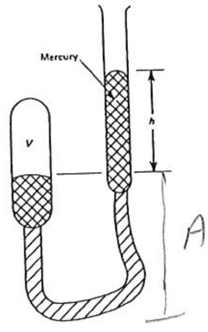
NATIONAL JUNIOR COLLEGE PHYSICS JC2
Additional Exercise 2004 (Term 1)

IDEAL GASES (30 Jan – 3 Feb)



1. In the Boyle's Law experiment, the atmospheric pressure is such as to support a column of mercury of height A. When h is halved, the volume of trapped gas changes from V to

A $2V$ **B** $0.5V$ **C** $2\left(\frac{A+h}{2A+h}\right)V$ **D** $\left(\frac{A+h}{A+2h}\right)V$

2. An ideal gas exerts a pressure of 80 Pa when its temperature is 400 K and the number of molecules present in unit volume is N. Another sample of the same gas exerts a pressure of 40 Pa when its temperature is 300 K. How many molecules are present in half unit volume of this second sample?

A N/3 **B** 2N/3 **C** 3N/2 **D** 4N/3

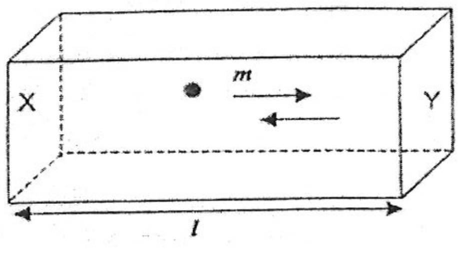
3. The mass of an oxygen molecule is 16 times that of a hydrogen molecule. At room temperature, the ratio

$$\left(\frac{mean\ \ translational\ \ kinetic\ \ energy\ \ of\ \ an\ \ oxygen\ \ molecule}{mean\ \ translational\ \ kinetice\ \ energy\ \ of\ \ a\ \ hydrogen\ \ molecule}\right)$$

is given, by the simple kinetic theory of gases, as

A 16 **B** 4 **C** 1 **D** 0.0625

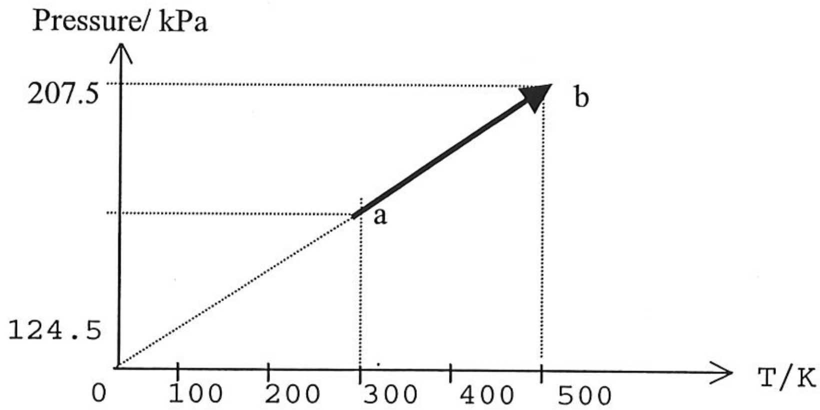
4. The figure shows a hollow box of width l. Most of the air has been removed from the box so that only a small number of molecules remain.
The figure shows one molecule of mass m. This molecule travels horizontally with a constant speed u between the two vertical side faces X and Y, colliding with each at regular intervals.



(a) What type of collision occurs when the molecule hits and rebounds from X and Y, considering the model used in the kinetic theory of gases?
(b) Deduce the expressions
  (i) in terms of l and u for the frequency f with which the molecule collides with face Y of the box;
  (ii) in terms of f, m and u for the mean force F exerted on face Y by this molecule as a result of these collisions.
  (iii) in terms of m, u, and V for the mean pressure exerted on face Y by this molecule as a result of these collisions, where V is the volume of the box.
(c) The box is now refilled with air so that a large number of molecules are present. The speed of these molecules is represented by the symbol $C_{rms.}$ State in **words** the meaning of this symbol.
(d) The expression for the kinetic theory equation can be given by $p = \frac{1}{3}\rho\, C_{rms}{}^2$

Show that the mean translational kinetic energy of the gas is given by $\frac{3}{2}NKT$

5. A fixed mass of helium gas (molar mass = 0.0040 kg) is enclosed in a container which has a fixed volume of $1.0 \times 10^{-3}\ m^3$. Figure below shows a graph of pressure against temperature for temperatures between 300 K and 500 K.



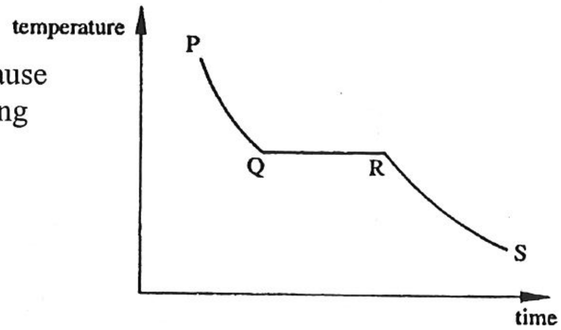
(a) By reference to the above figure, comment on whether the gas behaves as an ideal gas.
(b) Calculate (i) the number of moles of gas present
(ii) the mass of gas present.
(c) The temperature of the helium gas is raised from 300 K to 500 K via a process ***a-b*** as shown in the above figure. Determine, for the process ***a-b***, the following:
(i) the work done on the gas,
(ii) the increase in internal energy of the gas, and hence
(iii)the heat supplied to the gas.
(d) A second container, identical to that described in this question, contains a mixture consisting of equal masses of hydrogen (molar mass = 0.0020 kg) and helium, the total mass being the same as the original mass calculated in **(b)(ii)**.
(e) Calculate the pressure exerted by this mixture of gases at a temperature of 300 K.
(f) State how would you expect the gradient of a pressure against temperature graph for this mixture of gases to differ from that shown in the diagram. Explain your answer.

THERMODYNAMICS (4 – 7 Feb)

1. The element of a 2.5 kW electric kettle takes 200 s to raise the temperature of 1 kg of water from 20 °C to 100 °C. Assuming that the specific heat capacity of water is 4 kJ kg^{-1} K^{-1}, the mean rate of energy loss to the kettle and the surroundings, in kW, is

A 0.45 **B** 0.80 **C** 0.90 **D** 1.6

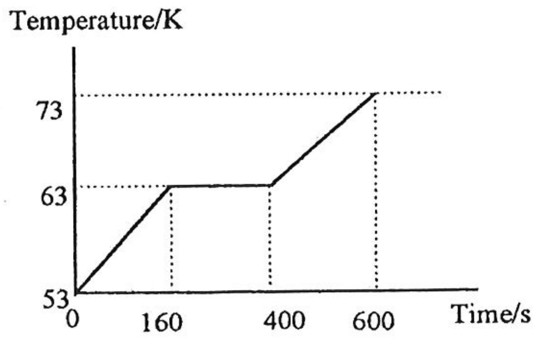
2. The graph shows a cooling curve for naphthalene which has been heated to a temperature above its melting point.



