FORM TP 2004253

TEST CODE **02238020**

MAY/JUNE 2004

CARIBBEAN EXAMINATIONS COUNCIL

ADVANCED PROFICIENCY EXAMINATION

PHYSICS

UNIT 2 - PAPER 02

2 hours and 15 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of **NINE** questions.
2. Section A consists of **THREE** questions. Candidates must attempt **ALL** questions in this section. Answers for this section must be written in this answer booklet.
3. Section B consists of **SIX** questions. Candidates must attempt **THREE** questions in this section, **ONE** question from **EACH** Module. Answers for this section must be written in the answer booklet provided.
4. All working **MUST** be **CLEARLY** shown.
5. The use of non-programmable calculators is permitted.

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}
Elementary charge	e	=	1.60×10^{-19} C
The Planck's constant	h	=	6.63×10^{-34} J s
Unified atomic mass constant	u	=	1.66×10^{-27} kg
Rest mass of electron	m_e	=	9.11×10^{-31} kg
Rest mass of proton	m_p	=	1.67×10^{-27} kg
Acceleration of free fall	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

Attempt ALL questions. You MUST write in this answer booklet. You must NOT spend more than 30 minutes on this section.

1. (a) A student wishes to determine the electromotive force (e.m.f.), E, and internal resistance, r, of a battery. V is a voltmeter and R is a variable resistor. She sets up the circuit shown in Figure 1a and finds that it does not work.

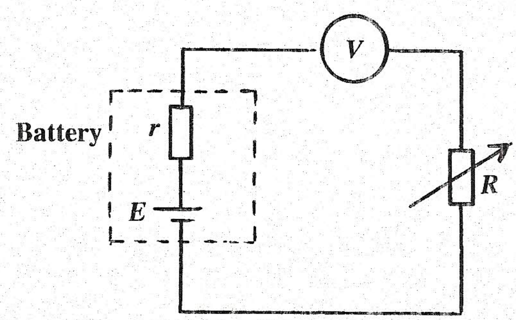

Figure 1a

(i) Identify the problem affecting the circuit.

____

[1 mark]

(ii) Redraw the circuit so that it will work.

[1 mark]

(iii) State which readings should be taken.

____

____

[1 mark]

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(b) The experimental quantities are related by the equation $\frac{1}{V} = \frac{1}{E} + \frac{r}{E}\frac{1}{R}$.

Figure 1*b* shows a graph of $\frac{1}{V}$ against $\frac{1}{R}$ for data obtained from the redrawn circuit.

