EE2005 – ELECTRICAL DEVICES AND MACHINES

TUTORIAL 1 – MAGNETIZATION CURVES AND MAGNETIC CIRCUITS

1. A cast iron toroid has a mean length of 20 cm. It has a circular cross-section whose diameter is 2 cm. The core is wound by the coil of 100 turns and carries a current of 5 A. The value of the flux density in the iron is 1.0 T. Calculate the flux in the iron, mmf and the magnetic field intensity.

   [Ans: 0.314 mWb; 500 At; 2500 At/m]

2. (a) A 100-turn coil is uniformly wound on a ferromagnetic ring of mean diameter 200 mm and cross-sectional area 800 mm^2. If the current in the coil is 5 A and the magnetic flux in the core is 2 mWb, determine (i) the mmf and the magnetic field intensity at the mean circumference of the ring, (ii) the relative permeability of the iron.

   [Ans: (i) 500 At, 795.77 At/m; (ii) 2500]

   (b) An iron circuit has a cross-sectional area of 1000 mm^2 and length 500 mm. If the flux density in the core is 1.2 T, and the relative permeability of the iron is 1500, determine the reluctance of the magnetic circuit, and the mmf needed to produce the flux.

   [Ans: 2.65 x10^5 At/Wb; 318.31 At]

3. Figure 1 shows an electromagnetic system which is made up of three sections.

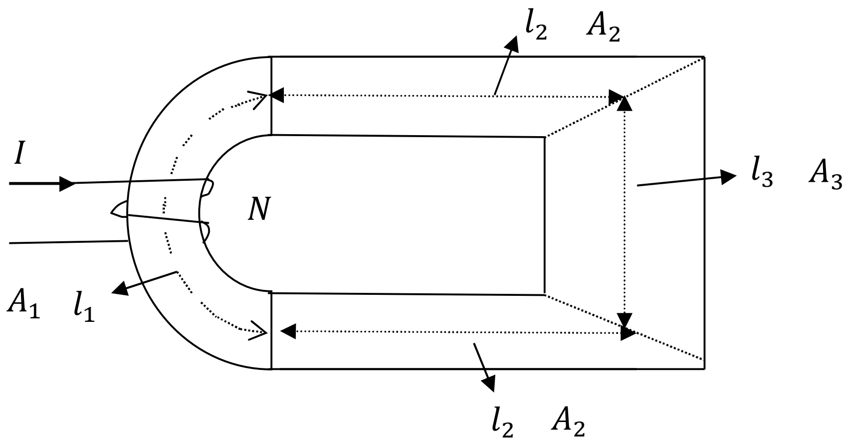

Figure 1

The details are as follows:

$A_1 = A_2 = 30\text{x}10^{-4}\ m^2, \quad A_3 = 60\ \text{x}10^{-4}\ m^2$
(cross-sectional areas of the various sections)
$l_1 = 0.225\pi\ m$ (mean length of arc section)
$l_2 = l_3 = 0.45\ m$ (mean lengths of the core sections)
$\mu_1 = 2000, \quad \mu_2 = \mu_3 = 2500$
(relative permeabilities of the various sections)
$N = 200$ turns, $\qquad I = 0.8\ A$

(a) Draw the magnetic equivalent circuit showing the reluctances of various parts.
(b) Determine the flux in the core.
(c) Determine the flux densities in various parts of the core.
(d) Determine the current required in the coil to produce a flux density of 0.4 T in the circular core.

[**Ans: (a) $\Re_{total}$ = 213117 H^{-1}; (b) 0.75 mWb; (c) 0.125 T, 0.25 T; (d) 1.28 A**]

4. The magnetic circuit in Figure 2 has a 200-turn coil wound on the left limb. The cross-sectional areas of the left limb, center limb and the right limb are 12 cm^2, 8 cm^2 and 4cm^2, respectively. Given the following data for the iron circuit, calculate the current in the coil to give a flux of 0.88 mWb in the center limb. Neglect leakage and fringing.

[**Ans: 0.76A**]

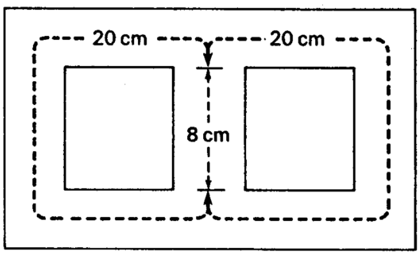

Figure 2

H(At/m)	260	350	500	650	975
B(T)	0.8	0.9	1.0	1.1	1.2

5. Suspose the data for the iron circuit in Q4 is not given. Instead, the relative permeability of the iron $\mu_r = 2450$ is now provided. Calculate the current in the coil to give a flux of 0.88 mWb in the center limb.

[**Ans: 0.4287 A**]

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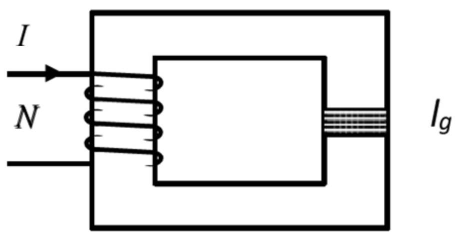
TUTORIAL 2 – MAGNETIC CIRCUITS AND INDUCTANCE

1. The magnetic structure with an air gap length of $l_g = 0.1$ cm is shown in Figure 1, where the core is wound uniformly with 250 turns. The mean length of the core is 39.9 cm and the cross-sectional area is 8 cm^2. Given the following data for the iron circuit, determine the current I needed to produce a flux of 0.72 mWb in the air gap.

