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PHYSICS

9702/41

Paper 4 A Level Structured Questions

May/June 2016

MARK SCHEME

Maximum Mark: 100

Published

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- 1 (a) (gravitational) potential at infinity defined as/is zero B1
- (gravitational) force attractive so work got out/done as object moves from infinity
(so potential is negative) B1 [2]
- (b) (i) $\Delta E = m\Delta\phi$
 $= 180 \times (14 - 10) \times 10^8$ C1
 $= 7.2 \times 10^{10} \text{ J}$ A1
 increase B1 [3]
- (ii) energy required $= 180 \times (10 - 4.4) \times 10^8$
 or
 energy per unit mass $= (10 - 4.4) \times 10^8$ C1
 $\frac{1}{2} \times 180 \times v^2 = 180 \times (10 - 4.4) \times 10^8$
 or
 $\frac{1}{2} \times v^2 = (10 - 4.4) \times 10^8$ C1
 $v = 3.3 \times 10^4 \text{ ms}^{-1}$ A1 [3]
- 2 (a) e.g. time of collisions negligible compared to time between collisions
- no intermolecular forces (except during collisions)
- random motion (of molecules)
- large numbers of molecules
- (total) volume of molecules negligible compared to volume of containing vessel
 or
 average/mean separation large compared with size of molecules
- any two B2 [2]
- 2 (b) (i) mass $= 4.0 / (6.02 \times 10^{23}) = 6.6 \times 10^{-24} \text{ g}$
 or
 mass $= 4.0 \times 1.66 \times 10^{-27} \times 10^3 = 6.6 \times 10^{-24} \text{ g}$ B1 [1]
- (ii) $\frac{3}{2} kT = \frac{1}{2} m \langle c^2 \rangle$ C1
- $\frac{3}{2} \times 1.38 \times 10^{-23} \times 300 = \frac{1}{2} \times 6.6 \times 10^{-27} \times \langle c^2 \rangle$
- $\langle c^2 \rangle = 1.88 \times 10^6 \text{ (m}^2\text{s}^{-2}\text{)}$ C1
- r.m.s. speed $= 1.4 \times 10^3 \text{ ms}^{-1}$ A1 [3]

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- 3 (a)** acceleration/force proportional to displacement (from fixed point) M1
 acceleration/force and displacement in opposite directions A1 [2]
- (b)** maximum displacements/accelerations are different B1
 graph is curved/not a straight line B1 [2]
- (c) (i)** $\omega = 2\pi / T$ and $T = 0.8 \text{ s}$ C1
 $\omega = 7.9 \text{ rad s}^{-1}$ A1 [2]
- (ii)** $a = (-)\omega^2 x$ C1
 $= 7.85^2 \times 1.5 \times 10^{-2}$
 $= 0.93 \text{ ms}^{-2}$ or 0.94 ms^{-2} A1 [2]
- (iii)** $\Delta E = \frac{1}{2} m \omega^2 (x_0^2 - x^2)$ C1
 $= \frac{1}{2} \times 120 \times 10^{-3} \times 7.85^2 \times \{(1.5 \times 10^{-2})^2 - (0.9 \times 10^{-2})^2\}$ C1
 $= 5.3 \times 10^{-4} \text{ J}$ A1 [3]
- 4 (a) (i)** product of speed and density M1
 reference to speed in medium (and density of medium) A1 [2]
- (ii)** α : ratio of reflected intensity and/to incident intensity B1
 Z_1 and Z_2 : (specific) acoustic impedances of media (on each side of boundary) B1 [2]
- (b)** in muscle: $I_M = I_0 e^{-\mu x}$
 $= I_0 \exp(-23 \times 3.4 \times 10^{-2})$ C1
 $I_M / I_0 = 0.457$ C1
 at boundary: $\alpha = (6.3 - 1.7)^2 / (6.3 + 1.7)^2$
 $= 0.33$ C1
 $I_T / I_M = [(1 - \alpha)] = 0.67$ C1
 $I_T / I_0 = 0.457 \times 0.67$
 $= 0.31$ A1 [5]

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5 (a) (i) 1011 A1 [1]

(ii)

0	0.25	0.50	0.75	1.00	1.25	1.50
1011	0110	1000	1110	0101	0011	0001

All 6 correct, 2 marks. 5 correct, 1 mark. A2 [2]

(b) sketch: 6 horizontal steps of width 0.25 ms shown M1
 steps at correct heights and all steps shown A1
 steps shown in correct time intervals A1 [3]

(c) increase sampling frequency/rate M1
 so that step width/depth is reduced A1
 increase number of bits (in each number) M1
 so that step height is reduced A1 [4]

