JC2 H2 Physics 2025 Preliminary Exam

Paper 1 Solutions

Qn	1	2	3	4	5	6	7	8	9	10
Ans	A	B	C	B	B	B	A	C	A	D

Qn	11	12	13	14	15	16	17	18	19	20
Ans	D	A	A	D	D	C	A	D	B	A

Qn	21	22	23	24	25	26	27	28	29	30
Ans	A	C	A	D	D	B	D	A	D	C

1 **Ans: A**
$[\Delta H] = [RT] = \text{J mol}^{-1}\ \text{K}^{-1} \times \text{K} = \text{J mol}^{-1}$

2 **Ans: B**
Option C and D is out as they can be seen to be inaccurate. Option A and B, each has average value of 1.4925, which is accurate. But Option B is less precise than Option A.

3 **Ans: C**
After 3 s, $x_2 - x_1 = (u_1t + \frac{1}{2} a_1t^2) - (u_2t + \frac{1}{2} a_2t^2)$
$36 = (0 + \frac{1}{2} a_1(3^2) - (0 + \frac{1}{2} a_2(3^2))$
$a_1 - a_2 = 8$

After 5 s, $x_2' - x_1' = \frac{1}{2} a_1(5^2) - \frac{1}{2} a_2(5^2)$
$= \frac{1}{2} (5^2)(a_1 - a_2)$
$= \frac{1}{2} (5^2)(8)$
$= 100$ m

4 **Ans: B**
Acceleration-time graph is similar to the force-time graph.
Acceleration is the gradient of v-t graph.

Since acceleration is (i) always positive, (ii) increases and decreases, therefore gradient of v-t is also always positive, and increases and decreases.

5 **Ans: B**
Change in momentum = final – initial = 0 – mv
Force = rate of change in momentum
$= \frac{mv}{t} = \frac{V\rho}{t} = \frac{AL\rho v}{t} = A\rho v^2$

6 **Ans: B**
Taking rightward to be positive,
$5000u_1 + 5000u_2 = 10000(0.50)$
$u_1 + u_2 = 1$ --- (1)

and $\frac{1}{2}(5000)u_1^2 + \frac{1}{2}(5000)u_2^2 = \frac{1}{2}(10000)(0.5^2) + 11250$
$u_1^2 + u_2^2 = 5$ --- (2)

Solving the simultaneous equation, we get either
- $u_1 = -1.0$ m s^{-1} and $u_2 = 2.0$ m s^{-1}, OR
- $u_1 = 2.0$ m s^{-1} and $u_2 = -1.0$ m s^{-1}

The first set of answers is rejected because in this case, the carriages are moving away from each other at the start and will never collide.

Hence, only the second set of answers is possible. Therefore, $u_2 = -1.0$ m s^{-1}.

7 **Ans: A**
From the graph, the resultant force = gradient of graph = −3.0 N
Since the block is slowing down, net force is towards the left.
Hence, F is smaller than 5.0 N by 3.0 N.
Therefore F = 5.0 – 3.0 = 2.0 N.

8 **Ans: C**

$T\cos 18° = W$

$T = \dfrac{520}{\cos 18°} = 550$ N

$T\sin 18° = R$

$R = \dfrac{520}{\cos 18°}(\sin 18°) = 170$ N

9 **Ans: A**
One force is the resultant of the normal contact force and friction. The other force is the weight. The overall resultant must provide a horizontal centripetal force towards the centre of circle.

10 **Ans: D**
Vertical component of N = weight mg
Horizontal component of N provides centripetal force = $mr\omega^2$
Solve the simultaneous equations to find r.

11 **Ans: D**
$F = mv^2/r$
For same F and m, $v^2 \propto r$
$r_1 / r_2 = (100/50)^2 = 4$
$r_1 = 4 r_2$

12 **Ans: A**
Since $\Delta\phi = \dfrac{E}{m}$, magnitude of g $= \dfrac{\Delta\phi}{x} = \dfrac{E}{mx}$
Potential at P > potential at Q since mass loses potential energy as it moves from P to Q. Hence, direction of g is from P to Q, higher potential to lower potential.

13 **Ans: A**

$pV = nRT$

$\frac{1}{p} = \frac{1}{nRT}V$, hence, gradient $= \frac{1}{nRT}$

When n and T are both halved, gradient $= \frac{1}{\frac{n}{2}R\frac{T}{2}} = 4\frac{1}{nRT}$,

Therefore the new gradient is 4 times that of the original graph.

14 **Ans: D**

Gases behave ideally when pressure is low.
Hence, consider the pV values when $p = 0$.

From the graph, when $p = 0$, $(pV)_{\text{boiling liquid}} = 5.95$ kJ and $(pV)_{\text{triple-point}} = 2.275$ kJ

Using the equation, $\frac{T_{\text{boiling liquid}}}{T_{\text{triple point}}} = \frac{(pV)_{\text{boiling liquid}}}{(pV)_{\text{triple point}}}$

$\frac{T_{\text{boiling liquid}}}{273.16} = \frac{5.95}{2.275}$

$T_{\text{boiling point}} = 714$ K

15 **Ans: D**

Key thing to remember is, period of oscillation = 2 × period of energy-time graph
Therefore, period of oscillation = 400×10^{-3} s
Hence, $\omega = 2\pi / T = 15.708$ rad s^{-1}

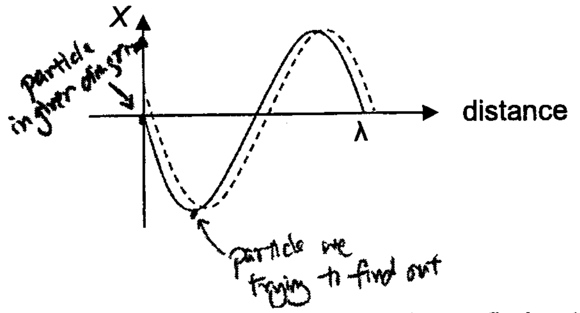
Also, max U = 1.0
$\frac{1}{2} m x_0^2 \omega^2 = 1.0$
$\frac{1}{2}(0.0900)(x_0^2)(15.708^2) = 1.0$
$x_0 = 0.300$

Hence, max a $= x_0\omega^2 = 74$ m s^{-2}

16 **Ans: C**
From the diagram, period = 500 μs
Frequency = 2000 Hz
Wavelength = 330 / 2000 = 0.165 m
At 0.04125 m away, the particle we are trying to find out is ¼ λ away

From the given displacement-time graph, we know that
- the air particle is at equilibrium position at t = 0 s.
- it is moving in the positive direction a small time t after 0 s.

