Indian Institute of Technology Mandi

School of Computing and Electrical Engineering
IC 160: Electrical Systems Around Us
Fall 2013 – Exam I

Last Name: ______________ **First Name:** ________________ **Roll No.:** ______________

Note : The exam carries a weight of 30%. You have 50 minutes for 14 problems. This is a closed book, closed notes exam. No cheat sheets are allowed in the exam. Only non-programmable calculators are acceptable. Answer the questions in the space provided. If you do, please make a comment on the front to look at the back. Good luck!

Problem	Points	Score	Problem	Points	Score
1	6		8	4	
2	5		9	4	
3	3		10	7	
4	5		11	3	
5	4		12	3	
6	6		13	3	
7	4		14	3	

1. (6 points) Answer the following:
   a. (1 point) Name a renewable energy resource.
   b. (3 points) Describe three main advantages that renewable energy resources have over non-renewable resources for generation of electricity.
   c. (2 points) You are a scientist who wants to use more renewable energy. Suggest at least two ways how you would persuade people to want more renewable energy sources.

a) Any of : Wind, Tidal, Solar, Geothermal

b) Will not run out; no waste; no fuel cost ; environment friendly

c) Present scientific evidence for limitless supply, pollution-free etc.

2. (5 points) The generators at a power plant produce a voltage of 25,000 V. For long distance transmission, on overhead power lines, this is stepped up to 400,000 V. It is later stepped down to 240 V for domestic use.
   a. (1 points) Explain why the voltage is stepped up to 400,000 V.
   b. (2 points) Give one advantage and one disadvantage of increasing the thickness of overhead power lines.
   c. (1 points) What is the difference between a step-up transformer and a step-down transformer?
   d. (1 points) Why does a transformer not work with a battery?

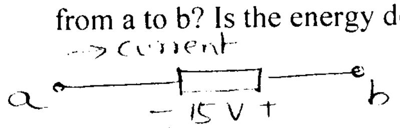
a) High voltage ⇒ less current ⇒ lower heating loss

b) Pro : less resistance   Con : Costlier, heavier

c) Increase / decrease voltage

d) Batteries produce DC voltage. Transformers work on AC voltage.

3. (3 points) Suppose that terminals of an electrical device are labeled a and b. If v_{ab}=-15V, how much energy is exchanged when a positive charge of 4C moves through the device from a to b? Is the energy delivered to the device or taken from the device?



$w = \int_0^{\infty} p(t)\, dt = vq = -15 \times 4 = -60J$

Energy is taken from (supplied by) the device.

4. (5 points) The electronics aboard a sailboat consume 30 W when operated from a 12 V source. If a fully-charged lead-acid storage battery is rated for 12 V and 80 ampere-hours, for how many hours can the electronics be operated from the battery without recharging? How much energy in kilowatt hours is initially stored in the battery? If the battery costs Rs. 10,000 and has a life of 250 charge-discharge cycles, what is the cost of the energy in Rupees per kilowatt hour?

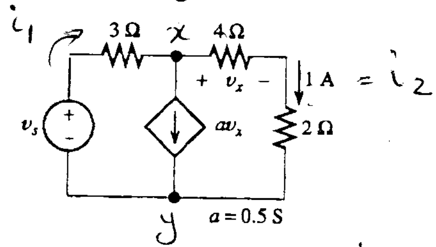
Current drawn by electronics $= \frac{30}{12} = 2.5$ A (1)

No. of hours withot recharging $= \frac{80 \text{ Ah}}{2.5 \text{ A}} = 32$ h (1)

Initial energy in battery $= 12 \times 80 = 960$ Wh $= 0.96$ kWh (2)

Cost of energy $= \frac{10,000}{250 \times 0.96} = 41.67$ Rs/kWh

5. (4 points) Solve for v_s in the following circuit.



