CLASS TEST

S.No.: 01SK_ABCDEFGHI_26625

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MACHINE

(DC + TRANSFORMER + INDUCTION)

ELECTRICAL ENGINEERING

Date of Test : 26/06/2025

ANSWER KEY

1.	(c)	7.	(c)	13.	(d)	19.	(a)	25.	(b)
2.	(a)	8.	(d)	14.	(a)	20.	(b)	26.	(c)
3.	(b)	9.	(d)	15.	(b)	21.	(d)	27.	(b)
4.	(c)	10.	(c)	16.	(b)	22.	(c)	28.	(d)
5.	(a)	11.	(d)	17.	(c)	23.	(d)	29.	(b)
6.	(b)	12.	(a)	18.	(b)	24.	(a)	30.	(c)

DETAILED EXPLANATIONS

1. (c)

For maximum torque (T_{max})

$$s_{max,\,T} = \frac{R_2}{X_2}$$

$$s_{max,\,T} = \frac{1}{4}$$

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

Now at T_{max} speed of motor,

$$N_r = (1 - s)\, N_s = (1 - 0.25) \times 1000$$

$$N_r = 750 \text{ rpm}$$

2. (a)

In a wave winding the armature current get equally divided between two parallel paths but in lap winding there can be a problem of circulating currents between two parallel paths and hence causing unequal currents in both paths.

3. (b)

$$\text{Time constant} = \frac{L}{r} = 0.2; \quad I^2 r = 400 \text{ W}$$

$$\text{Energy stored in Joules} = \frac{1}{2} L I^2 = \frac{1}{2} \times I^2 r \times \frac{L}{r}$$

$$= \frac{1}{2} \times 400 \times 0.2 = 40 \text{ Joules}$$

4. (c)

$$V = 240 \text{ V}, \qquad I_a = 40 \text{ A}$$

$$N_1 = 1500 \text{ rpm}, \qquad R_a = 0.3\ \Omega$$

$T \alpha I_a^2$, since the torque is constant.

$$\therefore \quad I_{a1}^2 = I_{a2}^2$$

$$\Rightarrow \quad I_{a1} = I_{a2} = 40 \text{ A}$$

During starting the induced emf is zero, hence the current is limited only by the resistance in the armature circuit.

$$\therefore \quad \text{Total resistance} = \frac{240}{40} = 6\ \Omega$$

Extra resistance to be added in series with armature = 6 – 0.3 = 5.7 Ω

5. (a)

Impedance under block rotor condition,

$$Z_b = \frac{V_b}{I_b} = \frac{82.5}{9.3} = 8.87\ \Omega$$

Resistance under block rotor condition,

$$R_b = \frac{W_b}{I_b^2} = \frac{500}{(9.3)^2} = 5.78\ \Omega$$

Rotor resistance referred to stator,

$$R_2' = R_b - R_1$$
$$= 5.78 - 2.5 = 3.28\ \Omega$$

6. (b)

Rotor input (or) air gap power

$$= 45 - 1.5 = 43.5\ \text{kW}$$
$$s = 0.04$$

Internal mechanical power developed is

$$= 43.5\ (1 - 0.04) = 43.5 \times 0.96 = 41.76\ \text{kW}$$

7. (c)

$$T_{st} = 0.8\ T_{\max}$$

$$0.8 = \frac{2s_{\max}}{s_{\min}^2 + 1}$$

$$s_{\max}^2 - \frac{2}{0.8}s_{\max} + 1 = 0$$

$$s_{\max}^2 - 2.5\ s_{\max} + 1 = 0$$

$$s_{\max} = 0.5$$

$$\therefore \quad 0.5 = \frac{0.03 + R_{ext}}{0.18}$$

$$0.09 = 0.03 + R_{ext}$$

$$R_{ext} = 0.09 - 0.03 = 0.06\ \Omega$$

8. (d)

We know, $$\frac{N_{\Delta(P)}}{N_{Y(P)}} = 5$$

Also, $$\frac{N_{\Delta(P)}}{N_{Y(P)}} = \frac{V_{\Delta(P)}}{V_{Y(P)}}$$

$$V_{Y(P)} = \frac{400}{\sqrt{3}}\ \text{V}$$

$$V_{\Delta(P)} = \frac{N_{\Delta(P)}}{N_{Y(P)}} V_{Y(P)} = 5 \times \frac{400}{\sqrt{3}} = \frac{2000}{\sqrt{3}}\ \text{V}$$

