Revisit open reflection
- doubling & doubling
- 2 waves a line

Talking about transmission lines - homes for TEM waves
- waveguides house TE/TM waves

Characteristic impedance lets us describe waves in their homes
- relates $I$ & $V$ at one point
  \[ Z_0 = \sqrt{\frac{L}{C}} \]

Propagation coefficient lets us relate waves @ 2 points
- $\gamma = \alpha + j\beta$
- \[ V(z) = V_0 e^{-\gamma z} \]
- \[ t(z) = \frac{d}{dz} \]

Recall a plane wave complex exponential is $A e^{j(\omega t-kz)}$

Generalized this $V(z)$ equation to define variable reflection co-efficient and impedance $Z(z)$ & $\Gamma(z)$

Reflection coefficient discusses how a finite line interacts with a load
- $\Gamma = \frac{Z_L-Z_0}{Z_L+Z_0}$
- when $V_L = 0$

Generates a reflection where extra current has to go somewhere

Can use this wave description to write voltage on line
\[ V(z) = V_0 e^{-\gamma z} + V_{0e} e^{\gamma z} \]
\[ = V_0 e^{j(\omega t-kz-\frac{\gamma z}{2})} + V_{0e} e^{j(\omega t-kz+\frac{\gamma z}{2})} \]
From this we've learned 3 key skills we want to practice:

- Transmission line propagation modeling
- Calculating reflection coefficients
- Calculating line properties from geometry

-HW be hard to do by hand

-But \( Z_0 = \sqrt{\frac{1}{\lambda}} \Rightarrow V \approx \frac{1}{\sqrt{\lambda}} \)
- Know how to sketch fields + IV

Calculate \( \Gamma \) for these situations:

1. \( Z_L = \infty \)
   - Note: input voltage is \( V/2 \)
   - \( \Gamma = \frac{\infty - Z_0}{\infty + Z_0} = 1 \)
2. \( Z_L = 0 \)
   - No source impedance here
   - No reflection on incident wave \( \frac{1}{Z_0} \) lumped model
   - \( \Gamma_L = 1 \) and \( \Gamma_S = -1 \)

3. \( Z_L = \frac{Z_0}{2} \)
   - Frequency dependent
   - Complex, results in phase
   - Both OK — harder for squares

4. \( Z_L = \frac{14 \lambda - Z_0}{\sqrt{10 \lambda + Z_0}} \)

5. \( Z_L = Z_0 / \| Z_{\text{line}} = Z_0 \)
   - Load impedance is \( Z_0/\| Z_{\text{line}} = Z_0 \)
   - \( \Gamma_L = 0 \)
   - And line is \( \infty \), what about reflections?

\( Z(\lambda) \) describes impedance of terminated line away from load.
Modeling propagation
- revisit last class example, lossless line w/ open term

\[ V_{in} \text{ is boundary cond. to wave eq. on t-line} \]
- per custom, set \( z = 0 \) to be load location
- Let \( V = \frac{1}{10} \frac{1}{\sqrt{s}} \)

1) \( V \)
- \( t = 0.5 \text{ ns} \)
- nothing asserted yet, no wave
- rising edge propagates then falling edge
- \( \text{sol. is } V_{in}(t - z/v) \)
- \( u \) for reflected wave, can imagine \( 16 \) at \( 2L \)
- not using \( V_{in} e^{-2z} \) be phase tricky

2) \( V \)
- \( t = 10 \text{ ns} \)
- just reach load

3) \( V \)
- \( t = 19.5 \text{ ns} \)
- wave just gets eaten by input term.