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MAY/JUNE 2017

CARIBBEAN EXAMINATIONS COUNCIL

CARIBBEAN ADVANCED PROFICIENCY EXAMINATION®

PHYSICS

UNIT 2 – Paper 02

2 hours 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY.

1. This paper consists of SIX questions in TWO sections. Answer ALL questions.
2. Write your answers in the spaces provided in this booklet.
3. Do NOT write in the margins.
4. Where appropriate, ALL WORKING MUST BE SHOWN in this booklet.
5. You may use a silent, non-programmable calculator to answer questions, but you should note that the use of an inappropriate number of figures in answers will be penalized.
6. If you need to rewrite any answer and there is not enough space to do so on the original page, you must use the extra lined page(s) provided at the back of this booklet. **Remember to draw a line through your original answer.**
7. **If you use the extra page(s) you MUST write the question number clearly in the box provided at the top of the extra page(s) and, where relevant, include the question part beside the answer.**

DO NOT TURN THIS PAGE UNTIL YOU ARE TOLD TO DO SO.

LIST OF PHYSICAL CONSTANTS

Speed of light in free space	c	=	3.00×10^{8} m s^{-1}
Permeability of free space	μ_0	=	$4\pi \times 10^{-7}$ H m^{-1}
Permittivity of free space	ε_0	=	8.85×10^{-12} F m^{-1}
	$\frac{1}{4\pi\varepsilon_0}$	=	9.0×10^{9} m F^{-1}
Elementary charge	e	=	1.60×10^{-19} C
Planck's constant	h	=	6.63×10^{-34} J s
Unified atomic mass constant	u	=	1.66×10^{-27} kg (931 MeV)
Energy equivalence	$1u$	=	931 MeV/c^2
Rest mass of electron	m_e	=	9.11×10^{-31} kg
Rest mass of proton	m_p	=	1.67×10^{-27} kg
Acceleration due to gravity	g	=	9.81 m s^{-2}
1 Atmosphere	atm	=	1.00×10^{5} N m^{-2}
Avogadro's constant	N_A	=	6.02×10^{23} per mole

SECTION A

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

1. Five parallel-plate capacitors are constructed so that they are identical in every respect except for the thickness of the dielectric between the plates. The capacitance, C, of each capacitor is measured and recorded as well as the thickness, d, of the dielectric. The results are shown in Columns 1 and 2 of Table 1.

TABLE 1: CAPACITANCE VERSUS THICKNESS

Thickness, d (mm)	**Capacitance, C (nF)**	**$1/d$ (mm^{-1})**	**$1/d$ (m^{-1})**
0.5	12.90		
1.0	6.10		
1.5	4.50		
2.0	2.80		
2.5	1.75		

(a) Complete Columns 3 and 4 in Table 1. **[2 marks]**

(b) Use the results in Table 1 to plot, on the grid provided in Figure 1 **(page 7)**, a graph of capacitance, C (nF), versus $\frac{1}{d}$ (m^{-1}), and draw the best straight line through the points. **[4 marks]**

(c) (i) A capacitor of capacitance 10 nF is to be constructed using the same materials used in constructing those above. From your graph, determine the thickness of the dielectric required for this 10 nF capacitor.

[2 marks]

