National Junior college
Physics Department
2004 JC2 Common Test 1
Suggested Solution

1(a) An isothermal process is one that takes place at <u>constant temperature</u>. In general, for a process to be isothermal, the walls of the container must be <u>good thermal conductors</u> and the process has to <u>take place slowly</u> to allow time for the system to maintain thermal equilibrium with its surrounding.

Comments:
Below are some of the common mistakes:

- It is a process that does not involve a change in internal energy and hence there is no change in temperature. *(Wrong, it is defined in terms of temperature and not internal energy & the internal energy can change in an isothermal process for real system.)*
- Container must be thermally insulated. *(A thermally insulated container does not allow heat to flow in or out of the system therefore q = 0. The temperature of the system will change if work is done on the system, hence not isothermal.)*
- Isothermal process can be achieved during phase transition (boiling or melting). *(Not always true unless it occurs at constant pressure, a general answer is required and not a specific example).*

1(b) (i)

Process α is a constant pressure process, therefore V ∝ T

$$V_1 = \frac{2.00\times10^{-4}}{300}\times600 = 4.00\times10^{-4}\,m^3$$

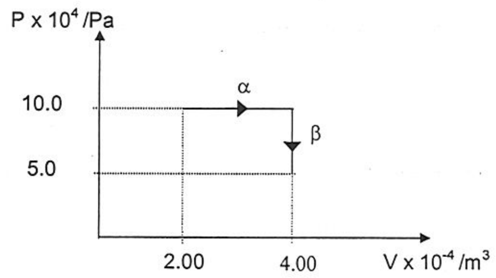
Process β is a constant volume process, therefore P ∝ T

$$P_2 = \frac{1.00\times10^{5}}{600}\times300 = 5.00\times10^{4}\,Pa$$

Comments:

- A substantial number of students use $PV = nRT$ to determine n before using the same equation to find V_1 and P_2. This method is longer and time is wasted.

1b(ii)



Comments:

- Most students knew the shape of the graph but failed to obtained full marks for this question. Marks were deducted for the following:

  (1) Missing arrows (1 mark per arrow)
  (2) Missing axis label (1 mark per axis)
  (3) Failed to label the relevant pressure and volume (1 mark per value)
  (4) Missing process label (1 mark per label)

- Some students included additional process arrows showing a cyclic process in the diagram, one mark was deducted.

1(b)(iii) ΔU $= \frac{3}{2}\left(P_f V_f - P_i V_i\right)$ = - 30 J

Isochoric process, therefore w = 0, hence q = ΔU = -30 J

Amount of heat extracted = 30 J

Comments:

- Most students were able to deduce that q = ΔU, but they were unable to calculate ΔU correctly.
- Of those students who got this question correctly, most tried to find n or N before using the equation $U = \frac{3}{2}nRT$ or $U = \frac{3}{2}NkT$ to determine ΔU. The additional step of finding n or N is unnecessary.

1(c)

Since $c \propto \sqrt{T}$

$$\frac{c_1}{c_2} = \sqrt{\frac{600}{300}}$$

$$= \sqrt{2}$$

Comments:

- A lot of students were able to do this part. Some went through the entire process of deriving the above relation using $pV = \frac{1}{3}Nm\langle c^2 \rangle$ which is impressive but not required for this part.

2(a)

Constructive interference means that when two waves meet at a point, they are <u>in phase</u> (or their phase difference is zero) and they <u>superposed to produce maximum amplitude</u>.

Destructive interference means that when two waves meet at a point, they are in <u>anti-phase</u> (or their phase difference is π radians) and they <u>superposed to produce minimum or zero amplitude</u>.

Comments:

- Majority of the students knew what the two terms meant intuitively but were unable to express their thoughts clearly. Some of the key words (*underlined*) were left out.

2 (b)(i)(1.)

When S_1 is moved slowly towards B along AB, the path difference (S_1P-S_2P) of the 2 waves from S_1 and S_2 will be changing continuously.

Thus at P, the phase of each sound wave received at P will be changing too. When the two waves meet in phase at P, constructive interference occurs and the sound intensity received is a maximum.