There is no change in temperature from Q to R because
A energy is only lost when the temperature is falling
B energy is absorbed during the change of state
C latent heat is the source of energy loss to the surroundings
D the specific heat capacity of naphthalene is zero while it is changing state

3. The first law of thermodynamics can be written as $\Delta U = \Delta Q + \Delta W$ for an ideal gas. Which of the statement in A to D is most correct?
   A ΔU is always zero when no heat enters or leaves the gas.
   B ΔU is zero when heat is supplied and the temperature stays constant.
   C $\Delta Q = -W$ when the temperature increases very slowly.
   D ΔW is the work done by the gas in the written law.

4. The graph refers to an experiment in which an initially solid specimen of nitrogen absorbs heat at a constant rate. Nitrogen melts at 63 K and the specific heat capacity of solid nitrogen is 1.6×10^3 $Jkg^{-1}K^{-1}$.



   (a) Calculate the specific latent heat of fusion of nitrogen.
   (b) Calculate the specific heat capacity of liquid nitrogen.

5. **(a) (i)** Explain what is meant by adiabatic change for a system.
   (ii) Explain the difference between the internal energy of an ideal gas and a real gas, and the reason for this difference.
   (iii) Explain why the specific latent heat of vapourisation is higher than the specific latent heat of fusion for the same substance.
   (b) An ideal gas is contained in a hollow cylinder sealed at one end, with a movable frictionless piston at the other end.
   (i) State how the thermal energy Q supplied to the system is related to the increase in internal energy U and the work done W on the gas.
   The gas is heated isothermally. Does the gas expand or contract? Explain your answer.
   (ii) Initially, the gas occupies a volume of 1.0×10^{-3} m^3 at a pressure of 200 kPa and at a temperature of 27 °C. The gas undergoes a cycle of changes in the following sequence:
   1. *Compressed isothermally to half of its initial volume;*
   2. *Heated at constant volume to 450 K;*
   3. *Expanded isothermally back to the original volume;*
   4. *Cooled at constant volume to the initial condition.*

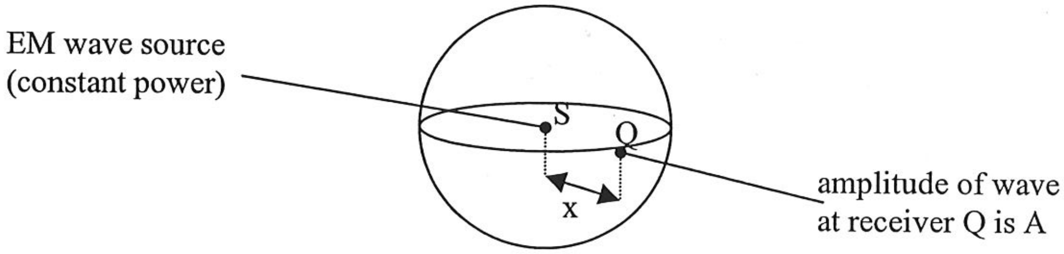
   Calculate the pressure at the end of stages *1* and *2*.
   Sketch a pressure-volume (p-V) diagram showing the gas undergoing these four processes and indicate clearly on the graph the cycles *1* to *4*.
   (iii) Briefly describe (calculations are not required) how you could use the p-V diagram to find the thermal efficiency of the gas, which can be defined as:

$$\frac{\text{(work done by the gas)} - \text{(work done on the gas)}}{\text{work done by the gas}}$$

WAVE (8 – 11 Feb)

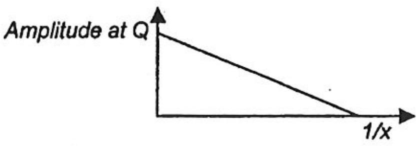
1. What statement about transverse wave is correct?
   A When sound waves travel in a solid, it is transverse in nature.
   B Transverse wave requires an elastic medium for transmission.
   C All electromagnetic waves are transverse wave and they travel at 3×10^8 ms^{-1} in all medium.
   D Only transverse waves can be polarized.

2.

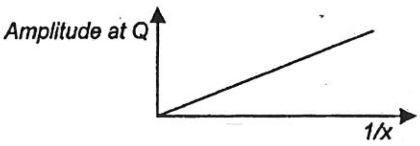


In the above diagram, the electromagnetic waves emitted from a point source S spread out in a sphere. Q is a receiver. If the power of the source remains unchanged and Q moves with radially inward, which of the following graph best represent the relationship between the amplitude A received by Q and 1/x ?

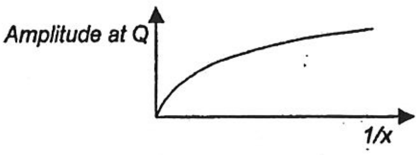
A



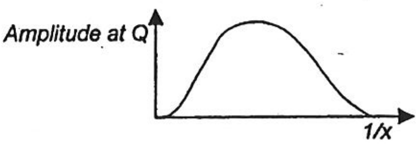
B



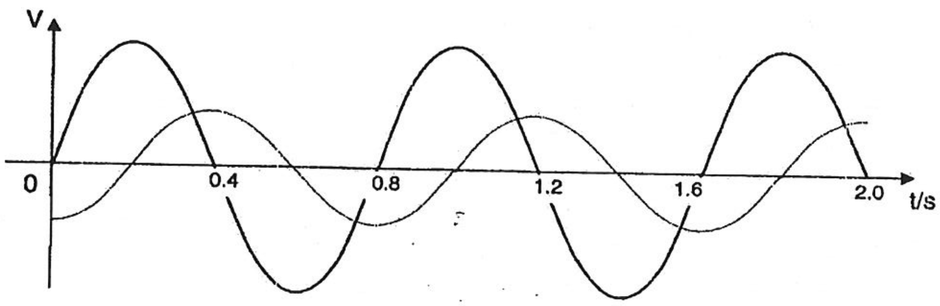
C



D



3. Two sinusoidal voltages of the same frequency are shown in the diagram.



What is frequency of the signals and the phase difference between them?

	frequency / Hz	phase difference /rad
A	2.50	$\pi /4$
B	1.25	$\pi /2$
C	2.50	π
D	1.25	$\pi /4$

4. A 100W light bulb is 10% efficient (ie 90% as infrared and 10% as visible light). A normal person can still see the light (a faith speck of light) with the naked eye from a distance of 20.0km on a dark night. If the area of the person's pupil of the eye is 0.5cm^2, find the power of the light that the eye is receiving.

5. Sound travels by means of longitudinal waves in air and solids. A progressive sound wave of wavelength λ and frequency f passes through a solid from left to right. Fig 1 represents the equilibrium positions of a line of atoms in a solid. Fig 2 represents the positions of the same atoms at $t = t_o$.

a. Explain why the wave is longitudinal.

b. Copy Figure 2 and on it label C for compression and R for rarefaction and indicate the size of one wavelength.

c. Taking motion to the right as positive, sketch the graphs of pressure against position and displacement of the atoms against position.

d. The period of the wave is T. Give a relationship between λ, T and the speed v of the wave in the solid. Explain how the wave speed differs from the speed of the atoms.

