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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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Question	Answer	Mark	Total
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	
	$\frac{1}{3} Nm\langle c^2\rangle = NkT$ *or* $\frac{1}{3} m\langle c^2\rangle = kT$	B1	
	$\langle E_K\rangle = \frac{1}{2} m\langle c^2\rangle$ <u>so</u> $\langle E_K\rangle = \frac{3}{2} kT$	B1	[3]
(c) (i)	$\langle E_K\rangle = \frac{3}{2} \times 1.38 \times 10^{-23} \times (273 + 12)$	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* $P = mc\Delta\theta \pm h$
or $44.9 = 1.58 \times 10^{-3} \times c \times (25.5 - 19.5) \pm h$
or $33.3 = 1.11 \times 10^{-3} \times c \times (25.5 - 19.5) \pm h$ 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 $(-48 \times 1.1 \times 10^{-2})$
= 0.59 — A1 [2]

(c) $0.33/100 = 0.59 \times (I_3/I_2) \times 0.59$ — C1
ratio = 9.5×10^{-3} — A1
or
$0.33/100 = \exp(-48 \times 2.2 \times 10^{-2}) \times (I_3/I_2)$ — (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. $1/C_T = (1/200) + (1/600)$
$C_T = 150\ \mu F$ — A1 [1]

2. $Q = CV$
$= 150 \times 10^{-6} \times 12$ *or* $600 \times 10^{-6} \times 3.0$ *or* $200 \times 10^{-6} \times 9.0$
$= 1.8 \times 10^{-3}$ C — A1 [1]

3. $V = Q/C = 1.8 \times 10^{-3} / 600 \times 10^{-6}$ *or* $V = [200/(200 + 600)] \times 12$
= 3(.0) V — A1 [1]

(ii) energy = $\frac{1}{2}CV^2$ or energy = $\frac{1}{2}QV$ 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	
		$= 9.7 \times 10^{-2} \times 1.6 \times 10^{5}$		
		$= 1.6\ (1.55) \times 10^{4}\ \text{V m}^{-1}$	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	
		$= 4.1\ (4.12) \times 10^{7}\ \text{C kg}^{-1}$	A1	[3]
	(d) (i)	$m = (3 \times 1.60 \times 10^{-19}) / (4.12 \times 10^{7})$	C1	
		$m = 1.16 \times 10^{-26} / 1.66 \times 10^{-27}$		
		$= 7(.0)$ u (*allow* 7.1 u)	A1	[2]
	(ii)	3 protons, 4 neutrons	A1	[1]
10	(a) (i)	change in flux linkage $= 40 \times (5.0 - 3.0) \times 10^{-6}$		
		$= 8(.0) \times 10^{-5}$ Wb	A1	[1]
	(ii)	time taken $= 8.0 \times 10^{-5} / 5.0 \times 10^{-4}$		
		$= 0.16$ (s)	C1	
		speed $= 3.0 \times 10^{-2} / 0.16$		
		$= 0.19\ (0.188)\ \text{m s}^{-1}$	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)	
		$= 0.19\ (0.188)\ \text{m s}^{-1}$	(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 $(1/\lambda)$-axis (when extrapolated) straight line with positive gradient	B1 B1	 [2]
		(ii)	gradient = *hc* where *c* is the speed of light	B1	[1]
		(iii)	maximum kinetic energy when electron emitted from surface energy is required to bring an electron to the surface	B1 B1	 [2]
		(iv)	each photon has more energy fewer photons per unit time fewer electrons per unit time / less current	M1 M1 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 disadvantage: greater exposure / more risk to health / more expensive / person must remain stationary	B1 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)		$A = \lambda N$ $N = 39 \times 10^{-3} / 1.5 \times 10^{-7} = 2.6 \times 10^{5}$ $m = (2.6 \times 10^{5} / 6.0 \times 10^{23}) \times 7 \times 10^{-3}$ *or* $2.6 \times 10^{5} \times 1.66 \times 10^{-27} \times 7$ $= 3.0 \times 10^{-21}$ kg	C1 C1 A1	 [3]
	(c)		$2/39 = \exp(-1.5 \times 10^{-7} \times t)$ *or* $2/39 = (1/2)^{[t/(53.3 \times 24 \times 3600)]}$ $t = 2.0 \times 10^{7}$ s	C1 A1	 [2]