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 : 2022**

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).

SECTION A (10 Marks)

Answer all questions in the section

1. Choose the correct answer for each item (i) to (x) and write its letter in the answer booklet provided.

(i) Which quantity is measured in farad as the nature and behaviors of electrical quantities are considered?

A. Reactance

B. Inductance

C. Impedance

D. Capacitance

E. Resistance

Correct answer: D. Capacitance

Reason: The SI unit of capacitance is farad, defined as one coulomb of charge stored per volt of potential difference.

(ii) A Transformer having 1000 primary turns is connected to 250 V A.C supply. If secondary voltage is 400 V, what is the number of secondary turns?

A. 1700

B. 1800

C. 1600

D. 1650

E. 1550

Correct answer: C. 1600

Reason: $V_p/V_s = N_p/N_s$, so $N_s = (V_s/V_p) \times N_p = (400/250) \times 1000 = 1600$.

(iii) How are the transformer laminations insulated from each other?

A. By mica strip

B. By thin coat of varnish

C. By glass

D. By P.V.C

E. By rubber insulation

Correct answer: B. By thin coat of varnish

Reason: Thin varnish insulation prevents eddy currents between laminations, reducing losses.

(iv) Which of the following devices apply magnetic effect to operate?

A. Fuse

B. Cell

C. Bell

D. Toaster

E. Cooker

Correct answer: C. Bell

Reason: An electric bell works by magnetic effect of current attracting and releasing an armature to produce sound.

(v) Which one can cause accidents in an electrical workshop?

A. Wearing goggles

B. Sweeping the floor

C. Large working space

D. Wearing loose sleeve shirts

E. Using wooden chairs

Correct answer: D. Wearing loose sleeve shirts

Reason: Loose clothing can get caught in machines or wiring, creating safety hazards.

(vi) Which statement is true about the purpose of the commutator in D.C. machine?

A. It takes away generated voltage.

B. It converts output current to voltage.

C. It converts D.C voltage to A.C voltage.

D. It rectifies A.C voltage to D.C voltage.

E. It converts AC current to D.C current.

Correct answer: D. It rectifies A.C voltage to D.C voltage

Reason: In a DC generator, the commutator converts the alternating emf induced in the armature into unidirectional current.

(vii) Where is it appropriate to use wattmeter for measuring purposes?

A. In measuring apparent power

B. In measuring true power

C. In measuring reactive power

D. In measuring average power

E. In measuring estimated power

Correct answer: B. In measuring true power

Reason: Wattmeter is designed to measure real (true) power consumed in a circuit.

(viii) What will happen in an induction motor if the air gap is increased?

A. Bearing friction will increase

B. Windage losses will be more

C. Copper losses will be reduced

D. The power factor will be low

E. The power input will be more

Correct answer: D. The power factor will be low

Reason: A larger air gap increases reluctance, requiring more magnetizing current, which lowers power factor.

(ix) Which of the following are the main effects of an electric current?

A. Magnetic, Electromagnetic and Electricity

B. Chemical, Magnetic and boiling

C. Heating, repelling and attracting

D. Magnetic, Heating and Electric

E. Heating, Chemical and Magnetic

Correct answer: E. Heating, Chemical and Magnetic

Reason: Electric current produces heating (Joule effect), chemical (electrolysis), and magnetic effects.

(x) Why are electrical appliances connected in parallel?

A. Parallel circuit is simple in connection and economical.

B. Appliances drew high current and power.

C. Appliances drew high current and less resistance.

D. Appliances in parallel reduce power loss and cost.

E. The operation of appliances is independent of each other.

Correct answer: E. The operation of appliances is independent of each other

Reason: In parallel, each appliance receives full supply voltage and can be switched on/off independently.

SECTION B (45 marks)

Answer all questions from this section

2. (a) Draw an electrical symbol of an air cored transformer.

The electrical symbol of an air cored transformer is two coils (primary and secondary) drawn parallel without a magnetic core line between them, indicating there is no iron core.

(b) Calculate the efficiency of a transformer for a single phase transformer with an input and output power of 2 kW and 1.9 kW respectively.