Figure 1

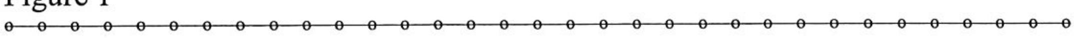
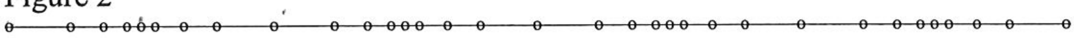
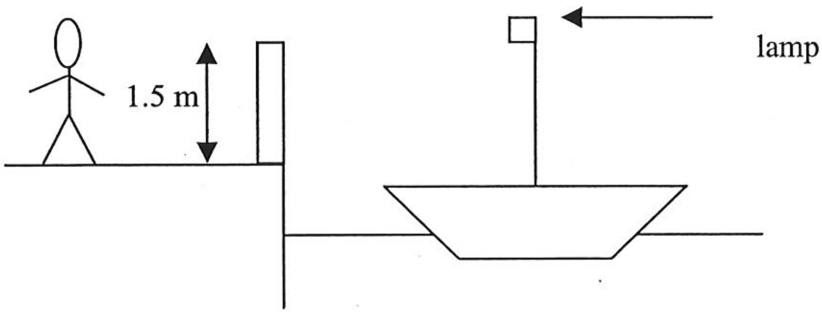


Figure 2



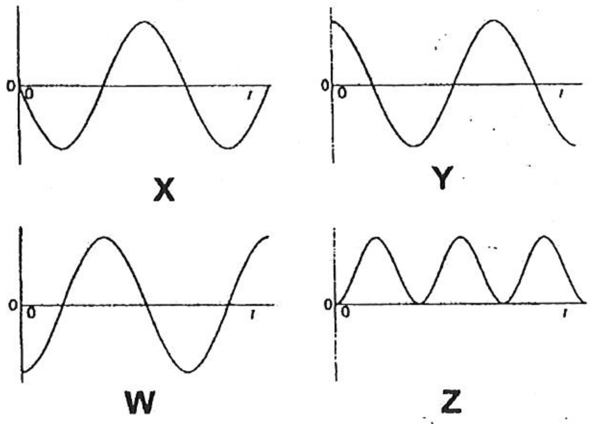
OSCILLATIONS (12 – 14 Feb)

1. A boat with a lamp at the top of its mast is oscillating in a vertical simple harmonic motion near a pier with a wall 1.5 m high as shown. The boy observes that the lamp remains below the wall for 2.0 s before emerging and remains above the wall for 2.0 s before disappearing. The boy also observes that the lamp rises to a maximum distance of 1.0 m above the wall. Assuming that the boy's eye is at the same level as the wall, the speed of the lamp as it emerges above the wall is



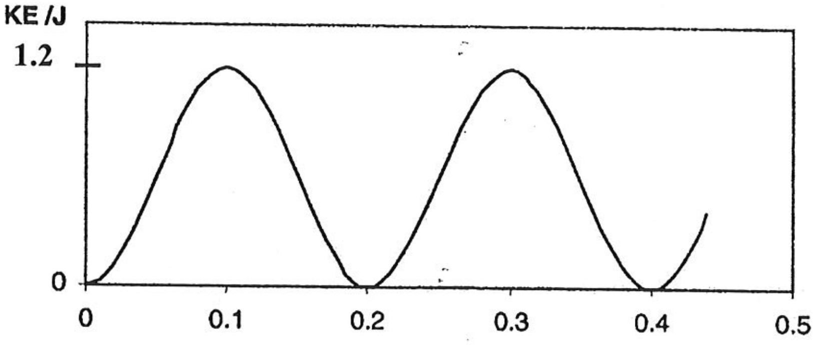
A $0.80\ ms^{-1}$
B $1.6\ ms^{-1}$
C $2.4\ ms^{-1}$
D $3.2\ ms^{-1}$

2. The following graphs relate to a mass oscillating in simple harmonic motion. The displacement of the mass from its equilibrium position is a maximum at t = 0 s.
Which of the following pairs of graphs X to Z shows the graph of velocity of the mass against time and the acceleration against time respectively?



A X and Y B Y and Z
C X and W D Y and W

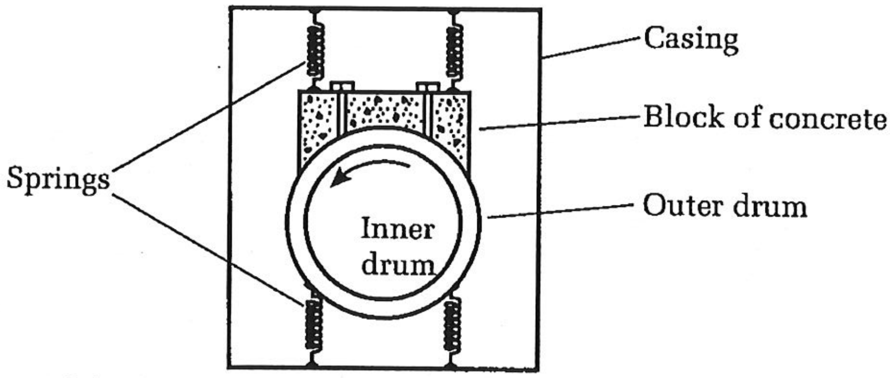
3. The graph below illustrates how the kinetic energy of a body in simple harmonic motion varies with time.



What is the angular frequency of the motion?

A 2.5 rad s^{-1} B 5.0 rad s^{-1} C 16 rad s^{-1} D 31 rad s^{-1}

4. The drums of an automatic washing machine are suspended from the casing by springs, at the top and bottom, as shown in the diagram. The inner drum rotates within the outer drum at variable speeds according to the washing programme.



The total mass of the drums is 20 kg. A block of concrete of mass 20 kg is added to the outer drum. The natural period of oscillation of the system is 1.6 s. The period of oscillation T of the system is given by the expression $T = 2\pi\sqrt{\frac{M}{k}}$

where M is the total mass of the load in the system and k is the effective spring constant of the springs.

(a) (i) Explain what is meant by the *natural frequency of oscillation.*

(ii) Calculate the effective spring constant of the mass-spring system which gives the natural period of 1.6 s.

(b) When the washing machine enters the spin part of its programme, it starts from rest building up rotational speed gradually. As the speed increases the system is observed to oscillate with increasing amplitude which reaches a maximum value of 5.0 cm before decreasing again at higher speeds.

(i) Explain why does the system oscillate when the inner drum is rotated and why the amplitude reaches a maximum.

(ii) What will be the number of revolutions per second of the drum when the maximum amplitude of oscillation is observed?

(iii) Sketch a graph showing how the amplitude varies with frequency of rotation of the inner drum. Label the axes of the graph giving the axes suitable scales.

(iv) State and explain one effect on the oscillation of running the machine without the block of concrete fixed to the drum.

