جامعة بنها ـ كلية الهندسة ببنها ـ قسم الهندسة الكهربية

نموذج الإجابة لامتحان مادة الات وقوى كهربية ك 362 تخلفات السبت21 -5- 2016

مدرس بالقسم شوقي حامد عرفه

الفرقة الثالثة كهرباء الكترونيات لائحة قديمة

Benha University **Benha Faculty of Engineering** **Subject: Elect. Mach. & power (E362)**	**Time: 3hour** **Forth Year 21-5-2016** **Elect. Eng. Dept. تخلفات**

Solve only four questions & draw as much as you can (questions in two pages)

Question (1) **[15] Points**

1.a) Define: magnetic field- flux Density- core losses?

1.b) A ferromagnetic ring has a mean circumference length of 1.5 m and a cross sectional area of 5 cm^2 is wound with 500 turns of wire. When the excitation current is 5A the flux is found to be 2mWb. Determine the flux density and the relative permeability of the ring?

Question (2) **[15] Points**

2.a)) Explain the construction and theory of operation of a transformer?

2.b) A 50KVA, 2400V:240V, 60Hz, distribution transformer has a leakage impedance of (0.1+j0.20) Ω in the high voltage winding and (0.01+j0.01)Ω in the low voltage winding. Neglect the exciting branch impedance when a resistive load current is 50A and voltage is 240V in the low side?

i-Draw the equivalent circuit referred to the high side?

ii-Find the input voltage applied on the high side?

iii-Find the resistive load and p.f. ?

P.T.O.

Question (3) **[15] Points**

3.a) Sketch and explain the torque-speed characteristics of a 3-phase induction motor?

3.b) A three phase 220V, 60Hz, 6 poles,10HP, wye-connected induction motor has a stator impedance of (0.3+j0.5) Ω/phase and (0.1+j0.2)Ω/phase of the rotor winding referred to the stator side. The exciting branch impedance viewed from the stator side is (j15 Ω). The no load loss=200 watt and may be assumed constant and a slip of 0.02.

i-Draw the equivalent circuit?

ii- Determine shaft speed; mechanical power developed; developed torque; and efficiency?

Question (4) **[15] Points**

4.a)A 220 V shunt motor has the following parameters R_a=0.5 Ω ,R_f=100 Ω and rotational losses are 250 watt on full load the line current is 20A and the motor runs at 1000rpm

Determine i-Draw the equivalent circuit?

ii- Determine: the armature current, the field current, shaft speed, mechanical power developed, developed torque, and efficiency?

4.b) A separately excited DC generator has an open circuit terminal voltage of 220V. When loaded by resistive load the voltage across the load is 200V. The armature resistance is 0.5 Ω and the field supply voltage is 220V and field resistance is 100 Ω.

Determine **(i)** armature current and field current **(ii)** the efficiency?

Question (5) **[15] Points**

5.a) Explain the construction and theory of operation of a DC Motor?

5.b) - A three phase 460V, 60Hz, 6 poles, wye-connected cylindrical rotor synchronous motor has a synchronous reactance of 3 Ω/phase. R_s is negligible and I_s=25A/phase and unity p.f.

i-Draw the equivalent circuit? ii-Find the rotor speed and torque angle?

iii-Find the P_{out} and the maximum torque?

With my Best Wishes

Answer

Question (1) **[15] Points**

1.a) Define: magnetic field- flux Density- core losses?

A magnetic field is a condition resulting from electric charges in motion. The magnetic field of a permanent magnet is attributed to the uncompensated spinning of electrons about their own axis within the atomic structure of the material and to the parallel alignment of these electrons with similar uncompensated

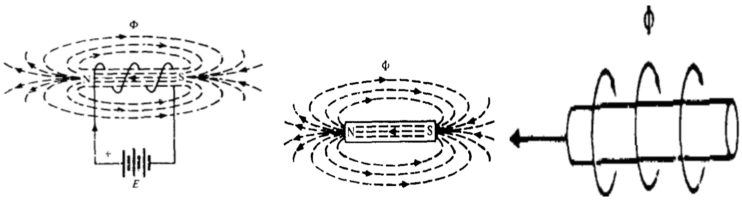


FIGURE 1-1 Direction of magnetic flux: (a) around a current-carrying conductor; (b) in a coil: (c) about a magnet.

