TEST CODE **02238020**

FORM TP 2006266

MAY/JUNE 2006

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.

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

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SECTION A

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

1. The circuit shown in Figure 1 may be used to study the discharge of a capacitor. When the movable contact is connected to P the capacitor charges.

(a) Explain how energy is stored in the capacitor when the switch is connected to P.

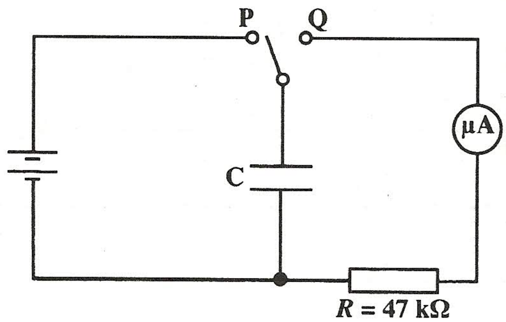


Figure 1

[2 marks]

(b) When the switch is moved to Q the stored energy is discharged and causes a current to flow through the resistor, R. The graph opposite shows how the discharge current through the resistor varies with time. The equation of the graph is:

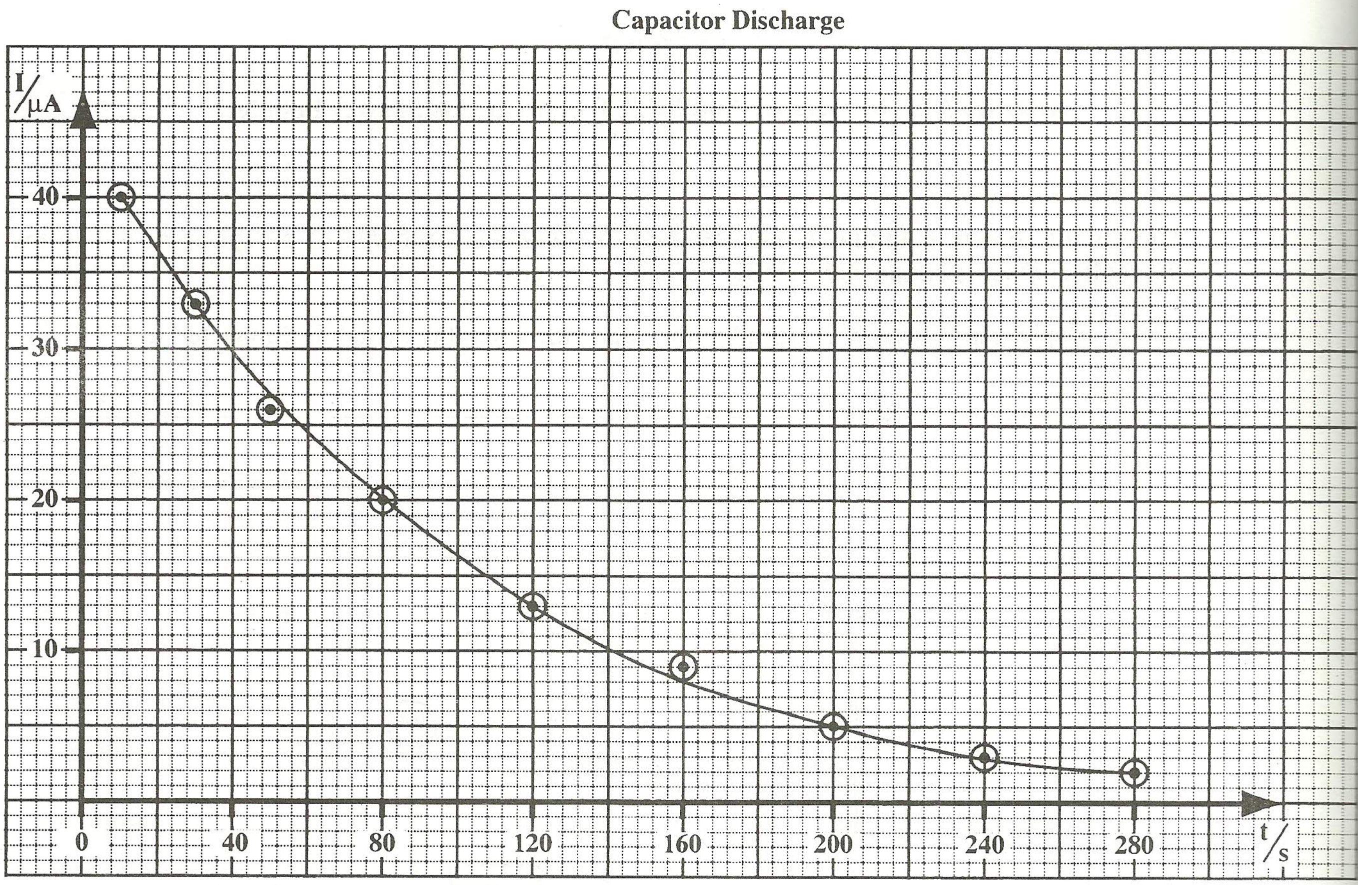
$$I = I_0 e^{-\frac{t}{RC}}$$

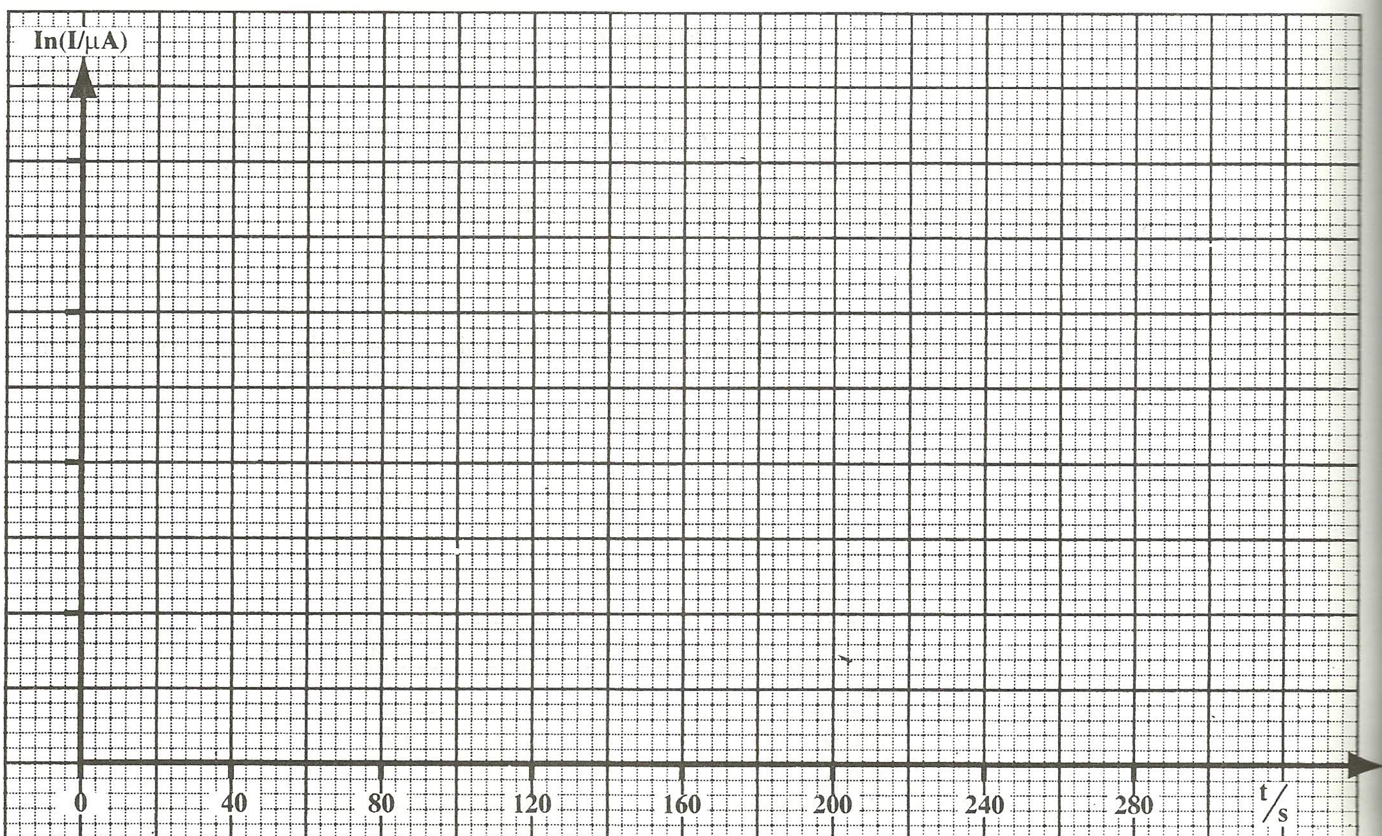
(i) Use data from the graph to complete the table below and then plot a graph of ln I against t.

