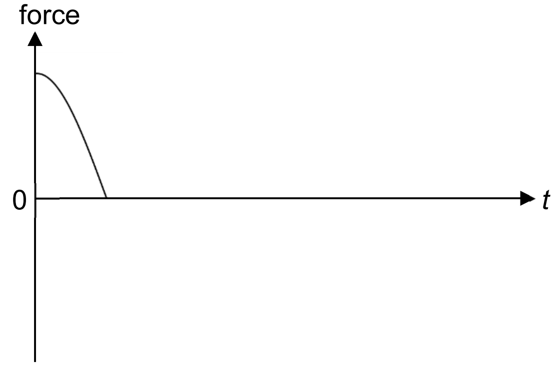
2018 Raffles Institution Preliminary Examinations – H2 Physics

Paper 2 – Solutions

1 **(a)** **(i)** The rate of change of (total) momentum of a system of bodies is directly proportional to the resultant external force acting on the system and the direction of the change is in the direction of the force.

(ii) If the system is isolated from all external forces, then the resultant external force acting on it is zero. By Newton's second law, the total momentum of the system will not change, which means that it is conserved.

(b) **(i)**



One quarter of SHM sinusoidal function

(ii) By conservation of energy,

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

$$0.100 v_A{}^2 + 0.050 v_B{}^2 = 80 \times (0.060)^2 = 0.288$$

$$2v_A{}^2 + v_B{}^2 = 5.76 \quad \text{----- (1)}$$

By conservation of momentum,

$$m_A v_A + m_B v_B = 0$$

$$v_B = -2v_A \quad \text{----- (2)}$$

Substitute (2) into (1),

$$2v_A{}^2 + 4v_A{}^2 = 5.76$$

$$v_A = 0.98 \text{ m s}^{-1}$$

Hence, $v_B = 1.96 \text{ m s}^{-1}$

(c) **(i)** Taking moments about O,

$$T \sin 55^\circ \times 0.15 = (0.050 \times 9.81 \times 0.25) + (4.0 \times 0.20)$$

$$T = 7.509 = 7.51 \text{ N}$$

(ii) Resolving the forces horizontally,

$$F_x = T \cos 55^\circ = 7.509 \times \cos 55^\circ = 4.307 = 4.31 \text{ N}$$

Horizontal component is 4.31 N
(Direction is leftward.)

Resolving the forces vertically,

$F_y + T\sin 55^\circ = (0.050 \times 9.81) + 4.0$

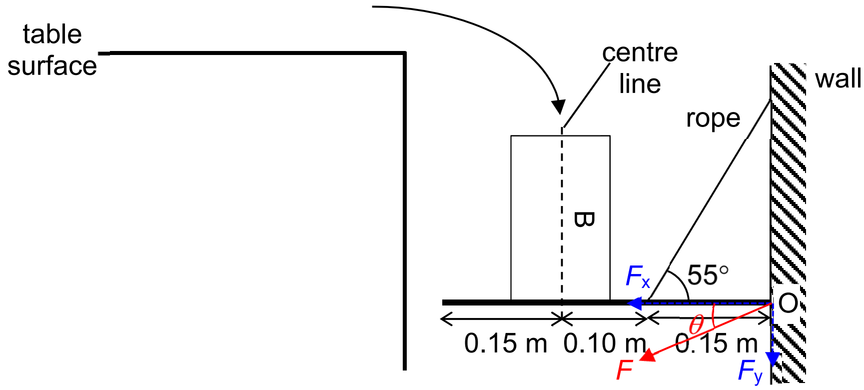
$F_y = (0.050 \times 9.81) + 4.0 - (7.509 \times \sin 55^\circ) = -1.661 = -1.66$ N

Vertical component is 1.66 N

(Direction is downward.)

(iii) $\tan\theta = \dfrac{F_y}{F_x} = \dfrac{1.661}{4.307}$

$\theta = 21.09^\circ = 21.1^\circ$



2 **(a)** **(i)** **1.** 1 cycle

$T = 1.90$ ms

$f = \dfrac{1}{T} = \dfrac{1}{(1.90 \times 10^{-3})} = 526.3 = 526$ Hz

(Students are allowed to use one or more cycles.)

