الإجابة النموذجية لمادة أجهزة التحويل والالات الخاصة ك ٥٩٢ يوم الخميس الموافق ٢٠١٥/١/١٥

د شوقي حامد عرفه ابراهيم

Benha University	**Time: 3hours**
Benha Faculty of Engineering	**Fifth Year 2014/2015**
Subject: Special Machines (E592)	**Elect. Eng. Dept.**

<u>Solve & draw as much as you can (questions in two pages)</u>

<u>Question (1)</u> **<u>[12] Points</u>**

a- Explain how a single phase induction motor operates?

b- Write four methods used to start a single phase induction motor?

c- A (120V, 60Hz) single phase induction motor of the split phase type has a standstill impedance of the main winding of (2+j3.5) Ω and (9.15+j8.4) Ω of the auxiliary winding. Draw the equivalent circuit and determine the phase displacement angle and the starting torque?

<u>Question (2)</u> **<u>[12] Points</u>**

a- Explain the idea of operation of a linear induction motor?

b- A (100-poles, three-phase, 240V, 50Hz) moving-rail LIM has a pole pitch of 0.5m and a slip of 20%. The rotor copper loss is 800W. Draw the equivalent circuit and determine the synchronous velocity and the rail speed and the thurst force?

<u>Question (3)</u> **<u>[12] Points</u>**

a-Explain one circuit used to drive stepper motor?

b- A stepper motor has a step-angle of 2 degrees and stepping frequency of 1800 pulse/s. Determine:

i-Resolution ii-Rotor speed iii-Number of steps required to make 20.6 revolutions?

P.T.O.

Question (4) **[12] Points**

a- Draw the equivalent circuit of the two-phase induction motor?

b-A symmetrical two phase balanced supply **(220V, 50Hz, 4-poles)** squirrel-cage induction motor has a stator impedance of **(0.53+j2.45) Ω/phase** and **(0.96+j2.94) Ω/pha**se of the rotor winding referred to the stator side. The exciting reactance viewed from the stator side is **70 Ω**. The windage, friction, and core losses equal **200 watt** and may be assumed constant. The slip is equal to 4%.

i-Draw the equivalent circuit? ii-Find the $\boldsymbol{\omega}_{syn}$, I_s, I_r , P_{gap}, P_{copper} , T_{dev}, $\boldsymbol{\omega}_r$, P_{inp} , P_{out} ?

Question (5) **[12] Points**

a-Explain how to reverse the direction of rotation of the universal motor?

b- A universal series motor has a resistance of 30 and total inductance of 0.5H. When the motor is connected to a DC supply of 250V it takes 0.8 A and rotates by 2000 rpm. if the motor is connected to an AC supply of 250V, 50Hz and takes 0.8 A. Find the speed and pf?

Answer

Question (1) **[12] Points**

a- Explain how a single phase induction motor operates?

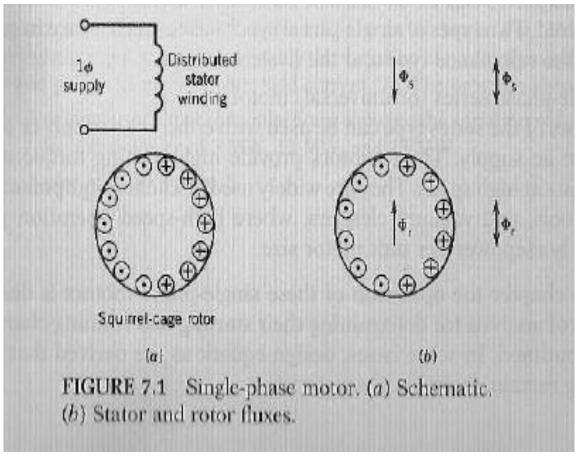


FIGURE 7.1 Single-phase motor. (a) Schematic. (b) Stator and rotor fluxes.