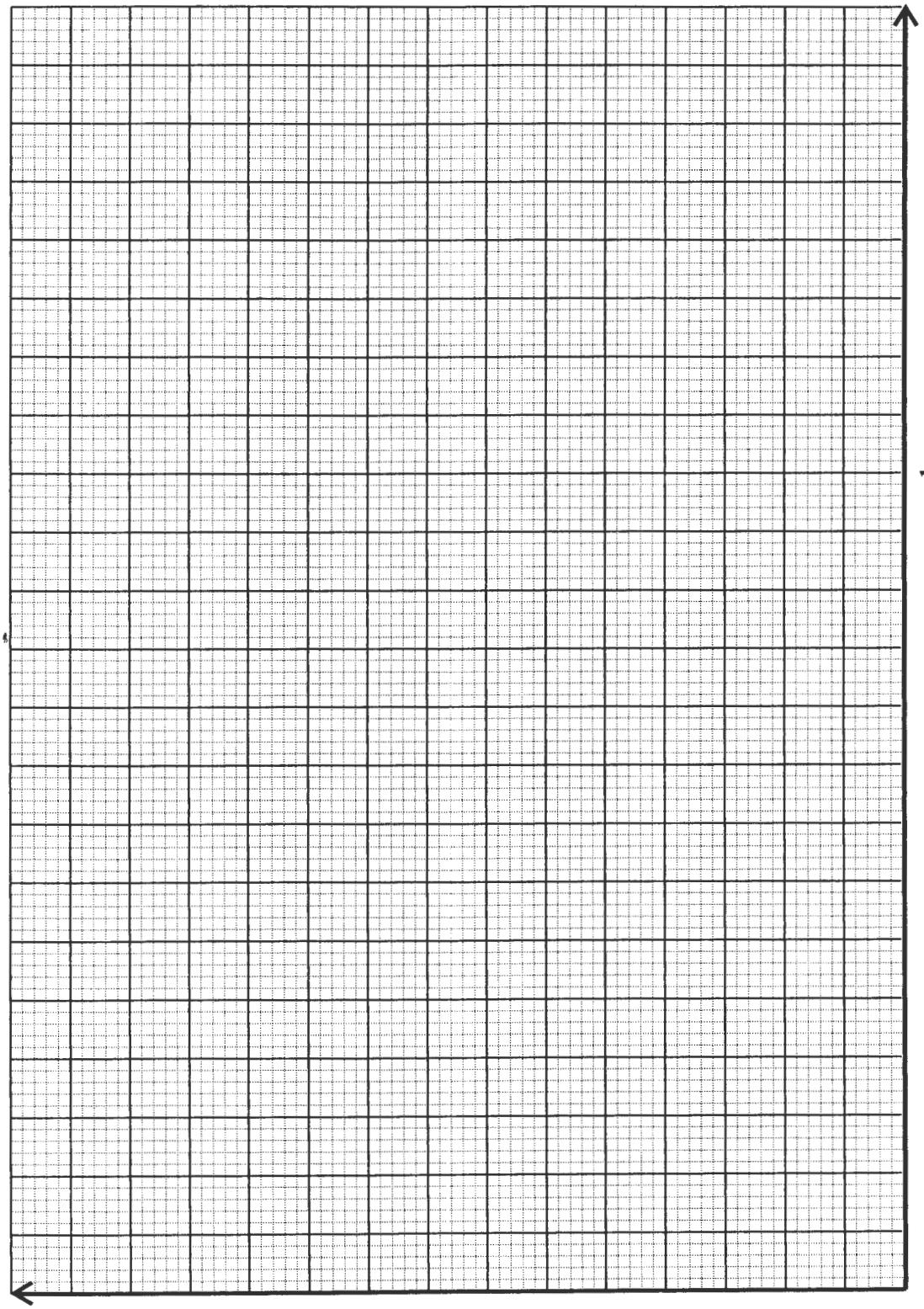

Figure 1. Capacitance, *C (nF)*, versus $\frac{1}{d}$ (m^{-1})

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(ii) Sketch a graph of the voltage charging characteristic when the 10 nF capacitor is charged to 200 volts.

[2 marks]

(d) (i) State the formula which is used to calculate the capacitance of a parallel plate capacitor of area, A, and separation, d between the plates with dielectric of constant, k.

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[1 mark]

(ii) State another term for the dielectric constant, k.

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[1 mark]

(e) Calculate the capacitance of a parallel-plate capacitor made from two circular metal plates of radius 15 cm separated by 1.0 mm of insulating material of dielectric constant 10.

[3 marks]

Total 15 marks

2. (a) (i) Identify the circuit shown in Figure 2.

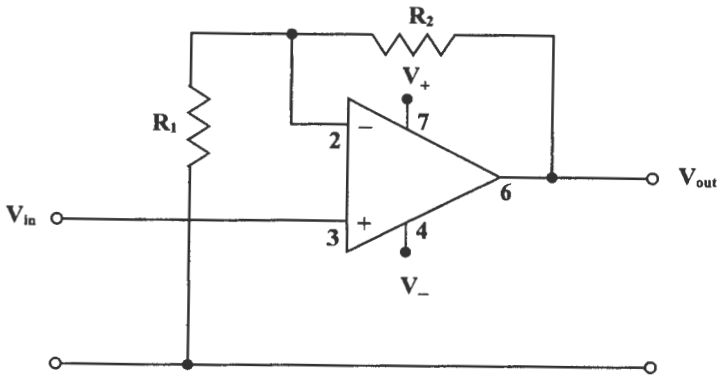

Figure 2. Circuit

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[1 mark]

(ii) State the equation for the closed loop gain, A_{CL} (V_{out} / V_{in}), of the circuit.

