CARIBBEAN EXAMINATIONS COUNCIL

ADVANCED PROFICIENCY EXAMINATION

PHYSICS

UNIT 02 – Paper 02

2 hours 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.

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 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 number	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) You are asked to do an experiment to investigate how the resistance, R, of a thermistor varies with the temperature θ.

(i) Outline TWO precautions that you would take to improve the accuracy of your results.

_____

_____

_____

_____

[2 marks]

(ii) Construct a suitable circuit that could be used for this investigation.

[2 marks]

(b) Table 1 shows a typical set of results for a thermistor.

Temp/K	$\frac{1}{T} \times 10^{+3}/K^{-1}$	Resistance/Ω	1n R_T
283	3.53	670	6.51
303	3.30	350	5.86
333	3.00	130	4.87
353	2.83	90	4.50
363	2.75	65	4.17
373	2.68	50	3.91

Table 1

The thermistor obeys the relationship $R_T = R_o e^{A/T}$ where R_T and R_o are the resistances at T K and 273 K respectively, and A is a constant dependent on the material. Use the graph on page 5 to calculate values for

(i) the constant A

[3 marks]

(ii) R_o using a value for T of 333 K.

[3 marks]

Total 10 marks

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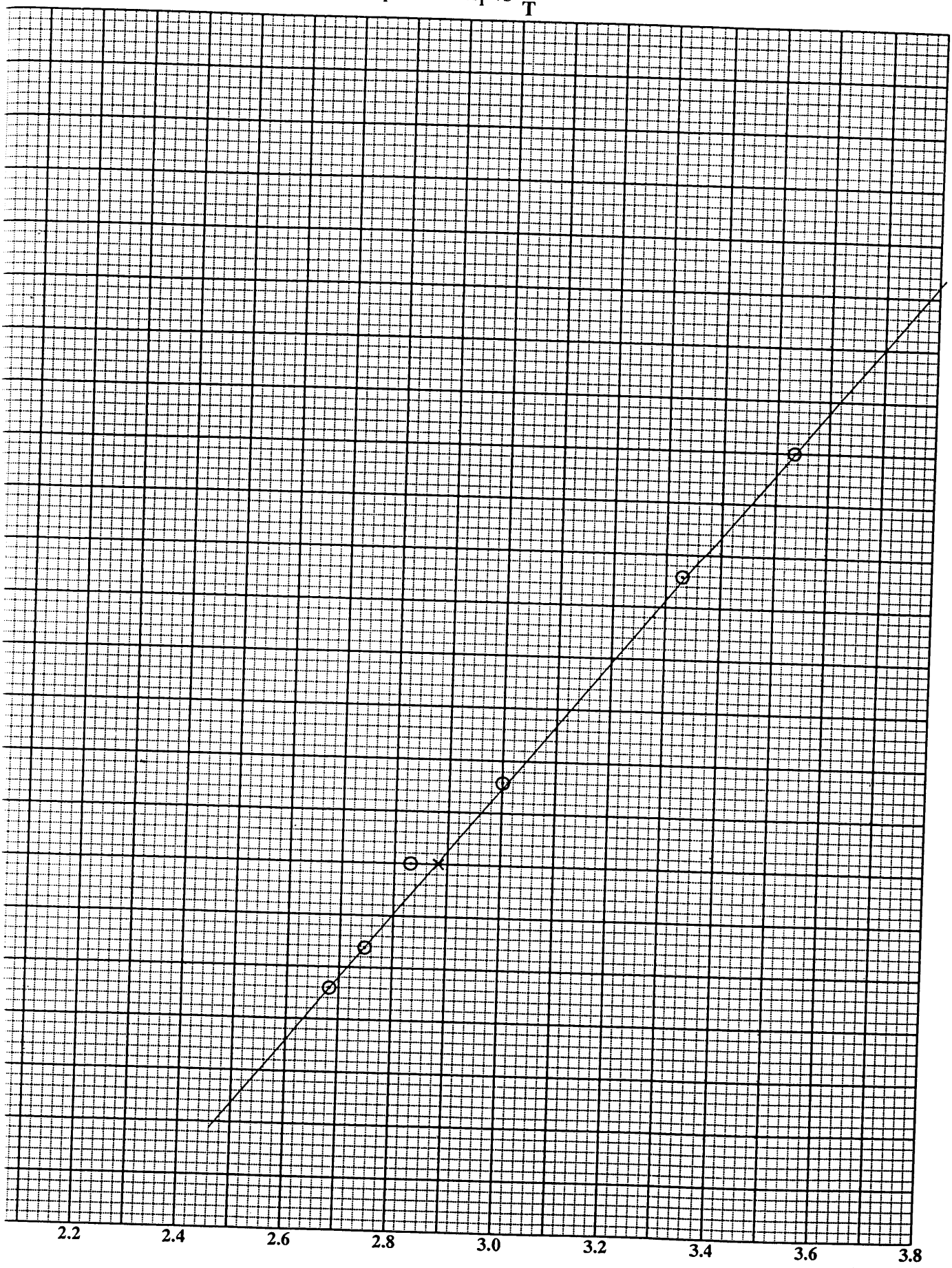
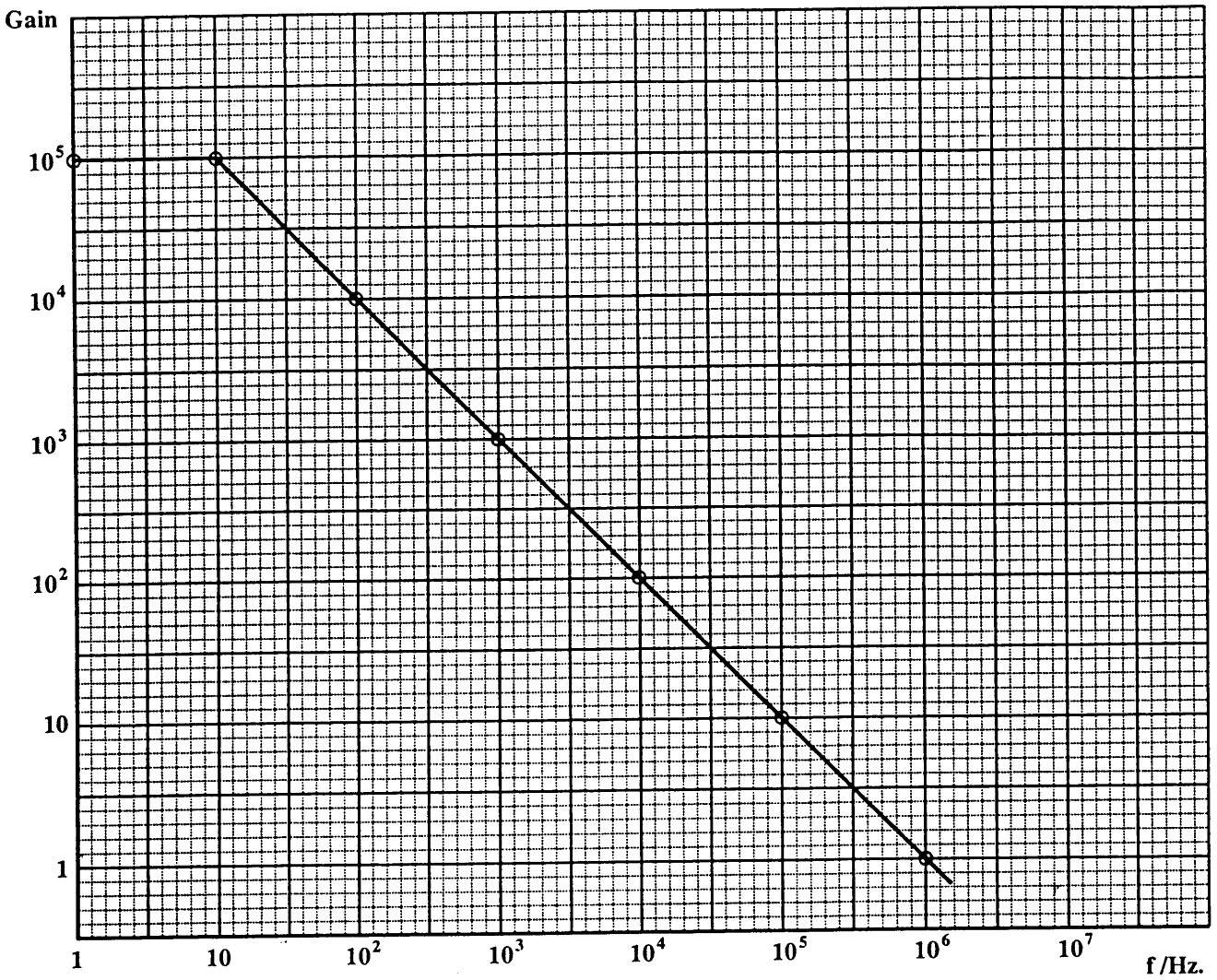
Graph of $\ln R_T$ vs $\frac{1}{T}$



2. An operational amplifier has a very large open loop gain A_0. The graph below shows how the gain varies with frequency.



(a) Draw a circuit diagram to show how the amplifier could be used over a wider range of frequencies at a reduced gain.

[3 marks]

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(b) What feature allows the gain to be reduced?

[1 mark]

(c) What adjustment can you make to your circuit to lower the gain?

[2 marks]

(d) What effect(s) would this have on the amplifier?