[Ans: 3.423 A]



H(At/m)	350	650	975	1200
B(T)	0.9	1.1	1.2	1.25

Figure 1

Suppose the data for the iron circuit is not given, but $\boldsymbol{\mu_r = 2450}$ is provided instead. Calculate the current need to establish at flux of 0.72 mWb in the air gap. Also, find the inductance of the coil.

[**Ans: 3.33 A, 54 mH**]

2. Calculate the inductance of a magnetic toroid core with a 25 cm mean diameter and a circular cross-sectional area 6.25 cm^2. The toroid is wound uniformly with 1000 turns of wire. Find the emf induced when a current increasing at a rate of 200 A/s flows in the winding. The magnetic material has a relative permeability of 800.

   Suppose a coil of 1000 turns has a flux of 2 μWb linking with it when carrying a current of 2 A. If this current is reduced to 0.5 A in 1 ms, determine the magnitude of the average voltage induced in the coil and the final flux.

[**Ans: 0.8 H; 160 V; 1.5 V; 0.5 μWb**]

3. Consider the magnetic structure of Figure 2 which consists of three sections, namely, the left limb, the center limb and the right limb.

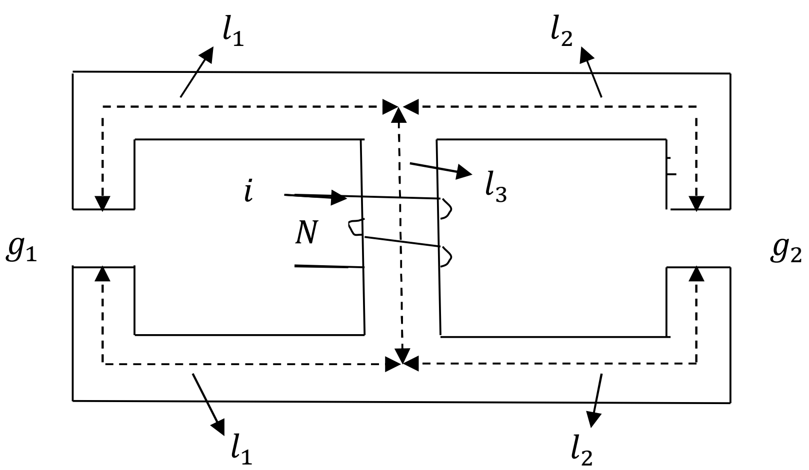


Figure 2

The dimensions of the magnetic structure are as follows:

$l_1 = l_2 = 3.95\ cm$	$l_3 = 4\ cm$	(mean lengths of core)
$A_1 = A_2 = 1\text{x}10^{-4}\ m^2$,	$A_3 = 2\text{x}10^{-4}\ m^2$	(cross-sectional areas)
$g_1 = 0.1\ cm$	$g_2 = 0.1\ cm$	(air gap lengths)

The permeability of the magnetic material is $\mu = 2000\mu_o$, where $\mu_o = 4\pi\text{x}10^{-7}$ H/m. The coil consists of $N = 400$ turns and has a total resistance of 1 Ω.

(a) What is the inductance of the system?

[Ans: (a) 37.92 mH]

(b) If a dc current of 2.5 A is flowing through the coil, calculate:
- (i) Flux density in the core.
- (ii) The energy stored in the air gap, the energy stored in the magnetic core and the total magnetic energy stored in the system.

[Ans: (i) 1.185 T; (ii) 0.1117 J, 0.00665 J, 0.1184 J]

(c) If the coil is now connected to a 50 Hz AC source, determine the amplitude of the input voltage required to establish the same flux density in the core as in part (b)(i) above.

[Ans: 29.9 V]

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TUTORIAL 3 – MAGNETIC LOSSES AND ELECTROMECHANICAL ENERGY CONVERSION

1. The core losses in a certain specimen of iron were found to be 4000 W at a frequency of 50 Hz. When the supply frequency is changed to 30 Hz maintaining the flux density unchanged, the core losses were found to be 1800 W. Calculate the eddy current loss at the frequency of 50 Hz.

   [**Ans: 2500 W**]

2. An inductor core is designed to operate at 120 V at 60 Hz. Estimate the effect on the hysteresis and eddy current losses of operating at 150 V at 50 Hz. Assume that the Steinmetz index n = 1.6.

   [**Ans: Losses increase by 0.59 and 0.56, respectively**.]

3. The electromagnet shown in Figure 1 is used to lift a steel bar. The system is excited by a coil of 2500 turns wound over the semi-circular part of the magnetic core. The cross section of the magnetic core is 20 mm x 40 mm throughout the structure. The air gap 'g' is 10 mm. Assume that the permeabilities of the magnetic core and the steel bar are infinitely high. The permeability of free space $\mu_0 = 4\pi \times 10^{-7}$ H/m.

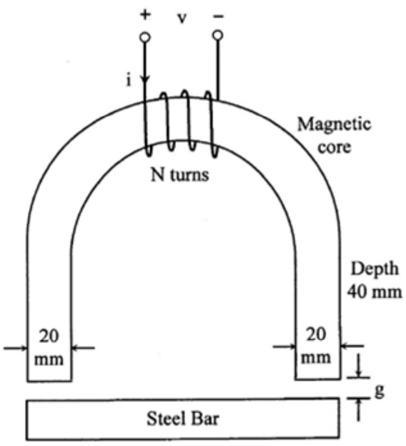

Figure 1

(a) Find the coil current required to produce a flux density of 1.25 T in the air gap.
(b) Determine the energy stored in the magnetic system.
(c) Calculate the force acting on the steel bar.