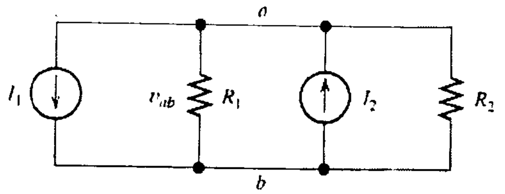
As $i_2 = 1A$ $\quad V_{xy} = 6V$ $\quad$ and $\quad V_x = 4\ V$ (1)

Current from current source $= aV_x = 0.5 \times 4 = 2\ A$ (1)

So $i_1 = 1A + 2A = 3A$ (1)

and $V_s = 3 \times 3 + V_{xy} = 9 + 6 = 15\ V$ (1)

6. (6 points) The following circuit has I1=3A, I2=1A, R1=12 ohms, R2=6 ohms.
   a. (2 points) Determine the value of vab.
   b. (2 points) Determine the power for each current source and state whether it is absorbing energy or delivering it.
   c. (2 points) Compute the power absorbed by R1 and R2.



a) By using the nodal analysis technique,
let $V_b = 0$ (reference node)
Then by KCL at node b

$$I_1 + \frac{V_a}{R_1} - I_2 + \frac{V_a}{R_2} = 0$$

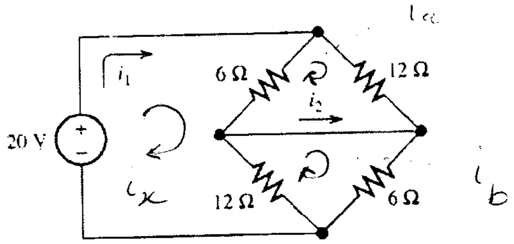
which gives $V_a = -8\ V$, $\quad$ So $V_{ab} = -8\ V$

b) Power for source 1 $= 8 \times 3 = 24\ W$ (delivering energy)
Power for source 2 $= 8 \times 1 = 8\ W$ (absorbing it)

c) Power absorbed by $R_1 = \frac{V_{ab}^2}{R_1} = \frac{64}{12} = 5.33\ W$

Power absorbed by $R_2 = \frac{V_{ab}^2}{R_2} = \frac{64}{6} = 10.66\ W$

7. (4 points) Find the values of i1 and i2 in the following circuit using mesh current analysis technique.



Writing the KCL equations

$$12 i_a + 6(i_a - i_x) = 0$$

$$6 i_b + 12(i_b - i_x) = 0$$

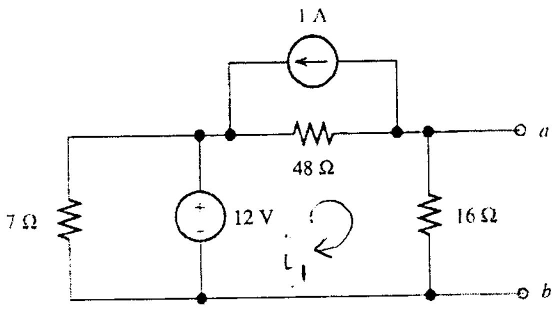
$$20 = 6(i_x - i_a) + 12(i_x - i_b)$$

Solving we get $i_x = 2.5$ A $\quad i_a = 0.833$ A $\quad i_b = 1.667$ A

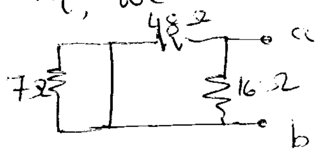
So, $i_1 = i_x = 2.5$ A

$i_2 = i_b - i_a = 0.833$ A

8. (4 points) Find the Thevenin and Norton equivalents for the following circuit. What effect does the 7 ohm resistor have on the equivalent circuits?



To calculate R_t, we zero the sources to get



which gives $R_t = 12\ \Omega$

To find V_{ab} use mesh current analysis technique to get

$$12 = 48(i_1 + 1) + 16 i_1$$

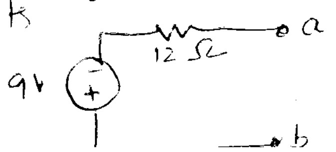
$$i_1 = -\frac{9}{16} \text{ A}$$

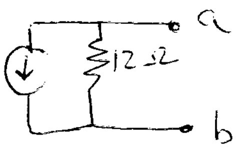
$$V_{ab} = -\frac{9}{16} \times 16 = -9 \text{ V}$$

The 7 Ω resistor has no effect in calculating R_t or V_{ab}.

