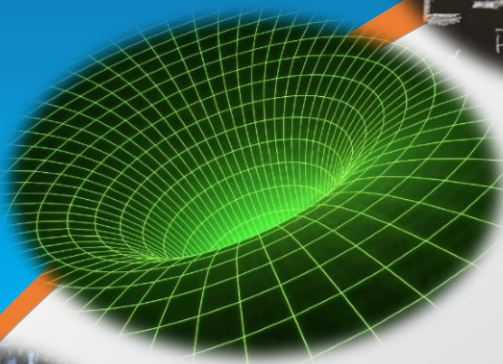
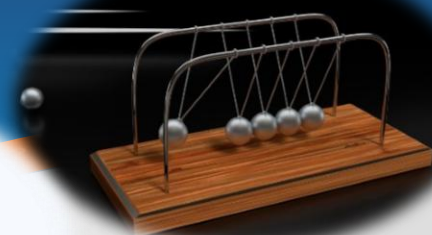
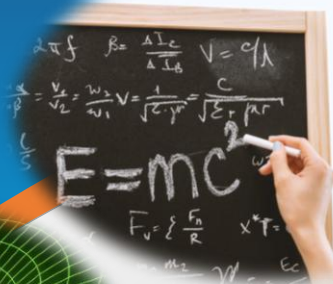




**CARIBBEAN
EXAMINATIONS
COUNCIL**

CAPE[®] PHYSICS UNIT 2



Subject Report with Exemplars

May/June 2024

CARIBBEAN EXAMINATIONS COUNCIL

**REPORT ON CANDIDATES' WORK IN THE
CARIBBEAN ADVANCED PROFICIENCY EXAMINATION**

MAY/JUNE 2024

**PHYSICS
UNIT 2**

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INTRODUCTION

This was the sixth examination since the revised syllabus.

For Unit 2, this year, the percentage of candidates earning acceptable grades, Grades I–V, was approximately 96.9 per cent compared with 95.8 per cent in 2023 and 97.8 per cent in 2022.

Candidate performance improved on all modules.

Module 1: Electricity and Magnetism

Module 2: AC Theory and Electronics

Module 3: Atomic and Nuclear Physics

PAPER 01 — MULTIPLE CHOICE

Paper 01 consisted of 45 multiple-choice items. It was designed to provide adequate coverage of the content with items taken from all sections of the syllabus. Approximately 70.4 per cent of candidates earned grades I–III on this paper; the mean score was 35 out of 45 marks.

PAPER 02 — STRUCTURED ESSAY

Paper 02 consisted of three questions, one drawn from each of the modules in the syllabus.

Each question was worth 30 marks. Candidates were required to answer all three questions. The mean score for the entire paper was 37 out of 90. Three candidates obtained full marks for Question 1 while 94 or 4.3 per cent of those attempting Question 2 obtained full marks. For Question 3, five candidates obtained full marks.

Question 1

Part (a) required candidates to define the term *magnetic flux density*. Two definitions were accepted for this term.

The number of magnetic field lines or the magnetic flux per unit (cross sectional) area

The force acting per unit length per unit current on a current carrying conductor perpendicular to the magnetic field

Most candidates achieved only partial marks because they wrote of the magnetic flux as being 'for a certain area' instead of stating that it is *per unit area*. In some instances, candidates did not include the perpendicular condition.

Candidate's Response to Part (a)

(a) Define the term 'magnetic flux density'.

Magnetic flux density refers to the strength of a magnetic field when a
✓ it acts per unit ✓ current per unit length, L , of a conductor perpendicular ✓
to the field.

$$B = \frac{F}{IL \sin 90}, \quad F = \text{force (N)}, \quad I = \text{current (A)}, \quad L = \text{length in field (m)} \quad [2 \text{ marks}]$$

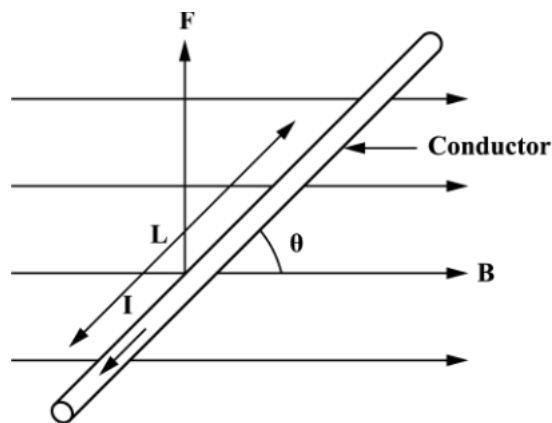
Examiner's Comments

The candidate was able to provide an accurate definition of the term.

For Part (b) (i), candidates had to draw a fully labelled diagram to illustrate the direction of the force, F , acting on a straight conductor of length, L , carrying a current, I , at an angle, θ , to a uniform magnetic field of flux density, B .

The task was difficult for candidates; they knew how to apply Fleming's left-hand motor rule but were unable to represent the terms diagrammatically with the correct orientation in a 3D diagram. Many candidates understood that the formula $F = BIL \sin \theta$ could be used but were unfamiliar with the orientations of the vector terms in the formula.

Expected Response to Part (b) (i)



For Part (b) (ii), candidates were asked to write the expression for the force, F , experienced per unit length of the conductor in terms of B , I , L and θ . Many candidates stated $F = BIL \sin \theta$ but failed to divide by L . The exemplars below show two responses, one with and the other without the division.

Candidates' Responses to Part (b) (ii)

- (ii) Write the expression for the force, F , experienced per unit length of the conductor in terms of B , I , L and θ .

..... $F = BIL \sin \theta$

.....

[2 marks]

- (ii) Write the expression for the force, F , experienced per unit length of the conductor in terms of B , I , L and θ .

..... $F = BIL \sin \theta$ ✓

..... $\frac{F}{L} = BI \sin \theta$ ✓

[2 marks]

Part (b) (iii) highlighted a situation where a 3.5 m long wire carries a current of 7.5 A, making an angle of 30° with a uniform magnetic field of field strength, 2.0 mT. Candidates had to calculate the magnitude of the magnetic force experienced by the wire. The calculation was well done by most candidates though some did not convert and some who knew they had to convert, did not convert correctly, that is from mT to T by dividing by 1000.

