HONG KONG ADVANCED LEVEL EXAMINATION
AL PHYSICS
1989 Structural Question

7. A student wishes to deduce the internal diameter of a hollow spherical shell of uniform thickness (external diameter = 10 cm) using the following method:

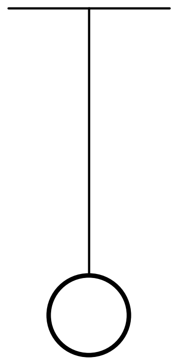

Figure 7.1

(a) Indicate on Figure 7.1 the directions of the torsional oscillations of the shell. (1 mark)

(b) If I = the moment of inertia of the shell of the axis of oscillation, and
c = the torsional constant of the wire,

find an expression for the period of oscillation of the shell. (3 marks)

(c) It is found that the time for 20 torsional oscillations is 20.4 s. If the shell is now replaced by a uniform solid sphere, of the same material and the same external diameter, the time for 20 torsional oscillations becomes 24.2 s. Determine the ratio of the moment of inertia of the hollow shell to that of the solid sphere. (2 marks)

(d) If the moment of inertia of a solid sphere, of mass m and radius r about a diameter is $2mr^2/5$, deduce the internal diameter of the hollow shell. (4 marks)

8.

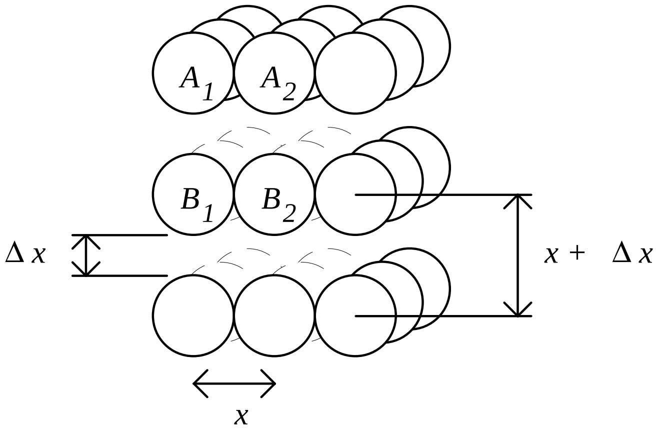

Figure 8.1

In a typical solid model, layers of atoms are arranged in a cubic square lattice array with each atom at an equilibrium distance x from its nearest neighbours, both in its own layer and in the layers above or below. Suppose a long steel wire, with many layers, is stretched a little so that each layer is now $x + \Delta x$ form those above or below it, as illustrated in Figure 8.1.

(a) What is the elastic strain produced? (1 mark)

(b) Assume that the deformation is elastic, and that the binding force holding the pair of atoms A_i and B_i (i = 1, 2, ...) together when the wire is stretched can be considered as acting like a spring.

(i) If this 'spring constant' is k, what is the force between the atoms A_i and B_i ? (1 mark)

(ii) If each layer contains N atoms, what is the total force between pairs of atoms in adjacent planes? (1 mark)

(iii) Determine the elastic stress acting between the two layers of atoms. (3 marks)

(c) Use the information in (a) and (b) to determine an expression for the Young modulus of the solid. (2 marks)

(d) It is known that for steel, Young modulus is 2×10^{11} N/m^2 and that the interatomic spacing is 0.30 nm.

(i) Estimate a value for k. (1 mark)

(ii) Suppose that a steel wire breaks at a tensile tress of 10^9 N/m^2, estimate the increase in distance, Δx, between layers of atoms before breaking occurs. (2 marks)

9.

