higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

T470(E)(N25)T
NOVEMBER EXAMINATION

NATIONAL CERTIFICATE

ELECTROTECHNICS N4

(8080074)

25 November 2014 (Y-Paper)
13:00–16:00

REQUIREMENTS: **Graph paper.**

Calculators may be used.

ENGINEERING

This question paper consists of 6 pages and a formula sheet of 2 pages.

Copyright reserved

DEPARTMENT OF HIGHER EDUCATION AND TRAINING
REPUBLIC OF SOUTH AFRICA

NATIONAL CERTIFICATE
ELECTROTECHNICS N4
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.

ENGINEERING

Copyright reserved

QUESTION 1

1.1 An aluminium conductor 2 000 m long is connected in parallel with a copper conductor with the same length. When a current of 300 A is passed through the combination, it is found that the current through the copper conductor is 100 A. The diameter of the aluminium conductor is 30 mm.

Calculate the following:

1.1.1 The diameter of the copper conductor if the resistivity of copper is 0,017 micro-ohm metres and that of aluminium 0,027 micro-ohm metres (7)

1.1.2 The voltage drop across the conductors (1)

1.2 A resistance of 3 ohms is connected in parallel with a resistance of 15 ohms. The combination is connected in series with a third resistance of 3,5 ohms if the whole circuit is connected across a battery having an EMF of 24 V and an internal resistance of 2 ohms.

Calculate the following:

1.2.1 The terminal voltage of the battery (3)

1.2.2 The current through each resistor of the parallel resistors. (3)

1.3 Define temperature coefficient of resistance at 0 °C. (3)

1.4 A conductor of effective length of 500 mm moves with a velocity of 10 m/s perpendicular to a magnetic field of uniform flux density of 3 T.

Calculate the following:

1.4.1 The EMF induced in the conductor (1)

1.4.2 The force acting on the conductor when it carries a current of 10 A (1)

1.4.3 The power required to move the conductor (1)
[20]

ENGINEERING

Copyright reserved

QUESTION 2

2.1 Two capacitors each having a potential difference (PD) of 500 V and 250 V respectively are connected in series across a DC supply.

Calculate the total capacitance and the capacitance across each capacitor if a charge of 1 500 micro-coulomb is measured across the capacitors. (4)

2.2 The field coils of a motor has a resistance of 300 ohms at 100 °C. After a run at full load, the resistance increases to 600 ohms at 350 °C.

Find the temperature coefficient of resistance at 100 °C. (4)

2.3 A battery having an EMF of 55 volts and an internal resistance of 0,3 ohms is connected in parallel with a direct-current generator of EMF 75 volts and internal resistance of 0,25 ohms. The combination is used to supply a load having a resistance of 2,5 ohms.

Use Kirchhoff 's laws to calculate the following:

2.3.1 The value and direction of the current through the battery (5)

2.3.2 The value and direction of the current through the generator (2)

2.3.3 The potential difference across the load (2)

2.4 Define the *ampere*. (3)
[20]

QUESTION 3

3.1 Calculate the speed of a 8 pole series generator having a wave wound armature with 600 conductors and resistance of 1,2 ohm supplying a load of 23,75 kW at 950 V. The resistance of the field winding brush contact resistance is 0, 8 ohm. The field sets up a flux per pole of 20 mWb. (5)

3.2 What type of winding would be used for:

3.2.1 A high-voltage low-current (1)

3.2.2 A high-current low-voltage DC machine. (1)

3.3 The open-circuit characteristics of a shunt-excited DC machine is as follows:

Terminal voltage (V)	20	40	80	120	160	170	180
Field current (A)	0,2	0,4	0,8	1,2	2,0	2,4	3,0

Plot a graph and determine the open-circuit voltage if the field circuit resistance is 60 ohms. (8)

ENGINEERING

Copyright reserved

3.4 A short-shunt compound generator supplies a load current of 200 A. It has a shunt-field resistance of 30 ohms, an armature resistance of 0, 1 ohms and a series field resistance of 0, 4 ohms.

