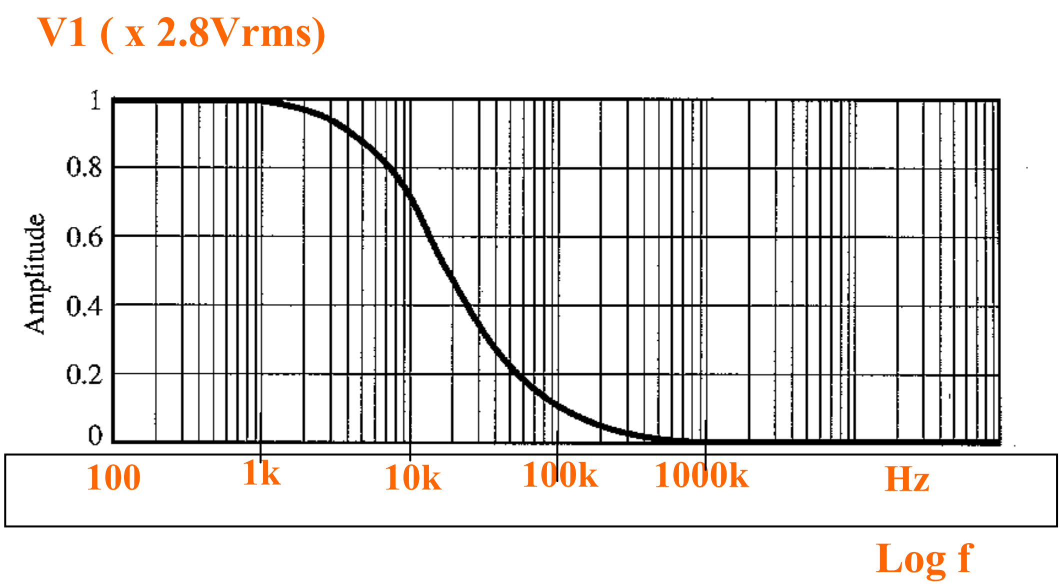
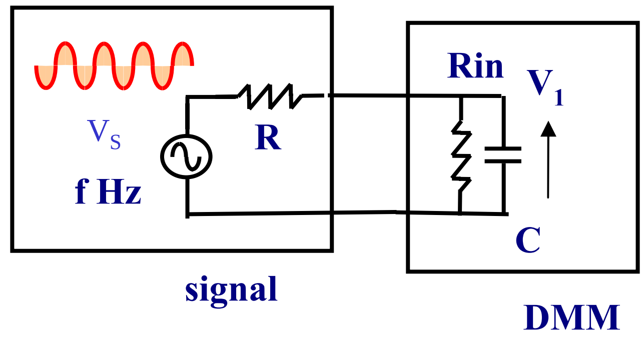
(13)

1

1. In the circuit, V_1 versus log-frequency f is given as shown.
Find roughly the magnitude of V_S in V, bandwidth of DMM, and V_1 at bandwidth in Vrms. (13)





magnitude Vm ≈ 4V **(5)**

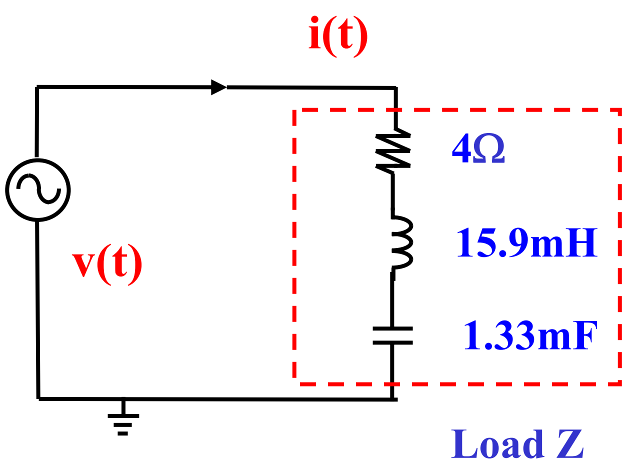
bandwidth ≈ 10kHz **(4)**

At bandwidth, V1 ≈ 0.7 x 2.8 Vrms **(4)**

(7)

