higher education
& training

Department:
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NATIONAL CERTIFICATE

ELECTROTECHNICS N6

(8080096)

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09:00–12:00

This question paper consists of 6 pages and a formula sheet of 5 pages.

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ELECTROTECHNICS N6
TIME: 3 HOURS
MARKS: 100

INSTRUCTIONS AND INFORMATION

1. Answer ALL the questions.
2. Read ALL the questions carefully.
3. Number the answers according to the numbering system used in this question paper.
4. Sketches must be large, neat and fully labelled.
5. Write neatly and legibly.

QUESTION 1: DC MACHINES

1.1 State ONE condition under which a DC machine is working at maximum efficiency. (2)

1.2 Name THREE types of variable losses in a DC machine. (3)

1.3 Explain how the speed of a DC motor varies in relation to the armature voltage. (2)

1.4 The following readings were obtained when doing a load test on a DC shunt motor using a brake drum:

Spring balance reading	10 kg and 35 kg
Speed of motor	950 r/min
Line current	30 A
Distance of the drum	40 cm
Applied voltage	200 V

Use the data provided above to calculate the following quantities:

1.4.1 The output power (2)

1.4.2 The efficiency (4)

[13]

QUESTION 2: AC CIRCUIT THEORY

2.1 A 3-phase, star-connected system with 230 V between each phase and a neutral, has resistances of 4 Ω, 5 Ω and 6 Ω respectively in the three phases.

Calculate the following:

2.1.1 The current flowing in each phase (6)

2.1.2 The neutral current (6)

2.1.3 The total power absorbed (2)

2.2 Explain what is meant by a *3-phase balanced load*. (2)

[16]

QUESTION 3: TRANSFORMERS

3.1 Name FOUR of the most common three-phase transformer connections. (4)

3.2 A 650 kVA, single-phase transformer working at a power factor of 0,8 lagging has a maximum efficiency of 95%. The secondary current at maximum efficiency is 85% of the full-load current.

Calculate the following quantities:

3.2.1 The iron loss at maximum efficiency (4)

3.2.2 The copper loss at maximum efficiency (2)

3.2.3 The copper loss at full load (1)

3.2.4 The full-load efficiency (2)
[13]

QUESTION 4: AC MACHINES – GENERATORS

4.1 Explain the term *armature reaction* as applied to alternators. (3)

4.2 A three-phase, star-connected alternator in open-circuit, is required to generate a line voltage of 3 600 V, 50 Hz when driven at 500 r/min. The stator has 3 slots per pole per phase and 20 conductors per slot.

Assume that ALL the conductors per phase, are connected in series and that the coils are full-pitched. The distribution factor is 0,96.

Calculate the following:

4.2.1 The number of poles (2)

4.2.2 The useful flux per pole (9)

4.3 Define the term *distribution factor*. (2)
[16]

QUESTION 5: AC MACHINES – SYNCHRONOUS MOTORS

5.1 What do V-curves represent in synchronous motor theory? (3)

5.2 A 7 000 VA, 450 V, three-phase, star-connected synchronous motor is fully loaded and draws 5,5 kW at a leading power factor. The synchronous impedance is (0,35 + j3,5) ohms per phase.

Calculate the following quantities:

5.2.1 The power factor (1)

5.2.2 The phase current (2)

5.2.3 The EMF to which the machine is excited (6)

5.2.4 The load angle in electrical degrees (1)

[13]

QUESTION 6: AC MACHINES – INDUCTION MOTORS

6.1 An 8-pole, 3-phase, 50 Hz induction motor develops its maximum torque of 185 Nm when running at 360 r/min. The rotor resistance is 0,3 ohms.

Calculate the torque developed by the rotor when running at a slip of 5%.

HINT: $$T_{MAXIMUM} = \frac{3 \cdot S \cdot {E_0}^2}{2 \cdot \pi \cdot N({R_2}^2 + [S \cdot X_0]^2)}$$ (9)

6.2 Define the term *slip of an induction motor*. (2)

6.3 Name THREE methods that are used to measure the slip of an induction motor. (3)

6.4 Complete the following sentence by writing only the missing word next to the question number (6.4.1–6.4.2) in the ANSWER BOOK.

When a load is placed on a three-phase induction motor, its speed will be (6.4.1) and slip (6.4.2). (2)

[16]

QUESTION 7: GENERATION AND DISTRIBUTION OF AC

A 3-phase, 50 Hz transmission line, 100 km long delivers 20 MW at 0,9 power factor lagging and at 110 kV. The resistance and reactance of the line per phase per km are 0,2 Ω and 0,4 Ω respectively while the capacitance is $0{,}08 \times 10^{-3}$ F/km.