Table 1

t/s	I/μA	ln(I/μ A)
20.0	36.6	3.60
60.0		
100.0	16.5	2.80
140.0		
180.0	6.5	1.87
220.0		

[4 marks]


Capacitor Discharge
I/μA
40
30
20
10
0
40
80
120
160
200
240
280
t/s


ln(I/μA)
0
40
80
120
160
200
240
280
t/s

(ii) What is the equation of this new graph? **[1 mark]**

(c) (i) Find the gradient of the graph you have drawn. **[1 mark]**

(ii) Given that R has a resistance of 47 kΩ, deduce the capacitance of the capacitor C.

[2 marks]

Total 10 marks

2. Table 2 on the right shows the values of the input voltage to an inverting amplifier and the corresponding values of the output voltage.

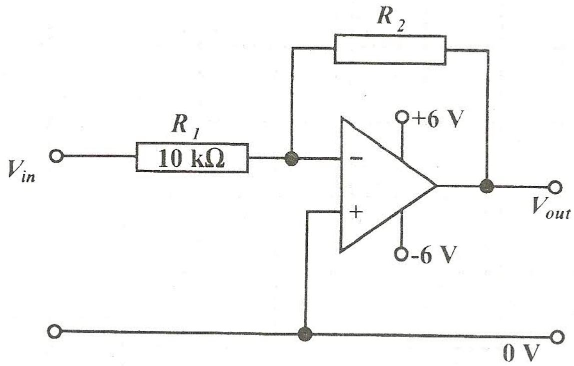


Figure 2

Table 2

V_{in}/V	V_{out}/V
-3.00	5.78
-2.00	5.78
-1.00	5.78
-0.75	5.78
-0.50	4.92
-0.30	2.97
-0.10	0.97
0.15	-1.49
0.25	-2.45
0.50	-4.89
0.75	-5.66
1.00	-5.66
2.00	-5.66
3.00	-5.66

(a) Use the data in the table to plot the transfer characteristic (V_{out} versus V_{in}) of the amplifier. **[4 marks]**

The following graph refers to question 2.

(b) Determine the gradient of the linear region of the graph.

[2 marks]

(c) (i) If R_1 is 10 kΩ what is the resistance of R_2?

[2 marks]

(ii) What is the largest positive input voltage which can be used if the amplifier is not saturated?

[2 marks]

Total 10 marks

GO ON TO THE NEXT PAGE

3. (a) In Millikan's experiment to determine the charge of the electron, a small drop of oil is held stationary between two parallel charged plates (Figure 3) when the weight of the drop is balanced by the electric force (i.e. when $mg = qE$).

(i) How much charge is on the drop of mass 3.9×10^{-15} kg when it is held stationary by a p.d. of 200 V between plates 10 mm apart?

(ii) How could the charge on this drop be changed?

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(iii) To hold the drop stationary when the charge changes the p.d. must be adjusted. Draw a diagram of a circuit which could be connected to P and Q to achieve this, assuming that a power supply with a fixed output of 400 V d.c. is available.

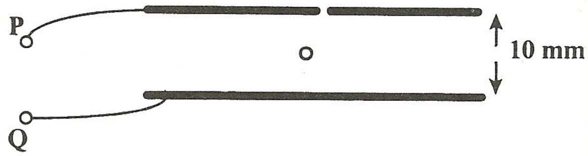

Figure 3

[4 marks]

(b) Table 3 below shows the charges (in arbitrary units) on a single oil drop measured in an experiment like the one above. (N.B. The units of charge used are NOT coulombs.)

Table 3

Result #	**Charge**	**Result #**	**Charge**	**Result #**	**Charge**
1	18	11	33	21	12
2	24	12	15	22	15
3	15	13	21	23	24
4	30	14	15	24	12
5	21	15	12	25	6
6	24	16	27	26	33
7	6	17	30	27	24
8	18	18	18	28	18
9	21	19	21	29	30
10	18	20	6	30	12

(i) Plot a scatter graph of charge against result number on the grid opposite.

(ii) How do these results suggest that charge is quantized?

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(iii) Deduce the value of the charge on the electron (in arbitrary units) implied by these data.

[6 marks]

Total 10 marks

The following graph refers to question 3 (b) (i).

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) Explain the term 'drift velocity'.

(ii) Define the 'coulomb' and the 'volt'.

(iii) Figure 4 shows electrons moving through a cross section of a wire. Show that the current, I, through the wire is given by $I = nevA$

where
n is the number density of the electrons,
e is the charge on the electron,
v is the drift velocity of the electrons, and
A is the cross sectional area of the wire.

