OHM'S LAW

$V = IR$

$P = \frac{V^2}{R} = I^2 R$

KIRCHOFF'S LAWS

KCL $I_{IN} = I_{OUT}$

KVL $V_{GAINS} = V_{LOSSES}$

POWER

$P = \frac{V^2}{R} = I^2 R = VI$

SERIES

$R_{eq} = R_1 + R_2$

CURRENT IS THE SAME

$V_{R_N} = V_{TOTAL} \frac{R_N}{R_1 + R_2 + \ldots}$

$C_{eq} = \frac{1}{1/C_1 + 1/C_2 + \ldots}$

$L_{eq} = L_1 + L_2$

PARALLEL

$R_{eq} = \frac{1}{1/R_1 + 1/R_2 + \ldots}$

$I_{RN} = I_{TOTAL} \frac{1/R_N}{1/R_1 + 1/R_2 + \ldots}$

VOLTAGE SAME THROUGH EACH RESISTOR

$C_{eq} = C_1 + C_2 + \ldots$

$L_{eq} = \frac{1}{1/L_1 + 1/L_2 + \ldots}$

NODAL ANALYSIS

1. LABEL A NODE AS GROUND [IDEALLY ON ONE SIDE OF A VOLTAGE SOURCE]. LABEL OTHER NODES AS $a, b, \ldots$
2. LABEL UNKNOWN NODE VOLTAGES AS $V_a, V_b, \ldots$, AND LABEL THE CURRENT IN EACH RESISTOR AS $I_1, I_2 \ldots$
3. WRITE KIRCHOFF'S CURRENT EQUATIONS FOR EACH UNKNOWN NODE
4. REPLACE CURRENTS IN YOUR KCL WITH EXPRESSIONS LIKE THIS: $\frac{V_a - V_b}{R_1}$
5. SOLVE THE MULTIPLE EQUATIONS FOR THE MULTIPLE UNKNOWN VOLTAGES

INDUCTORS

$V_L = L \cdot \frac{di}{dt} i_L$

$i = \frac{1}{L} \int_0^t v_L dt + i_L(0)$

SINUSOIDS

$V_L(t) = \underbrace{L \cdot \omega \cdot I_P}_{V_P} \sin(\omega t)$

$i_L(t) = I_P \cos(\omega t)$

IF INDUCTOR HAS BEEN CONNECTED FOR A LONG TIME, THE INDUCTOR WILL LOOK LIKE A SHORT

CAPACITORS

$i_C = C \cdot \frac{d}{dt} V_C$

$V_L = \frac{1}{C} \int_0^t i_C dt + V_C(0)$

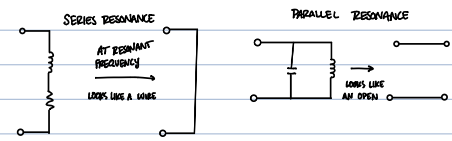
SINUSOIDS

$V_C(t) = \underbrace{\frac{1}{C} \frac{1}{\omega} I_P}_{V_P} \sin(\omega t)$

$i_C(t) = I_P \cdot \cos(\omega t)$

IF CAPACITOR HAS BEEN CHARGING FOR A LONG TIME, THE CAPACITOR WILL LOOK LIKE AN OPEN

CAPACITOR + INDUCTOR IN SERIES



RESONANT FREQUENCY

$\omega_0 = \frac{1}{\sqrt{LC}}$ OR $\omega_0 = \frac{1}{\sqrt{L_{eq} C_{eq}}}$

FIRST ORDER TRANSIENT CIRCUITS

FOR ALL FIRST ORDER TRANSIENTS

$v_x(t) = v_x(\infty) + (v_x(0) - v_x(\infty)) e^{-\frac{t}{\tau}}$

$i_x(t) = i_x(\infty) + (i_x(0) - i(\infty)) e^{-\frac{t}{\tau}}$

RC IN SERIES $\tau = R_{TH} C$

RL IN SERIES $\tau = \frac{L}{R_{TH}}$

R_{TH} WHEN $t = \infty$

TRANSIENT CIRCUITS

TRANSIENT ANALYSIS INVOLVES DIFFERENTIAL EQUATIONS

SIGNALS PROCESSING + CONTROL SYSTEMS DRIVE STUDY OF TRANSIENTS

AC

- VOLTAGES THAT CHANGE WITH TIME

$v(t) = V_P \cos(\omega t + \phi)$

$i(t) = I_P \cos(\omega t + \phi)$

$f = \frac{1}{T}$

$\omega = 2\pi f$

$\phi = \frac{-\Delta t}{T} \cdot 360 = \frac{-\Delta t}{T} \cdot 2\pi$

CONVERSION

$a + bj = \left(\sqrt{a^2 + b^2}\right) e^{j \arctan\left(\frac{b}{a}\right)}$

$e^{j\alpha} = \cos(\alpha) + j\sin(\alpha)$

$e^{j(\omega t + \theta)} = \cos(\omega t + \theta) + j\sin(\omega t + \theta)$

$\cos(\alpha) = \frac{e^{j\alpha} + e^{-j\alpha}}{2}$

$\sin(\alpha) = \frac{e^{j\alpha} - e^{-j\alpha}}{2}$

RECTANGULAR

$A \cdot D = (a + bj)(c + dj) = (ac - bd) - (bc - ad)j$

$\frac{A}{D} = \frac{a + bj}{c + dj} = \frac{ac + bd}{c^2 + d^2} + \frac{bc - ad}{c^2 + d^2} j$

