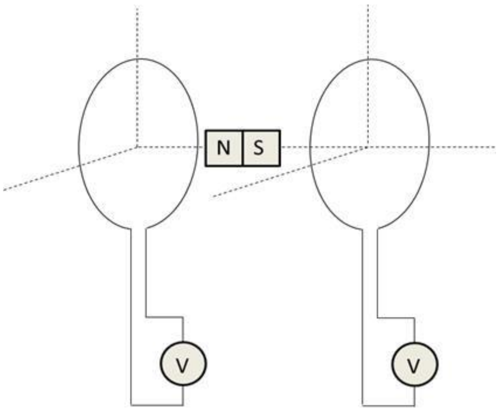
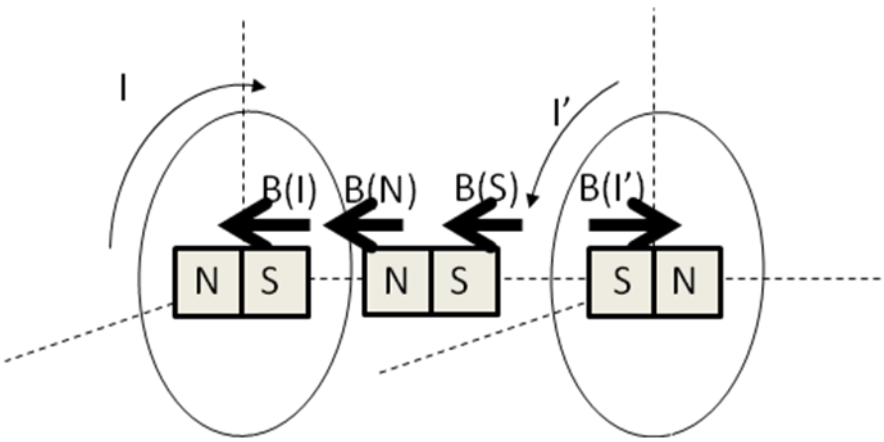
Conceptual Question 1: (1 point in both cases, continuous evaluation mode and non-continuous evaluation mode)

A magnet is located between two conductor loops along the axis thereof with its north pole located to the left. Which direction should have each current in each loop so that the magnet is moved to the left?. Note that in magnets, the magnetic field has its output by the positive pole and has its entrance on the negative pole. Furthermore, two magnets repel if the same poles are oriented toward each other.



Solution:

As the magnet is moved leftward, the magnetic field that is in the left loop will have to simulate a south pole (S) to attract the north pole (N) of the magnet and the magnetic field of the loop on the right have to generate a S pole, that repels the magnet S pole. Thus, the loop on the left must present a current through the loop clockwise and the right current is counterclockwise.



Problem 1: (3 points in case of continuous evaluation mode and 2 points in case of non-continuous evaluation mode)

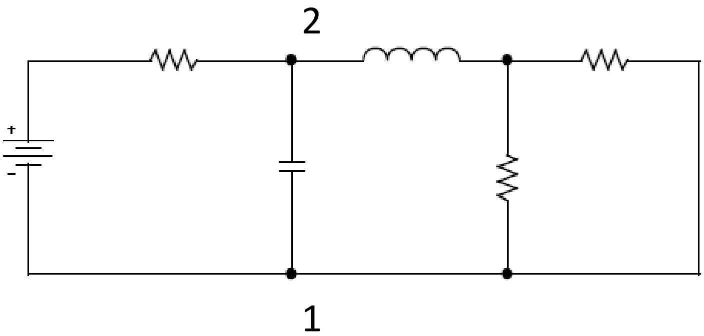
Given the DC circuit in the figure in which all resistor values are 20 Ω, capacitor value is 1 μF, inductor value is 1 nH, and DC source voltage is 12 V.

a) Draw the equivalent circuit for DC steady state analysis,

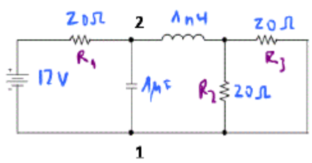
b) Indicate how many nodes, loops, meshes and branches have the circuit drawn in previous part a),

c) Apply Kirchhoff`s Rules (avoiding the use of equivalent resistances) to calculate the current flowing through each of the resistors in steady state,

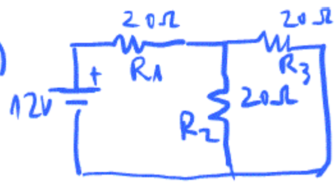
d) Calculate the potential across the nodes 1 and 2.



