Time: 45 Minutes **EE 101: Electrical Sciences** **Marks: 10**

Quiz-2 (01 Nov 2014)

1. The details of an iron-cored inductor are shown in Figure 1 (a) where the dimensions are in cm. The core is 2 cm deep. The linearized B-H curve of the core is shown in Figure 1 (b).

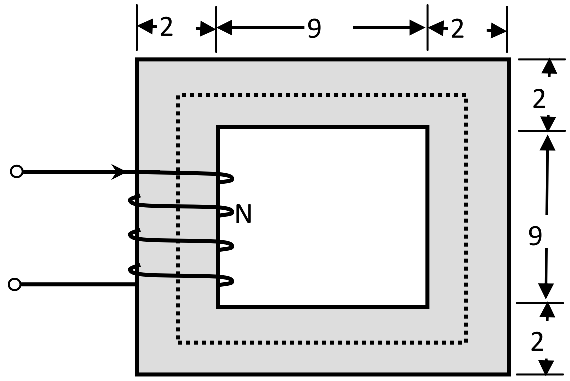


Figure 1(a)

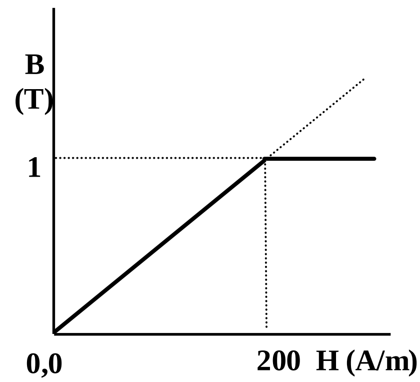


Figure 1(b)

   a. Draw the magnetic equivalent circuit for the system. [2]
   b. Calculate the inductance of the coil if the number of turn N=22. [1]
   c. What is the maximum current I_{max} that the inductor can take before it saturates? [2]

2. The circuit shown in Figure 2 operates in linear mode and the op-amp is assumed ideal.
   a. Find the expression for output voltage v_o in terms of $i_{s1}, i_{s2}, R_1, R_2, R_3$ and R_4. [3]
   b. If $i_{s1} = 10\ \mu A$, $i_{s2} = 0\ \mu A$, $R_1 = R_3 = 10\ k\Omega$ and $R_2 = R_4$, find the value of R_2 that yield $v_o = -1$ V. [2]

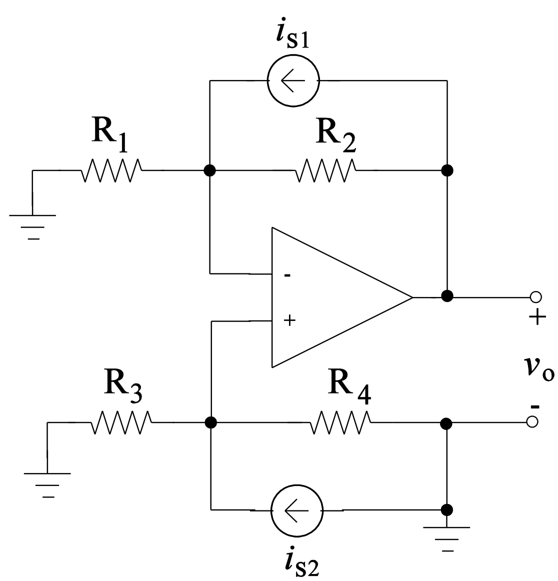
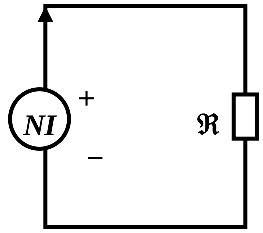


Figure 2

Sol: 1a. The magnetic equivalent circuit as shown below



where, $\mu = \frac{B}{H} = \frac{1}{200}$

Mean length l = 4×11 cm = 0.44 m

Cross section A = 2×2×10^{-4} m^2 = 4×10^{-4} m^2

Reluctance $\Re = \frac{l}{\mu A} = \frac{0.44}{(1/200)\times 4\times 10^{-4}} = 0.22\times 10^{6}\ \text{H}^{-1}$ [2]

1b. Inductance $L = \frac{N^2}{\Re} = \frac{22^2}{0.22\times 10^{6}} = 2.2\times 10^{-3}\ \text{H}$ [1]

1c. Saturation occurs at B = 1 T,

Therefore $\varphi_{\max} = 1\times 4\times 10^{-4} = \frac{Ni_{\max}}{\Re} = \frac{22\times i_{\max}}{0.22\times 10^{6}}$ and, then

$$i_{\max} = \frac{Ni_{\max}}{\Re} = \frac{4\times 10^{-4}\times 0.22\times 10^{6}}{22} = 4\ \text{A}$$ [2]

Sol: 2a. Let v_n and v_p denote the voltages at inverting and non-inverting terminals of op-amp. Now applying KCL at the node formed between R_1-R_2 , we have

$$\frac{v_n}{R_1} - i_{s1} + \frac{v_n - v_o}{R_2} = 0 \quad \Rightarrow \quad v_n = \frac{\left(i_{s1} + \frac{v_o}{R_2}\right)}{\frac{1}{R_1} + \frac{1}{R_2}}$$

On applying the KCL at the node formed between R_3-R_4 , we have

$$\frac{v_p}{R_3} - i_{s2} + \frac{v_p}{R_4} = 0 \quad \Rightarrow \quad v_p = i_{s2}(R_3 \parallel R_4)$$

In linear mode of operation, $v_n = v_p$ so

$$\frac{\left(i_{s1} + \frac{v_o}{R_2}\right)}{\frac{1}{R_1} + \frac{1}{R_2}} = i_{s2}(R_3 \parallel R_4)$$

On simplification we have

$$\mathrm{v_o} = -i_{s1}R_2 + i_{s2}(R_3 \parallel R_4)\left(1 + \frac{R_2}{R_1}\right) \qquad [3]$$

2b. For $\mathrm{i_{s2}} = 0\ \mu\mathrm{A}$, from the relation derived in part (a) we get $\mathrm{v_o} = -i_{s1}R_2$

$$\therefore\ R_2 = -\frac{v_o}{i_{s1}} = -\frac{-1\ V}{10\ \mu A} = 100\ k\Omega$$

[2]

Alternatively:

For $\mathrm{i_{s2}} = 0\ \mu\mathrm{A}$, we have , $v_n = v_p = 0\ V$.

This means that the current i_{s1} flows only through R_2 and therefore $\mathrm{v_o} = -i_{s1}R_2$