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 : 2012**

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 the items (i) – (x) choose the correct answer from among the given alternatives and write its letter beside the item number.

(i) Candela is the unit of

A. light flux

B. luminous intensity

C. illumination

D. luminous efficiency

E. luminous flux

Correct answer: B. Luminous intensity.

(ii) The atom which consists of one proton in the nucleus with an electron revolving around it is called

A. hydrogen

B. beryllium

C. helium

D. lithium

E. oxygen

Correct answer: A. Hydrogen.

(iii) The quality of a capacitor can be expressed in terms of

A. power dissipation

B. cost

C. capacitance value

D. material used

E. size

Correct answer: C. Capacitance value.

(iv) The heat energy required to change 1 kg of a substance from a liquid to a gaseous state at the same temperature is called

A. specific heat capacity

B. heat capacity of freezing

C. heat of the body

D. specific latent heat of fusion

E. specific latent heat of vaporization

Correct answer: E. Specific latent heat of vaporization.

(v) Transformer cores are laminated in order to

A. reduce cost

B. reduce hysteresis loss

C. minimize eddy current loss

D. increase voltage

E. simplify its construction

Correct answer: C. Minimize eddy current loss.

(vi) The universal measuring instrument is the one which is used to measure

A. only a.c quantities

B. both a.c and d.c quantities

C. only d.c quantities

D. bigger and smaller electric quantities

E. high and low power quantities

Correct answer: B. Both a.c and d.c quantities.

(vii) The strands of a cable are mostly bunched together in order to

A. reduce the heat generated in the cable

B. increase the diameter of the cable

C. reduce the cross-sectional area of the cable

D. increase the flexibility of the cable

E. reduce the I^2R which normally occurred in the cable

Correct answer: D. Increase the flexibility of the cable.

(viii) A rectifying component is said to be a half wave rectifier, if

A. it produces pulsating waves

B. it contains one diode in the circuit connected

C. it produces waves without ripples

D. it increases the flexibility of the cable

E. it contains two diodes in the circuit connected

Correct answer: B. It contains one diode in the circuit connected.

(ix) Sulphation in a lead-acid battery occurs due to

A. trickle charging

B. incomplete charging

C. constant charging

D. fast charging

E. heavy discharging current

Correct answer: B. Incomplete charging.

(x) Transfer of heat by conduction means heat is transmitted through

A. solid material

B. liquid

C. heated particles

D. air molecules

E. gaseous material

Correct answer: A. Solid material.

2. A twin core copper cable has a resistance of 2.2 Ω per core, what is the length of a cable if the diameter of a cable is 1 mm and resistivity of copper is 1.73×10^{-8} Ω·m.

   Radius r = 0.5 mm = 0.0005 m.

   Area $A = \pi r^2 = 3.142 \times (0.0005)^2 = 7.85 \times 10^{-7}$ m².

   $R = \rho L/A$.

   $L = RA/\rho = (2.2 \times 7.85 \times 10^{-7})/(1.73 \times 10^{-8})$.

   $= 1.727 \times 10^{-6} / 1.73 \times 10^{-8} \approx 99.8$ m.

3. (a) Define the cathode ray oscilloscope.

   It is an instrument used to display the waveform of electrical signals.

   (b) What is the importance of the electron gun in the oscilloscope?

   It generates and accelerates electrons to form a focused beam that strikes the screen to produce a visible trace.

   (c) Mention the importance of using oscilloscope in the electronic system.

   It is used to measure voltage, frequency, phase difference, and to analyze waveforms.

4. (a) State Lens's law of electromagnetism.

   The direction of an induced current is such that it opposes the change producing it.

(b) A coil of 500 turns is limited by a flux of 0.4 mWb. If the flux is reversed in 0.01 second, find the e.m.f induced in the coil.

Change in flux = $2 \times 0.4 \times 10^{-3} = 0.0008$ Wb.

e.m.f = $N\Delta\Phi/\Delta t = 500 \times 0.0008 / 0.01 = 40$ V.

5. When an electric heater of 50 watts is used to heat a metal block of mass 50 kg in 10 minutes, a temperature rise of 12°C is produced.

   (a) How much heat energy is produced by the heater in 10 minutes?

   $Q = P \times t = 50 \times (10 \times 60) = 50 \times 600 = 30{,}000$ J.

   (b) Calculate the specific heat capacity of metal.

   $Q = mc\Delta T \rightarrow c = Q/(m\Delta T) = 30{,}000 / (50 \times 12) = 30{,}000/600 = 50$ J/kgK.

6. Calculate the brightness (or illuminance) of snow under illumination of (i) 44,000 lux (ii) 0.22 lux. Assume that snow behaves like a perfect diffuser having a reflection factor of 85%.

   Illuminance = E × reflection factor.

   (i) $44{,}000 \times 0.85 = 37{,}400$ lux.

   (ii) $0.22 \times 0.85 = 0.187$ lux.

7. What do you understand by the following terms as used in a.c circuit?

   (a) Root mean square value is the square root of the mean of the squares of instantaneous values of an alternating current or voltage.

   (b) Frequency is the number of cycles of a waveform completed per second, measured in hertz.

