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 : 2009**

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).

(i) Which of the following materials can be used for making cable sheaths?

A. Lead

B. Copper

C. Aluminium

D. Cast iron

E. Carbon

Correct answer: A. Lead

Reason: Lead is used for making cable sheaths because it is highly resistant to moisture, gases, and chemicals. This provides protection to the insulation and conductors inside the cable, ensuring durability and safety. Other materials like copper and aluminium are mainly used as conductors, not as sheathing.

(ii) Why should the oil used in a transformer be free from moisture?

A. Moisture will reduce the density of the oil which is slightly undesirable

B. Moisture will reduce the dielectric strength of the oil and hence insulation is weakened

C. Moisture will reduce the lubricating property of the oil

D. Moisture will develop rust

E. Moisture will reduce viscosity of the oil which will affect the cooling system

Correct answer: B. Moisture will reduce the dielectric strength of the oil and hence insulation is weakened

Reason: Transformer oil is mainly used for insulation and cooling. Moisture contamination lowers its dielectric strength, leading to possible breakdown and failure of insulation, which can damage the transformer.

(iii) Which of the following instruments can be used to measure only a.c. currents?

A. Moving iron instruments

B. Electrodynamics instruments

C. Induction type instruments

D. Hotwire instruments

E. Permanent magnet ammeter instrument

Correct answer: C. Induction type instruments

Reason: Induction type instruments work on the principle of electromagnetic induction, which only occurs with alternating current (a.c.). Other instruments, like moving iron and electrodynamics types, can measure both a.c. and d.c.

(iv) Which of the following circuits having a voltage source will produce more current?

A. 5 volts across a 5 Ω resistance

B. 5 volts across two 5 Ω resistances in series

C. 5 volts across two 5 Ω resistances in parallel

D. 500 volts across a 1 MΩ resistance

E. 5 volts across two 50 Ω resistances in parallel

Correct answer: C. 5 volts across two 5 Ω resistances in parallel

Reason: Two 5 Ω resistances in parallel give an equivalent resistance of 2.5 Ω. Current = V/R = 5/2.5 = 2 A. This is greater than the current in other options, so it produces the most current.

(v) Which of the following will need the highest level of illumination?

A. Proof reading

B. Bed rooms

C. Hospital wards

D. Railway platforms

E. Shopping centres

Correct answer: A. Proof reading

Reason: Proof reading requires a high level of visual accuracy to detect small printing errors. This needs strong and uniform illumination compared to bedrooms, hospitals, or shopping centres.

(vi) If the frequency of power supply in a pure capacitive circuit is doubled, the current will

A. be reduced to half

B. double

C. remain the same

D. increase by four

E. decrease by four

Correct answer: B. double

Reason: Current in a pure capacitive circuit is given by I = VωC. Since ω (angular frequency) is proportional to supply frequency, doubling the frequency doubles the current.

(vii) The residual magnetism of a d.c. shunt generator can be regained by

A. connecting the shunt field to a battery

B. running a generator on no load for sometime

C. earthing the shunt field

D. reversing the direction of the generator

E. interchanging the polarities of the main pole

Correct answer: A. connecting the shunt field to a battery

Reason: If residual magnetism is lost, a small d.c. supply (battery) is applied to the shunt field winding to restore magnetism. This process is called flashing the field.

(viii) Which statement is true?

A. The electromotive force around a closed path is equal to the conduction current plus electric displacement through any surface bounded by the path.

B. The electromotive force around a closed path is equal to the time derivative of the electric displacement through any surface bounded by the path.

C. The total electric displacement through the surface enclosing a volume is not equal to the total charge within the volume.

D. The net magnetic flux emerging through any closed surface is zero.

E. The electromotive force around a closed path is equal to the charges flowing through any surface bounded by the path.

Correct answer: D. The net magnetic flux emerging through any closed surface is zero.

Reason: This is Gauss's law for magnetism, which states that magnetic monopoles do not exist. Hence, the total flux through a closed surface is always zero.

