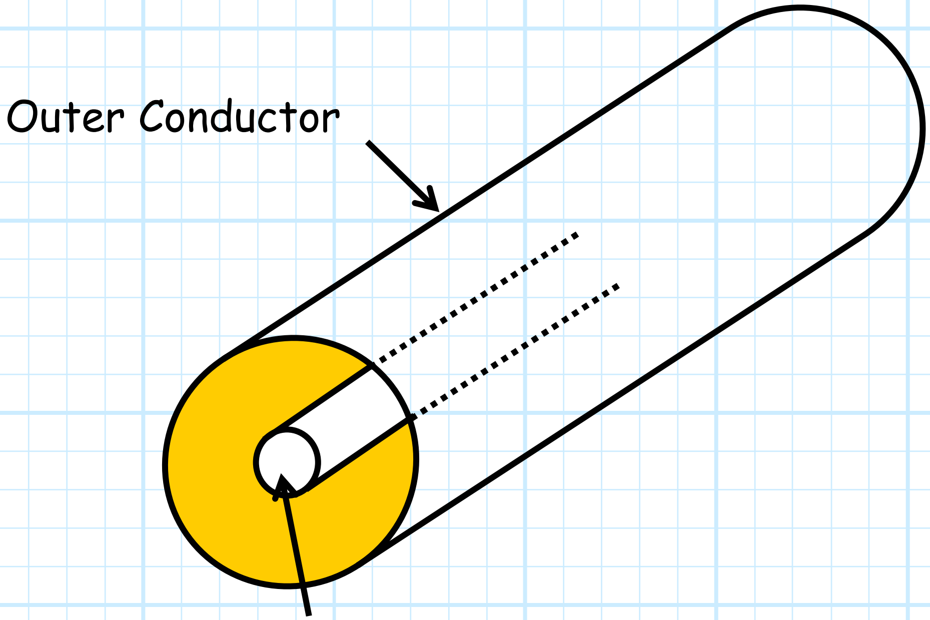
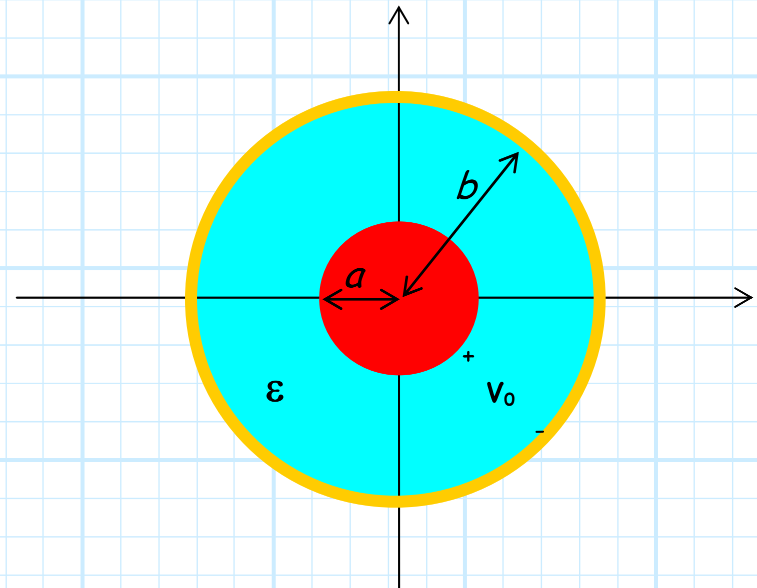
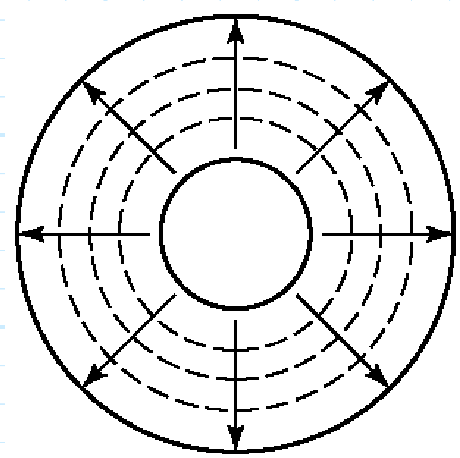
Coaxial Transmission Lines

The most **common** type of transmission line!





Coax Cross-Section



The **electric** field (⟶)points in the direction $\hat{a}_\rho$.

The **magnetic** field (- - - -)points in the direction $\hat{a}_\phi$.

E. M. Power flows in the direction $\hat{a}_z$. ➡ A TEM wave!

Remember EECS 220!!!

Recall from EECS 220 that we can use **electrostatics** to determine the **capacitance** per/unit length of a coaxial transmission line:

$$C = \frac{2\pi\varepsilon}{\ln[b/a]} \qquad \left[\frac{\text{farads}}{\text{meter}}\right]$$

And from **magnetostatics** we find that the **inductance** per unit length is :

$$L = \frac{\mu_0}{2\pi}\ln\left[\frac{b}{a}\right] \qquad \left[\frac{\text{Henries}}{\text{m}}\right]$$

Combining these results, the **characteristic impedance** of a coaxial transmission line is:

$$Z_o = \sqrt{\frac{L}{C}} = \frac{1}{2\pi}\sqrt{\frac{\mu_0}{\varepsilon}}\ln\left[\frac{b}{a}\right]$$

and so:

$$\beta = \omega\sqrt{LC} = \omega\sqrt{\mu_0\,\varepsilon}$$

TEM Wave Propagation

Therefore the **propagation velocity** of each TEM wave within a coaxial transmission line is:

$$v_p = \frac{\omega}{\beta} = \frac{1}{\sqrt{\mu_0\,\varepsilon}} = \frac{1}{\sqrt{\mu_0\,\varepsilon_0}}\,\frac{1}{\sqrt{\varepsilon_r}} = c\,\frac{1}{\sqrt{\varepsilon_r}}$$

where $\varepsilon_r = \varepsilon/\varepsilon_0$ is the relative dielectric constant, and c is the "speed of light" ($c = 3\times 10^8\ m/s$).Note then that we can likewise express β in terms ε_r:

$$\beta = \omega\sqrt{\mu_0\,\varepsilon} = \omega\sqrt{\mu_0\,\varepsilon_0}\,\sqrt{\varepsilon_r} = \frac{\omega}{c}\sqrt{\varepsilon_r}$$

Coax Geometry and Size

Now, the **size** of the coaxial line (*a* and *b*) determines **more** than simply Z_0 and β (*L* and *C*) of the transmission line. Additionally, the line radius determines the **weight** and bulk of the line, as well as its **power handling** capabilities.

Unfortunately, these two characteristics **conflict** with each other!

1. Obviously, to **minimize** the weight and bulk of a coaxial transmission line, we should make *a* and *b* as **small** as possible.

2. However, for a given line voltage, reducing *a* and *b* causes the **electric field** within the coaxial line to **increase** (recall the units of electric field are *V/m*).

A higher electric field causes **two** problems: first, it results in greater **line attenuation**; second, it can result in **dielectric breakdown**.

Dielectric breakdown results when the electric field within the transmission line becomes so large that the dielectric material is **ionized**. Suddenly, the dielectric becomes a **conductor**, and the value *G* gets **very** large!

This generally results in the **destruction** of the coax line, and thus must be **avoided**. Thus, **large** coaxial lines are required when extremely **low-loss** is required (i.e., line length ℓ is large), **or** the delivered **power** is large.

Otherwise, we try to keep our coax lines as **small** as possible!