Flux Density

The flux density is a measure of the concentration of lines of flux in a particular; section of a magnetic circuit. Expressed mathematically.

$$B = \frac{\Phi}{A}$$

ϕ = flux, webers (Wb) , A = cross-sectional area (m^2)

B = flux density (Wb/m^2), or tesla (T)

Core losses=eddy current +hysteresis losses

Magnetic Hysteresis Loss

$$\mathbf{P_h = K_h \cdot \mathit{f} \cdot B^n_{max}}$$

where:

P_h = hysteresis loss (W/unit mass of core)

f = frequency of flux wave (Hz)

$\mathbf{B^n_{max}}$ = maximum value of flux density wave (T)

k_h = constant

EDDY CURRENTS AND EDDY-CURRENT LOSSES

Eddy currents are circulating currents produced by transformer action in the iron cores of electrical apparatus. Figure 1.15(a) shows a block of iron that may be viewed as an infinite number of concentric shells or loops. The eddy voltages generated in these shells by a changing magnetic field are proportional to the rate of change of flux through the window of the respective shells. Thus,

$$e_e \propto \frac{d\phi}{dt}$$

Expressed in terms of frequency and flux density, as obtained from Eq. (1–25),

$$E_e \propto f \cdot B_{max} \qquad \textbf{(1–28)}$$

Slicing the core into many laminations and insulating one from the other will reduce the magnitude of the eddy currents by providing smaller paths, and hence lower eddy voltages. This is shown in Figure 1.15(b). Laminated cores are made by stacking insulated steel stampings to the desired thickness or depth. Each lamination is insulated by a coating of insulating varnish or oxide on one or both sides. Laminating the core results in much smaller shells, significantly reducing the heat losses in the iron.

The eddy-current loss, expended as heat power in the resistance of each shell, is proportional to the square of the eddy voltage.

$$P_e \propto E_e^2 \qquad \textbf{(1–29)}$$

Substituting Eq. (1–28) into Eq. (1–29) and applying a proportionality factor results in

$$P_e = k_e f^2 B_{max}^2 \qquad \textbf{(1–30)}$$

where: P_e = eddy-current loss (W/unit mass)
f = frequency of flux wave (Hz)

B_{max} = maximum value of flux density wave (T)
k_e = constant

The constant k_e is dependent on the lamination thickness, electrical resistivity, density and mass of the core material, and the units used.

1.b) A ferromagnetic ring has a mean circumference length of 1.5 m and a cross sectional area of 5 cm^2 is wound with 500 turns of wire. When the excitation current is 5A the flux is found to be 2mWb. Determine the flux density and the relative permeability of the ring?

mmf=N*I=H*L=500*5=2500=1.5*H At, H=1666.7At/m

$\beta=\Phi/A=(2*10^{-3})/(5*10^{-4})=4Wb/m^2$, $\beta=\mu_o*\mu_r*H=4pi*10\text{^}-7*1666.7*\mu_r=4T$

then μ_r=1909.82

Question (2) **[15] Points**

2.a)) Explain the construction and theory of operation of a transformer?

Essentially, a transformer consists of two or more windings coupled by mutual magnetic flux. If one of these windings, the *primary,* is connected to an alternating-voltage source, an alternating flux will be produced whose amplitude will depend on the primary voltage, the frequency of the applied voltage, and the number of turns. The mutual flux will link the other winding, the *secondary,*[1] and will induce a voltage in it

whose value will depend on the number of secondary turns as well as the magnitude of the mutual flux and the frequency. By properly proportioning the number of primary and secondary turns, almost any desired *voltage ratio,* or *ratio of transformation,* can be obtained.