For delta side, $$V_{\Delta(L)} = V_{\Delta(P)} = \frac{2000}{\sqrt{3}}\ \text{V}$$

9. **(d)**

For maximum efficiency at unity power factor using condition,

$$\text{kVA}_m = (\text{kVA})_{fl}\sqrt{\frac{P_i}{P_{cu}}} = 400\sqrt{\frac{700}{2800}} = 400\sqrt{\frac{1}{4}} = 200 \text{ kVA}$$

At maximum efficiency,

$$P_c = P_i$$

$$\%\eta_{\max} = \frac{200}{200+\frac{700}{1000}+\frac{700}{1000}} = 99.30\%$$

10. **(c)**

For a 3-phase induction motor, spatial displacement,

$$\delta = 90 + \phi_2$$

where 'ϕ_2' is power factor angle,

$$\cos\phi_2 = 0.707$$

$$\phi_2 = 45°$$

$$\delta = 90° + 45° = 135°$$

11. **(d)**

For dc series motor;

Given, $V_t = 220$ V,

$N_r = 1500$ rpm

$I_a = 25$ A,

$R_a = 0.4\ \Omega$,

$R_{se} = 0.6\ \Omega$

Torque; $T \propto I_a^2$

back emf at 1500 rpm,

$$E_{b1} = V_t - I_{a1}(R_a + R_{se})$$

$$= 220 - 25\,(0.4 + 0.6)$$

$$E_{b1} = 195 \text{ V}$$

We know that, $E_b \propto N$

Back emf at 1200 rpm;

$$\frac{E_{b2}}{195} = \frac{1200}{1500}$$

$$E_{b2} = \frac{12}{15}\times 195 = 156 \text{ V}$$

Let us assume R_{ext} to be connected in series:

$$E_{b2} = V_t - I_{a2}(R_a + R_{se} + R_{ext})$$

To obtain rated torque at 1200 rpm, armature current must be same;

i.e. $I_{a2} = 25$ A

Now, $156 = 220 - 25\,(0.4 + 0.6 + R_{ext})$

$$220 - 156 = 25\,(1 + R_{ext})$$

$$R_{ext} = 1.56\ \Omega$$

12. (a)

At no load;

$$\text{Back emf, } E_{b0} = V_t - I_{a0}(R_a)$$
$$E_{b0} = 220 - 3(0.5)$$
$$E_{b0} = 218.5 \text{ V}$$

At full load;

$$\text{Back emf, } E_{b\,fl} = V_t - I_{a\,fl}(R_a)$$
$$= 220 - 45\,(0.5)$$
$$E_{b\,fl} = 197.5 \text{ V}$$

As flux is given constant;

then, we can write; $E_b \propto N$

or,
$$\frac{E_{b\,fl}}{E_{b0}} = \frac{N_{fl}}{N_0}$$

$$N_{fl} = \left(\frac{197.5}{218.5}\right) \times 1500$$
$$= 1355.83 \approx 1356 \text{ rpm}$$

13. (d)

Given:

S.C. Test (H.V): 57.5 V, 8.34 A, 284 W

$$Z_{eq} = \frac{57.5}{8.34} = 6.894\ \Omega$$

$$R_{eq} = \frac{284}{(8.34)^2} = 4.083\ \Omega$$

$$X_{eq} = \sqrt{Z_{eq}^2 - R_{eq}^2} = 5.555\ \Omega$$

For voltage regulation to be zero;

$$\text{Power factor; } \cos\phi = \cos\tan^{-1}\left(\frac{R_{eq}}{X_{eq}}\right) = \cos\,(36.32°)$$
$$\cos\phi = 0.805 \text{ leading}$$

14. (a)

Primary is star connected and secondary is delta connected.

$$(V_L)_{\text{primary}} = 11000 \text{ V}$$

$$(V_{ph})_{\text{primary}} = \frac{11000}{\sqrt{3}} \text{ V}$$

$$\frac{(V_{ph})_{sec}}{(V_{ph})_{prim}} = \frac{1}{5}$$

$$\therefore \quad \text{Turns ratio} = \left(\frac{\text{High voltage}}{\text{Low voltage}}\right)_{\text{phase}}$$

$$\therefore \quad (V_{ph})_{sec} = \frac{11000}{5\sqrt{3}} \text{ V}$$

$$(V_{ph})_\Delta = (V_L)_\Delta$$

$$\text{Output kVA} = \sqrt{3}V_L I_L$$

$$= \sqrt{3}\times\frac{11000}{5\sqrt{3}}\times 423 = 930.6 \text{ kVA}$$

15. (b)