5. **Fig. 3.1** shows the displacement-time graph for the centre of a loudspeaker cone when it is displaced manually and then allowed to vibrate naturally.

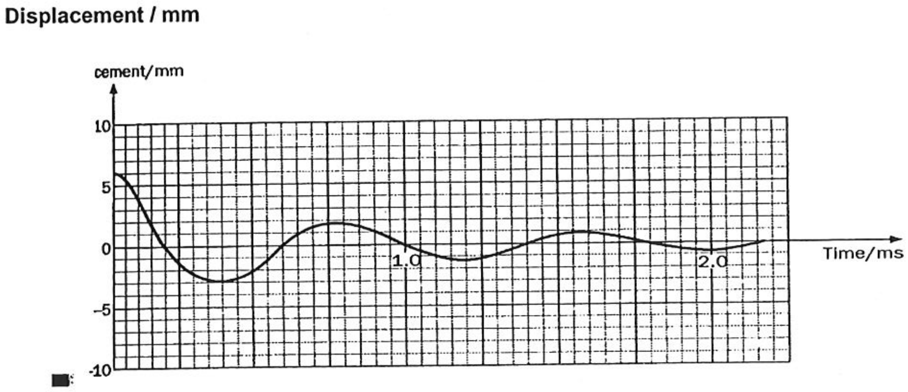


Fig. 3.1

(a) State the feature of the graph which shows that the oscillations are damped.

(b) (i) Calculate the natural frequency of oscillation of the cone.

(ii) Calculate the maximum acceleration of the cone during the time interval shown in **Fig. 3.1**.

(c) The graph in **Fig. 3.2** shows how the amplitude of the cone varies with frequency when a signal generator provides alternating current of different frequencies but similar amplitude to the loudspeaker. The frequency of the cone vibration is inversely proportional to its mass. Draw on **Fig. 3.2** to show the effect of using

(i) a cone of greater mass (label this graph **C**); and

(ii) a cone of the same stiffness and mass, but with less damping (label this graph **D**).

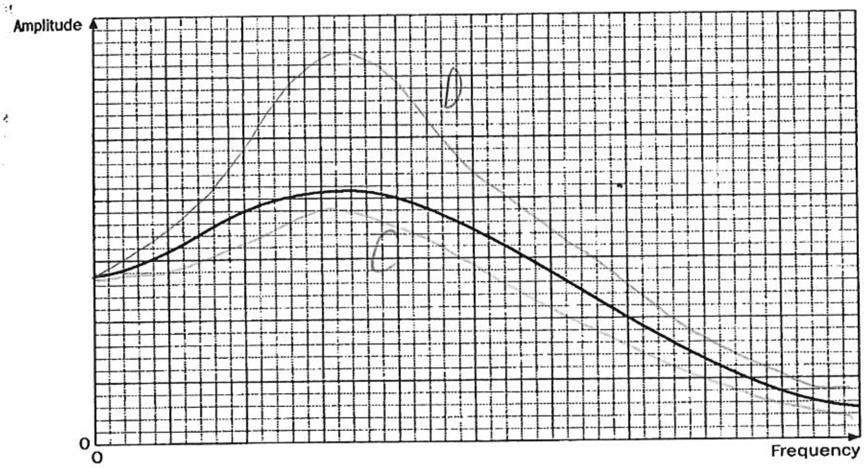
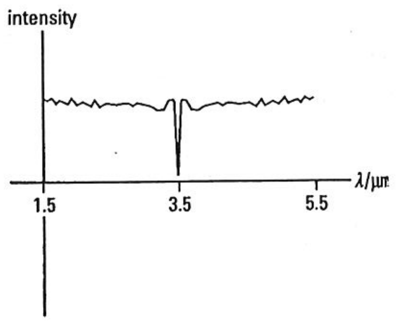


Fig. 3.2

(d) Hydrogen chloride (HCl) gas absorbs electromagnetic radiation very strongly in the infrared region of the spectrum, at a wavelength of 3.5 μm.

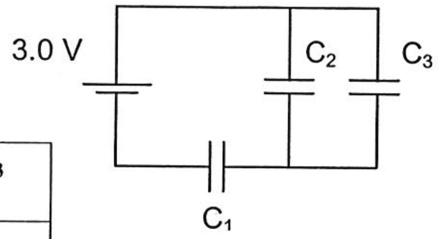


The absorption spectrum of HCl.

5(d)This frequency corresponds to a natural frequency for vibration of the molecule, so the incident waves cause resonance. The chlorine atom is about 35 times the mass of a hydrogen atom, so a simple model of the vibrating molecule assumes the chlorine atom is fixed in position and the hydrogen atom behaves like a mass on a spring obeying Hooke's Law. Estimate the 'spring constant' for the interatomic bond. You may assume that a mass, m, on a spring oscillates at a frequency, $f = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$. (The mass of the hydrogen atom is 1.7×10^{-27} kg)

CAPACITANCE, CHARGE & FIELD (15 – 21 Feb)

1. In the circuit shown, three capacitors each of capacitance 3.0 μF is connected to a battery of e.m.f. 3.0 V. What is the amount of charge stored by each capacitor at equilibrium?

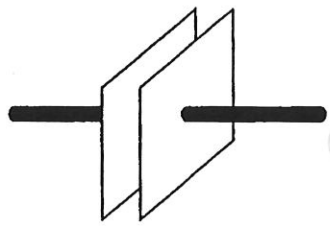


	charge on C_1 / μC	charge on C_2 / μC	charge on C_3 / μC
A	6.0	3.0	3.0
B	6.0	6.0	6.0
C	13.5	6.8	6.8
D	13.5	13.5	13.5

2. A 3μF capacitor is connected in series with a 6μF capacitor, and a 6V battery is connected across the combination. Which of the following statements is **not** correct?

   A The combined capacitance is 2μF
   B The total energy stored is 36 μJ.
   C The p.d. across the 6 μF capacitor is 2V.
   D The 6 μF capacitor stores twice the charge that the 3 μF capacitor stored.

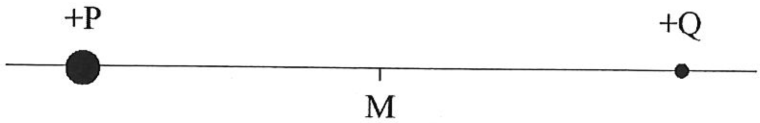
3. The diagram shows a pair of insulated charged parallel plates. There is a uniform electric field in the central region between the plates. Which of the statement(s) about the central region between the plates is (are) correct?



   1 The potential is constant in the region.
   2 There is a uniform potential gradient in the region.
   3 Equipotentials are evenly spaced in the region.

