SOLUTIONS

Solution of pre-tutorial:

a) Vc(0-) = 6 V

b) Vc(0+) = 6 V

c) dVc(0-)/dt = 0 V/s

d) dVc(0+)/dt = 0 V/s

e) diL(0-)/dt = 0 A/s

f) diL(0+)/dt = 3 A/s

Solution of problem 2:

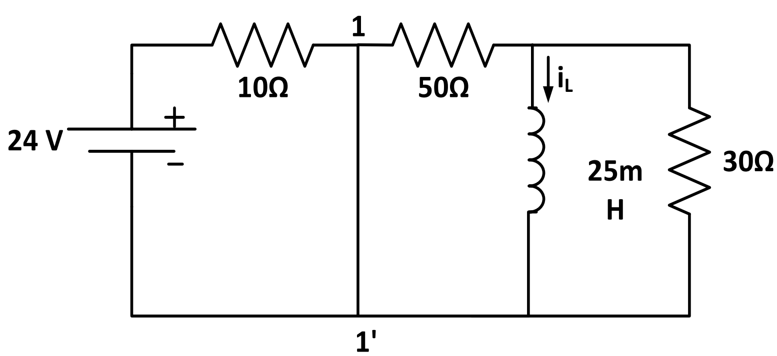


Fig. 1.

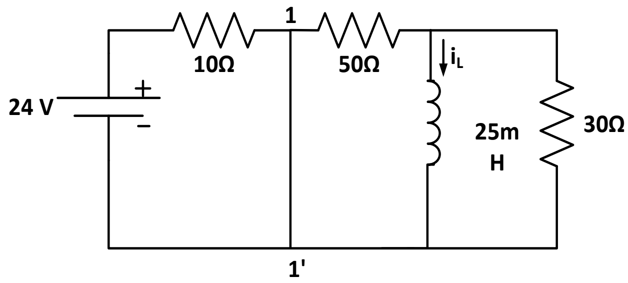


Fig. 1.2

For t < 0, the circuit is shown in Fig. 1.1. Inductor will be short circuiting to DC source,

$\therefore\ i_L(0) = \dfrac{24}{10+50} = 0.4$ A for t < 0.

For t > 0, the circuit is shown in Fig. 1.2. ,

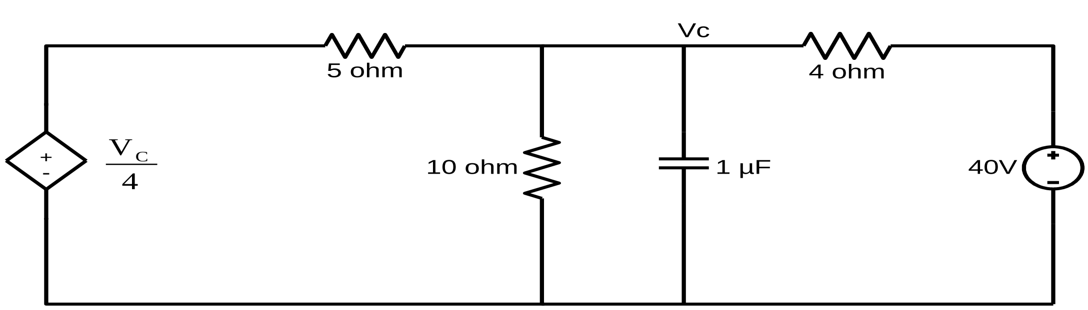
where $R_{eq} = 30 \parallel 50 = 18.75\ \Omega$ and L = 25 mH in series with $V_0 = 0$ V.

