UNIVERSITY OF KWAZULU-NATAL

School of Engineering
Electrical, Electronic & Computer Engineering

ENEL2EL: ELECTRICAL ENGINEERING
MAIN EXAMINATIONS, MAY/JUNE 2014

Time allowed: 3 hours

Instructions to Candidates:

1. This paper contains 6 questions
2. Answer **TWO Questions in Section A** and **TWO Questions in Section B**
3. **USE AND LABEL A SEPARATE ANSWER BOOK FOR EACH SECTION.**
4. The marks for each question/section are indicated.
5. Answers should show sufficient working steps to indicate the solution method used.
6. Any additional examination material is to be placed in the answer book and must indicate clearly the question number and the Student I.D. number

The following materials are provided
1. Formula sheet
2. Graph paper

Examiners
1. Prof. Thomas Afullo
2. Dr. Remy Tiako

Independent Moderator
1. Prof V. Srivastava

SECTION A: Answer ANY TWO Questions
(USE A SEPARATE BOOKLET FOR THIS SECTION)

Question 1-A: [25]

a) In Figure Q1(a), determine, using Kirchhoff's Current Law:

i) The nodal equations
ii) The node voltages
iii) The currents through all the resistors

[11]

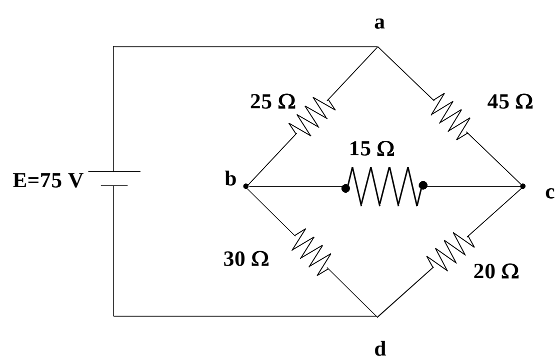


Fig. Q1(a)

b) Consider the circuit shown in Fig. Q1(b). Determine:

i) The Thevenin resistance seen by the load, R_L.
ii) The Thevenin voltage
iii) The Norton current
iv) The load current, and power dissipated by the load.

[7]

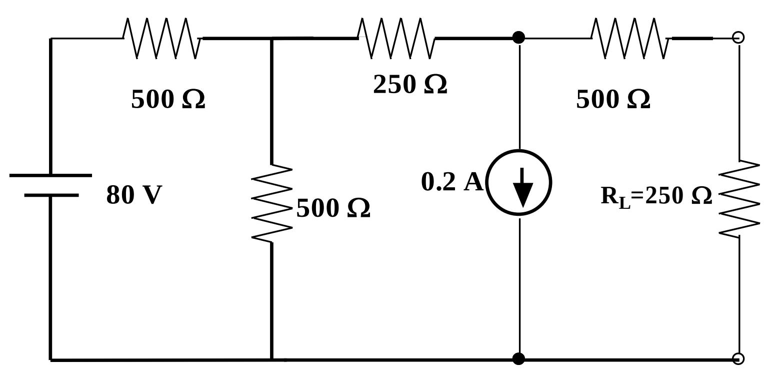


Fig. Q1 (b)

c) Consider the circuit in Fig. Q1(c), which includes one dependent source.

i) Using Kirchhoff's voltage Law, write down the loop equations, incorporating the constraining equation imposed by the dependent source.

ii) Solve for the loop currents

iii) Determine the total power dissipated in the 20-Ω resistor with potential v_{ab}.

[7]

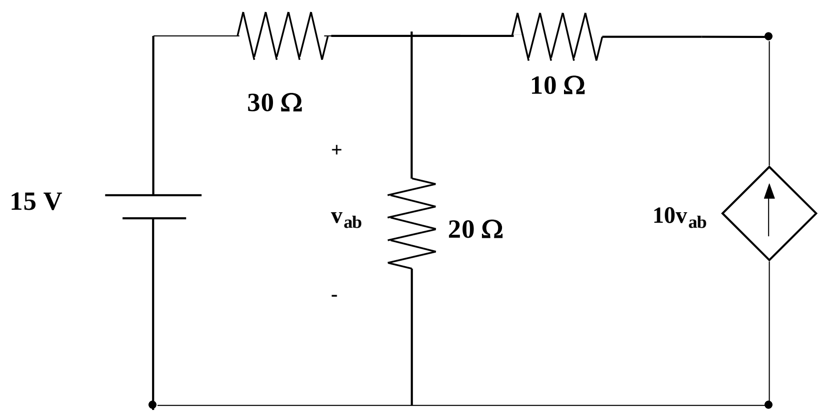


Fig. Q1 (c)

