HONG KONG ADVANCED LEVEL EXAMINATION
AL PHYSICS
1983 Structural Question

1. A student suggests that gravity can be thought of in the following way:

   "Gravity behaves like an invisible, elastic 'sponge' surrounding the earth. When a ball is thrown up in the air it falls back to the earth because the 'sponge' is compressed and forces the ball back downwards. Things like rockets can escape from the earth because they have enough energy to break right through the 'sponge'."

   (a) A ball is thrown vertically into the air. Sketch the variation of the force acting on the ball with time during its upward and downward motion, according to

   (i) the student's 'sponge' theory,

   (ii) Newton's theory.

   (b) What experiments would you perform in the school laboratory to convince the student that Newton's theory is more likely to be valid? A brief description of the purpose of each experiment is all that is required.

(8 marks)

2. (a) When a jet aeroplane is just taking off from the runway, the speed of the air stream over the top surface of its wings is 90 m/s, while the speed under the bottom surface is 55 m/s. Calculate the mass of the jet plane if the wings have an area of 200 m^2.

(Density of air = 1.29 kg/m^3, acceleration of free fall = 10 m/s^2)

(b) A man notices a fast moving aircraft vertically above him. If the aircraft is travelling parallel to the ground at a height of 5 km, and a supersonic speed of 500 m/s, estimate the time interval before the man hears the sonic boom. Assume that the speed of sound in air is 330 m/s.

(8 marks)

3. (a) Different A-level students make the following statements. In each case state whether or not you agree with the statement, and give brief reasons.

Student A: The internal energy of an ideal gas can be considered as the total kinetic energy of all its molecules.

Student B: The internal energy of a real gas can be considered as the total kinetic energy of all its molecules.

Student C: The internal energy of a gas can be increased without heating it.

(b)

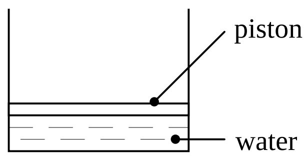


Figure 1

A small mass *m* of water is enclosed in a cylinder by a piston of negligible weight (Figure 1). The water is heated until it completely evaporates. If the pressure outside the cylinder is standard atmospheric pressure and frictional forces between the sides of the cylinder and the piston are negligible, what fraction of the energy required to evaporate the water is converted to internal energy of the surrounding atmosphere? Assume that there are no energy losses to the surroundings through heating.

Data: Standard atmospheric pressure = 101 kPa
Specific latent heat of vaporisation of water = 2.3×10^6 J/kg
Density of water vapour at 101 kPa and 373 K = 0.60 kg/m^3
Density of water = 958 kg/m^3

(7 marks)

4.

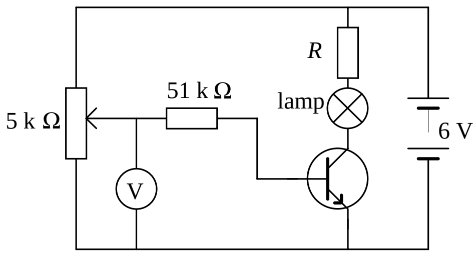


Figure 2

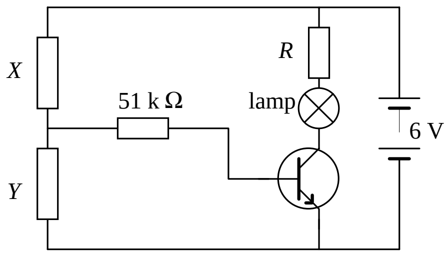


Figure 3

A student has been given the task of building a simple transistor circuit which will make a small lamp glow when a thermistor is warmed.

(a) As a first step he sets up the circuit in Figure 2. He knows that a current of 10 mA will make the lamp glow brightly. What value of *R* should he choose to ensure that the current through the lamp cannot exceed this value?

(b) By adjusting the 5 kΩ potentiometer he finds that he can turn the lamp on and off. When the lamp just begins to glow, he notes that the voltmeter reading is 1.1 V. The student now removes the voltmeter and replaces the potentiometer by a fixed resistor and a thermistor in series. In Figure 3, one of these components is placed in position *X* and the other in position *Y*. If the resistance of the thermistor decreases with temperature, should it be placed in position *X* or position *Y* if the lamp is to glow when the thermistor is warmed? Give reasons.

(c) At room temperature, the resistance of the thermistor is 4.7 kΩ. What value should the student choose for the fixed resistor if the lamp is to start glowing when the thermistor is warmed? Give reasons.

(7 marks)

5.

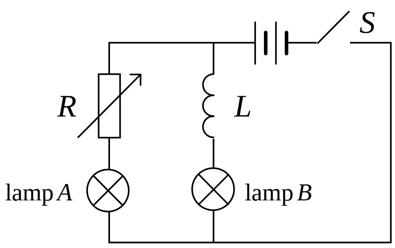


Figure 4

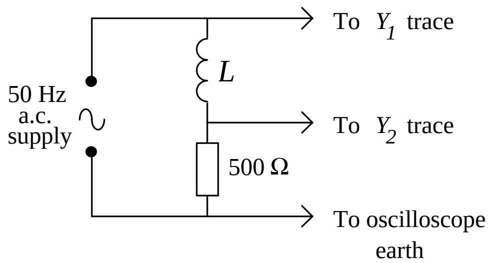


Figure 5

(a) In the circuit in Figure 4, *L* is a very large inductance. With switch *S* closed, resistor *R* is adjusted until the two lamps glow with equal brightness. Assume that this adjustment has been made and that switch *S* has been opened, and left open for some considerable time. If the switch is now closed, what will be observed? Explain.

