2025 Preliminary Examination H2 Physics Paper 3 Solutions

1 **(a)** **(i)**

$$s = ut + \frac{1}{2}at^2$$

$$240 - 180 = 0 + \frac{1}{2}(9.81)t_1^{\,2}$$

$$t_1 = 3.497 \text{ s}$$

$$240 - 150 = 0 + \frac{1}{2}(9.81)t_2^{\,2}$$

$$t_2 = 4.284 \text{ s}$$

$$\text{time} = t_2 - t_1 = 4.284 - 3.497 = 0.787 \text{ s}$$

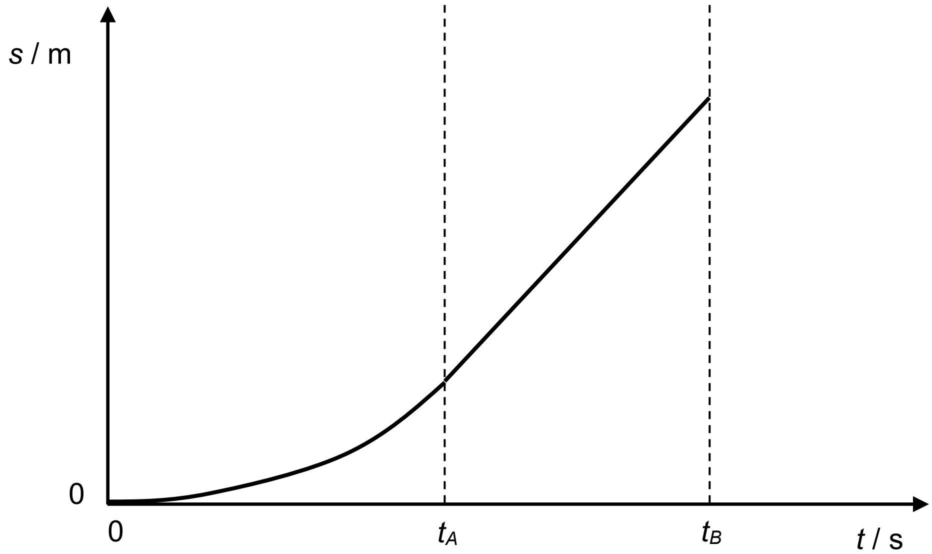
(ii) The time taken will be smaller/shorter as the average speed will be higher and the distance travelled remains the same.

(iii) $v^2 = u^2 + 2as$

$v^2 = 0 + 2(9.81)(240)$

$v = 68.6 \text{ m s}^{-1}$

(b)



B1 – Correct shape between 0 to t_A with zero gradient at t = 0

B1 – Constant gradient between $t = t_A$ and $t = t_B$ (no kink at t_A)

2 **(a)** The principle of conservation of momentum states that when bodies in a system interact, the total momentum of the system remains constant, provided no net external force acts on it.

(b) Taking velocity to the right as positive.

By the principle of conservation of momentum for bodies A and B,

$$p_i = p_f$$

$$m_A u_A + m_B u_B = m_A V_A + m_B V_B$$

$$(60)(11) + (90)(-5) = (60)V_A + (90)V_B$$

$$V_A + 1.5V_B = 3.5 \qquad \text{eq (1)}$$

Since collision is elastic,

$$u_A - u_B = V_B - V_A$$
$$(11) - (-5.0) = V_B - V_A$$
$$V_B - V_A = 16 \qquad \text{eq (2)}$$

eq (1) – 1.5 × eq (2):

$$2.5V_A = -20.5$$
$$V_A = -8.2 \text{ m s}^{-1} \qquad \text{(shown)}$$

(c) **(i)** area under $F - t$ graph $= m(v - u)$

$$\frac{1}{2} \times 0.40 \times F_{\text{max}} = (60)[1 - (-8.2)]$$
$$F_{\text{max}} = 2760 \text{ N}$$

(ii) By adding soft padding to the walls, so that the duration of collision can be lengthened (to reduce the maximum force experienced by the skaters when they hit the walls).

3 **(a)** **(i)** Elastic potential energy of bow = area under graph

$= \frac{1}{2} \times 210 \times 0.60 = 63.0$ J

By conservation of energy, assuming that loss in elastic potential energy = gain in kinetic energy of the arrow

$$63.0 = \frac{1}{2} \times 32 \times 10^{-3} \times v^2$$
$$v = 62.7 \text{ m s}^{-1}$$

(ii) The force required to hold the compound bow at maximum draw is lower.

This allows easier aiming / more accurate aiming / archers to hold the bow steady for longer periods without tiring their muscles.

Alternative answer:
For the same draw, the compound bow has greater elastic potential energy and is able to shot an arrow with greater speed.

