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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 $GM = 4\pi^2 x^3/T^2$ — 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 $= ½M\omega^2 x_0^2$ — B1

change $= ½ \times 70 \times 10^{-3} \times 54.25 \{(2.2 \times 10^{-2})^2 - (1.0 \times 10^{-2})^2\}$ — 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 $= \frac{1}{2}(28 + 54)\ \text{N C}^{-1}$ — C1

average force $= 8.5 \times 10^{-9} \times \frac{1}{2}(28 + 54)$ — C1
$= 3.49 \times 10^{-7}$ N

change in potential energy $= 3.49 \times 10^{-7} \times 2.0 \times 10^{-2}$
$= 7.0 \times 10^{-9}$ 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 $= 8.5 \times 10^{-9} \times (2.70 - 1.96)$
$= 6.3 \times 10^{-9}$ J (*allow 1 s.f.*) — (A1)
(*allow range 54 ± 1*)

or ΔV is area under curve — (C1)
$\Delta V = 0.74$ V — (C1)

change in potential energy $= 8.5 \times 10^{-9} \times 0.74$
$= 6.3 \times 10^{-9}$ 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) $\omega (= 2\pi \times 750) = 4700\ \text{rad s}^{-1}$ — 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]