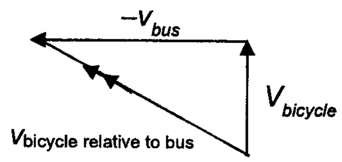
Tampines Meridian Junior College
2025 JC2 H2 Physics Preliminary Examination Paper 1
Suggested Solution

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

Q1 Ans: D

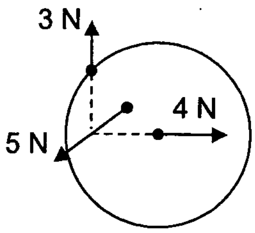


Q2 Ans: B

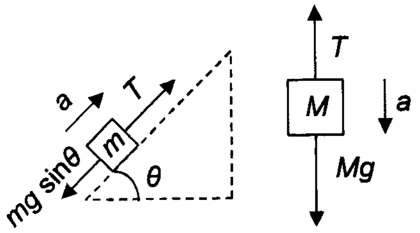
Gradient of the graph started with maximum magnitude before slowing decreasing and becoming zero. Acceleration (given by gradient of V-t graph) of an object falling in the presence of air resistance will decreases until terminal velocity is reached and become zero. Thus option B is the answer.

Q3 Ans: C

To ensure rotational equilibrium, the line of action of the forces must pass through a single point.



Q4 Ans: D



Let T be tension in string

$T - mg\sin\theta = ma$ ....(1)

$Mg - T = Ma$ ....(2)

$(2)+(1)$

$Mg - mg\sin\theta = Ma + ma$

$$a = \frac{Mg - mg\sin\theta}{M+m} = \frac{(M - m\sin\theta)}{(M+m)}g$$

Q5 Ans: B

Torque by 30 N couple = 30 (2)(0.065) = 3.9 N m (anti-clockwise)
Torque by 25 N couple = 25 (2)(0.12) = 6.0 N m (clockwise)
Torque by 15 N couple = 15 (2)(0.10) = 3.0 N m (clockwise)
Net torque = 3.0 + 6.0 – 3.9 = 5.1 N m (clockwise)

Q6 Ans: B

Area under the graph gives the elastic potential energy of the spring. As extension is doubled from x_1 to x_2, area changes from ½ F_1x_1 to ½ F_2x_2. Hence change in EPE= ½ F_2x_2 - ½ F_1x_1

Q7 Ans: B

$v = r\omega$

$8.4 = (16)\omega$

$\omega = 0.525$ rad s^{-1}

$\theta = \omega t = (0.525)(8.0) = 4.2$ rad

Q8 Ans: D

Angular speed and the linear speed are different ways of describing the same motion; they do not cause each other.

By Newton's second law, net force causes acceleration and hence changes in both angular speed and the linear speed simultaneously.

Q9 Ans: C

For an object of mass *m* orbiting around Earth,
Gravitational force provides for centripetal force

$$G\frac{M_{Earth}m}{r^2}=\frac{mv^2}{r}$$

$$GM_{Earth}\left(\frac{1}{r}\right)=v^2$$

Since they are both orbiting around same Earth,

$$\left(\frac{1}{r}\right)\propto v^2$$

$$\left(\frac{v_{ISS}}{v_{satellite}}\right)^2=\frac{r_{satellite}}{r_{ISS}}$$

$$v_{ISS}=v_{satellite}\sqrt{\left(\frac{r_{satellite}}{r_{ISS}}\right)}=3.1\sqrt{\left(\frac{4.2\times10^4}{6.8\times10^3}\right)}=7.7\text{ km s}^{-1}$$

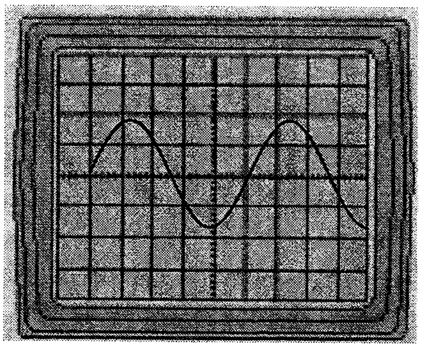
Q10 Ans: A

The potential energy – time graph should be a sinusoidal squared graph. As the displacement at t_1, t_2, t_3 is zero, the speed is the maximum, kinetic energy is maximum, and hence potential energy is zero.

Q11 Ans: B

2 kHz has a period of 0.5 ms.

A typical CRO screen has 10 horizontal divisions of 1 cm each. The period will span over 5 divisions with a 0.1 ms cm^{-1} setting.



Q12 Ans: A

The two supports have to be node. Taking distance between 2 walls as *L*, the wavelength of the given wave is 2*L*, and the next possible stationary wave has wavelength *L*.

