Tampines Meridian Junior College
2025 JC2 H2 Physics Preliminary Examination Paper 3
Suggested Solution

1 **(a)** Elastic collision: The **total** kinetic energy (KE of the system) of the colliding bodies is conserved before and after the collision.

Or The relative speed of approach of the two bodies is equal to their relative speed of separation.

(b) By conservation of linear momentum,

$$m_A u_A + m_B u_B = m_A v_A + m_B v_B$$

$$(2.4) + 0 = v_A + 4v_B \quad [\text{C1: sub } u_p \text{ and } m_B = 4m_A]$$

By conservation of kinetic energy

$$\frac{1}{2}m_A u_A{}^2 + \frac{1}{2}m_B u_B{}^2 = \frac{1}{2}m_A v_A{}^2 + \frac{1}{2}m_B v_B{}^2$$

$$(2.4)^2 + 0 = v_A{}^2 + 4v_B{}^2 \quad [\text{C1: sub } u_A\text{ , } m_B = 4m_A]$$

By relative speeds

$$u_A - u_B = v_B - v_A$$

$$(2.4) - 0 = v_B - v_A \quad [\text{C1: sub } u_p]$$

Note: only two C1 marks available

Solving simultaneously with any of the two above equations,

$$v_A = -1.44 \text{ m s}^{-1} \quad [\text{A1}]$$

(c) By conservation of linear momentum,

The total momentum of a system of objects remains constant provided no resultant external force acts on the system.

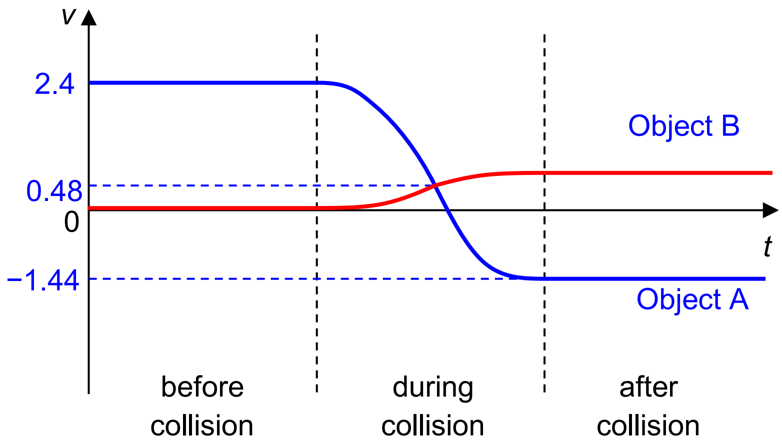
Since no external resultant force is acting on the system,

$$m_A u_A + m_B u_B = m_A v_o + m_B v_o$$

$$(2.4) + 0 = 5v_o \quad [\text{B1: sub } u_p \text{ and } m_{He} = 4m_p]$$

$$v_o = 0.48 \text{ m s}^{-1} \quad (\text{shown})$$

(d)



[B1] Before collision: u_A at 2.4 m s^{-1} and u_B at 0 m s^{-1}

[B1] shape: Smooth and continuous curvature, 0.48 m s^{-1} label

[B1] After collision: v_A at −1.44 m s^{-1} and u_B at 0 m s^{-1}

2 (a)

$$\frac{\text{kinetic energy of the child at Q with resistive force}}{\text{kinetic energy of the child at Q if there is no resistive force}}$$

$$= \frac{\frac{1}{2} m v_Q^{\ 2}}{mgh}$$

$$= \frac{\frac{1}{2}(4.8^2)}{9.81(7.0)}$$ [M1]

$= 0.168$ [A1]

(b)

$$\text{percentage efficiency} = \frac{EPE}{KE} \times 100\%$$

$$= \frac{\frac{1}{2} k x^2}{\frac{1}{2} m v_Q^{\ 2}} \times 100\%$$

$$= \frac{54(2.1^2)}{20(4.8^2)} \times 100\%$$ [M1]

$= 51.7\ \%$ [A1]

(c) Any 2:

- Energy loss due to work done by resistive force / friction
- Sound produced due to collision with the soft board
- Deformation of the soft board

3 (a) Gravitational field strength at a point is the gravitational force per unit mass [B1] on a small test mass placed at that point.

