

UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS
GCE Advanced Subsidiary Level and GCE Advanced Level

**MARK SCHEME for the October/November 2009 question paper
for the guidance of teachers**

9702 PHYSICS

9702/41

Paper 41 (A2 Structured Questions),
maximum raw mark 100

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Page 2	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	41

Section A

- 1 (a) $F \propto Mm / R^2$ (words or explained symbols) M1
either M and m are point masses
or $R \gg$ diameter of masses ... (do not allow 'size') A1 [2]
- (b) (i) equatorial orbit B1
period 24 hours / same angular speed B1
from west to east / same direction of rotation B1 [3]
(allow one of the last two marks for 'always overhead' if 2nd or 3rd marks not scored)
- (ii) gravitational force provides centripetal force
/ gives rise to centripetal acceleration(in 'words') B1
 $GM / x^2 = x\omega^2$ M1
 $g = GM / R^2$ M1
to give $gR^2 = x^3\omega^2$ A0 [3]
- (iii) $\omega = 2\pi / (24 \times 3600) = 7.27 \times 10^{-5} \text{ rad s}^{-1}$ C1
 $9.81 \times (6.4 \times 10^6)^2 = x^3 \times (7.27 \times 10^{-5})^2$ C1
 $x^3 = 7.6 \times 10^{22}$
 $x = 4.2 \times 10^7 \text{ m}$ A1 [3]
(use of $g = 10 \text{ m s}^{-2}$, loses 1 mark but once only in the Paper)

[Total: 11]

- 2 (a) either $pV = NkT$ or $pV = nRT$ and $n = N / N_A$ C1
clear correct substitution e.g.
 $2.5 \times 10^5 \times 4.5 \times 10^3 \times 10^{-6} = N \times 1.38 \times 10^{-23} \times 290$ M1
 $N = 2.8 \times 10^{23}$ A0 [2]
(allow 1 mark for calculation of $n = 0.467 \text{ mol}$)
- (b) (i) volume = $(1.2 \times 10^{-10})^3 \times 2.8 \times 10^{23}$ or $\frac{4}{3} \pi r^3 \times 2.8 \times 10^{23}$ C1
= $4.8 \times 10^{-7} \text{ m}^3$ A1 [2]
 $2.53 \times 10^{-7} \text{ m}^3$
- (ii) either $4.5 \times 10^3 \text{ cm}^3 \gg 0.48 \text{ cm}^3$ or ratio of volumes is about 10^{-4} B1
justified because volume of molecules is negligible B1 [2]

[Total: 6]

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	41

- 3 (a) e.g. two objects of different masses at same temperature (M1)
 same material would have different amount of heat (A1)
 e.g. temperature shows direction of heat transfer (M1)
 from high to low regardless of objects (A1)
 e.g. when substance melts/boils (M1)
 heat input but no temperature change (A1)
 any two, M1 + A1 each, max 4 [4]
- (b) (i) energy losses (to the surroundings) M1
 either increase as the temperature rises
 or rise is zero when heat loss = heat input A1 [2]
- (ii) idea of input power = maximum rate of heat loss C1
 power = $m \times c \times \Delta\theta / \Delta t$
 $54 = 0.96 \times c \times 3.7 / 60$ C1
 $c = 910 \text{ J kg}^{-1} \text{ K}^{-1}$ A1 [3]
- [Total: 9]**
- 4 (a) (i) amplitude = 0.2 mm A1 [1]
- (ii) period = 1.2 ms C1
 frequency = 830 Hz A1 [2]
- (b) (i) any two of zero, 0.6 ms and 1.2 ms A1 [1]
- (ii) any two of 0.3 ms, 0.9 ms, 1.5 ms A1 [1]
- (c) either $v = \omega x_0 = 2\pi f x_0$
 $= 2\pi \times 830 \times 0.2 \times 10^{-3} = 1.05 \text{ m s}^{-1}$
 or slope of graph = 1.0 m s^{-1} (allow $\pm 0.1 \text{ m s}^{-1}$) C1
 $E_K = \frac{1}{2}mv^2$
 $= \frac{1}{2} \times 2.5 \times 10^{-3} \times 1.05^2$ C1
 $= 1.4 \times 10^{-3} \text{ J}$ A1 [3]
- (d) (i) large / maximum amplitude of vibration B1
 when impressed frequency equals natural frequency of vibration B1 [2]
- (ii) e.g. metal panels on machinery vibrate / oscillate (M1)
 motor in machine impresses frequency on panel (A1)
 e.g. car suspension system vibrates / oscillates..... (M1)
 going over bumps would give large amplitude vibrations (A1)
 any feasible example, M1 + A1 [2]

