Test 1 SEE 3433: Solution

Dummy units: $A \equiv 1$ $m \equiv 1$ $Nm \equiv 1$ $mH \equiv 10^{-3}$ $J \equiv 1$ $kV \equiv 10^{3}$ $Wb \equiv 1$

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

$\mu_o \equiv 4\pi \cdot 10^{-7}$ $cm \equiv 10^{-2}$ $mm \equiv 10^{-3}$

Question 1 (4 marks)

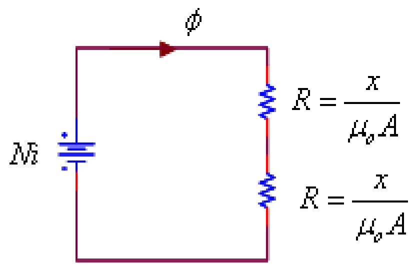
$$W_{fc} = \int \lambda \, di \qquad W_{fc} = \int 6x^2 \cdot i^2 \, di \rightarrow W_{fc} = 2 \cdot x^2 \cdot i^3$$

$$f_m = \frac{d}{dx} W_{fc} \qquad f_m = \frac{d}{dx} 2 \cdot x^2 \cdot i^3 \rightarrow f_m = 4 \cdot x \cdot i^3$$

For $i := 2A$ $x := 1m$

$f_m := 4x \cdot i^3$ $f_m = 32\,Nm$

Question 2 (3 + 5 = 8 marks)



a) $$L = \frac{\lambda}{i} = \frac{N\phi}{i}$$

From the magnetic circuit,

$$N \cdot i = \phi \cdot 2 \cdot R = \phi \cdot 2 \cdot \frac{x}{\mu_o \cdot A}$$

$$N \cdot i = \phi \cdot \frac{2 \cdot x}{\mu_o \cdot A} \qquad i = \phi \cdot \frac{2 \cdot x}{\mu_o \cdot A} \cdot \frac{1}{N}$$

Substitute into the definition of L

$$L = \frac{\mu_o \cdot A \cdot N^2}{2 \cdot x}$$

b) By neglecting the reluctance of the magnetic core, the magnetic circuit is now linear.

For a linear magnetic circuit, $W_f = W_{fc}$

The field energy, $W_f = W_{fc} = \frac{1}{2} \cdot L \cdot i^2$

To calculate L:

$A_g := 5 \cdot cm \cdot 5 \cdot cm$ $N := 1000$ $x := 2mm$

$$L := \frac{\mu_o \cdot A_g \cdot N^2}{2 \cdot x} \qquad L = 785.398\,mH$$

and $i := 10A$

$W_f := \frac{1}{2} \cdot L \cdot i^2$ $\quad W_f = 39.27\,J$

$f_m := f_m \quad x := x$

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

$$f_m = \frac{1}{2} \cdot i^2 \cdot \frac{d}{dx} \frac{\mu_o \cdot A_g \cdot N^2}{2 \cdot x} = \frac{1}{2} \cdot \frac{i^2 \cdot \mu_o \cdot A_g \cdot N^2}{2} \cdot \frac{d}{dx} \frac{1}{x}$$

$f_m := -\frac{1}{2} \cdot \frac{i^2 \cdot \mu_o \cdot A_g \cdot N^2}{2 \cdot x^2}$ $\quad f_m = -1.963 \times 10^4\,Nm$

Question 3 (3 + 2 = 5 marks)

$p := 8 \quad N := 96 \cdot 6 \quad a := p \quad \omega_m := \frac{2\pi}{60} \cdot 600 \quad \phi := 0.05 \cdot Wb \quad I_a := 100 \cdot A$

$K_a := \frac{N \cdot p}{\pi \cdot a} \quad K_a = 183.346$

a) The generated voltage, $E_a := K_a \cdot \phi \cdot \omega_m$ $\quad E_a = 576\,V$