2. uncertainty in the time scale is the smallest division: 0.1 ms

If used one period in (a)(i)1., $\Delta T = 0.1$ ms

$\dfrac{\Delta f}{f} = \dfrac{\Delta T}{T}$

$\Delta f = \dfrac{\Delta T}{T} \times f$

$= \dfrac{0.1}{1.9} \times 526.3$

$= 27.7 = 30$ Hz (1 s.f.)

Absolute uncertainty given to 1 s.f.

OR

If used two periods in (a)(i)1., $2\Delta T = 0.1$ ms

$\Delta T = \dfrac{1}{2}(0.1) = 0.05$ ms

$$\frac{\Delta f}{f} = \frac{\Delta T}{T}$$

$$\Delta f = \frac{\Delta T}{T} \times f$$

$$= \frac{0.05}{1.90} \times 526.3$$

$$= 13.85 = 10 \text{ Hz (1 s.f.)}$$

Absolute uncertainty given to 1 s.f.

(ii)

$$\phi = \frac{\Delta t}{T} \times 2\pi$$

$$\frac{4}{5}\pi = \frac{\Delta t}{T} \times 2\pi$$

$$\Delta t = \left(\frac{4\pi}{5}\right)\left(\frac{T}{2\pi}\right) = \frac{2}{5}(1.90) = 0.76 \text{ ms}$$

$$1.50 + 0.76 = 2.26 \text{ ms}$$

(iii)

$$I = \frac{P}{4\pi r^2} \quad \Rightarrow \quad I \propto \frac{P}{r^2}$$

$$\frac{I_1}{I} = \frac{P_1}{r_1^2} \times \frac{r^2}{P}$$

for $I_1 = I$

$$r_1^2 = \frac{P_1}{P} r^2$$

$$r_1 = \sqrt{\frac{0.25P}{P}}\, r = \sqrt{0.25}\,(120) = 60 \text{ cm}$$

(b) (i) All the particles in a progressive wave oscillate with the same amplitude.
The particles in a stationary wave oscillate with amplitudes that range from zero at the nodes to a maximum at the antinodes.

(ii) All the particles within a wavelength of a progressive wave have different phases.
All the particles between two adjacent nodes of a stationary wave have the same phase. Particles in adjacent segments have a phase difference of π radians.

3 (a) (i) At equilibrium, pressures in both chambers are the same.

Using $pV = nRT$

$$\frac{n_X R T_X}{V_X} = \frac{n_Y R T_Y}{V_Y}$$

$$n_X = n_Y \frac{T_Y}{T_X}\frac{V_X}{V_Y} = (1.2)\left(\frac{300}{450}\right)\left(\frac{2.5}{4.0}\right)$$

$$= 0.50 \text{ mol}$$

(ii)

$$p = \frac{nRT}{V}$$

$$p_X = \frac{1.2 \times 8.31 \times 300}{4.0} \quad \text{OR} \quad p_Y = \frac{0.50 \times 8.31 \times 450}{2.5}$$

$p_X = p_Y = 747.9 = 750$ Pa

(iii) With some gas removed, there are fewer gas molecules in Y which results in a smaller overall rate of change of momentum of molecules as they collide with the walls of the chamber. Hence the average force on the walls decreases which implies gas pressure is reduced.

(b) **(i)** Since process A to B is isothermal $\therefore$ $T_A = T_B$

$\therefore\ p_A V_A = p_B V_B$

$$p_A = \frac{(2.9\times10^5)(0.015)}{0.040}$$
$$= 1.09\times10^5 = 1.1\times10^5 \text{ Pa}$$

(ii) Using $p = \frac{1}{3}\frac{Nm}{V}\langle c^2\rangle$

$$\langle c^2\rangle = \frac{3pV}{Nm} = \frac{3(1.09\times10^5)(0.040)}{0.060}$$
$$c_{rms} = \sqrt{\langle c^2\rangle} = 466.9 = 470 \text{ m s}^{-1}$$

