TEST CODE **002475**

FORM TP 23247

MAY/JUNE 2003

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.
5. The use of non-programmable calculators is permitted.

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 teacher asks one of her students to test the $I - V$ characteristic of a diode to be used in a control circuit. The student suspects that the current, I, is related to the voltage, V_I, by the relation $I \propto V^n$.

(a) (i) Draw a circuit diagram that could be used to examine the $I - V$ characteristic of the diode.

[2 marks]

(ii) Explain how the readings would be taken.

_____

_____

_____

_____

[2 marks]

(b) The graph in Figure 1 shows the $I - V$ characteristic that was obtained for the diode.

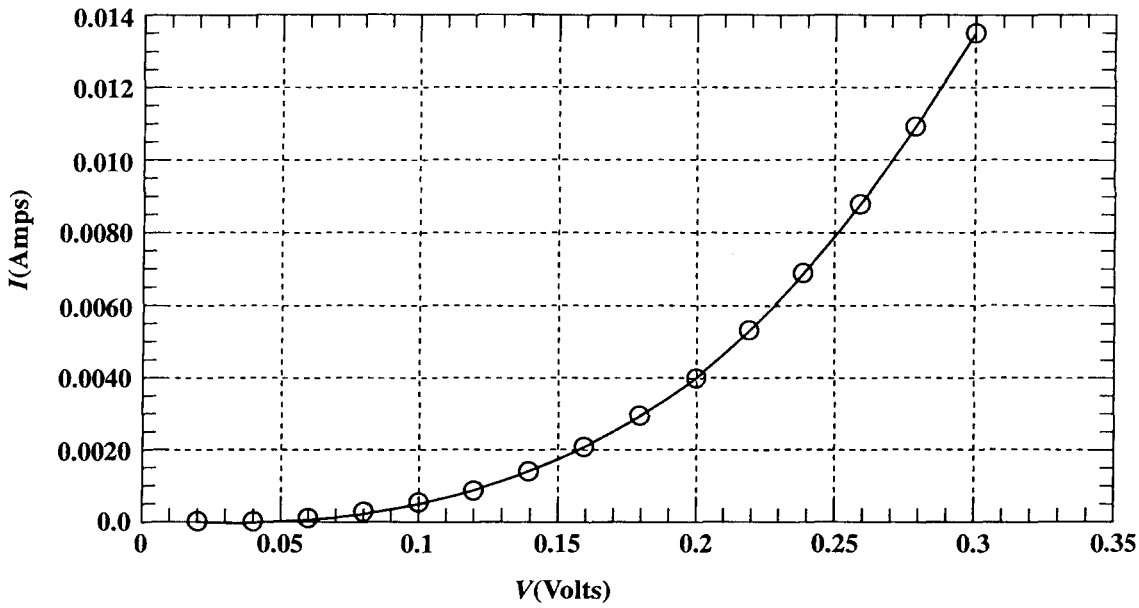

Figure 1

(i) Assume that $I = AV^n$ and use the graph to determine the value of n.

[4 marks]

(ii) Deduce the FULL equation relating the current, I, to the voltage, V, for the diode.

[2 marks]

Total 10 marks

2. The circuit shown in Figure 2 was used to study the transfer characteristics of an operational amplifier connected as a non-inverting amplifier.

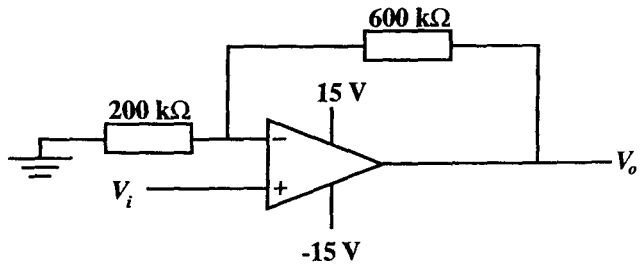

Figure 2

(a) Determine the theoretical gain of the amplifier.

[2 marks]

(b) The input voltage, V_i, was varied and the corresponding output voltage, V_o, was recorded. The results obtained are recorded in Table 1.

V_i	–5	–4	–3	–2	–1	0	1	2	3	4	5
V_o	–13.0	–13.1	–11.8	–8.0	–3.8	0	3.8	8.1	11.9	13	13.1

Table 1

On the graph page on page 7, plot a graph of V_o versus V_i. **[4 marks]**

(c) From your graph, determine the

(i) gradient of the linear section

[2 marks]

(ii) gain of the operational amplifier

[1 mark]

(iii) saturation voltages of the operational amplifier.

