

**HONG KONG ADVANCED LEVEL EXAMINATION  
AL PHYSICS  
1986 Structural Question**

1.

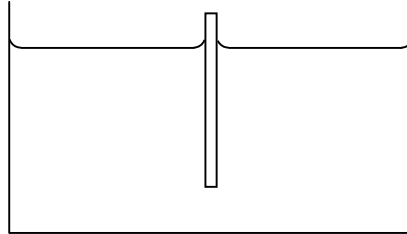


Figure 1

A uniform cylindrical object of length 0.20 m and cross-sectional area  $10 \times 10^{-4} \text{ m}^2$  is made of a material of density  $800 \text{ kg/m}^3$ . It is held vertically with its upper surface protruding from water in a wide container as shown in Figure 1 (not drawn to scale). It is released at time  $t = 0$  and sinks into the water, but it does not completely submerge.

- (a) For this part of the question, i.e. part (a), you may assume that there is no loss of energy due to viscosity and that the cylinder remains upright.
- (i) Find the equilibrium position of the object.  
(Hint: When an object is partially immersed in a liquid, it experiences an upward force equal to the weight of the liquid displaced.)
  - (ii) Find the resultant force acting on the object in terms of the vertical displacement  $x$  from the equilibrium position.
  - (iii) Draw a sketch graph showing the force experienced by the object as a function of time  $t$ .
  - (iv) At what time will the object first return to its original position at  $t = 0$ ?
  - (v) What is the maximum possible amplitude of this motion? Explain your answer.
  - (vi) Indicate how energy is conserved in this process.
- (b) In practice, the assumptions of part (a) might not apply and the object would behave differently.
- (i) Assuming that it remained upright, briefly describe the motion which would be observed in practice and explain how energy is conserved in this case.
  - (ii) For larger amplitudes of oscillation, the cylinder would not remain upright. Describe what you would expect to happen and explain briefly why this would be so.

(16 marks)

2. (a) The density of a particular gas at standard temperature and pressure (273 K and  $1.01 \times 10^5$  Pa) is  $1.43 \text{ kg/m}^3$ . What is the mass of 1 mole of the gas? (The molar gas constant  $R$  may be taken to be  $8.31 \text{ J mol}^{-1} \text{ K}^{-1}$ .)
- (b) A cylinder of compressed gas of volume  $0.50 \text{ m}^3$  is initially at a pressure of  $20 \times 10^5$  Pa. This is used to inflate a non-elastic balloon to a volume of  $5.0 \text{ m}^3$  at a pressure of  $10^5$  Pa. Assume that the temperature of the gas does not change.
- What would be the final pressure in the cylinder?
  - What is the maximum volume to which a non-elastic balloon could be inflated at the pressure of  $10^5$  Pa?
  - Is the assumption that the temperature of the gas remains constant justifiable? Explain briefly.

(9 marks)

3.

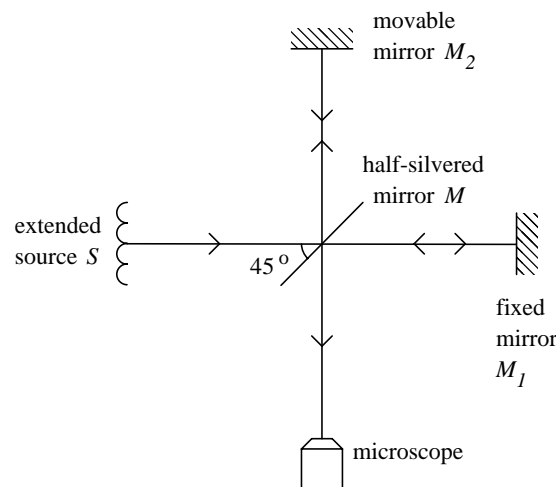


Figure 2

In the optical arrangement shown in Figure 2, monochromatic light from an extended monochromatic source  $S$  falls onto a thin, half-silvered mirror  $M$ . The incident light then divides into two beams, one proceeding by transmission towards mirror  $M_1$ ; the other proceeding by reflection towards  $M_2$ . The beams are reflected at each of these mirrors and are sent back along their directions of incidence, each beam eventually entering the microscope. Due to the finite dimension of the source  $S$ , this produces divergent light rays which are incident at slightly different angles on  $M$ , and consequently an interference pattern of bright and dark fringes is observed on looking through the microscope.