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[1 mark]

(b) In an experiment to determine the frequency response of an open loop (no feedback) operational amplifier, a constant sinusoidal input voltage of amplitude 0.1 mV is used. The input frequency is varied, while the output voltage amplitude is observed. The results are shown in Columns 1 and 2 of Table 2.

TABLE 2: FREQUENCY RESPONSE OF OPEN LOOP AMPLIFIER

Frequency f/Hz × 10^3	**Output Voltage/V**	**Gain A_{OL}**	**$\text{Log}_{10} A_{OL}$**	**$\text{Log}_{10} f$**
0.001	7.079			
0.010	5.010			
0.100	0.960			
1.000	0.095			
10.00	0.010			
100.00	0.001			

(i) Complete Columns 3, 4 and 5 of Table 2, given that A_{OL} is the gain of the amplifier. **[4 marks]**

(ii) On the grid provided in Figure 3 (**page 11**), plot a graph of frequency response, $\log_{10} A_{OL}$ versus $\log_{10} f$, and draw a smooth curve through the points. **[4 marks]**

(iii) From the graph, determine the frequency response curve, and hence the bandwidth of the circuit when R_f = 100 kΩ and R_1 = 330 Ω. **[5 marks]**

Total 15 marks

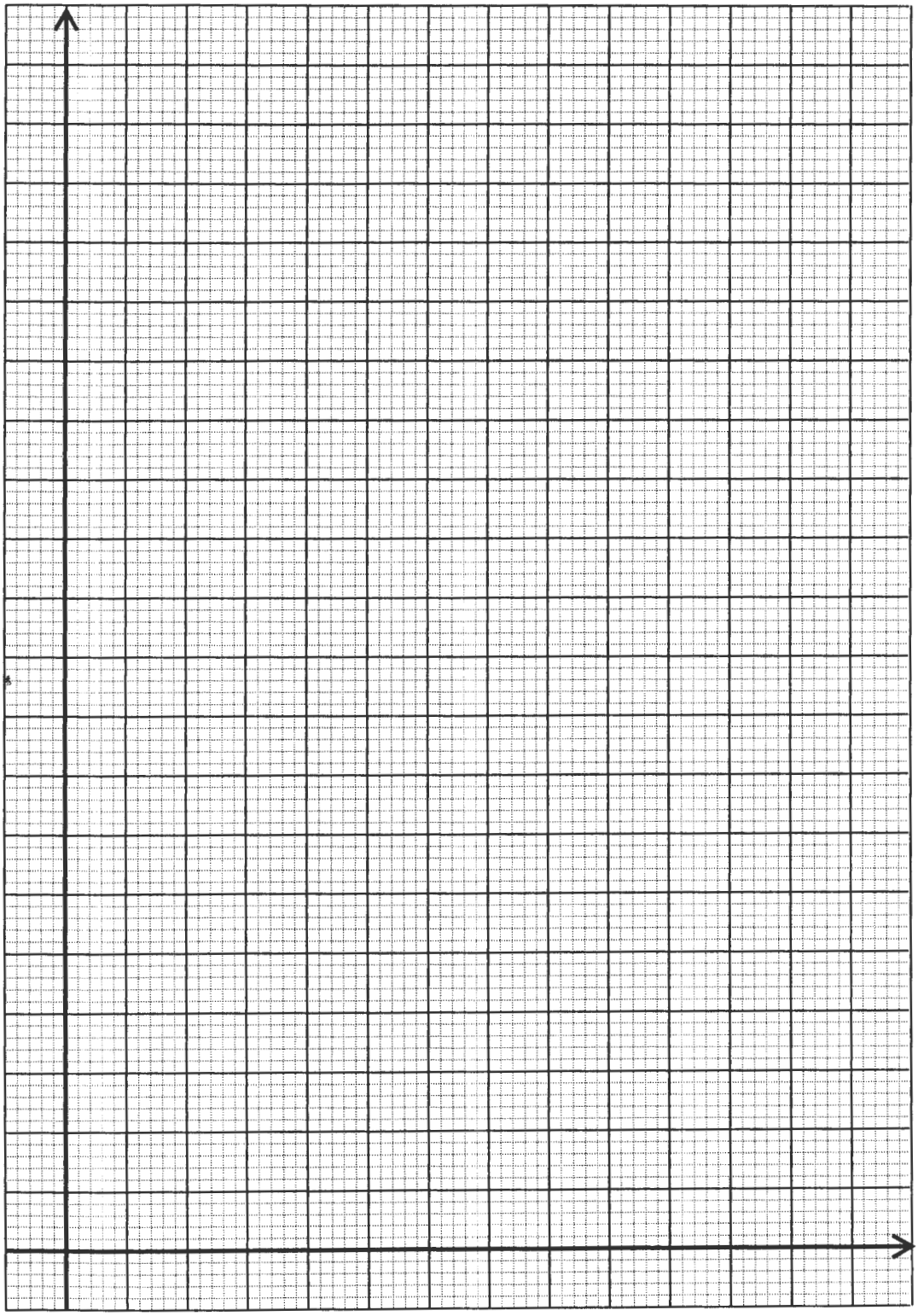

Figure 3. $\text{Log}_{10} A_{OL}$ versus $\text{Log}_{10} f$

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3. (a) Figure 4 shows an experiment to demonstrate the photoelectric effect.

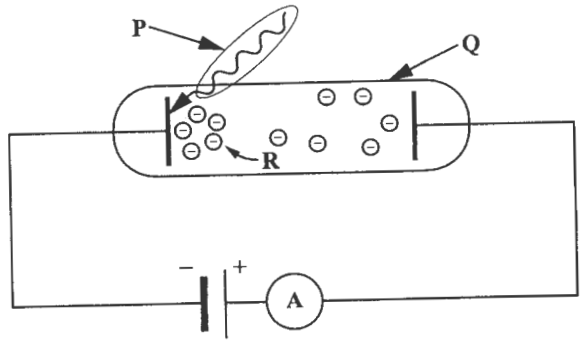

Figure 4. Photoelectric effect

What do labels P, Q and R show?

P .....

Q .....

R .....

[3 marks]

(b) The graph in Figure 5 **(page 13)** was obtained from a plot of stopping potential, V_S (volts), against frequency, f (Hz), of incident radiation in the experiment in (a) using an unknown metal.

(i) Determine the slope of the graph in SI units.

[4 marks]

