EEE 3351

ELECTROMECHANICS & ELECTRICAL MACHINES

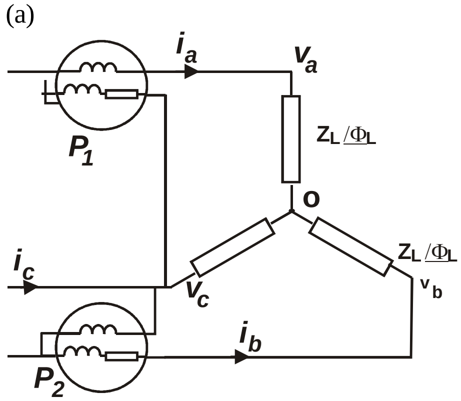
UNIVERSITY EXAMINATIONS

FEBRUARY/MARCH 2014

MODEL SOLUTIONS

4.

(a)



$$P_1 = (v_{ac} i_a)\big|_{AV} = (v_a - v_b) i_a\big|_{AV}$$

$$P_2 = (v_{bc} i_b)\big|_{AV} = (v_b - v_c) i_b\big|_{AV}$$

$$P_1 + P_2 = (v_a i_a)\big|_{AV} + (v_b i_b)\big|_{AV} - v_c (i_a + i_b)\big|_{AV}$$

if there is no neutral

$$i_a + i_b + i_c = 0$$

And therefore

$$P_1 + P_2 = (v_a i_a)\big|_{AV} + (v_b i_b)\big|_{AV} + (v_c i_c)\big|_{AV}$$

$$P_1 + P_2 = P_a + P_b + P_c$$

(b)

V_L= 380 V, S_1 = 5 kVA, S_2 = 10 kVA, pf_1 = 0.8, $p.f._2$ = 0.9. 20 A, P_T = 20 kW.

$$S_1 = 4000 + j3000$$

$$S_2 = 9000 + j4350$$

$$S_T = 13000 + j7350 = 14900\underline{/29.5^\circ}$$

$$I_L = \frac{S_T}{\sqrt{3} V_L} = \frac{14900}{\sqrt{3} \times 380} = \underline{\underline{22.6 \quad A}}$$

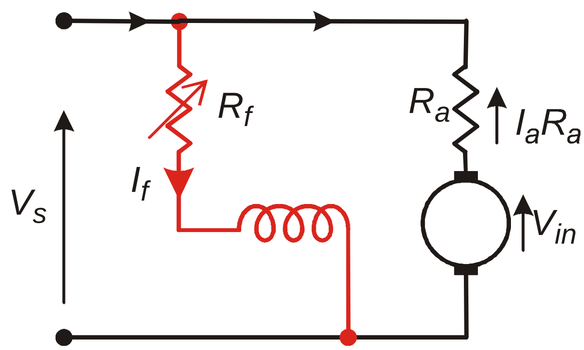
$$P_1 + P_2 = 13 \times 10^3$$

$$P_1 - P_2 = V_L I_L \sin \varphi_L = 380 \times 22.6 \times \sin 29.6^\circ = 4.2 \times 10^3$$

$$2P_1 = 17.2 \times 10^3 \Rightarrow P_1 = \underline{\underline{8.6 \times 10^3 \quad W}}$$

$$P_2 = (13 - 8.6) \times 10^3 = \underline{\underline{4.4 \times 10^3 \quad W}}$$

5.
(a)
DC Shunt



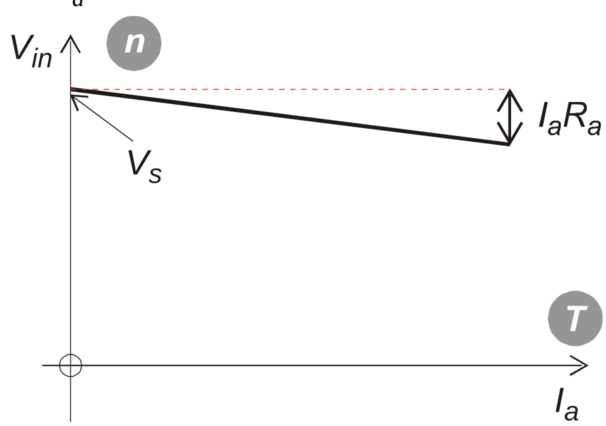
$V_s = V_{in} + I_a R_a$

$T = \frac{1}{2\pi}\left(\frac{2pZ}{c}\right)\phi I_a$

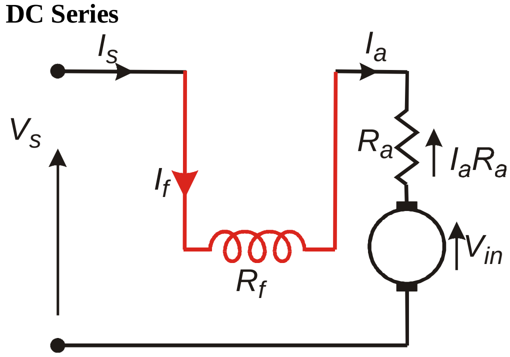
At constant field current (and therefore constant flux)

