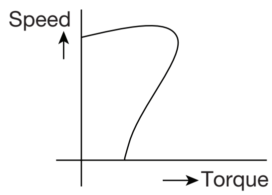
Number of Questions: 35 **Section Marks: 90**

Directions for questions 1 to 35: Select the correct alternative from the given choices.

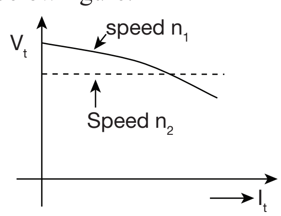
1. Which machine has the following torque speed characteristics.



(A) DC – shunt motor
(B) DC – Compound motor
(C) Induction motor
(D) Servo motor

2. A 200 V, 50 A, 4-pole DC-motor has commutator with a diameter of 60 cm rotates at 1500 rpm and has a brush width of 2 cm. The commutation time of DC motor is.
(A) 0.212 m sec (B) 0.424 m sec
(C) 1.2 m sec (D) 0.824 m sec

3. The DC shunt machine external characteristics as shown in the below figure.



(A) $n_2 < n_1$ (B) $n_2 > n_1$
(C) $n_1 = n_2$ (D) any of the above

4. The stored magnetic energy can be calculated by equation(s)
(1) $\frac{1}{2}\frac{\psi^2}{L}$ (2) $\frac{1}{2}HB$
(A) Only 1 (B) Only 2
(C) Both 1 and 2 (D) None of the above

5. The magnitude of electromagnetic torque in all rotating machines can be expressed as
(A) T_e α (Stator field strength) (Rotor field strength) sinδ
(B) T_e α (Stator field strength) (Rotor field strength) cosδ
(C) T_e α (Stator field strength) (Rotor field strength)
(D) None of the above

6. Which of the following statements are correct when three phase induction motor fails to start.
(1) One or more fuses may be blown
(2) Voltage may be too low
(3) The starting load may be too heavy
(A) Only 1 (B) Both (1) and (2)
(C) Both (2) and (3) (D) All of the above

7. Two 1 – ϕ transformers are connected in parallel at no load one has a turn ratio of 4000/440 V and a rating of 250 KVA, the other has a ratio of 4,000/500 V and a rating of 300 KVA. The leakage reactance of each transformer is 3%. The no load circulating current is
(A) 568.18 A (B) 1250 A
(C) 1168.18 A (D) 31.81 A

8. A 500 KVA, 50 Hz single phase, 6000/5000 V auto transformer has an emf per turn 10 V and maximum flux density 1.2 wb/m^2. The core area of the transformer is
(A) 0.0375 mm^2 (B) 0.0375 cm^2
(C) 375 cm^2 (D) 375 mm^2

9. A 100 KVA, 200 V, 50 Hz, 1 – ϕ alternator has an armature resistance of 0.02 ohm and an armature leakage reactance of 0.08 ohm. Calculate the voltage induced in the armature when the alternator is delivering rated current at a load power factor of 0.8 leading.
(A) 187.88 V (B) 212.11 V
(C) 233.44 V (D) 170.00 V

10. A 3-phase, Y-connected synchronous generator supplies a current of 20 A having phase angle of 30° lagging at 400 V. Calculate the direct axis current (Assume X_d = 20 ohm and X_q = 8 ohm)
(A) 5.54 A (B) 14.41 A
(C) 7.05 A (D) 10 A

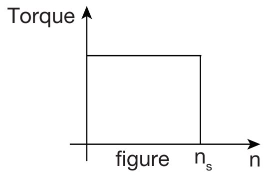
11. A stepper motor has a step angle of 3° and stepping frequency is 3000 rps. The shaft speed of motor is.
(A) 3000 rpm (B) 25 rpm
(C) 3000 rps (D) 25 rps

12. The hysteresis loop of a magnetic material has an area of 10 cm^2 with the scales given as 1 cm = 2AT and 1cm = 25 mwb at 60 Hz. The total hysteresis loss is
(A) 60 W (B) 30 W
(C) 25 W (D) 50 W