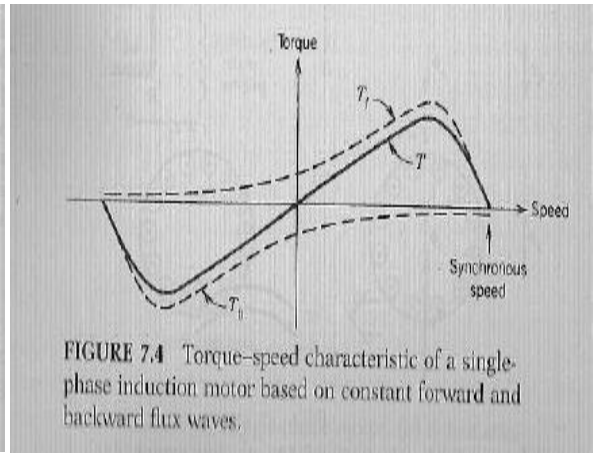
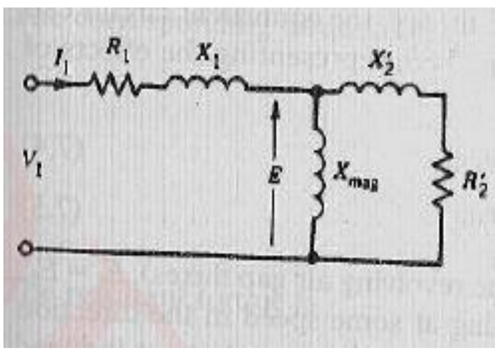


FIGURE 7.4 Torque–speed characteristic of a single-phase induction motor based on constant forward and backward flux waves.



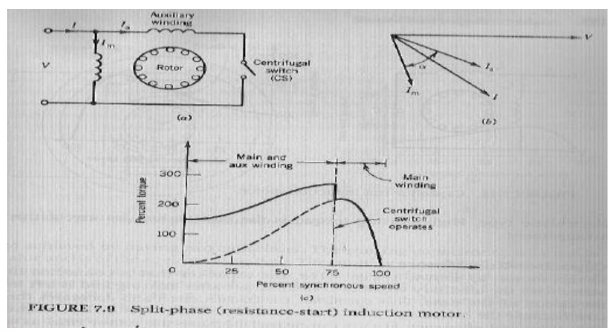


FIGURE 7.9 Split-phase (resistance-start) induction motor.

b- Write four methods used to start a single phase induction motor?

1-Split phase IM
2-Capacitor start and run IM
3-Capacitor start and capacitor run IM
4-Capacitor start IM
2-Shaded pole IM

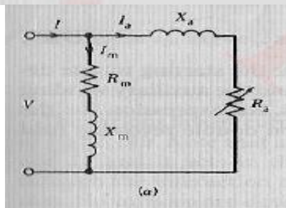
c- A (120V, 60Hz) single phase induction motor of the split phase type has a standstill impedance of the main winding of (2+j3.5) Ω and (9.15+j8.4) Ω of the auxiliary winding. Draw the equivalent circuit and determine the phase displacement angle and the starting torque?

Maximum Starting Torque

If the number of turns (N_a) for the starting winding is specified, the resistance in the auxiliary winding can be determined so as to maximize the starting torque. For the standstill condition, the motor can be represented by the circuit shown in Fig. 7.15*a*. Let

$Z_m = R_m + jX_m$, impedance of the main winding

$Z_a = R_2 + jX_a$, impedance of the auxiliary winding



Split-phase induction motor at starting condition.