   A 1, 2 and 3 **B** 1 and 2 only
   C 2 and 3 only **D** 1 only

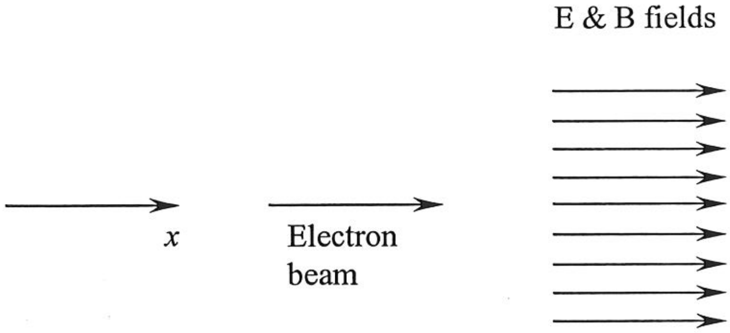
4. Two positive point charges P and Q are fixed at the points shown. The charge of P is greater than that of Q. M is the mid-point between the charges.



The electric field due to the two charges will be zero at a point, other than at infinity, that is

   A to the left of P. **B** between P and M.
   C between M and Q. **D** to the right of Q.

5. A beam of electrons travelling with uniform velocity in the positive x-direction enters a region where a uniform electric field E and a uniform magnetic field B are both directed along the positive x-direction, as shown.



In this region the electrons will

A continue along the positive x-direction with decreasing velocity.
B continue along the positive x-direction with increasing velocity.
C continue along the positive x-direction with unchanged velocity.
D move in a helical path along the positive x-direction.

6. **(a)** Explain what is meant by *the gravitational potential at a point on Jupiter's surface is* $-1.77 \times 10^9\ J\,kg^{-1}$.

(b) A space shuttle of mass m_s is launched from planet **A** (mass m_A, radius R_A) and travels along the line joining the centres of planets **A** and **B** (mass m_B, radius R_B). Given that the distance between the centres of mass of the planets is x and $m_A < m_B$,

(i) write down an expression for the **total** gravitational potential energy, U_s, of the shuttle when it is at a distance r from the centre of mass of planet **A**;

(ii) sketch a labelled graph of U_s against r; and

(iii) by reference to your graph in **(ii)**, explain how the gravitational force, F_s, on the shuttle varies with r.

(c) An asteroid S_1 of mass m moves with speed v in a circular orbit of radius a around the Earth of mass M.

(i) Show that its kinetic energy is equal to $-\frac{1}{2}$ times its gravitational potential energy.

(ii) Write down an expression for its total energy.

(iii) A second asteroid S_2, of mass $2m$ but of the same total energy as S_1, moves in an *elliptical* orbit as shown in **Figure 6.1** below. Its distance of closest approach to the centre of the Earth (**BE** in **Figure 6.1**) is $a/2$ and **BC** is $2a$.

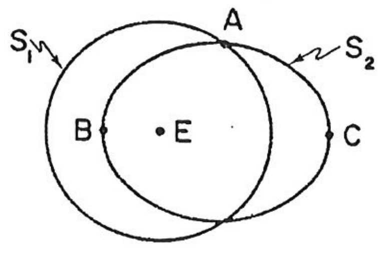
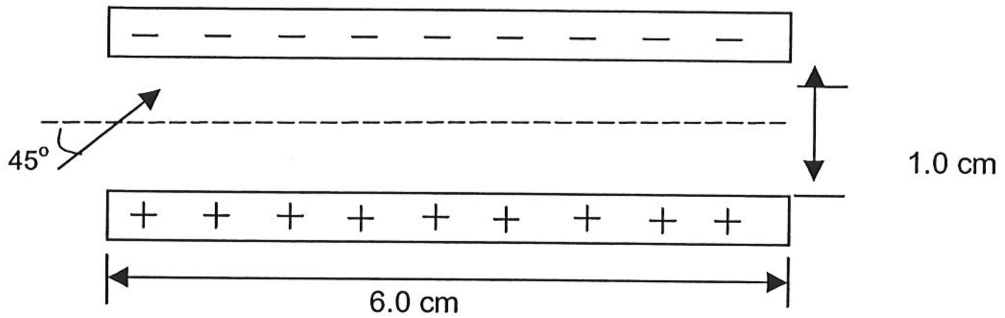


Figure 6.1

Determine the speed of S_2, in terms of G, M and a, at

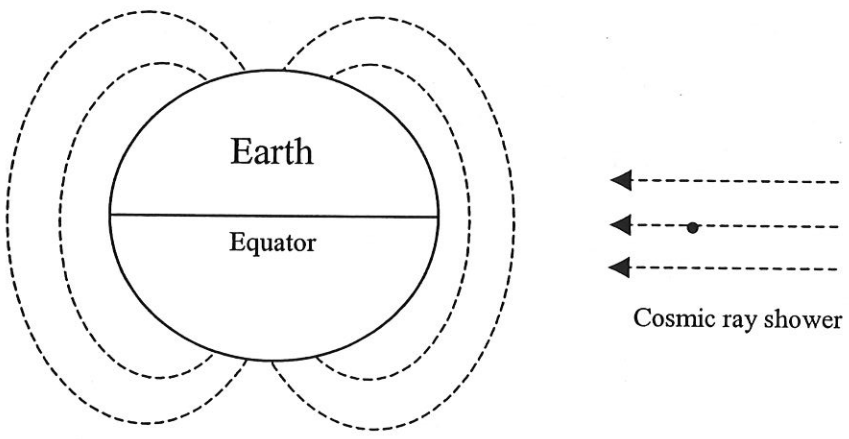
1. A and;
2. C.

7. Suppose electrons enter the uniform field midway between two plates, moving at an upward 45° angle as shown below. The electric field strength in the region between the two plates is 5.0×10^{3} NC^{-1}.



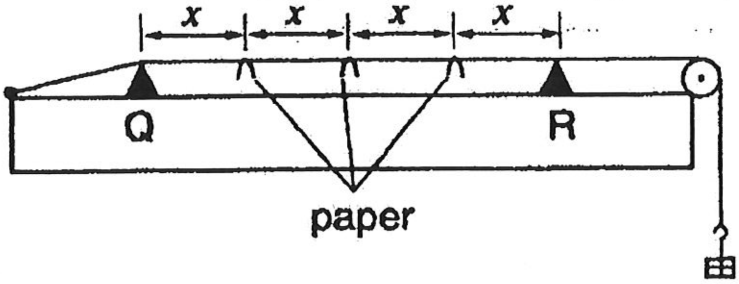
(a) Find the potential difference between the two plates.
(b) For an electron which just enters the field as shown in the figure, draw a diagram to show the electrostatic force acting on the electron and the direction of the electric field. Determine the magnitude of this force. Hence find the acceleration of this electron.
(c) What maximum speed can this electron have to avoid striking the upper plate? Ignore fringing of the field.
(d) Determine the kinetic energy lost by the electron from the point of entry to the highest position between the two plates reached by the electron.

8. The figure below shows a charged particle which is part of a cosmic ray shower directed towards the Earth's equator. The figure also shows the magnetic field of the Earth.
(a) The particle has a charge of 3.2×10^{-19} C, a mass of 6.7×10^{-27} kg, and a speed of 3.0×10^{7} ms^{-1}. The magnetic flux density in the upper atmosphere is 50 μT. Calculate:
(i) The magnitude of the electromagnetic force experienced by the particle as it enters the upper atmosphere;
(ii) The radius of the path followed by the particle.
(b) The particle is slowed down by the atmosphere. State and explain how its path will change.