13. The reactance voltage in dc machines can be expressed as
(A) Coefficient of self Inductance × Rate of change of current
(B) $L \times \frac{2I}{T_C}$
(C) Both (A) and (B)
(D) None of the above

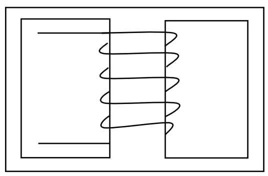
14. The maximum power developed in synchronous motor when.
(A) θ = α (B) θ = α + 90
(C) θ = α – 90 (D) θ + α = 0

15. Which motor has the following torque speed characteristic as shown in the figure



(A) Universal motor (B) Stepper motor
(C) Hysteresis motor (D) Reluctance motor

16. The transformer has core area of 2 cm^2 and lengths 10 cm in each outer leg and an area of 3 cm^2 and a length of 5 cm in the central leg as shown in the figure. A coil of 1500 turns carrying 20 mA is placed around the central leg. Calculate *B* in the centre leg (μ = 0.005 H/m)



(A) 0.8 T (B) 1.2 T
(C) 0.6 T (D) 1.4 T

17. A 6 – pole, DC machine has 40 slots and 8 conductors per slot. The total flux per pole is 25 mwb. The machine is rotated at a speed of 1500 rpm. The generated emf of the machine when it is lap connected winding is.
(A) 200 V (B) 600 V
(C) 400 V (D) 300 V

18. A 3-phase, 8-pole, 50 Hz star connected cylindrical rotor alternator develops an open circuit emf of 415 V. The armature has 48 slots with two layer winding full pitched with 2 turns each. The alternator has mean air gap diameter 0.2 m, core length 0.5 m. The peak value of fundamental flux density wave in air gap.
(A) 0.05 T (B) 2.38 T
(C) 1.2 T (D) 1.82 T

19. Two 1 – ϕ transformers, one is 200 KVA and the other is 100 KVA are connected in parallel to the same bus – bar on the primary side, their no – load secondary voltages being 2000 V and 1800 respectively. The resistance and reactance are 2.0 Ω, 3.0 Ω and 6 Ω, 4 Ω respectively. The no – load circulating current of transformers is
(A) 40 A (B) 13.34 A
(C) 15.44 A (D) 17.88 A

20. The speed of separately excited d. c. motor is controlled by a chopper. The supply voltage is 100 V, armature circuit resistance = 0.2 ohm, armature circuit inductance = 10 mH and motor constant = 0.02 V/rpm. The motor drives a constant load torque requiring an average current of 15 A. calculate the range of speed control for continuous motor current
(A) 0 to 4850 rpm (B) 0 to 9700 rpm
(C) 0 to 1500 rpm (D) 0 to 3000 rpm

21. In a double cage induction motor, if the outer cage has an impedance at stand still (3 + *j*1.5) ohm. Calculate the slip at which the two cages develop equal torques, if the inner Cage has an impedance of (0.5 + *j*3) ohm at stand still.
(A) 38.06% (B) 20%
(C) 5.02% (D) 4.08%

22. A 20 kW, 4-pole, 50 Hz, 3-phase induction motor has friction and windage losses 2% of the output. The full load copper loss at a slip of 5% is
(A) 1073 watts (B) 1020 watts
(C) 1473 watts (D) 1420 watts

23. A 200 V, d. c shunt machine has an armature circuit resistance of 0.4 Ω and field circuit resistance of 100 Ω. If this machine is connected to 200 V supply mains and line current of 50 A. The ratio of e. m. f generated when the machine is working as a generator and motor is
(A) 1.18 (B) 1.22
(C) 0.81 (D) 1.02

24. A 3000 V star connected synchronous motor has synchronous impedance of 0.2 + *j*3Ω per phase if an excitation e.m.f of 400 V and input power of 1200 kW at rated voltage is given to the motor. The armature current is.
(A) 769.83 A (B) 576.19 A
(C) 192.33 A (D) 285.56 A