Hence, the displacement-distance graph is:



Therefore, the particle we are trying to find out
- starts at negative amplitude at t = 0 s
- moving up a small time after 0 s.

Therefore, answer is C.

17 **Ans: A**
Using Malus's Law, $I = I_0 \cos^2 \theta$,

Initially when polariser is vertical: $I_1 = I_0 \cos^2 0°$
After polariser is rotated by θ: $I_2 = I_0 \cos^2 \theta$

Hence, $I_2 / I_1 = \cos^2 \theta$
and $I_2 / I_1 = V_2 / V_1 = 2.20 / 3.50 = 0.6286$

Therefore, $\cos \theta = \sqrt{0.6286} = 0.7928$
$\theta = 37.5°$

18 **Ans: D**
$d = 10^{-3} / 500 = 2.0 \times 10^{-6}$
$d \sin 45° = n\lambda$
$(2.0 \times 10^{-6}) \sin 45° = n(600 \times 10^{-9})$
$n = 2.36$

Hence, max order = 2
Max number of bright fringes = 2 + 2 + 1 = 5

19 **Ans: B**
$\sin \theta = \lambda / b$
To decrease θ, either decrease λ or increase b.
Hence, decreasing period increases frequency, and hence decreases λ.

20 Ans: A

Resistance, $R = \frac{\rho l}{A}$ and potential drop across each wire $V = IR = I\left(\frac{\rho l}{A}\right) = I\rho\left(\frac{l}{A}\right)$

Since current and resistivity are constants, the potential drop increases with distance from X (i.e. length of wire in this case), and the smaller the cross-sectional area A, the larger is the drop per unit length of wire. So the last segment has the largest potential drop per unit length.

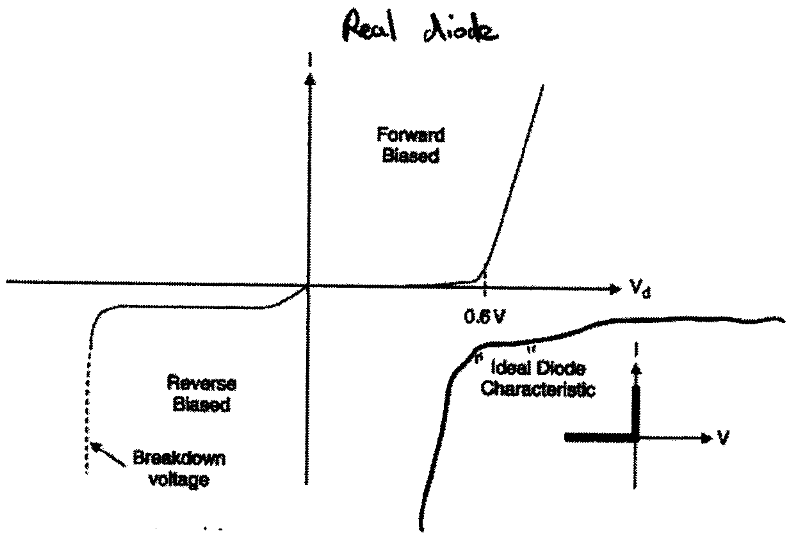
21 Ans: A

Since the thermistor's resistance decreases as its temperature increases, in accordance with the potential divider principle, the potential difference (p.d.) across it decreases with increasing temperature.

The thermistor and the fixed resistor are in series thus their potential differences add up to 10 V. Therefore the p.d. across the fixed resistor increases as the p.d. across the thermistor decreases due to increase in temperature.

When the p.d. across the fixed resistance exceeds the threshold p.d. of the diode (normally around 0.3 – 0.7 V) the diode becomes forward biased and current starts to flow downwards through the lamp to light it up.

Option C is wrong as the lamp will light up immediately regardless of temperature. (It will get brighter as the temperature increases.)



22 Ans: C

Resultant potential is determined through the scalar sum hence the direction of field is irrelevant. As |V| α |$\frac{Q}{r}$|, the potential at **C** due the +2Q charge is equal in magnitude and opposite sign to that due to the -Q charge, as it is twice the charge and twice the distance from **C**, hence, the sum of their potential will be zero.

23 Ans: A

Magnetic flux density due to horizontal wire $= \dfrac{\mu_o I}{2\pi d}$

$= \dfrac{(4\pi \times 10^{-7})(7.00)}{2\pi(3.00)}$

$= 4.67 \times 10^{-7}$ T, out of the page

Magnetic flux density due to vertical wire $= \dfrac{\mu_o I}{2\pi d}$

$= \dfrac{(4\pi \times 10^{-7})(6.00)}{2\pi(4.00)}$

$= 3.00 \times 10^{-7}$ T, into the page

Resultant B = 1.67×10^{-7} T out of the page.

24 Ans: D

Constant rate of cutting of flux ⇒ constant emf induced between centre and rim.

25 Ans: D

By Lenz's law, since the external B-field increases, the induced B setup by the induced current will be in opposite direction to the external field. At the front of the loop, current will be going upwards ⇒ use this to deduce direction of induced current.

Use $\varepsilon = \dfrac{\Delta\Phi}{\Delta t} = \dfrac{N(\Delta B)(A)}{\Delta t}$ to get the magnitude of the induced emf.

26 Ans: B

$V_p I_p = V_s I_s$

$I_s = \dfrac{120x60}{4500} = 1.6A$

Percentage power lost = $= \dfrac{I_s^2 R}{P_{total}} = \dfrac{1.6^2 x1.0}{120x60} x100\% = 0.036\%$

27 **Ans: D**

Option A is incorrect because photoelectric effect can occur even for very low intensity but sufficiently high frequency radiation (above the threshold frequency f_0).

Option B is incorrect because photoelectrons are emitted only if the frequency of radiation is greater than a minimum frequency known as threshold frequency f_0; since $\lambda_0 = \frac{c}{f_0}$, the wavelength of the radiation must be <u>smaller</u> than the threshold wavelength, which is instead a <u>maximum</u> value.