SUPERPOSITION (22 – 28 Feb)

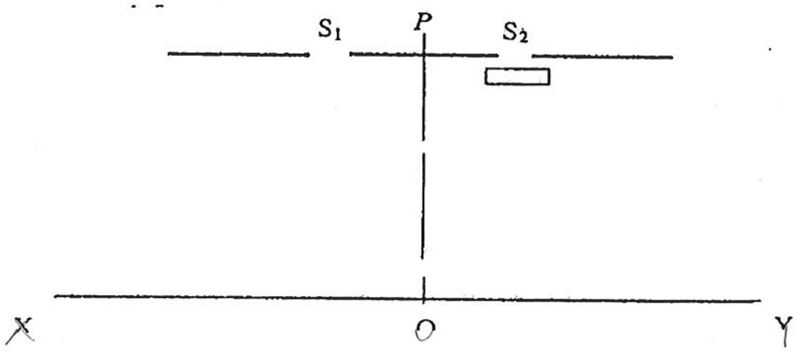
1. A wire is stretched over two supports, Q and R, a distance 4x apart. Three light pieces of paper rest on the wire, as shown.



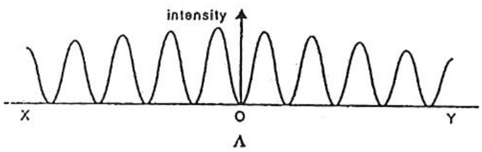
When the wire is made to vibrate at one particular wavelength 2x, which of the following best describes the subsequent behaviour of the three pieces of paper.

A All three pieces of paper stay on the wire.
B The middle piece of paper stays on, but the others fall off the wire.
C The middle piece of paper falls off, but the others stay on the wire.
D All three pieces of paper fall off the wire.

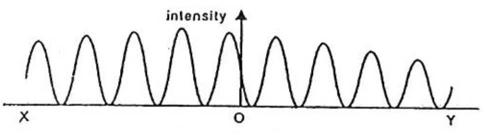
2. The diagram below shows coherent light incident on two fine parallel slits S1 and S2 and fringes are observed on a screen XY. Line OP is the perpendicular bisector of S1S2.



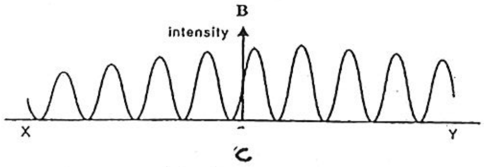
A piece of transparent plastic is then placed over S2 such that it delays the light from it by one and a quarter of a cycle. Which of the following graphs best represents the variation of light intensity along the screen in the direction of X to Y?



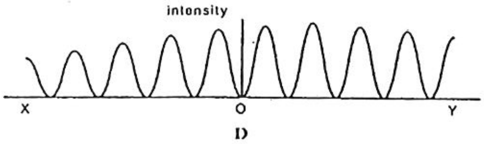
A



B

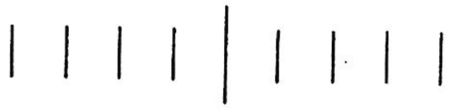


C

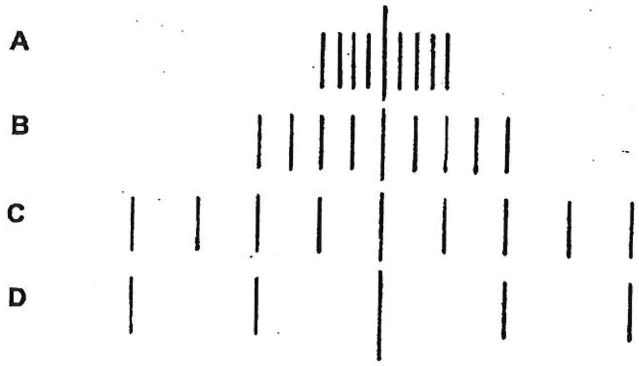


D

3. The figure shows the first four diffraction orders obtained on each side of the zeroth order when a beam of monochromatic light is incident on a diffraction grating of slit separation d. The angle of diffraction in each case can be considered to be small.



Which of the patterns indicated, on the same scale, by A to D is obtained when the grating is exchanged for one with slit separation $d/2$?



4. A ship at X is equidistant from two shore-based radio transmitters P and Q. Both transmitters operate on a wavelength of 300 m and radiate signals of equal amplitude.

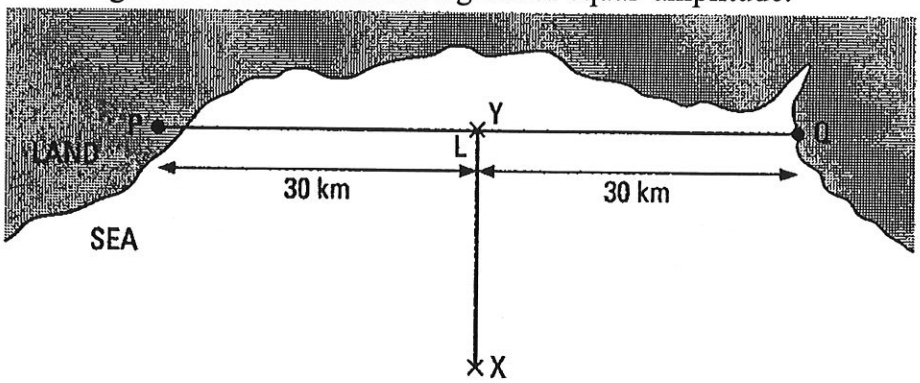


Figure 3.1

(a) On **Figure 3.1**, the ship at X detects zero signal amplitude. What information does this give about the signals from P and Q?

(b) The ship moves in a straight line from X to Y. Throughout the journey the amplitude of the signal detected by the ship is zero. Explain this.

(c) The ship moves in the direction YQ until the signal detected has an amplitude twice that from either transmitter alone. How far has the ship moved? Explain your answer.

(d) When the ship sails from Y to the harbour alongside transmitter Q the detected signal rises and falls in amplitude. Calculate how many dips in intensity will be passed.

5. **(a)** A spectrometer and diffraction grating were set up. The emission spectrum of an element was viewed in the second order and five visible lines were observed. The angular positions of these lines measured against the scale on the spectrometer are shown in the table.

The angular position of the zero order = 126.4°
Number of rulings per unit length = 4.5 x 10^5 m^{-1}

Spectral line	1	2	3	4	5
Colour	violet	green	green	orange	red
Angular position	147.9°	154.5°	154.8°	162.7°	168.4°

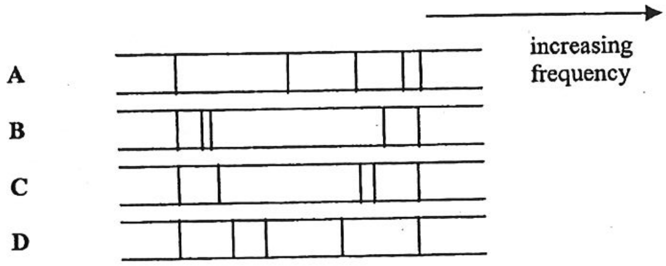
(i) Calculate the wavelength of the orange line from the angular position given.
(ii) State one advantage and one disadvantage of using the second order spectrum instead of the first order spectrum.

