

**MARK SCHEME for the October/November 2010 question paper
for the guidance of teachers**

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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	GCE AS/A LEVEL – October/November 2010	9702	41

Section A

- 1 (a) force per unit mass *(ratio idea essential)* B1 [1]
- (b) graph: correct curvature M1
from $(R, 1.0g_S)$ & at least one other correct point A1 [2]
- (c) (i) fields of Earth and Moon are in opposite directions M1
either resultant field found by subtraction of the field strength
or any other sensible comment A1
so there is a point where it is zero A0 [2]
(allow $F_E = -F_M$ for 2 marks)
- (ii) $GM_E / x^2 = GM_M / (D - x)^2$ C1
 $(6.0 \times 10^{24}) / (7.4 \times 10^{22}) = x^2 / (60R_E - x)^2$ C1
 $x = 54R_E$ A1 [3]
- (iii) graph: $g = 0$ at least $\frac{2}{3}$ distance to Moon B1
 g_E and g_M in opposite directions M1
correct curvature (by eye) and $g_E > g_M$ at surface A1 [3]
- 2 (a) (i) no forces (of attraction or repulsion) between atoms / molecules / particles B1 [1]
- (ii) sum of kinetic and potential energy of atoms / molecules M1
due to random motion A1 [2]
- (iii) (random) kinetic energy increases with temperature M1
no potential energy
(so increase in temperature increases internal energy) A1 [2]
- (b) (i) zero A1 [1]
- (ii) work done $= p\Delta V$ C1
 $= 4.0 \times 10^5 \times 6 \times 10^{-4}$
 $= 240 \text{ J}$ *(ignore any sign)* A1 [2]
- (iii)
- | change | work done / J | heating / J | increase in internal energy / J |
|-------------------|---------------|-------------|---------------------------------|
| P $\rightarrow$ Q | +240 | -600 | -360 |
| Q $\rightarrow$ R | 0 | +720 | +720 |
| R $\rightarrow$ P | -840 | +480 | -360 |
- (correct signs essential)*
(each horizontal line correct, 1 mark – max 3) B3 [3]

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- 3 (a) (i) resonance B1 [1]
- (ii) amplitude 16 mm and frequency 4.6 Hz A1 [1]
- (b) (i) $a = (-)\omega^2 x$ and $\omega = 2\pi f$ C1
 $a = 4\pi^2 \times 4.6^2 \times 16 \times 10^{-3}$ C1
 $= 13.4 \text{ ms}^{-2}$ A1 [3]
- (ii) $F = ma$ C1
 $= 150 \times 10^{-3} \times 13.4$
 $= 2.0 \text{ N}$ A1 [2]
- (c) line always 'below' given line and never zero M1
peak is at 4.6 Hz (or slightly less) and flatter A1 [2]
- 4 (a) charge / potential (difference) (*ratio must be clear*) B1 [1]
- (b) (i) $V = Q / 4\pi\epsilon_0 r$ B1 [1]
- (ii) $C = Q / V = 4\pi\epsilon_0 r$ and $4\pi\epsilon_0$ is constant M1
so $C \propto r$ A0 [1]
- (c) (i) $r = C / 4\pi\epsilon_0$ C1
 $r = (6.8 \times 10^{-12}) / (4\pi \times 8.85 \times 10^{-12})$ C1
 $= 6.1 \times 10^{-2} \text{ m}$ A1 [3]
- (ii) $Q = CV = 6.8 \times 10^{-12} \times 220$
 $= 1.5 \times 10^{-9} \text{ C}$ A1 [1]
- (d) (i) $V = Q/C = (1.5 \times 10^{-9}) / (18 \times 10^{-12})$
 $= 83 \text{ V}$ A1 [1]
- (ii) *either* energy = $\frac{1}{2}CV^2$ C1
 $\Delta E = \frac{1}{2} \times 6.8 \times 10^{-12} \times 220^2 - \frac{1}{2} \times 18 \times 10^{-12} \times 83^2$ C1
 $= 1.65 \times 10^{-7} - 6.2 \times 10^{-8}$
 $= 1.03 \times 10^{-7} \text{ J}$ A1 [3]
- or* energy = $\frac{1}{2}QV$ (C1)
 $\Delta E = \frac{1}{2} \times 1.5 \times 10^{-9} \times 220 - \frac{1}{2} \times 1.5 \times 10^{-9} \times 83$ (C1)
 $= 1.03 \times 10^{-7} \text{ J}$ (A1)