(iii)
$$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}\Delta(pV)$$
$$\Delta U = \frac{3}{2}(p_C V_C - p_B V_B)$$
$$= \frac{3}{2}\left[0.015(5.2\times10^5 - 2.9\times10^5)\right]$$
$$= 5175 = 5200 \text{ J}$$

Using the First Law of Thermodynamics,

$\triangle U = W + Q = 0 + Q$

$Q = 5200$ J

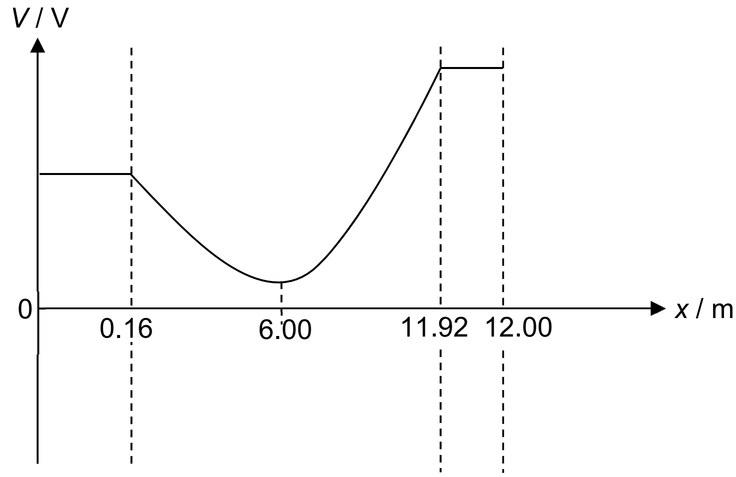
(iv) By ensuring that the process from C to A takes place rapidly such that there is insufficient time for any heat transfer to take place between the system and its surroundings.

4 **(a)** Electric field strength is numerically equal to the potential gradient at that point.
OR
Electric field strength is the negative of the potential gradient.

(b) **(i)** 6.0 m

(ii)
$$\frac{Q}{4\pi\varepsilon_0 r}\times 2=\frac{7.2\times10^{-9}}{4\pi\times8.85\times10^{-12}\times6.0}\times2$$
$$=21.6=22\text{ V}$$

(iii)



(iv) **1.** No it will not reach the surface of Q.
It does not have sufficient kinetic energy to reach Q, as the electric potential at the surface of Q is higher than the electric potential at the surface of P.

2. Being positively charged, it will be repelled by sphere P's electric field and accelerates with increasing kinetic energy as the electric potential decreases towards x = 6.0 m / mid-point.
After passing x = 6.0 m, it decelerates towards sphere Q with decreasing kinetic energy as the electric potential increases, but it does not have sufficient energy to reach Q.
Its kinetic energy drops to zero somewhere before 11.92 m and it returns to sphere P with its kinetic energy increasing towards x = 6.0 m then decreasing after x = 6.0 m, and the cycle repeats again.

OR

Being positively charged, it will be repelled by sphere P's electric field and accelerates towards the point x = 6.0 m as the resultant electric field is in the positive x-direction, as shown by the negative of the potential gradient.
After passing x = 6.0 m, it decelerates towards sphere Q as the resultant electric field direction is in the negative x-direction, and its velocity reaches zero before reaching Q.
It will then return to sphere P, accelerating towards x = 6.0 m, then decelerating after the mid-point, and the cycle repeats again.

5 **(a)** **(i)** Resistance of a conductor is defined as the <u>ratio</u> of the potential difference across it to the current flowing through it i.e. $R=\frac{V}{I}$

Resistivity is the <u>constant of proportionality</u> for the relationship between a conductor's resistance and its length and cross-sectional area i.e. $R=\rho\frac{l}{A}$

OR

Resistance of a conductor is <u>dependent on the length and cross-sectional area</u> (i.e. $R=\rho\frac{l}{A}$) of the conductor whereas resistivity is a <u>characteristic of the conductor's material</u> which is independent of length and cross-sectional area.