$v = f\lambda$

$f = \dfrac{v}{2L}$

$f' = \dfrac{v}{L} = 2f$

Q13 Ans: C

$d\sin\theta = n\lambda$

$3\lambda_x = 5\lambda_y$

$\dfrac{\lambda_x}{\lambda_y} = \dfrac{5}{3}$

Q14 Ans: B

Using first law of thermodynamics $\Delta U = Q + w$, *Q* = 0 and *W* = +ve for adiabatic compression. Hence ΔU and temperature increased.

Q15 Ans: A

Using $Q = mc\Delta\theta = 0.200 \times 390 \times 30 = 2300$ J
since final temperature at thermal equilibrium is 50 °C.

Q16 Ans: D

KE = 3/2 Nk T

$(c_{rms})^2 \alpha \ T$

$\dfrac{T_2}{T_1} = \dfrac{1.2^2 c^2{}_{rms}}{c^2{}_{rms}}$

$T_2 = 1.44 \times 350$

$= 500$ K

Q17 Ans: C

Force on a charge in the field is given by $F = q\,E$. Since it's a uniform electric field, E is constant. Both proton and electron have the same magnitude of charge q.
Therefore the proton should experience the same magnitude of force as the electron.

The other options are correct statements because

Option A: Since the work done by the electric force on both the electron and proton is positive, therefore change in electric potential energy is negative for both ($W_{by\ electric\ force} = -\Delta U$)
Hence they both lose electric potential energy.

Option B: The proton experiences an upward electric force that is of same magnitude as that on the electron but has a larger mass.
Therefore it will experience a smaller acceleration and undergo a smaller deflection.
Hence the work done by electric force is smaller for proton, giving it a smaller $|\Delta U|$.

Option D: The proton loses less electric potential energy than the electron. By conservation of energy, the gain in kinetic energy must be less than that of the electron.

Q18 Ans: D

The resistors are connected in parallel to the power supply.

$$R_{effective} = \left(\frac{1}{1300} + \frac{1}{1900}\right)^{-1} = 772\ \Omega$$

$$I = \frac{240}{772} = 0.31\ \text{A}$$

$$P_{total} = \frac{240^2}{1300} + \frac{240^2}{1900} = 75\ \text{W}$$

Q19 Ans: C

At about 2.4 V, the graph of the diode and lamp intersects. Hence the V and I values are the same. Since $R = V/I$, the diode and lamp have the same resistance.

Q20 Ans: B

For the voltmeter reading to be highest, the combined resistance of the thermistor and LDR has to be lowest (by potential divider principle).
High brightness (i.e. high intensity of light) would give LDR lowest resistance. High temperature would give thermistor lowest resistance.

Q21 Ans: C

As electron moves to the left, conventional current (middle finger) will be to the right. Using right hand grip rule for wire, magnetic field acting on electron will be out of paper. Applying Flemming's left hand grip rule, force on electron

Q22 Ans: B

For wire to start to lift off, magnetic force= weight of wire.

$$mg = BIL\sin\theta$$
$$0.004(9.81) = 0.040(0.30)(\sin 30^\circ)I$$
$$I = 6.54A$$

Q23 Ans: A

To determine the induced e.m.f.:
$\varepsilon = BLv\cos\theta$ where v is the velocity of rod at the bottom of slope, and L is length of rod.

To determine v:
$v^2 = u^2 + 2as$
$v^2 = 0 + 2(g\sin\theta)y$
$v = \sqrt{2y(g\sin\theta)}$

Hence,
$\varepsilon = BLv\cos\theta = BL\left[\sqrt{2y(g\sin\theta)}\right]\cos\theta = BL\sqrt{2yg}\left[\left(\sqrt{\sin\theta}\right)(\cos\theta)\right]$

	θ / °	*Induced emf* / V
A	35	0.620 $BL\sqrt{2yg}$ (largest)
B	40	0.614 $BL\sqrt{2yg}$
C	45	0.595 $BL\sqrt{2yg}$
D	50	0.563 $BL\sqrt{2yg}$

Q24 Ans: D

Inserting an iron core concentrates the magnetic field lines and provides better linkage between coils P and Q. Hence the flux linkage through both coils will be larger and amplitude of the induced voltage in coil Q will increase.

Option A is incorrect – although increasing the frequency will increase the amplitude in coil Q (due to a faster rate of change of flux linkage), the number of cycles per unit time (i.e. frequency) will also increase.

Option B is incorrect – decreasing the cross-sectional area of coil P will have no effect on the flux density created by coil P. Hence no change to the flux linkage of both coils.

Option C is incorrect – decreasing the number of turns in coil Q will result in a lower amplitude as $\frac{V_Q}{V_P}=\frac{N_Q}{N_p}$.

Q25 Ans: C

Option A: Mean power dissipated = $\dfrac{\left(\frac{V_0}{\sqrt{2}}\right)^2}{8.0}=\dfrac{\left(\frac{60}{\sqrt{2}}\right)^2}{8.0}=225\text{ W}$

Option B: Mean power dissipated = ½ (225) = 112.5 W

Option C: Mean power dissipated = $\dfrac{V_0^2}{8.0}=\dfrac{(60)^2}{8.0}=450\text{ W}$

Option D: Mean power dissipated = ½ (450) = 225 W

Q26 Ans: B

Current from the a.c. supply can flow in both directions around the circuit.
But the setup of diodes result in current flowing through R to be only in the upward direction.