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- 5 (a) field into (the plane of) the paper B1 [1]
- (b) force due to magnetic field provides the centripetal force B1
 $mv^2 / r = Bqv$ C1
 $B = (20 \times 1.66 \times 10^{-27} \times 1.40 \times 10^5) / (1.6 \times 10^{-19} \times 6.4 \times 10^{-2})$ B1
 $= 0.454 \text{ T}$ A0 [3]
- (c) (i) semicircle with diameter greater than 12.8 cm B1 [1]
- (ii) new flux density = $\frac{22}{20} \times 0.454$ C1
 $B = 0.499 \text{ T}$ A1 [2]
- 6 (a) (i) e.g. prevent flux losses / improve flux linkage B1 [1]
- (ii) flux in core is changing B1
e.m.f. / current (induced) in core B1
induced current in core causes heating B1 [3]
- (b) (i) that value of the direct current producing same (mean) power / heating in a resistor M1
A1 [2]
- (ii) power in primary = power in secondary M1
 $V_P I_P = V_S I_S$ A1 [2]
- 7 (a) (i) e.g. electron / particle diffraction B1 [1]
- (ii) e.g. photoelectric effect B1 [1]
- (b) (i) 6 A1 [1]
- (ii) change in energy = $4.57 \times 10^{-19} \text{ J}$
 $\lambda = hc / E$ C1
 $= (6.63 \times 10^{-34} \times 3.0 \times 10^8) / (4.57 \times 10^{-19})$
 $= 4.4 \times 10^{-7} \text{ m}$ A1 [2]
- 8 (a) splitting of a heavy nucleus (*not atom/nuclide*) M1
into two (lighter) nuclei of approximately same mass A1 [2]
- (b) ${}^1_0\text{n}$
 ${}^4_2\text{He}$ (*allow* ${}^4_2\alpha$) M2
 ${}^7_3\text{Li}$ A1 [3]
- (c) emitted particles have kinetic energy B1
range of particles in the control rods is short / particles stopped in rods /
lose kinetic energy in rods B1
kinetic energy of particles converted to thermal energy B1 [3]

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Section B

- 9 (a) (i) non-inverting (amplifier) B1 [1]
- (ii) $(G =) 1 + R_2 / R_1$ B1 [1]
- (b) (i) gain = $1 + 100 / 820$ C1
output = 17 mV A1 [2]
- (ii) 9V A1 [1]
(R_2 / R_1 scores 0 in (a)(ii) but possible 1 mark in each of (b)(i) and (b)(ii)
($1 + R_1 / R_2$) scores 0 in (a)(ii), no mark in (b)(i), possible 1 mark in (b)(ii)
($1 - R_2 / R_1$) or R_1 / R_2 scores 0 in (a)(ii), (b)(i) and (b)(ii))
- 10 (a) (i) density $\times$ speed of wave (in the medium) B1 [1]
- (ii) $\rho = (7.0 \times 10^6) / 4100$
 $= 1700 \text{ kg m}^{-3}$ A1 [1]
- (b) (i) $I = I_T + I_R$ B1 [1]
- (ii) 1. $\alpha = (0.1 \times 10^6)^2 / (3.1 \times 10^6)^2$ C1
 $= 0.001$ A1 [2]
2. $\alpha \approx 1$ A1 [1]
- (c) *either* very little transmission at an air-skin boundary M1
(almost) complete transmission at a gel-skin boundary M1
when wave travels in or out of the body A1 [3]
or no gel, majority reflection (M1)
with gel, little reflection (M1)
when wave travels in or out of the body (A1)
- 11 (a) (i) unwanted random power / signal / energy B1 [1]
- (ii) loss of (signal) power / energy B1 [1]
- (b) (i) *either* signal-to-noise ratio at mic. = $10 \lg (P_2 / P_1)$ C1
 $= 10 \lg (\{2.9 \times 10^{-6}\} / \{3.4 \times 10^{-9}\})$
 $= 29 \text{ dB}$ A1
maximum length = $(29 - 24) / 12$ C1
 $= 0.42 \text{ km} = 420 \text{ m}$ A1 [4]
- or* signal-to-noise ratio at receiver = $10 \lg (P_2 / P_1)$ (C1)
at receiver, $24 = 10 \lg (P / \{3.4 \times 10^{-9}\})$
 $P = 8.54 \times 10^{-7} \text{ W}$ (A1)
power loss in cables = $10 \lg (\{2.9 \times 10^{-6}\} / \{8.54 \times 10^{-7}\})$ (C1)
 $= 5.3 \text{ dB}$
length = $5.3 / 12 \text{ km}$
 $= 440 \text{ m}$ (A1)

