TEST CODE **02238020**

FORM TP 2008248

MAY/JUNE 2008

CARIBBEAN EXAMINATIONS COUNCIL

ADVANCED PROFICIENCY EXAMINATION

PHYSICS

UNIT 02 – Paper 02

2 hours 30 minutes

READ THE FOLLOWING INSTRUCTIONS CAREFULLY

1. This paper consists of **SIX** questions.
2. Section A consists of **THREE** questions. Candidates must attempt **ALL** questions in this section. Answers for this section must be written in the spaces provided in this question paper.
3. Section B consists of **THREE** questions. Candidates must attempt **ALL** questions in this section. 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
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 your answers in this answer booklet.

1. When a capacitor discharges through a resistor its current at any instant is given by the equation:

$$I = I_o e^{-t/RC}$$

Using the circuit shown in Figure 1, a student collected data to plot a linear graph from this function.

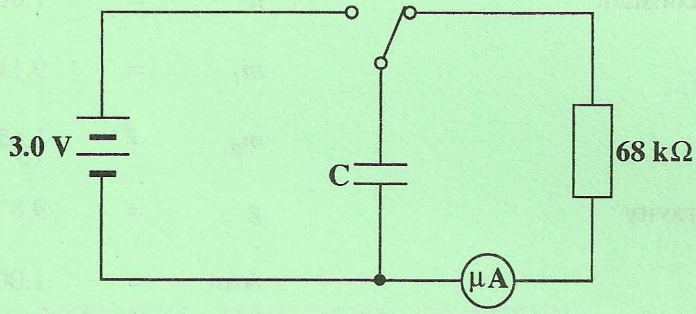


Figure 1

(a) In the space below write a suitable linear equation and then complete the table so that the straight line graph may be plotted. (Note that there is no need to convert the μA to amperes.) **[3 marks]**

Equation: ____

t/s	I/μA	ln (I/μA)
20	36	
40	30	
60	25	
80	20	
100	18	
120	15	
140	12	

(b) Use the student's results to plot on page 5 the required linear graph. **[5 marks]**

(c) Use the graph to find

(i) the value of the current at time $t = 0$

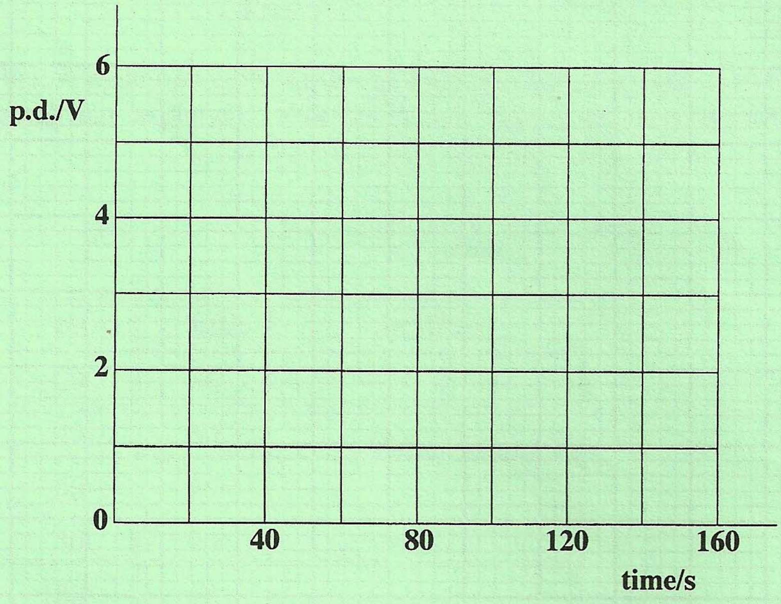
____

____

(ii) the time constant for the discharge.

[4 marks]

(d) (i) On the grid below sketch a graph to show how the potential difference (p.d.) across the capacitor varies with time during this discharge.



(ii) Write an equation for this voltage change using the actual values for the constants in it.