$T_s = KI_m I_a \sin\alpha$

$$R_a = \frac{X_a}{X_m}(R_m + |Z_m|)$$

$$I_m = \frac{120\angle 0}{2+j3.5} = \frac{120\angle 0}{4.03\angle 60.3} = 29.8\angle -60.3A$$

$$I_a = \frac{120\angle 0}{9.15 + j8.4} = \frac{120\angle 0}{12.42\angle 42.6} = 9.7\angle -42.6A$$

$$R_a = \frac{X_a(R_m + |Z_m|)}{X_m} = \frac{8.4(2 + |2 + j3.5|)}{3.5} = 14.5\Omega$$

Displacement angle=δ =-60.3—42.6=-17.7^{o}

$T_s=K_{sr}*I_m*I_a*\sin\delta= K_{sr}*9.7*29.8*\sin(-17.7)=87.9K_{sr}$ Nm

Question (2) **[12] Points**

a- Explain the idea of operation of a linear induction motor?

LIM Performance

The synchronous velocity of the traveling wave is

$$V_s = 2T_p f \text{ m/sec} \quad (5.113)$$

where T_p is the pole pitch and f is the frequency of the supply. Note that the synchronous velocity does not depend on the number of poles. If the velocity of the moving member is V, then the slip is

$$s = \frac{V_s - V}{V_s} \quad (5.114)$$

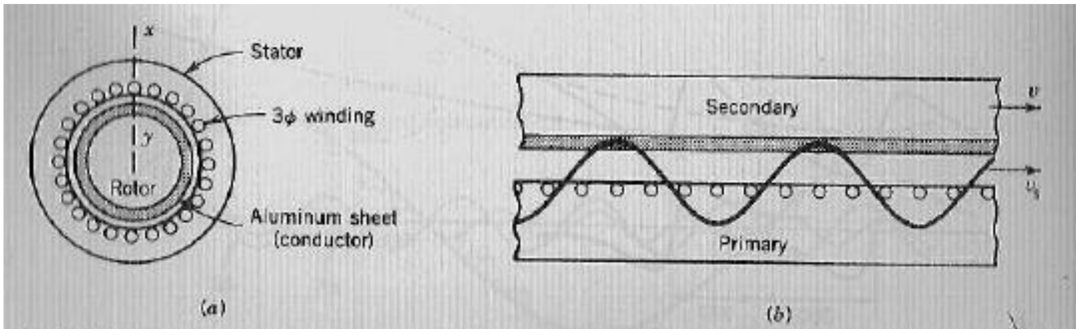


FIGURE 5.45 Induction motors. (*a*) Rotary induction motor. (*b*) Linear induction motor (LIM).

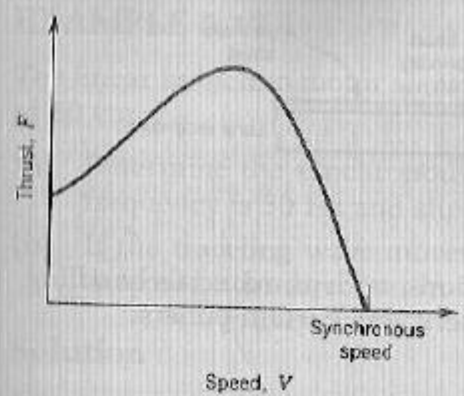


FIGURE 5.46 Thrust–speed characteristic of a LIM.

The per-phase equivalent circuit of the linear induction motor has the same form as that of the rotary induction motor as shown in Fig. 5.15. The thrust–velocity characteristic of the linear induction motor also has the same form as the torque–speed characteristic of a rotary induction motor, as shown in Fig. 5.46. The thrust is given by

$$F = \frac{\text{air gap power, } P_g}{\text{synchronous velocity, } V_s}$$

$$= \frac{3I_2'^2R_2'/s}{V_s} \text{ newtons} \qquad (5.115)$$

b- A (100-poles, three-phase, 240V, 50Hz) moving-rail LIM has a pole pitch of 0.5m and a slip of 20%. The rotor copper loss is 800W. Draw the equivalent circuit and determine the synchronous velocity and the rail speed and the thrust force?

$$u_s = 2\tau_p f = 2 * 0.5 * 50 = 50m/_S,$$

$$u = (1 - S)u_s = (1 - 0.2)50 = 40\,^m/_S$$

$$S = \frac{p_{copr}}{p_{gap}}\ , \qquad p_{gap} = \frac{800}{0.2} = 4000W, thurst\ force = F = \frac{p_{gap}}{u_s} = \frac{4000}{50} = 80N$$

