HONG KONG ADVANCED LEVEL EXAMINATION
AL PHYSICS
1988 Structural Question

7. An ice-skater is spinning about a vertical axis through his body at a speed of 0.5 revolutions per second. He extends his arms horizontally with a weight of mass 2 kg in each hand. Assume that the moment of inertia of the skater himself remains constant at 0.8 kg m^2.

   (a) If the distance of the weights from the axis of rotation is 0.9 m, find

   (i) the total moment of inertia of the skater and the weights about the vertical axis, (2 marks)

   (ii) the total angular momentum of the skater and the weights about the vertical axis. (2 marks)

   (b) (i) If the skater pulls his hands to his sides so that the two weights are at a distance of 0.2 m from the axis of rotation, calculate his final rotational speed. Friction on ice can be neglected. (2 marks)

   (ii) What is the change in the total kinetic energy of the skater and the weights? Has this kinetic energy been increased or decreased? How do you account for this change? (4 marks)

8. (a)

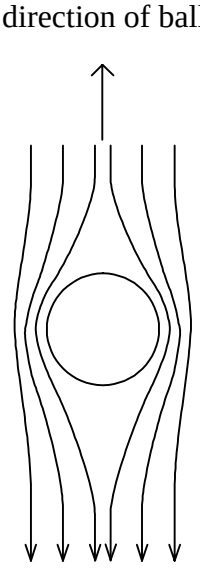

Figure 8.1

(i) Figure 8.1 shows the streamlines around a tennis ball when it is projected in a straight line through still air. In Figure 8.2, sketch the streamlines in the vicinity of the ball if; apart from the forward motion, it is also spinning about an axis, through its centre, perpendicular to the plane of paper in an anti-clockwise direction. (2 marks)

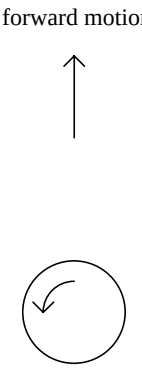

Figure 8.2

(ii) Describe, with reasons, the subsequent motion of the ball. (4 marks)

(b) (i) One end of an open tube is put vertically into water. By blowing strongly across the open end, water can be drawn up the tube. Suppose a few centimetres of the tube is above the water surface. What should be the air velocity at the open end for water in the tube to rise up by 1 cm? Explain your working. (Surface tension effects may be ignored.) (3 marks)

(Density of air = 1.29 kg/m^3,
Density of water = 1 000 kg/m^3,
Acceleration due to gravity = 10 m/s^2)

(ii) Mention one daily application making use of the principle described in (b)(i). (1 mark)

9. Figure 9.1 shows a diffraction grating with a total of 10 000 parallel slits, each slit being 10^{-6} m from the next. Light of wavelength λ = 589.0 nm from a sodium vapour lamp falls perpendicularly onto the grating.

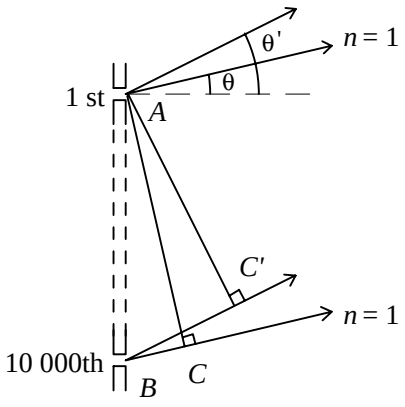

Figure 9.1

(a) (i) Calculate the angle θ in degrees (to an accuracy of 3 decimal places) for the first order of maximum intensity. (2 marks)

(ii) What is the path difference *BC* (in terms of wavelength λ) between waves from the 1st and 10 000th slit? (1 mark)

(b) Now consider waves emerging at a slightly larger angle θ' such that the resultant amplitude of the waves from all the slits in this new direction is zero. What is the path difference *BC*' (in terms of λ) between waves from the 1st and 10 000th slits? (2 marks)

(Hint: consider the path difference between light from the slit pairs 1st and 5 001st, 2nd and 5 002nd etc.)

