Cambridge International AS & A Level

**Cambridge International Examinations**
Cambridge International Advanced Subsidiary and Advanced Level

**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 <u>attractive</u> 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

$\tfrac{1}{2} \times 180 \times v^2 = 180 \times (10 - 4.4) \times 10^8$

*or*

$\tfrac{1}{2} \times v^2 = (10 - 4.4) \times 10^8$ — 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 = $1.4 \times 10^3$ m s$^{-1}$ — A1 [3]

| | | | | |
|---|---|---|---|---|
| 3 | (a) | acceleration/force proportional to displacement (from fixed point) | M1 | |
| | | acceleration/force and displacement in opposite directions | A1 | [2] |
| | (b) | <u>maximum</u> 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 | |
| | | $\omega = 7.9\ \text{rad}\,\text{s}^{-1}$ | A1 | [2] |
| | (ii) | $a = (-)\omega^2 x$<br>$= 7.85^2 \times 1.5 \times 10^{-2}$ | C1 | |
| | | $= 0.93\ \text{m}\,\text{s}^{-2}$ or $0.94\ \text{m}\,\text{s}^{-2}$ | A1 | [2] |
| | (iii) | $\Delta E = ½\, m\omega^2 (x_0^{\,2} - x^2)$ | C1 | |
| | | $= ½ \times 120 \times 10^{-3} \times 7.85^2 \times \{(1.5 \times 10^{-2})^2 - (0.9 \times 10^{-2})^2\}$ | 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) | $\alpha$: ratio of reflected <u>intensity</u> and/to incident <u>intensity</u> | B1 | |
| | | $Z_1$ and $Z_2$: (specific) acoustic impedances of media (on each side of boundary) | B1 | [2] |
| | (b) | in muscle: $I_M = I_0\, e^{-\mu x}$<br>$= I_0 \exp(-23 \times 3.4 \times 10^{-2})$ | C1 | |
| | | $I_M / I_0 = 0.457$ | C1 | |
| | | at boundary: $\alpha = (6.3 - 1.7)^2 / (6.3 + 1.7)^2$<br>$= 0.33$ | C1 | |
| | | $I_T / I_M = [(1 - \alpha) =]\ 0.67$ | C1 | |
| | | $I_T / I_0 = 0.457 \times 0.67$<br>$= 0.31$ | A1 | [5] |

**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]

| | | | | |
|---|---|---|---|---|
| | **(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 $QV$ <u>and</u> $C = Q / V$ | 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<br>*or*<br>current in $R_2$ = current in $R_1$ | B1 | |
| | | $V_{IN}$ (– 0) = $IR_2$ <u>and</u> (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 × 3.8) / (6.0 × $10^{28}$ × 0.10 × $10^{-3}$ × 1.60 × $10^{-19}$) | C1 | |
| | | = 5.1 × $10^{-7}$ 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] |

| | | | | |
|---|---|---|---|---|
| | **(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 < $g$<br>*or*<br>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 $\frac{1}{2} I_0^2 \times R \times t$<br>*or*<br>power = $I_{\text{r.m.s.}}^2 \times R$ and energy = power × $t$ | 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<br>(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] |

| | | | | |
|---|---|---|---|---|
| | **(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] |