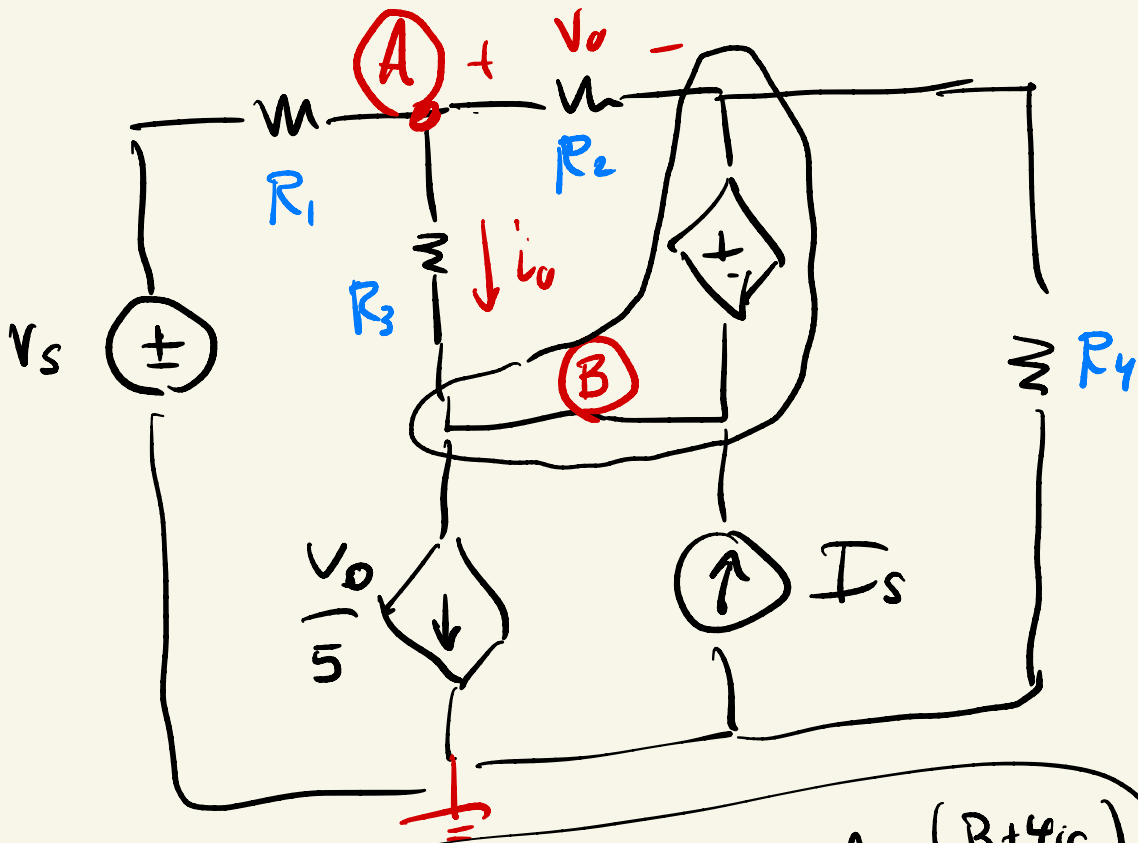




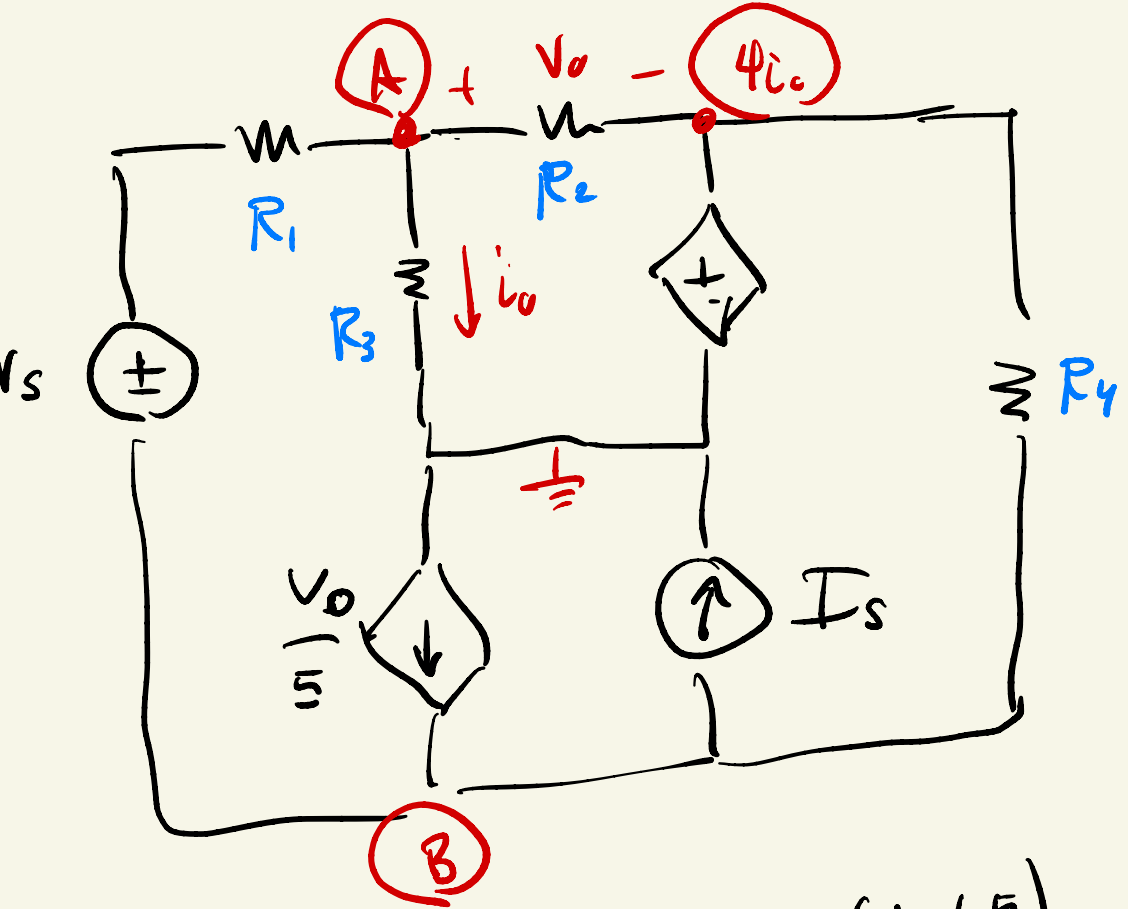
node A:

$$\frac{A - V_s}{R_1} + \frac{A - B}{R_3} + \frac{A - (B + 4i_o)}{R_2} = 0$$

$$i_o = \frac{A - B}{R_3}$$

$$V_o = A - B - 4i_o$$

$$\frac{B + 4i_o - A}{R_2} + \frac{B + 4i_o}{R_4} + \frac{B - A}{R_3} + \frac{V_o}{5} - I_s = 0$$



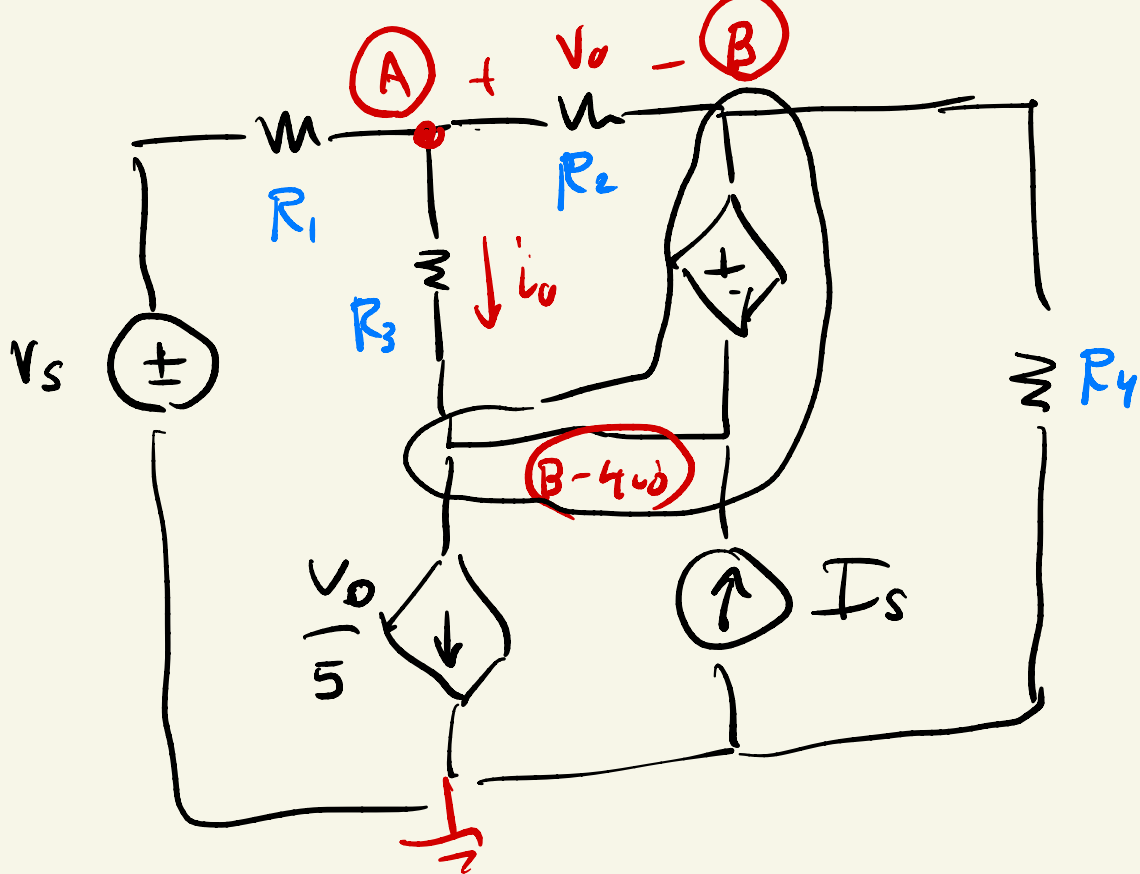
$$i_o = \frac{A}{R_3}$$

$$V_o = A - 4i_o$$

$$\frac{A - 65 - B}{R_1} + \frac{A}{R_3} + \frac{A - 4i_o}{R_2} = 0$$

$$\frac{B - (A - 65)}{R_1} - \frac{V_o}{R_2} + I_s$$

$$+ \frac{B - 4i_o}{R_4} = 0$$



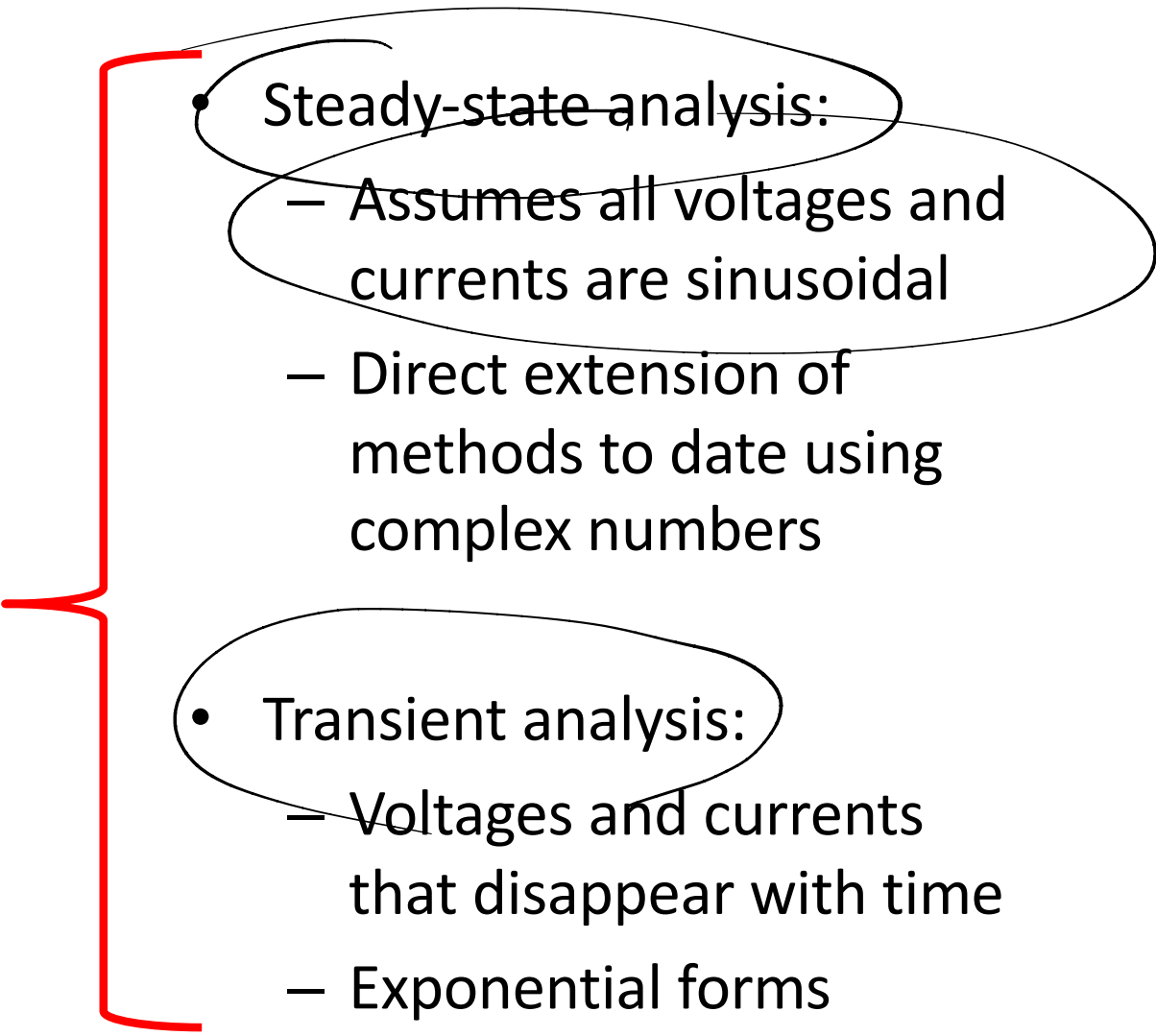
Phasors – 1

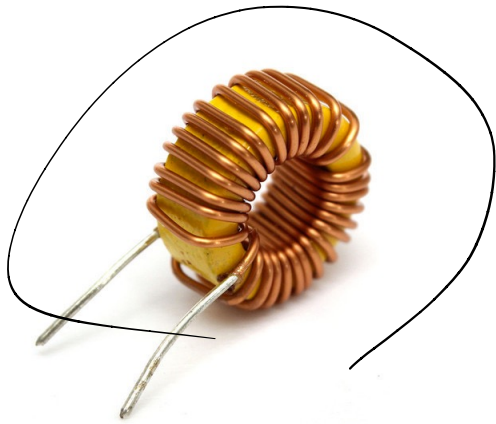
introducing L & C

So Far – Resistive DC Circuits

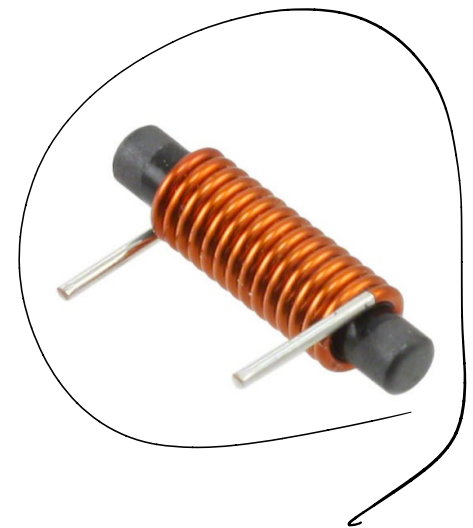
- Circuit variables
 - Voltage, current, and power
- 2-terminal components
 - Passive sign convention
 - Independent and dependent sources
 - Resistors
- Basic tools:
 - KVL, KCL, Ohm's Law
 - Extensions:
 - Series/parallel R
