ELEC 225 Circuit Theory I Fall 2013

Review Topics for Exam #1

The following is a list of topics that could appear in one form or another on the exam. Not all of these topics will be covered, and it is possible that an exam problem could cover a detail not specifically listed here. However, this list has been made as comprehensive as possible.

Although every effort has been made to ensure that there are no errors in this review sheet, some might nevertheless appear. The textbook is the final authority in all factual matters, unless errors have been specifically identified there. You are ultimately responsible for obtaining accurate information when preparing for your exam.

<u>Background Topics and Concepts</u>
These concepts will not be assessed explicitly on the exam. However, you need to have a good command of them in order to solve the problems that will appear on it. That is, this is assumed knowledge.

Passive sign convention for Ohm's law and power calculations
- $v = iR$ or $v = -iR$
- $p = iv$ or $p = -iv$
- sign depends on direction of current relative to polarity of voltage
- if p is positive, then power is absorbed (dissipated)
- if p is negative, then power is delivered (supplied)

Power calculations for resistors
- $p = i^2 R$ or $p = \frac{v^2}{R}$
- power is always dissipated in resistors (p is always positive)

Ideal independent voltage sources
- maintains indicated voltage between its two terminals at all times
- current through source determined by circuit external to source
- source has no fixed resistance (i.e., no Ohm's law calculations are possible)
- a short circuit can be represented by a voltage source of 0 V

Ideal independent current sources
- maintains indicated current through its branch at all times
- voltage across source determined by circuit external to source
- source has no fixed resistance (i.e., no Ohm's law calculations are possible)
- an open circuit can be represented by a current source of 0 A

Possible contradictions involving ideal voltage and current sources
- two or more voltage sources of different values in parallel is meaningless
- two or more current sources of different values in series is meaningless

Dependent voltage sources
- voltage is determined by a voltage or current elsewhere in circuit; the controlling voltage or current is always multiplied by a constant (the "gain")
- as with indep. voltage sources, current is unconstrained but instead determined by circuit external to source
- equiv. to a short circuit (0 V) if controlling quantity is zero

Dependent current sources

- current is determined by a voltage or current elsewhere in circuit; the controlling voltage or current is always multiplied by a constant (the "gain")
- as with indep. current sources, voltage is unconstrained but instead determined by circuit external to source
- equiv. to an open circuit if (0 A) controlling quantity is zero

Series and parallel connections

- devices in parallel have the same voltage across them and are connected between the same two circuit nodes
- devices in series have the same current flowing through them and lie along the same circuit path with no intervening junctions

Circuit node

- definition: an interconnected network of conductors with no intervening devices
- All points in a node have the same potential (voltage) relative to some reference point
- A node can consist of several individual connection points (i.e., it is possible for a node to consist of many branching wires)

Kirchhoff's voltage law (KVL)

- simply a restatement of the law of conservation of energy in circuit terms
- around any circuit loop, sum of voltage rises = sum of voltage drops
- voltage rises or drops can be given either positive or negative signs in KVL equation, but must be consistent within a single KVL equation
- corollary: voltage between two points = sum of voltage drops and rises between those two points
- corollary: devices in parallel share the same voltage

Kirchhoff's current law (KCL)

- simply a restatement of the law of conservation of mass (charge) in circuit terms
- at any circuit node or region, sum of currents entering = sum of currents leaving
- currents entering or leaving can be given either positive or negative signs in KCL equation, but must be consistent within a single KCL equation
- corollary: devices in series share the same current

Series resistors

- all have the same current flowing through them, but different voltages across them
- $R_{eq} = R_1 + R_2 + \cdots + R_N$
- if one resistor is order(s) of magnitude **larger** than the rest, then $R_{eq} \approx$ that value

Parallel resistors

- all have the same voltage across them, but different currents through them
- $R_{eq} = \dfrac{1}{\dfrac{1}{R_1} + \dfrac{1}{R_2} + \cdots + \dfrac{1}{R_N}}$
- special case for only two resistors: $R_{eq} = \dfrac{R_1 R_2}{R_1 + R_2}$
- if one resistor is order(s) of magnitude **smaller** than the rest, then $R_{eq} \approx$ that value
- equiv. resistance of any finite resistor in parallel with an infinite resistance is equal to the finite value
- if two or more resistors are in parallel, majority of current flows through resistor of least value

Conductance

- $G = 1/R$
- Ohm's law for conductances: $i = Gv$, $v = i/G$
- series conductances: $G_{eq} = \dfrac{1}{\dfrac{1}{G_1} + \dfrac{1}{G_2} + \cdots + \dfrac{1}{G_N}}$
- parallel conductances: $G_{eq} = G_1 + G_2 + \cdots + G_N$

Voltage divider

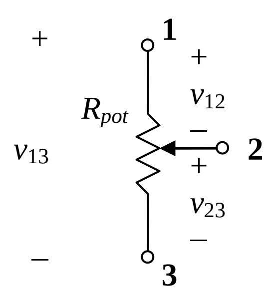
- formed by two or more resistors in series (all **must** share the same current)
- let total voltage across entire set of resistors = v_{tot}
- let voltage across k^{th} resistor = v_k
- $v_k = \dfrac{R_k}{R_1 + R_2 + \cdots + R_N} v_{tot}$

Current divider

- formed by two or more resistors in parallel (all **must** share the same voltage)
- let total current flowing into network of resistors = i_{tot}
- let current flowing through k^{th} resistor = i_k
- $i_k = \dfrac{R_{eq}}{R_k} i_{tot}$
- special case for only two resistors: $i_1 = \dfrac{R_2}{R_1 + R_2} i_{tot}$ and $i_2 = \dfrac{R_1}{R_1 + R_2} i_{tot}$
- using conductances: $i_k = \dfrac{G_k}{G_1 + G_2 + \cdots + G_N} i_{tot}$

Potentiometers

- wiper arm ("tap") effectively divides the resistor into two parts and provides a connection to the junction
- voltage across "fixed" ends (terminals 1 and 3 below) usually remains constant
- KVL: $v_{13} = v_{12} + v_{23}$



New or Revisited Topics and Concepts

These are topics that could be assessed explicitly on the exam. They will guide the composition of the exam.