2a. In the circuit, $\mathbf{v(t)} = 120\sqrt{2}\,\mathbf{cos}(2\pi 60\mathbf{t})\mathbf{V}$.
Find the frequency and period of v(t) , and the V phasor of v(t). Show also the impedance of load Z is roughly
$4 + j4\Omega$, and hence show that $\mathbf{i(t)} \cong 30\,\mathbf{cos}(2\pi 60\mathbf{t} - 45^{o})\mathbf{A}$
. (24)

2b. Plot v(t) and i(t) together. Show clearly the phase angles and amplitudes. Find the phase angles between v(t) and i(t). Does v(t) lead i(t) ? Plot also phasor V and I in a phasor diagram. (14)



2a

Find frequency f of v(t)

$$\mathbf{f} = 60\,\mathbf{Hz}$$ **(2)**

Find period of v(t)

$$\mathbf{T} = \frac{1}{\mathbf{f}} = \frac{1}{60\,\mathbf{Hz}} \cong 16.7\,\mathbf{ms}$$ **(3)**

Find V phasor

$$\mathbf{V} = 120\sqrt{2}\angle 0^{o}\,\mathbf{V}$$ **(2)**

(31)

Find impedance Z

$$\frac{1}{j\omega C} = \frac{1}{j(2\pi 60)(1.33\mathrm{mF})} \cong -2j\Omega \quad \textbf{(3)}$$

$$j\omega L = j * 2\pi 60 * 15.9\mathrm{mH} \cong 6j\Omega \quad \textbf{(3)}$$

$$Z = R + j\omega L + \frac{1}{j\omega C} = 4 + j6 - j2\Omega \quad \textbf{(2)}$$

$$= 4 + j4\ \Omega$$

$$= 4\sqrt{2}\angle 45^\circ\ \Omega$$

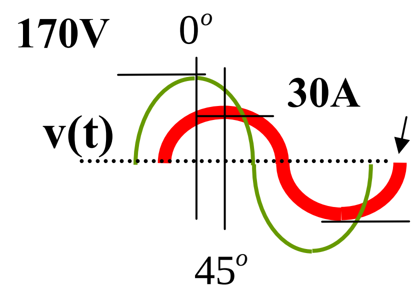
Find I

$$\therefore I = \frac{V}{Z} = \frac{120\sqrt{2}\angle 0^\circ\ V}{4\sqrt{2}\angle 45^\circ\ \Omega} \quad \textbf{(5)}$$

$$= 30\angle -45^\circ\ A \quad \textbf{(3)}$$

$$\therefore i(t) = 30\cos(2\pi 60t - 45^\circ)\ A$$

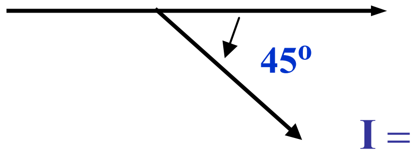
2b



(7)

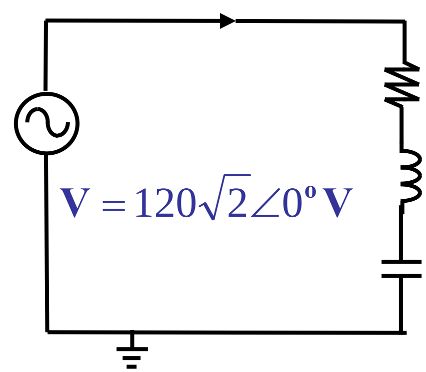
i(t) lags v(t) by 45° (3)

$$V = 120\sqrt{2}\angle 0^\circ\ V \quad \textbf{(5)}$$



$$I = 30\angle -45^\circ\ A$$

$$I = 30\angle -45^\circ\ A$$

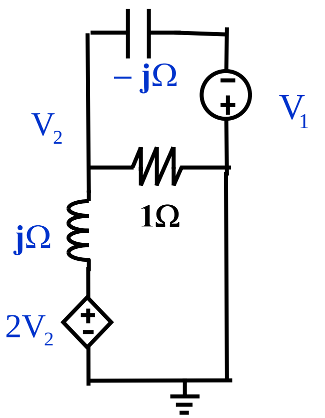


$$V = 120\sqrt{2}\angle 0^\circ\ V$$

(20)

3

3. In the circuit, if $\mathbf{V_1(t) = 4\cos(1kt)V}$, find $V_2(t)$. The **voltage controlled voltage source is in volt and equal to** $2V_2(t)$. Hint: apply KCL. (20)



