

2016 VJC Prelim H1 Paper 1 **Suggested Solutions**

1	A	11	C	21	C
2	B	12	C	22	B
3	B	13	D	23	C
4	A	14	C	24	C
5	B	15	C	25	D
6	B	16	D	26	A
7	D	17	C	27	C
8	B	18	C	28	B
9	B	19	B	29	C
10	C	20	C	30	B

1 **Ans: A**

Energy produced = Pt

$$= 3.0 \times 10^9 \times 2.0 \times 10^{-12}$$

$$= 6.0 \times 10^{-3} \text{ J}$$

$$= 6.0 \times 10^{-15} \text{ TJ}$$

2 **Ans: B**

Minimum hypotenuse length is given by sides of 8.8 cm and 6.8 cm.

$$\text{Minimum hypotenuse length} = \sqrt{8.8^2 + 6.8^2}$$

$$= 11.12 \text{ cm}$$

Maximum hypotenuse length is given by sides of 9.2 cm and 7.2 cm.

$$\text{Maximum hypotenuse length} = \sqrt{9.2^2 + 7.2^2}$$

$$= 11.68 \text{ cm}$$

$$\text{Average} = (11.12 + 11.68)/2$$

$$= 11.40 \text{ cm}$$

Uncertainty = extreme – average

$$= 11.68 - 11.40$$

$$= 0.28 \approx 0.3 \text{ cm}$$

3 **Ans: B**

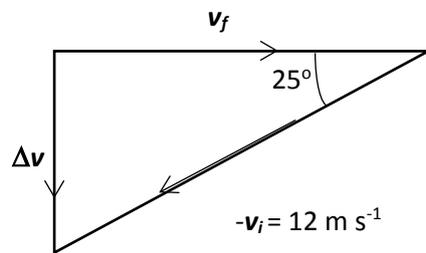
$$\begin{aligned}\text{Uncertainty of period} &= \frac{0.5 + 0.5}{20} \\ &= 0.05 \text{ s}\end{aligned}$$

4 **Ans: A**

- The ball starts with zero speed. So when $s = 0$, $v = 0$.
- The ball can move either up or down. So v should change sign.
- But the ball is always below the point P. So s should always have the same sign.

5 **Ans: B**

Remember: $\Delta \mathbf{v} = \mathbf{v}_f - \mathbf{v}_i$

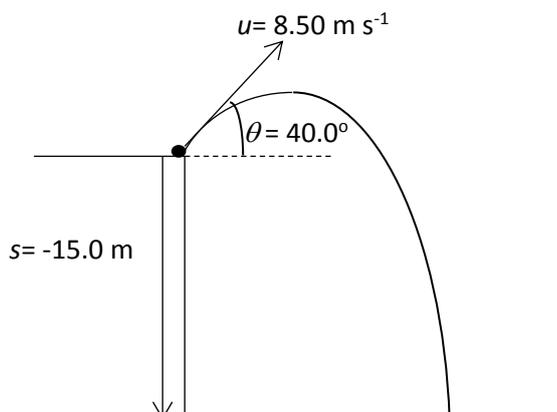


The horizontal component of $\mathbf{v}_i = \mathbf{v}_f$ since there's no horizontal acceleration, so $\Delta \mathbf{v}$ is vertical.

$$\begin{aligned}\Delta \mathbf{v} &= 12 \sin 25^\circ \\ &= 5.1 \text{ m s}^{-1}\end{aligned}$$

6 **Ans: B**

Take upwards as positive.



Vertically, $s = (u \sin \theta)t + \frac{1}{2}at^2$

$$-15.0 = (8.50 \times \sin 40.0^\circ)t - (\frac{1}{2} \times 9.81)t^2$$

Solving, $t = 2.39 \text{ s}$ (reject negative answer)

7 **Ans: D**

Taking moments about pivot:

$$W_{\text{rubber}} \times (1.90 L) = W_{\text{steel}} \times (0.10 L)$$

$$1.0L \times A \times \rho_{\text{rubber}} \times 1.90Lg = 3.00L \times A \times \rho_{\text{steel}} \times 0.10L$$

$$\Rightarrow \frac{\rho_{\text{steel}}}{\rho_{\text{rubber}}} = \frac{1.0LA \times 1.90L}{3.00LA \times 0.10L} \\ = 6.33$$

8 **Ans: B**

$$\begin{aligned} \text{Torque by a couple} &= F \times \text{perpendicular distance between them} \\ &= F \times L \sin\theta \end{aligned}$$

9 **Ans: B**

Weight of helicopter is the gravitational force of Earth on the helicopter. So by N3L, the helicopter will exert an equal and opposite gravitational force on the Earth.

