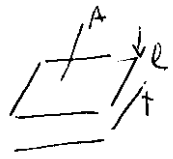
1.

(a) 

A = area
L = distance of separation

With defn of symbols.

$$C = \frac{Q}{V} = \frac{D A}{E L} = \varepsilon \frac{A}{L} = \varepsilon_r \varepsilon_0 A/L$$ 5

$$\frac{F}{A} = P = \frac{1}{2} \varepsilon_r \varepsilon_0 E^2$$

$$E = \frac{V}{d} = \frac{20\,10^3}{0.015}$$

$$P = \frac{1}{2}\, 26\, 8.85\, 10^{-12} \left(\frac{20\,10^3}{0.015}\right)^2 = \underline{204.5 N/m^2}$$ 6

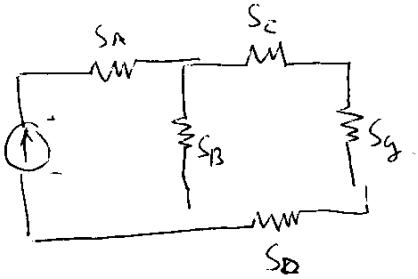
(b) $L = 1km$, $V = 10kV$, $f = 50Hz$, $R_1 = 6mm$, $R_2 = 14mm$.

(i) $$C = \frac{2\pi\varepsilon L}{\ln R_2/R_1} = \frac{2 \times 8.85\, 10^{-12} \times 10^3}{\ln 14/6} = 2.63\, 10^{-7}$$
$$= \underline{0.263 \mu F}.$$ 4

(ii) $$W_p = \frac{1}{2} C V_p^2$$
$$= \frac{1}{2}\, 2.263 \left[(10.10^3 \sqrt{2})\right]^2 = \underline{26.33 J}$$ 4

(iii) $$I = \omega C V = 2\pi f C V$$
$$= 2\pi\, 50\, 2.63\, 10^{-7}\, 10\, 10^3 = \underline{0.827 A}$$ 4

2.



(a) $S_g = \dfrac{l}{\mu A} = \dfrac{10^{-3}}{4\pi\, 10^{-7}\, 159\, 10^{-6}} = \underline{\underline{5 \times 10^6 \text{ A/Wb}}}$ 5

(b) $S = [3 + 3//3]\, 10^6 = 7.5 \times 10^6 \text{ A/Wb}$

$L = \dfrac{N^2}{S} = \dfrac{100^2}{7.5\, 10^6} = 1.3\, 10^{-3} = \underline{\underline{1.3 \text{ mH}}}$ 5

(c) $F = \phi S = NI$

$\phi = \dfrac{NI}{S} = \dfrac{20 \cdot 100}{7.5\, 10^6} = 2.67\, 10^{-4}$ $\underline{\underline{267\ \mu\text{Wb}}}$ 5

(d) $\phi_g = 267 \cdot \frac{1}{2} = 133\ \mu\text{Wb}$

$B_g = \dfrac{133\, 10^{-6}}{159\, 10^{-6}} = \underline{\underline{0.84 \text{ T}}}$ 5

(e) $W = \frac{1}{2} L I^2 = \frac{1}{2} (1.3\, 10^{-3})\, 20^2 = \underline{\underline{0.26 \text{ J}}}$ 5

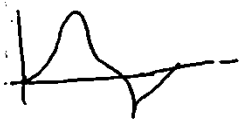
(f) $W_g = \frac{1}{2} \dfrac{B^2}{\mu} = \frac{1}{2} \dfrac{0.84^2}{4\pi\, 10^{-7}} = 5.61\, 10^5 \text{ J/m}^3$

volume $= 1\, 10^{-3} \times 159\, 10^{-6} = 159\, 10^{-9}$

$W_g = 5.61\, 159\, 10^5\, 10^{-9} = 0.089 = \underline{\underline{0.089 \text{ J}}}$ 5

#3.