$V_1(t) = 4\cos(1kt)V \Rightarrow 4\angle 0^{\circ}\,\mathrm{V}$ **(2)**

$$\frac{2V_2 - V_2}{j\Omega} = \frac{V_2}{1\Omega} + \frac{V_2 + 4}{-j\Omega} \quad \textbf{(7)}$$

$$2V_2 - V_2 = jV_2 - (V_2 + 4)$$

$$2V_2 = jV_2 - 4$$

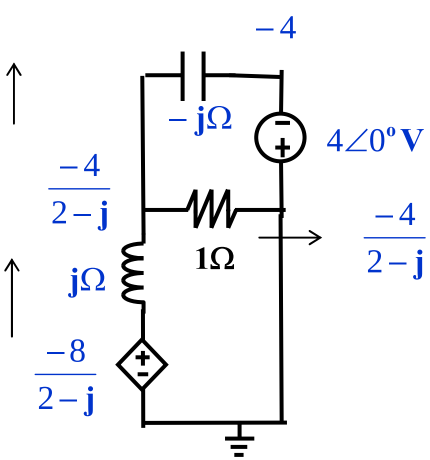
$$\therefore V_2 = \frac{-4}{2-j} = \frac{-4\angle 0^{\circ}}{\sqrt{5}\angle -26.6^{\circ}} \quad \textbf{(7)}$$

$$V_2 = \frac{-4}{\sqrt{5}}\angle 26.6^{\circ} \quad \textbf{(2)}$$

$$\therefore V_2(t) = \frac{-4}{\sqrt{5}}\cos(1kt + 26.6^{\circ})V \quad \textbf{(2)}$$

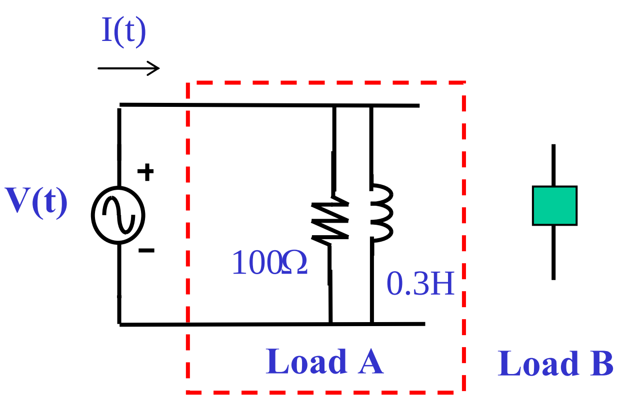
$$\frac{-4+4(2-j)}{(2-j)*-j} = \frac{4-4j}{-1-2j} = \frac{4+4j}{2-j} \uparrow$$

$$\frac{-4}{(2-j)*j} = \frac{-4}{1+2j} \uparrow$$



4. Load A is connected to V(t) as shown. $\mathbf{V(t)} = 200\sqrt{2}\,\mathbf{cos}(2\pi 50\mathbf{t})\mathbf{V}$
(a) Show that the power absorbed by load A is 400W. Find also the power stored by load A.
(b) Show that the power supplied by V(t) is roughly 583VA. Find also the power factor of load A. (25)

4. (c) Show that $\mathbf{I(t)} \cong 4.1\mathbf{cos}(2\pi 50\mathbf{t} + 47^{\circ})\mathbf{A}$
(d) If load B is connected in parallel to load A such that the power factor of the combined load is 1, find the element and value of load B. Show also new $\mathbf{I(t)} \cong 2.8\mathbf{cos}(2\pi 50\mathbf{t})\mathbf{A}$
. (25)



4a

power absorbed by load A = P **(2)**

$$\mathbf{P} = \frac{\mathbf{V}^2}{\mathbf{R}} = \frac{200\mathbf{V_{rms}}^2}{100\Omega} = 400\mathbf{W} \qquad \mathbf{(4)}$$

power stored by load A = Q **(2)**

$$\mathbf{Q} = \frac{\mathbf{V}^2}{\boldsymbol{\omega}\mathbf{L}} = \frac{200\mathbf{V_{rms}}^2}{2\boldsymbol{\pi}\mathbf{(50Hz)0.3H}} \cong 424.4\mathbf{VAR(L)} \qquad \mathbf{(5)}$$