Equation: ____________________________________

____

[3 marks]

Total 15 marks

2. (a) You are provided with a chip which has four NAND gates (a quad-NAND). Draw diagrams to show how the following logic gates might be constructed using (parts of) this chip.

(i) a NOT gate

(ii) an AND gate

(iii) an OR gate

[3 marks]

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(b) (i) Complete the truth table below for the circuit shown in Figure 2.

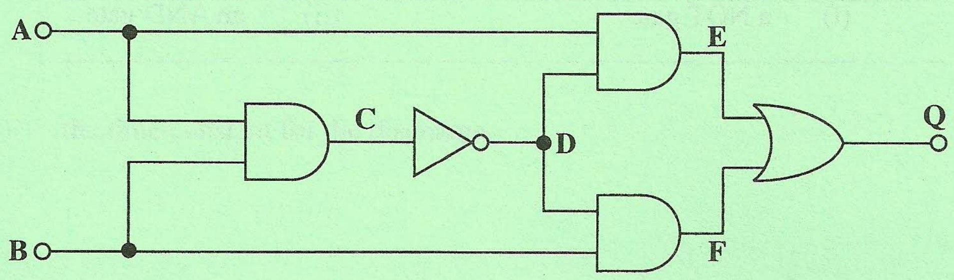

Figure 2

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

[4 marks]

(ii) Replace all of the components in the circuit Figure 2 with NAND gates (Step 1) and then minimise the number of gates so that the circuit could be made using a single quad-NAND chip (Step 2).

Step 1:

Step 2:

[4 marks]

(c) Draw a diagram showing the construction of a bistable (or flip-flop) from two NAND gates and explain, with the aid of a sequential truth table, how it could operate as an electronic latch. I_1 and I_2 are the inputs on the flip-flop; Q and $\overline{Q}$ are the two outputs.

Sequential truth table:

#	I_1	I_2	Q	$\overline{Q}$
1	0	1		
2	1	1		
3	0	1		
4	1	0		
5	1	1		
6	1	0		

[4 marks]

Total 15 marks

3. (a) Figure 3a shows how the current in the photocell (Figure 3b) varies with the applied voltage.

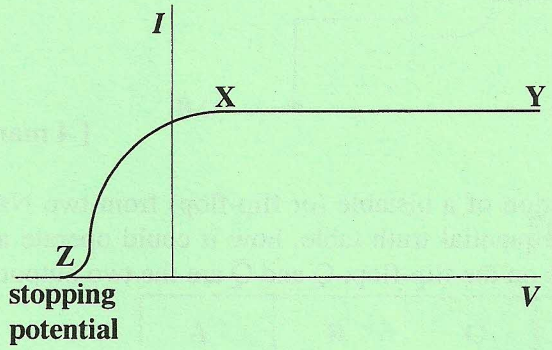

Figure 3a

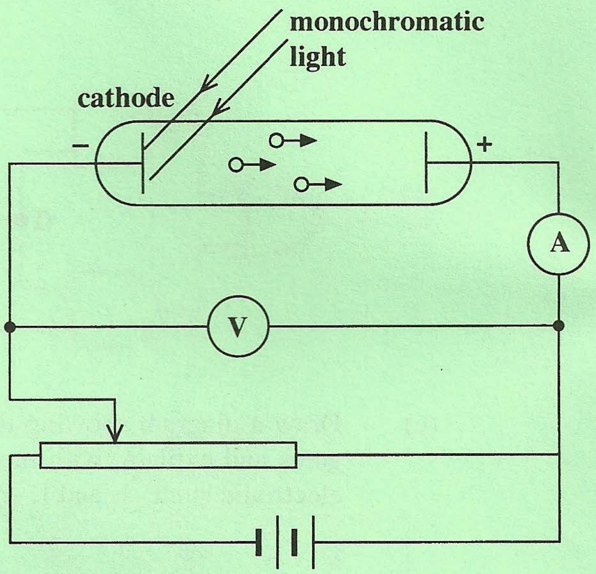

Figure 3b

(i) Add a curve to the graph in Figure 3a to show the effect of increasing the intensity of the light. LABEL the curve A. **[1 mark]**

(ii) Add another curve, labelled B, to show the expected result if radiation with a shorter wavelength were used. **[1 mark]**

(iii) Explain why the current stays constant between X and Y on the graph.

