Queen's College
S6 Mock Examination 2021-2022

PHYSICS PAPER 1
Section B: Question-Answer Book B

Date: 18 February 2022
Time: 8:30 a.m. – 11:00 a.m.
(2.5 hours)

This paper must be answered in English

Class: ____________________

Class No.: ________________

Block: ___________________

INSTRUCTIONS FOR SECTION B

(1) After the announcement of the start of examination, you should write your Class, Class No. and Block 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) Supplementary answer sheets will be provided on request. Write your Class and Class No. on each sheet.

Question No.	**Marks**	**Score**
1	7	
2	8	
3	11	
4	13	
5	10	
6	7	
7	8	
8	12	
9	8	
TOTAL (84 marks):		

Section B: Answer **ALL** questions. Parts marked with * involve knowledge of the extension component. Write your answers in the spaces provided.

1. Read the following passage about **clothes dryers** and answer the questions that follow.

> Clothes dryers are used to remove moisture from clothes. Clothing can be dried much faster than natural drying.
>
> The working principle of a clothes dryer is simple. Wet clothes are placed inside a rotating drum (called "tumbler"). The dryer draws in room temperature air and heats it with a powerful heating element. The hot air is circulated through the tumbler to dry the clothes as they tumble. The warm moist air is forced out of the dryer through an exhaust vent to outdoors.
>
> In order to disinfect the clothing, the clothes dryer should reach a temperature of 60 °C or above. Most germs and bacteria will be killed.

(a)

(i) Name the phenomenon that occurs during drying of wet clothes. (1 mark)

....

(ii) Hence suggest **TWO** reasons to explain why clothing can be dried much faster by using a clothes dryer compared to indoor drying. (2 marks)

....

....

....

....

(b) A load of wet clothes initially at 20 °C are dried using a clothes dryer. The temperature of the warm moist outgoing air is 60 °C. It operates for 45 minutes to dry the clothes completely. Assume that the wet clothes contain 2.2 kg of water and the clothes dryer operates at a power of 3.5 kW.

Given: specific heat capacity of water = 4200 J kg^{-1} $°C^{-1}$
specific latent heat of vaporization of water = 2.26×10^6 J kg^{-1}

(i) Calculate the energy absorbed by water when the clothes are dried completely. (2 marks)

(ii) Estimate the energy efficiency of the clothes dryer. (2 marks)

* 2. A man tries to open a wine bottle by injecting air into the bottle by a pump. Figure 2.1 shows a wine bottle which is sealed with a cork. The pressure and volume of the air inside the bottle is 100 kPa and 6 cm^3 respectively. The air pressure outside is also 100 kPa. He carefully inserts a needle into the bottle through the cork. When the tip of needle reaches the air between the cork and the wine, air is pumped into the bottle until the cork pops out. The temperature of the air inside the bottle is kept constant at 25 °C throughout.

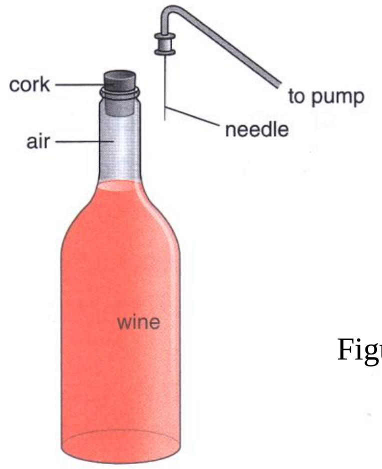

Figure 2.1

(a) By using the kinetic theory, explain why the pressure of air inside the bottle increases when air is pumped in. (2 marks)

(b) You are given with the following data:

Area of upper surface of the cork = 5 cm^2
Area of lower surface of the cork = 4 cm^2
Friction between the cork and the bottle = 200 N

Find the minimum air pressure inside the bottle for the cork to pop out. Assume that the weight of the cork is negligible. (2 marks)

(c) Air is pumped into the bottle at a rate of 2×10^{21} molecules per minute. Find the time taken for the pressure inside the bottle to reach the value in (b). (3 marks)

(d) State one method in keeping the air temperature constant inside the bottle. (1 mark)

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3. Small quadcopter drones are becoming popular recently for taking aerial photographs and videos. Figure 3.1 shows a drone with four identical sets of blades (called ‘rotors’) which are controlled by four individual motors. When the blades rotate at high speeds, air is pulled downwards and a lifting force is produced. By varying the speed of the motor, the magnitude of the lifting force can be controlled.