 - Voltage/current division
- Powerful analysis tool
 - Node method

What's Coming

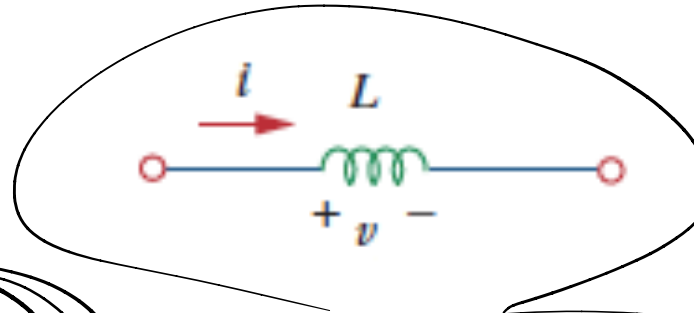
- Two new devices :
 - Inductors (L)
 - Capacitors (C)
 - Time varying voltages and currents
 - Steady-state analysis:
 - Assumes all voltages and currents are sinusoidal
 - Direct extension of methods to date using complex numbers
 - Transient analysis:
 - Voltages and currents that disappear with time
 - Exponential forms
- 



Inductor



- L (unit is Henries, H)
- V-I rules:



$$v(t) = L \frac{di(t)}{dt} \quad i(t) = \frac{1}{L} \int_0^t v(\tau) d\tau + i(0)$$

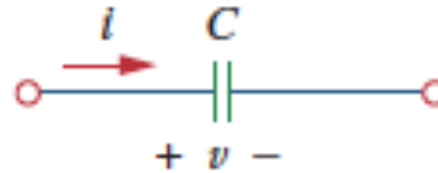
- Notes:
 - If $i(t)$ jumps then $v(t)$ would be infinite $\rightarrow i(t)$ cannot jump, it is continuous
 - If $i(t) = \text{a constant}$ then $v(t) = 0 \rightarrow$ inductor acts like a short circuit



Capacitor



- C (unit is Farads, F)
- V-I rules:

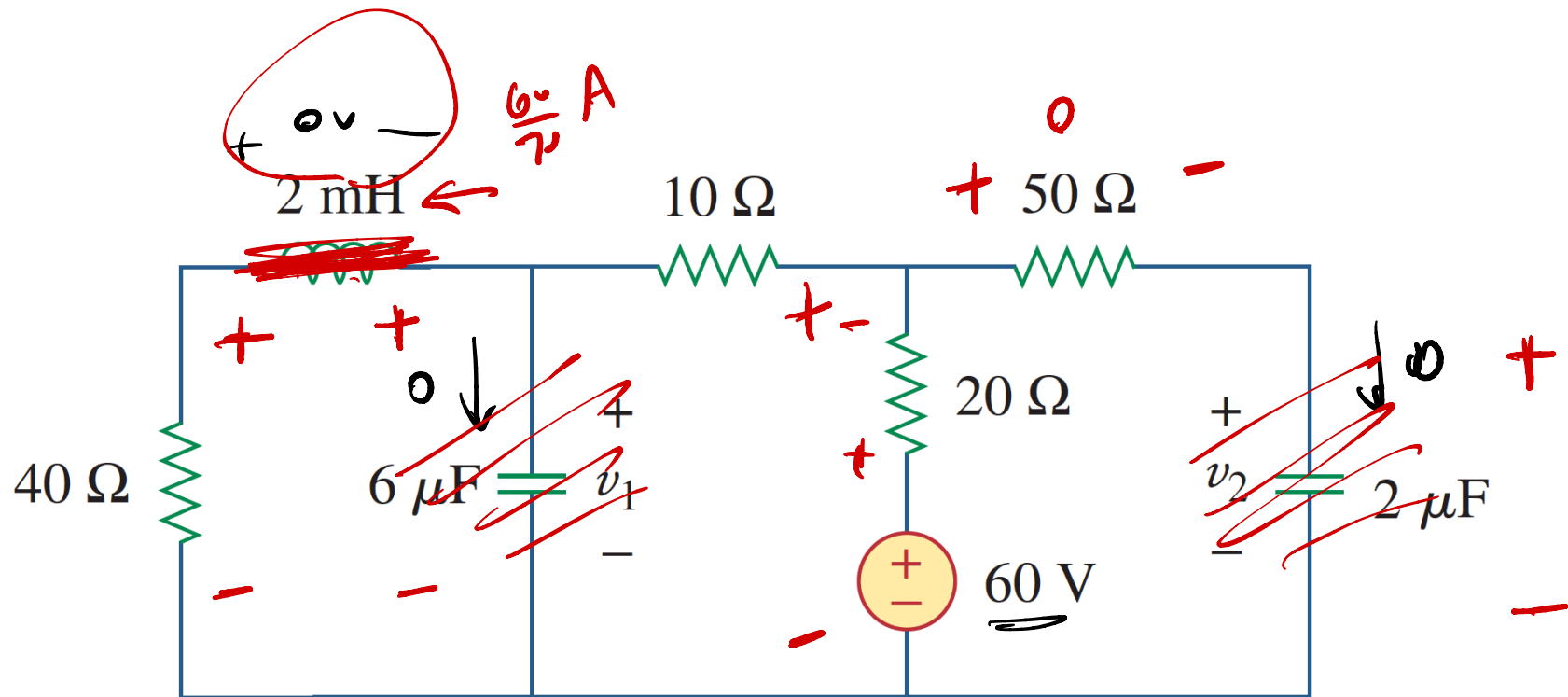


$$i(t) = C \frac{dv(t)}{dt} \quad v(t) = \frac{1}{C} \int_0^t i(\tau) d\tau + v(0)$$

- Notes:

- If $v(t)$ jumps then $i(t)$ would be infinite $\rightarrow v(t)$ cannot jump, it is continuous
- If $v(t)$ a constant then $i(t) = 0 \rightarrow$ inductor acts like an open circuit

Example: Find the voltages v_1 and v_2 for this circuit assuming constant voltage/current conditions.