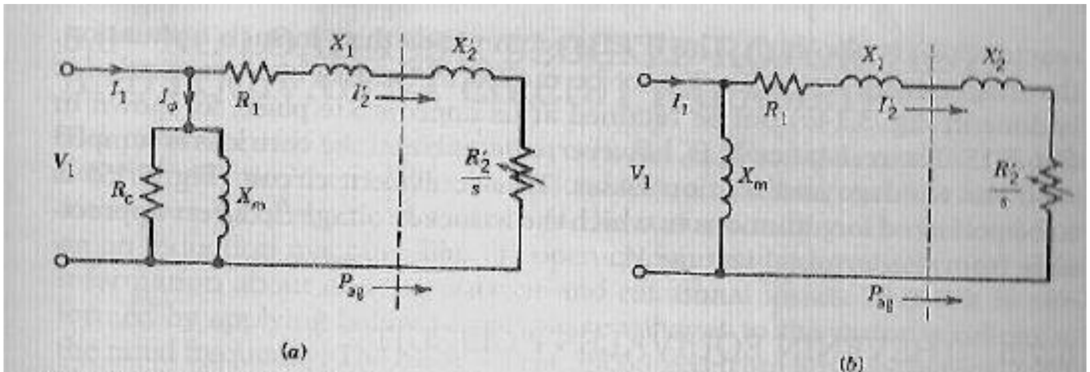


FIGURE 5.14 Approximate equivalent circuit.

$X_2'=0$

Question (3) **[12] Points**

a-Explain one circuit used to drive stepper motor?

8.3 STEPPER MOTORS

A stepper motor rotates by a specific number of degrees in response to an input electrical pulse. Typical step sizes are 2°, 2.5°, 5°, 7.5°, and 15° for each electrical pulse. The stepper motor is an electromagnetic incremental actuator that can convert digital pulse inputs to analog output shaft motion. It is therefore used in digital control systems. A train of pulses is made to turn the shaft of the motor by steps. Neither a position sensor nor a feedback system is normally required for the stepper motors to make the output response follow the input command. Typical applications of stepper motors requiring incremental motion are printers, tape drives, disk drives, machine tools, process control systems, X–Y recorders, and robotics. Figure 8.15 illustrates a simple application of a stepper motor in the paper drive mechanism of a printer. The stepper motor is directly coupled to the platen so that the paper is driven a certain incremental distance whenever the controller receives a digital-command pulse.

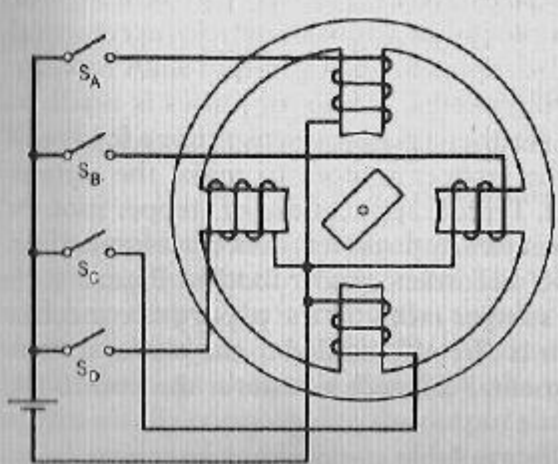


FIGURE 8.16 Basic circuit for a four-phase, two-pole stepper motor.

Unipolar Drive Circuit

Figure 8.23 shows a simple unipolar drive circuit suitable for a three-phase variable-reluctance stepper motor. Each phase winding is excited by a separate drive circuit. The main switching device is a transistor. A phase winding is excited by applying a control signal to the base of the transistor. The control signal may require several stages of amplification before it attains the required current level for the base of the transistor.

