Number of Questions: 25 **Section Marks: 90**

Directions for questions 1 to 25: Select the correct alternative from the given choices.

1. The torque equation of induction motor under running condition is (N_s = synchronous speed, N_r = rotor speed)

(A) $\dfrac{3}{2\pi N_r}\left(\dfrac{SE_2^2 R_2}{R_2^2+(SX_2)^2}\right)$

(B) $\dfrac{3}{2\pi N_s}\left(\dfrac{SE_2^2 R_2}{R_2^2+(SX_2)^2}\right)$

(C) $\dfrac{3}{2\pi N_r}\left(\dfrac{E_2^2 R_2}{\left(\dfrac{R_2}{S}\right)^2+X_2^2}\right)$

(D) $\dfrac{3}{2\pi N_s}\left(\dfrac{SE_2^2 R_2}{\left(\dfrac{R_2}{S}\right)^2+X_2^2}\right)$

2. The frequency of injecting an e.m.f in the Rotor circuit of induction motor is
   (A) Same as supply frequency
   (B) Same as rotor frequency
   (C) Half of supply frequency
   (D) Two times of supply frequency

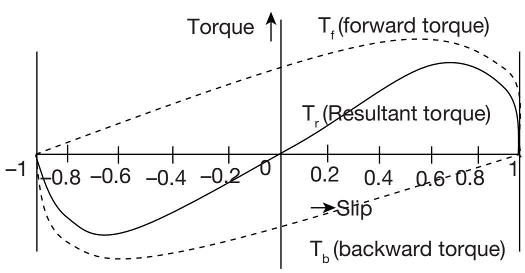
3. Backward torque equation in single phase Induction motor is

(A) $-k\left(\dfrac{I_2^2 R_2}{S}\right)$ (B) $-k\left(\dfrac{I_2^2 R_2}{(1-S)}\right)$

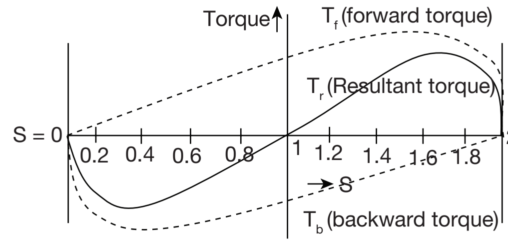
(C) $-k\left(\dfrac{I_2^2 R_2}{2-S}\right)$ (D) $-k\left(\dfrac{SI_2^2 R_2}{(2-S)}\right)$

4. Which of the following diagram represents Torque-Slip characteristic of single phase induction motor.

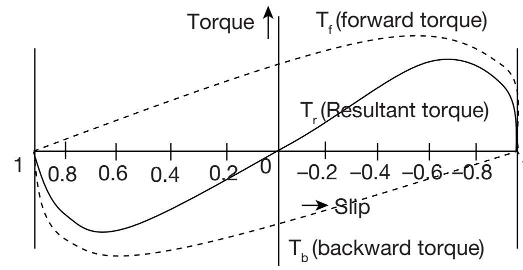
(A)



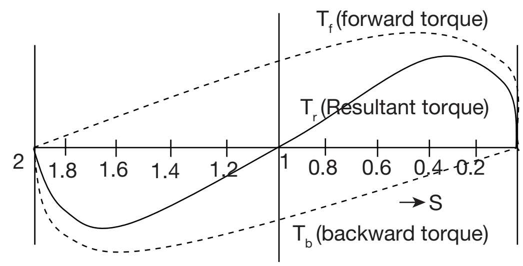
(B)



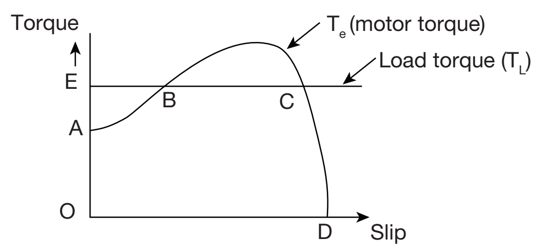
(C)



(D)



5. Which of the following statements is correct for the below figure



   (A) the operating region is *BC*.
   (B) the operating region is *CD*.
   (C) the operating region is *AB*.
   (D) at starting Load torque is more, so the motor will not start.