Candidates' Responses to Part (b) (iii)

- (iii) **A 3.5 m long wire carries a current of 7.5 A, making an angle of 30° with a uniform magnetic field of field strength, 2.0 mT.**

Calculate the magnitude of the magnetic force experienced by the wire.

$$\begin{aligned}
 F &= BIL \sin \theta \\
 &= (2 \times 10^{-2}) (7.5) (3.5) \sin 30^\circ \\
 &= 2.63 \times 10^{-2} \text{ N}
 \end{aligned}$$

[3 marks]

- (iii) **A 3.5 m long wire carries a current of 7.5 A, making an angle of 30° with a uniform magnetic field of field strength, 2.0 mT.**

Calculate the magnitude of the magnetic force experienced by the wire.

$$\begin{aligned}
 F &= BIL \sin \theta \\
 F &= (2 \times 10^{-3} \text{ T}) \times (7.5) \times (3.5) \times \sin(30^\circ) \\
 F &= 0.02625 \text{ N} \\
 F &= \underline{\underline{2.6 \times 10^{-2} \text{ N (2.s.f.)}}}
 \end{aligned}$$

[3 marks]

Examiner's Comments

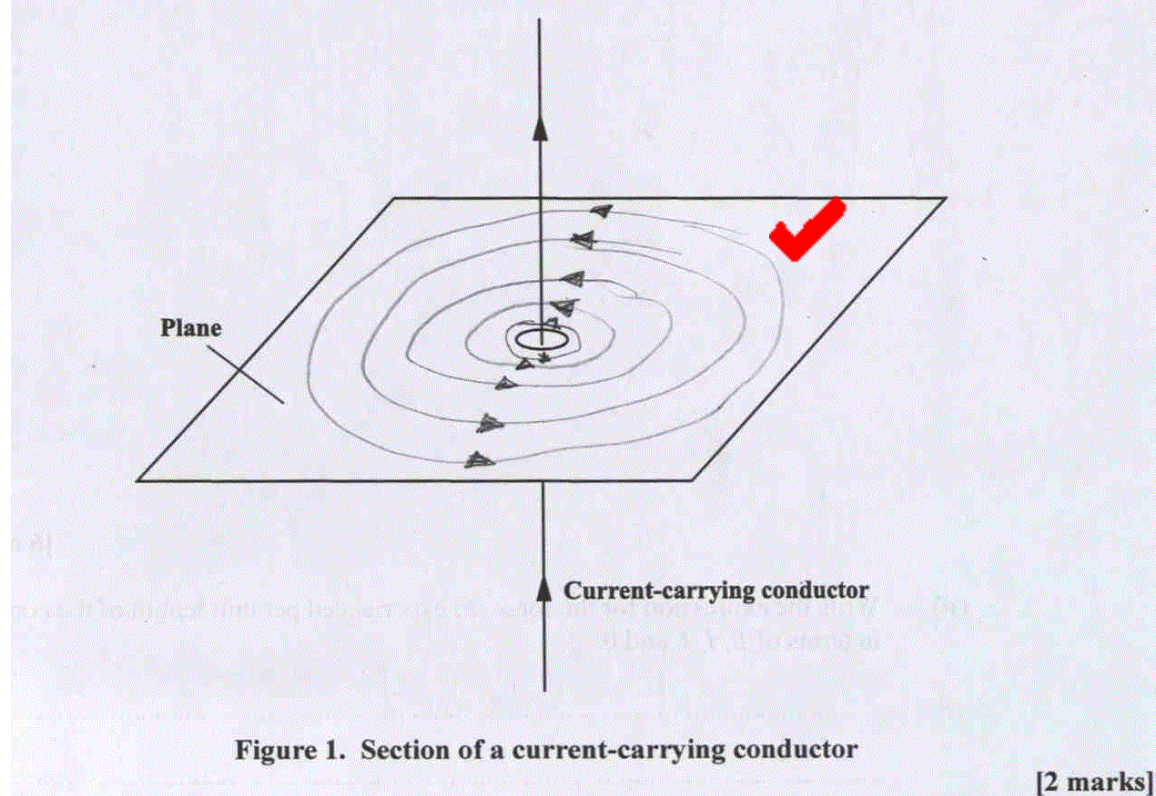
Both candidates failed to pay keen attention to the details of the question and so, they did not divide by L to get an expression the magnitude of F/L.

Part (c) required candidates to sketch the pattern of the magnetic field around the conductor in the plane normal to the axis of the conductor. A significant number of candidates did not recall that magnetic field lines are arranged in concentric circles around the current-carrying conductor and therefore produced inaccurate magnetic field patterns. The question was well done by the better candidates.

Candidate's Response to Part (c)

(c) Figure 1 shows a section of a current-carrying conductor of uniform cross-section.

On Figure 1, sketch the pattern of the magnetic field around the conductor in the plane normal to the axis of the conductor.



Examiner's Comments

Accurately executed.

Part (d) consisted of two subparts all based on the premise that an electron travels at $2.5 \times 10^7 \text{ m s}^{-1}$ in a plane perpendicular to a uniform 10 mT magnetic field. For Part (d) (i), candidates had to determine an expression for the magnitude of the force acting on the electron. A fair number of candidates derived the correct expression.

Candidate's Response to Part (d) (i)

(d) An electron travels at $2.5 \times 10^7 \text{ m s}^{-1}$ in a plane perpendicular to a uniform 10 mT magnetic field.

(i) Determine an expression for the magnitude of the force acting on the electron.

$$\begin{aligned}
 F &= BIL \\
 \text{but } L &= \frac{v}{t} \\
 \therefore F &= \frac{BIv}{t} \\
 \text{but } \frac{I}{t} &= Q
 \end{aligned}
 \rightarrow \therefore F = BQv$$

Where F is the force acting on the electron
 B is the magnetic flux density
 Q is the charge of the electron (e)
 v is the velocity of the electron

($F = Bqv$)

[3 marks]

For Part (d) (ii), it was further stated that the electron will travel in a circular path. Candidates were then asked to determine an expression for the radius of that path. Again, a fair number of candidates determined the correct expression.

Candidate's Response to Part (d) (ii)

Calculate the radius of the path.

$$\begin{aligned}
 r &= \frac{9.11 \times 10^{-31} \times 2.5 \times 10^7}{10 \times 10^{-3} \times 1.6 \times 10^{-19}} \\
 &= 0.014 \text{ m} = 1.4 \text{ cm} \\
 &= 1.4 \times 10^{-2} \text{ m}
 \end{aligned}$$

[2 marks]

Part (d) (iii) required candidates to calculate the radius of the path the electron will travel. Those who did Part (ii) correctly were able to easily calculate the radius. Again, some candidates either did not convert or they converted incorrectly and lost both marks.

Candidate's Response to Part (d) (iii)

(iii) Calculate the radius of the path.

$$r = \frac{9.11 \times 10^{-31} \times 2.5 \times 10^7}{10 \times 10^{-3} \times 1.6 \times 10^{-19}} = 0.014 \text{ m} = 1.4 \text{ cm}$$
$$= 1.4 \times 10^{-2} \text{ m}$$

[2 marks]

Examiner's Comments

The preceding exemplars demonstrate an excellent execution of the objectives set out in this question. The candidate was able to draw on prior knowledge of circular motion and relate it to the motion of an electron (particle) in a circular orbit. Consequently, the candidate was able to determine the radius of the circular path from the relationship of the forces involved, that is, ($F_B = F_c$).

For Part (e) (i), candidates had to state Lenz's law. A fair number of candidates gave a correct or partially correct definition.

Candidate's Response to Part (e) (i)

(e) (i) State Lenz's law.

Lenz law states that when there is a change of magnetic flux linked with a conductor, the direction of the induced current is such that it opposes the change or motion creating it.

[2 marks]

Examiner's Comments

The candidate was able to produce an accurate rendition of Lenz's law.

For Part (e) (ii), candidates were asked to describe a simple experiment that can be performed to demonstrate Lenz's law using a bar magnet, a galvanometer and a solenoid. Most candidates were familiar with the setup and execution of the experiment. Candidates indicated the observation of the experiment (galvanometer deflection) but failed to identify the observation of repulsion (opposition to motion) as the verification of Lenz's law.