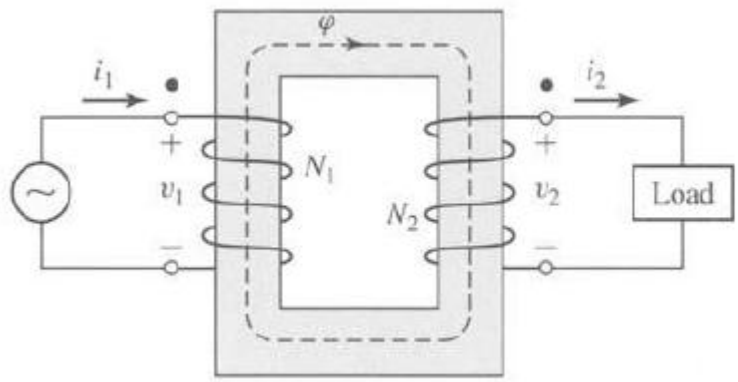
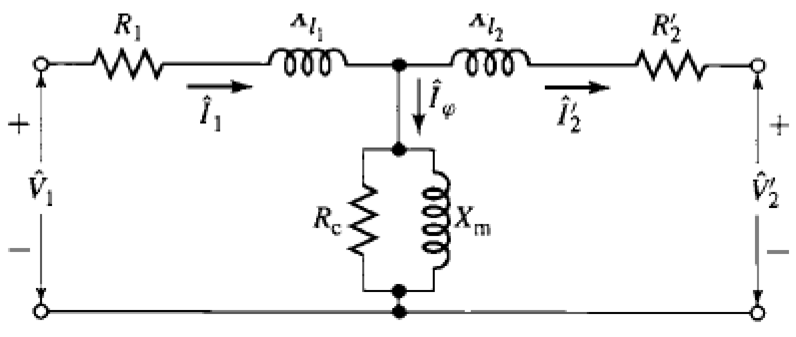


Figure 2.6 Ideal transformer and load.

$$\frac{i_1}{i_2} = \frac{N_2}{N_1}, \qquad \frac{v_1}{v_2} = \frac{N_1}{N_2}$$



(d)

$$X'_{l_2} = \left(\frac{N_1}{N_2}\right)^2 X_{l_2}$$

$$R'_2 = \left(\frac{N_1}{N_2}\right)^2 R_2$$

$$V'_2 = \frac{N_1}{N_2} V_2$$

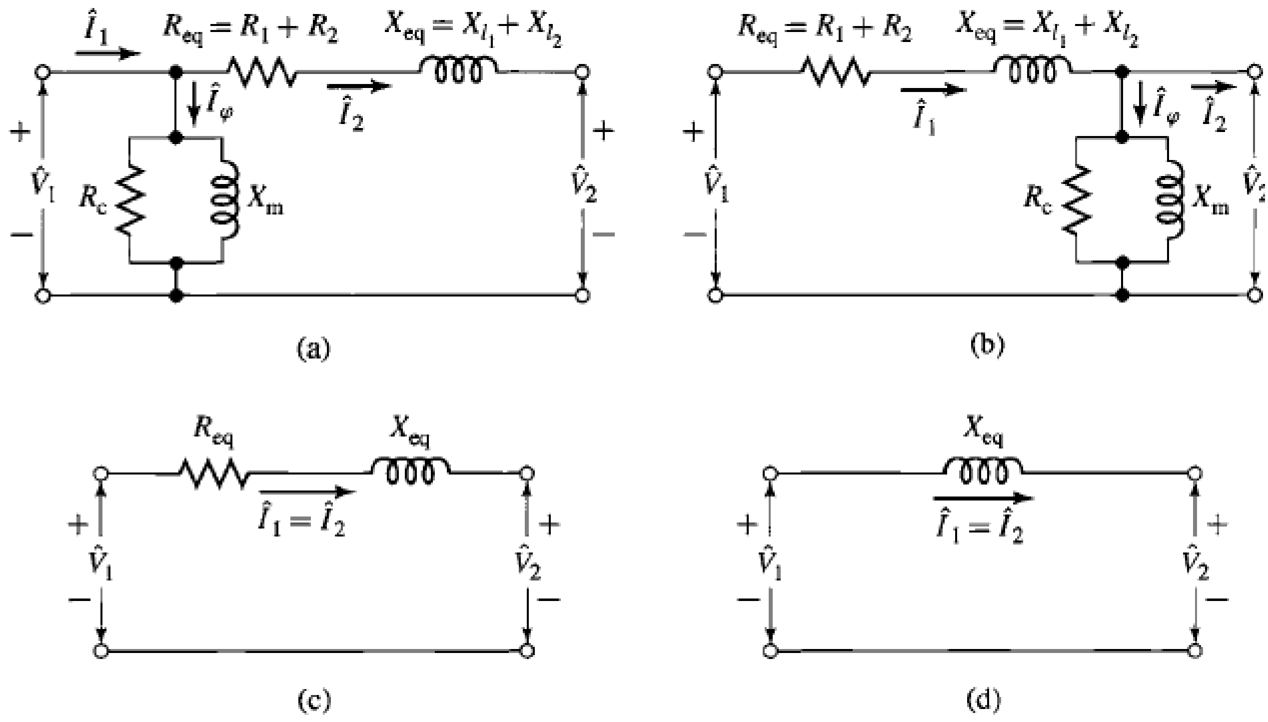


Figure 2.12 Approximate transformer equivalent circuits.