Figure 3.1

(a)

(i) By using suitable physics law, explain how the lifting force is produced when the blades are rotating. (2 marks)

(ii) Compare the magnitude of the following forces when a drone takes off:
total lifting force, gravitational force acting on the drone. (1 mark)

(b) Consider a drone hovering steadily in mid-air. Figure 3.2 shows **one** of the rotors. The rotating blades pull the air swept by them and impart the air with a downward velocity v of 7.7 m s^{-1}. The area swept out by the blades is 0.0143 m^2.

Given: density of air = 1.23 kg m^{-3}

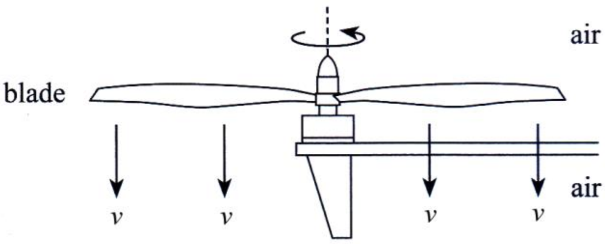

Figure 3.2

(i) Show that the mass of air swept by the blades per second is 0.135 kg.

(1 mark)

(ii) Find the lifting force produced by one rotor. (2 marks)

(iii) Hence estimate the mass of the drone. (2 marks)

(c) It is known that the blades of the four rotors should not be rotated together in the same direction.

(i) What would happen to the drone if all rotors rotate in the same direction?

(1 mark)

(ii) Figure 3.3 shows a simplified diagram of the drone. Rotor 1 is rotating anti-clockwise. On the diagram, mark down the correct direction of rotation of the other three rotors. The direction of rotation of rotor 1 has been marked for you. (2 marks)

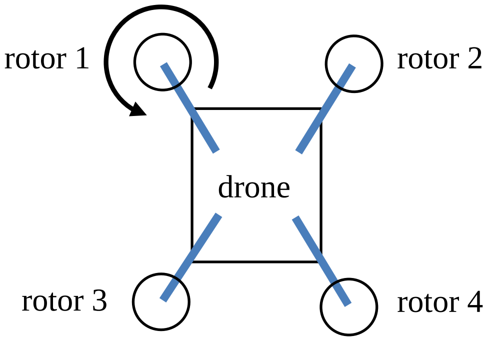

Figure 3.3

* 4. A small sphere is suspended with a light inextensible string of 2.2 m long from a fixed support which is 4 m above the ground. The sphere is whirling in a conical pendulum such that the string makes an angle of 40° with the vertical. Neglect air resistance.

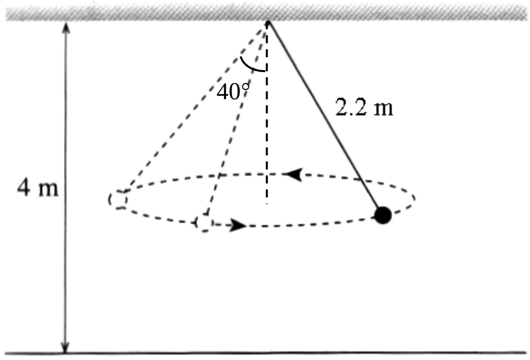

Figure 4.1

(a)

(i) On Figure 4.1, use an arrow to indicate the acceleration of the sphere, if any, at the position shown in solid line. (1 mark)

(ii) Find the radius of the conical pendulum. (1 mark)

(iii) Find the rate of rotation (in revolutions per second) of the sphere. (3 marks)

(b) Suddenly the string breaks and the sphere falls to the ground.

(i) Describe and explain the path along which the sphere falls. No calculations are required. (3 marks)

(ii) Find the speed of the sphere just before hitting the ground. (3 marks)

(iii) Find the time required for the sphere to reach the ground. (2 marks)

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5. Figure 5.1 shows the top view of a ripple tank. S_1 and S_2 are two coherent sources which vibrate in phase. At $t = 0$, they are turned on to send continuous water waves out. X and Y are two points on the ripple tank. Y is equidistant from S_1 and from S_2.

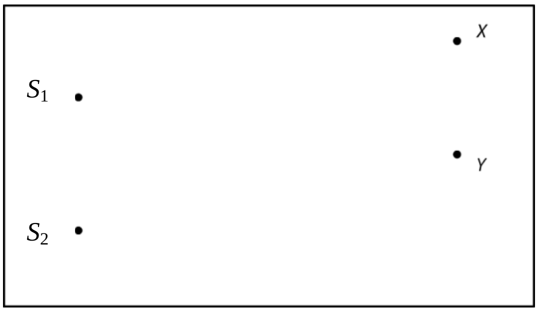


Figure 5.1

Figure 5.2 shows the displacement–time graph at point X.