[1 mark]

Total 10 marks

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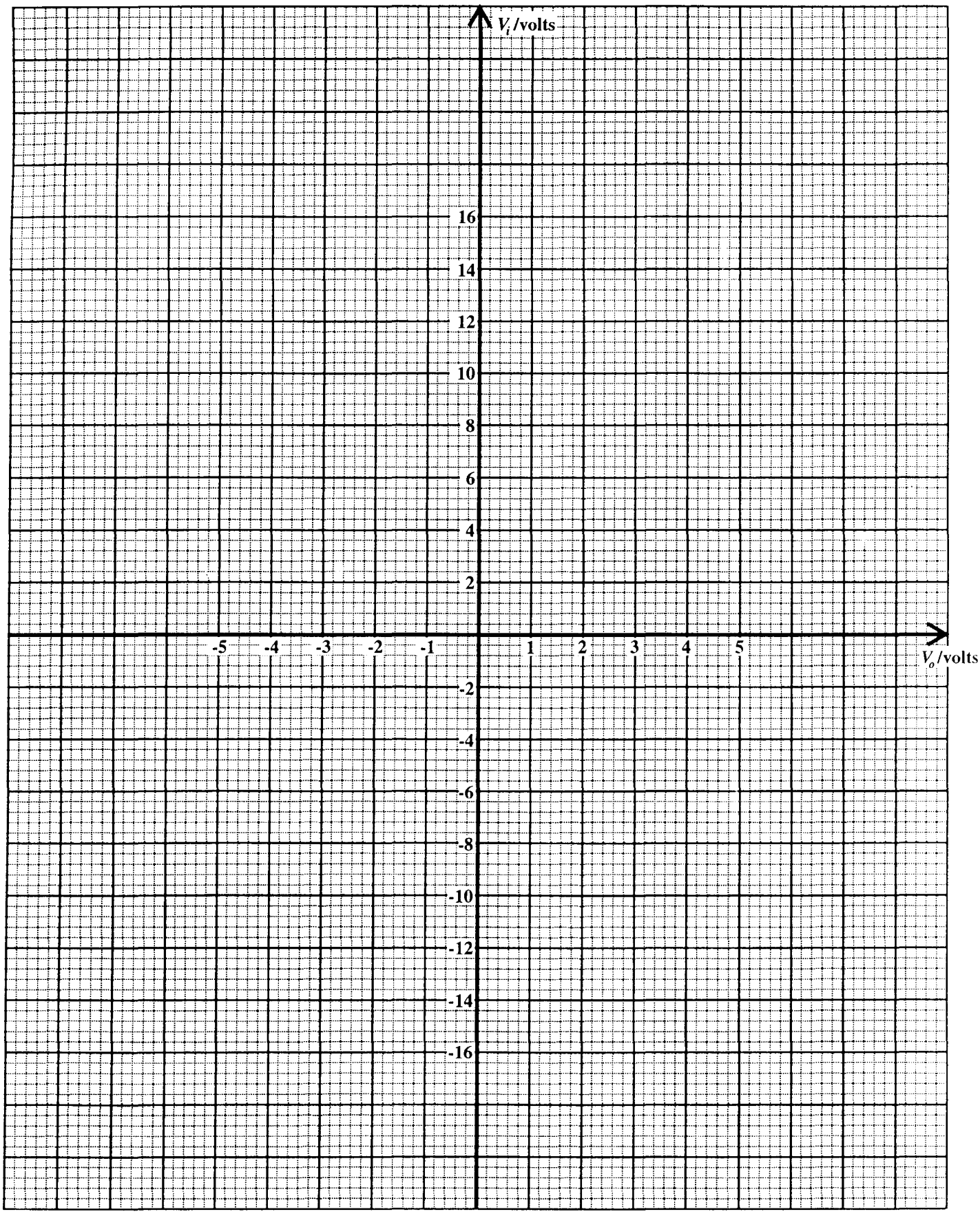

V_i/volts
16
14
12
10
8
6
4
2
-5
-4
-3
-2
-1
1
2
3
4
5
V_o/volts
-2
-4
-6
-8
-10
-12
-14
-16

3. A student varied the wavelength, λ, of light incident on a calcium sample and measured the stopping potential, V_s of the resulting photo emissions.

(a) Complete Table 2 below to show the missing frequency.

λ(nm)	V_s (v)	f(Hz) x 10^{14}
253.6	1.95	11.8
313.2	0.98	
365.0	0.50	
404.7	0.14	7.4

Table 2

[2 marks]

(b) On the graph paper on page 9, plot a graph of stopping potential, V_s, versus frequency, f.