[Total: 12]

Page 4	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	41

- 5 (a) work done per / on unit positive charge M1
moving charge from infinity to the point A1 [2]
- (b) (i) α -particle and gold nucleus repel each other B1
all kinetic energy of α -particle converted into electric potential energy B1 [2]
- (ii) 1 potential energy = $(79 \times 2 \times \{1.6 \times 10^{-19}\}^2) / (4\pi \times 8.85 \times 10^{-12} \times d)$ C1
kinetic energy = $4.8 \times 1.6 \times 10^{-13} = 7.68 \times 10^{-13} \text{ J}$ C1
equating to give $d = 4.7 \times 10^{-14} \text{ m}$ A1 [3]
- (ii) 2 $F = Qq / 4\pi\epsilon_0 d \times 1 / d = 7.68 \times 10^{-13} \times 1 / (4.7 \times 10^{-14})$ C1
 $= 16 \text{ N}$ A1 [2]
- [Total: 9]**
- 6 (a) concentric circles ...*(at least three lines)* M1
with increasing separation A1
correct direction clear B1 [3]
- (b) (i) correct position to left of wire B1 [1]
- (ii) $B = (4\pi \times 10^{-7} \times 1.7) / (2\pi \times 1.9 \times 10^{-2})$ C1
 $= 1.8 \times 10^{-5} \text{ T}$ A1 [2]
- (c) distance $\propto$ current C1
current = $(2.8 / 1.9) \times 1.7$
 $= 2.5 \text{ A}$ A1 [2]
- [Total: 8]**
- 7 (a) e.g. more (output) power available
e.g. less ripple for same smoothing capacitor
any sensible suggestion B1 [1]
- (b) (i) curve showing half-wave rectification B1 [1]
- (ii) similar to (i) but phase shift of 180° B1 [1]
- (c) (i) correct symbol, connected in parallel with R B1 [1]
- (ii) 1 larger capacitor / second capacitor in parallel with R B1 [1]
(not increase R)
2 same peak values B1
correct shape giving less ripple B1 [2]
- [Total: 7]**

Page 5	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	41

- 8 (a) neutron is a single nucleon / particle B1 [1]
- (b) binding energy = $4 \times 7.07 \times 1.6 \times 10^{-13}$ C1
 $= 4.52 \times 10^{-12} \text{ J}$
binding energy = $c^2 \Delta m$ C1
 $4.52 \times 10^{-12} = (3.0 \times 10^8)^2 \times \Delta m$
 $\Delta m = 5.03 \times 10^{-29} \text{ kg}$ A1 [3]
- (c) (i) fusion(do not allow fussion) B1 [1]
- (ii) $(2 \times 1.12) + 3x = 28.28$ C1
..... -17.7 C1
 $x = 2.78 \text{ MeV per nucleon}$ A1 [3]
(use of $+17.7$ gives $x = 14.6 \text{ MeV}$, allow 1 mark only)

[Total: 8]

Page 6	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	41

Section B

- 9 (a) resistance of wire = $\rho L / A$ B1
as crack widens, L increases M1
and A decreases M1
so resistance increases A0 [3]

- (b) $\Delta L / L = \Delta R / R$ B1
= $(146.2 - 143.0) / 143.0 \times 100$ C1
 $\Delta L / L = 2.24\%$ A1 [3]

[Total: 6]

- 10 at 16 °C, $V^+ = 1.00 \text{ V}$ and $V^- = 0.98 \text{ V}$ or $V^+ > V^-$ B1
at 16 °C, output is positive M1
diode R is 'on' and diode G is 'off' A1
as temperature rises, diode R goes 'off' and diode G goes 'on' B1 [4]
(allow e.c.f. from 2nd to 3rd marks and also 3rd to 4th marks)

[Total: 4]

- 11 large / 1 T magnetic field applied along body (allow 'across') (1)
r.f. pulse applied (1)
causes hydrogen nuclei / protons (1)
to resonate (1)
(nuclei) return to equilibrium state / after relaxation time (1)
r.f. (pulse) emitted (1)
pulses detected, processed and displayed (1)
resonant frequency depends on magnetic field strength (1)
calibrated non-uniform field enables nuclei to be located (1)
any six points, one mark each B6 [6]

[Total: 6]