10 **Ans: C**

Statement C is **false** because the collision forces are internal, not external, forces, and so the total momentum of the system should be conserved throughout the whole duration of the collision.

11 **Ans: C**

$$\begin{aligned} \text{Area under F-t graph} &= \text{change in momentum} \\ \frac{1}{2} \times (30 + 15) \times 1500 - \frac{1}{2} \times 15 \times 1500 &= m(v - 10) \\ v &= 32.5 \text{ m s}^{-1} \end{aligned}$$

12 **Ans: C**

Since object is at constant speed up the inclined plane:

$$\text{Total w.d by 50 N force} = \text{Gain in GPE} + \text{w.d against friction}$$

$$1500 = 50 \times 12 + \text{w.d against friction}$$

$$\therefore \text{w.d against friction} = 1500 - 600 = 900 \text{ J}$$

13 **Ans: D**

When boat is travelling at constant speed v , the driving force is equal to the drag force. Then the power P is given by:

$$\begin{aligned} P &= Fv \\ &= Dv \\ &= (kv^2)v \end{aligned}$$

$$\text{ie. } P = kv^3$$

When both engines are working:

$$2 \times 30 \text{ kW} = k(10)^3 \quad \text{---- (1)}$$

When only one engine is working:

$$30 \text{ kW} = kv^3 \quad \text{---- (2)}$$

(2)/(1): and solve for v :

$$v = 7.9 \text{ m s}^{-1}$$

14 **Ans: C**

The electrical power is the input power = IV

$$\text{Efficiency} = \frac{\text{output power}}{\text{input power}} = \frac{P_{out}}{IV}$$

$$0.80 = \frac{4.0 \times 10^6}{25 \times 10^3 \times I}$$

$$I = 200 \text{ A}$$

15 **Ans: C**

Upon reflection at the wall, both pulses undergo a 180 degree phase change, the earlier pulse will end up positive and the later will end up negative, ruling out B and D. If the reflection of the earlier pulse meets the later pulse before it reflects, their superposition will yield C as the answer.

16 **Ans: D**

After passing through a polarizer, unpolarised light's intensity is halved (therefore we eliminate options A/B). Amplitude becomes $A/\sqrt{2}$

Since the polarization angle is 75° , using Malus' Law:

$$A' = A/\sqrt{2} \cos 75^\circ = A/\sqrt{2} \sin 15^\circ$$

17 **Ans: C**

$$I = k \frac{A^2}{r^2}$$

$$\frac{I'}{I} = \frac{A'^2}{A^2} \frac{r^2}{r'^2}$$

$$I' = 5 \frac{(2A)^2}{A^2} \frac{3^2}{4^2} = 11.25 \approx 11 \text{ W m}^{-2}$$

18 **Ans: C**

When a loud sound is heard for the 3rd time:



$$l = \frac{5}{4} \lambda$$

$$15 = 1.25 \lambda$$

$$\lambda = 12 \text{ cm}$$

19 **Ans: B**

20 **Ans: C**

path difference , $\Delta x = \sqrt{1.6^2 + 1.2^2} - 1.6 = 0.4 \text{ m}$

$$\lambda = \frac{v}{f} = \frac{320}{400} = 0.8 \text{ m}$$

$$\therefore \Delta x = 0.5\lambda$$

The 2 waves arrive out of phase at all times, resulting in destructive interference.

21 **Ans: C**

Recall " $P = IV$ ", so $V = P/I$

The electrical potential difference between two points in a wire carrying a current may be defined as the ratio of the power supplied to the current between the points.