(ii)

$$R=\frac{\rho L}{A}$$

$$L=\frac{RA}{\rho}$$

$$=\frac{(2.0)\left[\pi\left(1.0\times10^{-3}/2\right)^2\right]}{1.5\times10^{-6}}$$

$$=1.047=1.0\text{ m}$$

(b) **(i)**

$$V=RI$$

$$I=\frac{V}{R}$$

$$=\frac{6.0}{2.0+4.0}$$

$$=1.0\text{ A}$$

(ii) number density of conduction electrons,

$$n=\frac{\text{no. of mol}\times N_A}{\text{volume}}$$

$$=\frac{\text{density}}{\text{molar mass}}\times N_A$$

$$=\frac{8.96\times10^3}{0.064}\times\left(6.02\times10^{23}\right)$$

$$=8.428\times10^{28}=8.4\times10^{28}\text{ m}^{-3}$$

$$I=nAv_dq$$

$$v_d=\frac{I}{nAq}$$

$$=\frac{1.0}{\left(8.43\times10^{28}\right)\left[\pi(1.0\times10^{-3}/2)^2\right]\left(1.60\times10^{-19}\right)}$$

$$=9.440\times10^{-5}=9.4\times10^{-5}\text{ ms}^{-1}$$

(iii)
$$t = \frac{d}{v_d}$$
$$= \frac{0.20}{9.44 \times 10^{-5}}$$
$$= 2.119 \times 10^{3} = 2.1 \times 10^{3} \text{ s}$$

(iv) When the switch is closed, the electric field is established in the circuit almost instantaneously.
Hence, all free electrons including those in the lamp filament present in the circuit will start to drift at the same time.

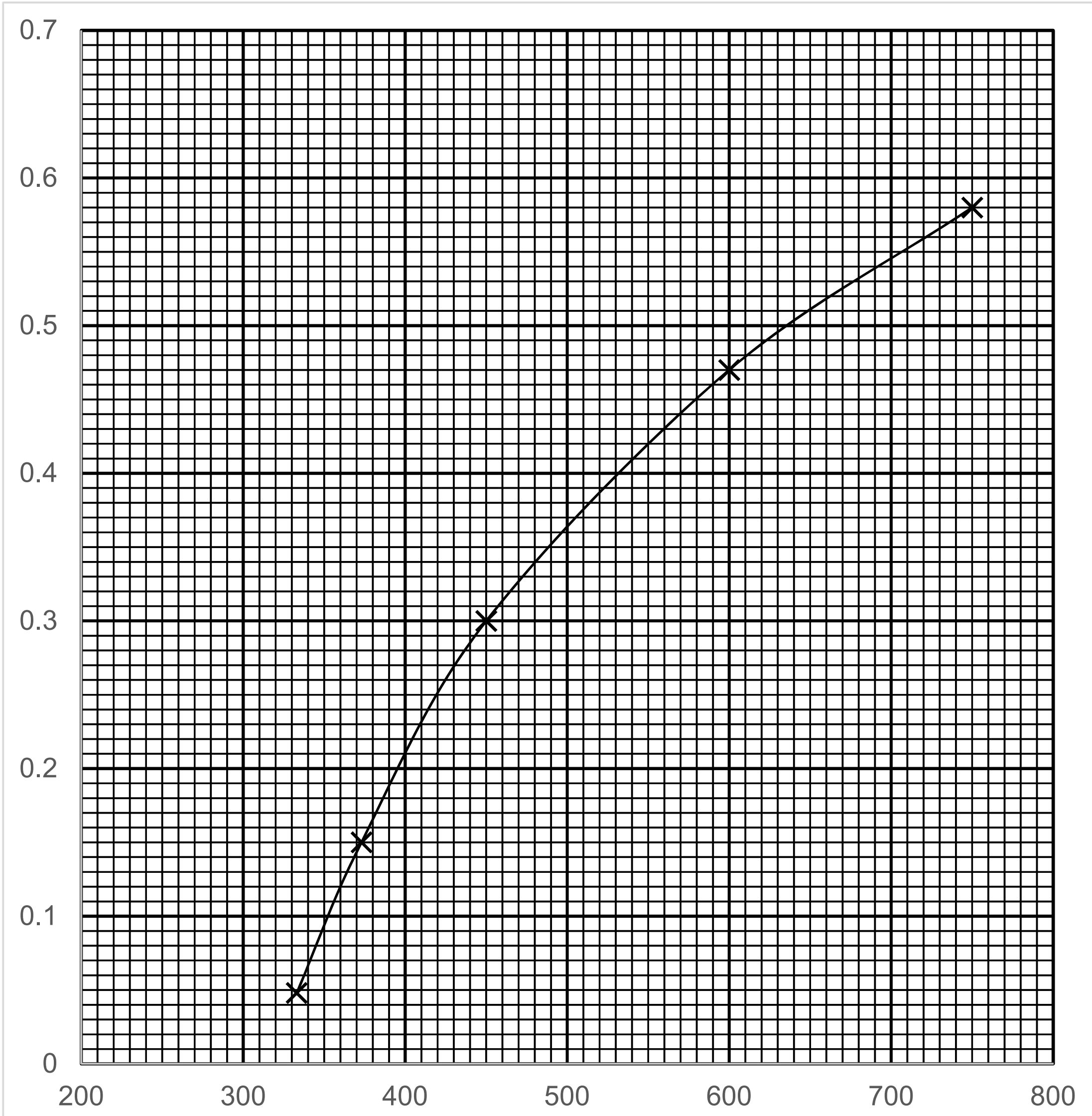
(c) (i)
$$L_{XJ} = \frac{V_{XJ}}{V_{XY}} L_{XY}$$
$$= \frac{3.0}{6.0}(1.0)$$
$$= 0.50 \text{ m}$$

