

HONG KONG ADVANCED LEVEL EXAMINATION  
AL PHYSICS  
1995 Structural Question

1. Figure 1.1 shows a light spring fixed vertically to the ground at its lower end and with a small aluminium pan of negligible weight attached to its upper end. When a small block of mass 0.1 kg is placed on the pan, a compression of 5 cm is observed after the pan settles. Assume the spring obeys Hooke's law and damping can be neglected.

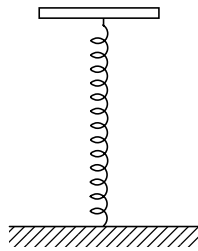


Figure 1.1

- (a) Find the force constant (i.e. force per unit extension or compression) of the spring. (1 mark)
- (b) (i) If the block and the pan are pushed slightly downwards and released, calculate the period of oscillation of the system. (2 marks)
- (ii) Find the maximum amplitude of oscillation for which the block would not leave the pan. (3 marks)
- (iii) Figure 1.2 shows the variation of kinetic energy of the block with its height above the ground. (The gravitational potential energy of the block is taken to be zero at the ground.)

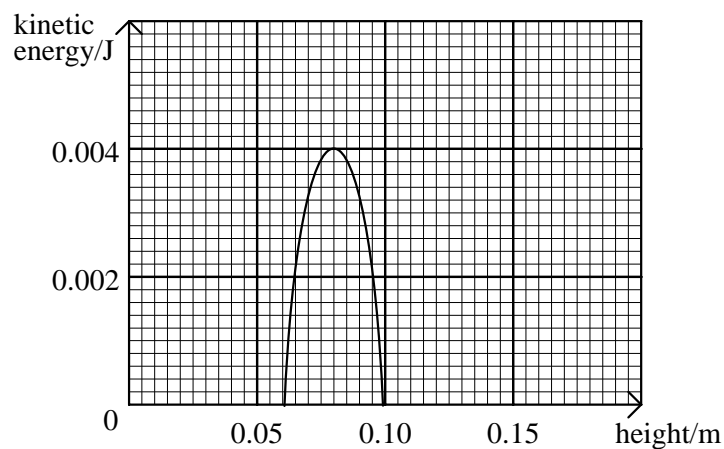
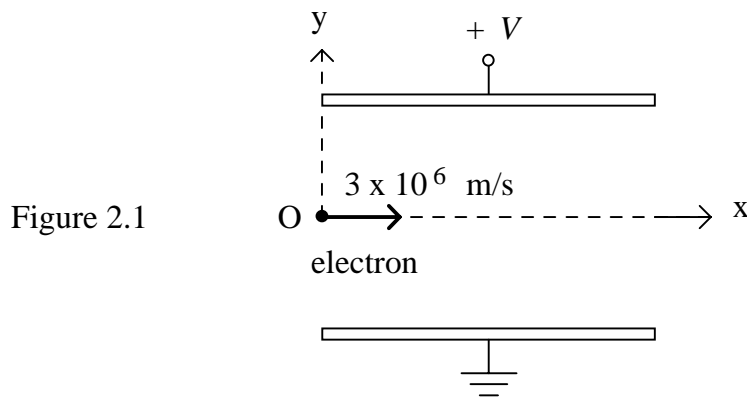


Figure 1.2

- (I) Find the amplitude of oscillation of the block. (1 mark)
- (II) If the total energy of the system remains constant at 0.109 J, find the maximum elastic potential energy stored in the spring. (2 marks)
- (c) The system is now brought to a planet with a smaller gravitational field strength than that of the earth. How would the answers to (b)(i) and (b)(ii) be affected? Explain briefly. (2 marks)
2. In Figure 2.1, a potential difference is applied across two parallel plates to establish a region of uniform electric field in between. An electron is fired with an initial velocity of  $3 \times 10^6$  m/s into that region. After  $5 \times 10^{-8}$  s, the electron leaves the parallel plates with a velocity of  $5 \times 10^6$  m/s.



Assume that the electric field is zero outside the region in between the parallel plates. The effect of gravity on the electron is negligible.

(Given: mass of electron =  $9 \times 10^{-31}$  kg.)