(b) Gravitational force provides for centripetal force of satellite. [B1]

By Newton's 2nd Law [B1], gravitational field strength must thus be equal to the centripetal acceleration (OR $mg = ma \rightarrow g = a$)

(c)(i) If obey inverse square law, $g = \frac{k}{r^2} \rightarrow \lg(g) = -2\lg(r) + \lg k$ [B1]

Consider points (7.95, 1.20) and (8.55 , 0)

Gradient $= \frac{1.20 - 0}{7.95 - 8.55} = -2$ [B1] working (showing coordinates) and answer

Therefore must obey the inverse square law.

(c)(ii) For $r = 4.18 \times 10^8$ m → lg (r) = 8.62

(note: should not round off to 2 s.f. and use 8.6 for finding corresponding lg g value as it will greatly affect the accuracy of the final answer).

From graph, lg (g) = − 0.14 [B1]

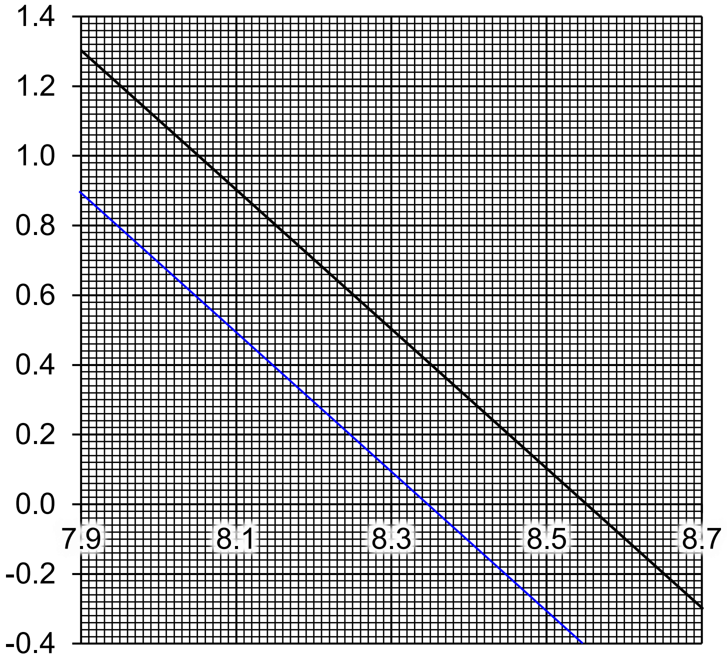
$g = 0.7244$

$$g = \frac{v^2}{r}$$

$$0.7244 = \frac{v^2}{4.18 \times 10^8} \text{ [C1]}$$

$$v = 17400 \text{ m s}^{-1} \text{ [A1]}$$

(c)(iii)



Same gradient, lower than original graph (of planet X) [B1]

4 **(a)** **(i)** Plane polarisation occurs when particles in a wave oscillate only in a single direction perpendicular to the direction of energy transfer of the wave (or direction of wave propagation). [B1]

(ii) Since sound waves are longitudinal waves, particles in the wave oscillate parallel / along to the direction of energy transfer of the wave (or direction of wave propagation). [B1]

(b) **(i)** **1.** *A* [B1]

2. $2I$ [B1]

(ii) By Malus' law,

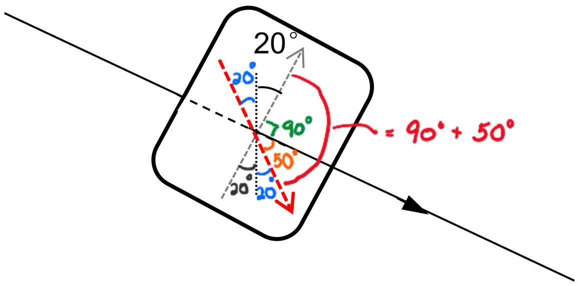
$$I = I_o \cos^2 \theta$$

$$I_Y = I \cos^2 \theta$$

$$= I \cos^2 20° \quad \text{[C1]}$$

$$= 0.883\, I \quad \text{[A1]}$$

(iii)



Minimum angle = 140° [B1]

5 **(a)** The Principle of Superposition states that when two or more waves meet at a point, the resultant displacement at that point is equal to the vector sum of the displacements of the individual waves at that point [B1].