Page 7	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	41

- 12 (a)** e.g. signal can be regenerated M1
so that there is minimal noise A1
e.g. extra data can be added M1
so that signal can be checked for errors A1 [4]
(any two, sensible suggestions, M1 + A1, max 4)
- (b) (i)** 1101 B1 [1]
(ii) 5 B1 [1]
- (c) (i)** block X: serial-to parallel B1
block Y: DAC / digital-to-analogue (converter) B1 [2]
- (ii)** takes the simultaneous / all bits of a number M1
and transmits them one after another / down a single line A1 [2]
- (d)** increase number of bits in digital number at each sampling M1
so that step height is reduced A1
increase sampling frequency / reduce time between samples M1
so that depth / width of step is reduced A1 [4]
(do not allow 'smoother output')

[Total: 14]

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	GCE A/AS LEVEL – October/November 2009	9702	42

Section A

- 1 (a) (i) force per (unit) mass(*ratio idea essential*) B1 [1]
- (ii) $g = GM / R^2$ C1
 $9.81 = (6.67 \times 10^{-11} \times M) / (6.38 \times 10^6)^2$ (*all 3 s.f*) M1
 $M = 5.99 \times 10^{24}$ kg A0 [2]
- (b) (i) either $GM = \omega^2 r^3$ or $gR^2 = \omega^2 r^3$ C1
either $6.67 \times 10^{-11} \times 5.99 \times 10^{24} = \omega^2 \times (2.86 \times 10^7)^3$
or $9.81 \times (6.38 \times 10^6)^2 = \omega^2 \times (2.86 \times 10^7)^3$ C1
 $\omega = 1.3 \times 10^{-4} \text{ rad s}^{-1}$ A1 [3]
(*use of $r = 2.22 \times 10^7 \text{ m}$ scores max 2 marks*)
- (ii) period of orbit = $2\pi / \omega$ C1
= $4.8 \times 10^4 \text{ s}$ (= 13.4 hours) A1
period for geostationary satellite is 24 hours (= $8.6 \times 10^4 \text{ s}$) A1
so no A0 [3]
- (c) satellite can then provide cover at Poles B1 [1]
- [Total: 10]**
- 2 (a) sum of kinetic and potential energies of molecules / particles / atoms M1
random (distribution) A1 [2]
- (b) $+\Delta U$: increase in internal energy B1
 $+q$: heating of / heat supplied to system B1
 $+w$: work done on system B1 [3]
- (c) (i) work done = $p\Delta V$ C1
= $1.0 \times 10^5 \times (2.1 - 1.8) \times 10^{-3}$
= 30 J M1
 $w = 30 \text{ J}$, $q = 0$ so $\Delta U = 30 \text{ J}$ A1 [3]
- (ii) these three marks were removed, as insufficient data was given in the question.
- [Total: 8]**

Page 3	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	42

- 3 (a) straight line through origin B1
negative gradient B1 [2]

- (b) $a = -\omega^2 x$ and $\omega = 2\pi f$ C1
 $750 = (2\pi f)^2 \times 0.3 \times 10^{-3}$ C1
 $f = 250 \text{ Hz}$ A1 [3]

- (c) straight line between $(-0.3, +190)$ and $(+0.3, -190)$ A2 [2]
(allow 1 mark for end of line incorrect by one grid square or line does not extend to $\pm 0.3 \text{ mm}$)

[Total: 7]

- 4 (a) charge / potential (ratio must be clear) B1 [1]

- (b) potential (at surface of sphere) = $Q / 4\pi\epsilon_0 R$ M1
 $C = Q / V = 4\pi\epsilon_0 R$ A0 [1]

- (c) (i) $C = 4\pi \times 8.85 \times 10^{-12} \times 0.63$ C1
 $= 7.0 \times 10^{-11}$ A1
farad / F B1 [3]

- (ii) energy = $\frac{1}{2}CV^2$ C1
 $0.25 \times \frac{1}{2}C \times (1.2 \times 10^6)^2 = \frac{1}{2}CV^2$ C1
 $V = 6.0 \times 10^5 \text{ V}$ A1 [3]
(use of 0.75 rather than 0.25, allow max 2 marks)

[Total: 8]

- 5 (a) (i) concentric circles, anticlockwise (minimum 3 circles) M1
separation of lines increases with distance from wire A1 [2]

- (ii) direction from Y towards X A1 [1]

- (b) (i) flux density at wire Y = $(4\pi \times 10^{-7} \times 5.0) / (2\pi \times 2.5 \times 10^{-2})$ C1
 $= 4.0 \times 10^{-5} \text{ T}$ C1
force per unit length = BI
 $= 4.0 \times 10^{-5} \times 7.0$ C1
 $= 2.8 \times 10^{-4} \text{ N}$ A1 [4]

- (ii) either force depends on product of the currents in the two wires M1
so equal A1
or (isolated system so) Newton's 3rd law applies (M1)
so equal (A1) [2]

[Total: 9]

