TEST CODE **002475**

FORM TP 22248

MAY/JUNE 2002

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.

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

GO ON TO THE NEXT PAGE

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) A student wants to measure the internal resistance, r, and the e.m.f., E, of a cell. She has available the cell, an ammeter, a voltmeter and a variable resistor.

Draw a circuit to show how the student could connect the circuit to measure the internal resistance and e.m.f. of the cell.

[2 marks]

1. (b) An expression relating the measured potential difference, V, the internal resistance, r, the e.m.f. of the cell and the current, I, through the cell is given by $V = E - Ir$.

From the data collected, the student plotted a graph of voltmeter reading against current through the cell. The following graph shown in Figure 1 was obtained.

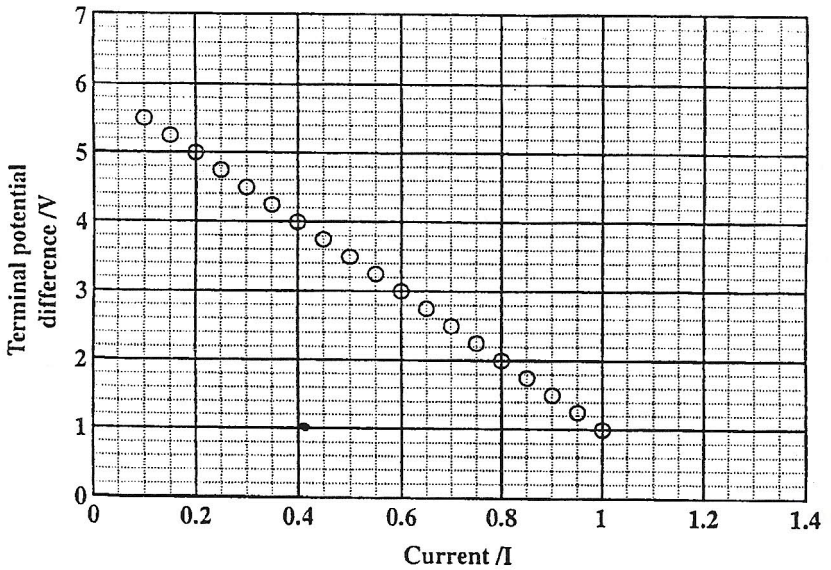


Figure 1

(i) Draw the BEST straight line through the points. **[1 mark]**

(ii) From the graph, deduce the following:

a) The value of the internal resistance

_____

_____

_____

[2 marks]

b) The e.m.f. of the cell

_____

_____

_____

[1 mark]

1. (iii) Hence, calculate the current through the circuit and the potential difference across the terminals of the cell when it is connected to a 3Ω resistor.

[3 marks]

(iv) What instrument would you use instead of the voltmeter to obtain MORE accurate voltage readings?

[1 mark]

Total 10 marks

2. (a) A professor asks one of his students to design a circuit to give full wave-rectification using four diodes.

(i) Draw a circuit to show how the student may design such a circuit using four diodes.

[4 marks]

(ii) How can the student modify this circuit to give half-wave rectification.

[2 marks]

2. (b) Another student had available two diodes, two similar power supplies and a resistor and designed a circuit as shown in Figure 2.

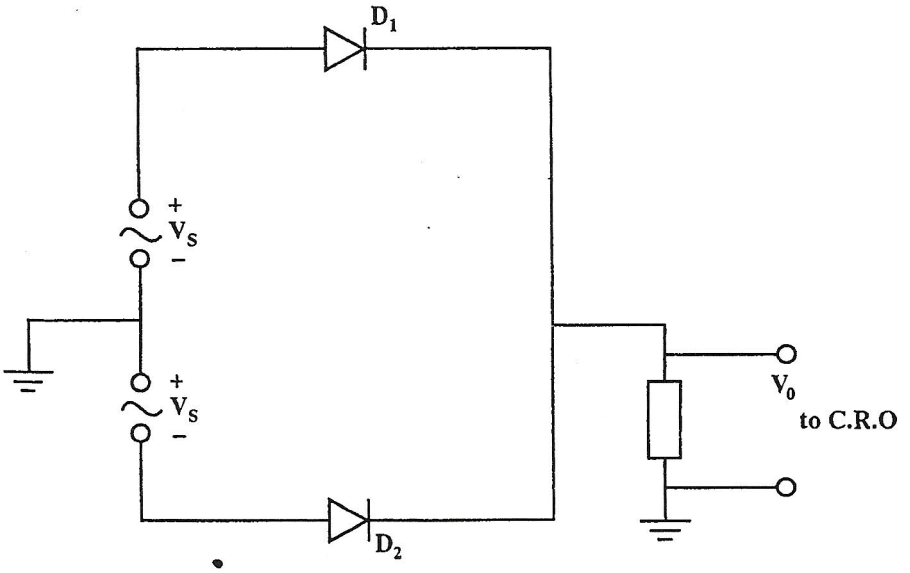


Figure 2

(i) Briefly describe what happens to D_1 and D_2 as 1 cycle of voltage V_s is applied to the circuit.

