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 : 2015**

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).

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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) The reactance offered by a capacitor to alternating current of frequency 50 Hz is 10 Ω. If frequency is increased to 100 Hz, reactance becomes

A. 20 Ω

B. 5 Ω

C. 25 Ω

D. 40 Ω

E. 15 Ω

Correct answer: B. 5 Ω

Reason: Capacitive reactance Xc = 1/(2πfC). Doubling frequency halves the reactance.

(ii) Which of the following material has a negative temperature coefficient of resistance?

A. Brass

B. Tungsten

C. Aluminium

D. Carbon

E. Gold

Correct answer: D. Carbon

Reason: Resistance of carbon decreases as temperature increases, hence negative coefficient.

(iii) The ratio of ampere-hour efficiency to watt-hour efficiency of lead acid cell is always

A. less than one

B. just one

C. greater than one

D. undefined

E. extremely high

Correct answer: C. greater than one

Reason: Watt-hour efficiency includes energy losses due to internal resistance, making it lower than ampere-hour efficiency.

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(iv) Which type of focusing is used by a CRO?

A. Electromagnetic

B. Electrostatic

C. Deflection

D. Electrodynamic

E. Thermostatic

Correct answer: B. Electrostatic

Reason: CRO uses electrostatic focusing through focusing anodes to concentrate electron beams.

(v) What is the basic requirement of a d.c armature winding?

A. It must be a closed one

B. It must be a lap winding

C. It must be a single layer winding

D. It must be a wave winding

E. It must be back pitched winding

Correct answer: A. It must be a closed one

Reason: Armature winding must form closed paths to allow continuous current.

(vi) D.C potentiometer is an instrument which measure

A. unknown e.m.f

B. large voltage

C. large power

D. direct resistance

E. variable reluctance

Correct answer: A. unknown e.m.f

Reason: DC potentiometer measures unknown emf by balancing against a standard without drawing current.

(vii) Conductors are stranded in order to

A. make cable more rigid

B. make cable more flexible

C. increase the diameter

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D. reduce losses

E. reduce weight

Correct answer: B. make cable more flexible

Reason: Stranding increases flexibility for bending and reduces damage.

(viii) The efficiency of a nickel iron cell is less compared to lead acid cell, due to its

A. lower e.m.f

B. higher e.m.f

C. higher internal resistance

D. higher temperature of electrolyte used

E. smaller quantity of electrolyte used

Correct answer: C. higher internal resistance

Reason: Ni-Fe cells have high internal resistance, reducing their efficiency.

(ix) Which one of the following statement is TRUE for both series and parallel d.c circuits?

A. Power are additive

B. Voltages are additive

C. Current are additive

D. Elements have individual currents

E. Voltage and current are additive

Correct answer: A. Power are additive

Reason: Total power consumed is sum of individual powers in both series and parallel circuits.

(x) The term luminance is defined as

A. the amount of light in lumens falling on unit area (square meter).

B. the capacity of radiated energy to produce light

C. the property of a body producing a magnetic field when carrying current

D. the transportation of electric charges along a path or around a circuit

E. the causes of mechanical displacement or motion.

Correct answer: A. the amount of light in lumens falling on unit area (square meter)

Reason: Luminance measures luminous intensity per unit area in a given direction.

2. (a) What is the transformer?

A transformer is a static electrical device used to transfer electrical energy between two or more circuits at the same frequency but with different voltage levels, through electromagnetic induction.

(b) Briefly explain the working principle of a transformer.

When an alternating current flows in the primary winding, it produces a varying magnetic flux in the core. This flux links with the secondary winding, inducing an emf in it according to Faraday's law of electromagnetic induction.

3. (a) What is the meaning of the term "Mutual inductance" as used in electrical technology?

Mutual inductance is the property of two coils where a change in current in one coil induces an emf in the other coil due to magnetic flux linkage.

(b) Two coils, A and B have self-inductances of 120 μH and 300 μH respectively. If a current of 1A flowing through coil A produces flux linkages of 100 μWb turns in coil B. Calculate mutual inductance between the two coils.

Flux linkages in B = 100 μWb-turns = 100×10^{-6} Wb-turns
Current in A = 1 A
Mutual inductance M = Flux linkages / Current = $(100 \times 10^{-6}) / 1 = 100$ μH

Mutual inductance = 100 μH

4. (a) State three factors which influences the force on current carrying conductor.

Strength of the magnetic field.
Magnitude of current through the conductor.
Length and orientation of the conductor in the magnetic field.

(b) A sample of copper has a resistance of 10 Ω at a temperature of 0°C. What will be its resistance at 50°C?

$R0 = 10\ \Omega$, $T = 50°C$, $\alpha = 0.004/°C$

$Rt = R0(1 + \alpha t) = 10(1 + 0.004 \times 50) = 10(1.2) = 12\ \Omega$

Resistance = 12 Ω

5. A moving coil instrument gives a full scale deflection when the current is 40 mA and its resistance is 25 Ω. Calculate the value of the shunt to be connected in parallel with the meter to enable it to be used as an ammeter for measuring currents up to 50 A.

