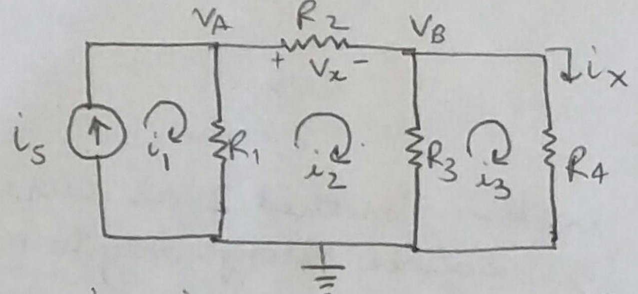
3.2)



$i_1 = i_s$, We use method 2 as current belongs only to one mesh. (mesh 1)

a) KVL in loop 2: $i_2R_2 + (i_2 - i_3)R_3 - (i_1 - i_2)R_1 = 0$

KVL in loop 3: $i_3R_4 - (i_2 - i_3)R_3 = 0$

in matr[redacted]

$$\begin{bmatrix} R_1+R_2+R_3 & -R_3 \\ -R_3 & R_3+R_4 \end{bmatrix}\begin{bmatrix} i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} R_1 i_s \\ 0 \end{bmatrix}$$

(b)

$$\begin{bmatrix} i_2 \\ i_3 \end{bmatrix} = \frac{1}{(R_1+R_2+R_3)(R_3+R_4)-R_3^2}\begin{bmatrix} R_3+R_4 & R_3 \\ R_3 & R_1+R_2+R_3 \end{bmatrix}\begin{bmatrix} R_1 i_s \\ 0 \end{bmatrix}$$

Optional: Node voltage.

$$V_A = (i_1 - i_2)R_1$$
$$= i_s\left(1 - \frac{R_1(R_3+R_4)}{(R_1+R_2)(R_3+R_4)+R_3R_4}\right)R_1 = \frac{R_2(R_3+R_4)+R_3R_4}{(R_1+R_2)(R_3+R_4)+R_3R_4} R_1 i_s$$

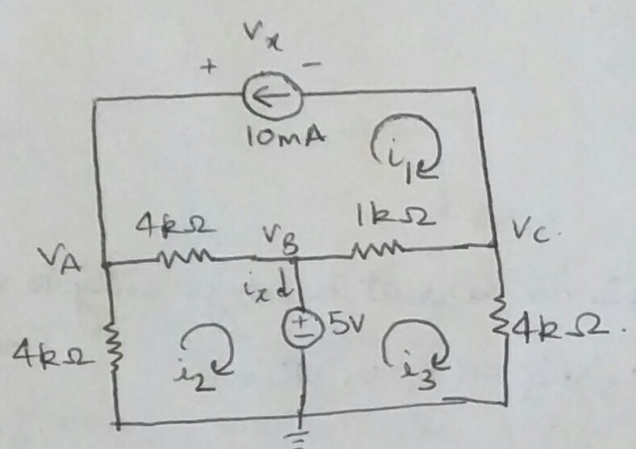
$$V_B = i_x R_4 = i_3 R_4 = \cancel{i_s}\, \frac{i_s R_1R_3R_4}{(R_1+R_2)(R_3+R_4)+R_3R_4}$$

c) $$V_x = V_A - V_B = i_s\left[\frac{R_1R_2(R_3+R_4)}{(R_1+R_2)(R_3+R_4)+R_3R_4}\right] \Big\} B$$

$$\boxed{i_x = i_3 = \frac{i_s R_1 R_3}{(R_1+R_2)(R_3+R_4)+R_3R_4}}$$

or $$\boxed{V_x = i_2 R_2 = \frac{i_s R_1R_2(R_3+R_4)}{(R_1+R_2)(R_3+R_4)+R_3R_4}}$$

3.5)



Using method 2 as current source belongs only to mesh 1.

a) $i_1 = -10mA$.

[redacted]

mesh 2: $4000 i_2 + (i_2 - i_1) \times 4000 + 5 = 0$.

mesh 3: $1000(i_3 - i_1) + 4000 i_3 - 5 = 0$.

$$\Rightarrow \begin{bmatrix} 8000 & 0 \\ 0 & 5000 \end{bmatrix} \begin{bmatrix} i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} -45 \\ -5 \end{bmatrix}$$

$\Rightarrow i_2 = -5.625\ mA \qquad i_3 = -1\ mA$.

