Electronics Classwork 2 - Solutions, 13th January 2005

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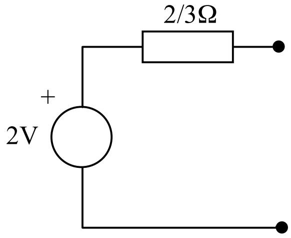
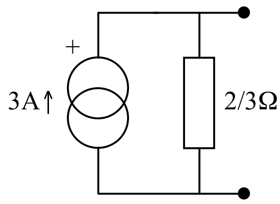
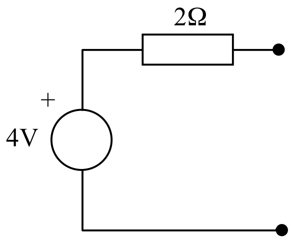
1.

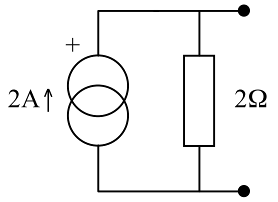
(a) Circuit forms a potential divider so $V_T = V_{oc}$=2/(1+2) x3V=2V. Resistance between terminals if voltage source is shorted out, R_o = 1Ω//2Ω = 1x2/(1+2) = 2/3Ω. Norton Current $I_N=V_T/R_o$=2/(2/3)=3A.





(b) 2A current flows in a loop through both resistors. $V_T=V_{oc}$=2A x 2Ω = 4V. Resistance between terminals if we open circuit the current source is simply R_o = 2Ω. $I_N = I_{sc}$ = 2A as the whole current will flow down the current source rather than through the 2Ω resistor. [Note that the 1Ω resistor is irrelevant and plays no role in the circuit!]

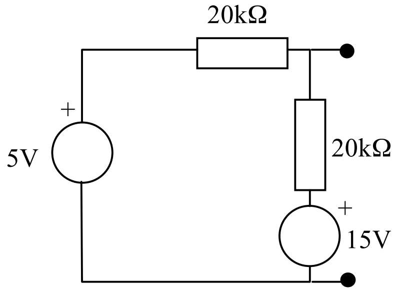




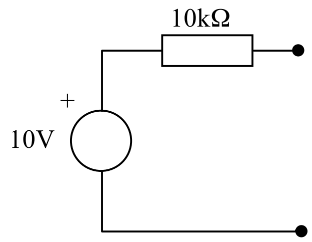
(c) The Voltage source is shorted out which cannot happen in practice so the circuit will not work

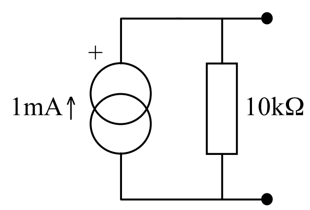
(d) Two different current sources are placed in series and as both cannot produce their desired current simultaneously the circuit could not function in practice.

(e) Convert the 0.5mA current source in parallel with the 10kΩ resistor into its Thevenin equivalent, a 5V voltage source in series with a 10kΩ resistor, which then adds in series with the other 10k resistor to give a 20k resistor:

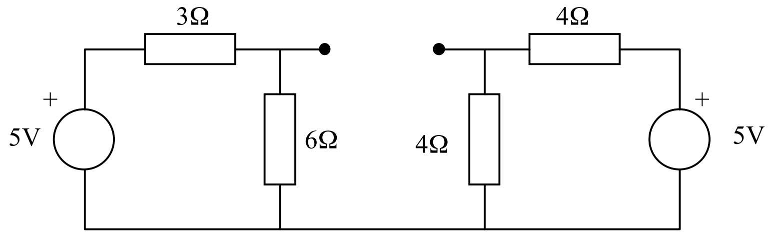


By superposition we can consider each voltage source separately and work out the V_{oc} for each then add them up at the end. Short out the 5V source and we simply see a potential divider operating on the 5V source to give a terminal voltage of V_{oc1}= 2.5V (the two resistors are equal). Shorting the 5V source we likewise see V_{oc2}= 7.5V at the terminals. $V_T= V_{oc1}+ V_{oc2}$=10V. R_o=20k//20k=10k. $I_N=V_T/R_o$=1mA.

