2022 VJC Prelim H2 P3 Suggested solution

1(a) At maximum height,

Loss in KE of mass = gain in GPE of mass + gain in EPE in cord [CONCEPT]

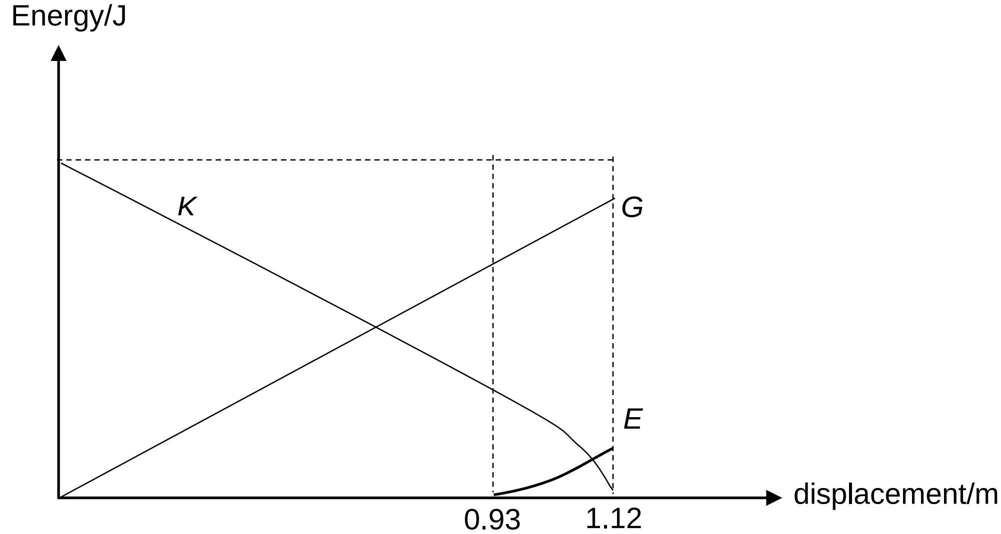
$$\frac{1}{2}mv^2 - 0 = mgh + \frac{1}{2}kx^2$$

$$\frac{1}{2}(150\times10^{-3})(5.7^2) - 0 = (150\times10^{-3})(9.81)(1.12) + \frac{1}{2}(45)x^2$$

$x = 0.19$ m

(b) Length of unstretched cord = 1.12 – 0.19 = 0.93 m

(c)



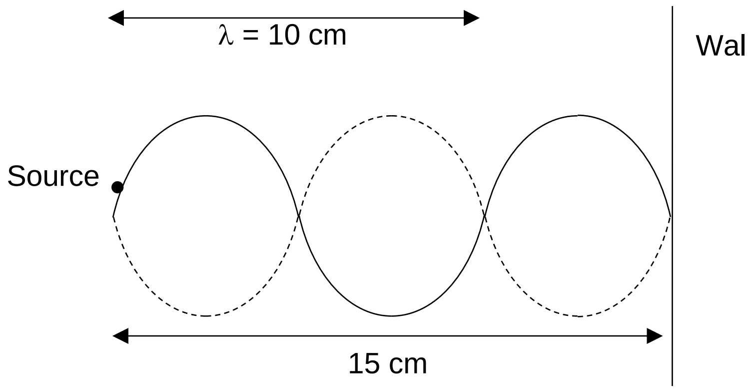
(G should end lower so that G + E = initial K at 1.12 m)

(d) Since the tension acting on the ball is always towards the center and perpendicular to the displacement of the ball [APPLICATION], there is no work done by the tension. [CONCLUSION]
[CONCEPT: WD = force x displacement in the direction of the force]

2(a) When the sound wave hits the wall, it will be <u>reflected</u> in the opposite direction and <u>interfere</u> with the original wave. [APPLICATION]

Now we have 2 waves of the <u>same amplitude, frequency and wavelength moving in opposite directions interfering with each other [APPLICATION]</u>, giving rise to a stationary wave. [CONCLUSION]
[CONCEPT: conditions for formation of stationary wave]

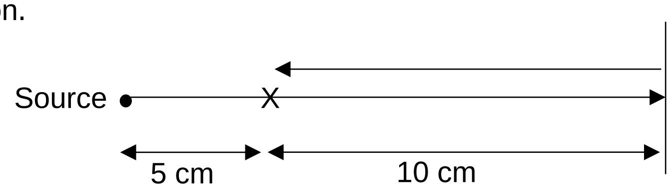
(b)



(c) From above diagram, λ = 10 cm

Frequency $f = \frac{v}{\lambda} = \frac{360}{0.10} = 3600$ Hz

d(i) After hitting the wall, the wave will continue to spread out as before, but in the opposite direction.



