ECE341
Electromagnetic Fields

Gong Gu

Introduction: Why EM Fields?

The electromagnetic force is one of the four fundamental forces of Nature.
(What are the other three?)
Charged particles interact by the EM force, via EM fields.
But why do we (electrical engineers) care?

Circuit theory is a simple part of EM (**black boxes: lumped components**)

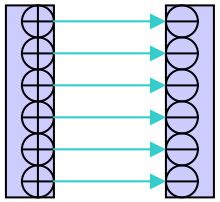
Inside the black boxes:

$J = en\mu E$

Velocity ∝ Force? What about Newton's laws?

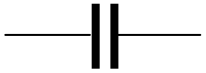
$V \propto E,\ J = \sigma E = IA$

$I = V/R$

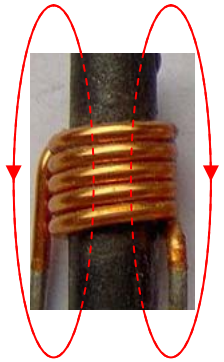


$Q \equiv Cv = CEd$

$dv/dt \rightarrow dQ/dt \rightarrow i$



$i = C\ dv/dt$



$B \propto i$

$di/dt \rightarrow dB/dt \rightarrow E \rightarrow v$

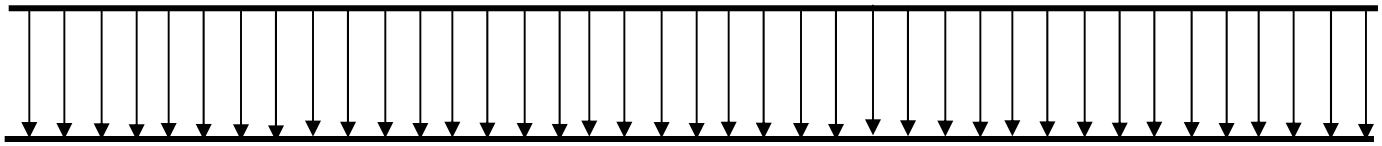
Changing B field induces E

$v = L\ di/dt$

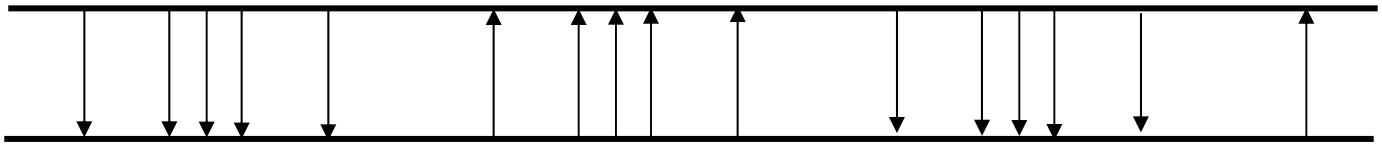
"Lumped" components when dimensions << wavelength

Simplest example: a pair of wires

(the term “transmission line” is a bit confusing)



Length << λ



Length ~ λ

f	λ	Comments
60 Hz	5000 km	Power
600 kHz	500 m	Medium wave AM radio
0.3 GHz	1 m	
1.5 GHz	20 cm	CPU clock rate
30 GHz	1 cm	Data communication
300 GHz	1 mm	

microwave

$f\lambda = c$,

$c = 3 \times 10^8$ m/s

This course is about electromagnetics (EM), the electrical foundation of Electrical and Computer Engineering, or, how electricity ***really*** works.
-- Look into the black boxes.

- Circuit theory is a simple part of EM, so it was taught first.
- However there are an increasing number of cases in ECE where circuit theory fails (e.g. faster computers, higher communications frequencies, power electronics, power system transients,), and EM must supplement circuit theory. *But, don't worry*…
- Also EM is the basis for many devices (machinery, antennas, etc.), and one of the physical foundations of any active electronic device.
- Serious hazards for electrical and computer engineers in all areas, such as interference and non-ideal behavior of circuit elements, are increasing with the higher frequencies today for Electrical and Computer Engineers in all areas.

Read this introduction again at the end of the semester after we have presented all the material. You will have a deeper understanding and a delight from it.