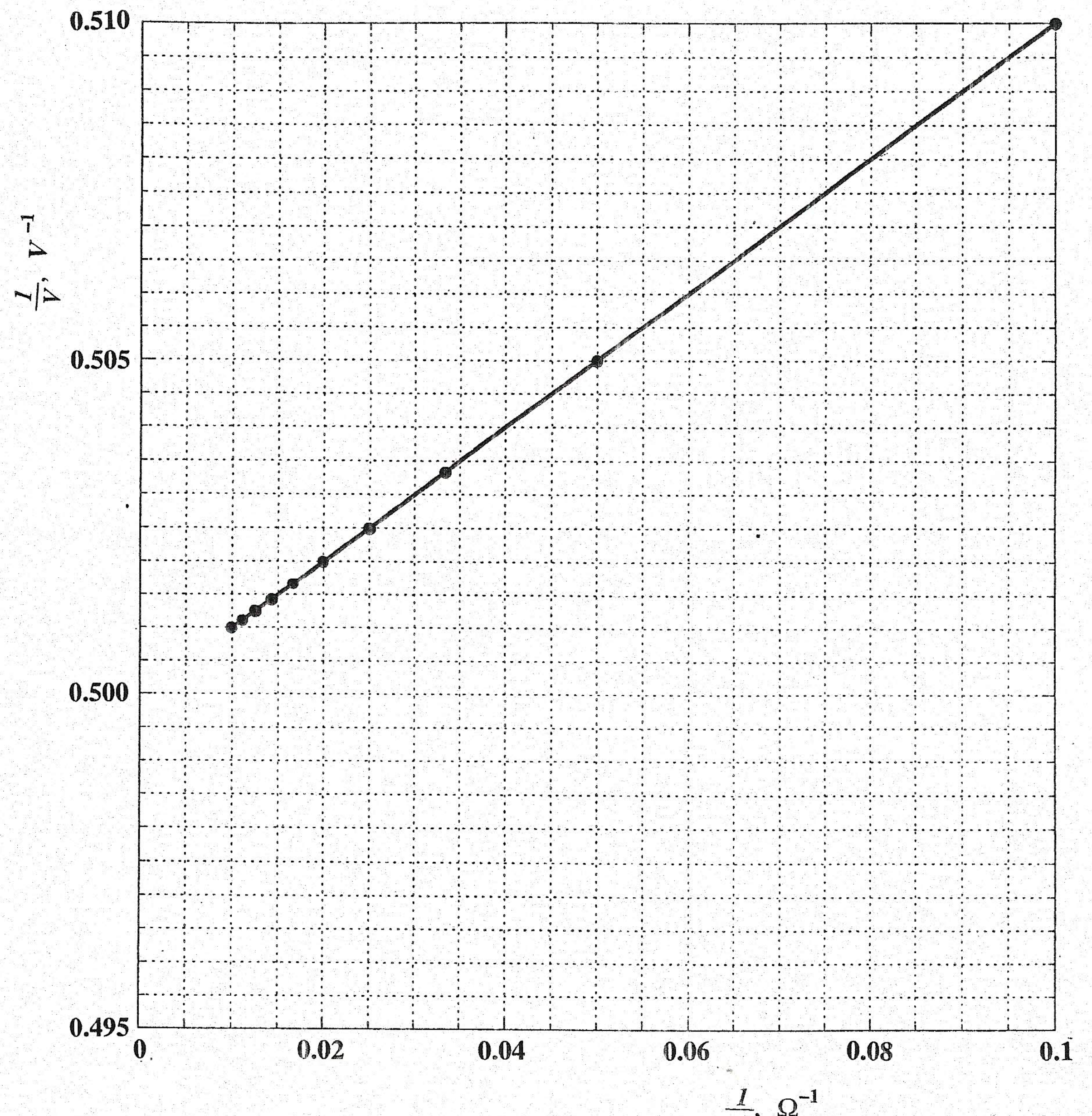


Figure 1*b*

Determine

(i) a) the e.m.f., E, of the battery

[3 marks]

b) the internal resistance, r, of the battery.

[3 marks]

(ii) If the resistance of the voltmeter were comparable to that of R, how would this have affected the result?

[1 mark]

Total 10 marks

2. (a) The markings on an old transformer are not shown. A student connects the circuit shown in Figure 2*a* in an attempt to determine the properties of the transformer.

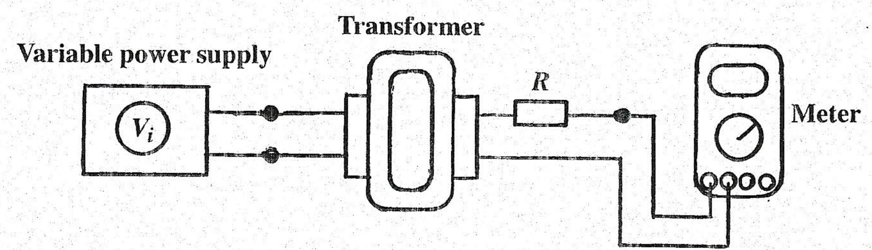


Figure 2*a*

The following data were obtained.

Input voltage, V_i (V)	240	200	160	140	120
Output voltage, V_o (V)	47.8	39.7	31.8	28.1	24.2

(i) Plot a graph of input voltage, V_i, against output voltage, V_o on the grid on page 7. **[4 marks]**

(ii) Use the graph to determine the turns ratio of the transformer.

