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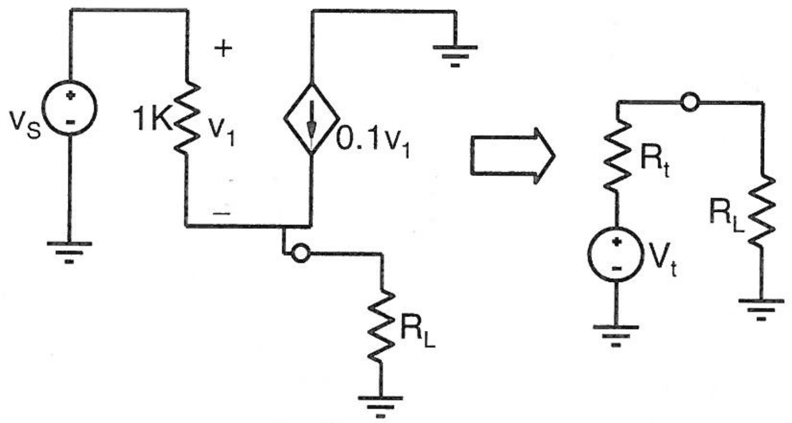
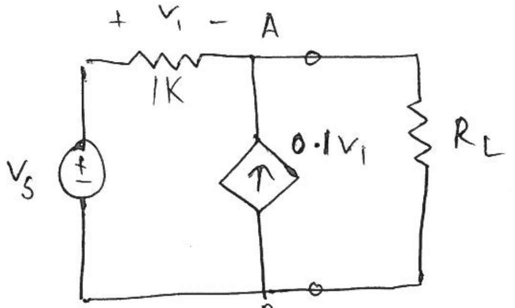
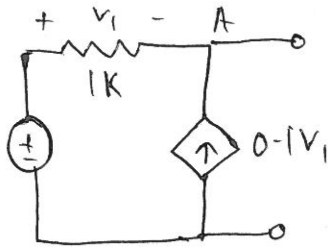
1 (a). Use Thevenin's theorem to carry out the circuit transformation shown below and determine the value of Thevenin's voltage (V_t) and resistance (R_t). [4]



Equivalent Circuit



V_{Th} = open circuit voltage V_{AB}



Observe that here, current through 1K = $0.1V_1$

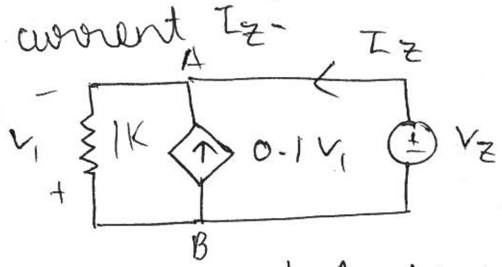
$\Rightarrow \frac{V_1}{1K} = 0.1V_1 \Rightarrow \frac{V_1}{1000} = 0.1V_1$

$\Rightarrow \boxed{V_1 = 0}$

$\Rightarrow V_{AB} = V_A - V_B = \boxed{V_S = V_{Th}}$

For R_{Th}, we turn-off all ideal sources and connect AB with another Ideal source V_Z providing

current I_Z -



Apply KCL at A, $\frac{V_1}{1K} + 0.1V_1 + I_Z = 0$

$\Rightarrow I_Z + (0.1 + 0.001)V_1 = 0$

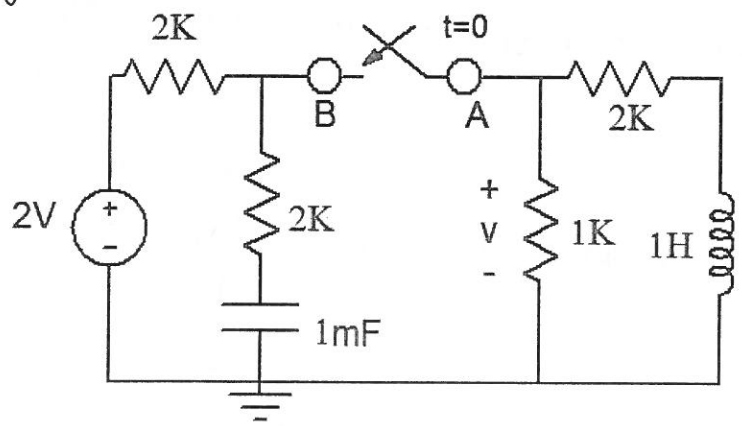
$\Rightarrow V_1 = -\frac{I_Z}{0.101}$

By KVL, $V_Z + V_1 = 0$

$\Rightarrow V_Z = \frac{I_Z}{0.101}$

$\Rightarrow \frac{V_Z}{I_Z} = \boxed{R_{Th} = \frac{1000}{101} = 9.9\,\Omega}$

1 (b). For the circuit shown, determine the voltage V across the 1K resistor immediately after switch is closed at t=0 . Assume that the circuit had enough time to reach steady state prior to closing of switch. [3]