25. A 200 KVA lighting transformer has a full load loss of 5 kW, the losses being equally divided between iron and copper. During a day, the transformer operates on full load for 5 hours, on half load for 8 hours, the output being negligible for the remainder of the day. The all day efficiency of the transformer is
(A) 72.07% (B) 94.75%
(C) 92.75% (D) 97.56%

26. The equivalent circuit of a 400V, 3-phase, 1500 rpm induction motor with a stator connected winding has the following impedances per phase referred to the stator at stand still.
Stator: (0.2 + *j*2) ohm; Rotor : (0.8 + *j*4) ohm
Magnetising branch : (20 + *j*40) ohm
The maximum torque developed in the induction motor is.
(A) 155.17 Nm (B) 165.53 Nm
(C) 122.016 Nm (D) 141.38 Nm

27. Two alternators *A* and *B* operate in parallel and supply a load of 20 MW at 0.8 p.f lagging. By adjusting steam supply and excitation of machine *A*, its power output and p.f are 8000 kW and 0.9 lagging respectively. The p.f of alternator *B* is

(A) 0.732 leading (B) 0.732 lagging
(C) 0.447 leading (D) 0.447 lagging

28. A 2,000 V, 3-phase star-connected, synchronous, motor has a resistance of 0.4 ohm per phase and a synchronous reactance of 3 ohm per phase. The motor is operating at 0.6 power factor leading with a line current of 150 A. The generated e.m.f per phase is.
(A) 1154 volts (B) 1511 volts
(C) 1607 volts (D) 700 volts

29. A 50 Hz, 6-pole induction motor has full load slip of 8% the rotor resistance /phase = 0.02 ohm and stand still reactance = 0.4 ohm. Calculate the speed at which maximum torque occurs.
(A) 1000 rpm (B) 1050 rpm
(C) 900 rpm (D) 950 rpm

30. A load of 800 KVA at 0.85 power factor lagging is to be shared by two three phase transformers *A* and *B* of equal ratings. If the equivalent delta impedances as referred to secondary are $(3 + j6)\Omega$ for *A* and $(2 + j4)\Omega$ for *B*. The load supplied by transformer *A* is
(A) 1195.13 KVA (B) 597.56 KVA
(C) 268.57 KVA (D) 531.43 KVA

31. A 250 V, 2000 rpm, 15 A, separately excited DC motor has an armature resistance of 3 Ω. Rated DC voltage is applied to both the armature and field winding of the motor. If the armature draws 10 A form the source, the torque developed by the motor is
(A) 14.68 Nm (B) 4.89 Nm
(C) 17.90 Nm (D) 8.95 Nm

Common Data Questions for 32 and 33:

A 3-phase induction motor having a 4 – pole, Star connected stator winding runs on 415 V, 50 Hz. The rotor resistance and stand still reactance are 0.15 ohm and 0.8 ohm per phase. The ratio of stator to rotor turns is 1.5, full load slip is 4%

32. The developed full load torque is
(A) 124.48 Nm (B) 304.54 Nm
(C) 248.56 Nm (D) 314.46 Nm

33. The maximum torque of the machine is
(A) 248.56 Nm (B) 304.54 Nm
(C) 320.46 Nm (D) 504.56 Nm

Linked Answer Questions 34 and 35:

A 200 W, 230 V, 50 Hz capacitor start motor has the following constants, for the main and auxiliary windings;
Main winding $Z_m = (4 + j3.5)$ ohm
auxiliary winding $Z_a = (9 + j3)$ ohm
Assume the main and auxiliary winding currents are in quadrature at starting.

