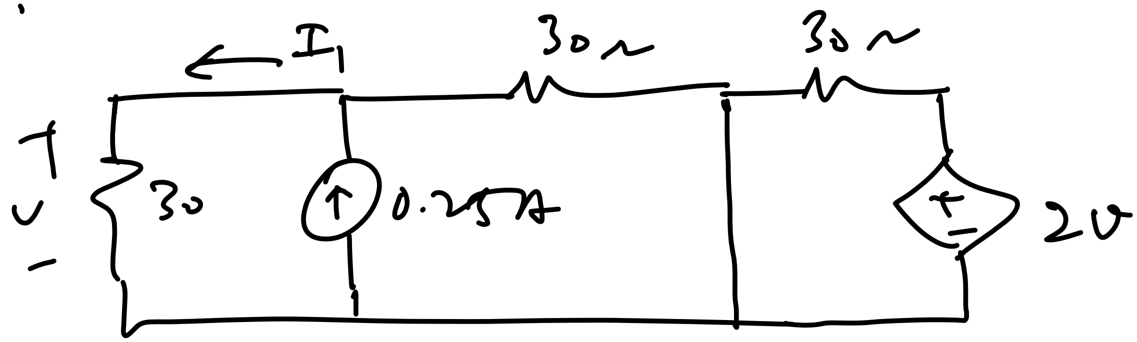
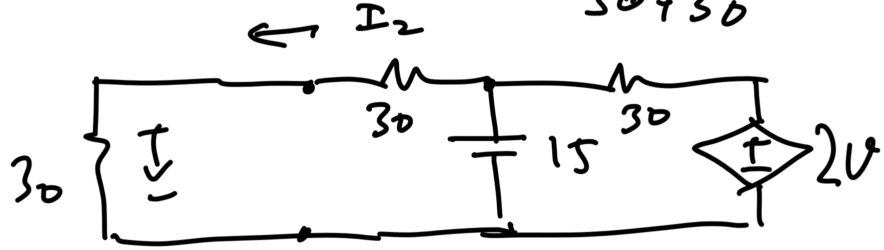
AY1213

Section A :

Q.1.(a)



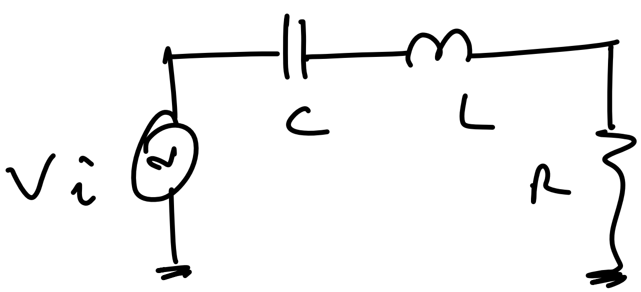
$$I_1 = 0.25 \times \frac{30}{30+30} = 0.125A$$

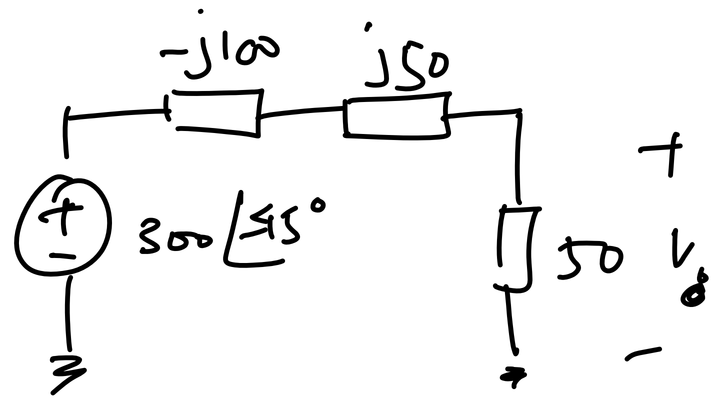


$$I_2 = \frac{15}{30+30} = 0.25A$$

$$I = I_1 + I_2 = 0.375A$$

(b)





$$V_i(t) = 300 \sin(\overset{\omega}{1000}t - 45^\circ)$$

$$V_i = 300 \angle{-45^\circ}$$

$$C = 10\,\mu F \qquad Z_C = -j\frac{1}{\omega C} = -j\frac{1}{1000 \times 10 \times 10^{-6}} = -j\,100\,\Omega$$

$$L = 50\,mH \qquad Z_L = j\omega L = j\,1000 \times 50 \times 10^{-3} = j\,50$$

$$V_o = \frac{50}{50 + j50 - j100} \times 300\angle{-45^\circ} = \frac{50}{50 - j50} \times 300\angle{-45^\circ} =$$

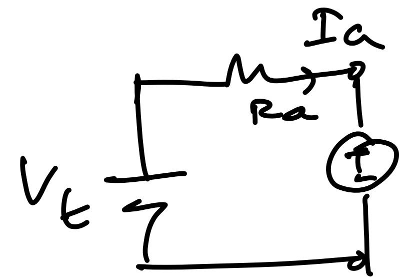
$$= \frac{1}{1-j} \times 300\angle{-45^\circ}$$

$$= \frac{1}{\sqrt{2}\angle -45^\circ} \times 300 \angle -45^\circ$$

$$= \frac{300}{\sqrt{2}} \angle 0^\circ$$

$$V_o(t) = \frac{300}{\sqrt{2}} \cdot \sin(1000t) \text{ V.}$$

Q.2 (a) Linear DC m/c



E_b, starting $u = 0$

$$V_t - I_a \cdot R_a = E_b \quad \text{— (1)}$$

$$E_b = B \cdot l \cdot u \quad \text{— (2)}$$

$$I_a = \frac{F}{Bl} \quad \text{— (3)}$$

(ii) No Load:

Starting Current: $u = 0 \rightarrow E_b = 0$

$$\therefore I_a = \frac{V_t - E_b}{R_a} = \frac{120}{0.4} = 300\,A.$$

$$Force = B \cdot l \cdot I_a = 0.5 \times 1.0 \times 300 = 150\,N.$$

(iii) U_{ss}:

$$F_m = F_{load} = 0. \Rightarrow I_a = 0.$$

$$E_b = V_t - I_a \cdot R_a = 120\,V.$$

$$\therefore U_{ss} = \frac{E_b}{B \cdot l} = \frac{120}{0.5 \times 1.0} = 240\,m/s.$$

(iii) $F_{load} = 25\,N. \rightarrow I_a = \frac{F}{B.l} = \frac{25}{0.5\times 1.0} = 50\,A.$

$E_b = 120 - 50\times 0.4 = 100\,V$

$\therefore\; u_{ss} = \frac{E_b}{B\times l} = \frac{100}{0.5\times 1.0} = 200\,m/s.$

(iv). $\text{Efficiency} = \frac{P_o}{P_i} = \frac{E_b\times I_a}{V_t\times I_a} = \frac{100}{120} = \underline{\underline{83.33\,\%}}.$

Q.2(b) Magnetic Circuit:

$\longrightarrow \underset{\text{mmf}}{\mathcal{F}} = Ni\,, \quad \phi = \frac{Ni}{\mathcal{R}} \qquad \mathcal{R} = \frac{l}{\mu A} \rightarrow$

$\longrightarrow$ Amper's law $\oint H.dl = \sum i \Rightarrow H.2\pi R_{mean} = N\times I$

✓ $B = \mu H = \mu_r \cdot \mu_0 \cdot H = \mu_r \cdot \mu_0 \cdot \dfrac{NI}{2\pi \cdot R_{mean}}$