If the air gap 'g' is reduced to 5 mm, determine the coil current required to produce the same force as in part (c) above.

[**Ans: (a) 7.96 A; (b) 9.95 J; (c) 994.72 N; 3.98 A**]

4. The magnetic circuit, as shown in Figure 2 is excited by a 100-turn coil wound over the central limb. Determine the current in the coil that is necessary to keep the movable part suspended at a distance of 1 cm. What is the energy stored in the system? The relative permeability and the density of the magnetic material are 2000 and 7.85 g/cm^3 respectively. The acceleration due to gravity g = 9.81 m/s^2.

[**Ans: 14.28 A, 8.5 mJ**]

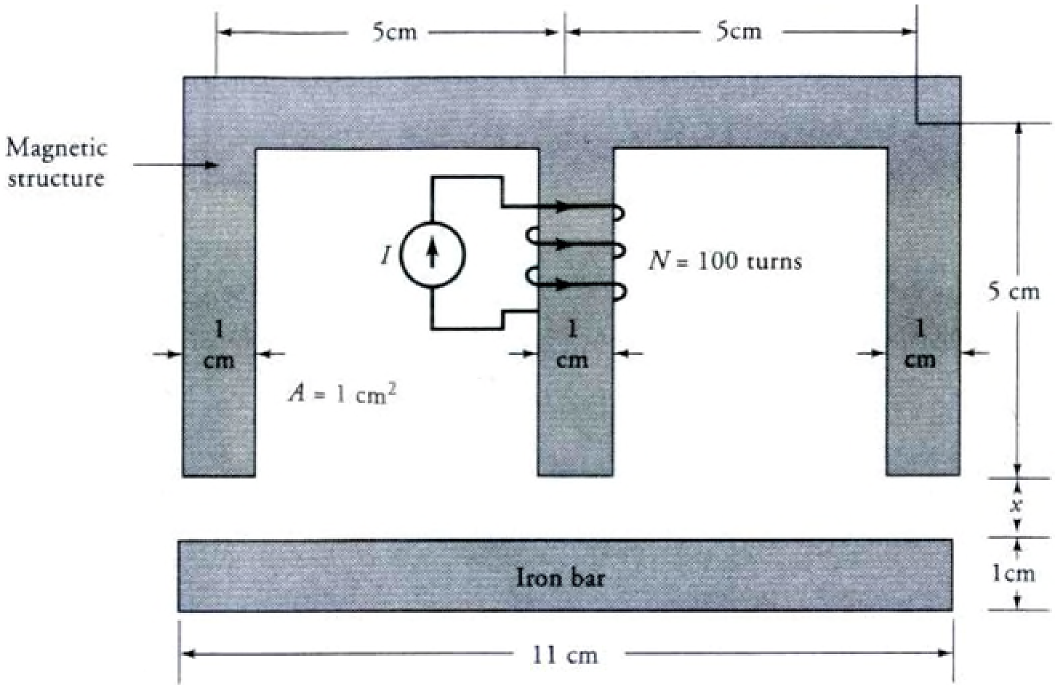

Figure 2

EE2005 – ELECTRICAL DEVICES AND MACHINES

TUTORIAL 4 - TRANSFORMER FUNDAMENTALS AND APPROXIMATE EQUIVALENT CIRCUITS

1. A single-phase, 1-kVA, 250/100-V, 60-Hz transformer has 120 turns on the primary winding. Calculate (a) the turns ratio, (b) the number of turns on the secondary winding, and (c) the rated currents of the two windings. Find the maximum flux in the core when the transformer is connected to a 250-V, 60-Hz source. If the 250-V terminals were connected to a 220-V, 50-Hz supply, determine the percent change in the flux density in the core.

   [**Ans: (a) 2.5; (b) 48 turns; (c) 4 A, 10 A; 7.82 mWb, 5.6%**]

2. Consider a 200 kVA, 22000/2200-V, 50 Hz single-phase transformer with the following parameters:

   $R_1 = 5.0\ \Omega$, $X_1 = 30\ \Omega$, $R_2 = 0.3\ \Omega$, $X_2 = 1.0\,\Omega$,
   $R_{c1} = 150\ k\Omega$, $X_{m1} = 75\ k\Omega$ H ,

   Draw the approximate equivalent circuits of the transformer referred to the high-voltage side and to the low voltage side, showing the proper numerical values of the parameters in the circuits.

3. The nameplate of a transformer reads: single-phase, 100 kVA, 11000/2200 V, 60 Hz.

   (a) Calculate the full-load (rated) currents in the high-voltage and low-voltage sides.

   [**Ans: 9.09 A, 45.45 A**]

   (b) The transformer has the following parameters:

   $R_1 = 6.0\ \Omega$, $X_1 = 30.16\ \Omega$, $R_2 = 0.28\ \Omega$, $X_2 = 1.21\,\Omega$,
   $R_{c1} = 125\ k\Omega$, $X_{m1} = 60.32\ \text{k}\Omega$,

   Draw the approximate equivalent circuit of the transformer referred to the high-voltage side and use it to carry out the following calculations.