Handwritten calculations and circuit diagrams:

Left side calculation (circled in red):

$$\frac{40}{70} \cdot 60 = 34.3 \text{ V}$$

Top middle calculation:

$$\frac{20}{70} \cdot 60 = 17.1 \text{ V}$$

Bottom right calculation (circled in red):

$$v_1 = \frac{40}{70} 60 = 34.3 \text{ V}, \quad v_2 = \frac{50}{70} 60 = 42.9 \text{ V}$$

Power/Energy for L & C

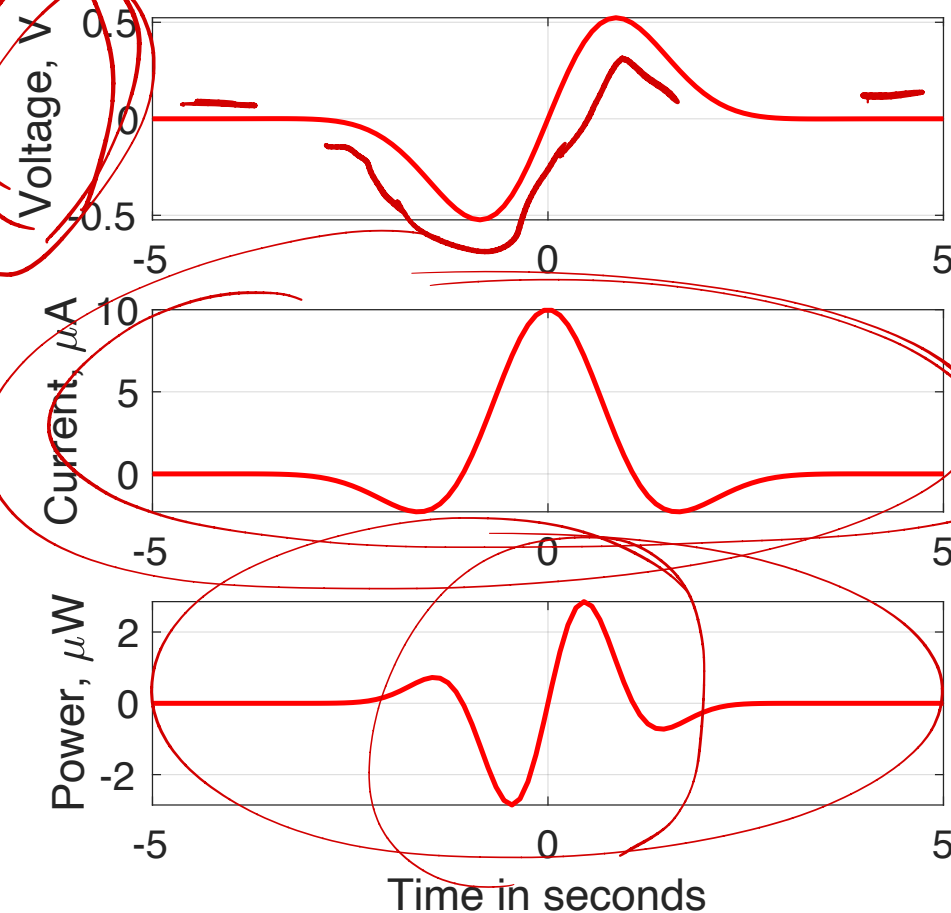
- Power

$$p(t) = v(t) i(t)$$

- Example:

10 μF capacitor

$$i(t) = C \frac{dv(t)}{dt}$$



- Energy

$$w(t) = \int p(s) ds = \int \underline{v(s)} \underline{i(s)} ds$$

– Inductor:

$$w(t) = \int L \frac{di(s)}{ds} i(s) ds = L \int i(s) di(s) = \frac{L i^2(t)}{2}$$

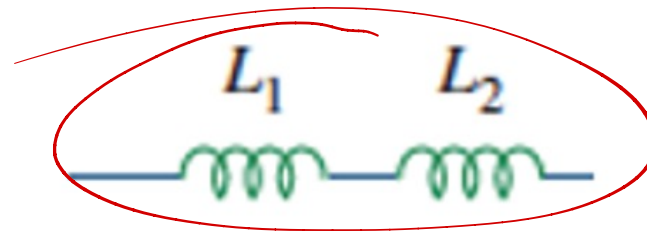
– Capacitor:

$$w(t) = \int \underline{v(s)} C \frac{dv(s)}{ds} ds = C \int v(s) dv(s) = \frac{C v^2(t)}{2}$$

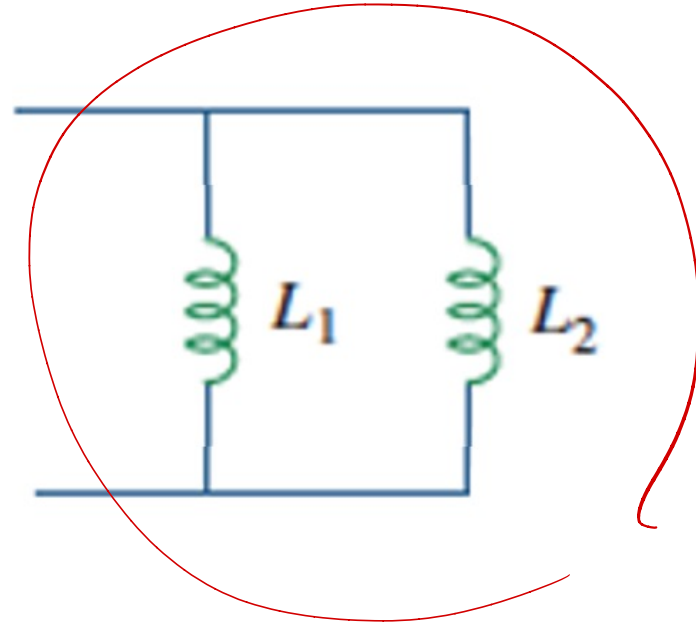
Series/Parallel Combining

- Inductors – just like resistors

$$L_{series} = L_1 + L_2$$



$$L_{parallel} = \frac{L_1 L_2}{L_1 + L_2}$$

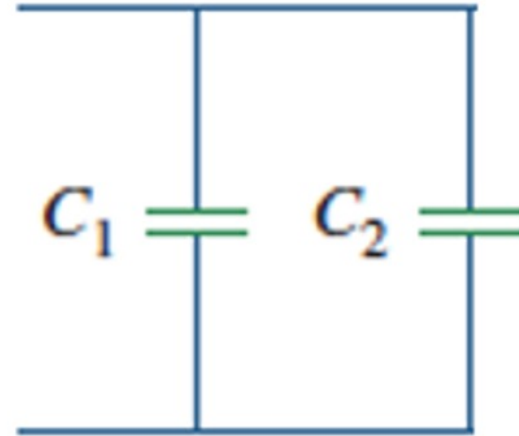


- Capacitors – just the opposite of resistors

