2024 Physics Prelim Exam H2 Paper 3 suggested solutions

1(a)

$$s_y = u_y t + \frac{1}{2}gt^2$$

From Fig. 1.1, $s_y = 1.75$ m and t = 0.600 s [1]

$$\therefore g = \frac{2s_y}{t^2} = \frac{2(1.75)}{(0.600)^2}$$

$$= 9.722 \text{ m s}^{-2}$$

$$= 9.72 \text{ m s}^{-2} \quad [1]$$

(b) % uncertainty = actual uncertainty/ data point. [1]

Hence the larger the data point, the smaller the % uncertainty since the absolute uncertainty is fixed. Hence more reliable. [1]

(c)

$$\frac{\Delta g}{g} = \frac{\Delta s_y}{s_y} + 2\frac{\Delta t}{t} \quad [1]$$

$$\Delta g = [\frac{0.001}{1.75} + 2(\frac{0.006}{0.600})](9.722)$$

$$= 0.2 \text{ m s}^{-2} \quad [1]$$

$$g = 9.7 \pm 0.2 \text{ m s}^{-2} \quad [1]$$

(d) Since $s_y = ½gt^2$, plot a graph of s_y against t^2, where, s_y = vertical distance travelled by the sphere, t = time taken to travel s_y. The gradient = $½g$. [1]

Random error is reduced when a best fit line is drawn using all the data points. [1]

2(a) By the principle of conservation of momentum, since there is no external force acting, the total change in momentum of the of ball and wall = 0. [1]

Therefore the change in momentum (impulse) of the wall is equal and opposite to the change in momentum of the ball . [1]

Therefore, Student A is wrong.

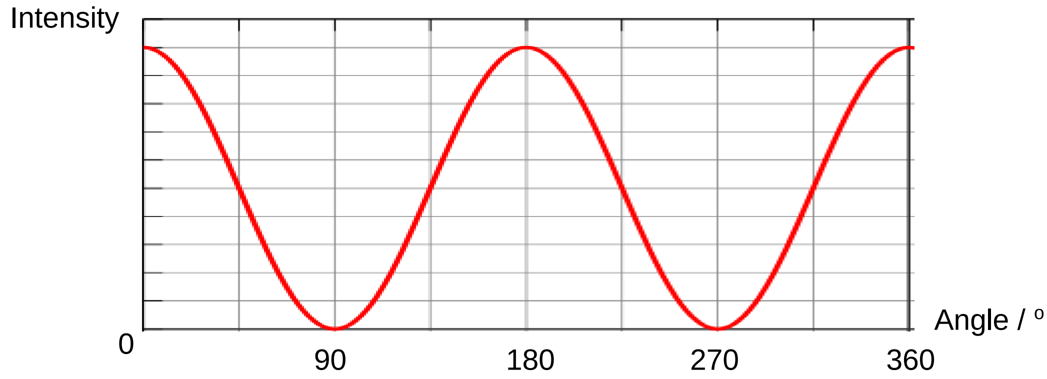
(b) Taking values from Fig 2.2,
Total momentum before collision = (1.2 x 4) + 0 = 4.8 kg m s^{-1} [1]
Total momentum after collision = (1.6 x 3.6) + (-0.8 x 1.2) = 4.8 kg m s^{-1} [1]

Since total momentum before collision is equal to the total momentum after collision, momentum is conserved in this collision. [1]

(c) Relative speed of approach = 4.0 – 0 = 4.0 m s^{-1}
Relative speed of separation = 1.6 – (-0.8) = 2.4 m s^{-1} [1]

Since relative speed of approach is not equal to relative speed of separation, the collision is inelastic. [1]

3 (a) (i)



Sinusoidally shaped graph [1]
Maximum intensity value at 0°, 180° and 360° and zero intensity at 90° and 270°. [1]

(ii) Using Malus's Law, intensity of transmitted beam, $I_t = I_o \cos^2\theta$ [1]

Therefore angle, $\theta = \cos^{-1}\left(\sqrt{\frac{I_t}{I_o}}\right) = \cos^{-1}\left(\sqrt{\frac{4.2}{7.6}}\right) = 42°$ [1]

(b) Diffraction refers to the spreading or bending of plane waves when they encounter an aperture or obstacle, [1]
whose linear dimension is comparable to the wavelength of the waves. [1]

(c)(i) For diffraction grating, $d\sin\theta = n\lambda$ [1]

Therefore, line spacing, $d = \frac{n\lambda}{\sin\theta} = \frac{3\left(4.3\times10^{-7}\right)}{\sin 68°} = 1.4\times10^{-6}\text{ m}$ [1]

(c)(ii) For diffraction grating, $d\sin\theta = n\lambda$

Different visible wavelength, $\lambda = \frac{d\sin\theta}{n} = \frac{\left(1.4\times10^{-6}\right)\left(\sin 68°\right)}{2} = 6.5\times10^{-7}\text{ m}$