Option C is incorrect because the maximum kinetic energy and thus speed of the photoelectrons is independent of intensity but depends on the frequency of radiation and work function of the metal, as given by $hf = \Phi + E_{k,max}$.

Option D is correct since $I = \frac{N_P}{t}\frac{hf}{A}$, at constant intensity and increased frequency, the rate of photons incident on the metal decreases, the lesser the rate of emission of photoelectrons.

28 **Ans: A**

Since the target is unchanged, the wavelengths of the peaks will remain the same.
However, with an increase in the p.d. between the target and cathode, the target will be bombarded with electrons of higher energy. These electrons will have a higher chance to remove an inner shell electron from the target, resulting in more de-excitations between energy levels and hence higher intensity of the peaks.

29 **Ans: D**

Total mass of reactant is less than total mass of products, so energy has to be supplied for the reaction to take place.

Energy supplied = (1.0086 +1.0097 −2.0150) u c^2 / (1.6 × 10^{-19}) = 3 MeV

30 **Ans: C**

When the source is first used:
Total number of disintegrations = $A_0 \times 10\ mins$ --- (1)

2 years later:
$A_2 = (\frac{1}{2})^{2/4} A_0 = (\frac{1}{2})^{0.5} A_0 = 0.7071\, A_0$

Total number of disintegrations = $A_2 \times t$
Total number of disintegrations = $0.7071\, A_0 \times t$ --- (2)

(2) = (1):
$0.7071\, A_0 \times t = A_0 \times 10\ mins$
t = 14.1 mins

Solution for 2025 SAJC Prelim Paper 2

1 **(a)** By Principle of Conservation of Momentum, total momentum of toy car and exhaust gas remains constant since no net external force acts on the system. [1]

(Since momentum is a vector quantity), exhaust gas gains backward momentum, hence toy car gains forward momentum. [1]

Rate of change of momentum of car is the force rocket produces on car. [1]

(b) (i) **1.** Any indication of calculating gradient of tangent at 2.0s [1]
$a = 2.8$ m s^{-2} (accept: range 2.6 to 3.1 m s^{-2}) [1]

2. Net force = ma
Forward force – resistive force = (0.440)(2.8)
4.6 – resistive force = (0.440)(2.8) [1]
resistive force = 3.368 = 3.4 N [1]

(ii) As v increases, gradient of v-t graph, which is the acceleration, decreases. [M1]
(Mass of car is also decreasing.)
Since forward force is constant (at 4.6 N), resistive force must be increasing (so that net force is decreasing). [A1]

(c) From Fig. 1.2, acceleration due to rocket engine is approximately 8.89 m s^{-2}. This is less than gravitational acceleration of 9.81 m s^{-2}. [M1]

This means that the rocket engine is unable to propel the car vertically at $t = 0$. [A1]

However, as the force by rocket engine is constant (at 4.6 N) and car is losing mass (continuously as exhaust gases are produced), eventually acceleration due to rocket force > 9.81 m s^{-2} (or force > weight) and the car will be lifted off. [B1]

2 **(a)** For a system in rotational equilibrium, sum of clockwise moments about any point equals sum of anticlockwise moments about the same point [1]

(b) **(i)** Taking moment about the pivot, [1]

$2.6 \times 0.4 = (4.0 - U) \times 0.4$ [1]

$U = (4.0 - 2.6)$

$= 1.4$ N

(ii) $U = \rho g V$ and $A = V / h$ [1]

or

$p = h\rho g$ and $A = U / p$

or

$A = U / h\rho g$

$A = 1.4 / (0.10 \times 1.0 \times 10^3 \times 9.81)$

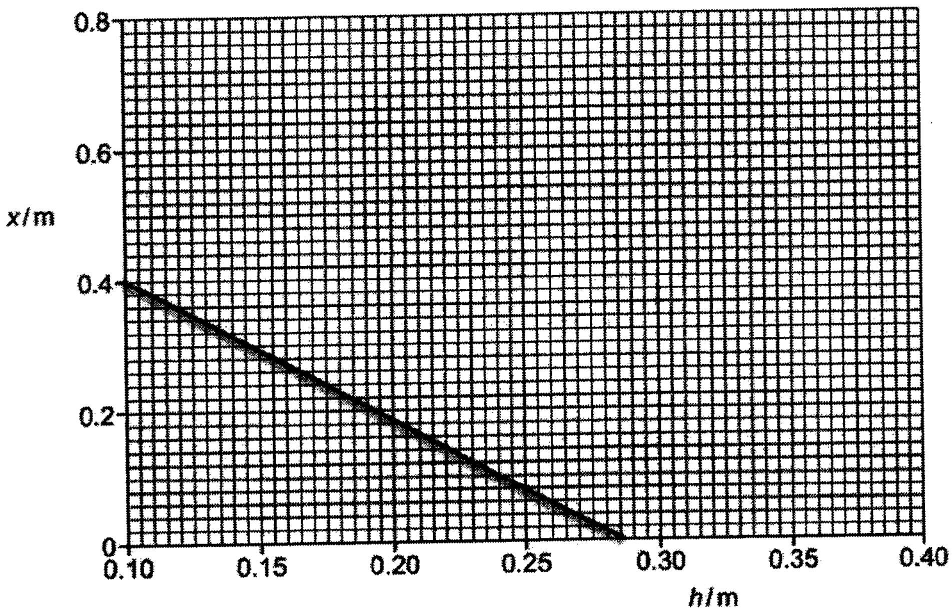
$= 1.43 \times 10^{-3}$ m^2

$= 1.4 \times 10^{-3}$ m^2 [1]

(c) line starting at (0.10, 0.40) [1]

straight line with negative gradient [1]

line ending at (0.28 to 0.29, 0) [1]



3 **(a)** **(i)** M = - gradient / G [1]
Proper substitution of values to find gradient = 5.9×10^{15} [1]

(ii) $GMm/r^2 = mr\omega^2$
$r^3 = (6.67 \times 10^{-11})(8.8 \times 10^{25})(0.72 \times 24 \times 60 \times 60)^2 / (4\pi^2)$
$r = 8.32 \times 10^7$ m [1]