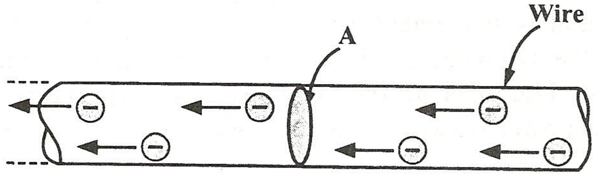

Figure 4

[8 marks]

(b) A cylindrical proton beam of kinetic energy 5.0 MeV and radius 1.5 mm is aimed at a target. The beam carries a current of 0.50 mA.

Calculate:

(i) The velocity of the protons
(ii) The number density of protons in the beam
(iii) The number of protons hitting the target in 1 second **[9 marks]**

(c) The beam of protons in (b) is to be deflected around a curve of radius 2.0 m. If the magnetic field is perpendicular to the beam, calculate its field strength.

[3 marks]

Total 20 marks

GO ON TO THE NEXT PAGE

5. (a) (i) Define 'magnetic flux density' and the 'tesla'.

(ii) Sketch the magnetic flux pattern due to a long straight wire carrying a current, and state the formula for the flux density, B, at a distance, r, from the wire.

(iii) Figure 5 shows two long parallel wires, both of length l, separated by a distance, r, carrying currents, I_1 and I_2, in opposite directions.

Show that the force between the two wires is given by $F = \dfrac{\mu_0 I_1 I_2 l}{2\pi r}$.

State whether this force is attractive or repulsive. **[8 marks]**

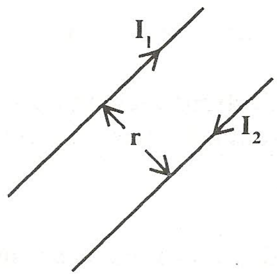

Figure 5

(b) Figure 6 shows a diagram of a current balance constructed in the following way: A 10 cm long section of wire is placed on top of the pan of an electronic balance. Leads are clipped to the wire running into a power supply and through the power supply to another segment of wire that is suspended directly above the wire and parallel with it. The distance between the two wires is 2.5 cm. The power supply provides a current, I, running through the wires. **The force on the lower wire is the increase in the reading of the balance.** When the power is switched on, the reading on the balance increases by 5.0×10^{-6} N.

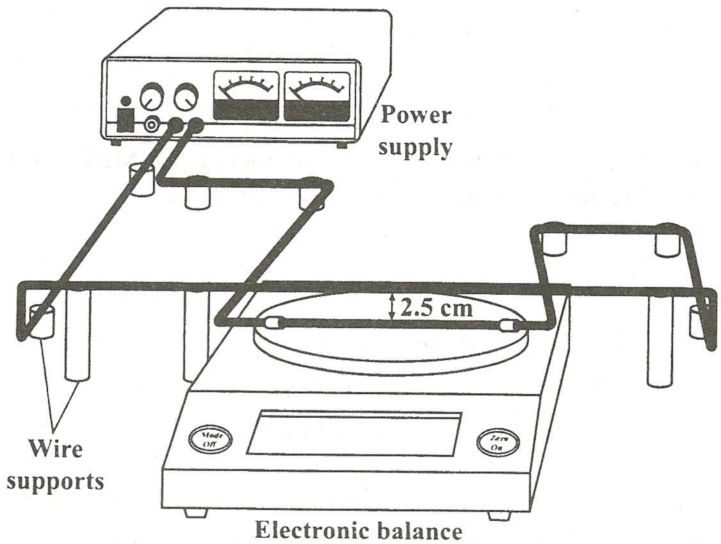

Figure 6

(i) Calculate the current through the wire.

(ii) The sensitivity of the balance is 0.1×10^{-6} N. Calculate the minimum current detectable using this balance. **[6 marks]**

(c) A solenoid is designed to produce a magnetic field of 0.0270 T at its center. It has a radius of 1.40 cm and length 40.0 cm. The wire carries a maximum current of 12.0 A.

Calculate

(i) the minimum number of turns per unit length that must be used

(ii) the total length of wire required. **[6 marks]**

Total 20 marks

MODULE 2

Answer EITHER Question 6 or Question 7.