(c)

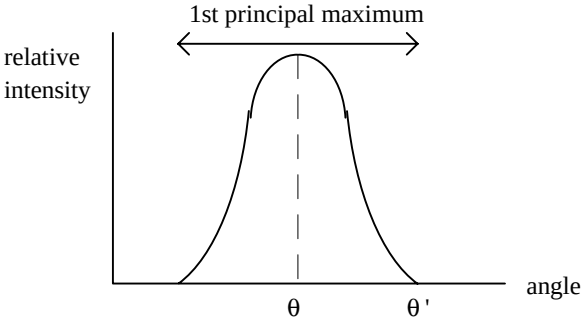

Figure 9.2

θ' is the angular position of the minimum intensity following the first order maximum intensity (Figure 9.2). Calculate the angular half-width [i.e. (θ' - θ)] for the first order spectral line. (3 marks)

(d) Suppose the incident light contains another wavelength λ' = 589.6 nm. Can these two spectral lines be distinguished as two separate lines? Explain your reasoning. (4 marks)

10. (a)

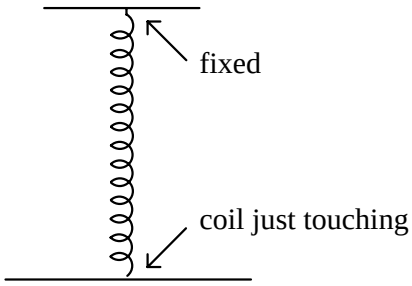

Figure 10.1

A d.c. electrical circuit includes a conductor in the form of a helical coil which is connected vertically between two terminals. The lower end of the conductor is not connected tightly but rests on the lower terminal, making electrical contact with it. When the circuit is switched on, it is found that current starts and stops periodically and that sparks appear at the lower terminal. Explain briefly

(i) the periodic bursts of current, (3 marks)

(ii) the appearance of sparks. (3 marks)

(b) The rate at which current is switched on and off depends on a number of factors. State one of these factors. (1 mark)

(c)

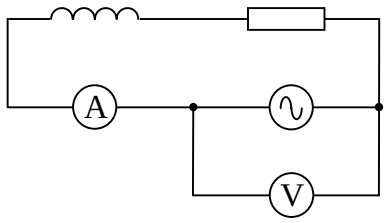

Figure 10.2

The coil is then connected in the circuit as shown in Figure 10.2. The a.c. source is a signal generator whose output frequency f and r.m.s. voltage V can be varied. As f is changed, V is adjusted so that the current recorded by the a.c. ammeter is kept constant at 10 mA r.m.s. The experiment is repeated a number of times, and V^2 is then plotted against f^2, as shown in Figure 10.3.

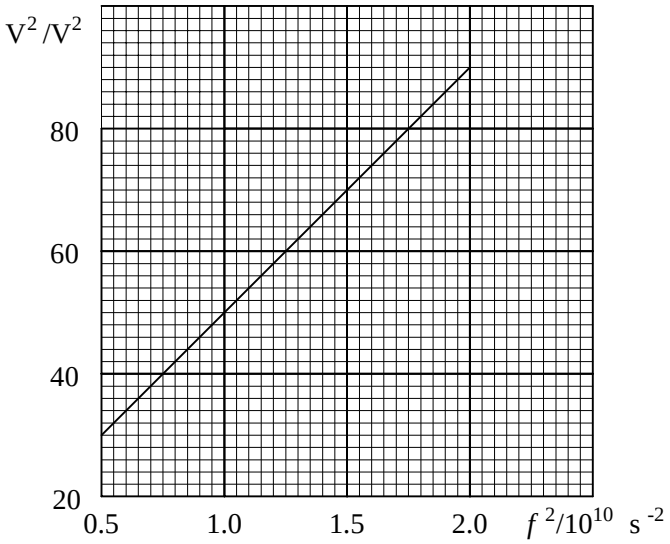

Figure 10.3

Use the graph to calculate the inductance of the coil. (3 marks)

11.