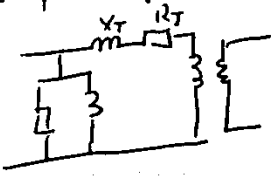
(a) Shape of no-load waveform:



⇒ non-sinusoidal due to hysteresis

⇒ peaky due saturation. ✓6

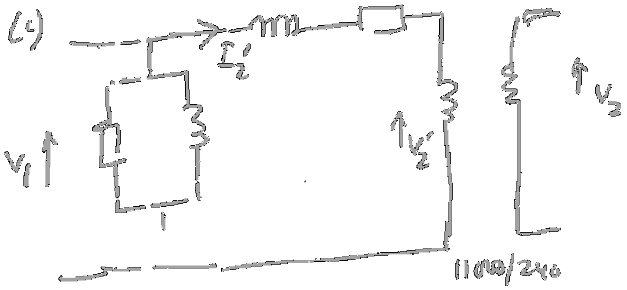
(b) Cause of voltage drop in trx:



series elements X_T and R_T i.e. the leakage reactance and winding resistance. ✓6

Equivalent cct.

(c)



75-kVA = S

Full load current $I_{2FL}' = \frac{75000}{11000} = 6.82\,A$

$I_2'^2 R_T = 1600 \longrightarrow R_T = 34.4\,\Omega$

$Z_T = \frac{V_1}{I_2'} = 45.5\,\Omega$

$\cos\phi_T = \frac{34.4}{45.5} \Rightarrow \phi_T = 40.9$, $\phi_L = 36.9°$.

$$R_{reg} = \frac{I_2' Z_T \cos(\phi_T - \phi_L)}{V_1} = \frac{6.82 \times 45.5 \cos(40.9 - 36.9)}{11000} = 0.028 = \underline{2.8\%}.$$

✓8

$V_2' = V_1 - I_2' Z_T$

$= 11000\angle 0° - 6.82\angle -36.9° \times 45.5\angle 40.5°$

$= 10690 - j\,21.6$

$V_1 \Rightarrow 10690\angle 0.1°$

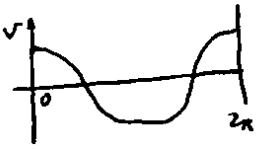
$16090 \times \frac{240}{11000} = \underline{233.2\,V}$

✓

7.

4 b. (a) $v = Blu$

$v = \frac{1}{t}\delta x$



$V_{Av} = \int_0^t \frac{Bln\,dt}{t} = \int_0^t \frac{BL\delta x}{t} = \int_0^t \frac{\delta\phi}{t}$

ϕ = total flux / pole

Integrating over 1 pole-pitch $\int\delta\phi = \phi$

t = time for 1 pole pitch $= \frac{1}{2n}$; $V_{Av} = \frac{\phi}{1/2n} = 2n\phi$

For a m/c with p pairs of poles $V_{Av} = 2np\phi$. 6

If rotor has Z conductors in parallel and there are C paths then $Z_s = \frac{Z}{C}$ = number of series connected conductors.

For commutator m/c output is dc = average induced voltage $= V = \frac{2pZ}{C} n\phi$ Z

For slip ring m/c output is ac and if sinusoidal waveform is assumed then form factor is 1.11. Thus rms output is $2pZ_s n\phi \times 1.11$ and taking into account the winding factor k $V = 2.22\,p\,Z_s\,n\phi k$ at freq 2

$f = np$; $V = 2.22 Z_s f \phi k$. [10]

(b) $p = 3$

$\phi = 0.06$ Wb

$Z = 664$

$n = 250$ rpm

$V = 2p\frac{Z}{C} n\phi = 2 \times 3 \times \frac{664}{2} \times \frac{250}{60} \times 0.06 = 498$ V 6

for $\phi' = 0.058$ and $V = 250$ V

$n = V \cdot \frac{C}{2pZ\phi} = 250 \times \frac{2}{2 \times 3 \times 664 \times 0.058}$ revs/s

$= 130$ rpm 4