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 : 2010**

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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(i) For the circuit shown in Figure 1, what will be the current, I flowing through the circuit?

A. 1 A

B. 2 A

C. 2 A

D. 4 A

E. 1/4 A

The three resistors are in series: $R = 3 + 3 + 3 = 9\ \Omega$.

Current, $I = V/R = 2/9 = 0.22\ A \approx 1/4\ A$.

Correct answer: E. It is correct because Ohm's law gives the current as 0.22 A, which matches 1/4 A.

(ii) Which one of the following is not a good material property for an electric contact?

A. High melting point

B. Good thermal conductivity

C. High resistance to erosion

D. High resistivity

E. High elasticity

Good contact materials must have low resistivity, good conductivity, resistance to erosion and high melting point.

Correct answer: D. High resistivity is not good, because it increases energy loss.

(iii) For a shunt generator, which loss is considered as constant?

A. Copper loss

B. Eddy current

C. Hysteresis loss

D. Friction loss

E. Mechanical loss

In a shunt generator, mechanical losses such as windage and friction are constant regardless of load.

Correct answer: E. Mechanical loss remains constant while copper loss changes with load current.

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(iv) Which of the following expressions is correct for the series reactance Xcs if three capacitors C1, C2 and C3 are connected in series?

A. $1/Xcs = 1/Xc1 + 1/Xc2 + 1/Xc3$

B. $Xcs = Xc1 + Xc2 + Xc3$

C. $Xcs = Xc1 + Xc2 + Xc3$

D. $Xcs = 1/Xc1 + 1/Xc2 + 1/Xc3$

E. $Xcs = 1/(1/Xc1 + 1/Xc2 + 1/Xc3)$

For capacitors in series, $1/Ceq = 1/C1 + 1/C2 + 1/C3$. In terms of reactance, $Xc = 1/(2\pi fC)$, so total reactance is additive.

Correct answer: C. Because in series, $Xcs = Xc1 + Xc2 + Xc3$.

(v) What will be the efficiency when the transformer operates at unity power factor and 60% of full load?

A. 93.1 %

B. 95.5 %

C. 91.3 %

D. 99.6 %

E. 96.0 %

The maximum efficiency occurs near full load, but at 60% load, efficiency slightly drops.

Correct answer: B. 95.5 % because at 60% load the transformer is close to its maximum efficiency but not equal.

(vi) Which of the following is a factor whereby the level of illumination on a surface does not depend on?

A. Candle power of the source

B. Distance from the source

C. Type of reflected surface

D. Increase glass shell diameter

E. Increase the supply voltage

Illumination depends on luminous intensity, distance from source, and reflecting surface.

Correct answer: E. Supply voltage does not directly define illumination because it is a property of the light source.

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(vii) A bridge used for measurement of capacitance is

A. Wheatstone bridge

B. Wein bridge

C. Maxwell bridge

D. Schering bridge

E. Anderson bridge

Capacitance is accurately measured by the Schering bridge.

Correct answer: D. It is correct because Schering bridge is specifically designed for capacitance.

(viii) Polarization in simple cells refers to

A. Giving polarities to cells

B. Supplying large amount of energy

C. Insulating the anode

D. Destroying the cell

E. Insulating the cathode

Polarization occurs due to accumulation of hydrogen bubbles, which insulate the cathode.

Correct answer: E. Because hydrogen bubbles prevent current flow by insulating the cathode.

(ix) A generator can be described as a machine which converts

A. Heat energy into electrical energy

B. An electrical energy into mechanical energy

C. Solar energy into electrical energy

D. Mechanical energy into electrical energy

E. Chemical energy into electrical energy

Generators work on electromagnetic induction, converting mechanical energy into electrical energy.

Correct answer: D. It is correct because a generator converts mechanical rotation into electrical power.

(x) The common effect of an electric current in a day to day domestic use is

A. Luminous

B. Chemical

C. Heating

D. Magnetic

E. Temperature

In domestic appliances like electric irons, kettles, cookers, the heating effect is most used.

Correct answer: C. Heating is the most common everyday effect of electric current.

2. (a) State Coulomb's law.

Coulomb's law states that the electrostatic force between two point charges is directly proportional to the product of the charges and inversely proportional to the square of the distance between them. The force acts along the line joining the two charges.

(b) Two point charges 10 μC and 20 μC are placed at a distance of 30 cm apart in a medium of $\varepsilon r = 6$. Find the force between them.