   (c) Cycle is one complete set of positive and negative values of an alternating quantity.

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

   To reduce polarization and local action, which limit the efficiency of the cell.

   (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. (a) How is conductor size indicated?

It is indicated by cross-sectional area in mm^2 or by gauge number (SWG or AWG).

(b) Mention four common materials used for cable insulation.

PVC (polyvinyl chloride).

Rubber.

Paper impregnated with oil.

XLPE (cross-linked polyethylene).

10. A four pole, lap connected d.c. generator has 600 armature conductors and runs at 1200 r.p.m. If the flux per pole is 0.06 Wb:

(a) Calculate the e.m.f induced.

Z = 600, P = 4, A = P (lap) = 4, N = 1200 rpm, $\Phi = 0.06$.

$Eg = (\Phi Z N P)/(60 A)$.

$= (0.06 \times 600 \times 1200 \times 4)/(60 \times 4)$.

$= (172{,}800)/(240) = 720$ V.

(b) Find the speed at which it should be driven to produce the same e.m.f when wave connected.

For wave connection, A = 2.

$Eg = (\Phi Z N P)/(60 A)$.

$720 = (0.06 \times 600 \times N \times 4)/(60 \times 2)$.

$720 = (86{,}400N)/(120)$.

$720 = 720N$.

N = 1 r.p.m. × 1200 = 1200 × 2 = 2400 r.p.m.

12. (a) With the help of a simple diagram, explain how an ammeter and voltmeter instruments are connected to the load circuit.

An ammeter is always connected in series with the load so that it measures the current passing through the circuit. A voltmeter is connected in parallel with the load so that it measures the potential difference across the load.

(b) A moving coil instrument has a resistance of 10 Ω and gives a full-scale deflection when carrying a current of 50 mA. Find the resistance to be connected in shunt as an ammeter to measure up to 100 A and in series to measure voltage up to 700 V.

Current through instrument = 0.05 A, resistance = 10 Ω, voltage drop = 0.05 × 10 = 0.5 V.

For 100 A range, shunt current = 100 – 0.05 = 99.95 A.

Rsh = (V/I) = 0.5/99.95 = 0.005 Ω.

For 700 V range, series resistance = (V/I) – Rm = (700/0.05) – 10 = 14,000 – 10 = 13,990 Ω.

(c) The input power to a three-phase motor was measured by two wattmeter method. The readings were 5.2 kW and –1.7 kW and the line voltage was 400 V. Calculate

(i) the total power = 5.2 + (–1.7) = 3.5 kW.

(ii) the power factor.

$W1 + W2 = \sqrt{3}\ V_L I_L \cos\varphi$.

$W1 - W2 = \sqrt{3}\ V_L I_L \sin\varphi$.

$\tan\varphi = (W1 - W2)/(W1 + W2) = (5.2 - (-1.7))/(3.5) = 6.9/3.5 = 1.97$.

$\varphi = \tan^{-1}(1.97) = 63.4°$.

$\cos\varphi = 0.45$.

(iii) the line current.

$P = \sqrt{3}\ V_L I_L \cos\varphi$.

$3500 = \sqrt{3} \times 400 \times I_L \times 0.45$.

$3500 = 311 \times I_L \times 0.45 = 140\ I_L$.

$I_L = 3500/140 = 25$ A.

13. (a) Differentiate between auto-transformer and double wound transformer basing on their constructions.

An auto-transformer has a single winding tapped at different points to act as both primary and secondary, while a double wound transformer has separate primary and secondary windings.

State laws which are adopted by transformer to accomplish its working principle and then explain how transformer works.

Transformer works based on Faraday's law of electromagnetic induction which states that e.m.f is induced in a coil when the magnetic flux linking it changes. It also works based on mutual induction between primary and secondary coils.

(b) A 120 V.A, 6000/400 V, 3-phase 50 Hz transformer has iron loss of 1600 W. The maximum efficiency occurs at 3/4 full load. Find the efficiency of the transformer at

(i) full load and 0.8 power factor.

Full load rating = 120 kVA, output = 120 × 0.8 = 96 kW.

At ¾ load, copper loss = iron loss = 1600 W.

Full load copper loss = $(4/3)^2 \times 1600 = 2844$ W.

Total losses at full load = 1600 + 2844 = 4444 W.

Efficiency = 96,000/(96,000 + 4444) × 100 = 95.6%.

(ii) half load and unit power factor.

Output = 60 kW.

Cu loss = $(0.5)^2 \times 2844 = 711$ W.

Total loss = 1600 + 711 = 2311 W.

Efficiency = 60,000/(62,311) × 100 = 96.3%.

(iii) maximum efficiency.

At max efficiency, iron loss = copper loss = 1600 W.

Total loss = 3200 W.

Efficiency = Output/(Output + 3200).

For large load, efficiency ≈ 97%.

14. (a) A three phase induction motor has four wound poles and supplied from 50 Hz system. Calculate

(i) synchronous speed = $120f/P = 120 \times 50 / 4 = 1500$ r.p.m.

(ii) slip speed when slip is 4% = $0.04 \times 1500 = 60$ r.p.m.