- (a) What is the direction of the force acting on the electron when it is between the parallel plates? (1 mark)
- (b) Sketch on Figure 2.1 the path of the electron, showing its flight both inside and outside the region between the parallel plates. (2 marks)
- (c) Find the change in electric potential energy of the electron after flying between the parallel plates. (2 marks)
- (d) Find the magnitude of the acceleration of the electron when it is between the parallel plates. (3 marks)
- (e) Find the displacements of the electron in x- and y- directions after flying between the parallel plates. (2 marks)
- (f) What would the time of flight and the displacement in y-direction of the electron be if the potential difference across the plates is doubled? Explain briefly. (4 marks)

3.

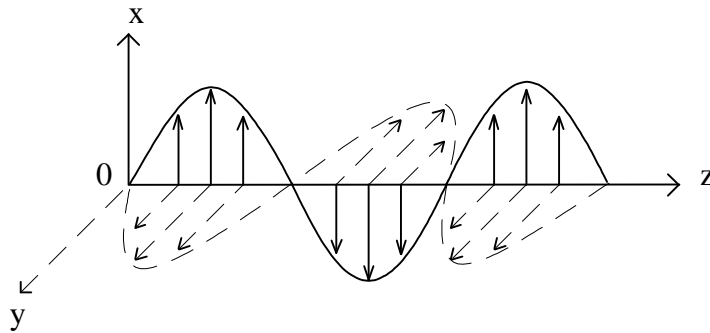


Figure 3.1

Figure 3.1 shows a section of a continuous plane polarized electromagnetic wave of frequency 10 000 MHz travelling in space at a certain time. The vectors in x-direction represent the varying electric field travelling along positive z-direction.

- (a) What is represented by the vectors in y-direction? (1 mark)
- (b) Using the reference frame provided below, sketch the wave form at a time  $0.5 \times 10^{-10}$  s later. (2 marks)

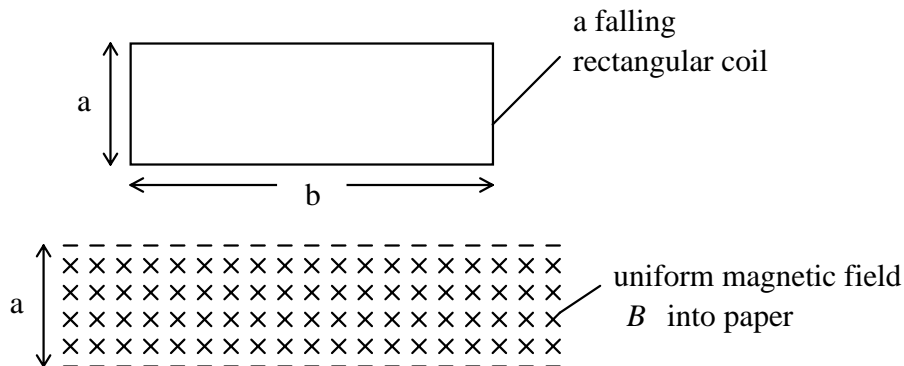


- (c) An antenna in the form of a straight rod is used to receive the electromagnetic wave. How should the antenna be orientated so that maximum signal (induced e.m.f. in the rod) is obtained? Explain briefly. (2 marks)
- (d) What happens to the signal received by the antenna in (c) when a grid of parallel conducting wires is placed in front of the antenna, with the conducting wires
- parallel to the x-direction,
  - parallel to the y-direction.

Explain briefly. (4 marks)

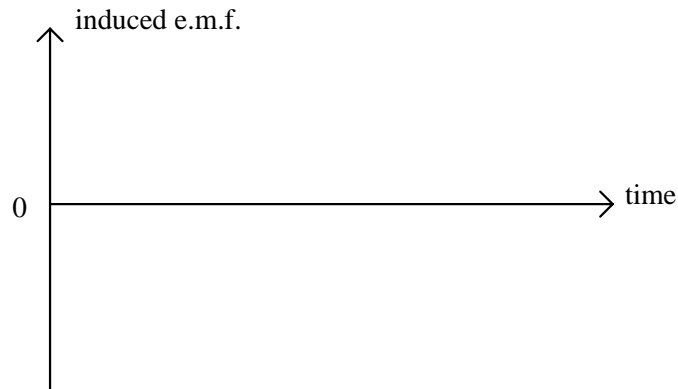
- (e) If an antenna is in the form of a plane circular loop, how should it be orientated to receive maximum signal? Explain briefly. (2 marks)

4.



