PHY 712 Electrodynamics
11-11:50 AM MWF Olin 107

Plan for Lecture 22:

Continue reading Chap. 8

A. Examples of waveguides

B. TEM, TE, TM modes

C. Resonant cavities

16	02-22(Fri)	Chap. 6	Maxwell's equations	Exam
17	02-25(Mon)	Chap. 6	Poynting Vector	#11
18	02-27(Wed)	Chap. 7	Reflectance and transmittance of electromagnetic plane waves	#12
19	02-28(Thur)	Chap. 7	Anisotropic media	#13
20	03-01(Fri)	Chap. 7	Dielectric models; Kramers-Kronig Relations	#14
21	03-04(Mon)	Chap. 8	TEM modes	#15
22	03-06(Wed)	Chap. 8	TE and TM modes	#16
23	03-07(Thur)	Chap. 8	Electromagnetic standing waves	
24	03-08(Fri)	Chap. 9		
	03-11(Mon)	*Spring Break*		
	03-13(Wed)	*Spring Break*		
	03-15(Fri)	*Spring Break*		
	03-18(Mon)	*APS Meeting*	(no class)	Exam
	03-20(Wed)	*APS Meeting*	(no class)	Exam
	03-22(Fri)	*APS Meeting*	(no class)	Exam
25	03-25(Mon)	Chap. 9		
26	03-27(Wed)	Chap. 9		
27	03-28(Thur)			
	03-29(Fri)	*Good Friday*		
28	04-01(Mon)			

Reminders:

- Topic choice for "computational project" due Friday 3/8/2013 (via email or written on paper)
- Outstanding homework due before 3/13/2013 (when mid term grades are due)
- Exam 2 will be available after 3/13/2013 and is due 3/25/3013

WFU Physics Colloquium

TITLE: Conformational dynamics that allow proteins to detect DNA mismatches and signal for repair

SPEAKER: Professor Keith Weninger,

Department of Physics,
North Carolina State University, Raleigh, North Carolina

TIME: Wednesday March 6, 2013 at 4:00 PM

PLACE: Room 101 Olin Physical Laboratory

Refreshments will be served at 3:30 PM in the Olin Lounge. All interested persons are cordially invited to attend.

ABSTRACT

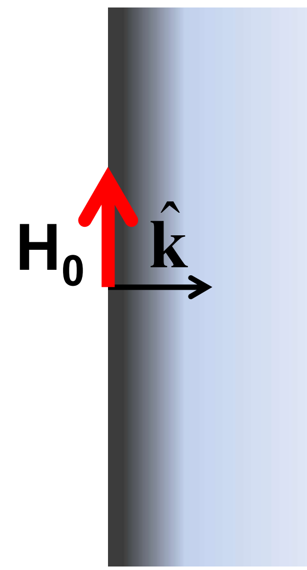
The DNA mismatch repair system is critical for accurate DNA replication. This system is highly conserved across organisms ranging from bacteria to humans reflecting the importance of minimizing genomic defects during cell division. The mismatch repair protein MutS has been identified the key factor that detects single DNA base mismatches and signals for their repair. A temporally resolved understanding of the molecular details of the MutS:DNA interactions during mismatch repair initiation has been difficult to obtain because these transient interactions occur within an overwhelming background of properly matched DNA basepairs.

Boundary values for ideal conductor

Inside the conductor:

$$\mathbf{H}(\mathbf{r},t) = e^{-\hat{\mathbf{k}}\cdot\mathbf{r}/\delta}\,\Re\left(\mathbf{H}_0 e^{i\hat{\mathbf{k}}\cdot\mathbf{r}/\delta - i\omega t}\right)$$

$$\mathbf{E}(\mathbf{r},t) = \delta\mu\omega\frac{1-i}{2}\hat{\mathbf{k}}\times\mathbf{H}(\mathbf{r},t)$$

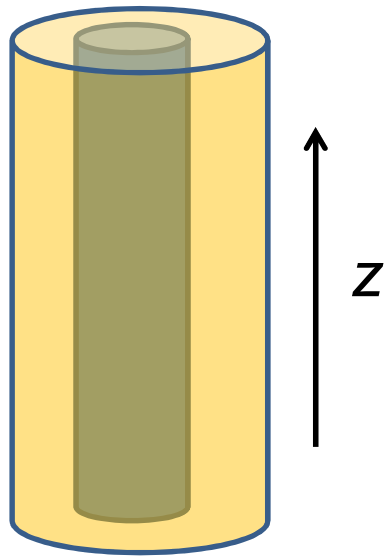


At the boundary of an ideal conductor, the **E** and **H** fields decay in the direction normal to the interface.