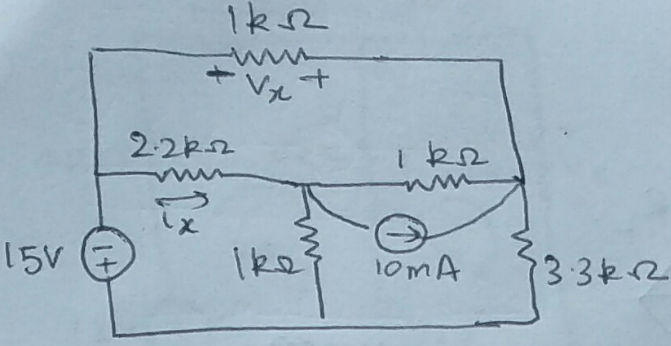
b) $V_C = i_3 \times 4000 = -1 \times 10^{-3} \times 4000 = -4V$

$V_A = -i_2 \times 4000 = 5.625 \times 10^{-3} \times 4000 = 22.5V$ } optional Node voltage.

c) optional: Node Voltage. $\left\{ \begin{aligned} V_x &= V_A - V_C \\ &= 22.5 - (-4) = 26.5V \end{aligned} \right\}$ or $\boxed{V_x = 4 \times 10^3 \times (i_2 - i_1) + 1 \times 10^3 \times (i_3 - i_1) = 26.5V}$

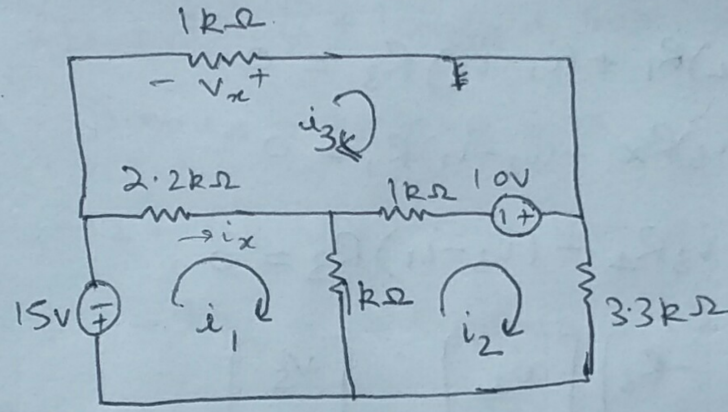
$$\boxed{\begin{aligned} i_x = i_2 - i_3 &= -5.625 - (-1) \\ &= -4.625\ mA. \end{aligned}}$$

3.8)



↓ Source transformation. (Method 1)

a)



$$\begin{bmatrix} (2.2+1)\times10^3 & -1\times10^3 & -2.2\times10^3 \\ -1\times10^3 & (1+1+3.3)\times10^3 & -1\times10^3 \\ -2.2\times10^3 & -1\times10^3 & (1+1+2.2)\times10^3 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} -15 \\ 10 \\ -10 \end{bmatrix}$$

b) $i_1 = -11.29\,mA$

$i_2 = -1.89\,mA$

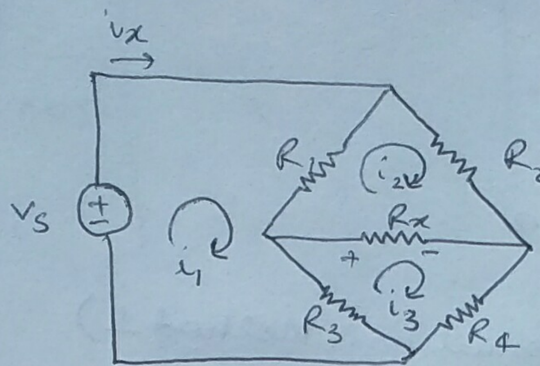
$i_3 = -8.74\,mA$

$i_x = i_1 - i_3 = -2.55\,mA$

$V_x = -i_3 \times 1000 = 8.74\ V$

3.10)

a)



mesh 1: $-V_s + (i_1 - i_2)R_1 + (i_1 - i_3)R_3 = 0$

mesh 2: $i_2R_2 + (i_2 - i_3)R_x + (i_2 - i_1)R_1 = 0$

mesh 3: $(i_3 - i_2)R_x + i_3R_4 + (i_3 - i_1)R_3 = 0$.

$$\Rightarrow \begin{bmatrix} R_1+R_3 & -R_1 & -R_3 \\ -R_1 & R_2+R_x+R_1 & -R_x \\ -R_3 & -R_x & R_x+R_3+R_4 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} V_s \\ 0 \\ 0 \end{bmatrix}$$

b) $R_1 = R_4 = 2k\Omega$ $\quad R_2 = R_3 = 500\Omega$, $R_x = 750\,\Omega$, $V_s = 15V$.

$$\Rightarrow \begin{bmatrix} 2500 & -2000 & -500 \\ -2000 & 3250 & -750 \\ -500 & -750 & 3250 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 15 \\ 0 \\ 0 \end{bmatrix}$$

$i_1 = 15.5\,mA$ $\quad i_2 = 10.6\,mA$, $i_3 = 4.8\,mA$.