From diagram, reflected wave travels 25 cm.

r_1 = 5 cm, amplitude $A_1 = 3.0 \times 10^{-5}$ m
r_2 = 25 cm, A_2 = ?

Intensity $I \propto A^2 \propto \frac{1}{r^2}$ [CONCEPT]

$\therefore A \propto \frac{1}{r}$

$$\frac{A_2}{A_1} = \frac{r_1}{r_2}$$

$$A_2 = A_1 \frac{r_1}{r_2}$$

$$= 3.0 \times 10^{-5} \times \frac{5}{25}$$

$$= 6.0 \times 10^{-6} \text{ m}$$

(ii) Since X was originally a node, it is a place of destructive interference.
$\therefore$ resultant amplitude = (3.0 – 0.6) = 2.4 x 10^{-5} m

3(a) The electric field strength at a point is defined as the **electric** force exerted **per unit positive charge** placed at that point.

(b)(i) (Before x = 10 cm, the electric field points to the right. After 10 cm, it points to the left.)
Since the electric field changes direction between A and B,
the charges have the same sign.
OR
At a point between A and B, the electric fields due to each charge cancel out to give a resultant field strength of zero.
So the charges have the same sign.

(ii) Any 1 point:
- Charge A is not the only charge present.
- The electric field strength is also influenced by charge B.
- The electric field strength is due to two/both charges.
- The electric field strength is the resultant of the two fields due to charges A and B.

(iii) From the graph, $E = 1.8 \times 10^3$ N C^{-1} where $x = 6.0$ cm.

Electric force on proton, $F_E = qE = (1.60 \times 10^{-19})(1.8 \times 10^3) = 2.88 \times 10^{-16}$ N

Acceleration of proton, $a = \dfrac{F_E}{m} = \dfrac{2.88\times10^{-16}}{1.67\times10^{-27}}$ = 1.72×10^{11} m s^{-2}

(iv) At x = 10 cm, field strength due to A = field strength due to B (in magnitude)

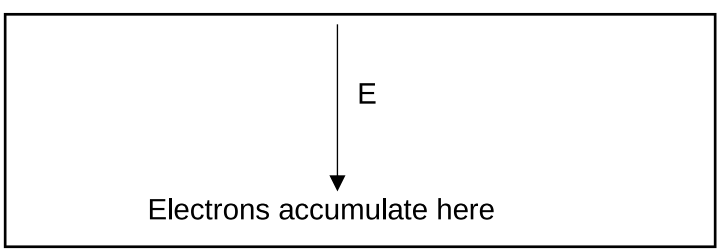
$|E_A| = |E_B|$ [CONCEPT]

$$\frac{Q_A}{4\pi\varepsilon_0 r_A^2} = \frac{Q_B}{4\pi\varepsilon_0 r_B^2}$$

$$\frac{Q_A}{Q_B} = \frac{r_A^2}{r_B^2} = \frac{(10.0\text{ cm})^2}{(5.0\text{ cm})^2} = 4$$

4(a) Magnetic force $F_B = Bev = (4.0 \times 10^{-3}) \times (1.60 \times 10^{-19}) \times (0.60 \times 10^{-3}) = 3.84 \times 10^{-25}$ N

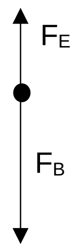
(b)



[Note: Direction of conventional current is opposite to that of electron flow.
Using FLHR, magnetic force is downwards, so electrons accumulate at the bottom.]

(c)(i) See above diagram.

(ii) **1.**



- The electric force F_E points upwards [APPLICATION].
- As the electric field gets stronger, F_E also gets stronger [APPLICATION]. The net force $\underline{F_{net} = F_E - F_B}$ gets weaker [CONCEPT: net force = vector addition]. So the rate of accumulation drops [CONCLUSION].
- Eventually $\underline{F_E = F_B}$, there's no more net force acting on the electron [APPLICATION], and the accumulation stops [CONCLUSION].

2. Accumulation stops: eE = Bev [CONCEPT]

E = Bv

Potential Difference, V = Ed = Bvd [CONCEPT]

$= (4.0 \times 10^{-3}) \times (0.60 \times 10^{-3}) \times (1.5 \times 10^{-2}) = 3.6 \times 10^{-8}$ V

5(a) Higher frequency/lower wavelength means higher energy photons OR E = hf [CONCEPT]

<u>violet</u> photons are energetic enough to liberate electrons, while <u>red</u> are not
OR
Energy of <u>violet</u> photons is higher than work function, while <u>red</u> photons is not [APPLICATION]

Increasing intensity means higher rate of photons [CONCEPT]. Higher rate of photons (incident on potassium leads to) more electrons produced for violet light [CONCLUSION].