[2 marks]

(e) Given that the closed loop gain is related to the open loop gain by the equation $A = \frac{A_0}{1 + \beta A_0}$ where β is a negative fraction of output fed back to the input, calculate a value of β when $A_0 = 10^5$ and $A = 10^2$.

[2 marks]

Total 10 marks

3. (a) (i) Describe an experiment that you can perform in the laboratory to show the existence of β-particles.

[3 marks]

(ii) How can you determine the sign of the charge of a β-particle?

[1 mark]

(b) (i) X-rays are produced by accelerating electrons through a potential difference of 40 000 V, before they strike a target. There is a minimum cut-off wavelength λ_0, produced. Calculate the value of λ_0.

[5 marks]

(ii) What change occurs in λ_0 if the accelerating potential difference is doubled?

[1 mark]

Total 10 marks

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) (i) Define the volt. Use this definition to derive the relationship

$$P = I V$$

(ii) The element of an electric heater is made of a high resistance wire, of resistance 7.90 ohms. A potential difference of 115 V is applied to the element. Determine the current in the wire and the power being used by the heater. What happens to the power if the potential difference is halved? What assumptions, if any, have you made? **[10 marks]**

(b) (i) State Kirchhoff's laws.

(ii)

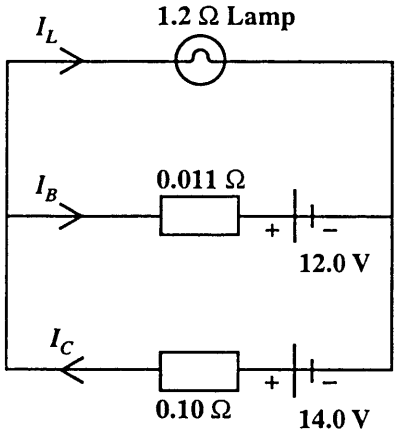

Figure 1

A battery of e.m.f 12.0 V and internal resistance 0.011 ohms powers a lamp of resistance 1.20 ohms, while at the same time it is being charged by a charger of internal resistance 0.10 ohms, see Figure 1. The charger can be considered to act as a battery of e.m.f 14.0 V. Calculate the currents I_L, I_B and I_C passing through the lamp, battery and charger respectively.

[10 marks]

Total 20 marks

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5. (a) Give a detailed explanation of the origin of the Hall effect and say what is the Hall potential difference. Include a diagram showing clearly any relevant vector quantities, for a specimen in which electron conduction predominates. **[8 marks]**

(b) (i) A rectangular slice of semi-conducting material of thickness 2.5 mm carries a current of 150 mA as shown in Figure 2. When a magnetic field of flux density 0.5 T is directed into the material parallel to the side of length 2.5 mm, a p.d of 8.75mV across its edges is produced due to the Hall effect. Calculate the number of charge carriers per unit volume, given that the magnitude of the charge of each carrier is 1.6×10^{-19}C. Explain your calculation.

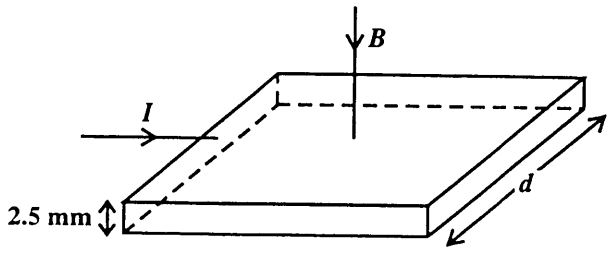

Figure 2

(ii) Deduce what type of material is best suited for a large Hall potential difference. How do the magnitude of the magnetic field and the thickness of the material affect the Hall potential difference? **[12 marks]**

Total 20 marks

Module 2

Answer EITHER Question 6 or Question 7.

6. Adders are combinations of logic gates that combine binary digits to obtain a sum. They are classified according to their ability to combine those digits.

(a) Write down the truth table for the Exclusive-OR (EX-OR) gate **[1 mark]**

(b) The circuit in Figure 3 shows a combination of four NAND gates with the inputs A and B, and output Y.

