TEST#1 SOLUTION SKEE4633/SEE3433

Using Mathcad

April-2019

Units: $mm \equiv 10^{-3}$ $cm \equiv 10^{-2}$ $A \equiv 1$ $J \equiv 1$ $Nm \equiv 1$ $T \equiv 1$ $N \equiv 1$

$kW \equiv 10^{3}$ $V \equiv 1$ $turns \equiv 1$ $rpm \equiv 1$ $weber \equiv 1$ $\Omega \equiv 1$

$mWb \equiv 10^{-3}$ $kV \equiv 10^{3}$ $kN \equiv 10^{3}$

Q1) $i = 6 \cdot x^2 \cdot \lambda^2 + 8 \cdot \lambda \cdot (2 \cdot x - 7)^2$

$$W_f = \int i\, d\lambda = \int \left[6 \cdot x^2 \cdot \lambda^2 + 8 \cdot \lambda \cdot (2 \cdot x - 7)^2\right] d\lambda$$

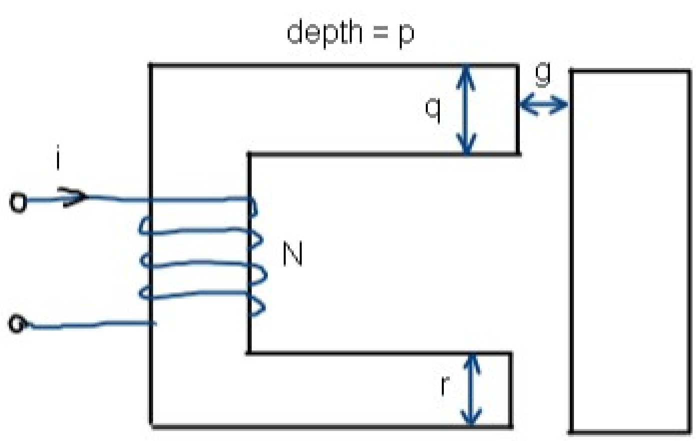
$$W_f = 2 \cdot x^2 \cdot \lambda^3 + 4 \cdot \lambda^2 \cdot (2 \cdot x - 7)^2$$

$$f_m = \frac{-\delta}{\delta x} W_f(\lambda, x) \qquad f_m = -\left[4 \cdot x \cdot \lambda^3 + 16 \cdot \lambda^2 \cdot (2 \cdot x - 7)\right]$$

$\lambda := 2$ $x := 2$

$f_m := -\left[4 \cdot x \cdot \lambda^3 + 16 \cdot \lambda^2 \cdot (2 \cdot x - 7)\right]$ $f_m = 128\,N$ 6 marks

Q2)



$p := 15cm$ $q := 40cm$ $r := 30cm$ $N := 1000$

$i := 5$ $\mu_o := 4\pi \cdot 10^{-7}$ $g := 4cm$

(a) The area normal to the flux,

3 marks

$$A_1 = p \cdot q \qquad A_2 = p \cdot r$$

$$R_1 = \frac{g}{\mu_o \cdot A_1} \qquad R_2 = \frac{g}{\mu_o \cdot A_2} \qquad R_T = R_1 + R_2 = \frac{g}{\mu_o} \cdot \left(\frac{1}{A_1} + \frac{1}{A_2}\right)$$

$$R_T = \frac{g}{\mu_o}\left(\frac{1}{p \cdot q} + \frac{1}{p \cdot r}\right) = \frac{g}{\mu_o \cdot p}\left(\frac{1}{q} + \frac{1}{r}\right) = \frac{g}{\mu_o \cdot p} \cdot \frac{r+q}{q \cdot r}$$

$$L = \frac{N^2}{R_T} = \frac{N^2 \cdot \mu_o \cdot p \cdot q \cdot r}{g \cdot (r+q)}$$

(b)

3 marks

$$R_T := \frac{g}{\mu_o \cdot p} \cdot \frac{r+q}{q \cdot r} \qquad R_T = 1.238 \times 10^6$$

$$\phi := \frac{N \cdot i}{R_T} \qquad \phi = 4.039\,\text{mWb}$$

$$A_1 := p \cdot q \qquad B_1 := \frac{\phi}{A_1} \qquad V_{ag1} := A_1 \cdot g$$

$$A_2 := p \cdot r \qquad B_2 := \frac{\phi}{A_2} \qquad V_{ag2} := A_2 \cdot g$$

$$W_f := \frac{B_1}{2 \cdot \mu_o} \cdot V_{ag1} + \frac{B_2}{2 \cdot \mu_o} \cdot V_{ag2} \qquad W_f = 128.571$$