Ifsd = 40 mA = 0.04 A

Rm = 25 Ω

Total current = 50 A

Shunt current Ish = 49.96 A

$Rsh = (Ifsd \times Rm) / Ish = (0.04 \times 25) / 49.96 = 1 / 49.96 = 0.02\ \Omega$

Shunt resistance = 0.02 Ω

6. An electric motor draws 18 A of current from a 240 V source. A wattmeter connected to the circuit indicates 3024 W. What is the power factor of the circuit?

P = 3024 W, V = 240 V, I = 18 A

Apparent power $S = VI = 240 \times 18 = 4320$ VA

Power factor $= P / S = 3024 / 4320 = 0.7$

Power factor = 0.7

7. Estimate the total luminous flux required to provide a service value of 120 lux in a room of 8 m by 7 m. Utilization factor and light loss factors are 0.6 and 0.8 respectively.

Area $= 8 \times 7 = 56\ m^2$

Required lumens $= E \times A = 120 \times 56 = 6720$ lm

Taking utilization × light loss factor $= 0.6 \times 0.8 = 0.48$

Lamp lumens required $= 6720 / 0.48 = 14{,}000$ lm

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Total luminous flux required = 14,000 lm

8. (a) Why modification of a simple primary cell is done.

To reduce polarization effect.
To lower internal resistance.

(b) List down two materials used as positive and negative electrodes for a Leclanché cell (battery) and name the instrument used to measure specific gravity of the battery.

Positive electrode: Carbon rod.
Negative electrode: Zinc rod.
Instrument: Hydrometer.

9. Mention three conditions to be fulfilled when connecting the transformers in parallel.

Transformers must have the same polarity.
They must have the same voltage ratio.
They should have the same phase sequence and similar impedance.

10. (a) List two losses that occur in induction motors.

Iron (core) losses.
Copper (I^2R) losses.

(b) A 3-phase induction motor running at a slip of 0.05 per unit has an input power to its rotor of 10 kW. Calculate the power dissipated in the rotor.

Slip s = 0.05, Rotor input = 10 kW
Rotor copper loss = s × Rotor input = 0.05 × 10,000 = 500 W

Power dissipated in rotor = 500 W

10. (a) List two losses that occur in induction motors.

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Iron losses, which include hysteresis and eddy current losses in the core due to alternating magnetic flux.
Copper losses, which are I^2R losses in the stator and rotor windings due to current flow.

(b) A 3-phase induction motor running at a slip of 0.05 per unit has an input power to its rotor of 10 kW. Calculate the power dissipated in the rotor.

Slip s = 0.05
Rotor input power = 10 kW = 10,000 W
Rotor copper loss (power dissipated) = s × Rotor input
= 0.05 × 10,000
= 500 W

So, the power dissipated in the rotor = 500 W

11. (a) Define the term "breakdown voltage of a material".

Breakdown voltage is the minimum voltage at which an insulating material becomes conductive, allowing current to pass through due to dielectric failure.

(b) A cloud is at a potential of 8×10^6 V relative to the ground. A charge of 40 C is transferred in lightning stroke between the cloud and the ground. Calculate the energy dissipated.

Energy = Q × V = $40 \times 8 \times 10^6 = 3.2 \times 10^8$ J

Energy dissipated = 3.2×10^8 J

12. (a) Describe four conditions under which a self-excited d.c generator can fail to build up voltage.

If there is no residual magnetism in the poles.
If the field winding connections are reversed, causing demagnetizing effect.
If the resistance of the field circuit is too high compared to critical resistance.
If the speed of the generator is less than the critical speed.

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(b) A long shunt compound generator delivers a load current of 60 A at 450 V and has armature series field and shunt field resistances of 0.06 Ω, 0.04 Ω and 240 Ω respectively. Calculate the generated voltage and the armature current. Allow 0.5 V per brush for contact drop.

Load current IL = 60 A
Shunt current Ish = V / Rsh = 450 / 240 = 1.875 A
Armature current Ia = IL + Ish = 60 + 1.875 = 61.875 A
Brush drop = 2 × 0.5 = 1 V

Voltage drop in armature = Ia × Ra = 61.875 × 0.06 = 3.71 V
Voltage drop in series field = IL × Rs = 60 × 0.04 = 2.4 V

Generated emf Eg = V + Armature drop + Series drop + Brush drop
Eg = 450 + 3.71 + 2.4 + 1 = 457.1 V

Armature current = 61.875 A, Generated voltage = 457.1 V

13. (a) Give six properties of a good heating element.

High resistivity to produce heat efficiently.
High melting point to withstand high temperatures.
Low temperature coefficient of resistance to maintain stability.
Ability to withstand oxidation and corrosion.
Mechanical strength to resist breaking.
Ductility to allow drawing into wires.

(b) A ply-wood board of 0.5 × 0.25 × 0.02 meter is to be heated from 25°C to 125°C in 10 minutes by dielectric heating employing a frequency of 30 MHz. Determine the power required in this heating process. Assume specific heat of wood is 1500 J/kg°C, weight of wood 600 kg/m³ and efficiency of process is 50%.

