Equations

1. Constants:

$$\epsilon_0 = 8.85 * 10^{-14}\frac{F}{cm}$$
$$k = 1.386 * 10^{-23}$$

2. $P = \frac{dW}{dt} = IV$
3. $I = \frac{dq}{dt}$
4. $V = \frac{W}{q}$
5. $R = \frac{\rho L}{A}$
6. Ohm's Law: $V = IR$
7. Coulomb's Law: $\vec{F} = \frac{1}{4\pi\epsilon_0}\frac{q_1 q_2}{r^2}\hat{r}$
8. Kirchhoff's Loop Law: $\sum V_i = 0$ (around a closed loop)
9. Kirchhoff's Current Law: $\sum I_i = 0$ (going into a node)
10. Conductance: $G = \frac{1}{R}$
11. Equivalent resistance: $R_{eq} = \frac{V_{test}}{I_{test}}$
12. Series capacitance: $\frac{1}{C_{total}} = \frac{1}{C_1} + \frac{1}{C_2} + \ldots$
13. Parallel capacitance: $C_{total} = C_1 + C_2 + \ldots$
14. Series inductor: $L_{total} = L_1 + L_2 + \ldots$
15. Parallel inductor: $\frac{1}{L_{total}} = \frac{1}{L_1} + \frac{1}{L_1} + \ldots$
16. $I_{cap} = C\frac{dV}{dt}$
17. $V_{ind} = L\frac{dI}{dt}$
18. Energy stored in capacitor: $\frac{1}{2}CV^2$
19. Energy stored in inductor: $\frac{1}{2}LI^2$
20. Voltage in RC circuit:

$$v_c(\infty) + (v_c(t_0) - v_c(\infty))\, e^{(\frac{-1}{RC})(t-t_0)}$$

21. Current in RL circuit:

$$I_L(\infty) + (I_L(t_0) - I_L(\infty))\, e^{(\frac{-R}{L})(t-t_0)}$$

22. Impedance of a capacitor: $\frac{-j}{\omega C}$
23. Impedance of an inductor: $j\omega L$
24. Equivalent impedance for impedances in series:

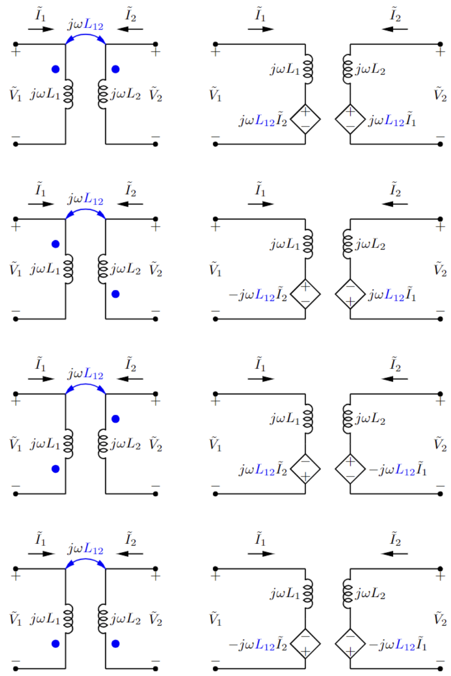
$$Z_{eq} = \sum_i^n Z_i$$

25. Equivalent impedance for impedances in parallel:

$$\frac{1}{Z_{eq}} = \sum_i^n \frac{1}{Z_i}$$

26. RMS value of signal: $S_{rms} = \sqrt{\frac{1}{T}\int_{t_0}^{t_0+T} s^2(t)dt}$
    as opposed to: $S_{avg} = \frac{1}{T}\int_{t_0}^{t_0+T} s(t)dt$
27. Maximum power extracted in DC circuits: $\frac{Vth^2}{4R_{th}}$
28. Maximum power extracted in AC circuits: $\frac{|\tilde{V}_{th}|^2}{8R_{th}}$
29. Resonant Frequency: $\omega_R = \frac{1}{\sqrt{LC}}$ with $Z_{eq} = \mathrm{Re}(Z_{eq})$
30. Average power: $P_{avg} = \frac{V_m I_m}{2}\cos(\theta_v - \theta_i)$
31. Reactive power: $V_{ar} = \mathrm{Im}(\frac{1}{2}\tilde{V}\tilde{I}^*)$
32. Apparent power: $P_{app} = \frac{|V_{rms}|^2}{|z|}$
33. Coupling coefficient in coupled circuit: $k = \frac{L_{12}}{\sqrt{L_1 L_2}}$
34. Voltage in magnetically coupled coils:

$$v_1(t) = L_1\frac{di_1(t)}{dt} + L_{12}\frac{di_2(t)}{dt}$$
$$v_2(t) = L_1\frac{di_2(t)}{dt} + L_{12}\frac{di_1(t)}{dt}$$



35. Voltage in ideal transformer:

$$\frac{v_2(t)}{v_1(t)} = \frac{N_2}{N_1}$$
$$\frac{i_2(t)}{i_1(t)} = -\frac{N_1}{N_2}$$

36. Terminated transformer circuit equations:

$$\tilde{V}_1 = \tilde{V}_2\frac{1}{n} \equiv \tilde{V}_2\frac{n_1}{n_2}$$
$$\tilde{I}_{out} = \frac{\tilde{I}_{in}}{n}$$
$$\tilde{V}_{in} = Z_{in}\tilde{I}_{in} + \tilde{V}_1$$
$$\tilde{V}_2 = Z_{out}\tilde{I}_{out}$$
$$\tilde{V}_2 = Z_{out}\frac{\tilde{I}_{in}}{n}$$
$$\frac{\tilde{V}_{in}}{\tilde{I}_{in}} = Z_{in} + \frac{Z_{out}}{n^2}$$
$$Z_1 = \frac{Z_{out}}{n^2}$$

37. Energy stored in magnetically coupled circuit:

$$E = \frac{1}{2}L_1 i_1^2 + \frac{1}{2}L_2 i_2^2 + L_{12} i_1 i_2$$

38. Kinetic energy of electron in conductance band:

$$K = E_{photon} - E_{gap} = \frac{hc}{\lambda} - E_{gap}$$

39. Equilibrium in pn junction: $pn = n_i^2$
$p \approx N_A = \rho_{h^+} \rightarrow III$ and $n \approx N_D = \rho_{e^-} \rightarrow IV$

I	II	III	IV	V	VI	VII	VIII
1 H Hydrogen							2 He Helium
3 Li Lithium	4 Be Beryllium	5 B Boron	6 C Carbon	7 N Nitrogen	8 O Oxygen	9 F Fluorine	10 Ne Neon
11 Na Sodium	12 Mg Magnesium	13 Al Aluminum	14 Si Silicon	15 P Phosphorus	16 S Sulfur	17 Cl Chlorine	18 Ar Argon
19 K Potassium	30 Zn Zinc	31 Ga Gallium	32 Ge Germanium	33 As Arsenic	34 Se Selenium	35 Br Bromine	36 Kr Krypton
37 Rb Rubidium	48 Cd Cadmium	49 In Indium	50 Sn Tin	51 Sb Antimony	52 Te Tellurium	53 I Iodine	54 Xe Xenon
55 Cs Cesium	80 Hg Mercury	81 Tl Thallium	82 Pb Lead	83 Bi Bismuth	84 Po Polonium	85 At Astatine	86 Rn Radon

