H2 PHYSICS

Exam papers with worked solutions

(Selected from Top JC)

SET A

PAPER 3

Compiled by

THE PHYSICS CAFE

Candidates answer on the Question Paper.
No Additional Materials are required.

READ THESE INSTRUCTIONS FIRST

Write your name and PDG on the spaces provided above.
Write in dark blue or black pen.
You may use a soft pencil for any diagrams, graphs or rough working.
Do not use staples, paper clips, highlighters, glue or correction fluid.

Section A
Answer **all** questions.

Section B
Answer any **two** questions. Write down the numbers of the two questions attempted in the boxes on the right.

You are advised to spend about one hour on each section.
At the end of the examination, fasten all your work securely together.
The number of marks is given in brackets [ ] at the end of each question or part question.

Data

speed of light in free space,	c = 3.00 x 10^{8} m s^{-1}
permeability of free space,	μ_0 = 4π x 10^{-7} H m^{-1}
permittivity of free space,	ε_0 = 8.85 x 10^{-12} F m^{-1}
	(1/(36π)) x 10^{-9} F m^{-1}
elementary charge,	e = 1.60 x 10^{-19} C
the Planck constant,	h = 6.63 x 10^{-34} J s
unified atomic mass constant,	u = 1.66 x 10^{-27} kg
rest mass of electron,	m_e = 9.11 x 10^{-31} kg
rest mass of proton,	m_p = 1.67 x 10^{-27} kg
molar gas constant,	R = 8.31 J K^{-1} mol^{-1}
the Avogadro constant,	N_A = 6.02 x 10^{23} mol^{-1}
the Boltzmann constant,	k = 1.38 x 10^{-23} J K^{-1}
gravitational constant,	G = 6.67 x 10^{-11} N m^2 kg^{-2}
acceleration of free fall,	g = 9.81 m s^{-2}

Formulae

uniformly accelerated motion,	$s = ut + \frac{1}{2}at^2$
	$v^2 = u^2 + 2as$
work done on/by a gas,	$W = p\Delta V$
hydrostatic pressure,	$p = \rho gh$
gravitational potential,	$\phi = -\frac{Gm}{r}$
displacement of particle in s.h.m.,	$x = x_0 \sin \omega t$
velocity of particle in s.h.m.,	$v = v_0 \cos \omega t$
	$v = \pm\omega\sqrt{x_0{}^2 - x^2}$
resistors in series,	$R = R_1 + R_2 + \ldots$
resistors in parallel,	$1/R = 1/R_1 + 1/R_2 + \ldots$
electric potential,	$V = \frac{Q}{4\pi\varepsilon_o r}$
alternating current/voltage,	$x = x_0 \sin \omega t$
transmission coefficient,	$T = exp(-2kd)$
	where $k = \sqrt{\frac{8\pi^2 m(U - E)}{h^2}}$
radioactive decay,	$x = x_0 exp(-\lambda t)$
decay constant,	$\lambda = \frac{0.693}{t_{\frac{1}{2}}}$

Section A

Answer **all** the questions in the spaces provided.

It is recommended that you spend about one hour on this section.

1 A block X of mass 2.0 kg moves with a velocity 9.0 m s^{-1} on a smooth horizontal table. Another block Y of mass 4.0 kg moves with a velocity of 3.0 m s^{-1} in front of X in the same direction. A light spring of force constant 150 N m^{-1} is attached to Y as shown in Fig. 1.1.

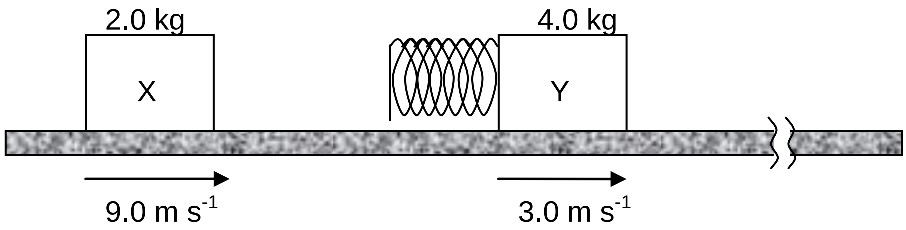

Fig. 1.1

When X collides with Y, there will be an instant when the spring experiences maximum compression. After which, they separate. You may assume that the total kinetic energy of the system before collision is equal to the total kinetic energy of the system after separation.

