2023 Preliminary Examinations H2 Physics Paper 1 Solutions

1 **B** When θ is zero, $F_2 = F$ (largest), $F_1 = 0$ (smallest).
When θ is 90°, $F_2 = 0$ (smallest), $F_1 = F$ (largest).

2 **C** $v_y^2 = u_y^2 - 2gy$

At the highest point, $v_y = 0$. Hence,

$0 = u_y^2 - 2gy$

$u_y = \sqrt{2gy}$

Since the maximum height reached is the same for all three paths, u_y is the same too.

Option A: $S_y = u_y t + at^2$, since all three paths end on ground level, time of flight is the same. Path Z has the longest range. $S_x = u_x t$, path Z has the highest horizontal component and the largest initial speed $\left(u = \sqrt{u_x^2 + u_y^2}\right)$.

Option B: $S_y = u_y t + at^2$, since all three paths end on ground level, time of flight is the same.

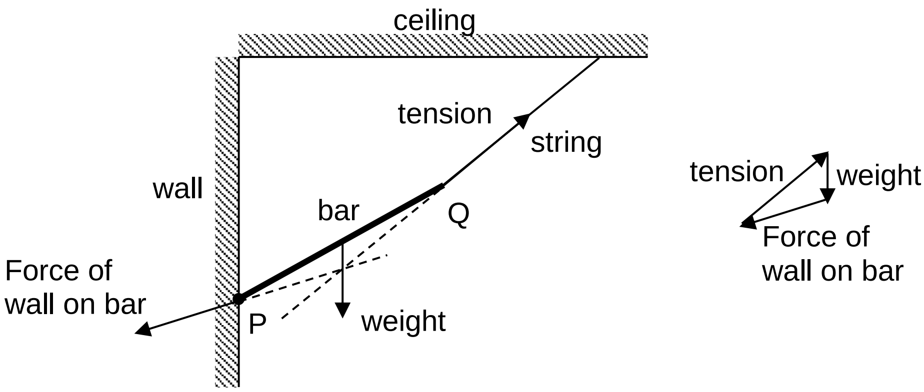
Option D: Path X has the shortest range. $S_x = u_x t$, path X has the lowest horizontal component.

3 **A** By Newton's second law, taking the direction of F_1 as positive,

$$F_{net} = ma$$
$$F_1 - F_2 = ma$$
$$a = \frac{F_1 - F_2}{m}$$

Since object was at rest, F_2 is initially zero $\left(\because F_2 \propto v^2\right)$ and acceleration is maximum initially. Acceleration then decreases as F_2 increases with increasing speed as object accelerates. Acceleration becomes zero eventually when $F_1 = F_2$ and object travels at constant (maximum) speed henceforth.

4 **A** At equilibrium, the lines of action of three forces must meet at a point.
The arrows in the vector triangle must form a closed loop.



5 **C** $P = h_o \rho_o g + h_w \rho_w g$

$= (0.120)(750)(9.81) + (0.060)(1000)(9.81)$

$= 1.4715 \times 10^3$

$= 1.47 \times 10^3$ Pa

6 **D** Work done is area under the force extension graph.
This would be the work done to stretch the spring from x_1 to x_2.

7 **C**

$$\text{total gain in energy} = \text{total loss in energy}$$
$$\text{gain in GPE}_\text{P} + \text{gain in KE}_\text{PQ} = \text{loss in GPE}_\text{Q} + \text{W.D. by friction}$$
$$m_P g\left(1.5\sin 30° - 0\right) + \text{gain in KE}_\text{PQ} = m_Q g\left(1.5 - 0\right) - f\left(1.5\right)$$
$$\begin{aligned}\text{gain in KE}_\text{PQ} &= m_Q g\left(1.5\right) - f\left(1.5\right) - m_P g\left(1.5\sin 30°\right)\\ &= \left(4.0\right)\left(9.81\right)\left(1.5\right) - \left(2.5\right)\left(1.5\right) - \left(3.0\right)\left(9.81\right)\left(1.5\sin 30°\right)\\ &= 33.0375\\ &= 33\text{ J}\end{aligned}$$

8 **D**

$$T + mg = \frac{mv^2}{r}$$
$$1.2 + 0.040 \times 9.81 = \frac{mv^2}{0.30}$$
$$\frac{1}{2}mv^2 = 0.23886$$

