Lecture 23

- Modern Physics
  - Relativity
    - The principle of relativity
    - The speed of Light

http://www.physics.wayne.edu/~apetrov/PHY2140/

Chapter 26
Lightning Review

Last lecture:

1. AC circuits and EM waves
   ✓ EM waves
   ✓ Spectrum of EM radiation

Review Problem: The phasor diagrams below represent three oscillating emfs having different amplitudes and frequencies at a certain instant of time $t = 0$. As $t$ increases, each phasor rotates counterclockwise and completely determines a sinusoidal oscillation. At the instant of time shown, the magnitude of $I$ associated with each phasor given in ascending order by diagrams

1. (a), (b), and (c).  
2. (a), (c), and (b).  
3. (b), (c), and (a).  
4. (c), (a), and (b).  
5. none of the above  
6. need more information

\[
tan \phi = \frac{X_L - X_C}{R} \]
\[
X_C = \frac{1}{2\pi fC}, \quad X_L = 2\pi fL \]
\[
Z = \sqrt{R^2 + (X_L - X_C)^2} \]
\[
\Delta v = \Delta V_m \sin(2\pi f + \phi) \]
Reminder (for those who don’t read syllabus)

**Reading Quizzes (bonus 5%)**: 

It is important for you to come to class prepared, i.e. be familiar with the material to be presented. To test your preparedness, a simple five-minute quiz, testing your qualitative familiarity with the material to be discussed in class, will be given at the beginning of some of the classes. No make-up reading quizzes will be given.

There could be one today…

… but then again…
In a certain $RLC$ circuit, the rms current is 6.0 A, the rms voltage is 240 V, and the current leads the voltage by 53°. (a) What is the total resistance of the circuit? (b) Calculate the total reactance $X_L - X_C$. 
In a certain RLC circuit, the rms current is 6.0 A, the rms voltage is 240 V, and the current leads the voltage by 53°. (a) What is the total resistance of the circuit? (b) Calculate the total reactance \( X_L - X_C \).

**Given:**
- RLC circuit
- \( \phi = -53^{\circ} \)
- \( V_{\text{RMS}} = 240 \text{ V} \)
- \( I_{\text{RMS}} = 5.0 \text{ A} \)

**Find:**
- (a) \( R = ? \)
- (b) \( X_L - X_C = ? \)

Recall that dissipated power is

\[
P = I^2 R \quad \text{and} \quad P = I \Delta V \cos \phi
\]

\[I^2 R = I \Delta V \cos \phi\]

\[
R = \left( \frac{\Delta V}{I} \right) \cos \phi = \left( \frac{\Delta V_{\text{rms}}}{I_{\text{rms}}} \right) \cos \phi
\]

\[
= \left( \frac{240 \text{ V}}{6.00 \text{ A}} \right) \cos (-53^{\circ}) = 24 \Omega
\]

Now that we know the resistance, the total reactance is

\[
\tan \phi = \frac{X_L - X_C}{R} \quad \text{or} \quad X_L - X_C = R \tan \phi
\]

\[
X_L - X_C = (24 \Omega) \tan (-53^{\circ}) = -32 \Omega
\]
A Brief Overview of Modern Physics

**20\textsuperscript{th} Century revolution**
- 1900 Max Planck
  - Basic ideas leading to Quantum theory
- 1905 Einstein
  - Special Theory of Relativity

**21\textsuperscript{st} Century**
- Story is still incomplete
Basic Problems

- The speed of every particle in the universe always remains *less than* the speed of light
- Newtonian Mechanics is a limited theory
  - It places no upper limit on speed
  - It is contrary to modern experimental results
  - Newtonian Mechanics becomes a specialized case of Einstein’s Theory of Special Relativity
    - When speeds are much less than the speed of light
Galilean Relativity

- Choose a frame of reference
  - Necessary to describe a physical event

According to Galilean Relativity, the laws of mechanics are the same in all inertial frames of reference
  - An inertial frame of reference is one in which Newton’s Laws are valid
  - Objects subjected to no forces will move in straight lines
Galilean Relativity – Example

- A passenger in an airplane throws a ball straight up
  - It appears to move in a vertical path
  - The law of gravity and equations of motion under uniform acceleration are obeyed
Galilean Relativity – Example, cont

- There is a stationary observer on the ground
  - Views the path of the ball thrown to be a parabola
  - The ball has a velocity to the right equal to the velocity of the plane
Galilean Relativity – Example, conclusion

- The two observers disagree on the shape of the ball’s path.
- Both agree that the motion obeys the law of gravity and Newton’s laws of motion.
- Both agree on how long the ball was in the air.
- **Conclusion:** There is no preferred frame of reference for describing the laws of mechanics.
Galilean Relativity – Limitations

- Galilean Relativity does *not* apply to experiments in electricity, magnetism, optics, and other areas
- Results do not agree with experiments
  - The observer should measure the speed of the pulse as \( v+c \)
  - Actually measures the speed as \( c \)
Luminiferous Ether

19th Century physicists compared electromagnetic waves to mechanical waves

- Mechanical waves need a medium to support the disturbance

The *luminiferous ether* was proposed as the medium required (and present) for light waves to propagate

- Present everywhere, even in space
- Massless, but rigid medium
- Could have no effect on the motion of planets or other objects
Verifying the Luminiferous Ether

Associated with an ether was an *absolute frame* where the laws of e & m take on their simplest form.

Since the earth moves through the ether, there should be an “ether wind” blowing.

If $v$ is the speed of the ether relative to the earth, the speed of light should have minimum or maximum values depending on its orientation to the “wind.”