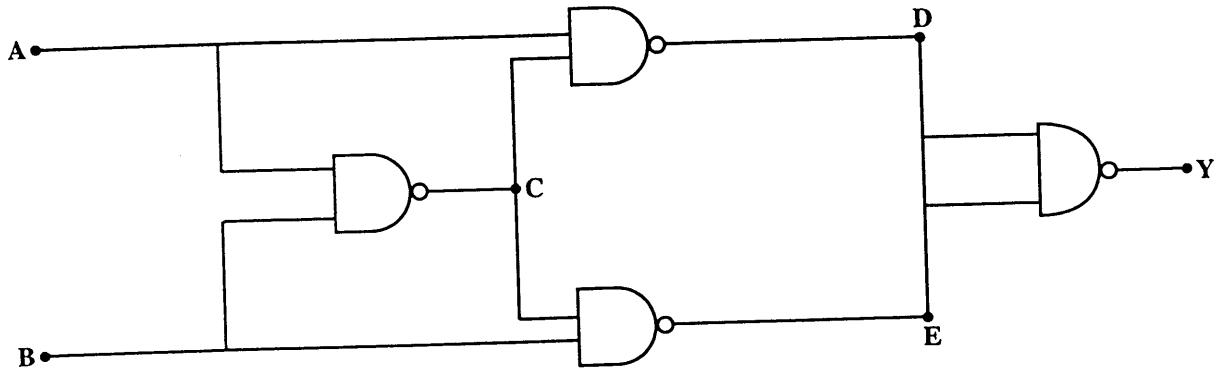

Figure 3

(i) Construct the truth table for the circuit.

(ii) Describe in words the logic function of the circuit. **[5 marks]**

(c) (i) Using the EX-OR gate, draw a circuit of a half adder showing clearly the inputs A and B and the outputs of the circuit.

(ii) Hence show how the full-adder circuit can be implemented from two half-adder circuits. **[5 marks]**

(d) Show the block diagram and explain the operation for the addition of the two binary numbers 110 and 101 using adders. **[9 marks]**

Total 20 marks

7. (a) Give THREE properties of an ideal operational amplifier. **[3 marks]**

(b) For the non-inverting amplifier shown in Figure 4, show that the closed loop voltage gain, A, is given by

$$A = 1 + \frac{R_f}{R_i}$$

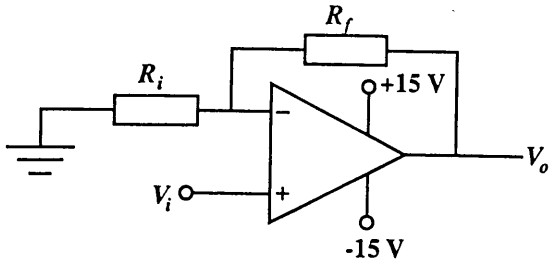

Figure 4

[5 marks]

(c) $R_f = 100$ k Ω and $R_i = 20$k Ω.

(i) Determine the closed loop gain.

(ii) When this circuit is used it saturates at ± 13V. If it is to be avoided, what is the maximum input voltage that can be used?

(iii) Determine the output voltage for a sinusoidal signal of peak input voltage 3 V.

(iv) Sketch the resulting output signal. **[7 marks]**

(d) It is desired to combine three signals V_1, V_2 and V_3 to produce an output $V_0 = -V_1 - 4V_2 - 12V_3$.

The input resistance at the inputs must not be less than 10 k Ω and all resistor values must be less than 200 kΩ.

Design a circuit to achieve this objective. **[5 marks]**

Total 20 marks

Module 3

Answer EITHER Question 8 OR Question 9.

8. (a) (i) Discuss the physical process described by the mathematical equation $E_2 - E_f = hf$ and state what EACH term represents.

(ii) What do you understand by the term 'work function'? State what energy transformation takes place when light is incident on a surface, causing an electron to be emitted, and give an equation relating the relevant quantities.

[8 marks]

(b) An incandescent light bulb rated at 60 W operates with an efficiency of 2.5%. Assuming that the light emitted is of wavelength 550 nm, determine the

(i) energy of each photon emitted

(ii) number of photons emitted per second.

[7 marks]

(c) If the emitted light is incident on a surface of work function 2.05 e.V, will electrons be emitted from the surface and if so what will their maximum kinetic energy?

$(1 \text{ e.V} = 1.6 \times 10^{-19} \text{J})$

[5 marks]

Total 20 marks

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9. (a) What do you understand by the following statements?

(i) $^{14}_{6}C$ has a half-life of 55 secs.

(ii) $^{14}_{6}C$ has a decay-constant of $1.25 \times 10^{-2}\ s^{-1}$.

(iii) The radioactive decay of $^{14}_{6}C$ is a random and spontaneous process.

[7 marks]

(b) Name ONE external condition that does not affect radioactive decay.

[1 mark]

(c) A radioactive sample contains 3.5×10^{-6} g of pure $^{11}_{6}C$. The table below correlates the activity, A of the sample with time, t.

t/h	A/decay s^{-1}
0	1.05×10^{14}
1	1.40×10^{13}
2	1.83×10^{11}
3	2.40×10^{11}
4	3.10×10^{10}

Determine the

(i) number of nuclei present initially

(ii) decay constant

(iii) half life

(iv) activity after 8 hours

(v) number of radioactive nuclei remaining after 8 hours.

[12 marks]

Total 20 marks

END OF TEST