- (a) Briefly explain how the bright and dark fringes are formed.
- (b) When a thin film is placed perpendicular to the light rays between  $M$  and  $M_2$ , a shift of 7 fringes is observed by the microscope. If the wavelength of the monochromatic light is 480 nm and the refractive index of the film is 1.45 at this wavelength, determine the thickness of the film.
- (c) The thin film is then removed. The mirror  $M_2$  is now moved at a constant rate in one direction, and kept perpendicular to the light beam from  $M$ . 800 fringes are observed to cross the centre of the field of view.
- Briefly explain this effect.
  - How far has the mirror  $M_2$  been displaced?
- (d) The light source is now replaced by a sodium discharge tube which emits yellow light consisting of two wavelengths, 589.0 nm and 589.6 nm. As  $M_2$  is again moved, it is observed that the interference pattern disappears and reappears periodically. Explain why this happens.

(11 marks)

4.

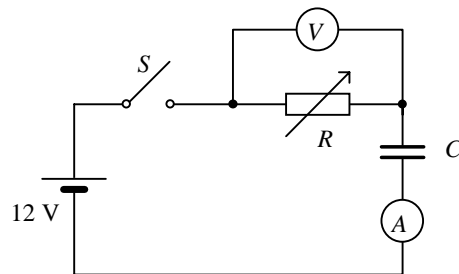


Figure 3

A student performs an experiment in which a  $500 \mu\text{F}$  capacitor  $C$  is to be charged at a constant rate, using the circuit in Figure 3. After switch  $S$  is closed, the microammeter shows an initial current reading of  $120 \mu\text{A}$ . By continuously adjusting the variable resistance  $R$ , the charging current is maintained at this magnitude throughout the subsequent charging process.

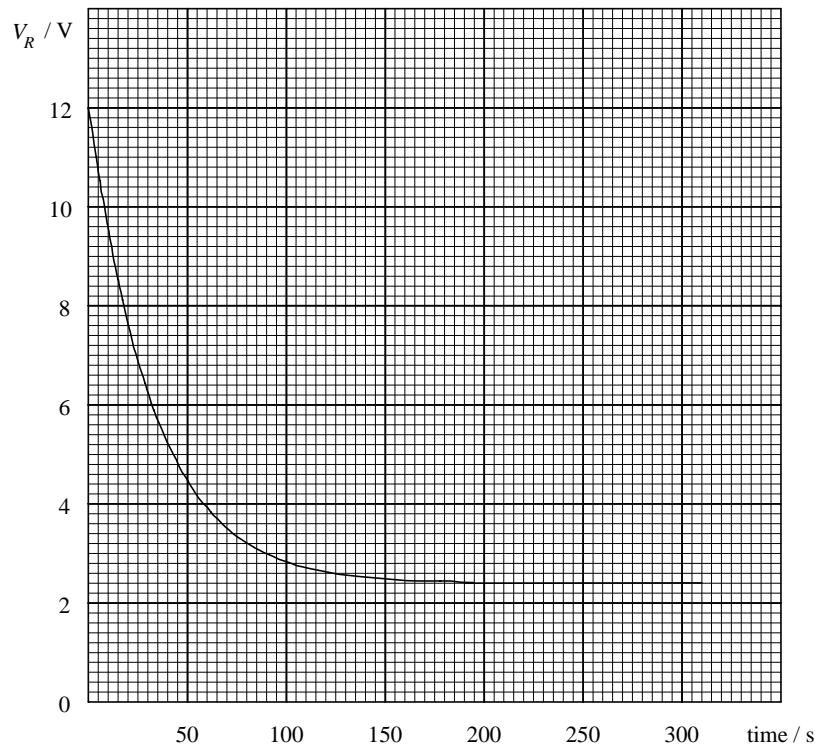


Figure 4

At the same time, the student also notes down, from the voltmeter  $V$ , the variation of the p.d. across  $R$  ( $V_R$ ) as a function of time. The observed variation is shown in Figure 4. The student then draws the conclusion that the capacitor is leaking. In answering the following questions, you may assume that a leaking capacitor can be regarded as a capacitor with a high resistance  $R_0$  (the leakage resistance) connected in parallel.