A rectangular coil of length  $a$ , breadth  $b$ , mass  $m$  and total resistance  $R$  falls freely, with its plane vertical. It enters a region of uniform magnetic field  $B$  normal to the plane containing the coil.

- (a) If it so happens that the coil falls at constant velocity  $v$  just as it enters the field region till it completely leaves that region, sketch the variation of induced e.m.f. in the coil with time during falling. (2 marks)



- (b) Write an expression for the induced current  $I$  in terms of  $B$ ,  $v$ ,  $R$  and the dimensions of the coil just as the coil enters the field region. (2 marks)
- (c) The induced current causes a heating effect in the coil. Use the answer obtained in (b) to find an expression for the total thermal energy generated in the falling process. (3 marks)
- (d) Where does the electrical energy come from? (1 mark)
- (e) (i) Write an equation relating the forces acting on the coil when it falls with constant velocity in the field region. (1 mark)

- (ii) Hence or otherwise express the total thermal energy obtained in (c) in terms of the mass and the dimensions of the coil. (2 marks)

5.

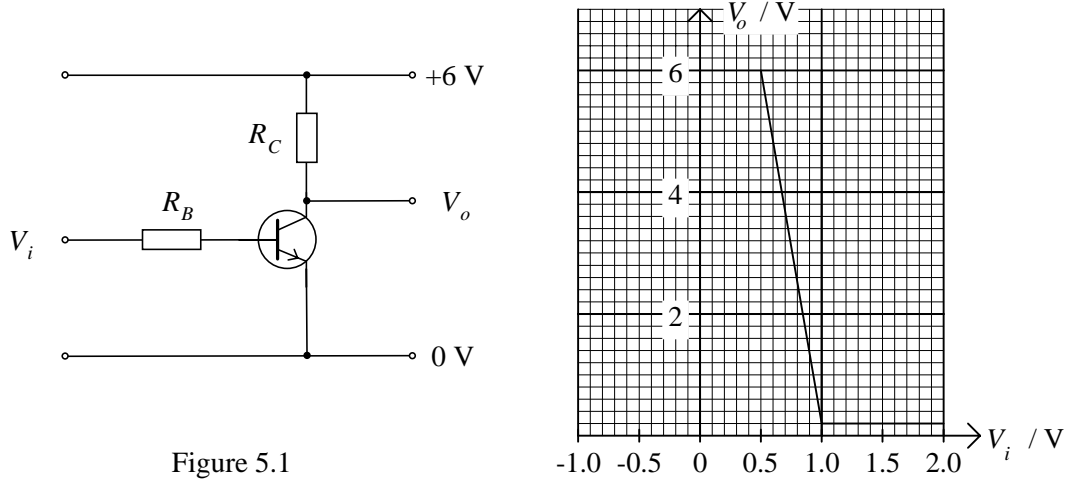


Figure 5.1

Figure 5.1 shows a typical silicon transistor circuit together with its input/output voltage characteristics.

- (a) If the input voltage  $V_i$  to the circuit is varied in the way shown on the graphs in Figure 5.2, sketch the variation of the output voltage  $V_o$  with time for each case. Label the axes with appropriate scales. (4 marks)

(i)

(ii)