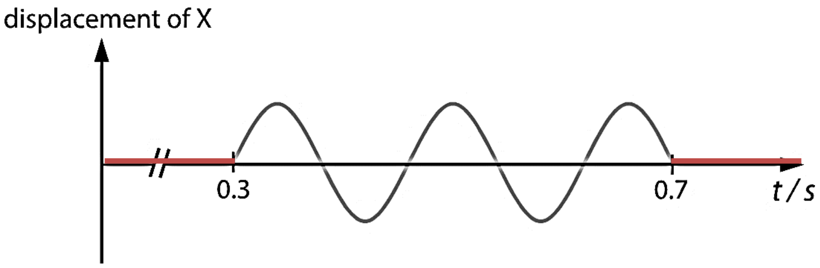


Figure 5.2

(a) Explain why the displacement at X is zero

(i) from $t = 0$ to $t = 0.3$ s, and (1 mark)

(ii) after $t = 0.7$ s. (2 marks)

(b) Given that the distance between S_1 and X is 9 cm. Find

(i) the speed of the water wave, and (1 mark)

(ii) the wavelength of the water wave λ. (2 marks)

(c) Express the path difference at *X* in terms of the wavelength λ only. (2 marks)

(d) On Figure 5.3, sketch the variation of the amplitude at the points between *X* and *Y* after time $t > 0.7$ s. (2 marks)

Figure 5.3

6. Figure 6.1 shows the structure of a simple camera. It consists of a lens and an image sensor. The distance between the lens and the sensor is adjustable. The opening in front of the lens allows light to enter the camera. Its size is adjustable. The focal length of the lens is 20 cm.