Textbook:
Ulaby *et al*, *Fundamentals of Applied Electromagnetics* (7/E or 6/E)

Recommended reference book:
Ramo *et al*, *Fields and Waves in Communication Electronics*

Homework
To be finished at the start of class on certain days, indicated in the schedule

Tests
Partially reflect homework and are certification that you learned what you should from the homework and study. There will be two major tests, on the days indicated in the schedule.

Lab (2 or 3 TBD)
Completion of all labs is required for course completion

Grade (Subject to change due to uncertainty in Lab)
Test 1: 25%; Test 2: 25%;
Lab: 15%;
Final exam: 35%

Schedule

The syllabus is online, as well as this introduction presentation.

The schedule is subject to changes, so check it often.

Website

http://web.eecs.utk.edu/~ggu1/files/UGHome.html

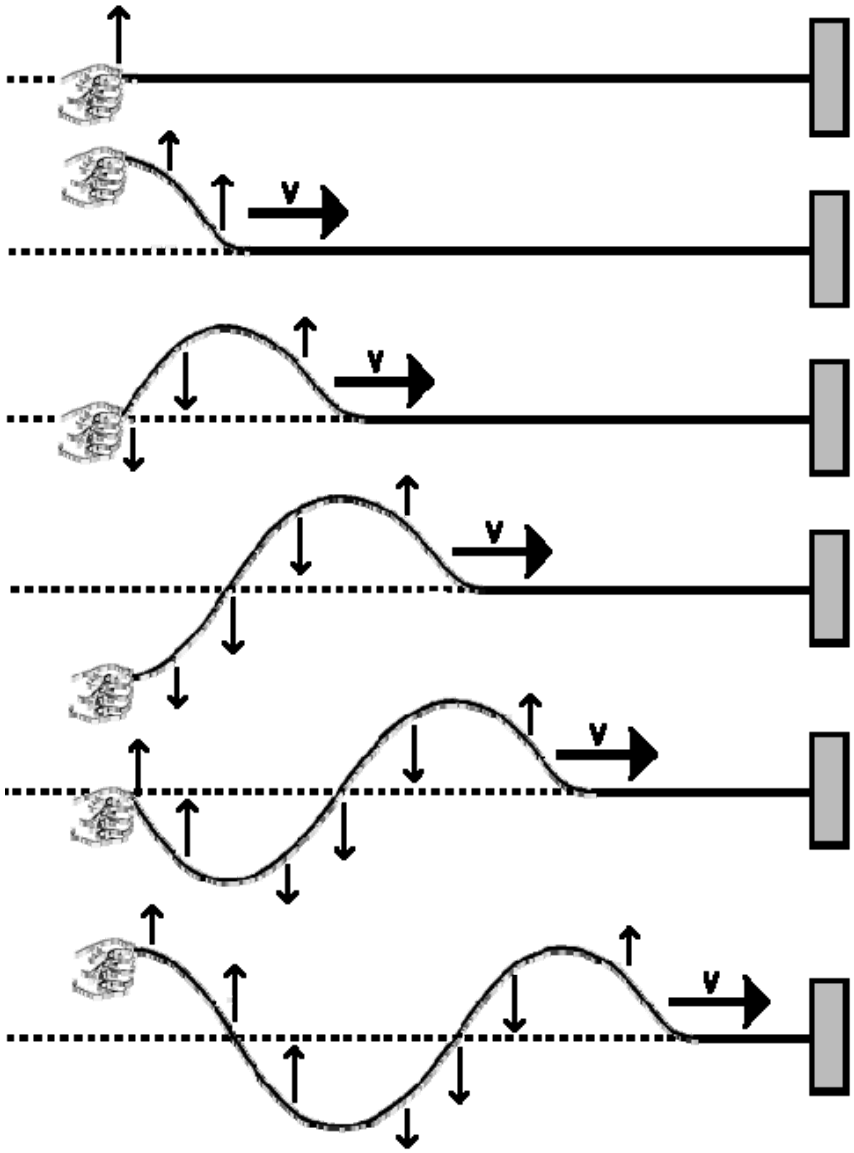
Extra project for Honors class ECE347

Tips

How to do well in this course (and others) and prepare to be a successful engineer:

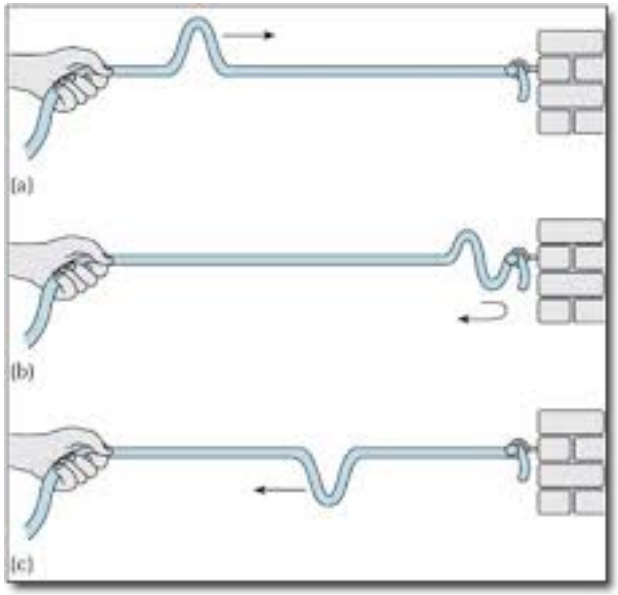
- Don't overload your schedule with courses and/or work;
- Aim toward becoming a good engineer;
- Don't miss classes;
- **See lab as an inquiry - not following a cook book**;
- Study daily, not just the four nights before tests;
- Ask questions, take notes;
- Don't rely on somebody else (*or my answer sheets online*) for homework.
- **Pursue understanding of the principles** - not just memorizing the symbols in some homework problems and equations;
- **Try to visualize phenomena - don't just manipulate math symbols**;
- **Relate this material to other courses**.
- Revisit and reinforce the above three during the course, and, in your future study (e.g. read this Introductions again at end of course).
- Read ahead, think in practical terms; see if using the book's CD helps.

Traveling Waves



The one-dimensional (1D) case

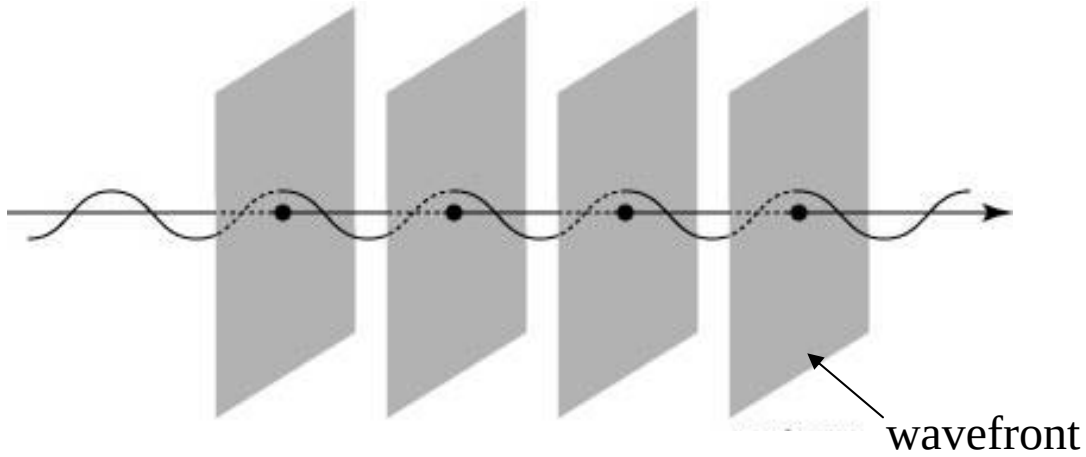
A traveling wave is the propagation of motion (disturbance) in a medium.