6. What is mean by jogging in induction motor?
   (A) The motor move a little at a time by constant starting and stopping.
   (B) The motor runs by 5^{th} (or) 7^{th} harmonic speed.
   (C) The motor start with very high speed.
   (D) None of the above

7. If the rotor resistance of a wound rotor induction motor is doubled, what will happen?

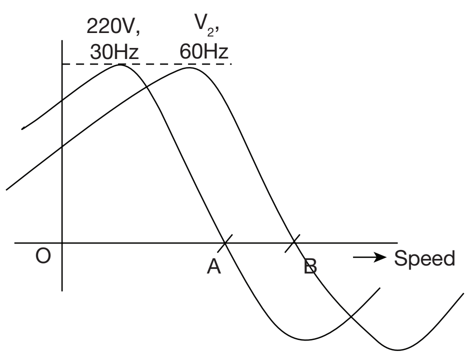
(A) Induced torque increases, efficiency decreases
(B) efficiency increases, induced torque decreases
(C) Both torque and efficiency increases
(D) Both torque and efficiency decreases

8. A three phase 60Hz two pole SCIM runs at 3580 rotations/min at no load. The slip and electrical frequency at no load are:
(A) 6.5%, 3.9Hz (B) 0.65%, 0.39Hz
(C) 5.6%, 3.3Hz (D) 0.56%, 0.33Hz

9. In a three phase induction machine, if the flux created by each phase takes the maximum value of ϕ_m, total magnitude of rotating flux at any given time is
(A) ϕ_m (B) $2\ \phi_m$
(C) $1.5\phi_m$ (D) $0.75\phi_m$

10. A 50kW, 440V, 50Hz two pole SCIM has 6% slip at full load. If full load friction and windage losses are 520W and core losses are 500W, what is the output power?
(A) 45.0 kW (B) 50 kW
(C) 52.4 kW (D) 43.2 kW

11. The torque-speed characteristics of 4-pole squirrel cage induction motor as shown in the figure. By varying the voltage and frequency, the flux in the air gap is maintained constant. Then the values of V_2, A and B are ________



(A) 440V, 900 rpm, 1800 rpm
(B) 220V, 900 rpm, 1800 rpm
(C) 110V, 1800 rpm, 900 rpm
(D) 110V, 900 rpm, 1800 rpm

12. A 400V, 50Hz, 6-pole, $3 - \Phi$ induction motor runs at a speed of 950 rpm. When connected to 400V line voltage, calculate the speed if the voltage increases to 500V.
(A) 950 rpm (B) 968 rpm
(C) 946 rpm (D) 985 rpm

13. Which of the following are the speed control method on stator side of an induction motor
(P) By changing applied voltage
(Q) By operating two motors in cascade
(R) By changing number of poles
(A) *P* and *Q* (B) *P* and *R*
(C) *Q* and *R* (D) *P*, *Q* and *R*

14. A 3-phase, 4-pole, 50 Hz induction motor takes 50 A at full load of 1450 rpm and develops a torque of 200 N-m. The starting current at rated voltage is 400 A by using star/delta method. Calculate the starting torque of the motor.
(A) 422.4 N-m (B) 52.8 N-m
(C) 211.2 N-m (D) 1267.2 N-m

15. The power input to the rotor of a 400V, 50Hz, 8 pole, 3 phase induction motor is 500 kW. Calculate the total rotor copper loss. When the rotor makes 180 cycles per minute.
(A) 470 kW (B) 3 kW
(C) 30 kW (D) 10 kW

16. The power to a 400V, 50 Hz, 8-pole, 3-phase induction motor running at 700 rpm is 50 kW. The stator losses are 2 kW and the friction and windage losses total 3 kW. Calculate the efficiency of the motor.
(A) 96% (B) 90%
(C) 89.56% (D) 83.56%

17. A 400V, 3-phase, 50Hz, 6-pole star connected induction motor takes a line current of 20A with 0.8 p.f lagging. Its total stator losses are 4% of the input, rotor copper losses are 4% of the input to the rotor and mechanical losses are 2% of the input of the rotor. Then the shaft-torque of the motor is
(A) 110.26 Nw-m (B) 105.85 Nw-m
(C) 99.50 Nw-m (D) 103.73 Nw-m