We know for a series R-L circuit, $i_L(t) = [i_L(0) - V_0/R_{eq}]e^{(-R_{eq}\,t/L)} + V_0/R$

$\therefore$ **$i_L(t) = 0.4\ e^{-750\,t}$ A for t > 0**

Solution of problem 3:

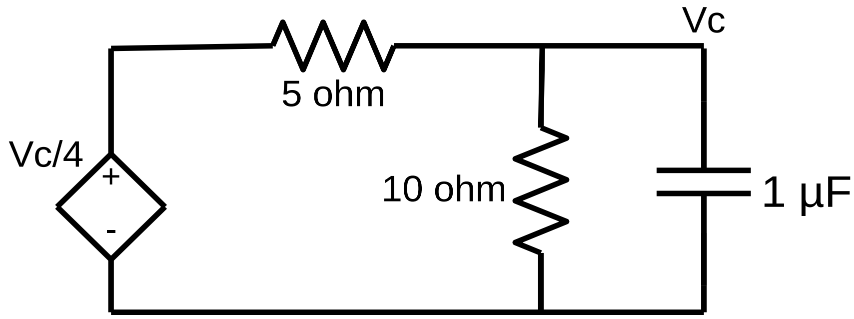
: For t < 0, the circuit becomes:



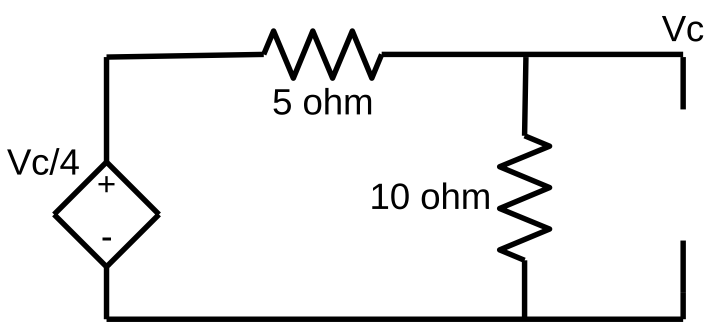
Using nodal analysis, we get (Vc – Vc/4)/5 + Vc/10 +(Vc– 40) /4 = 0 => Vc = 20 V = Vc(0).

(Note that capacitor is open circuit to the DC input for t < 0.)

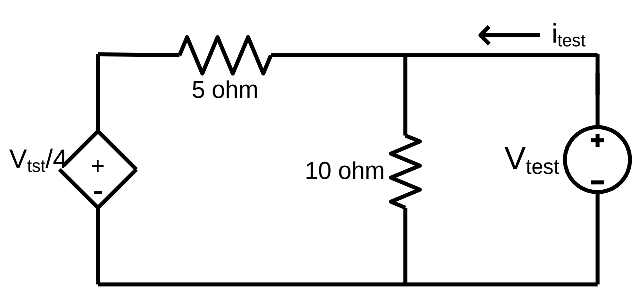
For t > 0, the circuit becomes:



For obtaining Thevenin's equivalent across the capacitor terminals, the above circuit is redrawn



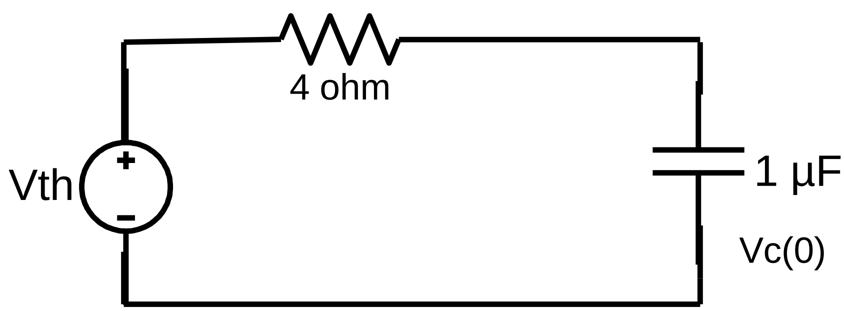
Then, Vth = Vc = 0 V. Next, Req = Rth is estimated using the following circuit:



Applying Nodal analysis, $(V_{test} – V_{test}/4)/5 + V_{test}/10 = i_{test}$

On solving, $Req = V_{test} / i_{test} = 4\ \Omega$

For t > 0, Thevenin equivalent circuit becomes

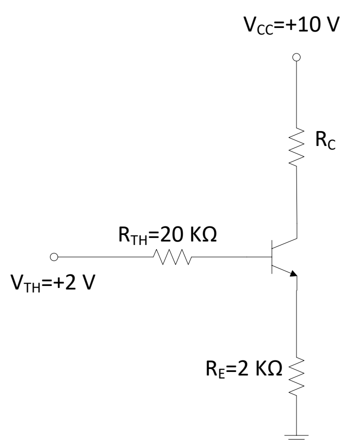


Since, for series R-C circuit, $Vc(t) = [Vc(0) – V_{th}]\ e^{-t/(RC)} + V_{th}$

Therefore, $\mathbf{Vc(t) = 20\ e^{(-250000\ t)}\ V}$ for t > 0.

Solution of problem 4:

1. The DC equivalent circuit will be as shown.
Using this, we get –



$V_{Th} = 10 \times R_2/(R_1+R_2) = 10 \times 25/(100+25) = 2V$

$R_{Th} = R_1R_2/(R_1+R_2) = 100 \times 25 /(100+25) = 20k\Omega$

$I_B = (V_{Th} – V_{BE})/(R_{Th} + (\beta+1) R_E)$

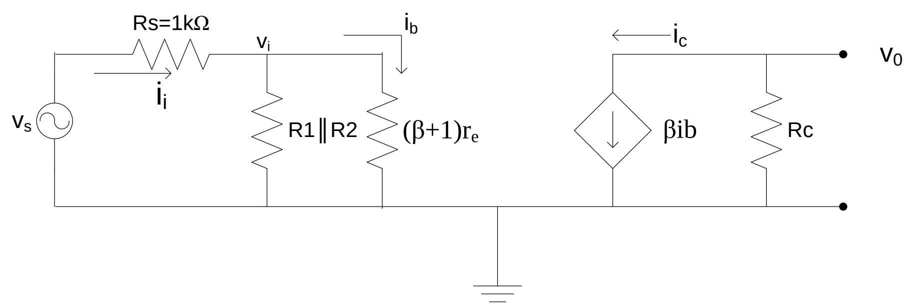
$= (2 – 0.7)/(20+(120+1)2) = 4.962 \times 10^{-3}$ mA

$I_C = \beta I_B = 120 \times 4.962 \times 10^{-3} = 0.595$ mA

$I_E = (\beta+1)I_B = (120+1)\times 4.962\times10^{-3} = 0.6$ mA

$r_e = 26mV/I_E = 26/0.6 = 43.33\Omega$

(a) The corresponding AC equivalent circuit will be as shown below



$R_1 || R_2 = R_{Th} = 20$ KΩ, $(\beta+1)r_e = 5.24$ KΩ $R_1||R_2||(\beta+1)r_e = 4.15$ KΩ

So, $i_b = \left(\frac{v_S}{1+4.15}\right)\frac{20}{25.24} = 0.154 v_S$ or $v_S = 6.494 i_b$

and, $v_O = -\beta i_b R_C = -120 R_C i_b$ $A_V = \frac{v_O}{v_S} = -\frac{120 R_C}{6.494} = -160$

Therefore, **R_C=8.66 KΩ**

(b) We already know that **I_B=0.004962 mA** and **I_C=0.595 mA**
With R_C=8.66 KΩ, we get V_C=10-0.595(8.66)=4.85 V
Also, V_E=2*(β+1)I_B=1.2 V Therefore V_{CE}=3.65 V

Solution of problem 5:

(a) Note that depending on how you round-off, different approaches may give slightly different answers!
This can be solved in several alternate ways, as given below (This assumes transistor to be in the active region without explicitly showing it. Why?)