_____

_____

[2 marks]

(ii) Sketch the waveform you would expect to see on the cathode ray oscilloscope (c.r.o).

[1 mark]

(iii) Compare the output waveforms from 2. (a) (i) and 2. (b) (i).

_____

_____

[1 mark]

Total 10 marks

3. (a) In an experiment to measure the work function of a metal, using the Photoelectric effect, the following set up shown in Figure 3 was used. The source emits light of wavelength 500 nm and intensity 1.0 μW cm^{-2}.

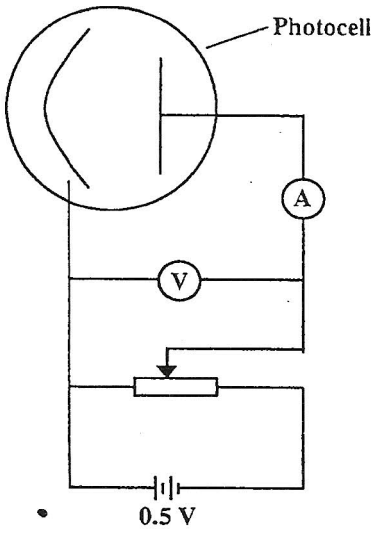


Figure 3

Table 1 shows the data collected.

Potential Difference, V/Volts	Current, I x 10^{-10} amps
–0.40	0.2
–0.34	0.5
–0.23	1.5
–0.12	3.0
0.0	4.0
0.11	4.4
0.22	4.5
0.33	4.6
0.46	4.7

Table 1

(i) Use the graph page on page 8 to plot a graph of current versus voltage for the metal. **[3 marks]**

(ii) From the graph record the stopping potential for the metal.

_____

[1 mark]

3. (iii) Hence, calculate the maximum kinetic energy of the photoelectrons.

_____

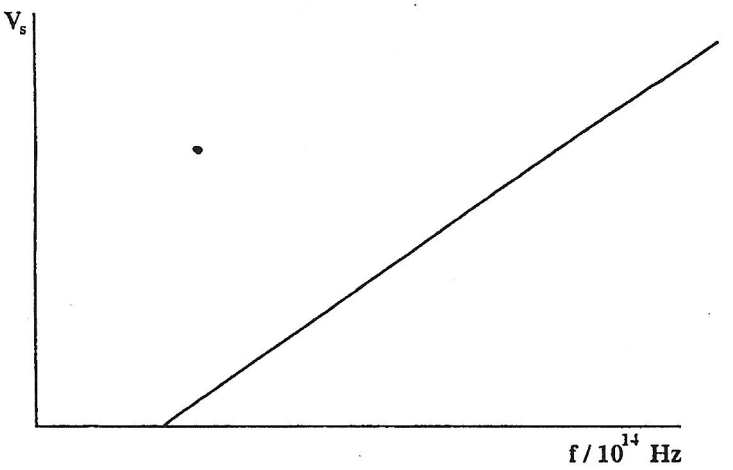
_____

_____

[2 marks]

(b) Sketch on your graph the expected curve when the intensity is now changed to 1.5 $\mu W\ cm^{-2}$. **[2 marks]**

(c) In an experiment, Figure 3 was used to investigate the photoelectric effect. The following graph was plotted of stopping potential, V_s, vs frequency, f, of the incident light.



(i) State how the stopping potential is reached.

_____

[1 mark]

(ii) How would you vary the frequency of the incident light?

_____

_____

[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) A copper coil passes through a rectangular region, where a constant magnetic field is directed into the page from Position 1 through Position 4 as shown in Figure 5.

