CAMBRIDGE INTERNATIONAL EXAMINATIONS

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MARK SCHEME for the October/November 2015 series

9702 PHYSICS

9702/43 Paper 4 (A2 Structured Questions), maximum raw mark 100

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1	**(a)**	(gravitational) force proportional to product of masses and inversely proportional to square of separation	M1	
		either point masses *or* particles *or* 'size' ≪ separation	A1	[2]
	(b)	gravitational force provides the centripetal force	B1	
		either $GMm/x^2 = mx\omega^2$ *or* mv^2/x	M1	
		either $\omega = 2\pi/T$ *or* $v = 2\pi x/T$ and working to $GM = 4\pi^2x^3/T^2$	A1	[3]
	(c)	*either* use of gradient of graph *or* line through origin so can use single point *or* line shown extrapolated to origin	B1	
		gradient = $(4.5 \times 10^{14})/0.35$ $6.67 \times 10^{-11} \times M = 4\pi^2 \times (4.5 \times 10^{14} \times 10^9)/(0.35 \times \{24 \times 3600\}^2)$		
		correct conversion for km^3 and power of 10	C1	
		correct conversion for day^2	C1	
		$M = 1.02 \times 10^{26}$ kg	A1	[4]
2	**(a)**	total volume of molecules negligible compared to that of containing vessel no intermolecular forces molecules in random motion time of collision small compared with the time between collisions large number of molecules *any two*	B2	[2]
	(b)	in a real gas there is a range of velocities *or* must take the average of v^2	B1	[1]
	(c) (i)	*either* $p = \frac{1}{3}\rho\langle c^2\rangle$ *or* $1.0 \times 10^5 = \frac{1}{3} \times 1.2 \times \langle c^2\rangle$	C1	
		$\langle c^2\rangle = 2.5 \times 10^5$	C1	
		$c_{r.m.s.} = 500\,m\,s^{-1}$	A1	[3]
	(ii)	$T \propto \langle c^2\rangle$	C1	
		$\langle c^2\rangle = 2.5 \times 10^5 \times 480/300$ $= 4.0 \times 10^5\,m^2\,s^{-2}$ (*allow ECF from* ***(c)(i)***)	A1	[2]
3	**(a)**	same temperature	B1	
		no (net) transfer of thermal energy (between the bodies)	B1	[2]
	(b) (i)	41.3 K	B1	[1]
	(ii)	330.4 K	B1	[1]

(c) $\Delta E_K = \frac{3}{2} \times 1.9 \times 60$
$= 171$ J C1

work done $= p\Delta V$
$= 1.2 \times 10^5 \times 950 \times 10^{-6}$ C1
$= 114$ J C1

thermal energy $= 114 + 171$
$= 285$ (290) J A1 [4]

4 **(a)** acceleration/force proportional to distance from a fixed point or displacement M1

either acceleration/force and displacement in opposite directions
or acceleration/force (always) directed towards a fixed point/mean position/equilibrium position A1 [2]

(b) $h\rho g = Mg / A$ B1
$h \times 790 \times 4.9 \times 10^{-4} = 70 \times 10^{-3}$ leading to $h = 0.18$ m or 18 cm A1 [2]

(c) **(i)** **1.** $\omega^2 = (790 \times 4.9 \times 10^{-4} \times 9.81) / (70 \times 10^{-3})$ C1
$= 54.25$

$\omega = 7.37$ (rad s^{-1})
period ($= 2\pi / \omega$) = 0.85 s C1

$t_1 = 0.43$ s A1 [3]

2. $t_3 = 1.28$ s (*allow 2 s.f.*) A1 [1]

(ii) energy of peak $= \frac{1}{2} M\omega^2 x_0^2$ B1

change $= \frac{1}{2} \times 70 \times 10^{-3} \times 54.25 \{(2.2 \times 10^{-2})^2 - (1.0 \times 10^{-2})^2\}$ C1
$= 7.3 \times 10^{-4}$ J A1 [3]

5	**(a)**	charges in metal do not move	B1	
		no (resultant) force on charges so no (electric) field	B1	[2]
		(*allow 1/2 for "no field inside sphere"*)		
	(b)	*either* average field strength = ½ (28 + 54) $N C^{-1}$	C1	
		average force = $8.5 \times 10^{-9} \times$ ½ (28 + 54)	C1	
		= 3.49×10^{-7} N		
		change in potential energy = $3.49 \times 10^{-7} \times 2.0 \times 10^{-2}$		
		= 7.0×10^{-9} J (*allow 1 s.f.*)	A1	
		(*allow range 54 ± 1*)		
		or (for a point charge) $V = Ex$	(C1)	
		$\Delta V = (54 \times 5.0 \times 10^{-2}) - (28 \times 7.0 \times 10^{-2})$	(C1)	
		change in potential energy = $8.5 \times 10^{-9} \times (2.70 - 1.96)$		
		= 6.3×10^{-9} J (*allow 1 s.f.*)	(A1)	
		(*allow range 54 ± 1*)		
		or ΔV is area under curve	(C1)	
		ΔV = 0.74 V	(C1)	
		change in potential energy = $8.5 \times 10^{-9} \times 0.74$		
		= 6.3×10^{-9} J (*allow 1 s.f.*)	(A1)	[3]
		(*allow range 0.70 to 0.84*)		
6	**(a)**	magnetic fields are equal in magnitude/strength/flux density	M1	
		magnetic fields are opposite in direction	M1	
		fields superpose/add/cancel to give zero/negligible resultant field	A1	[3]
	(b)	core causes increase in magnetic flux in the solenoid/induced poles in core *or* field induced in core	B1	
		changing flux threads/cuts the turns on the solenoid	M1	
		(by Faraday's law) an e.m.f. is induced in the solenoid	A1	
		by Lenz's law, this e.m.f. opposes the battery e.m.f.	A1	[4]
7	**(a)**	**(i)** V_0 (= $14\sqrt{2}$) = 19.8 (20) V	A1	[1]
		(ii) ω (= $2\pi \times 750$) = 4700 $rad\, s^{-1}$	A1	[1]
	(b)	large amount of charge required to charge capacitor	M1	
		capacitor would charge and discharge rapidly/in a very short time *or* capacitor would charge and discharge 750/1500 times per second	M1	
		$I = Q/t$, so large current	A1	[3]

