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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

$= 7.2 \times 10^{10}$ 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

$v = 3.3 \times 10^4$ m s^{-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 = $4.0 / (6.02 \times 10^{23}) = 6.6 \times 10^{-24}$ g
or
mass = $4.0 \times 1.66 \times 10^{-27} \times 10^3 = 6.6 \times 10^{-24}$ g B1 [1]

(ii) $\frac{3}{2}kT = \frac{1}{2}m\langle c^2\rangle$ C1

$\frac{3}{2} \times 1.38 \times 10^{-23} \times 300 = \frac{1}{2} \times 6.6 \times 10^{-27} \times \langle c^2\rangle$

$\langle c^2\rangle = 1.88 \times 10^6$ (m^2 s^{-2}) C1

r.m.s. speed = 1.4×10^3 m s^{-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) $a = (-)\omega^2 x$
$= 7.85^2 \times 1.5 \times 10^{-2}$ C1

$= 0.93\ \text{m s}^{-2}$ or $0.94\ \text{m s}^{-2}$ 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 μF (allow ± 200 μF) A1 [3]

(c) energy = ½ CV^2 or energy = ½ QV and $C = Q / V$ C1

Δ energy = ½ × 2800 × 10^{-6} × ($9.0^2 - 6.0^2$) C1

= 6.3 × 10^{-2} 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_{IN} (– 0) = IR_2 and (0) – V_{OUT} = IR_1 M1

$V_{OUT} / V_{IN} = -R_1 / R_2$ 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) $V_H = (0.13 \times 3.8) / (6.0 \times 10^{28} \times 0.10 \times 10^{-3} \times 1.60 \times 10^{-19})$ C1

= 5.1 × 10^{-7} V A1 [2]

10 (a) (non-uniform) magnetic flux in core 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 Hz — A1 [2]

(b) zero — A1 [1]

(c) $I_{\text{r.m.s.}} = I_0 / \sqrt{2}$ — C1

$= 0.53$ 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 = power $\times$ t — C1

energy $= 0.53^2 \times 450 \times 30 \times 10^{-3}$

$= 3.8$ 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) $A = A_0 \exp(-\ln 2 \times t / T_{½})$

$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\ln 2 \times 42.0 / T_{½})$
or
$1.21 \times 10^2 = 3.62 \times 10^4 \exp(-\lambda \times 42.0)$ C1

$T_{½}$ = 5.1 minutes (306 s) A1 [2]

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

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