(b) The elastic potential energy of the bow, designed to be transferred to the arrow, instead dissipates as vibrations and noise within the bow's components.
This can cause broken strings and damage the bow.

(c) **(i)** By conservation of energy,
loss in kinetic energy = gain in gravitational potential energy

$$\left(\frac{1}{2} \times 32 \times 10^{-3} \times 52^2\right) - E_{K,final} = 32 \times 10^{-3} \times 9.81 \times (8.0 - 1.5)$$
$$43.264 - E_{K,final} = 2.040$$
$$E_{K,final} = 41.2 \text{ J}$$

(ii)

$$S_y = u_y t + \frac{1}{2}at^2$$

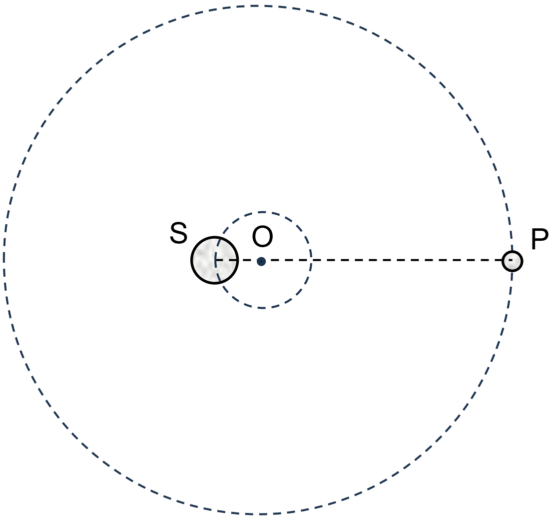
$$8.0 - 1.5 = (52 \times \sin 15)t + \frac{1}{2}(-9.81)t^2$$

$$4.905t^2 - 13.459t + 6.5 = 0$$

$$t = 0.6256 \text{ s or } 2.118 \text{ s}$$

$$S_x = u_x t$$
$$= 52 \times \cos 15° \times 0.6256$$
$$= 31.4 \text{ m}$$

4 (a) (i)



(ii) Star S and planet P attract each other by Newton's law of gravitation. By Newton's third law, the force of attraction on star S by planet P is equal in magnitude and opposite in direction to the force of attraction on P by S. (The magnitude of this gravitational force of attraction is $\frac{GM_S M_P}{r^2}$.)
Since the only force acting on each star is this gravitational force of attraction, the gravitational force provides the centripetal force on each star.

Hence the magnitude of the centripetal force on each star is the same.

(iii) Since both S and P orbit at the same angular velocity ω,

$$\not{M}(r_S \not{\omega}^2) = 0.12\not{M}(r_P \not{\omega}^2)$$

$$\frac{r_S}{r_P} = 0.12$$

(b) (i) period $T = 1500$ days

$$\omega = \frac{2\pi}{T} = \frac{2\pi}{1500 \times 24 \times 3600}$$
$$= 4.85 \times 10^{-8} \text{ rad s}^{-1}$$

(ii)

$$r_S = \frac{v_S}{\omega} = \frac{70}{4.848 \times 10^{-8}} = 1.44 \times 10^9 \text{ m}$$

(iii) $\frac{r_S}{r_P} = 0.12 \quad \Rightarrow \quad r_P = \frac{r_S}{0.12}$

$$r_S + r_P = r_S\left(1 + \frac{1}{0.12}\right) = 1.444 \times 10^9 (9.333) = 1.35 \times 10^{10} \text{ m}$$

(iv) Gravitational force between S and P provides the centripetal force for their circular motion.

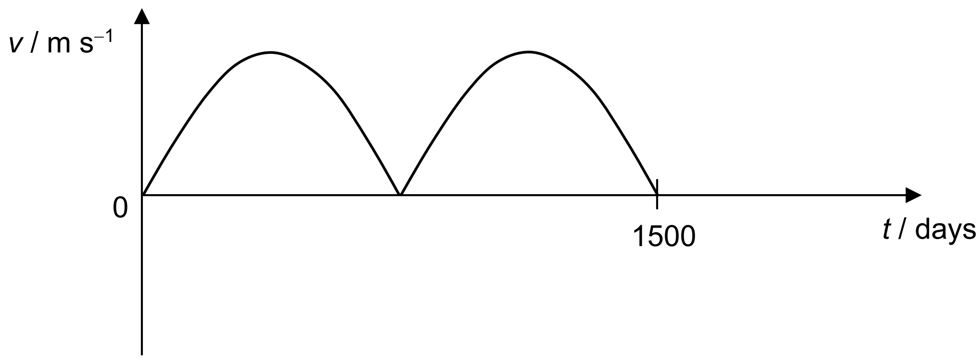
$$G\frac{M(0.12\cancel{M})}{(r_S + r_P)^2} = \cancel{M} r_S \omega^2$$

$$M = \frac{(r_S + r_P)^2 r_S \omega^2}{0.12G}$$

$$M = \frac{\left(1.348 \times 10^{10}\right)^2 \times 1.444 \times 10^9 \times \left(4.848 \times 10^{-8}\right)^2}{0.12 \times 6.67 \times 10^{-11}}$$