Q27 Ans: B

$$\frac{1}{2}mv^2=9.3\times10^{-16}$$

$$\frac{1}{2}\left(9.11\times10^{-31}\right)v^2=9.3\times10^{-16}$$

$$v=4.52\times10^{7}\text{ m s}^{-1}$$

$$\lambda=\frac{h}{mv}=\frac{h}{\left(9.11\times10^{-31}\right)\left(4.52\times10^{7}\right)}=1.6\times10^{-11}\text{ m}$$

Q28 Ans: D

$\Delta x \Delta p \approx h$

$(7.2\times10^{-9})(\Delta p)\approx(6.63\times10^{-34})$

$\Delta p \approx 9.2\times10^{-26}$ kg m s^{-1}

Since the uncertainty in the position is the slit width (*y*-direction), the uncertainty in momentum is also in the *y*-direction.

Q29 Ans: C

Most particles passed through undeflected or with a small deflection

Since very few of the particles were scattered through large angles, the probability of the particle getting close to the centre of the positive charge is small. This shows that the atom consists of mostly empty space.

Small fraction (<1%) of α-particles are deflected through large angles;

To produce such a large deflection, there must be a large force

All the positive charges in the atom are concentrated as a nucleus in a small region of space as compared to the diameter of the atom.

Few particles are reflected backwards, through an angle close to 180°

As such, the nucleus is small and very massive.

Q30 Ans: D

Property	**α-particles ($^4_2\mathrm{He}$)**	**β-particles ($^{\ 0}_{-1}\mathrm{e}$)**	**γ-rays (γ)**
Stopped by	10^{-2} mm aluminium or a few cm of air	5 mm aluminum	100 mm lead

Since the radiation is not affected by the 7 mm aluminum sheet, beta radiation is absent.

Since the presence of 0.1 mm aluminum sheet decreases the count rate, alpha radiation must be present and is blocked by the sheet.

Since the 10 cm lead reduces the radiation to nearly zero, gamma radiation must be present and is blocked by the lead.

Tampines Meridian Junior College

2025 JC2 H2 Physics Preliminary Examination Paper 2

Suggested Solution

1 **(a)**

$$\mu = \frac{ve}{F}$$

$$[\mu] = \frac{[v][e]}{[F]}$$

$$= \frac{\text{m s}^{-1}\ (\text{C})}{\text{N}}$$ [M1]

$$= \frac{\text{m s}^{-1}\ (\text{A s})}{\text{kg m s}^{-2}}$$

$$= \text{A kg}^{-1}\ \text{s}^{2}$$ [A1]

−1 if use C and/or N

−1 if poor presentation

(b) **(i)** Zero error or wrongly calibrated scale [B1]

(ii) Reading scale from different angles [B1]

Must explain if write parallax error.

(c) **(i)**

$$R_X = \frac{V}{I} = \frac{3.00}{4.9 \times 10^{-3}}$$ [B1]

$$= 612\ \Omega$$

(ii)

$$\frac{\Delta R_X}{R_X} = \frac{\Delta V}{V} + \frac{\Delta I}{I}$$

$$\frac{\Delta R_X}{612} = \frac{0.03}{3.00} + \frac{0.1}{4.9}$$

$$\Delta R_X = 20\ \Omega$$ [M1]

$$R_X \pm \Delta R_X = 610 \pm 20\ \Omega$$ [A1]

(d) When plotting a graph, a best fit line shows the average trend of the data points, thus reducing random error present. Those readings which are too far out from the graph are not taken into account so the results will be more reliable. [B1]

OR

By using multiple sets of values and plotting them on a graph, any consistent deviation from the expected trend can be observed. If all points lie away from the expected line or curve in a similar manner, this may indicate the presence of a systematic error.

OR

When several data points are collected and plotted, it becomes easier to identify anomalous readings (readings that deviate significantly from the general pattern or trend). These readings are not taken into account so the mean value of resistance of X will be closer to the actual value..

2 **(a)** At top of trajectory, vertical component of velocity is zero and horizontal component of velocity is constant, hence it will have minimum KE [B1]
or
At top of trajectory, gravitational potential energy of object is greatest hence kinetic energy is the lowest since only 2 forms of energies are involved. [B1]

(b) Min KE is when object is at the highest point with only horizontal velocity.
$\frac{1}{2} m v_x^2 = 12.5$ J

$v_x = u_x = \sqrt{\frac{12.5}{0.5 \times 0.25}} = 10 \text{ ms}^{-1}$ [M1]

$u \cos 40° = 10$ [M1]

$u = 13 \text{ ms}^{-1}$ [A0]

