

**HONG KONG ADVANCED LEVEL EXAMINATION  
AL PHYSICS  
1991 Structural Question**

7. (Given:  $GM_E = 4.0 \times 10^{14} \text{ N m}^2 \text{ kg}^{-1}$  where  $G =$  gravitational constant  
 $M_E =$  mass of earth)

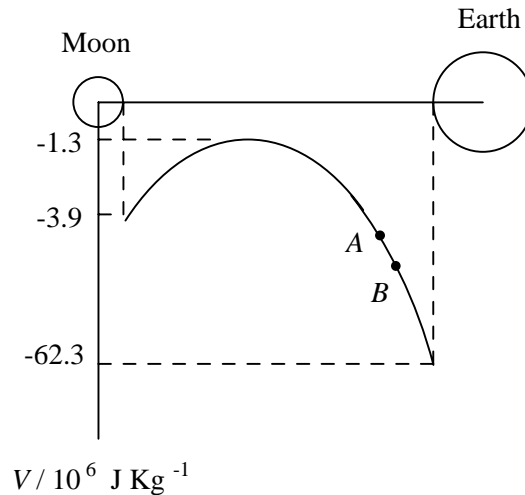


Figure 7.1

A spacecraft (mass  $m$ ) has just finished its mission on the moon and is planning to return to the earth. Figure 7.1, which is not to scale, shows how the gravitational potential,  $V$ , between the surface of the moon and the surface of the earth varies along the line of centres.

- (a) Explain why there is a point of maximum on the graph. (2 marks)
- (b) If the spacecraft is to just succeed in reaching the earth,
- (i) what is the minimum energy per unit mass that has to be supplied?
  - (ii) What is the minimum speed of the spacecraft at take off? (3 marks)
- (c) At points  $A$  and  $B$ , the spacecraft is so far away from the moon that its gravitational attraction on the spacecraft is negligible. The spacecraft is coasting through space with its motors off. If it had a velocity of 5 200 m/s when at point  $A$ , 28 000 km from the centre of the earth, what would be its velocity at point  $B$ , 20 000 km from the centre of the earth? (3 marks)
- (d) As the spacecraft is returning to the earth at a very high speed, frictional force between the spacecraft and the atmosphere would cause its surface to reach a very high temperature. In order to protect the astronauts, what sort of material should the spacecraft be made of and why? (2 marks)

8. Figure 8.1 shows a petrol pump in a garage. The pump delivers petrol with a density of  $750 \text{ kg/m}^3$  at a rate of  $1.2 \times 10^{-2} \text{ m}^3/\text{s}$ . The input to the pump is from a pipe with a cross-sectional area  $A_1$  of  $4 \times 10^{-3} \text{ m}^2$  at a suction pressure  $P_1$  of  $1 \times 10^4 \text{ Pa}$ . The discharge of the pump is at a gauge pressure  $P_2$  of  $2.8 \times 10^5 \text{ Pa}$  into a pipe with a cross-sectional area  $A_2$  of  $8 \times 10^{-4} \text{ m}^2$ . The pipes at the entrance and exit are at the same horizontal level and the temperature of the petrol remains constant throughout the flow.

