2022-DSE
PHY
PAPER 1B

B

DIOCESAN BOYS' SCHOOL

HONG KONG DIPLOMA OF SECONDARY EDUCATION EXAMINATION 2022

G 12 FINAL EXAMINATION

PHYSICS PAPER 1

SECTION B: Question-Answer Book B

This paper must be answered in English

INSTRUCTIONS

(1) After the announcement of the start of the examination, you should first write your Name, Class and Class number in the spaces provided on Page 1.

(2) Refer to the general instructions on the cover of the Question Paper for Section A.

(3) Answer **ALL** questions.

(4) Write your answers in the spaces provided in this Question-Answer Book.

(5) Graph paper and supplementary answer sheets will be provided on request. Write your Name, Class, Class number, and fill in the question number box on each sheet. Fasten them with string INSIDE this Question-Answer Book.

(6) No extra time will be given to candidates for filling in the question number boxes after the 'Time is up' announcement.

(7) The diagrams in this section are **NOT** necessarily drawn to scale.

(8) Unless otherwise specified, numerical answers should be either exact or correct to 3 significant figures.

(9) Take $g = 9.81$ m s^{-2}.

Name	
Class	
Class Number	

	Teacher Use Only
Question No.	Marks
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
Total	

Section B: Answer **ALL** questions. Write your answers in the spaces provided.

Structured Questions (84 marks)

Question No.	1	2	3	4	5	6	7	8	9	10
Marks	4	7	11	11	9	8	6	10	12	6

Question 1 (4 marks)

Milk-tea contained in a plastic cup is initially at 15 °C. The cup together with the milk-tea is then cooled by placing it in a jug of melting ice as shown. The milk tea has a specific heat capacity of 4.2 J g^{-1} K^{-1} and a mass of 330 g . The heat capacity of the cup is 300 J K^{-1} .

Given: specific latent heat of fusion of ice = 3.34×10^5 J kg^{-1}

(a) Assuming heat exchange occurs only among the milk-tea, the plastic cup and the melting ice, find the mass of ice melted when the cup with milk-tea is just cooled to 0 °C . (2 marks)

(b) When water at 0 °C is used in the jug instead of melting ice, the cooling is slower. Explain why cooling is faster when melting ice is used in the jug. (2 marks)

Question 2 (7 marks)

An ideal gas in a car tyre has a constant volume of 31 L . The pressure of the ideal gas in the tyre is 290 kPa at 17 °C . (1 L = 0.001 m^3)

(a) Calculate the amount of gas in mol in the tyre. (2 marks)

(b) A pump is used to increase the pressure in the tyre. On each stroke of the pump, 0.012 mol of the same ideal gas is forced into the tyre. Assume that the temperature is kept constant upon each stroke.

(i) In terms of kinetic theory, explain why the pressure of the gas is increased upon each stroke of the pump. (2 marks)

(ii) Calculate the number of strokes of the pump required to increase the pressure to at least 500 kPa . (3 marks)

Question 3 (11 marks)

Two athletes, ***A*** and ***B***, are running in an inter-school competition. At the end of the race, both are running in a straight line. Athlete ***B*** would like to overtake athlete ***A*** before the tape (finishing line).

At the instant t = 0 s, athlete ***A*** is 190 m from the tape and is running at a constant speed of 10 ms^{-1}. Athlete ***B*** is 200 m from the tape with a speed of 8 ms^{-1}. ***B*** accelerates uniformly in 8 s until he reaches a speed of 12 ms^{-1}.

(a) Find the respective distances of ***A*** and ***B*** from the tape just when the speed of ***B*** has reached 12 ms^{-1}. (3 marks)

(b) Both athletes then run at their respective constant speeds.

(i) Find the time taken for ***B*** to overtake ***A*** after his speed has reached 12 ms^{-1}. (2 marks)

(ii) How far is ***B*** from the tape when he overtakes ***A***? (1 mark)

(c) Athlete ***B*** eventually wins the race.