(i) $N = 250$, I ?, $B = 1.25\ wb/m^2$, $\mu = \mu_r \mu_0$

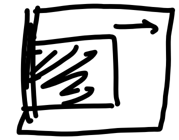
$= 2500 \times 4\pi \times 10^{-7}$

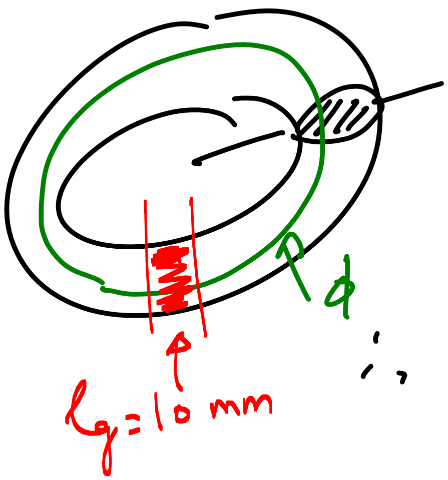
From Ampere's law $B = \dfrac{\mu_r \mu_0 \cdot N \cdot I}{2\pi \cdot R_{mean}}$

$$I = \frac{B \times 2\pi \times R_{mean}}{\mu_r \cdot \mu_0 \cdot N} = \frac{1.25 \times 2 \times \cancel{\pi} \times \left(\frac{8+12}{2}\right) \times 10^{-2}}{2500 \times \cancel{4\pi} \times 10^{-7} \times 250}$$

$= 1A$

(ii) $\Phi = B \times A$





$D = 12 - 8 = 4$ cm

$r = 2$ cm

$A = \pi r^2 = \pi \times 2^2 \times 10^{-4}\ m^2 = 4\pi \times 10^{-4}$.

$\therefore\ \Phi = 1.25 \times 4\pi \times 10^{-4}$ wb.

(iii) $B = 1.25\ wb/m^2$ $\qquad \Phi = 1.25 \times 4\pi \times 10^{-4}$ wb.

$$R = R_c + R_g = \frac{l_c}{\mu_r \mu_0 . A} + \frac{l_g}{\mu_0 . A_g}$$

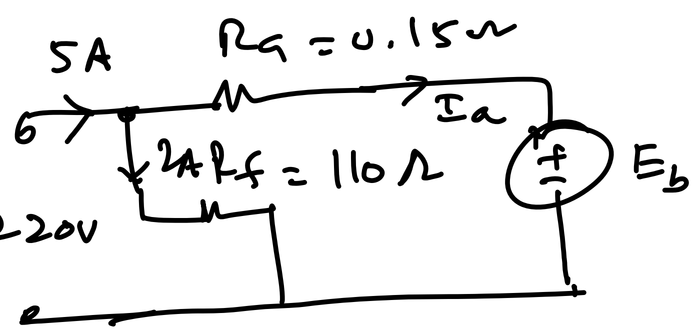
$$A_g = \pi . (2 + 0.01)^2 \times 10^{-4} \simeq 4\pi \times 10^{-4}.$$

$$R = \frac{2\pi \times 8\times 10^{-2}}{2500 \times 4\pi\times10^{-7} \times 4\pi\times10^{-4}} + \left(\frac{0.01}{4\pi\times10^{-7} \times 4\pi\times10^{-4}}\right)$$

$$= 645987$$

$$I = \frac{R \times \phi}{250} = 40.6\ A.$$

Q3 (a)



$I_a = I_{line} - 2$

$I_{a,\ no\ load} = 5 - 2 = 3\ A.$

E_b at no load $= 220 - 3\times0.15$

$= 219.55\ V.$

At rated load: $I_{line} = 48\ A$

$I_a = 48 - 2 = 46\ A.$

$E_b = 220 - 46\times0.15 = 213.1\ V.$

Speed $= 1100$ rpm.

$E_b \propto$ speed. $\quad E_b = K\phi \cdot \omega$.

$$\frac{\text{Speed (no Load)}}{\text{Speed (rated load)}} = \frac{E_b \text{ no load}}{E_b \text{ rated load}}$$

$$\text{Speed}_{N.L.} = \frac{219.55}{213.1} \times 1100 = 1133 \text{ rpm.}$$

3 (b) 10 KVA Xformer

const core loss = 150 W

Full load copper loss = 250 W.

Copper loss $\propto$ Load level.

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} = \frac{P_{out}}{P_{out} + P_{losses}}$$

(i) Full load, 0.8 p.f.

$P_{out} = 15\% \times p.f.$

$= 10 \times 10^3 \times 0.8 = 8000\,W.$

$P_{loss} = \underline{\underline{P_{core}}} + P_{\underline{\underline{copper}}} = 150 + 250 = 400\,W.$

$\therefore \eta = \dfrac{8000}{8000 + 400} = 96.4\,\%$

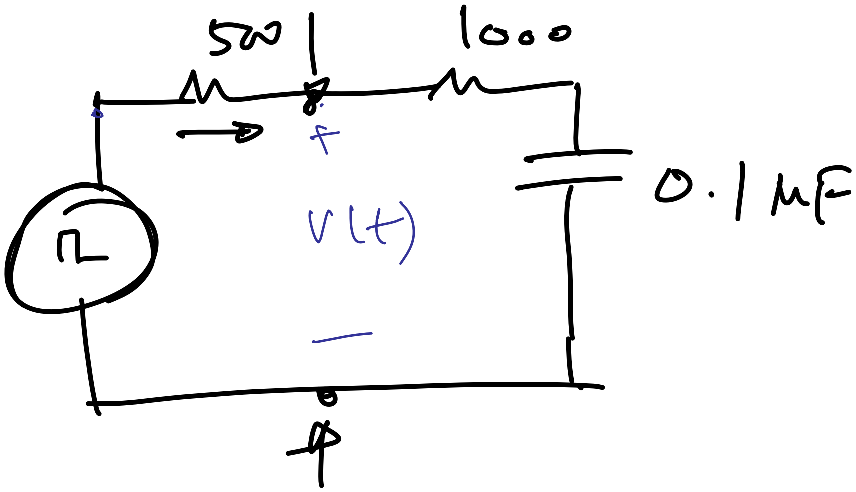
(ii) At 50% rated load u.p.f.

$P_o = 10 \times 10^3 \times (0.5) \times 1 = 5000\,W.$

$P_{losses} = 150 + 250 \times (0.5) = 275\,W.$

$\eta = \dfrac{5000}{5000 + 275} = 94.8\,\%$

4. (a)