(c) **(i)** $s_y = u_y t + \frac{1}{2} a t^2$

taking upwards as positive,

$-100 = 13 \sin 40° t + \frac{1}{2}(-9.81) t^2$ [C1]

$t = -3.74$ s (rej) or $t = 5.45$ s [A1]

(ii) $s_x = u_x t = 10(5.45) = 55$ m [A1] allow ecf

(iii) $v_y = u_y + at$

taking upwards as positive,

$v_y = 13 \sin 40° + (-9.81)(5.45) = -45.1 \text{ m s}^{-1}$ [C1]

$v = \sqrt{(45.1)^2 + (10)^2} = 46 \text{ m s}^{-1}$ [A1]

$\theta = \tan^{-1}(\frac{45.1}{10}) = 77°$ (clockwise) below horizontal [A1]

3 **(a)** It is due to the difference in pressure between the bottom surface and top surface. [B1]

(b)(i) $W = mg$

$= V_o \rho_o g$ [B1]

(b)(ii) $U = V_o \rho_f g$ [B1]

(c) In order to sink,

$W > U$ [M1]

$V_o \rho_o g > V_o \rho_f g$

$\rho_o > \rho_f$ [A1]

(d) As the (downward) velocity of the object increases, the (upward) drag force (or fluid resistance) is increasing. [B1]

Hence the downward acceleration (or net force) decreases. [B1]
(also accept: hence the velocity increases at a decreasing rate)

When the (sum of) drag force and upthrust is equal to the weight [B1]
The net force is zero and acceleration is zero, resulting in terminal velocity.

4 **(a)** Consider the top most position.

When the angular speed is just enough for person to stay in contact with the wall, person is about to lose contact with the wall.

As such, normal contact force = 0 at top most position

Component of weight parallel to floor of cylinder provides for the centripetal force [B1]

$mg \sin\theta = \mathrm{m}r\omega^2$

$(9.81)\sin 50° = (8.0)\omega^2$ [M1]

$\omega = 0.97$ rad s^{-1} [A0]

(b) At the bottom most position,

The resultant of the normal contact force from wall and component of weight parallel to floor provides for the centripetal force.

$N_{wall} - mg \sin\theta = \mathrm{m}r\omega^2$ [C1]

$N_{wall} = (65)(8.0)(0.97)^2 + (65)(9.81)\sin 50°$

$N_{wall} = 980$ N [A1]

(c) Gain in gravitational potential energy

$= 65(9.81)(2 \times 8.0 \times \sin 50°)$ [C1]

$= 7800$ J [A1]

(d) Average power

$= \dfrac{\text{work done}}{\text{time}}$

$= \dfrac{\text{gain in gravitational potential energy}}{\text{time}}$

$= \dfrac{7800}{\frac{1}{2}\left(\frac{2\pi}{0.97}\right)}$ [C1]

$= 2400$ W [A1]

Allow ecf from (c)

5 **(a)** Simple harmonic motion is defined as the motion of a particle about a fixed point such that its acceleration is proportional to its displacement from the fixed point and is directed towards the point (or opposite in direction to the displacement). [B1]

(b) $p = mv$ -------- (1)

$E_K = \frac{1}{2}mv^2$ -------- (2) [C1 for both (1) & (2)]

sub (1) into (2)

$$E_K = \frac{p^2}{2m}$$

$$m = \frac{p^2}{2E_K}$$

$$= \frac{0.72^2}{2(0.86)} \quad \text{[M1]}$$

$$= 0.30 \text{ kg} \quad \text{[A0]}$$

(c) **(i)** $T_{\text{rod}} = T_{\text{pendulum}}$

$$\frac{1}{0.55} = 2\pi\sqrt{\frac{L}{9.81}} \quad \text{[M1]}$$

$$L = 0.82 \text{ m} \quad \text{[A1]}$$

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

$$= \frac{0.50}{1.82}(2\pi)$$

$$= 1.73 \text{ rad} \quad \text{[B1]}$$

(d) **(i)** <u>Damping</u> due to viscous forces [B1]

(ii)

$$E_{\text{total}} = \frac{1}{2}m\omega^2 x_o^{\ 2}$$

$$= \frac{1}{2}m\left(\frac{2\pi}{T}\right)^2 x_o^{\ 2}$$

$$E_f - E_i = \frac{1}{2}m\left(\frac{2\pi}{T}\right)^2 \left(x_{o_f}^{\ 2} - x_{o_i}^{\ 2}\right)$$

$$= \frac{1}{2}(0.30)\left(\frac{2\pi}{1.05 \times 2}\right)^2 (0.016^2 - 0.020^2) \quad \text{[M1]}$$

$$= -1.93 \times 10^{-4} \text{ J}$$

decrease in $E = 1.93 \times 10^{-4}$ J [A1]

6 **(a)** From graph, resistance = 1.85 Ω

(b) Effective resistance of the 4 components:

$$R_{eff} = \left[\frac{1}{2.5+3.6} + \frac{1}{1.85+4.5}\right]^{-1} = 3.111\,\Omega \text{ [C1 for working]}$$

