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PHYSICS **9702/41**

Paper 4 A Level Structured Questions **October/November 2016**

MARK SCHEME

Maximum Mark: 100

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1	**(a)**	gravitational force provides/is the centripetal force	B1	
		$GMm/r^2 = mv^2/r$ *or* $GMm/r^2 = mr\omega^2$ **and** $v = 2\pi r/T$ *or* $\omega = 2\pi/T$	M1	
		with algebra to $T^2 = 4\pi^2r^3/GM$	A1	[3]
		or		
		acceleration due to gravity is the centripetal acceleration	(B1)	
		$GM/r^2 = v^2/r$ *or* $GM/r^2 = r\omega^2$ **and** $v = 2\pi r/T$ *or* $\omega = 2\pi/T$	(M1)	
		with algebra to $T^2 = 4\pi^2r^3/GM$	(A1)	
	(b) (i)	equatorial orbit/orbits (directly) above the equator	B1	
		from west to east	B1	[2]
	(ii)	$(24 \times 3600)^2 = 4\pi^2r^3/(6.67 \times 10^{-11} \times 6.0 \times 10^{24})$	C1	
		$r^3 = 7.57 \times 10^{22}$		
		$r = 4.2 \times 10^7$ m	A1	[2]
	(c)	$(T/24)^2 = \{(2.64 \times 10^7)/(4.23 \times 10^7)\}^3$ $= 0.243$	B1	
		T = 12 hours	A1	[2]
		or		
		$k\ (= T^2/r^3) = 24^2/(4.23 \times 10^7)^3$ $= 7.61 \times 10^{-21}$	(B1)	
		$T^2\ (= kr^3) = 7.61 \times 10^{-21} \times (2.64 \times 10^7)^3$ $= 140$		
		T = 12 hours	(A1)	
2	**(a) (i)**	$p \propto T$ *or* pV/T = constant *or* $pV = nRT$	C1	
		$T\ (= 5 \times 300 =)$ 1500 K	A1	[2]
	(ii)	$pV = nRT$		
		$1.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 300$ *or* $5.0 \times 10^5 \times 4.0 \times 10^{-4} = n \times 8.31 \times 1500$	C1	
		n = 0.016 mol	A1	[2]

(b)	**(i)**	**1.** heating/thermal energy supplied	B1	
		2. work done on/to system	B1	[2]
	(ii)	**1.** 240 J	A1	
		2. same value as given in **1.** (= 240 J) **and** zero given for **3.**	A1	
		3. zero	A1	[3]

3 (a) $2k/m = \omega^2$ — M1

$\omega = 2\pi f$ — M1

$(2 \times 64 / 0.810) = (2\pi \times f)^2$ leading to $f = 2.0$ Hz — A1 [3]

(b) $v_0 = \omega x_0$ *or* $v_0 = 2\pi f x_0$
or
$v = \omega(x_0^2 - x^2)^{1/2}$ <u>and</u> $x = 0$ — C1

$v_0 = 2\pi \times 2.0 \times 1.6 \times 10^{-2}$

$= 0.20\ \mathrm{m\,s^{-1}}$ — A1 [2]

(c) frequency: reduced/decreased — B1
maximum speed: reduced/decreased — B1 [2]

4 (a) (i) noise/distortion is removed (from the signal) — B1
the (original) signal is reformed/reproduced/recovered/restored — B1 [2]

or

signal detected above/below a threshold creates new signal — (B1)
of 1s and 0s — (B1)

(ii) noise is superposed on the (displacement of the) signal/cannot be distinguished
or
analogue/signal is continuous (so cannot be regenerated)
or
analogue/signal is not discrete (so cannot be regenerated) — B1

noise is amplified with the signal — B1 [2]

(b) **(i)** gain/dB = $10\lg(P_2/P_1)$

$32 = 10\lg[P_{MIN}/(0.38 \times 10^{-6})]$
or
$-32 = 10\lg(0.38 \times 10^{-6}/P_{MIN})$ C1

$P_{MIN} = 6.0 \times 10^{-4}$ W A1 [2]

(ii) attenuation $= 10\lg[(9.5 \times 10^{-3})/(6.02 \times 10^{-4})]$ C1

$= 12$ dB

attenuation per unit length (= 12/58) = 0.21 dB km^{-1} A1 [2]

5 **(a)** in an electric field, charges (in a conductor) would move B1

no movement of charge so zero field strength
or
charge moves until $F = 0$ / $E = 0$ B1 [2]

or

charges in metal do not move (B1)
no (resultant) force on charges so no (electric) field (B1)

(b) at P, $E_A = (3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2]$ (= 10.79 N C^{-1}) M1

at P, $E_B = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]$ (= 10.79 N C^{-1}) M1

or

$(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] - (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2] = 0$
or
$(3.0 \times 10^{-12})/[4\pi\varepsilon_0(5.0 \times 10^{-2})^2] = (12 \times 10^{-12})/[4\pi\varepsilon_0(10 \times 10^{-2})^2]$ (M2)

fields due to charged spheres are (equal and) <u>opposite in direction</u>, so $E = 0$ A1 [3]

(c) potential $= 8.99 \times 10^9 \{(3.0 \times 10^{-12})/(5.0 \times 10^{-2}) + (12 \times 10^{-12})/(10 \times 10^{-2})\}$ C1

$= 1.62$ V A1 [2]

(d) $\frac{1}{2}mv^2 = qV$

$E_K = \frac{1}{2} \times 107 \times 1.66 \times 10^{-27} \times v^2$ C1

$qV = 47 \times 1.60 \times 10^{-19} \times 1.62$ C1

$v^2 = 1.37 \times 10^8$

$v = 1.2 \times 10^4$ m s^{-1} A1 [3]