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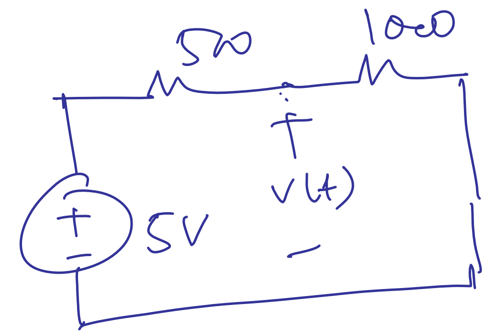
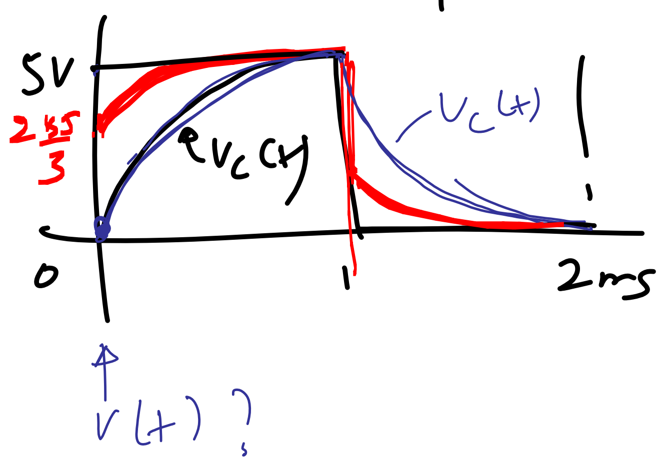
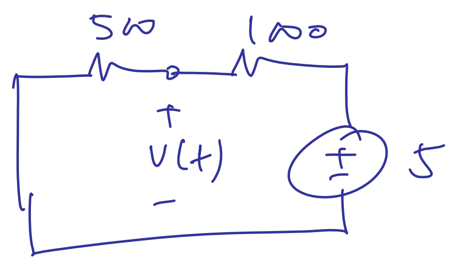




$$v(t) = 5 \times \frac{1000}{1500} = \frac{5\times 2}{3}\ V.$$



$$v(t) = 5 \times \frac{500}{1500} = \frac{5}{3}\ V.$$

(ii)

$$v_c(t) = 5 \times \left(1 - e^{-t/\tau}\right)$$

$$\tau = R_{TH} \times C$$
$$= 1500 \times 0.1 \times 10^{-6}$$

$$i_c(t) = \left[5 - v_c(t)\right] \times \frac{1}{1500}$$

$$V(t) = 5 - i_c(t) \times 500$$
$$= 5 - \frac{500}{1500}\left(5 - v_c(t)\right) = 5 - \frac{1}{3}\left(5 - 5\left(1 - e^{-t/\tau}\right)\right)$$
$$= 5 - \frac{5}{3} + \frac{5}{3}\left(1 - e^{-t/\tau}\right).$$
$$= \frac{2 \times 5}{3} + \frac{5}{3}\left(1 - e^{-t/\tau}\right).$$

$v_c(t) = 5\left(1 - e^{-t/\tau}\right)$ 0 to 1ms

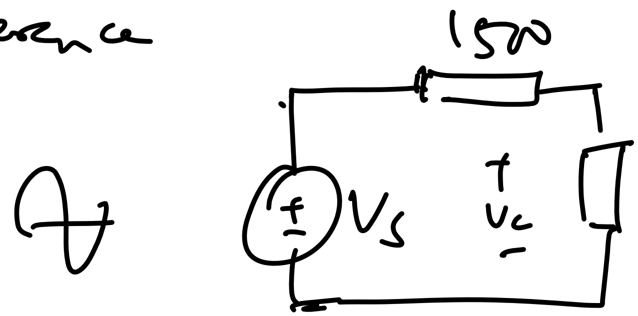
(iii)

$v_c(t) = 5 \times e^{-t/\tau}$ $\tau = 1500 \times 0.1 \times 10^{-6}$ S

1ms to 2ms

Sinusoidal

(iv) Phase difference



$-j \times \frac{1}{2\pi \times 500 \times 0.1 \times 10^{-6}}$

$= -j\,3183$

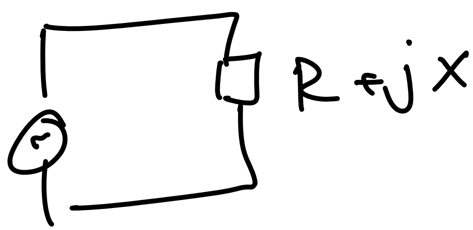
$V_c = V_s \times \frac{-j\,3183}{1500 - j\,3183} = V_s \times \frac{3183\angle -90^\circ}{3518\angle -65^\circ} = |\,| \angle -25^\circ$

phase difference $= \phi_c - \phi_s = -25 - 0 = \underline{\underline{-25^\circ}}$.

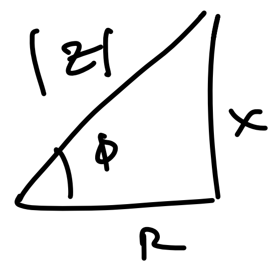
V_c is lagging V_s by $\underline{25^\circ}$.

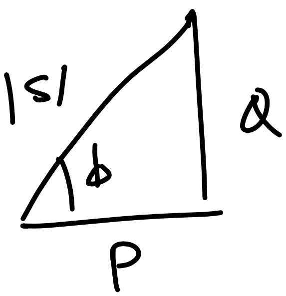
4 (b) Load 1, 1000 W, 230 V rms, p.f. = 0.8 lagg.

Load 2 500 W, 230 V rms, p.f = 0.75 leadig.



$Z = R + jX = \sqrt{R^2 + X^2} \angle \tan^{-1}\frac{X}{R}$





✓

$|S| = \frac{P}{p.f} = |V|\cdot|I| \Rightarrow$

$= |V|\cdot\frac{|V|}{|Z|}$

$= \frac{|V|^2}{Z} \Rightarrow \boxed{\frac{|V|^2}{|S|} = |Z|}$

$R = |Z|\cdot\cos\phi$

$X = |Z|\cdot\sin\phi$

$p.f = \cos\phi$

Load 1.

$$|S| = \frac{P}{p.f.} = \frac{1000}{0.8} = 1250 \text{ VA}$$

$$|Z| = \frac{230^2}{1250} = 42.3 \; ; \; \phi = \cos^{-1}(0.8) = 36.86^\circ$$

$$R = |Z| \cdot \cos\phi = 33.856$$

$$X = |Z| \cdot \sin\phi = 25.392 \rightarrow L = \frac{X}{\omega} = \frac{25.392}{2\pi \times 50} = 80.8 \text{ mH}$$

Load 2.

$$|S| = \frac{500}{0.75} = 666.67 \text{ VA}$$

$$|Z| = \frac{230^2}{|S|} = 79.349\,\Omega \; ; \; \phi = \cos^{-1}(0.75) = 41.4^\circ$$

$$R = |Z| \cdot \cos\phi = 59.5\,\Omega.$$

$$X = \frac{1}{\omega C} \Rightarrow C = \frac{1}{\omega X}$$

$$X = |Z| \sin\phi = 52.48\,\Omega \rightarrow = \frac{1}{2\pi \times 50 \times 52.48} = 60.7\,\mu\text{F}$$

(ii) Load 1 : $P_1 = 1000\,W$, $Q_1 = |S|\sin\phi$

$= 1250 \times \sin 36.87^\circ = 750\ VAR$

Load 2 $P_2 = 500\,W$, $Q_2 = -|S| \cdot \sin 41.4^\circ$

$= -666.67 \times \sin 41.4$

$= -441\ VAR.$

$P_{Load} = 1000 + 500 = 1500\,W.$

$Q_{Load} = Q_1 + Q_2 = 750 - 441 = \underline{309.}$

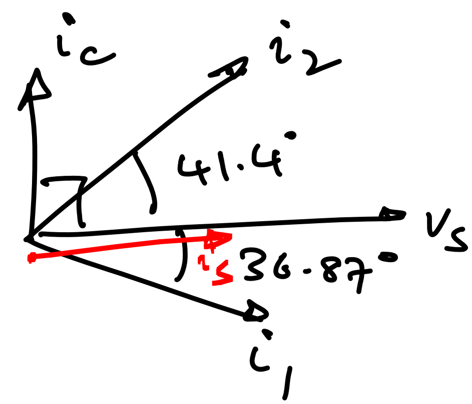
$Q_C = -309$

$Q_C = \frac{V^2}{X_C} = -\frac{V^2}{1/\omega C} = -V^2 \times \omega \times C$

$-309 = -(230)^2 \times 2\pi \times 50 \times C$

$C = 18.6\ \mu F$

(iii)