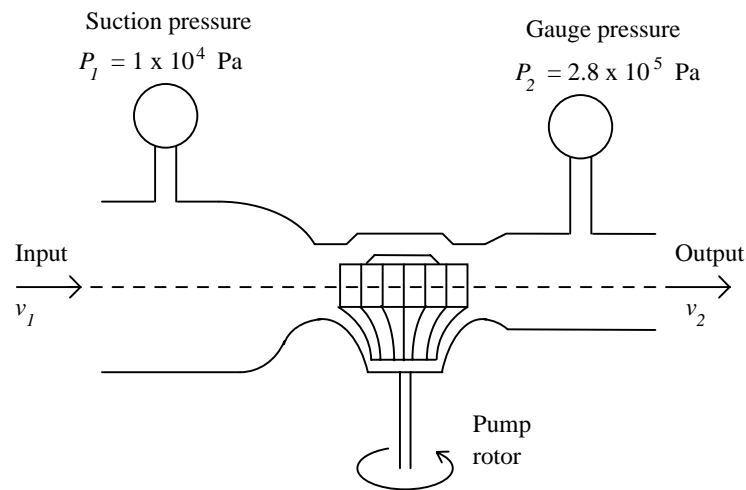


Figure 8.1

- Find the average flow speeds  $v_1$  and  $v_2$  of the petrol into and out of the pump. (2 marks)
- Find the change in kinetic energy per unit mass of petrol. (2 marks)
- By considering the work done per unit mass of petrol at the entrance and exit of the pump, find the work done by the pump in delivering a unit mass of petrol. (4 marks)
- Find the mechanical power developed in the pump in order to maintain the above flow conditions. (2 marks)
- Explain why, in reality, the mechanical power of the pump required is higher than that calculated in (d). (2 marks)

9.

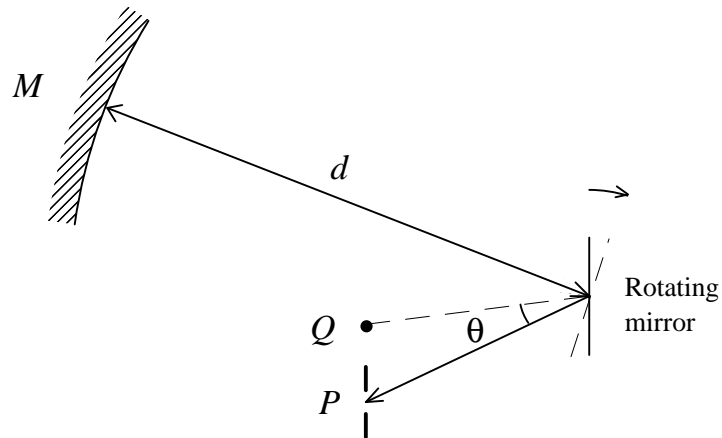


Figure 9.1

Figure 9.1 shows the main parts of an apparatus used to determine the speed of light  $c$ .

- (a) When the rotating mirror is stationary, an image of the illuminated slit at  $P$  is produced back at  $P$ . State the condition required. Explain your answer briefly. (2 marks)
- (b) When the mirror is rotating at  $n$  rev/s, the image of  $P$  becomes displaced to  $Q$ . The reflected ray suffers an angular displacement of  $\theta$ .
- (i) Why is the image displaced? (2 marks)
- (ii) Derive a mathematical relationship between the angular displacement of the image  $\theta$  and the speed of light  $c$ . (3 marks)

(c)

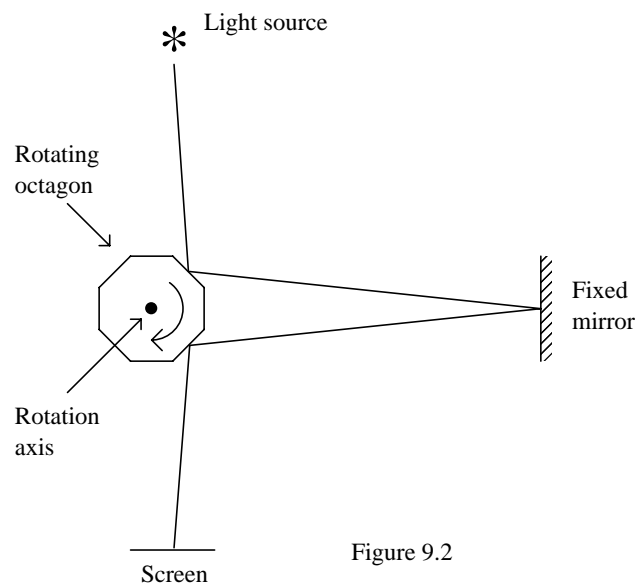


Figure 9.2

In practice, the angular displacement  $\theta$  of the image is very small and difficult to measure accurately. An improved version of the apparatus replaces the rotating mirror with a rotating octagon with reflecting surfaces as shown in Figure 9.2. The speed of the rotating octagon is adjusted till there is no displacement of the image on the screen.