Hence, terminal p.d.:

$$V_{\text{terminal}} = \left(\frac{3.111}{3.111+0.70}\right)6.0 \text{ [M1]}$$

$$= 4.9 \text{ V [A0]}$$

Alternative:

$$I = \frac{V}{R_{total}} = \frac{6.0}{3.111+0.70} = 1.5744 \text{ A}$$

$$V_{\text{terminal}} = E - Ir$$

$$= 6.0 - (1.5744)(0.70) \text{ [M1]}$$

$$= 4.9 \text{ V}$$

(c)

$$I = \frac{V_{\text{terminal}}}{1.85+4.5}$$

$$= \frac{4.9}{1.85+4.5} \text{ [M1]}$$

$$= 0.771 \text{ A [A1]}$$

(d) $V_{\text{thermistor}} = IR_T = (0.771)(1.85) = 1.43 \text{ V}$ [B1]

OR

$$V_{\text{thermistor}} = \frac{1.85}{1.85+4.5}(4.9) = 1.43 \text{ V [B1]}$$

(d) For the galvanometer to read zero, the potentials at C and D must be the same (i.e. no p.d. between C and D).
For p.d. across CD to be zero,

$$V_{AC} = V_{\text{thermistor}}$$

$$V_{AB} = \left(\frac{2.5}{2.5+3.6}\right)(4.9) = 2.008 \text{ V [C1 for working to show } V_{AC} = V_{\text{thermistor}}\text{]}$$

$$\frac{V_{AC}}{V_{AB}} = \frac{L_{AC}}{L_{AB}}$$

$$L_{AC} = \frac{V_{AC}}{V_{AB}} \times L_{AB} = \frac{1.43}{2.008}(1.0) = 0.71 \text{ m [A1]}$$

OR

For p.d. across CD to be zero,

$V_{AC} = V_{\text{thermistor}}$

$\left(\frac{R_{AC}}{2.5+3.6}\right)(4.9) = 1.43$ [C1 for working to show $V_{AC} = V_{\text{thermistor}}$]

$R_{AC} = 1.776\ \Omega$

$L_{AC} = \frac{1.776}{2.5}(1.0) = 0.71\text{ m}$ [A1]

7 **(a)** **(i)** Number of protons = 57, number of neutrons = (141 – 57) = 84 [B1]

(ii) Mass defect, $\Delta m = [(141-57)(1.009) + 57(1.007) - 140.911]$ [M1]

$= 1.244(1.66\times10^{-27})$

$= 2.06504\times10^{-27}\text{ kg}$

Binding energy $= \Delta mc^2$

$= (2.06504\times10^{-27})(3.00\times10^{8})^2$ [M1]

$= 1.858536\times10^{-10}\text{ J}$ [M1]

$= 1161.585\text{ MeV}$

$= 1162\text{ MeV}$ [A0]

(iii) B.E. per nucleon of Pu-239 $= \frac{1807}{239}$

$= 7.56\text{ MeV}$

B.E. per nucleon of La-141 $= \frac{1162}{141}$

$= 8.24\text{ MeV}$ [M1: for both energies]

Since plutonium-239 nucleus has a lower binding energy per nucleon, it is less stable against fission [B1]

and is more likely to undergo nuclear fission. [A1]

(b) **(i)** $^{141}_{57}\text{La} \rightarrow\ ^{141}_{58}\text{Ce} +\ ^{0}_{-1}\beta$

Electron or beta particle [B1]

(ii) There is emission of a neutrino (or anti-neutrino, or third particle) along with an electron. [M1]

The energy/momentum is shared between the electron and neutrino (anti-neutrino) in various ways (or such that the neutrino also has a range of energy/momentum), while maintaining conservation of energy and momentum. [A1]

Hence the electrons and neutrinos are emitted with a range of energies.

8 **(a)** The dense core emits white light [1]
As the white light passes through the cooler gas layer, photons of energy corresponding to the energy level differences in the gas are absorbed [1]

(b) Since the wavelength corresponding to Hydrogen are darker/thicker [1]
There is more hydrogen than helium [1]

(c) Since there are more lines present in Fig 8.1 than there are present in Fig 8.2 and 8.3, [M1 – comparing the spectra]

These lines are likely caused by other gases. [A1 – other lines indicate other gases]

(d) **(i)** $c = f\lambda$

$$f = \frac{3\times10^{8}}{410\times10^{-9}} \quad [\text{B1}]$$
$$= 7.3\times10^{14}\ \text{Hz}$$

(ii) $E = hf$

$$= \left(6.63\times10^{-34}\right)\left(7.3\times10^{14}\right) \quad [\text{M1}]$$
$$= 4.84\times10^{-19}\ \text{J} \quad [\text{A1}]$$