To move satellite to infinity, GPE + KE + $\Delta E = 0$
ΔE = - GPE – KE
$= -(-GMm/r) - \frac{1}{2} mv^2$ [1]
$= (6.67 \times 10^{-11})(8.8 \times 10^{25})(1200)/(8.32 \times 10^7) - \frac{1}{2}(1200)(8400^2)$
$= 4.23 \times 10^{10}$ J [1]

(b) At lower orbit (smaller *r*), total energy decreases / becomes more negative because $E_T = -GMm/(2r)$. [1]

Thrust must be directed opposite to the satellite's velocity, because the thrust must do negative work on the satellite to cause the required decrease in its total energy. [1]

4 **(a)** Taking downslope as positive, mg sin θ – T = ma [1]

At equilibrium position: mg sin θ – T = 0
mg sin θ – ke = 0
mg sin θ = ke [1]

At further extension x: mg sin θ – k(e+x) = ma
mg sin θ – ke – kx = ma
ke – ke – kx = ma [1]

$$a = -\frac{k}{m}x$$

(b) k and m are constants, therefore a is proportional to x. [1]
Negative sign shows that a is always opposite to x [1]

(c) $v = \pm\,\omega\sqrt{x_0^2 - x^2}$

when v = 0.25 v_0,
$0.25v_0 = \omega\sqrt{x_0^2 - x^2}$
$0.25(x_0\omega) = \omega\sqrt{x_0^2 - x^2}$ [1]
$0.25(3.0) = \sqrt{3.0^2 - x^2}$
$x^2 = 8.25$
x = 2.87 = 2.9 cm [1]

(d) **(i)** The driving frequency of the oscillator is equal to the natural frequency of the mass-spring system, resulting in resonance. [1]

(maximum energy is transferred to the system) and the mass-spring system oscillates with maximum amplitude, [1]

(ii) $a_0 = x_0\omega^2 = (0.060)(2\pi \times 1.2)^2 = 3.41 = 3.4\ \text{m s}^{-2}$ [1]

5 **(a)** current (through a conductor is directly) proportional to potential difference (across the conductor) or vice versa
(provided that) temperature (of conductor remains) constant [1]

(b) **(i)** $R = \rho L / A$
$\rho = (18 \times 7.2 \times 10^{-8}) / 0.94 = 1.4 \times 10^{-6}\ \Omega\ m$ [1]

(ii) current in the battery: increase [1]
voltmeter reading: decrease [1]

(iii) cross marked on the resistance wire to right of the arrowhead of S, but not touching the right-hand end of the resistance wire [1]

(c) **(i)** $I = Anvq$
$q = 0.93 / [(7.2 \times 10^{-8}) \times (9.0 \times 10^{28}) \times (1.3 \times 10^{-3})]$
$q = 1.1 \times 10^{-19}$ C [1]

(ii) charge / q (value) is below 1.6×10^{-19} (C) [1]
or
charge cannot be below 1.6×10^{-19} (C)
or
(the charge carriers / q) should have a charge of 1.6×10^{-19} (C)

(d) Before t_1 / when current constant, the (total) resistance is constant

At t_1 / when current increases, the (total) resistance decreases (due to decrease of external resistance)

After t_1, temperature (of lamp) increases so the resistance of the lamp increases (so total resistance increases so the current in the ammeter decreases)

[3]

6 (a) (i) 10.0 eV electron has sufficient energy to excite mercury atom from ground state to energy level of –1.57 eV (because –1.57 – (–10.38) = 8.81 eV).

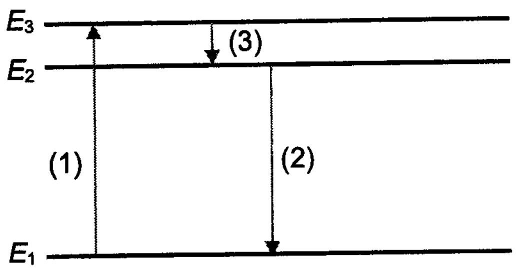
As atom de-excites from –1.57 to –5.74 eV, a photon is emitted. [1]

$$\frac{hc}{\lambda} = [-1.57 - (-5.74)] \times (1.6 \times 10^{-19})$$

$$\lambda = \frac{(6.63 \times 10^{-34})(3.00 \times 10^{8})}{6.672 \times 10^{-19}}$$ [1]

$$\lambda = 2.98 \times 10^{-7}\,\text{m}$$

(ii)



(iii) The phosphor atom absorbs a single high-energy UV photon, but it de-excites in multiple, smaller steps (or 2 steps). (Hence the emitted photons have less energy and longer wavelengths.) [1]

(b) (i) An incident photon transfers its entire energy (, given by E = hf,) to a single electron (on the metal surface). (note: emphasis is one-to-one, cannot accept photons) [1]

Part of this energy is used by the electron to overcome the work function of the metal. The remaining energy is converted into the (maximum) kinetic energy of the emitted photoelectron. [1]

(ii) Photon energy: $E = hc / \lambda = (6.63 \times 10^{-34})(3.00 \times 10^{8}) / (310 \times 10^{-9}) = 6.42 \times 10^{-19}$ J
Work function: $\Phi = 2.28 \times 1.60 \times 10^{-19} = 3.65 \times 10^{-19}$ J [1 for E or Φ]
$KE_{max} = E - \Phi = (6.42 \times 10^{-19}) - (3.65 \times 10^{-19}) = 2.77 \times 10^{-19}$ J [1]

(c) (i) $KE = p^2/2m$
$p = \text{sqrt}\,[2(9.11 \times 10^{-31})(2.77 \times 10^{-19})] = 7.10 \times 10^{-25}$ kg m s^{-1} [1]

de Broglie wavelength: $\lambda = h/p = 6.63 \times 10^{-34} / (7.10 \times 10^{-25}) = 9.34 \times 10^{-10}$ m. [1]

(ii) A pattern is formed because the electron's wavelength is of the same order of magnitude as the atomic spacing of about 10^{-10} m. [1]

(iii) Electrons with lower kinetic energy have longer wavelengths and are diffracted more (or range of wavelengths and range of angles of diffraction) [1]

This overlapping of many patterns causes the observed pattern to be smeared or blurred (sharp inner ring due to electrons with max KE). [1]