Solution:

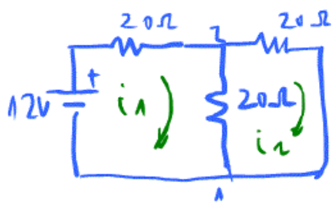


a)



b) Nodes = 3 , meshes = 2
Loops = 3 , branches = 4
independent loops = 2

c)



$40 i_1 - 20 i_2 = 12\,V$

$-20 i_1 + 40 i_2 = 0\,V$

$i_1 = \dfrac{\begin{vmatrix} 12 & -20 \\ 0 & 40 \end{vmatrix}}{\begin{vmatrix} 40 & -20 \\ -20 & 40 \end{vmatrix}} = \dfrac{12 \cdot 40}{1600 - 400} = 0.4\,A$

$i_2 = \dfrac{\begin{vmatrix} 40 & 12 \\ -20 & 0 \end{vmatrix}}{1200} = \dfrac{12 \cdot 20}{1200} = 0.2\,A$

$i_{R1} = 0.4\,A$

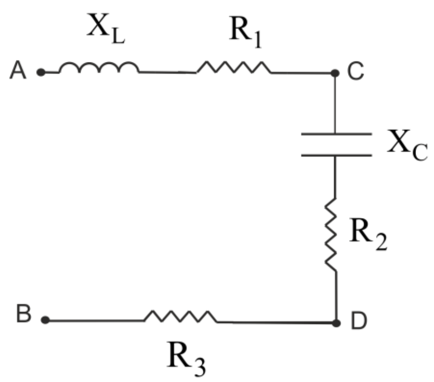
$i_{R2} = i_1 - i_2 = 0.2\,A$

$i_{R3} = 0.2\,A$

d) $V_{12} = -V_{21} = -20\Omega(i_1 - i_2) = -20\Omega \cdot (0.2\,A) = -4\,V.$

Problem 2: (3 points in case of continuous evaluation mode and 2 points in case of non-continuous evaluation mode)

A sinusoidal alternating current with of 60 Hz frequency flows through nodes A and B in the circuit of figure. The r.m.s voltage across these points is 130 V. Under these conditions, determine:



a) The expression of the instantaneous voltage across A and B,
b) The AB r.m.s current in the circuit,
c) The voltages $V_A - V_C$ and $V_C - V_D$,
d) The power factor and the average power,
e) The phasor diagram drawing the r.m.s current AB and the r.m.s voltaje AB, using the last one as the origin reference.

Data: X_L=8jΩ; X_C=-3jΩ; R_1=6Ω; R_2=R_3=3Ω

Solution:

a)

$$v_{AB}(t) = V_o sen(2\pi ft)$$

$$V_o = \sqrt{2} V_{AB} = 183{,}3 \text{ V}$$

$$v_{AB} = 183{,}3 sen(120\pi t)$$

b)

$$\vec{Z} = (R_1 + R_2 + R_3) + j(X_L - X_C) \Rightarrow \vec{Z} = 12 + j\,5 \;\; \Omega$$

$$Z = \sqrt{(12\;\Omega)^2 + (5\;\Omega)^2} = 13\,\Omega$$

$$tg\varphi = \frac{5}{12} \Rightarrow \varphi = 22{,}62^{\circ}$$

$$\vec{Z} = Z\angle\varphi \Rightarrow \vec{Z} = 13\angle\,22{,}62^{\circ} \;\; \Omega$$