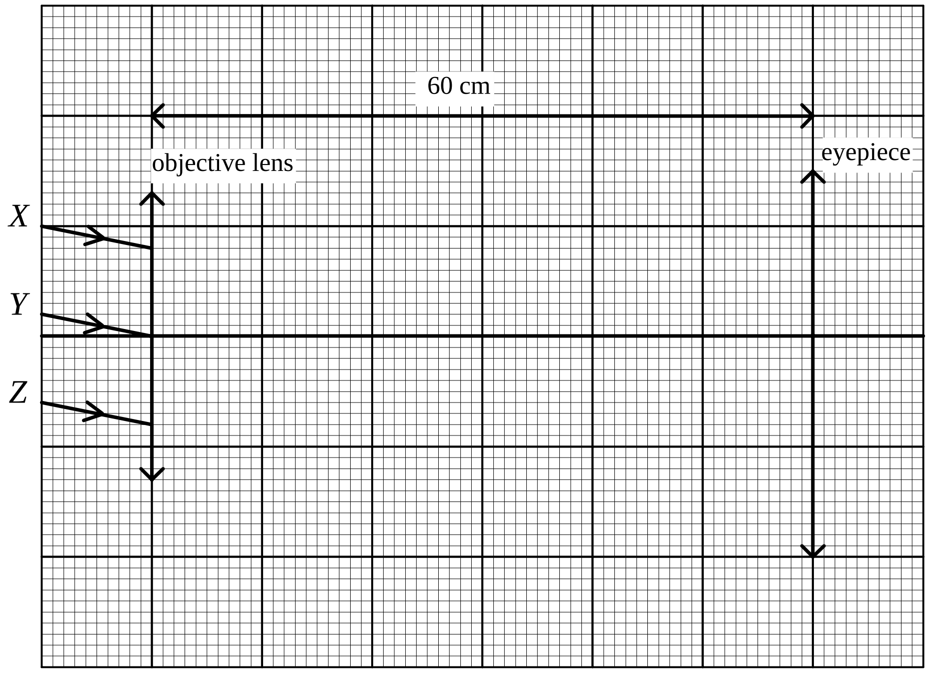

Figure 9.1

A student set up two converging lenses to form a simple type of astronomical telescope for use in normal adjustment. Light rays *X*, *Y* and *Z* from a distant object fall upon the objective lens as shown in Figure 9.1. The focal lengths of the objective and the eyepiece are 50 cm and 10 cm respectively.

(a) Draw the ray paths for *X*, *Y* and *Z* as they pass through the telescope, showing how they emerge from the eyepiece. (3 marks)

(b) Use your diagram to explain the meaning of angular magnification of the telescope. How is this related to the focal lengths of the lenses? (3 marks)

(c) (i) What is meant by eye-ring of a telescope? (2 marks)

(ii) Outline the steps you would take to determine experimentally the position of the eye-ring of this telescope. (3 marks)

10. (a)

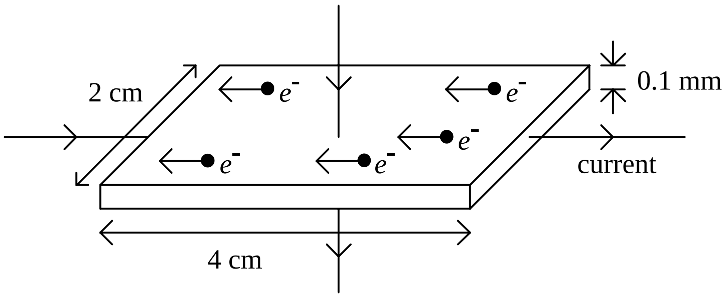

Figure 10.1

Figure 10.1 shows an aluminium plate with a current of 50 mA passing through it.

(i) Calculate the average drift velocity of the conducting electrons, given that there are 10^{29} conducting electrons per m^3 of aluminium and the charge of an electron is 1.6×10^{-19} C. (2 marks)

(ii) A uniform magnetic field of 1.5 T is now applied normally downwards to the plate and covers the whole surface area. Mark on Figure 10.1 the direction of the force experienced by each electron and calculate its magnitude. (3 marks)

(b) It is found that an electric field and a p.d. (the Hall p.d.) are created across the plate and soon attain maximum values. Explain why this happens. (4 marks)

(c) An experiment is being set up to demonstrate the Hall voltage and it is decided to use a germanium slice. The circuit diagram for the experiment is shown in Figure 10.2.