Calculate the armature EMF if the terminal voltage is 220 V. (5)
[20]

QUESTION 4

4.1 A sinusoidal AC supply has a maximum value of 353,607 V and a periodic time of 60 milliseconds.

Calculate the following:

4.1.1 The RMS value of the voltage (1)

4.1.2 The average value of the voltage (1)

4.1.3 The frequency (1)

4.1.4 The instantaneous value 3 milliseconds after the commencement of the cycle (2)

4.2 A 60 kVA 6 000/600 V, 60 Hz single-phase transformer has 600 turns on the primary winding.

Calculate the following:

4.2.1 The turns ratio (1)

4.2.2 The number of secondary turns (2)

4.2.3 The secondary full-load current (2)

4.2.4 The maximum value of the core flux (2)

4.3 In a certain circuit having two parallel branches the instantaneous branch circuits are represented by:

$$i_1 = 45Sin(wt + \frac{\pi}{4})$$

$$i_2 = 60Sin(wt - \frac{\pi}{4})$$

4.3.1 Determine the total current and write it in the form

$$i = I_{max}Sin(wt + \theta)$$

(5)

4.3.2 Represent these currents by drawing a phasor diagram. (3)
[20]

ENGINEERING

QUESTION 5

5.1 At what speed must a FOUR pole alternator be driven to produce an EMF having a frequency of 50 Hz? (2)

5.2 What motor is superior in efficiency, and the most extensively used of all types of electric motors? (2)

5.3 An impedance of 50 $\angle -45°$ ohms and an impedance of 50 $\angle 45°$ ohms are connected in parallel to a 500 volt, 50Hz supply.

Determine the following:

5.3.1 The total impedance (3)

5.3.2 The current in each branch (2)

5.3.3 The current flowing in the circuit (1)

5.3.4 The overall power factor and (1)

5.3.5 Draw the phasor diagram to present the current in the circuit. (3)

5.4 A milli-ammeter with a 50 ohms coil resistance indicates a full-scale deflection when a current of 500 mA flows through it.

Calculate the value of the resistances required to enable the instrument to be used as a:

5.4.1 50 V voltmeter (2)

5.4.2 1 A ammeter (2)

5.5 Why are coal fired power stations normally built far away from the main load points? (2)

[20]

TOTAL: 100

ENGINEERING

Copyright reserved

ELECTROTECHNICS N4

FORMULA SHEET

Any applicable formula may also be used.

1. Principles of electricity

$$E = V + Ir$$

$$V = IR$$

$$R_{se} = R_1 + R_2 + \dots R_n$$

$$R_p = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \dots \frac{1}{R_n}}$$