22 **Ans: B**

$$R = \frac{\rho l}{A}$$

$$R_{AL} = \frac{\rho_{AL} L}{\pi \left(\frac{d}{2}\right)^2} = \frac{(2\rho_s)L}{\pi \left(\frac{d}{2}\right)^2} \text{-----(1)}$$

$$R_s = \frac{\rho_s L}{\pi \left(\frac{d_s}{2}\right)^2} \text{-----(2)}$$

$$(1) = (2),$$

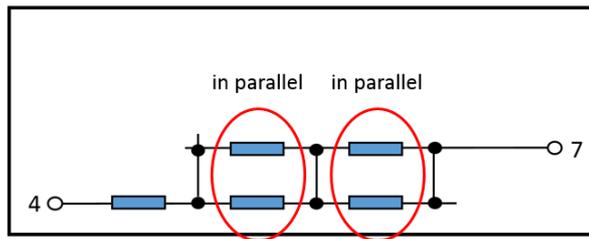
$$\frac{(2\rho_s)L}{\pi \left(\frac{d}{2}\right)^2} = \frac{\rho_s L}{\pi \left(\frac{d_s}{2}\right)^2}$$

$$\frac{2}{d^2} = \frac{1}{d_s^2}$$

$$d_s^2 = \frac{1}{2} d^2$$

$$d_s = \frac{1}{\sqrt{2}} d = 0.71d$$

23 **Ans: C**



Effective resistance,

$$R_{\text{eff}} = 1.00 + \left(\frac{1}{1.00} + \frac{1}{1.00} \right)^{-1} + \left(\frac{1}{1.00} + \frac{1}{1.00} \right)^{-1}$$
$$= 1.00 + 0.50 + 0.50 = 2.00 \Omega$$

24. **Ans: C**

Effective resistance of the 3 parallel resistors,

$$R_{\text{eff}} = \left(\frac{1}{1.0} + \frac{1}{2.0} + \frac{1}{5.0} \right)^{-1} = 0.588 \Omega$$

Potential difference across each resistor, $V = IR_{\text{eff}} = (5.0)(0.588) = 2.94 \text{ V}$

Current through 2.0Ω resistor, $I_2 = V/R = 2.94/2.0 = 1.47 \approx 1.5 \text{ A}$

25. **Ans: D**

- The direction of the flux density due to 1 and 2 must be the same
- The resultant direction of the flux density due to 1 and 2 must upwards

Therefore using Right hand grip rule, we can conclude that the current in 1 and 2 must be anticlockwise and

- The direction of the flux density due to 2 and 3 must be opposite to each other.

And also that the current in 3 is opposite to 2 and hence must be clockwise

26 **Ans: A**

Since the currents in QR and XY are out of phase, the currents in PS and XY are in phase as PSRQ are in a loop. Like currents attract, therefore the attractive force between them is always positive. Also the currents vary from zero to a maximum, so the attractive force also varies from zero to a maximum.

27 **Ans: C**

$$\begin{aligned} \tau &= Fd \\ &= 2F_B \frac{l}{2} \\ &= NBIL \times L \\ &= 20 \times 0.01 \times 5 \times 10^{-3} \times (8 \times 10^{-3})^2 \\ &= 6.4 \times 10^{-8} \text{ Nm} \end{aligned}$$

28 Ans: B

de Broglie wavelength

$$\lambda = \frac{h}{p} = \frac{h}{mv} = \frac{6.63 \times 10^{-34}}{(1.67 \times 10^{-27})(1.5 \times 10^7)} = 2.6 \times 10^{-14} \text{ m}$$

29 Ans: C

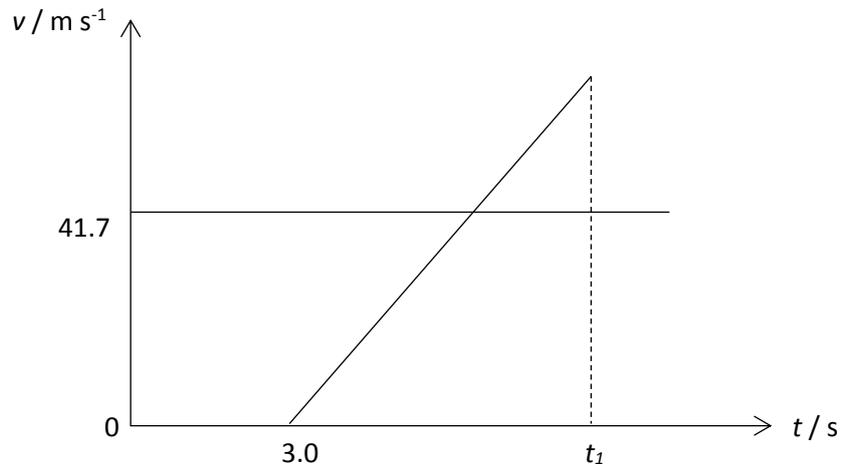
Increasing the frequency of the radiation will increase the maximum kinetic energy of the electrons. Therefore the stopping potential of the electrons will increase.