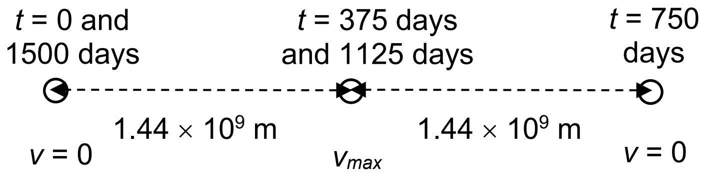
$$M = 7.71 \times 10^{25} \text{ kg}$$

(c)



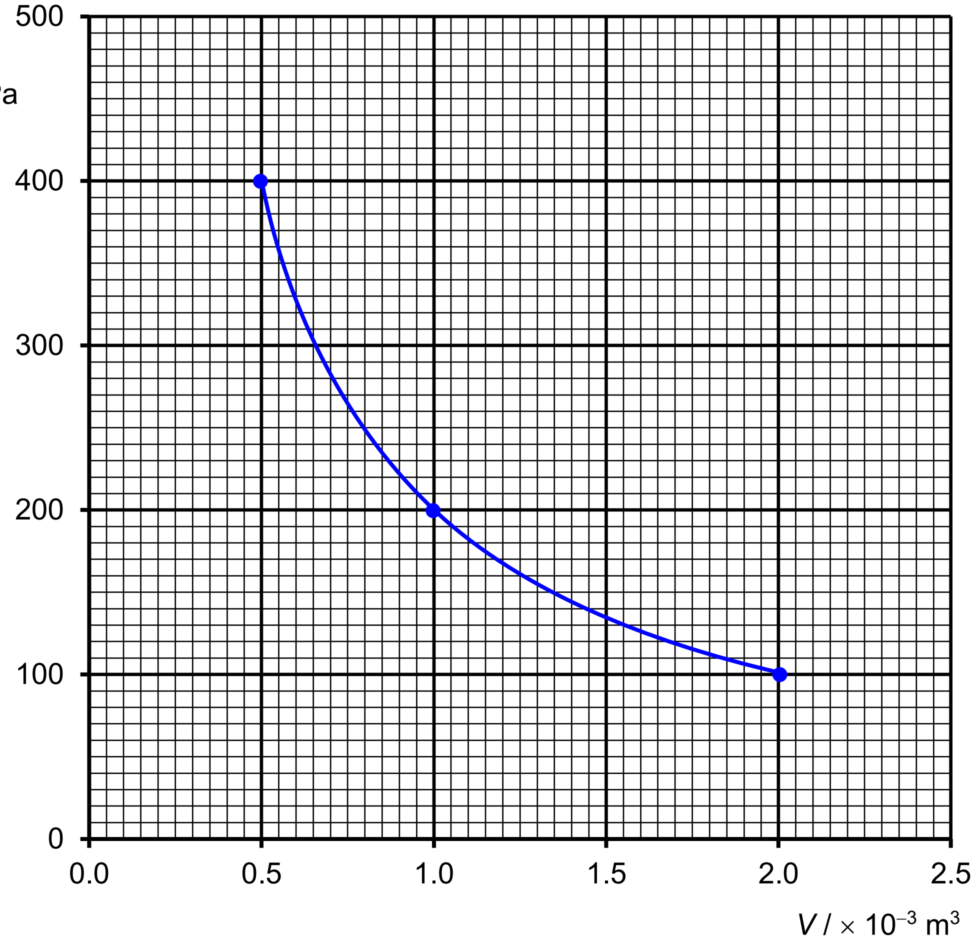
Note

Star S will appear to be moving in simple harmonic motion.



5 **(a)** The first law of thermodynamics states that the increase in internal energy of a system is equal to the sum of the heat supplied to the system and the work done on the system, and the internal energy of a system depends only on its state.

(b) **(i)**



(ii) Since the gas expands, the area under the graph gives the work done **by** the gas.
(or the negative work done **on** the gas)

Since internal energy is proportional to temperature, $\Delta U = 0$ as there is no change in temperature,

$0 = Q + W_{on}$

$Q = -W_{on}$ OR $Q = +W_{by}$

Hence, the amount of heat supplied to the gas is equal to the area under the curve AB.

(c) For experiment 1, the volume remains constant and work done on gas = 0
Hence, increase in internal energy is equal to heat supplied.

