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All Examiners are instructed that alternative correct answers and unexpected approaches in candidates’ scripts must be given marks that fairly reflect the relevant knowledge and skills demonstrated.

Mark schemes must be read in conjunction with the question papers and the report on the examination.

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Section A

1 (a) (i) angle (subtended) at centre of circle by an arc equal in length to the radius (of the circle) B1 B1 [2]

(ii) angle swept out per unit time / rate of change of angle by the string M1 A1 [2]

(b) friction provides / equals the centripetal force B1 C1

\[ 0.72 \ W = m d \omega^2 \]
\[ 0.72 \ mg = m \times 0.35 \omega^2 \]
\[ \omega = 4.49 \text{ (rad s}^{-1}) \]
\[ n = (\omega / 2\pi) \times 60 \]
\[ = 43 \text{ min}^{-1} \text{ (allow 42)} \]

(c) either centripetal force increases as \( r \) increases or centripetal force larger at edge so flies off at edge first A1 [2]

\( (F = m r \omega^2 \text{ so edge first – treat as special case and allow one mark}) \)

2 (a) molecule(s) rebound from wall of vessel / hits walls B1 B1 [3]

change in momentum gives rise to impulse / force either (many impulses) averaged to give constant force / pressure or the molecules are in random motion B1 [3]

(b) (i) \( p = \frac{1}{3} \rho <c^2> \) C1

\[ 1.02 \times 10^5 = \frac{1}{3} \times 0.900 \times <c^2> \]
\[ <c^2> = 3.4 \times 10^5 \]
\[ c_{\text{RMS}} = 580 \text{ m s}^{-1} \]

(c) \( c_{\text{RMS}} \) depends on temperature (alone) so no effect B1 B1 [2]

\( <c^2> \propto T \text{ or } <c^2> = 2 \times 3.4 \times 10^5 \text{ (allow 820)} \)

\( c_{\text{RMS}} = 830 \text{ m s}^{-1} \) A1 [2]
3 (a) (i) amplitude = 0.5 cm A1 [1]
(ii) period = 0.8 s A1 [1]

(b) (i) \( \omega = \frac{2\pi}{T} \)
\[ = 7.85 \text{ rad s}^{-1} \]
correct use of \( v = \omega \sqrt{(x_0^2 - x^2)} \)
\[ = 7.85 \times \sqrt{((0.5 \times 10^{-2})^2 - (0.2 \times 10^{-2})^2)} \]
\[ = 3.6 \text{ cm s}^{-1} \]
(if tangent drawn or clearly implied (B1)
\( 3.6 \pm 0.3 \text{ cm s}^{-1} \) (A2)
but allow 1 mark for > ±0.3 but ≤ ±0.6 cm s\(^{-1}\))

(ii) \( d = 15.8 \text{ cm} \) A1 [1]

(c) (i) (continuous) loss of energy / reduction in amplitude (from the oscillating system) B1
caused by force acting in opposite direction to the motion / friction / viscous forces B1 [2]

(ii) same period / small increase in period B1
line displacement always less than that on Fig.3.2 (ignore first \( T/4 \)) M1
peak progressively smaller A1 [3]

4 (a) work done moving unit positive charge
from infinity to the point M1

(b) (i) \( x = 18 \text{ cm} \) A1 [1]

(ii) \( V_A + V_B = 0 \)
\[ (3.6 \times 10^{-9}) / (4\pi \epsilon_0 \times 18 \times 10^{-2}) + q / (4\pi \epsilon_0 \times 12 \times 10^{-2}) = 0 \]
\[ q = -2.4 \times 10^{-9} \text{ C} \]
(\( \text{use of } V_A = V_B \text{ giving } 2.4 \times 10^{-9} \text{ C scores one mark} \)) A1 [3]

(c) field strength = (–) gradient of graph B1
force = charge \( \times \) gradient / field strength or force \( \propto \) gradient B1
force largest at \( x = 27 \text{ cm} \) B1 [3]

5 (a) at \( t = 1.0 \text{ s} \), \( V = 2.5 \text{ V} \)
energy = \( \frac{1}{2} CV^2 \)
\[ 0.13 = \frac{1}{2} \times C \times (8.0^2 - 2.5^2) \]
\[ C = 4500 \mu\text{F} \] M1

(b) use of two capacitors in series in all branches of combination
connected into correct parallel arrangement M1
A1 [2]
6 (a) parallel (to the field) B1 [1]