$$R = \rho \frac{\ell}{a}$$

$$\frac{R_1}{R_2} = \frac{1 + \alpha_o T_1}{1 + \alpha_o T_2}$$

$$R_t = R_\theta \left[1 + \alpha_\theta \left(t - \theta\right)\right]$$

$$P = VI = I^2 R = \frac{V^2}{R}$$

$$\Phi = \frac{mmf}{S} = \frac{IN}{S}$$

$$H = \frac{IN}{\ell}$$

$$F = B\ell I$$

$$E = \frac{\Delta\Phi}{\Delta t} . N$$

$$E = B\ell v$$

$$E = \frac{L\Delta I}{\Delta t}$$

$$L = \frac{\Delta\Phi}{\Delta I} . N$$

$$Q = VC$$

$$Q_{se} = Q_t = Q_1 = Q_2 \dots = Q_n$$

$$C_{se} = \frac{1}{\frac{1}{C_1} + \frac{1}{C_2} + \dots \frac{1}{C_n}}$$

$$Q_p = Q_1 + Q_2 + \dots Q_n$$

$$C_p = C_1 + C_2 + \dots C_n$$

2. Direct-current machines

$$E = \frac{2Z}{c} . \frac{Np}{60} . \Phi$$

$$c = 2a$$

$$E_{gen} = V + I_a R_a$$

$$E_{mot} = V - I_a R_a$$

$$R_{start} = \frac{(V - E)}{I_a} - R_a$$

3. Alternating-current machines

$$E_m = 2\pi BANn$$

$$e = E_m \sin\left(2\pi f . t \times 57{,}3\right)^\circ$$

$$E_{ave} = 0{,}637\ E_m$$

$$E_{rms} = 0{,}707\ E_m$$

$$T = \frac{1}{f}$$

ENGINEERING

Copyright reserved

$$f = \frac{Np}{60}$$

$$\omega = 2\pi f$$

$$Z_L = R + j\omega L$$

$$Z_c = R - j\frac{1}{\omega C}$$

$$pf = \cos\phi = \frac{R}{Z}$$

$$S = VI$$

$$P = V.I\cos\phi = I^2R$$

$$Q = V.I\sin\phi$$

4. Transformers

$$E = 4{,}44\ f\ \Phi_m\ N$$

$$k_t = \frac{N_1}{N_2} = \frac{V_1}{V_2} = \frac{I_2}{I_1}$$

5. Measuring instruments

$$R_{SH} = \frac{i_m\ R_m}{I_{sh}}$$

$$R_{se} = \frac{V}{i_m} - R_m$$

ENGINEERING

Copyright reserved

higher education & training

Department:
Higher Education and Training
REPUBLIC OF SOUTH AFRICA

MARKING GUIDELINE

NATIONAL CERTIFICATE

NOVEMBER EXAMINATION

ELECTROTECHNICS N4

25 NOVEMBER 2014

This marking guideline consists of 8 pages.

Copyright reserved

QUESTION 1

1.1 1.1.1

$$A_a = \frac{\pi d_a^2}{4} = \frac{\pi(30x10^{-3})^2}{4} = 7{,}0685834x10^{-4}\,m^2 \checkmark$$

but $I_a = I_T - I_c = 300 - 100 = 200A \surd$

$$Va = IaRa$$
$$= 200x0{,}076394372 = 15{,}27887454\ V \checkmark$$
$$R_c = \frac{V_c}{I_c} = \frac{15{,}27887454}{100} = 0{,}152788744\ \Omega \checkmark$$

$$R_a = \frac{P_a x L_a}{A_a} = \frac{0{,}027x10^{-6}\,x\,2\,000}{7{,}0685834x10^{-4}} = 0{,}076394473\ \Omega \checkmark$$

$$d = \sqrt{\frac{4P_cL_c}{\pi R_c}} = \sqrt{\frac{4x0{,}017x10^{-6}x2000}{\pi(0{,}152788744)}} = 16{,}833mm \checkmark\checkmark$$

(7)

1.1.2 V11 = 15,279 V (1)

1.2 1.2.1

$$R_T = R_{se} + \frac{1}{\frac{1}{R_1}+\frac{1}{R_2}} \qquad I = \frac{E}{R_T + r} \qquad V = IR_T$$

$$= 3{,}5 + \frac{1}{\frac{1}{3}+\frac{1}{15}} \qquad = \frac{24}{6+2} \qquad = 3x6$$

$$= 3{,}5 + \frac{1}{0{,}4} \qquad = \frac{24}{8} \qquad = \underline{18\ V} \checkmark$$

$$= 3{,}5 + 2{,}5 \qquad = \underline{3\ A} \checkmark$$

$$= \underline{6\ \Omega} \checkmark$$

(3)

1.2.2 $I_P = 2,A$

But $V_P = I\ R_P = 3 \text{ x}2{,}5 = \underline{7{,}5\ V} \checkmark$

Thus $I_1 = \frac{V}{R_1} = \frac{7{,}5}{3} = 2{,}5\ A$ ✓

$I_2 = \frac{V}{R_2} = \frac{7{,}5}{15} = 0{,}5\ A$

(3)

1.3 The temperature coefficient of resistance of a material at 0 ˚C is the increase in resistance of a sample having a resistance of one ohm at0 ˚C, when its temperature is raised by 1 ˚C (or 1 K) ✓✓✓ (3)

Copyright reserved

1.4 1.4.1 EMF = BLV = 3 x 0,5 x 10 = 15 V ✓

1.4.2 F = BLI = 3 x 0,5 x 10 = 15 N ✓

1.4.3 P = VI = 15 x 10 = 150 W (3)
[20]

QUESTION 2

2.1 $C_S = \frac{1}{\frac{1}{6}+\frac{1}{3}} = 2\ \mu F$ ✓✓

$Q_T = Q_1 = Q_2 = V_1C_1 = V_2C_2$

$C_1 = Q_1 / V_1 = 1\ 500/250 = 6\ \mu F$✓

$C_2 = Q_2 / V_2 = 1\ 500/500 = 3\ \mu F$✓ (4)