6 (a) sketch: from $x = 0$ to $x = R$, potential is constant at V_s B1
 smooth curve through (R, V_s) and $(2R, 0.5V_s)$ B1
 smooth curve continues to $(3R, 0.33V_s)$ B1 [3]

(b) sketch: from $x = 0$ to $x = R$, field strength is zero B1
 smooth curve through (R, E) and $(2R, 0.25E)$ B1
 smooth curve continues to $(3R, 0.11E)$ B1 [3]

7 (a) line has non-zero intercept/line does not pass through origin B1
 charge is/should be proportional to potential (difference)
 or
 charge is/should be zero when p.d. is zero
 (therefore there is a systematic error) B1 [2]

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(b)	reasonable attempt at line of best fit	B1	
	use of gradient of line of best fit clear	M1	
	$C = 2800 \mu\text{F}$ (allow $\pm 200 \mu\text{F}$)	A1	[3]
(c)	energy = $\frac{1}{2} CV^2$ or energy = $\frac{1}{2} QV$ <u>and</u> $C = Q / V$	C1	
	$\Delta \text{ energy} = \frac{1}{2} \times 2800 \times 10^{-6} \times (9.0^2 - 6.0^2)$	C1	
	$= 6.3 \times 10^{-2} \text{ J}$	A1	[3]
8	(a) op-amp has infinite/(very) large gain	B1	
	op-amp saturates if $V^+ \neq V^-$	M1	
	V^+ is at earth potential so P (or V^-) must be at earth	A1	[3]
	(b) input resistance to op-amp is very large or current in R_2 = current in R_1	B1	
	$V_{\text{IN}} (-0) = IR_2$ <u>and</u> $(0) - V_{\text{OUT}} = IR_1$	M1	
	$V_{\text{OUT}} / V_{\text{IN}} = -R_1 / R_2$	A1	[3]
	(c) relay coil connected between V_{OUT} and earth	M1	
	correct diode symbol connected between V_{OUT} and coil or between coil and earth	M1	
	correct polarity for diode ('clockwise')	A1	[3]
9	(a) 0.10 mm	B1	[1]
	(b) $V_{\text{H}} = (0.13 \times 3.8) / (6.0 \times 10^{28} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$	C1	
	$= 5.1 \times 10^{-7} \text{ V}$	A1	[2]
10	(a) (non-uniform) magnetic flux <u>in core</u> is changing	M1	
	induces (different) e.m.f. in (different parts of) the core	A1	
	(eddy) currents form in the core	M1	
	which give rise to heating	A1	[4]

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(b)	as magnet falls, tube cuts magnetic flux	M1	
	e.m.f./ (eddy) currents induced in metal/aluminium (tube)	A1	
	(eddy) current heating of tube	M1	
	with energy taken from falling magnet	A1	
	or		
	(eddy) currents produce magnetic field	(M1)	
	that opposes motion of magnet	(A1)	
	so magnet B has acceleration $< g$		
	or		
	magnet B has smaller acceleration/reaches terminal speed	A1	[5]
11	(a) period = 15 ms	C1	
	frequency $(= 1 / T) = 67 \text{ Hz}$	A1	[2]
	(b) zero	A1	[1]
	(c) $I_{\text{r.m.s.}} = I_0 / \sqrt{2}$	C1	
	$= 0.53 \text{ A}$	A1	[2]
	(d) energy $= I_{\text{r.m.s.}}^2 \times R \times t$ or $\frac{1}{2} I_0^2 \times R \times t$		
	or		
	power $= I_{\text{r.m.s.}}^2 \times R$ and energy $= \text{power} \times t$	C1	
	energy $= 0.53^2 \times 450 \times 30 \times 10^{-3}$		
	$= 3.8 \text{ J}$	A1	[2]
12	(a) (in a solid electrons in) neighbouring atoms are close together (and influence/interact with each other)	M1	
	this changes their electron energy levels	M1	
	(many atoms in lattice) cause a spread of energy levels into a band	A1	[3]

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- (b) photons of light give energy to electrons in valence band B1
- electrons move into the conduction band M1
- leaving holes in the valence band A1
- these electrons and holes are charge carriers B1
- increased number/increased current, hence reduced resistance B1 [5]

13 (a) e.g. background count (rate)/radiation

multiple possible counts from each decay

radiation emitted in all directions

dead-time of counter

(daughter) product unstable/also emits radiation

self-absorption of radiation in sample or absorption in air/detector window

three sensible suggestions, 1 each B3 [3]

(b) $A = A_0 \exp(-\ln 2 \times t / T_{1/2})$

$$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\ln 2 \times 42.0 / T_{1/2})$$

or

$$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\lambda \times 42.0)$$
 C1

$$T_{1/2} = 5.1 \text{ minutes (306 s)}$$
 A1 [2]

(c) discrete energy levels (in nuclei) B1 [1]