In order to excite a phase winding, a sufficiently high base current is passed through the base of the transistor. The transistor is saturated and its collector–emitter path behaves like a short circuit. The supply voltage V_s appears across the phase winding and the resistance R_{ext} connected in series with the winding. The dc supply voltage V_s is chosen so that it produces the rated current I in the winding.

$$V_s = I(R_w + R_{ext}) \qquad (8.27)$$

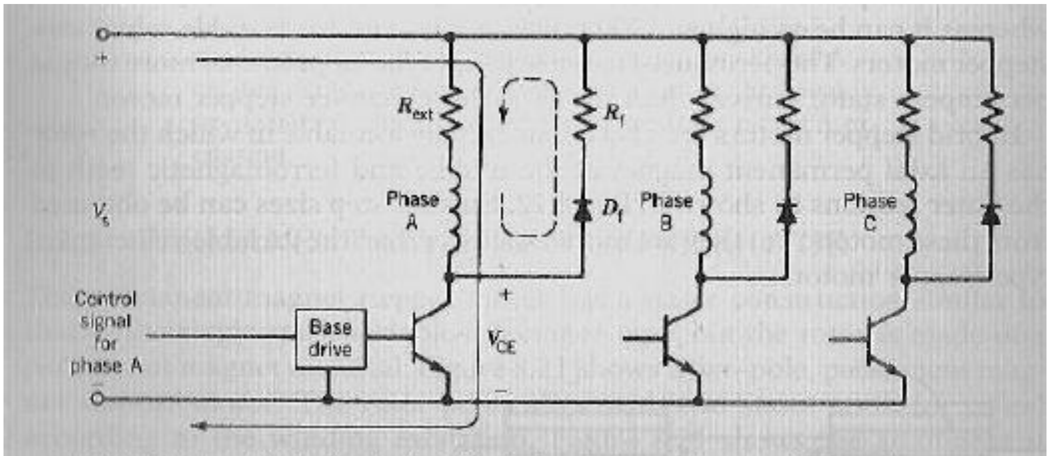


FIGURE 8.23 Unipolar drive circuit for a three-phase variable-reluctance stepper motor.

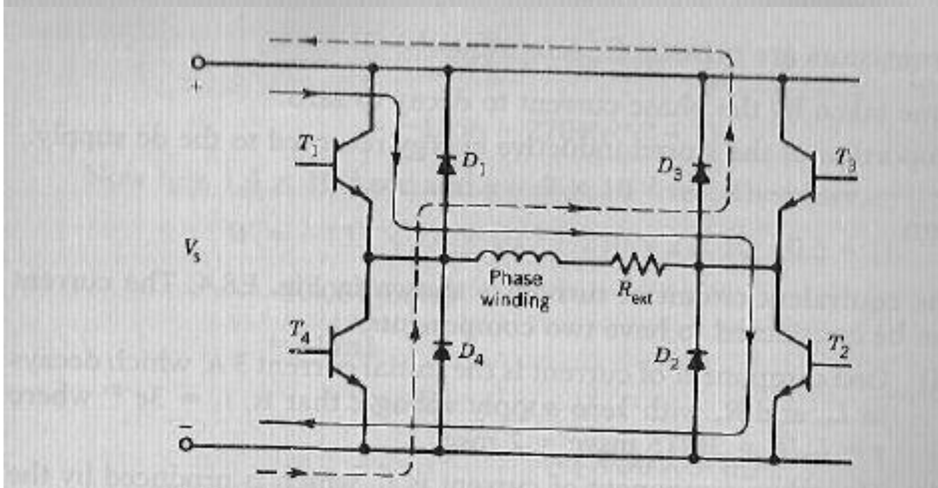


FIGURE 8.24 One phase of a bipolar drive circuit.

b- A stepper motor has a step-angle of 2 degrees and stepping frequency of 1800 pulse/s. Determine:

i-Resolution ii-Rotor speed iii-Number of steps required to make 20.6 revolutions?