Efficiency η = (Output Power / Input Power) × 100

η = (1.9 / 2.0) × 100 = 95%

Therefore, the efficiency of the transformer is 95%.

3. A moving coil instrument gives full-scale deflection with 15 mA and has a resistance of 5 Ω. Calculate the resistance required to enable the instrument to read up to:
   (a) 1 A in parallel connection.
   (b) 10 V in series connection.

Given: Ifsd = 15 mA = 0.015 A, Rm = 5 Ω

(a) For 1 A range as ammeter (shunt resistance):

Ish = 1 – 0.015 = 0.985 A

Rsh = (Ifsd × Rm) / Ish = (0.015 × 5) / 0.985 = 0.075 / 0.985 = 0.076 Ω

(b) For 10 V range as voltmeter (series resistance):

Rs = (V / Ifsd) – Rm = (10 / 0.015) – 5 = 666.7 – 5 = 661.7 Ω

4. Calculate the supply voltage necessary for charging a battery of 110 cells at 30 A at the beginning and at the end of the charge. Each cell possesses a p.d of 2.1 volts at the beginning and 2 volts at the end of charge. Allow 0.06 Ω for the resistance of the connecting leads.

Number of cells = 110

Current, I = 30 A

Lead resistance, R = 0.06 Ω

At beginning:

Vcell = 2.1 V → Vbattery = 110 × 2.1 = 231 V

Voltage drop in leads = I × R = 30 × 0.06 = 1.8 V

Supply voltage = 231 + 1.8 = 232.8 V

At end:

Vcell = 2.0 V → Vbattery = 110 × 2 = 220 V

Supply voltage = 220 + 1.8 = 221.8 V

5. Study the circuit shown in the following circuit and answer the questions that follow.
   (a) Find the value of I1 and I2
   (b) Calculate the total current I.

If V = 12 V, R1 = 6 Ω, R2 = 3 Ω (typical NECTA setup):

I1 = V / R1 = 12 / 6 = 2 A

I2 = V / R2 = 12 / 3 = 4 A

Total current, I = I1 + I2 = 6 A

6. A lamp rated 230 V gives an illumination of 6000 lux and it takes 1.5 A from the mains. Calculate:
   (a) Efficiency of the lamp.
   (b) Mean spherical candle power.

Power input = V × I = 230 × 1.5 = 345 W

(a) Efficiency = (Useful luminous power / Electrical power input) × 100

If illumination = 6000 lumens at 1 m^2 → total flux = 6000 lm

Assuming 1 lumen ≈ 0.001464 W (conversion for luminous efficacy):

Useful output ≈ 6000 × 0.001464 = 8.78 W

Efficiency = (8.78 / 345) × 100 ≈ 2.55%

(b) MSCP (mean spherical candle power):

Φ = 6000 lm

MSCP = Φ / (4π) = 6000 / 12.566 = 477 cd

7. A 4 poles, long shunt compound generator supplies 100 A at a terminal voltage of 500 V. If the armature resistance is 0.02 **Ω**, series field resistance is 0.04 **Ω**, shunt field is 100 **Ω** and the brush drop is 2 V, find the generated E.M.F.

Terminal voltage = 500 V

Load current, IL = 100 A

Shunt field current, Ish = V / Rsh = 500 / 100 = 5 A

Armature current, Ia = IL + Ish = 100 + 5 = 105 A

Voltage drop in armature = Ia × Ra = 105 × 0.02 = 2.1 V

Voltage drop in series field = IL × Rs = 100 × 0.04 = 4 V

Brush drop = 2 V

Generated emf Eg = Vt + IaRa + ILRs + brush drop

= 500 + 2.1 + 4 + 2 = 508.1 V

8. Find the efficiency of a water heater which heats 140 liters of water with a specific heat capacity of 4180 J/kg°C from 10ºC to 60ºC in 3 hours, given that, the water is heated by a 3 kW heater element.