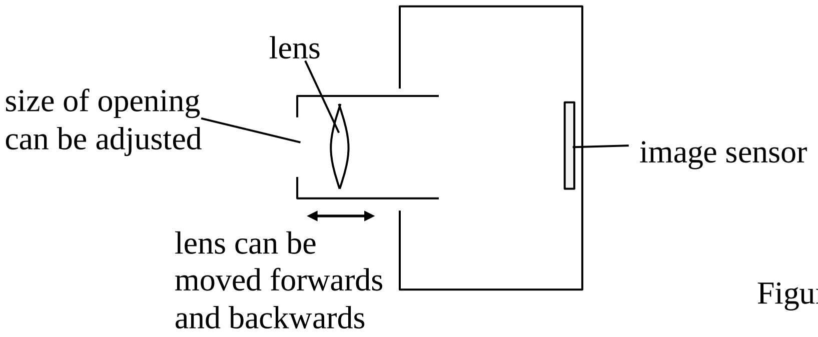


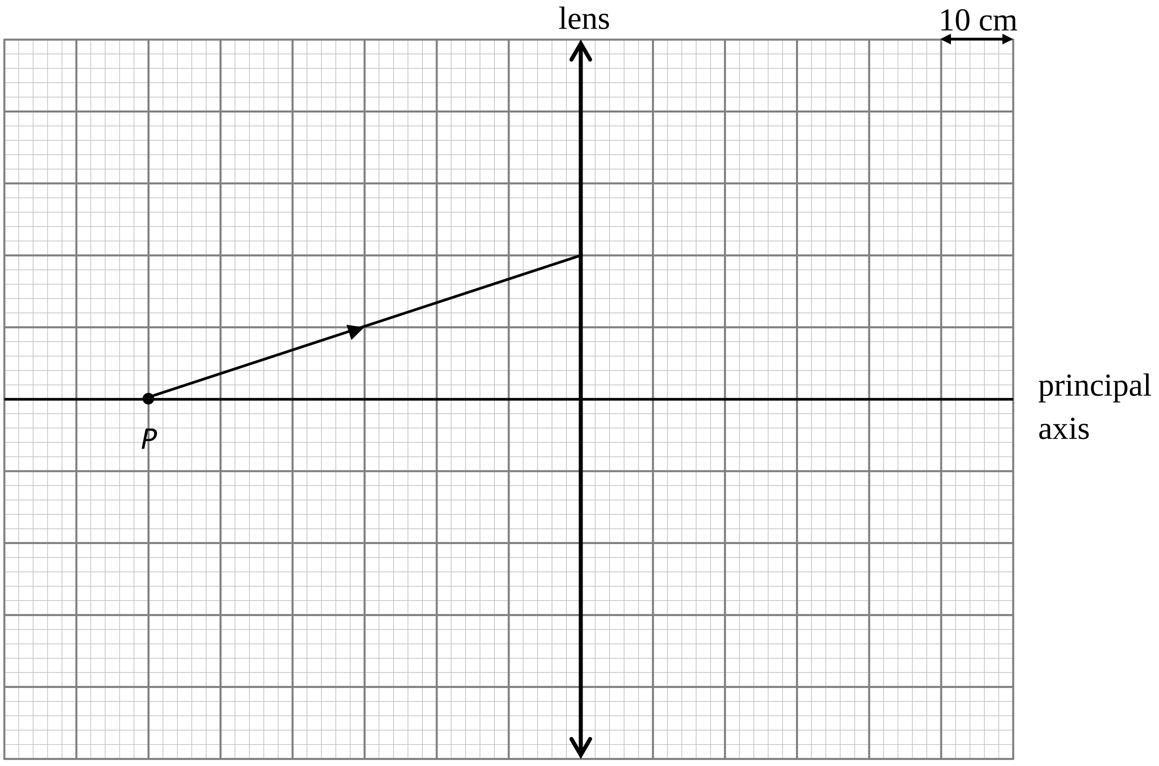
Figure 6.1

(a) A **point** object *P* is placed 60 cm in front of the lens. A sharp image is captured on the image sensor.

(i) Is the image captured real or virtual? (1 mark)

....

(ii) Draw a ray diagram to locate the image of *P*. Suitable construction lines should be drawn clearly. (3 marks)



Lens-to-sensor distance = ...

(b) The camera with the lens-to-sensor distance found in (a) is used to take a picture of another point object *Q*, which is at another distance from the camera. Figure 6.2 shows *Q* and its image. The image does not fall on the image sensor, so the picture of *Q* appears blurred.

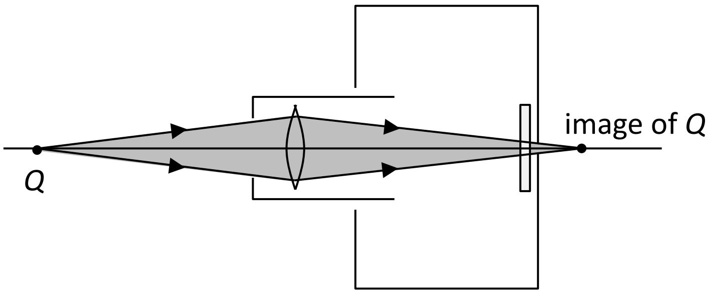


Figure 6.2

(i) Is *Q* closer to or farther away from the camera than *P*? (1 mark)

(ii) **Without changing the lens-to-sensor distance**, suggest how the size of the opening should be adjusted in order for the camera to take a reasonably sharp picture of both *P* and *Q*. (1 mark)

(iii) Describe how the adjustment in (ii) would affect the picture taken. (1 mark)

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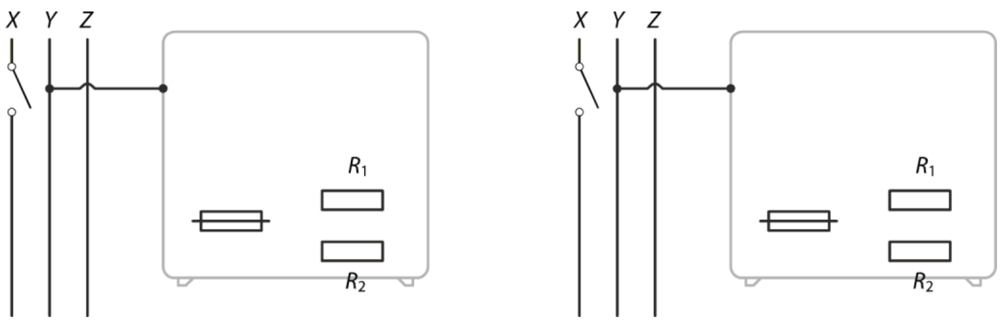
7. A heater is able to output high power or low power in two different modes. It consists of two identical heating elements R_1 and R_2, each rated 600 W, 220 V. A fuse is used to protect the circuit from being overloaded. Figure 7.1 shows the incomplete circuit diagrams of the heating elements in high and low power modes respectively.



high power mode **low power mode**

Figure 7.1

(a) Identify which of the wires *X*, *Y* or *Z* is the live wire. (1 mark)

....

(b) Complete **BOTH** circuit diagrams in Figure 7.1 to show the correct connections of the heating elements to the mains. (2 marks)

(c) The heater is connected to the mains of 220 V. The low power mode is selected.

(i) Assume that the resistance of each heating element does not change with temperature. Calculate the output power. (2 marks)

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(ii) In reality, would the output power be higher, the same or lower than the value obtained in (i) if the heater is operating? (1 mark)

....