In steady-state, the capacitor will have been fully charged to have $q = 2 \times 1mF$
$= 2mC$

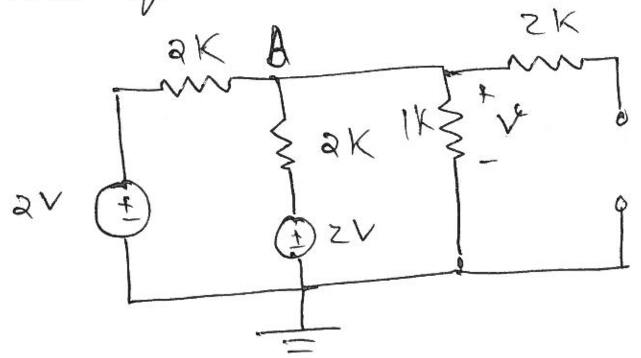
+2mC will be on the upper plate and -2mC on the lower plate.

The instant the switch is closed, current through Inductor will not change instantaneously (otherwise $L\frac{di}{dt} = \infty$) ∴ $I_L = 0$

Further, voltage across the capacitor won't change instantaneously,

$V_C = 2V$ (otherwise $C\frac{dV}{dt} = \infty$)

New equivalent circuit:

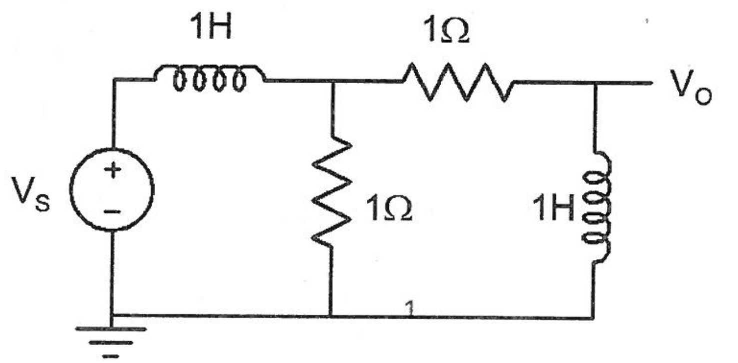


Apply Nodal analysis at B.

$\Rightarrow \frac{v-0}{1K} + \frac{v-2V}{2} + \frac{v-2V}{2} = 0$

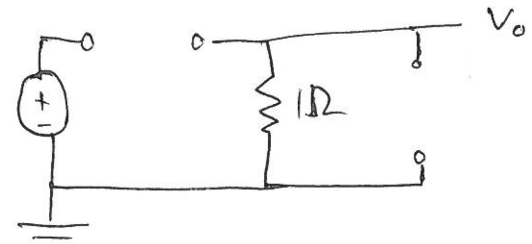
$\Rightarrow \frac{v}{1} + v - 2V \Rightarrow \boxed{v = 1V}$

1(c). Determine the nature of the filter (low pass/high pass/band pass/band stop) shown below using qualitative arguments. [2]



As $\omega \to 0$, both inductors behave as opens.

$\Rightarrow V_o = 0$ in the figure below

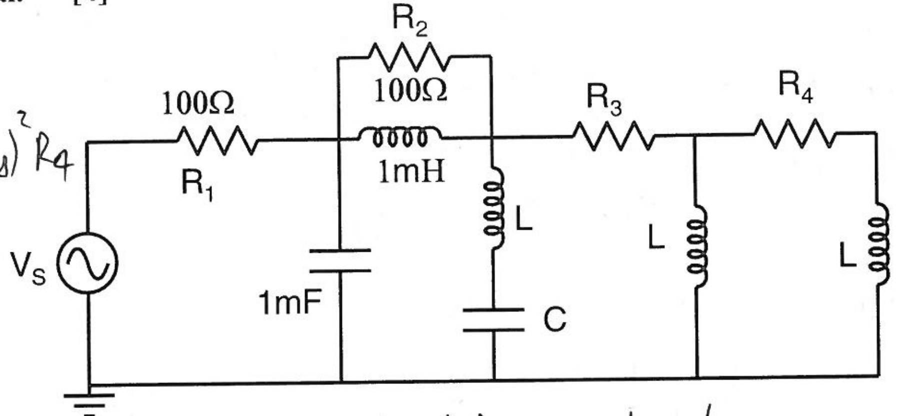


As $\omega \to 0$, both inductors behave as shorts

$\Rightarrow V_o \approx 0$

$\Rightarrow$ The filter is a band pass filter

2(a). The power dissipated in resistors R_3 and R_4 in the circuit shown below was measured to be zero and power measured in resistors R_1 and R_2 was measured to be equal. Using sinusoidal steady state analysis estimate the frequency of the input signal. [4]