$$\boldsymbol{Resolution = \frac{360}{\beta} = \frac{360}{2} = 180 step/rev},$$

$$\boldsymbol{Rotor\ speed = \frac{\beta f_p}{360} = \frac{2 * 1800}{360} = 10 rps = 600 rpm} \quad .$$

$$\boldsymbol{total\ rotor\ angle \theta = 20.6 * 360 = 7416\ deg. = \beta * steps}$$

$$\boldsymbol{Number}\text{of steps} = \frac{7416}{2} = 3708\text{steps}$$

Question (4) **[12] Points**

a- Draw the equivalent circuit of the two-phase induction motor?

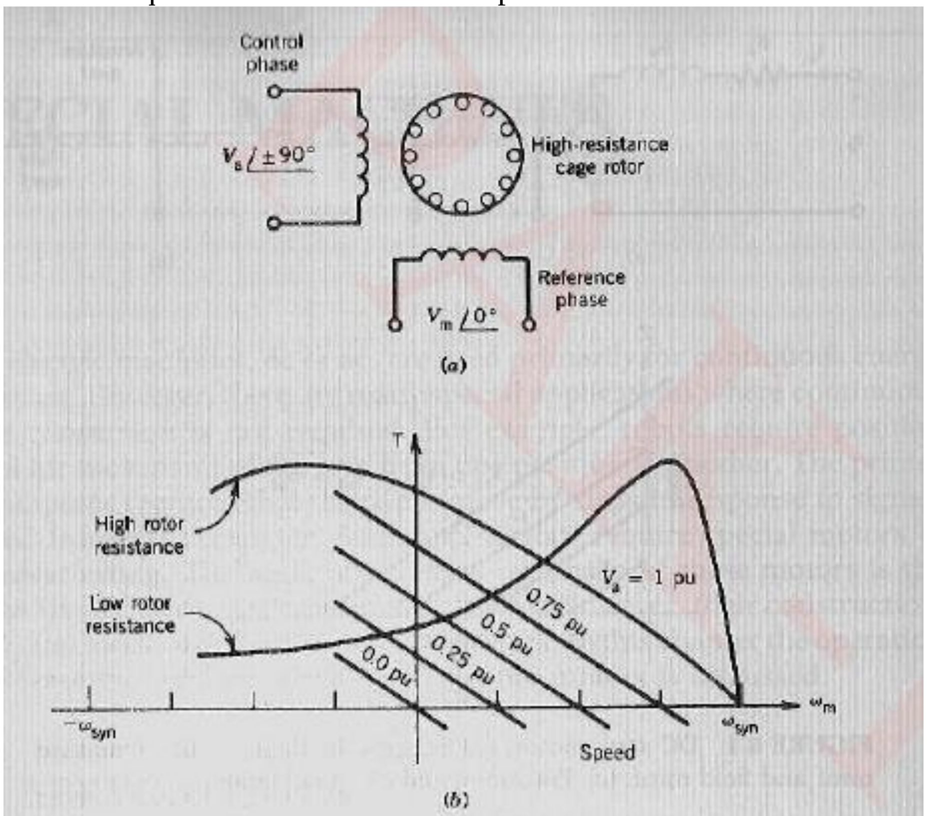


FIGURE 8.2 Two-phase ac servomotor. (*a*) Schematic diagram. (*b*) Torque–speed characteristics.

