THE UNITED REPUBLIC OF TANZANIA

NATIONAL EXAMINATIONS COUNCIL

CERTIFICATE OF SECONDARY EDUCATION EXAMINATION

082 **ELECTRICAL ENGINEERING SCIENCE**

(For Both School and Private Candidates)

Time : 3 Hours **ANSWERS** **Year : 2016**

Instructions

1. This paper consists of sections A, B and C.
2. Answer all questions in section A and B and **three (3)** questions from section C.
3. Non-programmable calculators may be used.
4. Communication devices and any unauthorised materials are **not** allowed in the examination room.
5. Write your **Examination Number** on every page of your answer booklet(s).

1. For each of items (i) – (x), choose the correct answer from among the given alternatives and write its letter beside the item number in the answer booklet provided.

(i) An atom is said to be electrically neutral if
A. it loses electrons
B. neutrons are positively charged
C. it gains more electrons than protons
D. electrons are negatively charged
E. the number of protons and electrons are equal

Correct answer: E. the number of protons and electrons are equal
Reason: An atom is neutral when the positive charges from protons balance the negative charges from electrons.

(ii) Which of the following electrical quantities explains the relationship according to Ohm's law in a closed electrical circuit?
A. voltage, power and current
B. current, voltage and resistance
C. resistance, energy and current
D. power, energy and kilowatt hour
E. current, power and energy

Correct answer: B. current, voltage and resistance
Reason: Ohm's law states V = IR, relating voltage, current, and resistance.

(iii) What is the purpose of a commutator in a d.c generator?
A. To reduce sparking at brushes
B. To convert the induced a.c into d.c
C. To increase output voltage
D. To provide smoother output
E. To induce Voltage in brushes

Correct answer: B. To convert the induced a.c into d.c
Reason: In a DC generator, the commutator rectifies the alternating emf generated in the armature into direct current.

(iv) What is the relationship between voltage and current when an alternating voltage is applied across a pure resistance?

A. Voltage is out of phase

B. Current is leading voltage by 90°

C. Voltage is leading current by 90°

D. Voltage is in phase with current

E. Angle between voltage and current is 90°

Correct answer: D. Voltage is in phase with current

Reason: In a pure resistor, current and voltage rise and fall together with no phase difference.

(v) What type of cooling is used in high current rectifiers?

A. Natural cooling system

B. Forced air cooling system

C. Heat sink cooling system

D. Oil cooling system

E. Water cooling system

Correct answer: D. Oil cooling system

Reason: High current rectifiers generate large heat and require oil cooling for effective heat dissipation.

(vi) Which of the following can be connected in a circuit in order to extend range of a voltmeter?

A. A parallel resistor

B. A shunt resistor

C. A series resistor

D. A series resistor of low value

E. A parallel resistor of high value

Correct answer: C. A series resistor

Reason: Voltmeters are extended by connecting a high resistance (multiplier) in series to limit current.

(vii) The correct formula for converting Fahrenheit to Centigrade is:

A. $(F - 32) \times 5/9$

B. $(F + 32) \times 9/5$

C. $(F - 32) \times 9/5$

D. (F × 9/5) + 32

E. (F × 5/9) + 32

Correct answer: A. (F – 32) × 5/9

Reason: The Celsius equivalent of Fahrenheit is given by C = (F – 32) × 5/9.

(viii) The cathode ray tube consists of two sets of deflection coils known as

A. scanning coils

B. focusing coils

C. electrostatic coils

D. brightness coils

E. reflection coils

Correct answer: A. scanning coils

Reason: In CRTs, scanning coils deflect the electron beam horizontally and vertically to form images.

(ix) Which of the following is the correct definition of the current density of a conductor?

A. The temperature of the air surrounding the conductor.

B. A factor which takes into consideration the type of a metal.

C. The increase in the resistance of a 1 Ω resistor of a material when subjected to a rise in temperature of 1 °C.

D. The amount of current which the conductor can carry safely without excessive heating per unit cross-section area.

E. The current carrying capacity of the conductor.

Correct answer: D. The amount of current which the conductor can carry safely without excessive heating per unit cross-section area

Reason: Current density J = I/A, which is current per unit cross-sectional area.

(x) What will happen if the cross-sectional area of a conductor is doubled?

A. The length of that conductor will be halved.

B. The resistivity of that conductor will be halved.

C. The resistance of that conductor will be halved.

D. Resistivity of the conductor will be doubled.

E. The length of the conductor will be doubled.

Correct answer: C. The resistance of that conductor will be halved

Reason: Resistance $R = \rho L/A$. If cross-sectional area doubles, resistance halves (since R is inversely proportional to area).