34. The phase angle between auxiliary winding current and supply voltage is
(A) 41.18 lead (B) 71.57 lead
(C) 18.43 lead (D) 48.82 lead

35. The value of starting capacitor is
(A) 239.81 μF (B) 13.28 μF
(C) 10.28 μF (D) 102.81 μF

Answer Keys

1. C	**2.** B	**3.** A	**4.** C	**5.** A	**6.** D	**7.** B	**8.** C	**9.** A	**10.** B
11. D	**12.** B	**13.** C	**14.** A	**15.** C	**16.** B	**17.** A	**18.** B	**19.** D	**20.** A
21. A	**22.** A	**23.** B	**24.** D	**25.** B	**26.** B	**27.** B	**28.** B	**29.** D	**30.** D
31. A	**32.** A	**33.** B	**34.** D	**35.** A					

Hints and Explanations

1. The torque – speed characteristics of Induction motor same as the given figure. Choice (C)

2. Peripheral velocity of diameter

$$v = \pi Dn = \pi \times 60 \times \frac{1500}{60} \text{ cm/s}$$

But v × time of commutation = Brush width

$$\text{Time of commutation} = \frac{2}{\pi \times 1500} = 0.424\text{m sec}$$

Choice (B)

3. As the speed of the DC-machine decreases, the terminal voltage also decreases up to rated current.
Choice (A)

4. Choice (C)

5. Choice (A)

6. Choice (D)

7. Reactances seen from the secondary side are

$$X_{1(\Omega)} = \frac{3}{100} \times \frac{440 \times 440}{250 \times 10^3} = 0.023\Omega$$

$$X_{2(\Omega)} = \frac{3}{100} \times \frac{500 \times 500}{300 \times 10^3} = 0.025\Omega$$

The difference of induced voltage is 60V

$$\text{The circulating current is} = I_C = \frac{60}{0.023 + 0.025}$$

= 1,250A Choice (B)

8. $E = 4.44\ \phi_m f N$ volt

$$\phi_m = \frac{\frac{E}{N}}{4.44 f} = \frac{10}{4.44 \times 50} = 0.045$$

$$\text{Core area} = \frac{0.045}{1.2} = 0.03753 = 375\text{cm}^2$$

Choice (C)

9. $\text{Full load rated current} = \frac{100 \times 1000}{200} = 500\ \text{A}$

$IR_a = 500 \times 0.02 = 10$ V
$IX_L = 500 \times 0.08 = 40$ V
$E = [(V\cos\phi + IR_a)^2 + (V\sin\phi - IX_L)^2]^{1/2}$
$= [(200 \times 0.8 + 10)^2 + (200 \times 0.6 - 40)^2]^{1/2}$
$= 187.88$ V Choice (A)

10. $\cos\phi = \cos30° = 0.866$
$\sin\phi = \sin30 = 0.5$

$$\tan\delta = \frac{I_a X_q \cos\varphi}{V + I_a X_q \sin\varphi} = \frac{20 \times 8 \times 0.866}{400 + 20 \times 8 \times 0.5} = 0.288$$

$\delta = 16.10°$
$I_d = I_a \sin(\phi + \delta) = 20 \sin(30 + 16.10) = 14.41$ A
Choice (B)

11. $$\eta = \frac{\beta \times f}{360°}$$

$$= \frac{3 \times 3000}{360} = 25\ \text{rps}$$ Choice (D)

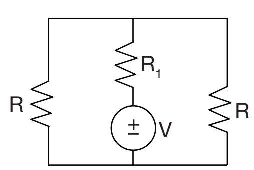
12. Hysteresis loss $P_h = 2 \times 10 \times 25 \times 60 \times 10^{-3}$
$P_h = 30$ watts Choice (B)

13. Choice (C)

14. Choice (A)

15. By observing the torque – speed characteristics of the given motors, the Hysteresis motor has similar characteristics. Choice (C)

16. $V_m = m.\ m.\ f = NI = 1500 \times 20 \times 10^{-3} = 30$AT
The equivalent electrical circuit for the problem



$$\text{Total resistance} = \frac{R \times R}{R + R} + R_1 = \frac{R}{2} + R_1$$

Hence total reluctance =

$$R = \frac{1}{2} \times \frac{10 \times 10^{-2}}{0.005 \times 2 \times 10^{-4}} + \frac{5 \times 10^{-2}}{0.005 \times 3 \times 10^{-4}}$$