(a) **(i)** Explain why X and Y move with a common velocity at the instant of maximum compression.

....

....

.... [1]

(ii) Calculate this common velocity.

common velocity = ………………………………….. m s^{-1} [1]

(iii) Hence determine the maximum compression of the spring.

maximum compression = …………………………. m [2]

(b) **(i)** State the *principle of conservation of linear momentum*.

....

....

.... [1]

(ii) Calculate the velocities of X and Y after they separate.

velocity of X = …………………………… m s^{-1}

velocity of Y = ……………….………….. m s^{-1} [3]

2 **(a)** State what is meant by *simple harmonic motion*.

....

....

.... [2]

(b) Noise from machinery may be produced by large amplitude vibrations. Reduction in noise levels may be achieved by the following methods:

1. damping

2. avoiding electric motors having the same frequency of rotation as the natural frequency of any part of the machinery

(i) Explain the meaning of the term *damping.*

....

....

.... [2]

(ii) Explain why a small change in electric motor frequency may reduce the noise from a machine considerably.

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.... [4]

3 A small charged metal sphere is situated in an earthed metal box. Fig. 3.1 illustrates the electric field between the sphere and the metal box.

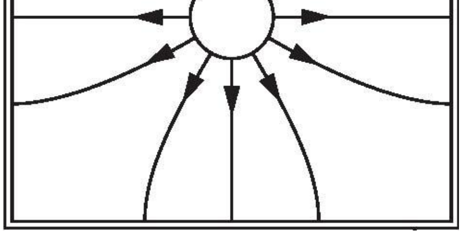

Fig. 3.1

(a) By reference to Fig. 3.1, state and explain

(i) whether the sphere is positively or negatively charged,

....

....

.... [1]

(ii) why it appears as if the charge on the sphere is concentrated at the centre of the sphere.

....

.... [1]

(b) On Fig. 3.1, draw an arrow to show the direction of the force on a stationary electron situated at point A. [2]

(c) The radius *r* of the sphere is 2.4 cm. The magnitude of the electric potential *V* at the surface of the sphere is 280 V.

(i) Define *electric potential*.

....

....

.... [1]

(ii) Determine the magnitude of charge *q* on the sphere.

q = ... nC [2]

(d) A lead sphere is placed in a lead box in free space, in a similar arrangement to that shown in Fig. 3.1. Explain why it is **not** possible for the gravitational field to have a similar shape to that of the electric field.

--- [1]

4 A simple iron-cored transformer is illustrated in Fig. 4.1.

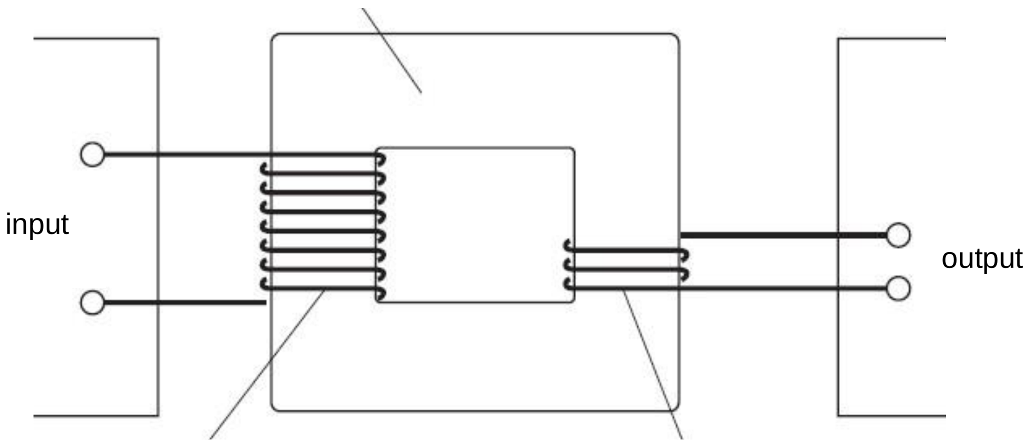

Fig. 4.1

Fig. 4.2 shows the variation with time of the *magnetic flux linkage* in the core of a transformer.

