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Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T520(E)(M25)T
APRIL EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

(8080085)

25 March 2013 (X-Paper)
09:00–12:00

Calculators may be used.

This question paper consists of 5 pages and a 2-page formula sheet.

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DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE

ELECTROTECHNICS N5

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. Write neatly and legibly.

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QUESTION 1

1.1 Briefly explain the term *commutation.* (2)

1.2 What is meant by *armature reaction*? (2)

1.3 The armature resistance of a six-pole, 500 V wave connected series motor is 0,5 Ω, which takes 61 amperes from the supply. The motor has 72 slots with 10 conductors in each slot. The total flux per pole is 50 mWb. Calculate the speed of the motor. (6)

1.4 A 40 kW, 500 V, DC shunt motor has an armature resistance of 0,35 Ω. The full-load armature current is 100 A. What resistance should be inserted in series in the armature circuit to obtain a 20% speed reduction and a decrease of 20% of the rated torque?
The flux remains constant. (6)

1.5 A 55 kW, 650 V, DC shunt motor has a speed of 1 800 r/min and the full load efficiency is 85%. The armature circuit resistance is 0,3 ohms and the total voltage drop is 2,5 V at the brushes. The field current is 3 A.

Calculate:

1.5.1 The full-load line current (2)

1.5.2 The full-load shaft torque in N.m (4)
[22]

QUESTION 2

2.1 Sketch the phasor diagram for a series circuit at resonance. (3)

2.2 The following ordinates were taken during a half cycle of a symmetrical alternating current wave. The current varying in a linear manner between successive points:

Phase angle in degrees	0	30	60	90	120	150	180
Current in amperes	0	10,1	22,4	30	27	22,4	0

Without plotting the graph, determine the following:

2.2.1 The mean value (6)

2.2.2 The RMS value (2)

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2.3 A coil with a resistance of 10 Ω and an inductance of 0,0191 H is connected in parallel with a circuit with a 75 μF capacitor in series with a 5 Ω resistance. The circuit is connected to a 120 V, 50 Hz supply.

Determine:

2.3.1 The current in each branch (3)

2.3.2 The total supply current, power factor and power (4)
[18]

QUESTION 3

3.1 3.1.1 Explain how iron losses are affected when the frequency of a transformer is changed. (1)

3.1.2 Name ONE method that can be used to minimise eddy current losses in a transformer. (1)

3.1.3 List THREE methods of reducing leakage flux in transformers. (3)

3.2 If one transformer is too small, then we can connect a second transformer in parallel to the first one. Name FOUR requirements necessary before the two transformers can be connected in parallel. (4)

3.3 A 12 kVA, 2 500/500 V single-phase transformer, operating at no-load, has resistances and leakage reactance as follows:

Primary winding: Resistance 8,5 Ω, reactance 15 Ω
Secondary winding: Resistance 0,5 Ω, reactance 0,9 Ω

Determine the approximate value of the secondary voltage at full-load, with a power factor of 0,85 (lagging), when the primary supply voltage is 2 500 V. (6)

3.4 A three-phase, 660 V, star-connected motor has an output of 85 kW, with an efficiency of 90% and a power factor of 0,8.

Calculate:

3.4.1 The line current (3)

3.4.2 If the motor windings were connected in delta, what would be the three-phase voltage supply suitable for the motor? (2)
[20]

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QUESTION 4

4.1 Name THREE conditions to be met when connecting alternators in parallel to busbars. (3)

4.2 Explain the term *hunting* with reference to synchronous motors. (3)

4.3 Explain the term *distribution factor* (kd). (3)

4.4 TWO wattmeters are used to measure the input power to a balanced three-phase load, which has a unity power factor. EACH meter indicates 17,5 kW. The power factor drops to 0,8 lagging but the power remains unchanged.

Calculate the readings on the wattmeters. (8)

4.5 THREE identical coils are connected in star across a three-phase, 370 V, 50 Hz supply. The readings on TWO wattmeters connected to measure the total power are 2,5 kW and 1,8 kW respectively.

Calculate:

4.5.1 The power factor (3)

4.5.2 The line current (2)
[22]

QUESTION 5

5.1 A three-phase induction motor has 8 poles and is supplied from a 50 Hz supply.

Calculate:

5.1.1 The synchronous speed (3)

5.1.2 The rotor speed when the slip is 8% (3)

5.1.3 The rotor frequency when the rotor runs at 250 r/min (2)

5.2 TWO similar single-phase alternators are connected in parallel. Each machine has a synchronous impedance of 0,9+ j10,5 ohms. When excited, an open circuit EMF of 2 300 V is generated. The machines have a phase displacement of 40 electrical degrees relative to each other.