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- (ii) use an amplifier M1
coupled to the microphone A1 [2]
(repeater amplifiers scores no mark)

- 12 (a) (carrier wave) transmitted from Earth to satellite (1)
satellite receives greatly attenuated signal (1)
signal amplified and transmitted back to Earth B1
at a different (carrier) frequency B1
different frequencies prevent swamping of uplink signal (1)
e.g. of frequencies used (6/4 GHz, 14/11 GHz, 30/20 GHz) (1)
(two B1 marks plus any two other for additional physics) B2 [4]

- (b) advantage: e.g. much shorter time delay M1
because orbits are much lower A1
e.g. whole Earth may be covered (M1)
in several orbits / with network (A1)
disadvantage: e.g. *either* must be tracked M1
or limited use in any one orbit A1 [4]
more satellites required for continuous operation

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- (c) (i) fields of Earth and Moon are in opposite directions M1
either resultant field found by subtraction of the field strength
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= $4.0 \times 10^5 \times 6 \times 10^{-4}$
= 240 J (*ignore any sign*) A1 [2]
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 $= 29 \text{ dB}$ A1
maximum length = $(29 - 24) / 12$ C1
 $= 0.42 \text{ km} = 420 \text{ m}$ A1 [4]
- or signal-to-noise ratio at receiver = $10 \lg (P_2 / P_1)$ (C1)
at receiver, $24 = 10 \lg (P / \{3.4 \times 10^{-9}\})$
 $P = 8.54 \times 10^{-7} \text{ W}$ (A1)
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length = $5.3 / 12 \text{ km}$
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(repeater amplifiers scores no mark)

- 12 (a) (carrier wave) transmitted from Earth to satellite (1)
satellite receives greatly attenuated signal (1)
signal amplified and transmitted back to Earth B1
at a different (carrier) frequency B1
different frequencies prevent swamping of uplink signal (1)
e.g. of frequencies used (6/4 GHz, 14/11 GHz, 30/20 GHz) (1)
(two B1 marks plus any two other for additional physics) B2 [4]

- (b) advantage: e.g. much shorter time delay M1
because orbits are much lower A1
e.g. whole Earth may be covered (M1)
in several orbits / with network (A1)
disadvantage: e.g. *either* must be tracked M1
or limited use in any one orbit A1 [4]
more satellites required for continuous operation