By conservation of energy,

$$\frac{1}{2}mv^2 + mgh = \frac{1}{2}mu^2$$
$$0.23886 + 0.040 \times 9.81 \times \left(2 \times 0.30\right) = \frac{1}{2} \times 0.040 \times u^2$$
$$u^2 = 23.715$$

$$a = \frac{u^2}{r} = \frac{23.715}{0.30} = 79.1\text{ m s}^{-2}$$

9 **B** Graph G_1 for path from S to Q means that the two stars have different masses (since there is no point where resultant force is zero). Graph G_3 shows that star X has a smaller mass than star Y (the values of g at start is lesser than at the end). The point of $g = 0$ is closer to X. Since the spacecraft is accelerating, it is possible for the time duration from P to point of $g = 0$ to be approximately equal to the time duration from point of $g = 0$ to R.

10 **C** Given $\phi_\text{Q} = -2.0\text{ J kg}^{-1}$

$$\frac{\phi_\text{R}}{\phi_\text{Q}} = \frac{\text{PQ}}{\text{PR}} = \frac{1}{4}$$

$$\phi_\text{R} = -\frac{1}{4}(2.0) = -0.5\text{ J}$$

Work done = $m\,(\phi_\text{R} - \phi_\text{Q})$ = (3.0) (–0.5 + 2.0) = 4.5 J

Work done is positive, since direction of external force is same as direction of displacement from Q to R.

11 **A** The defining equation of simple harmonic motion is $a = -\omega^2 x$ with a and x having opposite signs. Hence, the graphs are a – t and x – t.

12 **B** Total energy E,

$$E = \frac{1}{2}m{v_0}^2$$
$$= \frac{1}{2}m\left(\omega x_0\right)^2$$
$$= \frac{1}{2}m\left[\left(\frac{2\pi}{T}\right)x_0\right]^2$$
$$= \frac{2\pi^2 m{x_0}^2}{T^2}$$
$$\frac{E'}{E} = \left(\frac{x_0'}{x_0}\right)^2\left(\frac{T}{T'}\right)^2$$
$$E' = \left(\frac{x_0'}{x_0}\right)^2\left(\frac{T}{T'}\right)^2 E$$
$$= (2)^2\left(\frac{1}{3}\right)^2(18) \quad \left(\because x_0' = 2x_0 \text{ and} T' = 3T\right)$$
$$= 8.0 \text{ mJ}$$

13 **C** $\dfrac{I_1}{I} = \cos^2 20^0$, and $\dfrac{I_2}{I_1} = \cos^2\left(\theta - 20^0\right)$

$$\therefore \frac{I_1}{I}\times\frac{I_2}{I_1} = \frac{I_2}{I} = \cos^2 20^0 \cos^2\left(\theta - 20^0\right) = 0.25$$
$$\therefore \cos 20^0 \cos\left(\theta - 20^0\right) = 0.50$$
$$\therefore \cos\left(\theta - 20^0\right) = \frac{0.50}{\cos 20^0} = 0.53209$$
$$\therefore \theta - 20^0 = 57.853^0 \Rightarrow \theta = 77.853^0 \approx 78^0$$

14 **D** A stationary wave forms between G and H. As such the phase difference between E and F is π as they are in adjacent loops.
As the frequency and period of points E and F are the same, F has to travel faster and hence possesses a higher maximum speed and thus maximum kinetic energy as compared to E.

15 **A**

$$\frac{1}{5.0\times10^5}\sin\theta_{\text{red}} = (1)\left(700\times10^{-9}\right) \quad \Rightarrow \theta_{\text{red}} = 20.49°$$
$$\frac{1}{5.0\times10^5}\sin\theta_{\text{blue}} = (1)\left(400\times10^{-9}\right) \quad \Rightarrow \theta_{\text{blue}} = 11.54°$$
$$\Delta\theta = 8.95 = 9.0°$$

16 **A** Constant pressure compression – in the p−T diagram it is still a horizontal line. $pv = nRT$. Since temperature decreases in a constant pressure compression, it is represented by a horizontal line from right to left.