[3 marks]

(c) From the graph, determine

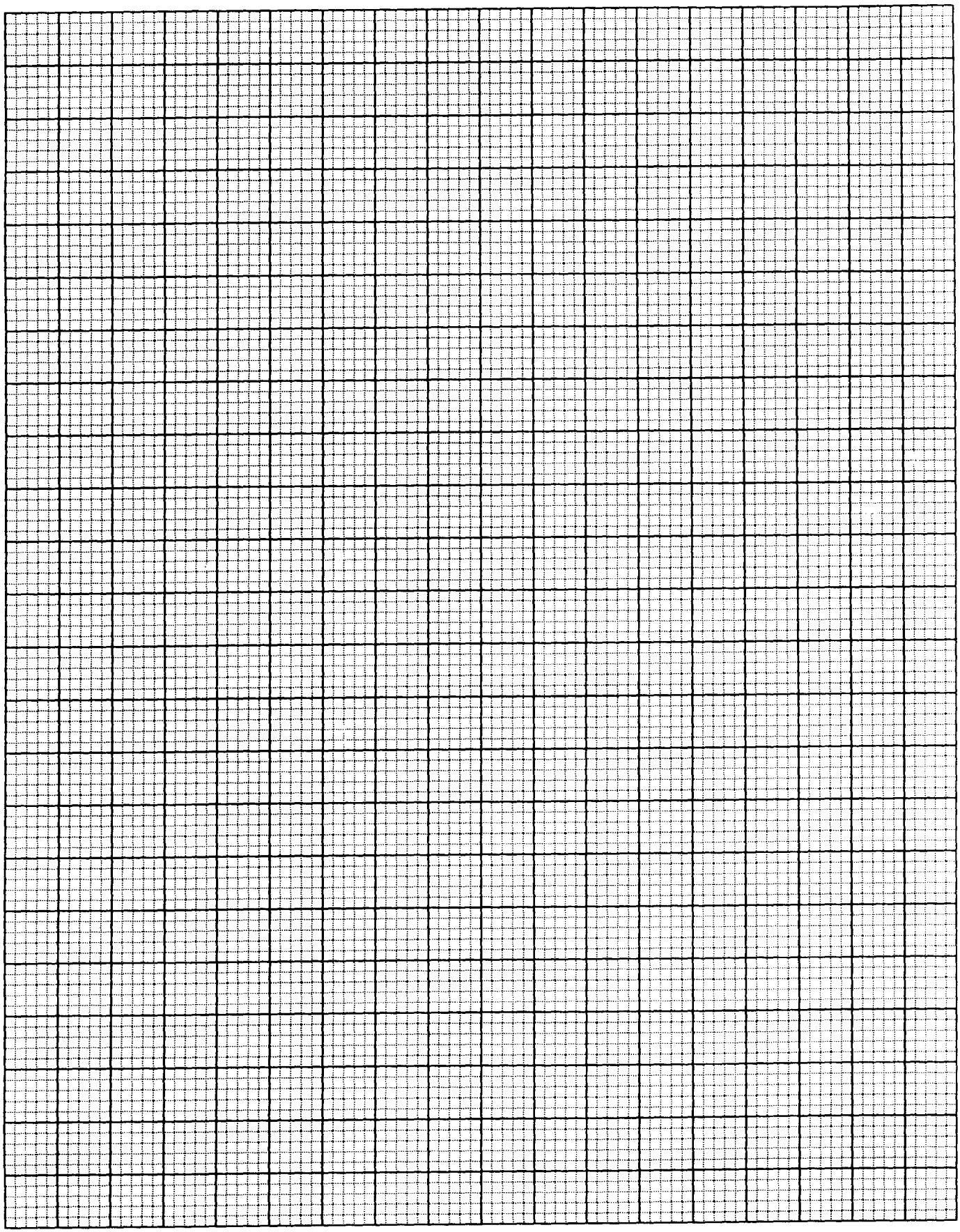
(i) Planck's constant

[3 marks]

(ii) the work function, in eV, of calcium.

[2 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) State Coulomb's law for electrostatic charges and define 'electric field'.

[2 marks]

(b) Figure 3 shows the reproductive organs of a flower.