(d) You are given fuses of ratings 2 A, 6 A and 8 A. Which of these fuses is the most suitable choice for the fuse of the heater? Explain your answer by suitable calculations. (2 marks)

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8. Figure 8.1 shows a rectangular loop of dimension $a \times b$ moving at a constant speed of $v = 80\ \mathrm{m\,s^{-1}}$ through a region of constant magnetic field strength of 2.5 T.

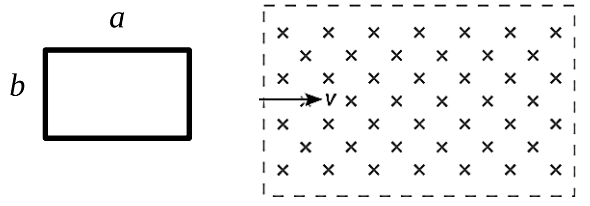

Figure 8.1

Figure 8.2 shows how the magnetic flux Φ through the loop varies with time *t*.

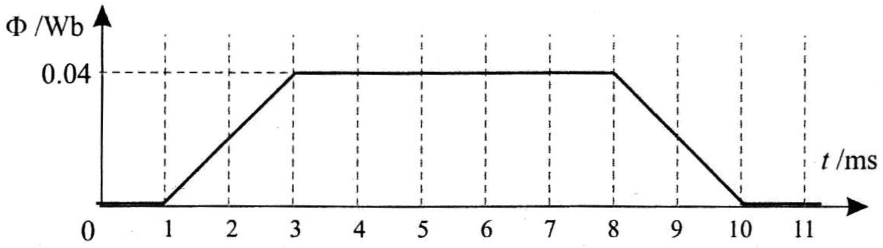

Figure 8.2

* (a) Find the length *a* and width *b* of the loop. (3 marks)

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* (b) Find the magnitude of the maximum induced current flowing in the loop. Given that the resistance of the loop is 5 Ω. (3 marks)

(c) What is the direction of the induced current in the loop, if any, when the loop is leaving the magnetic field? (1 mark)

(d)

(i) Find the maximum applied force needed. State its direction. (3 marks)

(ii) On Figure 8.3, sketch how the applied force *F* varies with time. (2 marks)

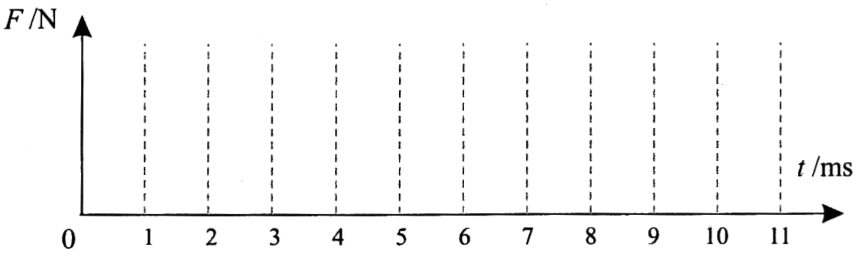

Figure 8.3

9. Plutonium-238 ($^{238}_{94}Pu$) is a radioactive isotope which undergoes α decay with a half-life of 87.7 years. In each decay, an energy 5.59 MeV is released.

(a) Write down the decay equation of Pu-238. You may use symbol '*X*' to represent the daughter nucleus. (1 mark)

....

....

* (b) Find the mass defect (in a.m.u.) of the decay. (1 mark)

....

....

(c) The energy released by the decay of Pu-238 can be used as an energy source in a radioisotope thermoelectric generator (RTG), which is used to provide electrical power to spacecrafts or satellites used in remote space missions.

* (i) An RTG has an initial output power of 500 W when it is launched. If 7 % of the energy released by Pu-238 is converted to the output energy of the RTG, estimate the initial activity of the Pu-238 source used. (2 marks)

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* (ii) Estimate the time for the power of the RTG to drop to 400 W. (2 marks)

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....

(iii) State one potential risk of the RTG. Explain briefly. (2 marks)

....

....

END OF PAPER

Queen's College

S6 Mock Examination 2021-2022

Solution to Physics Paper 1B

1. (a) (i) Evaporation (1A)

(ii) *Any two of the following:* (2A)

The air is heated so the higher temperature increases rate of evaporation.

The humid air is extracted out so the low humidity increases rate of evaporation.

The tumbling motion enables the clothing to have a larger surface area in contact with hot air.