30 Ans: B

$$P = \frac{E}{t} = \frac{Nhc}{t\lambda}$$
$$\frac{N}{t} = \frac{P}{hc/\lambda} = \frac{(0.15)(60)}{(6.63 \times 10^{-34})(3.0 \times 10^8) / 4.4 \times 10^{-7}} = 2.0 \times 10^{19} \text{ s}^{-1}$$

2016 VJC Prelim H1 Paper 2 **Suggested Solutions**

1(a)



Note: $150 \text{ km h}^{-1} = 41.7 \text{ m s}^{-1}$

(b) Motorcycle overtakes car: both have travelled the same distance. Areas under the 2 graphs are equal.

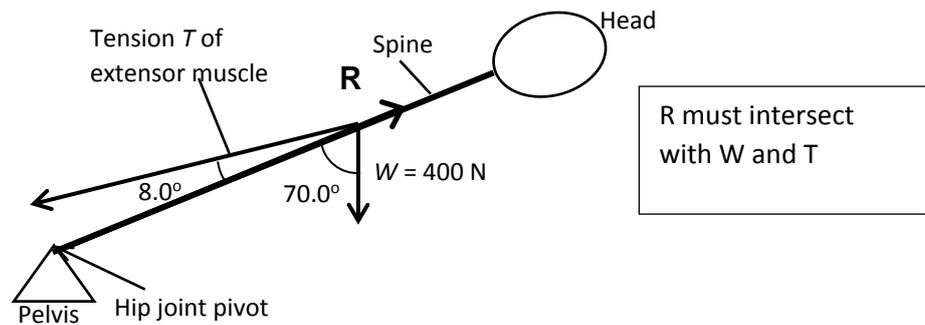
Using $v = u + at$, maximum speed of motorcycle = $a(t_1 - 3.0)$

$$\frac{1}{2} a(t_1 - 3.0)^2 = 41.7 t_1$$

$$\frac{1}{2} (12)(t_1 - 3.0)^2 = 41.7 t_1$$

Solving, $t_1 = \underline{12 \text{ s}}$ (reject the answer which is less than 3.0 s)

2(a)



(b) As R, W and T intersect at a point, taking moment about that point would mean that there is no net moment. This would allow the person to be in rotational equilibrium.

(c)(i) R, W and T must form a closed triangle so that there is no net force acting on the body.

(ii)

Using sine rule:

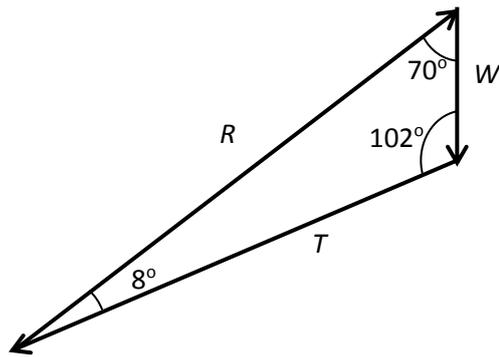
$$\frac{W}{\sin 8^\circ} = \frac{R}{\sin 102^\circ} = \frac{T}{\sin 70^\circ}$$

$$\frac{400}{\sin 8^\circ} = \frac{R}{\sin 102^\circ} = \frac{T}{\sin 70^\circ}$$

Solving for R and T we get:

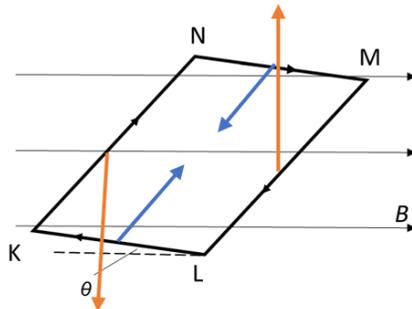
$$R = \underline{2.8 \times 10^3 \text{ N}}$$

$$T = \underline{2.7 \times 10^3 \text{ N}}$$



3(a) Magnetic Flux Density is the force per unit current, per unit length experienced by a wire at right angles to the magnetic field.