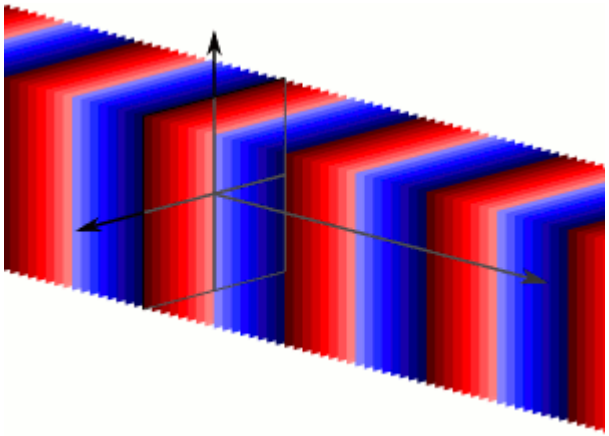
Reflection

Traveling Wave in Higher Dimensions

Plane waves in 3D

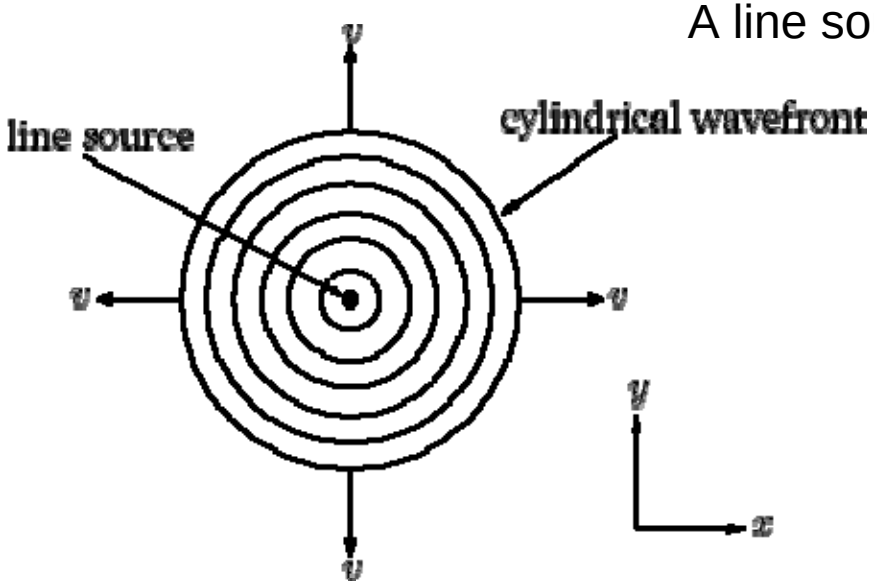


Example: sound waves



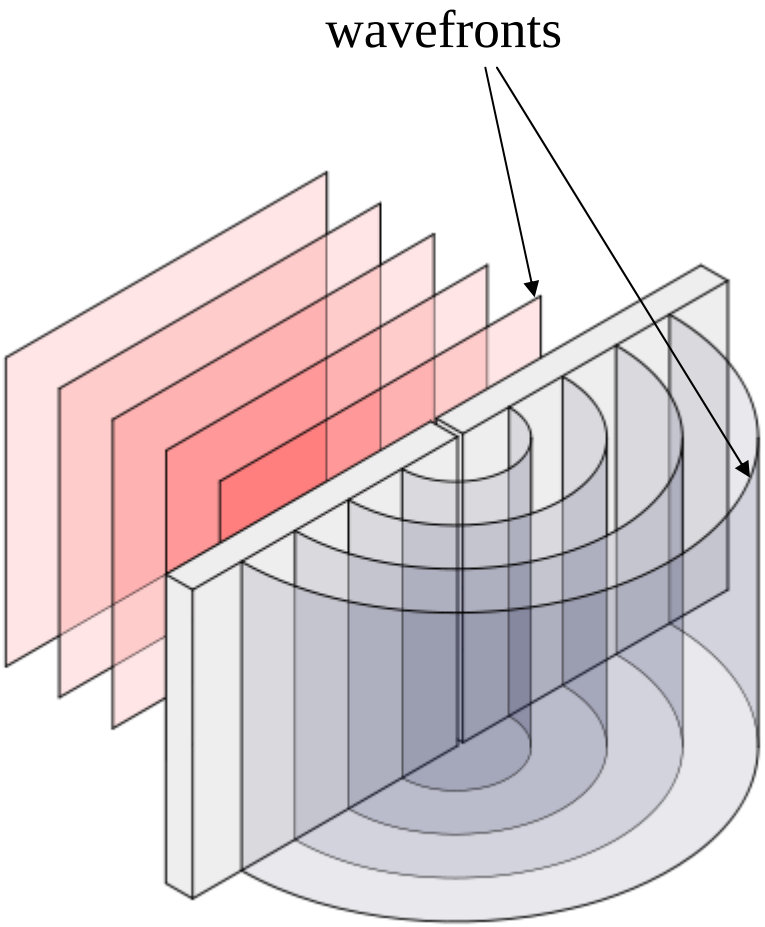
Watch animation: http://en.wikipedia.org/wiki/Plane_wave

A line source makes a cylindrical wave.