Candidate's Response to Part (e) (ii)

(ii) You are provided with a bar magnet, a galvanometer and a solenoid.

* Describe a simple experiment that can be performed to demonstrate Lenz's law.

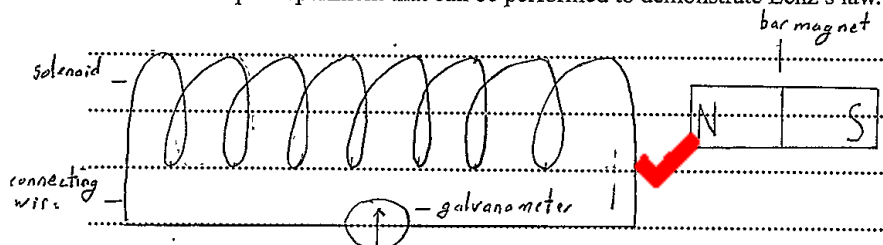


DIAGRAM SHOWING THE SETUP NECESSARY FOR INVESTIGATION

Step 1: Set up the apparatus as shown above. The following results will be seen:
 Inward movement of north end →

Step 2: Move the north end of the bar magnet into the solenoid at a notable speed. It will be seen that for each receding, current flows such that the end of the solenoid closest to the bar magnet becomes magnetically opposing.

Step 3: Record the deflection and direction of the galvanometer.

Step 4: Remove the north end of the same speed.

Step 5: Record the direction of deflection of the galvanometer.

Bar magnet and its solenoid	direction of movement	Galvanometer deflection	Nearest Solenoid Pole
North	inward	↗	North
South	inward	↖	South
North	outward	↖	South
South	outward	↗	North

Total 30 marks

Examiner's Comments

The candidate used a diagram to substantiate the steps listed to demonstrate Lenz's law; this is commendable.

Overall performance on Question 1 was fair with approximately 40 per cent of candidates scoring above 15 out of 30 marks.

Recommendations

- Precise terminology should be emphasized when teaching definitions.
- Candidates should use SI units when performing calculations.
- The need for unit conversion when applying formulae should be stressed.
- Candidates should practise correct conversions involving multiple and submultiple units.
- The relationship $F = BIL \sin \theta$ should be taught in tandem with a 3D diagram to show the orientations of the terms.
- Instruction should extend beyond demonstrating induced current for the verification of Faraday's law to include verification of Lenz's law.
- Experimental discussions should include not only observations but deductions from the observations.

Question 2

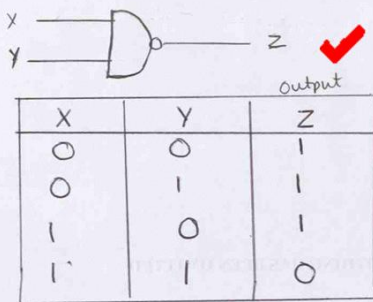
This question tested candidates' knowledge of logic gates. The question was fairly done overall. There were very few candidates who did not attempt the question and quite a number got more than 50 per cent.

Part (a) required candidates to draw both the symbol and the truth table for the following two-input logic gates: NAND, OR and EXNOR. Many candidates were able to draw the circuit symbols of the gates and the truth tables. However, some drawings were untidy.

Candidate's Response to Part (a) (i)

(a) Draw the symbol **and** the truth table for EACH of the following two-input logic gates.

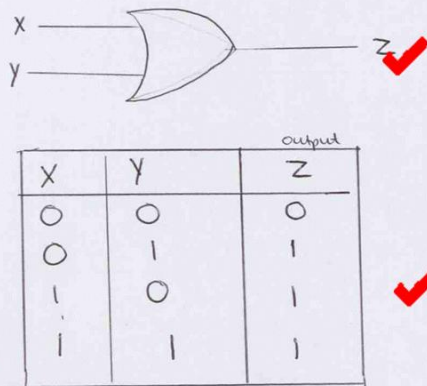
(i) NAND



[3 marks]

Candidate's Response to Part (a) (ii)

(ii) OR



[3 marks]

Candidate's Response to Part (a) (iii)

(iii) EXNOR (same gate)

X	Y	output Z
0	0	1
0	1	0
1	0	0
1	1	1

[4 marks]

Examiner's Comments

The candidate drew the correct symbol for the gate and the truth table.

For Part (b), candidates had to complete a truth table based on a given figure. Most candidates were able to fill out the truth table correctly and were awarded full marks for this part. However, there were a few candidates who were unable to do so.

Candidate's Response to Part (b)

(b) Figure 2 shows a logic circuit with three binary inputs, A, B and C.

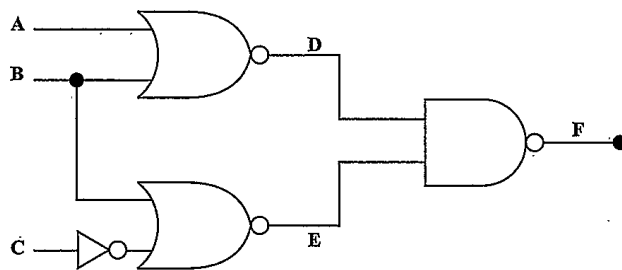


Figure 2: Logic circuit with binary inputs, A, B and C

Table 1 is a truth table for the logic circuit in Figure 2 which shows combinations of the binary inputs, A, B and C. Complete Table 1 by deducing the corresponding values of C', D, E and F.

TABLE 1: TRUTH TABLE WITH BINARY INPUTS, A, B, C

A	B	C	C'	D	E	F
0	0	0	1	1	0	1
0	0	1	0	1	1	0
0	1	0	1	0	0	1
0	1	1	0	0	0	1
1	0	0	1	0	0	1
1	0	1	0	0	1	1
1	1	0	1	0	0	1
1	1	1	0	0	0	1

For a NOR gate:

A	B	C
0	0	1
0	1	0
1	0	0
1	1	0

For a NAND gate:

A	B	C
0	0	1
0	1	1
1	0	1
1	1	0

[8 marks]

Examiner's Comments

The candidate correctly filled out the truth table.

In Part (c), candidates were required to use the truth table from Part (b) to determine and sketch the resulting output waveform on the grid provided. The sketch had to include the binary equivalent of the output waveform. Some candidates were able to draw the timing diagram but quite a few forgot to put in the binary equivalent on the diagram. Others were unable to draw the timing diagram.

Candidate's Response to Part (c)

(c) Figure 3 is a timing diagram which shows the input waveforms to the circuit in Figure 2.