2. (a) State the laws of electrostatic charges.

Like charges repel each other.

Unlike charges attract each other.

(b) Name the two particles of an atom and state their electrical charges.

Proton, which carries a positive charge.

Electron, which carries a negative charge.

3. Define the following terms as applied in electrical heating:

(a) Quantity of heat

Quantity of heat is the amount of energy transferred due to temperature difference, expressed as $Q = mc\Delta T$.

(b) Temperature

Temperature is the measure of average kinetic energy of particles in a substance.

(c) Specific heat capacity

Specific heat capacity is the amount of heat required to raise the temperature of 1 kg of a substance by 1°C.

4. (a) Define the term "grounding" as applied in electrical equipment.

Grounding is the process of connecting the metallic body of electrical equipment to the earth to provide safety against electric shocks by diverting leakage currents.

(b) Briefly explain the difference between constant current system and constant voltage system as used in charging systems of secondary cells.

In constant current system, the charging current is kept constant and voltage rises with time.

In constant voltage system, a fixed voltage is applied across the battery and current reduces gradually as the battery charges.

5. A 2-core copper cable supplies current to a 240 V single phase load of 18 kW at 0.78 power factor. The cable is 40 m long and each conductor has a cross-sectional area of 35 mm^2. Calculate:
   (a) Load current
   (b) Conductor resistance.

(a) Load current $I = P / (V \times pf) = 18000 / (240 \times 0.78) = 18000 / 187.2 = 96.1$ A

(b) Resistance per meter = ρ / A, with ρ for copper = 1.72×10^{-8} Ωm, $A = 35 \times 10^{-6}$ m^2

$R/m = (1.72 \times 10^{-8}) / (35 \times 10^{-6}) = 4.91 \times 10^{-4}$ Ω/m

Length of 2-core = $2 \times 40 = 80$ m

Total resistance = $80 \times 4.91 \times 10^{-4} = 0.039$ Ω

6. (a) Define the term "armature reaction" as used in d.c machines.

Armature reaction is the distortion of the main field flux in a DC machine due to the magnetic field produced by the armature current.

(b) Give two disadvantages of armature reaction on d.c machines.

It causes sparking at the brushes due to flux distortion.

It reduces the efficiency of the machine by weakening the main field flux.

7. If the equation of an alternating current flowing through a certain circuit is given by $i = 50 \sin 628t$, Determine the
   (a) maximum value of current
   (b) frequency.

Equation: $i = 50 \sin 628t$

Maximum current = 50 A

Angular frequency $\omega = 628$ rad/s

Frequency $f = \omega / (2\pi) = 628 / 6.283 = 100$ Hz

(a) Maximum current = 50 A

(b) Frequency = 100 Hz

8. Briefly describe three major parts of cathode ray tube.

The electron gun, which produces and accelerates the electron beam.

The deflection system, which consists of deflection plates or coils that steer the electron beam to different positions on the screen.

The fluorescent screen, which glows when struck by the electron beam to form visible images.

9. Two cells each 1.5 V e.m.f and internal resistances of 1 Ω are connected in series to a load of 3 Ω. Calculate the load current.

Total emf = 1.5 + 1.5 = 3 V

Total internal resistance = 1 + 1 = 2 Ω

Total resistance = 2 + 3 = 5 Ω

Current I = E / R = 3 / 5 = 0.6 A

Load current = 0.6 A

10. Study Figure 1 carefully, then find the branches current and total current.

The figure shows a 24 V supply connected to 6 Ω in series with parallel of 2 Ω and 9 Ω, then 3 Ω in series.

Step 1: Combine parallel 2 Ω and 9 Ω

Rp = (2 × 9)/(2 + 9) = 18/11 = 1.64 Ω

Step 2: Total resistance = 6 + 1.64 + 3 = 10.64 Ω

Total current It = 24 / 10.64 = 2.26 A

Step 3: Voltage across parallel = I × Rp = 2.26 × 1.64 = 3.7 V

Current through 2 Ω = 3.7 / 2 = 1.85 A

Current through 9 Ω = 3.7 / 9 = 0.41 A

So, branches: 1.85 A and 0.41 A; total 2.26 A

11. The magnetic flux in the core of an electromagnet is 1.5 mWb. The flux density in the core is 0.75 T. If the cross sectional area of the magnetic core is square, find the length of one side.

