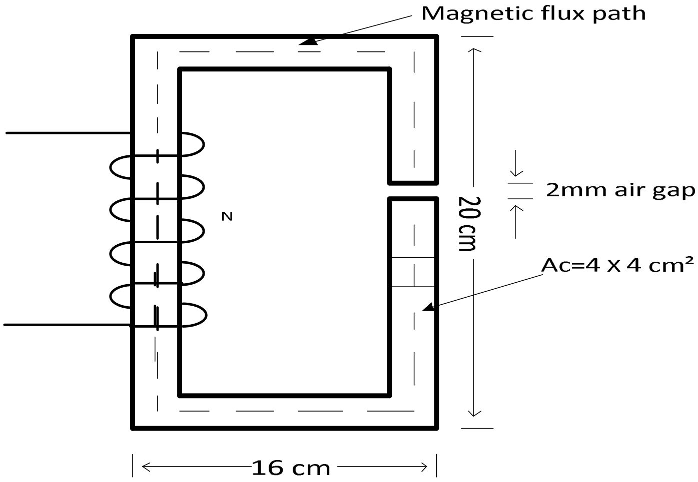
Tutorial-9 (Solutions)

1. **(Pre-tutorial question)**
   Fig. 1(a) shows a rectangular magnetic core with an air gap. Find the exciting current needed to cause a flux density of $B_g = 1.2T$ in the air gap. Given $N = 400\ turns$ and $\mu_r(iron) = 4000$.



Solution:

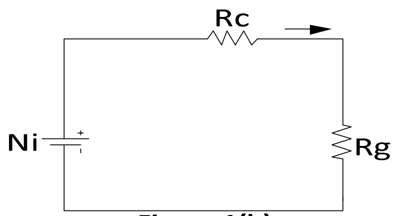


Figure-1(b)

It is a simple series magnetic circuit with its analog shown in Fig. 1(b).

Core length, = $l_c = 2[(20-4)+(16-4)] - 0.2 = 55.8cm$

Cross-sectional area of core, $A_c = 16cm^2$

Core reluctance, $\Re_c = \frac{l_c}{\mu_r \mu_0 A_c} = \frac{55.8\times10^{-2}}{4000\times4\pi\times10^{-7}\times16\times10^{-4}} = 0.694\times10^5$

Air gap length, $l_g = 0.2\ cm$

Area of air gap, $A_g = 16cm^2$

Air gap reluctance, $\Re_g = \frac{l_g}{\mu_0 A_g} = \frac{2\times10^{-3}}{4\pi\times10^{-7}\times16\times10^{-4}}$

Total, $\Re = \Re_c + \Re_g = 10.64\times10^5 AT/Wb$

Flux in the magnetic circuit, $\Phi = BA = 1.2\times16\times10^{-4} = 1.92\ mWb$

Now, $Ni = \Phi(\Re_c + \Re_g) = \Phi\Re = 1.92\times10^{-3}\times10.64\times10^5 = 2043AT$

So Exciting current, $i = \frac{\Phi\Re}{N} = \frac{2043}{400} = \mathbf{5.11A}$

2. Derive the output voltage expression for the following circuit.

Solution

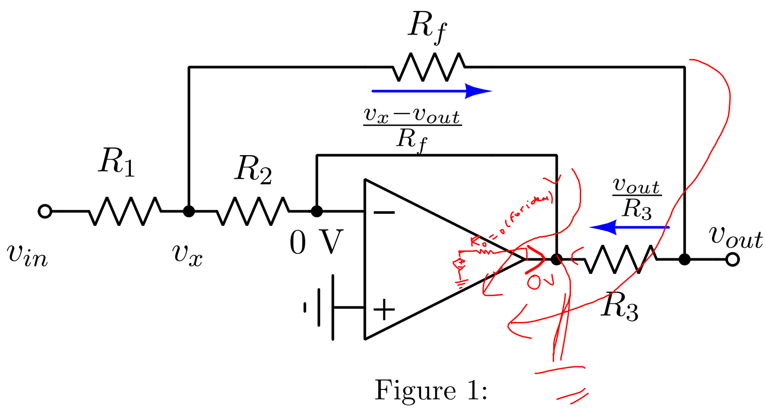


Figure 1:

If we assume a virtual short at the opamp input terminals and write the KCL at the intermediate node,

$$\frac{v_{in} - v_x}{R_1} = \frac{v_x}{R_2} + \frac{v_x - v_{out}}{R_f}.$$

Important points:

(i) Even though there is no real ground at the opamp negative input terminal, there exists a low impedance path for the current to flow (unity feedback connection). Hence v_x is not equal to zero.