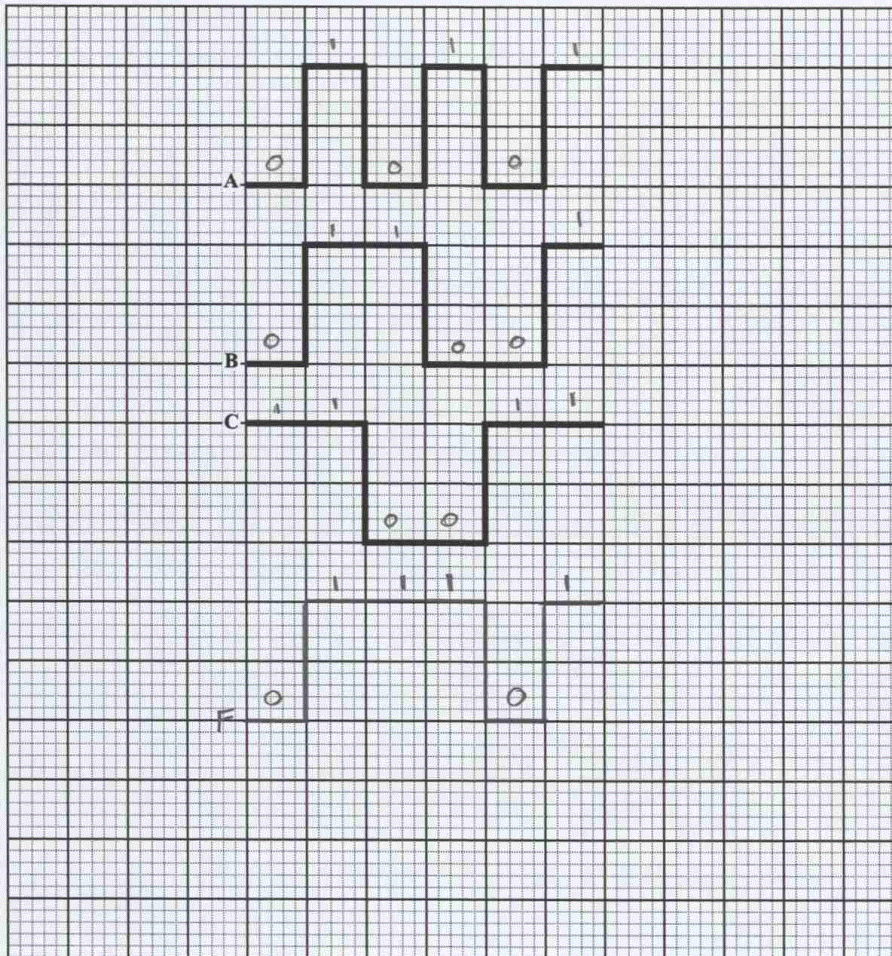


Figure 3. Timing diagram for logic circuit in Figure 2

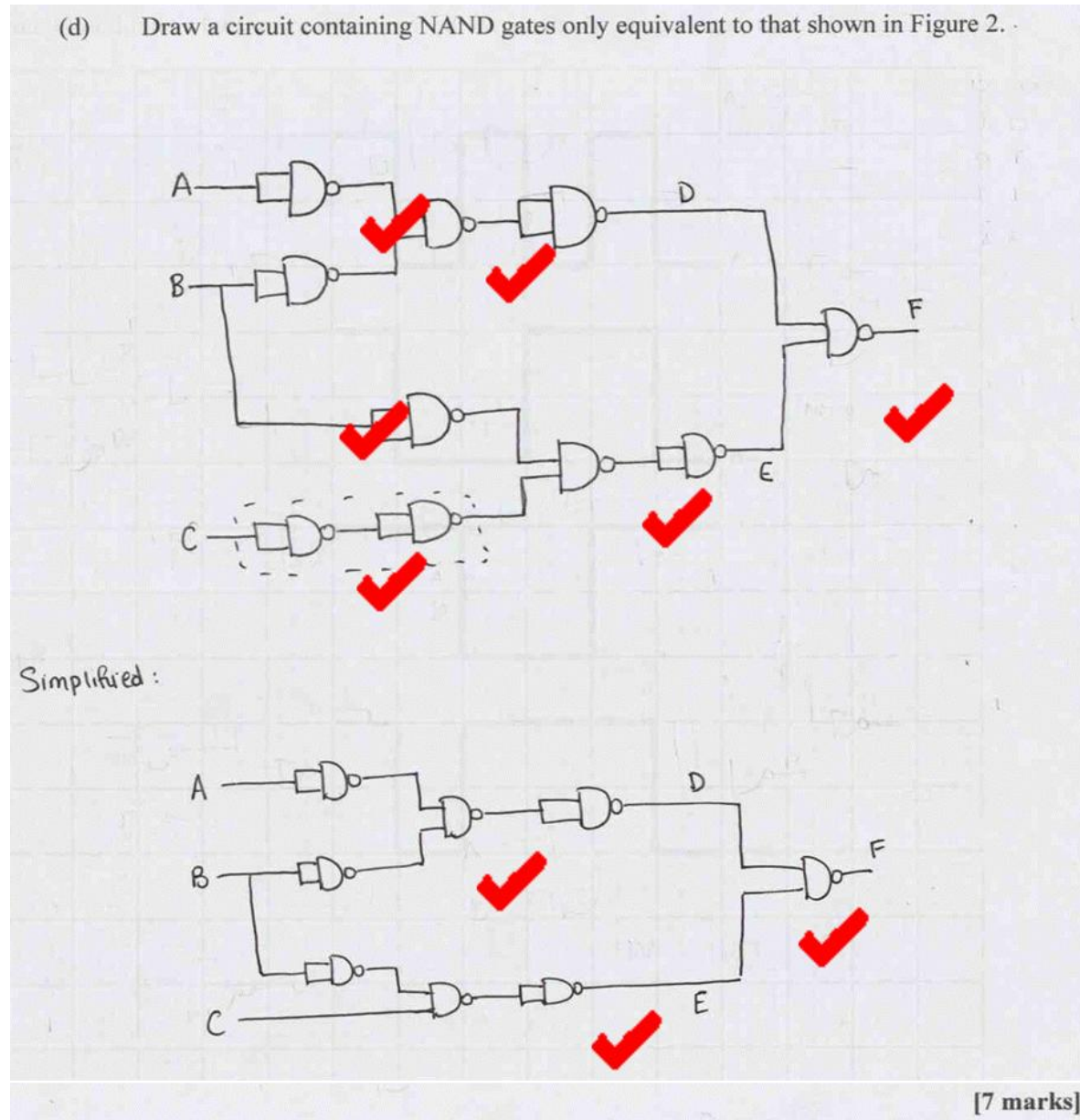
Use your truth table in (b) to determine and sketch the resulting output waveform on the grid provided in Figure 3. On your sketch, include the binary equivalent of the output waveform. **[5 marks]**

Examiner's Comments

The candidate correctly drew the timing diagram and correctly included the binary equivalents.

Part (d) asked candidates to draw a circuit containing NAND gates only equivalent to that shown in Figure 2 from Part (b).

Candidate's Response to Part (d)



Examiner's Comments

The candidate drew the equivalent circuit by correctly replacing the gates with their NAND equivalent and then removed the redundant NOT gates and redrew the circuit without them.

Recommendations

- Candidates should practise drawing circuit symbols and develop a clear understanding of the equivalent circuits for logic gates. They should also recognize that the removal of redundant NOT gates must be supported by correct equivalent circuit analysis, rather than assumption.
- Candidates should undertake further practice in deriving truth tables for combinational logic circuits.
- Candidates should allocate time to practising timing diagrams for individual logic gates and more complex logic circuits.

Question 3

Part (a) required candidates to identify six parts of the Millikan oil drop experiment apparatus. The parts were labelled A to F.