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	GCE A/AS LEVEL – October/November 2009	9702	42

- 6 (a) (i) e.m.f. induced proportional / equal to M1
rate of change of (magnetic) flux (linkage) A1 [2]
- (ii) e.m.f. (induced) only when flux is changing / cut B1
direct current gives constant flux B1 [2]
- (b) (i) (induced) e.m.f. / current acts in such a direction to produce effects B1
to oppose the change causing it B1 [2]
- (ii) (induced) current in secondary produces magnetic field M1
opposes (changing) field produced in primary M1
so not in phase A0 [2]
- (c) (i) alternating means that voltage / current is easy to change B1 [1]
- (ii) high voltage means less power / energy loss (during transmission) B1 [1]

[Total: 10]

- 7 (a) each line corresponds to a (specific) photon energy B1
photon emitted when electron changes its energy level B1
discrete energy changes so discrete levels B1 [3]
- (b) (i) $E = hc / \lambda$... (allow ratio ideas) C1
 $= (6.63 \times 10^{-34} \times 3.0 \times 10^8) / (486 \times 10^{-9})$
 $= 4.09 \times 10^{-19} \text{ J}$ A1 [2]
- (ii) four transitions to/from $-5.45 \times 10^{-19} \text{ J}$ level B1
all transitions shown from higher to lower energy (level) B1 [2]

[Total: 7]

- 8 (a) (constant) probability of decay M1
per unit time A1 [2]
(reference to decay of isotope / mass / sample / nuclide, allow max 1 mark)

- (b) *either* when time = $t_{1/2}$, $N = \frac{1}{2}N_0$
or $\frac{1}{2}N_0 = N \exp(-\lambda t_{1/2})$ M1
either $2 = \exp(\lambda t_{1/2})$
or $\frac{1}{2} = \exp(-\lambda t_{1/2})$ M1
(taking logs), $\ln 2 = 0.693 = \lambda t_{1/2}$ A1 [3]

- (c) $A = \lambda N$
 $1.8 \times 10^5 = N \times (0.693 / \{1.66 \times 10^8\})$ C1
 $N = 4.3 \times 10^{13}$
mass = $60 \times (N / N_A)$ or $60 \times N \times u$ C1
 $= (60 \times 4.3 \times 10^{13}) / (6.02 \times 10^{23})$
 $= 4.3 \times 10^{-9} \text{ g}$ A1 [3]

[Total: 8]

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	GCE A/AS LEVEL – October/November 2009	9702	42

Section B

- 9 (a) e.g. reduces gain
increases bandwidth
less distortion
greater stability(1 each, max 2) B2 [2]

- (b) gain = $-R_F / R_i$
= $-8.0 / 4.0$ M1
numerical value is 2 A0 [1]

- (c) (i) 2, 6 and 7 A1 [1]

- (ii) e.g. digital-to-analogue converter (*allow DAC*)
adding / mixing signals with 'weighting' B1 [1]

[Total: 5]

- 10 (a) (i) e.m. radiation / photons is produced whenever a charged particle
is accelerated M1
wavelength depends on magnitude of acceleration A1
electrons have a distribution of accelerations A1
so continuous spectrum A0 [3]

- (ii) *either* when electron loses all its energy in one collision
or when energy of electron produces a single photon B1 [1]

- (b) (i) parallel beam (in matter) B1
 $I = I_0 \exp(-\mu x)$ M1
 I , I_0 , (μ) and x explained A1 [3]

- (ii) *either* low-energy photons absorbed (much) more readily
or low-energy photons (far) less penetrating B1
low-energy photons do not contribute to X-ray image B1
low energy photons could cause tissue damage B1 [3]

[Total: 10]

Page 6	Mark Scheme: Teachers' version	Syllabus	Paper
	GCE A/AS LEVEL – October/November 2009	9702	42

11 (a) amplitude modulation(*allow AM*) B1 [1]

(b) (i) frequency = 1 / period C1
 = 100 kHz A1 [2]

(ii) frequency = 10 kHz A1 [1]

(c) (i) vertical line at 100 kHz B1
 vertical lines at 90 kHz and 110 kHz B1
 lines at 90 kHz and 110 kHz same length and shorter than at 100 kHz B1 [3]

(ii) 20 kHz B1 [1]

[Total: 8]

12 (a) (i) base stations B1 [1]

(ii) cellular exchange B1 [1]

(b) base station / X sends / receives signal to / from handset B1
 call relayed to cellular exchange / Y (and on to PSTN) B1
 computer at cellular exchange monitors signal from base stations B1
 selects base station with strongest signal B1
 allocates a (carrier) frequency / time slot for the call B1 [5]

[Total: 7]