$i_x = i_1 = 15.5\,mA$.

$v_x = (i_3 - i_2)R_x = (4.8 - 10.6)\times 10^{-3} \times 750$

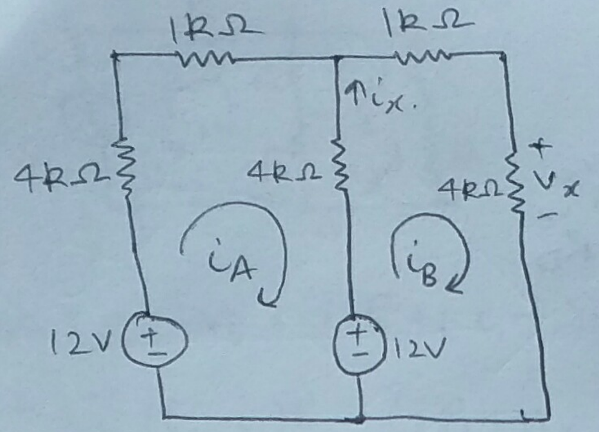
$= -4.35V$.

c) Voltage across $R_x = 0$ $\Rightarrow$ $\underline{i_2 = i_3}$ so R_4?

$V_{R_x} = 0$.

$$\begin{bmatrix} 2500 & -2000 & -500 \\ -2000 & 3250 & -750 \\ -500 & -750 & 1250+R_4 \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} 15 \\ 0 \\ 0 \end{bmatrix}$$ $\therefore R_4 = 125\Omega$.

3.15) a)



mesh A: $-12 + 4000 i_A + 1000 i_A + 4000(i_A - i_B) + 12 = 0.$

$= 9000 i_A - 4000 i_B = 0$

mesh B: $-12 + (i_B - i_A) \times 4000 + 1000 i_B + 4000 i_B = 0$

$\Rightarrow -4000 i_A + 9000 i_B = 12.$

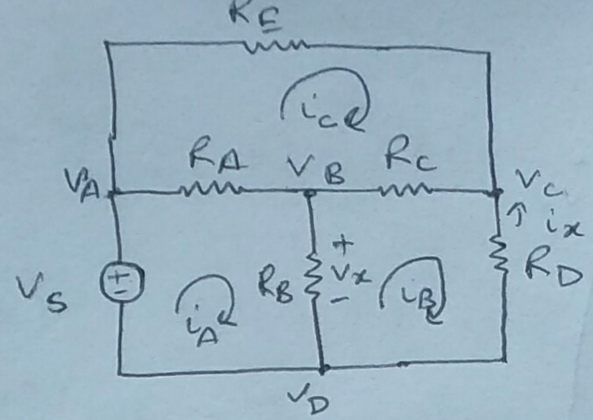
b) $\Rightarrow \begin{bmatrix} 9000 & -4000 \\ -4000 & 9000 \end{bmatrix} \begin{bmatrix} i_A \\ i_B \end{bmatrix} = \begin{bmatrix} 0 \\ 12 \end{bmatrix}$

$i_A = 0.7 mA \qquad i_B = 1.7 mA.$

c) $V_x = i_B \times 4000 = 1.7 \times 10^{-3} \times 4000 = 6.8 V$

$i_x = i_B - i_A = (1.7 - 0.7) mA = 1 mA.$

3.17)



a) mesh A: $-V_S + (i_A - i_C)R_A + (i_A - i_B)R_B = 0$

mesh B: $(i_B - i_A)R_B + (i_B - i_C)R_C + i_B R_D = 0$

mesh C: $(i_C - i_B)R_C + (i_C - i_A)R_A + i_C R_E = 0.$

$$\begin{bmatrix} R_A + R_B & -R_B & -R_A \\ -R_B & R_B + R_C + R_D & -R_C \\ -R_A & -R_C & R_A + R_C + R_E \end{bmatrix} \begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \begin{bmatrix} V_S \\ 0 \\ 0 \end{bmatrix}$$

c) Nodal easier to solve, if V_D is ground. & $V_A = V_S$.
Hence, only two unknowns instead of 3 as here.