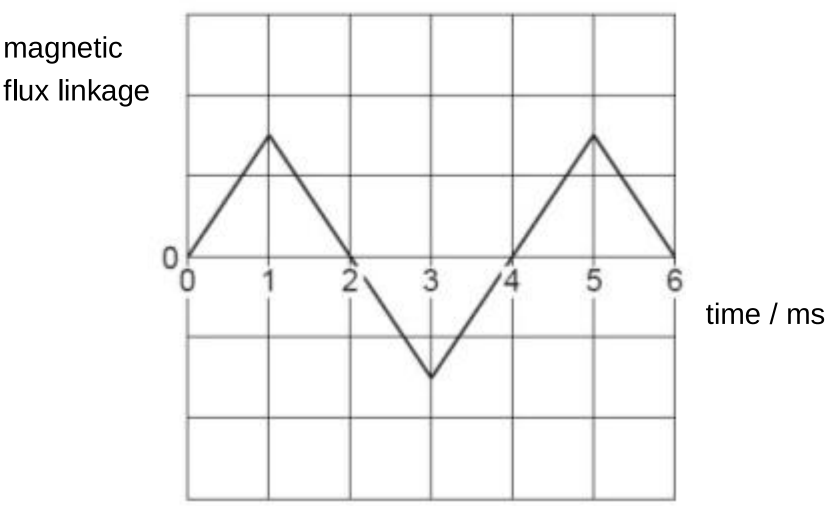

Fig. 4.2

(a) Define *magnetic flux linkage*.

....

....

.... [1]

(b) Sketch on Fig. 4.3 the variation with time of the e.m.f. induced in the secondary coil.

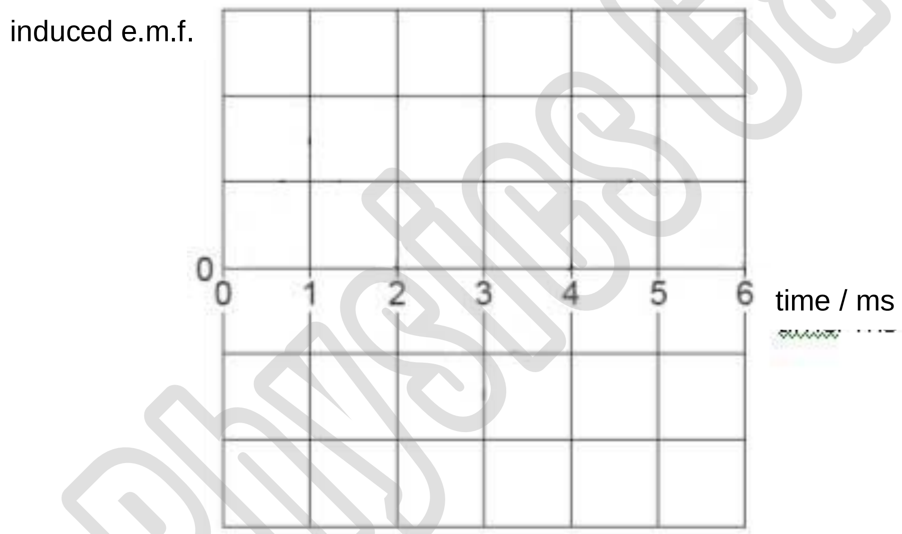

Fig. 4.3

[3]

(c) The iron core of the transformer has a cross sectional area of 3.1×10^{-4} m^2 and the maximum magnetic flux density in the iron core is 0.55 T. Use the graph of Fig. 4.2 to calculate the maximum e.m.f. induced in the secondary coil with three turns.

maximum e.m.f. induced = …………… V [2]

(d) State and explain the effect on the maximum e.m.f. induced in the secondary coil if the iron core is replaced by one made of wood.

....

....

.... [2]

5 Fig. 5.1 shows the variation with volume of the pressure of an ideal gas contained within a cylinder. The gas which is initially at state X, can be compressed to state Z either directly along the curve path XZ or indirectly from X to Y to Z.