____

____

____

[2 marks]

(iv) Explain why the current decreases when the voltage across the tube is reversed (region XZ in Figure 3a).

____

____

____

____

[1 mark]

(v) How can the stopping potential be used to calculate the maximum kinetic energy of the photoelectrons?

____

[1 mark]

(b) The relationship between the maximum kinetic energy, E_{max} , of the electrons and the frequency of the incident radiation is given by the equation $hf = E_{max} + \Phi$.

(i) By plotting a suitable graph on the grid shown on page 12, using the data in the table below, determine a value for the Planck's constant h.

E_{max} / J x 10^{-19}	1.3	1.8	2.2	2.9	3.5	4.1
f / Hz x 10^{14}	7.5	8.4	9.0	10.2	11.0	11.7

Calculations

[7 marks]

(ii) Calculate the value of the work function for this photocathode.

[2 marks]

Total 15 marks

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SECTION B

Attempt ALL questions.

You MUST write your answers in the answer booklet provided.

4. (a) Define magnetic flux and state Lenz's law. **[2 marks]**

(b) Figure 4 (a) shows a metal ring placed on top of a large coil, with an iron core threading the centre of the ring and the coil. A current is suddenly started in the coil and the ring jumps several centimetres into the air.

(i) Explain why the ring jumps into the air.

(ii) Describe and explain the motion of the ring, if any, when a slot is cut into the ring as shown in Figure 4(b).

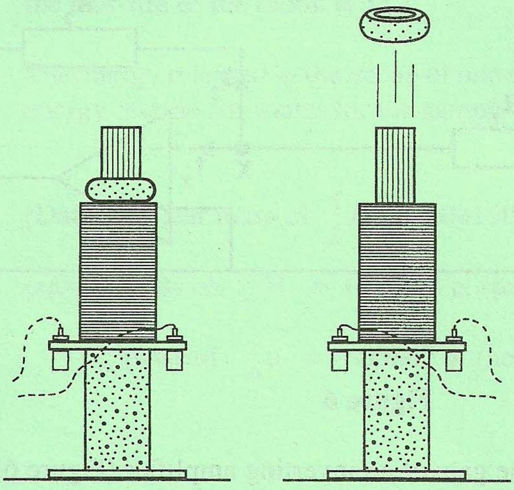

Figure 4(a)

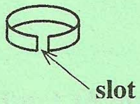

Figure 4(b)

[4 marks]

(c) Figure 5 shows a circular coil of 150 turns, each of diameter 0.1 m which rotates 25 times each second about a diameter between the poles of a permanent magnet. The magnet produces a uniform magnetic field of flux density 4.0 x 10^{-4} T. At $t = 0$, the coil is in the position shown.

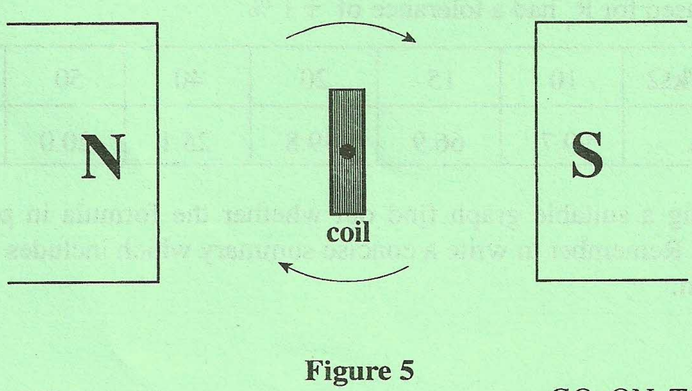

Figure 5

(i) Calculate the total magnetic flux Φ through the coil at time $t = 0$

(ii) Given that the rate of change of total flux at any time t is equal to $2\pi f\, \Phi \sin 2\pi ft$ (f is the frequency of rotation) find

a) the maximum instantaneous value of the induced e.m.f. in the coil

b) the r.m.s. value of the e.m.f. induced in the coil.