The main errors in labelling the Millikan apparatus occurred when candidates interchanged the labels for the anode (+ve) and cathode (-ve) plates. There were also issues with stating the appropriate type of radiation to charge the drop as well as identifying the atomizer.

Candidate's Response to Part (a) – Sample 1

Figure 4 shows a simplified version of the apparatus used in R. A. Millikan's famous experiment.

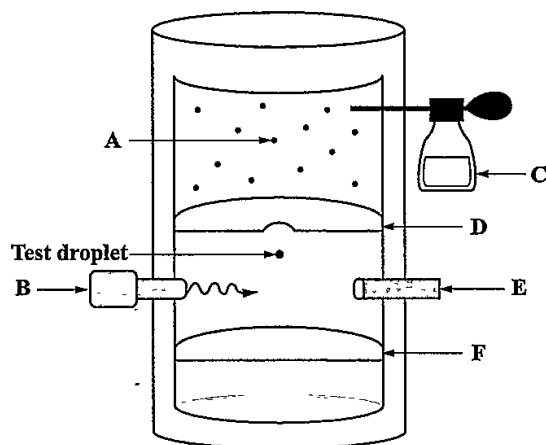


Figure 4. Apparatus used in R. A. Millikan's experiment

(a) Identify EACH of the components labelled A–F.

- ✓ A oil droplet / mist of oil droplets
- ✓ B X-rays (source)
- ✓ C atomizer
- ✓ D anode (metallic)
- ✓ E microscope
- ✓ F cathode (metal)

[6 marks]

Candidate's Response to Part (a) – Sample 2

Figure 4 shows a simplified version of the apparatus used in R. A. Millikan's famous experiment.

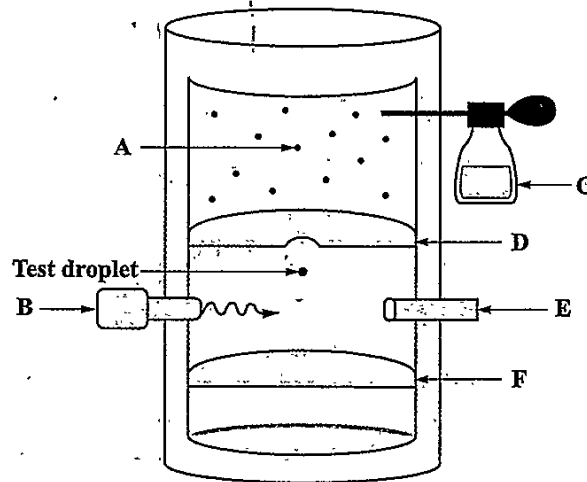


Figure 4. Apparatus used in R. A. Millikan's experiment

(a) Identify EACH of the components labelled A–F.

- A Oil droplets ✓
- B α -ray tube ✓
- C atomiser ✓
- D charged plate (positive) ✓
- E graduated microscope ✓
- F negative plate ✓

[6 marks]

Examiner's Comments

The candidates gave accurate responses.

For Part (b) (i), candidates had to complete a table with results from an experiment. Candidates seemed unaware of the precedence of using consistent significant figures over consistent decimal places when presenting tabulated data.

Candidate's Response to Part (b) (i)

- (b) It can be shown that for Millikan's experiment, the charge Q , in Coulombs, on the test droplet and the voltage V , in Volts, of the supply are related by the equation

$$Q = \frac{K}{V} \quad Q = \left(\frac{1}{V}\right)k$$

where K is a constant derived from the properties of the droplet.

Table 2 shows results derived from a simulated experiment in which the charge on different droplets and the corresponding balance voltages were obtained.

TABLE 2: RESULTS OF EXPERIMENT

$Q/C (\times 10^{-19})$	$V/V (\times 10^3)$	$\frac{1}{V} / V^{-1} (\times 10^{-4})$
4.80	5.01	2.00
8.00	4.17	2.40
11.2	2.14	4.67
17.6	1.48	6.76
22.4	1.07	9.35
32.0	0.83	12.0

- (i) Complete Column 3 of Table 2. (3 sig figs!) [2 marks]

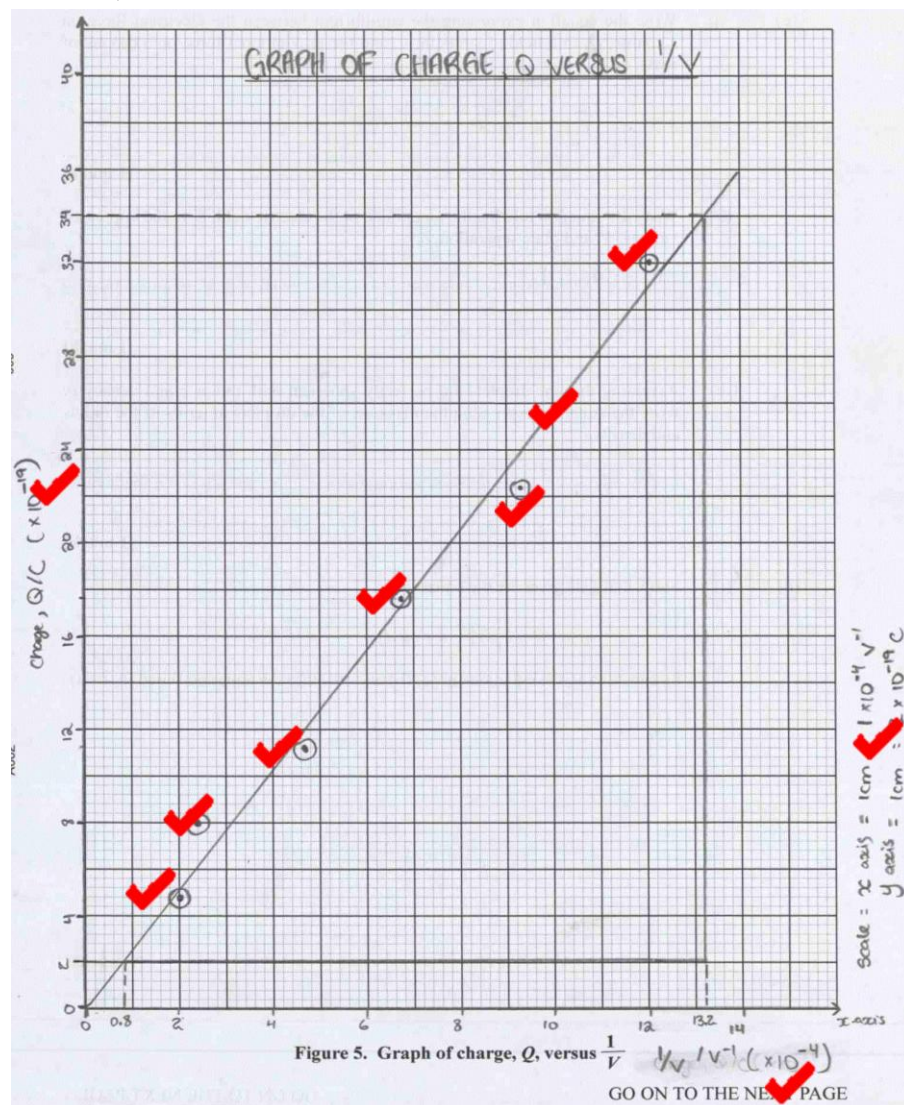
Examiner's Comments

The candidate demonstrated an understanding of the importance of maintaining consistency in significant figures rather than relying solely on decimal places when presenting data, recognizing the distinction between precision and accuracy.