2.2 $R_t = R_{25}[1+\alpha_{100}(t-\theta)]$

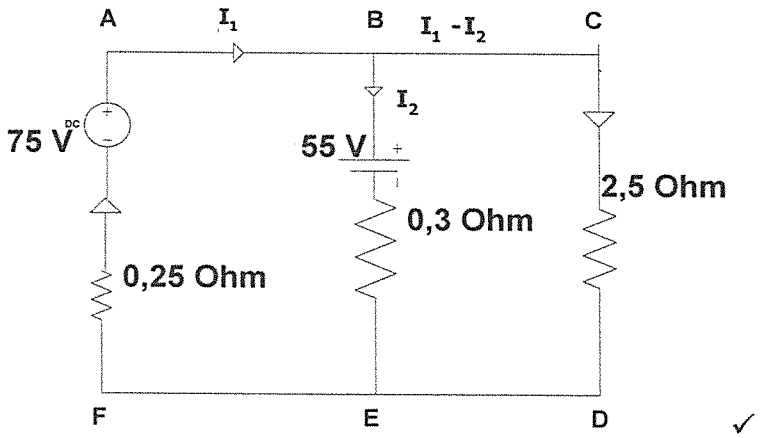
$600 = 300[1+\alpha_{100}(350°-100°)]$

$\alpha_{100}(250°) = \frac{(\frac{600}{300}-1)}{0,004}$ ✓✓✓✓

$\alpha_{100} = (\frac{2-1}{250})$

$\alpha_{100} = 0,004\ per\ °C$ (4)

2.3



✓

Copyright reserved

2.3.1 Consider loop:ABEFA

$\sum E - \sum IR = 0$

$(E_1 - E_2) - (I_1R_1 + I_2R_2) = 0$

$(75 - 55) - (I_1 0{,}25 + I_2 0{,}3) = 0$ √

$20 - I_1 0{,}25 + I_2 0{,}3 = 0 \ldots\ldots\ldots (1)$

lus:ACDFA

$\sum E - \sum IR = 0$

$(E_1 - (I_1R_1 + R_3(I_1 - I_2) = 0$

$75 - [0{,}25I_1 + 2{,}5(I_1 - I_2)] = 0$ √

$75 - 2{,}75\, I_1 + 2{,}5\, I_2 = 0 \ldots\ldots (1)$

Eq. (1)x2,5/0,3 166,67- 2,083 I_1 -2,5 I_2 =0 ✓

Eq. (2) + (3) = 241,67 – 4,83 I_1 =0 ✓

Thus: I_1 =241,67/4,83 = 50 A

Substitute I_1 = 50 A into/in Eq.

20 –0,25(50) =0,3 I_2

I_2 = 7,5/0,3 = 25 A ✓

$I_1 - I_2$ = 25 A (5)

2.3.2 $I_G = I_1$ 50 A✓ (2)

2.3.3 $I_L = I_1 - I_2$ 25 A

$V_L = I_L \times R_L$

= 25 x 2,5

= 62,5 V (2)

2.4 The ampere is defined as the current which if maintained in two straight parallel conductors of infinite length of negligible cross-sectional area, and placed 1 metre apart in a vacuum, would produce between the conductors a force of 2×10^{-7} newton per metre of length. ✓✓✓ (3)

[20]

QUESTION 3

3.1 Vloed =0,02 Wb P = 4 C = 2 Z = 600

$I_a = I_L = P / V = 23{,}75x10^3 / 950 = 25A$ √

$E = V + I_a(R_a + R_{se})$

= 950 + 25 (1,2 + 0,8)