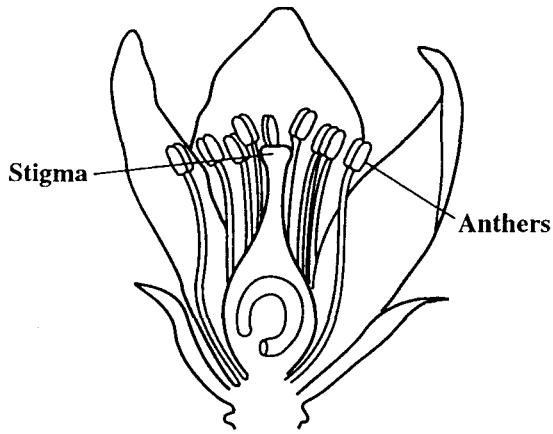

Figure 3

The reproduction of some flowers depends on insects transporting pollen grains from one flower to another. Bees are positively charged and collect the grains electrically. When a bee hovers near a flower's anther, which is electrically insulated, the pollen grains 'jump' to the bee, where they cling during the flight to the next flower. As the bee nears this flower's stigma, which is electrically connected to ground, the pollen grain jumps from the bee to the stigma, fertilizing the flower.

(i) Explain why the pollen grain

a) 'jumps' to the bee
b) clings to the bee during the flight
c) 'jumps' away from the bee to the stigma. **[5 marks]**

(ii) a) Assuming that a bee with a charge of 45.0×10^{-12}C is a spherical conductor, calculate the magnitude of the bee's electric field at the location of a pollen grain 1.5 cm from the bee's centre.

b) State whether this field is uniform or non-uniform.

[3 marks]

(c) A spherical drop of water carrying a charge of 30×10^{-12} C has a potential of 500 V at its surface.

(i) Calculate the radius of the drop.

(ii) Two such drops of the same charge and radius combine to form a single spherical drop.

Calculate the potential at the surface of the new drop. **[10 marks]**

Total 20 marks

5. (a) Figure 4 shows positive charge carriers drifting at velocity, v, in the direction of an applied electric field, E, in a conductor of length, L, and cross-sectional area, A.

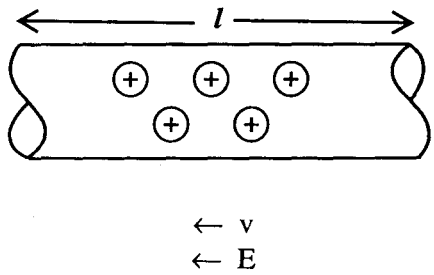

Figure 4

(i) Explain what is meant by 'drift velocity', v.

(ii) Show that the current, I, flowing through the conductor is given by I = ne vA, where n is the number of charge carriers
e is the charge on EACH carrier
v is the drift velocity
A is the cross sectional area of the conductor.

(iii) Write down an equation defining the resistivity of a piece of metal of length l and cross sectional area A. **[8 marks]**

(b) A length of Nichrome wire with cross sectional area 2.60×10^{-6} m^2 has a potential difference of 110 V across it. Nichrome has a resistivity of 5.00×10^{-7} Ωm. The element dissipates thermal energy at a rate of 5 000 W.

Calculate

(i) the current flowing through the wire

(ii) the length of the wire. **[5 marks]**

(c) Given that each cubic metre of nichrome contains 9.0×10^{28} conduction electrons, calculate the drift velocity of the electrons. **[2 marks]**

(d) The wire is placed at right angles to a magnetic field of 1.5×10^{-2} T. Calculate

(i) the average force experienced by EACH electron due to the field

(ii) the TOTAL force experienced by the wire due to the field. **[5 marks]**

Total 20 marks

MODULE 2

Answer EITHER Question 6 OR Question 7.

6. (a) (i) State THREE characteristics of the ideal operational amplifier and their implications for the ideal operational amplifier.

(ii) What effect does negative feedback have on the gain and bandwidth of an operational amplifier? **[8 marks]**

(b)

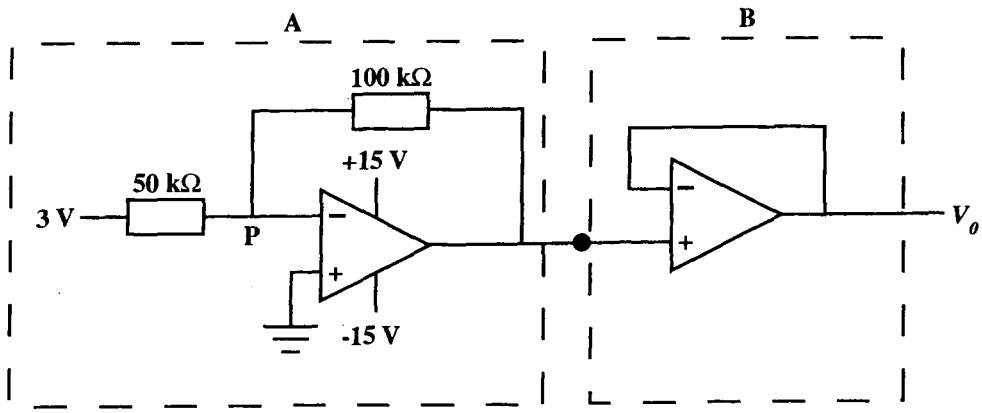

Figure 6

Figure 6 shows two circuits A and B cascaded to produce an output, V_0.

