EEE 3352

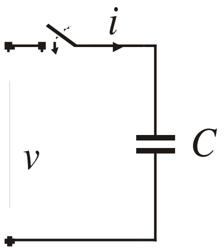
ELECTROMECHANICS & ELECTRICAL MACHINES

TERM II TEST

NOVEMBER 2020

MODEL SOLUTIONS

1.
(a)



Parallel plate capacitor:

C	= capacitance
A	= area of plate
l	= separation of plates
v	= voltage across the plates
i	= current charging/discharging the capacitor

Voltage-current relation on capacitance: $i = C\dfrac{dv}{dt}$

Power: $P = vi = Cv\dfrac{dv}{dt}$;

Energy stored: $W = \int Pdt = \int_0^V cvdv = C\dfrac{V^2}{2} = \dfrac{1}{2}qV$;

Energy per unit volume: $w = \dfrac{\frac{1}{2}qV}{Al} = \dfrac{1}{2}\dfrac{q}{A}\dfrac{V}{l}$; $w = \dfrac{1}{2}DE$;

Knowing $D = \varepsilon E$; where D is electric flux density, E is electric field intensity and ε is permittivity of medium between the plates;

$w = \frac{1}{2}\varepsilon E^2$

(b)
Energy stored before pulling apart:

$$W_1 = \tfrac{1}{2}\varepsilon E_1^2 \times \text{Volume}_1 = \tfrac{1}{2}\times 8.85\times 10^{-12}\times\left(\frac{1000}{1.5\times 10^{-3}}\right)^2\times 1\times(1.5\times 10^{-3}) = 0.00295\ \text{J}$$

Energy stored after pulling apart:

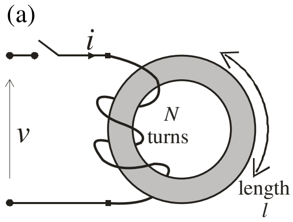
$$W_2 = \tfrac{1}{2}\varepsilon E_2^2 \times \text{Volume}_2 = \tfrac{1}{2}\times 8.85\times 10^{-12}\times\left(\frac{1000}{1.5\times 10^{-3}}\right)^2\times 1\times(2\times 10^{-3}) = 0.0022125\ \text{J}$$

Change is energy or work done: $\Delta W = W_1 - W_2 == 0.00295 - 0022125 = 0.0007375\text{J}$

Force as associated with work done: $F_{\text{mech}} = \dfrac{\Delta W}{\Delta l} = \dfrac{0.0007375}{(2-1.5)\times 10^{-3}} = 1.475\ \text{N}$

2.

(a)



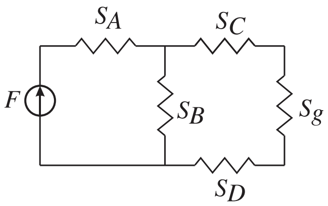
$$Li = N\phi$$

$$v = L\frac{di}{dt}; P = vi = Li\frac{di}{dt}$$

$$W = \int Pdt = \int_0^I Lidi = L\frac{I^2}{2} = \frac{1}{2}N\phi I \quad ; \quad w = \frac{\frac{1}{2}N\phi i}{Al} = \frac{1}{2}\frac{\phi}{A}\frac{NI}{l}\ ; \ w = \frac{1}{2}BH = \frac{B^2}{2\mu}$$

(b)

S_A = 3 x10^6 A/Wb; S_B = 9 x10^6 A/Wb; S_C = 2 x10^6 A/Wb; S_D = 2 x10^6 A/Wb; ; A = 159 mm^2, l_g =1 mm.;



(i)

$$S_g = \frac{l_g}{\mu A} = \frac{1\times10^{-3}}{1\times4\pi\times10^{-7}\times(159\times10^{-6})} = \underline{\underline{5\times10^6 \text{ A/Wb}}}$$

(ii)

$$S_T = [3+9//(2+2+5)]10^6 == 7.5\times10^6 \quad \text{A/Wb}$$

$$L = \frac{N^2}{S_T} = \frac{100^2}{7.5\times10^6} = 1.3\times10^{-3}\text{ H} = \underline{\underline{1.3\text{ mH}}}$$

(iii)

$$\phi = \frac{F}{S} = \frac{NI}{S} = \frac{20\times10}{7.5\times10^6} = 2.67\times10^{-4} = \underline{\underline{267 \quad \mu\text{Wb}}}$$

(iii)

$$\phi_g = \tfrac{1}{2}\phi = \tfrac{1}{2}\times2.67\times10^{-4} = 1.33\times10^{-4}\text{ Wb};\quad B_g = \frac{\phi_g}{A} = \frac{133\times10^{-6}}{159\times10^{-6}} = \underline{\underline{0.84 \quad \text{T}}}$$

(iv)

$$W = \tfrac{1}{2}LI^2 = \tfrac{1}{2}\times0.84\times20^2 = \underline{\underline{0.26 \quad \text{J}}}$$

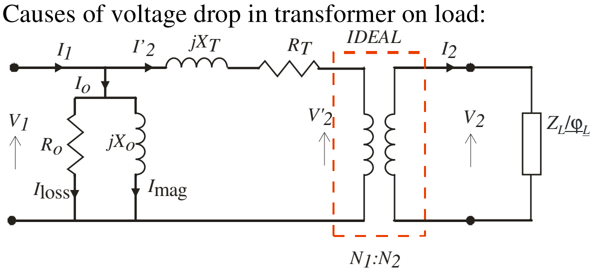
(v)

$$W_g = \frac{1}{2}\frac{B^2}{\mu}\times(Volume) = \frac{1}{2}\times\frac{0.84^2}{4\pi\times10^{-7}}\times(1\times10_{-3})\times(159\times10^{-6}) = \underline{\underline{0.089 \quad \text{J}}} \approx \underline{\underline{0.09 \quad \text{J}}}$$

3.

(a)

Causes of voltage drop in transformer on load:



As in the equivalent circuit, the series elements R_T and X_T cause voltage drop when load current I_2 flows.

(b)

S_r = 75 kVA, $V_1/V_2 = N_1/N_2$= 11000/240; V_{1NL} = 310V;

$$I'_{2FL} = \frac{S_r}{V_1} = \frac{75\times10^3}{11000} = 6.82 \text{ A}$$

(i)

$$I_2'^2 R_T = 1600 \rightarrow R_T = 34.4 \ \Omega$$

$$Z_T = \frac{V_1}{I_2'} = \frac{310}{6.82} = 45.5\ \Omega;\ \cos\phi_T = \frac{R_T}{Z_T} = \frac{34.4}{45.5} = 0.756 \rightarrow \phi_T = 40.9^\circ \text{ and } p.f = 0.8 \rightarrow \phi_L = 36.9^\circ$$

$$\text{Reg} = \frac{I'_2 Z_T}{V_1}\cos(\varphi_T - \varphi_L) = \frac{6.82\times45.5}{11000}\times\cos(40.9^\circ - 36.9^\circ) = 0.028 = \underline{\underline{2.8\%}}$$

(ii)

$$V_2' = V_1 - I_2' Z_T = 11000\angle0^\circ - 6.82\angle-36.9^\circ \times 45.5\angle40.9^\circ = 10690 - j21.6 = 10690\angle0.1^\circ$$

$$V_2 = V_2' \frac{N_2}{N_1} = 10690\times\frac{240}{11000} = \underline{\underline{233.2 \text{ V}}}$$