(b) (i)



(ii) $F_{KN} = NBIy$

Taking moments about the mid-point of LM,

$$\tau = xF_{KN} \cos \theta = NBIyx \cos \theta$$

(c) (i) At rotational equilibrium, the sum of torques must be zero.

$$\tau_{\text{coil}} = \tau_{\text{spring}}$$

$$NBI A = k\phi$$

$$\phi = \frac{NBA}{k} I$$

$$\therefore \phi \propto I$$

(ii) From (b)(ii), in a uniform field, the torque applied on the side of the coil depends on the cosine of the angle to the field as it rotates and hence does not vary linearly.

However, in a radial field, the magnetic forces on the coil are always perpendicular to the plane of the coil and the torque will be independent of the position of the coil. So, a linear relationship between the current and the magnetic flux density, as seen in (c)(i), is obtained as required by a galvanometer.

4(a)(i) Current, $I = \frac{V}{R_{total}} = \frac{12}{10+5} = 0.80 \text{ A}$

p.d. across the relay, $V_{relay} = IR_{relay} = (0.80)(5) = \underline{4.0 \text{ V}}$

- (ii) (reasoning: When $R_{variable}$ increases, the p.d. across $R_{variable}$ increases. This will lead V_{relay} to drop. When V_{relay} drops to 3.0 V, the signal switches to red.)

If $V_{relay} = 3.0 \text{ V}$ and its resistance remains 5.0Ω , the current through it is:

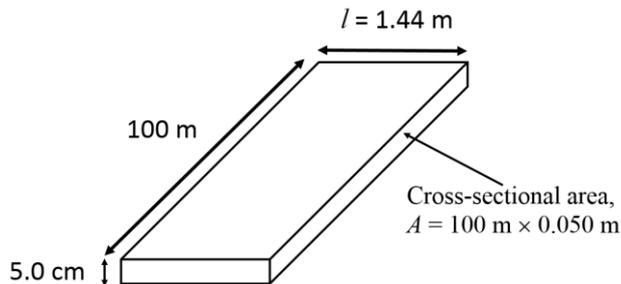
$$I = \frac{V_{relay}}{R_{relay}} = \frac{3}{5} = 0.60 \text{ A}$$

Since $V_{variable} + V_{relay} = 12 \text{ V}$, then $V_{variable} = 9.0 \text{ V}$

The variable resistance, $R_{variable} = \frac{V_{variable}}{I} = \frac{9.0}{0.60} = 15 \Omega$

The minimum increase in $R_{variable}$ required is $15 - 10 = \underline{5.0 \Omega}$

- (b)(i) (The picture is not required. It's to help you visualise the shape of the "ballast" resistor.)



$$\begin{aligned} \text{Resistance, } R &= \frac{\rho l}{A} \\ &= \frac{(340)(1.44)}{(100 \times 0.050)} = \underline{98 \Omega} \end{aligned}$$

(ii) $R_{\text{effective}} = \left(\frac{1}{5} + \frac{1}{97.9} \right)^{-1}$
 $= \underline{4.8 \Omega}$

5(a)(i) $300 \text{ km}^2 = 300 \times 10^6 \text{ m}^2$

$$\begin{aligned} \text{Mass of water} &= (300 \times 10^6)(30)(1000) \\ &= \underline{9.0 \times 10^{12} \text{ kg}} \end{aligned}$$

(ii) Gain in KE = Loss in GP
 KE transferred = mgh
 $= (9 \times 10^{12})(9.81)(400)$
 $= \underline{3.5 \times 10^{16} \text{ J}}$

(b) Rate of transfer of KE = $(500 \times 10^6)(10/4)$
 $= \underline{1.3 \times 10^9 \text{ W}}$

(c)(i) Energy = Power \times time
 $3.53 \times 10^{16} = 1.25 \times 10^9 t$
 $t = 2.83 \times 10^7 \text{ s}$
 $= \underline{\underline{327 \text{ days}}}$

- (ii) Loss of water through evaporation or friction in pipe, and any other acceptable answer.