(i) Determine the output voltage, V_0, of the circuit.

(ii) Suggest a practical use for circuit B.

(iii) The entire circuit in Figure 6 saturates at ± 13 V. What is the maximum input voltage that will NOT saturate this circuit? **[7 marks]**

(c) Three signals V_1, V_2 and V_3 are to be combined to produce an output $V_0 = -3V_1 - V_2 - 5V_3$.

The input resistance of the inputs must NOT be less that 10 kΩ and all resistor values must be less than 200 kΩ.

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

Total 20 marks

7. (a) (i) State the relationship between peak voltage, V_p, and root mean square voltage, V_{rms}, for an alternating sinusoidal voltage.

(ii) Calculate the value of the direct current that will produce the same quantity of thermal energy in a particular resistor, as an alternating current that has a maximum value of 2.60 A. **[3 marks]**

(b) Explain the operation of an ideal transformer when a small alternating voltage is supplied to its primary winding. **[7 marks]**

(c) A transformer on a utility pole operates at 8.5 k V_{rms} on the primary side and supplies electrical energy to nearby houses at voltage of 120 V_{rms}. Assume that the transformer is ideal.

(i) Calculate the turns ratio, $\frac{N_P}{N_S}$, of the transformer.

(ii) The average rate of energy consumption in the houses served by the transformer is 78 kW. Calculate the peak value of the current in BOTH windings of the transformer.

(iii) Calculate the resistive load in the secondary circuit of the transformer. **[10 marks]**

Total 20 marks

MODULE 3

Answer EITHER Question 8 OR Question 9.

8. (a) Explain what is meant by

(i) wave-particle duality

(ii) de-Broglie hypothesis

(iii) the photoelectric effect. **[8 marks]**

(b) Sodium has a work function of 2.2 eV. Find

(i) its threshold wavelength

(ii) the maximum energy of the photoelectrons when the metal is illuminated by light of wavelength 4×10^{-7} m

(iii) the stopping potential.

(c) Explain whether or not red light will cause electrons to be emitted from sodium in (b). **[12 marks]**

Total 20 marks

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

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

(iii) Draw a diagram to show the path of a stream of Beta particles and Gamma rays in a uniform electric field.

(iv) What instrument could be used to detect Beta and Gamma radiation?

[8 marks]

(b) The radioactive nuclide $^{99}_{43}Tc$ (Technetium) can be injected into a patient's blood stream to monitor the blood flow or to check for tumors. The nuclide is produced by a device containing $^{99}_{42}Mo$ (Molybdenum), a radioactive nuclide that decays to $^{99}_{43}Tc$ with a half life of 67 hours. Once a day, the device is emptied of its $^{99}_{43}Tc$. The Tc – 99 is produced in an excited state by $^{99}_{42}Mo$. $^{99}_{43}Tc$ de-excites to its lowest energy state by emitting a gamma ray photon, (which is recorded by detectors around the patient). The de-excitation of $^{99}_{43}Tc$ has a half life of 6 hours.

(i) Write a nuclear equation to represent the $^{99}_{42}Mo$ decaying to $^{99}_{43}Tc$.

(ii) A patient is injected with an 8.2×10^7 Bq sample of 99 Tc. How many gamma ray photons are initially produced within the patient each second?

(iii) A small tumor that has collected ^{99}Tc emits 38 gamma ray photons per second at a given time. How many ^{99}Tc nuclei are located in the tumor at this time?

[6 marks]

(c) Analysis of potassium and argon atoms in a moon rock sample shows that the ratio of the number of stable ^{40}Ar atoms present to the number of radioactive ^{40}K atoms is 10.3. Assume that all the argon atoms were produced by the decay of potassium atoms, with a half life of 1.25×10^9 years.

(i) Calculate

a) the fraction of the original ^{40}K atoms remaining in the rock

b) the number of half lives that has elapsed

c) the age of the rock

(ii) From your answers in (c) (i) deduce the age of the solar system.

[6 marks]

Total 20 marks

END OF TEST