Physics 112

Study Notes for Exam III

Chapter 25 Electromagnetic Waves

5. Induced Fields and Waves

   Maxwell postulates reverse of Faraday Law: ***B*** field may be produced by time-varying *electric* flux. Predicts self-propagating EM waves with speed $v = \frac{1}{\sqrt{\mu_0 \varepsilon_0}} = c$. Know how directions of ***E, B*** and ***v*** are related. Be able to interpret all features of Eq. 25.14 (*cf* §15.3)

6. Properties of EM waves

   Wave Eq. 25.15

   Eqs. 25.16 relate field amplitudes to intensity. The terms E_0 and B_0 here are maximum field strengths (amplitudes). The 2 in each denominator provides the appropriate time-averaging. Using the language of Chapter 26, it would be correct to call the intensity of 25.16 I_{rms} (and we often do).

   Fields also have closely related energy densities: $u_E = \frac{1}{2}\varepsilon_0 E^2$ and $u_B = \frac{B^2}{2\mu_0}$

   Inverse square law Eq. 25.17
   Polarization & Malus' Law.
   Know how a polarizer attenuates unpolarized incident light.

7. Photon Model

   Underlies much of Chapter 28
   Be able to relate luminous power, wavelength and number of photons/second

8. EM Spectrum

   Know the order of the broad spectrum regions in Fig. 25.34. Know the order of visible colors. What wave property do all EM waves have in common?
   Thermal Radiation: Stefan-Boltzmann Law Eq. 25.21; Wien Law Eq. 25.22
   This is the same as the 'Blackbody' radiation of §29.1 which Planck successfully modeled only when he assumed discrete energies $E = hf$.
   Note that Eq. 25.21 can be expressed in terms of the *intensity* of the surface of the emitting blackbody itself (*e.g.* a stovetop burner or a star): $I_{\text{surf}} = e\sigma T^4$.
   Numerical value of σ ($5.67 \times 10^{-8}\ Wm^{-2}K^{-4}$) will be on front page of exam.
   Skip sections **Color Vision** and **X Rays and Gamma Rays.**
   Look at STOP TO THINK 25.6.

Chapter 26 AC Circuits

1. Sinusoidally varying line voltage Eq. 26.1; Also be able to work with angular frequency $\omega = 2\pi f$. [Note on units: Because cycles and radians are both dimensionless, both f and ω have units of s^{-1}. The unit *Hertz* (Hz) is used only for complete cycles per second. If a frequency is given in Hz, you know it's f not ω.
   Resistive loads: Impedance (resistance) independent of frequency
   Average Power dissipated: Eq. 26.7
   RMS Voltage & Current
2. Understand transformers and transmission efficiency
   Skip section on household electricity
3. Skip
4. Capacitor Circuits:
   Know and be able to compute and apply definition of capacitive reactance (impedance similar to resistance).
   Understand and compute frequency dependence of X_C and I_C.
5. Inductor Circuits:
   Know and be able to compute and apply definition of inductive reactance (impedance similar to resistance).
   Understand and compute frequency dependence of X_L and I_L.
6. Oscillating Circuits
   Resonant Frequency $\omega_{res} = \dfrac{1}{\sqrt{LC}}$
   Be able to discuss analogy to damped and driven mechanical oscillator
   Impedance and peak current in driven RLC oscillator circuits Eq. 26.30
   The impedance $Z \equiv \sqrt{R^2 + \left(X_L - X_C\right)^2}$ is just the denominator. Text may not use letter Z for this. Z = R only at the resonant frequency.

Chapter 27 Relativity

1. Introduction to Relativity
2. Galilean Relativity: Inertial Frames (remember why we need Newton's *First* law).
   Classical (Galilean = 'common sense') velocity transforms
3. Principle of Relativity: Laws of physics are the same in all inertial reference frames. Equivalently, this may be stated "There is no experiment that can identify a frame of absolute rest."