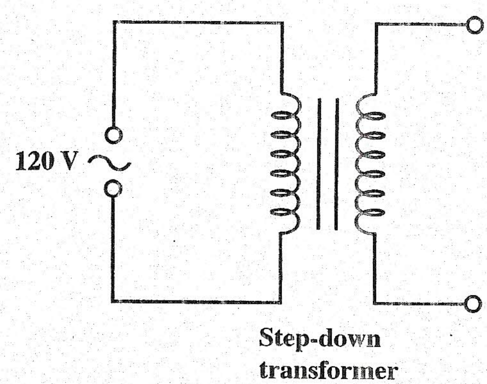
[2 marks]

(iii) If the number of turns in the secondary windings is quoted at 30 000, what is the number of turns in the primary windings?

[1 mark]

(b) You need to produce an approximately 4 V DC output from an AC power supply whose output is shown in Figure 2*b*. You have available a transformer, a capacitor, a diode, a cathode ray oscilloscope and a resistor to represent the load.

(i) On the diagram below, complete the design of a circuit to achieve this objective, using all of these components.



[1 mark]

(ii) Figure 2*b* shows the output voltage from the AC power supply.

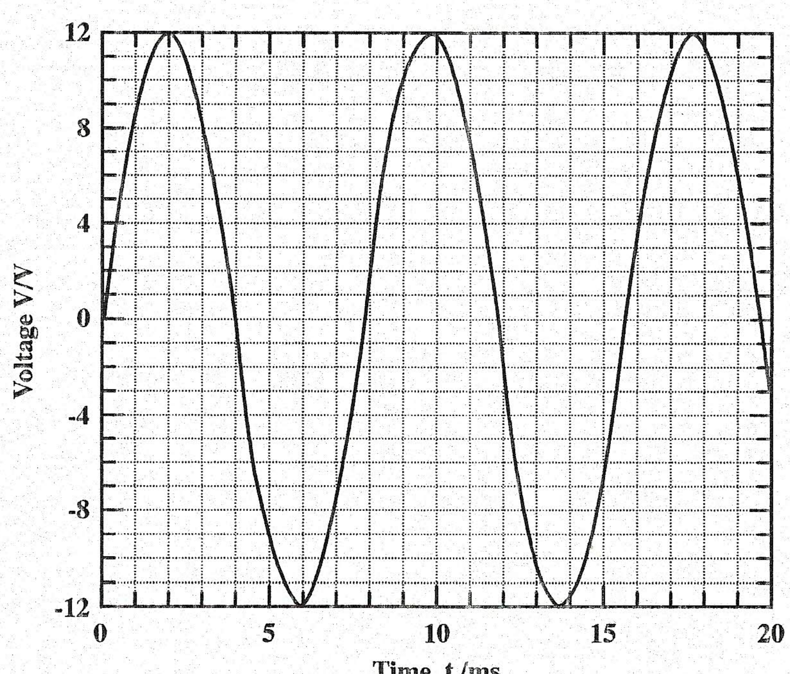


Figure 2*b*

On Figure 2*b*, sketch the output voltage that would be seen on the oscilloscope.
[2 marks]

Total 10 marks

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3. (a) Figure $3a$ shows an experimental arrangement used to investigate the photoelectric effect of a metal.

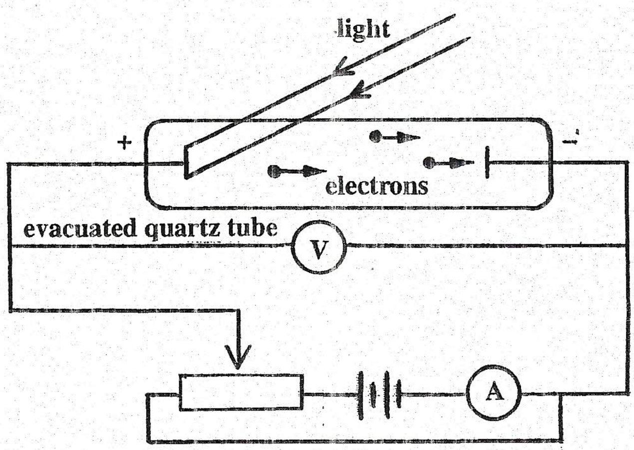

Figure $3a$

The photoelectric equation can be written as $hf - \Phi = \frac{1}{2}m_e v^2$, h is Planck's constant, f is the frequency of light used, Φ is the work function for the metal, m_e is the mass of the electron and v is the velocity of the emitted photoelectrons.