Since red light photons are not energetic enough to liberate electrons, even at very high intensity it will still not emit any electrons from the metal surface [CONCLUSION].

(b) Work function, $\phi = hf_o$ where f_o is the threshold frequency

$$f_o = \frac{\phi}{h} = \frac{4.5 \times 10^{-19}}{6.63 \times 10^{-34}}$$
$$= 6.78 \times 10^{14}$$
$$= 6.8 \times 10^{14} \text{ J}$$

'Show' question: Write to more sf than the show answer

So photons below threshold frequency of 6.8×10^{14} Hz will not release electrons from the metal surface.

(c)(i) E_k is 0 for f <u>below</u> the <u>threshold frequency</u> 6.8×10^{14} Hz (allow $\pm0.4\times10^{14}$ Hz) because <u>no electrons</u> are emitted from the metal surface.

$E_k = hf - \phi$, so plotting E_k against f gives a graph of constant gradient/straight line is obtained (after threshold frequency).

(ii) $$h = \text{gradient} = \frac{(5.0-0)\times10^{-18}}{(14.4-6.8)\times10^{14}} = 6.6\times10^{-34} \text{ J s}$$

6(a) Binding energy is defined as the amount of energy needed to split a nucleus into its individual nucleons.

(b) **(i)** ${}^{4}_{2}He \rightarrow {}^{3}_{2}He + {}^{1}_{0}n$

(ii) Q = Difference in total BE [CONCEPT]

= 4(6.8465) – 3(2.2666)

= 20.5862 MeV

(iii) mass of neutron + mass of ${}^{3}_{2}He$ – mass of ${}^{4}_{2}He$ = $\frac{Q}{931.494}$

mass of ${}^{4}_{2}He$ – mass of ${}^{3}_{2}He$ = mass of neutron - $\frac{Q}{931.494}$

= 1.0097 u - $\frac{20.5862}{931.494}$

= 0.9876 u

(iv) Since energy is supplied to make the process happen, this is a mass excess reaction.
So $m_{helium\text{-}4} < m_{helium\text{-}3} + m_{neutron}$
$m_{helium\text{-}4} - m_{helium\text{-}3} < m_{neutron}$

7 (a) Newton's law of gravitation states that the force of attraction between two point masses is directly proportional to the product of their masses and inversely proportional to the square of their distance apart.

(b) (i)

$$g = \frac{GM_E}{r^2} = \frac{GM_E}{\left(R_E + 350\times10^3\right)^2}$$
$$= \frac{\left(6.67\times10^{-11}\right)\left(6.0\times10^{24}\right)}{\left(6.4\times10^6 + 350\times10^3\right)^2}$$
$$= 8.78\ Nkg^{-1}$$

It is along the line joining point P and the centre of the Earth and is pointing towards the Earth's centre.

(ii)

$$F_G = m\omega^2 r \text{ [CONCEPT]}$$
$$gm = m\left(\frac{2\pi}{T}\right)^2 r$$
$$T = \sqrt{\frac{4\pi^2 r}{g}} = \sqrt{\frac{4\pi^2\left(6.4\times10^6 + 350\times10^3\right)}{8.78}} = 5510\ s$$

(c) (i) Gravitational potential at a point is defined as work done per unit mass by an external agent to move the unit mass from infinity to that point.

(ii) Since gravitational force is attractive, the force that the external agent exerts (which points towards infinity) is opposite to the displacement of the unit mass. So the work done by external agent to move unit mass from infinity to that point is always negative [APPLICATION]. So the gravitational potential at that point is also negative [CONCLUSION].
[CONCEPT: WD by force = force x displacement in the direction of the force]

(iii) Gravitational field strength, a *vector*, is given by the gradient of the potential graph. [CONCEPT]

Near the surface of the Earth, the net gravitational strength is directed *towards* the Earth. Near the surface of the Moon, the net gravitational strength is directed *towards* the Moon [APPLICATION.

Therefore, the gradient of the potential graph near the surface of the Earth and that near the surface of the Moon have *opposite* signs [CONCLUSION].

(iv) To reach the surface of the Earth, the spacecraft require a minimum kinetic energy that is just sufficient to overcome the gravitational potential energy difference between the surface of the moon and point P [APPLICATION].