6. The graph in Figure 7 shows how the gain of an operational amplifier varies with frequency.

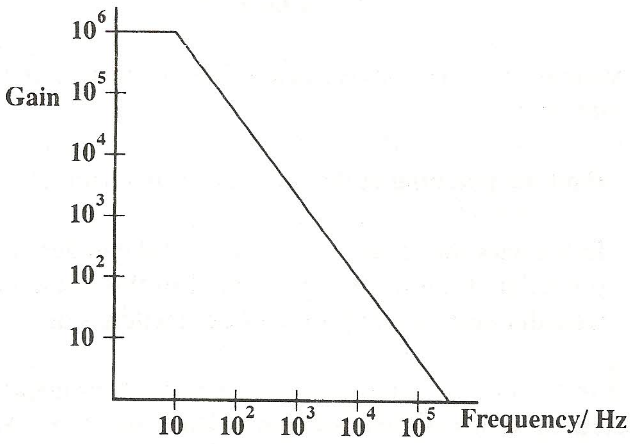

Figure 7

(a) (i) Explain why the scales on the axes are logarithmic rather than linear.

(ii) What value does the graph give for the open loop gain of the op-amp.? **[2 marks]**

(b) (i) A non-inverting amplifier with a gain of +100 is constructed using this op-amp. Use the graph to determine its bandwidth.

(ii) Draw a circuit diagram to show how the non-inverting amplifier could be constructed.

(iii) Write the formula for the gain of this amplifier.

(iv) State the ratio of the feedback resistance to resistance of the input resistor in this non-inverting amplifier. **[6 marks]**

In the circuit shown in Figure 8 the **same** op-amp. is connected as a comparator.

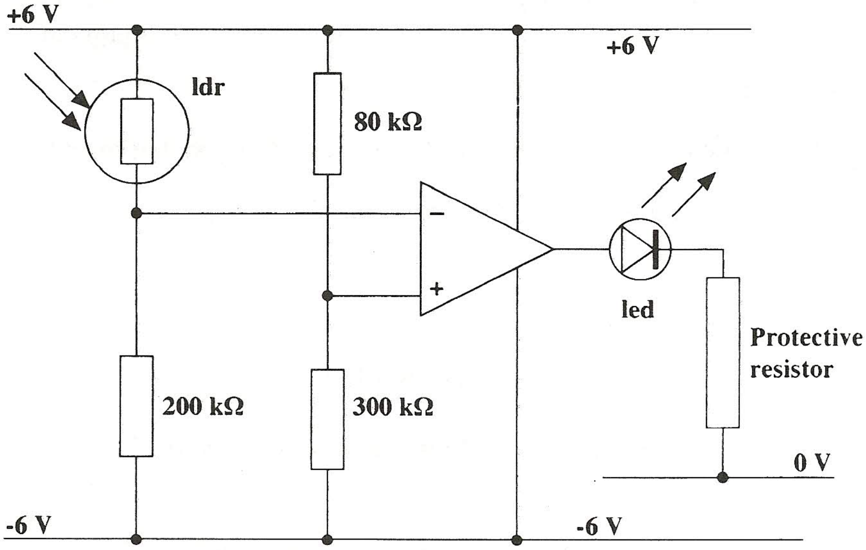

Figure 8

(c) Using your answer to (a) above determine the maximum input voltage to the op-amp. if it is not saturated. **[2 marks]**

(d) (i) Find the potential at the non-inverting terminal of the op-amp in Figure 8.

(ii) In the dark the resistance of the light-dependent resistor (ldr) is 400 kΩ. Find the potential at the inverting terminal in this situation and use this value to explain why the light emitting diode (led) switches on. **[7 marks]**

(e) The led in the circuit is rated 2.4 V, 25 mA. A protective resistor, as shown, has to be connected in series with it so that it does not burn out. What is the value of this resistance? **[3 marks]**

Total 20 marks

7. (a) Many items of equipment in the home are controlled by digital processors (microprocessors).

(i) Name an item found in the home which is controlled by a microprocessor.

(ii) State the function of the microprocessor in the item you have named.

(iii) State TWO benefits resulting from the use of microprocessors.

[4 marks]

(b) (i) Figure 9 illustrates a circuit which has inputs, I_1 and I_2, and output, X.

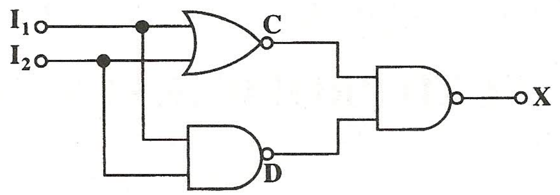

Figure 9

Identify the logic gates shown in Figure 6 and write out their respective truth tables.