Part (b) (ii) asked candidates to plot a graph of Q vs $\frac{1}{V}$ and draw a line of best fit through the points. The graph was generally well done, showing that graphing skills are improving; however, too many candidates did not fully label the graph with the quantity and the unit, and many omitted the exponent value attached to the quantity value.

Candidate's Response to Part (b) (ii) – Sample 1

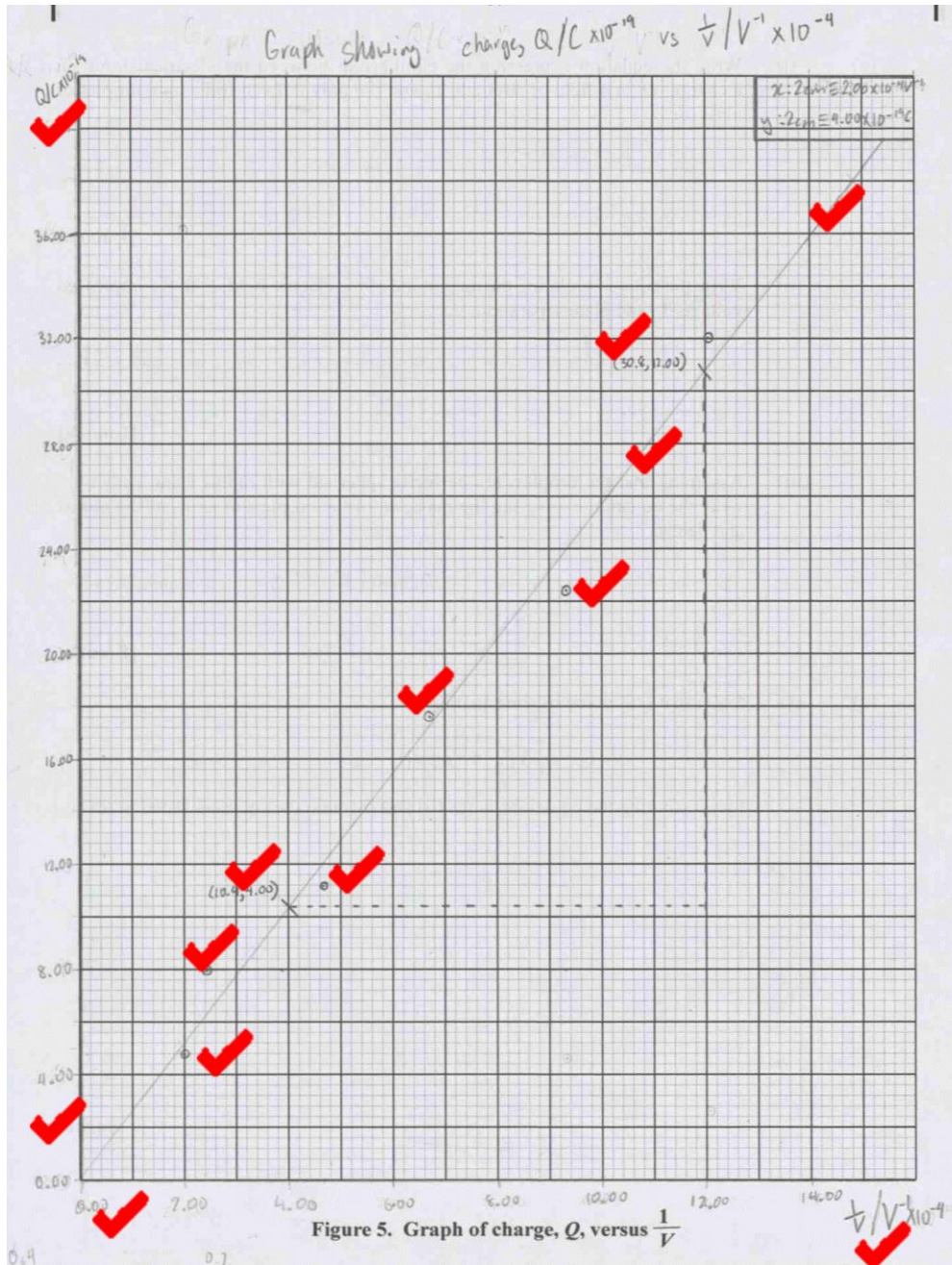
- (ii) On the grid provided in Figure 5 on page 17, plot a graph of charge, Q , versus $\frac{1}{V}$. Draw the line of best fit through the points. **[4 marks]**



Examiner's Comments

The graph could have been perfect if the candidate had used a thinner pencil point and drew smaller circles to represent the coordinates.

Candidate's Response to Part (b) (ii) – Sample 2



Examiner's Comments

The candidate's line of best fit was almost perfect. The coordinate markers were appropriate in size.

For Part (b) (iii), candidates had to use the graph to determine the constant K (given that the equation relating Q and V is given by $Q = \frac{K}{V}$). While most candidates showed proficiency in identifying coordinates and correctly substituting them to determine the gradient, in many cases the triangle used was either too small or it utilized points on the line outside of the range of the data. When stating the final answer, units were not provided. Candidates were penalized for this misdemeanour.

Candidate's Response to Part (b) (iii) – Sample 1

(iii) Use the graph in (b) (ii) to determine a value for the constant, K.

$$\begin{aligned}
 Q &= \frac{K}{V} \\
 Q &= k \times \frac{1}{V} + 0 \\
 y &= m x + c \\
 m = \text{gradient} &= K \\
 m &= \frac{y_2 - y_1}{x_2 - x_1} = \frac{(33.2 \times 10^{-19}) - (6 \times 10^{-19})}{(13 \times 10^{-4}) - (2.4 \times 10^{-4})} \left(\frac{C}{V} \right) \\
 &= 2.566 \times 10^{-15} \text{ CV} \\
 \therefore K &= 2.57 \times 10^{-15} \text{ CV}
 \end{aligned}$$

[4 marks]

Candidate's Response to Part (b) (iii) – Sample 2

(iii) Use the graph in (b) (ii) to determine a value for the constant, K.

$$\begin{aligned}
 \text{So, recall } Q &= \frac{K}{V} \therefore K = QV \\
 \text{From graph, gradient } m &= \frac{Q}{V^{-1}} = QV, \text{ hence} \\
 \text{gradient} &= K \\
 \text{Using points } & \left(\begin{array}{cc} x_1 & y_1 \\ 1 \times 10^{-4} & 2.5 \times 10^{-19} \\ x_2 & y_2 \\ 14 \times 10^{-4} & 37 \times 10^{-19} \end{array} \right) \\
 K &= \frac{y_2 - y_1}{x_2 - x_1} = \frac{(37 \times 10^{-19} - 2.5 \times 10^{-19}) \text{ C}}{(14 \times 10^{-4} - 1 \times 10^{-4}) \text{ V}^{-1}} \\
 K &= 2.65 \times 10^{-15} \text{ CV}
 \end{aligned}$$

[4 marks]

Examiner's Comments

These candidates provided accurate responses.

