Chapter 1

$$ \begin{align} i(t)&=\frac{dq}{dt} \Leftrightarrow q(t)=\int i(t)\cdot dt\ P&=v\times i=i\times \frac{W}{q}\ v&=\frac{W}{q} \Leftrightarrow W=v\times q = \int v\times i \cdot dt\ \end{align} $$

Chapter 4

$$ \begin{align} \text{Load line: } i_x &= -\frac{v_x}{R_T}+ \frac{v_t}{R_T}\ \text{General: } A_v &= \frac{v_{out}}{v_{in}}\ \text{Inverting: } A_v &= -\frac{R_f}{R_{in}}\ \text{Non Inverting: } A_v &= 1+\frac{R_f}{R_{in}}\ \end{align} $$

Inverting

Non-inverting

Chapter 5

Capacitor

$$ \begin{align} C &= \frac{q}{v}\ i(t) = C\frac{dv}{dt} &\Leftrightarrow v(t) = \frac{1}{C}\int_0^t i(t)\cdot dt\ \text{Series: }\frac{1}{C_T} &= \sum^N_{i=0}\frac{1}{C_i}\ \text{Parallel: }C_T &= \sum^N_{i=0}C_i\ \text{Energy: }E &= \frac{1}{2}Cv^2 \end{align} $$

Differential equation solution

Where $v_s=v_\infty$:

$$ \begin{align}

```
\tau &= R\times C\\

v_C(t) &=
\begin{cases}
    \begin{array}{lr}
        v_0                               & t\leq 0\\
        v_\infty+(v_0-v_\infty)e^{-t/\tau}      & t > 0
    \end{array}
\end{cases}\\

& v_0 e^{-t/\tau} \text{ (Natural response, no input)}\\
& v_\infty\left(1-e^{-t/\tau}\right) \text{ (Forced response, input)}\\

i_C(t) &= \frac{v_s-v_C(t)}{R}=\frac{-(v_0-v_\infty)e^{-t/\tau}}{R}
```

\end{align} $$

1. Remove all independent sources, find equivalent resistance and capacitance, find τ.
2. Set C as open circuit, find initial capacitor voltage v_0 at $t=0$
3. Set C as open circuit, find final capacitor voltage v_∞ at $t\to\infty$

Inductor

$$ \begin{align} L &= \frac{\lambda}{i}\ v(t)=L\frac{di}{dt} &\Leftrightarrow i(t)=\frac{1}{L}\int_0^tv\cdot dt\ \text{Series: }L_T &= \sum^N_{i=0}L_i\ \text{Parallel: }\frac{1}{L_T} &= \sum^N_{i=0}\frac{1}{L_i}\ \text{Energy: }E &= \frac{1}{2}Li^2 \end{align} $$

Differential equation solution

Where $v_s/R=i_\infty$:

$$ \begin{align}

```
\tau &= \frac{L}{R}\\

i(t) &=
\begin{cases}
    \begin{array}{lr}
        i_0                                     & t\leq 0\\
        i_\infty+(i_0-i_\infty)e^{-t/\tau}      & t > 0
    \end{array}
\end{cases}\\

& i_0 e^{-t/\tau} \text{ (Natural response, no input)}\\
& i_\infty\left(1-e^{-t/\tau}\right) \text{ (Forced response, input)}\\
```

\end{align} $$

Voltage drop in DC for capacitor and inductor at steady state

```
CAPACITOR:          INDUCTOR:
v_T _               v_T _
    |   <- V_1          |   <- V_1
C1  = ) <- V_D1     L1  3 ) <- V_D1
    |                   |
C2  =               C2  3
    |                   |
   ...                 ...
    |                   |
CN  =               LN  3
    |                   |
GND *               GND *
```

Capacitor

Current through capacitors in series is the same, so all capacitors have same charge stored q.

$$ \begin{align} \text{Voltage drop over capacitor i: } v_{Di} &= v_T\frac{C_T}{C_i}\ \text{Voltage divider: } v_i &= v_T\frac{C_T}{\frac{1}{C_i}+\frac{1}{C_{i+1}}+\dots+\frac{1}{C_N}}\ \end{align} $$