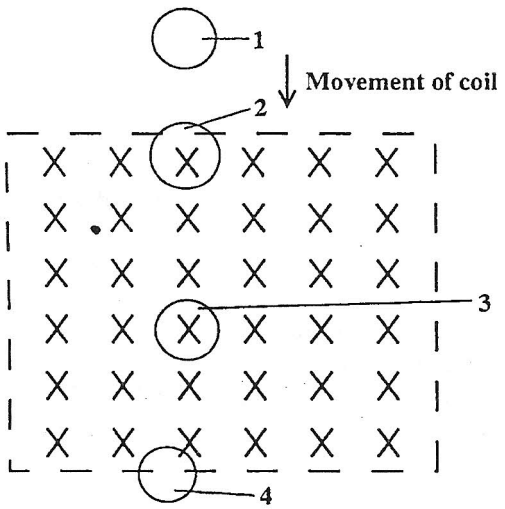
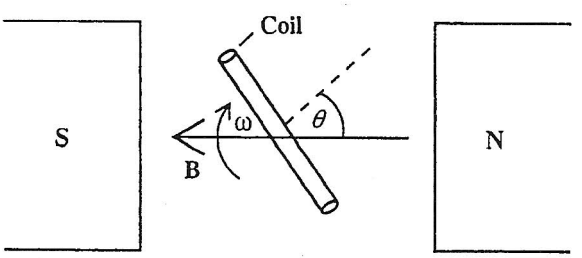


Figure 5

Determine whether an induced current exists in the ring as it passes through EACH of the four positions. **[8 marks]**

(b)



The diagram shows a coil of one turn rotating about a horizontal axis in its own plane at right angles to a magnetic field produced by two fixed poles of two magnets. If the angular velocity of the coil is ω show that the maximum e.m.f., E_0 induced is given by

$$E_0 = \omega AB$$

where A is the area of the coil and B the uniform magnetic flux density.

[3 marks]

4. (c) A wire loop of radius 20 cm has a resistance of 2.0 Ω. The loop is at right angles to a uniform magnetic field as shown in Figure 6. The magnetic field strength is increasing at the rate of 0.10 T s^{-1}.

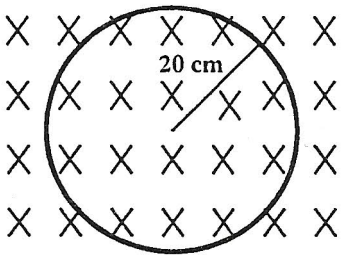


Figure 6

Calculate the

(i) induced e.m.f. in the loop

(ii) induced current in the loop. **[5 marks]**

(d) The magnetic field is now set at a constant value, B, and the coil is rotated at 10 rev s^{-1}. The plane of the coil is parallel to the direction of the field strength, B. A voltmeter connected to the coil through rotating contacts reads a peak value of 13.0 mV. Find the magnetic field strength, B. **[4 marks]**

Total 20 marks

5. (a) (i) Derive an expression for the equivalent resistance of THREE resistors in parallel.

(ii) Distinguish between the electromotive force of a cell and the terminal potential difference across a cell. **[5 marks]**

(b) For sensitive manual control of the current in a circuit, a parallel combination of rheostats are used as shown in Figure 7. The full resistance of R_1 is 25 times the full resistance of R_2.

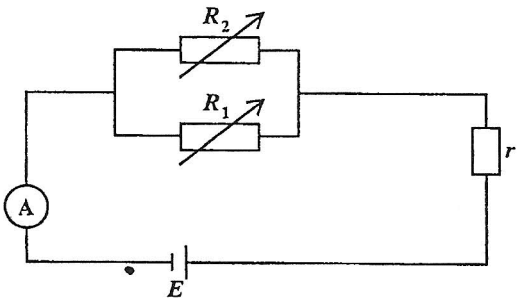


Figure 7

What procedure should be used to adjust the current, I, to a desired value? **[3 marks]**

(c)

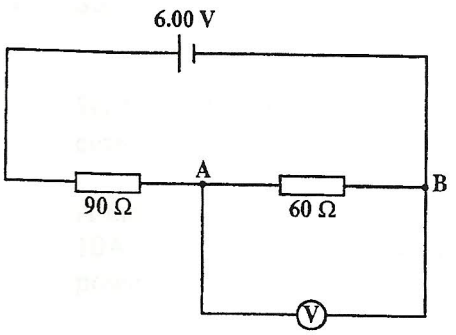


Figure 8 (i)

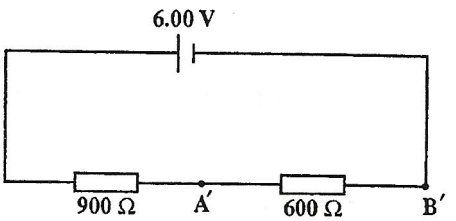


Figure 8 (ii)

The 6.00 V cell in the circuits shown in Figures 8 (i) and 8 (ii) above has zero internal resistance. A voltmeter which was calibrated accurately is connected across AB and reads 2.0 V.