Show that the photoelectric equation can be written as $V = \frac{hc}{e}\left(\frac{1}{\lambda}\right) - \frac{hc}{e}\left(\frac{1}{\lambda_0}\right)$, where

V is the stopping potential, c is the speed of light, e is the charge on the electron, λ is the wavelength of light used and λ_0 is the cut-off wavelength for the metal.

[4 marks]

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(b) Figure 3*b* shows a graph of V against $\frac{1}{\lambda}$ for the data obtained.

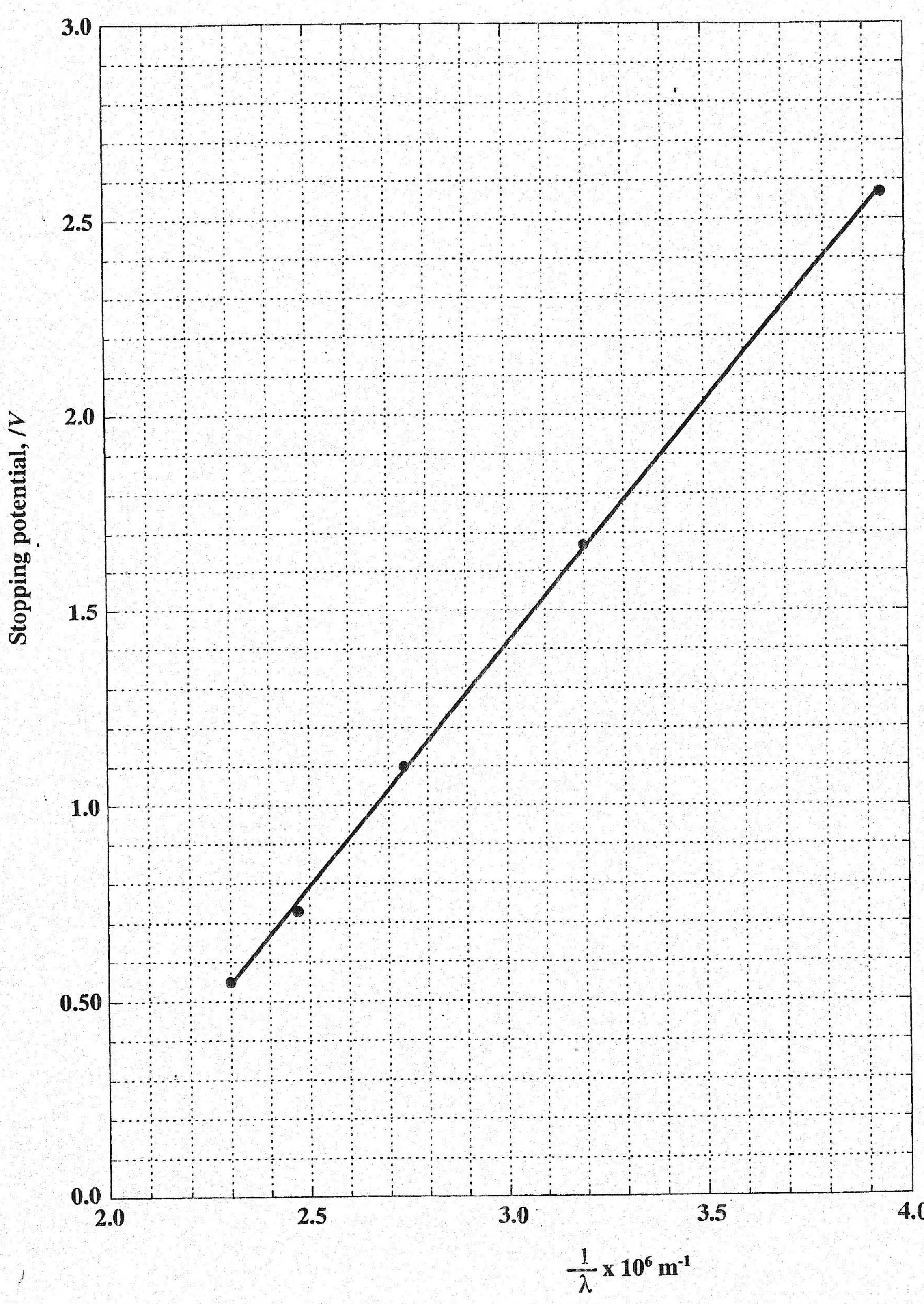

Figure 3*b*

Use the graph to determine

(i) Planck's constant

[3 marks]

(ii) the cut-off wavelength λ_0.