Mass of water = 140 kg

Temperature rise = 50 °C

Heat required = mcΔT = 140 × 4180 × 50 = 29,260,000 J

Input energy = Power × time = 3000 × (3 × 3600) = 3000 × 10800 = 32,400,000 J

Efficiency = (29,260,000 / 32,400,000) × 100 = 90.3%

9. Given the equation of an alternating current flowing through a certain circuit which is given by, $i = 14.14 \sin(314t)$. Determine:
   (a) the maximum value of current;
   (b) the r.m.s value of current,
   (c) the frequency of the current.

$i = 14.14 \sin(314t)$

(a) Maximum value = 14.14 A
(b) $I_{rms} = I_{max} / \sqrt{2} = 14.14 / 1.414 = 10$ A
(c) Angular frequency $\omega = 314$ rad/s → $f = \omega / 2\pi = 314 / 6.283 = 50$ Hz

10. A current of 6 A flows through a coil of 400 turns which is wound over a ring made from a non-magnetic material. The ring has a circumference of 500 mm and a uniform cross-sectional area of 0.5 cm^2. If the permeability of free space is $4\pi \times 10^{-7}$ and relative permeability of non-magnetic material is 10, calculate:
    (a) the magnetic field density;
    (b) the flux density;
    (c) the total flux.

Given: N = 400, I = 6 A, l = 500 mm = 0.5 m, $A = 0.5\ cm^2 = 0.5 \times 10^{-4}\ m^2$, $\mu_r = 10$, $\mu_0 = 4\pi \times 10^{-7}$

Magnetomotive force = NI = 400 × 6 = 2400 At
Magnetic field strength, H = NI / l = 2400 / 0.5 = 4800 A/m
Permeability $\mu = \mu_0 \times \mu_r = 4\pi \times 10^{-7} \times 10 = 1.256 \times 10^{-5}$ H/m

(a) Magnetic field density $B = \mu \times H = 1.256 \times 10^{-5} \times 4800 = 0.0603$ T
(b) Flux density B is same as above, 0.0603 T
(c) Total flux $\Phi = B \times A = 0.0603 \times 0.5 \times 10^{-4} = 3.015 \times 10^{-6}$ Wb

Perfect, let's now continue with **Section C (Questions 11–14)**, carefully copying each question first, then solving step by step with clear explanations.

SECTION C (45 marks)

Answer any three (3) questions from this section

11. (a) Briefly explain how each of the three major losses in A.C generator takes place.

Copper losses occur due to the resistance of stator and rotor windings. When current flows, heat is produced according to I^2R, leading to energy loss.

Iron losses occur in the magnetic core due to alternating flux. These include hysteresis loss, caused by repeated magnetization and demagnetization of the core, and eddy current loss, caused by circulating currents in the core.

Mechanical losses occur due to friction in bearings and air resistance (windage) as the rotor rotates. These reduce the mechanical power available for conversion into electricity.

(b) Calculate the line current when three similar coil each having a resistance and inductance of 20 Ω and 0.05 H respectively, are connected in star to a three phase 50 Hz supply with 400 V between lines.

R = 20 Ω, L = 0.05 H, f = 50 Hz, line voltage VL = 400 V

Inductive reactance $XL = 2\pi fL = 2 \times 3.142 \times 50 \times 0.05 = 15.7\ \Omega$

Impedance per phase $Z = \sqrt{(R^2 + XL^2)} = \sqrt{(20^2 + 15.7^2)} = \sqrt{(400 + 246.5)} = \sqrt{646.5} = 25.4\ \Omega$

Phase voltage $Vph = VL / \sqrt{3} = 400 / 1.732 = 231$ V

Phase current Iph = Vph / Z = 231 / 25.4 = 9.1 A

Line current IL = Iph = 9.1 A

12. A coil of resistance 100 Ω and inductance 100 μH is connected in series with a 100 pF capacitor. The circuit is connected to a 10 V variable frequency supply. Calculate:
    (a) The resonant frequency.
    (b) The current at resonance.
    (c) The voltage across L and C at resonance then, comment on the voltage obtained.
    (d) Q factor of a circuit.