7 **(a)** **(i)** Planck's constant. [1]

(ii) For the oil droplets to acquire negative charges, electrons need to be removed from air molecules to attach to them. [1]

OR

Air is needed for the oil droplets to experience viscous force to acquire a terminal velocity (for the determination of the droplet's mass). [1]

(b) **(i)** Reading from the graph, $W = 5.1 \times 10^{-14}$ N [1]

$$\frac{QV}{d} = W \quad \Rightarrow \quad Q = \frac{Wd}{V}$$ [1]

$$= \frac{(5.1 \times 10^{-14})(0.00442)}{470}$$

$$= 4.80 \times 10^{-19} \text{ C}$$ [1]

(ii) The density of air is very small (or 1/800) when compared to that of oil. [1]

(iii) $$\frac{(1.66 + 6.53 + 1.59 + 4.80 + 3.18 + 7.83) \times 10^{-19}}{1 + 4 + 1 + 3 + 2 + 5}$$ [1]

$= 1.599 \times 10^{-19}$ C (to 4 sig. fig.) [1]

(c) **(i)** Stroboscope / light gates / video camera [1]

(ii) The very small weight (mass) is quickly balanced out by the (effects of) air resistance. [1]

(iii) At terminal velocity, $F_D = W$

$6\pi \eta r v = 7.0 \times 10^{-14}$ [1]

Terminal velocity, $v = \dfrac{0.00100}{T} = \dfrac{0.00100}{6.2} = 0.0001613 \text{ m s}^{-1}$ [1]

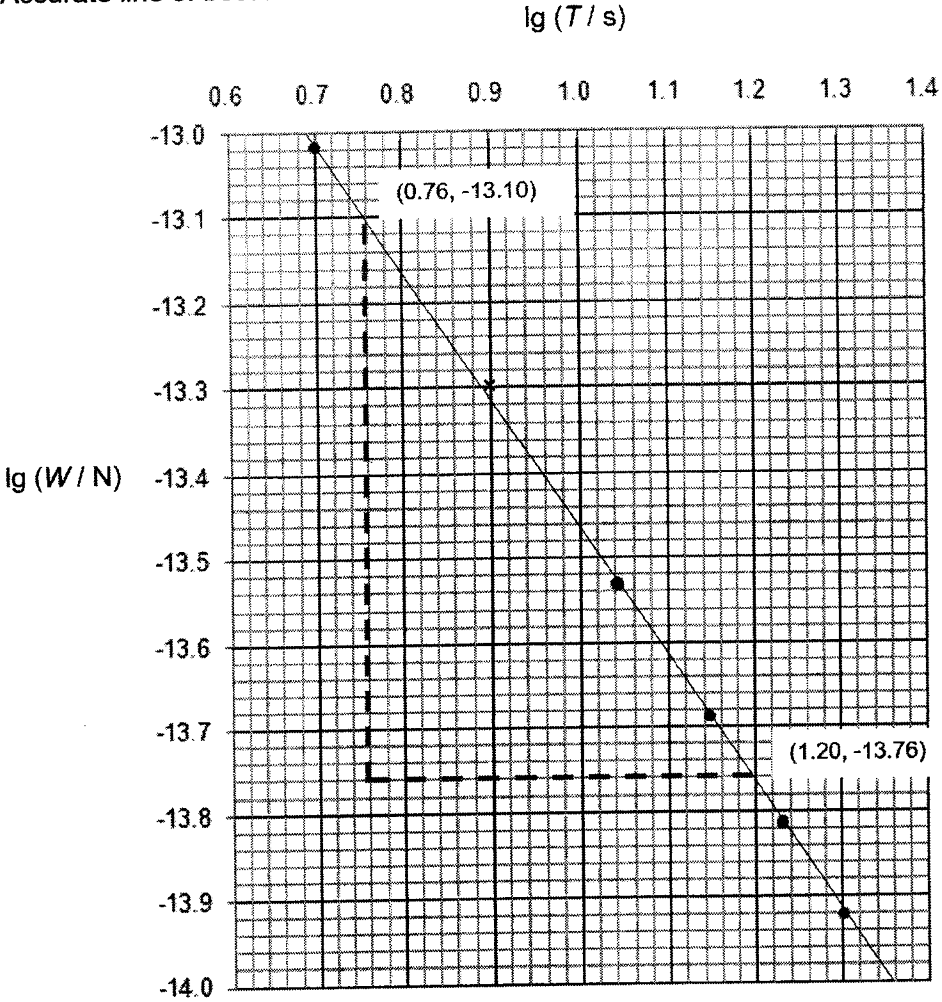
$$r = \frac{7.0 \times 10^{-14}}{6\pi (1.8 \times 10^{-5})(0.0001613)}$$

$= 1.28 \times 10^{-6}$ m [1]

(d) **(i)** When $T = 8.0$ s, $W = 4.7 \times 10^{-14}$ N.

lg (W / N) = -13.33 [1]

(ii) Correct plot [1]
Accurate line of best fit [1]



(iii) Gradient = b $= \dfrac{-13.10 - (-13.76)}{0.76 - 1.20}$ [1]

$= -1.50$ (range: -1.4 to -1.6) [1]

(iv) $W = aT^{-1.5} = a(\frac{1}{T})^{1.5}$

$v = \frac{d}{T}$, (where *d* is the 1.00 mm fall by the droplet.) [1]

Since <u>*a* and *d* are constants</u>,
$W \propto v^{1.5}$ [1]

Solution for 2025 SAJC H2 Physics Prelim Paper 3

1 **(a)** constant velocity in one direction [1]
constant acceleration in the perpendicular direction to the velocity [1]

(b) **(i)** Work done by spring = Loss in elastic potential energy
$F_{ave} \times (8.0 \times 10^{-2}) = 0.24$
$F_{ave} = 3.0$ N [1]

(ii) Using Principle of conservation of energy,

Loss in Elastic PE = Gain in GPE + Gain in KE
$0.24 = mgh + ½ mv^2$ [1]
$0.24 = (4.5 \times 10^{-2})(9.81)(8.0 \times 10^{-2} \times \sin 15°) + ½(4.5 \times 10^{-2})v^2$
$v = 3.2$ m s^{-1} [1]