(i) Calculate the resistance of the voltmeter.

(ii) Calculate the voltmeter reading when it is connected across A′B′.

(iii) What do the results suggest concerning the use of voltmeters?

[12 marks]

Total 20 marks

Module 2

Answer EITHER Question 6 OR Question 7.

6. (a) (i) State THREE ideal properties of Op-Amps.

(ii) For the Op-Amp circuit in Figure 8 show that the output V_0 is given by

$$V_0 = -\frac{R_f}{R_1} V_1 - \frac{R_f}{R_2} V_2.$$

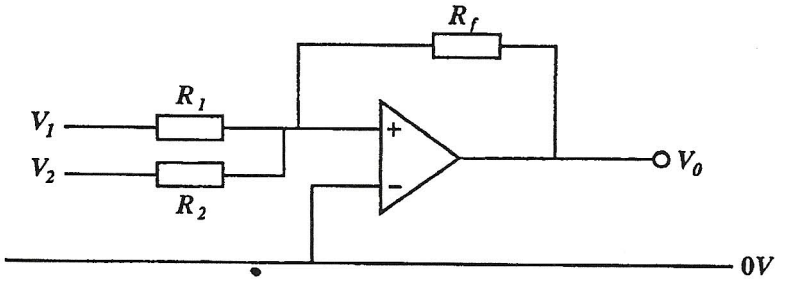


Figure 8

(iii) Suggest a practical use for this ~~current~~ circuit. **[7 marks]**

(b) (i) Write an equation relating the r.m.s. value and the peak value of an alternating current.

(ii) A car battery-charger runs off the 120 V r.m.s. a.c. power line, and supplies 10A d.c. at 14 V. If the charger is 80% efficient in converting line power to d.c. power, how much current does it draw from the a.c. line?

(iii) If electricity cost 16 cents/kWh, how much does it cost to run the charger for 10 hours? **[7 marks]**

6. (c) Electrical power of 8 000 kW is supplied to an industrial consumer at a considerable distance from a generating station. This is represented in Figure 9.

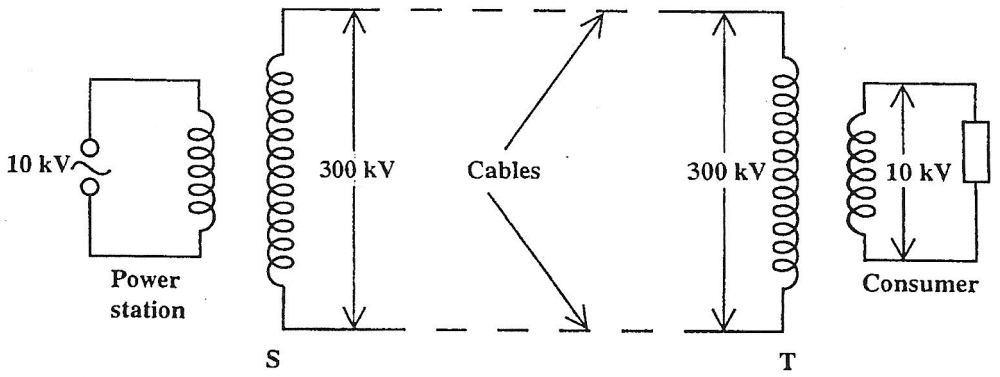


Figure 9

In order to do this, the electric supply company makes use of a circuit containing two transformers, S and T. The transformers are ideal and the supply cables have neglible resistance. There is a potential difference of 300 kV r.m.s. between the supply cable.

The power is generated at 10 kV r.m.s. and is supplied to the consumer at 10 kV r.m.s.

Calculate the

(i) r.m.s. current supplied to the consumer

(ii) ratio N_s/N_p for EACH transformer

(iii) current in the supply cable. **[6 marks]**

Total 20 marks

7. (a) Figure 10 shows the gain-response curve for an ideal operational amplifier.

