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MARK SCHEME for the March 2016 series

9702 PHYSICS

9702/42 Paper 4 (A Level Structured Questions), maximum raw mark 100

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1	**(a)**	force proportional to product of the (two) masses and inversely proportional to the square of their separation	M1	
		either reference to point masses *or* separation << 'size' of masses	A1	[2]
	(b)	gravitational force provides / is the centripetal force	B1	
		$GMm/r^2 = mv^2/r$ *or* $GMm/r^2 = mr\omega^2$ *and* $v = r\omega$ and algebra leading to $v = (GM/r)^{1/2}$	B1	[2]
	(c) (i) 1.	$v_A/v_B = (r_B/r_A)^{1/2}$		
		$= (2.2 \times 10^{10}/1.3 \times 10^{8})^{1/2}$	C1	
		$= 13\ (13.0)$	A1	[2]
	2.	$v = 2\pi r/T$ *or* $v \propto r/T$ *or* vT/r = constant	C1	
		$T_A/T_B = (r_A/r_B) \times (v_B/v_A)$		
		$= (1.3 \times 10^{8}/2.2 \times 10^{10}) \times (1/13)$	C1	
		$= 4.5\ (4.54) \times 10^{-4}$	A1	
		or		
		$T^2 = 4\pi^2 r^3/GM$ *or* $T^2 \propto r^3$ *or* T^2/r^3 = constant	(C1)	
		$T_A/T_B = (r_A^3/r_B^3)^{1/2}$		
		$= [(1.3 \times 10^{8})^3/(2.2 \times 10^{10})^3]^{1/2}$	(C1)	
		$= 4.5\ (4.54) \times 10^{-4}$	(A1)	[3]
	(ii)	$T = 2\pi/1.7 \times 10^{-4}$		
		$= 3.70 \times 10^{4}$ s	C1	
		$T_B = 3.70 \times 10^{4}/4.54 \times 10^{-4}$		
		$= 8.1 \times 10^{7}$ s	A1	[2]
		If identifies T_A as T_B then 0/2		
2	**(a) (i)**	sum of kinetic and potential energy of atoms/molecules	M1	
		reference to random (distribution)	A1	[2]
	(ii)	no forces (of attraction or repulsion) between molecules	B1	[1]
	(b)	$pV = NkT$ *or* $pV = nRT$ *and* $R = kN_A$, $n = N/N_A$	B1	
		$^1/_3\, Nm\langle c^2\rangle = NkT$ *or* $^1/_3\, m\langle c^2\rangle = kT$	B1	
		$\langle E_K\rangle = {}^1/_2\, m\langle c^2\rangle$ <u>so</u> $\langle E_K\rangle = {}^3/_2\, kT$	B1	[3]
	(c) (i)	$\langle E_K\rangle = {}^3/_2 \times 1.38 \times 10^{-23} \times (273 + 12)$	C1	
		$= 5.9\ (5.90) \times 10^{-21}$ J	A1	[2]
		(*use of* T = 12 K *not* T = 285 K scores 0/2)		
	(ii)	number $= (17/32) \times 6.02 \times 10^{23}$	C1	
		$= 3.2\ (3.20) \times 10^{23}$	A1	[2]

(iii) internal energy $= 5.9 \times 10^{-21} \times 3.2 \times 10^{23}$
$= 1900\ (1890)\ \text{J}$ — A1 [1]

3 (a) the (thermal) energy per unit mass to raise the temperature — M1
of a substance by one degree — A1 [2]

(*If ratio not clear for M1 mark, allow 1/2 marks for an otherwise correct answer*)

(b) (i) to allow for / determine / cancel heat transfer to / from tube / surroundings — B1 [1]

(*do not allow 'to stop / prevent' heat loss*)

(ii) *either* $P = mc\Delta\theta \pm \text{h}$
or $44.9 = 1.58 \times 10^{-3} \times c \times (25.5 - 19.5) \pm \text{h}$
or $33.3 = 1.11 \times 10^{-3} \times c \times (25.5 - 19.5) \pm \text{h}$ — B1
$(44.9 - 33.3) = (1.58 - 1.11) \times 10^{-3} \times c \times (25.5 - 19.5)$ — C1
$c = 4100\ (4110)\ \text{J kg}^{-1}\,\text{K}^{-1}$ — A1 [3]

(*allow 1/3 for use of only 33.3 W, 1.11 g s^{-1} leading to 5000 J kg^{-1} K^{-1}*)
(*allow 1/3 for use of only 44.9 W, 1.58 g s^{-1} leading to 4740 J kg^{-1} K^{-1}*)

