

MARK SCHEME for the October/November 2013 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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Page 2	Mark Scheme	Syllabus	Paper
	GCE A LEVEL – October/November 2013	9702	41

Section A

- 1 (a) work done in moving unit mass from infinity (to the point) M1 A1 [2]
- (b) (i) gravitational potential energy = GMm/x
energy = $(6.67 \times 10^{-11} \times 7.35 \times 10^{22} \times 4.5) / (1.74 \times 10^6)$ M1
energy = 1.27×10^7 J A0 [1]
- (ii) change in grav. potential energy = change in kinetic energy B1
 $\frac{1}{2} \times 4.5 \times v^2 = 1.27 \times 10^7$
 $v = 2.4 \times 10^3 \text{ m s}^{-1}$ A1 [2]
- (c) Earth would attract the rock / potential at Earth('s surface) not zero / <0 / at Earth, potential due to Moon not zero M1
escape speed would be lower A1 [2]
- 2 (a) (i) N : (total) number of molecules B1 [1]
- (ii) $\langle c^2 \rangle$: mean square speed/velocity B1 [1]
- (b) $pV = \frac{1}{3}Nm\langle c^2 \rangle = NkT$
(mean) kinetic energy = $\frac{1}{2} m\langle c^2 \rangle$ C1
algebra clear leading to $\frac{1}{2} m\langle c^2 \rangle = (3/2)kT$ A1 [2]
- (c) (i) *either* energy required = $(3/2) \times 1.38 \times 10^{-23} \times 1.0 \times 6.02 \times 10^{23}$ C1
= 12.5 J (12J if 2 s.f.) A1 [2]
or energy = $(3/2) \times 8.31 \times 1.0$ (C1)
= 12.5 J (A1)
- (ii) energy is needed to push back atmosphere/do work against atmosphere M1
so total energy required is greater A1 [2]
- 3 (a) (i) any two from 0.3(0) s, 0.9(0) s, 1.50 s (allow 2.1 s etc.) B1 [1]
- (ii) *either* $v = \omega x$ and $\omega = 2\pi/T$ C1
 $v = (2\pi/1.2) \times 1.5 \times 10^{-2}$ M1
= 0.079 m s⁻¹ A0 [2]
or gradient drawn clearly at a correct position (C1)
working clear (M1)
to give $(0.08 \pm 0.01) \text{ m s}^{-1}$ (A0)

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	(b) (i) sketch: <u>curve</u> from ($\pm 1.5, 0$) passing through (0, 25) reasonable shape (<i>curved with both intersections between $y = 12.0 \rightarrow 13.0$</i>)	M1	
		A1	[2]
	(ii) at max. amplitude potential energy is total energy total energy = 4.0 mJ	B1	
		B1	[2]
4	(a) (i) force proportional to product of (two) charges and inversely proportional to square of separation reference to point charges	M1	
		A1	[2]
	(ii) $F = 2 \times (1.6 \times 10^{-19})^2 / \{4\pi \times 8.85 \times 10^{-12} \times (20 \times 10^{-6})^2\}$ $= 1.15 \times 10^{-18} \text{ N}$	C1	
		A1	[2]
	(b) (i) force per unit charge on <i>either</i> a stationary charge or a positive charge	M1	
		A1	[2]
	(ii) 1. electric field is a vector quantity electric fields are in opposite directions charges repel <i>Any two of the above, 1 each</i>	B2	[2]
	2. graph: line always between given lines crosses x-axis between 11.0 μm and 12.3 μm reasonable shape for curve	M1	
		A1	[3]
5	(a) (i) field shown as right to left	B1	[1]
	(ii) lines are more spaced out at ends	B1	[1]
	(b) Hall voltage depends on angle <i>either</i> between field and plane of probe or maximum when field normal to plane of probe or zero when field parallel to plane of probe	M1	
		A1	[2]
	(c) (i) (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage) (<i>allow rate of cutting of flux</i>)	M1	
		A1	[2]
	(ii) e.g. move coil towards/away from solenoid rotate coil vary current in solenoid insert iron core into solenoid (<i>any three sensible suggestions, 1 each</i>)		
		B3	[3]