4. Events & Measurements
   Be careful to distinguish between the time an event occurs and the time light signaling the event is received by an observer.
5. Simultaneity
   All observers using synchronized clocks in the same inertial frame must agree on the simultaneity of any two events. Events simultaneous in one inertial frame will not be simultaneous in a different inertial frame.
6. Time Dilation
   Time differences are measured between two events. Equation 27.6 works *only* when the interval $\Delta\tau$ is that in the *proper time frame*. Be sure you can confidently identify the *proper time frame* in any situation.
7. Length Contraction
   Moving meter sticks are shorter. Be sure you can confidently identify the *proper length frame* in any situation. Do not assume that the *proper time frame* and the *proper length frame* are necessarily the same one. They are generally not.
8. Relativistic Velocity Addition
   Important thing here is to identify speeds u, u' and v. The u, u' terms are speeds of something in frames S and S' respectively. As usual, v is the speed of S relative to S'. Try using the 'subscript sandwich' method described in class.
9. Relativistic Momentum
   A particle of mass m and velocity $\boldsymbol{u}$ in frame S has momentum $\boldsymbol{p} = \gamma m\boldsymbol{u}$. Figure 27.22 (a) correctly shows how $\boldsymbol{p}$ depends on $\boldsymbol{u}$. A particle's momentum may increase without bound but its speed can never reach c. The horizontal axis in part (b) of that figure is mislabeled (in my book). The horizontal axis should be p not t.
10. Relativistic Energy
    Total Energy of a free particle of mass m is $E = \gamma mc^2 = \gamma E_0$. This energy is the sum of the rest energy mc^2 and the kinetic energy $K = (\gamma - 1)E_0$.
    Equivalence of mass and energy: Kinetic energy can be converted to mass in the form of new particles. Likewise, particle/antiparticle pairs can annihilate each other to produce pure energy. These processes are routinely observed in high energy accelerator labs.
    Conservation of Energy: When two or more particles are bound together by strong forces, the mass of the bound system is less than the sum of the masses of the separated pieces. The mass difference is related to the binding energy by $E_{binding} = \Delta mc^2$. Table 27.1 includes masses of separate and bound constituents in *atomic mass units u*. (We'll wait for nuclear physics to do binding energy problems.)

Worked Problems

There will be three worked problems on Exam III. The major topic areas include:

A. Electromagnetic Waves
   - Frequencies, wavelengths, wavespeed. $c = f\lambda$; Eq. 25.14
   - Be able to use Eqs. 25.16 and 25.17 to relate field amplitudes, radiation intensity and distance between source and observer.
   - Polarization & Malus' Law

B. AC Circuit Problems
   - Power dissipated in resistive AC circuits. RMS Current/Voltage.
   - Transformers
   - RLC Series Circuits: The denominator of text Eq. 26.30 is called the *impedance* and is typically denoted *Z* (units are Ω). Note that Eq. 26.30 can be used for any combination of RLC. If one of these components is absent, just omit the corresponding term from the equation.

C. Relativity
   - Time-dilation and length contraction are easily combined in single problems. Be sure you can confidently identify the reference frame that is proper in either time or length. To do that, you must explicitly identify events (*e.g.* leaving Mars and arriving at Venus).
   - Relativistic Velocity Addition
   - Relativistic Momentum and Energy
     - For your convenience, here are a couple equations we didn't discuss that you may find useful. They are derived from the definitions of relativistic momentum and energy. (If you're good at algebra, you may be interested in trying to prove them yourself.)
     - Combine $E = \gamma mc^2$ and $\vec{p} = \gamma m\vec{u}$, eliminating m and γ to get $\vec{\beta} = \frac{\vec{p}c}{E}$
     - Combine the same two definitions eliminating their explicit dependence on velocity to find $E^2 = E_0^2 + (pc)^2$. This is very similar to the (now familiar) classical relation $K = \frac{p^2}{2m}$.
   - Mass-Energy Equivalence