6	(a)	reference to input (voltage) and output (voltage)	B1	
		there is no time delay between change in input and change in output	B1	[2]
		or		
		reference to rate at which output voltage changes	(B1)	
		infinite rate of change (of output voltage)	(B1)	
	(b) (i)	$2.00/3.00 = 1.50/R$	C1	
		or		
		$V_+ = (3.00 \times 4.5)/(2.00 + 3.00) = 2.7$ $2.7 = 4.5 \times R/(R + 1.50)$	(C1)	
		resistance = 2.25 kΩ	A1	[2]
	(ii) 1.	correct symbol for LED	M1	
		two LEDs connected with opposite polarities between V_{OUT} and earth	A1	[2]
	2.	below 24 °C, $R_T > 1.5$ kΩ or resistance of thermistor increases/high	B1	
		$V_- < V_+$ or V_- decreases/low (must not contradict initial statement)	M1	
		V_{OUT} is positive/+5 (V) <u>and</u> LED labelled as 'pointing' from V_{OUT} to earth	A1	[3]
7	(a)	region (of space) where a force is experienced by a particle	B1	[1]
	(b) (i)	gravitational	B1	
	(ii)	gravitational and electric	B1	
	(iii)	gravitational, electric and magnetic	B1	[3]
	(c) (i)	force (always) normal to direction of motion	M1	
		(magnitude of) force constant *or* speed is constant/kinetic energy is constant	M1	
		magnetic force provides/is the centripetal force	A1	[3]
	(ii)	$mv^2/r = Bqv$	B1	
		momentum or p or $mv = Bqr$	B1	[2]

8	strong <u>uniform</u> magnetic field	B1	
	nuclei precess/rotate about field (direction)	(1)	
	radio-frequency pulse (applied)	B1	
	R.F. or pulse is at Larmor frequency/frequency of precession	(1)	
	causes resonance/excitation (of nuclei)/nuclei absorb energy	B1	
	on relaxation/de-excitation, nuclei emit r.f./pulse	B1	
	(emitted) r.f./pulse detected and processed	(1)	
	non-uniform magnetic field	B1	
	allows position of nuclei to be located	B1	
	allows for location of detection to be changed/different slices to be studied	(1)	
	any two of the points marked (1)	B2	[8]
9	**(a)** (induced) e.m.f. proportional to rate of change of (magnetic) flux (linkage)	M1 A1	[2]
	(b) flux linkage $= BAN$		
	$= \pi \times 10^{-3} \times 2.8 \times \pi \times (1.6 \times 10^{-2})^2 \times 85 = 6.0 \times 10^{-4}$ Wb	B1	[1]
	(c) e.m.f. $= \Delta N\Phi / \Delta t$		
	$= (6.0 \times 10^{-4} \times 2) / 0.30$	C1	
	$= 4.0$ mV	A1	[2]
	(d) sketch: $E = 0$ for $t = 0 \rightarrow 0.3$ s, 0.6 s $\rightarrow 1.0$ s, 1.6 s $\rightarrow 2.0$ s	B1	
	$E = 4$ mV for $t = 0.3$ s $\rightarrow 0.6$ s (either polarity)	B1	
	$E = 2$ mV for $t = 1.0$ s $\rightarrow 1.6$ s	B1	
	with opposite polarity	B1	[4]

10 **(a)** electromagnetic radiation/photons incident on a surface B1

causes emission of electrons (from the surface) B1 [2]

(b) $E = hc / \lambda$

$= (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (436 \times 10^{-9})$ C1

$= 4.56 \times 10^{-19}$ J (4.6×10^{-19} J) A1 [2]

(c) **(i)** $\Phi = hc / \lambda_0$

$\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (1.4 \times 1.60 \times 10^{-19})$ C1

$= 890$ nm A1 [2]

(ii) $\lambda_0 = (6.63 \times 10^{-34} \times 3.00 \times 10^{8}) / (4.5 \times 1.60 \times 10^{-19})$

$= 280$ nm A1 [1]

(d) caesium:
wavelength of photon less than threshold wavelength (or v.v.)
or
$\lambda_0 = 890$ nm > 436 nm
so yes A1

tungsten:
wavelength of photon greater than threshold wavelength (or v.v.)
or
$\lambda_0 = 280$ nm < 436 nm
so no A1 [2]

11 in metal, conduction band overlaps valence band/no forbidden band/no band gap B1

as temperature rises, no increase in number of free electrons/charge carriers B1

as temperature rises, lattice vibrations increase M1

(lattice) vibrations restrict movement of electrons/charge carriers M1

(current decreases) so resistance increases A1 [5]

12 **(a)** **(i)** time for number of atoms/nuclei or activity to be reduced to one half M1

reference to (number of…) original nuclide/single isotope
or
reference to half of original value/initial activity A1 [2]

(ii) $A = A_0 \exp(-\lambda t)$ <u>and</u> either $t = t_{½}$, $A = ½A_0$ or $½A_0 = A_0 \exp(-\lambda t_{½})$ M1

so $\ln 2 = \lambda t_{½}$ (and $\ln 2 = 0.693$), hence $0.693 = \lambda t_{½}$ A1 [2]

(b) $A = \lambda N$

$N = 200 / (2.1 \times 10^{-6})$ C1

$= 9.52 \times 10^{7}$ C1

mass = $(9.52 \times 10^{7} \times 222 \times 10^{-3}) / (6.02 \times 10^{23})$
or
mass = $9.52 \times 10^{7} \times 222 \times 1.66 \times 10^{-27}$ C1

$= 3.5 \times 10^{-17}$ kg A1 [4]