The force $F = (1/4\pi\varepsilon_0\varepsilon r) \times (q1q2/r^2)$. Substituting, $q1 = 10 \times 10^{-6}$ C, $q2 = 20 \times 10^{-6}$ C, r = 0.3 m, $\varepsilon r = 6$.

$F = (9 \times 10^9 / 6) \times (10 \times 10^{-6} \times 20 \times 10^{-6}) / (0.3^2)$.

$F = (1.5 \times 10^9 \times 200 \times 10^{-12}) / 0.09$.

$F = 0.3 / 0.09 = 3.33$ N.

(c) If the charges in 2(b) above are placed in air, what will be the force between them?

In air, $\varepsilon r = 1$.

$F = (9 \times 10^9 \times 200 \times 10^{-12}) / 0.09$.

$F = 1.8 / 0.09 = 20$ N.

3. State Faraday's laws of electromagnetic induction.

The first law states that whenever there is a change in magnetic flux linked with a circuit, an e.m.f. is induced in the circuit. The second law states that the magnitude of the induced e.m.f. is directly proportional to the rate of change of magnetic flux linkage.

4. (a) Define the term 'resistance' as used in electric circuit.

Resistance is the opposition that a material or component offers to the flow of electric current through it.

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(b) A d.c arc has a voltage current relation given by $V = 20 + 40/I$, is connected in series with a resistor R. The total voltage applied is 120 V. If the voltage across the arc is half the voltage across the resistor, find the value of the resistor.

Let Va be the voltage across the arc and Vr across the resistor. Total voltage = 120 V. Given Vr = 2Va. So Va + Vr = 120 → Va + 2Va = 120 → 3Va = 120 → Va = 40 V, Vr = 80 V.
From the arc relation, 40 = 20 + 40/I → 40 – 20 = 40/I → 20 = 40/I → I = 2 A.
Therefore, R = Vr/I = 80/2 = 40 Ω.

5. Find an expression for the current when a voltage $E = 283 \sin 100\pi t$ is applied to a coil having R = 50 Ω and L = 0.159 H.

Frequency $f = 100\pi/2\pi = 50$ Hz. Inductive reactance $X_L = 2\pi fL = 2\pi \times 50 \times 0.159 = 50$ Ω.
Impedance $Z = \sqrt{(R^2 + X_L^2)} = \sqrt{(50^2 + 50^2)} = \sqrt{5000} = 70.7$ Ω.
RMS voltage $V = 283/\sqrt{2} = 200$ V.
Current $I = V/Z = 200/70.7 = 2.83$ A.

6. Explain four (4) indicators which show that a cell is fully charged.

A fully charged cell is indicated when its voltage reaches the maximum rated value.
The specific gravity of the electrolyte becomes constant and equal to its rated value.
The cell begins to gas freely during charging.
The temperature of the cell becomes steady and does not increase further.

7. (a) Give three (3) differences between lap winding and wave winding as used in d.c generator.

Lap winding has as many parallel paths as the number of poles, while wave winding always has two parallel paths regardless of poles.
Lap winding is suitable for low voltage, high current machines, whereas wave winding is suitable for high voltage, low current machines.
Lap winding requires more conductors and is more costly, while wave winding requires fewer conductors and is more economical for high voltage.

(b) The induced e.m.f in a d.c generator running at 2500 r.p.m is 500 V. Calculate the induced e.m.f when it runs at 1000 r.p.m.

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E is proportional to speed. So $E_2 = (N_2/N_1) \times E_1 = (1000/2500) \times 500 = 200$ V.

8. A 230 V, 2 hp d.c motor drives a pump. The input power to the motor is 1700 W. Determine the current taken by the motor and efficiency of the motor.

2 hp = 2 × 746 = 1492 W output.
Efficiency = Output/Input = 1492/1700 × 100% = 87.8%.
Current = Input/Voltage = 1700/230 = 7.39 A.

9. A moving coil instrument gives full-scale deflection with 25 mA. The resistance of the coil is 5 Ω. It is required to convert this meter into an ammeter to read up to 5 A. Find the:

(a) Resistance of the shunt to be connected in parallel with the meter.
Voltage across meter = Im × Rc = 0.025 × 5 = 0.125 V.
Shunt current Ish = 5 – 0.025 = 4.975 A.
Rsh = Vm/Ish = 0.125/4.975 = 0.025 Ω.

(b) Value of the series resistance for the above meter to read up to a voltage of 20 V.
Voltage = 20 V, Im = 0.025 A.
Required resistance = V/Im – Rc = 20/0.025 – 5 = 800 – 5 = 795 Ω.

10. Mention three (3) properties of a good illumination.

A good illumination should have sufficient intensity for clear visibility.
It should be uniformly distributed without glare or shadows.
It should be economical and comfortable to the eyes.