(ii) Due to the unity feedback, opamp output terminal is at 0 V.

(iii) $\frac{v_x}{R_2} \neq \frac{-v_{out}}{R_3}$. An ideal opamp (a VCVS) can supply any amount of current at the output.

The second equation we have is,

$$\frac{v_x - v_{out}}{R_f} = \frac{v_{out}}{R_3}$$

Solving the above two equations will give $v_{in} = v_{out}\left[\frac{R_1}{R_3} + \frac{(R_f+R_3)(R_1+R_2)}{R_2R_3}\right]$.

3. In the circuit shown in fig. 3, find the average power absorbed by (a) the source, (b) each of the two resistors, (c) each of the inductance, (d) mutual inductance.

Tutorial-9 (Solutions)

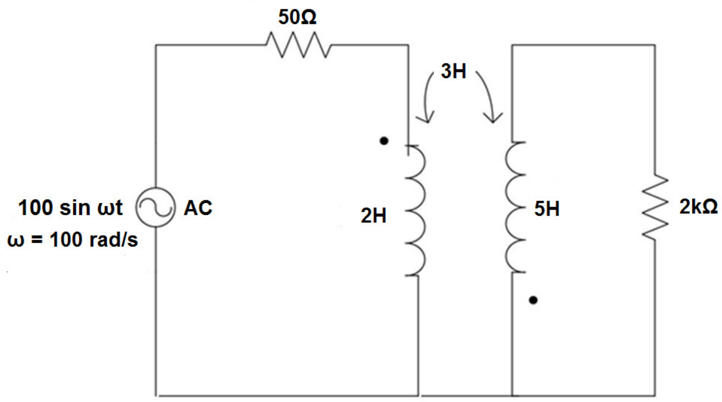


Fig. 3

Solution:

KVL in the loop – 1:

$100 - I_1(50 + j200) - j300I_2 = 0$

$\Rightarrow I_1(5 + j20) + j30I_2 = 10$ -------------------- (1)

KVL in the loop – 2:

$-jw5I_2 - 2000I_2 - jw3I_1 = 0$

$\Rightarrow j3I_1 + I_2(20 + j5) = 0$ -------------------------(2)

Solving equation (1) & (2)

$$\mathbf{I_2 = 0.069\angle -168.04^0\ A,\ I_1 = 0.475\angle 64.04^0\ A}$$

a) Power absorbed the source = $V_{eff}\ I_{eff}\cos\emptyset = -\frac{100}{\sqrt{2}} \times \frac{0.475}{\sqrt{2}}\cos(64.04^0)$
$= \mathbf{-10.40\ W}$ *(-ve sign indicates power delivered)*

b) $P_{50} = I_{1eff}^2 \times 50 = \mathbf{5.64\ W}$ **,** $P_{2K} = I_{2eff}^2 \times 2K = \mathbf{4.76W}$

c) & d) Power absorbed by each inductance and mutual inductance **is zero.**

4. Find the equivalent inductances seen at terminals 1 and 2 in the network of Fig. 4 if the following terminals are connected together: (a) none, (b) A to B, (c) A to C.

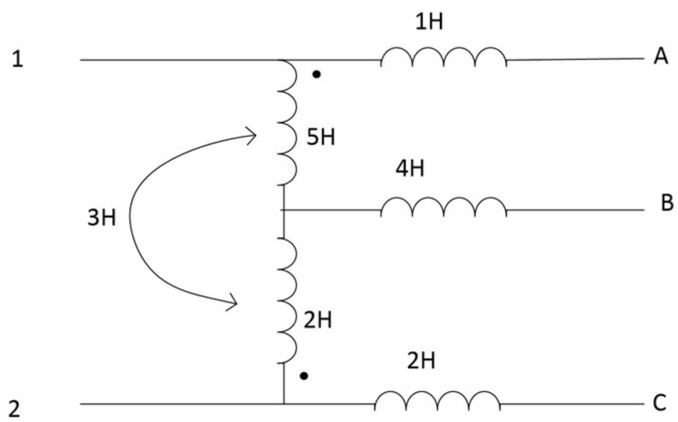
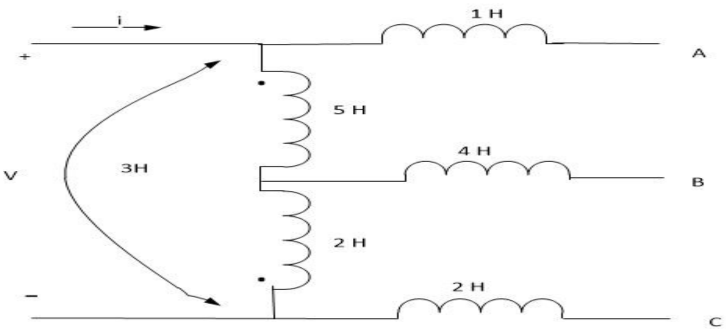