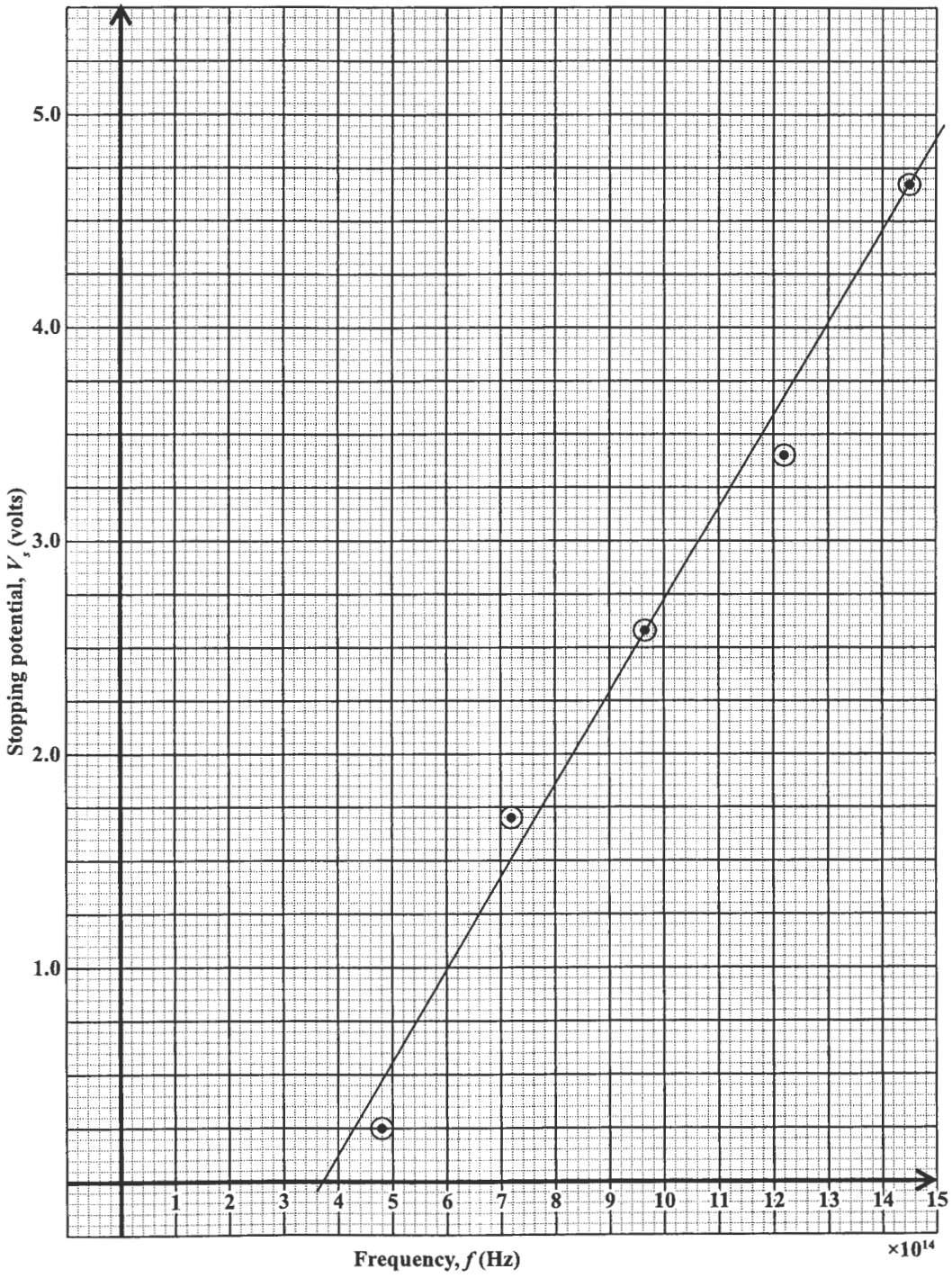

Figure 5. Stopping potential (V_s) versus frequency (f)

(ii) With the aid of the graph in Figure 5 **on page 13**, formulate the algebraic equation relating the stopping potential, V_s, to the frequency, f, of incident radiation.

[3 marks]

(iii) What does the slope of the graph represent?

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[1 mark]

(iv) From the graph, determine the threshold wavelength for the unknown metal.

[4 marks]

Total 15 marks

SECTION B

Answer ALL questions.

Write your answers in the spaces provided in this booklet.

4. (a) With the aid of suitable diagrams, derive the formula for the equivalent resistance of two resistors, R_1 and R_2, in parallel.

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[5 marks]

(b) (i) State Kirchhoff's voltage law.

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[2 marks]

(ii) By applying Kirchhoff's current law to node X and Kirchhoff's voltage law to the loops L_1 and L_2, determine the value of the current, I_2, in the 20 kΩ resistor in the circuit shown in Figure 6.

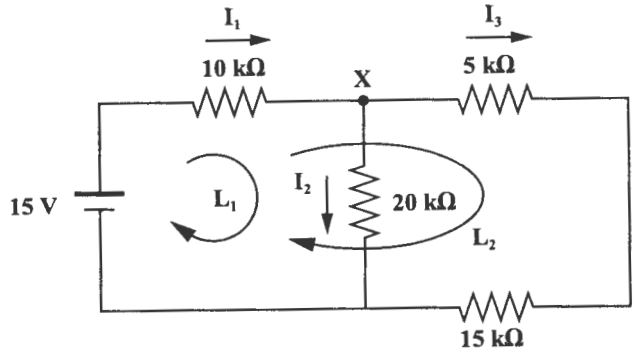

Figure 6. Circuit

[8 marks]

Total 15 marks

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5. (a) Explain what is a 'semiconductor'. Include typical values for its resistivity in your response.

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[3 marks]

(b) With the aid of diagrams, describe the formation of a depletion layer at an unbiased p-n junction. Include conditions for the depletion layer to begin and end formation.

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[5 marks]

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(c) A diode with the characteristic shown is placed in a circuit as indicated in Figure 7.