   (c) Calculate the:
   (i) No-load current and no-load power factor,
   (ii) No-load power loss (i.e., core loss), and
   (iii) Full-load copper loss.

   [**Ans: (i) 0.2 A, 0.44 (lag); (ii) 968 W; (iii) 1074 W**]

   (d) Calculate the input voltage and the input current while supplying full load at 0.85 lagging power factor at rated voltage. Take the rated secondary voltage as the reference.

   [**Ans: 11397 V, 9.26 A]**

   (e) Repeat part (d) above using the approximate equivalent circuit of the transformer referred to the low-voltage side.

EE2005 – ELECTRICAL DEVICES AND MACHINES

TUTORIAL 5 – TRANSFORMER EFFICENCY AND TESTING

1. The maximum efficiency of a 100-kVA transformer is 98.4% and occurs at 90 per-cent of full load. Calculate the efficiency of the transformer at unity power factor at (a) full load and (b) 50 percent of full load. [Hint: Use the expression for efficiency and note the condition for maximum efficiency and the core losses are assumed constant.]

   [**Ans: 98.39; 98.12**]

2. In a 50-kVA, 11-kV/400-V, single-phase transformer, the core and copper losses are 500 W and 600 W, respectively under rated conditions. Calculate (a) the efficiency at unity power factor at full load, (b) the load for maximum efficiency (Hint: kVA at maximum efficiency = rated kVA x $\sqrt{\frac{P_{core}}{P_{cu(fl)}}}$) and (c) the iron and copper losses for this load.

   [**Ans: 97.85 %; 45.64 kVA; 500 W; 500 W**]

3. A 500-kVA, 30/10-kV, 50-Hz, single-phase transformer has the high-voltage winding resistance of 18 Ω and the low-voltage winding resistance of 4 Ω. Use the approximate equivalent circuit referred to the low voltage side to do the calculations.

   (a) Determine the total copper loss of the transformer at full load.

   [Ans: 15 kW]

   (b) If the total core loss of the transformer is 10 kW, estimate the efficiency of the transformer at half load at 0.85 lagging power factor.

   [**Ans: 93.92%**]

   (c) What is the maximum efficiency of the transformer at 0.85 lagging power factor?

   [**Ans: 94.55%**]

4. The 75-kVA, 4600/230-V, 50-Hz transformer gave the following test results.

   Open-Circuit Test (with 4600 V side open)

   V_{OC} = 230 V, I_{OC} = 13.04 A, P_{OC} = 521 W

   Short-Circuit Test (with 230 V side shorted)

   V_{SC} = 160.8 V, I_{SC} = 16.3 A, P_{SC} = 1200 W

   (a) Determine the parameters of the approximate equivalent circuit of the transformer referred to the primary side.

   [**Ans: R_{c1} = 40.616 kΩ, X_{m1} = 7164 Ω, R_{e1} = 4.517 Ω, X_{e1} = 8.77 Ω**]

   (b) Draw the approximate equivalent circuit referred to the low-voltage side showing all the circuit parameter values.

   (c) Use the circuit in (b) to calculate the voltage regulation and the efficiency of the transformer when it delivers full load at 0.85 lagging power factor at rated voltage.

   [**Ans: 3.01%, 97.32%**]

EE2005 – ELECTRICAL DEVICES AND MACHINES

TUTORIAL 6 - AUTOTRANSFORMERS AND THREE-PHASE TRANSFORMER BANKS

1. A 1000/200-V, 25-kVA, 50-Hz transformer is connected as an autotransformer to yield a transformation ratio of 1000/1200. Calculate its kVA rating. Calculate also the currents in the two windings when the autotransformer is fully loaded.
   [**Ans:150 kVA; 125 A; 25 A**]

2. The primary and secondary voltages of an autotransformer are 440 V and 360 V respectively. If the secondary current is 80 A, determine the primary current. Calculate the power transferred to the load inductively and conductively. Also, determine the kVA rating of the autotransformer.
   [**Ans: 65.45 A; 5.235 kVA; 23.56 kVA; 28,8 kVA**]

3. A 10-kVA, 2400/240-V, 50-Hz distribution transformer is to be used as a step-up autotransformer. The input voltage is 2400 V. Determine the current ratings of the two windings and the maximum power that can be delivered with this connection. Calculate the amount of power transferred by (a) conduction, and (b) magnetic induction. Ignore losses.
   [**Ans: 4.167 A, 41.67 A, 110 kVA, 100 kVA, 10 kVA**]

4. A three-phase transformer bank is to handle 500 kVA and have a 34.5/11-kV voltage ratio. Find the rating of each individual transformer in the bank (high voltage, low voltage, and apparent power) if the transformer bank is connected in the following arrangements: (a) Y-Y, (b) Y-Δ, (c) Δ-Y, (d) Δ-Δ.
   [**Ans: Y-Y 19.9 kV 6.35 kV 167 kVA; Y-Δ 19.9 kV 11.0 kV 167 kVA; Δ-Y 34.5 kV 6.35 kV 167 kVA; Δ-Δ 34.5 kV 11.0 kV 167 kVA**]

5. An ideal three-phase step down transformer, connected Δ-Y delivers power to a balanced three-phase load of 120 kVA at 0.8 power factor. The input line voltage is 11 kV and the turns- ratio of the transformer, phase to phase is 10. Determine the line voltage, line currents, phase voltages and phase currents on both the primary and the secondary sides. What is the power (kW) consumed by the load?
   [**Ans: V_{LY} = 1.9 kV; $V_{L\Delta}$ = 11 kV; I_{LY} = 36.4 A; $I_{L\Delta}$ = 6.3 A; $I_{\phi\Delta}$ = 3.64 A; 96 kW**]