$= 50{,}000 + 33{,}333.34$
$= 83{,}333.34$AT/wb

$$\phi(\text{total}) = \frac{V_m}{R} = \frac{30}{83{,}333.34} = 3.6 \times 10^{-4}$$

$$B(\text{in centre leg}) = \frac{\varphi}{s} = \frac{3.6 \times 10^{-4}}{3 \times 10^{-4}} = 1.2\text{T}$$

Choice (B)

17. For lap winding $A = P = 6$
$Z = 40 \times 8 = 320$

$$E = \frac{\varphi Z N}{60} \times \frac{P}{A}$$

$$= \frac{25 \times 10^{-3} \times 320 \times 1500}{60} = 200$$ Choice (A)

18. $$N_{ph} = \frac{48 \times 2}{3} = 32$$

$$\text{Slots per pole phase} = \frac{48}{8 \times 3} = 2$$

$$\text{Slot angular pitch} = \gamma = \frac{180}{8} = 22.5$$

$$K_d = \frac{\sin\frac{2 \times 22.5}{2}}{2\sin\frac{22.5}{2}} = 0.98$$

$K_P = 1$
$E = 4.44\ \phi f N_{ph} .\ K_w\ (\because K_w = K_p K_d)$

$$\phi = \frac{4}{P} B_{1p} l_r$$

$$B_{ip} = \frac{P\varphi}{4lr} = \frac{8 \times 0.0596}{4 \times 0.1 \times 0.5} = 2.384\text{T}$$ Choice (B)\

19. $\text{Total impedance} = \sqrt{(R_A + R_B)^2 + (X_A + X_B)^2}$

$= \sqrt{5^2 + 10^2} = 11.18\Omega$

$$\text{Circulating current} = \frac{200}{11.18} = 17.88\ \text{A}$$ Choice (D)

20. The minimum speed is zero when $E_b = 0$
$V_t = E_b + I_a R_a$
$= 15 \times 0.2 = 3$ V
Maximum speed corresponds to $\alpha = 1$ when
$V_t = V = 100$ V
$E_b = V - I_a R_a = 100 - 15 \times 0.2 = 97$V

$$N = E_b / K_a\phi = \frac{97}{0.02} = \frac{9700}{2} = 4850\ \text{rpm}$$ Choice (A)

21. S – be the slip at which two cage develop equal torques.

$$Z_1 = \sqrt{\left(\frac{3}{s}\right)^2 + (1.5)^2} \text{ and } Z_2 = \sqrt{\left(\frac{0.5}{S}\right)^2 + 3^2}$$

$$\left(\frac{I_1}{I_2}\right)^2 = \left(\frac{Z_2}{Z_1}\right)^2 = \frac{\left(\frac{0.25}{S^2}\right) + 9}{\frac{9}{S^2} + 2.25}$$

Power input to outer cage $P_1 = \dfrac{I_1^2 R_1}{S}$

$$P_1 = I_1^2 \times \frac{3}{S}$$

$$P_2 = I_2^2 \times \frac{0.5}{S}$$

$$\frac{T_1}{T_2} = \frac{P_1}{P_2} = \left(\frac{I_1}{I_2}\right)^2 \times 6 = \frac{\left(\frac{0.25}{S^2}\right)+9}{\left(\frac{9}{S^2}\right)+2.25} \times 6$$

$T_1 = T_2$

$(9/S^2 + 2.25) = \left(\dfrac{0.25}{S^2}+9\right)6$

$\Rightarrow \dfrac{9}{S^2} - \dfrac{1.5}{S^2} = 51.75 \Rightarrow \dfrac{7.5}{S^2} = 51.75$

$\Rightarrow S^2 = 0.145 \Rightarrow S = 0.38$ Choice (A)

22. Motor output P_{out} = 20,000 watts
Friction and windage loss P_w = 2% × 20,000
= 0.02 × 20,000 = 400 watts
rotor gross output = 20,000 + 400 = 20,400

rotor copper loss = $\dfrac{0.05}{0.95} \times 20,400 = 1073.68$

Choice (A)