- (i) Explain how this is possible. (2 marks)
- (ii) If the lowest speed of rotation for the image to remain in the same position is 3000 rev/s and the separation between the rotating octagon and the fixed mirror is 6 km, calculate the speed of light  $c$ . (3 marks)

10. (Given: magnetic field at the centre of a coil of  $N$  turns  $B = \frac{\mu_0 NI}{2r}$

permeability of vacuum  $\mu_0 = 4\pi \times 10^{-7}$  H/m  
 acceleration due to gravity  $g = 10 \text{ m/s}^2$ )

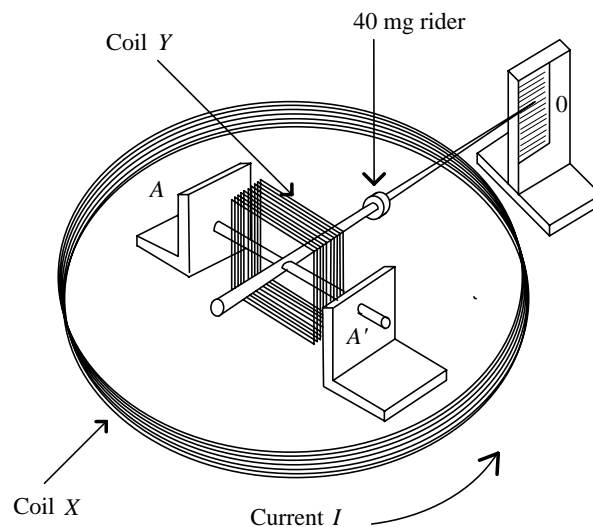
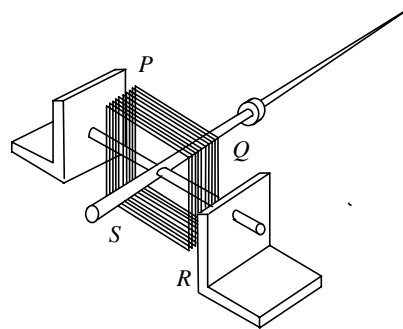


Figure 10.1

A student sets up the above apparatus to measure current. Coil X is a 100-turn circular coil of mean diameter 300 mm. Square coil Y, also of 100 turns, is pivoted at the centre of Coil X and is free to turn about a horizontal axis AA', in the plane of coil X. When there is no current, the rider is adjusted to make the pointer horizontal.

Coils *X* and *Y* are connected in series. When a current *I* flows through the coils, the rider has to be moved 80 mm to the right to restore the pointer to a horizontal position.

- (a) In the spaces provided, indicate the direction of the magnetic field produced by coil *X* at its centre when a current *I* flows in the direction shown. Determine the magnetic field *B* at the centre of *X*. (2 marks)
- (b) In which direction should the current in Coil *Y* be flowing? Indicate the current direction and the corresponding directions of the forces acting on the 4 sides of Coil *Y* in the diagram below. (3 marks)



- (c) If the mass of the rider is 40 mg and Coil *Y* is of side 30 mm, estimate the value of the current *I*, assuming that the magnetic field due to coil *X* is uniform across the coil *Y*. (4 marks)
- (d) What is the advantage of using this method to measure current? (2 marks)

11. (Given: Planck constant  $h = 6.63 \times 10^{-34}$  Js  
 charge of electron  $e = 1.60 \times 10^{-19}$  C  
 speed of light in vacuum  $c = 3.00 \times 10^8$  m/s)