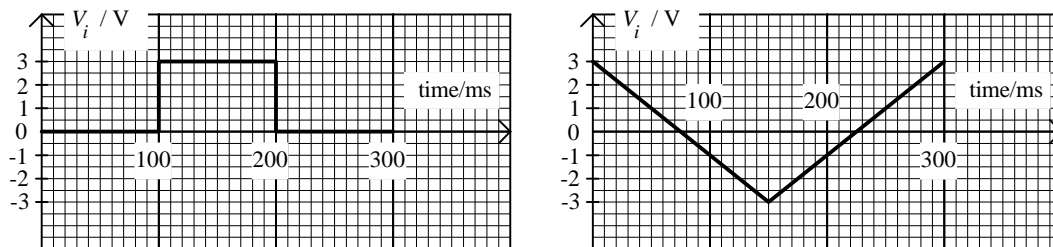
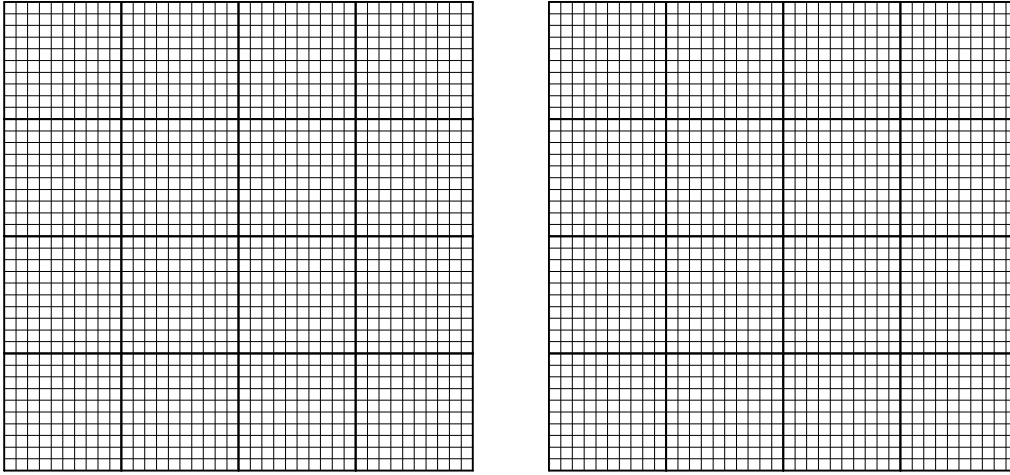


Figure 5.2



- (b) It is given that the current amplification factor of the silicon transistor is 80 and  $R_C = 1.5 \text{ k}\Omega$ .
- When  $V_i$  is 1 V, what are the collector current and base current? (3 marks)
  - Hence determine the value of  $R_B$ . (The voltage between the base and the emitter is constantly 0.5 V when conducting.) (2 marks)
- (c) If an input signal varying between -0.24 V and +0.24 V is to be accurately amplified without distortion, two resistors and two capacitors are added to the original circuit. The resulting circuit is shown in Figure 5.3.

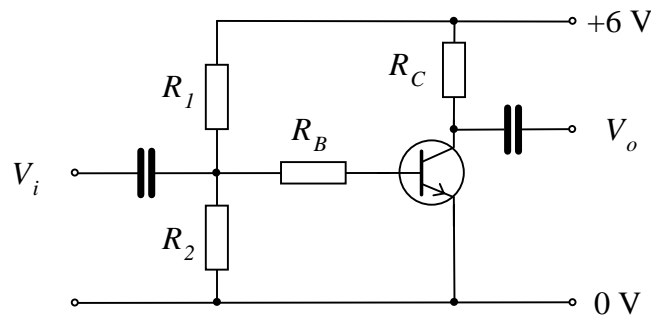


Figure 5.3

- What should be the value of  $R_1/R_2$  for providing an optimal bias voltage for the transistor? (2 marks)
- What is the peak voltage of the output signal? (2 marks)

Figure 6.1

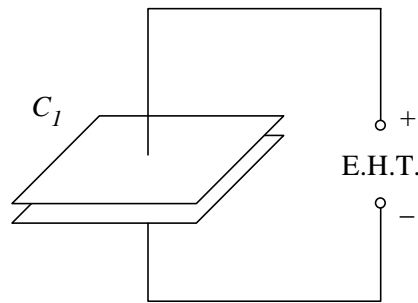
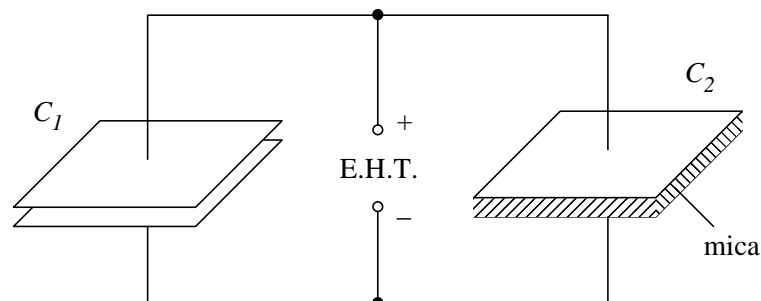


Figure 6.1 shows a capacitor  $C_1$ , formed by two square metal plates of length 0.25 m, connected with a variable E.H.T. supply. The capacitance of the capacitor is  $3.70 \times 10^{-10}$  F.