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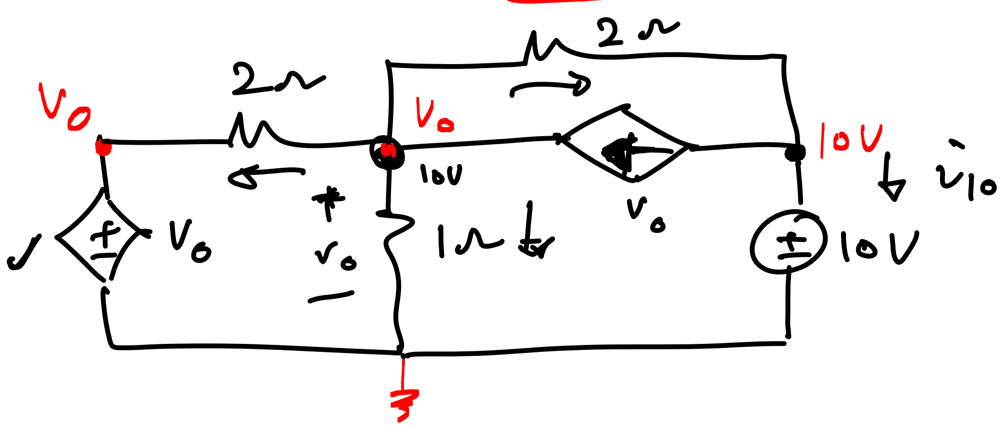


KCL at V_o:

$$\frac{V_o - 10}{2} - V_o + \frac{V_o}{1} + 0 = 0$$

$$V_o - 10 - \cancel{2V_o} + \cancel{2V_o} = 0 \Rightarrow V_o = 10$$

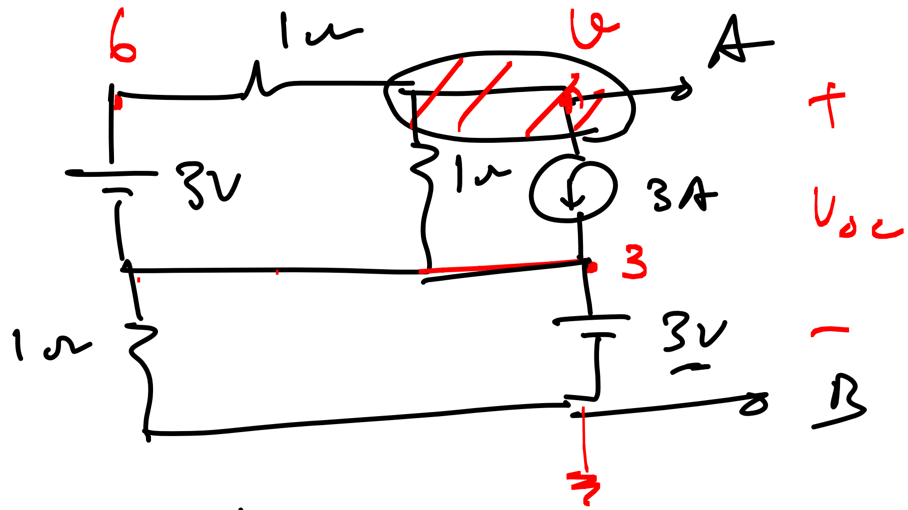
KCL at 10V.

$$v_o + \cancel{\frac{10-10}{2}}^{\,0} + i_{10} = 0$$

$$i_{10} = -V_o = -10 \text{ A}.$$

$$P_{10V} = 10 \times (-10) = -100\,W \qquad -ve \Rightarrow \text{delivering}$$

1 (b).



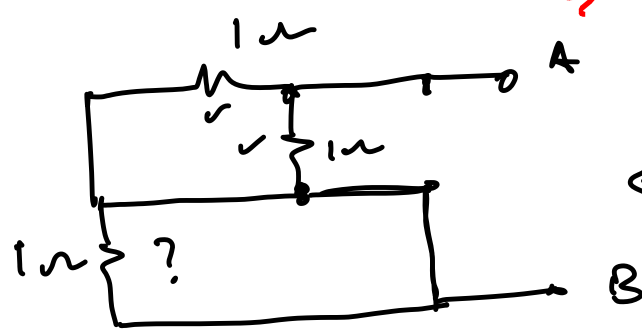
KCL at v:

$$3 + \frac{v-3}{1} + \frac{v-6}{1} = 0$$

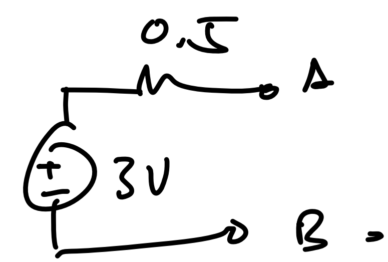
$$\cancel{3} + v - \cancel{3} + v - 6 = 0$$

$$2v = 6 \Rightarrow v = 3V.$$

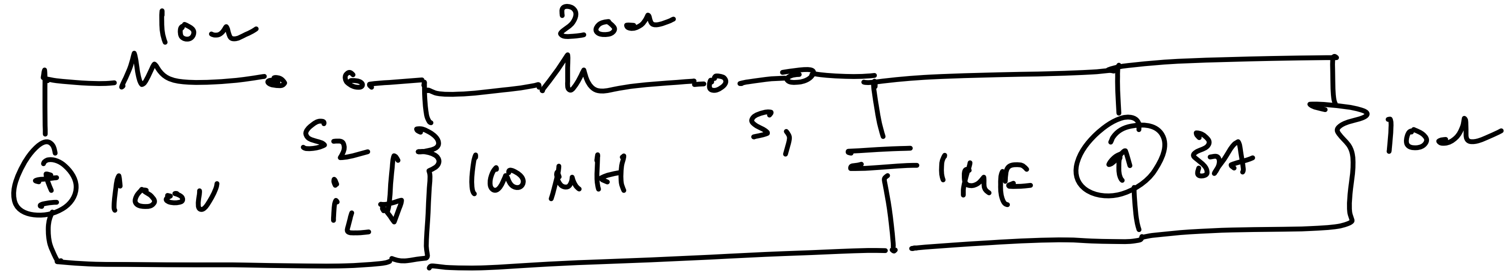
$$V_{TH} = 3V.$$



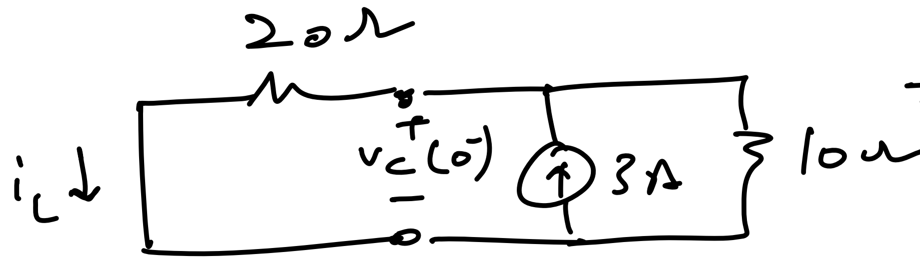
$\leftarrow$ $R_{TH} = 0.5\Omega$



Q.2 (a) Before $t=0$.