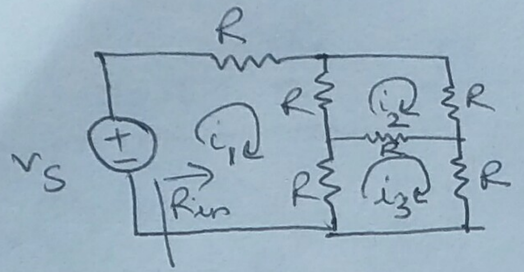
d)
$$\begin{bmatrix} i_A \\ i_B \\ i_C \end{bmatrix} = \frac{1}{\det(A)} \begin{bmatrix} V_S(R_A(R_B+R_C+R_D) + R_C(R_B+R_D+R_E) + R_E(R_B+R_D)) \\ V_S(R_A(R_B+R_C) + R_B(R_C+R_E)) \\ V_S(R_A(R_B+R_C+R_D) + R_B R_C) \end{bmatrix}$$

$$\det(A) = R_A(R_B R_D + R_B R_E + R_C R_D + R_C R_E + R_D R_E) + R_B(R_C R_D + R_C R_E + R_D R_E).$$

$$i_x = -i_B = -\frac{R_A(R_B+R_C) + R_B(R_C+R_E)}{\det(A)} \cdot V_S$$

$$v_x = (i_A - i_B)R_B = \frac{R_A R_D + R_C(R_D+R_E) + R_E R_D}{\det(A)} \cdot R_B V_S.$$

3.23)



a) mesh 1: $-V_s + i_1 R + (i_1 - i_2)R + (i_1 - i_3)R = 0.$

mesh 2: $(i_2 - i_1)R + i_2 R + (i_2 - i_3)R = 0$

mesh 3: $(i_3 - i_1)R + (i_3 - i_2)R + i_3 R = 0.$

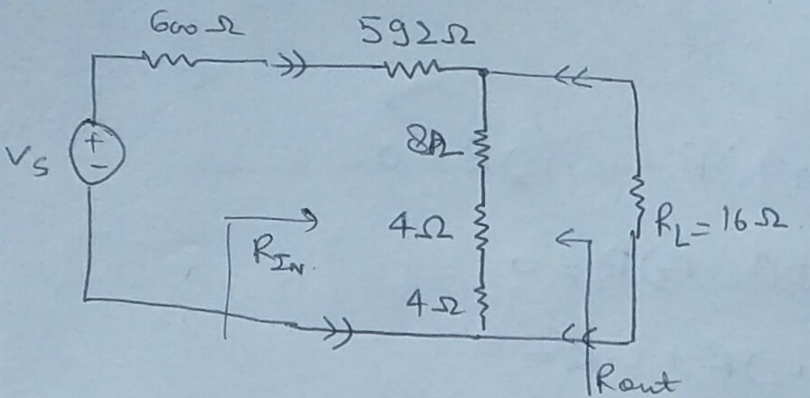
$$\Rightarrow \begin{bmatrix} 3R & -R & -R \\ -R & 3R & -R \\ -R & -R & 3R \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} = \begin{bmatrix} V_s \\ 0 \\ 0 \end{bmatrix}$$

$$R_{in} = \frac{V_s}{i_1}$$

$i_1 = \frac{V_s}{2R}$ on solving above matrix

$$\therefore \boxed{R_{in} = 2R}$$

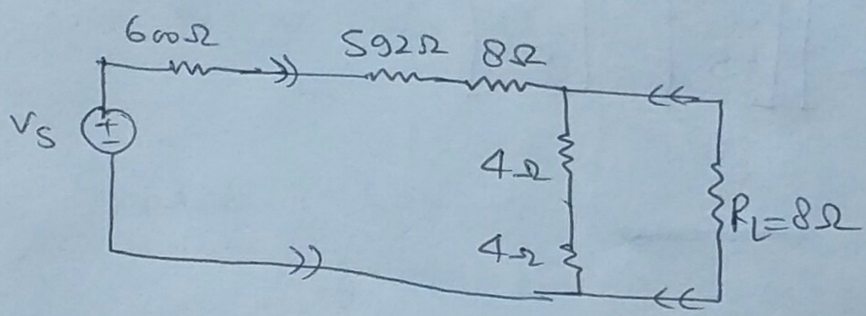
3.91) when speakers $R_L = 16\,\Omega$.