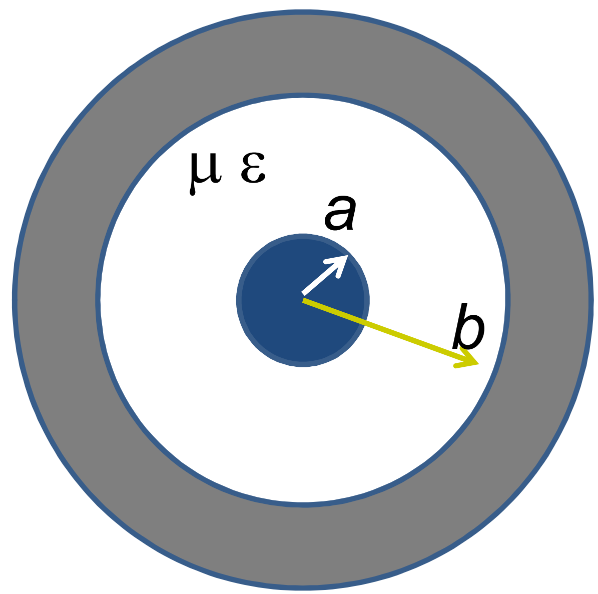
Waveguide terminology

- TEM: transverse electric and magnetic (both E and H fields are perpendicular to wave propagation direction)
- TM: transverse magnetic (H field is perpendicular to wave propagation direction)
- TE: transverse electric (E field is perpendicular to wave propagation direction)

Wave guides



Top view:



Inside medium, μ ε assumed to be real

Coaxial cable
TEM modes

(following problem 8.2 in Jackson's text)

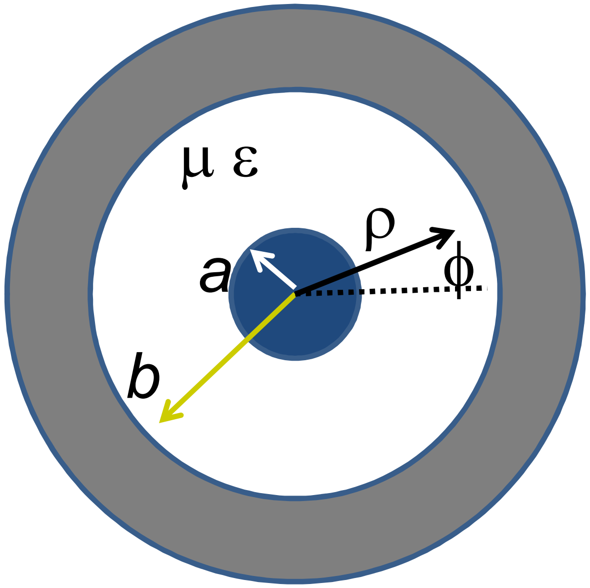
$$\text{Maxwell's equations inside medium: for } a \leq \rho \leq b$$

$$\nabla \times \mathbf{E} = i\omega\mathbf{B} \qquad \nabla \cdot \mathbf{E} = 0$$

$$\nabla \times \mathbf{B} = -i\omega\mu\varepsilon\mathbf{E} \qquad \nabla \cdot \mathbf{B} = 0$$

Electromagnetic waves in a coaxial cable -- continued

Top view:



Example solution for $a \leq \rho \leq b$

$$\mathbf{E} = \hat{\boldsymbol{\rho}} \Re\left(\frac{E_0 a}{\rho} e^{ikz - i\omega t} \right)$$

$$\mathbf{B} = \hat{\boldsymbol{\varphi}} \Re\left(\frac{B_0 a}{\rho} e^{ikz - i\omega t} \right)$$

$$\hat{\boldsymbol{\rho}} = \cos\phi\,\hat{\mathbf{x}} + \sin\phi\,\hat{\mathbf{y}}$$

$$\hat{\boldsymbol{\varphi}} = -\sin\phi\,\hat{\mathbf{x}} + \cos\phi\,\hat{\mathbf{y}}$$