18. The rotor of a 6-pole, 50Hz slip ring induction motor has a resistance of 0.2 Ω per phase and runs at 950 rpm at full load. Calculate the external resistance per phase which must be added in order to lower the speed to 900 rpm and the torque being 1.5 times as before.
(A) 0.2 Ω (B) 0.66 Ω
(C) 0.266 Ω (D) 0.33 Ω

19. A 3-phase induction motor has a 6-pole, *Y* – connected stator winding. The motor runs on 60 Hz supply with 250V between lines. The motor resistance and standstill reactance per phase are 0.15 Ω and 0.82 Ω respectively. Calculate the rotor gross output power at a slip of 4% (rotor turns to stator turns ratio is 0.8)
(A) 3278.96W (B) 29510.64W
(C) 9836.88W (D) 8545.55W

20. A 3-phase induction motor having a 4-pole, star connected stator winding runs on 250V, 50Hz supply. The rotor resistance and standstill reactance are 0.2 ohm and 0.8 ohm per phase. The ratio of stator to rotor turns is 1.5. Calculate the developed torque at a full load slip of 5%.
(A) 42.5 N-m (B) 85.00 N-m
(C) 106.26 N-m (D) 58.50 N-m

21. Calculate the power factor of an induction motor at a slip of 5 percent, when the rotor resistance and stand still reactance of a 3-phase induction motor are 0.02 and 0.08 Ω per phase respectively.

(A) 0.24 (B) 0.74
(C) 0.85 (D) 0.98

22. Calculate the percentage tapping required on an auto transformer required for a squirrel cage motor to start the motor against 1/5 of full load torque. The short circuit current on normal voltage is 6 times the full load current and the full load slip is 4%.

(A) 62.74% (B) 37.26%
(C) 4.56% (D) 13.41%

23. A 3-phase, 500/300V, *Y-Y* connected wound rotor induction motor has 0.04 Ω rotor resistance and 0.2 Ω standstill reactance per phase. When the ratio of starting torque to maximum torque is 0.8, then the slip at maximum torque is ________

(A) 0.4 (B) 0.8
(C) 1 (D) 0.5

24. A 6-pole induction motor and a 8-pole induction motor are connected in cumulative cascade. When the frequency in the secondary circuit of the 8-pole motor is 2Hz and supply frequency is 60Hz. Calculate combined speed of the set.

(A) 870.30 rpm (B) 514.28 rpm
(C) 1160.40 rpm (D) 497.30 rpm

25. A three phase, two pole 50Hz induction motor is observed to be operating at a speed of 2900rpm, with an input power 15.7kW and terminal current of 22.6A. stator winding has a resistance of 0.2 Ω /phase. What is the I^2R power dissipated in the rotor?

(A) 419W (B) 513W
(C) 493W (D) 503W

Answer Keys

1. B	**2.** B	**3.** C	**4.** D	**5.** D	**6.** A	**7.** D	**8.** D	**9.** C	**10.** B
11. A	**12.** B	**13.** B	**14.** A	**15.** C	**16.** D	**17.** C	**18.** B	**19.** C	**20.** A
21. D	**22.** B	**23.** D	**24.** D	**25.** B					

Hints and Explanations

1. Choice (B)

2. rotor frequency $f_r = S \times$ supply frequency, therefore the injecting e.m.f has same frequency of rotor frequency with opposite phase sequence. Choice (B)

3. Backward slip = 2 – S

∴ Backward torque $T_b = -k\left(\dfrac{I_2^2 R_2}{2-S}\right)$

Choice (C)

4. Choice (D)

5. Choice (D)

6. Choice (A)

7. Torque adjusts according to new speed, hence for most motors, it will decreases. Since more I^2R losses happen, h decreases. Choice (D)

8. $S_{nl} = \dfrac{n_s - n_{nl}}{n_s} = \dfrac{3600-3580}{3600} \times 100 = 0.56\%$

$f' = sf = 0.0056 \times 60 = 0.33$Hz Choice (D)

