Basic Electronics

Further Problems 1 - Solutions

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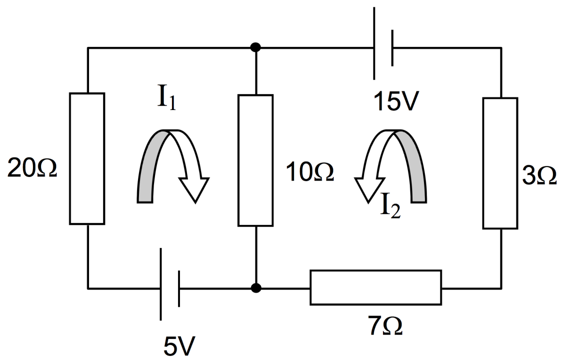
1. One mole of copper (Cu) occupies (63.54 g)/(8.92 g/cm^3)=7.123cm^3 and contains 6.02×10^{23} atoms. With each contributing one conduction electron this results in a number density $6.02 \times 10^{23}/7.123 \times 10^{-6} = 8.45 \times 10^{28}\text{m}^{-3}$.

2. Use $R = \rho L/A$. At room temperature this gives $R = 14\,\Omega$. At higher temperatures $\rho(T) = \rho_0(1 + \alpha(T - T_0))$. Taking room temperature to be about 300 K gives $\rho = 5.6 \times 10^{-8}(1 + 0.0045(2000 - 300))$ increasing the resistance to $R = 121\,\Omega$.

3. There are two loops so we can identify two currents I_1 and I_2 as shown in the figure. Kirchhoff's current law gives the current in the $10\,\Omega$ resistor as $I_1 + I_2$.



For loop 1 apply Kirchhoff's voltage law to give

$$5 - 20I_1 - 10(I_1 + I_2) = 0$$

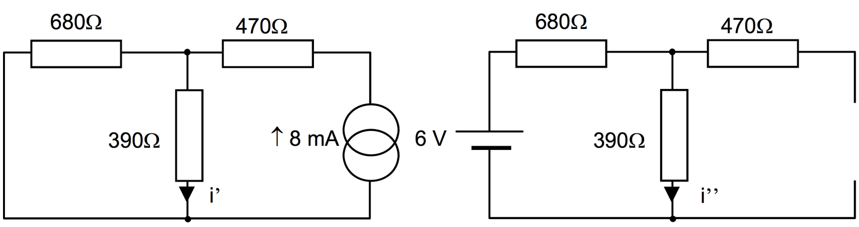
For loop 2 apply Kirchhoff's voltage law to give

$$15 - 10(I_1 + I_2) - (7 + 3)I_2 = 0$$

Solve to get $I_1 = -100\,\text{mA}$ and $I_2 = 800\,\text{mA}$

4. The principle of superposition allows the effect of each source to be considered independently. For each source, replace each *other*
   - voltage source with a short circuit or
   - current source with an open circuit.

   This gives two circuits as shown below.



In the left figure we use the current divider rule

$$i' = 8\,\text{mA} \times \frac{680}{680 + 390} = 5.1\,\text{mA}$$

In the right figure we find no current flows in the $470\,\Omega$ resistor so

$$i'' = \frac{6}{680 + 390} = 5.6\,\text{mA}$$

The total current in the $390\,\Omega$ resistor is therefore

$$I_{390} = i' + i'' = 10.7\,\text{mA}$$

5. For the Thévenin and Norton equivalent circuits we need (a) the open-circuit voltage v_{oc} across terminals A and B, i.e. with no load connected across AB, and (b) the short circuit current i_{sc} through AB when A and B are connected together. As there are two sources we can make use of the principle of superposition.

   (a) Considering first the voltage source and replacing the current source with its circuit-equivalent (an open-circuit) the circuit becomes figure (i). As AB is open, there is zero current flowing, hence no voltage drop across the resistor, and

   $$v_{oc_1} = 12\,\text{V}$$

   Considering now the current source contribution and replacing the voltage source with its circuit equivalent (a short-circuit) the circuit becomes figure (ii). The current source generates a voltage $1\,\text{mA} \times 9\,\text{k}\Omega = 9\,\text{V}$ across the resistor. As the current source is in the clockwise sense, terminal A is at a *lower* potential than terminal B hence the voltage we would measure across AB is negative and