Responses to Part (c) confirm that most candidates recall equations when required. Part (c) (i) required candidates to write the equation expressing the equilibrium between the electrical force on a charge, Q , in a field strength, E , and the gravitational force on a droplet of mass, m . Part (c) (ii) was another equation question. Candidates had to write the equation relating the magnitude of the electric field, E , to the impressed voltage, V and plate separation, d . Part (c) (iii) was based on the assumption that the droplets are perfectly spherical with a radius r , and density ρ . Candidates had to write the equation expressing the mass, m , of the droplets in terms of the radius and density.

Candidate's Response to Part (c) (i)

- (c) (i) Write the equation expressing the equilibrium between the electrical force on a charge, Q , in a field of strength, E , and the gravitational force on a droplet of mass, m .

$$m \cdot g = EQ \quad \checkmark$$

Candidate's Response to Part (c) (ii) – Sample 1

- (ii) Write the equation relating the magnitude of the electric field, E , to the impressed voltage, V , and plate separation, d .

$E = \frac{V}{d}$, minus sign is typically ignored in calculations, so $E = \frac{V}{d}$ ✓

[1 mark]

Candidate's Response to Part (c) (ii) – Sample 2

- (ii) Write the equation relating the magnitude of the electric field, E , to the impressed voltage, V , and plate separation, d .

$$E = \frac{V}{d} \quad \checkmark$$

[1 mark]

Candidate's Response to Part (c) (iii)

- (iii) Assuming that the droplets are perfectly spherical with radius r and density ρ , write the equation expressing the mass, m , of the droplets in terms of the radius and density.

$$m = \rho V = \rho \times \frac{4}{3} \pi r^3$$

$$m = \frac{4}{3} \pi \rho r^3$$

[1 mark]

Examiner's Comments

The responses were accurate.

For Part (d) (i), candidates were asked to show that Q is given by the equation $Q = \left(\frac{1}{V}\right) \left[\frac{4}{3}\pi r^3 \rho g d\right]$ by substituting the equations in (c) (i), (ii) and (iii) into the equation stated in (c) (i). This question exposed candidates' weakness in manipulating and combining equations to derive formulae.

Candidate's Response to Part (d) (i) – Sample 1

- (d) (i) Show that Q is given by the equation

$$Q = \left(\frac{1}{V}\right) \left[\frac{4}{3}\pi r^3 \rho g d\right]$$

by substituting the equations in (c) (ii) and (iii) into the equation stated in (c) (i).

$$EQ = mg$$

$$\frac{V}{d} Q = mg$$

$$\frac{V}{d} Q = \frac{4}{3}\pi r^3 \rho g$$

$$Q = \frac{\frac{4}{3}\pi r^3 \rho g d}{V}$$
~~$$Q = \left(\frac{1}{V}\right) \left[\frac{4}{3}\pi r^3 \rho g d\right]$$~~

[2 marks]
as required

Candidate's Response to Part (d) (i) – Sample 2

- (d) (i) Show that Q is given by the equation

$$Q = \left(\frac{1}{V}\right) \left[\frac{4}{3}\pi r^3 \rho g d\right]$$

by substituting the equations in (c) (ii) and (iii) into the equation stated in (c) (i).

$$EQ = mg$$

$$\frac{V}{d} Q = \frac{4}{3}\pi r^3 \rho g \quad \checkmark$$

$$Q = \frac{4}{3}\pi r^3 \rho g \cdot \frac{d}{V} \quad \checkmark$$
~~$$Q = \left(\frac{1}{V}\right) \left[\frac{4}{3}\pi r^3 \rho g d\right] \text{ Q.E.D.}$$~~

$$\therefore Q = \left(\frac{1}{V}\right) \left[\frac{4}{3}\pi r^3 \rho g d\right] \text{ Q.E.D.} \quad \checkmark \quad [2 \text{ marks}]$$

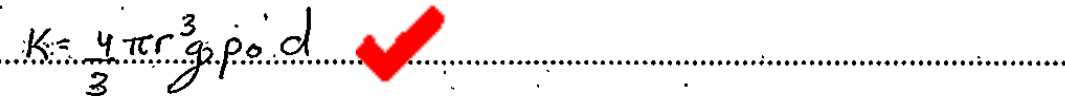
Examiner's Comments

The candidates followed the instructions to use data from Parts (c) (i), (ii) and (iii), and presented easy-to-follow steps to reach a solution.

Part (d) (ii) required candidates to deduce an expression for K. Most candidates recognized the equation for K and stated it correctly.

Candidate's Response to Part (d) (ii)

(ii) Hence, deduce an expression for K.

$$K = \frac{4}{3} \pi r^3 \rho g d$$


[1 mark]

Examiner's Comments

The candidate answered correctly.

For Part (d) (iii), candidates were given experimental data in a table and asked to determine a value for the magnitude of K. Many candidates, building on earlier parts, correctly substituted values from the given table to obtain the correct answer. However, a significant number of candidates overlooked the required unit conversion (mm to m) or failed to include the appropriate unit in the final answer.

Candidate's Response to Part (d) (iii)

(iii) Given the experimental data in the following table, determine a value for the magnitude of K.

Symbol	Quantity	Value
d	Plate separation	6 mm
r	Radius of typical droplet	2×10^{-6} m
ρ	Density of droplet	1.2×10^3 kg m ⁻³

$$\begin{aligned}
 K &= \frac{4}{3} \pi r^3 \rho g d \\
 &= \frac{4}{3} \pi (2 \times 10^{-6})^3 \times 1.2 \times 10^3 \times 9.81 \times 6 \times 10^{-3} \\
 K &= 2.37 \times 10^{-15} \text{ CV}
 \end{aligned}$$

[3 marks]

Examiner's Comments

The candidate used order of quantities in the equation from Part d (ii) effectively to perform an accurate substitution.

Part (e) (i) asked candidates to state the direction of the buoyancy force on an oil droplet in the presence of air in the Millikan apparatus. It was gratifying to see that most candidates correctly stated the direction of the buoyancy force.

Candidate's Response to Part (e) (i)

(e) The original Millikan experiment was performed in the presence of air which exerted a buoyancy force on the droplet.

(i) State the direction of the buoyancy force.

 Upward

[1 mark]

Examiner's Comments

The response was concise and accurate.

For Part (e) (ii), candidates had to calculate the magnitude of the buoyancy force given that the density of air is 1.3 kg m^{-3} . It was evident from the performance that candidates struggled with the application of the theory.

Candidate's Response to Part (e) (ii) – Sample 1

(ii) Calculate the magnitude of the buoyancy force given that the density of air is 1.3 kg m^{-3} .

