Physics 106b – 2011 Assignment 9

Due: Friday, 4-15-11, 4:00 pm
Reading: Ch. 37

To encourage you to start from the basic premises as much as possible, you may only use basic definitions (such as $v \equiv \frac{dx}{dt}$), mathematics, equations from physics 105 or an equivalent mechanics course ($\mathbf{F} = m\mathbf{a}$, $s = \Delta x = v_0 t + \frac{1}{2}at^2$, etc.), principles which are not ordinarily expressed in equations (*e.g.* "Electric fields superpose." or "The electric field inside a conductor is zero."), and the following equations as starting points for these problems:

Definition of electric field: $\mathbf{E} = \frac{\mathbf{F}}{q}$ **Field of a point charge:** $\mathbf{E}_{\substack{\text{point}\\\text{charge}}} = \frac{kq}{r^2}\hat{\mathbf{r}}$

Field of an extended object: $\mathbf{E} = \int \frac{k\,dq}{r^2}\hat{\mathbf{r}}$

Gauss's Law: $\oint \mathbf{E}\cdot\hat{\mathbf{n}}\,dA = \frac{q_{\text{net, enclosed}}}{\varepsilon_0}$ $k = \frac{1}{4\pi\varepsilon_0}$ **Definition of flux:** $\phi_E \equiv \int \mathbf{E}\cdot\hat{\mathbf{n}}\,dA$.

If field is uniform and angle between field and area is constant, $\phi_E = EA\cos\theta$

$E_{\substack{\text{due to}\\\text{sheet}\\\text{charge}}} = \frac{\sigma}{2\varepsilon_0}$ $E_{\substack{\text{total,}\\\text{at metal}\\\text{surface}}} = \frac{\sigma}{\varepsilon_0}$ **Definition of voltage:** $V \equiv \frac{U_{\text{Elec}}}{q}$

Connections between *V* and E: $\Delta V_{AB} = -\int_A^B \mathbf{E}\cdot d\ell$ $\mathbf{E} = -\nabla V$, where $\vec{\nabla} \equiv \hat{\mathbf{i}}\frac{\partial}{\partial x} + \hat{\mathbf{j}}\frac{\partial}{\partial y} + \hat{\mathbf{k}}\frac{\partial}{\partial z}$

<u>If</u> field is uniform: $\Delta V_{AB} = -\mathbf{E}\cdot\ell$ $E = -\frac{dV}{dx}$

Voltage of a point charge: $V_{\substack{\text{point}\\\text{charge}}} = \frac{kq}{r}$ **Voltage of an extended object:** $V = \int \frac{k\,dq}{r}$

Definition of capacitance: $Q = CV$ $\frac{1}{C_{series}} = \frac{1}{C_1} + \frac{1}{C_2} \Leftrightarrow C_{series} = \frac{C_1 C_2}{C_1 + C_2}$

$C_{parallel} = C_1 + C_2$

Energy density of the electric field: $u_E = \frac{\varepsilon_0 E^2}{2}$ $U = \int_{all\ space} u_E \, dV$

Dielectric constant: $\kappa \equiv \frac{E_{plates}}{E_{Tot}}$ $C_{\substack{parallel\\plate}} = \frac{\kappa\varepsilon_0 A}{d}$ $U = \frac{1}{2}CV^2$

Ohm's Law: $V = IR$ $\frac{1}{R_{parallel}} = \frac{1}{R_1} + \frac{1}{r_2} \Leftrightarrow R_{parallel} = \frac{R_1 R_2}{R_1 + R_2}$ $R_{series} = R_1 + R_2$

Definition of resistivity: $R = \frac{\rho L}{A}$ **Resistivity in the Drude model:** $\rho = \frac{m}{ne^2\tau}$ **Drift velocity:** $I = nqAv_d$

Electrical power: $P = VI$ $P = I^2R$ $P = V^2/R$ **Output voltage of a real battery:** $V_{out} = \varepsilon - Ir$

RC charging: $V_C = \varepsilon\left(1 - e^{-t/RC}\right)$ **RC discharging:** $V_C = V_0 e^{-t/RC}$