Question 2-A [25]

a) The circuit of Fig. Q2(a) is a simple model of an automotive ignition system. The switch models the "points" that switch electric power to the spark plug after the fuel-air mixture is compressed. R is the resistance between the electrodes. Determine:

i. The expression and solution for the inductor voltage and current during charging (switch is at position 1 in Fig. Q2(a)).

ii. The expression for the inductor voltage and current during discharging (switch is changed to position 2)

iii. The value of L and R_1 so that the voltage across the spark plug gap after the switch is changed (after the coil is fully fluxed) is 27,000 V, and so that this voltage will change exponentially with a time constant τ=21 μS.

[12]

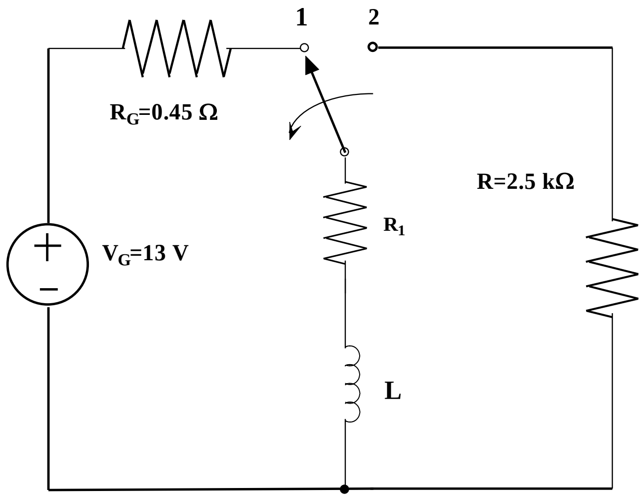


Fig. Q2(a)

b) For a domestic load, the voltage and current at 60 Hz are given by:

$$v(t) = 100\cos(377t + 15^{o})\ \text{V};\quad i(t) = 2\cos(377t - 15^{o})\ \text{A}$$

i. Convert voltage and current into phasor quantities
ii. Compute the load impedance
iii. Determine the real power and reactive power
iv. Compute the complex power and the power factor

[6]

c) For the circuit shown in Fig. Q2(c), with frequency f=50 Hz,
i. Calculate the power factor
ii. Calculate the new reactive power when the power factor is corrected to unity (pf=1.0).
iii. Determine the parallel capacitance required to obtain pf of 1.0.

[7]

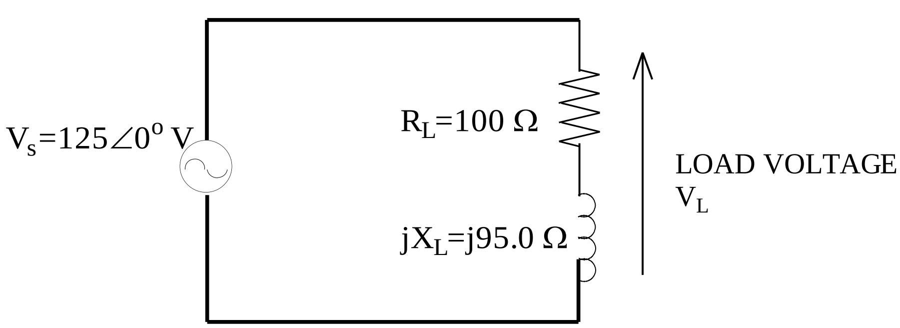


Fig. Q2(c)

Question 3-A [25]

a) For the circuit in Fig. Q3(a) below, determine:

i) The Thevenin equivalent
ii) The load impedance that gives maximum power transfer
iii) The load power for the above load impedance

[12]

