TEST CODE **02238020**

FORM TP 2007255

MAY/JUNE 2007

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 separate answer booklet provided.
4. All working **MUST** be **CLEARLY** shown.
5. The use of non-programmable calculators is permitted, but candidates should note that the use of an inappropriate number of figures in answers will be penalised.

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 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

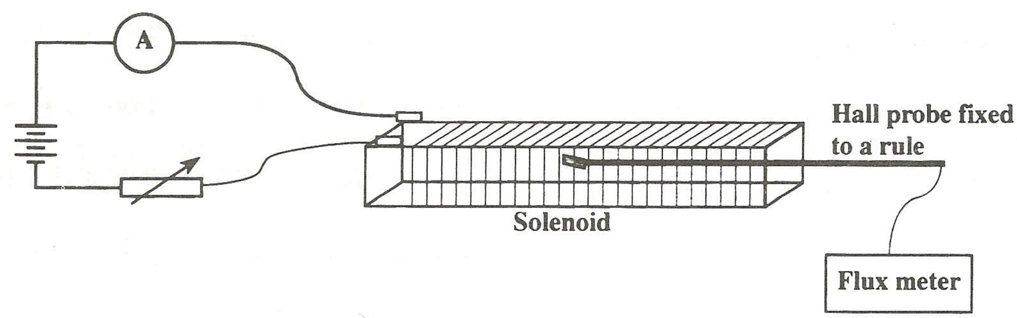
Attempt ALL questions. You MUST write in this answer booklet.

1. According to the texts, the field along the axis of an **infinitely long** solenoid is given by:

$$B = \mu_0 nI$$

where B is the magnetic flux density, n is the number of turns of wire per unit length and I is the current flowing.

Solenoids are not infinitely long so experiments, like the one below, are performed with long relatively thin coils to investigate the extent to which the formula applies. The solenoid used was wound on a wooden former with a 5 cm square cross-section and the distance covered by the coils of wire was 32 cm.



(a) Why did the experimenter insert an ammeter and rheostat in the solenoid circuit?

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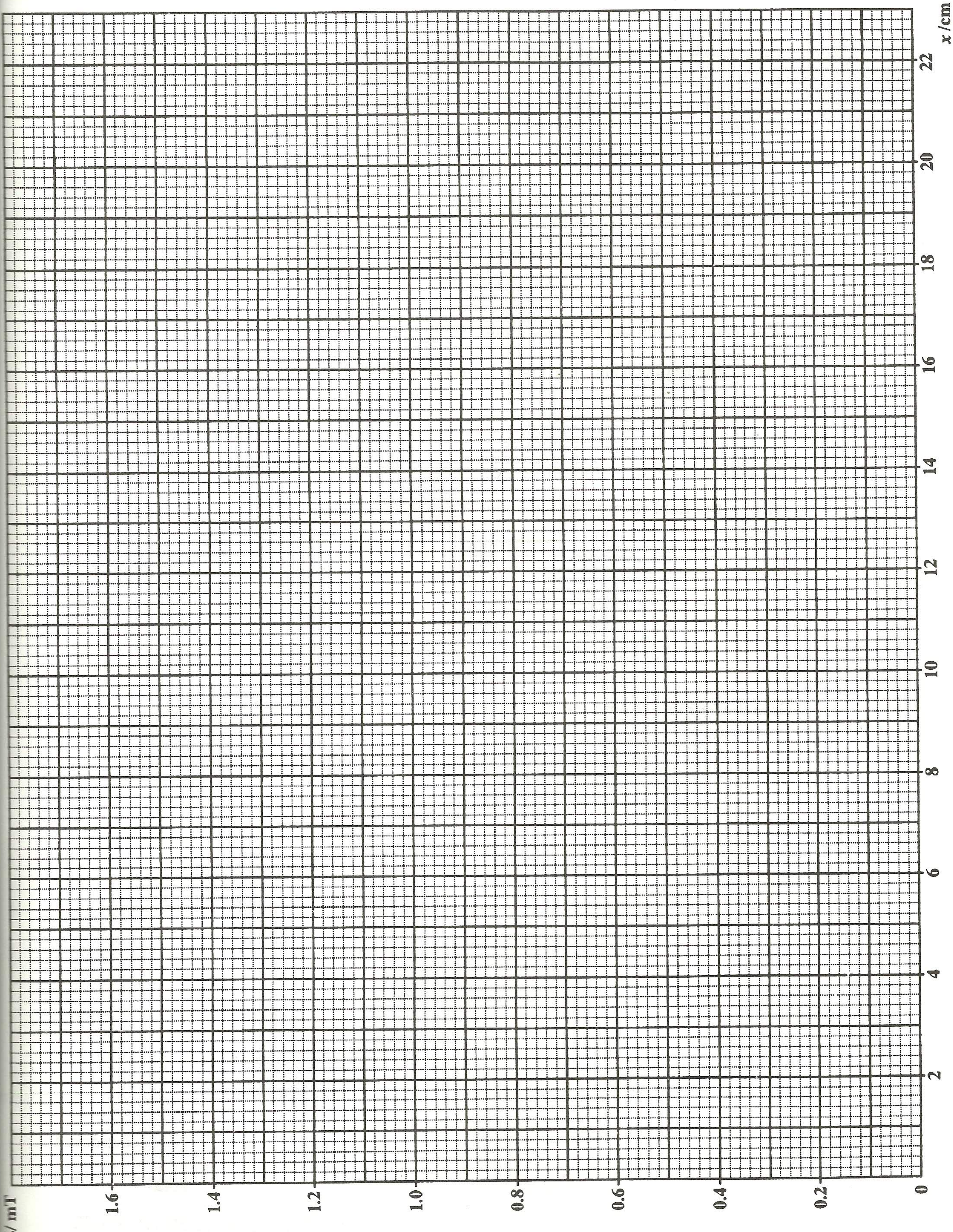
[1 mark]



