UNIVERSITY OF CAMBRIDGE INTERNATIONAL EXAMINATIONS

GCE Advanced Subsidiary Level and GCE Advanced Level

MARK SCHEME for the May/June 2012 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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Section A

1 **(a)** work done in bringing unit mass from infinity (to the point) B1

(b) gravitational <u>force</u> is (always) attractive B1
either as r decreases, object/mass/body does work
or work is done by masses as they come together B1 [2]

(c) *either* force on mass = mg (where g is the acceleration of free fall /gravitational field strength) B1
$g = GM/r^2$ B1
if r @ h, g is constant B1
ΔE_P = force × distance moved M1
$= mgh$ A0
or $\Delta E_P = m\Delta\phi$ (C1)
$= GMm(1/r_1 - 1/r_2) = GMm(r_2 - r_1)/r_1r_2$ (B1)
if $r_2 \approx r_1$, then $(r_2 - r_1) = h$ and $r_1r_2 = r^2$ (B1)
$g = GM/r^2$ (B1)
$\Delta E_P = mgh$ (A0) [4]

(d) $½mv^2 = m\Delta\phi$
$v^2 = 2 \times GM/r$ C1
$= (2 \times 4.3 \times 10^{13}) / (3.4 \times 10^6)$ C1
$v = 5.0 \times 10^3\,\mathrm{m\,s^{-1}}$ A1 [3]
(Use of diameter instead of radius to give $v = 3.6 \times 10^3\,\mathrm{m\,s^{-1}}$ scores 2 marks)

2 **(a)** **(i)** *either* random motion
or constant velocity until hits wall/other molecule B1 [1]

(ii) (total) volume of molecules is negligible M1
compared to volume of containing vessel A1
or
radius/diameter of a molecule is negligible (M1)
compared to the average intermolecular distance (A1) [2]

(b) *either* molecule has component of velocity in three directions
or $c^2 = c_X^2 + c_Y^2 + c_Z^2$ M1
random motion and averaging, so $\langle c_X^2\rangle = \langle c_Y^2\rangle = \langle c_Z^2\rangle$ M1
$\langle c^2\rangle = 3\langle c_X^2\rangle$ A1
so, $pV = ⅓Nm\langle c^2\rangle$ A0 [3]

(c) $\langle c^2\rangle \propto T$ or $c_{rms} \propto \sqrt{T}$ C1
temperatures are 300 K and 373 K C1
$c_{rms} = 580\,\mathrm{m\,s^{-1}}$ A1 [3]
(Do not allow any marks for use of temperature in units of °C instead of K)

3	**(a)**	(numerically equal to) quantity of (thermal) energy required to change the state of unit mass of a substance	M1	
		without any change of temperature	A1	
		(Allow 1 mark for definition of specific latent heat of fusion/vaporisation)		
	(b)	*either* energy supplied = 2400 × 2 × 60 = 288000 J	C1	
		energy required for evaporation = 106 × 2260 = 240000 J	C1	
		difference = 48000 J		
		rate of loss = 48000 / 120 = 400 W	A1	
		or energy required for evaporation = 106 × 2260 = 240000 J	(C1)	
		power required for evaporation = 240000 / (2 × 60) = 2000 W	(C1)	
		rate of loss = 2400 – 2000 = 400 W	(A1)	[3]
4	**(a)**	$a = (–)\omega^2 x$ and $\omega = 2\pi/T$	C1	
		$T = 0.60\,\text{s}$	C1	
		$a = (4\pi^2 \times 2.0 \times 10^{-2}) / (0.6)^2$		
		$= 2.2\,\text{m s}^{-2}$	A1	[3]
	(b)	sinusoidal wave with all values positive	B1	
		all values positive, all peaks at E_K and energy = 0 at $t = 0$	B1	
		period = 0.30 s	B1	[3]
5	**(a)**	force per unit positive charge acting on a stationary charge	B1	[1]
	(b) (i)	$E = Q / 4\pi\varepsilon_0 r^2$	C1	
		$Q = 1.8 \times 10^4 \times 10^2 \times 4\pi \times 8.85 \times 10^{-12} \times (25 \times 10^{-2})^2$	M1	
		$Q = 1.25 \times 10^{-5}\,\text{C} = 12.5\,\mu\text{C}$	A0	[2]
	(ii)	$V = Q / 4\pi\varepsilon_0 r$		
		$= (1.25 \times 10^{-5}) / (4\pi \times 8.85 \times 10^{-12} \times 25 \times 10^{-2})$	C1	
		$= 4.5 \times 10^5\,\text{V}$	A1	[2]
		(Do not allow use of V = Er unless explained)		

6 **(a)** **(i)** peak voltage = 4.0 V — A1

(ii) r.m.s. voltage (= 4.0/√2) = 2.8 V — A1

(iii) period T = 20 ms — M1
frequency = 1 / (20 × 10^{-3}) — M1
frequency = 50 Hz — A0 [2]

(b) **(i)** change = 4.0 – 2.4 = 1.6 V — A1 [1]

(ii) $\Delta Q = C\Delta V$ or $Q = CV$ — C1
= 5.0 × 10^{-6} × 1.6 = 8.0 × 10^{-6} C — A1 [2]