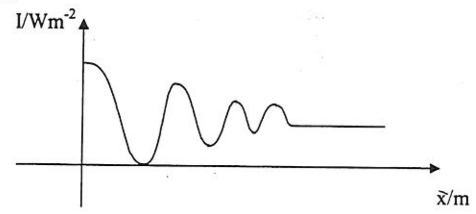
When the two waves meet completely out phase at P, destructive interference occurs and the sound intensity is a minimum.

Hence a series of maxima and minima is detected at P as S_1 moves towards B.

Comments:

1. Students knew that the minima and maxima are due to the constructive and destructive interference of the wave but they failed to link that the observation is due to the path difference introduce when the source S1 is moved. Many students answered in general terms without referring to the movement of source S1.
2. Many students thought that the phase difference due to the source difference has changed. It is actually the phase difference due to the path difference that has changed.
3. Students use symbols without defining what they mean, eg: $\phi_T = \phi_s + \phi_p$, A, n etc
4. Many students mentioned that as x increases, the phase difference will alternate between 0 and π.
5. Some students refer phase difference as "phrase" difference.
6. Some students thought that stationary waves are formed. Some gave theirs answers as diffraction patterns.
7. Many students did not refer to the signal received at P. Their description about the interference position tends to be vague.
8. Quite a number of students skipped the question totally.

2(b)(ii) Graph of I vs x



Comments:

Many students drew:
1. Constant minima.
2. Decreasing minima as x increases.
3. Intensity graph on the negative axis.

2(b)(iii)(1.)
When x is zero, the path difference at P due to the two waves S_1P and S_2P is zero. Hence the two waves are in phase. Constructive interference occurs and therefore the intensity received is the greatest. As for other values of x at which the waves meet in phase at P, the amplitude of the wave due to S_1 is decreasing with increasing distance x. Therefore, the constructive interference at P at x values other than zero is smaller than when x equals zero.

Comments:
1. Many students knew that the intensity is greatest at x = 0 due to the zero phase difference between the two waves. Many did not mention that for other values of x at which the waves meet in phase at P, the amplitude of the wave due to S_1 is decreasing with increasing distance x. Many students did not realize that as x increases, the waves actually spread over an area and thus the amplitude of the wave has decreased.

2(b)(iii)(2.)
At very large distance, the amplitude of S_1 would have dropped/decreased significantly ($I \propto 1/r^2$, $I \propto A^2$). Therefore, the intensity I received at P is mostly due to the wave from S_2 only. Hence I becomes a constant.

Comments:
Many students gave the answers that as intensity decreases with an increase in x, therefore the intensity I will be very small, approaching zero and hence it will be a constant. They did not realize that I is the signal received at P due to S1 and S2.

Some students used the information given in the question to answer this question. They argued that since maxima decreases and that the minima increases, they will meet at a constant value. Some even mentioned that since no interference occurs, therefore I is constant. Only the better students managed to extend that I is constant because it is contributed by S2.

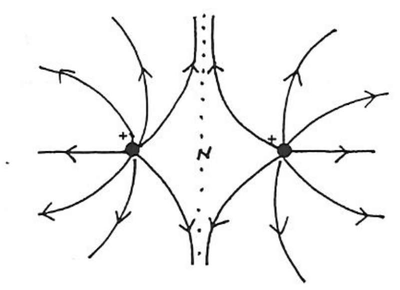
2(b)(iv)
wavelength, λ = 1.7 m
At the 4th minimum, the path difference of the waves at P = $7/2\,\lambda = x$
Hence x = 3.5 x 1.7 = 5.95 m

Comments:
Poorly done. Only those students who shows the knowledge of path and phase difference are able to solve the problem.

Q3ai Electric field strength at a point is the electric force acting on a unit positive charge placed at that point.

Comments:
Most defined electric field strength as electric force acting on a unit charge, without mentioning unit positive charge.

Q3aii



Things to note:

- Electric field is directed away from the charges;
- Asymptote at the perpendicular bisector of the line joining the charges;
- Field lines are only straight along the line joining the charges;
- Equal number of field lines near each charge;
- N is marked correctly.