Given that,

$$V_{OC} = 230 \text{ V},$$
$$I_{OC} = 1.3 \text{ A},$$
$$P_{OC} = 100 \text{ W}$$

$$R_C = \frac{V_{0C}^2}{P_{0C}} = \frac{230^2}{100} = 529\ \Omega$$

Power factor angle,

$$\phi_{OC} = \cos^{-1}\left(\frac{P_{OC}}{V_{OC}I_{OC}}\right) = \cos^{-1}\left(\frac{100}{230\times 1.3}\right) = 70.46°$$

$$X_\phi = \frac{R_C}{\tan\phi_{OC}} = \frac{529}{\tan 70.46°} = 187.73\ \Omega$$

Referred to high voltage side,

$$R_C = 529\times\left(\frac{400}{230}\right)^2 = 1600\ \Omega$$

$$X_\phi = 187.73\times\left(\frac{400}{230}\right)^2 = 567.8\ \Omega$$

16. (b)

Load characteristic is

$$T_L \propto N^2$$

For dc series motor, torque-current relation is given by

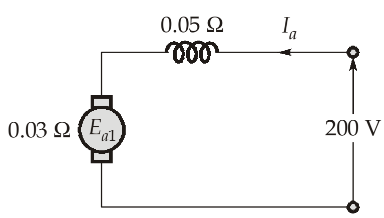
$$T_d \propto I_a^2$$

$$\therefore \quad \frac{I_{a2}}{I_{a1}} = \frac{N_2}{N_1}$$

$$\frac{I_{a2}}{15} = \frac{750}{1500}$$

$$I_{a2} = 7.5 \text{ A}$$

Case-I:



$$E_{a1} = 200 - 15\times(0.03 + 0.05)$$
$$E_{a1} = 198.8 \text{ V}$$

Case-II:

When additional resistance added in series with the armature circuit,

$$I_{a2} = 7.5 \text{ A},$$
$$N_2 = 750 \text{ rpm}$$

Now, $$E_a \propto \phi\omega_m$$

$$\frac{E_{a2}}{E_{a1}} = \frac{N_2}{N_1}\frac{I_{a2}}{I_{a1}} \qquad \text{(In dc series motor } \phi \propto I_a\text{)}$$

$$\frac{E_{a2}}{198.8} = \frac{750\times 7.5}{1500\times 15}$$

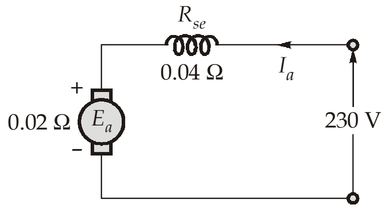
$$E_{a2} = 49.7 \text{ V}$$

$$E_{a2} = 200 - 7.5(0.08 + R_{ext}) = 49.7$$

$$0.08 + R_{ext} = \frac{200 - 49.7}{7.5}$$

$$R_{ext} = 20.04 - 0.08$$
$$= 19.96\ \Omega$$

17. (c)



Armature power developed,

$$= \text{shaft power + rotational losses}$$
$$= 1.5 \text{ kW} + 0.1 \text{ kW}$$
$$E_bI_a = 1.6 \text{ kW}$$

Back emf is given by,

$$E_b = \frac{NP\phi Z}{A\times 60} = \frac{N\times 0.035\times 500}{60} \qquad \text{(For lap } A = P\text{)}$$

and armature current, $$I_a = \frac{230 - E_b}{0.06}$$

$$E_b\left(\frac{230 - E_b}{0.06}\right) = 1600$$

$$230\,E_b - E_b^2 - 96 = 0$$

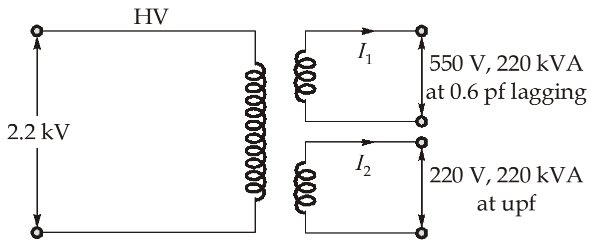
$$E_b = 229.58 \text{ V}$$

$$\text{Speed, } N = \frac{60E_b}{\phi Z} = \frac{60\times 229.58}{0.035\times 500}$$

$$N = 787.13 \text{ rpm}$$

18. (b)

Consider the below circuit:



Rated current in winding - 1

$$I_1 = \frac{220 \times 1000}{550} = 400\angle -53.13° \text{ A}$$

Rated current in winding - 2

$$I_2 = \frac{220 \times 1000}{220} = 1000\angle 0° \text{ A}$$

Current in HV side due to rated current in winding - 1

$$I_1' = \frac{(400\angle -53.13) \times 0.55}{2.2} = 100\angle{-53.13°} \text{ A}$$

Current in HV side due to rated current in winding - 2

$$I_2' = \frac{(1000\angle 0°) \times 0.22}{2.2} = 100\angle 0° \text{ A}$$

$$\text{HV side current} = 100\angle{-53.13°} + 100\angle 0°$$

$$I = 178.885\angle{-26.565} \text{ A}$$

$$|I| = 178.885 \text{ A}$$

19. (a)

$$V_{t1} = 400 \text{ V}; \quad I_{a1} = 150 \text{ A}$$

$$R_a = 0.12\ \Omega; \quad N_1 = 1500 \text{ rpm}$$

The value of load resistance,

$$R_L = \frac{400}{150} = 2.67\ \Omega$$

Load current 100 A, the terminal voltage,

$$V_{t2} = 100 \times R_L = 100 \times 2.67 = 267 \text{ V}$$

$$I_{a2} = 100\text{A}; \quad R_a = 0.12\ \Omega$$

$$E_g = \frac{\phi NZ}{60} \times \left(\frac{P}{A}\right) \Rightarrow E_g \ \alpha \ N$$

$$\frac{E_{g1}}{E_{g2}} = \frac{N_1}{N_2} = \frac{V_{t1} + I_{a1}R_a}{V_{t2} + I_{a2}R_a}$$

$$\Rightarrow \quad \frac{400 + 150 \times 0.12}{267 + 100 \times 0.12} = \frac{1500}{N_2}$$

$$N_2 = 1001.19 \text{ rpm}$$

20. (b)

There is a change of flux/pole due to armature reaction,

$$E_G \ \alpha \ \phi_1 N_1$$

$$\Rightarrow \quad I_f = \frac{230}{200} = 1.15 \text{ A}$$

$$(V - IR) \ \alpha \ \phi_1 N_1$$

$$[230 - (10 - 1.15)(0.1)] \ \alpha \ 1400\phi_1 \quad \text{...(1)}$$

$$[230 - (200 - 1.15)(0.1)] \ \alpha \ N_2\phi_2 \quad \text{...(2)}$$

Equation (2) divided by (1),

$$\frac{210.1}{229.1} = \frac{N_2}{1400} \times 0.96$$

$\Rightarrow$ $N_2 = 1337$ rpm

$$\therefore \text{ Torque developed } (T_d) = \frac{210.115 \times (200 - 1.15)}{\left(\frac{2\pi \times 1337}{60}\right)} = 298.4 \text{ N-m}$$

21. (d)

$V_{sc} = 120$ V, $I_{sc} = 9.6$ A, $P_{sc} = 460$ W

$$Z_e = \frac{V_{sc}}{I_{sc}} = \frac{120}{9.6} = 12.5\ \Omega$$

$$R_e = \frac{P_{sc}}{I_{sc}^2} = \frac{460}{(9.6)^2} = 4.99\ \Omega$$

$R_{lm} = 1.5\ \Omega$

$R_2' = R_e - R_{lm} = 4.99 - 1.5 = 3.49\ \Omega$

Given, $V_0 = 220$ V, $I_0 = 4.6$ A, $P_0 = 125$ W

Core, friction and windage losses

$$= 125 - (4.6)^2\left(1.5 + \frac{3.49}{4}\right) = 74.8 \text{ W}$$

22. (c)

Synchronous speed, $N_s = \dfrac{120f}{P} = \dfrac{120 \times 50}{4} = 1500$ rpm

Forward slip, $s_f = \dfrac{N_s - N_r}{N_s} = \dfrac{1500 - 1420}{1500} = 0.053$

Backward slip, $s_b = (2 - s) = (2 - 0.053) = 1.947$

The effective rotor resistance in backward branch

$$= \frac{R_2}{2(2-s)} = \frac{7.5}{2(2-0.053)}$$

$$= 1.926\ \Omega \approx 1.93\ \Omega$$

23. (d)

Given transformer rating 50 kVA, 22 kV/220 V percent resistance = 1% percent reactance = 8%.

Taking hv side voltage as base voltage is 22 kV.