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- 6 (a) force due to magnetic field is constant B1
force is (always) normal to direction of motion
this force provides the centripetal force A1 [3]
- (b) $mv^2 / r = Bqv$ M1
hence $q / m = v / Br$ A0 [1]
- (c) (i) $q / m = (2.0 \times 10^7) / (2.5 \times 10^{-3} \times 4.5 \times 10^{-2})$ C1
 $= 1.8 \times 10^{11} \text{ C kg}^{-1}$ A1 [2]
- (ii) sketch: curved path, constant radius, in direction towards bottom of page M1
tangent to curved path on entering and on leaving the field A1 [2]
- 7 (a) *either* if light passes through suitable film / cork dust etc. M1
diffraction occurs and similar pattern observed A1
or concentric circles are evidence of diffraction (M1)
diffraction is a wave property (A1) [2]
- (b) (speed increases so) momentum increases M1
 $\lambda = h/p$ so λ decreases M1
hence radii decrease A1 [3]
(special case: wavelength decreases so radii decreases – scores 1/3)
or
(speed increases so) energy increases (B1)
 $\lambda = h / \sqrt{2Em}$ so λ decreases (M1)
hence radii decrease (A1)
- (c) electron and proton have same (kinetic) energy C1
either $E = p^2 / 2m$ *or* $p = \sqrt{2Em}$ C1
ratio = $p_e / p_p = \sqrt{(m_e / m_p)}$ C1
 $= \sqrt{\{(9.1 \times 10^{-31}) / (1.67 \times 10^{-27})\}}$
 $= 2.3 \times 10^{-2}$ A1 [4]
- 8 (a) energy to separate nucleons (in a nucleus) M1
separate to infinity A1 [2]
- (b) (i) fission B1 [1]
- (ii) 1. U: near right-hand end of line B1 [1]
2. Mo: to right of peak, less than 1/3 distance from peak to U B1 [1]
3. La: 0.4 $\rightarrow$ 0.6 of distance from peak to U B1 [1]

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- (iii) 1. right-hand side, mass = 235.922 u
mass change = 0.210 u C1 A1 [2]
2. energy = mc^2
 $= 0.210 \times 1.66 \times 10^{-27} \times (3.0 \times 10^8)^2$ C1
 $= 3.1374 \times 10^{-11} \text{ J}$ C1
 $= 196 \text{ MeV}$ (need 3 s.f.) A1 [3]
(use of 1 u = 934 MeV, allow 3/3; use of 1 u = 930 MeV or 932 MeV, allow 2/3)
(use of 1.67×10^{-27} not 1.66×10^{-27} scores max. 2/3)

Section B

- 9 (a) operates on / takes signal from sensing device B1
(so that) it gives an voltage output B1 [2]
- (b) thermistor and resistor in series between +4 V line and earth M1
 V_{OUT} shown clearly across *either* thermistor or resistor A1
 V_{OUT} shown clearly across thermistor A1 [3]
- (c) e.g. remote switching
switching large current by means of a small current
isolating circuit from high voltage
switching high voltage by means of a small voltage/current
(any two sensible suggestions, 1 each to max. 2) B2 [2]
- 10 (a) pulse (of ultrasound) B1
produced by quartz / piezo-electric crystal (1)
reflected from boundaries (between media) B1
reflected pulse detected B1
by the ultrasound transmitter (1)
signal processed and displayed B1
intensity of reflected pulse gives information about the boundary (1)
time delay gives information about depth (1)
(four B marks plus any two from the four, max. 6) B2 [6]
- (b) shorter wavelength B1
smaller structures resolved / detected (*not more sharpness*) B1 [2]
- (c) (i) $I = I_0 e^{-\mu x}$ C1
ratio = $\exp(-23 \times 6.4 \times 10^{-2})$ C1
 $= 0.23$ A1 [3]
- (ii) later signal has passed through greater thickness of medium M1
so has greater attenuation / greater absorption / smaller intensity A1 [2]

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- 11 (a) left-hand bit underlined B1 [1]
- (b) 1010, 1110, 1111, 1010, 1001
(5 correct scores 2, 4 correct scores 1) A2 [2]
- (c) significant changes in detail of V between samplings
so frequency too low M1
A1 [2]
- 12 (a) e.g. logarithm provides a smaller number
gain of amplifiers is series found by addition, (not multiplication)
(any sensible suggestion) B1 [1]
- (b) (i) optic fibre B1 [1]
- (ii) attenuation/dB = $10 \lg(P_2/P_1)$ C1
 $= 10 \lg(\{6.5 \times 10^{-3}\}/\{1.5 \times 10^{-15}\})$ C1
 $= 126$
length = $126 / 1.8$
 $= 70 \text{ km}$ A1 [3]