9. Vector addition of three fluxes, 120° electrical apart;
⇒ gives flux of $1.5\phi_m$ at each instant Choice (C)

10. At full load, rated output is given Choice (B)

11. For constant flux v/f ratio is constant

$$\therefore \frac{V_1}{f_1} = \frac{V_2}{f_2} \Rightarrow v_2 = \frac{220}{30} \times 60 = 440\text{V}$$

$$N_1 = \frac{120 \times f_1}{P} = \frac{120 \times 30}{4} = 900 \text{ rpm}$$

$$N_2 = \frac{120 f_2}{P} = \frac{120 \times 60}{4} = 1800 \text{ rpm}$$

Choice (A)

12. Synchronous speed $N_s = \dfrac{120 f}{P}$

$$= \frac{120 \times 50}{6} = 1000\text{rpm}$$

$$\text{Slip } S_1 = \frac{1000-950}{1000} = 0.05$$

$$S_2 = S_1\left(\frac{V_1}{V_2}\right)^2 = 0.05 \times \left(\frac{400}{500}\right)^2 = 0.032$$

Speed $N_2 = 1000(1 - 0.032) = 968$ rpm Choice (B)

13. By operating two motors in cascade connection mode is rotor side speed control method.

Choice (B)

14. $\dfrac{T_{st}}{T_f} = \left[\dfrac{I_{SC}}{I_f}\right]^2 S_f$

$I_{st} = I_{SC} = 400$A
$I_f = 50$ A

$$N_S = \frac{120 \times 50}{4} = 1500 \text{ rpm}$$

$$S = \frac{N_S - N}{N_S} = \frac{50}{1500} = 0.033$$

$T_f = 200$ N-m

$T_{st} = 200 \times \left(\frac{400}{50}\right)^2 \times 0.033 = 422.4$ N-m

Choice (A)

15. Synchronous speed $N_s = \frac{120f}{P}$

$= \frac{120 \times 50}{8} = 750 \text{ rpm}$

Rotor frequency $f_r = sf_s$

$\frac{180}{60} = S \times 50 \Rightarrow S = 0.06$

Rotor speed $N_r = N_s(1 - S) = (1 - 0.06) \times 750$
$= 705$ rpm
Total rotor copper loss = S × rotor Input
$= 0.06 \times 500 = 30$ kW

Choice (C)

16. Synchronous speed $N_s = \frac{120 \times 50}{8} = 750 \text{ rpm}$

Slip $= \frac{N_s - N}{N_s} = \frac{750 - 700}{750} = 0.067$

Motor input = 50 kW
Output power = rotor Input power – rotor copper loss – friction and windage losses
Rotor input power = Input power – stator loss
$= 50 - 2 = 48$ kW
$P_{out} = 48 - 0.067 \times 48 - 3 = 41.784$

$\%\eta = \frac{P_{out}}{P_{in}} = \frac{41.784}{50} \times 100 = 83.568\%$

Choice (D)

17. $P_{in} = \sqrt{3} \times 400 \times 20 \times 0.8 = 11085.12\text{W}$
Stator losses $= 0.04 \times P_{in} = 443.40\text{W}$
Rotor input P_r = stator output = P_{in} – Stator losses
$= 10641.72\text{W}$
Rotor copper loss $= 0.04 \times P_r = 425.66\text{W}$
Mechanical losses $= 0.02 \times P_r = 212.83\text{W}$
Shaft output $P_{out} = 10641.72 - 425.66 - 212.83$
$= 10003.23$ watts

Slip $= \frac{\text{rotor copper loss}}{\text{rotor input}} = 4\%$

Speed of rotor $N_r = (1 - S)N_s$

$= (1 - 0.04) \times \frac{120 \times 50}{6} = 960$ rpm

Angular rotor speed $\omega_r = \frac{2\pi N_r}{60}$

$= \frac{2\pi \times 960}{60} = 100.53$ rad/sec

Shaft torque $= \frac{P_{out}}{\omega_r} = \frac{10003.23}{100.53} = 99.50$ Nw-m

Choice (C)

18. Torque $T = \frac{KS R_2}{R_2^2 + (SX_2)^2}$

$T_2 = 1.5\, T_1$

$N_s = \frac{120 \times 50}{6} = 1000 \text{ rpm}$

$S_1 = \frac{50}{1000} = 0.05$

$S_2 = \frac{100}{1000} = 0.1$

X_2 is not given $T \alpha \frac{ks}{R_2}$

$\frac{T_1}{T_2} = \frac{k S_1}{R_2}\left(\frac{R_2 + r}{k S_2}\right)$

$\Rightarrow \frac{T_1}{1.5T_1} = \frac{0.05}{0.1} \times \frac{R_2 + r}{R_2}$

$\Rightarrow 1.33 = \frac{R_2 + r}{R_2} \Rightarrow (1.33 - 1)R_2 = r$

$\Rightarrow r = 0.66\ \Omega$

Choice (B)