(Given: permittivity of free space =  $8.85 \times 10^{-12}$  F/m)

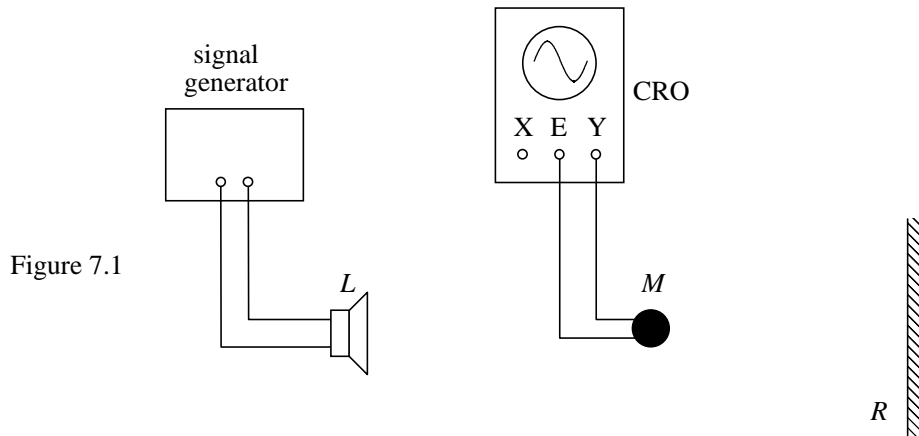
- (a) (i) Express the electric field strength between the parallel plates,  $E$ , in terms of the potential difference across the plates,  $V_0$ . (2 marks)
- (ii) It is known that electric breakdown occurs (i.e. conduction happens between the plates) when the electric field strength between the plates reaches  $3 \times 10^6$  V/m. Find the potential difference at which electric breakdown occurs for capacitor  $C_1$ . (2 marks)
- (b) Another capacitor  $C_2$ , identical to  $C_1$  but with a sheet of mica in between, is also connected to the same E.H.T. supply as shown in Figure 6.2.

Figure 6.2



- (i)  $C_1$  and  $C_2$  are then disconnected from the supply and the charges on each of them are measured by an electrometer. The readings on the output meter of the electrometer are 0.12 mA and 0.60 mA respectively. Find the ratio of the capacitance of  $C_2$  to that of  $C_1$ . Show your working. (2 marks)
- (ii) With both  $C_1$  and  $C_2$  charged to a potential difference of 500 V, the E.H.T. supply in Figure 6.2 is then removed, and the mica sheet is also removed from  $C_2$ . Find the resulting charge and potential difference of  $C_2$ . (4 marks)
- (c) Give two advantages of placing a sheet of mica between the plates of a capacitor in practice. (2 marks)

7. A student uses the apparatus shown in Figure 7.1 to determine the speed of sound in air. A loudspeaker,  $L$ , is connected to the signal generator and a microphone,  $M$ , is connected to the Y-input and the earth terminal of a CRO. The loudspeaker  $L$  and the reflecting plate  $R$  are placed on a metre rule (not shown) with the microphone  $M$  between them. The axis of the loudspeaker is along the metre rule and perpendicular to the reflecting plate.