Base apparent power, $S_B = 50$ kVA

As primary is Δ connected.

Phase voltage, V_P = line voltage, V_L

$$\therefore \text{ Base impedance, } Z_{base} = \frac{3(V_{\phi,\text{base}})^2}{S_{base}} = \frac{3 \times (22000)^2}{50 \times 10^3} = 29040\ \Omega$$

The per unit impedance of transformer,

$Z_{eq\ pu} = 0.01 + j0.08$ pu

∴ High voltage side impedance,

$$Z_{ph\ hv} = Z_{eq\ pu} \times Z_{base}$$
$$= (0.01j + j0.08) \times 29040$$
$$= 290.40 + j2323.2\ \Omega$$

24. (a)

We know,Field current, $I_f = \dfrac{400}{200} = 2$ A

At no load, $I_{a0} = 5.6 - 2 = 3.6$ A

$E_{a0} = 400 - (0.18 \times 3.6) - 2 = 397.35$ V

At full load, $I_a(fl) = 60.3 - 2 = 58.3$ A

$E_a(fl) = 400 - 0.18 \times 58.3 - 2 = 387.506$ V

Assuming initial flux be ϕ ,

New flux value due to weakening,

$$\phi' = (1 - 0.04)\phi = 0.96\ \phi$$

$$\frac{n(fl)}{n(nl)} = \frac{387.506}{397.35} \times \frac{1}{0.96} = 1.016$$

25. (b)

We know, flux/pole $= \dfrac{\pi Dl}{P} \times$ pole pitch

$$= \frac{\pi \times 30 \times 10^{-2}}{4} \times 20 \times 10^{-2} \times 0.4 = 0.0188 \text{ Wb}$$

Induced emf, $E = \dfrac{P\phi n}{60}\dfrac{Z}{A} = \dfrac{0.0188 \times 1500 \times 400}{60} = 188$ V

Gross mechanical power developed

$$= \frac{188 \times 30}{1000} = 5.64 \text{ kW}$$

Torque developed $= \dfrac{5.64 \times 1000}{\dfrac{2\pi \times 1500}{60}} = 35.905$ N-m

26. (c)

Armature resistance is assumed negligible,

Also field current is ignored in comparison to armature current

$$I_L = I_a$$

$$200 = K_e \times 600 \quad \text{...(i)}$$

$$T = K_t \times 20 = K_L \times (600)^2 \quad \text{...(ii)}$$

When 20 Ω resistor added in armature circuit

$$(200 - 20I_a) = K_e \times n \quad \text{...(iii)}$$

$$K_t I_a = K_L n^2 \quad \text{...(iv)}$$

Dividing equation (iii) by (i) and (iv) by (ii),

$$\frac{200 - 20I_a}{200} = \frac{n}{600}$$

$$\frac{I_a}{20} = \frac{n^2}{(600)^2}$$

$$I_a = \frac{20n^2}{(600)^2}$$

$$1 - \frac{1}{10}\left[\frac{20n^2}{(600)^2}\right] = \frac{n}{600}$$

$$(600)^2 - 2n^2 = 600n$$

$$2n^2 + 600n - (600)^2 = 0$$

$$n = 300, -600$$

practical value, $n = 300$ rpm

$$\frac{I_a}{20} = \frac{n^2}{(600)^2} = \frac{(300)^2}{(600)^2} = \frac{1}{4}$$

$$I_a = \frac{20}{4} = 5 \text{ A}$$

27. (b)

- As torque remain rated at 1500 rpm and 1000 rpm, so armature current and flux will be same.
- At 1500 rpm, using motor equation

$$V = E_b + I_a R_a$$

$$240 = E_b + 50 \times 0.2$$

$$E_b = 230 \text{ V}$$

$$E_{b2} = \frac{N_2}{N_1} E_{b1} \qquad \text{(as } \phi \text{ is constant)}$$

$$E_{b2} = \frac{1000}{1500} \times 230 = 153.33 \text{ V}$$

At 1000 rpm, R_{ext} is introduced

Applying motor equation, $V = E_{b2} + I_a(R_a + R_{ext})$

$$240 = 153.33 + 50(0.2 + R_{ext})$$

$$240 = 153.33 + 10 + 50R_{ext}$$

$$R_{ext} = 1.5334 \ \Omega$$

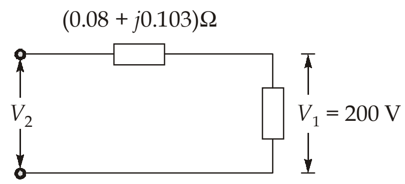
28. (d)