6(a) Newton's 2nd Law states that the rate of change of momentum is directly proportional to the net force and the change in momentum occurs in the direction of the force.

(b)(i)1. Considering the whole system:

$$F_{\text{net}} = Ma$$

$$0.030 \times 9.81 = (0.080 \times 2 + 0.030)a$$

$$a = \underline{\underline{1.55 \text{ m s}^{-2}}}$$

2. Consider the forces acting on the tray with the mass:

$$mg - T = ma$$

$$0.110 \times 9.81 - T = 0.110 \times 1.55$$

$$T = \underline{\underline{0.909 \text{ N}}}$$

3. Considering the forces acting on the 30g mass:

$$mg - N = ma$$

$$0.030 \times 9.81 - N = 0.030 \times 1.55$$

$$N = \underline{\underline{0.248 \text{ N}}}$$

(c)(i) $F - mg \sin 10^\circ - 500 = ma$
 $F - 900 \times 9.81 \times \sin 10^\circ - 500 = 900 \times 0.60$
 $F = \underline{\underline{2.5 \times 10^3 \text{ N}}}$

(ii)1. At constant speed, the new driving force $F = 660 + 900 \times 9.81 \times \sin 10^\circ = 2.19 \times 10^3 \text{ N}$

$$P = Fv$$

$$= 2.19 \times 10^3 \times 20$$

$$= \underline{\underline{44 \text{ kW}}}$$

2. The mechanical energy provided by the engine is converted into gain in gravitational P.E.

There no change in KE as the car is travelling at constant speed.

(d)(i)1. Elastic collision is one where the total momentum and total KE of the system are conserved. An example is the head-on collision 2 billiard balls.

2. An inelastic collision is one where the total momentum of the system is conserved but not the total KE. An example is the collision of a car with a wall.

(ii)1. Taking the initial direction of the asteroid to be positive:

Total momentum before collision = total momentum after collision

$$M_1 u_1 - m_2 u_2 = (M_1 + m_2) V$$

$$4000 \times 15 - 20 \times 2000 = (4000 + 20) V$$

$$V = 4.98 = \underline{\underline{5.0 \text{ m s}^{-1}}}$$

2. This is an inelastic collision. The speed of approach is 2015 m s^{-1} , but the speed of separation is zero since they are joined together. So relative speed of approach is not equal to relative speed of separation.

7(a)(i) The phase difference between two waves arriving at a point is the difference in fraction of a cycle each wave leads or lags the other by.

(ii) When two waves are coherent, they have constant phase difference.

(b)(i)

$$I \propto A^2$$

$$I = kA^2$$

$$\therefore A_1 = \sqrt{I/k}$$

$$\therefore A_2 = \sqrt{3I/k}$$

As the two waves have zero path difference at point A and are in phase when they are produced at the speakers, constructive interference happens at A.

$$A_A = A_1 + A_2$$

$$I_A = kA_A^2 = k(\sqrt{I/k} + \sqrt{3I/k})^2$$

$$= k(I/k + 3I/k + 2\sqrt{3I/k})$$

$$= 7.46I$$

(ii)

$$\lambda = \frac{v}{f} = \frac{336}{2800} = 0.120 \text{ m}$$

$$\Delta x = 4.02 - 3.72 = 0.3 \text{ m}$$

$$= 2.5 \lambda$$

Since the path difference is exactly 2.5 wavelengths, the 2 waves arrive out of phase resulting in destructive interference. So a minimum signal is detected at B.

(iii) At point B, the path difference is 0.3 m.

When the wavelength is equal to $\frac{0.3}{(n + \frac{1}{2})}$ where n is an integer starting from zero,

destructive interference occurs, corresponding to minima.

When the wavelength is equal to $\frac{0.3}{(n)}$, constructive interference occurs,

corresponding to maxima.