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TUTORIAL 7 - THREE-PHASE TRANSFORMERS

1. A three-phase transformer is assembled by connecting three 480-VA, 240/80-V, single-phase transformers. The constants for each transformer are R_1 =12.6 Ω, X_1 = 14.4 Ω, R_2 = 1.4 Ω, X_2 = 1.6 Ω, R_{c1} = 5.76 kΩ, and X_{m1} = 0.456 kΩ. If the transformer bank is connected in the Y-Y, Y-Δ, Δ-Y and Δ-Δ configurations, draw the per-phase Y-Y equivalent circuit for each configuration.

2. Three identical single-phase transformers, each rated 50 kVA, 2300/230 V, 50 Hz, are connected to form a three-phase Δ/Y transformer bank. The total effective impedance of each single-phase transformer referred to its high-voltage side is (1.33+j4.0) Ω. Using the one phase Y-Y equivalent circuit referred to the primary side, determine the input current and input voltage of the three-phase transformer bank when it delivers full load at 0.9 lagging power factor at rated voltage. Ignore the no-load current.
[**Ans: 37.65 A, 2365 V**]

3. A 100-kVA, 2300/460-V, 50-Hz, Y/Δ-connected, three-phase transformer has the total effective impedance of (0.045+j0.16) Ω/phase referred to its low-voltage side. The transformer is connected to a three-phase source through three-phase feeders. The impedance of each feeder is (0.5+j1.5) Ω. The transformer delivers full load at 460 V and 0.85 lagging power factor.

   (a) Draw the one phase Y-Y equivalent circuit of the system referred to the primary side.
   (b) Determine the sending end voltage of the three-phase source.
   (c) Calculate the complex power input at the sending end of the feeder.

   [**Ans:** (b) **2398 V, (c) (86.6+j58) kVA**]

EE2005/3010 ELECTRICAL DEVICES AND MACHINES

TUTORIAL 8 – Induction Motors 1

Q1. A 220-V, 3-phase, 6-pole, 50-Hz induction motor is running at a slip of 3.5 percent. Determine:

a. The speed of the rotating field in rev per min.
b. The speed of the rotor in rev per min.
c. The slip speed of the rotor.
d. The rotor frequency (i.e. the frequency of the voltage induced in the rotor) in hertz.

[Ans : (a) 1000 rpm (b) 965 rpm (c) 35 rpm (d) 1.75 Hz]

Q2. The air-gap power of a 6-pole, 60-Hz induction motor running at a speed of 1100 rpm is 5 kW. Determine the power developed?

[Ans : 4583.35 W]

Q3. A 3-phase, 8-pole, 50-Hz induction motor is running at a speed of 710 rpm with an input power of 35 kW. The stator copper loss at this operating condition is known to be 1200 W while the rotational losses are 600 W. Determine:

a. The rotor copper losses.
b. The power developed.
c. The output power.

[Ans : (a) 1802.554 W (b) 31997.446 W (c) 31397.446 W]

Q4. A 3-phase, 440-V, 50-Hz, 4-pole, Y-connected induction motor has a stator resistance of 0.12 ohm/phase. The rotational losses of the motor are 2.4 kW. At full-load, the motor takes an input power of 42.5 kW at a power factor of 0.85 lagging and runs at 1470 rpm. Determine:

a. The input current and stator copper losses.
b. The air-gap power and rotor copper losses.
c. The developed torque, load torque and efficiency of the motor.

**[Ans : (a) 65.608 A, 1549.587 W (b) 40950.413 W, 819.008 W,
(c) 260.698 N-m, 245.108 N-m, 88.78 %]**

Q5. A 4-pole, 440-V, 50-Hz, Y-connected, 3-phase induction motor has a stator impedance of (0.15 + *j* 0.8) ohm/phase and a rotor impedance (referred to the stator) of (0.2 + *j* 0.8) ohm/phase at standstill. The magnetizing reactance is 30 ohms/phase. The rotational losses of the motor are 750 W. Using the equivalent circuit, determine the following when the motor operates at a full-load slip of 4 %.

a. Input current and input power factor.
b. Air-gap power and developed power.
c. Load torque and efficiency of the motor.

**[Ans : (a) 47.841 A, 0.899 lag (b) 31733.978 W, 30464.619 W
(c) 197.051 N-m, 90.693 %]**

EE2005/3010 ELECTRICAL DEVICES AND MACHINES

TUTORIAL 9 – Induction Motors 2

Q1. A 3-phase, 440-V, 50-Hz, 4-pole, Y-connected induction motor has the following per-phase parameters referred to the stator.

$$R_1 = 0.4\ \Omega, R_2 = 0.5\ \Omega, X_1 = 1.2\ \Omega, X_2 = 1.5\ \Omega, X_M = 80\ \Omega$$

a) Determine the speed at which maximum torque is developed.
b) Determine the corresponding maximum torque developed, input current and input power factor.
c) Determine the starting torque developed.
d) What resistance should be added in each phase of the rotor circuit, referred to the stator, to obtain maximum starting torque developed?