By referring the transformer impedance to LV side,

$$R_{LV} = 0.05 + \frac{3}{(10)^2} = 0.08 \ \Omega$$

$$X_{LV} = 0.05 + \frac{5.3}{(10)^2} = 0.103 \ \Omega$$

Drawing circuit representation,



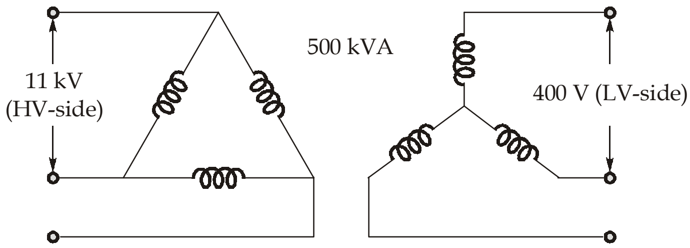
$$\text{Current, } I_2 = \frac{20 \times 1000}{200} = 100 \text{ A}$$

$$\text{Voltage drop} = 100(0.08 \times 0.8 + 0.103 \times 0.6) = 12.58 \text{ V}$$

$$\text{Voltage regulation} = \frac{12.58}{200} \times 100 = 6.29\%$$

29. (b)

For given transformer configuration,



Phase current at star side,

$$I_{PY\,(\text{rated})} = \frac{500}{\sqrt{3} \times 0.40} = 721.687 \text{ A}$$

Phase current at delta side,

$$I_{P\Delta\,(\text{rated})} = \frac{500}{3 \times 11} = 15.151 \text{ A}$$

$$\text{At lv side, resistance } R_{LV} = \frac{2000}{3 \times (721.687)^2} = 1.28 \times 10^{-3}\ \Omega$$

$$\text{At hv side, resistance } R_{HV} = \frac{2500}{3 \times (15.15)^2} = 3.63\ \Omega$$

Turn ratio,

$$\frac{\text{Phase voltage (hv side)}}{\text{Phase voltage (lv side)}} = \frac{11}{0.40/\sqrt{3}} = 47.63$$

Referred values on delta side (Δ side)

$$R_{eq} \text{ (HV)} = 3.63 + 1.28 \times 10^{-3} (47.63)^2 = 6.53\ \Omega \text{ (per phase)}$$

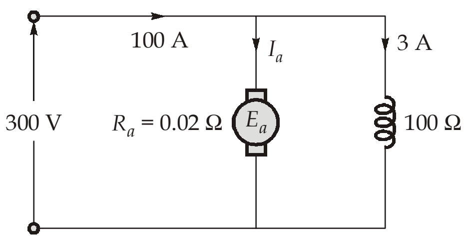
$$X(\text{p.u.}) = 0.05$$

$$Z_{\text{base (HV)}} = \frac{11000}{15.15} = 726.024\ \Omega$$

$$X_{eq\ HV} = 0.05 \times 726.024 = 36.30\ \Omega \text{ (per phase)}$$

30. (c)

Case-I:



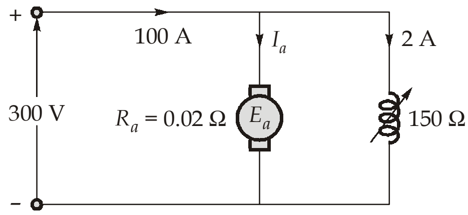
Armature current, $I_{a1} = 100 - 3 = 97$ A

Back emf, $E_{a1} = 300 - 97 \times 0.02$

$E_{a1} = 298.06$ V

Case-II:

When 50 Ω external resistance added in field circuit,



Load torque is constant

$$T \propto \phi I_a$$

$$\phi_2 I_{a2} = \phi_1 I_{a1}$$

$$\phi \propto I_f$$

$$I_{a2} = I_{a1}\frac{\phi_1}{\phi_2} = 97 \times \frac{3}{2} = 145.5 \text{ A}$$

$$E_{a2} = 300 - 145.5 \times 0.02$$

$$E_{a2} = 297.09 \text{ V}$$

We know that, $E_a \propto \phi\omega_m$

$$\frac{E_{a2}}{E_{a1}} = \frac{\phi_2}{\phi_1} \times \frac{N_2}{N_1}$$

$$\frac{297.09}{298.06} = \frac{2}{3} \times \frac{N_2}{1600}$$

$$N_2 = 2392.18 \text{ rpm}$$

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