Calculate:

5.2.1 The circulating current (6)

5.2.2 The terminal voltage (2)

5.2.3 The power supplied from one machine to the other (Assume that there is no external load.) (2)
[18]

TOTAL: 100

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ELECTROTECHNICS N5

FORMULA SHEET

Armature ampere-turns/pole $= \frac{1}{2} \cdot \frac{I_a}{C} \cdot \frac{Z}{2P}$

$$E = V \pm I_a R_a$$

$$E = \frac{2pNZ\Phi}{60c}$$

$$T = 0{,}318 \frac{I_a}{c} ZP\Phi$$

$$k = n\sqrt{\frac{R_1}{r_m}}$$

$$r_1 = R_1 \left[\frac{k-1}{k}\right]$$

$$r_1 = R_s \frac{1-y}{1-y^m}$$

$$R_1 = bR_1\ (k-1) \times \frac{1-b^n}{1-b} + r_m$$

$$y = \frac{I_2}{I_1}$$

$$r_1 = bR_1\ (k-1)$$

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

$$\frac{T_1}{T_2} = \frac{K\Phi_1 I_{a1}}{K\Phi_2 I_{a2}}$$

$$I_{ave/} = \frac{i_1 + i_2 + i_3 + \ldots i_n}{n}$$

$$I_{rms/wk} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \ldots + i_n^2}{n}}$$

$$f = \frac{1}{2\pi\sqrt{LC}}$$

$$f = \frac{1}{2\pi L}\sqrt{\frac{L}{C} - R^2}$$

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

$$P_1 = V_L I_L \, Cos\, (30 - \phi)$$

$$P_2 = V_L I_L \, Cos\, (30 + \phi)$$

$$\tan\phi = \frac{\sqrt{3}\,(P_2 - P_1)}{(P_2 + P_1)}$$

% Voltage regulation

$$= I_1 \frac{(R_e \, Cos\phi \pm X_e \, Sin\phi)}{v_1} \times \frac{100}{1}$$

$$Z_e = \sqrt{R_e^2 + X_e^2}$$

$$\%Z_e = \frac{I\,Z_e}{V} \times \frac{100}{1}$$

$$S_1 = S \frac{Z_2}{Z_1 + Z_2}$$

$$E = 2{,}222 \; k_d k_p \; Z\Phi f$$

$$I_r = \frac{E_r}{Z_r}$$

$$E_o = V_p \frac{Z_r}{Z_s}$$

$$Cos\phi_r = \frac{R}{Z_r}$$

$$s = \frac{2\pi T(n_s - n_r)}{2\pi T\; n_s}$$

$$L = 0{,}05 + 0{,}2\, Lin \frac{d}{r}$$

$$C = \frac{1}{36 Lin \dfrac{d - r}{r}}$$

$$C = \frac{1}{18 Lin \dfrac{de}{r}}$$

% Regulation

$$= \frac{V_s - V_R}{V_R} \times \frac{100}{1}$$

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MARKING GUIDELINE

NATIONAL CERTIFICATE
APRIL EXAMINATION
ELECTROTECHNICS N5
7 APRIL 2015

This marking guideline consists of 9 pages.

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QUESTION 1

1.1 Due to the resistance loss in the armature circuit, ✓ the shunt current also decreases causing a further terminal voltage drop. ✓ (2)

1.2 Commutating poles improve commutation. ✓ (1)

Compensating windings minimize armature reaction. ✓ (1)

1.3 1.3.1 p = 4 c = 2 Z = 800 mech deg. = 5° and Elect deg = p x 5 = 20° Ia = 270 A Field winding = 1600 t/p

Demag At/p = 0.5 x Ia / c x Z/2p x (4θ / 360)
= 0,5 x 270/2 x 800 / 8 x(4 x 20 / 360) ✓ = 1500 At/p ✓
Cross-mag At / p = 0,5 x 270 / 2 x 800 / 8 x [1 – (4 x 20 / 360)] ✓
= 5250 At ✓ (2)

1.3.2 MMF = N I ✓
I = 1500 / 1600
= 0,94 A ✓ (2)

1.4 1.4.1 V = 535 V Ia = 40 A N1 = 550 rpm Ra = 0, 5 Ω ϕ 1 = 100% (1) ϕ 2 = 70 % (0,7) T1 = 100% (1) T2 =140 % (1,4) (2)

T α Ia ϕ
T1 / T2 = Ia_1 ϕ1 / Ia_2 ϕ2 ✓
Ia_2 = T2 Ia_1 ϕ1 / T1 ϕ 2
= 1,4 x 40 x 1 / 1 x 0,7 ✓
= 80 A✓ (3)