(c) $V_0 = 27$ *or* $V_{rms} = 19.1$ — C1
$33.3 = 27^2/2R$ *or* $33.3 = 19.1^2/R$ — C1
$R = 11\ \Omega$ — A1 [3]

4 (a) amplitude = 1.8 cm *and* period = 0.30 s — A1 [1]

(b) $E_K = ½m\,\omega^2 (x_0^2 - x^2)$ *or* $E_K = ½mv^2$ *and* $v = \pm\,\omega\sqrt{(x_0^2 - x^2)}$ — C1
$= ½ \times 0.080 \times (2\pi/0.30)^2 \times [(1.8 \times 10^{-2})^2 - (1.2 \times 10^{-2})^2]$ — C1
$= 3.2 \times 10^{-3}\ \text{J}$ — A1 [3]

5 (a) (i) (series of) 'highs' and 'lows' / 'on' and 'off' / 1's and 0's / two values — M1
with no intermediate values / the values are discrete — A1 [2]

(ii) *either* use higher sampling frequency / rate
or use more bits in each sample / each digital number
or use more levels in each sample — B1 [1]

(b) voltage = 30 mV — A1 [1]

6 (a) speed $= Z/\rho$
$= 1.4 \times 10^6/940\ (=1490)$ — C1
time $= (1.1 \times 10^{-2} \times 2)/1490$ — C1
$= 1.5 \times 10^{-5}\ \text{s}$ — A1 [3]
(time of 7.4×10^{-6} s is one way only and scores 2/3 marks)
(use of speed of light is wrong physics and scores 0/3 marks)

	(b)	$I = I_0 \exp(-\mu x)$ *or* $I_2 = I_1 \exp(-\mu x)$	C1	
		ratio = exp (– 48 × 1.1 × 10^{-2})		
		= 0.59	A1	[2]
	(c)	0.33 / 100 = 0.59 × (I_3 / I_2) × 0.59	C1	
		ratio = 9.5 × 10^{-3}	A1	
		or		
		0.33 / 100 = exp (– 48 × 2.2 × 10^{-2}) × (I_3 / I_2)	(C1)	
		ratio = 9.5 × 10^{-3}	(A1)	[2]
	(d)	ratio I_3 / I_2 increases	B1	[1]
		(accept: "there is an increase in the proportion of the intensity that is reflected")		
7	**(a)**	(capacitance =) charge / potential (difference)	B1	[1]
	(b)	$V = V_1 + V_2 + V_3$	B1	
		either $Q/C = Q/C_1 + Q/C_2 + Q/C_3$ *or* $V/Q = V_1/Q + V_2/Q + V_3/Q$		
		and so $1/C = 1/C_1 + 1/C_2 + 1/C_3$	B1	[2]
	(c) **(i)** **1.**	$1/C_T$ = (1 / 200) + (1 / 600)		
		C_T = 150 μF	A1	[1]
	2.	$Q = CV$		
		= 150 × 10^{-6} × 12 *or* 600 × 10^{-6} × 3.0 *or* 200 × 10^{-6} × 9.0		
		= 1.8 × 10^{-3} C	A1	[1]
	3.	$V = Q$ / C = 1.8 × 10^{-3} / 600 × 10^{-6} *or* V = [200 / (200 + 600)] × 12		
		= 3(.0) V	A1	[1]
	(ii)	energy = ½CV^2 or energy = ½QV and $C = Q/V$	C1	
		$^1/_2 \times C \times 3^2 = 2 \times {^1/_2} \times C \times V^2$	C1	
		V = 2.1 V	A1	[3]
8	**(a)**	decreases gain	B1	
		increases bandwidth / decreases distortion / increases (operating) stability	B1	[2]
	(b) **(i)**	additional resistor connected between 7.2 kΩ resistor and earth	B1	
		V^- joined to lower end of 7.2 kΩ resistor <u>and</u> V^+ joined to V_{IN}	B1	[2]
	(ii)	either 5 = 1 + (7.2 / R) or 5 = 1 + (7200 / R)	C1	
		R = 1.8 kΩ	A1	[2]
	(iii)	horizontal line from (0, 8.0) to (1.8, 8.0)	B1	
		straight line from (1.8, 8.0) to (5.0, 0)	B1	[2]
		(*allow a tolerance of* ± ½ *small square when marking the graph*)		