Comments:
- Most did not draw the asymptote.
- Some drew the field lines radiated straight and not aware of the repulsive nature of like charges.

Q3b

$$E_A = \frac{2.0x10^{-9}}{4\pi\varepsilon_o(120x10^{-3})^2} = 1248.9Vm^{-1}$$, pointing away from A.

$$E_B = \frac{3.0x10^{-9}}{4\pi\varepsilon_o(160x10^{-3})^2} = 1053.7Vm^{-1}$$, pointing toward B.

Resultant field at P = $\sqrt{E_A^{\,2} + E_B^{\,2}} = 1630Vm^{-1}$

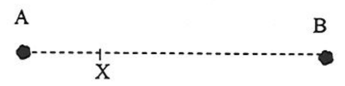
$\theta = \tan^{-1}(\frac{E_A}{E_B}) = 49.8°$

Comments:
- Some were not aware that the electric field strength (vector quantity) at P due to the charges at A and B are at right angles to each other. Hence they are not allowed to add or subtract the 2 vectors directly.
- Most students did not find the direction of the resultant electric field strength at P.

Q3ci The potential due to A and B are of opposite sign. The scalar sum of their potential will be zero at a point on the line AB.

Comments:
- Most did not explain why zero potential at a point but just mentioned that the potentials cancel each other. Some just said that the charges are opposite.

Q3cii



$V_x = 0$

$V_A + V_B = 0$

$\frac{2.0x10^{-9}}{4\pi\varepsilon_o(AX)} + \frac{-3.0x10^{-9}}{4\pi\varepsilon(0.200 - AX)} = 0$

AX = 80 mm

Comments:
- Some wrongly equated the 2 field strengths at X.
- Some used $V_A = V_B$, but substituted negative charge for V_B.

Q4(a)

Gain in KE = Work Done by Electric field

$\frac{1}{2}mv^2 = e(500)$

v = 1.325 x 10^7 = **1.33 x 10^7 ms^{-1}**

Comments:
- Students forgot to square root the answer.

4(b)

In order for electron to move horizontally,

Magnetic Force = Electric Force

$qvB = qE$

$v = \frac{E}{B}$

$B = \frac{1\times10^4}{1.325\times10^7}$ =7.547 x 10^{-4} = **7.55 x 10^{-4} ms^{-1}**

Direction of B: Out of plane of the paper

Comments:
- Magnetic field are confused with magnetic force.
- Many forgot the unit, T.
- $F_B = F_E$ and NOT B = E

4(c)

When the source is replaced by proton, $M_p > M_e$, thus $V_p < V_e$ upon entering the cross field region. The magnetic force will be smaller as it is dependent on the speed of the charged particle. The electric field remain unchanged as the charge for both proton and electron are the same in magnitude.

As a result, the proton will be deflected upward upon entering the cross field region.

Comments:
- Many students did not note the change of the direction of magnetic force for proton, as a result they conclude that both the electric and magnetic force are acting upward thus deflecting the proton upward.

5a The dark lines arise due to selective absorption of the photons in the white light by the atoms in the vapour.
The atoms (or electrons in the atoms)are excited to higher energy levels.

Comments:
Below are some of the common mistakes:
- 'Atoms are being absorbed in the process.'
- 'Dark lines are caused when electrons loses energy and photons are emitted.'
- Many students go to great lengths to explain in detail instead of stating briefly how dark lines in the absorption spectrum arise.

5b

$$E = \frac{hc}{657x10^{-9}} = 3.03x10^{-19} J$$

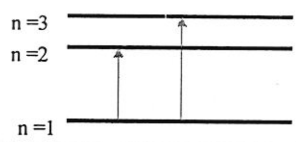
$$E = \frac{hc}{423x10^{-9}} = 4.7x10^{-19} J$$

Comments:
- A handful substituted the values of wavelength into the equation E = hf.

5c Dark lines are due to photons absorbed by the electrons in the atoms, exciting the electrons to higher energy levels.
So possible transitions are:
n=1 to n=2 and n=1 to n=3
Check in which atom these transitions correspond to the photon energy that you found in Q5b.