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Section A

- 1 (a) (i) rate of change of angle / angular displacement swept out by radius M1 A1 [2]
- (ii) $\omega \times T = 2\pi$ B1 [1]
- (b) centripetal force is provided by the gravitational force B1
either $mr(2\pi/T)^2 = GMm/r^2$ or $mr\omega^2 = GMm/r^2$ M1
 $r^3 \times 4\pi^2 = GM \times T^2$ A1
 $GM/4\pi^2$ is a constant (c) A1
 $T^2 = cr^3$ A0 [4]
- (c) (i) either $T^2 = (45/1.08)^3 \times 0.615^2$ or $T^2 = 0.30 \times 45^3$ C1
 $T = 165$ years A1 [2]
- (ii) speed = $(2\pi \times 1.08 \times 10^8) / (0.615 \times 365 \times 24 \times 3600)$ C1
= 35 km s^{-1} A1 [2]
- 2 (a) atoms / molecules / particles behave as elastic (identical) spheres (1)
volume of atoms / molecules negligible compared to volume of containing vessel (1)
time of collision negligible to time between collisions (1)
no forces of attraction or repulsion between atoms / molecules (1)
atoms / molecules / particles are in (continuous) random motion (1)
(any four, 1 each) B4 [4]
- (b) $pV = \frac{1}{3} Nm\langle c^2 \rangle$ and $pV = nRT$ or $pV = NkT$ B1
 $\frac{1}{3} Nm\langle c^2 \rangle = nRT$ or $= NkT$ and $\langle E_K \rangle = \frac{1}{2} m\langle c^2 \rangle$ B1
 $n = N/N_A$ or $k = R/N_A$ B1
 $\langle E_K \rangle = \frac{3}{2} \times R/N_A \times T$ A0 [3]
- (c) (i) reaction represents either build-up of nucleus from light nuclei M1
or build-up of heavy nucleus from nuclei A1 [2]
so fusion reaction
- (ii) proton and deuterium nucleus will have equal kinetic energies B1
 $1.2 \times 10^{-14} = \frac{3}{2} \times 8.31 / (6.02 \times 10^{23}) \times T$ C1
 $T = 5.8 \times 10^8 \text{ K}$ A1 [3]
(use of $E = 2.4 \times 10^{-14}$ giving $1.16 \times 10^9 \text{ K}$ scores 1 mark)
- (iii) either inter-molecular / atomic / nuclear forces exist B1
or proton and deuterium nucleus are positively charged / repel [1]

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- 3 (a) (i) 8.0 cm A1 [1]
- (ii) $2\pi f = 220$ C1
 $f = 35$ (condone unit) A1 [2]
- (iii) line drawn mid-way between AB and CD (allow ± 2 mm) B1 [1]
- (iv) $v = \omega a$ C1
 $= 220 \times 4.0$
 $= 880 \text{ cm s}^{-1}$ A1 [2]
- (b) (i) 1. line drawn 3 cm above AB (allow ± 2 mm) B1 [1]
2. arrow pointing upwards B1 [1]
- (ii) 1. line drawn 3 cm above AB (allow ± 2 mm) B1 [1]
2. arrow pointing downwards B1 [1]
- (iii) $v = \omega \sqrt{a^2 - x^2}$
 $= 220 \times \sqrt{4.0^2 - 2.0^2}$ C1
 $= 760 \text{ cm s}^{-1}$ A1 [2]
(incorrect value for x , 0/2 marks)
- 4 (a) (i) work done moving unit positive charge from infinity to the point M1
A1 [2]
- (ii) charge / potential (difference) (ratio must be clear) B1 [1]
- (b) (i) capacitance = $(2.7 \times 10^{-6}) / (150 \times 10^3)$ C1
(allow any appropriate values)
capacitance = 1.8×10^{-11} (allow 1.8 ± 0.05) A1 [2]
- (ii) either energy = $\frac{1}{2}CV^2$ or energy = $\frac{1}{2}QV$ and $Q = CV$ C1
energy = $\frac{1}{2} \times 1.8 \times 10^{-11} \times (150 \times 10^3)^2$ or $\frac{1}{2} \times 2.7 \times 10^{-6} \times 150 \times 10^3$
= 0.20 J A1 [2]
- (c) either since energy $\propto V^2$, capacitor has $(\frac{1}{2})^2$ of its energy left
or full formula treatment C1
energy lost = 0.15 J A1 [2]