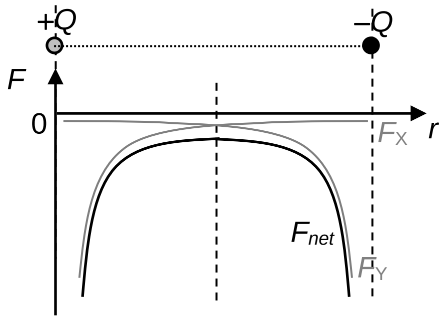
Constant temperature expansion – Temperature is constant and pressure decreases. It is represented by a downward vertical line in the p−T diagram.

Constant volume process **–** From $pV = nRT$, since V is constant, the graph of p against T is a straight line passing through the origin. This is why option D is wrong.

17 **D** Since temperature is constant, $\Delta U = 0$.
Since the kettle is rated as 500 W, rate of electrical work done on the coil is 500 W.
The heating coil continues to lose heat to the water. From the first law of thermodynamics,
$\frac{dQ}{dt} = -500\text{ W}$.

18 **A** Taking towards the right as positive,

The forces acting on the electric due to +Q and −Q are both towards the left.



19 **B** Since oil drop is stationary, weight of oil drop is equal to electric force.

$$mg = q\frac{V}{d} = 3.2\times10^{-19}\times\frac{5000}{0.016} = 1.0\times10^{-13}\text{ N}$$

$$mg - q\frac{V'}{d} = ma$$

$$1.0\times10^{-13} - \left(3.2\times10^{-19}\times\frac{4000}{0.016}\right) = \frac{1.0\times10^{-13}}{9.81}\times a$$

$$a = 1.96\text{ m s}^{-2}$$

OR

$$mg = q\frac{V}{d} = q\frac{5000}{d}$$

$$F_E' = q\frac{4000}{d} = \frac{4}{5}mg = 0.8mg$$

$$mg - 0.8mg = ma$$

$$a = 1.96\text{ m s}^{-2}$$

20 **B** Since current is flowing through the specimen, current must be the same in each section.
$I_X = I_Y = I_Z$
Since $I = nevA$, as I, n and e are constant, v is inversely related to A.
$v_X > v_Z > v_Y$

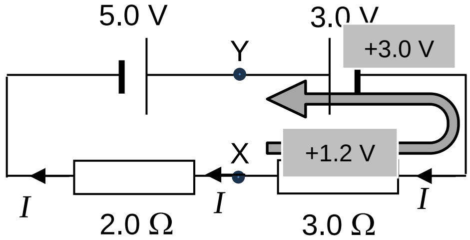
21 **C** p.d. across the 400 Ω resistor = p.d. across the 600 Ω resistor
Since $I = \frac{V}{R}$,

Current through the 600 Ω resistor = $\left(\frac{400}{400+600}\right)I = \frac{2}{5}I$

$$\frac{\text{power dissipated across 120 }\Omega}{\text{power dissipated across 600 }\Omega} = \frac{I^2(120)}{\left(\frac{2}{5}I\right)^2(600)} = 1.25 = 1.3$$

22 **D** Effective e.m.f. = 2.0 V
p.d. across the 3.0 Ω resistor = $\frac{3.0}{2.0+3.0}(2.0) = 1.2\text{ V}$

p.d. between X and Y = 1.2 + 3.0 = 4.2 V
(going from negative terminal to positive terminal of 3.0 V battery, potential increases by 3.0 V)



23 **A** Since X and Z carry the same current of 3.0 A and are the same distance from Y, the magnitude of the forces $F_{\text{on Z due to Y}}$ and $F_{\text{on X due to Y}}$ are the same.

$$\frac{F_{\text{on Z due to Y}}}{L_z} = \frac{\mu_0 I_Y}{2\pi d} \times I_Z = \frac{\mu_0 \times 5.0}{2\pi d} \times 3.0 = 8.0 \times 10^{-6}\ \text{N m}^{-1}$$

Since the I_X and I_Y are in same directions, the two wires attract each other and the force per unit length acting on X due to Y is 8.0×10^{-6} N m^{-1} to the right.

$$\frac{F_{\text{on X due to Z}}}{L_z} = \frac{\mu_0 I_Z}{2\pi (2d)} \times I_X = \frac{\mu_0 \times 3.0}{2\pi (2d)} \times 3.0 = 8.0 \times 10^{-6} \times \frac{1}{2} \times \frac{3.0}{5.0}$$

$= 2.4 \times 10^{-6}$ N m^{-1} to the left

Resultant force per unit length on wire X = $(8.0 - 2.4) \times 10^{-6} = 5.6 \times 10^{-6}$ N m^{-1} to the right

24 **D** When the magnitude of the magnetic flux density increases, the frame experiences an increase in magnetic flux linkage out of the plane of the paper. By Lenz's law, an induced current will flow in the frame to create a magnetic field into the plane of the paper to oppose this change. Hence, this leads to a clockwise current flowing through the frame.