[1 for n = 2; 1 for answer]

4(a) Electric field strength at a point is electric force per unit positive charge at that point. [1]

(b)(i) $F = (2e)E$ [1]

$= 2 \times (1.6 \times 10^{-19})(7.5 \times 10^{4})$

$= 2.4 \times 10^{-14}$ N [1]

(b)(ii) Time taken for alpha particles to travel 1 m in the horizontal direction,

$$t = \frac{s_x}{u_x} = \frac{1.0}{1.50 \times 10^{7}}$$

$$= 6.67 \times 10^{-8}\ s \quad [1]$$

(b)(iii) Acceleration in the vertical direction,

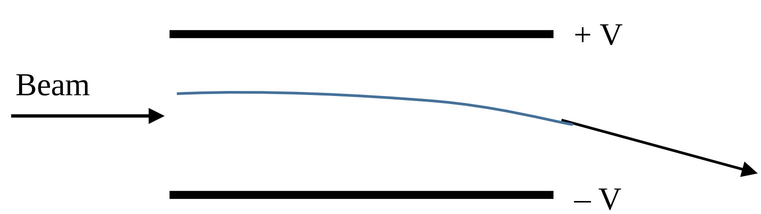
$$a = \frac{F}{m} = \frac{F}{4u} = \frac{2.4 \times 10^{-14}}{4 \times 1.66 \times 10^{-27}} = 0.3614 \times 10^{13}\ m s^{-2} \quad [1]$$

Displacement in vertical-direction during time t,

$$s = \frac{1}{2} a t^2 = \frac{1}{2}(0.3614 \times 10^{13})(6.67 \times 10^{-8})^2 = 0.008039 \approx 0.0080\ m \quad [1]$$

The particles will not hit any of the plates as the vertical displacement of the electron is less than 0.0125 m when it is travellling between the two parallel plates.

(b)(iv)



Parabolic path curves downward inside the plates

Straight path outside the plates

5(a) Magnetic flux density is defined to be the magnetic force acting per unit current and per unit length on a conducting wire [1]
placed at right angles to the direction of the magnetic field. [1]

(b)(i) Direction of the magnetic flux density is *into* the plane of the page. [1]

(ii) Magnetic force on a charge particle, $F_B = Bqv\sin\theta$ [1]

$$= \left(4.8\times10^{-3}\right)\left(1.6\times10^{-19}\right)\left(1.7\times10^{7}\right)\left(\sin 90°\right)$$ [1]

$$= 1.3\times10^{-14}\text{ N}$$

(iii) For circular motion, magnetic force provides for the circular motion,

$$\therefore F_B = \frac{mv^2}{r}$$ [1]

Therefore, the electron will move in a circular motion of radius,

$$r = \frac{mv^2}{F_B}$$

$$= \frac{\left(9.11\times10^{-31}\right)\left(1.7\times10^{7}\right)^2}{1.3\times10^{-14}} = 0.020\,\text{m}$$ [1]

Required distance, $d = 2r = 2\left(0.020\right) = 0.040\,\text{m}$ [1]

6(a)(i) $V_{\text{rms}} = \frac{V_0}{\sqrt{2}} = \frac{170}{\sqrt{2}} = 120$ V [1]

(ii) $\omega = 2\pi/T = 314$

$T = 0.0200$ s [1]

(b)(i)

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$

$$\frac{V_S}{170} = \frac{3500}{2000}$$ [1]

$V_S = 298$ V [1]

(ii) $V_S = I_S R$

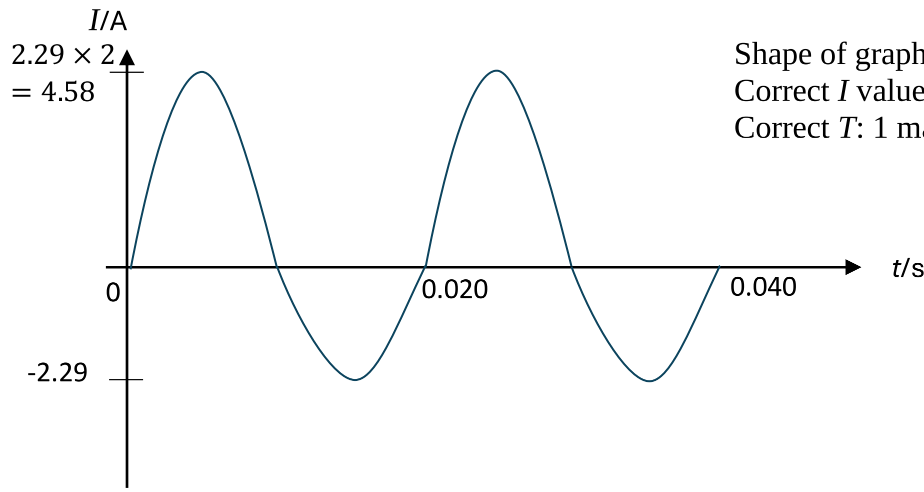
$298 = I_S(130)$

$I_S = 2.288$ A [1]

$$\frac{I_P}{I_S} = \frac{N_S}{N_P} = \frac{3500}{2000}$$

$I_P = 4.00$ A [1]