(b) **(i)**

$$x = \frac{\lambda D}{a} = \frac{(590 \times 10^{-9})(3.2)}{1.50 \times 10^{-3}} \quad [C1]$$

$$x = 0.00126 \text{ m} \quad [A1]$$

(ii) As the slits are widened, the extent of diffraction of the waves when they passes through the slits will become lesser. [M1]
This will result in the waves not being able to overlap one another resulting in no interference[M1] and thus no fringes formed [A0]

(iii)

$$\tan\theta = \frac{1.5}{3.2}$$

$\theta = 25.1°$ [C1]

$d \sin\theta = n\lambda$

$$n = \frac{d \sin\theta}{\lambda} = \frac{\frac{0.001}{700}\sin(25.1)}{590 \times 10^{-9}} \quad [C1]$$

$n = 1.03 = 1.0$ [C1]

Max. bright fringes = $n \times 2 + 1 = 3$ [A1]

[1] for finding *d*
[1] diffraction formula

6 **(a)** $PV = nRT$

$$n = \frac{PV}{RT}$$

$$= \frac{(4.5 \times 10^5)(0.075)}{(8.31)(273 + 60)} \text{ [C1]}$$

$$= 12.2 \text{ mol} \quad \text{[A1]}$$

(b) **(i)** since pressure, n and R are constant,

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{V_1}{T_1}T_2 = \frac{0.075}{333} \times (150 + 273) \text{ [C1]}$$

$$= 0.0953 \text{ m}^3 \quad \text{[A1]}$$

(ii)

$$\Delta U = \frac{3}{2}nR\Delta T$$

$$= \frac{3}{2}(12.2)(8.31)(150 - 60) \quad \text{[C1]}$$

$$= 1.37 \times 10^4 \text{ J} \quad \text{[A1]}$$

(iii) $WD_{by} = P\Delta V = (4.5 \times 10^5)(0.0953 - 0.075)$ [C1]

$$= 9.14 \times 10^3 \text{ J} \quad \text{[A1]}$$

(iv) $\Delta U = q + w$

$$q = \Delta U - w$$

$$= 1.37 \times 10^4 - (-9.14 \times 10^3) \text{ [C1]}$$

$$= 2.28 \times 10^4 \text{ J} \quad \text{[A1]}$$

7 **(a)** Horizontal lines [B1]

For between x = 0 cm to x = 5.0 cm, V value is 380 V

For between x = 40.0 cm to x = 50.0 cm, V value is 750 V

(b) Electric force will be directed towards sphere A and decreasing in magnitude, from surface of A to position of lowest potential

At position of lowest potential, electric force is zero

Electric force will be directed towards sphere B and increasing in magnitude, from position of lowest potential to surface of sphere B.

([B1] describing how the magnitude and direction of force is changing from A to lowest potential.

[B1] identify point of lowest potential to be zero force/ neutral point

[B1] describing how the magnitude and direction of force is changing from lowest point to B.)

(c) Position of zero field strength/ neutral point/ minimum potential is closer to sphere A [M1] (or potential at surface of/ close to A is smaller than potential at surface of/ close to B)

Therefore sphere A has a smaller magnitude of charge [A1]

(d) Method 1: Consider a point of resultant potential

Consider x = 30 cm, V = 400 V (or any other appropriate point)

$$V_A + V_B = 400$$

$$\frac{1}{4\pi\varepsilon_0}\left(\frac{1.2\times10^{-9}}{0.30}\right)+\frac{1}{4\pi\varepsilon_0}\left(\frac{Q_B}{0.50-0.30}\right)=400 \quad [C1]$$

$$Q_B = 8.1\times10^{-9}\ \text{C} \quad [A1]$$

If consider x = 5.0 cm, V = 380 V, then $Q_B = 8.22\times10^{-9}$ C

If consider x = 40.0 cm, V = 750 V, then $Q_B = 8.04\times10^{-9}$ C

Method 2: Consider neutral point

x = 14.0 cm

$|E_A| = |E_B|$

$$\frac{1}{4\pi\varepsilon_0}\left(\frac{1.2\times10^{-9}}{0.14^2}\right) = \frac{1}{4\pi\varepsilon_0}\frac{Q_B}{(0.50-0.14)^2}$$ [C1]

$Q_B = 7.9\times10^{-9}$ C [A1]

allow range of $7.19 \text{ nC} \le Q_B \le 8.77 \text{ nC}$

based on readoff of position of neutral point to be $13.5 \text{ cm} \le Q_B \le 14.5 \text{ cm}$