(iii) If the coil were fixed and the magnet were rotated at the same rate in the same direction, what difference would this make to the induced e.m.f?

[9 marks]

Total 15 marks

5. (a) Figure 6 shows an inverting amplifier.

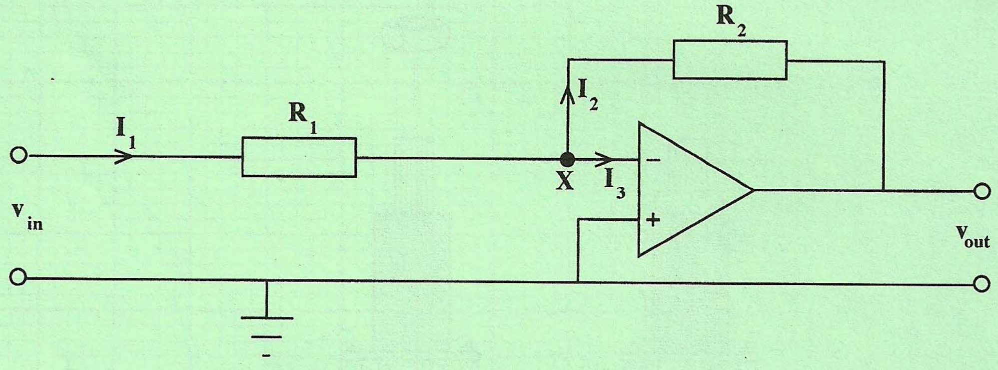

Figure 6

Derive the equation for the gain of an inverting amplifier (Figure 6)

$$A = -R_2 / R_1$$

where R_2 is the value of the feedback resistance and R_1 is the input resistance.

In your answer remember to state clearly TWO assumptions which you need to make about the properties of the operational amplifier used. **[5 marks]**

(b) To test how well this equation works in a practical situation the following data were collected by varying the input resistance whilst keeping the feedback resistance R_2 constant. The resistors used for R_1 had a tolerance of ± 1 %.

R_1/kΩ	10	15	20	40	50	75
A	99.7	66.9	49.8	25.1	20.0	13.5

By plotting a suitable graph find out whether the formula in part (a) applies to this situation. Remember to write a concise summary which includes the reasoning for your conclusion. **[10 marks]**

Total 15 marks

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PHYSICS – UNIT 02 - Paper 02

Insert for Question 5 (b) **Registration Number** ....

Centre Number .... **Candidate's Number** ....

TO BE ATTACHED TO YOUR ANSWER BOOKLET

6. (a) (i) Explain what is meant by the 'binding energy of the nucleus'.

(ii) Calculate the binding energy per nucleon (in joules) for an α-particle (helium-4 nucleus).

(iii) The binding energy per nucleon of helium-4 is much higher than that of other elements near to it in the periodic table. Comment on the significance of this fact.

[7 marks]

(b) Radon is a radioactive gas which emits α-particles. The activity of a sample of this gas is found to be 4 500 Bq at a particular time

(i) Write an equation for the decay of radon given that a radon nucleus (Rn) has 86 protons and 136 neutrons. The daughter product is an isotope of polonium (Po).

(ii) Calculate a value for the number of radon atoms present at the particular instant if the half-life of the radon is 55 s.

(iii) The energy released in the decay of one radon nucleus is 6.3 MeV. Find the rate of energy release (in watts) for the sample above with an activity of 4 500 Bq.

[8 marks]

[Data: nuclear mass of ${}^{4}_{2}He$ = 4.00150 u

nuclear mass of ${}^{1}_{0}\mathrm{H}$ = 1.00728 u (proton)

mass of ${}^{1}_{0}\mathrm{n}$ = 1.00867 u (neutron)]

Total 15 marks

END OF TEST