The generated voltage for each turn, $E_t := \frac{E_a}{\frac{N}{a}}$ $\quad E_t = 8\,V$

b) The developed torque, $T := K_a \cdot \phi \cdot I_a$ $\quad T = 916.732\,Nm$

The developed torque for each turn, $T_t := \frac{T}{N}$ $\quad T_t = 1.592\,Nm$

Question 4 (2 + 2 + 2 = 6 marks)

Machine's parameters: $P := 100 \cdot kW \quad V := 100 \cdot V \quad N_m := 800 \cdot rpm \quad I_{f\_full} := 0.8 \cdot A \quad R_{fw} := 100 \cdot \Omega$

a) Maximum value of generated voltage occurs when $R_{fc} = 0$

$R_f = R_{fc} + R_{fw} = R_{fw} = 100$

Draw field resistance line at $R_f = 100\ \Omega$

The maximum generated voltage, $E_{a\_max} = 111 \cdot V$

b) Draw a field resistance line that intersect the magnetization curve at 100 V.

For this case, $I_f := 0.8 \cdot A$

$R_f := \frac{100}{0.8} \quad R_f = 125$

$R_{fc} := R_f - R_{fw} \quad R_{fc} = 25\,\Omega$

c) Draw a field resistance line passing through the linear portion of the magnetization curve.

For this case,

$$I_f := 0.45 \cdot A$$

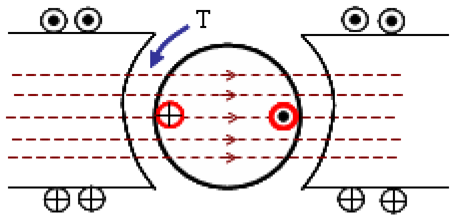
$$E_a := 95 \cdot V$$

$$R_{f\_critical} := \frac{95}{0.45} \qquad R_{f\_critical} = 211.111\,\Omega$$

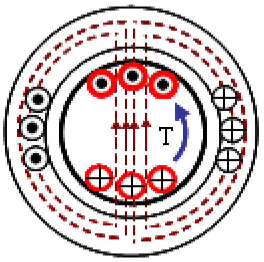
$$R_{fc} := R_{f\_critical} - R_{fw} \qquad R_{fc} = 111.111\,\Omega$$

Question 5 (2 + 2 = 4 marks)

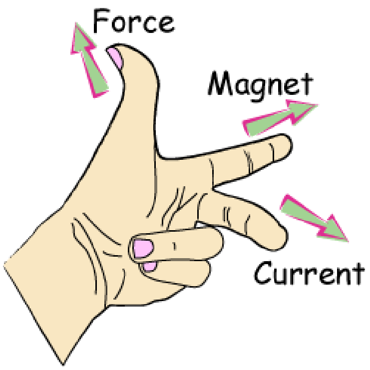
Motor's problem: Use Fleming's left hand rule



(a)

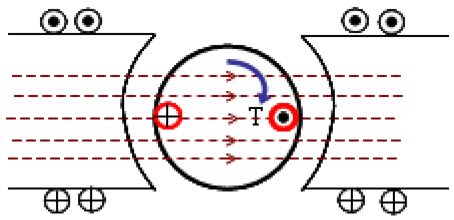


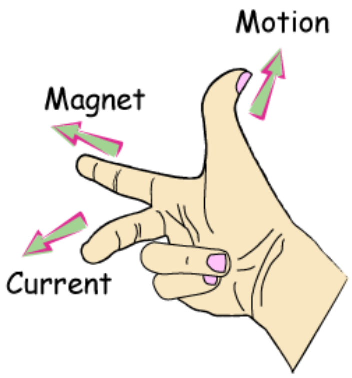
(b)



Question 6 (2 marks)

Generator's problem: Use Fleming's right hand rule





(1 + 1 +1 + 1 = 4 marks)

Q7 (b) **Q8** (a) **Q9** (c) **Q10** (d)