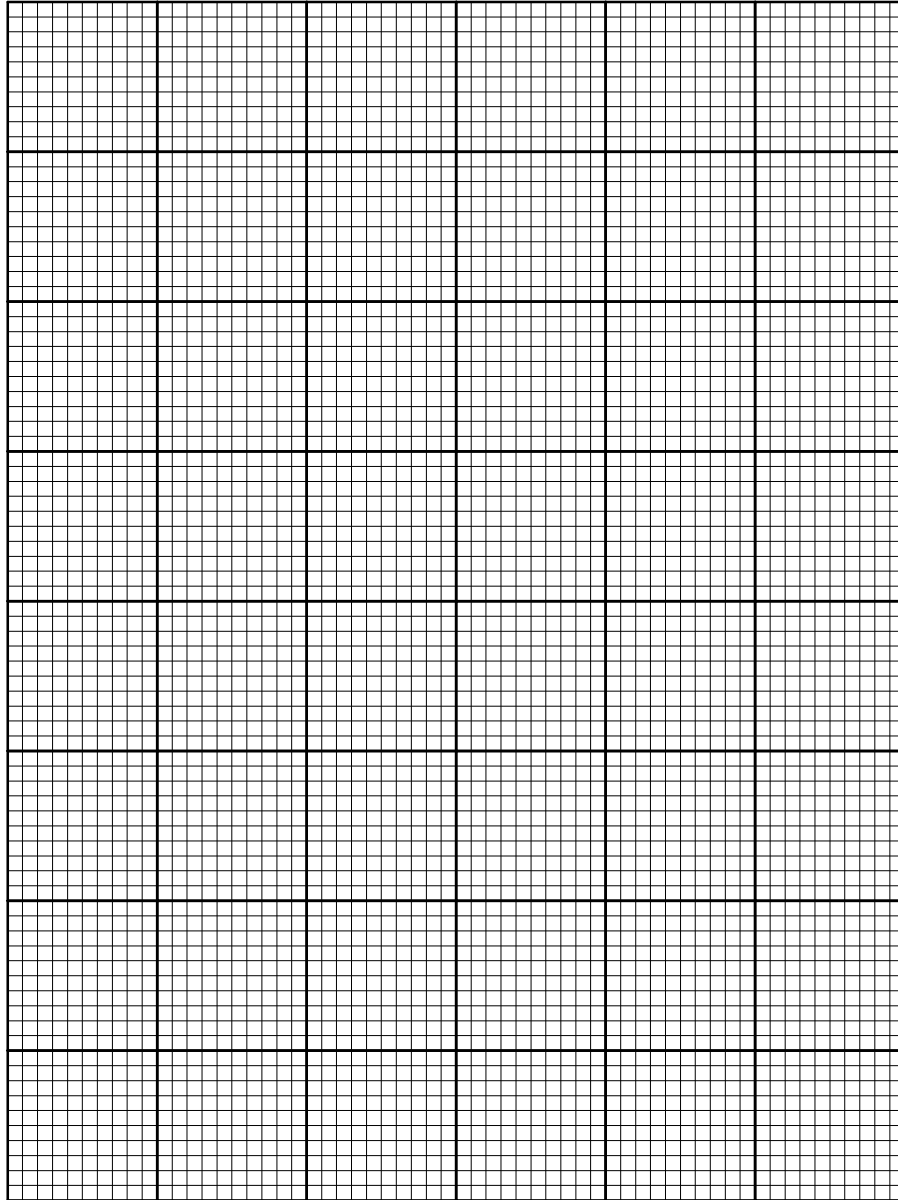
- (a) Give one property that the reflecting plate should have. (1 mark)
- (b) With the signal generator set at a certain frequency, briefly describe the procedures you would follow to set up stationary sound waves between the loudspeaker and the reflecting plate. (2 marks)
- (c) With the stationary waves set, the microphone  $M$  is moved along the axis of the loudspeaker and the trace on the CRO screen is seen to vary in size. Consecutive positions of  $M$  are recorded whenever the trace has its smallest amplitude. The procedure is repeated for different signal frequencies. The results are recorded in Table 7.1 below:

Frequency of signal generator/kHz	Positions of $M$ corresponding to the smallest amplitude of the CRO trace/cm	Wavelength $\lambda$ /cm	Period $T$ /ms
2.500	27.0, 34.0, 41.0, 47.9, 54.5, 61.6, 68.7		
2.941	16.0, 22.0, 28.1, 33.7, 39.6, 45.7, 51.5		
3.571	18.7, 23.7, 28.4, 33.3, 38.4, 43.5, 48.1		
4.545	31.8, 35.8, 39.8, 43.6, 47.4, 51.5, 55.5		
6.250	26.4, 29.4, 32.4, 35.2, 38.2, 41.5, 44.7		

Table 7.1

- (i) Show clearly how you determine the wavelength of sound in air by using the data corresponding to the frequency 2.500 kHz. (1 mark)

- (ii) Complete Table 7.1 and plot a graph of wavelength  $\lambda$  against period  $T$ .  
(5 marks)