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(b) Since the field of the solenoid is symmetrical, the experimenter started his measurements of the magnetic flux density from the centre of the solenoid ($x = 0$) and continued in steps to the end ($x = 16$ cm) and beyond. Use the experimenter's results for a solenoid current of **0.94 A**, Table 1, to plot on the page opposite a graph showing how the field varies along the axis of the solenoid.

Table 1

x/cm	0.0	2.0	4.0	6.0	8.0	9.0	10.0	12.0	14.0	16.0	18.0	20.0	22.0
B/mT	1.41	1.39	1.40	1.41	1.40	1.38	1.34	1.18	0.95	0.70	0.42	0.20	0.06

[5 marks]

(c) What conclusions can be made about

(i) the region where the given formula applies?

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____

(ii) the field strength at the end of the solenoid?

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[2 marks]

(d) Use the formula to find the TOTAL number of turns of wire in the solenoid.

[2 marks]

Total 10 marks

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2. The circuit diagram in Figure 1 shows a op-amp. connected as a temperature sensor. The LED comes on when the temperature exceeds a certain value. In order to design the circuit correctly a calibration graph needs to be plotted from Table 2.

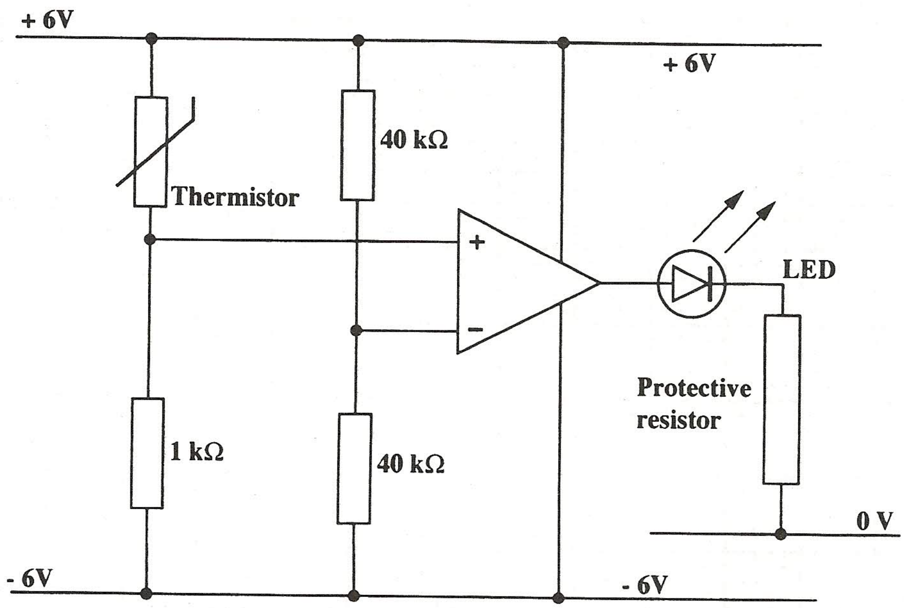

Figure 1

θ/°C	40	50	60	70	80	90	100
R/kΩ	2.17	1.55	1.18	0.89	0.70	0.56	0.44

Table 2

(a) Plot a graph of R against θ on the grid on page 7 **[4 marks]**

(b) (i) Use your graph to find the resistance of the thermistor at 75°C.

(ii) State, with reasons, whether the LED will be ON or OFF when the thermistor's temperature is 75°C.

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___

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(iii) At what temperature will the light emitting diode come on as the temperature is raised from 40°C?

[6 marks]

Total 10 marks