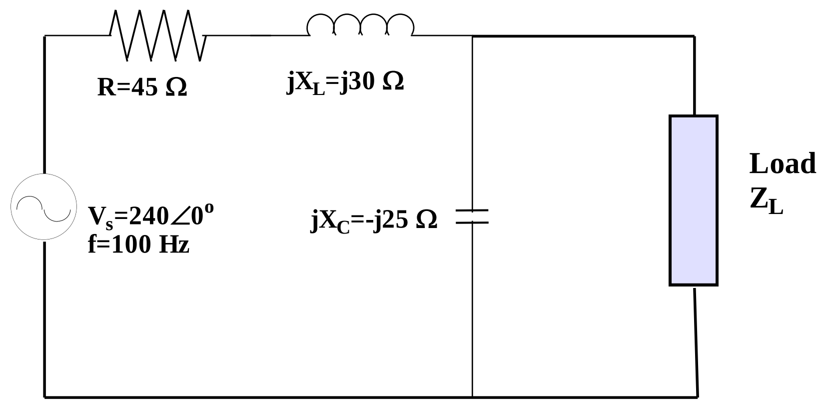


Fig. Q3(a)

b) For the circuit shown in Fig. Q3(b), use the mesh method to determine:

i. The loop equations
ii. The loop currents
iii. The voltage V

[13]

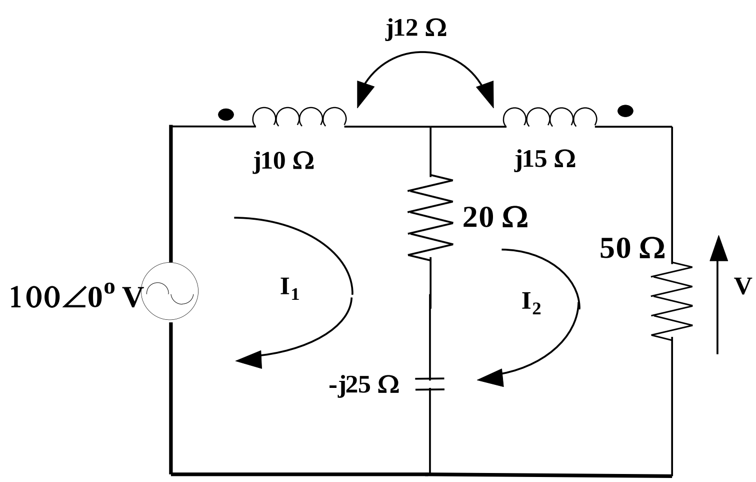


Fig. Q3(b)

SECTION B: Answer ANY TWO Questions
(USE A SEPARATE BOOKLET FOR THIS SECTION)

Question 1B [25 Marks]

The magnetic core as shown in Fig. B1 is made of Cast steel and is symmetrical about the centre leg. The magnetizing coils are identical and each coil comprises of N = 120 turns, has a resistance of 3.45 Ω and is supplied from a DC voltage source. All dimensions are in millimeters and the length of the air gap is 0.5 mm. The permeability of free space μo is $4\pi \times 10^{-7}$ H/m and the BH curve is attached to the exam paper.