1.4.2 E1 = V – Ia Ra
= 535 – (40 x 0,5) ✓
= 515 V ✓

E2 = V – Ia_2 Ra
= 535 – (80 x 0,5) ✓
= 495 V ✓

E1 / E2 = N1 ϕ1 / N2 ϕ2
N2 = E2 N1 ϕ1 / E1 ϕ2 ✓
= 495 X 550 X 1 / 515 X 0,7 ✓
= 755,2 r/pm ✓ (7)

[20]

QUESTION 2

2.1.1 ZA $= R - jXc$
$= 8{,}8 - j\,(1/2\pi fc)$
$= 8{,}8 - j\,(1 / 2\,\pi\,50 \times 200 \times 10^{-6})$
$= 8{,}8 - j\,15{,}92$

$= 18{,}19 < -61{,}07$ ✓

IA $= V / ZA$
$= 300 < 0 / 18{,}19 < -61{,}07$
$= 16{,}49 < 61{,}07$ A ✓

IB $= IT - IA$
$= 25 < j0 - 16{,}49 < 61{,}07$
$= 25 + j\,0 - (7{,}98 + j14{,}43)$ ✓
$= 17{,}02 - j14{,}43$
$= 22{,}31 < -40{,}29$ A ✓ (4)

2.1.2 Cos ϕ $=$ Cos $40{,}29$ ✓

$= 0{,}76$ Lagging ✓ (2)

2.1.3 Z B $= VB / IB$
$= 300 < 0 / 22{,}31 < -40{,}29$ ✓
Z B $= 13{,}45 < 40{,}29$ ✓ $= (10{,}26 + j8{,}7)$ (2)

2.1.4 XL $= 8{,}7\ \Omega$ ✓ (from ZB $= 10{,}26 + j\,8{,}7$) ✓ (1)

2.1.5 R $= 10{,}26\ \Omega$ ✓ (from ZB $= 10{,}26 + j\,8{,}7$) (1)

2.2 $C_1 = 370 \times 10^{-12}$ for (Imax)
$C_2 = 340 \times 10^{-12}$ for $I_2 = 0{,}707$ Im

$XC_1 = 1 / 2\pi f c$
$= 10^{12} / 2\pi\, 2{,}5 \times 10^6 \times 370 = 172{,}06\ \Omega$ ✓

$XL_1 = XC_1 = 172{,}06$ resonance ✓

$XL_1 = 2\,\pi f L$
$L = XL / 2\pi f = 172{,}06 / 2\,\pi \times 10^6 \times 2{,}5 = 10{,}95\ \mu H$ ✓
$XC_2 = 1 / 2\pi f C_2 = 10^{12} / 2\pi \times 10^6 \times 340 \times 2{,}5 = 187{,}24\ \Omega$ ✓

Increase in XC $= 187{,}24 - 172{,}06 = 15{,}18\ \Omega$ ✓

$I_1 = V / Z_1$ $Z_1 = R$ (resonance) ✓

$I_2 = 0,707\ I_1 \qquad = 0,707\ V / Z_1 \qquad = \quad V/ Z_2$

$Z_2 = \sqrt{R^2 + (15,18)^2}$ ✓

$0,707\ V / Z_1 = \quad V / Z_2$

$0,707\ V / R = \quad V / \sqrt{R^2 + (15,18)^2}$ ✓

$(0,707\ V)^2 / R^2 \quad = V^2 / R^2 + (15,18)^2$

$[R^2 + (15,18)^2] / R^2 \quad = V^2 / (0,707V)^2$

$[R^2 + (15,18)^2] / R^2 \quad = 1 \ / \ 0,707^2$

$R^2 + (15,18)^2 \quad = R^2 \ / \ 0,707^2$ ✓

$0,707^2\ R^2 + (0,707^2)(15,18^2) \quad = R^2$

$R^2 - 0,707^2\ R^2 \quad = (0,707^2)(15,18^2)$

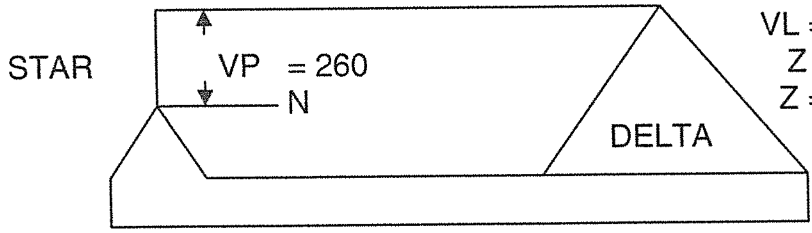
$R^2\ (1 - 0,707^2) \quad = (0,707^2)(15,18^2)$