(b) (i) torque = \( F \times d \)
\[ 2.1 \times 10^{-3} = F \times 2.8 \times 10^{-2} \]
\[ F = 0.075 \text{ N} \]
*(use of 4.5 cm scores no marks)*

(ii) zero A1 [1]

(c) \( F = BILN(\sin \theta) \)
\[ 0.075 = B \times 0.170 \times 4.5 \times 10^{-2} \times 140 \]
\[ B = 7.0 \times 10^{-2} \text{ T} = 70 \text{ mT} \] A0 [2]

(d) (i) (induced) e.m.f. is proportional to / equal to rate of change of (magnetic) flux (linkage) M1

(ii) change in flux linkage = \( BAN \)
\[ = 0.070 \times 4.5 \times 10^{-2} \times 2.8 \times 10^{-2} \times 140 \]
\[ = 0.0123 \text{ Wb turns} \]
induced e.m.f. = 0.0123 / 0.14
\[ = 88 \text{ mV} \]
*(Note: This is a simplified treatment. A full treatment would involve the averaging of B \( \cos \theta \) leading to a \( \sqrt{2} \) factor)*

7 (a) charge is quantised / discrete quantities B1 [1]

(b) (i) parallel so that the electric field is uniform / constant B1
horizontal so that \( either \) oil drop will not drift sideways
\( or \) field is vertical
\( or \) electric force is equal to weight B1 [2]

(ii) \( qE = mg \)
\[ q \times 850 / (5.4 \times 10^{-3}) = 7.7 \times 10^{-15} \times 9.8 \]
\[ q = 4.8 \times 10^{-19} \text{ C and is negative} \] A1 [3]

(c) charge changes by \( 1.6 \times 10^{-19} \text{ C} \) between droplets / integral multiples M1
so charge on electron is \( 1.6 \times 10^{-19} \text{ C} \) A0 [1]

8 (a) since momentum before combining is zero B1
momenta must be equal and opposite after B1
equal momenta so photon energies equal B1 [3]

(b) \( E = mc^2 \)
\[ = 9.1 \times 10^{-31} \times (3.0 \times 10^8)^2 \]
\[ = 8.19 \times 10^{-14} \text{ (J)} \]
\[ = (8.19 \times 10^{-14}) / (1.6 \times 10^{-13}) \]
\[ = 0.51 \text{ MeV} \] A1 [3]
Section B

9 (a) blocks labelled sensing device / sensor / transducer processor / processing unit / signal conditioning B1 [2]

(b) (i) two LEDs with opposite polarities (ignore any series resistors) correctly identified as red and green M1 A1 [2]

(ii) correct polarity for diode to conduct identified hence red LED conducts when input (+)ve or vice versa M1 A0 [1]

10 large / strong (constant) magnetic field nuclei rotate about direction of field / precess (1) radio frequency / r.f. pulse causes resonance in nuclei, nuclei absorb energy (1) (pulse) is at the Larmor frequency (1) on relaxation / nuclei de-excite emit (pulse of) r.f. detected and processed B1 B1 B1 B1 non-uniform field (superimposed) allows for position of nuclei to be determined and for location of detection to be changed (1) (B6 plus any two extra details, 1 each, max 2) B2 [8]

11 (a) (i) frequency of carrier wave varies in synchrony with displacement of information signal M1 A1 [2]

(ii) 1. zero (accept constant) B1 [1]

2. upper limit 530 kHz lower limit 470 kHz changes upper limit → lower limit → upper limit at 8000 s⁻¹ B1 B1 B1 B1 [3]

(b) e.g. more radio stations required / shorter range more complex electronics larger bandwidth required (any two sensible suggestions, 1 each) B2 [2]

12 (a) (i) picking up of signal in one cable from a second (nearby) cable M1 A1 [2]

(ii) random (unwanted) signal / power that masks / added to / interferes with / distorts transmitted signal (allow this mark in (i) or (ii)) B1 B1 [2]

(b) if \( P \) is power at receiver,

\[
30 = 10\lg \left( \frac{P}{(6.5 \times 10^{-6})} \right)
\]

\[
P = 6.5 \times 10^{-3} \text{ W}
\]

loss along cable = \( 10\lg \left( \frac{(26 \times 10^{-3})}{(6.5 \times 10^{-3})} \right) \) = 6.0 dB

length = 6.0 / 0.2 = 30 km A1 [5]