23. given line current I_L = 50 A

$I_f = \dfrac{200}{100} = 2$ A

Armature current I_a = 50 + 2 = 52 A
Generated e. m. f in generator $E_{g1} = V_t + I_a R_a$
= 200 + 52 × 0.4 = 220.8 volts
Generated emf in motor E_{m1} = 200 – 48 × 0.4 = 180.8

ratio = $\dfrac{E_{g1}}{E_{M1}} = \dfrac{220.8}{180.8} = 1.22$ Choice (B)

24. given $V_t = \dfrac{3000}{\sqrt{3}}$ = 1732.05 V

$E_f = \dfrac{4000}{\sqrt{3}}$ = 2309.5 V

$Z_s = \sqrt{0.2^2 + 3^2}$ = 3.006Ω

$\alpha_z = \tan^{-1}\left(\dfrac{0.2}{3}\right)$ = 3.81°

Per phase input power

$$\frac{1200 \times 1000}{3} = \frac{1732.05 \times 2309.5}{3.006} \sin(\delta - \alpha_z) + \left(\frac{1732.05}{3.006}\right)^2 \times 0.2$$

40,0000 = 13330728.36 . $\sin(\delta - \alpha_Z)$ + 66400.73
333599.27 = 1330728.36. $\sin(\delta - \alpha_Z)$
0.25 = $\sin(\delta - \alpha_Z) \Rightarrow \delta - \alpha_Z = 14.51$

$\Rightarrow \delta = 18.32°$

$I_a Z_s = [1732.05^2 + 2309.05^2 - 2 \times 1732.05 \times 2309.5 \cos 18.32]^{1/2}$

$I_a = \dfrac{858.40}{3} = 285.56$A Choice (D)

25. The lighting transformers taken a load of unity p. f
Iron loss for 24 hours = 2.5 × 24 = 60 kWh
Full load copper loss = –2.5 kW
Copper loss for 5 hours = 12.5 kWh
Copper loss for 8 hours at half load

$= \dfrac{2.5}{4} \times 8$ = 5 kWh

Total losses = 60 + 12.5 + 5 = 77.5
Total output = (200 × 5) + 100 × 4 = 1400 kWh

$\eta_{\text{all – day}} = \dfrac{1400}{1477.5} \times 100$ = 94.75% Choice (B)

26. Maximum slip $S_m = \dfrac{R_2^1}{\sqrt{R_1^2 + (X_1 + X^1{}_2)^2}}$

$= \dfrac{0.8}{\sqrt{0.2^2 + 6^2}}$ = 0.1332 = 13.32%

Maximum value of gross torque developed by rotor

$$T_{gmax} = \frac{P_{g\max}}{\frac{2\pi N_s}{60}} = \frac{\frac{3 I_2^{1\,2} R_2^1}{S_m}}{\frac{2\pi N_s}{60}}$$

$$I^1{}_2 = \frac{V_1}{\sqrt{(R_1 + R_2^1)^2 + (X_1 + X_2^1)^2}}$$

$$= \frac{400/\sqrt{3}}{\sqrt{(0.2+0.8)^2 + (2+4)^2}} = 37.96\text{A}$$

$T_{gmax} = \dfrac{3 \times 37.96^2 \times 0.8 \times 60}{0.133 \times 2\pi \times 1500}$ = 165.53 Nm Choice (B)

27. $\cos\phi = 0.8$, $\phi = 36.86°$
$\tan\phi = 0.7508$
$\cos\phi_A = 0.9 \Rightarrow \phi_A = 25.84°$
$\tan\phi_A = 0.4843$
Load kW = 20,000 kW, load KVAR = 15,016(lag)
kW of A = 8,000, KVAR of A = 8,000 × 0.4843 = 3874.4
kW of B = 20,000 – 8000 = 12,000 kW
KVAR of B = 15016 – 3874.4 = 11141.6 KVAR
∴ KVA of B = 12,000 – j11141.6
= 16374.83∠–42.87
cos 42.87 = 0.732 lagging