$R^2 \quad = (0,707^2)(15,18^2) \ / \ (1 - 0,707^2)$ (10)

$R \quad = \quad 15,18\ \Omega$ ✓ **[20]**

QUESTION 3

3.1 Transformer load



$V_L = V_P = 450{,}33$
$Z = 50 + j\,75$
$Z = 90{,}14 \angle 56{,}31$

3.1.1

$V_L = \sqrt{3}\, V_P = \sqrt{3} \times 260 \quad = 450{,}33\ \text{V}$ ✓ (2)
$= V_P = 450{,}33$ ✓

3.1.2

$I_P(\text{load}) = V_P / Z_P$
$= 450{,}33 \angle 0 / 90{,}14 \angle 56{,}31$ ✓
$= 5 \angle -56{,}31$ ✓ (2)

3.1.3

$I_L = \sqrt{3} \times 5 \quad = 8{,}66\ \text{A}$ ✓ (1)

3.1.4

$P = \sqrt{3}\, I_L V_L \cos\phi$
$= \sqrt{3} \times 8{,}66 \times 450{,}33 \times 0{,}55$ ✓

$= 3{,}72\ \text{kW}$ ✓ (2)

$\cos\phi = \cos 56{,}31$

pf $= 0{,}55$ ✓ (1)

3.2 Single ph Trf. 15 kVA

$V1 / V2 = 3500 / 700 = N1 / N2$
$R1 = 7{,}5\ \Omega \quad R2 = 0{,}5\ \Omega \quad X1 = 15\ \Omega \quad X2 = 0{,}65\Omega \quad V1 = 3500\text{V} \quad \cos\phi = 0{,}8$

$I_1 = VA / V_1$
$= 15000 / 3500$
$= 4{,}29\ \text{A}$

$Re = R1 + R2\,(N1 / N2)^2$
$= 7{,}5 + 0{,}5(5)^2$
$= 20\ \Omega$ ✓

$Xe = X1 + X2\,(N1 / N2)^2$
$= 15 + 0{,}65\,(5)^2$
$= 31{,}25\ \Omega$

$Ze = \sqrt{(Re)^2 + (Xe)^2}$

$= \sqrt{(20)^2 + (31{,}25)^2}$

$= 37{,}1$ OR $20 + j\,31{,}25 = 37{,}1 \angle 57{,}38$ ✓

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REG. = I_1 (Re cos ϕ + Xe sin ϕ) / V_1

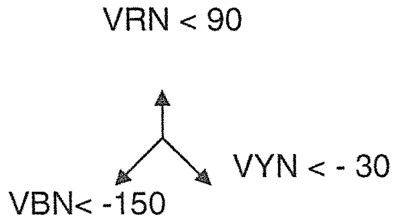
= 4,29 [(20) (0,8) + (31,25) (0,6)] / 3500
= 4,29 [16 + 18,75] / 3500
= 0,043 per unit ✓

FULL V2 = NO LOAD V2 – CHANGE
= (700) – (N/L V2 x reg)
= 700– (700 x 0,043)
= 700 – 30,1
= 669,9 V✓ (4)

3.3 3.3.1 3 PH. Star con motor VL = 500V P out = 100 kW η = 0,8
COS ϕ = 0,8
P in = 100 / 0,8
= 125 kW
P = $\sqrt{3}$ IL VL COSϕ
125 000 = $\sqrt{3}$ IL (500) (0,8) ✓

IL = 180,42 A ✓

FOR DELTA CON. MOTOR WINDING :
IL = $\sqrt{3}$ IP = $\sqrt{3}$ 180,42 = 312,5 ✓
P = $\sqrt{3}$ IL VL COS ϕ
125000 = $\sqrt{3}$ x 312,5 x V x 0,8
VL = 288,68 V ✓



Vp =380

3.4 3.4.1 Correctly connected

VRY = VRN + VNY OR
= 380 < 90 + 380 < 150 380 X $\sqrt{3}$ = 658,18,54
= (0 + j 380) + (-329 + j 190) ✓
= - 329 + j 570
= 658,13 < 120
VRY = VBR=VYB= 658,13 ✓

With one phase reversed

$VRY = 380 < 0 + 380 < -120$
$= (380 - j\,0) + (-190 - j\,329{,}09)$ ✓
$= 190 - j\,329{,}09$
$= 380 < -60$ ✓ (8)

[20]