$$\vec{I} = \frac{\vec{V}_{AB}}{\vec{Z}} = \frac{130\ \angle 0^{o}\ \mathrm{V}}{13\angle\ 22{,}62^{o}\ \Omega} = 10\ \angle -22{,}62^{o}\,\mathrm{A}$$

c)

$$Z_{AC} = \sqrt{R_1^2 + X_L^2} = 100\ \mathrm{V}$$

$$V_{AC} = I\ Z_{AC} = 10\ \mathrm{A}\ 10\Omega = 100\ \mathrm{V}$$

$$Z_{CD} = \sqrt{R_2^2 + X_C^2} = 3\sqrt{2}\ \Omega$$

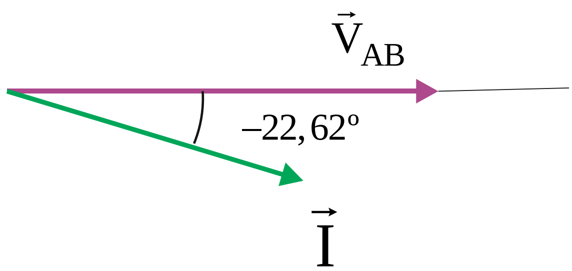
$$V_{CD} = I\ Z_{CD} = 10\ \mathrm{A}\ 3\sqrt{2}\ \ \Omega = 42{,}3\ \mathrm{V}$$

d)

$$\cos\varphi = \cos\left(22{,}64^{o}\right) = 0{,}923$$

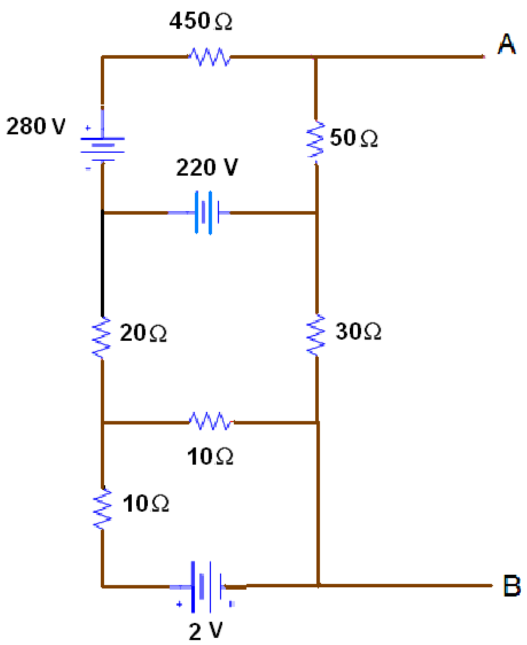
$$P = IV_{AB}\cos\varphi = 130\mathrm{V}\ 10\mathrm{A}\ 0{,}923 = 1200\ \ \mathrm{W}$$

e)



Problem 3: (3 points in case of continuous evaluation mode and 2 points in case of non-continuous evaluation mode)

a) Calculate and draw the equivalent Thèvenin circuit of the DC circuit in the figure across A and B,
b) Calculate and draw the equivalent Norton circuit using the result in a).



Solution:

R_{th} = 58,63 Ω

V_{th} = -69,45 V

I_N = -1.185 A

Problem 4: (1 point in case of non-continuous evaluation mode)

A spaceship whose shape is a 100 m rod, moving at a speed of 36,000 km/h perpendicular to the poles, is near to landing on the surface of the south magnetic pole. The magnitude of Earth's magnetic field is about 30000 nT at the Equator and 60000 nT at the poles. The Earth's magnetic field direction is horizontal at the Equator. The Earth's magnetic field direction is vertical at the poles.

Electrical protection of the spacecraft is designed for up to 200V. This 200V limit: Will be reached?

Solution:

Assuming that a constant B, and using Faraday`s Law, given that the angle of B respecting to v is 180º → ε=VBL

$\varepsilon=10000*6*10^{-5}*100=60$ V is the emf induced in spaceship, the limit of 200V will not be reached.