(b) A student investigating the first-order spectrum from a diffraction grating, illuminated normally with monochromatic light, found that the angle between the two first-order spectra was 60°. If alternate slits in the grating were suddenly to become opaque, what is the new angle subtended between the two first-order spectra?

QUANTUM PHYSICS (29 Feb – 6 Mar)

1. Fig. 28 shows five energy levels of an atom, one much lower than the other four. Five transition lines are indicated, each of which produces photons of definite energy and frequency.

Which one of the spectra below best corresponds to the set of transitions indicated?



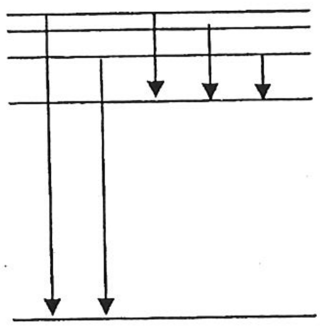


Fig. 28

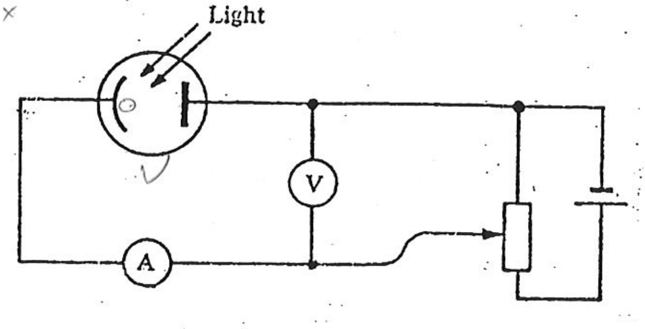
2. The diagram below shows an experiment on the photoelectric effect. Light of wavelength 355 nm falls on a metal cathode which has a work function 3.2 x 10^{-19}. The photoelectric current, measured on A, is observed as the voltage, measured on V, is gradually increased from zero. The current falls to zero when the voltage is

A 5.5 V
B 3.5 V
C 2.0 V
D 1.5 V

$hf = \phi + \frac{1}{2}mv_{max}^2$

$\frac{1}{2}mv_{max}^2 = hf - \phi$

$eV = \frac{1}{2}mv_{max}^2$



3. Transitions between three energy levels in a particular atom give rise to the three spectral line of frequencies, in increasing magnitudes f_1, f_2 and f_3. Which one of the following equations correctly relates f_1, f_2 and f_3?

A $\dfrac{1}{f_1} = \dfrac{1}{f_2} + \dfrac{1}{f_3}$

B $f_1 = f_2 + f_3$

C $f_3 = f_1 + f_2$

D $f_3 = f_2 - f_1$

4. A very weak parallel beam of light may be detected using a device known as a photomultiplier as shown in **Fig 7.1**.

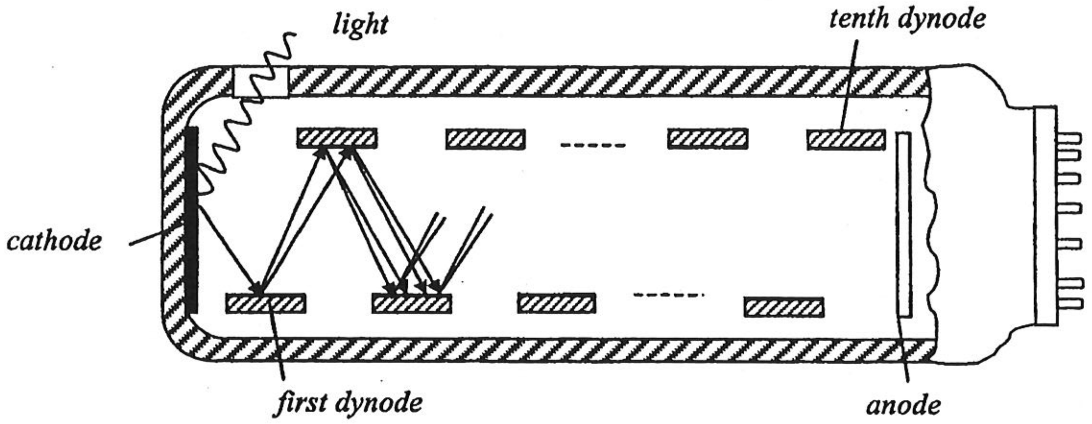


Fig 7.1

The incident light causes photoelectrons to be emitted from a cathode. These are accelerated and strike a target electrode, called the first dynode. For each electron incident, two electrons will leave the dynode. These two electrons are accelerated to a second dynode, so producing 4 electrons, which are all accelerated to the third dynode and so on. The photomultiplier contains a series of ten dynodes in all.

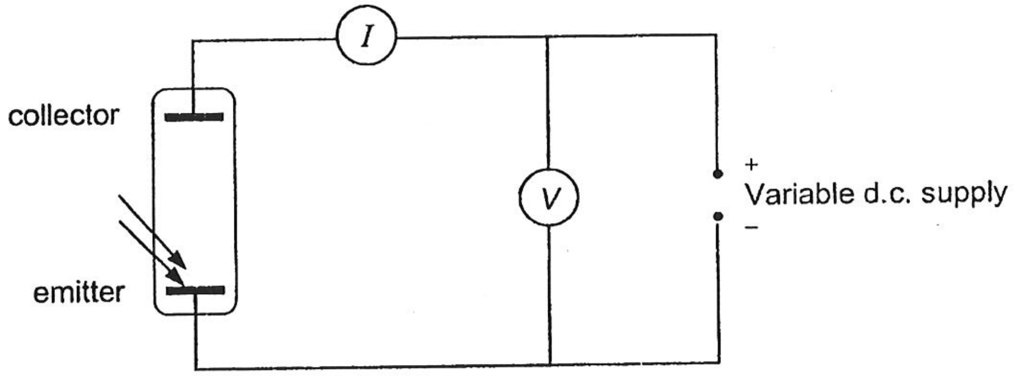
(a) Name the process that takes place at the cathode. Give a possible reason why the process has a low efficiency (ie rate of photoelectron emitted is smaller than rate of photons incident)?

(b) If a single photoelectron arrives at the first dynode, how many electrons leave the tenth dynode?

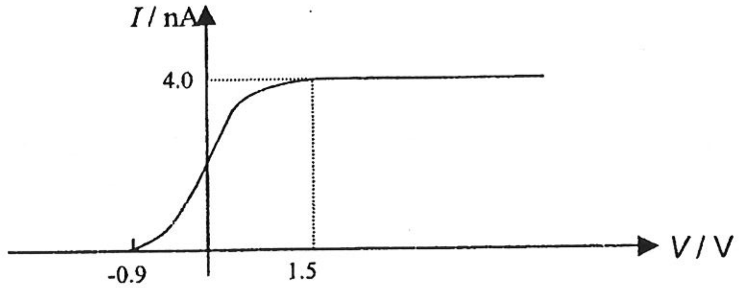
(c) Electrons emitted from the tenth dynode are collected and they constitute a current of 7.2 μA. Determine the rate at which photoelectrons were emitted from the cathode?