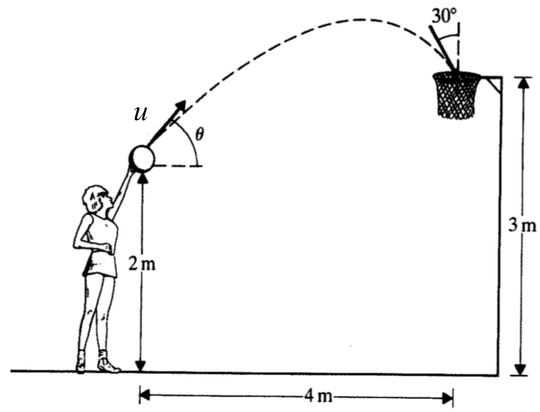
(i) By how much time does ***B*** win the race? (1 mark)

(ii) How far is ***A*** from the tape just when ***B*** wins the race? (1 mark)

(d) Sketch (i) the distance-time graph of ***A*** and (ii) the speed-time graph of ***B*** throughout the race. (3 marks)

Question 4 (11 marks)

At time $t = 0$ s, Natalie is taking a shot at goal in a netball match. The ball is projected at a position 2 m above the ground with initial speed u and angle of projection θ. The height of the net is 3 m and the horizontal separation between the ball and the net is 4 m. At time $t = T$, the ball drops into the net at 30° to the vertical as shown.



The acceleration due to gravity is g. Take the upward and rightward directions to be positive. Air resistance is neglected.

(a) Consider displacement-time and velocity-time equations. Show that

(i) the vertical component of initial speed is given by $\frac{1}{T} + \frac{gT}{2}$; (2 marks)

(ii) when the ball drops into the net, $\tan 30° = -\frac{u\cos\theta}{u\sin\theta - gT}$. (2 marks)

(b) Briefly explain the negative sign in the equation in *part (a) (ii)*. (1 mark)

(c) Using *part (a)* and taking $g = 9.81$ ms^{-2}, find the time T in seconds. (2 marks)

(d) Show that the correct angle of projection θ is about 66°. (2 marks)

(e) The height of the net is then lowered to 2 m at the same horizontal level of the point of projection. At the same position, Natalie increases her angle of projection to drop the ball into the net with a projection speed of 8.66 ms^{-1}. What is the new angle of projection? (2 marks)
(Given: $\sin 2\theta = 2\sin\theta\cos\theta$)

Question 5 (9 marks)

(a) Given that the mass of the Earth is approximately 81 times the mass of the Moon and the radius of the Earth is 3.67 times the radius of the Moon, calculate an approximate value for the acceleration due to gravity on the surface of the Moon. (2 marks)

(b) The Earth may be regarded as a sphere of radius R = 6370 km and suppose the Moon rotates about the Earth in a circular orbit of radius r. Given that the period of the Moon's orbit is 27.5 days, find the ratio r / R. (3 marks)

(c) The Earth rotates with a period of 24 hours. At a certain height above the equator, a satellite describes a circular orbit with a period of 1.5 hours in the same sense as the Earth's rotation. At 12:00 noon, the satellite is directly above an observatory. The satellite rotates much faster than the Earth such that the satellite will next be directly above the observatory when the Earth has rotated slightly (less than 30°) at an angle θ.

(i) What is the angle θ (in degrees) rotated by the Earth? (2 marks)

(ii) What is the time when the satellite is directly above the observatory again? (2 marks)

Question 6 (8 marks)

A glass prism *PQR* with a layer of rectangular transparent material attached on one of its faces *PR* is shown. The prism is right-angled at $\angle PQR$.

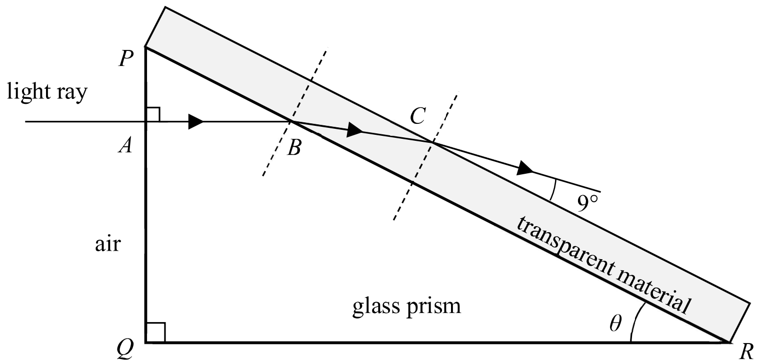


Fig. 6A

A light ray enters the prism from air at point *A* perpendicularly, parallel to *QR*. At point *B* on the interface between the glass and the transparent material (*PR*), it is refracted at an angle ϕ (not shown in the figure). The light ray eventually leaves the transparent material at *C*, forming an angle of 9° with the surface of transparent material.