- (iii) Hence find the speed of sound in air. (2 marks)
- (iv) Why did the student not use frequencies of uniform intervals, say for example, of 0.5 kHz? (1 mark)
- (v) Explain why the graph does not pass through the origin. (1 mark)
- (d) Explain an advantage of performing the experiment outdoors. Suggest one remedial measure when doing the experiment indoors. (2 marks)

8. (a) A student uses the circuit in Figure 8.1 to measure the resistance of a resistor,  $R$ , with an unknown order of magnitude. The voltmeter and the ammeter are ordinary moving-coil meters used in school laboratories. He first connects  $K$  to  $X$  with a flying lead and then to  $Y$ .

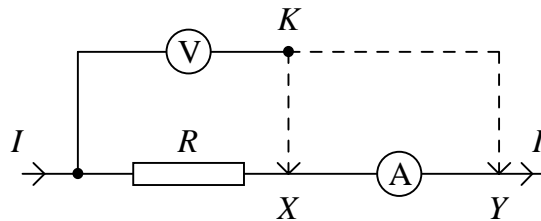


Figure 8.1

- (i) Describe the change in the readings of the voltmeter and the ammeter, if any, when the flying lead from  $K$  is moved from  $X$  to  $Y$  for
- (I)  $R$  of a few ohms, (1 mark)
- (II)  $R$  of a few kilo-ohms. (1 mark)
- (ii) The student decides to connect  $K$  to  $Y$ . The voltmeter and the ammeter read  $6\text{ V}$  and  $0.8\text{ mA}$  respectively.
- (I) Comment, with reasons, on his choice of connecting  $K$  to  $Y$ . (2 marks)
- (II) Find the true value of  $R$  if the resistance of the ammeter is  $20\ \Omega$ . (1 mark)
- (b) The circuit in Figure 8.2 is employed to measure the e.m.f.,  $E$ , and the internal resistance,  $r$  (a few ohms), of a dry cell. (Assume the voltmeter and the ammeter used are ideal.)

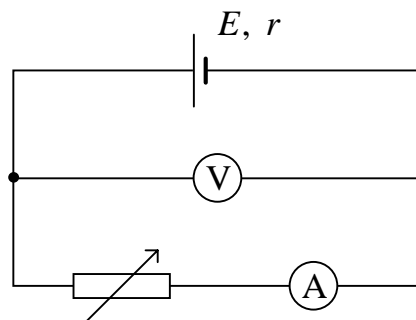
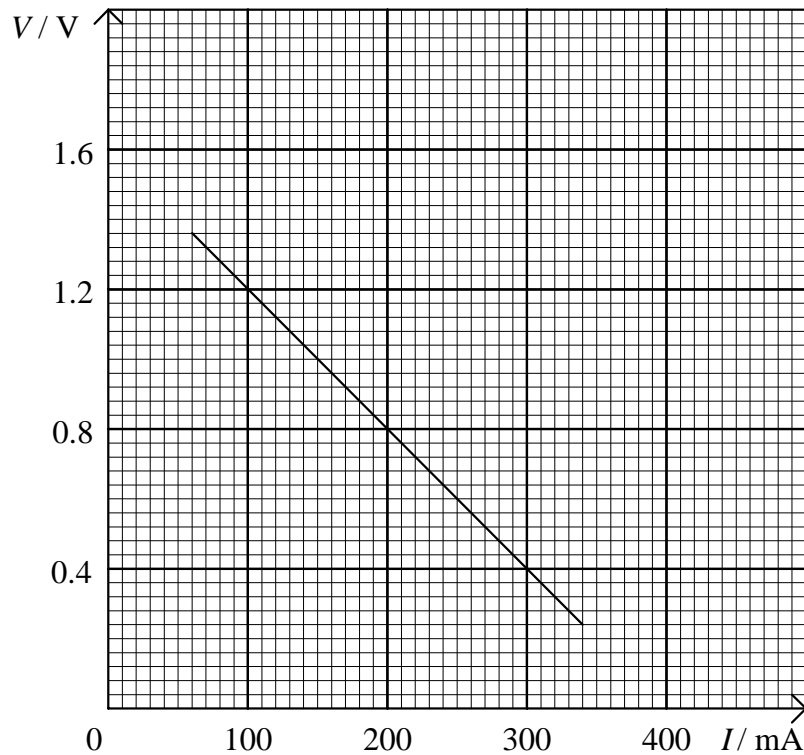


Figure 8.2

- (i) If the full-scale deflection of the ammeter is 500 mA, suggest which ranges of the voltmeter and the rheostat it would be suitable to use. (1 mark)
- (ii) The voltmeter readings,  $V$ , and the ammeter readings,  $I$ , obtained for different rheostat settings are used to plot the graph below.