Nodal analysis

- based on KCL applied to all nodes except reference node
- node definition: not just a "dot"; includes wires and other conductors connected to dot(s)
- definition of node voltage: voltage measured between a node and the reference node (ground); positive side of labeled polarity at node, negative side at reference node
- node voltages can be negative, which means the actual pos. side is at ground and neg. side is at the node if the voltage is instead expressed as a pos. quantity
- currents through resistors are expressed in terms of node voltages using Ohm's law (difference in node voltages divided by resistance)
- an indep. or dependent voltage source between non-reference node and ground establishes the value of that node voltage; a KCL eqn (nodal eqn) is not necessary for that node
- <u>supernode required if indep. or dep. voltage source is connected between two non-reference nodes (a "floating" voltage source)</u>
    - a supernode is a combination of two (or more) nodes; it encompasses the voltage source(s) and the nodes it (they) is (are) connected to
    - apply KCL to supernode; must account for all circuit branches entering all nodes in the supernode (except those that run between nodes in the supernode)
    - the difference between the two node voltages in the supernode is equal to the voltage source connected between them (this is a KVL eqn, and it replaces the nodal KCL eqn that is "lost" when the nodes are combined)
- treatment of dependent sources
    - surround dependent voltage sources not connected to ref. node with supernodes, just as with indep. voltage sources
    - dep. current sources treated the same as indep. current sources in KCL eqn
    - controlling voltages/currents must be expressed in terms of node voltages
- nodal equations should have only node voltages as unknowns
- in general, the solution of a system of simultaneous equations is required (for N nodes, there are $N-1$ independent equations in $N-1$ unknowns, although the number can be reduced if indep. voltage sources connected to ground are present)
- nodal equations should be manipulated into "standard form"
    - facilitates matrix solution
    - terms involving unknowns (node voltages) on left-hand side in same order
    - terms involving known quantities (constants) on right-hand side

Thévenin and Norton equivalent circuits (TECs and NECs)

- TEC and/or NEC is associated with a specific set of terminals; a different set of terminals in the same circuit has a different TEC/NEC
- portion of circuit for which TEC/NEC being found is the "internal" (or modeled) circuit; the rest is the "external" circuit; that is, the internal circuit is treated as a "black box"
- open-circuit voltage (v_{oc}) is evaluated at terminals with external circuit removed
- short-circuit current (i_{sc}) flows through short between terminals with external circuit removed
- a TEC/NEC "seen" by a device models the part of the circuit that does not include the device

- polarity of v_{oc} vs. direction of i_{sc}
- Thévenin equivalent voltage: $v_{th} = v_{oc}$
- Norton equivalent current: $i_N = i_{sc}$
- Thévenin and Norton equivalent resistances, $R_{th} = R_N = v_{oc} / i_{sc} = v_{th} / i_N$
- Thévenin (Norton) resistance can be found via three possible methods:
    - Find v_{oc} and i_{sc} and then evaluate the ratio $R_{th} = R_N = v_{oc} / i_{sc}$
    - If no dependent sources are present, deactivate all independent sources (replace voltage sources with shorts and current sources with opens), and find R_{eq} of the circuit using series/parallel combination and/or delta-wye formulas
    - If dependent sources are present, deactivate all independent sources, apply a test source (v_t or i_t), and evaluate the ratio $R_{th} = R_N = v_t / i_t$
- test source method always works; it can be used instead of v_{oc}/i_{sc} method or equivalent resistance method

Maximum power transfer to load

- for TECs or NECs: given constant v_{th} or i_N, if load resistance (R_L) is controllable but R_{th} (R_N) is not, set $R_L = R_{th}$ to achieve max. power transfer
- for TECs: given constant v_{th}, if Thévenin resistance (R_{th}) is controllable but R_L is not, set $R_{th} = 0$ (or as small as possible); this results in max. power transferred to load, but not max. power available from source
- for NECs: given constant i_N, if Norton resistance (R_N) is controllable but R_L is not, set $R_N \rightarrow \infty$ (or as large as possible); this results in max. power transferred to load, but not max. power available from source
- it is not always advisable to extract max. power from source; source or load could experience voltages, currents, and/or heat beyond ratings
- if $R_L = R_{th}$ (only!), power delivered to load is $P_L = (v_{th}^2)/(4R_{th})$
- if $R_L = R_{th}$, then percentage of power developed by source circuit that is dissipated in the load can never be more than 50% and is usually much less than 50%; however, this is the maximum power that can be transferred to load

<u>Relevant course material:</u>

HW:	#1-#3
Labs:	#1-#2
Textbook:	review only – Chap. 1; Secs. 2-1 through 2-4; Secs. 3-2 and 3-3
	new material – Secs. 3-1, 3-5, 3-6
Supplements:	Nodal Analysis – The Formal Process
	Procedure for Finding Thévenin Equivalent Circuits
	Introduction to Thévenin Equivalent Circuits