[3 marks]

Total 10 marks

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SECTION B

You must attempt THREE questions from this section. Choose ONE question EACH from Module 1, 2 and 3. You MUST write your answers in the answer booklet provided.

MODULE 1

Answer EITHER Question 4 OR Question 5.

4. (a) Two point charges have magnitudes of q_1 and q_2 and are separated by a distance r.

(i) State THREE facts about the electrostatic force that exists between these point charges.

(ii) Write an expression for the electric field experienced by charge q_2 due to charge q_1.

(iii) Figure 4*a* shows two negative point charges with equal charges.

Figure 4*a*

Copy the figure into your answer booklet and draw the resulting electric field lines. Indicate with an **X** on the diagram, the point where the resulting electric field is zero. **[7 marks]**

(b) Figure 4*b* shows two large parallel metal plates 10 cm apart and having a uniform electric field between them. An electron is released from the negative plate at the same time that a proton is released from the positive plate. They pass each other a distance *d* from the negative plate.

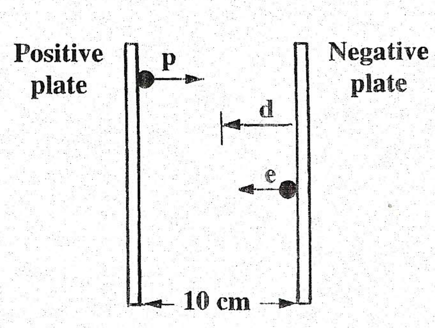

Figure 4*b*

(i) Find the value of *d*.

(ii) What assumption have you made to calculate the value of *d* ? **[9 marks]**

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(c) Figure 4*c* shows FOUR point charges arranged in a square of side 1.5 m.

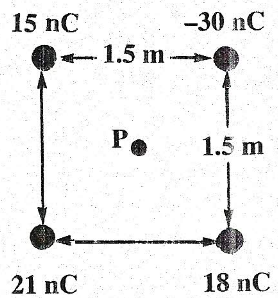

Figure 4*c*

Calculate the electric potential at point *P*, located at the centre of the square.

(Use Coulomb's constant, $\frac{1}{4\pi\varepsilon_0} = 9 \times 10^9$ N m^2 C^{-2}).

[4 marks]

Total 20 marks

5. (a) Explain, with the aid of a diagram, Fleming's Left Hand Rule. **[3 marks]**

(b) An electron, moving with velocity v, is about to enter a region with uniform magnetic field B. The electron moves perpendicularly to the magnetic field B as shown in Figure 5. The magnetic field is directed out of the page.

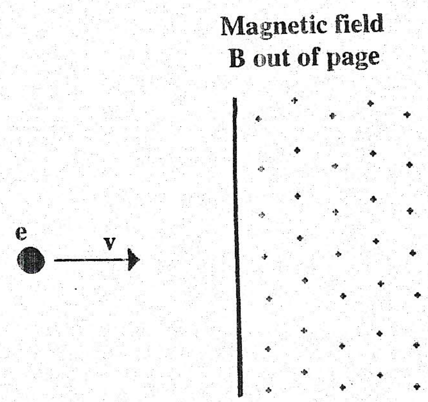

Figure 5

(i) Copy Figure 5 into your answer booklet and draw the path of the electron as it passes through the magnetic field. On the same diagram draw the path if the electron is replaced with a proton.

(ii) What work is done on the electron as it passes through the magnetic field? Explain your answer.

(iii) Show that the path described by the electron in the magnetic field is a circle of radius r given by $r = \frac{mv}{Be}$ where m is the mass of the electron and e is the electron's charge.