2.b) A 50KVA, 2400V:240V, 60Hz, distribution transformer has a leakage impedance of (0.1+j0.20) Ω in the high voltage winding and (0.01+j0.01)Ω in the low voltage winding. Neglect the exciting branch impedance when a resistive load current is 50A and voltage is 240V in the low side?

i-Draw the equivalent circuit referred to the high side?

ii-Find the input voltage applied on the high side?

iii-Find the resistive load and p.f. ?

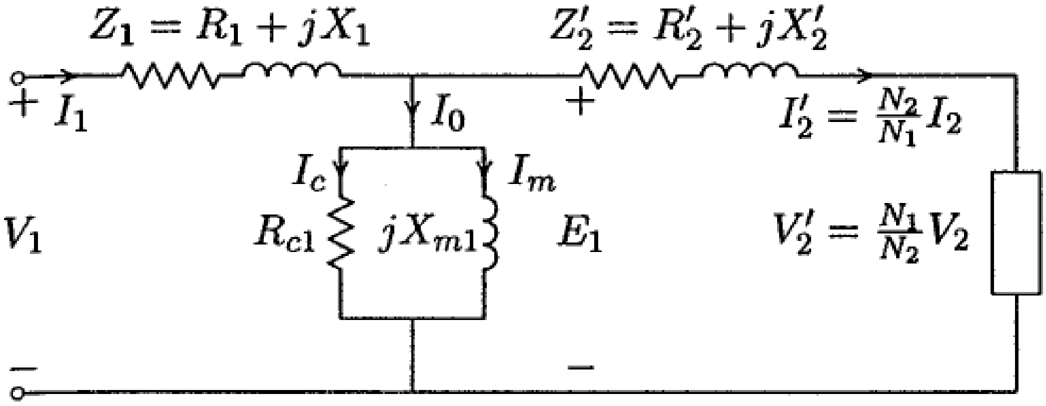


FIGURE 3.10
Exact equivalent circuit referred to the primary side.

a=V1/V2=2400/240=10, $Z'_2 = a^2 (Z_2) = (10)^2 (0.01+j0.01) = 1+j1$=----∟---Ω,

$Z_{eq}=R_{eq}+jX_{eq}=1+0.1+j0.2+j1=1.1+j1.2=1.63\angle 47.5\Omega$,

$V_1=V'_L+I'_L*Z_{eq}=240*10+(50/10)*1.63\angle 47.5 =(2400+5.50+j6)=2405.51\angle 0.14V$,

$R_L=V_L/I_L=240/50=4.8\ \Omega$, $Z_{total}=R_{eq}+jX_{eq}+ R'_L =1.1+j1.2+4.8*100=481.1+j1.2=481.1\angle 0.14\Omega$

and p.f =cos 0.14=0.999997=1, check $I=V_1/Z_{total}=2405.51\angle 0.14/481.13\angle 0.14=5\angle 0.A$

Question (3) **[15] Points**

3.a) Sketch and explain the torque-speed characteristics of a 3-phase induction motor?