(e) **(i)**

Hydrogen spectral wavelengths from GN-Z11 / nm	Hydrogen spectral wavelengths from stationary source on Earth / nm	z	v / m s^{-1}
676	656	0.0305	9.15×10^{6}
500	485	0.0309	9.27×10^{6}

$$z = \frac{500-485}{485} = 0.0309$$

$$v = 0.0309\times\left(3.0\times10^{8}\right)$$
$$= 9.27\times10^{6}\ \text{m s}^{-1}$$

[B1 per cell]

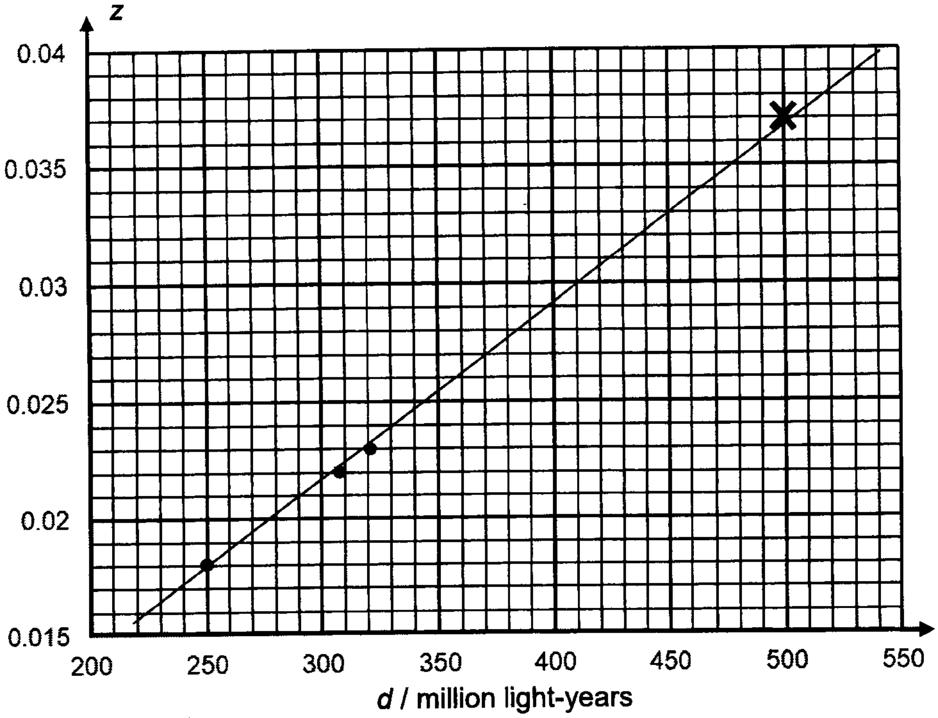
(ii) Since the wavelengths become longer,
They are closer to the red end of the visible spectrum [B1]
Hence they are called "red-shift"

(iii) The Andromeda Galaxy is moving toward Earth.

(f) **(i)** one lightyear $= 365\times24\times60\times60\times\left(3.0\times10^{8}\right)$
$= 9.46\times10^{15}$ m

(ii) The further the galaxy, the faster it is moving away from the Earth.

(iii)



Plot [B1]
Best fit line [B1]

(iv) Using (0.039, 530) and (0.018, 250)

$$\frac{H_o}{c} = \frac{(0.039 - 0.018)}{(530 - 250) \times (9.46 \times 10^{15} \times 10^{6})}$$

$$= 7.93 \times 10^{-27} \quad [C1]$$

$$H_o = (3 \times 10^{8})(7.93 \times 10^{-27}) \quad [C1]$$

$$= 2.38 \times 10^{-18} \quad [A1]$$

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,

$v_A = -1.44 \text{ m s}^{-1}$ [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.

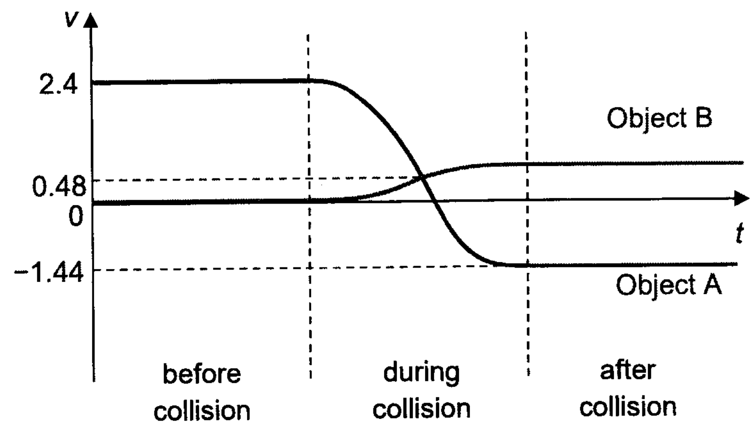
Since no external resultant force is acting on the system,

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

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

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

(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)

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

$$=\frac{\frac{1}{2}mv_Q^{\ 2}}{mgh}$$

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

$$=0.168$$ [A1]

(b)