[Ans : (a) 1223.4 rpm (b) 192.931 N-m, 62.217 A, 0.737 lag
(c) 74.825 N-m (d) 2.212 ohms]

Q2. A 3-phase, 220-V, 50-Hz, 4-pole, Y-connected induction motor is tested with the following results:

No-load :	220 V, 5.7 A, 380 W
Locked rotor :	79.5 V, 18.57 A, 675 W
DC test :	9.02 V, 17.2 A

a) Determine the per-phase parameters of the induction motor equivalent circuit referred to the stator and the rotational losses of the motor. Assume that $X_1 = X_2$.
b) Determine the efficiency of the induction motor when it is running at it's rated speed of 1410 rpm.

[Ans : (a) $R_1 = 0.262\ \Omega, R_2 = 0.39\ \Omega, X_1 = 1.192\ \Omega, X_2 = 1.192\ \Omega,$
$X_M = 21.091\ \Omega,\ P_{rot} = 354.463\text{W}$ (b) 83.538%]

Q3. Consider the induction motor with parameters as given in Q1. Obtain an expression for the developed power P_{dev} in terms of the slip *s* and hence determine the speed at which maximum power is developed by the motor and the value of the maximum developed power. Compare the answers with the answers obtained in Q1 for the power developed and the speed at which the maximum torque is developed.

$$[\text{Ans} : P_{dev_{\max}} = 25295.039 \text{ W}, n_m = 1274.55 \text{ rpm}]$$

EE2005/3010 ELECTRICAL DEVICES AND MACHINES

TUTORIAL 10 – Induction Motors 3

Q1. A 3-phase, 460-V, 60-Hz, 4-pole Y-connected induction motor has a full-load speed of 1740 rpm and the per-phase parameters referred to the stator are as follows.

$$R_1 = 0.25\ \Omega, R_2 = 0.2\ \Omega, X_1 = X_2 = 0.5\ \Omega, X_M = 30\ \Omega$$

The rotational losses of the motor are 1700 W. Determine

a) (i) The input current at starting.
   (ii) Starting torque developed.

b) (i) Full-load slip.
   (ii) Input current when running at full load.
   (iii) Ratio of the input starting current to the full-load input current.
   (iv) Input power factor at full load.
   (v) Full-load torque developed.
   (vi) Motor efficiency at full load.

c) (i) Slip at which maximum torque of the motor is developed.
   (ii) Maximum torque developed.
   (iii) Ratio of maximum torque developed to full-load torque developed.

d) What resistance should be added in each phase of the rotor circuit, referred to the stator, to obtain maximum starting torque developed?

[Ans : (a) 244.10 A, 183.489 N-m (b) 0.0333, 42.787 A, 5.705, 0.941 lagging, 162.989 N-m, 87.244 % (c) 0.1955, 429.381 N-m, 2.634 (d) 0.823 ohms]

Q2. A certain 3-phase induction motor has a torque developed of 345 N-m when running at a slip of 0.01. The rotor copper loss at this slip is 5.69 kW. Assume that the rotational losses are negligible.

a) If the rotor circuit resistance is increased by 5 times, determine the torque developed if the slip is also assumed to be increased by 5 times to 0.05.
b) What is the rotor copper loss with the conditions in (a).

[Ans : (a) 345 N-m (b) 28.4 kW]

Q3. Suppose that the stator winding resistance $R_1 = 0\ \Omega$.
Using the induction motor equivalent circuit and its Thevenin equivalent circuit, show that

$$\frac{T_{dev_{\max}}}{T_{dev}} = \frac{s_{\max}^2 + s^2}{2 s_{\max} s}$$

where

$T_{dev_{\max}}$ is the maximum torque developed with corresponding slip $s_{\max}$, and
T_{dev} is the torque developed at any slip s.

[The above equation shows the relationship between the torque developed at any speed and the maximum torque developed in terms of their respective slip values, if $R_1 = 0\ \Omega$.]

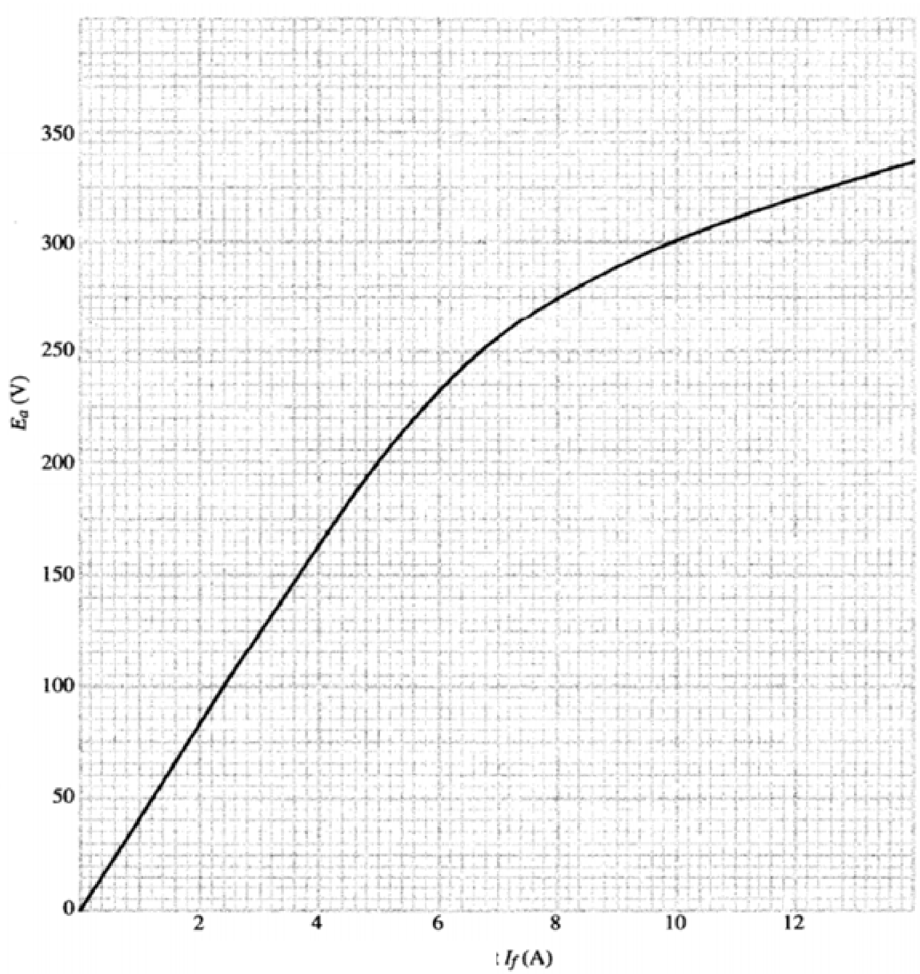
EE2005/3010 ELECTRICAL DEVICES AND MACHINES