Find:

$$k = \omega\sqrt{\mu\varepsilon}$$

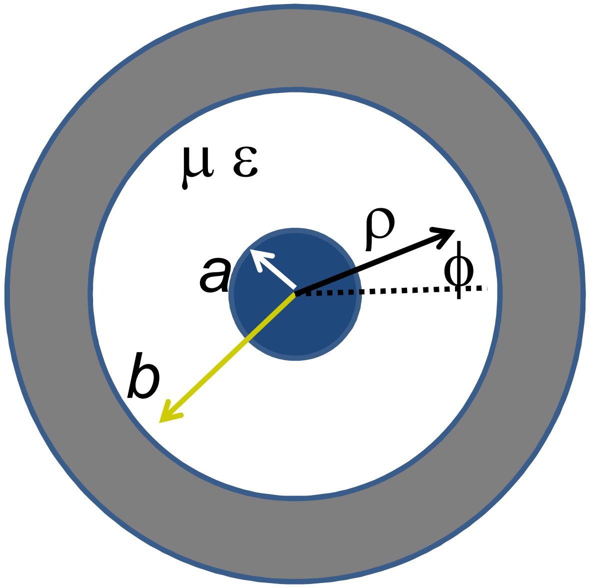
$$E_0 = \frac{B_0}{\sqrt{\mu\varepsilon}}$$

Poynting vector within cable medium (with μ, ε):

$$\langle \mathbf{S} \rangle_{avg} = \frac{1}{2\mu} \Re\left(\mathbf{E} \times \mathbf{B}^* \right) = \frac{|B_0|^2}{2\mu\sqrt{\mu\varepsilon}} \left(\frac{a}{\rho} \right)^2 \hat{\mathbf{z}}$$

Electromagnetic waves in a coaxial cable -- continued

Top view:



Time averaged power in cable material:

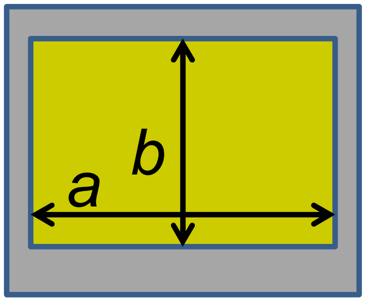
$$\int_0^{2\pi} d\phi \int_a^b \rho d\rho \left(\langle \mathbf{S} \rangle_{avg} \cdot \hat{\mathbf{z}} \right) = \frac{|B_0|^2 \pi a^2}{\mu\sqrt{\mu\varepsilon}} \ln\left(\frac{b}{a}\right)$$

Analysis of rectangular waveguide

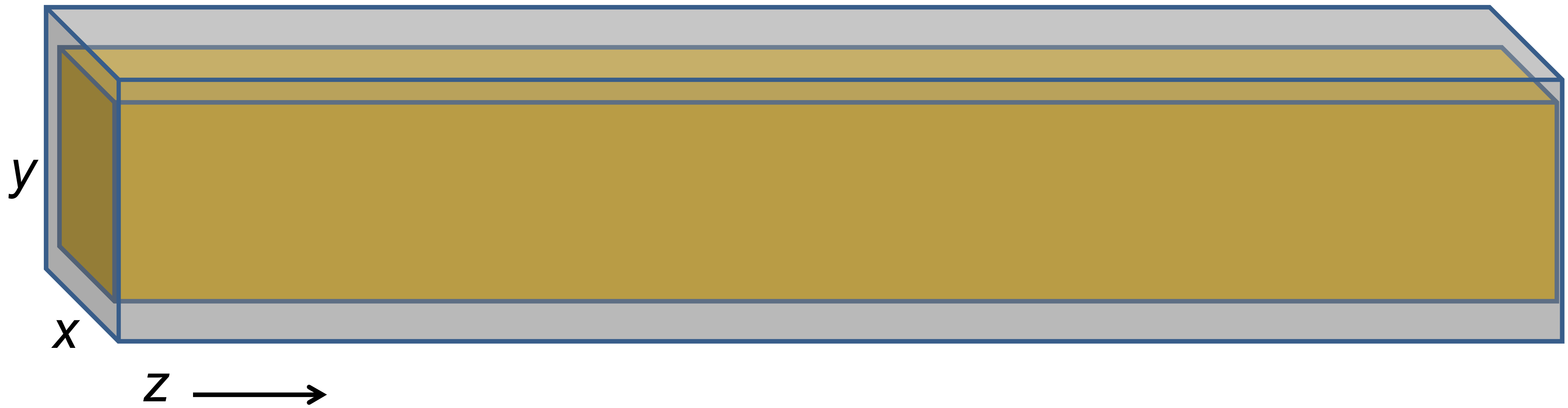
Boundary conditions at surface of waveguide:

$\mathbf{E}_{tangential}=0, \quad \mathbf{B}_{normal}=0$

Cross section view



Analysis of rectangular waveguide



$$\mathbf{B} = \Re\left\{\left(B_x(x,y)\hat{\mathbf{x}} + B_y(x,y)\hat{\mathbf{y}} + B_z(x,y)\hat{\mathbf{z}}\right)e^{ikz-i\omega t}\right\}$$

$$\mathbf{E} = \Re\left\{\left(E_x(x,y)\hat{\mathbf{x}} + E_y(x,y)\hat{\mathbf{y}} + E_z(x,y)\hat{\mathbf{z}}\right)e^{ikz-i\omega t}\right\}$$

$$k^2 = \mu\varepsilon\omega^2 - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{b}\right)^2$$

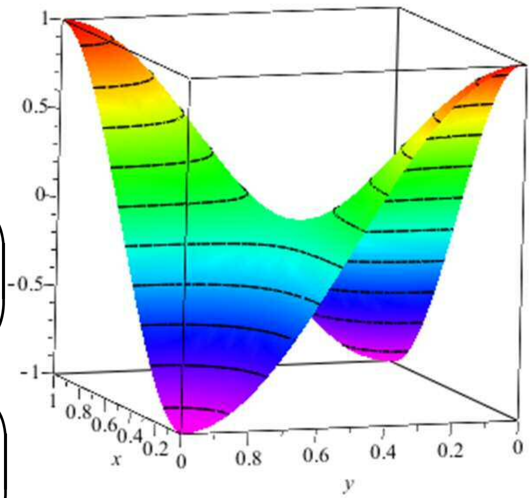
Solution for m=n=1

$$B_z(x,y) = B_0 \cos\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)$$

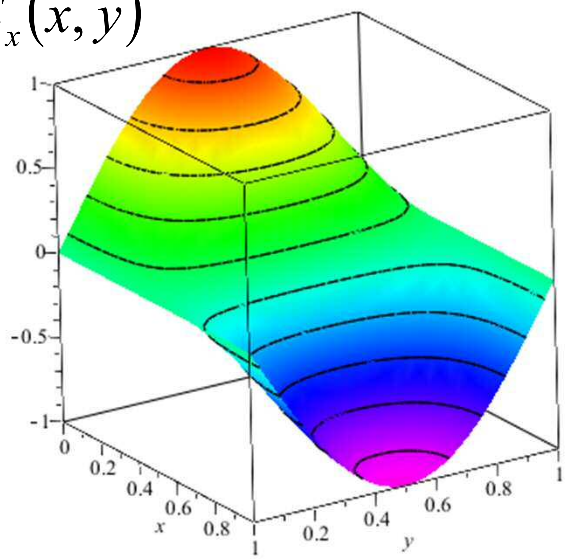
$$iE_x(x,y) = B_0\left(\frac{\omega n\pi/b}{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2}\right)\cos\left(\frac{m\pi x}{a}\right)\sin\left(\frac{n\pi y}{b}\right)$$

$$iE_y(x,y) = B_0\left(\frac{-\omega m\pi/a}{\left(\frac{m\pi}{a}\right)^2+\left(\frac{n\pi}{b}\right)^2}\right)\sin\left(\frac{m\pi x}{a}\right)\cos\left(\frac{n\pi y}{b}\right)$$