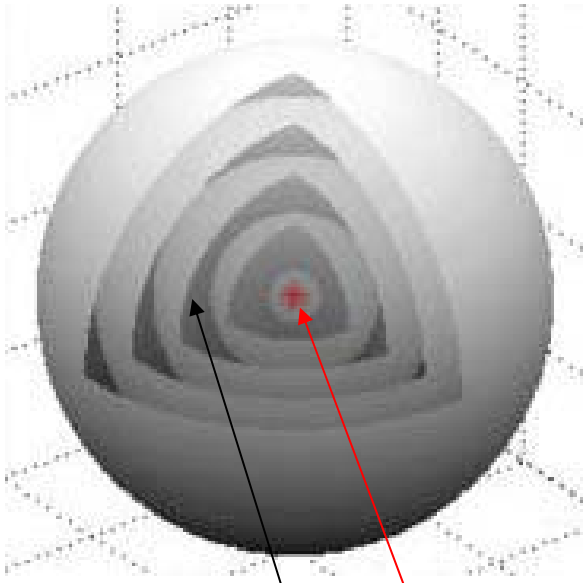
Cylindrical wave (3D; top view)

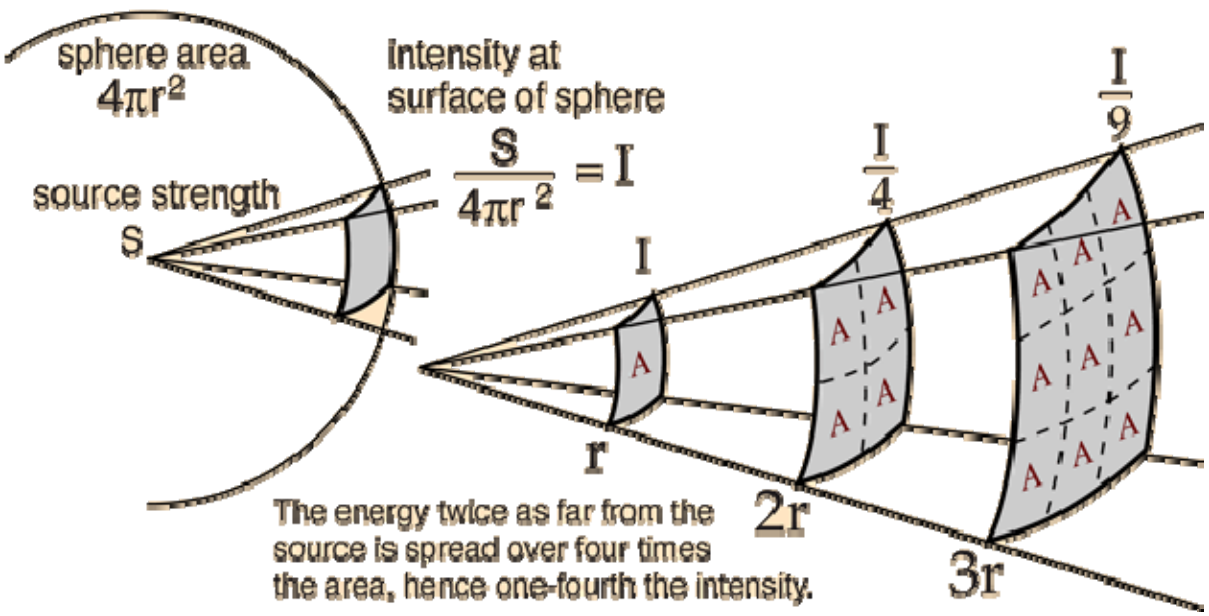
Water surface wave (2D)
(Circular wave)