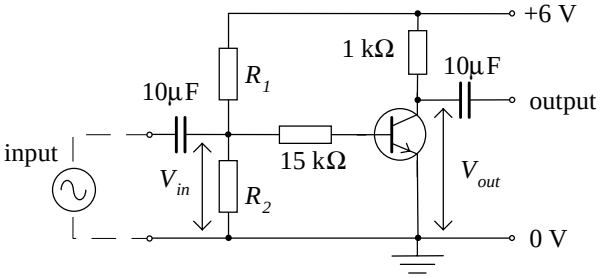

Figure 11.1

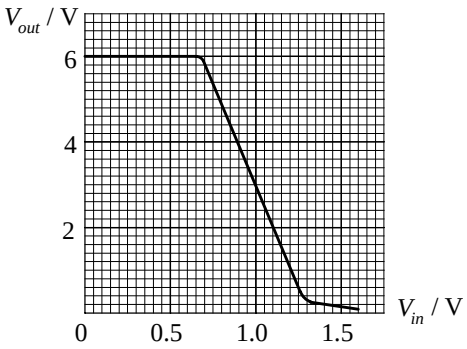

Figure 11.2

Figure 11.1 shows a simple amplifier circuit which consists of a NPN silicon transistor. The input/output voltage characteristic of the transistor is shown in Figure 11.2.

(a) The circuit is designed in such a way that, without any input signal, the d.c. potential at the collector of the transistor (V_{out}) is 3 V.

(i) Explain the advantage of setting the collector voltage at this value. (2 marks)

(ii) Assuming that the base current is negligible, what is the ratio of resistances R_1 to R_2? (2 marks)

(b) An input signal from a signal generator is fed into the amplifier via a 10 μF capacitor. Explain the use of such a large value capacitor. (2 marks)

(c) Suppose the signal generator superposes on V_{in} a voltage varying between ±0.1 V as shown in Figure 11.3. Making use of Figure 11.2, sketch on Figure 11.3 the expected variation in voltage of the output signal. (2 marks)

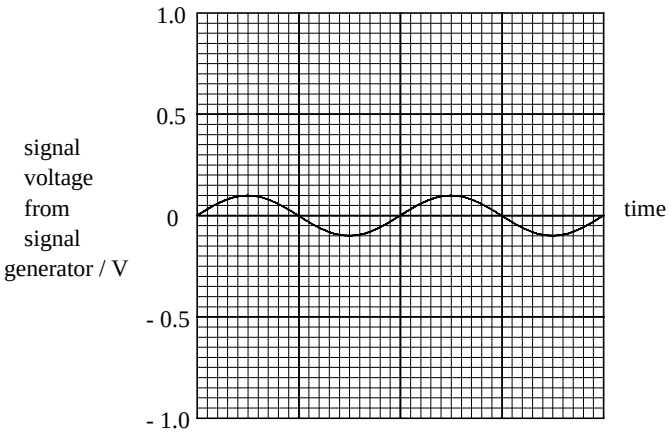

Figure 11.3

(d) Estimate the current gain (β) of the transistor within the linear region. (2 marks)

(e)

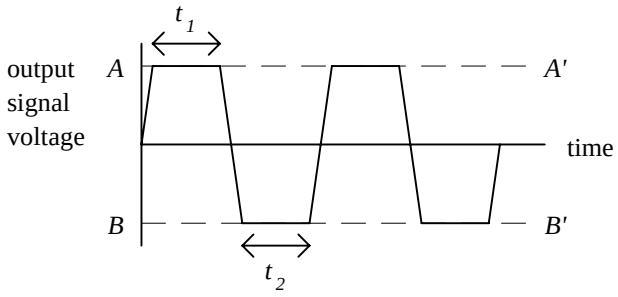

Figure 11.4

(i) When the input signal voltage from the signal generator is gradually increased, the output signal voltage appears in the form shown in Figure 11.4. Explain why this should happen. (3 marks)