(iv) On the Figure 5 in your answer booklet, draw the path of the electron if the magnetic field B was reduced to half its value. **[10 marks]**

(c) An electron is accelerated through an electric potential V. The electron then enters a region of constant magnetic field B oriented perpendicular to its path. In this region, the electron's path is circular with radius of curvature 10 cm. Another particle with the same charge as the electron but with charge mass m_x follows under the same condition. Its radius of curvature is 15 cm. Determine the mass, m_x, of the particle. **[7 marks]**

Total 20 marks

MODULE 2

Answer EITHER Question 6 OR Question 7.

6. (a) (i) Figure 6*a* shows an ideal non-inverting amplifier circuit.

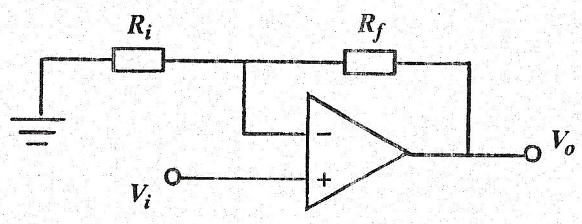

Figure 6*a*

Show that the closed loop voltage gain, A, in the circuit is given by $A = 1 + \frac{R_f}{R_i}$.

(ii) How does the circuit differ from that of an inverting amplifier circuit?

(iii) What is the input impedance of the non-inverting amplifier? **[8 marks]**

(b) The saturation voltage of the non-inverting amplifier shown in Figure 6*a* is 15 V. If $R_f = 100\text{ k}\Omega$ and $R_i = 50\text{ k}\Omega$, determine the maximum input voltage, v_i, such that saturation just occurs. **[2 marks]**

(c) The non-inverting amplifier circuit shown in Figure 6*b* is to be designed so that it can be adjusted from a gain of 20 to 50 by the rheostat R_s. The value of R_i is selected as $R_i = 1\text{ k}\Omega$.

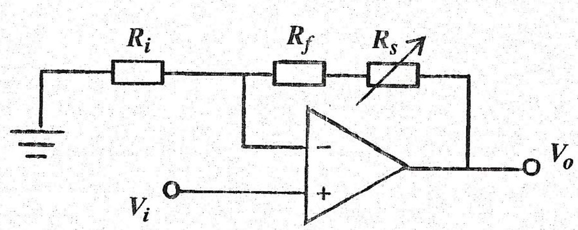

Figure 6*b*

Determine the value of R_f and the range of the rheostat R_s. **[6 marks]**

(d) In a certain application, it is desired to combine two signals v_1 and v_2 to form a signal v_0 according to the relation $v_0 = -v_1 - 20v_2$. The minimum input resistance for both signal inputs should be no less than 10 kΩ. Design a circuit to meet this requirement. **[4 marks]**

Total 20 marks

7. (a) (i) Construct the truth tables for the AND gate and the Exclusive –OR (EX-OR) gate.

(ii) A student is asked to design a circuit to switch on and off a light emitting diode for inputs A and B. She designs the circuit shown in Figure 7a.

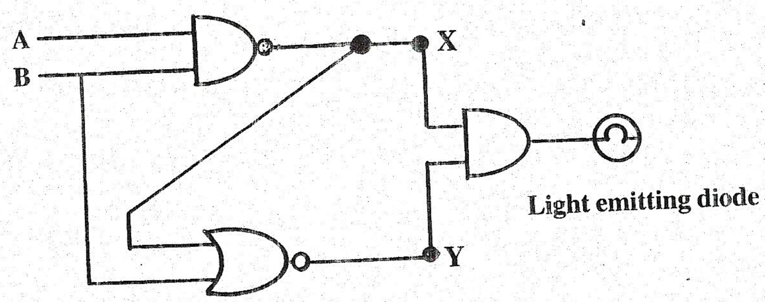

Figure 7*a*

Construct the truth table for the circuit and state whether or not the circuit will work.

[6 marks]

(b) (i) Explain the operation of the Half-Adder.

(ii) Figure 7b shows a Half-Adder circuit. Copy the waveforms A and B into your answer booklet. Under these waveforms, carefully sketch the resulting outputs S and C.