40. Current in pn junction:

$$J_N = q\mu_n n E_x + qD_n \frac{dn}{dx}$$

$$J_P = -qD_p \frac{dp}{dx} + q\mu_p p E_x$$

41. Width of depletion region:

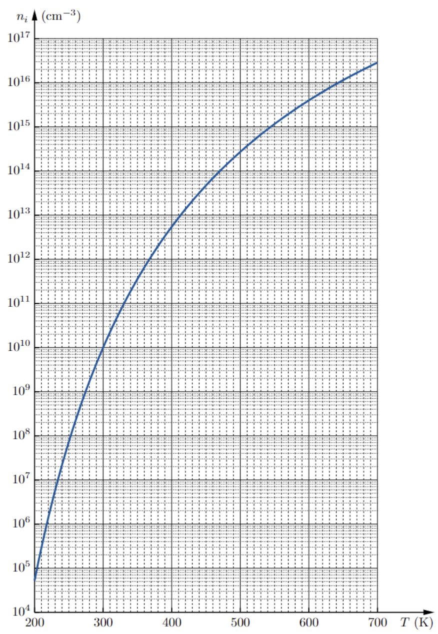
$$W = \left[\frac{2\epsilon_r \epsilon_0}{q} \left(\frac{N_A + N_D}{N_A N_D} \right) V_{bi} \right]^{1/2}$$

42. Built-in potential: $V_{bi} = \frac{kT}{q} \ln \left(\frac{N_A N_D}{n_i^2} \right)$

43. Charge on each side of depletion region:
$Q = q * \frac{N_A N_D}{N_A + N_D} * W A_{crosssec.}$

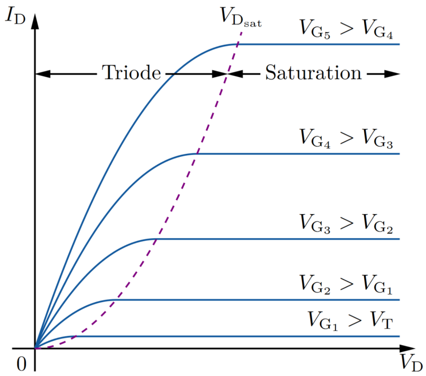
44. Depletion region width: $N_D x_n = N_A x_p$

45. Constants relevant to semiconductors:
$\epsilon_0 = 8.85 * 10^{-14} F/cm$
$k = 1.386 * 10^{-23}$
$hc = 1240 eV * nm$
$q = 1.6 * 10^{-19} C$
n_i can be found through the following table:



46. Current through non-ideal diode: $I = I_0(e^{qV_A/kT} - 1)$

47. $I_D - V_D$ characteristic graph:



48. Transistor equations:

$$V_{DS} = V_D - V_S$$

$$V_{GS} = V_G - V_S$$

$$k = \mu_n C_{ox} \left(\frac{W}{L} \right)$$

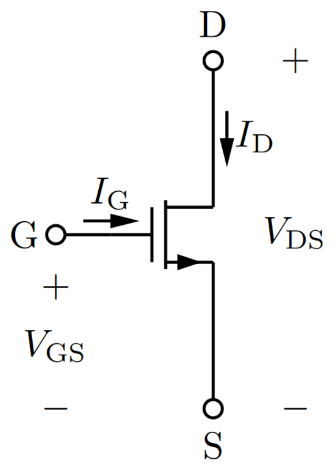
$$I_D = k \left[(V_{GS} - V_T) V_{DS} - \frac{1}{2} V_{DS}^2 \right] \begin{cases} V_{DS} \leq V_{GS} - V_T \\ V_D \leq V_G - V_T \end{cases}$$

$$I_D = k \left[\frac{1}{2} (V_{GS} - V_T)^2 \right] \begin{cases} V_{DS} \geq V_{GS} - V_T \\ V_D \geq V_G - V_T \end{cases}$$

49. Condition for CSA distortion less than 10% (Small Signal Amplification) : $v_{\hat{g}} < 0.2(V_G - V_T)$

50. Gain of a CSA: $A = -R_D k(V_G - V_T) = -g_m R_D$

51. Schematic of a MOSFET:



To find Thevenin voltage and Norton current:

(R_{eq}) Turn off all independent sources (dependent sources remain unchanged) and calculate the resulting resistance at the desired port. Notice that you may have to apply the i-v test if resistors cannot be combined through series and parallel connections, or if the circuit includes dependent sources.

(V_{th}) Leave the desired port open-circuited (i.e. no load connected) and find the voltage across it.

(I_N) Short-circuit the desired port (i.e. connect a short circuit across the port) and find the current through it.