	Calcium	Sodium
n=1 to n=2	$E = (9.7\text{-}6.7)x10^{-19}$ J $= 3.0 \times 10^{-19}$ J	$E = (8.2\text{-}4.8) x10^{-19}$ J $= 3.4 x10^{-19}$ J
n=1 to n=3	$E = (9.7 - 5) x10^{-19}$ J $= 4.7 x10^{-19}$ J	$E = (8.2\text{-}2.4) x10^{-19}$ J $= 5.8 x10^{-19}$ J

calcium



Comments:
- Students drew arrows to indicate de-excitation of electrons though involving the correct energy levels. But it shows they have not fully grasped the understanding how the spectrum originates.
- Students also calculated the energy difference between n =2 and n = 3 when they are making the comparisons. It suggests that students do not appreciate the fact that the vapour is cool.

5d To ionise the Na atoms, bombarding electrons should have E_k > IE of Na atoms
IE = E_{∞}- E_1 = 8.2 x 10^{-19} J

$$p = \frac{h}{\lambda} = \frac{h}{1.5x10^{-10}} = 4.42x10^{-24}$$

$$E_k = \frac{p^2}{2m} = \frac{p^2}{2(9.11x10^{-31})} = 107x10^{-19} J$$

Hence ionization is possible.

Comments:
- Students calculated IE = (8.2 - 2.4) x 10^{-19} J, indicating poor understanding of ionization energy.
- Many students calculated hc/λ, take it to be the energy of the bombarding electrons and compare it to IE of Na atoms!!!

5d Atom spacing = 0.20 nm = 0.20 x 10^{-9} m = 2.0 x 10^{-10} m
Atom spacing is COMPARABLE to the de Broglie wavelength of electron.
Hence, diffraction will be significant.

Comments:
A handful of students who do appreciate the wave-particle duality of nature gave the following explanations:
- 'electrons are smaller than the atom spacing. Hence they will go straight through w/o diffraction'

6 (a) (i)

The speed of water at B is much faster than the speed at A and C. Hence, by **Bernoulli's equation**, the pressure in and around B will be **lower than atmospheric** pressure, thus creating a partial vacuum at B.

Comments:

- Marks cannot be awarded if answered in point form since it is important to establish cause – effect relationship. Faster flow of water results in lower pressure, and not the other way around.

(ii) Assume $V_C = 0$,

$P_B + \frac{1}{2}\rho V_B^2 = P_C + \frac{1}{2}\rho V_C^2$

$45\,000 + \frac{1}{2}(1000)(V_B^2) = 100\,000 + 0$

$V_B = 10.5\ \text{ms}^{-1}$

Comments:

- Another acceptable assumption is "no leakage, ie. all water from B enters C"
- All other assumptions are either too general or a repetition of the conditions stated in the question.

(iii) Flow rate = $Av = \pi/4\ (2 \times 10^{-3})^2\ (10.5) = 3.3 \times 10^{-5}\ \text{m}^3\ \text{s}^{-1}$

6 (b)(i) The streamlines (or layers) of fluid around the object is irregular (or unsteady, non-laminar, whirlpool, etc.).

Comments:

- "Flow is not streamline" is too vague and does not "explain" the condition.
- Viscous flow may not be turbulent.
- Reynolds number 2000 is for fluid flow in a tube, hence not applicable here.

(ii)

$$F_{net} = ma$$
$$mg - kv^2 = ma$$
$$a = g - \frac{kv^2}{m} = 9.81 - \frac{(36)(0.20)^2}{0.50} = 6.93ms^{-2}$$

Comments:

- Most students ignore the weight of the object.

Q7

(a) Explain how equation (1) demonstrates the conservation of both nucleon number and charge. [2]

The nucleon number is conserved as both the nucleon number before and after nuclear reaction is 5.

The charge is conserved as both the charge before and after nuclear reaction is 3.