(c)



Shape of graph: 1 mark.
Correct I values: 1 mark
Correct T: 1 mark

7(a) $^{90}_{38}Sr \rightarrow {}^{90}_{39}Y + {}^{0}_{-1}e$ [1; no need neutrino]

(b) Energy released = (mass defect) c^2

$= (m_{Sr} - m_Y - m_e)\, c^2$ [1]

$= [(89.907738 - 89.907151) \times 1.66 \times 10^{-27} - 9.11 \times 10^{-31}] \times (3.00 \times 10^8)^2$

$= 5.7078 \times 10^{-15}$ [1]

$= 5.71 \times 10^{-15}$ J

(c)(i) Total energy that needs to be released per second, $E = \dfrac{\text{Power to be supplied}}{\text{Efficiency}}$

$= \dfrac{155}{0.070}$

$= 2214.3$ J [1]

Activity $= \dfrac{E}{\text{Energy released in one reaction}}$

$= \dfrac{2214.3}{5.71 \times 10^{-15}}$

$= 3.8779 \times 10^{17}$ [1]

$= 3.88 \times 10^{17}$ Bq

(ii) $A = \lambda N$

Number of strontium-90 needed $N = \dfrac{A}{\lambda}$ [1]

$= \dfrac{A\, \tau_{1/2}}{\ln 2}$

$= \dfrac{3.8779 \times 10^{17} \times 29 \times 365 \times 24 \times 3600}{\ln 2}$

$= 5.1165 \times 10^{26}$

$= 5.12 \times 10^{26}$ [1]

(iii) Mass of strontium-90 needed = number of nuclei x mass of 1 nuceus [1]
= $5.1165 \times 10^{26} \times 89.907738 \times 1.66 \times 10^{-27}$
= 76.4 kg [1]

8(a)(i)

$$T = 24 \text{ hours} \quad [1]$$

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{(24 \times 60 \times 60)}$$

$$= 7.3 \times 10^{-5} \text{ rad s}^{-1} \quad [1]$$

(ii)

Gravitational force provides centripetal force

$$\frac{GMm}{r^2} = mr\omega^2 \quad [1]$$

$$r = \sqrt[3]{\frac{GM}{\omega^2}} = \sqrt[3]{\frac{(6.67 \times 10^{-11})(5.9 \times 10^{24})}{(7.3 \times 10^{-5})^2}} \quad [1]$$

$$= 4.2 \times 10^7 \text{ m} \quad [1]$$

(iii) Communication, weather forecasting or navigation (GPS)

(iv)

Application	Advantage	Disadvantage
Communication	No break in the signal transmissions as it is fixed position in sky.	High altitude so there is a significant lag time in the signal transmissions.
Weather		
Navigation		

(b)(i) Gravitational field strength is equal to the negative gravitational potential gradient i.e. $g = - d\phi / dr$

(ii) Potential gradient at surface of star S_1 is steeper than that of S_2. [1]
Using relationship in (b)(i), gravitational field strength at the surface of star S_1 is greater than that of star S_2. [1]

(iii) From the graph, when the particle travels from S_2 to S_1, it loses gravitational pe (since it experiences a drop in gravitational potential). [1]

As the total energy of the particle is constant, it gains ke. So its ke at the surface of S_1 is larger than E_k. [1]

(iv) It is the point in which the resultant gravitational field strength is zero. [1]

(v)