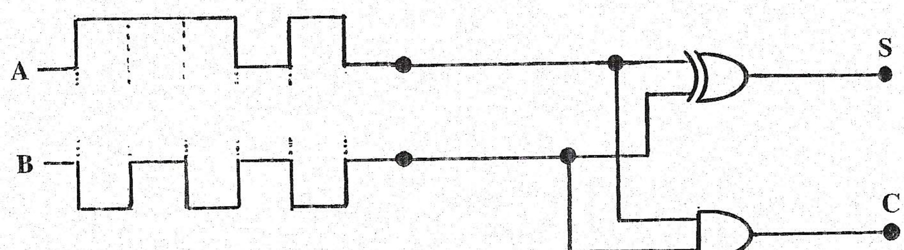

Figure 7*b*

(iii) Using the circuit shown in Figure 7b, draw a circuit to implement a Full-Adder and explain its operation.

(iv) Figure 7c shows a block diagram of a Full-Adder.

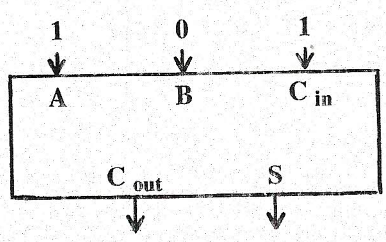

Figure 7*c*

If the inputs are as shown, determine the sum output, S, and carry output, C_{out}.

[14 marks]

Total 20 marks

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MODULE 3

Answer EITHER Question 8 OR Question 9.

8. (a) Explain the following terms:

(i) Continuous x-ray spectrum

(ii) Characteristic x-ray spectrum

(iii) Cut-off wavelength **[8 marks]**

(b) Figure 8 shows the x-ray spectrum produced when a molydebnum (Z = 42) target is bombarded with 35 keV electrons. The K_β and K_α wavelengths are 63.0 x 10^{-12} and 70.0 x 10^{-12} m respectively.

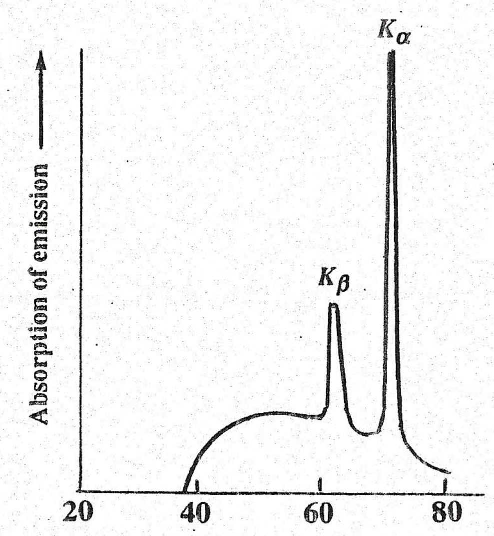

Figure 8

(i) Calculate the corresponding photon energies in eV.

(ii) It is desired to filter these radiations through a material that will absorb the K_β line much more strongly than it will absorb the K_α line. What substance from the table below could be used as the filtering material? Explain your answer.

The table below shows the ionization energies of the K electrons in molybdenum and in four neighbouring elements.

	Zirconium	Niobium	Molybdenum	Technitium	Ruthenium
Z	40	41	42	43	433
E_k, **keV**	18	18.99	20.00	21.04	22.12

(iii) Calculate the cut-off wavelength in picometers, for molybdenum.

[12 marks]

Total 20 marks

9. (a) (i) The radioactive decay of a sample obeys the following equation:

$$N = N_0 e^{-\lambda t}.$$

Explain the meaning of the symbols in the equation and define the terms activity, A, and half-life, $t_{\frac{1}{2}}$.

(ii) Show that the half-life of the sample can be written as $\frac{N \ln 2}{A}$. **[8 marks]**

(b) Figure 9 shows the results of an experiment to measure the half-life of a radioactive sample.