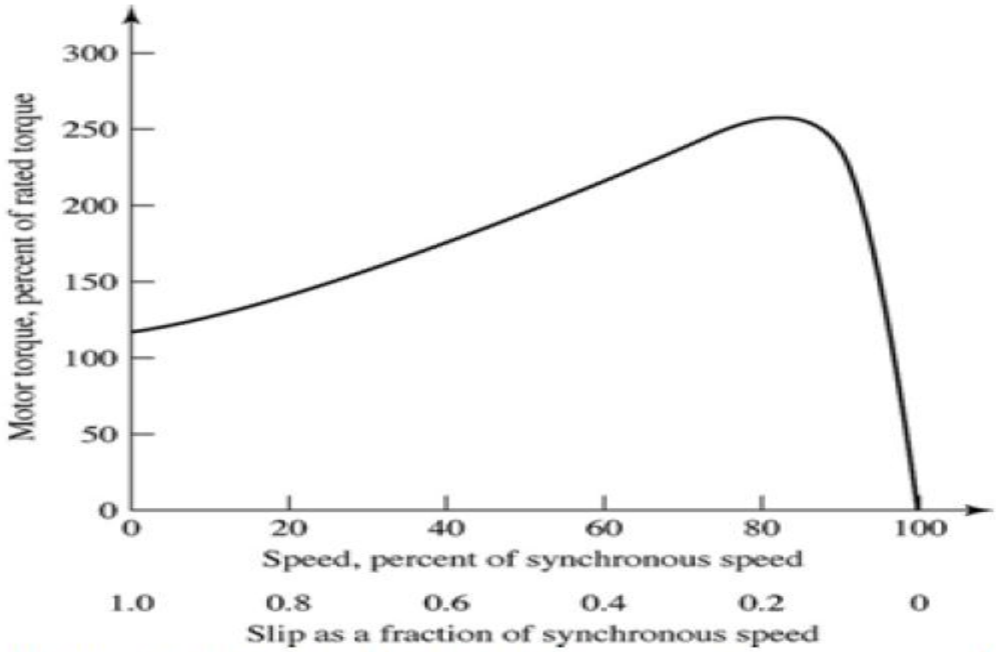


Figure 6.4 Typical induction-motor torque-speed

$$P_{\text{gap}} = n_{\text{ph}} I_2^2 \left(\frac{R_2}{s} \right)$$

$$P_{\text{rotor}} = n_{\text{ph}} I_{2s}^2 R_2$$

$$P_{\text{rotor}} = n_{\text{ph}} I_2^2 R_2$$

$$P_{\text{mech}} = P_{\text{gap}} - P_{\text{rotor}} = n_{\text{ph}} I_2^2 \left(\frac{R_2}{s} \right) - n_{\text{ph}} I_2^2 R_2$$

$$P_{\text{mech}} = n_{\text{ph}} I_2^2 R_2 \left(\frac{1-s}{s} \right)$$

$$P_{\text{mech}} = (1-s) P_{\text{gap}}$$

$$P_{\text{rotor}} = s P_{\text{gap}}$$

$$s = \frac{n_s - n}{n_s}$$

The slip is often expressed in percent.

n : rotor speed in rpm

$$n = (1-s) n_s$$

ω_m : mechanical angular velocity

$$\omega_m = (1-s) \omega_s$$

3.b) A three phase 220V, 60Hz, 6 poles,10HP, wye-connected induction motor has a stator impedance of (0.3+j0.5) **Ω**/phase and (0.1+j0.2)**Ω**/phase of the rotor winding referred to the stator side. The exciting branch impedance viewed from the stator side is (j15 **Ω**). The no load loss=200 watt and may be assumed constant and a slip of 0.02.

i-Draw the equivalent circuit?

ii- Determine shaft speed; mechanical power developed; developed torque; and efficiency?