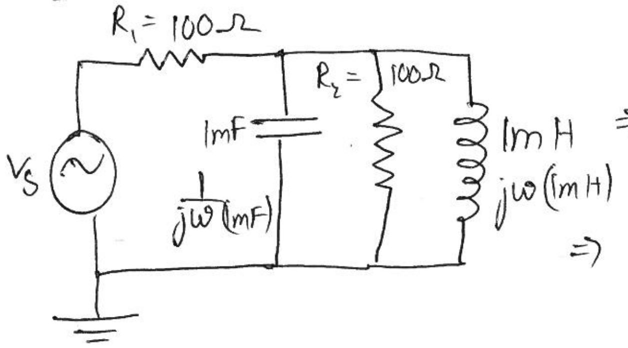
For power in R_3 and R_4 to be 0. $(I_{rms})_3^2 R_3 = (I_{rms})^2 R_4$

Current must not enter these 2 resistors

⇒ Net impedance of L and C in series must be 0 so that it the combination acts like a short.

$$\left(j\omega L - j\frac{1}{\omega C}\right) = 0 \Rightarrow \omega = \frac{1}{\sqrt{LC}}$$

Equivalent Circuit:



$$P_1 = P_2 \Rightarrow (I_{rms})_1^2 R_1 = (I_{rms})_2^2 R_2 \Rightarrow (I_{rms})_1 = (I_{rms})_2$$

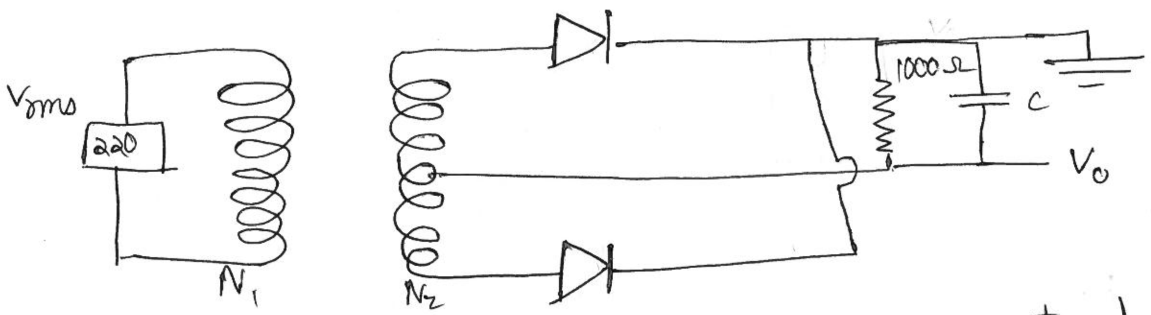
⇒ ~~Net impe~~ Same current must flow through both

⇒ Net impedance of parallel combination $= R_2$

$$\Rightarrow \frac{1}{R_2} = \frac{1}{R_2} + \frac{1}{\left(\frac{1}{j\omega\, 1mF}\right)} + \frac{1}{j\omega 1mH}$$

$$\Rightarrow \omega \times (1mF) = \frac{1}{\omega(1mH)} \Rightarrow \omega^2 = 10^6 \Rightarrow \boxed{\omega = 10^3\, rad\, s^{-1}}$$

2(b). Design a full wave rectifier based power supply circuit that will supply -10V to a load of 1000Ω with magnitude of ripple voltage less than 0.2V. As part of the design, sketch the complete circuit, determine transformer turns ratio, value of capacitance , diode peak current and peak inverse voltage. Assume that input is 220V rms with a frequency of 50Hz. [6]



In order to obtain negative voltage, we interchange the ground and load.

$(V_o)_{input,max} = 220\sqrt{2}$, $V_m = 10V + 0.7V = 10.7$

$V_M = 10V$

$$\frac{(V_o)_{max}}{(V_m)} = \frac{N_1}{\left(\frac{N_2}{2}\right)}$$

$$\Rightarrow \frac{N_1}{N_2} = \frac{1}{2}\left(\frac{V_{o\,max}}{V_m}\right) = 14.53$$

For ripple voltage $< 0.2V$

$$\Rightarrow \frac{V_M}{2fR_LC} < 0.2$$

$$\Rightarrow \frac{10}{2\times 50 \times 10^3 \times C} < 0.2 \Rightarrow \frac{10}{10^5 \times C} < 0.2 \Rightarrow \frac{10}{10^5} \times \frac{10}{2} < C$$

$$\Rightarrow C > 50\times 10^{-5}$$

$$\Rightarrow \boxed{C > 500\,\mu F}$$

Peak Inverse voltage $= 2V_M + V_\gamma$

$= 2(10) + 0.7$

$= 20.7V$

$$\text{Diode peak current} = \frac{V_M}{R_L}\left[1 + \pi\sqrt{\frac{2V_M}{V_\gamma}}\right]$$

$$= \frac{10}{10^3}\left[1 + \pi\sqrt{\frac{2(10)}{0.2}}\right]$$

$= 0.324\, A$

$\approx 324\, mA$