3. The intensity of γ – radiation, I, decreases exponentially with absorber thickness, x, according to the relation $I = I_o e^{-\mu x}$, where μ is the linear absorption coefficient of the absorber. The data in Table 3 was obtained in an experiment to measure the linear absorption coefficient of Lead.

(a) Fill in the missing values in the table.

Thickness of lead x, (cm)	**Intensity, I (counts per second)**	***ln I***
0.1	3772	8.24
0.2	3162	
0.4	2222	7.71
0.5	1863	
0.6	1562	
0.7	1309	

Table 3 **[1 mark]**

(b) (i) Plot a graph of *ln I* versus x on the graph page opposite and draw the BEST line through the points.

(ii) From your graph, determine

a) the absorption coefficient, μ.

b) the value of I_o.

[8 marks]

(c) Explain how the value of I_o can be measured directly.

[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 separate answer booklet provided.

MODULE 1

Answer EITHER Question 4 OR Question 5.

4. (a) (i) Why is the e.m.f. of a battery not necessarily the same as the p.d. across its terminals?

(ii) Describe in detail, with the aid of a diagram, how a slide-wire potentiometer could be used to determine the e.m.f. of a battery. You may assume that you have available a standard cell with an e.m.f. of 1.02 V.

(iii) Why would a potentiometer be expected to give a more accurate value for the e.m.f. than a moving coil voltmeter?

(iv) Using a potentiometer the e.m.f. of a cell is found to be 1.51 V but when a 5.0 Ω resistor is connected in parallel to the cell the p.d. across it is measured to be only 1.26 V. How much internal resistance does the cell have?

[12 marks]

(b) In Figure 2, Battery A has an e.m.f. of 7.0 V and negligible internal resistance. Battery B's e.m.f. is 5.0 V and its internal resistance is 1 Ω. The currents supplied by the batteries are labelled x and y respectively.

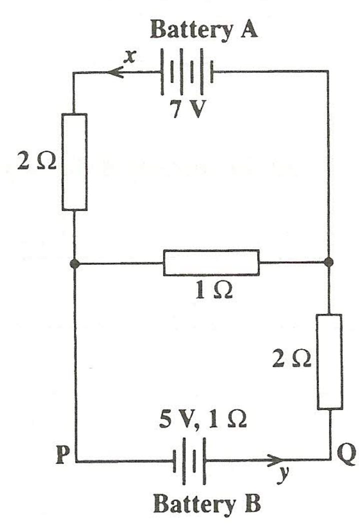

Figure 2

(i) Find the values of the currents x and y.