(ix) It is preferable to start d.c. series motor with some mechanical load

A. since it may develop excessive speed and damage itself

B. otherwise it will not run at no load

C. because a little load will act as a starter to the motor

D. to prevent mechanical vibrations

E. to provide strength

Correct answer: A. since it may develop excessive speed and damage itself

Reason: A d.c. series motor has very high speed at no load. Starting it without load may cause dangerous overspeed and damage. Hence, it must always be started with a mechanical load.

(x) Which of the following items is the indication of a fully discharged cell?

A. Gassing

B. Colour of the plate

C. Specific gravity

D. Breaking of the plate

E. Both gassing and colour of the plate

Correct answer: C. Specific gravity

Reason: In a fully discharged lead-acid cell, the specific gravity of the electrolyte falls close to 1.1 or below. This is the most reliable indicator of the state of charge. Other factors like gassing or colour change may occur but are not primary indicators.

2. State Lenz's law and Fleming's right hand rule.

Lenz's law states that the direction of the induced current in a conductor is such that it opposes the change in magnetic flux that produces it. This is a consequence of the law of conservation of energy.

Fleming's right hand rule states that if you stretch the thumb, forefinger, and middle finger of the right hand so that they are mutually perpendicular, with the forefinger pointing in the direction of the magnetic field and the thumb in the direction of motion of the conductor, then the middle finger will point in the direction of the induced current.

3. A circuit consists of a resistance of 20 Ω, an inductance of 0.05 H connected in series. A supply of 230 V at 50 Hz is applied across the circuit. Find the current, power factor and the power consumed by the circuit. Draw the vector diagram.

Resistance, $R = 20\ \Omega$

Inductance, $L = 0.05$ H

Supply voltage, $V = 230$ V

Frequency, $f = 50$ Hz

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

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

Current, $I = V / Z = 230 / 25.4 = 9.06$ A

Power factor = $R / Z = 20 / 25.4 = 0.787$

Power consumed, $P = VI \cos\varphi = 230 \times 9.06 \times 0.787 = 1640$ W

Vector diagram shows V as the hypotenuse, VR in phase with I, and VL leading by 90°.

4. A 4-pole, 1500 r.p.m. d.c generator has a lap wound armature, having 32 slots and 8 conductors per slot. If the flux per pole is 0.04 Wb. Calculate the e.m.f induced in the armature. What would be the e.m.f induced, if the winding is wave connected?

Number of poles, P = 4

Speed, N = 1500 rpm = 1500/60 = 25 rps

Slots = 32

Conductors per slot = 8

Total conductors, $Z = 32 \times 8 = 256$

Flux per pole, $\Phi = 0.04$ Wb

Lap winding: Number of parallel paths, A = P = 4

$E = (\Phi \times Z \times N \times P) / (60 \times A)$

$E = (0.04 \times 256 \times 1500 \times 4) / (60 \times 4) = (61440) / 240 = 256$ V

Wave winding: A = 2

$E = (0.04 \times 256 \times 1500 \times 4) / (60 \times 2) = 61440 / 120 = 512$ V

5. A 100 kVA, 50 Hz single phase transformer has a turn's ratio of 1000/250. The primary winding is connected to 500 V, 50 Hz supply. Find the secondary open circuit voltage and the maximum value of the flux in the core.

Turn's ratio = $N_p/N_s = 1000/250 = 4$

Primary voltage, $V_p = 500$ V

Secondary open circuit voltage, $V_s = V_p / 4 = 125$ V

From emf equation:

$E_p = 4.44\, f\, N_p\, \Phi_{max}$

$500 = 4.44 \times 50 \times 1000 \times \Phi_{max}$

$500 = 222000\, \Phi_{max}$

$\Phi_{max} = 500 / 222000 = 2.25 \times 10^{-3}$ Wb = 2.25 mWb

6. A moving coil instrument has a resistance of 5 Ω and gives a full scale reading of 50 mA. Calculate the:
   (a) Shunt resistance required to increase the range of 200 A.
   (b) Series resistance required to use it as a voltmeter of range 0-750 V.
   (c) Power consumed in both cases.