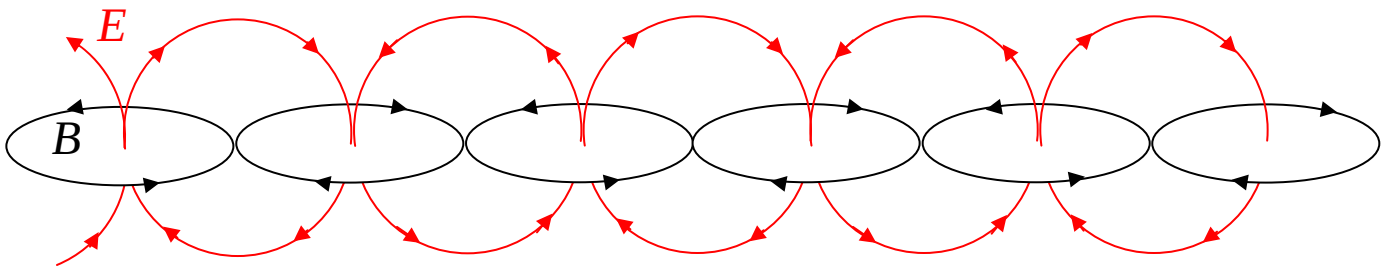
Make a cylindrical wave from a plane wave

A point source makes a spherical wave.





Electromagnetic Wave



Somehow start with a changing electric field E, say $E \propto \sin \omega t$

The changing electric field induces a magnetic field, $B \propto \dfrac{\partial E}{\partial t} \propto \cos \omega t$

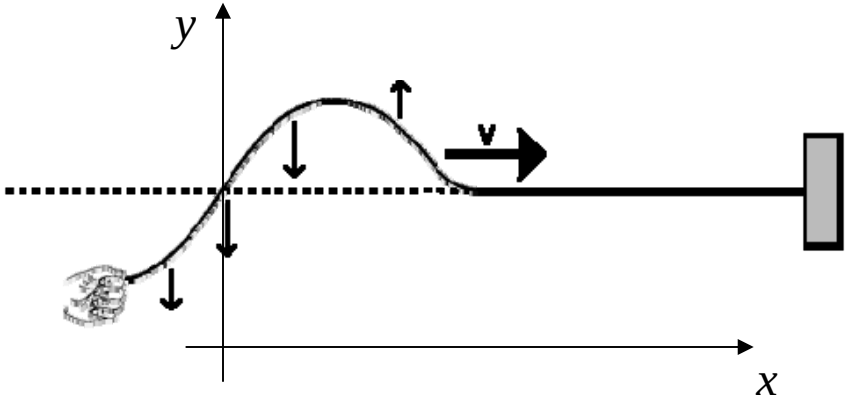
If the induced magnetic field is changing with time, it will in turn induce an electric field

$$E \propto \frac{\partial B}{\partial t} \propto \sin \omega t$$

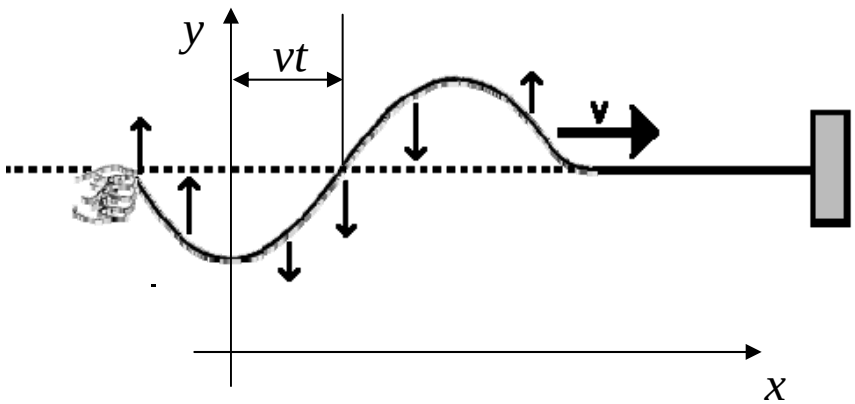
And so on and so on....
Just as the mechanical wave on a string.

Mathematical Expression of theTraveling Wave

A traveling wave is the propagation of motion (disturbance) in a medium.



At time 0,
$y = f(x)$



At time t,
$y = f(x-vt)$

This is the general expression of Traveling waves.

Quiz:
What kind of wave does $y = f(x+vt)$ stand for?