4b

power supplied by v(t) = S **(2)**

$$\therefore \mathbf{S} = \sqrt{\mathbf{P}^2 + \mathbf{Q}^2} \cong \sqrt{400^2 + 424.4^2} \cong 583.2\mathbf{VA} \qquad \mathbf{(4)}$$

power factor of load A = PF

$$\therefore \mathbf{PF} = \frac{\mathbf{P}}{\mathbf{S}} = \frac{400}{583.2} \cong 0.686 \textbf{ lagging}$$ (6)

4c

$$\therefore \theta \cong \mathbf{cos}^{-1} 0.686 \cong 46.7^{o}$$ (4)

$$\mathbf{I} = \frac{\mathbf{S}}{\mathbf{V}} = \frac{583.2\mathbf{VA}}{200\mathbf{V}_{\mathbf{rms}}} \cong 2.92\mathbf{A}_{\mathbf{rms}}$$ (6)

$$\mathbf{I(t)} \cong 2.92\sqrt{2}\,\mathbf{cos}(2\pi 50\mathbf{t} - 46.7^{o})\ \mathbf{A}$$

4d

load B is capacitance

$$\mathbf{Q} = \mathbf{V}^2\omega\mathbf{C}$$

$$\therefore \mathbf{C} = \frac{\mathbf{Q}}{\mathbf{V}^2\omega} = \frac{424.4\mathbf{VAR}}{200^2(2\pi 50)} \cong 33.8\mu\mathbf{F}$$ (9)

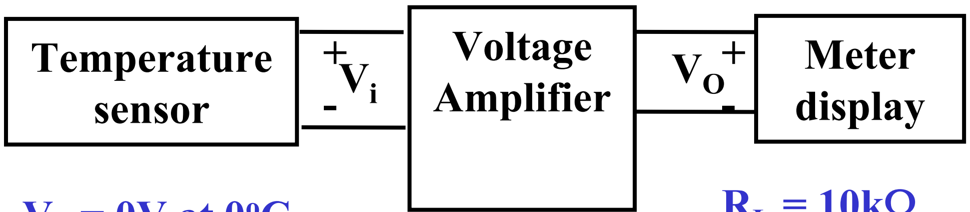
$$\mathbf{I} = \frac{\mathbf{V}}{\mathbf{R}} = \frac{200\mathbf{V}_{\mathbf{rms}}}{100\Omega} = 2\mathbf{A}_{\mathbf{rms}}$$ (6)

$$\mathbf{I(t)} = 2\sqrt{2}\,\mathbf{cos}(2\pi 50\mathbf{t})\ \mathbf{A}$$

(22)

7

7. A voltage amplifier is used to amplify the temperature sensor signal (0 to 100mV) to drive the meter display (0 to 2V) as shown. Draw the circuit model and then find the voltage gain of the voltage amplifier. (22).



$V_S = 0V$ at 0^oC $+1mV/^oC$

$R_S = 300\Omega$

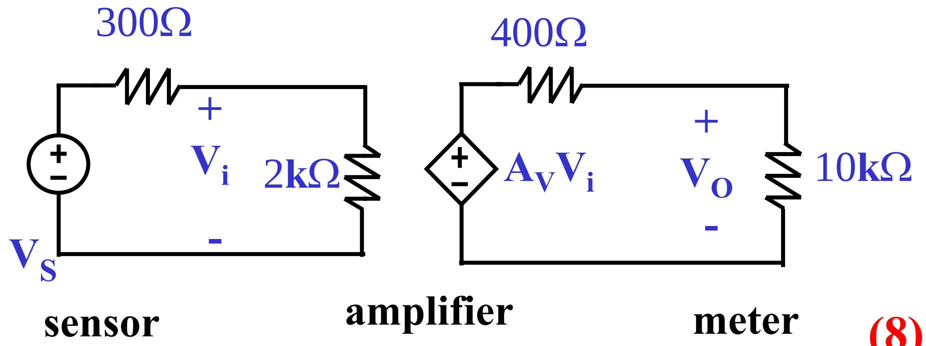
$R_i = 2k\Omega$

$R_O = 400\Omega$

$R_L = 10k\Omega$

$V_O = 2V$ when $V_S = 100mV$

Circuit Model



(8)