Full scale current, I_m = 50 mA = 0.05 A

Resistance of coil, R_m = 5 Ω

(a) For ammeter 200 A:

I_s = 200 A - 0.05 A = 199.95 A

Shunt resistance, $R_s = (I_m \times R_m) / I_s = (0.05 \times 5) / 199.95 = 0.25 / 199.95 = 0.00125\ \Omega$

(b) For voltmeter 750 V:

Total resistance required, $R = V/I_m = 750 / 0.05 = 15000\ \Omega$

Series resistance, $R_s = 15000 - 5 = 14995\ \Omega$

(c) Power consumed in ammeter case: $P = I_m^2 R_m = (0.05^2 \times 5) = 0.0125$ W

Power consumed in voltmeter case: $P = I_m^2 \times (R_m + R_s) = 0.0025 \times 15000 = 37.5$ W

7. An incandescent filament lamp is suspended 1.8 meters above a level work-bench. The lamp is fitted with a reflector such that the luminous intensity in all directions below the horizontal is 400 cd. Calculate the:
   (a) Illumination at a point A on the surface of the bench immediately below the lamp.
   (b) Illumination at the bench position 0.9 meter from A in a straight line.

Luminous intensity, I = 400 cd

Height, h = 1.8 m

(a) At A (directly under lamp):

$E = I / h^2 = 400 / (1.8^2) = 400 / 3.24 = 123.5$ lux

(b) At point 0.9 m away:

Slant distance, $d = \sqrt{(1.8^2 + 0.9^2)} = \sqrt{(3.24 + 0.81)} = \sqrt{4.05} = 2.01$ m

$\text{Cos } \theta = h / d = 1.8 / 2.01 = 0.895$

$E = (I \cos \theta) / d^2 = (400 \times 0.895) / (2.01^2) = 358 / 4.04 = 88.6$ lux

8. Give three (3) advantages and three (3) disadvantages of alkaline cell over the lead acid cell.

Advantages:

1. Alkaline cells have a longer shelf life compared to lead acid cells, since they self-discharge slowly.
2. They are lighter and more compact, making them suitable for portable devices.
3. They provide consistent voltage output over a longer period of discharge.

Disadvantages:

1. Alkaline cells are more expensive than lead acid cells in terms of cost per unit capacity.
2. They are not rechargeable in most cases, unlike lead acid cells.
3. They have lower current capacity, making them unsuitable for high power applications.
4. Give three (3) similarities and three (3) differences between magnetic and electric circuits.

Similarities:

1. Both obey Ohm's law equivalents (magnetic Ohm's law for magnetic circuits, Ohm's law for electric circuits).
2. Both have driving forces: MMF in magnetic circuits and EMF in electric circuits.
3. Both have opposing elements: reluctance in magnetic circuits and resistance in electric circuits.

Differences:

1. In electric circuits, current actually flows, while in magnetic circuits flux is not a flow of matter but a field effect.

2. Energy is lost in electric circuits due to resistance as heat, while in magnetic circuits energy loss is due to hysteresis and eddy currents.

3. Electric circuits require a closed conducting path, while magnetic flux can pass through air or non-magnetic materials.

4. Draw the circuit for single phase half wave rectifier. Also draw its input and output wave form for two periods.

The circuit consists of a single diode connected in series with the load resistance across an AC supply.
Input waveform: pure sinusoidal alternating current.
Output waveform: only the positive half cycles appear across the load, negative half cycles are blocked. The result is a pulsating DC.

11. An aluminium conductor has resistance of 3.6 Ω at 20 °C. Find its resistance at 50 °C, if temperature coefficient of resistance of aluminium is 0.00403/°C at 20 °C.

Resistance at T2, $R_t = R_0 [1 + \alpha (T_2 - T_0)]$

$= 3.6 [1 + 0.00403 (50 - 20)]$

$= 3.6 [1 + 0.00403 \times 30]$

$= 3.6 [1 + 0.1209]$

$= 3.6 \times 1.1209 = 4.04\ \Omega$

12. (a) Define the following terms as applied in transformers.
 (i) Voltage regulation
 (ii) Transformation ratio

Voltage regulation is the change in secondary voltage of a transformer from no-load to full-load, expressed as a percentage of full-load voltage, keeping primary voltage constant.