(iii) rotor frequency when the motor runs at 660 r.p.m.

Ns = 1500, Nr = 660, slip = (1500 – 660)/1500 = 0.56.

Rotor frequency = $s \times f = 0.56 \times 50 = 28$ Hz.

(b) A 415 V, 3-phase, 50 Hz induction motor having an output of 74.6 kW runs on full load at a power factor 0.7 lagging and with an efficiency of 85 percent. Find the capacitance per phase of mesh connected capacitor necessary to raise the power factor to

(i) unity.

P = 74.6 kW, $\eta = 0.85$, input power = 74.6/0.85 = 87.8 kW.

Reactive power before correction: $Q = P(\tan\varphi)$.

$\varphi = \cos^{-1}(0.7) = 45.6°$.

$Q = 74.6 \times \tan 45.6° = 74.6 \times 1.02 = 76.1$ kVAR.

Capacitance required per phase = $Q/(V^2\omega)$.

For 415 V, line, phase voltage = $415/\sqrt{3} = 240$ V.

$C = Q/(3 \times V_{ph}^2 \times 2\pi f)$.

= 76,100/(3 × 240² × 314).

= 76,100/54,278,400 = 1.4 × 10^{-3} F = 1400 μF.

(ii) 0.9 lagging.

cosφ2 = 0.9 → φ2 = 25.8°.

Q2 = P tanφ2 = 74.6 × 0.48 = 35.8 kVAR.

Q required = 76.1 – 35.8 = 40.3 kVAR.

C = 40,300/(54,278,400) = 7.42 × 10^{-4} F = 742 μF.

15. (a) Define Q-factor of a resonance series circuit.

Q-factor is the ratio of the reactive power stored in the circuit to the real power dissipated, or the ratio of resonant frequency to bandwidth.

(ii) An alternating quantity may have any shape of waveform such as sinusoidal, rectangular or saw tooth. Explain four advantages of alternating voltages and current which have sinusoidal waveforms.

They are mathematically easy to analyze.

They are efficient for power generation and transmission.

Most machines and appliances are designed to operate on sinusoidal supply.

They minimize losses and harmonic distortion.

(b) A 20 Ω resistor is connected in series with an inductor, a capacitor and an ammeter across a 25V variable frequency supply. When the frequency is 400 Hz, the current is at its maximum value of 0.5 A and the potential difference across the capacitor is 150 V. Calculate the

(i) capacitance of the capacitor.

Vc = 150 V, I = 0.5 A.

XC = V/I = 150/0.5 = 300 Ω.

C = 1/(2πfXC) = 1/(2π × 400 × 300) = 1.33 × 10^{-6} F = 1.33 μF.

(ii) resistance and inductance of the inductor.

At resonance, XL = XC = 300 Ω.

I = V/R = 25/20 = 1.25 A.

But given Imax = 0.5 A, so effective R = 25/0.5 = 50 Ω.

Hence inductor resistance = 50 – 20 = 30 Ω.

XL = 300 = 2πfL → L = 300/(2π × 400) = 0.119 H.

(c) An R-L-C series circuit consists of a resistance of 1000 Ω, an inductance of 100 mH and capacitance of 10 μF. If a voltage of 100 V is applied across the combination, find

(i) the resonance frequency.

$f = 1/(2\pi\sqrt{(LC)}) = 1/(2\pi\sqrt{(0.1 \times 10 \times 10^{-6})}) = 1/(2\pi\sqrt{1 \times 10^{-6}}) = 1/(2\pi \times 0.001) = 159$ Hz.

(ii) Q-factor of the circuit.

$Q = XL/R = (2\pi fL)/R.$

$= (2\pi \times 159 \times 0.1)/1000 = 0.1.$

(iii) the half power point.

$f1, f2 = fr \pm fr/2Q.$

$= 159 \pm 159/0.2.$

$= 159 \pm 795.$

Bandwidth is very large compared to fr, so circuit is weakly resonant.

16. (a) (i) State Kirchhoff's laws.

Kirchhoff's current law: The sum of currents entering a junction equals the sum leaving it.

Kirchhoff's voltage law: The sum of voltages in a closed loop equals zero.

(ii) Use Kirchhoff's law; calculate the current in each branch of the circuit shown in Figure 1.

By applying KVL, simultaneous equations can be solved for each branch current using mesh analysis.

(b) Three similar primary coils are connected in series to form a closed circuit as shown in Figure 2. Each coil has an e.m.f of 1.5 V and an internal resistance of 30 Ω. Calculate the currents and show that points A, B and C are at the same potential.

By symmetry, each branch has equal emf and resistance, so no current flows in the closed triangle, making A, B, and C equipotential points.

(c) Study Figure 3 and then calculate total resistance and total current of the circuit.

Resistors in parallel: $(1/RT) = 1/5 + 1/25 + 1/30.$

$= (1/5 + 1/25 + 1/30).$

LCM = 150, $(30 + 6 + 5)/150 = 41/150.$

$RT = 150/41 = 3.66\ \Omega.$

Total current $= V/R = 10/3.66 = 2.73$ A.