Volume = 0.5 × 0.25 × 0.02 = 0.0025 m³
Mass = ρV = 600 × 0.0025 = 1.5 kg
Heat required = mcΔT = 1.5 × 1500 × (125 – 25) = 1.5 × 1500 × 100 = 225,000 J

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Time = 10 min = 600 s
Power input = Heat / (time × efficiency) = 225000 / (600 × 0.5) = 225000 / 300 = 750 W

Power required = 750 W

(c) The output of diesel engine was found to be 4.9 kW and a dynamometer used to check the output contained 30 kg of water. How much did the temperature of water rise during a 30 minutes running period? Neglect losses.

Energy = Power × Time = 4900 × (30 × 60) = 4900 × 1800 = 8.82×10^6 J
Mass of water = 30 kg, c = 4200 J/kg°C
$\Delta T = Q / (mc) = 8.82 \times 10^6 / (30 \times 4200) = 8.82 \times 10^6 / 126{,}000 = 70$ °C

Temperature rise = 70 °C

14. (a) Define the following terms as used in illumination:
    (i) Coefficient of utilization: ratio of lumens received on working plane to lumens emitted by lamps.
    (ii) Maintenance factor: ratio of illumination under normal working to illumination under new conditions.
    (iii) Coefficient of reflection: ratio of light reflected by a surface to the total light falling on it.
    (iv) Depreciation factor: ratio of initial illumination to maintained illumination after some time.

(b) A room 25 m long by 6 m wide is to be lighted to a level of 20 lux, while the average lumen of lamps is 25 lm/W, maintenance factor of 0.8 and coefficient of utilization 0.5. Calculate
(i) Total lumen = 25 × 6 × 20 = 3000 lm
(ii) Total power = Lumen / (luminous efficiency × mf × cu) = 3000 / (25 × 0.8 × 0.5) = 3000 / 10 = 300 W
(iii) Number of lamps = 300 / 30 = 10 lamps

(c) It is required to provide an illumination on 100 lux in a factory hall 30 m by 15 m. Assume depreciation factor is 0.8, coefficient of utilization is 0.4 and efficiency is 141 lm/W. Suggest the number of lamps and their ratings.

Area = 30 × 15 = 450 m^2
Lumens required = 100 × 450 = 45,000 lm

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Including depreciation and utilization: Required lumen = 45,000 / (0.8 × 0.4) = 45,000 / 0.32 = 140,625 lm

Power required = Lumen / Efficiency = 140625 / 141 = 997 W ≈ 1000 W

Choose lamp combination: Two 500 W lamps, or three 400 W lamps (1200 W), or four 250 W lamps (1000 W).

15. (a) (i) Define the term "rectification" as applied in electrical circuits.

Rectification is the process of converting alternating current (AC) into direct current (DC).

(ii) Draw the circuit diagram of a full wave rectifier using a center tap transformer.

(Diagram involves transformer with center tap, two diodes connected to load resistor, each conducting alternately during positive and negative half cycles).

(iii) Draw the input and output wave form of the rectifier in 15(a)(ii) for one period.

(Input is sinusoidal, output is pulsating DC with both half cycles positive).

(b) (i) Give two advantages of half wave rectifier.

It has a simple circuit and low cost.

It requires only one diode.

(ii) A half wave rectifier is connected in series with a load of 16 Ω to a.c supply of 25 volts r.m.s value. The rectifier has a constant resistance of 2 Ω in the forward direction while the reverse current is zero. Calculate the average and peak values of the currents in the load.

Vrms = 25 V, Vp = √2 × Vrms = 35.35 V

Total resistance = 16 + 2 = 18 Ω

Peak current = Vp / R = 35.35 / 18 = 1.96 A

Average current = Ip/π = 1.96 / 3.142 = 0.624 A

Peak = 1.96 A, Average = 0.624 A

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16. (a) Mention three disadvantages of the electric system to be operated at a low power factor and hence enumerate three methods in which this case can be improved or minimized.

Disadvantages:

Increased current leading to more losses.

Larger size of equipment required.

Reduced efficiency of system.

Methods:

Use of capacitor banks for power factor correction.

Use of synchronous condensers.

Use of phase advancers.

(b) Three equal star-connected inductors take 8 kW at a power factor of 0.8 when connected across a 460 V, 3 phase wire supply. Calculate the

(i) line current

(ii) phase voltage

(iii) impedance per phase

(iv) resistance per phase

(v) inductance reactance per phase.

P = 8000 W, pf = 0.8, VL = 460 V

Apparent power S = P / pf = 8000 / 0.8 = 10,000 VA

Line current IL = S / (√3 × VL) = 10000 / (1.732 × 460) = 10000 / 796.7 = 12.6 A

(i) Line current = 12.6 A

(ii) Phase voltage Vph = VL/√3 = 460 / 1.732 = 266 V

(iii) Impedance Zph = Vph / Iph = 266 / 12.6 = 21.1 Ω

(iv) Resistance Rph = Z cosφ = 21.1 × 0.8 = 16.9 Ω

(v) Reactance Xph = Z sinφ = 21.1 × 0.6 = 12.7 Ω

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