Use voltage divider

$$V_O = A_V * V_i * \frac{10k\Omega}{10k\Omega + 400\Omega}$$

$$= A_V * V_S * \frac{2k\Omega}{2k\Omega + 300\Omega} * \frac{10k\Omega}{10k\Omega + 400\Omega}$$

(8)

$$2V = A_V * 100mV * \frac{2k\Omega}{2.3k\Omega} * \frac{10k\Omega}{10.4k\Omega}$$

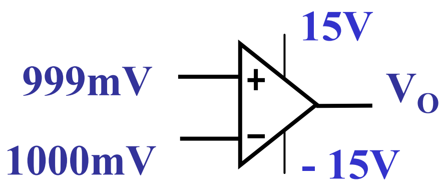
$$\therefore A_V \cong 24$$

(6)

(28)

8a. Find V_O of the 741 op amp. (10)

8a



741 op amp

$A = 200k$

$$V_O = A * Vi = A * (V_+ - V_-)$$

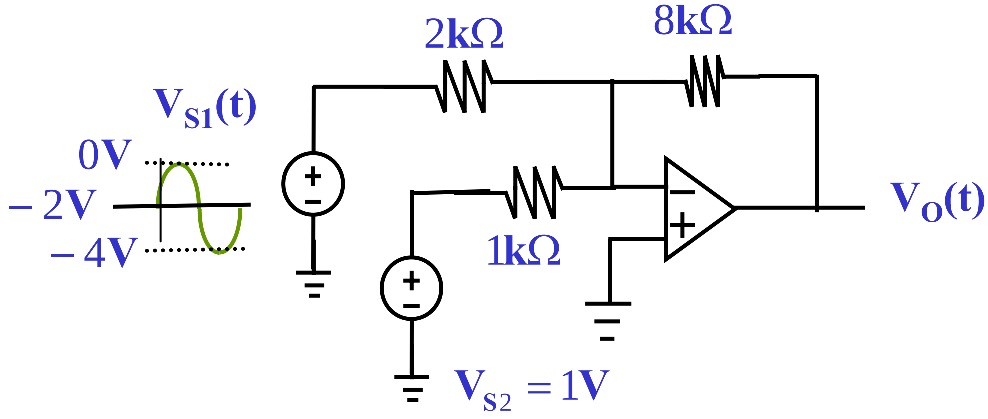
$$= 200k * (999mV - 1000mV) = -200V \quad (7)$$

$$V_O < -15V \Rightarrow \text{op amp saturates}$$

$$\Rightarrow V_O \cong -15V \quad (3)$$

8b

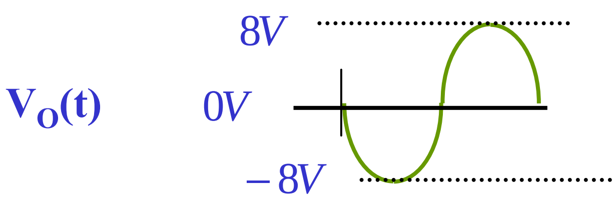
8b. Plot $V_O(t)$. Assume ideal op amp. (18)



$$V_O(t) \cong -\frac{R_2}{R_{S1}} V_{S1} - \frac{R_2}{R_{S2}} V_{S2} \quad (8)$$

$$= -\frac{8k\Omega}{2k\Omega} V_{S1}(t) - \frac{8k\Omega}{1k\Omega} V_{S2} \quad (2)$$

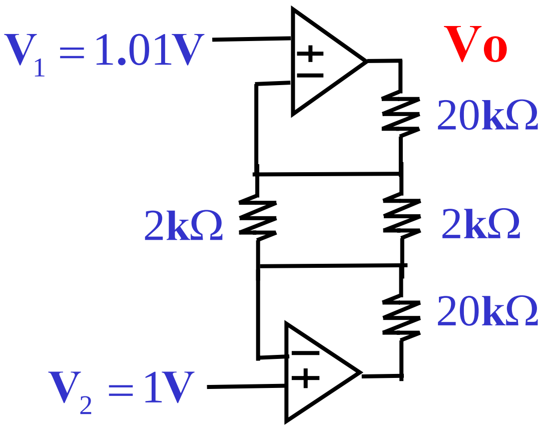
$$= -4V_{S1}(t) - 8V \quad (2)$$



(6)