$R_{In} = 592 + ((8+4+4) \parallel 16)$
$= 600\,\Omega$

$R_{out} = (600 + 592) \parallel (8+4+4)$
$= 15.79\,\Omega$

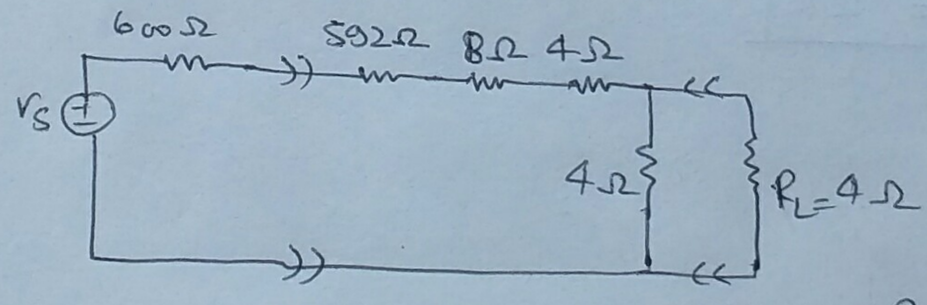
When $R_L = 8\,\Omega$.



$R_{In} = 592 + 8 + (4+4) \parallel 8$
$= 604\,\Omega$.

$R_{out} = (600 + 592 + 8) \parallel (4+4)$
$= 7.95\,\Omega$.

When $R_L = 4\,\Omega$.



$R_{In} = (600 + 592 + 8 + 4)$
$+ 4 \parallel 4$
$= 606\,\Omega$.

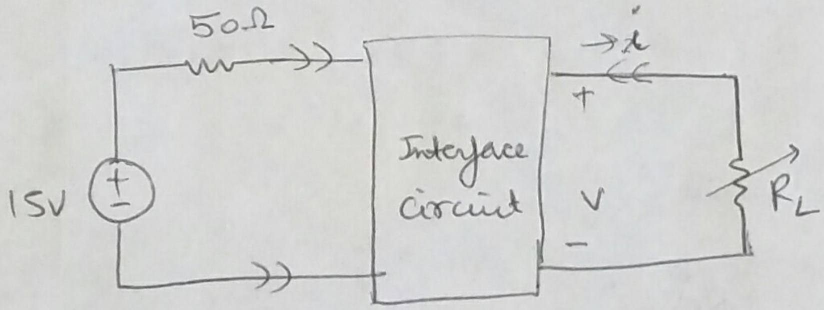
$R_{out} = (600 + 592 + 8 + 4) \parallel 4$
$= 3.99\,\Omega$.

Since all Rin are in between ~~of~~ $600\,\Omega \pm 2\%$.

& all Rout are in between 16, 8, 4, ± 2%.

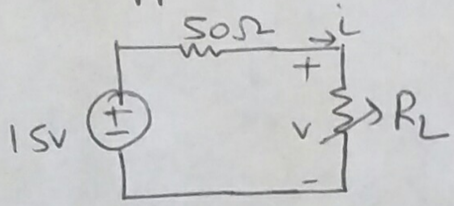
Hence, the claim is true.

3.93)



given, $v \le 5V$ & $i \le 100mA$.

Suppose the ~~source~~ interface circuit is simple.

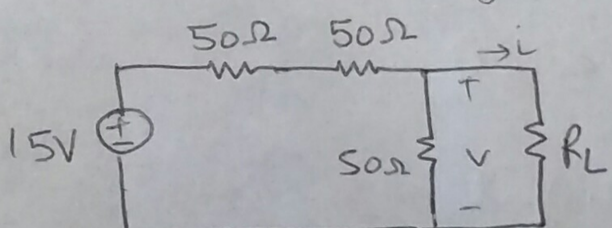


$$i = \frac{15}{R_L+50} \quad \& \quad V = \frac{R_L}{R_L+50} \times 15.$$

if $R_L = 0$, $i = 0.3A$ & $V = 0$

if $R_L = \infty$, $i = 0A$ & $V = 15V$.