(ii) Determine the p.d. between the points P and Q. **[8 marks]**

Total 20 marks

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5. (a) (i) Define the '*farad*', the unit of capacitance.

(ii) Describe how the dimensions of a parallel plate capacitor affect its capacitance.

[3 marks]

(b) Derive the formulae for the equivalent capacitance of

(i) two capacitors connected in series

(ii) two capacitors connected in parallel. **[5 marks]**

(c) (i) Find the equivalent capacitance of the network of capacitors in the circuit shown in Figure 3.

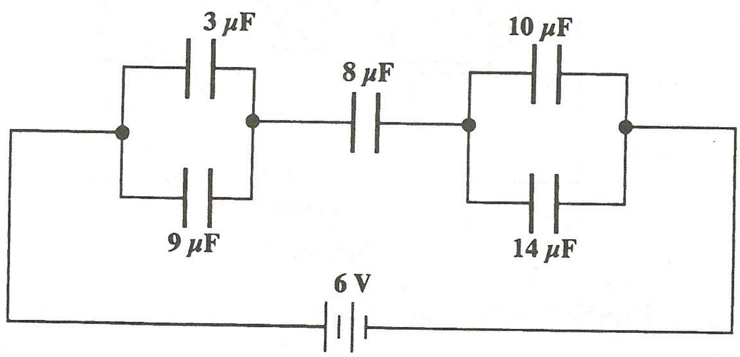

Figure 3

(ii) How much charge is stored by this system?

(iii) How much charge is stored by the 8 μF capacitor and what is the p.d. across it?

(iv) Find the charge on the 10 μF capacitor.

(v) What is the TOTAL energy stored by this system? **[12 marks]**

Total 20 marks

MODULE 2

Answer EITHER Question 6 OR Question 7

6. (a) Figure 4 shows the internal distribution of charge of a p–n junction with no applied bias. The net current through the junction is I_D and the voltage across the junction is V_D.

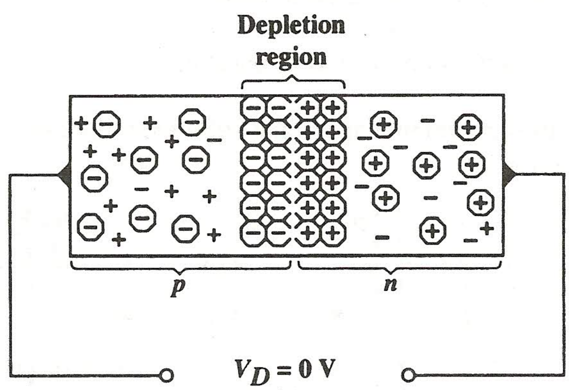

Figure 4

(i) Explain what is meant by the 'depletion region' and state how it arises.

(ii) Draw a similar diagram to show the junction under forward bias. Indicate the direction of the current, I_D, and comment on the thickness of the depletion region in this case.

(iii) Explain why a current flows for forward bias but the current is virtually zero in reverse bias. **[8 marks]**

(b) A number of Light Emitting Diodes (LEDs) can be combined to form an electronic display. One of the most common electronic displays is the seven-segment indicator. Figure 5 shows the seven-segment indicator and its schematic diagram. The voltage drop for each LED is 2.0 V.