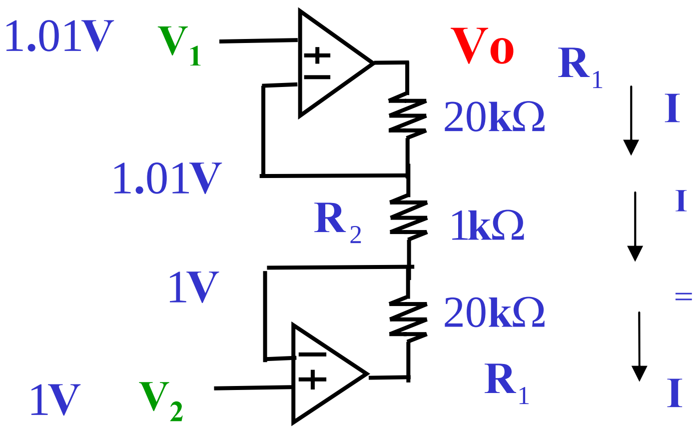
(30)

9a 9a. Find Vo. Assume ideal op amp. (18)



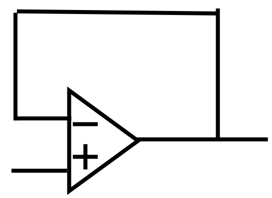
$$V_O = V_1 + I * 20k\Omega = 1.01V + 10\mu A * 20k\Omega$$
$$= 1.01V + 0.2V = 1.21V$$

(18)



$$I = \frac{V_1 - V_2}{R_2} = \frac{1.01V - 1V}{1k\Omega} = 10\mu A$$

9b Draw the circuit of an op amp **voltage follower** and name two advantages of the circuit. (12)



voltage follower

(6)

1. Very high input resistance
2. Very low output resistance

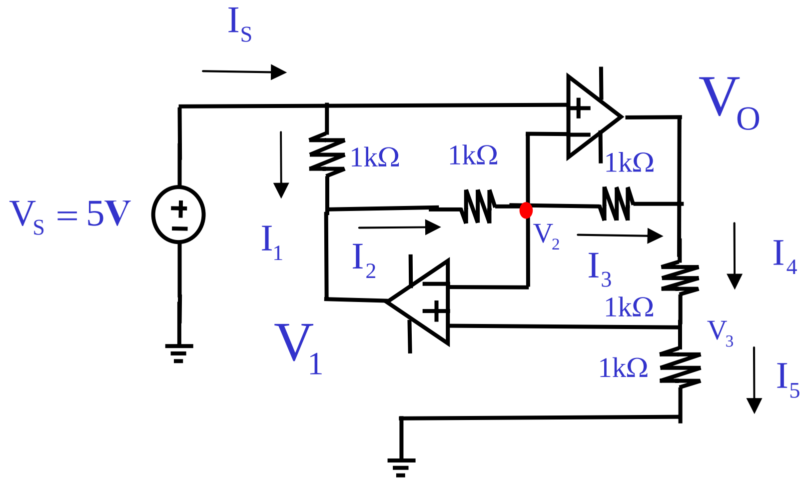
(6)

(28)

10

10. Find V_O and I_S.

Assume ideal op amp. (28)