(ii)
$$L_{XJ} = \frac{V_{XJ}}{V_{XY}} L_{XY}$$
$$= \left(\frac{\frac{1.0}{1.0 + 0.5}(3.0)}{6.0} \right)(1.0)$$
$$= 0.333 = 0.30 \text{ m}$$

6 **(a)**

$$e_{max} = \frac{373 - 300}{373}$$
$$= 0.196$$

(b) **(i)**



(ii) 320 K

(iii)

$$e_{max} = \frac{T_2 - T_1}{T_2} = 1 - \frac{T_1}{T_2}$$

When e_{max} = 0,

$$1 - \frac{T_1}{T_2} = 0$$

$$T_1 = T_2 = 320 \text{ K}$$

(iv) To obtain ideal efficiency close to 1, either T_2 would have to be very high or T_1 would have to be very low.
The components of the heat engine may not be able to withstand the high temperature.
At very low temperatures, water used in the cooling system may freeze.

(c) **(i)** $0.52 = \dfrac{T_2 - 330}{T_2}$

$T_2 = 688$ K

(ii) $0.31 = \dfrac{200}{\text{rate of thermal energy input}}$

rate of thermal energy input $= 6.45 \times 10^8$ W

(iii) Rate of thermal energy output

$= (6.45 - 2.00) \times 10^8$

$= 4.45 \times 10^8$ W

Alternative:

$= 0.69 \times (6.45 \times 10^8)$

$= 4.45 \times 10^8$ W

(iv) $4.45 \times 10^8 = \dfrac{m}{t} c \Delta T$

$\dfrac{m}{t} = \dfrac{4.45 \times 10^8}{(4200)(291 - 283)}$

$= 13200$ kg s^{-1}

(d) There could be energy lost due to friction between moving parts of the turbine **or** heat loss to the surroundings.

(e) The efficiency of the turbine is low (31% from from Fig. 6.2). Burning fossil fuel at home may be more efficient. However, there will be a lot of harmful emissions which would not be contained.
There is a large percentage of thermal energy (69%) which would be used in cogeneration plants. This energy would otherwise be wasted.

(f) **(i)** Solar power.
Singapore is situated at the equator and receives sunshine almost all year round.

OR Singapore receives more solar radiation than temperate countries.

(ii) Singapore's small physical size, high population density and land scarcity limit the amount of available space to install solar panels.
OR
The output of a solar cell is variable and dependent on weather conditions compared with a conventional generator that produces a stable output. As such, output from solar cell is largely dependent on environmental factors and weather conditions such as the amount of sunlight, cloud cover and shadow. This can result in imbalances between supply and demand.