Flux density $B = \Phi / A$

$A = \Phi / B = 1.5 \times 10^{-3} / 0.75 = 0.002\ m^2$

Side length $= \sqrt{A} = \sqrt{0.002} = 0.0447\ m = 4.47\ cm$

Length of one side = 4.47 cm

12. (a) Briefly describe four differences between magnetic and electric circuits.

In electric circuits current is the flow of electrons, in magnetic circuits flux is the flow of magnetic lines.

Electric circuits have resistance measured in ohms, magnetic circuits have reluctance measured in AT/Wb.

Voltage is the driving force in electric circuits, mmf is the driving force in magnetic circuits.

Current is measured in amperes, flux is measured in webers.

(b) A wooden ring of mean length 200 m and cross-section area of 5 cm² has a coil A of 1500 turns wound over it. A second coil B of 3000 turns is closely wound over the first coil. Take coefficient of coupling and relative permeability for vacuums as unity. Calculate:

(i) the self-inductance of coils A and B

(ii) the mutual inductance if the coils are closely coupled

(iii) the total inductances of the arrangement if the coils are connected in series

(iv) the total energy stored in the ring if current flowing is 10 A.

Mean length $l = 200$ m, Area $= 5 \times 10^{-4}\ m^2$, $\mu 0 = 4\pi \times 10^{-7}$, $N1 = 1500$, $N2 = 3000$

(i) $L1 = \mu 0 N1^2 A/l = (4\pi \times 10^{-7} \times 1500^2 \times 5 \times 10^{-4}) / 200 = 3.54 \times 10^{-3}$ H

$L2 = \mu 0 N2^2 A/l = (4\pi \times 10^{-7} \times 3000^2 \times 5 \times 10^{-4}) / 200 = 1.42 \times 10^{-2}$ H

(ii) Mutual inductance $M = \mu 0 N1 N2 A/l = (4\pi \times 10^{-7} \times 1500 \times 3000 \times 5 \times 10^{-4}) / 200 = 7.08 \times 10^{-3}$ H

(iii) Series aiding: $L = L1 + L2 + 2M = 0.00354 + 0.0142 + 0.01416 = 0.0319$ H

Series opposing: $L = L1 + L2 – 2M = 0.00354 + 0.0142 – 0.01416 = 0.00358$ H

(iv) Energy stored = $\frac{1}{2} LI^2 = 0.5 \times 0.0319 \times (10^2) = 1.595$ J

13. (a) Define the following terms as used in d.c generator:

(i) Conductor – A conductor is the part of the armature winding in which emf is induced by cutting magnetic flux.

(ii) Coil – A coil is a group of conductors connected together to form a closed path.

(iii) Turns – A turn is formed when a conductor passes once around the armature core.

(iv) Single layer winding – It is a winding in which each slot of the armature core carries only one conductor side.

(b) (i) An 8-pole, d.c generator has 320 conductors and its flux and speed are such that the average e.m.f generated in each conductor is 2 V. The current in each conductor is 100 A. Find the total current and generated e.m.f, when the winding is lap connected and when it is wave connected.

Lap winding: Number of parallel paths $A = P = 8$

Generated emf $E_g = (Z \times e)/A = (320 \times 2)/8 = 80$ V

Total current = $(Z \times I_c)/A = (320 \times 100)/8 = 4000$ A

Wave winding: $A = 2$

$E_g = (320 \times 2)/2 = 320$ V

Total current = $(320 \times 100)/2 = 16000$ A

(ii) Already included in calculation.

(c) A circuit of shunt generator shown in Figure 2 has no load induced e.m.f of 150 V and when it is loaded, the terminal voltage decreases to 140 V. The armature resistance and field resistances are 0.2 Ω and 100 Ω respectively. Find the load current.

$E_a = 150$ V, $V_t = 140$ V, $R_a = 0.2\ \Omega$, $R_f = 100\ \Omega$

Field current $I_f = V_t/R_f = 140/100 = 1.4$ A

Armature current $I_a = (E_a - V_t)/R_a = (150 - 140)/0.2 = 10/0.2 = 50$ A

Load current $I_L = I_a - I_f = 50 - 1.4 = 48.6$ A

14. (a) Two metal filament lamps, with luminous intensities of 150 cd and 300 cd are fixed 10 m apart on a level bench. A double sided matt white screen is placed on the line between the lamps so that each side directly faces one lamp. The screen is positioned so that both sides of the screen are equally illuminated. With the aid of a simple diagram, calculate;

(i) The distance between the screen and the large lamp.