Choice (B)

28. $\phi = \cos^{-1}(0.6) = 53.13$ lead

$\theta = \tan^{-1}\left(\dfrac{3}{0.4}\right) = 82.40$

$\theta + \phi = 82.40° + 53.13° = 135.53°$

$V = \dfrac{2000}{\sqrt{3}} = 1154.70$ volts

$Z_s = \sqrt{0.4^2 + 3^2} = 3.02\Omega$

$IZ_S = 150 \times 3.02 = 453$

$E_b = \sqrt{V^2 + (IZ_s)^2 - 2V(IZ_s)\cos(\theta + \varphi)}$

$= \sqrt{(1154.70)^2 + (453)^2 - 2 \times 1154.70 \times 453 \cos 135.53°}$

$= 1511.65$ volts Choice (B)

29. $S_m = \dfrac{R_2}{X_2} = \dfrac{0.02}{0.4} = 0.05$

$S_f = 0.08$

$N_S = \dfrac{120 \times 50}{6} = 1000$ rpm

$S_m = 0.05$

$N = (1 - 0.05) \times 1000 = 950$ rpm Choice (D)

30. $S_A = S \times \dfrac{Z_B}{Z_A + Z_B} = S \times \dfrac{1}{1 + \left(\dfrac{Z_A}{Z_B}\right)}$

$S = 800(0.85 - j0.52) = 680 - j416$

$Z_A / Z_B = \left(\dfrac{3 + j6}{2 + j4}\right) = 1.5$

$S_A = \dfrac{(680 - j416)}{1.5} = 531.43\angle -31.45°$ Choice (D)

31. Back emf $E_b = V - I_a R_a$

$= 250 - 15 \times 3$

$= 205$ volts

$E_b I_a = T\omega$

Torque $T = \dfrac{E_b I_a}{\omega} = \dfrac{205 \times 15 \times 60}{2\pi \times 2000} = 14.68$ Nm.

Choice (A)

32. $K = \dfrac{\text{rotor turns / phase}}{\text{stator turns / phase}} = \dfrac{1}{1.5}$

$E_2 = KE_1$

$= \dfrac{1}{1.5} \times \dfrac{415}{\sqrt{3}} = 159.73\text{V}$

Slip = 0.04

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

Full load torque = $T_f = \dfrac{3 \times 60}{2\pi N_S} \times \dfrac{SE_2^2 R_2}{R_2^2 + (SX_2)^2}$

$= \dfrac{3 \times 60}{2\pi \times 1500} \times \dfrac{0.04 \times 159.73^2 \times 0.15}{0.15^2 + (0.8 \times 0.04)^2}$

$= 124.28$ Nm Choice (A)

33. For maximum torque $S = \dfrac{R_2}{X_2} = \dfrac{0.15}{0.8} = 0.1875$

T_{max} = maximum torque

$= \dfrac{3 \times 60}{2\pi \times 1500} \times \dfrac{0.1875 \times 159.73^2 \times 0.15}{0.15^2 + (0.1875 \times 0.8)^2}$

$= 304.54$ Nm Choice (B)

34. Assume X_C be the reactance of the capacitor connected in the auxiliary winding

$Z_a = 9 + j3 - jX_C = 9 + j(3 - X_C)$

$Z_M = 4 + j3.5 = 5.31\angle 41.18°$

I_m lags behind V by 41.18°

given phase angle between I_m and I_a has to be 90°

I_a must lead V by $= 90° - 41.18 = 48.82$ Choice (D)

35. For auxiliary winding $\tan\phi_a = X/R$

$\Rightarrow \tan 48.82 = \dfrac{3 - X_C}{9}$ $(X = 3 - X_C)$

$\Rightarrow 3 - X_C = 10.28 \Rightarrow X_C = 13.28\Omega$

$X_C = 13.28\Omega$

$\dfrac{1}{\omega C} = 13.28$

$\Rightarrow C = \dfrac{1}{314 \times 13.28} = 239.81\mu\text{F}$ Choice (A)