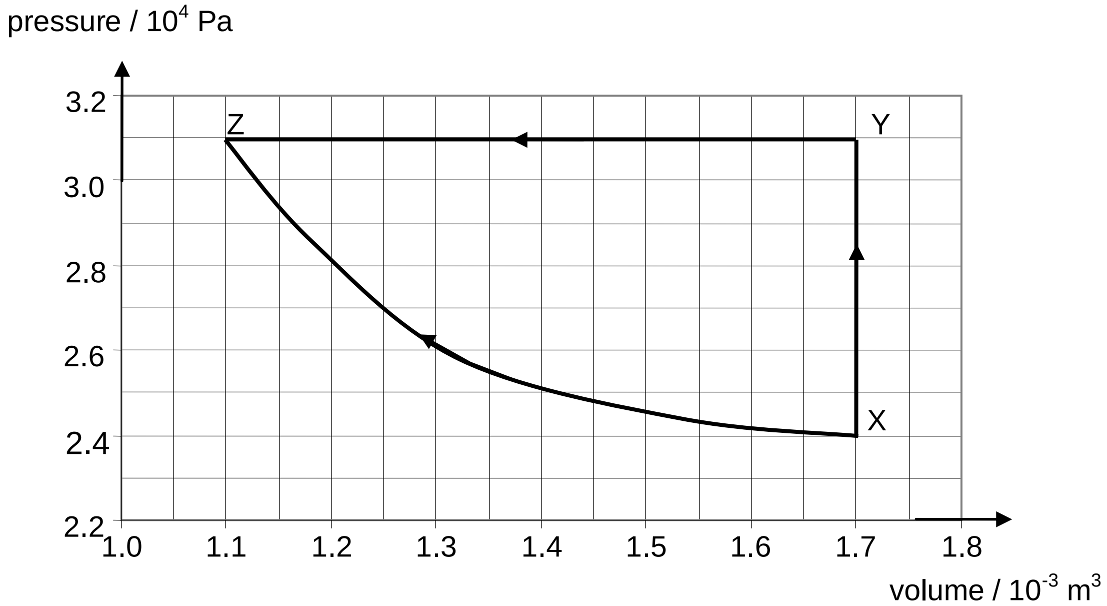

Fig. 5.1

(a) When the gas is compressed from X to Z along the curved path, 25.5 J of heat energy goes out of the gas. Use the graph to

(i) determine whether the change is isothermal, whereby an isothermal process is one which takes place at a constant temperature;

[3]

(ii) estimate the work done on the gas.

work done = ……………………………….. J [2]

(b) When the gas is compressed from X to Z along the paths XY and YZ, determine the quantity of heat supplied to the gas.

heat flow = …………………….……… J [3]

Section B

Answer **two** questions for this section. Each question carries 20 marks.

It is recommended that you spend about one hour on this section.

6 **(a)** Uranium-235 nuclei are fissioned by slow-moving neutrons to produce energy in a nuclear reactor. One such possible *nuclear fission* reaction is

$$^{235}_{92}\text{U} + ^{1}_{0}\text{n} \rightarrow ^{139}_{57}\text{La} + \text{X} + 2^{1}_{0}\text{n}$$

(i) Explain what is meant by *nuclear fission*.

....

....

.... [2]

(ii) State the number of protons and the number of neutrons in nucleus X.

Number of protons = ……………….. [1]

Number of neutrons = ……………….. [1]

(b) Part of the energy released in the reaction in **(a)** occurs as kinetic energy of the fission products (200 MeV).

(i) Suggest **one** other mechanism by which energy is released in the fission reaction.

....

.... [1]

(ii) Express 200 MeV in joules.

200 MeV = ……………….. J [2]

(iii) The reaction in **(a)** is used by a nuclear plant to generate thermal power of 3065 MW.

1. Calculate the number of fission processes taking place each second in the plant.

number of fission processes = ……………….. [2]

2. The nuclear plant has an overall efficiency of 30%. Calculate the waste heat produced in each second.

waste heat produced in each second = ……………….. W [1]

(iv) 97% of the waste heat is removed using water pumped from a river and the rest is ejected into the atmosphere. A regulation in a certain country requires that water taken from a river to cool a nuclear plant cannot be heated more than 3.5 °C when it is discharged back into the river. Determine the minimum mass of water needed in each second to cool the nuclear plant if the regulation is to be met. The specific heat capacity of water is 4.2×10^3 J kg^{-1} K^{-1}.

minimum mass of water = ……………….. kg [3]

(c) Cobalt-60 decays with the emission of beta particles and gamma radiation.

(i) Suggest a method by which the beta particles may be separated from the gamma radiation.