Comments:

- Students did not indicate the nucleon and the proton number. They simply state that
  "since the nucleon no. before reaction=nucleon number after reaction and the proton number remains unchanged before and after the reaction, thus nucleon number and charge are conserved"
- Students are not aware that we are dealing with nuclei rather than atoms, thus many state that since the number of electrons are equal to the number of

(b) By considering deuterium nucleus and tritium nucleus as charged spheres, calculate the minimum energy in MeV required to overcome their coulomb barrier and come in contact with each other. [3]

Min energy required ,

$$U = \frac{(e)(e)}{4\pi\varepsilon[(1.64+1.87)\times10^{-15}]} = \frac{(1.6x10^{-19})^2}{4\pi(8.85x10^{-12})[(1.64+1.87)\times10^{-15}]}\ J$$

$$= 6.65\ x10^{-14}\ J = 0.410\ \text{MeV}$$

Comments:

- Wrong formula was used. Many students used the Force formula.
- Wrong substitution:
  $U = \frac{(e)(e)}{4\pi\varepsilon[(1.64+1.87)\times10^{-15}]} = \frac{(1)(1)}{4\pi\varepsilon[(1.64+1.87)\times10^{-15}]}$
- Wrong conversion to MeV.

(c) Estimate the speed of a lithium nucleus at 1.0×10^9 K. [2]

Kinetic energy = K T

$\frac{1}{2}\ m\ v^2 = K\ T$

$\frac{1}{2}\ (6.017034)\ (1.66x10^{-27})\ v^2 = (1.38\ x10^{-23})\ (1.0 \times 10^9)$

$v = 1.66\ x10^{6}\ \text{m s}^{-1}$

Comments:

- Many used $KE = \frac{3}{2}NkT$ or $\frac{3}{2}nRT$
- Students were not able to convert u to kg. Some converted them by multiplying with 1.6×10^{-19} (charge of electron) rather than 1.66×10^{-27}.

(d) (i) Define half-life for a radioactive substance. [1]

It is the time taken for half the number of radioactive nuclei to decay.

(ii) Calculate the decay constant of tritium. [2]

λ = ln 2 / 12.4 x 365x 24 x 3600

= 1.77 x 10 s^{-1}

(iii) If the initial number of tritium atoms is 5.0 x 10^{30}, calculate the number of atoms that would have decayed in 10 years. [2]

No. of atoms present , $N = N_0 e^{-\lambda t}$

= (5.0 x 10^{30}) $e^{-(\ln 2/12.4)x10}$

= 2.86 x 10^{30}

No. of atoms decayed, N = 5.0 x 10^{30} – 2.86 x 10^{30}

= 2.14 x 10^{30}

Comments:
- Many thought that the no. of atoms decayed is direction proportional to time taken and used proportional method to find the no. of atoms decayed.
- Many did not read the question carefully and gave the no. of atoms present.

(e) Describe the path taken by a nucleus in the magnetic field if it is travelling:

(i) along the field, [1]

No change in path as no magnetic force is experienced by the nucleus (which is positive charge)

Comments:
- Many did not describe the path but mentioned only no deflection.

(ii) perpendicular to the field, and [1]

The nucleus will move in circular path.

(iii) at other angles to the field [1]

The nucleus will move in helical path.

(f) Calculate the magnetic flux density of the magnetic field needed to keep a lithium nucleus contained within a diameter of 0.20 m. [3]

magnetic force = mv^2 / r

B q v = mv^2 / r

B = m v / q r = (6.017034)(1.66x10^{-27})(1.66 x 10^6) / (3 x 1.6 x10^{-19}) (0.20 / 2)

= 0.345 T

Comments :
- Poorly done. Less than 20 students got the full 3 marks.
- The diameter was done instead of the radius.
- Many students did not realize that the number of charges is 3.
- Poor manipulation skills with formulae.
- Unable to infer/use the value of u.
- Poor recall of the units of B.

(g) What is meant by the term "plasma"? [1]

Plasma is a gas at high temperature where the electrons are separated from their nuclei.

Comments:
Many answered the question without referring to the term "plasma" as the "gas of particles" and the high temperature involved. Many students just mention as " it is".

(h) If the plasma is prevented from touching walls of the container, why will the container still get very hot?

Heat is conducted through radiation.

Comments:
- Poorly answered. Many students attribute the heat transfer to the high speed motion of the particles. Some mentioned that it is through conduction and convection.