(b) (i) $E = mc\Delta T + ml_v$

$E = (2.2)(4200)(60-20) + (2.2)(2.26\times10^6)$ *(both terms)* (1M)

$E = 5.3416\times10^6 \approx \underline{\underline{5.34\times10^6\text{ J}}}$ (1A)

(ii) $\eta = \dfrac{E}{Pt}\times100\% = \dfrac{5.3416\times10^6}{(3500)(45\times60)}\times100\% = \underline{\underline{56.5\%}}$ (1M+1A)

sub-total: 7

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2. (a) When air is pumped in, the number of gas molecules increases. (1A)

The gas molecules hit the container wall more frequently. (1A)

Hence pressure increases. ~~(more violently)~~

(b) $p_{in}A_{in} = p_{out}A_{out} + f$ (1M)

$p_{in}(4\times10^{-4}) = (100\times10^3)(5\times10^{-4}) + 200$

$p_{in} = \underline{\underline{6.25\times10^5\text{ Pa}}}$ *(625 kPa)* (1A)

(c) $pV = nRT$

$(625-100)\times10^3(6\times10^{-6}) = \Delta n(8.31)(273+25)$

$\Delta n = 1.272\times10^{-3}$ mol (1M)

$\therefore t = \dfrac{\Delta n\times N_A}{\text{rate of air pumped}} = \dfrac{(1.272\times10^{-3})(6.02\times10^{23})}{2\times10^{21}}$ (1M)

$t = \underline{\underline{0.383\text{ mins}}}$ *(23.0 s)* (1A)

(d) Air is pumped into the bottle slowly. (1A)

sub-total: 8

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3. (a) (i) The blades rotate and exert a downward force on air. (1A)
By Newton's Third law, (1A)
the air exerts an upward reaction force, which is the lifting force, on the blades.

(ii) lifting force > gravitational force (1A)

(b) (i) $\frac{m}{t} = \frac{\rho V}{t} = \frac{\rho(A \times vt)}{t} = (1.23)(0.0143 \times 7.7) = 0.1354 \approx \underline{\underline{0.135\,\text{kg}}}$ (1M)

(ii) Note that the lifting force = rate of change of momentum of air *(in magnitude)*

$F = \frac{m(v-u)}{t} = (0.135)(7.7-0) = 1.0429 \approx \underline{\underline{1.04\,\text{N}}}$ (1M+1A)

(iii) $4F = Mg$

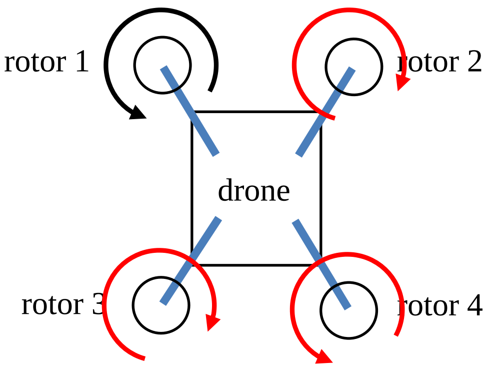
$4(1.0429) = M(9.81)$

$M = 0.4252 \approx \underline{\underline{0.425\,\text{kg}}}$ (1M+1A)

(c) (i) The drone will keep rotating (in the opposite direction). (1A)

(ii) *Rotors 1,4 same direction.*

Rotors 2,3 same direction, and opposite to rotors 1,4. (2A)



sub-total:11

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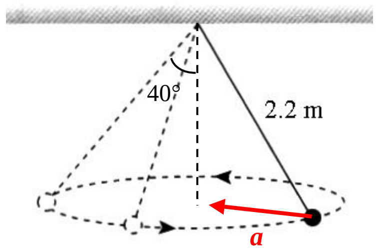
4. (a) (i) *Centripetal: points exactly to the centre of the circle* (1A)



(ii) $r = 2.2 \times \sin 40^\circ = 1.414 \approx \underline{\underline{1.41\,\text{m}}}$ (1A)

(iii) $\begin{cases} T\sin 40^\circ = mr\omega^2 \\ T\cos 40^\circ = mg \end{cases}$ (1M)

$\therefore \tan 40^\circ = \dfrac{r\omega^2}{g} = \dfrac{(1.414)\omega^2}{9.81}$

$\omega = 2.41 \text{ rad s}^{-1}$ (1A)

$\therefore f = \dfrac{\omega}{2\pi} = \underline{\underline{0.384 \text{ rev s}^{-1}}}$ (1A)

(b) (i)

When the string breaks, tension disappears so the <u>ball flies off tangentially</u> with an initial horizontal speed.