Use the nominal T-method to calculate:

7.1 The current at the sending end (4)

7.2 The voltage at the sending end (8)

7.3 The efficiency of transmission (1)
[13]

TOTAL: 100

ELECTROTECHNICS N6

FORMULA SHEET

DC MACHINES

$$E = V - Ia\ Ra$$

$$\frac{E_1}{E_2} = \frac{N_1\ \Phi_1}{N_2\ \Phi_2}$$

$$\frac{T_1}{T_2} = \frac{I_1\ \Phi_1}{I_2\ \Phi_2}$$

SPEED CONTROL

$$E = V - Ia\left(\frac{R\ Rse}{R + Rse} + Ra\right)$$

$$E = V - Ia\ Ra - Ise\ Rse$$

TESTING
DIRECT METHOD

$$\eta = \frac{2\pi Nr\ (W - S)}{60\ IV}$$

SWINBURNE
METHOD

$$\underset{motor}{\eta} = \frac{IV - (Ia^2 Ra + Ia_o\ V + Is\ V)}{IV}$$

$$\underset{generator}{\eta} = \frac{IV}{IV + Ia^2\ Ra + Ia_o\ V + Is\ V}$$

HOPKINSON
EFFICIENCIES
THE SAME

$$\eta = \sqrt{\frac{I_1}{I_1 + I_2}}$$

IRON LOSS

$$= I_2\ V - \left\{(I_1 + I_3)^2\ Ra + (I_1 + I_2 - I_4)^2\ Ra + (I_3 + I_4)\ V\right\}$$

$$= C$$

$$\underset{generator}{\eta} = \frac{I_1\ V}{I_1 V + (I_1 + I_3)^2\ Ra + I_3\ V + \frac{C}{2}}$$

$$\underset{motor}{\eta} = \frac{(I_1 + I_2)\ V - \left\{(I_1 + I_2 - I_4)^2\ Ra + I_4\ V + \frac{C}{2}\right\}}{(I_1 + I_2)\ V}$$

AC LOADS
STAR SYSTEMS

$$\bar{I}_R = \frac{V \underline{|o^\circ}}{Z_{RN} \underline{|\phi_1}}$$

$-$

$$\bar{I}_y = \frac{V \underline{|-120^\circ}}{Z_{YN} \underline{|\phi_2}}$$

Vrn = REFERENCE

R-Y-B SEQUENCE

$$\bar{I}_B = \frac{V \underline{|120^\circ}}{Z_{BN} \underline{|\phi_3}}$$

$$\bar{I}_N = \bar{I}_R + \bar{I}_B + \bar{I}_Y$$

BALANCED CIRCUIT

$$\bar{I}n = 0$$

DELTA-SYSTEMS

$$\bar{I}_{RY} = \frac{\bar{V}_{RY}}{\bar{Z}_{RY}} \quad \bar{I}_R = \bar{I}_{RY} - \bar{I}_{BR}$$

$$\bar{I}_{YB} = \frac{\bar{V}_{YB}}{\bar{Z}_{YB}} \quad \bar{I}_Y = \bar{I}_{YB} - \bar{I}_{RY}$$

$$\bar{I}_{BR} = \frac{\bar{V}_{BR}}{\bar{Z}_{BR}} \quad \bar{I}_B = \bar{I}_{BR} - \bar{I}_{YB}$$

THREE-WIRE SYSTEMS

$$V_{sn} = \frac{\frac{\bar{V}_{an}}{\bar{Z}_1} + \frac{\bar{V}_{bn}}{\bar{Z}_2} + \frac{\bar{V}_{cn}}{\bar{Z}_3}}{\frac{1}{\bar{Z}_1} + \frac{1}{\bar{Z}_2} + \frac{1}{\bar{Z}_3}}$$

$$\bar{V}_{aN} = \bar{V}_{aS} + \bar{V}_{sN}$$

$$\bar{V}_{bN} = \bar{V}_{bS} + \bar{V}_{sN}$$

$$\bar{V}_{cN} = \bar{V}_{cS} + \bar{V}_{sN}$$

$$\bar{I}_a = \frac{\bar{V}_{aS}}{\bar{Z}_1}$$

$$\bar{I}_B = \frac{\bar{V}_{bS}}{\bar{Z}_2}$$

$$\bar{I}_C = \frac{\bar{V}_{cS}}{\bar{Z}_3}$$

COMPLEX WAVE FORMS

$$e_1 = E_m \ Sin \ \omega t$$

$$e_2 = K_2 \ E_m \ Sin \ 2 \ \omega t$$

$$e_3 = K_3 \ E_m \ Sin \ 3 \ \omega t$$

$$e = E_m \ (Sin \ \omega t + k_2 \ Sin \ 2 \ \omega t + k_3 \ Sin \ 3 \ \omega t)$$