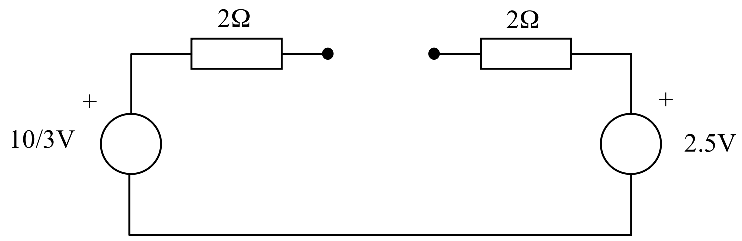




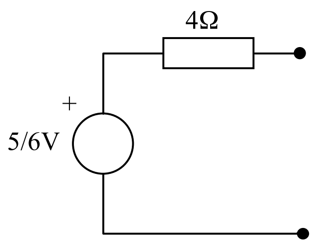
(f) Redraw with 2 voltage sources, splitting the connection at the top node:

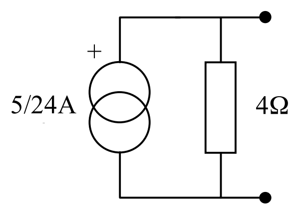


Each side is simply a potential divider (like part (a)) so convert each into its Thevenin equivalent



Voltages add (subtract) in series to give a total voltage of V_T=10/3-5/2=5/6V.
Resistors add in series to give R_o=2+2=4Ω. I_N=5/6/4=5/24A.



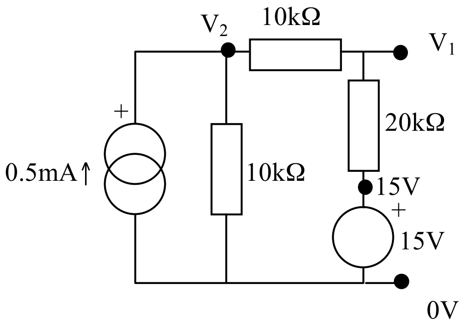


2. Connect 1Ω to output of circuit 1(f) and form a potential divider. Output voltage

V_o=1/(1+4) x 5/6 = 1/6 V

Which is consistent with our observation in lectures of a current of 1/6A in the 1Ω resistor.

3. Nodal analysis:



4 nodes including reference 0V and known +15V. Two unknown nodes V_1 and V_2.

Summing currents into V_1

$$(15-V_1)/20k + (V_2-V_1)/10k = 0 \qquad (1)$$

Summing currents into V_2

$$0.5mA + (0-V_2)/10k + (V_1-V_2)/10k = 0 \qquad (2)$$

[Note that dealing in units of V, kΩ and mA is entirely consistent]

From (1) x 200

$$150 - 10V_1 + 20V_2 - 20V_1 = 0 \qquad \Rightarrow \qquad 30V_1 = 150 + 20V_2$$

Rearrange:

$$V_1 = 5 + 2V_2/3 \qquad (3)$$

From (2) x 100

$$50 - 10\ V_2 + 10\ V_1 - 10V_2 = 0$$

Substitute for V_1 with equation 3:

$$50 - 20\ V_2 + 50 + 20\ V_2/3 = 0 \qquad \Rightarrow \qquad V_2\ (20\text{-}20/3) = 100$$

Rearrange

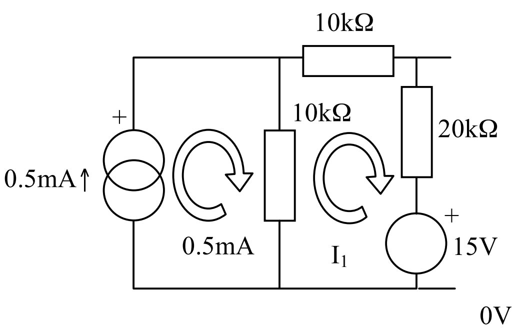
$$V_2 = 100x3/40 = 7.5V$$

Now find V_1 :

$$V_1 = 5+2x7.5/3 = 5+5 = 10\ V$$

Current in 10k resistor = $(V_1-V_2)/10=2.5/10=0.25$ mA (flows right to left)