(ii) Draw the truth table for the entire circuit shown in Figure 6 and state its function.

[6 marks]

(c) A student designed a logic circuit using NAND gates and a light-emitting diode (led) in order to monitor the opening and closing of two doors. Logic 1 represents a closed door; logic 0 represents an open door. A logic 1 output is required when only one or the other of the doors is open, but not when both are open.

(i) Write the truth table for the circuit.

(ii) Draw the logic circuit which uses only NAND gates and a single led to indicate logic 1 output.

(iii) What single logic gate is the circuit in (b) (ii) equivalent to? **[5 marks]**

(d) Figure 10 shows a power supply. The four ideal diodes P, Q, R and S are connected to form a bridge rectifier circuit.

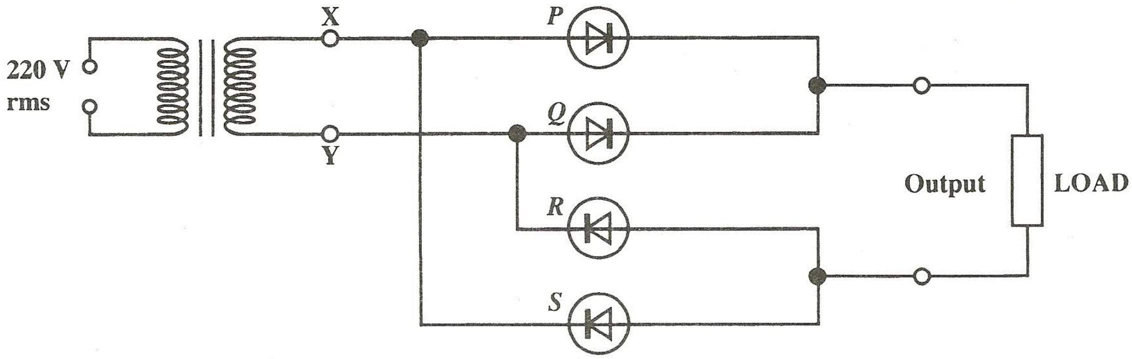

Figure 10

(i) State which diodes conduct when terminal X is positive with respect to terminal Y.

(ii) The input terminals X and Y are connected to the secondary coil of an ideal transformer. The primary coil contains 22000 turns and is connected to a 220 $V_{r.m.s}$ alternating supply. The input to the bridge rectifier circuit is 10 $V_{r.m.s.}$ Calculate the number of turns needed in the secondary coil of the transformer.

[5 marks]

Total 20 marks

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PHYSICS

UNIT 2 – PAPER 02

NOTE TO CANDIDATES

ERRATUM SHEET

Page 16 – Question 7 (b) (i) & (ii)

All references to Figure 6 should be replaced by Figure 9.

MODULE 3

Answer EITHER Question 8 or Question 9.

8. (a) With reference to the photoelectric effect explain what is meant by 'wave-particle duality', 'stopping potential', the 'work function' and 'the threshold wavelength'. **[4 marks]**

(b) Explain why

(i) the maximum kinetic energy of electrons emitted in the photoelectric effect does not depend on the intensity of the incident light

(ii) the total number of electrons emitted depends on the intensity of the incident light. **[4 marks]**

(c) Tungsten has a work function of 4.58 eV. The metal is illuminated with light of wavelength 2.00×10^{-7} m.

Calculate

(i) the threshold wavelength

(ii) the maximum kinetic energy, in eV, of the photoelectrons

(iii) the stopping potential

(iv) the maximum velocity of the photoelectrons. **[12 marks]**

Total 20 marks

9. (a) (i) Explain what is meant by the terms, 'activity', 'decay constant', and 'half life' of a radioactive sample.

(ii) Write an equation relating the activity to the decay constant.

(iii) Show that the half life, $t_{\frac{1}{2}}$, is related to the decay constant, λ, by $t_{\frac{1}{2}} = \frac{\ln 2}{\lambda}$.

(iv) What school laboratory instrument can be used to detect alpha and beta radiation?

[8 marks]

(b) A radioactive source has a half life of 1 minute. At time $t = 0$, the radioactive source is placed near a detector and the count rate is observed to be 2000 counts/s. The detection efficiency is 20 per cent.

Determine:

(i) the initial decay rate of the source

(ii) the number of nuclei present initially

(iii) the activity of the source after 30 seconds

(iv) the number of nuclei that decay in the first 10 minutes.

[12 marks]

Total 20 marks

END OF TEST