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- 5 (a) magnetic flux = BA
 $= 89 \times 10^{-3} \times 5.0 \times 10^{-2} \times 2.4 \times 10^{-2}$
 $= 1.07 \times 10^{-4} \text{ Wb}$ C1
A1 [2]
- (b) (i) e.m.f. = $\Delta\phi / \Delta t$ C1
(for $\Delta\phi = 1.07 \times 10^{-4} \text{ Wb}$), $\Delta t = 2.4 \times 10^{-2} / 1.8 = 1.33 \times 10^{-2} \text{ s}$ C1
e.m.f. = $(1.07 \times 10^{-4}) / (1.33 \times 10^{-2})$
 $= 8.0 \times 10^{-3} \text{ V}$ A1 [3]
- (ii) current = $8.0 \times 10^{-3} / 0.12$ M1
 $\approx 70 \text{ mA}$ A0 [1]
- (c) force on wire = BIL
 $= 89 \times 10^{-3} \times 70 \times 10^{-3} \times 5.0 \times 10^{-2}$ C1
 $\approx 3 \times 10^{-4} \text{ (N)}$ M1
suitable comment e.g. this force is too / very small (to be felt) A1 [3]
- 6 (a) power / heating depends on I^2 M1
so independent of current direction A1 [2]
- (b) *either* maximum power = $I_0^2 R$ or average power = $I_{\text{RMS}}^2 R$ M1
 $I_0 = \sqrt{2} \times I_{\text{RMS}}$ M1
maximum power = $2 \times$ average power
ratio = 0.5 A1 [3]
- 7 (a) force due to E -field is equal and opposite to force due to B -field B1
 $Eq = Bqv$ B1
 $v = E/B$ B1 [3]
- (b) *either* charge and mass are not involved in the equation in (a)
or F_E and F_B are both doubled
or E , B and v do not change M1
so no deviation A1 [2]
- 8 (a) minimum frequency for electron to be emitted (from surface) M1
of electromagnetic radiation / light / photons A1 [2]
- (b) $E = hc / \lambda$ or $E = hf$ and $c = f\lambda$ C1
either threshold wavelength = $(6.63 \times 10^{-34} \times 3.0 \times 10^8) / (5.8 \times 10^{-19})$
 $= 340 \text{ nm}$
or energy of 340 nm photon = $4.4 \times 10^{-19} \text{ J}$
or threshold frequency = $8.7 \times 10^{14} \text{ Hz}$
or $450 \text{ nm} \rightarrow 6.7 \times 10^{14} \text{ Hz}$ A1
appropriate comment comparing wavelengths / energies / frequencies B1
so no effect on photo-electric current B1 [4]

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Section B

- 9 (a) (i) edges can be (clearly) distinguished B1 [1]
- (ii) e.g. size of X-ray source / anode / target / aperture
scattering of X-ray beam
pixel size
(any two, 1 each) B2
further detail e.g. use of lead grid B1 [3]
- (b) X-ray image involves a single exposure B1
CT scan: exposure of a slice from many different angles M1
repeated for different slices A1
CT scan involves a (much) greater exposure B1 [4]
- 10 (a) e.g. infinite input impedance / resistance
zero output impedance / resistance
infinite gain
infinite bandwidth
infinite slew rate
(any three, 1 each) B3 [3]
- (b) (i) with switch open, V^- is less (positive) than V^+ M1
output is positive A1
with switch closed, V^- is more (positive) than V^+ so output is negative A1 [3]
(allow similar scheme if V^- more positive than V^+ treated first)
- (ii) 1. diodes connected correctly between output and earth M1
2. green identified correctly A1 [2]
(do not allow this mark if not argued in (i))
- 11 (a) (i) $I / I_0 = \exp(-1.5 \times 2.9)$ C1
 $= 0.013$ A1 [2]
- (ii) $I / I_0 = \exp(-4.6 \times 0.95)$
 $= 0.013$ A1 [1]
- (b) attenuation (coefficients) in muscle and in fat are similar B1
attenuation (coefficients) in bone and muscle / fat are different B1
contrast depends on difference in attenuation B1 [3]

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- 12 (a) (i) 1. signal has same variation (with time) as the data B1
2. consists of (a series of) 'highs' and 'lows' B1
either analogue is continuously variable (between limits)
or digital has no intermediate values B1 [3]
- (ii) e.g. can be regenerated / noise can be eliminated
extra data can be added to check / correct transmitted signal
(*any two reasonable suggestions, 1 each*) B2 [2]
- (b) (i) analogue signal is sampled at (regular time) intervals B1
sampled signal is converted into a binary number B1 [2]
- (ii) one channel is required for each bit (of the digital number) B1 [1]