(e) Method 1

Kinetic energy of electron = ½ m v^2

= ½ $(9.11 \times 10^{-31})(9.7 \times 10^{6})^2$

= 4.3×10^{-17} J [M1]

Gain in electric potential energy from surface of A to neutral point

= e ($V_{\text{neutral point}} - V_{\text{surface of A}}$)

= -1.6×10^{-19} (280 – 380)

= 1.6×10^{-17} J [M1]

Since kinetic energy of electron is more than required gain in electric potential energy from surface of A to neutral point,

electron is able to reach the surface of B. [A1]

Method 2

Minimum kinetic energy required to reach B

= gain in electric potential energy from surface of A to neutral point

= e ($V_{\text{neutral point}} - V_{\text{surface of A}}$)

= -1.6×10^{-19} (280 – 380)

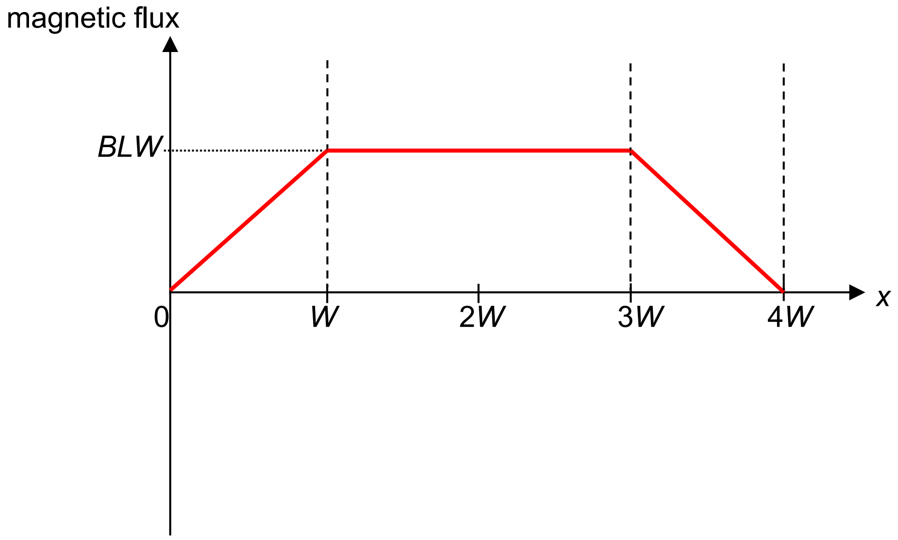
= 1.6×10^{-17} J [M1]

So minimum launch speed = $\sqrt{\frac{2(1.6\times10^{-17})}{9.11\times10^{-31}}} = 5.9\times10^{6}$ m s^{-1} [M1]

Since electron is ejected at a higher speed than the minimum lauch speed,

electron is able to reach the surface of B. [A1]

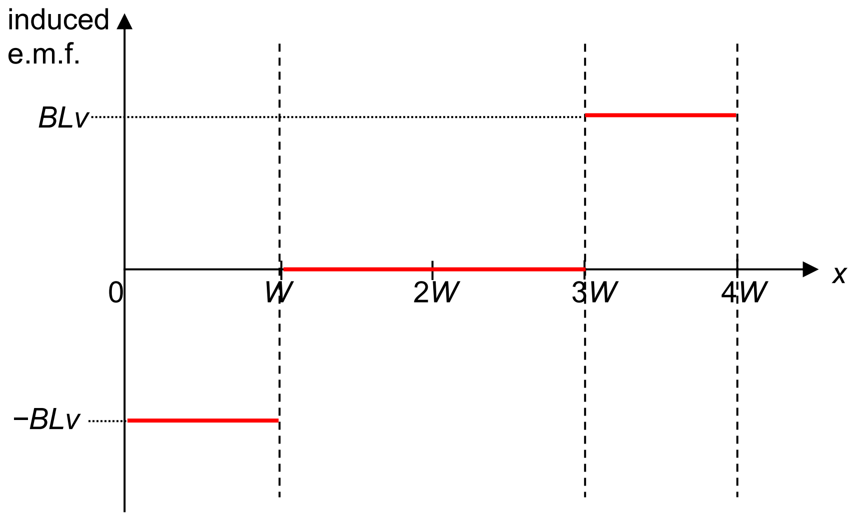
8 (a) (i)