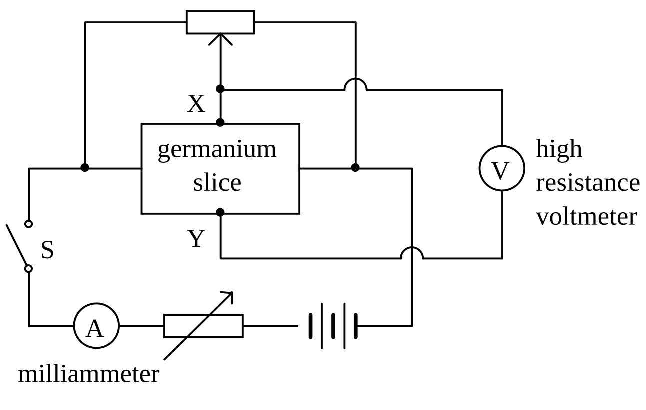

Figure 10.2

(i) Explain why a germanium slice was chosen in this experiment instead of an aluminium plate. (2 marks)

(ii) After switch *S* has been closed, a small p.d. is found to exist between *X* and *Y* even in the absence of a magnetic field. Explain why this is so. How would you arrange *X* and *Y* to be at the same potential? (3 marks)

(d) A uniform magnetic filed of 0.2 T is now applied acting perpendicularly downwards into the plane of the paper, covering the whole surface of the slice. If the reading of the milliammeter is 1 mA, estimate the Hall voltage that exists across the slice.

(the thickness of the slice = 0.1 mm,
number of charge-carriers per unit volume for germanium = 10^{20} m^{-3},
the charge on each carrier = 1.6×10^{-19} C.)(4 marks)

(e) Mention one practical application of the Hall effect. (1 mark)

11. Consider the transistor circuit in Figure 11.1 which has an input-output characteristic curve as shown in Figure 11.2.

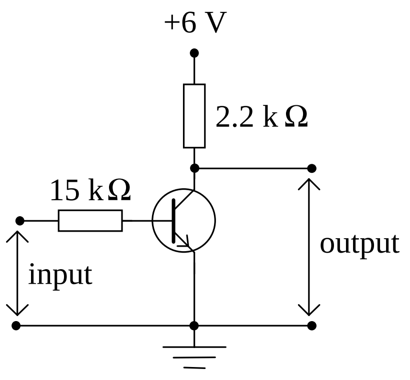

Figure 11.1

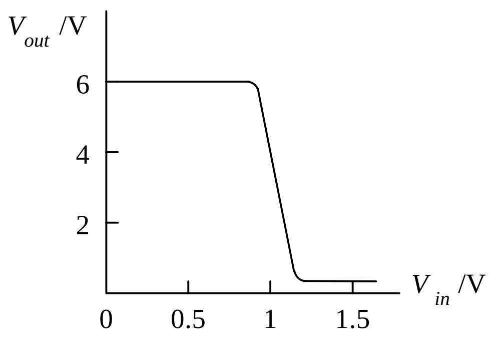

Figure 11.2

(a) Account for the shape of the characteristic curve. (3 marks)

(b) Suppose the transistor circuit shown in Figure 11.1 is symbolically represented by Figure 11.3.

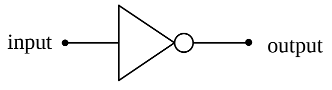

Figure 11.3

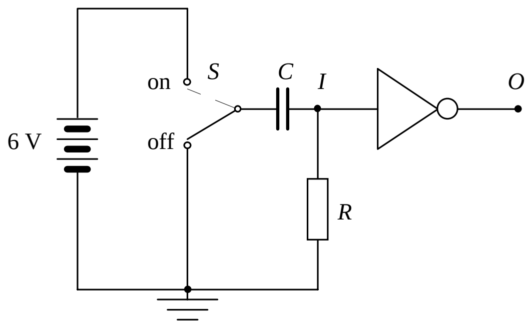

Figure 11.4

The transistor circuit is now connected to an *RC* circuit, as shown, with the capacitor initially uncharged. Now at time = t_1, *S* is switched from the OFF position to the ON position. *S* stays at the ON position from time = t_1 to time = t_3. At time = t_3, *S* is switched back to the OFF position and remains there. It is found that at time = t_2, the potential at point *I* has dropped below 1 V.