= 1 000 V✓

$E = (2Z/C)(NP/60)x\Phi_m$

1 000 = (2x600/2)(N4/60)x0,02✓

1 000 = 0,8N

N = 1 000/0,8

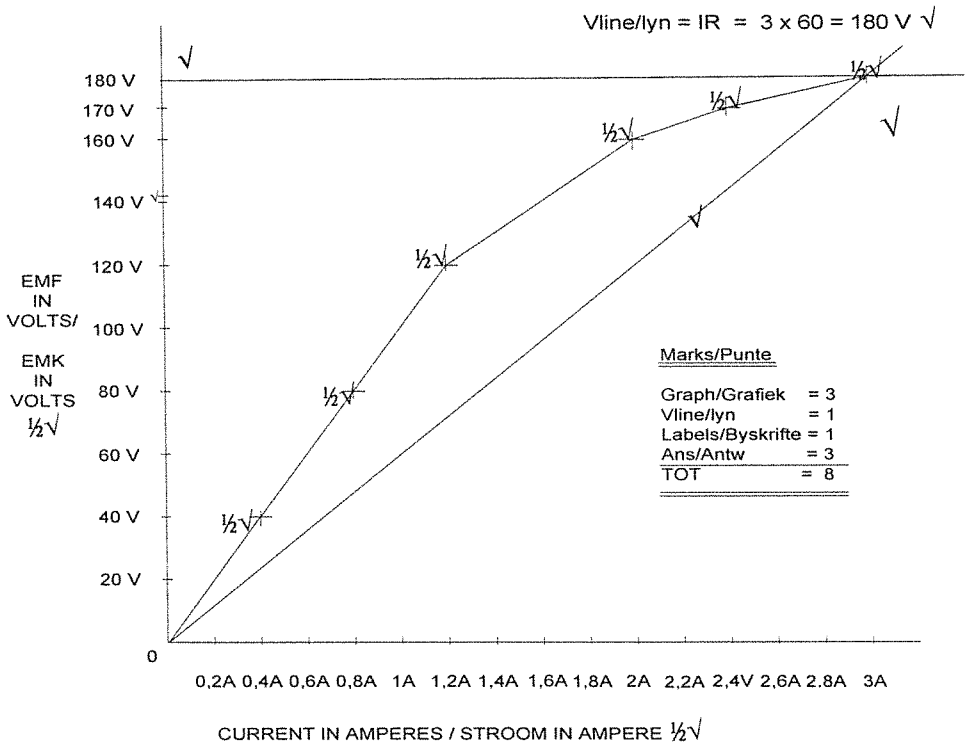
= 1 250 RPM✓ (5)

3.2 3.2.1 Wave ✓

3.2.2 Lap ✓ (2)

Copyright reserved

3.3



(8)

3.4

$$I_{SH} = \frac{V + I_L R_{SE}}{R_{SH}}$$

$$= \frac{220 + (200 \times 0,4)}{30} \quad ✓✓$$

$$= \frac{300}{30}$$

$$= \underline{10\ A}$$

$$E = V + I_a R_a + I_L R_{SE} \quad ✓$$

$$= 220 + (210 \times 0,1) + 200(0,4)$$

$$= 220 + 21 + 8(\quad ✓$$

$$= \underline{321\ V}$$

$$I_a = I_L + I_{SH}$$

$$= 200 + 10$$

$$= \underline{210\ A} \quad ✓$$

(5)
[20]

QUESTION 4

4.1 4.1.1 $E_R = 0{,}707\,E_M = 0{,}707 \times 353{,}607 = 250$ V ✓

4.1.2 $E_{AVE} = 0{,}637\,E_M = 0{,}637 \times 353{,}607 = 225{,}25$ V ✓

4.1.3 $f = 1/T = 1/60 \times 10^{-3} = 16{,}67$ Hz ✓

4.1.4 $e = E_M \sin 2\Pi ft \times 180/\Pi$
$= 353{,}607 \sin(2\Pi\, 16{,}67 \times 0{,}003 \times 180/\Pi)$ ✓
$= 353{,}607 \sin 18$
$= 353{,}607 \times 0{,}309$
$= 109{,}273$ V ✓ (5)