Given: refractive index of glass prism = 1.70
refractive index of transparent material = 1.09

(a) (i) Find the refracted angle ϕ at *B* . (2 marks)

(ii) Hence, find angle θ (i.e. $\angle PRQ$) . (2 marks)

(b) Another light ray enters the prism at A with an angle of incidence α ($0 < \alpha < 90°$) as in **Fig. 6B** .

(i) Express r in terms of θ and i , where r is the refracted angle at A and i is the incident angle at D . (1 mark)

(ii) Find the minimum value of α such that when the light ray arrives at point D on PR, total internal reflection occurs. (3 marks)

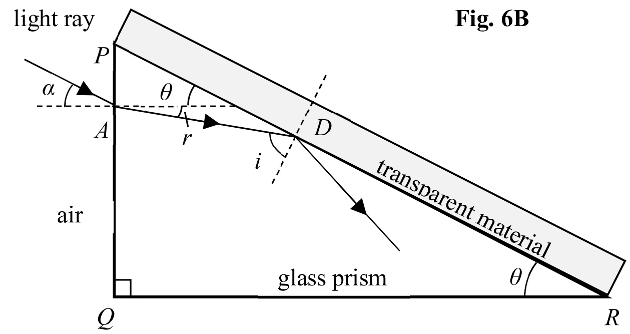


Fig. 6B

Question 7 (6 marks)

A set-up to investigate the interference of microwaves is shown in **Fig. 7A**. Microwaves emitted from a transmitter *T* pass through two narrow silts *A* and *B*, which are equidistant from *T*. The receiver, *R*, is connected to a meter, which indicates the intensity of microwaves received.

Fig. 7A

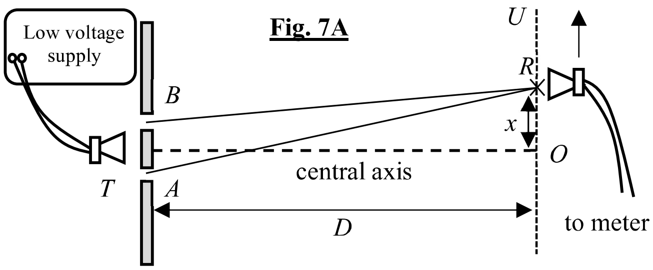
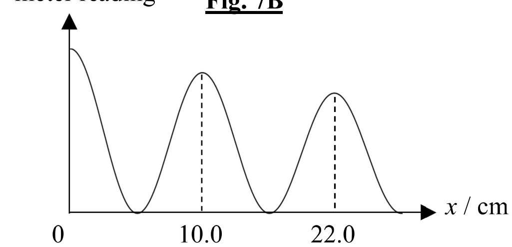


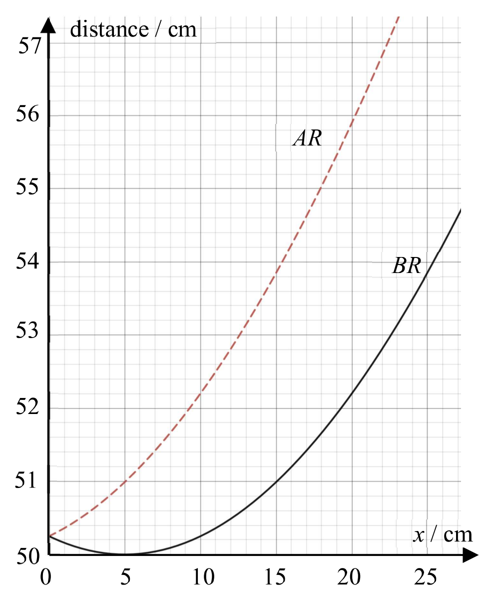
Fig. 7B



As the receiver *R* is moved from *O* towards *U*, the meter reading is found to vary, with the first three maxima occurring at $x = 0$ cm, $x = 10.0$ cm and $x = 22.0$ cm , where x is the perpendicular distance between the receiver and the central axis. The variation of the meter reading as the receiver is moved from *O* towards *U* is shown in **Fig. 7B**.

(a) Explain briefly why the meter shows maximum and minimum readings. (2 marks)

(b) The graphs show how the distances between the receiver *R* and the slits *A* and *B* (i.e. *AR* and *BR*) vary with x .