(2) $i_L(t=0^-) =$



$\Rightarrow v_C(0^-) = 3\times\frac{10\times 20}{10+20} = 20V$

$= 3\times\frac{10}{10+20}$

$= 1A.$

Energy in inductor $= \frac{1}{2}\times L\times I^2$

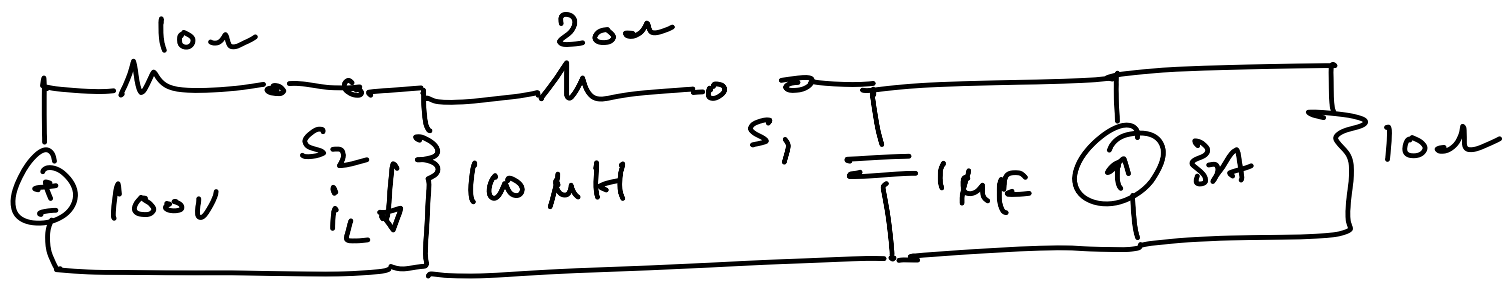
$= \frac{1}{2}\times 100\times 10^{-6}\times 1^2$ J

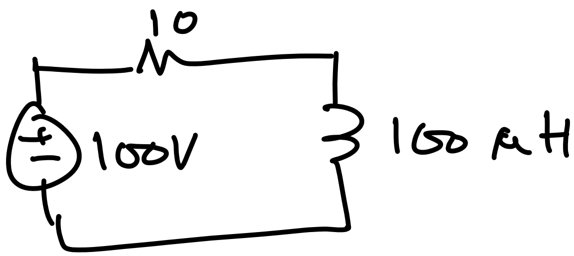
(ii) $v_c(0^+) = v_c(0^-) = 20\,V$.

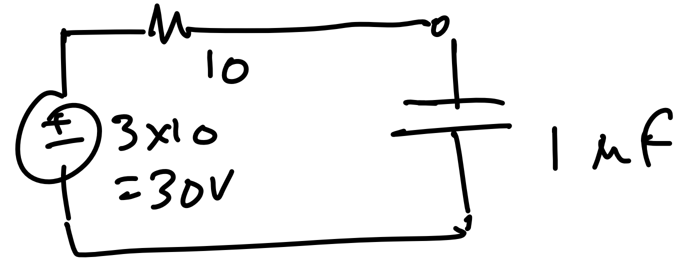
Energy in the capacitor immediately after $t=0$

$= \frac{1}{2} \times C \cdot V^2 = \frac{1}{2} \times 10^{-6} \times 20^2 \cdot J$.

(iii) After $t=0$:







$$\tau_1 = \frac{L}{R} = \frac{100\times10^{-6}}{10} = \underline{\underline{10\ \mu s}}, \qquad \tau_2 = R\times C = 10\times10^{-6} = 10\ \mu s.$$

$$i_L(t) = i_L(0)\cdot e^{-t/\tau_1} + \frac{V_{TH_1}}{R_{TH_1}}\left(1-e^{-t/\tau_1}\right)$$

$$= 1\times e^{-t/\tau_1} + \frac{100}{10}\left(1-e^{-t/\tau_1}\right) \text{ A}$$

$$V_C(t) = V_C(0)\times e^{-t/\tau_2} + V_{TH_2}\left(1-e^{-t/\tau_2}\right)$$

$$= 20\times e^{-t/\tau_2} + 30\left(1-e^{-t/\tau_2}\right) \text{ V.}$$

$$I_1 = \frac{100\angle \pi/12}{10\sqrt{2}\angle 45^\circ} = \frac{10}{\sqrt{2}} \cdot \angle 15^\circ - 45^\circ = \frac{10}{\sqrt{2}} \angle -30^\circ$$

$$I_2 = \frac{100\angle \pi/12}{10\sqrt{2}\angle -45^\circ} = \frac{10}{\sqrt{2}} \cdot \angle 15+45^\circ = \frac{10}{\sqrt{2}} \angle 60^\circ$$

$$i_1(t) = \frac{10}{\sqrt{2}} \cos(2000t - 30^\circ) \text{ A } \checkmark$$

$$i_2(t) = \frac{10}{\sqrt{2}} \cdot \cos(2000t + 60^\circ) \text{ A}.$$

$$\boxed{V_{rms} = \frac{V_m}{\sqrt{2}}}$$

2) ii

$$I_{1,rms} = \frac{10}{\sqrt{2}\times\sqrt{2}} = 5 \text{ A}.$$

$$I_{2,rms} = 5 \text{ A}. \quad \rightarrow \theta_1 - \theta_2 = -30^\circ - 60^\circ = -90^\circ$$

$i_2(t)$ is leading $i_1(t)$ by 90°.

3 (a) Magnetic circuit

$$\mathcal{R} = \frac{l}{\mu A} = \frac{l_{iron}}{\mu_{iron} \cdot A_c} + \frac{l_g}{\mu_0 \times A_c} = \frac{l_g}{\mu_0 \times A_c}$$

reluctance ($\mu_{iron} \to \infty$)

$$= \frac{2\times10^{-3}}{4\pi\times10^{-7} \times 16\times10^{-4}} = 9.95\times10^{5}$$

$N = 500$, $I = 4$ A.

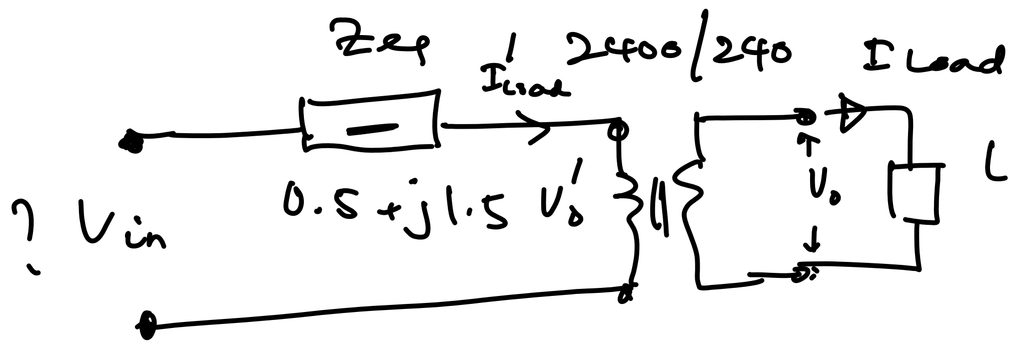
$mmf = NI = 500\times4$. A-t

(2) $\phi = \frac{mmf}{\mathcal{R}} = \frac{500\times4}{9.95\times10^{5}} = 2\times10^{-3}$ wb

(ii) Flux-linkage $\lambda = N\phi = 500\times2\times10^{-3} = 1$ wb-t.