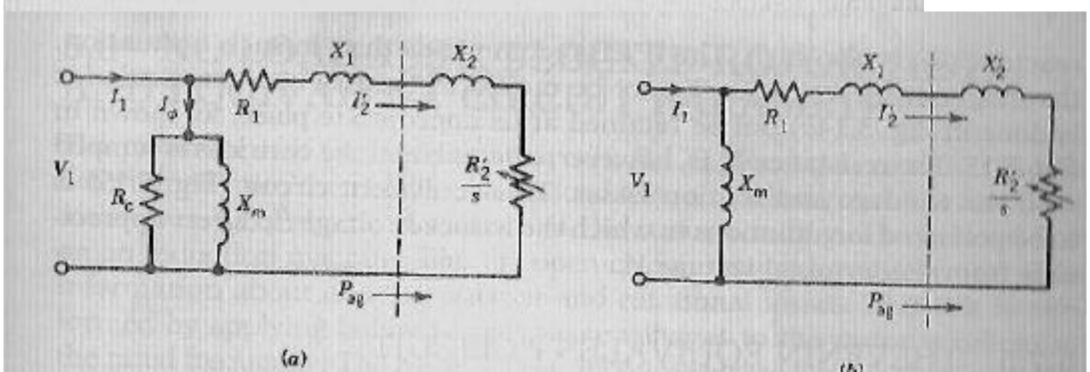


FIGURE 5.14 Approximate equivalent circuit.

b-A symmetrical two phase balanced supply **(220V, 50Hz, 4-poles)** squirrel-cage induction motor has a stator impedance of **(0.53+j2.45) Ω/phase** and **(0.96+j2.94) Ω/pha**se of the rotor winding referred to the stator side. The exciting reactance viewed from the stator side is **70 Ω**. The windage, friction, and core losses equal **200 watt** and may be assumed constant. The slip is equal to 4%.

i-Draw the equivalent circuit? ii-Find the ω_{syn}, I_s, I_r , P_{gap}, P_{copper} , T_{dev}, ω_r, P_{inp} , P_{out} ?

$$\frac{R_2'}{S} = \frac{0.96}{0.04} = 24\Omega,\ Z'_2 = 24 + j2.94 = 24.2\llcorner 7\ \Omega, \qquad j70\ //\ Z'_2 = 22.1\llcorner 25.2 = 20 + j9.4\ \Omega$$

$$Z_{in} = 0.53 + j2.45 + 20 + j9.4 = 23.7\llcorner 30\ \Omega,$$

$$I_1 = \frac{220\llcorner 0}{23.7\llcorner 30} = 9.3\llcorner -30A, \qquad I'_2 = \frac{70\llcorner 90}{76.8\llcorner 71.8} = 8.5\llcorner -12A$$

$$S = \frac{p_{copr}}{p_{gap}}, \qquad p_{gap} = \frac{2I'^2_2 R'_2}{S} = 2 * 8.5 * 8.5 * 24 = 3468W,$$

$$\omega_s = \frac{120f}{p} * \frac{2pi}{60} = 50pi\ \ rad/S = 1500rpm, T_{dev} = \frac{p_{gap}}{\omega_s} = \frac{3468}{50pi} = 22.1Nm$$

$$\omega_r = \omega_s(1 - S) = 48pi\ \ rad/S = 1440rpm,$$

Question (5) **[12] Points**

a-Explain how to reverse the direction of rotation of the universal motor?