Transformation ratio is the ratio of number of turns in primary winding to the number of turns in secondary winding, or equivalently the ratio of primary voltage to secondary voltage.

(b) What is the purpose of oil in the transformer?

Transformer oil serves two main purposes: insulation between winding and core, and cooling of the transformer by dissipating heat.

(c) A single phase, 20 kVA transformer has 1000 primary turns and 2500 secondary turns. The net cross-sectional area of the core is 100 cm^2. When the primary winding is connected to 500 V, 50 Hz supply, calculate the:

(i) Maximum value of the flux density in the core.
(ii) Voltage induced in the secondary winding.
(iii) Primary and secondary full load current.

Given:
$N_p = 1000$, $N_s = 2500$, $V_p = 500$ V, f = 50 Hz, Area = 100 cm^2 = 0.01 m^2, kVA = 20

From emf equation:
$V_p = 4.44 f N_p \Phi_{max}$
$\Phi_{max} = V_p / (4.44 f N_p) = 500 / (4.44 \times 50 \times 1000) = 500 / 222000 = 2.25 \times 10^{-3}$ Wb
Flux density, $B_{max} = \Phi_{max} / A = (2.25 \times 10^{-3}) / 0.01 = 0.225$ T

(ii) Voltage induced in secondary winding:
$V_s = (N_s / N_p) \times V_p = (2500/1000) \times 500 = 1250$ V

(iii) Full load current:
S = 20 kVA = 20000 VA
Primary current, $I_p = S / V_p = 20000 / 500 = 40$ A
Secondary current, $I_s = S / V_s = 20000 / 1250 = 16$ A

13. (a) How can the power factor of an inductive circuit be improved?

Power factor of an inductive circuit can be improved by connecting capacitors in parallel with the load to supply reactive power, thereby reducing the phase angle between current and voltage. Alternatively, synchronous condensers or phase advancers can be used for power factor correction.

(b) A circuit consists of three branches connected in parallel as shown in Figure 1. If the circuit is connected across a 230 V, 50 Hz supply, calculate the total current, power and power factor of the circuit.

$R1 = 10\ \Omega$, $R2 = 20\ \Omega$, $R3 = 15\ \Omega$ in series with L (150 μH)

Branch 1 current: $I1 = V / R1 = 230 / 10 = 23$ A

Branch 2 current: $I2 = 230 / 20 = 11.5$ A

Branch 3 impedance:

$XL = 2\pi fL = 2 \times 3.142 \times 50 \times 150 \times 10^{-6} = 0.0471\ \Omega$

$Z3 = \sqrt{(15^2 + 0.0471^2)} = 15.00007 \approx 15\ \Omega$

$I3 = V / Z3 = 230 / 15 \approx 15.33$ A, with angle $\varphi = \arctan(XL/R) = \arctan(0.0471/15) \approx 0.18°$

Total current, $I = I1 + I2 + I3 \approx 23 + 11.5 + 15.33 = 49.8$ A (almost in phase since angle small)

Power $= V \times I \times \cos\varphi = 230 \times 49.8 \times \approx 1 = 11454$ W

Power factor ≈ 1

14. (a) Define the following terms.

(i) Brightness

Brightness is the visual perception of the intensity of light emitted or reflected by a surface as seen by the human eye. It depends on both the luminous intensity and the sensitivity of the observer's eye.

(ii) Illumination

Illumination is the amount of luminous flux falling per unit area of a surface. It is measured in lux (lumens per square meter).

(iii) Luminous intensity

Luminous intensity is the amount of luminous flux emitted by a source per unit solid angle in a given direction. Its unit is candela (cd).

(iv) Luminous flux

Luminous flux is the total amount of visible light energy emitted by a source per unit time. Its unit is lumen (lm).

(v) Lumen

A lumen is the unit of luminous flux. It is defined as the flux emitted through a solid angle of one steradian by a source of one candela intensity.

(b) A light fitting producing luminous intensity of 1600 candela in all directions below the horizontal is suspended 40 m above the floor. Calculate the illumination produced at point P just below the lamp and a point Q 2.5 m away from P.