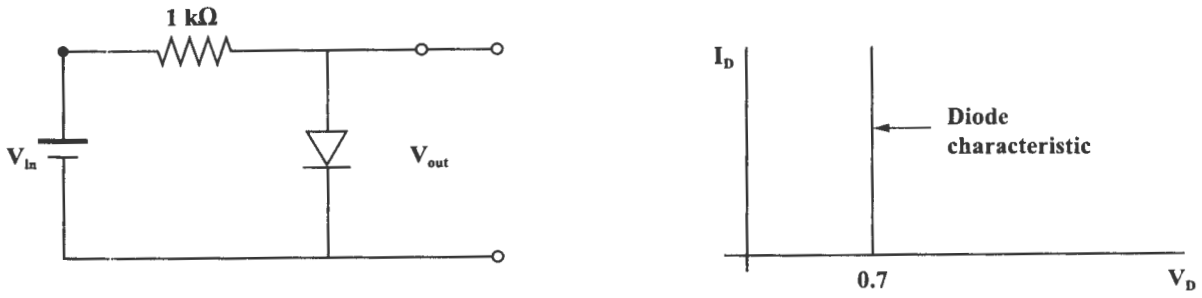

Figure 7. Diode in circuit

(i) Deduce the value of the output voltage, V_{out}, when V_{in} is 0.5 V.

[1 mark]

(ii) Explain your answer in (c) (i).

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[2 marks]

(iii) Deduce the value of the output voltage and the diode current when $V_{in} = 2.0$.

[1 mark]

(iv) Explain the answer given in (c) (iii).

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[3 marks]

Total 15 marks

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6. (a) Figure 8 is a schematic of the setup for a Millikan's oil drop experiment.

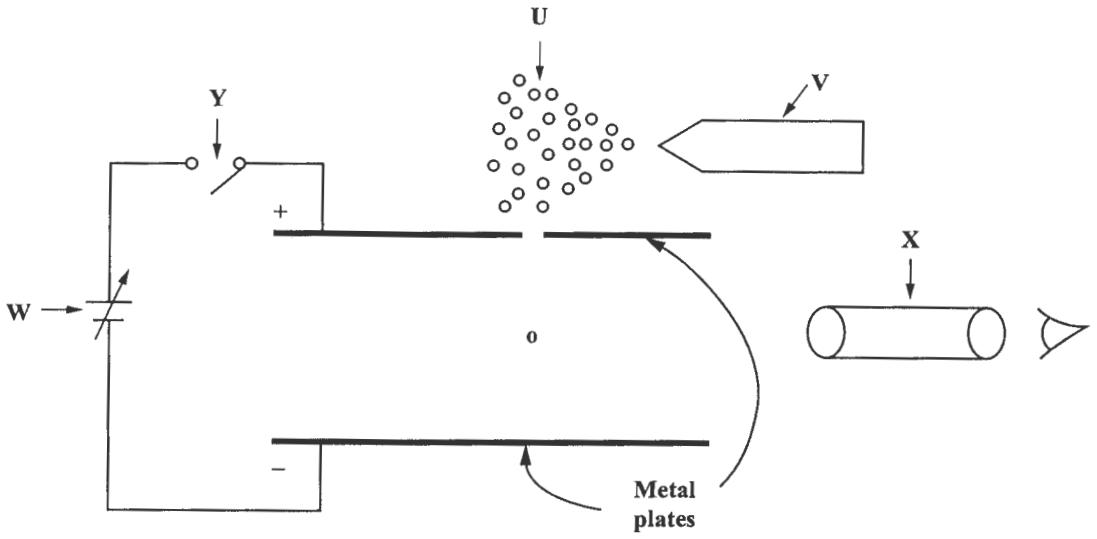

Figure 8. Schematic diagram for Millikan's oil drop experiment

Name the pieces of apparatus labelled *U*, *V*, *W*, *X* and *Y*.

U: .....

V: .....

W: .....

X: .....

Y: .....

[2 marks]

(b) (i) Outline the procedure for the Millikan oil drop experiment.

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[4 marks]

(ii) State the TWO major conclusions from this experiment.

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[2 marks]

(c) An oil drop in a Millikan experiment has a mass of 3.0×10^{-15} kg and is held stationary, suspended in the electric field between two metal plates 1.0 cm apart. The voltage between the plates is 350 V. How many excess electrons are likely to be on the oil drop?

[4 marks]

(d) The apparatus is adjusted so that some droplets move upwards with constant speed. Draw and label a diagram showing the forces acting on one such droplet when air is present between the plates.

[3 marks]

Total 15 marks

END OF TEST

IF YOU FINISH BEFORE TIME IS CALLED, CHECK YOUR WORK ON THIS TEST.