$I_E = V_E/5 = 0.526$ mA ⇒ $r_e = V_T/I_E = 49.4\ \Omega$

$I_1 = (V_C - V_A)/100 = 0.0594$ mA and $I_2 = V_A/100 = 0.0345$ mA
Therefore, $I_B = I_1 - I_2 = 0.0249$ mA ⇒ $\beta = (I_E/I_B) - 1 = 20.1$
Note that $V_B = V_A - 5I_B = 3.33$ V or $V_B = V_E + 0.7 = 3.33$ V so B-C is reverse biased and the transistor is indeed in the active mode.

Alternatively,

I_E=2.63/5=0.526 mA, V_B=2.63+0.7=3.33 V, I_B=(3.45-3.33)/5=0.024 mA

Note that B-C is reverse biased so transistor is in the active mode

Therefore $r_e=V_T/I_E$ = 0.026/0.526=49.4 Ω

and $\beta=(I_E/I_B)-1=20.9$

Alternatively,

I_B = (9.39-3.45)/100 -3.45/100 = 0.0249 mA

V_B=3.45-5(0.0249) =3.33 V V_E =2.63 V (as expected)

Note that B-C is reverse biased so transistor is in the active mode

I_E = 2.63/5 = 0.526 mA

Therefore, $r_e=V_T/I_E$ = 0.026/0.526=49.4 Ω

and $\beta=(I_E/I_B)-1=20.1$

Alternatively,

I_E = 2.63/5 = 0.526 mA

Therefore, $r_e=V_T/I_E$ = 0.026/0.526=49.4 Ω

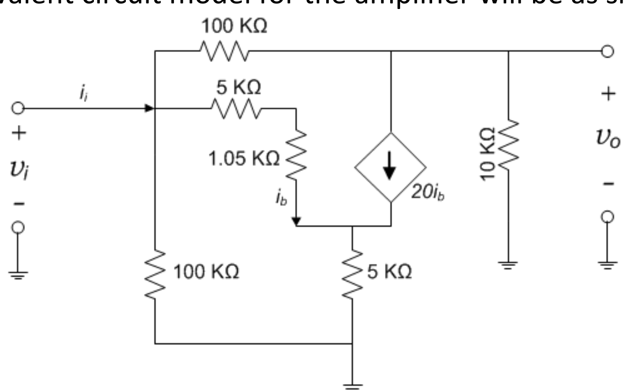
I_C = (15-9.39)/10 -(9.39-3.45)/100 = 0.502 mA

$$\frac{\beta+1}{\beta}=\frac{0.526}{0.502}=1.048$$

Therefore β=20.8

(b) Using r_e=50Ω and β=20

(i) The small signal equivalent circuit model for the amplifier will be as shown.



(ii) Gain Calculation

$$v_i=(5+1.05)i_b+(5)21i_b=111.05i_b$$ and $$\frac{v_i-v_O}{100}=20i_b+\frac{v_O}{10}$$

$$0.01v_i-0.18v_i=0.11v_O$$

Therefore $A_V=\frac{v_O}{v_i}=\frac{0.01-0.18}{0.11}=-\frac{0.17}{0.11}=-1.545$

(iii)**Input Impedance**

$$i_i=0.01v_i+i_b+0.01(v_i-v_O)=0.02v_i+0.009v_i+0.01545v_i \qquad i_i=0.04445v_i$$

Therrefor, $\mathbf{Z_i}$ = $\frac{v_i}{i_i}=22.5\,\text{K}\Omega$

(iv) Output Impedance

$v_{OC} = v_o = -1.545 v_i \qquad i_{SC} = 0.01 v_i - 20 i_{b,SC}$

Note that, we also have $v_i = 6.05 i_{b,SC} + 21.5 i_{b,SC} = 111.05 i_{b,SC} \quad \Rightarrow \quad i_{b,SC} = \dfrac{v_i}{111.05}$

Therefore, $i_{SC} = 0.01 v_i - \dfrac{20}{111.05} v_i = -0.17 v_i$ **Zo**= $\dfrac{v_{OC}}{i_{SC}}$ = 9.09 KΩ