Luminous intensity, $I = 1600$ cd

Height, $h = 40$ m

At P (directly below lamp):

$E = I / h^2 = 1600 / (40^2) = 1600 / 1600 = 1$ lux

At Q (2.5 m away):

Slant distance, $d = \sqrt{(40^2 + 2.5^2)} = \sqrt{(1600 + 6.25)} = \sqrt{1606.25} = 40.06$ m

$\cos \theta = h / d = 40 / 40.06 = 0.999$

$E = (I \cos \theta) / d^2 = (1600 \times 0.999) / (40.06^2) = 1598.4 / 1604.8 = 0.997$ lux

So illumination at P = 1 lux, at Q = 0.997 lux.

15. (a) Define the following terms as used in measurements and instrumentation.

(i) Instrument

An instrument is a device used to measure a physical quantity such as current, voltage, resistance, or temperature.

(ii) Accuracy

Accuracy is the closeness of the measured value to the true value of the quantity being measured.

(iii) Precision

Precision is the degree of repeatability of measurements under unchanged conditions, showing consistency of readings.

(iv) Resolution

Resolution is the smallest change in a measured quantity that an instrument can detect and display.

(v) Sensitivity

Sensitivity is the ratio of the change in output of an instrument to the corresponding change in input.

(vi) True value

True value is the actual value of the measured quantity that would be obtained with a perfect instrument.

(b) Figure 2 shows how an ammeter and voltmeter are used to check the resistance of a resistor marked 1 kΩ. Calculate the value of the resistance from the instrument readings, then comment on your results. Neglect ammeter resistance.

Total resistance in circuit = 1 kΩ + 0.5 kΩ = 1500 Ω

Current, I = V / R = 50 / 1500 = 0.0333 A

Voltage across 1 kΩ resistor = IR = 0.0333 × 1000 = 33.3 V

Measured resistance = V/I = 33.3 / 0.0333 = 1000 Ω

Comment: The measured value matches the true value of 1 kΩ since ideal instruments are assumed. In practice, voltmeter resistance being finite would slightly affect accuracy, giving a lower reading.

15. (a) State Ohm's law.

Ohm's law states that the current flowing through a conductor is directly proportional to the potential difference across it, provided the temperature and other physical conditions remain constant.

(b) Give two (2) limitations of Ohm's law.

1. Ohm's law does not apply to non-linear devices such as diodes and transistors, where V-I relationship is not proportional.

2. Ohm's law is invalid for materials whose resistance changes with temperature, like filament lamps and semiconductors.

(c) With reference to Figure 3, use Kirchhoff's laws to find the branch currents of the circuit.

Equation setup:

Let I_1 be the current in left loop, I_2 in right loop, and current through 4 Ω resistor be $(I_1 + I_2)$.

Loop 1 (a-b-c-d-a):

$42 = 8I_1 + 4(I_1 + I_2)$

$42 = 8I_1 + 4I_1 + 4I_2$

$42 = 12I_1 + 4I_2$ …(1)

Loop 2 (d-c-e-f-d):

$-10 = 6I_2 + 4(I_1 + I_2)$

$-10 = 6I_2 + 4I_1 + 4I_2$

$-10 = 4I_1 + 10I_2$ …(2)

From (1): $42 = 12I_1 + 4I_2 \rightarrow 12I_1 + 4I_2 = 42$ …(i)

From (2): $-10 = 4I_1 + 10I_2 \rightarrow 4I_1 + 10I_2 = -10$ …(ii)

Multiply (ii) by 3:

$12I_1 + 30I_2 = -30$ …(iii)

Subtract (i) from (iii):

$(12I_1 + 30I_2) - (12I_1 + 4I_2) = -30 - 42$

$26I_2 = -72$

$I_2 = -72 / 26 = -2.77$ A

Substitute in (i):

$12I_1 + 4(-2.77) = 42$

$12I_1 - 11.08 = 42$

$12I_1 = 53.08$

$I_1 = 53.08 / 12 = 4.42$ A

So, $I_1 = 4.42$ A, $I_2 = -2.77$ A (negative means opposite assumed direction).