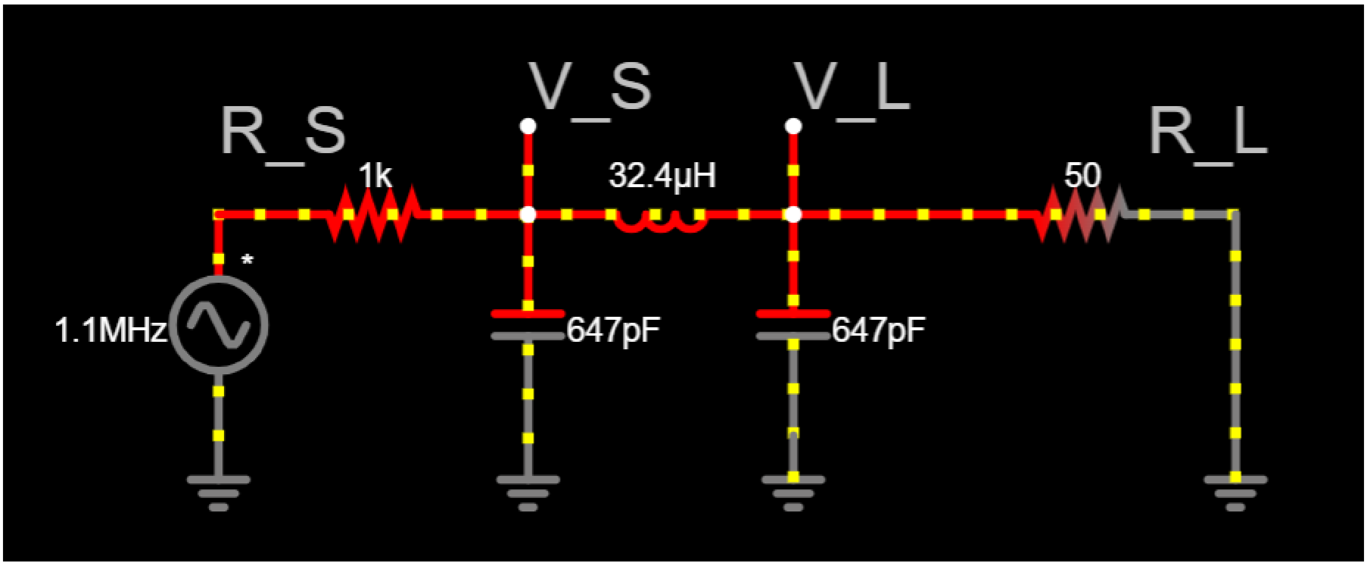
Inductor

No voltage drop in steady state (Inductor is a short circuit)

Chapter 7

Maximum power transfer in AC

$$ \begin{align} \text{Condition: } &\overline{Z_L} = \overline{Z_S^*}\ \text{Maximum power to load (50%): } &2P_\text{avg}=P_\text{rms}\cdot\sqrt{2} = P_\text{max} = \frac{{|V_S|}^2}{4R_S}\ & = \frac{{|V_L|}^2}{4R_L}\ \text{Total maximum power: } &2P_\text{avg}=P_\text{rms}\cdot\sqrt{2} = P_\text{max} = \frac{{|V_S|}^2}{2R_S} \end{align} $$



Complex Power

Where $\bar{V}=V\angle\theta$ and $\bar{I}=I\angle\phi$:

$$ \begin{align} \text{Complex [VA]: }\bar{S} &= \bar{V}*\text{rms}\times \bar{I}*\text{rms}^* = \frac{\bar{V}\times \bar{I}^*}{2} = \frac{VI}{2}\angle(\theta-\phi)\

```
\text{Apparent [VA]: } |S|\\
\text{Real [W]: } P &= |S| \cos(\theta-\phi) = \text{Re}(\bar{S})\\
\text{Reactive [VAR]: } Q &= |S| \cos(\theta-\phi) = \text{Im}(\bar{S})\\
Q &= P\tan(\arccos(\text{Power factor}))\\
\text{Power Factor} &= \frac{P}{|S|} = \cos\left(\arctan\left(\frac{Q}
{P}\right)\right)
```

\end{align} $$

Where $\bar{S}=|S|\angle\varphi$

$$ \varphi = \arctan\left(\frac{Q}{P}\right)$$

	Lagging	**Leading**
Voltage	Current behind	Current ahead
Load type	Inductive	Capacitive
Q	$Q>0$	$Q<0$
φ	$\varphi>0$	$\varphi<0$

Chapter 8

Constants

$$ \mu_0=4\pi \times 10^{-7} $$

$$ \begin{align} \text{Faraday's law: }\varepsilon &= -N\frac{d\varPhi}{dt}\ \text{Ampere's law: }B &= \frac{\mu_0 I}{2\pi r}\ \end{align} $$

Transformer

Step up: $n>1$
Step down: $n<1$

$$ \begin{align} \frac{V_s}{V_p} &= \frac{N_s}{N_p}=\frac{i_p}{i_s}=n\ \bar{Z}_{in} &= \frac{1}{n^2}\bar{Z}_L \end{align} $$

Motor

For permanent motors, define permanent torque constant $k_{TP}=k_T\varPhi$

$$ \begin{align} T &= k_T\times\varPhi \times i_a = k_{TP} \times i_a\ P_\text{mech} &= \omega_\text{mech} T = \omega_\text{mech} \times k_{TP}\times i_a \end{align} $$

Back emf

Define for permanent motors, define permanent armature constant $k_{aP} = k_a\varPhi$
Note, back emf should oppose v_a and i_a

$$ \begin{align} e_b=k_a\times \varPhi\times \omega_\text{mech} = k_{aP} \times\omega_\text{mech}\ \end{align} $$

Summary

For ideal motor, torque and armature constants are the same: $k_a=k_T$
Define p as number of magnetic poles and M as the number of parallel paths in armature winding.

$$ \begin{align} \text{Power dissipated: } P_e &= e_b\times i_a = k_{aP} \times \omega_\text{mech} \times i_a\ \text {Constants for ideal motor: } k_a &= k_T = \frac{pN}{2\pi M}

\end{align} $$

For permanent magnet DC motor in DC steady state:
Define viscous frictional damping coefficient b and load torque T_L

$$ \begin{align} &\begin{cases}

```
        0 &= v_a - i_a R_a - k_{aP} \omega_\text{mech} = v_a - i_a R_a - e_b \\
        k_{TP} i_a &= T_L + b\times \omega_\text{mech}

  \end{cases}\\

  &\text{Analog speed control (Voltage): } T = \frac{k_{TP}}{R}v_s -
  \frac{k_{TP}k_{aP}}{R} \omega_\text{mech}\\

  &\text{Analog speed control (Current): } T = \frac{k_{TP}R_S}{R}i_s -
  \frac{k_{TP}k_{aP}}{R} \omega_\text{mech}
```

\end{align} $$