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1 (a) (density =) mass / volume  
B1 [1]

(b) (i) \( d = \sqrt[3]{\frac{(6 \times 7.5)}{(\pi \times 8100)}} \)  
\[ = 0.12(1) \text{ m} \]  
A1 [1]

(ii) percentage uncertainty = \((4 + 5) / 3\)  
\[ (= 3\% \)  
or  
 fractional uncertainty = \((0.04 + 0.05) / 3\)  
\[ (= 0.03 \)  
C1

absolute uncertainty  
\[ (= 0.03 \times 0.121) = 0.0036 \]  
C1

\[ d = 0.121 \pm 0.004 \text{ m} \]  
A1 [3]

2 (a) force per unit positive charge  
B1 [1]

(b) (i) time  
\[ = \frac{5.9 \times 10^{-2}}{3.7 \times 10^7} \]  
\[ = 1.6 \times 10^{-9} \text{ s} \] (1.59 \times 10^{-9} \text{ s})  
A1 [1]

(ii) \( E = \frac{V}{d} \)  
C1

\[ = \frac{2500}{4.0 \times 10^{-2}} \]  
\[ = 6.3 \times 10^4 \text{ N C}^{-1} \] (6.25 \times 10^4 or 62500 N C^{-1})  
A1 [2]

(iii) \( a = Eq / m \) or \( F = ma \) and \( F = Eq \)  
C1

\[ = (6.3 \times 10^4 \times 1.60 \times 10^{-19}) / 9.11 \times 10^{-31} = 1.1 \times 10^{16} \text{ m s}^{-2} \]  
A1 [2]

(iv) \( s = ut + \frac{1}{2}at^2 \)  
\[ = \frac{1}{2} \times 1.1 \times 10^{16} \times (1.6 \times 10^{-9})^2 \]  
C1

\[ = 1.4 \times 10^{-2} \text{ (m)} \]  
C1

distance from plate  
\[ = 2.0 - 1.4 \]  
\[ = 0.6 \text{ cm} \] (allow 1 or more s.f.)  
A1 [3]

(v) electric force \( \gg \) gravitational force (on electron)/weight  
or  
acceleration due to electric field \( \gg \) acceleration due to gravitational field  
B1 [1]

(vi) \( v_x - t \) graph: horizontal line at a non-zero value of \( v_x \)  
B1

\( v_y - t \) graph: straight line through the origin with positive gradient  
B1 [2]
3 (a) force/load is proportional to extension/compression (provided proportionality limit is not exceeded) B1 [1]

(b) (i) \( k = \frac{F}{x} \) or \( k = \text{gradient} \) C1

\[ k = 600 \text{ N m}^{-1} \] A1 [2]

(ii) \( (W =) \frac{1}{2}kx^2 \) or \( (W =) \frac{1}{2}Fx \) or \( (W =) \) area under graph C1

\[ (W =) \frac{0.5 \times 600 \times (0.040)^2}{2} = 0.48 \text{ J} \] A1 [2]

\[ (W =) \frac{0.5 \times 24 \times 0.040}{1} = 0.48 \text{ J} \] A1 [2]

(iii) 1. \( (E_k =) \frac{1}{2}mv^2 \) C1

\[ = \frac{1}{2} \times 0.025 \times 6.0^2 \]

\[ = 0.45 \text{ J} \] A1 [2]

2. (work done against resistive force =) 0.48 – 0.45 [= 0.03(0) J] C1

average resistive force = 0.030 / 0.040

\[ = 0.75 \text{ N} \] A1 [3]

(iv) efficiency = [useful energy out / total energy in] \((\times 100)\) C1

\[ = \frac{0.45}{0.48} \times 100 \]

\[ = 0.94 \text{ or 94\%} \] A1 [2]

4 (a) the number of oscillations per unit time of the source/of a point on the wave/of a particle (in the medium) M1 A1 [2]

"or"

the number of wavelengths/wavefronts per unit time passing a (fixed) point (M1) (A1)

(b) \( T \) or period = 2.5 \times 250 (\mu s) (= 625 \mu s) M1

frequency = \( \frac{1}{(6.25 \times 10^{-4})} \) or \( \frac{1}{(2.5 \times 250 \times 10^{-6})} = 1600 \text{ Hz} \) A1 [2]

(c) (i) for maximum frequency: \( f_o = f_s v / (v - v_s) \) C1

\[ 1640 = (1600 \times 330) / (330 - v_s) \]

\[ v_s = 8.049 \text{ m s}^{-1} \] A1 [2]

(ii) loudspeaker moving towards observer causes rise in/higher frequency B1

loudspeaker moving away from observer causes fall in/lower frequency B1

"or"

repeated rise and fall/higher and then lower frequency caused by loudspeaker moving towards and away from observer (M1) (A1)
5 (a) wave incident on/passes by or through an aperture/edge
wave spreads (into geometrical shadow) B1

(b) \( n\lambda = d \sin \theta \) C1

substitution of \( \theta = 90^\circ \) or \( \sin \theta = 1 \) C1

\[ 4 \times 500 \times 10^{-9} = d \times \sin 90^\circ \]

line spacing = \( 2.0 \times 10^{-6} \) m A1 [3]

(c) wavelength of red light is longer (than 500 nm) M1

(each order/fourth order is now at a greater angle so) the fifth-order maximum cannot be formed/not formed A1 [2]

6 (a) work done or energy (transformed) (from electrical to other forms) charge B1 [1]

(b) (i) 1. \( V = IR \) or \( E = IR \) C1

\[ I = 14 / 6.0 \]

\[ = 2.3 (2.33) A \] A1 [2]

2. total resistance of parallel resistors = \( 8.0 \Omega \) C1

\[ \text{current} = 14 / (6.0 + 8.0) \]

\[ = 1.0 A \] A1 [2]

(ii) \( P = EI \) (allow \( P = VI \)) or \( P = V^2 / R \) or \( P = I^2R \) C1

change in power = \( (14 \times 2.33) - (14 \times 1.0) \)

or \( (14^2 / 6.0) - (14^2 / 14) \)

or \( (2.33^2 \times 6.0) - (1.0^2 \times 14) \)

\[ = 19 W (18 W if 2.3 A used) \] A1 [2]

(c) \( I = Anvq \)

ratio = \( (0.50n / n) \times (1.8 A / A) \) or ratio = \( 0.50 \times 1.8 \) C1

\[ = 0.90 \] A1 [2]
7  (a) hadron not a fundamental particle/lepton is fundamental particle
   or
   hadron made of quarks/lepton not made of quarks
   or
   strong force/interaction acts on hadrons/does not act on leptons  B1 [1]

   (b) (i) proton: up, up, down/uud  B1
         neutron: up, down, down/udd  B1 [2]

         (ii) composition: 2(uud) + 2(udd)
              = 6 up, 6 down/6u, 6d  B1 [1]

   (c) (i) most of the atom is empty space
         or
         the nucleus (volume) is (very) small compared to the atom  B1 [1]

         (ii) nucleus is (positively) charged  B1
              the mass is concentrated in (very small) nucleus/small region/small
              volume/small core
              or
              the majority of mass in (very small) nucleus/small region/small volume/small core  B1 [2]