$$i_{sc} = i_N = \frac{V_{ab}}{R_t} = \frac{9}{12} = \frac{3}{4} \text{ A}$$

Equivalent circuits



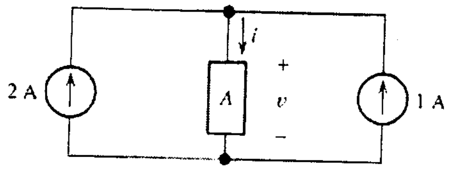


9. (4 points) Explain the following intuitively (no mathematical proofs needed):
   a. (2 points) The resistance in the Thevenin equivalent circuit is the same as the value in the Norton equivalent circuit.
   b. (2 points) Maximum power transfer occurs when load resistance is equal to the circuit resistance.

a) Because the blackbox circuit is the same and zeroing the sources gives the same value, they are equal

b) If load resistance is more, current will be smaller giving smaller power transfer. If load resistance is less, more power will be dissipated in the circuit, leading to smaller power transfer.

10. (7 points) Look at the following circuit. Device A has $v=3i^2$ for $i>=0$ and $v=0$ for $i<0$.
   a. (1 points) Will the superposition theorem be able to find the voltage across the device A?
   b. (2 points) Find the voltage across device A with 2 A source active and 1 A source zeroed.
   c. (2 points) Find the voltage across device A with 1 A source active and 2 A source zeroed.
   d. (2 points) Find the voltage across device A with both sources active.



a) Since the device is non-linear, superposition theorem will not apply.

b) With 2A source active, $V_1 = 3 \times 2^2 = 12$ V

c) With 1A source active $V_2 = 3 \times 1^2 = 3$ V

d) With both sources active $V = 3 \times 3^2 = 27$ V

11. (3 points) The capacitance value of a capacitor is given by C=200+50 sin(5000t) pF. A constant voltage of 50V is applied to the capacitor. Determine the current as a function of time.

$$\text{Current} = i = \frac{d}{dt}\left(C(t)\,v(t)\right) = v\,\frac{d}{dt}C(t)$$

$$= 50 \times \frac{d}{dt}\left\{200+50\sin(5000t)\right\}\times 10^{-12}$$

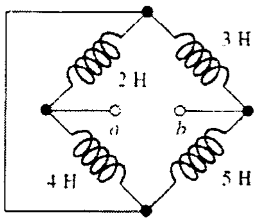
$$= 50\times 50\times 5000\cos(5000t)\times 10^{-12}$$

$$= 125\times 10^{-7}\cos(5000t)\ \text{A}$$

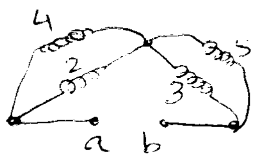
12. (3 points) Assuming zero initial current, what value of inductance corresponds to an open circuit? Short circuit? Explain your answers.

A fully discharged inductor ($L > 0H$) having zero current through it will initially act as open circuit (as it tries to maintain zero current). $L = 0H$ will act as short circuit initially.

13. (3 points) Determine the equivalent inductance between the terminals a and b in the following circuit.



The circuit can be redrawn as



So the equivalent inductance is given as

$$(4 \parallel 2) + (3 \parallel 5) = \frac{4}{3} + \frac{15}{8} = 77/24$$

14. (3 points) A 100 microFarad capacitance is initially charged to 1000V. At t=0, it is connected to a 1 kiloohm resistance. At what time has 50% of the initial energy stored in the capacitance been dissipated in the resistance?

$R = 1000\,\Omega$

$C = 100 \times 10^{-6}\,F$

Time constant $= RC = 10^{-1}$ sec

$V_{initial} = 1000$ V

$V_c(t) = V_i \, e^{-t/RC}$

Energy in capacitor $= \frac{1}{2} C V_c^2(t)$

So, $\frac{1}{2} C V_c^2(t) = \frac{1}{2}\left(\frac{1}{2} C V_i^2\right)$

$$V_i^2 e^{-2t/RC} = \frac{1}{2} V_i^2$$

$$\frac{2t}{RC} = \ln 2$$

$$t = 0.05 \ln 2$$