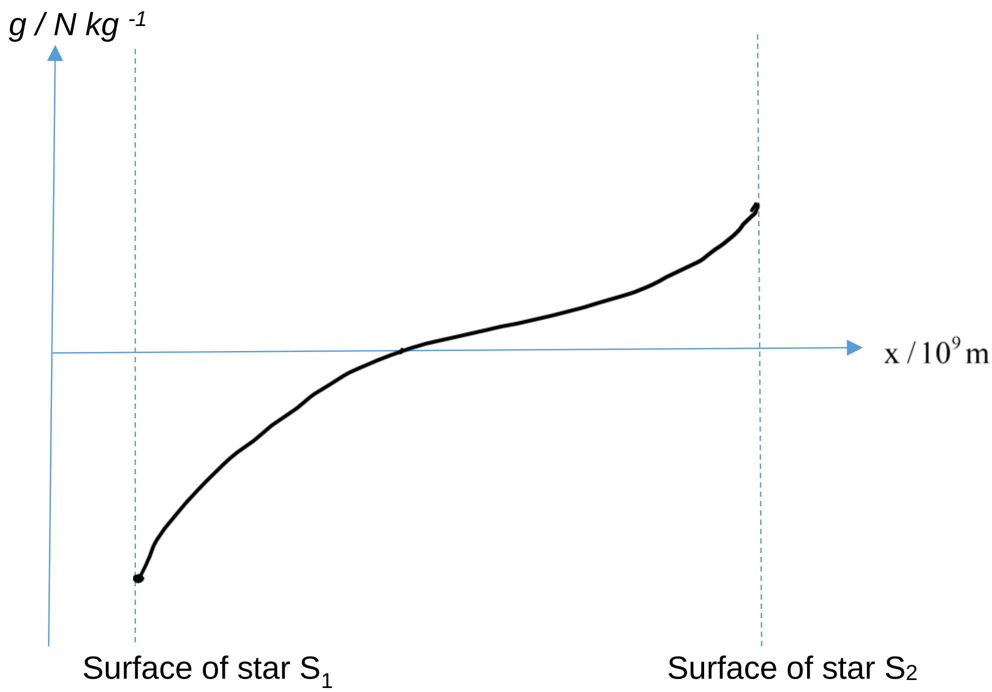
$$\frac{GM_1}{x^2} = \frac{GM_2}{(1.2\times10^{10} - x)^2} \quad [1]$$

From Fig. 8.2, x = 4.8 x 10^9 m [1]

$$\frac{M_1}{M_2} = \left[\frac{4.8\times10^9}{(1.2\times10^{10} - 4.8\times10^9)}\right]^2$$

$$= 0.44 \quad [1]$$

(vi)



Correct shape of curve with gravitational field strength at surface of star S_1 greater than S_2. [1]
Field strength is zero at the point of maximum potential. [1]

9(a)(i) Resistance = $\frac{\rho L}{A}$ [1]

$= \frac{\rho L}{\left(\frac{\pi d^2}{4}\right)}$ Cross sectional area of wire, $A = \frac{\pi d^2}{4}$

$= \frac{1.50 \times 10^{-6} \times 6.0 \times 10^{-2}}{\left(\frac{\pi \left(0.30 \times 10^{-3}\right)^2}{4}\right)}$

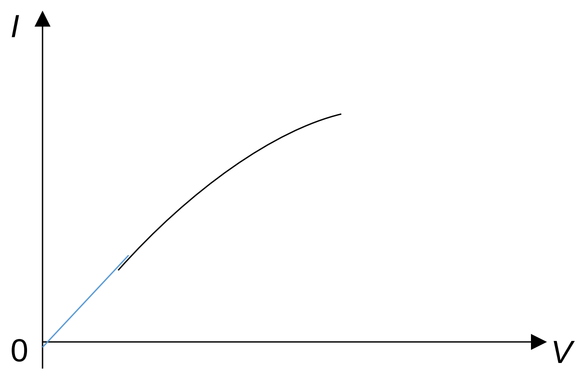
= 1.273 [1]

= 1.3 Ω

(ii)1. e.m.f. is the amount of other forms of energy converted to electrical energy per unit charge delivered by a source of e.m.f. [1]

p.d. is the amount of electrical energy converted to other forms of energy per unit charge flowing through a device. [1]

2.



[1; no need to show negative quadrant]

3. Read off the corresponding value of I.

Resistance = $\frac{V}{I}$ [1; must have both statements]

4. Fraction of power delivered = $\frac{\text{Power dissipated through X}}{\text{Total power dissipated in circuit}}$

$= \frac{I^2 R_X}{I^2 \left(R_X + R_{variable}\right)}$ (R_X and $R_{variable}$ are in series)

[1]

$= \frac{R_X}{\left(R_X + R_{variable}\right)}$

$= \frac{1.3}{\left(1.3 + 0.50\right)}$

= 0.72 [1]

(b)(i)

- As the resistance of the rheostat is increased, the total resistance across the voltmeter is increased. [1]
- Using the potential divider principle, the p.d. across the voltmeter will take up a bigger fraction of the e.m.f. [1]
- So the voltmeter reading will increase. [1]

(ii) S is to prevent short circuit of the cell [1] when the rheostat is set to 0 Ω. [1]

(iii)1. If voltmeter reads 1.2 V, then p.d. across S = 3.0 -1.2
= 1.8 V [1]

$\therefore$ current delivered by cell = current through S
= 1.8 / 0.60
= 3.0 A [1]

2. Current through rheostat = 1.2 / 10
= 0.12 A [1]

Current through bulb = Main current – current through rheostat [1]
= 3.0 – 0.12
= 2.9 A [1]

3.

- When the rheostat is set to 0 Ω, a current will still flow through S. [1]
- So power will be wasted [1], that's why the suggestion is not practical.