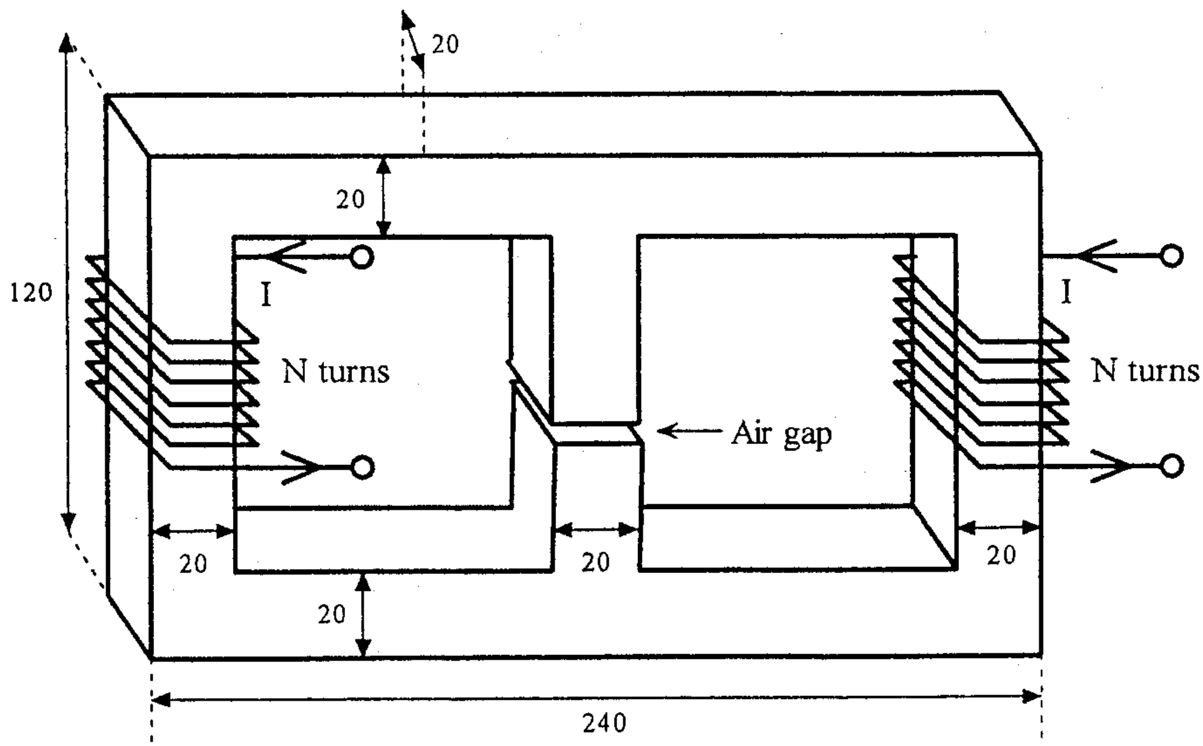


Figure 1B: Magnetic core of Question B1

(a) Draw the analogous electric circuit of the magnetic core showing MMFs, reluctances (with notations indicating corresponding average core lengths) and direction of magnetic fluxes.

[5]

(b) Determine the voltage that must be supplied to the magnetizing coil of Fig. B1 in order to produce a flux density of 1.1 T in the air gap. You may assume flux fringing to be negligible.

[15]

(c) Determine the reluctance of the central vertical leg.

[5]

Question 2B [25 Marks]

The name plate on a single phase 50 Hz transformer reads 100 kVA, 25-kV/250-V and has the following equivalent parameters referred to high voltage (HV) side:

Resistance representing the core losses: $R_c = 50\ k\Omega$

Magnetizing reactance of the primary winding: $X_m = 62.5\ k\Omega$

Equivalent resistance referred to HV side: $R_{eqhv} = 250\ \Omega$

Equivalent reactance referred to HV side: $X_{eqhv} = 140\ \Omega$

(a) If the open circuit and short circuit tests were performed on this transformer and all measurements were done on the high voltage side, calculate the expected measured values of active power and current for each of those two tests (i.e.: P_{oc}, I_{oc}, P_{sc} & I_{sc}). Note that the applied voltage for the open circuit test is the rated primary voltage and for the short circuit test, 7.5 % of rated primary voltage is used.

[9]

(b) Calculate the current that will flow through the secondary when the transformer supplies a load of 90 kVA with a lagging power factor of 0.8 at rated secondary voltage.

[**2]**

(c) Calculate the efficiency of the transformer for this load.

[7]

(d) Calculate the voltage regulation of the transformer from no load to full load at unity power factor.

[7]

Question 3B [25 Marks]

(a) A separately excited DC generator turning at 1500 rpm produces an induced voltage of 140 V. The armature resistance is 2 Ω and the machine delivers a current of 15 A. Calculate:

(i) The terminal voltage.

(ii) The heat dissipated in the armature.

(iii) The breaking torque exerted by the armature.

[5]

(b) The compound motor as shown in Fig. 2B has 1600 turns on the shunt field winding and 40 turns on the series field winding, per pole. The shunt field has a total resistance of 120 Ω, and the nominal armature current is 30 A. If the motor is connected to a 240 V line, calculate the following:

(i) The mmf per pole at full load.

(ii) The mmf per pole at no load.

[7]