9	(a)	direction of force due to electric field opposite to force due to magnetic field		B1	
		electric field is up the page		B1	[2]
	(b)	force due to electric field = force due to magnetic field or $Eq = Bqv$		B1	
		$E = Bv$		C1	
		$= 9.7 \times 10^{-2} \times 1.6 \times 10^{5}$			
		$= 1.6\ (1.55) \times 10^{4}\,\mathrm{V\,m^{-1}}$		A1	[3]
	(c)	$q/m = v/Br$		C1	
		$= 1.6 \times 10^{5} / (9.7 \times 10^{-2} \times 4.0 \times 10^{-2})$		C1	
		$= 4.1\ (4.12) \times 10^{7}\,\mathrm{C\,kg^{-1}}$		A1	[3]
	(d)	(i)	$m = (3 \times 1.60 \times 10^{-19}) / (4.12 \times 10^{7})$	C1	
			$m = 1.16 \times 10^{-26} / 1.66 \times 10^{-27}$		
			$= 7(.0)\,\mathrm{u}$ (*allow* 7.1 u)	A1	[2]
		(ii)	3 protons, 4 neutrons	A1	[1]
10	(a)	(i)	change in flux linkage $= 40 \times (5.0 - 3.0) \times 10^{-6}$		
			$= 8(.0) \times 10^{-5}\,\mathrm{Wb}$	A1	[1]
		(ii)	time taken $= 8.0 \times 10^{-5} / 5.0 \times 10^{-4}$		
			$= 0.16\,(\mathrm{s})$	C1	
			speed $= 3.0 \times 10^{-2} / 0.16$		
			$= 0.19\ (0.188)\,\mathrm{m\,s^{-1}}$	A1	
			or		
			$E = (\Delta\Phi / \Delta x) \times$ speed		
			speed $= 5.0 \times 10^{-4} / (8.0 \times 10^{-5} / 3.0 \times 10^{-2})$	(C1)	
			$= 0.19\ (0.188)\,\mathrm{m\,s^{-1}}$	(A1)	[2]
	(b)	a constant non-zero value of *E* from 0 to 3 cm and a different constant non-zero value of *E* from 3 to 6 cm		M1	
		E from 3–6 cm has the opposite sign to and larger value than *E* from 0–3 cm		A1	[2]
11	(a)	<u>minimum</u> frequency for electron(s) to be emitted (from surface)		M1	
		reference to frequency of electromagnetic radiation / photon		A1	
		or			
		frequency causing emission of electron(s) <u>from surface</u> with <u>zero kinetic energy</u>		(M1)	
		reference to frequency of electromagnetic radiation / photon		(A1)	[2]

	(b)	**(i)**	positive intercept on (1 / λ)-axis (when extrapolated)	B1	
			straight line with positive gradient	B1	[2]
		(ii)	gradient = *hc* where *c* is the speed of light	B1	[1]
		(iii)	maximum kinetic energy when electron emitted from surface	B1	
			energy is required to bring an electron to the surface	B1	[2]
		(iv)	each photon has more energy	M1	
			fewer photons per unit time	M1	
			fewer electrons per unit time / less current	A1	[3]
12	**(a)**	**(i)**	the penetration of the beam	B1	[1]
		(ii)	*either* decrease the accelerating voltage		
			or decrease voltage between cathode and anode	B1	[1]
	(b)		advantage: image gives depth / image is 3D / final image can be viewed from any angle	B1	
			disadvantage: greater exposure / more risk to health / more expensive / person must remain stationary	B1	[2]
13	**(a)**		$\lambda = \ln 2 / T_{½}$		
			$= \ln 2 / (53.3 \times 24 \times 60 \times 60) = 1.5 \times 10^{-7}\ \text{s}^{-1}$	A1	[1]
	(b)		$A = \lambda N$	C1	
			$N = 39 \times 10^{-3} / 1.5 \times 10^{-7} = 2.6 \times 10^{5}$		
			$m = (2.6 \times 10^{5} / 6.0 \times 10^{23}) \times 7 \times 10^{-3}$ *or* $2.6 \times 10^{5} \times 1.66 \times 10^{-27} \times 7$	C1	
			$= 3.0 \times 10^{-21}\ \text{kg}$	A1	[3]
	(c)		$2/39 = \exp(-1.5 \times 10^{-7} \times t)$ *or* $2/39 = (1/2)^{[t/(53.3 \times 24 \times 3600)]}$	C1	
			$t = 2.0 \times 10^{7}\ \text{s}$	A1	[2]