As the ball is acted on by its own <u>downward weight **only**</u>,

it will falls along a <u>parabolic path / in a projectile motion</u>. (3A)

(ii) Initial horizontal speed

$u = r\omega = (1.414)(2.41) = 3.41 \text{ m s}^{-1}$ (1A)

By conservation of energy, $\frac{1}{2}mv^2 - \frac{1}{2}mu^2 = mgh$

$v^2 = 2gh + u^2 = 2(9.81)(4 - 2.2\times\cos 40^\circ) + (3.41)^2$ (1M)

$v = \underline{\underline{7.55 \text{ m s}^{-1}}}$ (1A)

(iii) $s = \frac{1}{2}gt^2$ (1M)

$4 - 2.2\times\cos 40^\circ = \frac{1}{2}(9.81)t^2$

$t = \underline{\underline{0.687 \text{ s}}}$ (1A)

sub-total:13

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5. (a) (i) Waves from S_1 and S_2 <u>have not reached X</u> yet. (1A)

(ii) <u>Both waves reach X</u> and <u>destructive interference occurs</u>

<u>(or: the two waves cancel each other)</u>. (2A)

(b) (i) $v = \dfrac{S_1X}{t} = \dfrac{9}{0.3} = \underline{\underline{30 \text{ cm s}^{-1}}}$ (1A)

(ii) $T = \dfrac{0.7 - 0.3}{2.5} = 0.16 \text{ s}$

$\therefore \lambda = vT = (30)(0.16) = \underline{\underline{4.8 \text{ cm}}}$ (1M+1A)

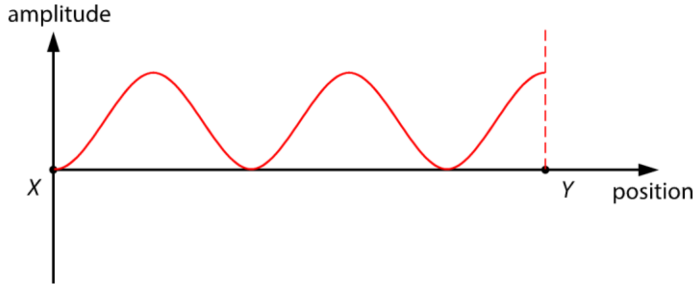
(c) At X, path difference

$$\Delta = S_2X - S_1X = 30(0.7) - 30(0.3) = 12\text{ cm} = \frac{12}{4.8}\lambda = \underline{\underline{2.5\lambda}}$$ (1M+1A)

(d) *X: amplitude = 0* *Y: amplitude = max.*

XY are of 2.5 waves apart. *Correct shape.* (2A)

sub-total:10



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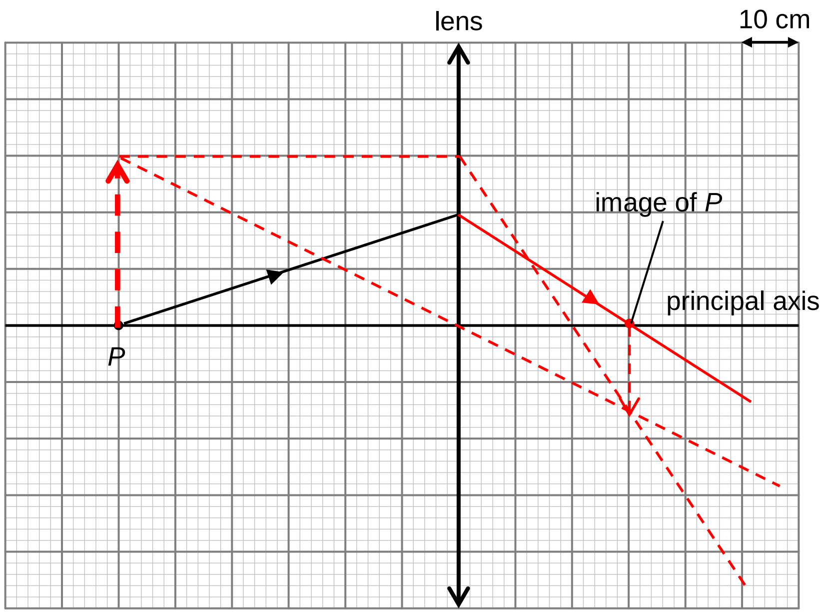
6. (a) (i) Real (1A)

(ii) ~~*Suitable construction lines drawn*~~ ~~(1A)~~

Correct ray drawn + correct point image (1A)



Lens-to-sensor distance = $\underline{\underline{30\text{ cm}}}$ *(consistent with ray diagram)* (1A)

(b) (i) Closer (1A)

(ii) Reduce the size of the opening. (1A)