Option A: Sliding the rod right or left will induce an e.m.f. across the rod. Since the rod is in the centre of the metal frame, it will produce currents in opposite directions in the left and right sections of the frame.

Option B: Sliding the rod right or left will induce an e.m.f. across the rod. Since the rod is in the centre of the metal frame, it will produce currents in opposite directions in the left and right sections of the frame.

Option C: By Lenz's law, there will be an anti-clockwise induced current that produces a magnetic field out of the plane of paper to oppose the decrease in magnetic flux density.

25 **B** Induced e.m.f. $E = B_v A f$,

where B_v is the vertical component of the Earth's field

$$\therefore E = B \sin 72^0 \times \pi r^2 \times f$$

$$= 5.6 \times 10^{-5} \sin 72^0 \times \pi (0.55)^2 \times 1.6 = 8.099 \times 10^{-5}\ \text{V} = 81\ \mu\text{V}$$

26 **A** **1st circuit:** Let supply be V_S

$$\frac{V_Q}{V_P} = \frac{N_Q}{N_P} = \frac{20}{1}$$

$V_Q = 20\ V_P = 20\ V_S$

$$\text{current through R} = \frac{V_Q}{R}$$

$$2.0 = \frac{20 V_S}{R}$$

$$\frac{V_S}{R} = 0.10$$

2nd circuit:

$$\frac{V_P'}{V_Q'} = \frac{N_P}{N_Q} = \frac{1}{20}$$

$$V_P' = \frac{1}{20} V_Q' = 0.050 V_S$$

$$\text{current through R} = \frac{V_P'}{R} = \frac{0.050 V_S}{R} = 0.050 \times 0.10 = 0.0050\ \text{A}$$

27 **D**

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

$$p = \sqrt{2mQV} = \frac{h}{\lambda}$$

$$\lambda = \frac{h}{\sqrt{2mQV}}$$

Hence $\lambda \propto \frac{1}{\sqrt{mQ}}$

Shortest wavelength corresponds to greatest product of mass and charge.

$$\lambda \propto \frac{1}{\sqrt{4(1.66\times10^{-27})(2\times1.60\times10^{-19})}} = 2.17\times10^{22}$$

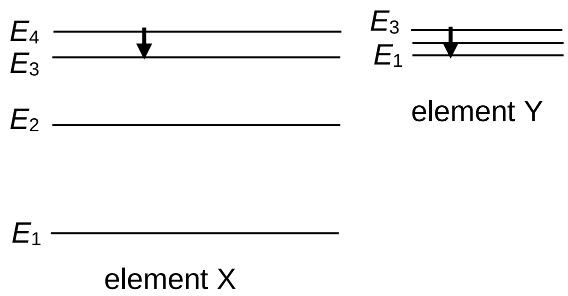
Option A: $\lambda \propto \frac{1}{\sqrt{(1.67\times10^{-27})(1.60\times10^{-19})}} = 6.11\times10^{22}$

Option B: $\lambda \propto \frac{1}{\sqrt{(9.11\times10^{-31})(1.60\times10^{-19})}} = 2.62\times10^{24}$

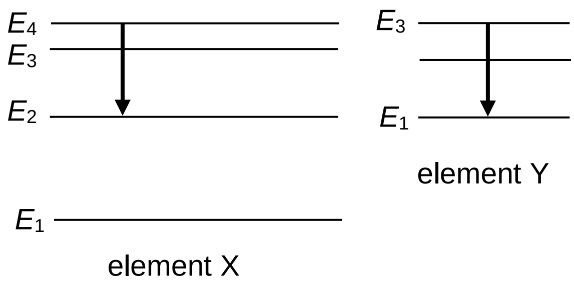
Option C: $\lambda \propto \frac{1}{\sqrt{2(1.66\times10^{-27})(1.60\times10^{-19})}} = 4.33\times10^{22}$

28 **C** Three spectral lines from Y means three energy levels for Y.