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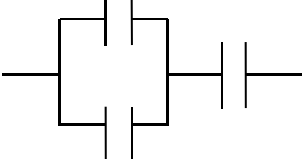
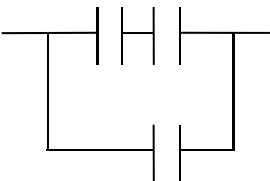
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Section A

- 1 (a) force proportional to product of the two masses and inversely proportional to the square of their separation
either reference to point masses *or* separation $\gg$ 'size' of masses M1
A1 [2]
- (b) gravitational force provides the centripetal force B1
 $GMm/R^2 = mR\omega^2$ M1
where m is the mass of the planet A1
 $GM = R^3\omega^2$ A0 [3]
- (c) $\omega = 2\pi / T$ C1
either $M_{\text{star}} / M_{\text{Sun}} = (R_{\text{star}} / R_{\text{Sun}})^3 \times (T_{\text{Sun}} / T_{\text{star}})^2$
 $M_{\text{star}} = 4^3 \times (1/2)^2 \times 2.0 \times 10^{30}$ C1
 $= 3.2 \times 10^{31} \text{ kg}$ A1 [3]
or $M_{\text{star}} = (2\pi)^2 R_{\text{star}}^3 / GT^2$ (C1)
 $= \{(2\pi)^2 \times (6.0 \times 10^{11})^3\} / \{6.67 \times 10^{-11} \times (2 \times 365 \times 24 \times 3600)^2\}$ (C1)
 $= 3.2 \times 10^{31} \text{ kg}$ (A1)
- 2 (a) (i) sum of kinetic and potential energies of the molecules M1
reference to random distribution A1 [2]
- (ii) for ideal gas, no intermolecular forces M1
so no potential energy (only kinetic) A1 [2]
- (b) (i) *either* change in kinetic energy $= 3/2 \times 1.38 \times 10^{-23} \times 1.0 \times 6.02 \times 10^{23} \times 180$ C1
 $= 2240 \text{ J}$ A1 [2]
or $R = kN_A$
energy $= 3/2 \times 1.0 \times 8.31 \times 180$ (C1)
 $= 2240 \text{ J}$ (A1)
- (ii) increase in internal energy = heat supplied + work done on system B1
2240 = energy supplied – 1500 C1
energy supplied = 3740 J A1 [3]
- 3 (a) work done bringing unit positive charge M1
from infinity (to the point) A1 [2]
- (b) (i) *either* both potentials are positive / same sign M1
so same sign A1 [2]
or gradients are positive & negative (so fields in opposite directions) (M1)
so same sign (A1)
- (ii) the individual potentials are summed B1 [1]
- (iii) allow value of x between 10 nm and 13 nm A1 [1]
- (iv) $V = 0.43 \text{ V}$ (allow $0.42 \text{ V} \rightarrow 0.44 \text{ V}$) M1
energy $= 2 \times 1.6 \times 10^{-19} \times 0.43$ A1
 $= 1.4 \times 10^{-19} \text{ J}$ A1 [3]

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- 4 (a) e.g. store energy (do not allow 'store charge')
in smoothing circuits
blocking d.c.
in oscillators
any sensible suggestions, one each, max. 2 B2 [2]
- (b) (i) potential across each capacitor is the same and $Q = CV$ B1 [1]
- (ii) total charge $Q = Q_1 + Q_2 + Q_3$ M1
 $CV = C_1V + C_2V + C_3V$ M1
(allow $Q = CV$ here or in (i))
so $C = C_1 + C_2 + C_3$ A0 [2]
- (c) (i)  A1 [1]
- (ii)  A1 [1]
- 5 (a) (i) region (of space)
either where a moving charge (may) experience a force
or around a magnet where another magnet experiences a force B1 [1]
- (ii) $(\Phi =) BA \sin \theta$ A1 [1]
- (b) (i) plane of frame is always parallel to B_v /flux linkage always zero B1 [1]
- (ii) $\Delta \Phi = 1.8 \times 10^{-5} \times 52 \times 10^{-2} \times 95 \times 10^{-2}$ C1
 $= 8.9 \times 10^{-6} \text{ Wb}$ A1 [2]
- (c) (i) (induced) e.m.f. proportional to rate of
change of (magnetic) flux (linkage) M1
(allow rate of cutting of flux) A1 [2]
- (ii) e.m.f. $= (8.9 \times 10^{-6}) / 0.30$
 $= 3.0 \times 10^{-5} \text{ V}$ A1 [1]
- (iii) This question part was removed from the assessment. All candidates were
awarded 1 mark. B1 [1]