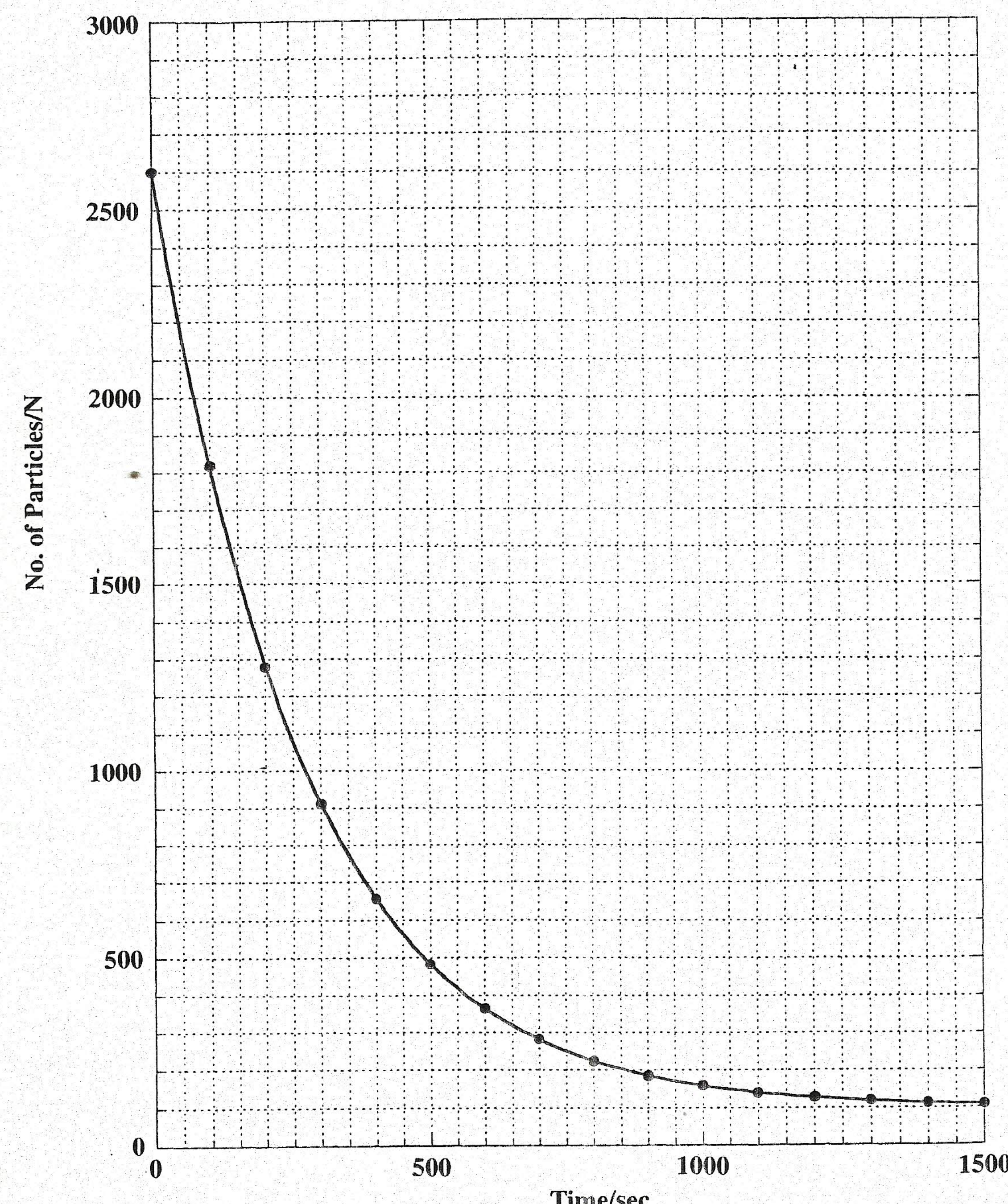

Figure 9

Determine

(i) the half-life of the sample

(ii) the decay constant

(iii) the activity at 1000 s. **[6 marks]**

(c) The thermal energy generated when radiations from radionuclides are absorbed in matter can serve as the basis for a small power source for use in satellites and remote weather stations. One such radionuclide is Plutonium, $^{238}_{94}Pu$ which is an alpha emitter with disintegration energy, Q, equal to 5.50 MeV. Plutonium, $^{238}_{94}Pu$, has a half-life of 90 years.

Calculate the rate at which thermal energy is generated in 1 kg of this material.

[Number of seconds in a year = 3.156×10^7]

[6 marks]

Total 20 marks

END OF TEST