- (a) Sketch on Figure 4, the expected variation of  $V_R$  with time if the capacitor is NOT leaking.
- (b) Explain the difference between the two curves, and indicate the reason why the fact that  $V_R$  approaches a constant value after 200 s suggests a leaking capacitor.
- (c)
  - (i) Sketch below the variation of charge  $Q$  stored in capacitor  $C$  as a function of charging time  $t$ . (No numerical values to be calculated.)
  - (ii) Calculate the final charge stored on capacitor  $C$ .
  - (iii) Calculate the leakage resistance  $R_0$ .

(12 marks)

5.

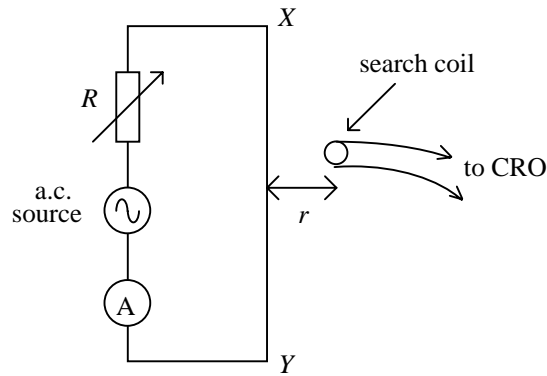


Figure 5

A student fixes a straight wire  $XY$ , about 1 m along, on a table and connects it in series with an a.c. power supply, a rheostat and an ammeter, as shown in Figure 5. He also connects a search coil to a CRO. Starting at a position near the middle of the straight wire, he places the search coil flat on the table at various distances  $r$  from the wire and measures the corresponding peak-to-peak voltages  $V$  on the CRO.

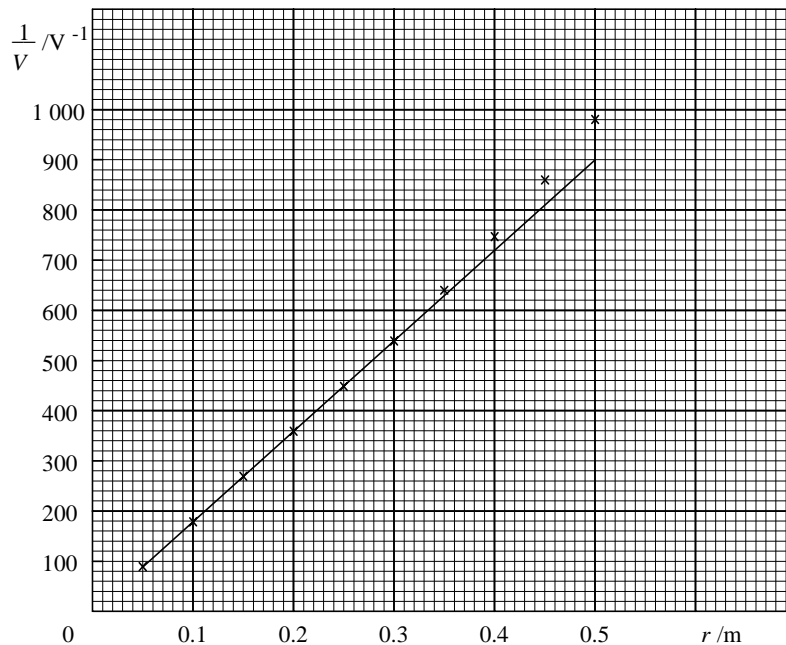


Figure 6

(a) The student plots  $1/V$  against  $r$ , as shown in Figure 6.

- (i) It is found that the first six data points lie on a straight line. What experimental conclusion can you draw about the variation of the magnetic flux density due to the alternating current at various distances from the wire?
- (ii) Explain why the data points for  $r > 0.3$  m depart from the fitted straight line.

- (b) (i) In this experiment, the variation of current with time  $t$  in the long straight wire is  $I_0 \sin(2\pi ft)$ , where  $I_0$  is the peak current and  $f$  the a.c. frequency. If the search coil is of area  $A$  and consists of  $N$  turns, find an expression for the peak-to-peak voltage  $V$  induced in the search coil when  $r \leq 0.3$  m.
- (ii) If  $I_0 = 14.1$  A,  $f = 50$  Hz,  $A = 3.14 \times 10^{-4}$  m<sup>2</sup> and  $\mu_0 = 1.26 \times 10^{-6}$  H/m, estimate the number of turns in the search coil.
- (c) Another student argues that the results obtained in this experiment are not accurate because the influence of the earth's magnetic field has not been considered. In this argument correct? Give a brief explanation.