-- [2]

(ii) An experiment is carried out on the gamma radiation emitted from cobalt-60. In the experiment, sheets of lead are placed between the source S and the counter C which is at a fixed distance from the source as shown in Fig. 6.1. The number of counts *N* in 10 minutes is measured for various total thickness *d* of lead and readings are tabulated as shown in Fig. 6.2. Source S is assumed to behave as a point source radiating equally in all directions. The readings tabulated are solely due to Cobalt-60.

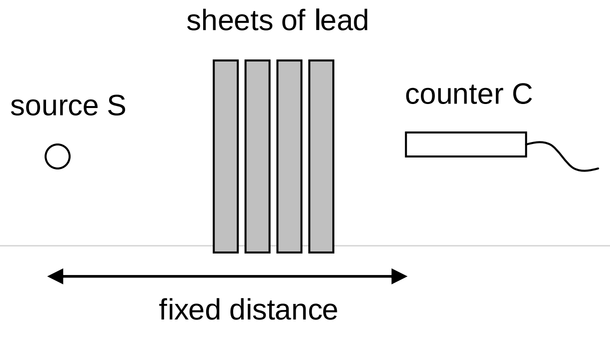

Fig. 6.1

Total thickness *d* of lead / mm	0	10	20	30	40
Number of counts *N* in 10 mins	4250	2510	1500	850	500

Fig. 6.2

1. Using values from Fig.6.2, plot a graph of ln *N* against *d* in Fig. 6.3.

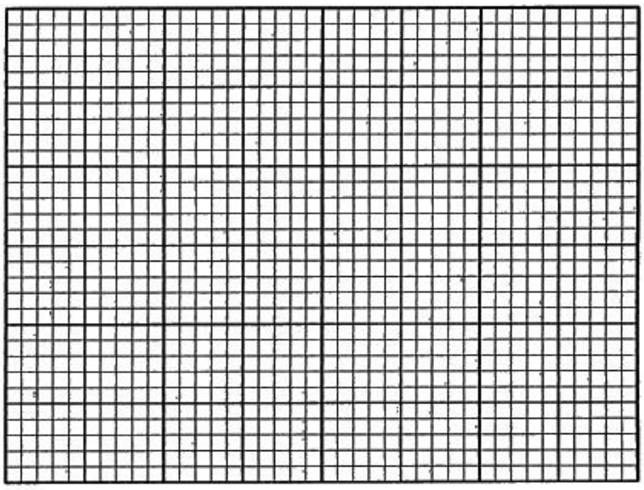

Fig. 6.3

[3]

2. Hence deduce the variation with *d* of *N* from the graph plotted.

....

....

.... [1]

(iii) Suggest a reason why actual readings obtained from such an experiment will likely show values higher than that in Fig. 6.2.

....

....

.... [1]

7 What is meant by the term *superposition* when applied to waves?

....

....

.... [2]

(a) Fig. 7.1 shows the principal components of a radio broadcasting station.

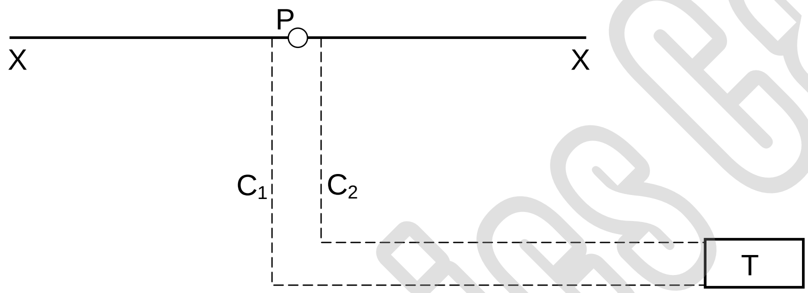

Fig. 7.1

XX is the aerial from which the radio waves are broadcast.
T is the transmitter, usually at a large distance from XX.
C_1 and C_2 are feeder cables connecting T to XX.

The aerial XX is designed to resonate with its transmitter by forming stationary current waves as shown in Fig. 7.2(a).