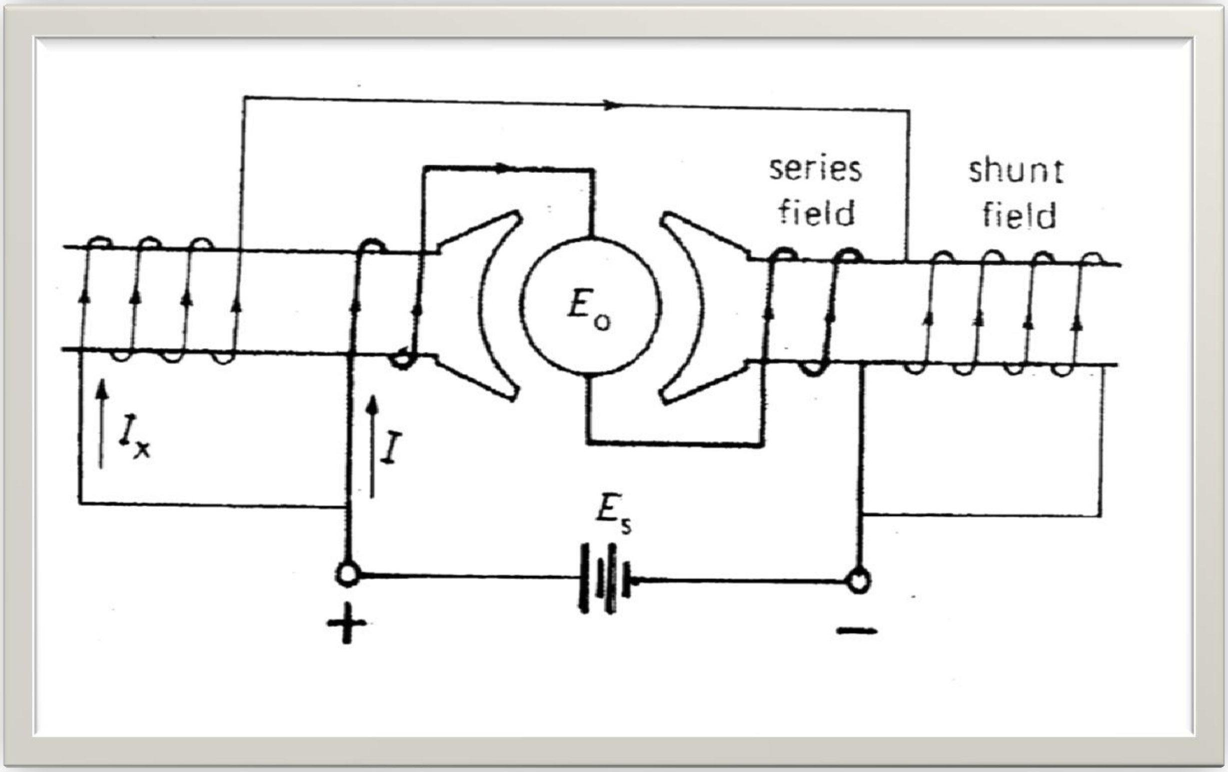
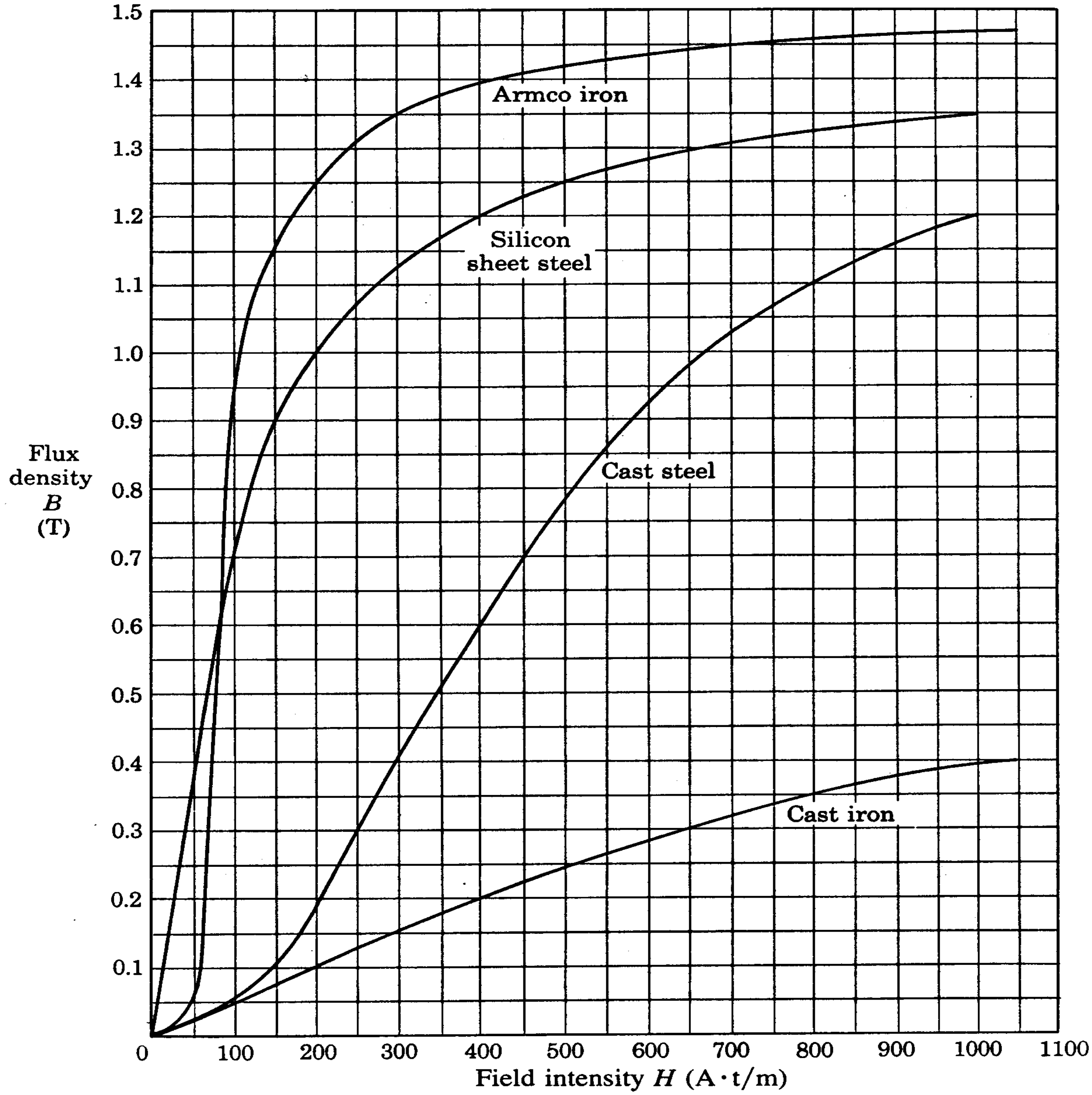