V_{ph}=220/√3=127V∟0V, Z_m=X_m=15∟90Ω, I_M=127/j 15=-j8.5=8.5∟-90A

Z_{eq}=R_{eq}+jX_{eq}=0.3+j0.5 +0.1/0.02+j0.2=5.3+j0.7=5.35∟7.5Ω,

Ir=V_1/Z_{eq}=127∟0/5.35∟7.5=23.7∟-7.5=23.54-j3.1A

Is=I_M+I_r= 2354-j3.1-j8.5=23.54-j11.6= 26.2∟-26.2 A, pf=cos26=0.9

n_s=120*60/6=1200rpm, ω_s=1200*pi/30=40pi=125.7rad/s

n_r=(1-S)ns=(1-0.02)1200=1176rpm, ω_r=1176*pi/30=123.15rad/s

Core losses + rotational losses =200W

Copper losses=3 I_L^2(R1+R2')=3*23.7^2*(0.3+0.1)=674W

P_{mech}=3*22.52^2*0.1(1-0.02)/0.02=8256.843W, T_{mech}=8256.8/123.145=67Nm

Output power= P_{mech} –rotational losses=8256.8-200=8056.8W

T_{out}=8056.8/123.145=65.5Nm

η=p_{out}/p_{in}= p_{out}/(p_{out}+losses)= 8056.8/(8056.8+200+674) =0.90

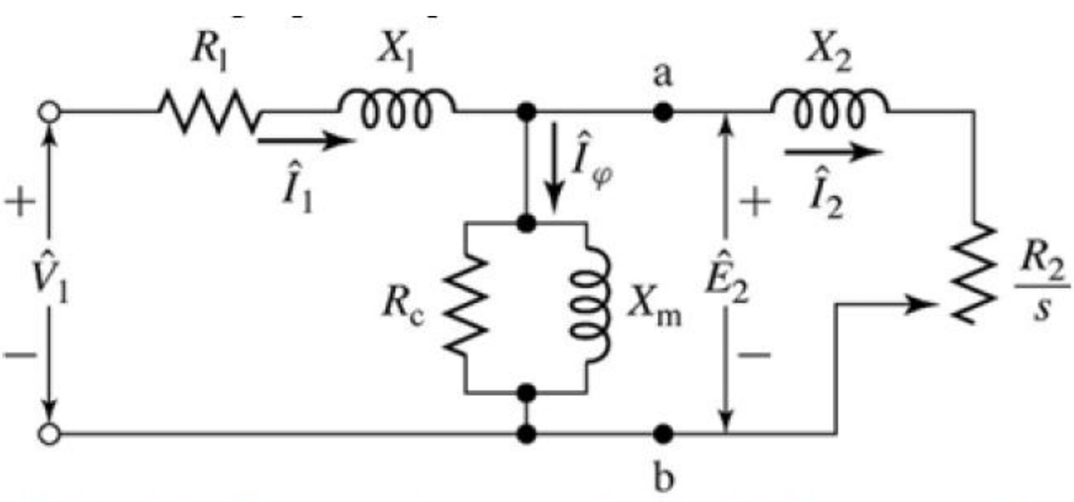


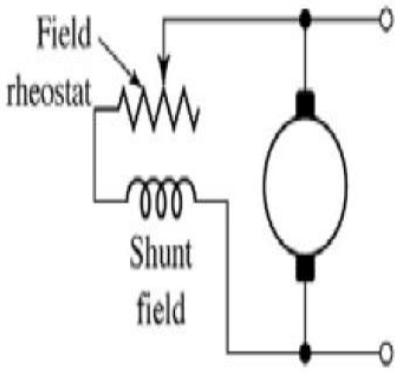
Figure 6.9 Single-phase equivalent circuit for a polyphase induction motor.

<u>Question (4)</u> **<u>[15] Points</u>**

4.a)A 220 V shunt has the following parameters R_a=0.5 Ω ,R_f=100 Ω and rotational losses are 250 watt on full load the line current is 20A and the motor runs at 1000rpm

<u>Determine</u> i-Draw the equivalent circuit?

ii- Determine: the armature current, the field current, shaft speed, mechanical power developed, developed torque, and efficiency?



$$T_{mech} = K_a \Phi_d i_a \quad e_a = K_a \Phi_d \omega_m$$

I_f=220/100=2.2A, I_a=20-2.2=17.8A, E_a= Va-IaRa=220-17.8*0.5=211V

P_{inp}=220*20=4400watt, P_{dev}=211*17.5=3694.3W,

P_{out}= P_{dev}- losses=3694.3-250=3944.3watt η=3944.3/4400=90%

4.b) A separately excited DC generator has an open circuit terminal voltage of 220V. When loaded by resistive load the voltage across the load is 200V. The armature resistance is 0.5 Ω and the field supply voltage is 220V and field resistance is 100 Ω.

Determine **(i)** armature current and field current **(ii)** the efficiency?

E_a =220V, I_f=220/100=2.2A, E_a=V_L+IaRa, I_a=(220-200)/0.5=40A,

P_{inp}=220*2.2+40*220= 9284W, P_{out}=200*40=8000W, η=8000/9284=86.2%

Question (5) **[15] Points**

5.a) Explain the construction and theory of operation of a DC Motor?

4.a) Explain the construction and theory of operation of a DC Motor?

Dc machines are characterized by their versatility.

- By means of various combinations of shunt-, series-, and separately-excited field windings they can be designed to display a wide variety of volt-ampere or speed-torque characteristics for both dynamic and steady-state operation.