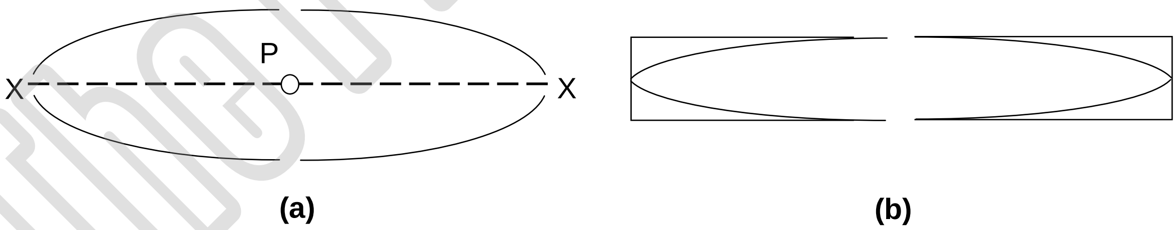

Fig. 7.2

The pattern of these waves is analogous to those produced in two closed air columns as shown in Fig. 7.2(b). Current nodes are formed at the outer ends, and current antinodes at the centre adjacent to P.

The solid lines in Fig. 7.2(a) represent the amplitude of the stationary current wave pattern for the 7.5 MHz transmission.

(i) The aerial could also be used to transmit at a frequency of 22.5 MHz, but not at a frequency of 15 MHz. Explain why.

--- [2]

(ii) Sketch the stationary wave pattern of the aerial current to be expected at 22.5 MHz.

[2]

(iii) Describe an advantage gained by introducing resonance between adjacent systems (in this case the transmitter and the aerial).

--- [1]

(b) Fig. 7.3 shows an arrangement used to determine the wavelength λ of monochromatic light emitted by a laser.

Fig. 7.3 (not to scale)

S_1 and S_2 are slits at right angles to the plane of the diagram. When illuminated by light from a laser they form coherent sources of light. An interference pattern is formed on the screen from which measurements can be taken to determine λ.

The distance x between neighbouring bright images in the interference pattern is given by

$$x = \frac{\lambda D}{a}$$

(i) Show on Fig. 7.3 the distances represented by the symbols D and a**.** [1]

(ii) Name the instrument you would use when determining each of these quantities x, a and D.

....

....

.... [2]

(iii) The wavelength of the light used is known to be 620 nm. Given that 2 mm is the minimum fringe spacing which can be seen, suggest a suitable value for *D* and determine *a*, which will provide this minimum fringe spacing.

D = ……………….. m [1]

a = ……………….. m [2]

(c) A parallel beam of monochromatic light of wavelength λ falls at normal incidence on a narrow slit S of width 0.20 mm, as shown in Fig. 7.4.

Fig. 7.4

(i) The intensity pattern of the light observed on the screen from the slit S is as shown in Fig. 7.5.

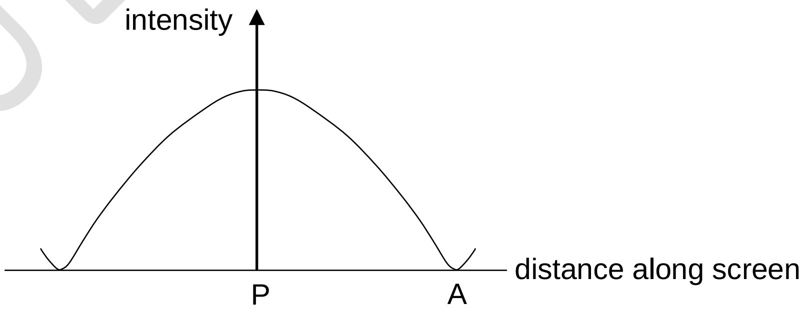

Fig. 7.5

Briefly discuss the effect on the intensity pattern of reducing the width of the slit S.

....

....

.... [2]

(ii) A small hole is made in the screen at A so that a photodetector can be placed behind the hole to monitor the intensity of light at that point. The slit S, which can be adjusted in width, is gradually reduced from 0.20 mm to zero. The graph of intensity at A against slit width, as it is closed, is shown in Fig.7.6.