Figure 2B: Compound motor of Question 3B $_{(b)}$

(c) A six pole armature is wound with 456 conductors. The speed and magnetic flux are such that 0.75 V is generated in each conductor. The conductor current is 30 A.

(i) Draw a schematic diagram showing the numbers of conductors in each current parallel path for a lap and wave wound armatures.
(ii) Determine the generated voltage and armature current for the lap winding connection.
(iii) Determine the generated voltage and armature current for wave winding connection.
(iv) What is the total generated power for the lap and wave connected winding?

[13]


1.5
1.4
1.3
1.2
1.1
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Flux density B (T)
Armco iron
Silicon sheet steel
Cast steel
Cast iron
0
100
200
300
400
500
600
700
800
900
1000
1100
Field intensity H (A·t/m)

FORMULA SHEET

Ampere's law: $\oint \mathbf{H} \cdot d\ell = N\,i = \Im$

Gauss' law: $\oint \mathbf{B} \cdot d\mathbf{A} = 0$

Permeability of free space: $\mu_0 = 4\pi \times 10^{-7}$

Reluctance of magnetic path: $\Re = \dfrac{\ell}{\mu A}$

$F = Bli \qquad E = Blv$

$E = V_a \pm I_a R_a \qquad E = k\Phi\omega \qquad T_{em} = k\Phi I_a \qquad \eta = \dfrac{P_{out}}{P_{in}} \qquad \epsilon = \dfrac{V_{nl} - V_{fl}}{V_{fl}}$

$I = |I|\angle -\theta \quad I^* = (|I|\angle -\theta)^* = |I|\angle\theta \quad I * I^* = |I|^2$

$S = V * I^* = \quad |V| * |I|\{Cos(\theta) + jSin(\theta)\} = \quad P + jQ = \quad |I|^2 (R + jX) = |I|^2 Z = \dfrac{|V|^2}{(R - jX)} = \dfrac{|V|^2}{Z^*}$

$(a + jb) * (a - jb) = a^2 + b^2 = \left(\sqrt{a^2 + b^2}\right)^2 \qquad \dfrac{1}{a + jb} = \dfrac{a - jb}{a^2 + b^2};$

$\dfrac{a + jb}{c + jd} = \dfrac{(a + jb) * (c - jd)}{c^2 + d^2} = \dfrac{(ac + bd) + j(bc - ad)}{c^2 + d^2} \qquad a + jb = \sqrt{a^2 + b^2}\angle atan\left(\dfrac{b}{a}\right)$

All symbols have the usual meaning.