(b) The large inductance is now connected in series with a 500 Ω resistor and a 50 Hz a.c. supply as shown in Figure 5. The Y_1 and Y_2 inputs of a double trace oscilloscope are connected as shown. (Note that the earth connection is common to both inputs.) With the time base set to 2 ms/cm the stationary pattern shown in Figure 6 is obtained.

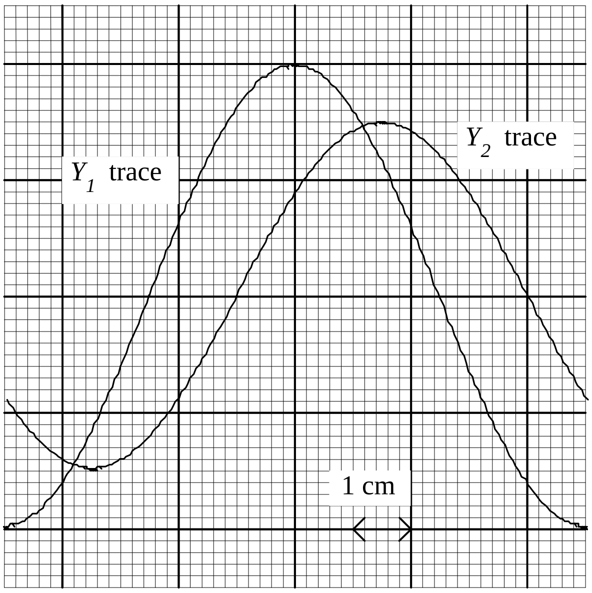
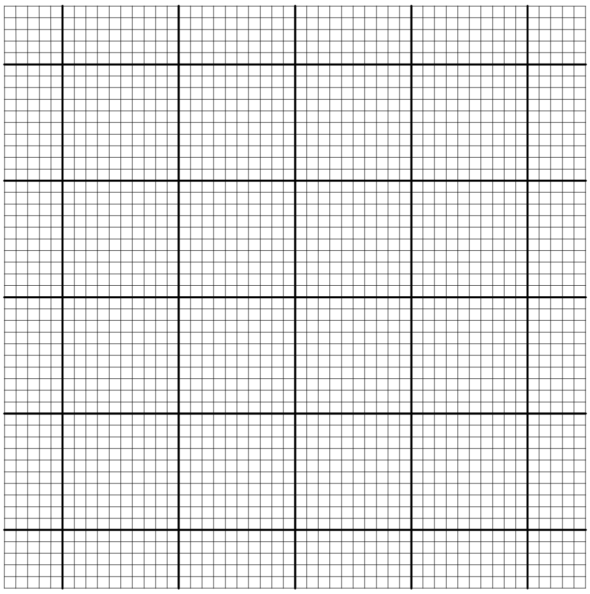


Figure 6

Calculate a value for L, giving a vector (phasor) diagram of the p.d.'s across the inductance and the resistor. (Assume that the inductance has negligible resistance.)

(c) Sketch the pattern you would expect to observe if the connections to the oscilloscope earth and the Y_2 input were interchanged.



(10 marks)

6.