[B1] correct shape

[B1] correct expression for maximum magnetic flux linkage

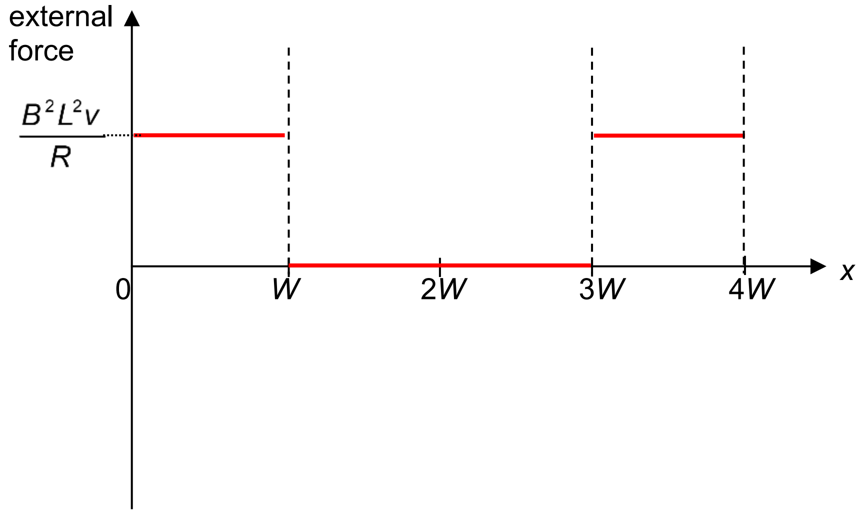
(ii)



[B1] correct shape

[B1] correct expression for maximum induced e.m.f.

(iii)



[B1] correct shape

[B1] correct expression for maximum external force applied

$$|F_{ext}| = |F_B| = BIL = B\left(\frac{\varepsilon}{R}\right)L = B\left(\frac{BLv}{R}\right)L = \frac{B^2L^2v}{R}$$

F_B is directed to the left as the frame is entering and exiting the field, hence to maintain constant speed, F_{ext} is directed to the right, hence positive value.

(b) **(i)** Faraday's Law of Electromagnetic Induction states that the induced e.m.f is directly proportional to the rate of change of magnetic flux linkage. [B2]

(ii) (Any 2)

Area enclosed by the coil

magnetic flux density

Speed of rotation of the coil / angular velocity of the coil

[B1] for any one correct

(iii) When the coil rotates at constant angular velocity, the magnetic flux density perpendicular to the coil varies sinusoidally. [B1] (alt: Area perpendicular to the flux)

As magnetic flux density is directly proportional to magnetic flux (linkage), it also varies sinusoidally. [B1]

Since induced e.m.f. is directly proportional to rate of change of magnetic flux (linkage), (Or by Faraday's Law) it also changes sinusoidally. [B1]

(c) **(i)** $F = NBIL\sin\theta$

$$B = \frac{F}{NIL\sin\theta}$$

$$= \frac{0.35}{50(7.0)(9.0\times10^{-2})(\sin 62°)}$$ [M1]

$$= 0.0126 \text{ T}$$ [A1]

If forget to include N turns, but have sin 62, give 1 mark

(ii) (From Fleming's left-hand rule) Force on PQ is upwards, hence the reading decreases. [B1]

Can BOD "out of paper"

(iii) Coil will rotate (or oscillate) about the vertical axis due to the couple provided the magnetic forces acting on the vertical sides. [B1]

(d) **(i)** To reduce energy losses or eddy currents [B1]

or To improve efficiency

(ii)

$$\frac{V_s}{V_p} = \frac{N_s}{N_p}$$

$$\frac{V_s}{102} = \frac{600}{30}$$

$$V_s = 2040 \text{ V}$$ [B1]