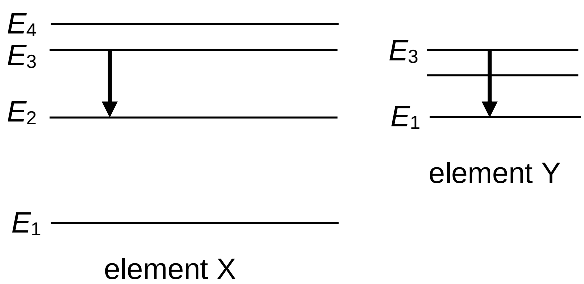
If $\Delta E = E_4 - E_3$ of X corresponds to $E_3 - E_1$ of Y, then the same ΔE will not be sufficient to excite X from ground to a higher level, resulting in 0 spectral line.



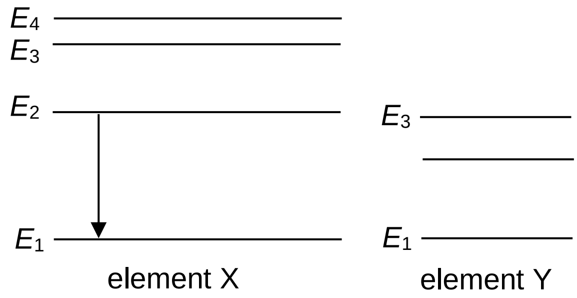
If $\Delta E = E_4 - E_2$ of X corresponds to $E_3 - E_1$ of Y, then the same ΔE will not be sufficient to excite X from ground to a higher level, resulting in 0 spectral line.



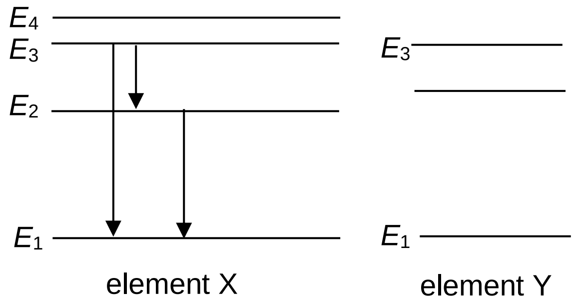
If $\Delta E = E_3 - E_2$ of X corresponds to $E_3 - E_1$ of Y, then the same ΔE will not be sufficient to excite X from ground to a higher level, resulting in 0 spectral line.



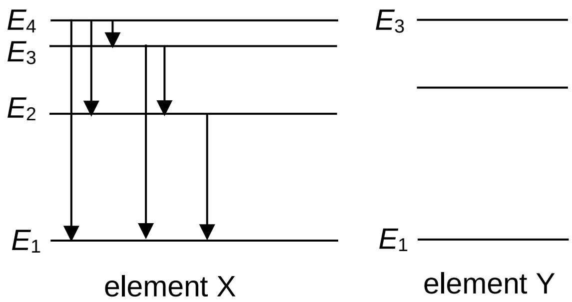
If $\Delta E = E_2 - E_1$ of X corresponds to $E_3 - E_1$ of Y,
then the same ΔE will excite X to E_2, resulting in 1 spectral line.



If $\Delta E = E_3 - E_1$ of X corresponds to $E_3 - E_1$ of Y,
then the same ΔE will excite X to E_3, resulting in 3 spectral lines.



If $\Delta E = E_4 - E_1$ of X corresponds to $E_3 - E_1$ of Y,
then the same ΔE will excite X to E_4, resulting in 6 spectral lines.



29 **D** Total energy of products = 939 + 940 = 1879 MeV
Total mass of deuteron = 1876 MeV
Hence, the deuteron needs to capture an energy of 1879 – 1876 = 3 MeV

30 **B** This shows the random nature of radioactive decay.
Option A: This is due to the law of decay, and not the spontaneous nature.
Option C: This is the spontaneous nature in which the rate of decay is unaffected by external conditions.
Option D: This is a fact not related to random nature.