energy independent of intensity (1)
(*any three, 1 each, max 3*) B3 [3]
- (c) *either* $E = hc/\lambda$ *or* $hc/\lambda = eV$ C1
 $\lambda = 450 \text{ nm}$ to give work function of 3.5 eV
energy = 4.4×10^{-19} or 2.8 eV to give $\lambda = 355 \text{ nm}$ M1
 $2.8 \text{ eV} < 3.5 \text{ eV}$ so no emission $355 \text{ nm} < 450 \text{ nm}$ so no A1 [3]
- or* work function = 3.5 eV
threshold frequency = $8.45 \times 10^{14} \text{ Hz}$ C1
 $450 \text{ nm} = 6.67 \times 10^{14} \text{ Hz}$ M1
 $6.67 \times 10^{14} \text{ Hz} < 8.45 \times 10^{14} \text{ Hz}$ A1

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Section B

- 9 (a) e.g. zero output impedance/resistance
infinite input impedance/resistance
infinite (open loop) gain
infinite bandwidth
infinite slew rate
1 each, max. 3 B3 [3]
- (b) (i) graph: square wave M1
correct cross-over points where $V_2 = V_1$ A1
amplitude 5V A1
correct polarity (*positive at $t = 0$*) A1 [4]
- (ii) correct symbol for LED M1
diodes connected correctly between V_{OUT} and earth A1
correct polarity consistent with graph in (i) A1 [3]
(*R points 'down' if (i) correct*)
- 10 X-ray images taken from different angles / X-rays directed from different angles B1
of one section/slice (1)
all images in the same plane (1)
images combined to give image of section/slice B1
images of successive sections/slices combined B1
image formed using a computer B1
image formed is 3D image (1)
that can be rotated / viewed from different angles (1)
(*four B-marks plus any two additional marks*) B2 [6]
- 11 (a) e.g. noise can be eliminated / filtered / signal can be regenerated
extra bits can be added to check for errors
multiplexing possible
digital circuits are more reliable / cheaper
data can be encrypted for security
any sensible advantages, 1 each, max. 3 B3 [3]
- (b) (i) 1. higher frequencies can be reproduced B1 [1]
2. smaller changes in loudness / amplitude can be detected B1 [1]
- (ii) bit rate = $44.1 \times 10^3 \times 16$ C1
= $7.06 \times 10^5 \text{ s}^{-1}$
number = $7.06 \times 10^6 \times 340$
= 2.4×10^8 A1 [2]
- 12 (a) (i) signal in one wire (pair) is picked up by a neighbouring wire (pair) B1 [1]
- (ii) outer of coaxial cable is earthed B1
outer shields the core from noise / external signals B1 [2]

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- (b) attenuation per unit length = $1/L \times 10 \lg(P_2/P_1)$ C1
- signal power at receiver = $10^{2.5} \times 3.8 \times 10^{-8}$
- $= 1.2 \times 10^{-5} \text{ W}$ C1
- attenuation in wire pair = $10 \lg(\{3.0 \times 10^{-3}\} / \{1.2 \times 10^{-5}\})$
- $= 24 \text{ dB}$ C1
- attenuation per unit length = $24 / 1.4$
- $= 17 \text{ dB km}^{-1}$ A1 [4]
- (other correct methods of calculation are possible)*