Therefore, $\frac{1}{2}mv^2 = m\left(\phi_P - \phi_{Moon}\right)$, where v is the minimum speed of the spacecraft. [CONCEPT]

$$\therefore v = \sqrt{2(\phi_P - \phi_{Moon})} = \sqrt{2((-1.3)-(-3.9))\times 10^6} = 2.28\times 10^3 \text{ ms}^{-1}$$

(d) (i) To *escape* the planet means the mass must have sufficient kinetic energy at the surface of the planet to just reach infinity with zero speed at infinity [CONCEPT].

By Conservation of Energy,

Total Energy at the surface = Total Energy at infinity [CONCEPT]

$$\frac{1}{2}mv^2 + \left(-\frac{GMm}{r}\right) = 0 + 0$$

$$v = \sqrt{\frac{2GM}{r}}$$

$$v = \sqrt{\frac{2(6.67\times 10^{-11})(1.20\times 10^{24})}{\left(\frac{7.5\times 10^6}{2}\right)}}$$

$$= 6.53\times 10^3 \text{ m s}^{-1}$$

(ii) The average speed of the nitrogen gas is *higher* than the escape speed on this planet [APPLICATION], so most gases would have escaped and hence the planet does not have an atmosphere [CONCLUSION].

8(a)(i) Resistance $R = \frac{\rho l}{A} = \frac{(1.2\times 10^{-5})(0.72)}{\pi(6.0\times 10^{-2}\times 10^{-3})^2}$

$= 764\ \Omega$

(ii) Power $P = \frac{V^2}{R} = \frac{230^2}{764}$ [1]

$= 69.2$ W

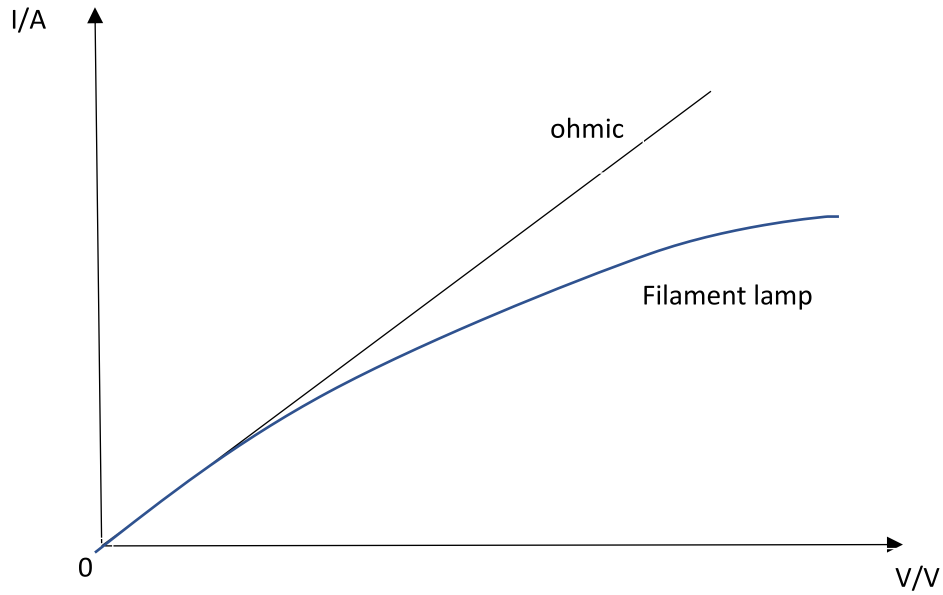
(iii) Material from filament will vaporise at high temperature.

(iv) 1. As filament gets thinner, its cross sectional area becomes effectively smaller [APPLICATION].

Since resistance α 1/cross sectional area [CONCEPT], resistance increases [CONCLUSION].

2. Power output is inversely proportional to resistance ($P = \frac{V^2}{R}$) [CONCEPT]. Since resistance of bulb increases [APPLICATION], power will drop as voltage *V* is constant [CONCLUSION].

(v)



(b) (i) 1. 2.10 V

2. $W = QV$ = (1) (2.10) = 2.10 J

3. No current flows when switch is open and voltmeter is ideal.

No energy is being generated.

(ii) p.d. across internal resistor = E – V = 2.10 -2.00 = 0.10 V

By potential divider principle [CONCEPT],

Voltage across internal resistor = $\frac{r}{r+R}E$

$$0.10 = \frac{r}{r+10}(2.10)$$

$$r = 0.50\ \Omega$$

(iii) Efficiency = $\frac{I^2R}{I^2(R+r)} = \frac{R}{R+r} = \frac{1}{1+\frac{r}{R}}$ [CONCEPT]

As R increases, $1 + \frac{r}{R}$ decreases [APPLCATION], hence efficiency increases [CONCLUSION].