(iii) Inductance $= \frac{\lambda}{I} = \frac{500 \times 2 \times 10^{-3}}{4} = \underline{250 \text{ mH}}$.

3(b). Single phase transformer



$|S| = 150 \times 10^3$ VA

Load : At 240V, p.f. = 0.85 lagging

$|I_{Load}| = \frac{|S|}{|V|} = \frac{150 \times 10^3}{240}$

$= 625$ A.

$\angle\phi = -\cos^{-1}(0.85) = -31.8°$

$I_{Load} = 625 \angle -31.8°$

$$I'_{Load} = \frac{625 \angle -31.8^\circ}{2400/240} = 62.5 \angle -31.8^\circ .$$

$$V_{in} = 2400\angle 0^\circ + I'_{Load} \times Z_{eq}$$

$$= 2400 \angle 0^\circ + 62.5 \angle -31.8^\circ \times (0.5 + j1.5)$$

$$= 2400 + \underbrace{62.5 \angle -31.8^\circ \times 1.58 \angle 71.56^\circ}$$

$$= 2400 + 98.75 \angle 39.76^\circ$$

$$= 2400 + 75.97 + j\,63.07$$

$$= 2475.97 + j\,63.07 = 2476.71 \angle 1.46^\circ$$

$$V_{0,NL} = 247.67 \text{ V}$$

(i) % Voltage regulation $= \dfrac{V_{NL} - V_{FL}}{V_{FL}} \times 100$

$= \dfrac{247.67 - 240}{240} \times 100 = 3.19\ \%$.

(ii) Efficiency : $\dfrac{P_{out}}{P_{in}} = \dfrac{|S| \times P.f.}{}$

$P_{in} = Re(V \cdot I^*) = Re\left(\dfrac{V_{in} \times I'^{*}_{Load}}{2}\right)$

$P_{in} = |V|_{rms} \cdot |I|_{rms} \times \cos\phi$.

ϕ : phase diff. between V_{in} and I'_{Load}

$= 1.46 - (-31.8^\circ)$

$= 33.26^\circ$

$P.f. = \cos 33.26^\circ =$

$$P_{in} = \frac{2476.71}{} \times \frac{62.5}{} \times \cos(33.26^\circ) = 129437\ W$$

$$\eta = \frac{150\times10^3 \times 0.85}{129437} \times 100 = 98.5\ \%$$

Q.4. a) Linear DC Machine.

$$E_b = B.l.u \quad , \quad F = B.l.I$$

$$V_t = I \times R + E_b$$

$B = 0.5\ wb/m^2$, $R = 0.25\ \Omega$, $l = 0.5\ m$, $V_t = 120\ V$

i) . No load $F_{load} = 0 \rightarrow I = 0$. $E_b = V_t = 120$

$$u_{ss} = \frac{E_b}{B \times l} = \frac{120}{0.5 \times 0.5} = 480\ m/s.$$

(ii)

$F_{load} = 20\ N \longrightarrow I = \frac{20}{B \times l} = \frac{20}{0.5 \times 0.5} = \underline{\underline{80\ A}}$

$E_b = V_t - I \times R = 120 - 80 \times 0.25$

$= 120 - 20 = 100V.$

$u_{ss} = \frac{E_b}{B \times l} = \frac{100}{0.5 \times 0.5} = 400\ m/s.$

(iii)

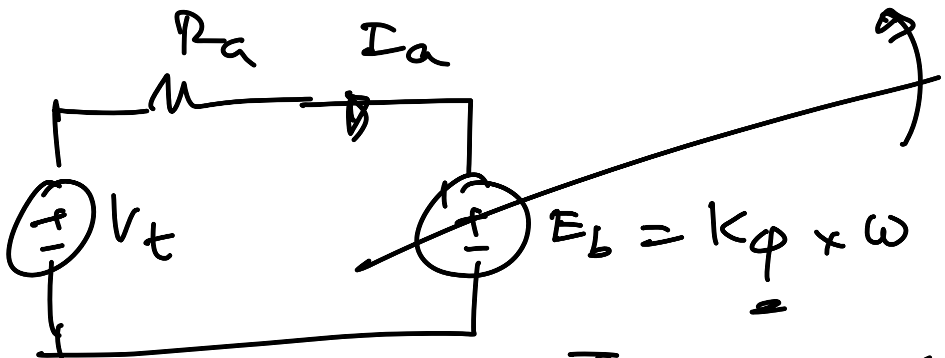
$V_t = 100V$ from $120V$.

$I = 80\ A \rightarrow E_b = 100 - 80 \times 0.25 = 80V.$

$u_{ss} = \frac{80}{0.5 \times 0.5} = 320\ m/s.$

Speed reduces when battery voltage is reduced.

Q. 4 (b) :



$E_b = K\phi \times \omega$.

$I_a = \dfrac{V_t - E_b}{R_a} = \dfrac{V_t - K\phi \cdot \omega}{R_a}$

$T_m = K\phi \times I_a$.

$K\phi = 2.42$ V/rad/s

$R_a = 0.2\,\Omega$

$V_t = 50$ V

$T_L = 5 + 0.05\,\omega + 0.001\,\omega^2$ N.m.

steady-state speed $\quad T_m = T_L$

$$T_m = K\phi \times I_a = K\phi \times \left[\frac{V_t - K\phi \cdot \omega}{R_a}\right]$$

$$= 2.42 \times \left[\frac{50 - 2.42 \times \omega}{0.2}\right] = 605 - 29.28\,\omega \,.$$

$$T_m = T_L$$

$$605 - 29.8\,\omega = 5 + 0.05\,\omega + 0.001\,\omega^2$$

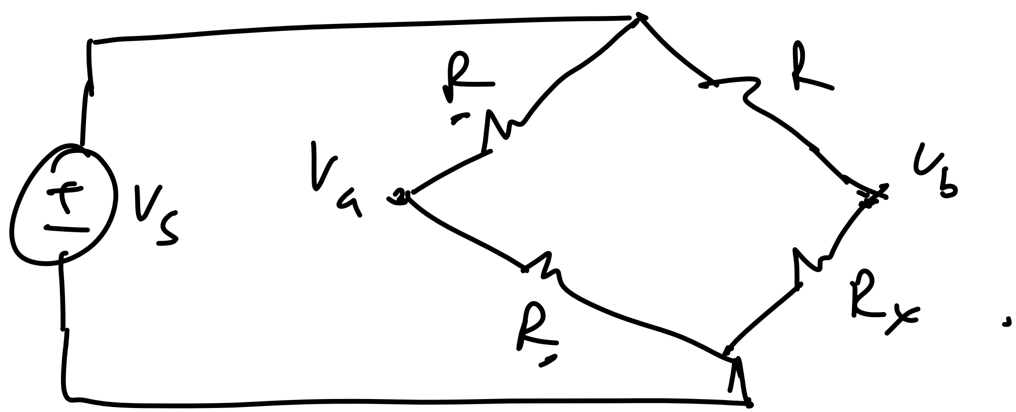
$$0.001\,\omega^2 + 29.85\,\omega - 600 = 0.$$

$$\underline{\omega = 20.086 \text{ rad/sec}} \checkmark \rightarrow \text{Steady-state speed}$$