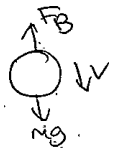
Archimedes Principle:
 buoyancy force (upthrust) = weight of fluid displaced

$F_B = V \rho_{\text{air}} g$ $\rho = \frac{m}{V}$
 $m = \rho V$

$= \frac{4}{3} \pi r^3 \times \rho_{\text{air}} \times g$

$= \frac{4}{3} \pi (2 \times 10^{-6})^3 \times 1.3 \times 9.81$

$= 4.27 \times 10^{-16} \text{ N}$



ie F_B is very small as $\rho_{\text{oil}} \gg \rho_{\text{air}} \therefore$ it does

Candidate's Response to Part (e) (ii) – Sample 2

- (ii) Calculate the magnitude of the buoyancy force given that the density of air is 1.3 kg m^{-3} .

Buoyancy Force = Weight of air displaced

Using the values from d(iii):

$$r = 2 \times 10^{-6} \text{ m}$$

$$\therefore \text{Volume of drop} = \frac{4}{3} \pi r^3 = \frac{4}{3} \times \pi \times (2 \times 10^{-6})^3$$

$$= 3.35 \times 10^{-17} \text{ m}^3$$

Volume of drop = Volume of air displaced

$$\therefore \text{Volume of air displaced} = 3.35 \times 10^{-17} \text{ m}^3$$

$$\text{Mass of air} = \rho V = 1.3 \times 3.35 \times 10^{-17}$$

$$= 4.36 \times 10^{-17} \text{ kg}$$

$$\text{Force exerted by air} = mg$$

$$= 4.36 \times 10^{-17} \times 9.81$$

$$= 4.27 \times 10^{-16} \text{ N}$$

[4 marks]

Total 30 marks

END OF TEST

$$= 4.27 \times 10^{-16} \text{ N}$$

Examiner's Comments

The responses consisted of well-crafted solutions. (Textbook approach).

For Question 3, approximately 19.5 per cent of candidates achieved at least 70 per cent of the total marks, while 32.8 per cent of candidates failed to achieve at least 30 per cent.

Recommendations

- Teachers should emphasize that physical quantities form the foundation of Physics and consist of both a numerical value and a unit. Students should therefore be encouraged to consistently include appropriate units when presenting their responses.
- Teachers should reinforce the importance of correct graphing, techniques with particular emphasis on appropriate scaling, accurate labelling of axes and the drawing of a suitable line of best fit.
- Teachers may need to allocate additional time to clarify the appropriate use of decimal places and significant figures when displaying data in tabular form.
- Students should practise deriving equations and putting them in the standard form $y = mx + c$.
- Students should practise combining equations appropriately to derive new equations.

PAPER 032 — ALTERNATIVE TO SCHOOL-BASED ASSESSMENT (SBA)

This paper consisted of three 15-mark questions. The first question was an experiment that had to be executed; the second question was analysis of the results from an executed experiment and the third question was an experiment that must be designed given a particular problem statement or apparatus.

Question 1

This question required candidates to perform an experiment to investigate the magnetic field strength at the centre of a solenoid and use this to determine the number of turns on the solenoid.

Some candidates could not change their results from $\times 10^5$ to mT and this error carried through the question. Some graphs were well drawn but there were others that were very poorly executed with no labels and incorrect scales. There were also instances where points were incorrectly plotted and the line of best fit was omitted.

Many candidates were able to find the gradient of the graph they had drawn but only a very few of them knew how the gradient related to the number of turns on the solenoid despite being given the equation in the question and so, many scored very few marks here.

While some candidates were able to correctly identify an error that can occur in the experiment, they could not go on to identify what should be done to prevent such an error from occurring. As a result, these candidates gave a completely unrelated precaution. In some cases, candidates were unable to identify either the error or the precaution.

Sources of error and precautions that could have been stated for the latter part of the question, Part (f), are shown in the table below.

Source of Error	Precaution
Excess heat in the coils	The heat can be minimized by opening the switch after each trial to allow the solenoid to cool.
Background field such as the Earth's B field	The probe can be calibrated and set to zero before taking the measurements.
Current fluctuation from the source	The rheostat is used to regulate the current.

Question 2

The first part of the question was well done; candidates drew the graph and filled out the table with the calculations necessary.

The graphs were well drawn, and most candidates were able to find the gradient and the find the half-life.

Many candidates lacked understanding of the assumption underlying the experiment and were therefore unable explain why it would affect the results. The expected response is provided below.

Major assumption: Effect of background radiation has been ignored.

Effect: Background radiation will increase values of R and R_0 . Considering the likely magnitude of the background count relative to R and R_0 , the ratio will be minimally affected and hence S would also be minimally affected; hence $t_{1/2}$ will be minimally affected.

Only a few candidates were able to state the precaution that must be taken when storing radioactive materials. Suitable precautions included *storing the materials in a lead-lined container* or *storing them in a special room*.

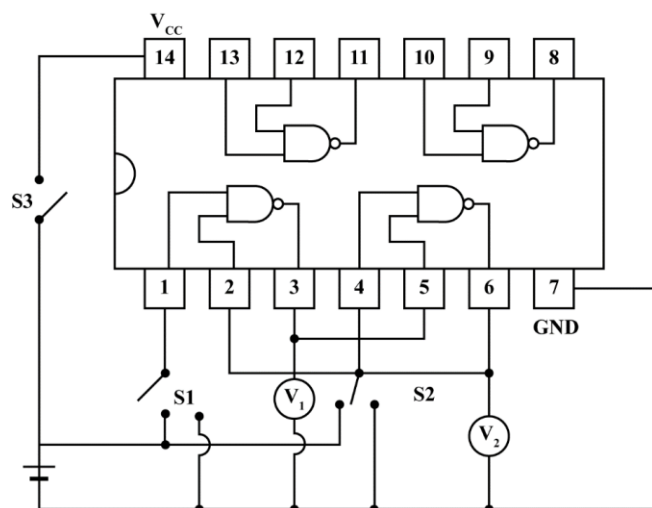
Question 3

This planning and design experiment was very poorly done. No candidate was able to describe the experiment or even draw the circuit necessary for executing the experiment.

For Part (a), additional apparatus and materials that candidates were expected to list include the following.

- 5V power supply
- 2 voltmeters (multimeters or 5 VDC)
- 1 SPST
- 2 SPDTs

The completed diagram for Part (b) should have been done as shown below.



For Part (c), it was expected that the procedure would have been given in six steps. Three marks were given if all six steps were provided; one mark was deducted for any incorrect step.

Procedure (where Terminal A is 1, Terminal B is 0; S1 is the most significant digit and S2 is the least significant digit)

1. Set up the circuit shown in the diagram.
2. Switch on the circuit using S3.
3. Set S1 and S2 to 0 0 and record V_1 and V_2 .
4. Set S1 and S2 to 0 1 and record V_1 and V_2 .
5. Set S1 and S2 to 1 0 and record V_1 and V_2 .
6. Set S1 and S2 to 1 1 and record V_1 and V_2 .

For Part (d), it was expected that candidates would have labelled the table of expected results with the column headings S1, S2, V1 and V2. Then for Part (e), the table would have been completed to show the analysis and conclusion. A sample of the completed table is shown below.

Input		Output		Explanation
S1	S2	V1	V2	
B	B	5V	0V	Hold previous value
A	B	5V	0V	Set condition
B	B	5V	0V	Set condition
B	A	0V	5V	Reset condition
B	B	0V	5V	Reset condition
A	A	0V/5V	5V/0V	Either set or reset