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

$$=\frac{\frac{1}{2}kx^2}{\frac{1}{2}mv_Q^{\ 2}}\times 100\%$$

$$=\frac{54(2.1^2)}{20(4.8^2)}\times 100\%$$ [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) <u>Gravitational force provides for centripetal force</u> of satellite. [B1]

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

(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]

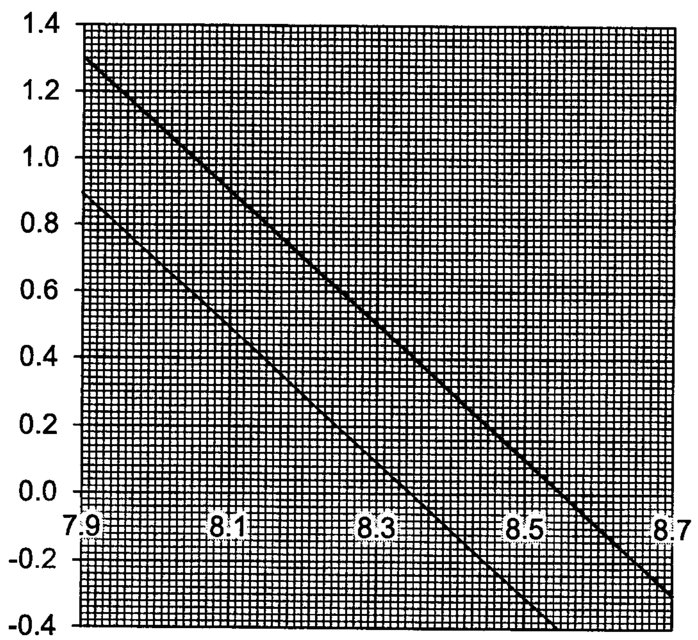
$g = 0.7244$

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

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

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

(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,

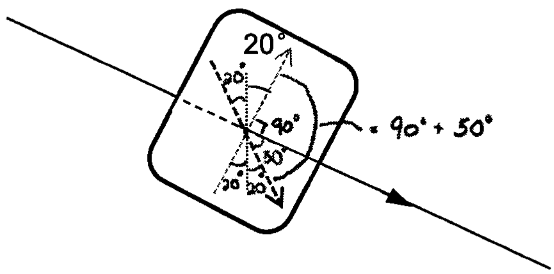
$I = I_o \cos^2 \theta$

$I_Y = I \cos^2 \theta$

$= I \cos^2 20°$ [C1]

$= 0.883\ I$ [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)

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

$$\theta = 25.1° \quad [C1]$$

$$d \sin\theta = n\lambda$$

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

$$n = 1.03 = 1.0 \quad [C1]$$

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)

$$V_A + V_B = 400$$

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

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

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

$|E_A| = |E_B|$

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

$Q_B = 7.9\times10^{-9}$ 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)

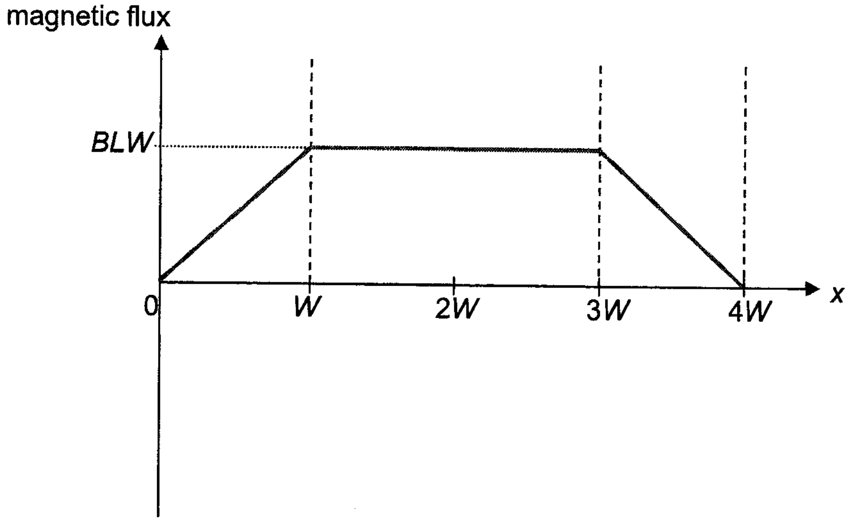
= 1.6×10^{-17} J [M1]