(iii) Using $v^2 = u^2 + 2as$,
$v^2 = 2.4^2 + 2(- 9.81 \sin 15°)(0.20)$ [1]
$v = 2.18 = 2.2$ m s^{-1}

(c) **(i)** Speed at maximum height = 2.18 cos 15° = 2.1 m s^{-1} [1]

(ii) Using $s_y = u_y t + ½ a_y t^2$, taking upward as positive,
$-0.40 = (2.18 \sin 15°)t + ½ (-9.81)t^2$ [1]
$t = 0.349 = 0.35$ s [1]

(iii) Horizontal displacement = (2.18 cos 15°)(0.349) = 0.735 m [1]

2 **(a)** $F = M_xD_x\omega_x^2 = M_yD_y\omega_y^2$

$(M)(2D)\ \omega_x^2 = (2M)(D)\ \omega_y^2$ [1]

$\omega_x = \omega_y$

(b) Gravitation force provides centripetal force

$GM(2M)/(3D)^2 = (2M)D\omega^2$

$\omega^2 = GM/(9D^3)$

$KE_x = ½\ M(2D\ \omega)^2 = 2GM^2/(9D)$ [1]

$KE_y = ½\ (2M)(D\ \omega)^2 = GM^2/(9D)$ [1]

$GPE = -\ GM(2M)/(3D)$ [1]

$E = 2GM^2/(9D) + GM^2/(9D) - GM(2M)/(3D)$

$E = -\ GM^2/(3D)$ [1]

(c) A negative total energy signifies that the system is gravitationally bound [1]

Or

The stars lack sufficient energy to overcome their mutual attraction and escape to an infinite separation.

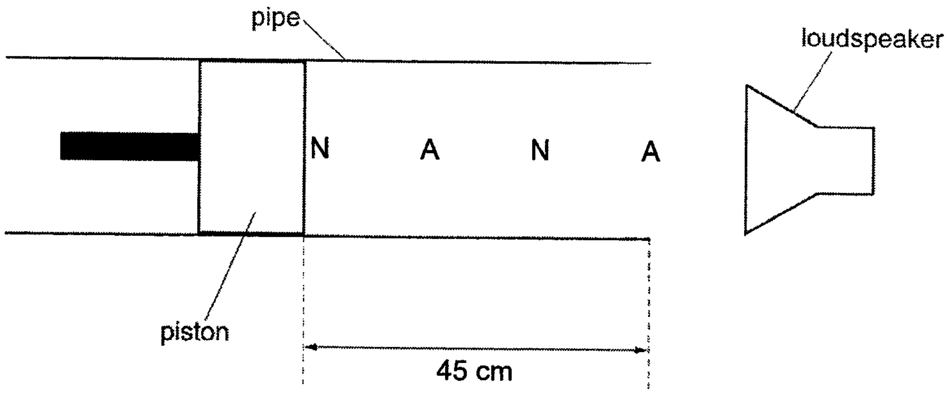
(d) Not possible since force between identical charges is repulsive and will not point towards the centre of motion. [1]

3 (a) (i) For maximum intensity, waves must be in phase at detection [1]
Phase difference at source means waves are not in phase / have 90° phase difference at O. [1]

(ii) Point B labelled on the line PQ below O and distance OB = distance OA [1]

(iii) $\lambda = (3.0 \times 10^8) / (2.5 \times 10^{10}) = 0.012$ m [1]
$x = \lambda D / a = (0.012)(2.3) / (0.18) = 0.153$ m [1]

(b) (i)



N at closed end and A at open end [1]
Correct number of N and A, and distance between N and A is constant [1]

(ii) Lowest frequency happens when ¼ λ = 0.45
λ = 1.8 m [M1]
f = 330 / 1.8 = 183 Hz [A1]

(iii) the node-antinode distance is longer OR wavelength is longer [M1]
(speed of sound is constant so) the frequency is lower [A1]

(iv) End correction [1]

(c) Path difference = 0.4 m = 2.5 λ. Therefore, P is a minima [1]

Intensity α amplitude² and intensity α $(1/r)^2$, therefore amplitude α 1/r

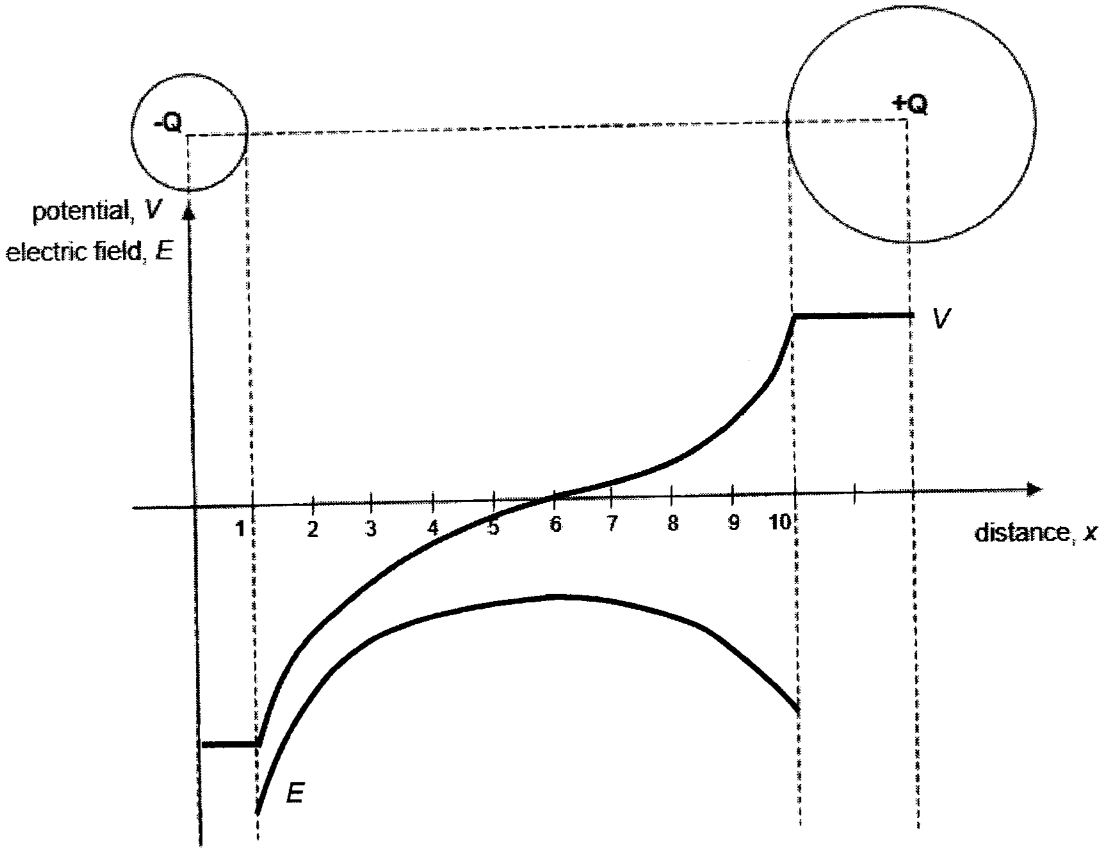
$$\frac{A_y}{A_x} = \frac{r_x}{r_y} = \frac{1.4}{1.8}$$ [1]