TUTORIAL 11 - DC Motors

Q1. The magnetisation curve of a DC machine obtained at 1200 rpm is shown below. The armature winding resistance (including the brushes, interpoles and compensating windings) is 0.125 ohm and the field winding resistance is 15 ohms. The DC machine operates as a separately-excited motor with an armature terminal voltage supply of 250 V. Its field circuit is connected to a separate 120 V dc supply. The motor has a no-load speed of 1085 rpm. Determine

a) The rotational losses of the motor.
b) The speed, load torque and efficiency of the motor when it draws its rated current of 200 A from the supply.
c) The required armature terminal voltage when the motor runs at 800 rpm and its developed torque reduces to 70% of the value in part (b).

[Ans :(a) 2693.333 W (b) 981.818 rpm, 411.48 N-m, 83.019 % (c) 200.833 V]



Q2. A 240-V DC shunt motor has an armature winding resistance of 0.3 ohm and field winding resistance of 120 ohms. The rotational losses and armature reaction in the motor are negligible. At full load, the motor takes an input power of 10 kW and runs at 1000 rpm.

a) Determine the internal generated voltage and developed torque of the motor at full load.
b) Determine the armature current and torque developed by the motor when it is running at a speed of 990 rpm.
c) Determine the speed of the motor when a 60 ohms resistance is added in series with the field winding. Assume that the motor is running with 50% full load torque and is operating in the linear part of the magnetisation curve.

[Ans :(a) 228.1 V, 86.402 N-m (b) 47.27 A, 102.963 N-m
(c) 1519.931 rpm]

Q3. A 240-V DC shunt motor has an armature winding resistance of 0.25 ohm and rotational losses of 500 W. The field winding resistance is 120 ohms.

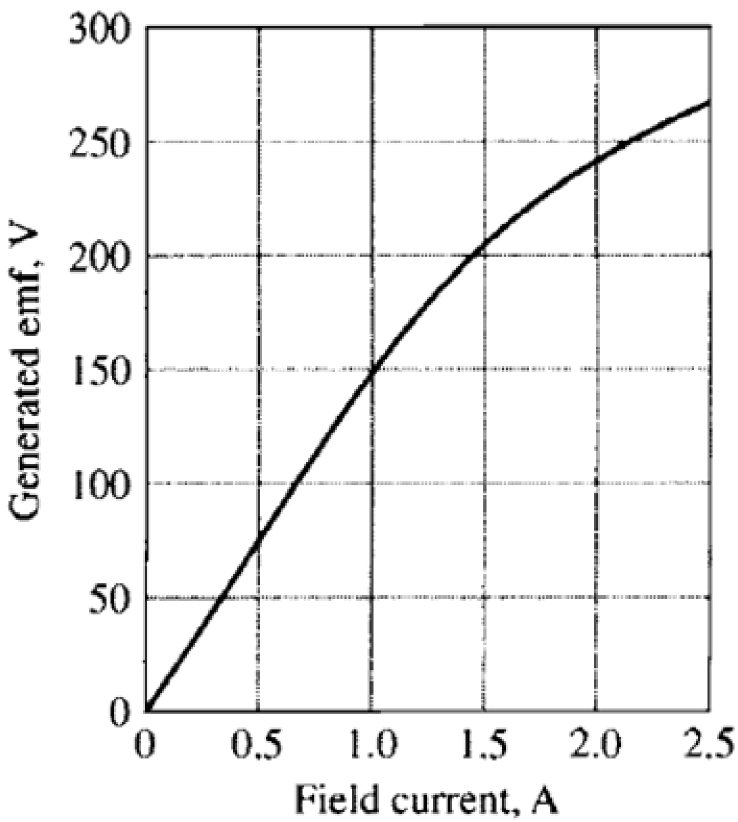
a) Determine the internal generated voltage, developed power, output torque and efficiency of the motor if it takes an input power of 20 kW at 240 V while running at 1200 rpm.
b) If the internal generated voltage is 230 V, determine the input current, motor speed, output power and developed torque of the motor.
c) What would be the input current and speed of the motor if the load is disconnected from the motor shaft?