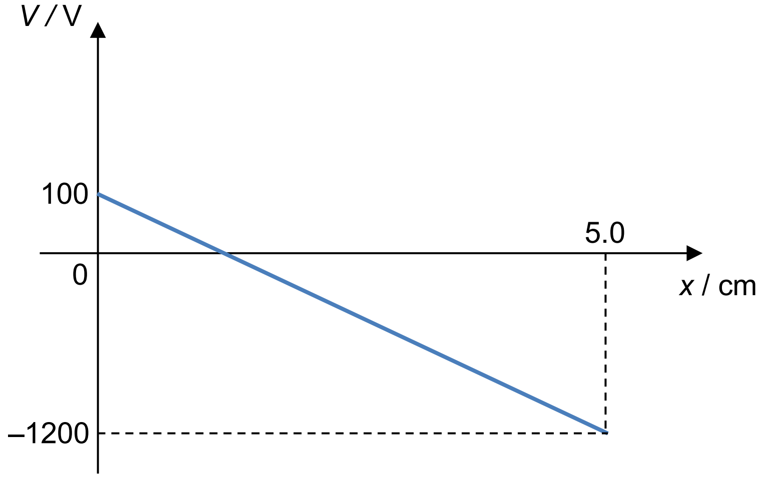
For experiment 2, the gas expands and work done on gas is negative.
Hence, increase in internal energy in experiment 2 is less than that of experiment 1. (increase in internal energy in experiment 2 is equal to heat supplied minus work done by gas)

Since internal energy is proportional to temperature, increase in temperature of experiment 2 is smaller than that in experiment 1 and gas in experiment 1 will have a higher final temperature.

OR For experiment 1, all the heat supplied was transferred into increasing the microscopic kinetic energy of the gas, whereas
For experiment 2, the heat supplied was transferred into increasing the microscopic kinetic energy of the gas as well as to do work against external pressure (the piston).
Since the amount of heat supplied is the same, the gain in kinetic energy for experiement 1 is higher and hence the gas in experiment 1 will have a higher final temperature.

6 **(a)** The electric potential at a point in an electric field is defined as the work done per unit positive charge by an external force in bringing a small test charge from infinity to that point.

(b)



(ii) The electric field strength is the negative of the gradient of the potential-distance graph in Fig. 6.2.

$$E = -\frac{dV}{dx}$$

$$= -\frac{-1200 - 100}{\left(5.0 \times 10^{-2}\right) - 0}$$

$$= 26000 \text{ N C}^{-1}$$

Alternative answer:

$$E = \frac{\Delta V}{d} = \frac{1300}{5.0 \times 10^{-2}}$$

$$= 26000 \text{ N C}^{-1}$$

(iii) $F_E = qE = ma$

$$a = \frac{qE}{m} = \frac{(1.60\times10^{-19})(26000)}{(131)(1.66\times10^{-27})} = 1.913\times10^{10}\ \text{m s}^{-2}$$

Since the electric field is uniform, the acceleration is also uniform.

Using kinematics equation,

$$v^2 = u^2 + 2as$$
$$= 0 + 2(1.913\times10^{10})(5.0\times10^{-2})$$
$$v = \sqrt{2(1.913\times10^{10})(5.0\times10^{-2})}$$
$$= 43700\ \text{m s}^{-1}$$

Alternative Answer:
By principle of conservation of energy,
gain in kinetic energy = loss of electric potential energy

$$\frac{1}{2}mv^2 - 0 = q(V_A - V_B)$$
$$\frac{1}{2}(131)(1.66\times10^{-27})v^2 = (1.60\times10^{-19})[100-(-1200)]$$
$$v = 43700\ \text{m s}^{-1}$$

(c) The positively charged xenon ions need to be neutralised so that they will not be attracted back towards the negatively charged plate B, which will reduce / cancel the thrust on the spacecraft created by the ejection of the ions or reduce speed of xenon ions.

Note: If the exited ions feel an attractive force back towards the spacecraft, by Newton's 3rd Law, the spacecraft feels a force in the opposite direction towards the ions. The attractive force experienced by the spacecraft towards the ions is opposite in direction to its thrust. Hence, the thrust on the spacecraft is reduced, reducing the ion thruster's efficiency.

7 **(a)** The alternating current in the primary coil sets up a varying magnetic field/flux/flux linkage which links the primary coil with the secondary coil. This induces an alternating e.m.f./current in the secondary coil.

(b)

$$\frac{V_S}{V_P} = \frac{N_S}{N_P}$$
$$\frac{5.0}{V_P} = 0.022$$
$$V_P = 227\ \text{V r.m.s.}$$

(c) **(i)** Max potential difference $= \sqrt{2}\times V_{rms}$

$$= \sqrt{2}\times5.0$$
$$= 7.07\ \text{V}$$

(ii) Zero
because diode is in reverse bias and there is no current in the circuit and by $V = IR$, no potential difference across R.

(iii)