Question 1: Answer all the questions. **(12 Marks)**

Your friend just built a circuit and connected a 300Ω bulb between a-b points as shown in **Figure 1**. Answer the following questions:

i) Determine the Thevenin equivalent circuit for the following circuit your friend has built.

ii) Determine the power absorbed by this bulb. Is the power the maximum power that can be achieved for this circuit? If not, then what should you do?

iii) Now, your friend connected another bulb with a different resistance instead of the 300Ω bulb and got the same absorbed power. Determine the new resistance of this bulb.

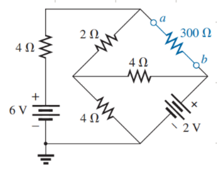
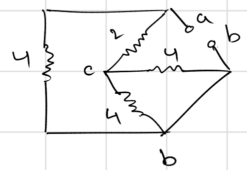
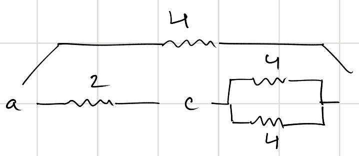


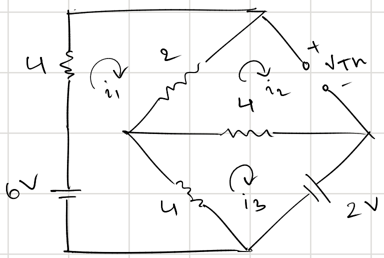
Figure 1

i)





$$R_{Th} = 4 \| (2 + 4\|4) = 2\,\Omega$$



$i_2 = 0$

loop 1: $i_1(4+2+4) - 2i_2 - 4i_3 - 6 = 0$

$\Rightarrow 10i_1 - 4i_3 - 6 = 0$

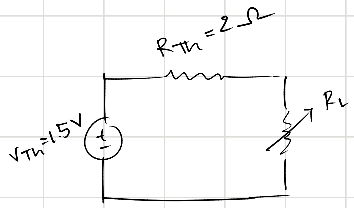
loop 2: $i_2(4+2) - 2i_1 - 4i_3 + V_{Th} = 0$

$\Rightarrow -2i_1 - 4i_3 + V_{Th} = 0$

loop 3: $i_3(4+4) - 4i_2 - 4i_1 + 2 = 0$

$\Rightarrow -4i_1 + 8i_3 + 2 = 0$

$i_1 = \frac{5}{8}$ $\quad i_3 = \frac{1}{16}$ $\quad V_{Th} = \frac{3}{2}$



ii) $R_{Th} \neq 300\,\Omega$

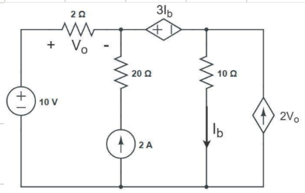
iii) $P = \frac{V_{Th}^2}{(R_{Th}+R_L)^2} \times R_L = \frac{1.5^2}{(2+300)^2} \times 300 = \frac{675}{91204}$

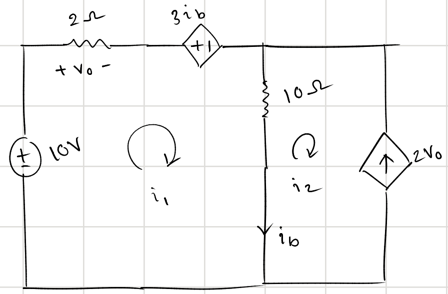
$$\frac{675}{91204} = \frac{V_{Th}^2}{(R_{Th}+R_L)^2} \times R_L$$

$R_L = 0.0133\,\Omega$

Question 2: Answer all the questions. **(13 Marks)**

Determine the value of V_o using the Superposition theorem for the circuit shown in **Figure 2**. Additionally, find the power delivered by the **10V** voltage source.





$i_1 - i_2 = i_b$

$i_1 = \frac{V_o}{2}$ $\quad i_2 = -2V_o$

loop 1: $i_1(2+10) - 10i_2 - 10 + 3i_b = 0$

$\Rightarrow 6V_o + 20V_o - 10 + 3i_b = 0$

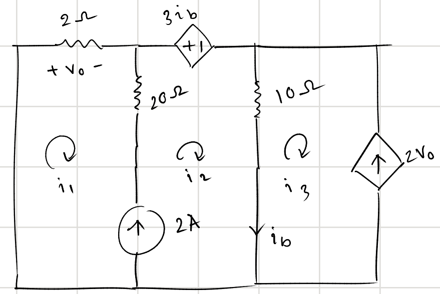
$\Rightarrow 26V_o + 3i_b = 10$

$\Rightarrow 26V_o + 3(i_1 - i_2) = 10$

$\Rightarrow 26V_o + 3\left(\frac{V_o}{2} + 2V_o\right) = 10$

$\Rightarrow 26V_o + \frac{15}{2}V_o = 10$

$\Rightarrow V_o = 10 \times \frac{2}{67} = \frac{20}{67}$



$i_1 = \frac{V_o}{2}$ $\quad i_3 = -2V_o$

$i_b = i_2 - i_3$ $\quad i_2 - i_1 = 2$

$= (2 + i_1) - i_3$

$= 2 + \frac{V_o}{2} + 2V_o = 2 + \frac{5}{2}V_o$

loop 1+2:

$V_o + 3i_b + 10i_2 - 10i_3 = 0$

$\Rightarrow V_o + 3\left(2 + \frac{5}{2}V_o\right) + 10i_b = 0$

$\Rightarrow V_o + 6 + \frac{15}{2}V_o + 20 + 25V_o = 0$

$\Rightarrow \frac{67}{2}V_o + 26 = 0$

$\Rightarrow V_o = -0.776$

superposition $\quad V_o = \frac{20}{67} - 0.776 = -0.4775$

$P_{10V} = \frac{V_o^2}{R} = 0.04455$ W

Question 3: Answer all the questions **(12 Marks)**

An AC current source, $i_s(t)$ **[Figure 3(a)]** is used in the following circuit shown in **Figure 3(b)**. Answer the following questions:

i) Determine the equation of $i_s(t)$.

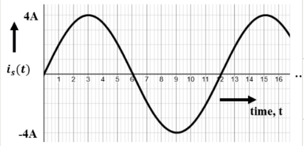


Figure 3(a)

i) $i_s(t) = 4\sin\left(\frac{2\pi}{12}t\right) = 4\sin\left(\frac{\pi}{6}t\right)$

$= 4\angle -90^\circ$

ii) Determine the equivalent impedance of this circuit.

iii) Determine $i_o(t)$ and also by how many degrees is $i_o(t)$, leading $i_s(t)$?

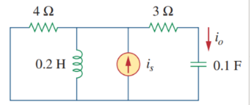
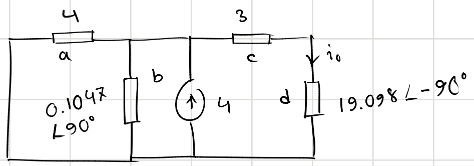


Figure 3(b)

ii) $X = a \| b \| (c+d)$

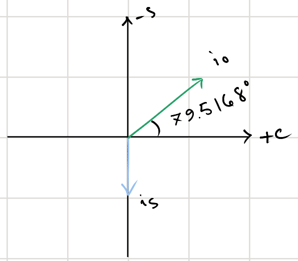
$= 0.105244 \angle 88.44389^\circ$



iii) $i_o = i \times \frac{a \| b}{(c+d) + (a \| b)}$

$= 0.02177 \angle 79.5168^\circ$

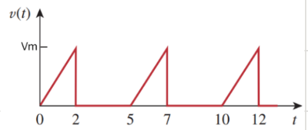
$i_o(t) = 0.02177 \cos\left(\frac{\pi}{6}t + 79.5168^\circ\right)$



$i_o(t)$ is leading $i_s(t)$ by $90^\circ + 79.5168^\circ = 169.5768^\circ$

When the voltage waveform of **Figure 4(a)** is applied across a 2-Ω resistor, the average power absorbed by the resistor is 4.267 W. Another AC circuit is shown in **Figure 4(b)**. Now answer the following questions:

i) Find the rms value, v_{rms} of the voltage waveform shown in **Figure 4(a)**.



i+ii) $v(t) \begin{cases} \frac{V_m}{2}t, & 0 < t < 2 \\ 0, & 2 < t < 5 \end{cases}$

$\int_0^5 v(t)^2\,dt = \int_0^2 \frac{V_m^2}{4} t^2\,dt + \int_2^5 0^2\,dt$

$= \frac{V_m^2}{12} t^3 \Big]_0^2 = \frac{2}{3} V_m^2$

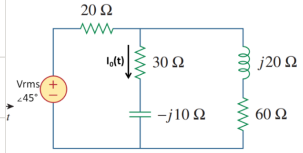
$V_{rms}^2 = \frac{1}{T}\int_0^5 v(t)^2\,dt = \frac{1}{5} \times \frac{2}{3} V_m^2 = \frac{2}{15} V_m^2$

$\frac{V_{rms}^2}{2} = 4.267 \Rightarrow V_{rms}^2 = 8.534$

$\Rightarrow V_m^2 = 8.534 \times \frac{15}{2} = 64.005$

$\Rightarrow V_m = 8\ V$

iii) Use this rms **[from (i)]** value as the maximum amplitude of the sinusoidal voltage source in the circuit shown in **Figure 4(b)**. Determine $I_0(t)$, and average power absorbed by the 30Ω resistor in the circuit.

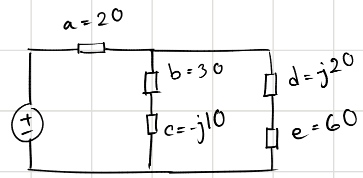


iii) $X = a + (b+c) \| (d+e)$

$= 42.022 \angle -3.3274^\circ$

$V = 2.92 \angle 45^\circ$

$I = \frac{V}{X} = 0.069487 \angle 48.3274^\circ$



$I_0 = I \times \frac{d+e}{(b+c)+(d+e)}$

$= 0.0485 \angle 60.422^\circ$

$I_0(t) = 0.0485 \cos\left(\frac{2\pi}{5}t + 60.422^\circ\right)$

$i_{rms} = \frac{0.0485}{\sqrt{2}} = 0.0343$

$P = i_{rms}^2 \cdot 30 = 0.03533\ W$