$V_2 = 5V$ **(3)**

$V_3 = 5V$ **(3)**

$I_5 = 5mA$ **(3)**

$I_4 = 5mA$ **(3)**

$\therefore V_O = V_3 + I_4 * 1k\Omega = 5V + 5mA * 1k\Omega = 10V$ **(4)**

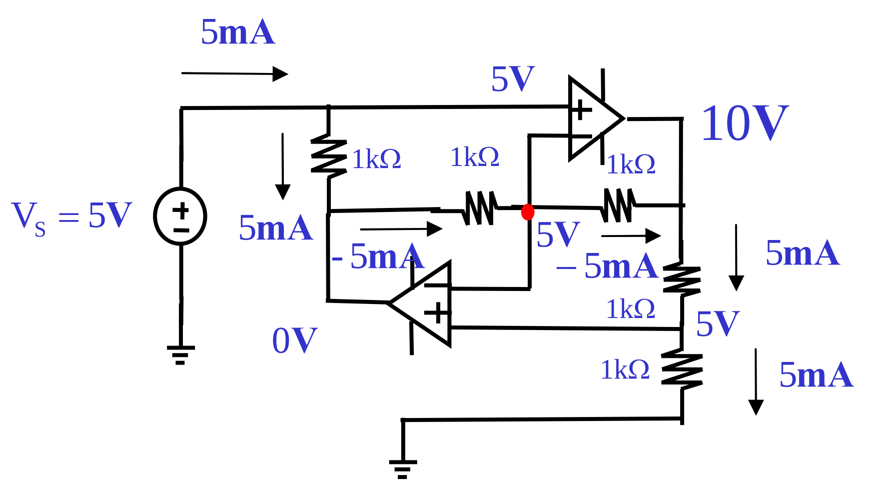
$I_3 = -5mA$ **(3)**

$I_2 = -5mA$ **(3)**

$I_1 = 5mA$ **(3)**

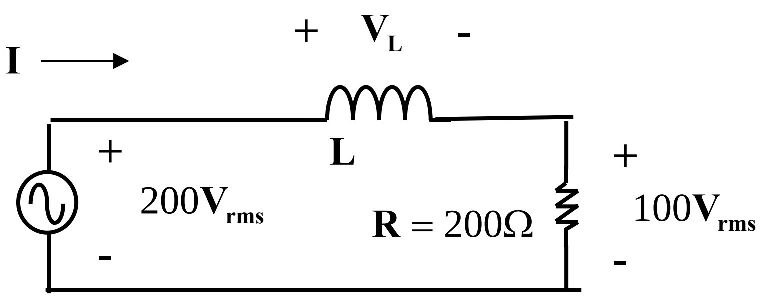
$\therefore V_1 = 0V$

$I_S = 5mA$ **(3)**

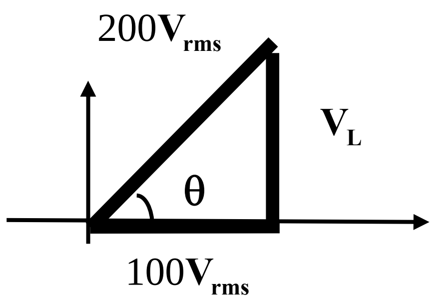


11a

11a. Find V_L and I . (12)



$$200V_{rms}\angle\theta = I(R + j\omega L) = 100V_{rms} + jV_L$$



$$V_L = \sqrt{200V_{rms}{}^2 - 100V_{rms}{}^2}$$
$$\cong 173V_{rms}$$

(9)

$$I = \frac{100V_{rms}}{200\Omega} = 0.5A_{rms}$$

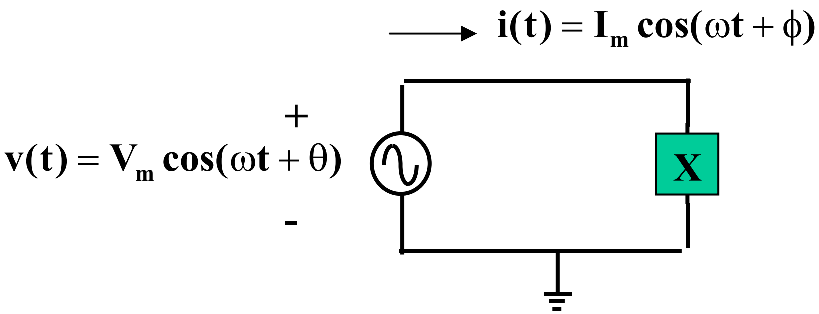
(3)

11b

11b. In the circuit, X is an unknown element. . (22)

(i) If $V_m = 10V$, $I_m = 2A$, $\theta = \phi = 45^o$, find X in Ω, power factor of X, and power absorbed by X.

(ii) If $V_m = 8V$, $I_m = 4A$, $\theta = 0^o$, $\phi = 90^o$, find X in Ω, power factor of X, and power absorbed by X.



$$X = R = \frac{V_m}{I_m} = \frac{10V}{2A} = 5\Omega \qquad (3)$$

$$PF = 1 \qquad (3)$$

$$P_R = I^2 * R = \left(\frac{4A}{\sqrt{2}}\right)^2 * 5\Omega = 40W \qquad (4)$$

$$X = C = -j2\Omega \qquad (5)$$

$$PF = 0 \qquad (3)$$

$$P = 0W \qquad (4)$$