   $$v_{oc_2} = -9\,\text{V}$$

   Superposing these two results we find

   $$v_{oc} = v_{oc_1} + v_{oc_2} = 12 - 9 = 3\,\text{V}$$

   (b) To find the short-circuit current we connect A and B together. Considering first the voltage source and replacing the current source with its circuit-equivalent the circuit becomes figure (iii). This gives a current, measured in the A to B sense

   $$i_{sc_1} = \frac{12}{9k} = \frac{4}{3}\,\text{mA}$$

   Replacing the voltage source with its circuit equivalent the circuit becomes figure (iv). All the current from the current source will clearly go through the loop with zero resistance (the current divider rule would confirm this). As the current in this loop is in an anti-clockwise sense (B to A), the current we need measured in the A to B sense is

   $$i_{sc_2} = -1\,\text{mA}$$

   Superposing these two results we find

   $$i_{sc} = i_{sc_1} + i_{sc_2} = \frac{1}{3}\,\text{mA}$$

(c) The Thévenin resistance R_{Th} is given by

$$R_{Th} = \frac{v_{oc}}{i_{sc}} = 9\,k\Omega$$

The Thévenin equivalent circuit is therefore a voltage source of 3 V in series with a resistance of 9 kΩ .

The Norton equivalent circuit is a current source of 1/3 mA in parallel with a resistance of 9 kΩ .

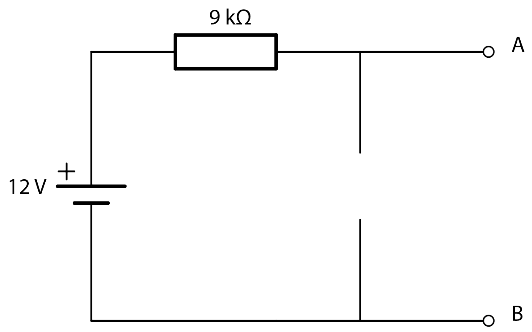


Figure (i):
Open circuit,
Voltage source only

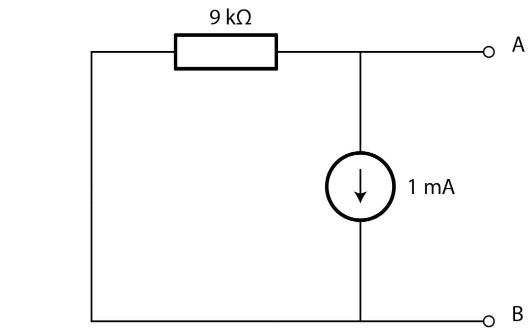


Figure (ii):
Open circuit,
Current source only

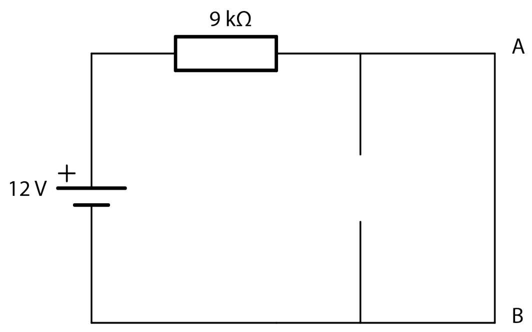


Figure (iii):
Short circuit,
Voltage source only

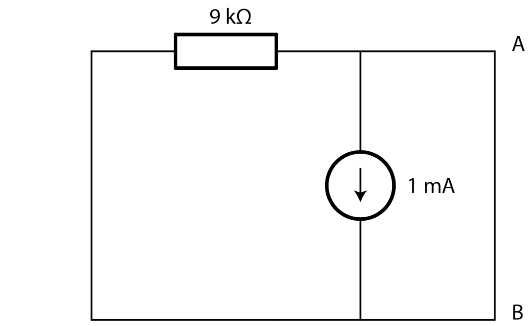


Figure (iv):
Short circuit,
Current source only

6. The voltmeter and R together form a parallel resistance R_T according to

$$\frac{1}{R_T} = \left(\frac{1}{R} + \frac{1}{10^4}\right)$$

Using $V = IR_T$ with V=12 and I=0.1, solve for $R = 121.5\,\Omega$.
Use the current divider rule to find the current flowing through R

$$I_R = 0.1 \times \frac{10^4}{10^4 + 121.5} = 0.0988\,A$$

The power dissipated in R is then

$$P_R = I_R^2 R = 1.17\,\mathrm{W}$$

CC
15-Dec-17