Fig. 4

Tutorial-9 (Solutions)

Solution:

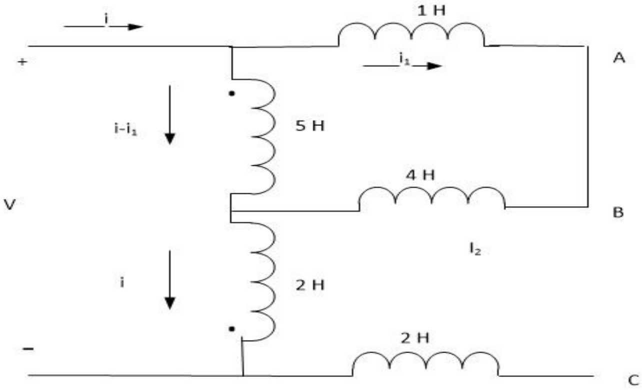
a)



$$V-\left(5\ \frac{di}{dt}-3\ \frac{di}{dt}\right)-\left(2\frac{di}{dt}-3\ \frac{di}{dt}\right)=0\ \Rightarrow v-\ \frac{di}{dt}=0$$

$\boldsymbol{L_{eq}=1\ H}$

b)



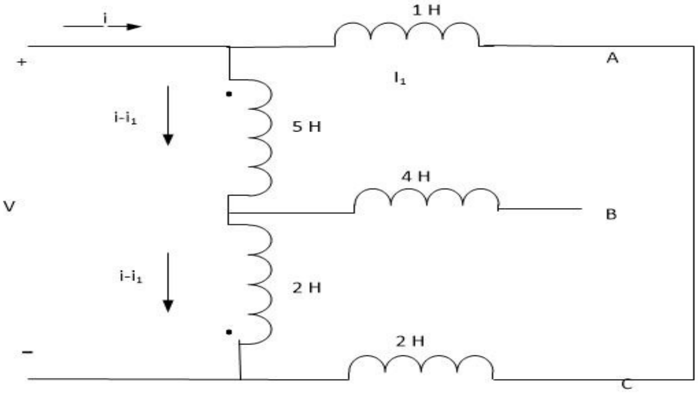
$$V-5\ \frac{d(i-i_1)}{dt}+3\frac{di}{dt}-2\frac{di}{dt}+3\frac{d(i-i_1)}{dt}=0\ \Rightarrow V-\ \frac{di}{dt}+2\frac{di_1}{dt}=0\text{--(1)}$$

$$-1\frac{di_1}{dt}-4\frac{di_1}{dt}+5\frac{d(i-i_1)}{dt}-3\frac{di}{dt}=0\ \Rightarrow\ \frac{di_1}{dt}=\ \frac{1}{5}\frac{di}{dt}\ \text{-----------------(2)}$$

Replacing the value of $\frac{di_1}{dt}$ from (2) in equation (1)

$$V-\ \frac{di}{dt}\left(1-\ \frac{2}{5}\right)=0\ \Rightarrow \boldsymbol{L_{eq}}=\frac{\mathbf{3}}{\mathbf{5}}\ \boldsymbol{H}$$

c)



Tutorial-9 (Solutions)

$$V - \left(5\ \frac{d(i-i_1)}{dt} - 3\ \frac{d(i-i_1)}{dt}\right) - \left(2\frac{d(i-i_1)}{dt} - 3\ \frac{d(i-i_1)}{dt}\right) = 0$$

$V - \frac{di}{dt} + \frac{di_1}{dt} = 0$ -------------- (1)

$-\frac{di_1}{dt} - 2\frac{di_1}{dt} + 2\frac{d(i-i_1)}{dt} - 3\frac{d(i-i_1)}{dt} + 5\frac{d(i-i_1)}{dt} - 3\frac{d(i-i_1)}{dt} = 0$

$\Longrightarrow \frac{di_1}{dt} = \frac{1}{4}\frac{di}{dt}$ -------------------- (2)

$V - \frac{di}{dt}\left(1 - \frac{1}{4}\right) = 0 \Longrightarrow \boldsymbol{L_{eq} = \frac{3}{4}H}$