[Ans :(a) 219.667 V, 17866.176 W, 138.196 N-m, 86.831 %
(b) 42 A, 1256.447 rpm, 8.7 kW, 69.922 N-m
(c) 4.088 A, 1308.224 rpm]

EE2005/3010 ELECTRICAL DEVICES AND MACHINES

TUTORIAL 12 - DC Generators

Q1. The magnetisation curve of a 250-V DC machine at a speed of 1200 rpm is given below. The machine is connected as a separately excited dc generator. The armature winding resistance of the machine is 0.14 ohm.



a) Suppose that the generator is supplying an armature current of 100 A. With the generator speed held at 1200 rpm, calculate the output power of the generator for constant field currents of

(i) 1.0 A
(ii) 2.0 A
(iii) 2.5 A

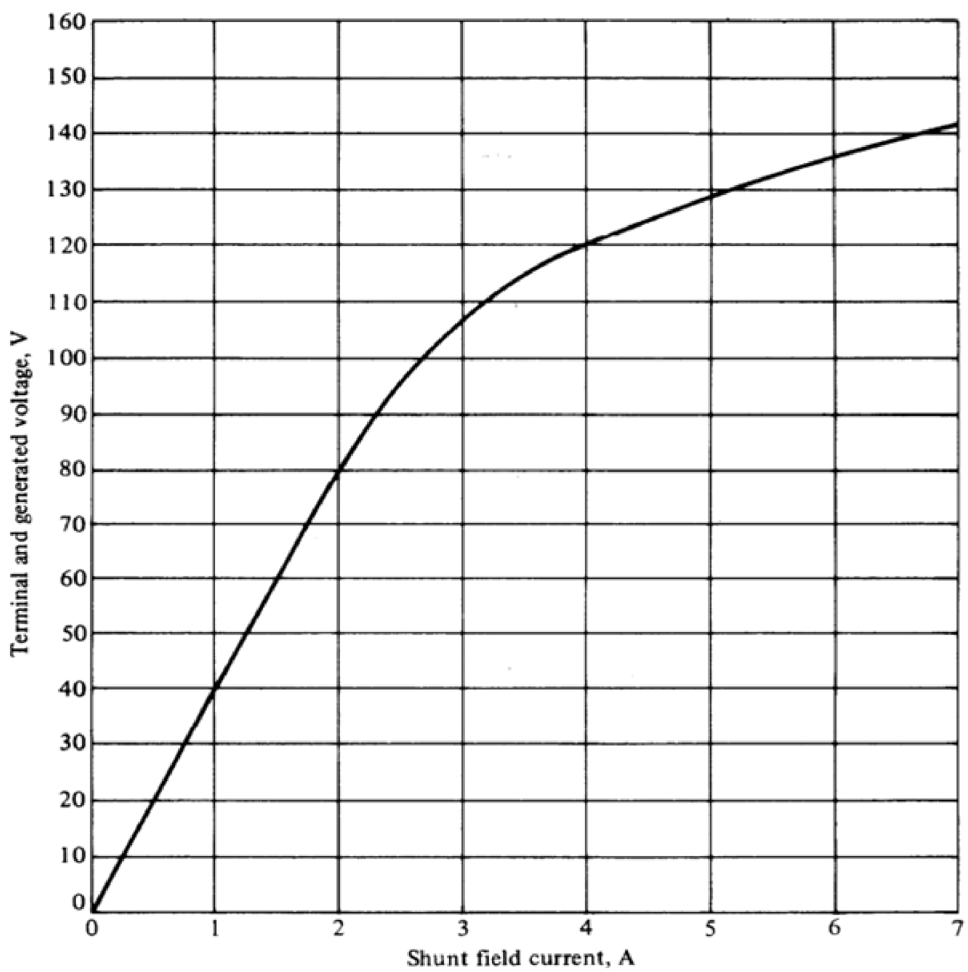
b) Repeat part (a) if the generator's speed is reduced to 900 rpm.

[Ans :(a) 13.6 kW, 22.6 kW, 25.6 kW (b) 9.85 kW, 16.6 kW, 18.85 kW]

Q2. The magnetisation curve of a 120-V, 10-kW, 1800-rpm DC machine is given below. The armature and field winding resistances of the machine are 0.20 ohm and 18 ohms, respectively. The field circuit has a rheostat of 0 to 15 ohms connected in series with the field winding. The rotational losses of the machine are 650 W. The DC machine operates as a separately-excited generator with a field circuit voltage of 130 V and it is driven at 1800 rpm. Calculate

a) The field rheostat setting to obtain a terminal voltage of 120 V at no-load condition.
b) The field rheostat setting when the generator supplies an output power of 9600 W at a rated terminal voltage of 120 V. Neglect armature reaction.
c) The efficiency of the generator for the above load condition.

[Ans :(a) 14.5 ohms (b) 3.667 ohms (c) 77.985 %]



Q3. The DC machine in Q2 is now operated as a shunt-connected DC generator and is driven at 1800 rpm. Determine

a) The field rheostat setting to obtain a terminal voltage of 120 V at no-load condition.
b) The terminal voltage when the generator delivers an armature current of 50 A. Neglect armature reaction. Use the field rheostat setting as obtained in (a).
c) The input shaft torque and efficiency of the generator for the load condition in (b).

[Ans :(a) 12 ohms (b) 105 V (c) 33.953 N-m, 76.289 %]