(12 marks)

6. The radiation level of a mixture of samples of radioactive iodine-131 and iodine-133 is monitored, and the number of counts per minute,  $C$  (excluding the background rate) are taken at different times  $t$ . A graph of  $\log_{10} C$  is then plotted against  $t$ , as shown in Figure 7.

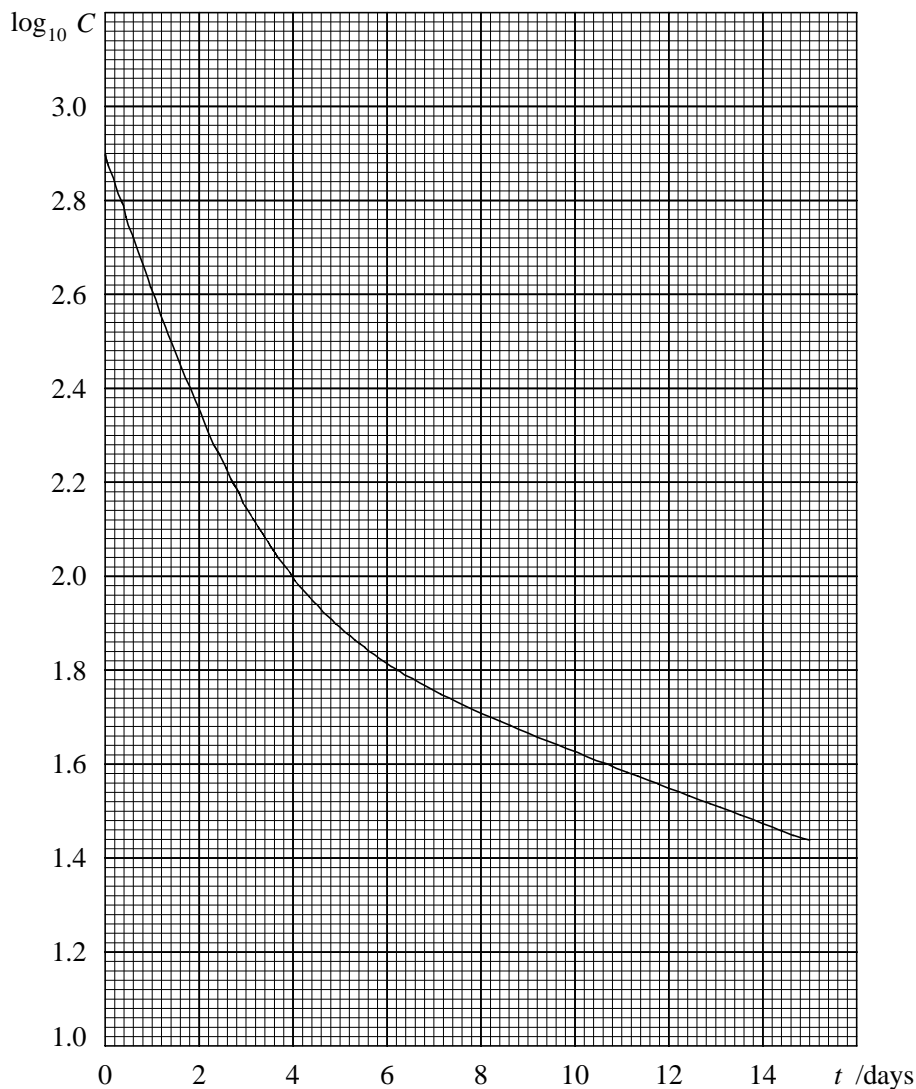


Figure 7

- (a) It is known that the half-life of iodine-131 is much longer than that of iodine-133. Explain why the curve approaches a straight line after 10 days.
- (b) From the decay curve, estimate the half-life of iodine-131. Explain your working.
- (c) (i) Determine the initial count-rate of iodine-133.
- (ii) Given that the half-life of iodine-133 is 20.8 hours, find the initial mass ratio of iodine-131 to iodine-133. (12 marks)