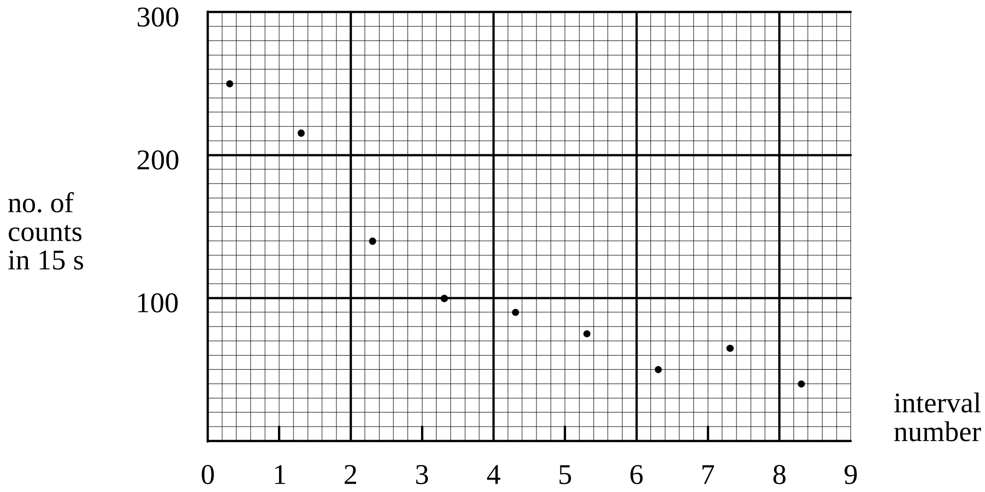


Figure 7

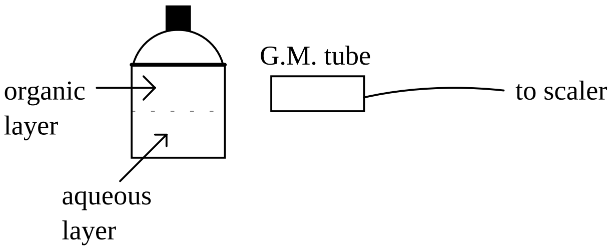


Figure 8

The points plotted in Figure 7 were obtained in an experiment to investigate the decay of the radioactive isotope ^{234}Pa (protactinium 234) using the experimental arrangement of Figure 8. The ^{234}Pa was extracted from an aqueous solution of uranyl nitrate (where it was in equilibrium with its parent ^{234}Th and grandparent ^{238}U) using an organic reagent. The decay scheme leading to the formation of ^{234}Pa in the solution of uranium salt is as follows:

$$^{238}\text{U} \xrightarrow{\alpha} {}^{234}\text{Th} \xrightarrow{\text{low energy } \beta} {}^{234}\text{Pa} \xrightarrow{2.32 \text{ MeV } \beta} {}^{234}\text{U}$$

half-life:	4.5×10^9 years	24.1 days	to be found	2.5×10^5 years

Figure 9

The organic reagent removes about 95% of the ^{234}Pa and some uranium, but no thorium. the thin walled polythene bottle containing the solution was shaken for about 30 s to extract the ^{234}Pa, and readings of the count rate were taken when the organic layer had separated from the aqueous layer using the set-up shown in Figure 8. Counts were taken for the first 15 s in every 30 s interval.

(a) Why are the α particles emitted by the ^{238}U and the β particles emitted by the ^{234}Th not counted by the GM tube?

(b) For a given solution, how would you try to maximize the count rate when performing this experiment?

(c) A student comments that the readings have been taken carelessly because the points plotted in Figure 7 do not fall on a smooth curve. Do you agree? Explain your reasoning.

(d) Use Figure 7 to estimate the half-life of ^{234}Pa. Explain your reasoning.

(e) Estimate the decay constant of ^{234}Pa. Explain your reasoning.

(f) Express in words the relationship between the decay constant and the probability of an atom decaying. (Do not write down any mathematical equations.)

(g) A student argues that he can estimate the initial activity from Figure 7 and then use the value of the decay constant estimated in part (e) above to make a rough calculation of the number of ^{234}Pa atoms originally present in the sample. Do you agree? Explain your reasoning.

(10 marks)

7.

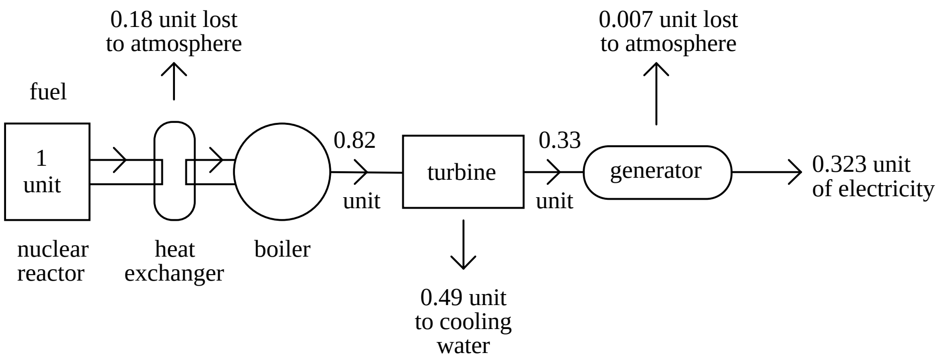


Figure 10

Figure 10 shows what happens to one unit of energy produced in the nuclear reactor of a nuclear power plant.

(a) Suppose the electrical power output of this plant is 1066 MW, calculate

(i) the total power generated by the reactor,

(ii) the power lost to the atmosphere.

(b) The turbine is cooled by circulating water through it at the rate of 48 m^3/s. Calculate the rise in temperature of the cooling water.

(Density of water = 10^3 kg/m^3,
specific heat capacity of water = 4 200 J kg^{-1} K^{-1})

(c) In the reactor, energy is produced by the fission of uranium-235 atoms,

$$^{235}U + n \longrightarrow {}^{141}Ba + {}^{92}Kr + 3n.$$

Masses of the above nuclides are: ^{235}U = 235.0409 u, ^{141}Ba = 140.9141 u,
^{92}Kr = 91.9250 u, n = 1.0086 u.

Calculate the number of uranium atoms which undergo fission in 1 s.

(1 u = 1.66×10^{-27} kg, speed of light in vacuum = 3×10^8 m/s.)

(d) The nuclear plant is designed to produce power continuously for 10 years without refuelling. Estimate the mass of uranium-235 that will be consumed in this time, assuming that only the above reaction takes place. (Avogadro constant = 6×10^{23} mol^{-1}.)

(10 marks)

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