Hence, since we want the voltage across load to be less than equal to 5V, we can connect 50Ω in parallel with R_L to reduce its equivalent resistance & add a ~~sere~~ 50Ω in series with the 50Ω resistance in circuit so we get rectified voltage division



$$V = \frac{(50 \parallel R_L)}{50+50+50 \parallel R_L} \times 15.$$

$$= \frac{\frac{50 \times R_L}{50+R_L}}{100 + \frac{50 \times R_L}{50+R_L}} \times 15.$$

for $R_L = 0$, $V = 0$, i.e. $\frac{15}{50+50} = 150mA$

$R_L = \infty$, $V = 5V$, $i =$

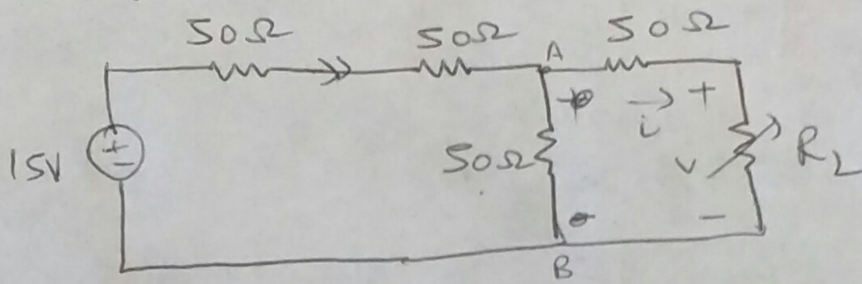
hence, voltage condition is met.

~~tes~~ i.e. for $R_L = 0$, no current flows in 50Ω resistor parallel to it (short circuit)

$$i = \frac{15}{50+50} = 150 mA$$

& as R_L increases, i would decrease.

so to decrease current through R_L, lets increase its resistance by adding 50Ω resistor so that when $R_L = 0$, there is a lesser current flowing through load side.



for $R_L = 0$, $i = \dfrac{15}{50+50+50\|150} \times \dfrac{1}{2}$ (current division $\frac{1}{2}$ at A as two 50Ω resistors inparallel)

$$= \frac{15}{125} \times \frac{1}{2}$$

$$= \frac{15}{250} = 60\,mA$$

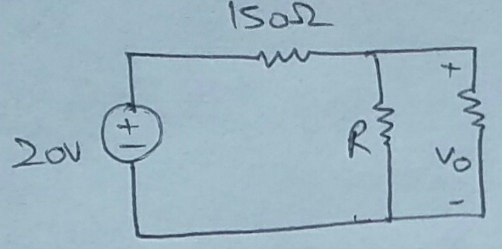
$\therefore$ for $R_L \geq 0$, $i \leq 60\,mA$.

& $V \leq 5V$

hence conditions are satisfied.

3.95)

Circuit 1:



$0 \le R \le 100\,\Omega$.

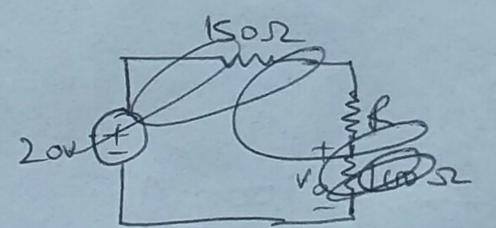
$$V_o = \frac{(100 \parallel R)}{(100 \parallel R) + 150} \times 20 \quad \therefore \quad 0 \le V_o \le 5\,V$$

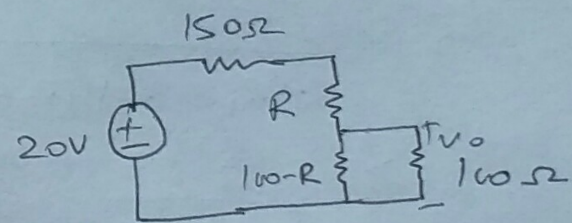
Power delivered from source $P = \dfrac{(20)^2}{150 + (100 \parallel R)}$

$\therefore\ 2 \le P \le 2.67$

but $P = 2.5W$ hence, circuit 1 fails as there can be a value of R where power rating is not satisfied.

Circuit 2:





$$\therefore\ V_o = \frac{(100-R) \parallel 100}{150 + R + (100-R) \parallel 100} \times 20.$$

when $R = 0\,\Omega$ $V_o = 5V$

when $R = 100\,\Omega$ $V_o \simeq 0V$.

Hence. $0 \le V_o \le 5V$

Power delivered by source $P = \dfrac{(20)^2}{150 + R + (100 \parallel (100-R))}$

$R = 0\,\Omega$, $P = 2W$.

$R = 100\,\Omega$, $P \simeq 1.6W$ $(< 2.5W)$

Hence, requirements are met in circuit 2.