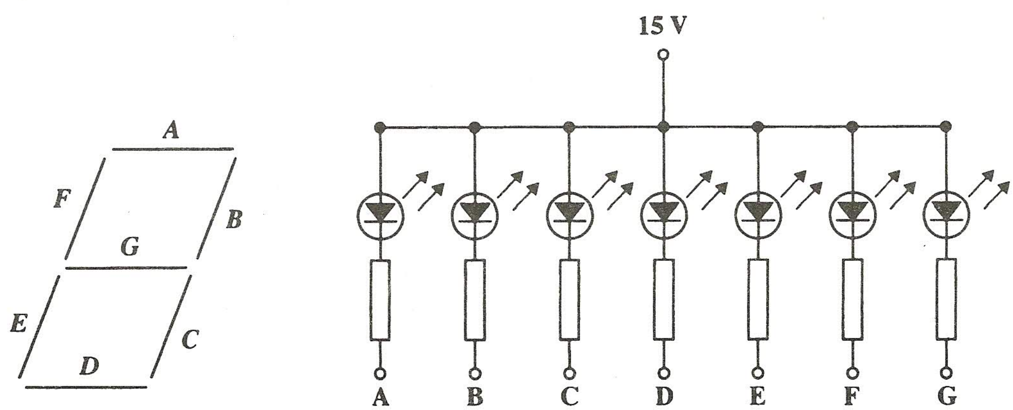

Figure 5

(i) For the LED indicator, indicate which segments should be grounded to form the number 2.

(ii) If the current in each segment is 20 mA, calculate the TOTAL current for this character.

(iii) Calculate the value of ONE of the identical protective resistors used in the display. **[5 marks]**

(c) The silicon diode in Figure 6 has a characteristic curve like that shown in Figure 7. It is connected to a sinusoidal supply with a peak voltage of 1.5 V, and a 1 kΩ resistor as shown in Figure 6.

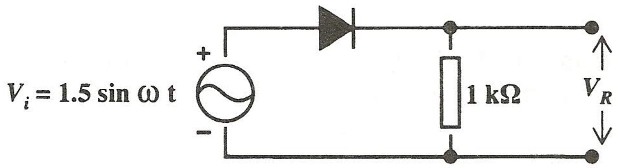

Figure 6

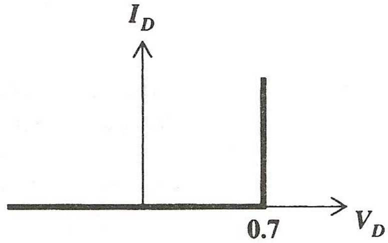

Figure 7

(i) Find the peak value of the potential difference across the 1 kΩ resistor.

(ii) What is the peak value of the current, I, through the resistor?

(iii) Sketch the waveforms for V_i, I and V_R, using the same scale on the *t*-axis for each sketch graph. [Each complete cycle should occupy at least 8 cm on the *t-axis* of your drawing.]

[7 marks]

Total 20 marks

7. (a) (i) Draw up the truth tables for a NOR gate and a NAND gate.

(ii) Show how a NAND gate could be constructed from a quad-NOR chip (i.e. a chip containing 4 NOR gates).

(iii) A two-door car has switches on both doors. The switches, which are on (logic 1) only when the doors are closed properly, are connected via a logic gate to a warning light. The light comes on if either door is not closed. Draw up a truth table to represent this action and then draw a diagram of the circuit required.

[7 marks]

(b) (i) Draw the circuit for an S-R flip-flop and describe how it is possible sometimes for the output to remain the same even though the input changes.

(ii) Figure 8 shows three T-type flip-flops (bistables) connected together. Their output changes when the input detects a downward pulse i.e. the input changes from logic 1 to logic 0.

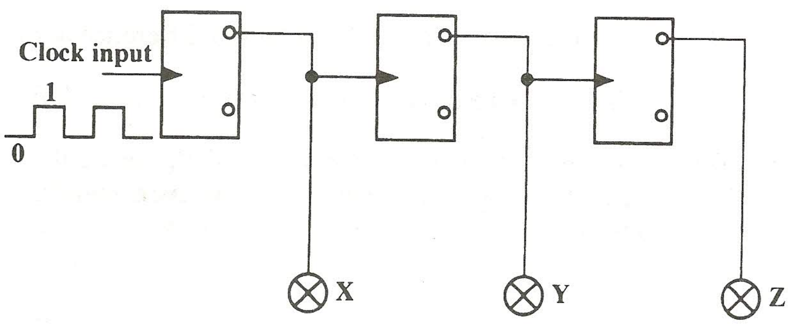

Figure 8

Copy and complete the truth table to show the outputs at X, Y and Z for four successive input pulses starting with all the outputs at zero.