(i) Using the graphs at $x = 10.0$ cm or 22.0 cm , determine the wavelength of the microwave. (2 marks)

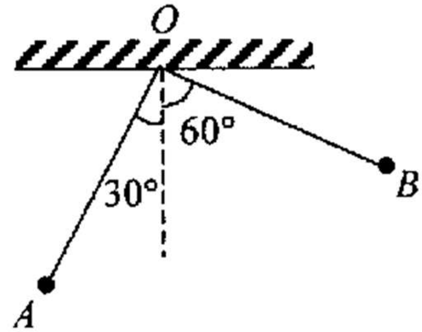
(ii) Using your answer in (b)(i), find the frequency of the microwave. (1 mark)

(iii) A student measures the perpendicular distance between the slits and the receiver, *D*, and the slit separation and then applies the formula $\Delta y = \frac{\lambda D}{a}$ to estimate the wavelength of the microwave. Explain why it is not strictly appropriate to apply this formula in this case. (1 mark)

Question 8 (10 marks)

Two charged particles A and B of masses M and m respectively are suspended by two insulating threads of the same length 5 cm from O. The magnitudes of charges of A and B are $+5 \times 10^{-7}$ C and $+8 \times 10^{-7}$ C respectively.

Due to the electrostatic forces between A and B, the threads AO and BO make angles of 30° and 60° respectively with the vertical as shown.



(a) Draw in the diagram above to show the electrostatic forces, F_A and F_B, acting on A and B respectively. State one nature of the electrostatic forces. (2 marks)

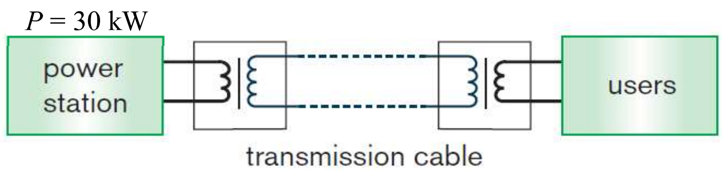
(b) Find the magnitude of electrostatic force F_A. (3 marks)

(c) Consider the balance of anticlockwise and clockwise moment of particle B about O. Find the mass m of particle B. (3 marks)

(d) What is the ratio of the masses $\frac{m}{M}$? (2 marks)

Question 9 (12 marks)

The electrical power demand P of the users living on an island is 30 kW. Through a step-up transformer, the power is transmitted at 1500 V from a power station to the island 10 km away. The high voltage is then stepped down on the users' side. The total resistance of the two transmission cables is 0.5 Ω and the transformers are ideal.



(a) The input voltage to the step-up transformer is 300 V. Find the turns ratio (primary to secondary) of the transformer. (1 mark)

(b) What is the current through the transmission lines? (1 mark)

(c) Find the percentage energy loss of the transmission system. (2 marks)

A bird stands on a segment of the transmission line as shown. The resistance R_1 of the bird is 1 MΩ and its feet are 5 cm apart. The resistance of the 5 cm cable segment is R_2.

(d) Given that the resistance of one 10 km transmission cable is 0.25 Ω and the cable is uniform in thickness, find the resistance of the 5 cm cable segment R_2. (2 marks)

(e) The bird and the cable segment are connected in parallel. The currents passing through the bird and the cable segment are I_1 and I_2 respectively. Find $\frac{I_1}{I_2}$. (2 marks)

(f) The bird will get an electric shock if the current passing through it is greater than 100 mA. Will the bird get an electric shock? Justify your answer by calculation. (2 marks)

(g) Later, a few more birds stay on the transmission line as shown. Explain whether the efficiency of the transmission system would be affected practically. (2 marks)

Question 10 (6 marks)

In the 1970's, nuclear powered electronic pacemakers were manufactured to regulate the heartbeats of patients with heart diseases. The pacemakers were installed inside the patients' bodies and were powered by a small radioactive source sealed in a metal container.

One model of pacemaker using a radioisotope of plutonium, Pu-238, is shown. Pu-238 undergoes alpha decay and has a half-life of 88 years.

(a) Explain why the alpha radiation emitted by Pu-238 source is not harmful to the patient when the pacemaker is installed in the body. (1 mark)

(b) The following equation represents the alpha decay of Pu-238.

$$^{238}_{92}\text{Pu} \rightarrow {}^{a}_{b}\text{Th} + {}^{c}_{d}\alpha$$

Write down the values of a, b, c and d . (1 mark)

a: ______ b: ______ c: ______ d: ______

(c) When a Pu-238-powered pacemaker was installed in a patient's body, the radioactive source had an activity of 9.3×10^{10} Bq . The energy released in each alpha decay is 5.5 MeV .
On a day 30 years after the pacemaker was installed,

(i) find the activity of the source; (2 marks)

(ii) hence, find the power of the source on this day in mW. (2 marks)

End of section B

END OF PAPER