As the frequency increases, the wavelength decreases. Hence a series of maxima and minima can be heard as the wavelength is gradually decreased from 0.12 m.

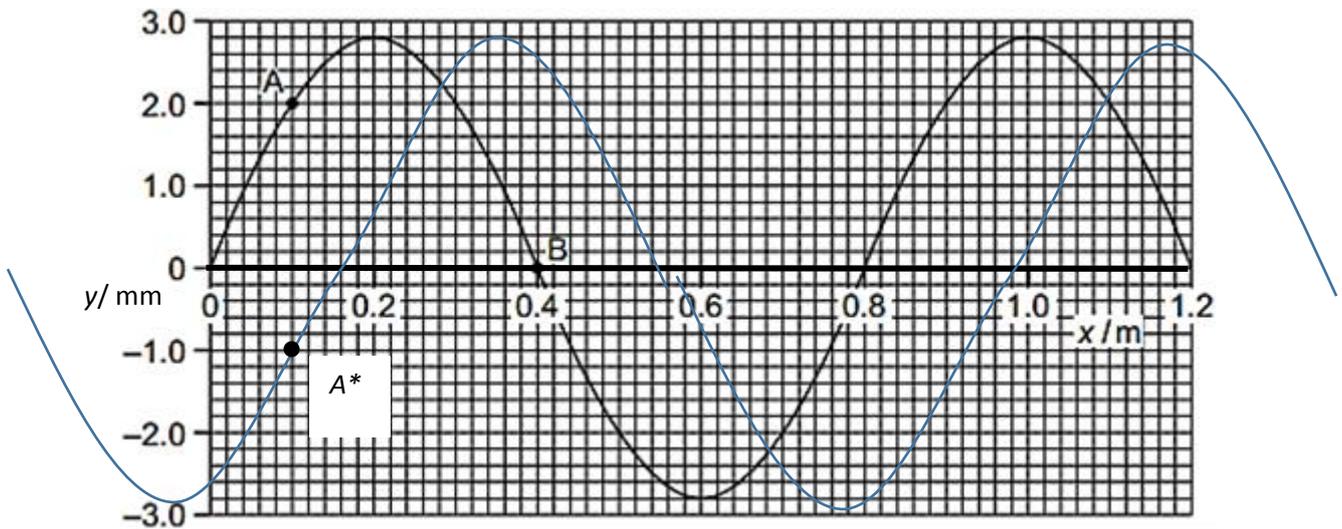
(c)(i) $\lambda = 0.80 \text{ m}$ from graph

$$v = f\lambda$$

$$f = \frac{v}{\lambda} = \frac{300}{0.80} = 375 \text{ Hz}$$

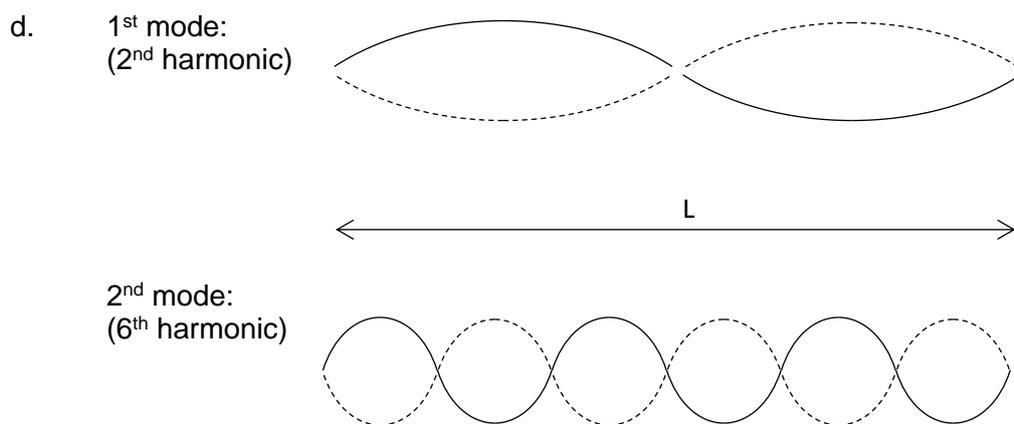
$$\therefore T = \frac{1}{f} = 2.7 \text{ ms}$$

(ii) $\Delta x = v\Delta t = 300 \times 0.53 \times 10^{-3} = 0.16 \text{ m}$



(iii)
$$\Delta\phi = \frac{\Delta t}{T} 2\pi$$

$$= \frac{0.53}{2.7} 2\pi = 1.23 \text{ rad}$$



Note that to obtain an antinode at $L/4$, you need the 2nd and 6th harmonics. The speed of the wave remains constant.