(iii)

$$I_{rms} = \frac{V_{rms}}{R}$$

$$= \frac{2040/\sqrt{2}}{98}$$

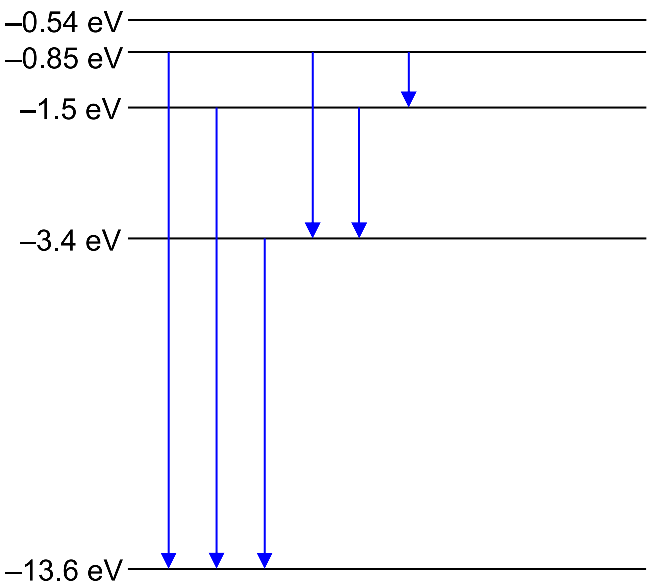
$$= 14.7 \text{ A}$$ [B1]

9 **(a)** **(i)** Particulate: photoelectric effect [B1]
Wave: diffraction / interference / superposition [B1]

(ii) When electrons transit from higher to lower energy levels, they emit a photon whose energy is equal to the energy difference between the two levels. [B1]

Since the energy levels have discrete (specific) energies, the photon emitted will have specific energies, and hence specific frequencies. Giving rise to a line emission spectrum. [B1]

(b) **(i)**



Gas atoms can be excited up to the –0.85 eV level. Hence a total of 6 transitions are possible.

[B1] show understanding that highest possible excited level is –0.85 eV

[B1] draw all six transitions correctly, arrows pointing down

(ii)

$$h\frac{c}{\lambda} = \Delta E$$

$\left(6.63\times10^{-34}\right)\frac{c}{\lambda} = \left(13.6-0.85\right)\left(1.60\times10^{-19}\right)$ [M1 - correct energy levels, M1 - correct sub

$\lambda = 9.75\times10^{-8} = 9.8\times10^{-8}$ m [A0]

(c) **(i)** Photoelectrons are emitted from metal Z with a range of kinetic energies. [B1]

As the collector plate is made more and more negative, more and more photoelectrons will not have sufficient energy to overcome the potential difference, [B1]

OR electrons experience a larger and larger repulsive force from the collector plate,

and hence less and less electrons will reach the collector plate, causing a gradual decrease in the current.

(ii) Maximum current = 2.7 mA

$$\frac{N}{t} = \frac{I}{e} = \frac{2.7 \times 10^{-3}}{1.6 \times 10^{-19}} \quad \text{[M1]}$$

$$= 1.69 \times 10^{16} \text{ s}^{-1} \quad \text{[A1]}$$

(iii) $$E_{k,\max} = eV_S = \left(1.6 \times 10^{-19}\right)(5.3) = 8.48 \times 10^{-19} \text{ J} \quad \text{[M1]}$$

$$h\frac{c}{\lambda} = \Phi + E_{k,\max}$$

$$\left(6.63 \times 10^{-34}\right)\frac{3.00 \times 10^{8}}{9.75 \times 10^{-8}} = \Phi + 8.48 \times 10^{-19} \quad \text{[M1]}$$

$$\Phi = 1.19 \times 10^{-18} \text{ J or } 1.18 \times 10^{-18} \text{ J (if use } 9.8 \times 10^{-8}\text{)}$$

$$= 1.2 \times 10^{-18} \text{ J} \quad \text{[A0]}$$

(iv). $$\Phi = h\frac{c}{\lambda_0}$$

$$1.2 \times 10^{-18} = \left(6.63 \times 10^{-34}\right)\frac{3.00 \times 10^{8}}{\lambda_0}$$

$$\lambda_0 = 1.66 \times 10^{-7} \text{ m}$$

$$= 166 \text{ nm} \quad \text{[B1]}$$

or 167 nm (if use 1.19×10^{-18})

or 169 nm (if use 1.18×10^{-18})

(v) Since the stopping potential is now larger, the energy of the photons incident on the metal Z is larger. [M1]

Hence the EM radiation from the new source has a higher frequency. [A1]

(vi) Photocurrent increases with intensity of light. [B1 for stating the characteristic]

Hence light meters can use the amount of photocurrent to detect the ambient light intensity. [B1 for how the characteristic is used]

(vii) The threshold wavelength is smaller than that of visible light, hence visible light will not cause emission of photoelectrons. [B1]