$$A_y = \frac{7}{9} A_x$$

$$\frac{I_{resultant}}{I_x} = \left(\frac{A_x - A_y}{A_x}\right)^2$$

$$\frac{I_{resultant}}{4.5 \times 10^{-6}} = \left(\frac{2}{9}\right)^2$$ [1]

Resultant $I = 2.22 \times 10^{-7}$ W m^{-2}



4 (a) (i) V-x graph:

Potential constant within both spheres [1]

Maximum potential for $-Q$ (twice) higher than that of $+Q$ [1]

Correct shape (hyperbola) and cut at 6 cm. [1]

(ii) E-x graph:

Graph is negative [1]

Magnitude of E at $-Q$ is higher than that at $+Q$. [1]

Correct shape (hyperbola) [1]

As the spheres are taken to be point charges, the turning point of the graph is at x = 6 cm, which is in the middle of the centres of both spheres. [1]

(b) Volume, V, of each drop $\frac{4}{3}\pi r^3$, hence, $V \propto r^3$

After combining, the volume of new drop is 2V, hence,

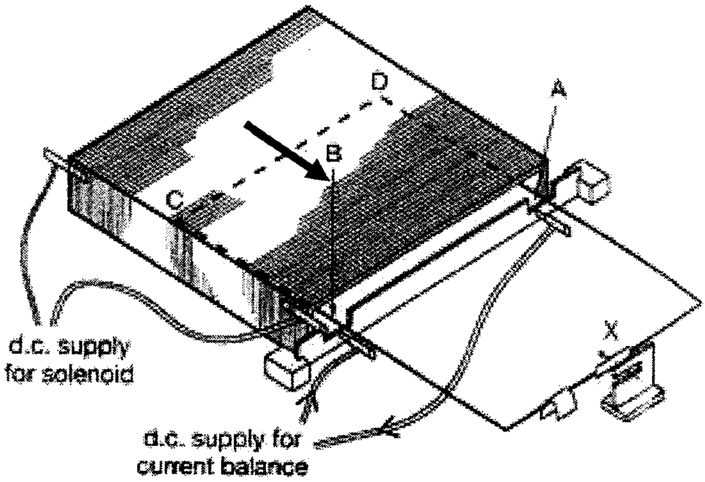
$$V \propto r^3 \Rightarrow \left(\frac{r'}{r}\right)^3 = \frac{2V}{V} \Rightarrow r' = (\sqrt[3]{2})r$$ [1]

Potential, $V = \frac{Q}{4\pi\varepsilon_o r}$, hence,

$$V \propto \frac{Q}{r} \Rightarrow \frac{V'}{V} = \left(\frac{Q'}{Q}\right)\left(\frac{r}{r'}\right) = \left(\frac{2Q}{Q}\right)\left(\frac{r}{(\sqrt[3]{2})r}\right)$$ [1]

$$V' = \frac{2}{\sqrt[3]{2}}(500) = 793.7 \text{ V} = 790 \text{ (3 sf)}$$ [1]

(c) (i)



(ii) F = B*I*L = (0.035)(6.0)(0.15) = 0.0315 N [1]

(iii) The perpendicular distance between the knife edge and each end is *d*.
Taking moments about **AB**,
Mg = 0.00315
M = 0.00321 kg [1]

(iv) Align the section **CD** so that it is parallel to the external magnetic field. [1]
There will be no moment caused by thus external magnetic field. [1]

5 **(a)** **(i)** cannot predict when a particular nucleus will decay [1]
or
cannot predict which nucleus will decay next

(ii) (decay is) not affected by external (environmental) factors [1]

(iii) fluctuations in (measured) count rate [1]

(b) **(i)** Any three points, 1 mark each: [3]
- large nuclei undergo fission whereas small nuclei undergo fusion
- fission involves one nucleus splitting into two (or more) (smaller) nuclei
- fusion involves two nuclei joining together to form one (larger) nucleus
- fission is (usually) initiated by neutron bombardment
- fusion is (usually) initiated by (very) high temperatures

(ii) binding energy per nucleon is greatest at nucleon numbers around 56 (may be shown on sketch graph with axes labelled 'binding energy per nucleon' and 'nucleon number') [1]

both fusion and fission involve an increase in binding energy (per nucleon) [1]

(c) **(i)** $^{66}_{29}\mathrm{Cu}$ [1]

(ii) the energy of the decay is fixed / constant [1]

the energies of the beta particles have a (continuous) range of values / varies / not constant [1]

another particle / an (anti)neutrino must possess the extra / remaining energy (difference between energy of the decay and the β kinetic energy) since total momentum has to be conserved [1]

(iii) Sharp peak at max KE, zero for all other energies (regardless of height) [1]

6 (a) (i) All collisions are perfectly elastic. [1]

(ii) Change in momentum of molecule after colliding with wall = $2mc_x$ [1]

Time between collision with the same wall = $\frac{2L}{c_x}$,

hence, by Newton's 2nd Law, force by wall on molecule = $\frac{2mc_x}{\frac{2L}{c_x}} = \frac{mc_x^2}{L}$ [1]

By Newton's 3rd Law, the molecule exerts this force on the wall and the pressure is $\frac{\text{Force on wall}}{\text{Area of wall}} = \frac{mc_x^2}{L^3}$ [1]