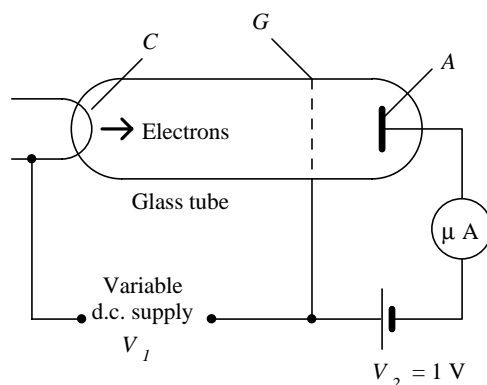


Figure 11.1

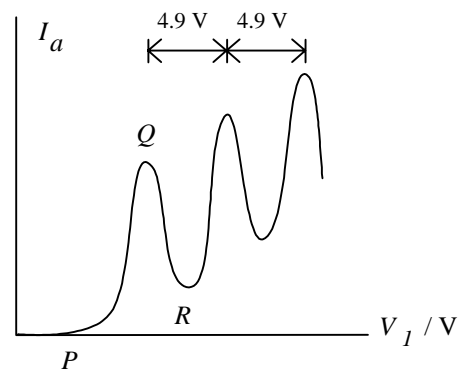


Figure 11.2

Figure 11.1 shows the schematic diagram of the apparatus used by Franck and Hertz. The electrons emitted at the cathode  $C$  are accelerated to the grid  $G$  by a potential difference of  $V_1$ . The electrode  $A$  has a voltage  $V_2$  of 1 V negative with respect to the grid  $G$ . Inside the glass tube there is mercury vapour at a pressure of about  $100 \text{ N/m}^2$ . A graph of anode current  $I_a$  against  $V_1$  is shown in Figure 11.2.

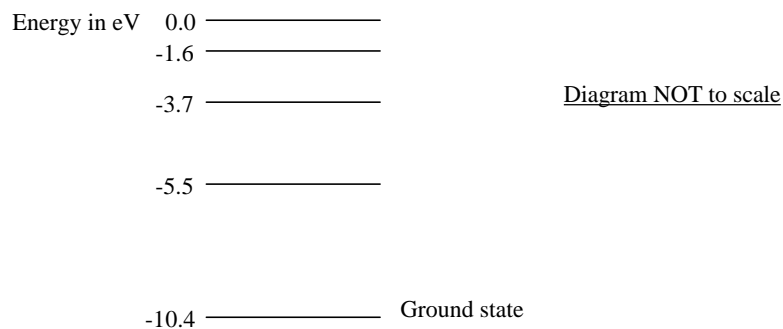
(a) Account for the shape of the graph when  $V_1$  is

- (i) less than  $P$ ,
- (ii) between  $P$  and  $Q$ ,
- (iii) between  $Q$  and  $R$ . (5 marks)

(b) From the graph in Figure 11.2, estimate the lowest excitation energy for mercury. (1 mark)

(c) What is the wavelength of the radiation emitted by the mercury atoms as they return to their ground state? Could such a radiation be detected? Explain your reasoning. (4 marks)

(d)



- (i) The energy level diagram shows that mercury has another excitation potential at 6.7 V. Why is this not shown by the graph in Figure 11.2? (2 marks)
- (ii) What would you expect to happen to a photon of energy 9 eV when it collides with a mercury atom? Explain your answer briefly. (2 marks)

12. A tiny charged oil drop falls at a terminal speed of  $1.50 \times 10^{-4}$  m/s in air between two horizontal and parallel plates placed 2.00 cm apart.
- (a) Given that the density of oil is  $900 \text{ kg/m}^3$ , the viscosity of air is  $1.81 \times 10^{-5} \text{ Ns/m}^2$  and  $g$  is  $9.80 \text{ m/s}^2$ , calculate the radius of the oil drop. (2 marks)
- (b) The oil drop can be held stationary when a p.d. of 2.50 kV is applied between the plates. Find the magnitude of the charge on the oil drop. (4 marks)
- (c) After the space between the plates has been irradiated by X-rays, the charge on the oil drop is increased. With the p.d. across the plates unchanged, the oil drop moves up with a terminal velocity of  $1.02 \times 10^{-4}$  m/s.
- (i) Explain briefly how the X-rays can alter the charge on the oil drop. (2 marks)
- (ii) Calculate the magnitude of the charge on the oil drop after it has been irradiated by the X-rays. (4 marks)
- (d) The experiment is repeated twice and the charges on the oil drops are found to be  $6.41 \times 10^{-19} \text{ C}$  and  $9.59 \times 10^{-19} \text{ C}$  respectively. Use this data and the results obtained in parts (b) and (c) to deduce a probable value of the charge of the electron. Explain your reasoning. (1 mark)

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