Pulse No.	X	Y	Z
0	0	0	0
1	1		
2	0		
3	1		
4	0		

Table 4

(iii) Outputs X, Y and Z of Figure 8 are connected to the inputs of the circuit below (Figure 9). Each of the inputs has a potential of 5 V if it receives a "1" and 0 V if it receives a "0".

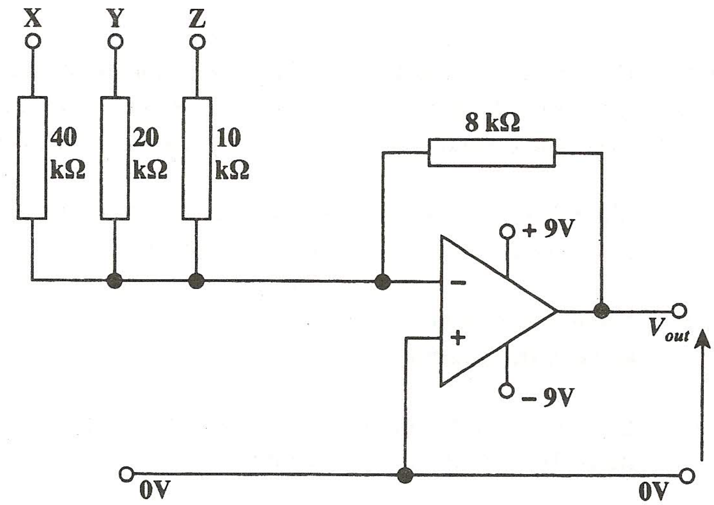

Figure 9

a) Write an equation relating V_{out} to the three input voltages, V_x, V_y and V_z.

b) Calculate the value of V_{out} for the following binary inputs (in the **reverse order** Z, Y, X)

i) 001 (i.e. Z = 0, Y = 0 and X = 1) ii) 101 iii) 110

c) Briefly describe how the circuit acts as a digital to analogue converter.

[13 marks]

Total 20 marks

MODULE 3

Answer EITHER Question 8 OR Question 9.

8. (a) (i) Describe, with the aid of a diagram of the apparatus required, how you would show that the decay of a radioactive source is random. Assume that you have available a small source containing a long-lived isotope of radium.

Show how you would display your observations and describe how you would draw your conclusion from these results.

(ii) What is the relationship between the number of parent atoms present and the activity of the source?

(iii) Explain the meaning of the term 'half-life' and write an equation relating the half-life and the decay constant λ.

[8 marks]

(b) The activity of a radioactive source is 2.5×10^6 Bq at time $t = 0$ and its half-life is 4.5 years.

(i) What was the number of parent atoms at time $t = 0$?

(ii) Find the activity of the source after 9 years.

(iii) What would the activity of the source be after 12 years?

(iv) The source cannot be disposed of until its activity is less than 100 Bq. For how many years must the source be retained before it is discarded?

[1 year = 3.15×10^7 s] **[12 marks]**

Total 20 marks

9. (a) Explain what is meant by the term 'photoelectric effect' and discuss why the existence of a cut-off frequency in the photoelectric effect favours a particle theory for light rather than a wave theory. **[3 marks]**

(b) Ultraviolet light of wavelength 400 nm is incident on a metal surface in an evacuated photocell. The power incident per unit area is 100 W m^{-2}, and the illuminated area of the metal is 5.0×10^{-6} m^2. A saturated photocurrent of 5×10^{-9} A is collected and the maximum kinetic energy of the photoelectrons is found to be 1.3×10^{-19} J.

Calculate

(i) the number of photons incident on the illuminated area each second

(ii) the number of photoelectrons emitted in this time. **[7 marks]**

(c) (i) Explain how the MAXIMUM kinetic energy of the photoelectrons may be measured.

(ii) Write down an equation to show how the principle of conservation of energy applies to the process of photoelectric emission and explain EACH term.

(iii) Use the equation you wrote in (c) (ii) to find the threshold wavelength of the photo-emission from the metal.

(iv) State, with a reason, whether or not photoelectrons will be emitted if radiation of wavelength 680 nm is incident on the metal surface.

[10 marks]

Total 20 marks

END OF TEST