POLAR

$A \cdot D = Ae^{j\theta} De^{j\phi} = AD e^{(\theta + \phi)}$

$\frac{A}{D} = \frac{Ae^{j\theta}}{De^{j\phi}} = \frac{A}{D} e^{j(\theta - \phi)}$

IMPEDANCE

$Z_L = j\omega L \qquad Z_c = \frac{-j}{\omega C} \qquad Z_R = R$

USED FOR ADDING + SUBTRACTING SINUSOIDAL WAVEFORMS

PHASOR

$$\left.\begin{array}{l} V(\omega) = V_p \cdot e^{j\phi} \\ I(\omega) = I_p \cdot e^{j\phi} \end{array}\right\} \text{FREQUENCY DOMAIN}$$

YOU CAN'T ADD VECTORS IN POLAR FORM

$$I_{Zn} = I_{TOTAL} \frac{\frac{1}{Z_n}}{\frac{1}{Z_1} + \frac{1}{Z_2} + \dots} \qquad I_{PHASOR} = \frac{V_{PHASOR}}{Z_{eq}}$$

$$V_{Zn} = V_{TOTAL} \frac{Z_n}{Z_1 + Z_2 + \dots}$$

FILTERS

- A FILTER PASSES SOME FREQUENCIES + FILTERS OUT OTHER FREQUENCIES
  - HIGH PASS: PASSES HIGH FREQUENCIES, REJECTS LOW
  - LOW PASS: PASSES LOW FREQUENCIES, REJECTS HIGH

ω_c = CORNER FREQUENCY

TRANSFER FUNCTION

$$H(s) = \frac{V_{OUT}}{V_{IN}}$$

TOP = 0 → ZERO
BOTTOM = 0 → POLE

CHARACTERISTIC EQUATION ← BOTTOM PART OF CHARACTERISTIC EQUATION

$s^2 + \_\_ s + \_\_ = 0$

LAPLACE IMPEDENCES

INDUCTOR → Ls

CAPACITOR → $\frac{1}{Cs}$

RESISTOR → R

2ND ORDER TRANSIENTS

s_1, s_2 REAL + NEGATIVE → OVERDAMPED	$b^2 - 4ac > 0$	}	$V = v(\infty) + Be^{s_1 t} + De^{s_2 t}$
s_1, s_2 EQUAL → CRITICALLY	$b^2 - 4ac = 0$	}	
UNDERDAMPED	$b^2 - 4ac < 0$	}	$V = v(\infty) + e^{\alpha t}(B\cos(\omega t) + D\sin(\omega t))$

$s_1 = \alpha + j\omega \qquad s = \alpha + j\omega$

NATURAL FREQUENCY $= \omega_n = \sqrt{\alpha^2 - \omega^2}$

TO SOLVE:
- DRAW FINAL CONDITIONS: FIND $v(\infty)$ OR $i(\infty)$
- INITIAL CONDITIONS: FIND $i(0)$ & $v(0)$
  - DRAW $t(0^-)$ [BEFORE SWITCH TURNS]
  - DRAW $t(0)$ [AFTER SWITCH TURNS]
    - i_L AND v_c CANNOT CHANGE INSTANTLY SO MODEL INDUCTORS + CURRENTS AS CURRENT + VOLTAGE SOURCES
  - SLOPE OF INITIAL CONDITIONS
    $\frac{di_L}{dt} L = V_L \qquad \frac{dV_c}{dt} C = i_C$
- USE INITIAL CONDITIONS AND/OR INITIAL SLOPES TO SOLVE TRANSIENT EQUATION

SYSTEMS

$$X_{IN}(s) \longrightarrow \boxed{H(s)} \longrightarrow X_{out}(s) = X_{in}(s) \cdot H(s)$$

DIODES

REVIEW

DO THESE

SATURDAY
- BODE PLOTS
- DIODES

MONDAY
- 2ND ORDER TRANSISTORS ~ ?
- TRANSFER FUNCTION ?
- DAMPING ?
- FILTERS ?

MAYBE:
- PHASORS

EXAM MATERIAL

- BODE PLOT
- 2ND ORDER TRANSIENTS
  - $H(s)$ FROM A CIRCUIT ← USUALLY ON FINAL
  - CHARACTERISTIC EQUATION
  - INITIAL + FINAL CONDITIONS ← WILL MOST LIKELY BE ON EXAM
  - FIND $i_L(t)$ OR $v_c(t)$

  } 10-20% POSSIBILITY
- SYSTEMS

- FEEDBACK SYSTEMS
- DIODE DC PROBLEM
  - NOTE: AC POWER + RMS IS NOT ON THIS EXAM. THEY WILL BE LATER IN CLASS

DO 2 OR 3 PRACTICE TESTS IN PREP FOR REVIEW SESSIONS