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Section A

- 1 (a) (i) number of molecules B1 [1]
- (ii) mean square speed B1 [1]
- (b) (i) 1. $pV = nRT$
 $n = (6.1 \times 10^5 \times 2.1 \times 10^4 \times 10^{-6}) / (8.31 \times 285)$
 $n = 5.4 \text{ mol}$ C1
C1
A1 [3]
2. either $N = nN_A$
 $= 5.4 \times 6.02 \times 10^{23}$
 $= 3.26 \times 10^{24}$ C1
A1
or
 $pV = NkT$
 $N = (6.1 \times 10^5 \times 2.1 \times 10^4 \times 10^{-6}) / (1.38 \times 10^{-23} \times 285)$ (C1)
 $N = 3.26 \times 10^{24}$ (A1) [2]
- (ii) either $6.1 \times 10^5 \times 2.1 \times 10^{-2} = \frac{1}{3} \times 3.25 \times 10^{24} \times 4 \times 1.66 \times 10^{-27} \times \langle c^2 \rangle$ C1
 $\langle c^2 \rangle = 1.78 \times 10^6$ C1
 $c_{\text{RMS}} = 1.33 \times 10^3 \text{ m s}^{-1}$ A1
or
 $\frac{1}{2} \times 4 \times 1.66 \times 10^{-27} \times \langle c^2 \rangle = \frac{3}{2} \times 1.38 \times 10^{-23} \times 285$ (C1)
 $\langle c^2 \rangle = 1.78 \times 10^6$ (C1)
 $c_{\text{RMS}} = 1.33 \times 10^3 \text{ m s}^{-1}$ (A1) [3]
- 2 (a) (i) 1. 0.1 s, 0.3 s, 0.5 s, etc (*any two*) A1 [1]
2. either 0, 0.4 s, 0.8 s, 1.2 s
or
0.2 s, 0.6 s, 1.0 s (*any two*) A1 [1]
- (ii) period = 0.4 s C1
frequency = $(1/0.4 =) 2.5 \text{ Hz}$ A1 [2]
- (iii) phase difference = 90° or $\frac{1}{2} \pi \text{ rad}$ B1 [1]
- (b) frequency = 2.4 – 2.5 Hz B1 [1]
- (c) e.g. attach sheet of card to trolley M1
increases damping / frictional force A1
e.g. reduce oscillator amplitude (M1)
reduces power/energy input to system (A1) [2]

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- 3 (a) (i) (tangent to line gives) direction of force on a (small test) mass B1 [1]
- (ii) (tangent to line gives) direction of force on a (small test) charge
charge is positive M1
A1 [2]
- (b) similarity:
e.g. radial fields
lines normal to surface
greater separation of lines with increased distance from sphere
field strength $\propto 1 / (\text{distance to centre of sphere})^2$
(allow any sensible answer) B1
- difference:
e.g. gravitational force (always) towards sphere B1
electric force direction depends on sign of charge on sphere / towards or
away from sphere B1
e.g. gravitational field/force is attractive (B1)
electric field/force is attractive or repulsive (B1)
(allow any sensible comparison) [3]
- (c) gravitational force = $1.67 \times 10^{-27} \times 9.81$
= $1.6 \times 10^{-26} \text{ N}$ A1
electric force = $1.6 \times 10^{-19} \times 270 / (1.8 \times 10^{-2})$ C1
= $2.4 \times 10^{-15} \text{ N}$ A1
electric force very much greater than gravitational force B1 [4]
- 4 (a) force on proton is normal to velocity and field M1
provides centripetal force (for circular motion) A1 [2]
- (b) magnetic force = Bqv B1
centripetal force = $mr\omega^2$ or mv^2/r B1
 $v = r\omega$ B1
 $Bqv = Bqr\omega = mr\omega^2$
 $\omega = Bq/m$ A1 [4]
- 5 (a) either $\phi = BA \sin \theta$ M1
where A is the area (through which flux passes)
 θ is the angle between B and (plane of) A A1
or
 $\phi = BA$ (M1)
where A is area normal to B (A1) [2]
- (b) graph: V_H constant and non zero between the poles and zero outside M1
sharp increase/decrease at ends of magnet A1 [2]