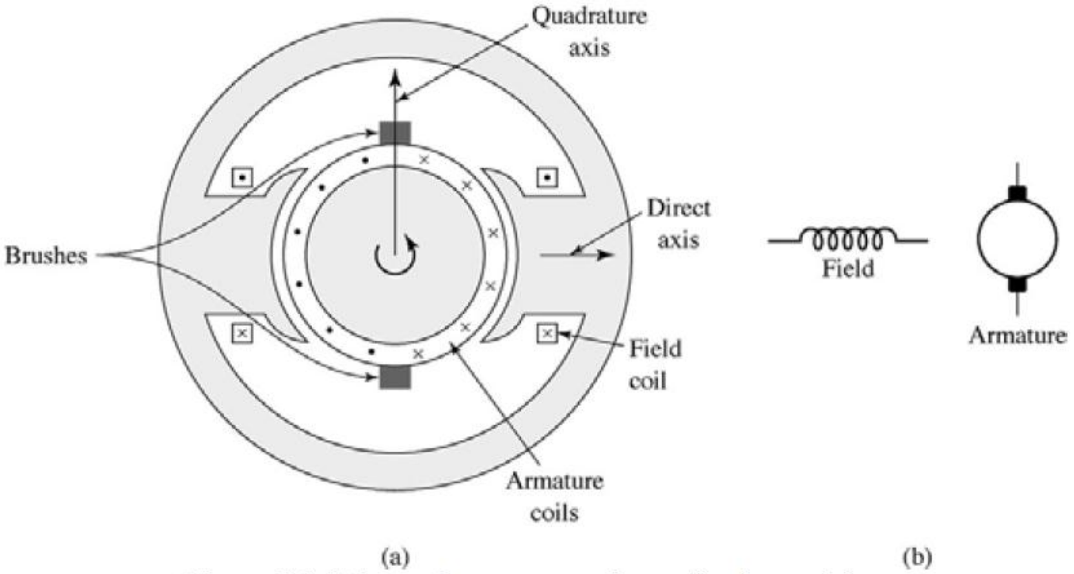


Figure 7.1 Schematic representations of a dc machine.

$$\boxed{T_{mech} = K_a \Phi_d i_a}$$

K_a : a constant determined by the design of the winding, the winding constant

i_a = current in external armature circuit

C_a = total number of conductors in armature winding,

m = number of parallel paths through winding

The rectified voltage e_a between brushes, known also as the speed voltage, is

$$\boxed{e_a = K_a \Phi_d \omega_m}$$

Note that the electric power equals the mechanical power.

$$e_a i_a = T_{mech} \omega_m$$

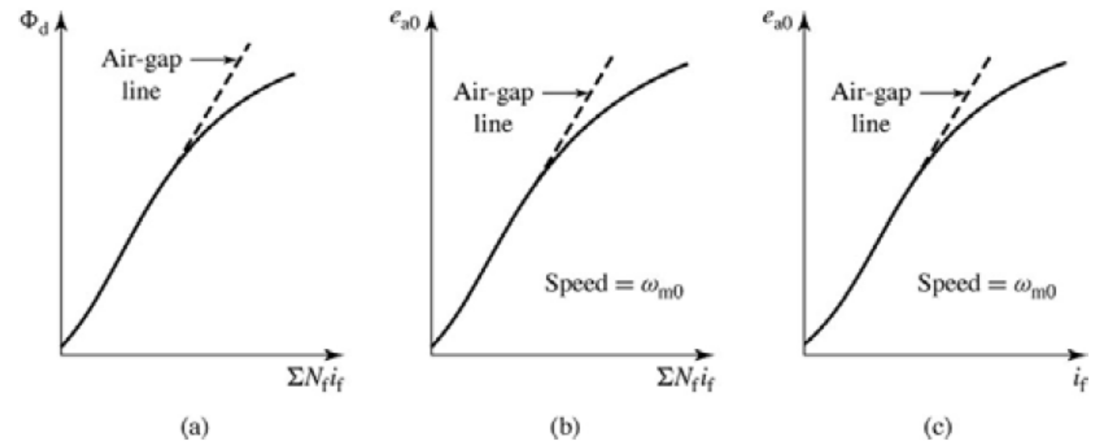


Figure 7.3 Typical form of magnetization curves of a dc machine.

Various methods of excitation of the field windings are shown in Fig. 7.4.