$V_{in} \propto n$

$T \propto I_a$



DC Series



$I_s = I_a = I_f = I$

Two assumptions:

- Neglect IR drops
- Neglect saturation

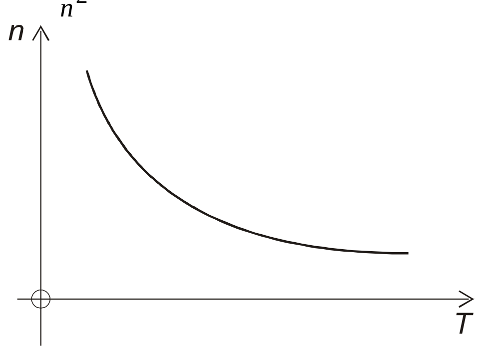
$$V_s = V_{in} = \left(\frac{2pZ}{c}\right) n\phi$$

$$\therefore n \propto \frac{1}{\phi} \propto \frac{1}{I}$$

$$T = \frac{1}{2\pi}\left(\frac{2pZ}{c}\right)\phi I_a$$

$$T \propto I^2$$

$$T \propto \frac{1}{n^2}$$



(b)

V_s = 400 V, I_s =50 A, I_f =2 A, n = 1000 r/min R_a = 0.5 Ω;, P_{W+F} = 600 W.

$$I_a = I_s - I_f = 50 - 2 = 58 \quad A$$

$$P_{Cu} = V_f I_f + I_a^2 R_a = 400 \times 2 + 48^2 \times 0.5 = 200 + 1152 = 1352 \quad W$$

$$P_{Loss} = P_{Cu} + P_{W+F} = 1352 + 600 = \underline{\underline{1852 \quad W}}$$

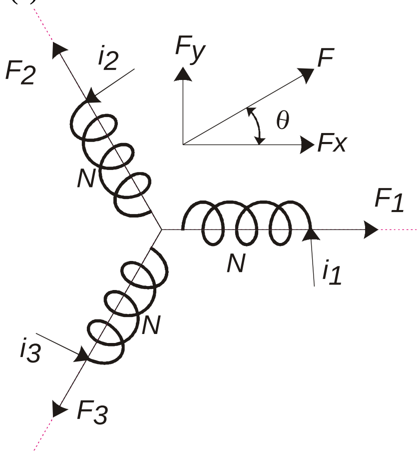
$$\eta = 1 - \frac{P_{Loss}}{P_{in}} = 1 - \frac{1850}{400 \times 50} = 0.9074 = \underline{\underline{90.7\%}}$$

$$P_{out} = 20000 - 1852 = 18148$$

$$T = \frac{P_{out}}{2\pi n} = \frac{18148}{2\pi \times 1000/60} = \underline{\underline{173.3 \quad Nm}}$$

6.

(a)



$$F_y = \frac{\sqrt{3}}{2}(F_2 - F_3)$$

$$= \frac{\sqrt{3}}{2} NI_m \left[\cos \overline{\omega t - 120^\circ} - \cos \overline{\omega t + 120^\circ} \right]$$

$$= \frac{\sqrt{3}}{2} NI_m \, 2 \sin \omega t \sin 120^\circ$$

$$F_y = \frac{3}{2} NI_m \sin \omega t$$

$$i_1 = I_m \cos \omega t$$

$$i_2 = I_m \cos \overline{\omega t - 120^\circ}$$

$$i_3 = I_m \cos \overline{\omega t + 120^\circ}$$

$$F_1 = NI_m \cos \omega t$$

$$F_2 = NI_m \cos \overline{\omega t - 120^\circ}$$

$$F_3 = NI_m \cos \overline{\omega t + 120^\circ}$$

$$F_x = F_1 - \frac{1}{2}(F_2 + F_3)$$

$$= NI_m \left[\cos \omega t - \frac{1}{2}(\cos \overline{\omega t - 120^\circ} + \cos \overline{\omega t + 120^\circ}) \right]$$

$$= NI_m \left[\cos \omega t - \frac{1}{2} 2 \cos \omega t \cos 120^\circ \right]$$

$$F_x = \frac{3}{2} NI_m \cos \omega t$$

$$|F| = \sqrt{F_x^2 + F_y^2} = \underline{\underline{\frac{3}{2} NI_m}}$$

$$\tan\theta = \frac{F_y}{F_x} = \tan\omega t$$

$$\underline{\underline{\theta = \omega t}}$$

(b)

f= 50 Hz, p = 3, f_R = 4 Hz

(i) $s = \frac{f_R}{f} = \frac{4}{50} = \underline{\underline{0.08}}$

(ii) $n = n_S(1-s) = \frac{f}{p}(1-s) = \frac{50}{3}(1-0.08) = 15.33 \;\; r/s = \underline{\underline{920 \;\; r/min}}$