Hall voltage: $V_H = \frac{IB}{nqt}$ **Gauss's Law for magnetic fields:** $\oint \mathbf{B} \cdot \hat{\mathbf{n}}\, dA = 0$

Lorentz force: $\mathbf{F} = q\mathbf{v} \times \mathbf{B}$

Force on a current-carrying wire: $d\mathbf{F} = I\, d\vec{\ell} \times \mathbf{B}$ **If wire is straight and B uniform:** $\mathbf{F} = I\,\vec{\ell} \times \mathbf{B}$

Biot-Savart Law: $d\mathbf{B} = \frac{\mu_0}{4\pi} \frac{I\, d\vec{\ell} \times \hat{\mathbf{r}}}{r^2}$

Ampère's Law: $\oint \mathbf{B} \cdot d\vec{\ell} = \mu_0 I_{\substack{net \\ threading}} + \mu_0 \varepsilon_0 \frac{d}{dt} \int \mathbf{E} \cdot \hat{\mathbf{n}}\, dA$ $B_{solenoid} = \mu_0 nI$ $B_{wire} = \frac{\mu_0 I}{2\pi r}$

Motional emf and/or induction: $\varepsilon_{loop} = -\frac{d\phi_B}{dt}$, where $\phi_B \equiv \int \mathbf{B} \cdot \hat{\mathbf{n}}\, dA$

Faraday's law: $\oint \mathbf{E} \cdot d\vec{\ell} = -\frac{d}{dt} \int \mathbf{B} \cdot \hat{\mathbf{n}}\, dA$ **Transformers:** $\varepsilon_s = \varepsilon_p \frac{N_s}{N_p}$ $I_s V_s = I_p V_p$

Radiation: $E = cB$ $c = \frac{1}{\sqrt{\mu_0 \varepsilon_0}}$ $\mathbf{S} = \frac{\mathbf{E} \times \mathbf{B}}{\mu_0}$ $S = P_{rad}\, c$

Interference: $m\lambda = d \sin\theta_{\max}$ **slit diffraction:** $\theta_{\min} = \frac{\lambda}{a}$ **hole diffraction:** $\theta_{\min} = 1.22 \frac{\lambda}{a}$

You may also use "common sense" equations, such as $dq = \sigma\, dA$**.**

Assigned exercises appear on the next page.

Assigned exercises:
FOR ALL QUESTIONS (as opposed to problems) EXPLAIN YOUR ANSWER BRIEFLY.

Individual problems:
37-59

Group problems:
34-76

37?12 (Think both about the angular resolution and the amount of energy collected. Because of the clever way the signals are combined, the effective *a* for the pair of small telescopes equals the separation between the telescopes.)

37-19
37-54 For this question, the diameter of the mirror plays the role of *a* in the diffraction equation. The relevant angle is that between a line from the center of the mirror to the center of the spot on the missile and a second line from the center of the mirror to the edge of the central diffraction spot on the missile.

You should also start working on your creative project. There will be 8 hours total on assignments freed up for you to work on this; **I have allocated about 3 hours from the current assignment for you to work on it this week.**

Creative project: Working on your own, or with no more than one other student, write a poem or song, research and write a summary of an historical incident or person's life, create a document that clearly explains something we've studied, create a document which clearly explains an application of something we've studied, create a page of useful web resources related to one of the topics we've covered, or do something else creative. Whatever you do should be closely related to what we've done in class or reading. It must not be a description of how difficult the class is or how much work the problem sets are, etc. (I rule this out because there are far too many songs and poems on this topic!) Your project should represent the result of about six hours of work; this does not mean there is a particular length requirement. If the project involves more than one person, my expectations will be proportionally higher. However, it is my intention to go quite easy on the grading for this. Once you have decided on what type of project you will do, and what its focus will be, you should clear it with me before proceeding further. If you wish, you can present your project to the rest of the class during the last week of classes. You may use Wikipedia, appropriately cited, as a source for your work, but it should not be the only source.