(iii) discharge time = 7 ms — C1
current = (8.0 × 10^{-6}) / (7.0 × 10^{-3}) — M1
= 1.1(4) × 10^{-3} A — A0 [2]

(c) average p.d. = 3.2 V — C1
resistance = 3.2 / (1.1 × 10^{-3})
= 2900 Ω *(allow 2800 Ω)* — A1 [2]

7 **(a)** sketch: concentric circles *(minimum of 3 circles)* — M1
separation increasing with distance from wire — A1
correct direction — B1 [3]

(b) **(i)** arrow direction from wire B towards wire A — B1 [1]

(ii) *either* reference to Newton's third law
or force on each wire proportional to product of the two currents — M1
so forces are equal — A1 [2]

(c) force <u>always</u> towards wire A/<u>always</u> in same direction — B1
varies from zero (to a maximum value) (1)
variation is sinusoidal / $\sin^2$ (1)
(at) twice frequency of current (1)
(any two, one each) — B2 [3]

8 **(a)** packet/quantum/discrete amount of energy — M1
of electromagnetic radiation — A1
(allow 1 mark for 'packet of electromagnetic radiation')
energy = Planck constant × frequency *(seen here or in **b**)* — B1 [3]

(b) each (coloured) line corresponds to one wavelength/frequency — B1
energy = Planck constant × frequency
implies specific energy change between energy levels — B1
so discrete levels — A0 [2]

9	**(a)**	**(i)** *either*	probability of decay (of a nucleus)	M1	
			per unit time	A1	
		or	$\lambda = (-)(\mathrm{d}N/\mathrm{d}t) / N$	(M1)	
			$(-)\mathrm{d}N/\mathrm{d}t$ and N explained	(A1)	[2]
		(ii)	in time $t_{½}$, number of nuclei changes from N_0 to $½N_0$	B1	
			$½ = \exp(-\lambda\, t_{½})$ *or* $2 = \exp(\lambda\, t_{½})$	B1	
			$\ln(½) = -\lambda\, t_{½}$ and $\ln(½) = -0.693$ *or* $\ln 2 = \lambda\, t_{½}$ and $\ln 2 = 0.693$	B1	
			$0.693 = \lambda\, t_{½}$	A0	[3]
	(b)		$228 = 538 \exp(-8\lambda)$	C1	
			$\lambda = 0.107$ (hours^{-1})	C1	
			$t_{½} = 6.5$ hours *(do not allow 3 or more SF)*	A1	[3]
	(c)		e.g. random nature of decay		
			background radiation		
			daughter product is radioactive		
			(any two sensible suggestions, 1 each)	B2	[2]

Section B

10	**(a)**		light-dependent resistor (allow LDR)	B1	
	(b)	**(i)**	two resistors in series between +5 V line and earth	M1	
			midpoint connected to inverting input of op-amp	A1	[2]
		(ii)	relay coil between diode and earth	M1	
			switch between lamp and earth	A1	[2]
	(c)	**(i)**	switch on/off mains supply using a low voltage/current output (allow 'isolates circuit from mains supply')	B1	[1]
		(ii)	relay will switch on for one polarity of output (voltage)	C1	
			switches on when output (voltage) is negative	A1	[2]
11	**(a)**	**(i)**	e.m. radiation produced whenever charged particle is accelerated	M1	
			electrons hitting target have distribution of accelerations	A1	[2]
		(ii)	*either* wavelength shorter/shortest for greater/greatest acceleration		
			or $\lambda_{min} = hc/E_{max}$		
			or minimum wavelength for maximum energy	B1	
			all electron energy given up in one collision/converted to single photon	B1	[2]
	(b)	**(i)**	hardness measures the penetration of the beam	C1	
			greater hardness, greater penetration	A1	[2]
		(ii)	controlled by changing the anode voltage	C1	
			higher anode voltage, greater penetration/hardness	A1	[2]
	(c)	**(i)**	long-wavelength radiation more likely to be absorbed in the body/less likely to penetrate through body	B1	[1]
		(ii)	(aluminium) filter/metal foil placed in the X-ray beam	B1	[1]
12	**(a)**		strong uniform (magnetic) field	M1	
			either aligns nuclei		
			or gives rise to Larmor/resonant frequency <u>in r.f. region</u>	A1	
			non-uniform (magnetic) field	M1	
			either enables nuclei to be located		
			or changes the Larmor/resonant frequency	A1	[4]
	(b)	**(i)**	difference in flux density = $2.0 \times 10^{-2} \times 3.0 \times 10^{-3} = 6.0 \times 10^{-5}$ T	A1	[1]
		(ii)	$\Delta f = 2 \times c \times \Delta B$	C1	
			$= 2 \times 1.34 \times 10^{8} \times 6.0 \times 10^{-5}$		
			$= 1.6 \times 10^{4}$ Hz	A1	[2]

13 (a) (i) no interference (between signals) near boundaries (of cells) B1

(ii) for large area, signal strength would have to be greater and this could be hazardous to health B1 [1]

(b) mobile phone is sending out an (identifying) signal M1
computer/cellular exchange continuously selects cell/base station with strongest signal A1
computer/cellular exchange allocates (carrier) frequency (and slot) A1 [3]