$$C_{series} = \frac{C_1 C_2}{C_1 + C_2}$$

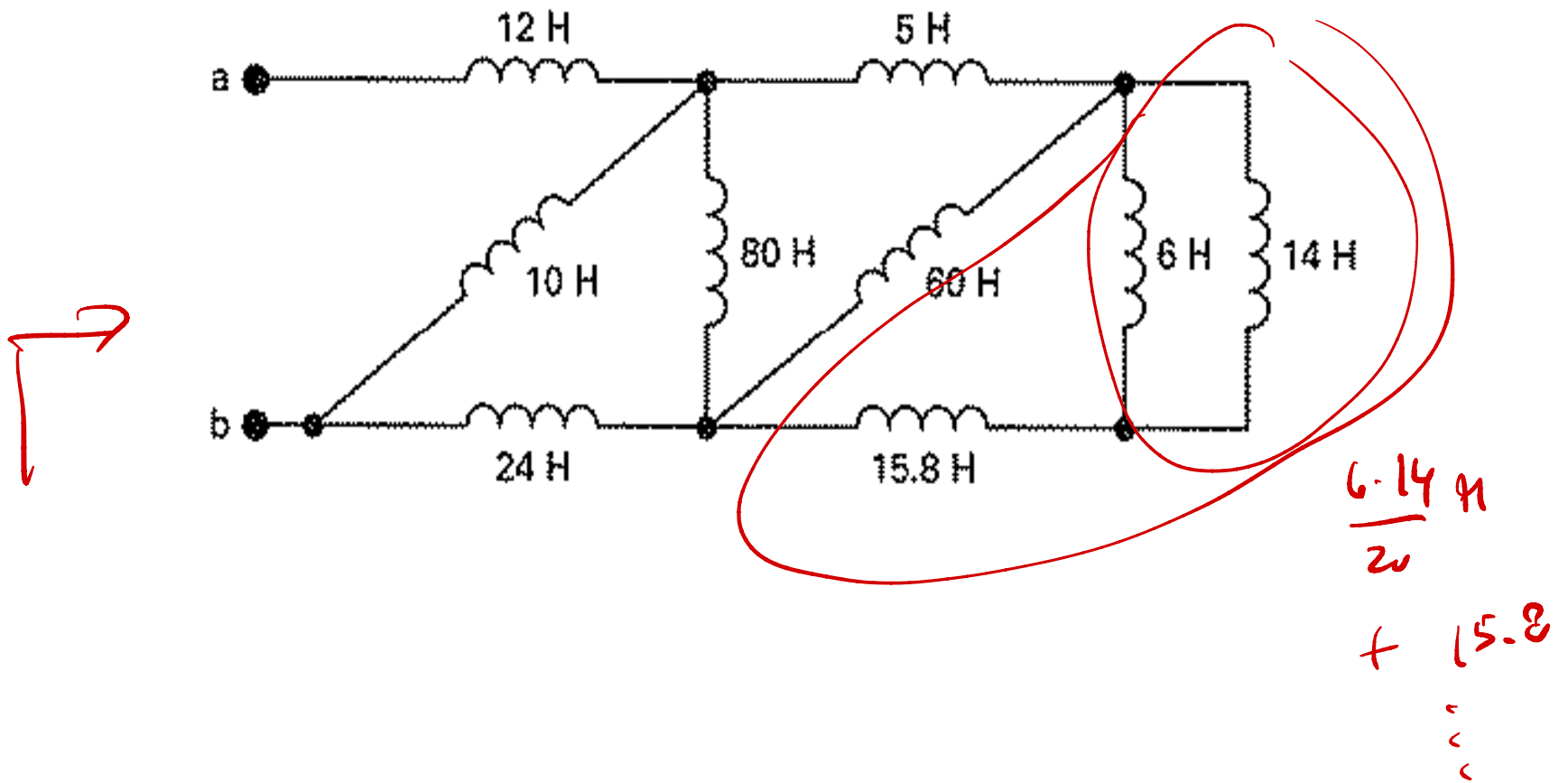


$$C_{parallel} = C_1 + C_2$$



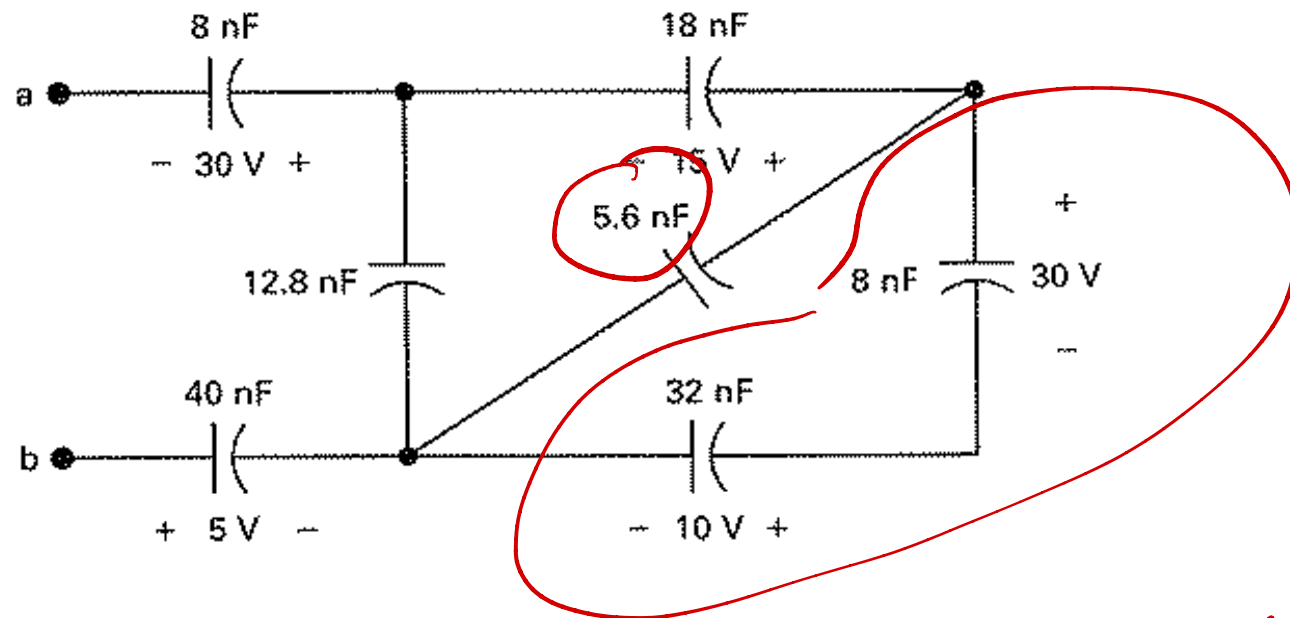
20 H

Example: find the equivalent inductance



5 nF

Example: find the equivalent capacitance

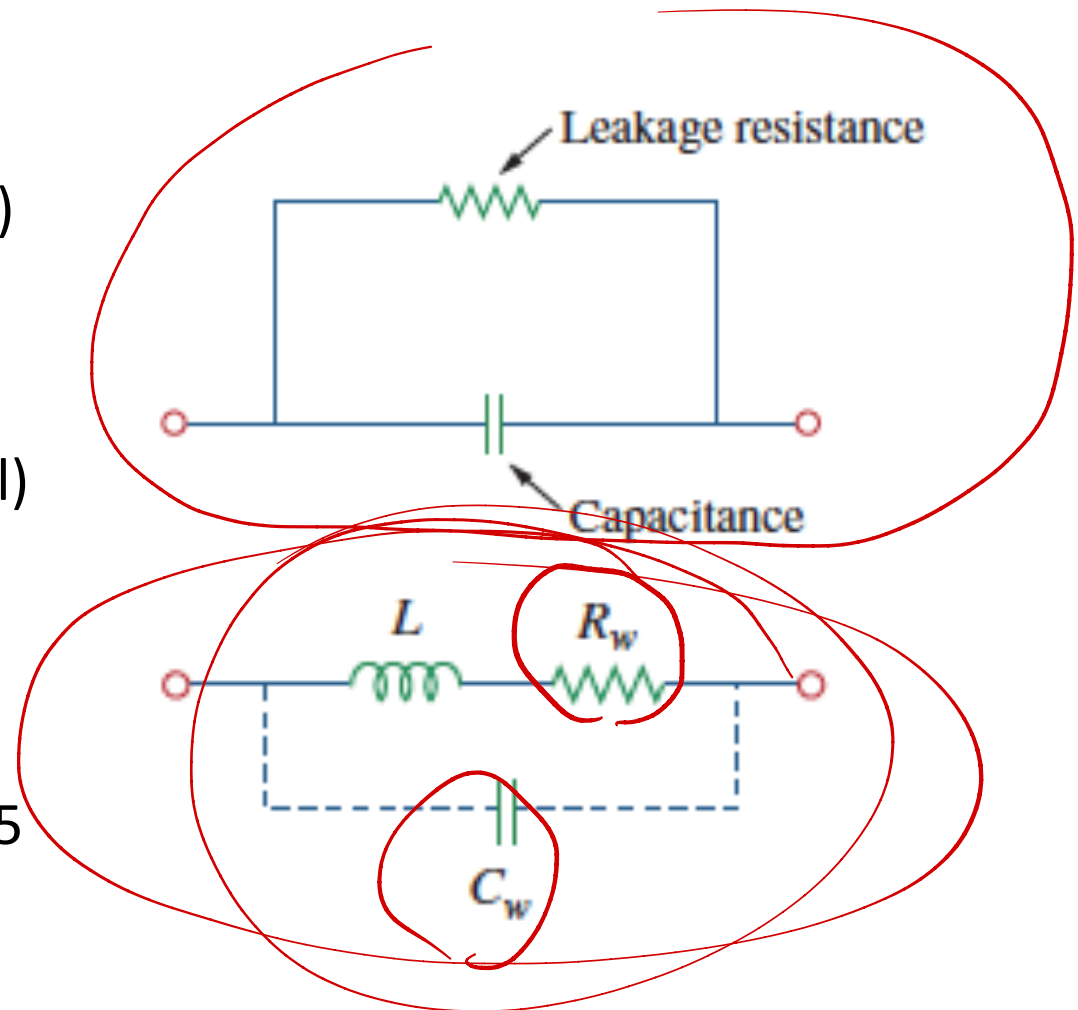


$$\frac{8\text{ nF} \cdot 32\text{ nF}}{40\text{ nF}}$$

$$+ 5.6\text{ nF}$$

More Realistic Device Models

- C:
 - Leakage resistance (large)
- L:
 - Winding resistance (small)
 - Winding capacitance (small)
- Will consider more in ELE 215



Practice problem: If a $10\ \mu F$ capacitor's voltage is $v(t) = 5(1 - e^{-10t})$ V consider it's power as a function of time. When is the power a maximum? What is that maximum? How much energy has been stored in the capacitor at this point?

0.693 sec, 625 μW , 12.5 μJ

Practice problem: A voltage of $20(1 - e^{-500t})$ volts appears across the parallel combination of a $100\ \mu F$ capacitor and a $10\ \text{ohm}$ resistor. What is the total power absorbed the the parallel combination as a function of time?

$$40 - 60e^{500t} + 20e^{-1000t}\ W$$

Practice problem: Find the inductor current and capacitor voltage assuming constant voltage/current conditions.

$$\frac{1}{3} \text{ A}, 4 \text{ V}$$