$$P = \frac{E_m^2 1 + E_m^2 2 + E_m^2 3 + ... + E_m^2 N}{2R}$$

$$P = \left(I_m^2 1 + I_m^2 2 + I_m^2 3 + ... + I_m^2 \ N \right) R$$

$$I = \sqrt{\frac{I_m^2 1 + I_m^2 2 + ... + I_m^2 N}{2}}$$

$$E = \sqrt{\frac{E_m^2 1 + E_m^2 2 + ... + E_m^2 N}{2}}$$

$$Cos \ \phi = \frac{I^2 \ R}{E \ I} = \frac{\frac{E^2}{R}}{E \ I}$$

TRANSFORMERS

$$\eta = \frac{S \ Cos \ \phi}{S \ Cos \ \phi + Po + Psc}$$

Any value of load at k of full-load

$$\eta = \frac{k \ S \ Cos \ \phi}{k \ S \ Cos \ \phi + Po + k^2 \ Psc}$$

MAXIMUM EFFICIENCY

$$K = \sqrt{\frac{Po}{Psc}}$$

$$\eta = \frac{k \ S \ Cos \ \phi}{k \ S \ Cos \ \phi + Po + k^2 \ Psc}$$

FORMULAE

$$\% R = \frac{I \text{ Re}}{V}$$

$$\% X = \frac{I \ Xe}{V}$$

$$\% Z_e = \% R_e + j \% X_e$$

$$V_{SC} = I \ Z_e$$

$$P_{SC} = I^2 \ R_e$$

$$Cos \ \phi_e = \frac{P_{SC}}{I_1 \ V_{SC}}$$

$$Reg = \frac{V_{SC} \ Cos \ (\phi_e \pm \phi_2)}{V}$$

$$Reg = \frac{I \ Z \ Cos \ (\phi_e \pm \phi_2)}{V}$$

$$Reg = \frac{I \ (\text{Re} \ Cos \ \phi_2 \pm Xe \ Sin \ \phi_2)}{V}$$

AC MACHINES
ALTERNATORS

$$n = \frac{f}{p}$$

$$Kd = \frac{Sin \frac{n\alpha}{2}}{n \ Sin \frac{\alpha}{2}}$$

$$Kp = Cos \ \frac{\psi}{2}$$

$$E = 2 \ Kf \ \ Kd \ \ Kp \ \ f \ \ \Phi \ Z$$

$$E = \sqrt{(V \ Cos \ \phi + IR)^2 + (V \ Sin \ \phi \pm IX)^2}$$

$$E = V + IR \ Cos \ \phi \pm IX \ \ Sin\phi$$

$$\overline{E} = E \underline{|\phi} + IR \underline{|o} + Ix \underline{|90}$$

$$Reg = \frac{E - V}{V}$$

SYNCHRONOUS MOTOR

$$\overline{V} + \overline{E} = \overline{E}_R \qquad \overline{E}_R = \overline{IZ}$$

$$\overline{E} = V \underline{|-\phi} + IR \underline{|180^\circ} + IX \underline{|-90^\circ}$$

INDUCTION MOTOR

$$\frac{Eo}{V_1} = \frac{Zr}{Z_s} \qquad E_2 = SEo$$

$$X_2 = SXo \qquad I_2 = \frac{E_2}{Z_2}$$

$$Z_2 = \sqrt{R_2^2 + (SXo)^2} \qquad Io = \frac{Eo}{Zo}$$

$$Zo = \sqrt{R_2^2 + Xo^2}$$

$$I_2 = \frac{SEo}{\sqrt{R_2^2 + (SXo)^2}} \qquad Io = \frac{Eo}{\sqrt{R_2^2 + Xo^2}}$$

MAXIMUM EFFICIENCY

$$R_2 = SXo$$

Rotor copper loss = S rotor input

$$S = \frac{N_1 - N_2}{N_1}$$

$$P = \sqrt{3}\, V_L\ I_L\ Cos\ \phi$$

$$KVA = \sqrt{3}\, V_L\ I_L$$