$$-29870.\ \cdots\ ?$$

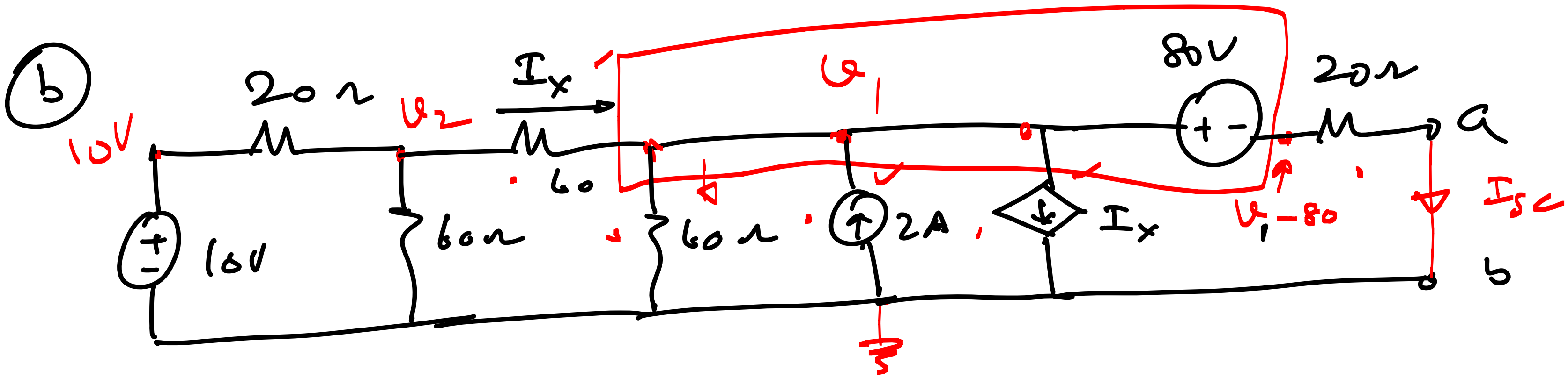
EE1002 AY 10/11

Q.1. (a)



$$V_{ab} = V_a - V_b = V_s \times \frac{1}{2} - \frac{R_x}{R_x + R} \times V_s = V_s \times \left[\frac{1}{2} - \frac{R_x}{R_x + R} \right].$$

$R_x \rightarrow V_{ab}, R, V_s$



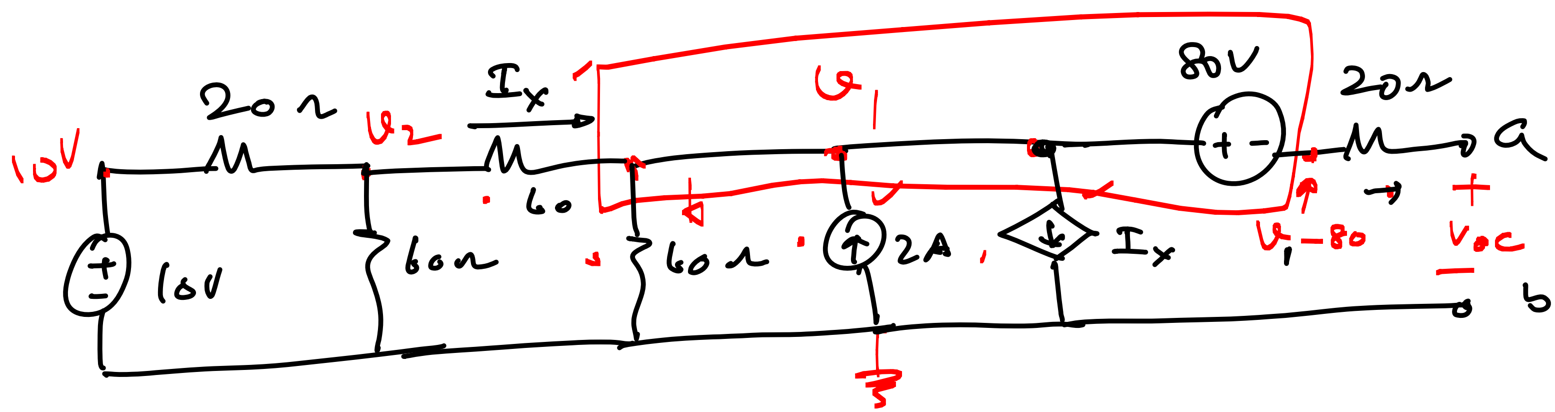
KCL at the S.N:

$$-\cancel{I_x} + \frac{v_1}{60} - 2 + \cancel{I_x} + \frac{v_1 - 80}{20} = 0$$

$$v_1 - 120 + 3v_1 - 240 = 0$$

$$\Rightarrow v_1 = \frac{360}{4} = 90\,V.$$

$$I_{sc} = \frac{v_1 - 80}{20} = \frac{90 - 80}{20} = 0.5\,A = I_N.$$



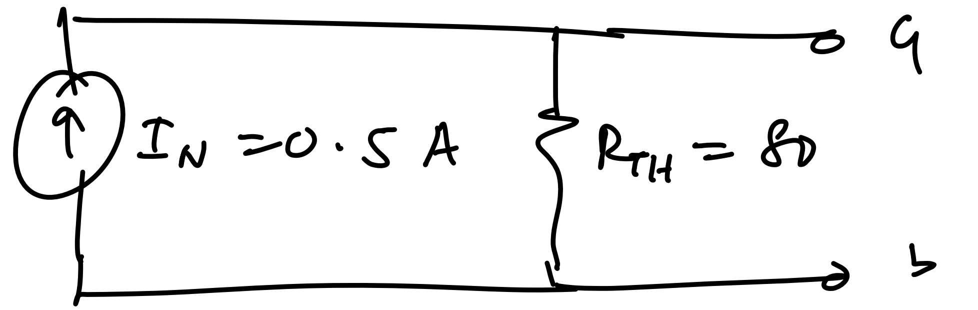
KCL at S-N.

$$\cancel{-I_x} + \frac{v_1}{60} - 2 + \cancel{I_x} + 0 = 0$$

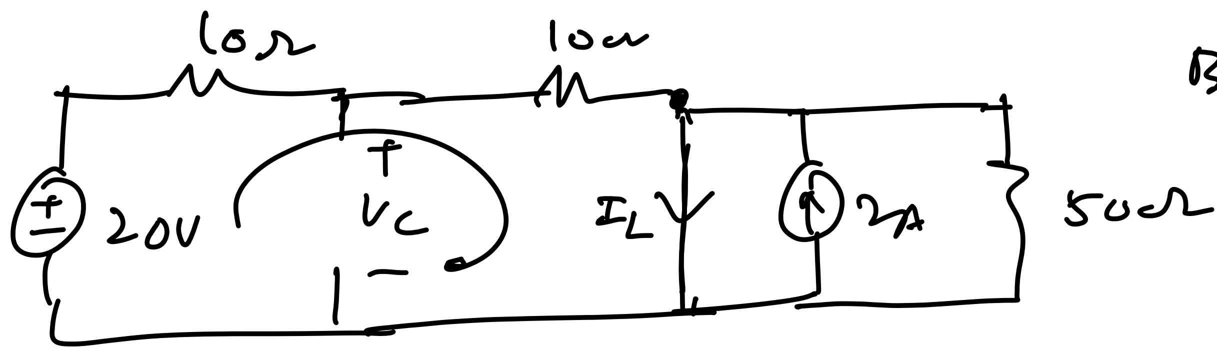
$$v_1 = 120V.$$

$$V_{oc} = v_1 - 80 - 0 = 120 - 80 = 40V.$$

$$I_{sc} = 0.5\,A \Rightarrow R_{TH} = \frac{V_{oc}}{I_{sc}} = \frac{40}{0.5} = 80\,\Omega.$$



Q 1.(c)