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- (c) (i) (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage) M1 A1 [2]
- (ii) short pulse on entering and on leaving region between poles pulses approximately the same shape but opposite polarities e.m.f. zero between poles and outside M1 A1 A1 [3]
- 6 (a) (i) connection to 'top' of resistor labelled as positive B1 [1]
- (ii) diode B and diode D B1 [1]
- (b) (i) $V_P = 4.0\text{ V}$
mean power = $V_P^2/2R$
 $= 4^2 / (2 \times 2700)$
 $= 2.96 \times 10^{-3}\text{ W}$ C1 C1 A1 [3]
- (ii) capacitor, correct symbol, connected in parallel with R B1 [1]
- (c) graph: half-wave rectification same period and same peak value M1 A1 [2]
- 7 (a) wavelength associated with a particle that is moving M1 A1 [2]
- (b) (i) kinetic energy = $1.6 \times 10^{-19} \times 4700$
 $= 7.52 \times 10^{-16}\text{ J}$
either energy = $p^2/2m$ *or* $E_K = \frac{1}{2}mv^2$ *and* $p = mv$ C1
 $p = \sqrt{(7.52 \times 10^{-16} \times 2 \times 9.1 \times 10^{-31})}$ C1
 $= 3.7 \times 10^{-23}\text{ N s}$
 $\lambda = h/p$ C1
 $= (6.63 \times 10^{-34}) / (3.7 \times 10^{-23})$
 $= 1.8 \times 10^{-11}\text{ m}$ A1 [5]
- (ii) wavelength is about separation of atoms can be used in (electron) diffraction B1 B1 [2]
- 8 (a) (i) $x = 2$ A1 [1]
- (ii) *either* beta particle *or* electron B1 [1]
- (b) (i) mass of separate nucleons = $\{(92 \times 1.007) + (143 \times 1.009)\}\text{ u}$
 $= 236.931\text{ u}$
binding energy = $236.931\text{ u} - 235.123\text{ u}$
 $= 1.808\text{ u}$ C1 C1 A1 [3]

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- (ii) $E = mc^2$ C1
energy = $1.808 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$
= $2.7 \times 10^{-10} \text{ J}$ C1
binding energy per nucleon = $(2.7 \times 10^{-10}) / (235 \times 1.6 \times 10^{-13})$ M1
= 7.18 MeV A0 [3]

- (c) energy released = $(95 \times 8.09) + (139 \times 7.92) - (235 \times 7.18)$ C1
= 1869.43 – 1687.3
= 182 MeV A1 [2]
(allow calculation using mass difference between products and reactants)

Section B

- 9 (a) light-emitting diode (allow LED) B1 [1]
- (b) gives a high or a low output / +5 V or –5 V output M1
dependent on which of the inputs is at a higher potential A1 [2]
- (c) (i) provides a reference/constant potential B1 [1]
(ii) determines temperature of ‘switch-over’ B1 [1]
- (d) (i) relay A1 [1]
(ii) relay connected correctly for op-amp output and high-voltage circuit B1
diode with correct polarity in output from op-amp B1 [2]
- 10 (a) background reading = 19 B1 [1]
- (b) A = 2 A1
B = 5 A1
C = 9 A1
D = 3 A1 [4]
(Allow 1 mark if only subtracts background reading)
- (c) (i) either 5, 14 or 14, 5 (A+D, B+C or v.v.) B1 [1]
(ii) Three numbers and ‘inside’ number is 8 (B+D) B1
Three numbers and ‘outside’ numbers are either 2,9 or 9,2 (A,C or v.v.) B1 [2]
- 11 (a) high frequency wave B1
the amplitude or the frequency is varied M1
the variation represents the information signal /
in synchrony with (the displacement of) the information signal. A1 [3]

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- (b) e.g. shorter aerial required
longer transmission range / lower transmitter power / less attenuation
allows more than one station in a region
less distortion
(allow any three sensible suggestions, 1 mark each)

B3 [3]

12 (a) (i) e.g. linking a (land) telephone to the (local) exchange

B1 [1]

(ii) e.g. connecting an aerial to a television

B1 [1]

(iii) e.g. linking a ground station to a satellite

B1 [1]

- (b) (i) attenuation = $10 \lg (P_2 / P_1)$
total attenuation = 2.1×40 (= 84 dB)
 $84 = 10 \lg (\{450 \times 10^{-3}\} / P)$
 $P = 1.8 \times 10^{-9} \text{ W}$
(answer $1.1 \times 10^8 \text{ W}$ scores 1 mark only)

C1

C1

A1 [3]

- (ii) maximum attenuation = $10 \lg (\{450 \times 10^{-3}\} / \{7.2 \times 10^{-11}\})$
= 98 dB
maximum length = $98 / 2.1$
= 47 km

C1

A1 [2]