4.2 4.2.1 $\frac{N_1}{N_2} = 6\,000/600 = 10$ (10:1) ✓

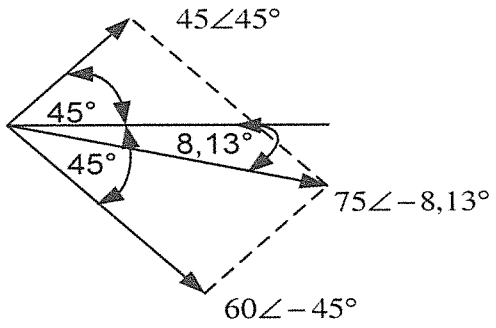
4.2.2 $\mathbf{N_2 = \frac{N_1 V_2}{V_1} = \frac{600 \times 600}{6000} = 60\ Turns}$ ✓✓

4.2.3 $\mathbf{I_2 = \frac{S}{V} = \frac{60\,000}{600} = 100\ A}$ ✓✓

4.2.4 Core Flux = E/4,44fN = 6 000/4,44 x 60 x 600 = 37,54 mWb ✓✓ (7)

4.3 4.3.1 $\mathbf{i_1 = 45\angle 45° = 31{,}82 + j31{,}82}$ ✓✓
$\mathbf{i_2 = 60\angle -45° = 42{,}43 - j42{,}43}$
Total I =74,246 - j 10,607 = $75\angle -8{,}13°$ ✓✓
$\mathbf{I_T = 75\ Sin(wt - 8{,}13°)}$ ✓ (5)

4.3.2



(3)
[20]

QUESTION 5

5.1 $$f = \frac{PN}{60}$$

$$N = \frac{fx60}{P} = \frac{50x60}{2} = 1\,500\ RPM$$ ✓✓ (2)

5.2 AC motors (or) Induction motors √√ (2)

5.3 $$Z_1 = 50\angle -45 = 35,36 - j35,36$$
$$Z_2 = 50\angle 45 = 35,36 + j35,36$$
$$Z_1 + Z_2 = 70,711 + j0$$ ✓

5.3.1 $$Z_T = \frac{Z_1 Z_2}{Z_1 + Z_2} = \frac{2500\angle 0°}{70,711\angle 0°} = 35,36\angle 0° = 35,36\ \Omega$$ ✓✓ (3)

5.3.2 $$I_1 = \frac{V}{Z_1} = \frac{500\angle 0°}{50\angle -45°} = 10\angle 45° = 7,071 + j7,071\ A$$ ✓

$$I_2 = \frac{V}{Z_2} = \frac{500\angle 0°}{50\angle 45°} = 10\angle 45° = 7,071 - j7,071\ A$$ ✓ (2)

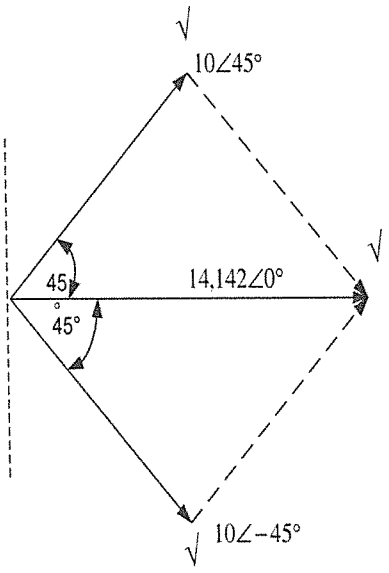
$$I_T = I_1 + I_2 = 14,142 + j0 = 14,142\angle 0°\ A$$ ✓ OR (1)

5.3.3 $$I_T = \frac{V}{Z_T} = \frac{500\angle 0°}{35,36\angle 0°} = 14,142\angle 0° = 14,142 + j0\ A = 14,142\ A$$ ✓

5.3.4 p.f = Cos 0 = 1✓ (1)

Copyright reserved

5.3.5



(3)

5.4 5.4.1 $$R_{SE} = \frac{V}{I_M} - R_M = \frac{50}{500x10^{-3}} - 50 = 50\,\Omega$$ ✓✓

$$I_{SH} = I_L - I_M = 1 - 500x10^{-3} = 0,5\,A$$ ✓

5.4.2 $$R_{SH} = \frac{I_M R_M}{I_{SH}} = \frac{500x10^{-3} \times 50}{0,5} = 50\,\Omega$$ ✓

(4)

5.5 To be near the coalfields in order to reduce transport cost ✓✓ (2)
[20]

TOTAL: 100

Copyright reserved