(ii) Estimate the p.d. between the collector and the emitter (V_{CE}) and the collector current (I_C) during time interval t_1 and t_2 when the voltage curve appears 'flat'. Give your answers in the table below. (2 marks)

Time interval	V_{CE}	I_C
t_1	_____	_____
t_2	_____	_____

12.

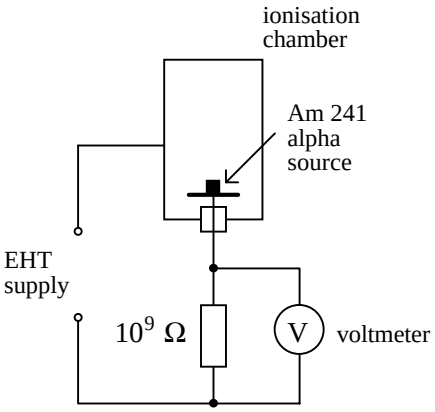

Figure 12.1

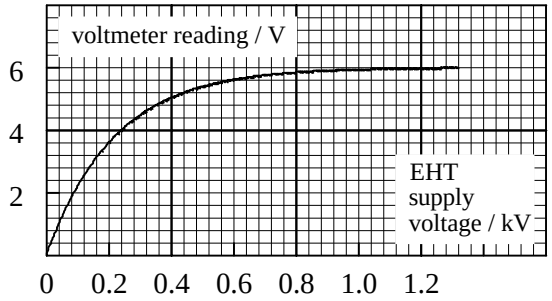

Figure 12.2

A student performs an experiment with an ionisation chamber, using the arrangement shown in Figure 12.1. The current flowing through the chamber is found by measuring the p.d. across the 10^9 Ω resistance using a voltmeter with an internal resistance of the order of 10^{14} Ω.

(a) After introducing an Americium-241 radioactive source (which emits alpha-particles) into the chamber, the student gradually increases the p.d. between the source and the chamber wall. A plot of the voltmeter readings against the E.H.T. supply voltages is shown in Figure 12.2. It is found that the voltmeter reading increases as the E.H.T. voltage is increased, but remains at 6 V when the E.H.T. voltage reaches 800 V.

(i) Why is the ionisation current not increased further by increasing the applied anode voltage? (2 marks)

(ii) At what anode voltage should the ionisation chamber be normally operated? Explain briefly. (2 marks)

(b) (i) Assuming the charge on a single ion to be the same as that on an electron, calculate the number of ion-pairs detected per second. (Charge of an electron = 1.6×10^{-19} C) (2 marks)

(ii) The activity of the Americium source used in the experiment is 2×10^5 Bq (1 Bq = 1 disintegration per second). Find the number of ion-pairs produced per alpha particle. You may assume that for each disintegration of an Americium nuclide, an alpha particle is produced. (1 mark)

(iii) Estimate the energy of the emitted alpha particles. You may assume that, on average, an alpha particle loses 30 eV of its energy for each ion-pair produced. (1 mark)

(c) (i) The student said, ‘one major source of error in this experiment to determine the alpha particle energy (as in (b) above) is that the energy

imparted to the emitted alpha particles by the potential field set up inside the chamber has not been considered.' Is he correct? Explain briefly. (2 marks)

(ii) Mention ONE other source of error besides the one given above.(1 mark)

(d) (i) If the volume of the chamber is significantly reduced, would the saturated current be increased or decreased? Explain briefly. (2 marks)

(ii) Another student wants to use the same set-up to measure the energy of gamma-ray photons emitted by a cobalt-60 radioactive source. Do you think that he can get a reliable result? Explain your answer. (2 marks)

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