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- 6 (a) *either* constant speed parallel to plate
or accelerated motion/force normal to plate/in direction field
so not circular B1
A0 [1]
- (b) (i) direction of force due to magnetic field opposite to that due to electric field B1
magnetic field into plane of page B1 [2]
- (ii) force due to magnetic field = force due to electric field B1
 $Bqv = qE$
 $B = E / v$ C1
 $= (2.8 \times 10^4) / (4.7 \times 10^5)$
 $= 6.0 \times 10^{-2} \text{ T}$ A1 [3]
- (c) (i) no change/not deviated B1 [1]
- (ii) deviated upwards B1 [1]
- (iii) no change/not deviated B1 [1]
- 7 (a) (i) minimum photon energy B1
minimum energy to remove an electron (from the surface) B1 [2]
- (ii) *either* maximum KE is photon energy – work function energy B1
or max KE when electron ejected from the surface B1
energies lower than max because energy required to bring electron to the surface B1 [2]
- (b) (i) threshold frequency = $1.0 \times 10^{15} \text{ Hz}$ (allow $\pm 0.05 \times 10^{15}$) C1
work function energy = hf_0 C1
 $= 6.63 \times 10^{-34} \times 1.0 \times 10^{15}$
 $= 6.63 \times 10^{-19} \text{ J}$ A1 [3]
(allow alternative approaches based on use of co-ordinates of points on the line)
- (ii) sketch: straight line with same gradient M1
displaced to right A1 [2]
- (iii) intensity determines number of photons arriving per unit time B1
intensity determines number of electrons per unit time (not energy) B1 [2]
- 8 (a) probability of decay (of a nucleus)/fraction of number of nuclei in sample that decay M1
per unit time A1 [2]
(allow $\lambda = (dN / dt) / N$ with symbols explained – (M1), (A1))
- (b) (i) number = $(1.2 \times 6.02 \times 10^{23}) / 235$ C1
 $= 3.1 \times 10^{21}$ A1 [2]

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- (ii) $N = N_0 e^{-\lambda t}$
negligible activity from the krypton B1
for barium, $N = (3.1 \times 10^{21}) \exp(-6.4 \times 10^{-4} \times 3600)$
 $= 3.1 \times 10^{20}$ C1
activity $= \lambda N$
 $= 6.4 \times 10^{-4} \times 3.1 \times 10^{20}$ C1
 $= 2.0 \times 10^{17} \text{ Bq}$ A1 [4]

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) gain $= 1 + (10.8 / 1.2)$ C1
 $= 10$ A1 [2]
- (ii) graph: straight line from (0,0) towards $V_{\text{IN}} = 1.0 \text{ V}$, $V_{\text{OUT}} = 10 \text{ V}$ B1
horizontal line at $V_{\text{OUT}} = 9.0 \text{ V}$ to $V_{\text{IN}} = 2.0 \text{ V}$ B1
correct $+9.0 \text{ V} \rightarrow -9.0 \text{ V}$ (and correct shape to $V_{\text{IN}} = 0$) B1 [3]
- 10 (a) nuclei spin/precess B1
spin/precess about direction of magnetic field B1
either frequency of precession depends on magnetic field strength
or large field means frequency in radio frequency range B1 [3]
- (b) non-uniform field means frequency of precession different in different regions of subject B1
enables location of precessing nuclei to be determined B1
enables thickness of slice to be varied/location of slice to be changed B1 [3]
- 11 (a) (i) either series of 'highs' and 'lows' or two discrete values M1
with no intermediate values A1 [2]
- (ii) e.g. noise can be eliminated (NOT 'no noise')
signal can be regenerated
addition of extra data to check for errors
larger data carrying capacity
cheaper circuits
more reliable circuits (any three, 1 each) B3 [3]

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- (b) (i) 1. amplifier B1 [1]
2. digital-to-analogue converter (allow DAC) B1 [1]
- (ii) output of ADC is number of digits all at one time B1
parallel-to-serial sends digits one after another B1 [2]

- 12 (a) e.g. no/little ionospheric reflection
large information carrying capacity
(any two sensible suggestions, 1 each) B2 [2]
- (b) prevents (very) low power signal received at satellite
being swamped by high-power transmitted signal M1
A1 [2]
- (c) attenuation/dB = $10 \lg(P_2/P_1)$ C1
 $185 = 10 \lg(\{3.1 \times 10^3\}/P)$ C1
 $P = 9.8 \times 10^{-16} \text{ W}$ A1 [3]