11. Give two (2) factors which determine the heat gained by a body when there is a temperature change.

The mass of the body determines the total heat absorbed.
The specific heat capacity of the material determines how much heat is required per degree rise in temperature.

12. (a) Define the term ‘capacitance’ of a capacitor.

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Capacitance is the ability of a capacitor to store electric charge per unit potential difference between its plates.

(b) Two capacitors A and B are connected in series across a 200 V d.c supply. The p.d across A is 120 V. When a capacitor of 3 μF is connected in parallel with B, the p.d across A is increased to 140 V. Calculate the capacitance of A and B.

In series, charge Q is same, so $V \propto 1/C$.
From first case: $VA/VB = CB/CA = 120/80 = 1.5 \rightarrow CB = 1.5\ CA$.
Second case: $VA/VB = CB'/CA = 140/60 = 2.33$. But $CB' = CB + 3 = 1.5CA + 3$.
So $(1.5CA + 3)/CA = 2.33 \rightarrow 1.5 + 3/CA = 2.33 \rightarrow 3/CA = 0.83 \rightarrow CA = 3.61$ μF.
Then $CB = 1.5 \times 3.61 = 5.42$ μF.

13. (a) Define the following terms.
    (i) Rectifier is a device used to convert alternating current (AC) to direct current (DC).
    (ii) Filter is a device used in rectifier circuits to smooth the DC output by removing ripples.

(b) A half wave rectifier is connected in series with load resistor of 14 Ω to an a.c supply of 20 V r.m.s value. The rectifier may be taken as having a constant resistance of 1.5 Ω in the forward direction while the reverse current being zero. Calculate the average and peak values of the currents in the load.

$Vm = \sqrt{2} \times Vrms = \sqrt{2} \times 20 = 28.3$ V.
Effective resistance = 14 + 1.5 = 15.5 Ω.
Peak current = Vm/R = 28.3/15.5 = 1.83 A.
Average current = $Im/\pi = 1.83/\pi = 0.58$ A.

14. (a) Given: Current = 200 A at power factor 0.5.
    Apparent power S = VI. Real power P = VIcosφ.
    So $P = VI \times 0.5 = V \times 200 \times 0.5 = 100V$.
    If power factor is improved to unity, I = P/V = 100V / V = 100 A.
    So total current = 100 A.

(b) When 50% motors are switched off, real power halves to 50V.
Capacitors are still connected, so total kVA remains at 100V.
New current = S/V = 100V / V = 100 A.

New power factor = P/S = 50V / 100V = 0.5.

So current = 100 A, power factor = 0.5.

15. (a) Power factor is the cosine of the angle between voltage and current in an AC circuit. It represents the ratio of real power to apparent power.

(b) Given: Delta connected load, R = 10 Ω, C = 100 μF, V = 410 V, f = 50 Hz.

Capacitive reactance $X_c = 1 / (2\pi fC) = 1 / (2 \times 3.14 \times 50 \times 100 \times 10^{-6}) = 31.8\ \Omega$.

Impedance $Z = \sqrt{(R^2 + (X_c)^2)} = \sqrt{(10^2 + 31.8^2)} = \sqrt{(100 + 1011.24)} = \sqrt{1111.24} = 33.33\ \Omega$.

Phase current = Vph / Z. In delta, Vph = VL = 410 V.

Iph = 410 / 33.33 = 12.3 A.

Line current $I_L = \sqrt{3} \times I_{ph} = 1.732 \times 12.3 = 21.3$ A.

Power factor $\cos\varphi = R / Z = 10 / 33.33 = 0.3$.

Power consumed $= \sqrt{3} \times V_L \times I_L \times \cos\varphi = 1.732 \times 410 \times 21.3 \times 0.3 = 4536$ W = 4.54 kW.

16. (a) The three means of heat transfer are conduction, convection, and radiation.

(b) Three types of electric heaters are immersion heaters, radiant heaters, and convection heaters.

(c) Given: Heater power = 4 kW = 4000 W, Efficiency = 80%. Effective power = 4000 × 0.8 = 3200 W.

Mass of water = 200 kg, c = 4200 J/kg°C, $\Delta T = (90 - 12) = 78$°C.

Heat required $Q = mc\Delta T = 200 \times 4200 \times 78 = 65{,}520{,}000$ J.

Time = Q / P = 65,520,000 / 3200 = 20,475 s.

Convert to hours: 20,475 / 3600 = 5.7 hours.

So time taken = 5.7 hours.

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