Extending to N molecules each with different speeds, total pressure

$$P = \frac{Nm\langle c_x^2\rangle}{L^3}$$ [1]

Since the molecules move randomly, $\langle c^2\rangle = \langle c_x^2\rangle + \langle c_y^2\rangle + \langle c_z^2\rangle = 3\langle c_x^2\rangle$,

$$P = \frac{Nm\langle c^2\rangle}{3L^3} = \frac{M\langle c_x^2\rangle}{3V}$$ where M = total mass, V = volume of cube. [1]

Hence, $P = \frac{1}{3}\rho\langle c^2\rangle$

(b) (i) It is the amount of heat required per unit mass to change a substance from the liquid phase to the gaseous phase without any change in temperature. [1]

(ii) 1. Work done by the gas $= P\Delta V$

$= 1.0 \times 10^5 \left[\frac{0.35}{1.6} - \frac{0.35}{790}\right]$ [1]

$= +\,2.18 \times 10^4$ J (must be positive) [1]

2. $Q = ml_v$

$= (0.35)(0.95 \times 10^6)$

$= 3.33 \times 10^5$ J [1]

3. $\Delta U = Q + W$

$= 3.3325 \times 10^5 + (-\,2.18 \times 10^4)$ [1]

$= 3.11 \times 10^5$ J [1]

{For **3.**, suggest that if '-ve' not used for W, and the answer given is 3.54×10^5 J, one mark be awarded, ie. penalise only for wrong sign for W.}

(c) (i) $P = \frac{m}{t} c\Delta T + h$, where h is the rate of heat loss

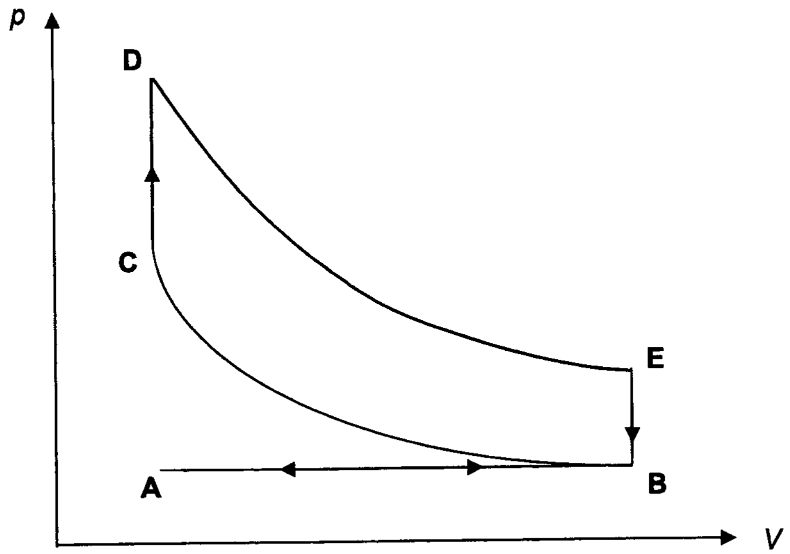
$25 = \frac{0.15}{60} c\,(19 - 15) + h$ ....(1)

$37 = \frac{0.23}{60} c\,(19 - 15) + h$ ....(2) [1]

$h = 2.50$ W [1]

(ii) The rate of heat lost would be different for each experiment causing error to the specific heat capacity calculated. [1]

(d) **(i)** **C** → **D** and **E** → **B**: Both vertical lines [1]
D → **E**: Downward curve [1]
such that **EB** is shorter than **CD** [1]



(ii) The area of the enclosed loop multiplied with the rate of the cycle (cycles per second). [1]

(iii) The area of the enclosed loop will be smaller (although the shape of the graph is unchanged). [1]

7 (a) (i) Faraday's law of electromagnetic induction states that the magnitude of the induced emf in a coil is directly proportional to the rate of change of magnetic flux linkage of the coil. [1]

Lenz's Law states that the direction of induced e.m.f. is such that its effects oppose the change which causes it. [1]

(ii) When the card is brought in range of a card reader, the varying (or sinusoidal) magnetic flux density / field generated by the card reader results in a changing magnetic flux linkage through the loops/coils of printed wire embedded in the card. [1]

By laws of electromagnetic induction, there is an emf induced in the coils (which is in the direction to oppose the varying magnetic field). [1]

The closed circuit allows the emf to induce a current (and thus supplies power to the internal transmitter, which can then send its data to the card reader). [1]

(iii) 1. $\varepsilon = -\frac{d\phi}{dt} = -\frac{d(NBA\sin 2\pi ft)}{dt} = -2\pi f\, NBA \cos 2\pi ft$ [1]

Peak e.m.f. $\varepsilon_0 = 2\pi f\, NAB_o = 2\pi\,(13.56 \times 10^6)\,(3)\,(4.0 \times 10^{-3})B_o$ [1]

$= 1.02 \times 10^6\, B_o$ [1]

2. $V_{rms} = V_o / \sqrt{2}$ [1]

$10.0 \times 10^{-3} = 1.02 \times 10^6\, B_o / \sqrt{2}$

$B_o = 1.38 \times 10^{-8}$ T [1]

(iv) The alternating magnetic field from machine will still induce an emf with either face of the card placed on machine / Alternating current will flow regardless of which face is used to tap machine. [1]

(b) The root-mean-square value of an alternating current is the value / magnitude of a steady direct current that will dissipate energy at the same (average) rate as the alternating current in a given resistance. [1]

(c) (i) Alternating voltage can be stepped up or down easily. [1]

(ii) Step-up transformer with turns ratio $\frac{N_s}{N_p} = 240/120 = 2.0$ [1]

(iii) Assuming no power losses in the transformer, [1]

P = IV

$1000 = 120\, I_p$

$I_p = 8.33$ A [1]

(iv) 1. By conservation of energy,

Power supplied to primary coil

= Power output from secondary coil + power loss in windings of transformer

= 1000 + 600 = 1600 W [1]

Output voltage of transformer $V_s = 240$ V

Secondary current = 1000 / 240 [1]

= 4.17 A [1]

2. efficiency = 1000/1600 x 100% = 62.5 % [1]