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

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

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

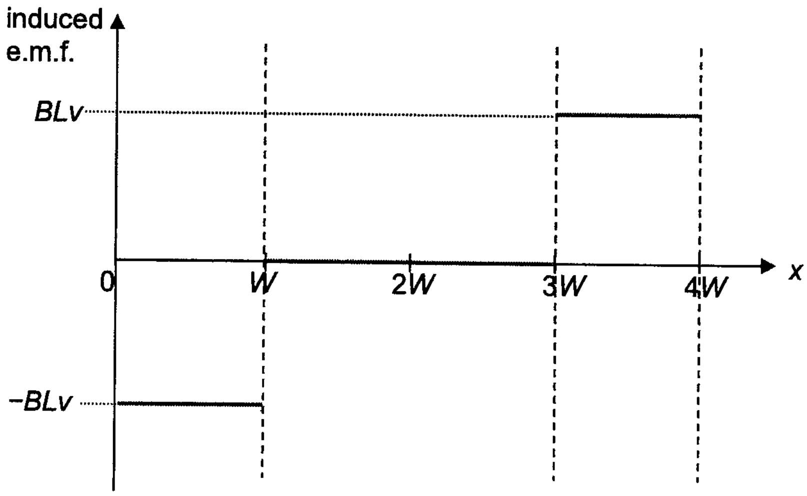
8 (a) (i)



[B1] correct shape

[B1] correct expression for maximum magnetic flux linkage

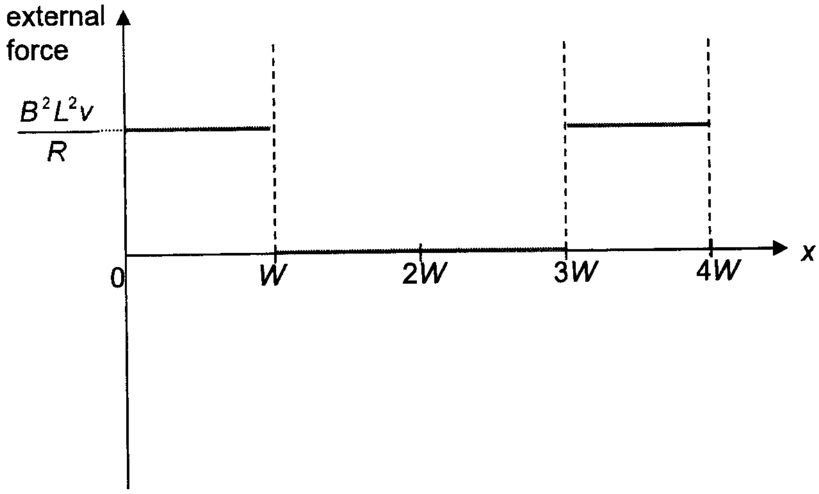
(ii)



[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, <u>the magnetic flux density perpendicular to the coil varies sinusoidally</u>. [B1] (alt: Area perpendicular to the flux)

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

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

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

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

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

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

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)

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

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

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

(iii)

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

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

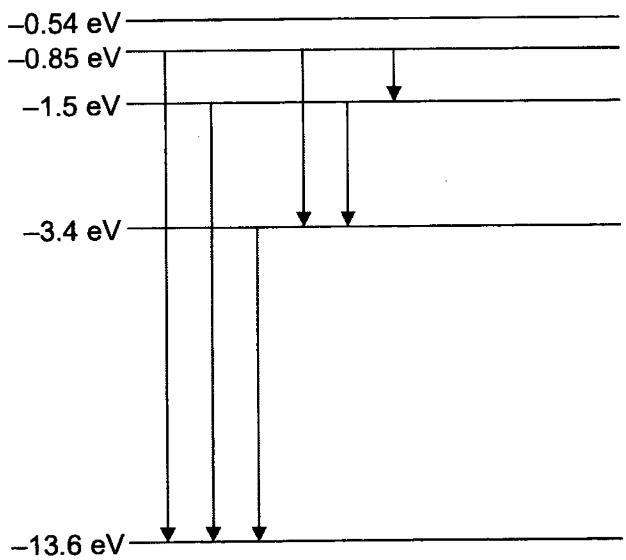
$$= 14.7 \text{ A} \quad \text{[B1]}$$

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)

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

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

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

$$\frac{N}{t}=\frac{I}{e}=\frac{2.7\times10^{-3}}{1.6\times10^{-19}} \quad \text{[M1]}$$
$$=1.69\times10^{16}\ \text{s}^{-1} \quad \text{[A1]}$$

(iii) $E_{k,\max}=eV_S=(1.6\times10^{-19})(5.3)=8.48\times10^{-19}$ J [M1]

$$h\frac{c}{\lambda}=\Phi+E_{k,\max}$$
$$(6.63\times10^{-34})\frac{3.00\times10^{8}}{9.75\times10^{-8}}=\Phi+8.48\times10^{-19} \quad \text{[M1]}$$
$$\Phi=1.19\times10^{-18}\ \text{J or } 1.18\times10^{-18}\ \text{J (if use } 9.8\times10^{-8})$$
$$=1.2\times10^{-18}\ \text{J} \quad \text{[A0]}$$

(iv). $$\Phi=h\frac{c}{\lambda_0}$$
$$1.2\times10^{-18}=(6.63\times10^{-34})\frac{3.00\times10^{8}}{\lambda_0}$$
$$\lambda_0=1.66\times10^{-7}\ \text{m}$$
$$=166\ \text{nm} \quad \text{[B1]}$$
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]