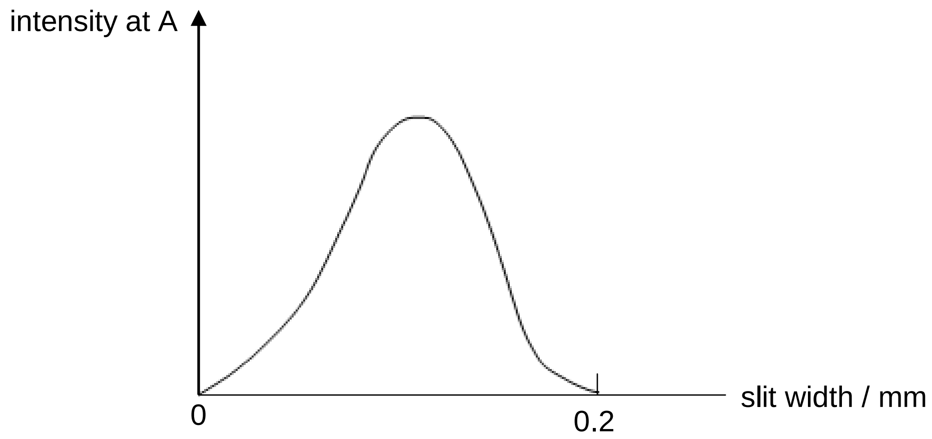

Fig. 7.6

Explain why the intensity rises and then falls as the slit is closed.

....

....

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....

....

.... [3]

(iii) A diffraction grating is used to measure the wavelength of monochromatic light. The narrow slit S in Fig. 7.4 is replaced with a diffraction grating. The spacing of the slits in the grating is 1.00×10^{-6} m. It is found that the first order diffracted beam occurs at an angle of 35° to the incident direction. Calculate the wavelength λ of the light.

wavelength, λ = ………………. m [2]

8 **(a)** A certain metal has a work function energy of 1.7 eV.

(i) Explain what is meant by this statement.

....

.... [1]

(ii) Calculate the threshold frequency for this metal.

frequency = ……………….. Hz [2]

(iii) Calculate the maximum kinetic energy of photoelectrons ejected from this metal surface when illuminated with monochromatic light of wavelength 560 nm.

maximum kinetic energy = ………………. J [3]

(b) When blue light is incident on another metal surface, electrons are emitted from the surface but no electrons are emitted when red light is incident on the same surface. Use Einstein's model of light to explain these observations.

....

....

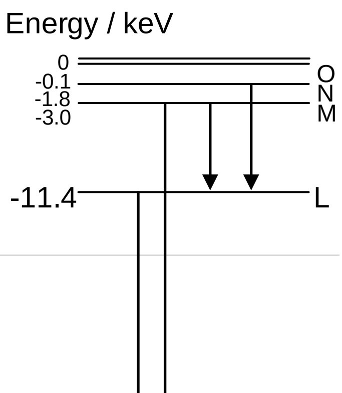
....

....

....

.... [3]

(c) Some of the energy levels within an atom of tungsten are given in Fig. 8.1. Electrons closest to the nucleus in an atom are referred to as the K-shell electrons. When these electrons are removed on bombardment by energetic electrons hitting the tungsten target in an X-ray tube, electrons from higher levels fall in to fill the gap. In doing so, they emit high energy X-rays. Fig. 8.2 is a graph showing how the intensity varies with the wavelength.



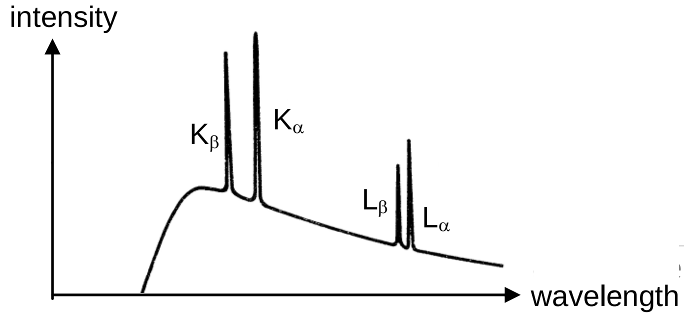


Fig. 8.2

(i) Use Fig. 8.1 and Fig. 8.2 to identify the transitions which result in K_α and K_β lines.

K_α: ……………………………………………………………………………………

K_β: ……………………………………………………………………………………

[2]

(ii) What is the wavelength of the K_α line?

wavelength = ……………….. m [3]

(iii) What is the minimum potential difference, in practice, which must be applied across the tube in order to get any K_α lines? Explain your answer.

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minimum potential difference = ……………….. kV [2]

(d) In the Scanning Tunnelling Microscope (STM), electrons cross a gap between a sharp metal tip and a conducting surface when the gap is small and a potential difference exists across it. Explain, in terms of wave particle duality, why an electron can cross this small gap.

....

.... [2]

(e) Calculate the speed of an electron which has a de Broglie wavelength of 1 nm.

speed = ……………….. m s^{-1} [2]