Express  $V$  in terms of  $E$ ,  $I$  and  $r$ . Hence deduce from the graph the e.m.f. and the internal resistance of the cell. (3 marks)

- (iii) It can be proved that when the resistance of the rheostat equals the internal resistance of the cell, maximum power output from the cell would be obtained. Find an expression of this maximum power output in terms of  $E$  and  $r$ , and calculate the corresponding output efficiency of the cell. (3 marks)

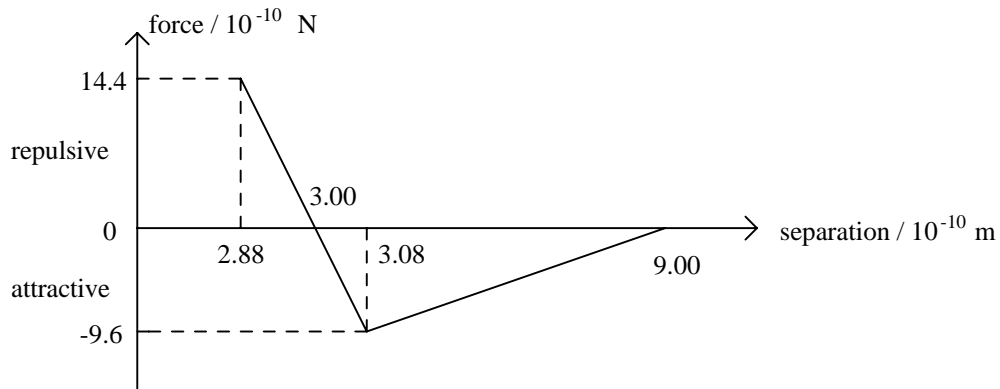


Figure 9.1

The graph in Figure 9.1 shows a simplified model of the force between two atoms plotted against their distance of separation.

(a) Use the graph to determine

(i) the energy required to separate two atoms completely. (2 marks)

(ii) the potential energy of the atoms at a separation of  $2.88 \times 10^{-10}$  m. (The potential energy is taken to be zero when the atoms are infinitely apart.) (2 marks)

(b) For a solid formed by the atoms mentioned, estimate

(i) the Young modulus of the solid. (Hint: the atoms in a solid can be considered as connected by 'small springs'.) (2 marks)

(ii) the breaking stress of the solid. (Assume the solid has a cubic arrangement of atoms.) (2 marks)

(c) The Young modulus and the breaking stress of a copper wire are  $4.3 \times 10^{11}$  Pa and  $2.0 \times 10^8$  Pa respectively. Compare the strength and stiffness of copper with those of the above solid. Give reasons for your points of comparison. (2 marks)

10. A geologist wants to find the age of a sample of rock containing  $^{40}\text{K}$  which decays to give the stable isotope  $^{40}\text{Ar}$ . The activity of the sample is found to be 1.6 Bq while the original activity of a similar rock having the same mass is 4.8 Bq. The half-life of  $^{40}\text{K}$  is  $1.3 \times 10^9$  years.

(a) (i) Find the decay constant of  $^{40}\text{K}$ . (2 marks)

(ii) Give the physical meaning of the decay constant of a radioactive isotope. (2 marks)

(b) Find the age of the rock sample. (2 marks)

- (c) Give two factors that determine the activity of a radioactive source. (2 marks)
- (d) The decay of  $^{40}\text{K}$  to  $^{40}\text{Ar}$  is spontaneous. How is the magnitude of the binding energy of  $^{40}\text{K}$  compared to that of  $^{40}\text{Ar}$ ? (2 marks)
- (e) Mention a difficulty involved in measuring such a small decay rate of 1.6 Bq. (1 mark)

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