19. Voltage/phase $= \frac{250}{\sqrt{3}} = 144.33\text{V}$

$K = 0.8$
Standstill motor e.m.f per phase is

$E_2 = \frac{250}{\sqrt{3}} \times 0.8 = 115.47\text{V}$

$S = 0.04$

Rotor impedance $= \sqrt{0.15^2 + (0.04 \times 0.8)^2} = 0.153\ \Omega$

$I_2 = \frac{SE_2}{Z_r} = \frac{0.04 \times 115.47}{0.153} = 30.18\text{A}$

Total copper loss in rotor $= 3I_2^2 R_2$
$= 3 \times 30.18^2 \times 0.15 = 409.87\text{W}$

Rotor gross output = rotor copper loss $\times \left(\frac{1-S}{S}\right)$

$= 409.87 \times \left(\frac{1 - 0.04}{0.04}\right) = 9836.88\text{W}$

Choice (C)

20. $K = \frac{\frac{\text{rotor turns}}{\text{phase}}}{\frac{\text{stator turns}}{\text{phase}}} = \frac{1}{1.5}$

$E_2 = kE_1 = \frac{1}{1.5} \times \frac{250}{\sqrt{3}} = 96.22\text{V}$

$S = 0.05$

$N_S = \frac{120 \times 50}{4} = 1500 \text{ rpm}$

$$T_f = \frac{180}{2\pi N_S} \times \frac{SE_2^2 R_2}{R_2^2 + (SX_2)^2}$$

$$= \frac{180}{2\pi \times 1500} \times \frac{0.05 \times 96.22^2 \times 0.2}{0.2^2 + (0.05 \times 0.8)^2} = 42.5 \text{ N-m}$$

Choice (A)

21. Rotor reactance per phase under running condition $= SX_2 = 0.05 \times 0.08 = 0.004$

Rotor impedance per phase = $\sqrt{0.02^2 + 0.004^2}$

$= 0.0204\ \Omega$

Power factor = $\dfrac{0.02}{0.0204} = 0.98$ Choice (D)

22. $\dfrac{T_{st}}{T_f} = \dfrac{1}{5} = 0.2$

$$\frac{I_{SC}}{I_f} = 6 \Rightarrow \left(\frac{I_{SC}}{I_f}\right)^2 = 36$$

$S_f = 0.04$

$$\frac{T_{st}}{T_f} = k^2 \left(\frac{I_{sc}}{I_f}\right)^2 S_f$$

$\Rightarrow\ 0.2 = k^2 \times 36 \times 0.04 \Rightarrow k = 0.372$

Choice (B)

23. $\dfrac{\text{starting torque}}{\text{maximum torque}} = \dfrac{2 \times S_m}{1 + S_m^2}$

$$0.8 = \frac{2S_m}{1 + S_m^2}$$

$\Rightarrow\ 0.8S_m^2 - 2S_m + 0.8 = 0$

$S_m = 2, 0.5$ Choice (D)

24. $N_s = \dfrac{120 \times 60}{(8+6)} = 514.28$ rpm

$$S = \frac{f^{11}}{f} = \frac{2}{60} = 0.033$$

$$S = \frac{N_s - N}{N_s} \Rightarrow N = (1 - S)N_s$$

$= (1 - 0.033) \times 514.28$

$= 497.30$ rpms Choice (D)

25. $P_{\text{stator}} = 3I^2_1 R_1 = 3(22.6)^2\, 0.2 = 306\text{W}$

$P_{\text{gap}} = P_{in} - P_{\text{Stator}} = 15.7 - 0.3 = 15.4\text{kW}$

$$N_s = \frac{120f}{P} = \frac{120}{2} \times 50 = 3000\text{rpm}$$

$$\text{Slip} = \frac{3000 - 2900}{3000} = 0.03334$$

$P_{\text{rotor}} = 0.03334 \times 15.4\text{kW} = 513\text{W}$ Choice (B)