(ii) The illumination on each side of the screen if it were positioned half way between the lamps.

Let distance from large lamp = x, then from small lamp = (10 – x).

Equal illumination: $I_1/d_1^2 = I_2/d_2^2 \rightarrow 300/x^2 = 150/(10 - x)^2$

$2/x^2 = 1/(10 - x)^2 \rightarrow (10 - x)^2 = x^2/2$

Take square root: $(10 - x) = x/\sqrt{2}$

$10 = x + x/\sqrt{2} = x(1 + 0.707) = 1.707x$

$x = 10/1.707 = 5.86$ m from large lamp

(i) Distance = 5.86 m

(ii) Halfway: $d_1 = 5$, $d_2 = 5$

Illumination = $150/25 + 300/25 = 6 + 12 = 18$ lux

(b) A drawing office containing a number of boards and having a total effective area of 70 m² is lighted by a number of 40W incandescent lamps giving 11 lm/W. An illumination of 80 lux is required on the drawing boards. Assuming that 60% of the total light emitted by the lamps is available for illuminating the drawing boards, estimate the number of lamps required.

Total lumens required = Illumination × area = $80 \times 70 = 5600$ lm

Available per lamp = $40 \times 11 \times 0.6 = 264$ lm

Number of lamps = $5600 / 264 = 21.2 \approx 22$ lamps

15. A current of 5 A flows through a non-inductive resistance in series with a choking coil when supplied at 250 V, 50 Hz. If the voltage across the resistance is 125 V and across the coil is 200 V; with the help of a vector diagram, calculate

(a) Impedance.

(b) Resistance of the coil.

(c) Reactance.

(d) The total power absorbed by the coil.

(e) The total power.

R of resistor = V/I = 125/5 = 25 Ω

Impedance Z = V/I = 250/5 = 50 Ω

Using Pythagoras: $Z^2 = R^2 + X^2 \rightarrow 50^2 = 25^2 + X^2 \rightarrow 2500 = 625 + X^2 \rightarrow X^2 = 1875 \rightarrow X = 43.3\ \Omega$

(a) Impedance = 50 Ω

(b) Resistance of coil $R_c = \sqrt{(Z^2 - X^2)} - R$ (if separate). Here coil resistance not separate, so Rc = 0 (assume ideal coil).

(c) Reactance = 43.3 Ω

(d) Power absorbed by coil = I^2Rc = negligible if Rc = 0

(e) Total power = $I^2R = 25 \times 25 = 625$ W

16. (a) A battery of 60 cells is charged from a supply of 250 V. Each cell has an e.m.f of 2 V at the start of charge and 2.5 V at the end. If the internal resistance of each cell is 0.1 Ω and if there is an external resistance of 19 Ω in the circuit. Calculate:

(i) initial charging current

(ii) final charging current

(iii) additional resistance which must be added to give a finishing charge of 2A rate.

Number of cells = 60

Internal resistance per cell = 0.1 Ω → Total internal resistance = 60 × 0.1 = 6 Ω

External resistance = 19 Ω

Total resistance = 19 + 6 = 25 Ω

(i) Initial charging current:

Total emf of battery = 60 × 2 = 120 V

Current = (Vsupply – Eb) / Rtotal = (250 – 120) / 25 = 130 / 25 = 5.2 A

(ii) Final charging current:

Total emf of battery = 60 × 2.5 = 150 V

Current = (250 – 150) / 25 = 100 / 25 = 4 A

(iii) Additional resistance to give 2 A finishing charge:

Required resistance R = (Vsupply – Eb) / I = (250 – 150) / 2 = 100 / 2 = 50 Ω

But internal + existing external resistance = 25 Ω

So extra resistance = 50 – 25 = 25 Ω

(i) Initial current = 5.2 A

(ii) Final current = 4 A

(iii) Additional resistance = 25 Ω

(b) A storage cell is charged at 5 A for 3.5 hours. If it is discharged through resistance R Ohms for a duration of 12 hours, the terminal voltage being 12 V and the ampere-hour efficiency of the cell is 85%. Calculate the value of resistance R.

Charge input = 5 × 3.5 = 17.5 Ah

Useful output = 17.5 × 0.85 = 14.875 Ah

Discharge current = 14.875 / 12 = 1.24 A

R = V / I = 12 / 1.24 = 9.68 Ω ≈ 9.7 Ω

So, resistance R = 9.7 Ω