QUESTION 4

4.1 $d1 = 125 \times 10^{-2}$ dia =0,6cm $r = 0{,}3 \times 10^{-2}$m
$d2 = 165 \times 10^{-2}$
$d3 = 235 \times 10^{-2}$

de $= \sqrt[3]{1{,}25 \times 1{,}65 \times 2{,}35}$ ✓

$= 1{,}69$ m ✓

$L = km\,[\,0{,}05 + 0{,}2 \log_e (de/r)\,]$ mH

$= 35\,[\,0{,}05 + 0{,}2 \log_e (1{,}69 / 0{,}003)$ mH ✓

$= 46{,}09$ mH ✓

C $= 35\,[\,1 / 18 \log_e (1{,}69 / 0{,}003)$ ✓
$= 0{,}307\mu f$ ✓ (6)

4.2 4.2.1 R = 22 ohms X = 30 ohms
P =2200 kW Vr = 31 kV $\cos\phi = 0{,}85 = 31{,}79$

I $= P / V \cos\phi$
$= 2200000 / 31000 \times 0{,}85$
$= 83{,}49$ A ✓

Vs $= V < \phi + IR + IX < 90$

$= 31000 < 31{,}87 + 83{,}49 \times 22 + 83{,}49 \times$
30 < 90 ✓
$= 26326{,}7 + j\,16367{,}8 + 1836{,}78 + j$
2504,7
$= 28163{,}48 + j\,18872{,}5$ ✓
$= 33902{,}1 < 33{,}83$ kV ✓ (4)

4.2.2 Reg $= Vs - Vr / Vr$
$= 33902 - 31000 / 31000$ ✓
$= 0{,}094$ ✓ (2)

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η = Po / Po + Losses

η = 2200 / $\frac{2200 + 83,49^2 \times 22}{1000}$ ✓

= 93,4 % ✓ (2)

4.3 Z = 5 + j 6 = 7,81 < 50,19 VL = 400V ϕ = 50,19 lag

Vp = 400 / √ 3
= 242,49 V ✓

IP = VP / ZP
= 230,9 < 0 / 7,81 < 50,19
= 29,56 < - 50,19 ✓

IL = IP = 29,56 < - 50,19 ✓

P2 + P1 = √ 3 VL IL COS ϕ
= √ 3 x 400 x 29,56 COS 50,19
= 13,112 kW .... (1)

TANϕ = √ 3 (P2 – P1) / P2 + P1

P2 – P1 = TAN 50,19 x 13,112 / √3 ✓
= 9,08 kW ....(2)

2 P1 = 4,03 (1 – 2)

P1 = 2,02 kW ✓

P2 = 13,112 - 2,02
= 11,092 kW ✓ (6)

[20]

QUESTION 5

5.1 P o = 650 kW V = 3800 V η = 85 % (0,85) Cos ϕ = 0,8

P in = P out / η
= 650000 / 0,85 ✓
= 764705,88 W ✓

IL = P in / √ 3 VL Cos ϕ
= 764705,88 / √ 3 x 3800 x 0,8 ✓
= 145,23 A

I (alt) = 145,23 A ✓

I (motor) = IL / √ 3
= 145,23 / √ 3
= 83,85 A ✓

S = √ 3 VL IL
= √ 3 x 3800 x 145,23 ✓
= 955873,81VA
= 955,87 KVA ✓ (7)

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5.2 5.2.1 f =50 Hz p = 4/2 = 2 Nr = 1000 rpm T = 170Nm

f = Ns / 60
∴ Ns = 60 x f / p ✓
= 60 x 50 / 2
= 1500 rpm ✓

Rotor input
P = 2 Π Ns T / 60
= 2 Π x 1500 x 170 / 60 ✓
= 26703,5 W
= 26,7 kW ✓ (4)

5.2.2 Rotor Cu Loss = S x Rotor input

S = Ns – Nr / Ns = 1500 – 1000 /1500 ✓
= 0,33 ✓
Rotor Cu Loss = 0,33 x 26703,5
= 8812,2 W ✓ (3)

5.3 f = 50 Hz ϕ = 0,3 wb kd = 0,96 N = 360 rpm

VL = √ 3 Vp
Vp = 20 / √ 3
= 11,557 kV ✓

Vp = 2 kf kd kp ϕf X
X = Vp / 2 kf kd ϕf
= 11547 / 2 x 1,11 x 0,96 x 1 x 0,3 x50 ✓
= 361,2 conductors / ph (say 362)
f = Np / 60
p = 60 f / N
= 60 x 50 / 375
= 8 pole pairs
= 16 poles ✓

Slots / phase
3 x 20 slots / phase = 60 slots / phase ✓

Cond / Slot = (cond. / ph) / (slots / ph)
= 362 / 60
= 6,03 ✓ (6)
[20]

TOTAL: 100

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