(iii) The picture becomes dimmer. (1A)

sub-total: ~~7~~

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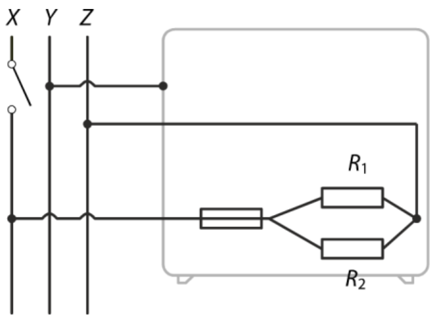
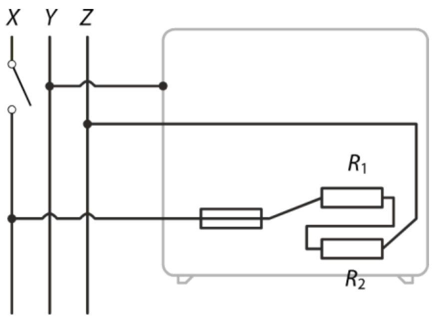
7. (a) Wire X (1A)

(b) *High power: 2 resistors in parallel* *Low power: 2 resistors in series*
Correct live and neutral wires connection. *Fuse in live wire.* (2A)



High power mode



Low power mode

(c) (i) Low power mode:
Voltage across each resistor = 110 V

$\therefore$ total power consumed $= (\frac{600}{4}) \times 2 = \underline{\underline{300\,\text{W}}}$ (1M+1A)

(ii) Lower (1A)

(d) Consider high power mode.

$I_{\max} = \frac{P}{V} = \frac{1200}{220} = 5.45\,\text{A}$ (1A)

The $\underline{\underline{6\text{ A}}}$ fuse rating is the most suitable. (1A)

sub-total: 8

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8. (a) The loop takes 2 ms *(from t = 1 to 3 ms)* to enter the magnetic field.

$a = vt = 80(2 \times 10^{-3}) = \underline{\underline{0.16\,\text{m}}}$ (1A)

$\Phi = BA$

$0.04 = (2.5)(0.16 \times b)$

$b = \underline{\underline{0.1\,\text{m}}}$ (1M+1A)

(b) $\varepsilon = N\frac{\Delta\Phi}{\Delta t} = \frac{0.04 - 0}{2 \times 10^{-3}} = 20\,\text{V}$ *(or: $\varepsilon = Blv$)* (1M+1A)

$\therefore I = \frac{\varepsilon}{R} = \frac{20}{5} = \underline{\underline{4\,\text{A}}}$ (1A)

(c) Clockwise (1A)

(d) (i) To keep the coil moving in constant speed, applied force = magnetic force.

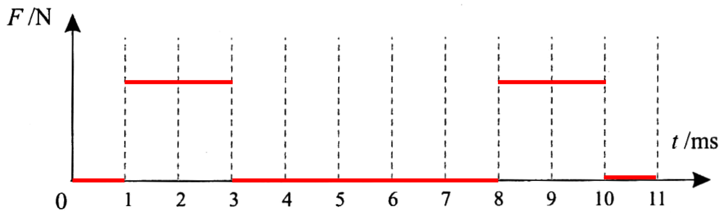
$F_{app} = BIl = (2.5)(4)(0.1) = \underline{\underline{1\text{ N}}}$ (1M+1A)

Direction: <u>to the right</u> (1A)

(ii)

Applied force is needed only when the loop is entering/leaving the magnetic field.
Applied force = 0 when there is no change in magnetic flux linkage through the loop.
Correct constant applied force. (2A)

sub-total:12



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9. (a) ${}^{238}_{94}Pu \rightarrow {}^{234}_{92}X + {}^{4}_{2}\alpha$ (1A)

(b) $E = \dfrac{5.59}{931} = \underline{\underline{6.00 \times 10^{-3}\text{ u}}}$ (1A)

(c) (i) $(A_0 \times E) \times 7\% = P_{output}$

$A_0 (5.59 \times 10^6 \times 1.6 \times 10^{-19}) \times 7\% = 500$

$A_0 = 7.986 \times 10^{15} \approx \underline{\underline{7.99 \times 10^{15}\text{ Bq}}}$ (1M+1A)

(ii) By $P = P_0 \times (\frac{1}{2})^{t/T_{1/2}}$

$400 = 500 \times (\frac{1}{2})^{t/87.7}$

$t = \underline{\underline{28.2\text{ years}}}$ (1M+1A)

(iii) If the spacecraft fails to launch and falls back to the earth, there may be risk of contamination to the environment if the fuel leaks. (2A)

sub-total: 8

Total mark = 84