Mesh analysis:



2 loops, one with known current 0.5mA and the second with unknown current I_1

Sum voltages around unknown loop:

$-15 = (I_1\text{-}0.5mA)10k + I_1\ 10k + I_1\ 20k$

Rearrange

$40\ I_1 = -15 + 5 = -10$

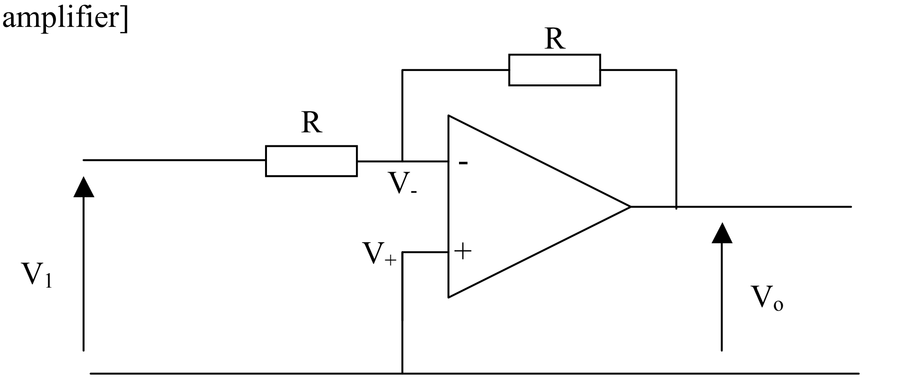
$I_1 = -1/4\ mA$ Current 0.25mA flows right to left.

4. Virtual earth approximation:

   Same voltage appears at each input, no current is drawn by either input

Use superposition and treat each input separately:

Short input V_2 to ground, effectively places +ve input to ground too: [forms a simple inverting amplifier]

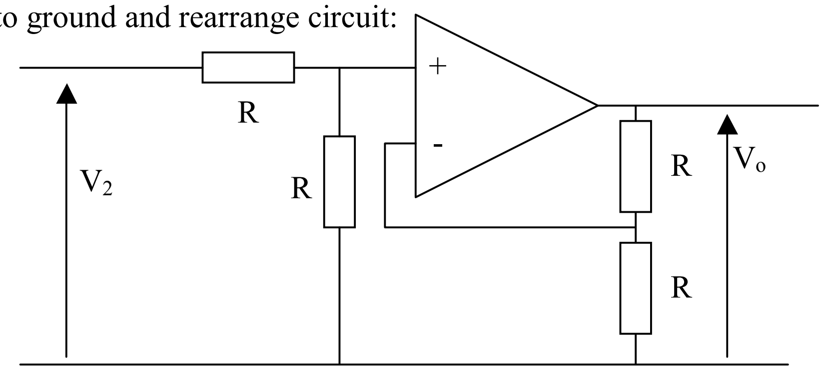


$V_+=V_-=0V$. Summing currents at V_-

$(V_1-V_-)/R + (V_{o1}-V_-)/R = 0 = (V_1-0)/R + (V_{o1}-0)/R$

$V_{o1}=-V_1$

Short input V_1 to ground and rearrange circuit:



Forms a potential divider at input so $V_+=R/(R+R)xV_2=V_2/2$

The rest of the circuit forms a simple non inverting amplifier: Summing currents at V_-

$(V_{o2}-V_-)/R+(0-V_-)/R=0=(V_{o2}-V_2/2)/R+(0-V_2/2)/R$

$V_{o2}=V_2$

Total $V_o=V_{o1}+V_{o2}=V_2-V_1$

So A=1