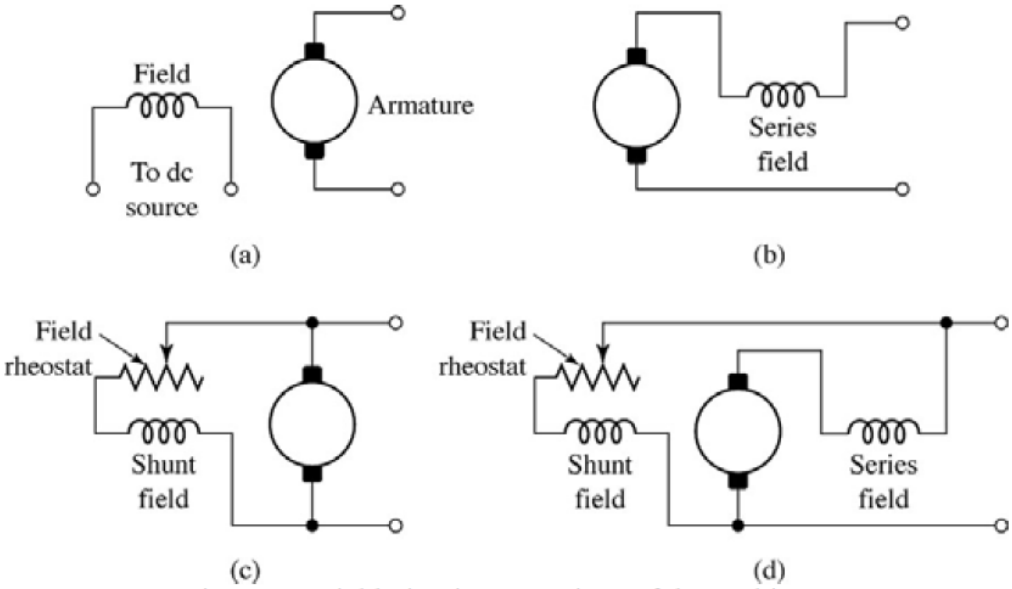
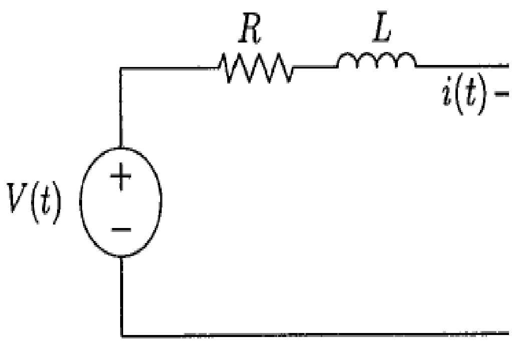


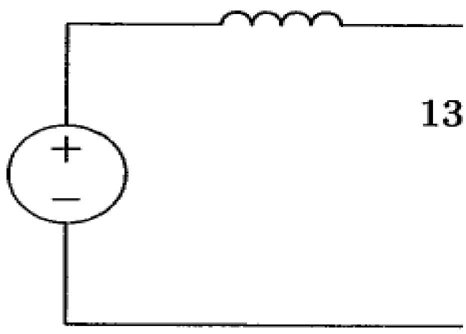
Figure 7.4 Field-circuit connections of dc machines:
(a) separate excitation, (b) series, (c) shunt, (d) compound.

5.b) - A three phase 460V, 60Hz, 4 poles, wye-connected cylindrical rotor synchronous motor has a synchronous reactance of 3 Ω/phase. R_s is negligible and I_s=25A/phase and unity p.f.

i-Draw the equivalent circuit? ii-Find the rotor speed and torque angle?

iii-Find the P_{out} and the maximum torque?





$n_r = n_s = 120*60/4 = 1800$ rpm, $\omega_r = \omega_s = 1800*pi/30 = 188.5$ rad/s, 460/√3=265.6∟0

$V_f = V_t - jI_aX_s$ =265.6∟0-j25*3=265.6-j75=276∟-15.8V

Torque angle=δ=-15.8°,

$$P_{dev} = \frac{3 * V_{ph} * V_f * sin\delta}{X_s} = \frac{3 * 265.6 * 276 * sin15.8}{3} = 19921W$$

$$T_{max} = \frac{3 * V_{ph} * V_f}{\omega_s X_s} = 388.1Nm$$