R = 100 Ω, $L = 100\ \mu H = 100 \times 10^{-6}$ H, $C = 100\ pF = 100 \times 10^{-12}$ F, V = 10 V

(a) Resonant frequency:

$fr = 1 / (2\pi\sqrt{(LC)}) = 1 / (2\pi\sqrt{(100 \times 10^{-6} \times 100 \times 10^{-12})})$

$= 1 / (2\pi\sqrt{(1 \times 10^{-14})}) = 1 / (2\pi \times 10^{-7}) = 1.59$ MHz

(b) At resonance, current $I = V / R = 10 / 100 = 0.1$ A

(c) Voltage across L (and also across C) = $I \times XL$

$XL = 2\pi frL = 2\pi \times 1.59 \times 10^{6} \times 100 \times 10^{-6} = 1000\ \Omega$

$VL = 0.1 \times 1000 = 100$ V

Comment: The voltage across L and C is 10 times greater than the supply voltage (resonance voltage rise effect).

(d) Q factor = $XL / R = 1000 / 100 = 10$

13. An inductance (L) 0.0637 H is connected in parallel with 30 Ω resistor. The combination is supplied by 200 V of 60 Hz

(a) Draw the circuit diagram including the parameters provided.

The circuit is a parallel branch: one branch has an inductor of 0.0637 H, the other a 30 Ω resistor, both connected across a 200 V, 60 Hz supply.

(b) Calculate the following parameters:

(i) Current in each branch.

(ii) Impedance of the circuit.

(iii) Phase angle of the circuit.

Given: V = 200 V, L = 0.0637 H, R = 30 Ω, f = 60 Hz

Inductive reactance $XL = 2\pi fL = 2 \times 3.142 \times 60 \times 0.0637 = 24\ \Omega$

(i) Current in resistor: $IR = V / R = 200 / 30 = 6.67$ A

Current in inductor: $IL = V / XL = 200 / 24 = 8.33$ A (lagging 90°)

(ii) Admittance of resistor YR = 1/R = 1/30 = 0.0333 S

Admittance of inductor YL = 1 / jXL = –j(1/24) = –j0.0417 S

Total admittance Y = 0.0333 – j0.0417

Magnitude of Y = $\sqrt{(0.0333^2 + 0.0417^2)}$ = 0.0533 S

Impedance Z = 1 / Y = 1 / 0.0533 = 18.8 Ω

(iii) Phase angle θ = arctan(Im/Re) = arctan(–0.0417 / 0.0333) = –51°

Thus, circuit is lagging with a phase angle of about –51°.

(c) What will happen to the circuit characteristics if R is removed?

If R is removed, the circuit will consist only of an inductor across the supply. The current will lag by 90°, the impedance will be equal to XL, and no active power will be consumed (only reactive power).

14. (a) What is the importance of insulation part of the cable?

The insulation prevents leakage of current between conductors and to the environment, ensuring safety and preventing short circuits. It also provides mechanical protection and withstands high voltage stresses.

(b) Each conductor of 3-core copper cable, 178 meters long has a cross-sectional area of 15 mm^2. The cable supplies power to a 413-V, 3 phase motor of 22 kW output which works at a full load at 0.72 p.f lagging with an efficiency of 87 per cent. Calculate:

(i) The voltage required at the supply of the cable

(ii) The power loss in the cable.

Length = 178 m, so total length for current flow (go and return) = 2 × 178 = 356 m

Cross-sectional area = 15 mm^2 = 15 × 10^{-6} m^2

Resistivity of copper ρ = 1.72 × 10^{-8} Ωm

Resistance per conductor = (ρ × length) / A = (1.72 × 10^{-8} × 356) / (15 × 10^{-6}) = 0.408 Ω

Motor output = 22 kW

Efficiency = 87% → Input power = 22000 / 0.87 = 25.3 kW

Power factor = 0.72

Line current $I_L = P / (\sqrt{3} \times V_L \times \cos \varphi) = 25300 / (1.732 \times 413 \times 0.72) = 48.9$ A

(i) Voltage drop per phase = $I \times R = 48.9 \times 0.408 = 19.95$ V

Total voltage required = $413 + 19.95 = 432.95$ V ≈ 433 V

(ii) Power loss in cable = $3 \times I^2 \times R = 3 \times (48.9^2) \times 0.408 = 2921$ W ≈ 2.92 kW