(c) To find expression for the force based on inductance

3 marks

$$f_m = \frac{1}{2} \cdot i^2 \cdot \frac{d}{dx}L(x)$$ and $$L(x) = \frac{N^2}{R_T}$$

but $dx = -dg$ and $$L(g) = \frac{N^2 \cdot \mu_o \cdot p \cdot q \cdot r}{g \cdot (r+q)}$$

therefore, $$f_m = -\frac{1}{2} \cdot i^2 \cdot \frac{d}{dg}L(g)$$

$$f_m = -\frac{1}{2} \cdot i^2 \cdot \frac{d}{dg}\frac{N^2 \cdot \mu_o \cdot p \cdot q \cdot r}{g \cdot (r+q)} = -\frac{1}{2} \cdot \frac{i^2 \cdot N^2 \cdot \mu_o \cdot p \cdot q \cdot r}{(r+q)} \frac{d}{dg}\frac{1}{g}$$

$$\frac{d}{dg}\frac{1}{g} = \frac{-1}{g^2}$$

$$f_m = \frac{1}{2} \cdot i^2 \cdot \frac{N^2 \cdot \mu_o \cdot p \cdot q \cdot r}{g^2 \cdot (r + q)}$$

$$f_m := \frac{1}{2} \cdot i^2 \cdot \frac{N^2 \cdot \mu_o \cdot p \cdot q \cdot r}{g^2 \cdot (r + q)} \qquad f_m = 252.449\,\text{Nm}$$

3 marks

Q3) $p := 8$ $\qquad \omega_{rpm} := 2000\text{rpm}$ $\qquad \phi := 40\text{mWb}$

$N := 64 \cdot 20$ $\qquad N = 1.28 \times 10^3\,\text{turns}$

a) To find the the induced voltage for lap-wound generator

2 marks

The number of parallel path, $a := p$ for lap-wound

$$E_a = K_a \cdot \phi \cdot \omega_m \qquad \omega_m = \frac{E_a}{K_a \cdot \phi} \qquad K_a := \frac{N \cdot p}{\pi \cdot a} \qquad K_a = 407.437$$

$$E_a := K_a \cdot \phi \cdot \frac{\omega_{rpm} \cdot 2 \cdot \pi}{60} \qquad E_a = 3.413 \times 10^3\,\text{V} \qquad E_t := \frac{E_a}{\frac{N}{a}} \qquad E_t = 21.333\,\text{V}$$

b) To find the the induced voltage for wave-wound generator

2 marks

The number of parallel path, $a := 2$ for wave-wound

$$E_a = K_a \cdot \phi \cdot \omega_m \qquad K_a := \frac{N \cdot p}{\pi \cdot a} \qquad K_a = 1.63 \times 10^3$$

$$E_a := K_a \cdot \phi \cdot \frac{\omega_{rpm} \cdot 2 \cdot \pi}{60} \qquad E_a = 1.365 \times 10^4\,\text{V} \qquad E_t := \frac{E_a}{\frac{N}{a}} \qquad E_t = 21.333\,\text{V}$$

c) The number of turns connected in series, N/a

Rated voltage accross each turn: 25 V
Rated current winding: 2.5 A

$V_{turn} := 25V$

$I_{turn} := 2.5A$

To find the kW rating of the generator for lap-wound generator

The number of parallel path, $a := p$ for lap-wound $a = 8$ 1.5 marks

$E_a := V_{turn} \cdot \frac{N}{a}$ $E_a = 4 \times 10^3\, V$

$I_a := a \cdot I_{turn}$ $I_a = 20\, A$

$P := E_a \cdot I_a$ $P = 80\, kW$

d) To find the kW rating of the generator for wave-wound generator

1.5 marks

The number of parallel path, $a := 2$

$E_a := V_{turn} \cdot \frac{N}{a}$ $E_a = 1.6 \times 10^4\, V$

$I_a := a \cdot I_{turn}$ $I_a = 5\, A$

$P := E_a \cdot I_a$ $P = 80\, kW$

Q4) A. Separately Excited DC generator

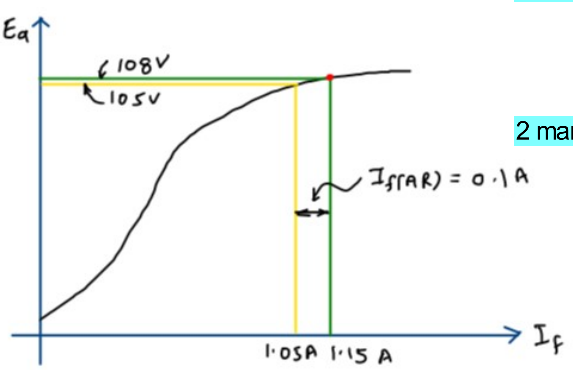
$R_a := 0.1\Omega$ $E_a := 108V$ $I_f := 1.15A$ $P_{max} := 10.8kW$

$I_a := \frac{P_{max}}{E_a}$ $I_a = 100\, A$ $V_f := 108$

(ii) Terminal voltage at full-load without armature reaction

2 marks

$V_t := E_a - I_a \cdot R_a$ $V_t = 98\, V$



(ii) Terminal voltage at full-load with armature reaction

2 marks

$I_{f\_AR} := 0.1A$

$I_{f\_eff} := I_f - I_{f\_AR}$ $I_{f\_eff} = 1.05$

From the graph, $I_f = 1.05A$ $E_a := 105V$

$V_t := E_a - I_a \cdot R_a$ $V_t = 95\, V$

B. Shunt DC generator

(iii) Terminal voltage at full-load without armature reaction — 2 marks

$I_a \cdot R_a = 10\,V$ $\quad I_{f\_AR} = 0$

From the graph, $V_t = 86V$ $\quad V_t = 94V$

(iv) Terminal voltage at full-load with armature reaction — 2 marks

$I_a \cdot R_a = 10\,V$ $\quad I_{f\_AR} = 0.1A$

From the graph, $V_t = 88V$