(d) The incident light has a wavelength of 365 nm. At this wavelength, one in three photons eject an electron from the photocathode. Find the power of the incident light.

5. **(a)** A photoemissive cell in which the emitter and the collector are of the same metal is connected in the as shown in the diagram.



The emitter of area 0.45 cm^2 is illuminated with monochromatic radiation of wavelength 300 nm and intensity 180 Wm^{-2} and the current I in the circuit is measured for various values of the applied potential difference V between the collector and emitter. The results are shown below. (The diagram is not drawn to scale)



(i) **1.** Why are photoelectrons emitted with a range of energies ranging from zero to a maximum?

2. If the intensity of light is now doubled, how will the current and the maximum velocity of the electrons be affected by the intensity of light?

3. Explain why the current remains at a value of 4.0 nA when V ≥ 1.5 V.

4. calculate the rate of incidence of photons on the emitter. [6]

(ii) From the graph,

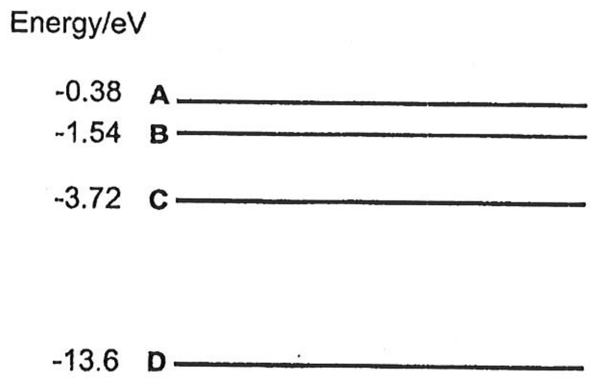
1. explain why I is not zero even when V is zero,

2. calculate the work function of the emitter,

3. calculate the rate of emission of electrons when V = 1.5 V. [6]

(iii) Comparing the answers from **(i) 4.** and **(ii) 3**, suggest a reason why the value of the rate of emission of electrons is to be expected. [2]

5. **(b)** The diagram shows four energy levels **A**, **B**, **C** and **D** within an atom. The outermost electron is at level **A**.



(i) Make a copy of the diagram. On it, show all the possible transitions between the four energy levels which result in photon *emission*.

(ii) Calculate the shortest possible wavelength of radiation emitted as a result of electron transition from level **A**. State the region of the electromagnetic spectrum at which the radiation will occur. [6]

NUCLEAR PHYSICS (7 – 14 Mar)

1. An experiment was carried out with a radioactive source of half-life 5 minutes on a day when the background count rate was 30 counts per minute. The initial count rate was 750 counts per minute. What would be the count rate 15 minutes later?

A 94 counts per minute
B 120 counts per minute
C 250 counts per minute
D 270 counts per minute

2. In the Rutherford scattering experiment most α particle passed through the foil undeflected. Which one of the following is a correct conclusion from this result?

A Most of the mass of an atom is within the nucleus.
B The diameter of the nucleus is much less than the diameter of the atom.
C The nucleus has a positive charge.
D The atom is overall neutral.

3. A stationary Thoron nucleus (Z=90, A=220) emits an α particle as it disintegrates. The total kinetic energy generated is shared between the α particle and the recoiling nucleus. What fraction of the total kinetic energy is taken by the α particle?

A 4/216 B 4/220 C 216/220 D 220/224

4. Three adjacent elements in a long radioactive series are actinium, francium and radium

$$\ldots\ldots \rightarrow \text{actinium (Ac)} \xrightarrow{\alpha} \text{francium (Fr)} \xrightarrow{\beta} \text{radium (Ra)} \rightarrow \ldots\ldots$$

(a) An atom of $^{223}_{87}Fr$ is formed when an atom of actinium decays with the emission of an α particle. The masses of actinium, francium and helium atoms, in atomic mass units (u), are 227.0278, 223.0198 and 4.0026 respectively.

4(a)(i) Write a nuclear equation describing this changes;

(ii) Compare the mass of the parent actinium atom with the sum of the masses of the decay products. Show how the values you obtain are consistent with the emission of the α particle with considerable kinetic energy.

(b) The mass of a proton is 1.0073u and that of a neutron is 1.0087u.

(i) Calculate the difference in mass between a $^{223}_{87}Fr$ nucleus and the sum of the masses of its constituent nucleons.

(ii) How do you account for this difference?

(c) The $^{223}_{87}Fr$ atom decays with the emission of a β particle into an atom of radium. Write a nuclear reaction equation for this change.

(d) The half-life of the actinium isotope is 19 days ad that of the francium isotope is 21 min. A sample of pure actinium is monitored for one day. Without calculation, comment briefly on how the concentration of francium varies during this time.

5. Nuclei of ^{238}Pu decays with a half-life of 90 years, emitting α particle of energy 5.1 MeV. This isotope is to be used to power a heart pacemaker.

(a) Calculate the decay constant of ^{238}Pu.

(b) Determine the minimum number of ^{238}Pu atoms of which must be present to give an initial power of 10 mW. State clearly any assumption made.

(c) Suggest one reason why ^{238}Pu is chosen for this application. Justify your answer.

Answers:

Ideal Gases
1. C 2. A 3. C 5(b) 0.05, 0.00020kg (c) 0, 125J, 125J (d) 187500Pa

Thermodynamics
1. C 2. C 3. B 4(a) 2400 Jkg^{-1} (b) 2000 $Jkg^{-1}K^{-1}$ 5(b) 400 kPa, 600 kPa

Waves
1. D 2. B 3. B 4. 10^{-3} W

Oscillations
1. B 2. C 3. C 4(a) 620 $N m^{-1}$ (b) 0.625
5(b) 1250Hz, 3.7×10^{-5} $m s^{-2}$ (d) 493 $N m^{-1}$

Charge & Fields
1. A 2. D 3. C 4. C 5. A
7(a) 50V (b) 8.0×10^{-16} N, 8.78×10^{14} $m s^{-2}$ (c) 4.19×10^{6} $m s^{-1}$
8(a) 4.8×10^{-16} N, 12.6 km

Superposition
1. A 2. C 3. D 4(c) 75m (d) 200 5(a) 6.58×10^{-7} m (b) 29.0°

Quantum
1. B 2. D 3. C 4. 1024, 4.4×10^{10} s^{-1}, 7.2×10^{-8} W
5(a) $1.22 \times 10^{16} s^{-1}$, 2.5×10^{10} s^{-1} (b) 9.4×10^{-8} m

Nuclear
1. B 2. B 3. C 4. 1.7985u 5. 2.44×10^{-10} s^{-1}, 5.02×10^{19} atoms