2nd harmonic: $v = f\lambda$
 $= 100L$

$$\begin{aligned}
6^{\text{th}} \text{ harmonic: } v &= f\lambda' \\
f &= v/\lambda' \\
&= \frac{100L}{\frac{L}{3}} \\
&= 300 \text{ Hz}
\end{aligned}$$

$$\begin{aligned}
8(a)(i) \text{ Max KE} &= eV_s \\
&= (1.6 \times 10^{-19})(1.7) \\
&= 2.72 \times 10^{-19} \text{ J}
\end{aligned}$$

$$\begin{aligned}
\text{Work function, } \phi &= hc/\lambda - \text{Max KE} \\
&= (6.63 \times 10^{-34})(3.00 \times 10^8)/(420 \times 10^{-9}) - 2.72 \times 10^{-19} \\
&= 2.0 \times 10^{-19} \text{ J}
\end{aligned}$$

$$\begin{aligned}
\text{Threshold wavelength, } \lambda_T &= hc/\phi \\
&= (6.63 \times 10^{-34})(3.00 \times 10^8)/(2.01 \times 10^{-19}) \\
&= \underline{\underline{990 \text{ nm}}}
\end{aligned}$$

(ii) The existence of this threshold wavelength cannot be explained by the classical wave theory of light. This leads to the photon theory of light, which can explain why light must be below a certain maximum wavelength for photoemission to occur.

(b)(i) Emission spectra lines are due to the electromagnetic radiations emitted when electrons within the atom lose energy. These electromagnetic radiations are in the form of photons whose energy is hf where f is the frequency of the radiation.

Since the emission spectral lines are discrete with well-defined frequencies, this implies that the electrons lose energies in discrete amounts.

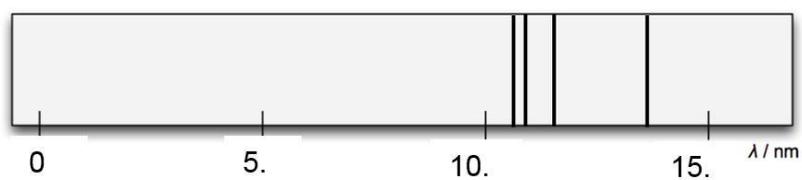
This is only possible if electrons transit between discrete energy levels in an atom.

(ii) When the vapour in a discharge tube is at low pressure, the ions are so far apart from each other that they will not distort each other's energy levels. Therefore their energy levels will remain discrete.

$$\begin{aligned}
(c)(i) \quad E &= \frac{hc}{\lambda} \Rightarrow \lambda = \frac{hc}{E} \Rightarrow \lambda_{\text{emission}} = \frac{hc}{\Delta E} \\
\text{Shortest wavelength} &= \frac{hc}{(121.9 - 4.9)e} = 10.6 \text{ nm (3 s.f.)} \\
\text{Longest wavelength} &= \frac{hc}{(7.6 - 4.9)e} = 460 \text{ nm (3 s.f.)}
\end{aligned}$$

(ii) Number of spectral lines occurs between two levels, number of ways to produce spectral lines is 5C_2 . Number of spectral lines is 10.

(d)



10.6 nm, 10.8 nm, 11.4 nm, 13.6 nm

(e)(i) 1. Ionisation energy is the energy required to remove (to infinity) the outermost electron in an atom.

2. 122 eV

(ii) The work function is the energy to remove an electron from the surface of a metal to infinity.

In a metal, the valence electrons are not tightly bound to any atom, but are delocalised, and are free to move in a sea of electrons.

But in an isolated atom, the valence electrons are tightly bound to the atom.

So less energy is needed to remove an electron from the metal surface to infinity.