(i) Sketch on Figure 11.5 the variation of the potential at point *I* with respect to time, from time = 0 to a time later than t_3. (4 marks)

(ii) With the help of the input-output characteristic curve, sketch on Figure 11.6 the corresponding variation of the output potential at *O* against time. (3 marks)

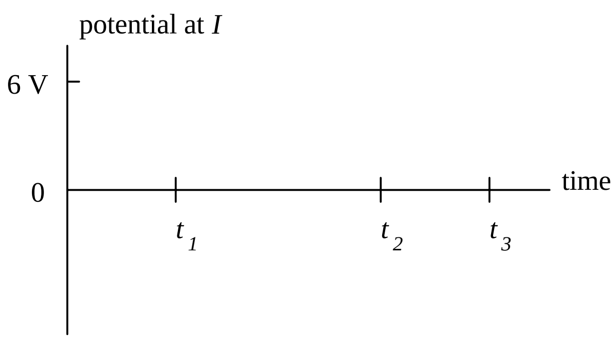

Figure 11.5

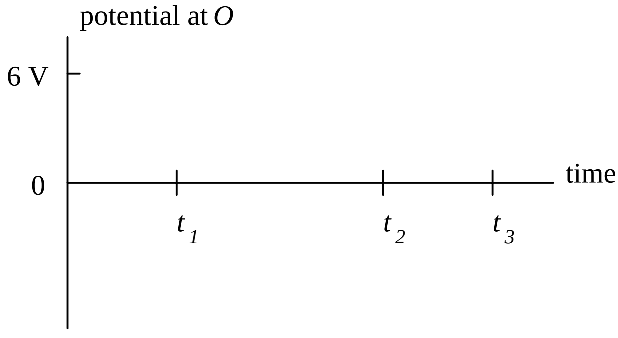

Figure 11.6

12.

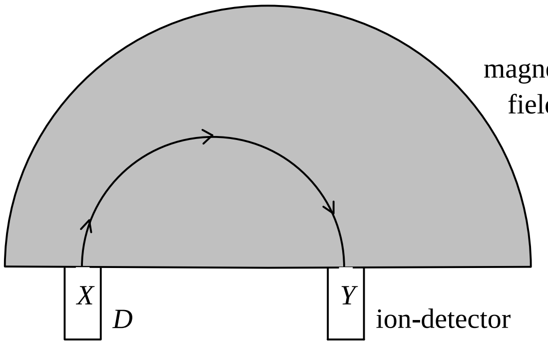

Figure 12.1

In a mass spectrometer, positive ions are produced in a chamber *D* and then accelerated through a potential difference *V*. Some of these ions pass through a small hole *X* into a uniform magnetic field *B*, traverse a circular path of radius *r* and then pass through another hole *Y* into a detector.

(a) Describe a method by which positive ions may be produced in the chamber *D*. (2 marks)

(b) Show that the charge to mass ratio of an ion passing through the hole *Y* into the detector is proportional to the accelerating potential *V*. (3 marks)

(c) When potassium ions are examined by this mass spectrometer, the detector registers a peak current when the accelerating p.d. is 613 V with another much smaller peak at 583 V. A student comments that this is due to the presence of isotopes. Explain why the above phenomenon may be explained by the presence of isotopes. (2 marks)

(d) If the relative atomic mass of potassium is 39.1, estimate

(i) the relative atomic masses of these two isotopes, (2 marks)

(ii) their relative proportion. (2 marks)

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