8	**(a)**		$hc/\lambda = \Phi + E_{MAX}$	M1	
			h = Planck constant, c = speed of light/e.m. radiation	A1	[2]
	(b)	**(i)**	gradient of line is hc	M1	
			h and c are both constants	A1	[2]
		(ii)	$\Phi = 2.28 \times 1.6 \times 10^{-19}$	C1	
			$= 3.65 \times 10^{-19}$ (J)		
			$hc/\lambda_0 = 3.65 \times 10^{-19}$		
			$\lambda_0 = (6.63 \times 10^{-34} \times 3.0 \times 10^{8})/(3.65 \times 10^{-19})$	C1	
			$= 5.45 \times 10^{-7}$ m	A1	[3]
9	**(a)**		energy required to separate the nucleons (in a nucleus)		
			or energy required to separate the protons and neutrons in a nucleus	M1	
			(*or energy released when nucleons combine (to form a nucleus)/energy released when protons and neutrons combine to form a nucleus*)		
			either completely *or* to infinity	A1	[2]
			(*either free protons and neutrons or from infinity*)		
	(b)	**(i)**	*either* different forms of same element *or* nuclei having same number of	M1	
			protons with different numbers of neutrons	A1	[2]
		(ii)	1784 MeV (*accept min. 3 s.f.*)	A1	
			7.57 MeV	A1	[2]
	(c)	**(i)**	$\lambda = \ln 2/(7.1 \times 10^{8} \times 365 \times 24 \times 3600) = 3.1 \times 10^{-17}\,s^{-1}$	B1	[1]
		(ii)	$A = \lambda N$		
			$5000 = 3.1 \times 10^{-17} \times N$	C1	
			$N = 1.61 \times 10^{20}$		
			mass $= 235 \times (1.61 \times 10^{20})/(6.02 \times 10^{23})$	C1	
			$= 0.063$ g (*accept min. 2 s.f.*)	A1	[3]

Section B

10	**(a)**	correct LED symbol	B1	
		separately connected between V_{OUT} and earth with opposite polarities	M1	
		diode B 'pointing' from V_{OUT} to earth	A1	[3]
		(*ignore protective resistors*)		
	(b)	diode in V_{OUT} line	M1	
		diode 'pointing' towards V_{OUT} from earth	A1	
		relay coil connected between V_{OUT} and earth	M1	
		switch connected across lamp	A1	[4]
		(*if a diode is placed across the relay it must point down otherwise max. 2/4; one diode but wrong direction max. 3/4*)		
11	**(a)**	e.g. scattering (in metal)		
		non-parallel beam (not just "A closer than B")		
		reflection (from metal)		
		diffraction in the metal/lattice		
		any two	B2	[2]
	(b) (i)	**1.** ratio $= e^{\mu x}$		
		$= \exp(0.27 \times 4.0)$	C1	
		$= 2.94$ (2.9)	A1	[2]
		2. ratio $= \exp(0.27 \times 2.5) \times \exp(3.0 \times 1.5)$	C1	
		$= 1.96 \times 90$		
		$= 177$ (180)	A1	[2]
		(*do not penalise unit error more than once*)		
	(ii)	each ratio gives measure of transmission	B1	
		ratios (in **(i)**) very different so good contrast	B1	[2]
12	**(a) (i)**	serial-to-parallel converter	B1	[1]
	(ii)	digital-to-analogue converter *or* DAC	B1	[1]
	(iii)	(audio) amplifier *or* AF amplifier	B1	[1]
	(b) (i)	4	A1	[1]
	(ii)	1011	A1	[1]
	(c)	correct levels at 0.25 ms intervals		
		0, 8, 11, 10, 15	A1	
		and 7, 4	A1	
		series of steps, each of depth 0.25 ms	M1	
		voltage levels shown in correct intervals	A1	[4]

13 (a) advantage: e.g. shorter time delay
greater coverage over a long time — B1

disadvantage: e.g. satellite needs to be tracked
more satellites for (continuous) coverage/communication
(*any sensible suggestions*) — B1 [2]

(b) (i) frequencies linking Earth with satellite — B1

6 GHz is uplink frequency }
4 GHz is downlink frequency } (*allow vice versa*) — B1 [2]

(ii) *either* signal from Earth to satellite is attenuated greatly
or downlink must be amplified greatly before transmission — B1

downlink would swamp uplink unless frequencies are different — B1 [2]