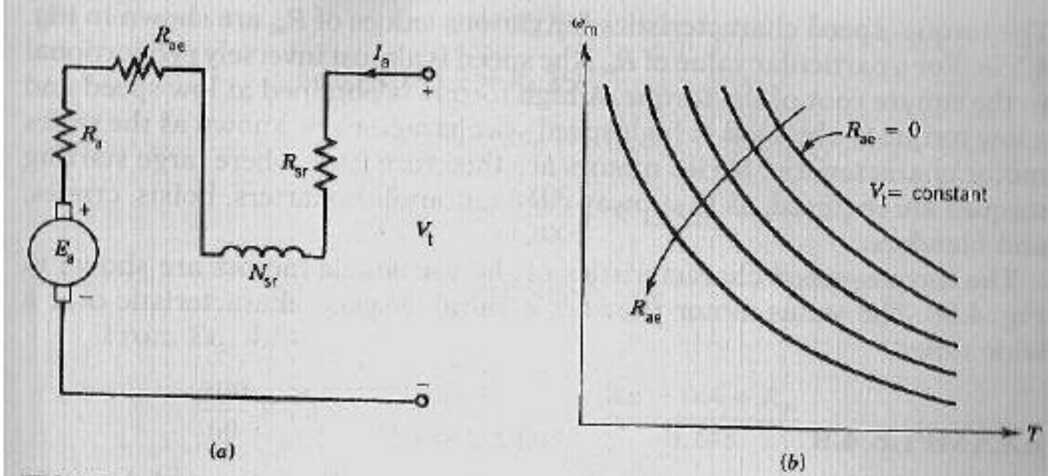


FIGURE 4.55 Series motor.

$$T = K_{sr} I_a^2 \tag{4.51}$$

Equation 4.51 shows that a series motor will develop unidirectional torque for both dc and ac currents. Also, from Fig. 4.55*a*,

$$E_a = V_t - I_a(R_a + R_{ae} + R_{sr}) \tag{4.52}$$

From Eqs. 4.50 and 4.52,

$$\omega_m = \frac{V_t}{K_{sr} I_a} - \frac{R_a + R_{sr} + R_{ae}}{K_{sr}} \tag{4.53}$$

From Eqs. 4.51 and 4.53,

$$\omega_m = \frac{V_t}{\sqrt{K_{sr}}\sqrt{T}} - \frac{R_a + R_{sr} + R_{ae}}{K_{sr}}$$

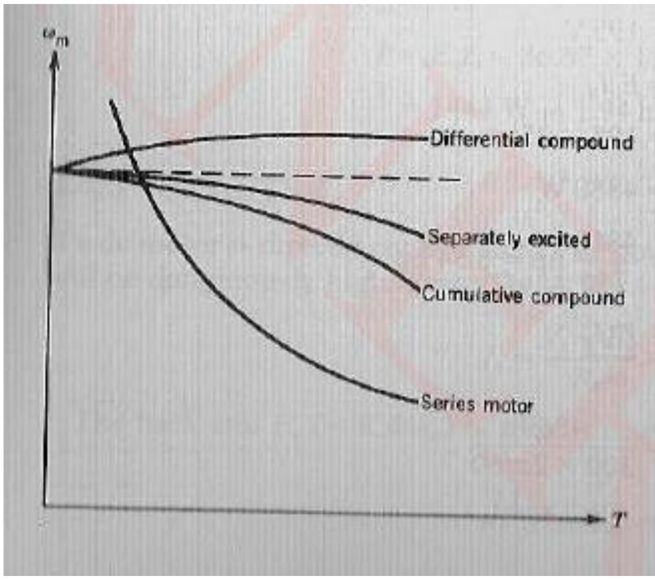


FIGURE 4.56 Torque–speed characteristics of different dc motors.

Reverse the direction of the field or the direction of the armature current to reverse the direction of the speed of the motor.

b- A universal series motor has a resistance of 30 and total inductance of 0.5H. When the motor is connected to a DC supply of 250V it takes 0.8 A and rotates by 2000 rpm. if the motor is connected to an AC supply of 250V, 50Hz and takes 0.8 A. Find the speed and pf?

For DC supply

$$V_{aDC} = K\Phi\omega_r + I_a R_a, \quad K\Phi = \frac{(250 - 0.8 * 30) * 60}{2pi * 2000} = 1.1 Nm/_A$$

For AC supply

$$V_{aac} = K\Phi\ \omega_r + I_a R_a + j2I_a pifL,$$

$$\omega_r = \frac{\sqrt{((250)^2 - (2 * 0.8 * 50pi * 0.5)^2)} - 0.8 * 30}{1.1} = 174.65\, rad/S = 1667.8 rpm$$

$$V_{aac} = K\Phi\ \omega_r + I_a R_a + j2I_a pifL = 1.1 * 174.65 + 0.8 * 30 + j40pi = 216.12 + j125.7$$
$$= 249.998 \angle 30.2 V, \qquad pf = cos30.2 = 0.8644$$