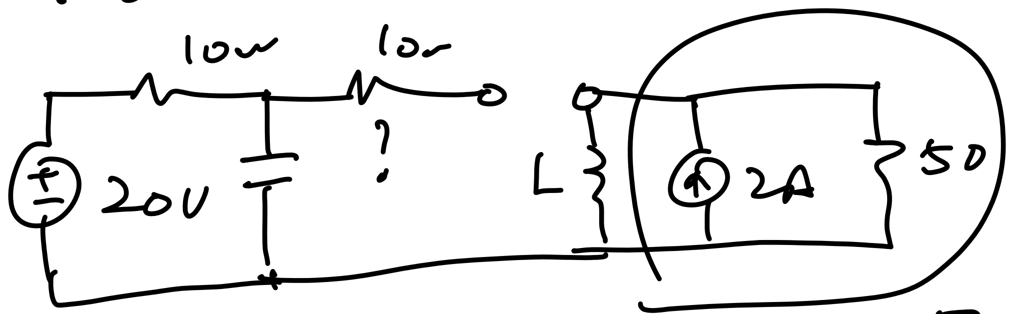


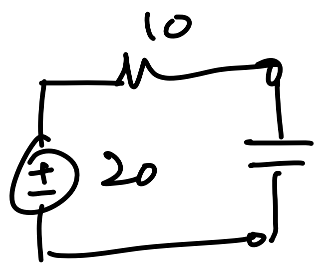
Before t=0.

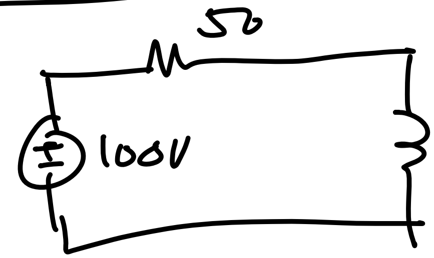
$$V_C = 20 \times \frac{10}{10+10} = 10V ,$$

$$I_L = 2 + \frac{20}{10+10} = 2+1 = 3A.$$

After t=0

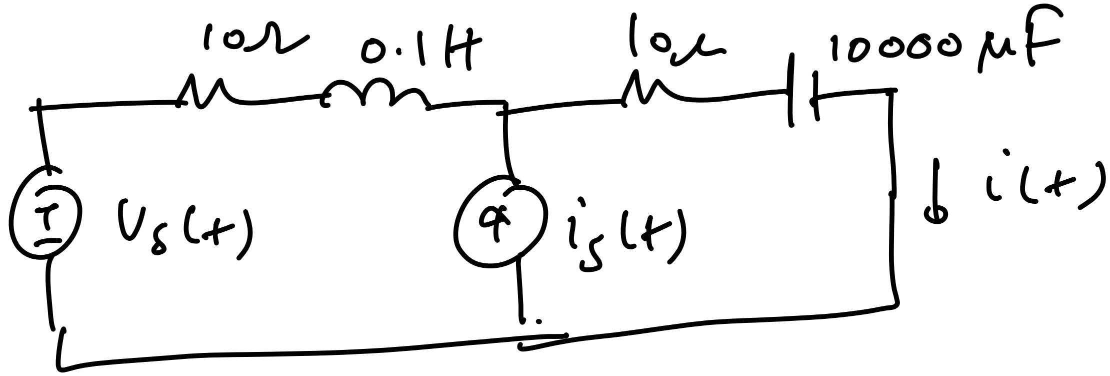






Theven's

Q 2 (a)



$\omega = 100$ rad/sec

$v_s(t) = 100 \sin(100t) \rightarrow 100 \angle 0^\circ$ V.

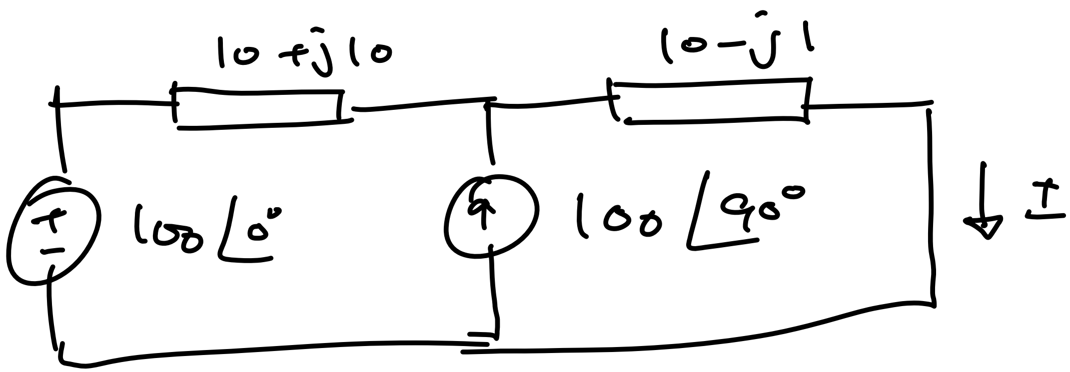
$i_s(t) = 100 \cos(100t) \rightarrow 100 \angle 90^\circ$ A

$= 100 \sin(100t + 90^\circ)$

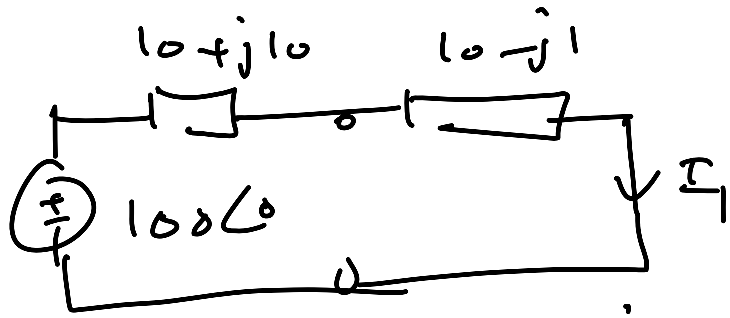
$R = 10\Omega \rightarrow Z_R = 10$

$L = 0.1$ H $\rightarrow Z_L = j\omega L = j\, 100 \times 0.1 = j10$

$C = 10^4 \times 10^{-6} = 10^{-2}$ F $\quad Z_C = -j \frac{1}{\omega C} = -j \frac{1}{100 \times 10^{-2}} = -j\,1$

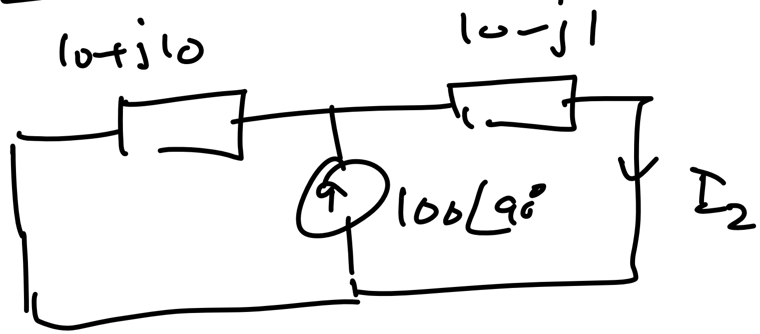


⇒ Superposition



+ $\quad I_1 = \dfrac{100\angle 0^\circ}{10+j10+10-j1}$

$= \dfrac{100\angle 0^\circ}{20+j9}$ ✓



$I_2 = 100\angle 90^\circ \times \dfrac{10+j10}{20+j9}$

$I = I_1 + I_2 \longrightarrow \underline{i(t)}$.