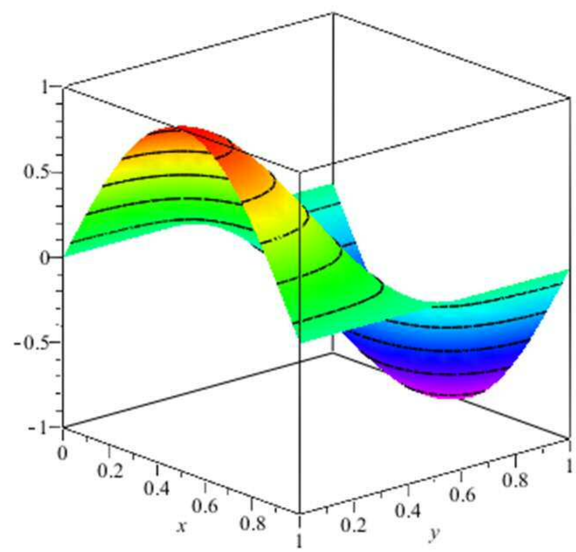
$B_z(x,y)$



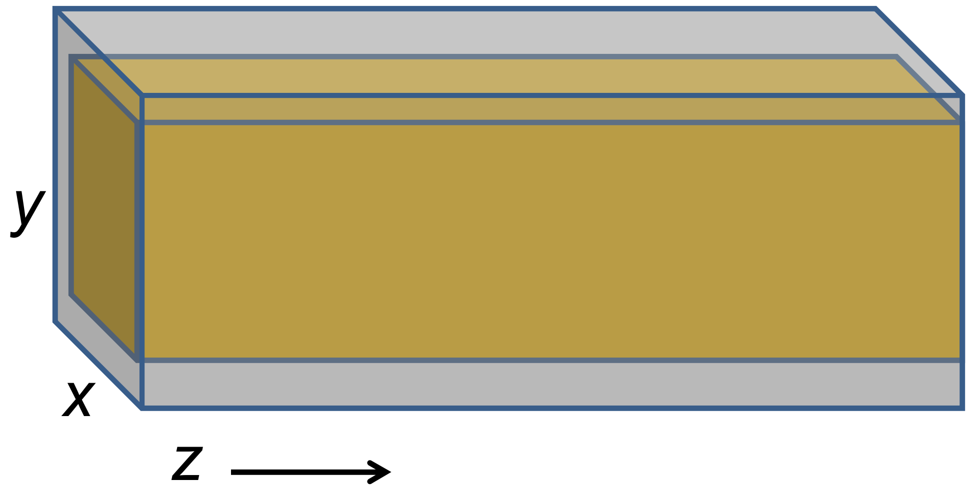
$iE_x(x,y)$



$iE_y(x,y)$



Resonant cavity



$$0 \le x \le a$$
$$0 \le y \le b$$
$$0 \le z \le d$$

$$\mathbf{B} = \Re\left\{\left(B_x(x,y,z)\hat{\mathbf{x}} + B_y(x,y,z)\hat{\mathbf{y}} + B_z(x,y,z)\hat{\mathbf{z}}\right)e^{-i\omega t}\right\}$$

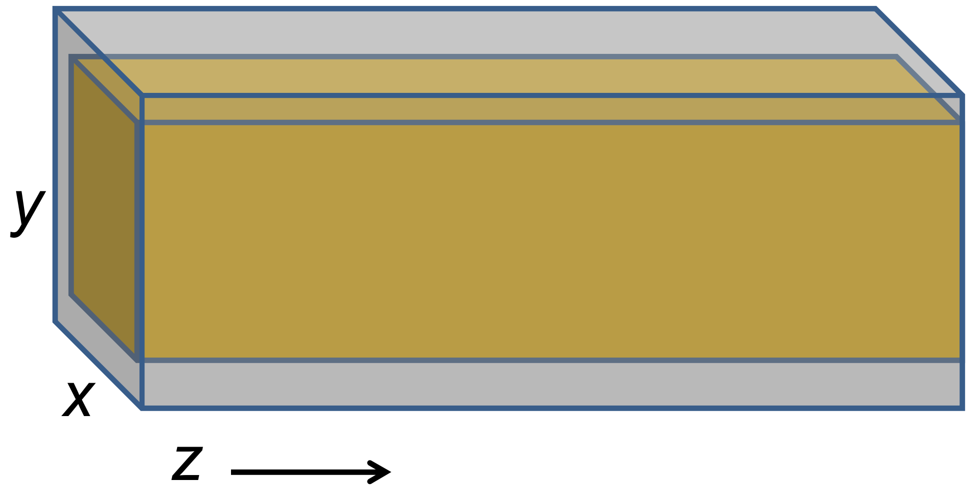
$$\mathbf{E} = \Re\left\{\left(E_x(x,y,z)\hat{\mathbf{x}} + E_y(x,y,z)\hat{\mathbf{y}} + E_z(x,y,z)\hat{\mathbf{z}}\right)e^{-i\omega t}\right\}$$

In general: $E_i(x,y,z) = E_i(x,y)\sin(kz)$ or $E_i(x,y)\cos(kz)$

$B_i(x,y,z) = B_i(x,y)\sin(kz)$ or $B_i(x,y)\cos(kz)$

$$\Rightarrow k = \frac{p\pi}{d}$$

Resonant cavity



$$0 \le x \le a$$
$$0 \le y \le b$$
$$0 \le z \le d$$

$$k^2 = \left(\frac{p\pi}{d}\right)^2 = \mu\varepsilon\omega^2 - \left(\frac{m\pi}{a}\right)^2 - \left(\frac{n\pi}{b}\right)^2$$

$$\Rightarrow \omega^2 = \frac{1}{\mu\varepsilon}\left(\left(\frac{m\pi}{a}\right)^2 + \left(\frac{n\pi}{b}\right)^2 + \left(\frac{p\pi}{d}\right)^2\right)$$