(iii) $80 \;\; r/\min, \;\; 920 \;\; r/\min$

(c)

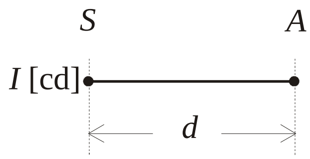
Synchronous machine:

Rtor has field winding excited by dc current; rotor speed is constant and equal to speed of rotating flux

Induction machine:

Rotor has windings short-circuited on themselves and are unexcited; rotor slips so its speed is a little less than the speed of the rotating magnetic flux

7.
(a)

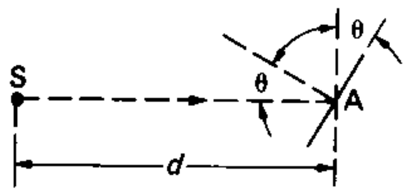


Inverse square law:

$$\frac{E_{at\ r}}{E_{at\ 1\ m\ radius}} = \frac{\phi/4\pi r^2}{\phi/4\pi} = \frac{4\pi}{4\pi r^2} = \frac{1}{r^2}$$

$$E_A = \frac{I}{d^2}$$

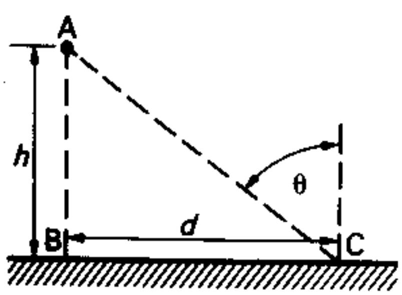
Cosine law of illumination:



$$\frac{E_{ABCD}}{E_{EFGH}} = \frac{\phi/S_{ABCD}}{\phi/S_{EFGH}} = \frac{S_{EFGH}}{S_{ABCD}} = \cos\theta$$

$$E_A = \frac{I}{d^2}\cos\theta$$

(b)



$$AC = \left(h^2 + d^2\right)^{\frac{1}{2}}$$

$$\cos\theta = \frac{h}{\left(h^2 + d^2\right)^{\frac{1}{2}}}$$

$$E_B = \frac{I_{AB}}{h^2}$$

$$E_C = \frac{I_{AC}\cos\theta}{AC^2} = I_{AC} \cdot \frac{h}{\left(h^2 + d^2\right)^{\frac{3}{2}}}$$

Assume that, in the lower hemisphere, the luminous intensity is uniform

$$I_{AB} = I_{AC} = I$$

$$I = E_B \cdot h^2$$

$$I = E_C \cdot \frac{\left(h^2 + d^2\right)^{\frac{3}{2}}}{h}$$

$$E_C = E_B \cdot \frac{h^3}{\left(h^2 + d^2\right)^{\frac{3}{2}}} = E_B\left[\frac{h}{\left(h^2 + d^2\right)^{\frac{1}{2}}}\right]^3 = E_B \cos^3\theta$$

$$E_C = E_B \cos^3\theta$$

(c)

E_{AV} = 400 lx

Lamp above A = O

Corner of court = A

Centre of court = B

θ = angle AOB

$$\cos\theta = \frac{7}{\sqrt{7^2 + 500}} = 0.2987$$

$$E_{BO} = \frac{400}{4} = 100 \quad lx$$

$$E_B = E_A \cos^3\theta \rightarrow E_A = \frac{E_B}{\cos^3\theta} = \frac{100}{0.2978^3} = 37{,}523 \quad lx$$

$$I = E_A d^2 = 37{,}523 \times 7^2 = 183{,}861 \quad cd$$

$$\phi_{lamp} = 4\pi \times 183{,}861 = 2{,}310{,}465 \quad lm$$

(i)

$$N = \frac{2{,}310{,}465}{2500} \approx \underline{\underline{92 \quad lamps}}$$

(ii)

$$N = \frac{2{,}310{,}465 \times 0.4}{2500} \approx \underline{\underline{37 \quad lamps}}$$