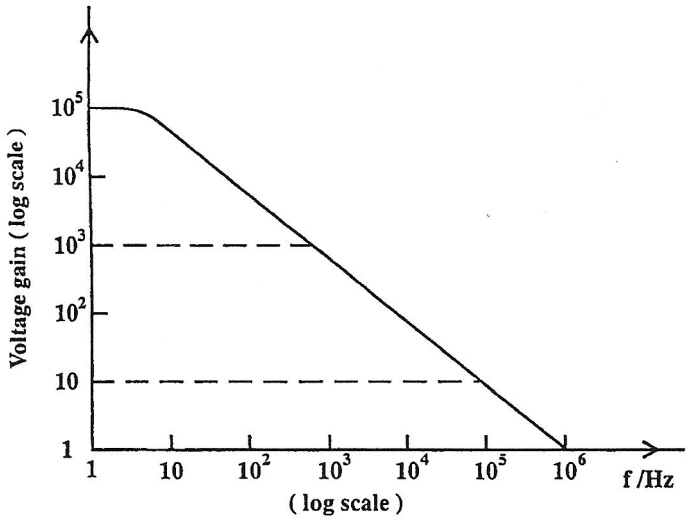


Figure 10

Explain the shape of the gain-frequency curve shown in Figure 10. **[5 marks]**

(b) (i) Distinguish between an analogue circuit and a digital circuit.

(ii) Write the truth table for the NAND gate.

(iii) Determine the output waveform for the circuit shown in Figure 11 if the input waveforms, A and B, are as shown.

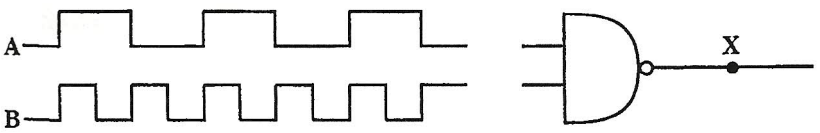


Figure 11

[6 marks]

(c) (i) A lamp in a room is to be operated from two switches, one at the back door and one at the front door. The lamp is to be on if the front switch is on and the back switch is off, or if the front switch is off and the back switch is on. The lamp is to be off if both switches are off or if both switches are on.

Draw a logic circuit to meet the requirements, showing the associated truth table.

(ii) You are provided with two OR gates, one AND gate and three INVERTERs. Show how you would design a half adder circuit from the given components.

(iii) Draw the resulting truth table for the sum and carry states. **[9 marks]**

Total 20 marks

Module 3

Answer EITHER Question 8 OR Question 9.

8. (a) (i) The Law of radioactive decay for a radioactive sample can be written as $N = N_0 e^{-\lambda t}$.

Explain the meaning of EACH symbol in the given expression.

(ii) Show that this expression may be written as $N = N_0 2^{-t/t_{1/2}}$ where $t_{1/2}$ is the half life of the sample.

(iii) Explain what are isotopes.

(iv) Why is carbon dating unable to provide accurate estimates of very old materials?

[8 marks]

(b) A nuclide $^{238}_{92}U$ decays to the nuclide $^{A}_{91}X$ in FIVE successive radioactive decays. Each decay involves the emission of EITHER an α-particle or a β-article. What is the value of A?

[6 marks]

(c) (i) An isotope of sodium, $^{24}_{11}Na$, and an isotope of potassium, $^{43}_{19}K$ form a radioactive mixture which initially contains twice as many atoms of sodium–24 ($t_{1/2}$ = 15 hours) as it does of potassium– 43, ($t_{1/2}$ = 22 hours). How long will it take for the number of atoms of each isotope equal?

(ii) Sketch the decay curves for the TWO isotopes. **[6 marks]**

Total 20 marks

9. (a) (i) Distinguish between nuclear fusion and nuclear fission.

(ii) Sketch a graph to show how the binding energy per nucleon varies with mass number. How can nuclear fission and fusion be explained from observing the shape of the curve?

[6 marks]

(b) Explain what is meant by the following:

(i) Mass defect

(ii) Binding energy of an atomic nucleus **[2 marks]**

(c) The nitrogen nucleus, ${}^{15}_{7}N$, has a mass of 15.9963 u.

What is the binding energy per nucleon of the nucleus? **[6 marks]**

(d) Show that a uranium nucleus can disintegrate spontaneously with the emission of an α-particle, according to the reaction ${}^{238}_{92}U \rightarrow {}^{234}_{90}Th + {}^{4}_{2}He$.

(Mass of ${}^{234}_{90}Th = 234.116550\ u$; Mass of ${}^{238}_{92}U = 238.12492\ u$; Mass of ${}^{4}_{2}He = 4.00387\ u$)

[2 marks]

(e) Assuming that the uranium-238 was at rest before the disintegration, calculate the

(i) total energy released in the disintegration

(ii) kinetic energy of the α-particle. **[4 marks]**

Total 20 marks

END OF TEST