PHYS 333

Information for Exam III

Office Hours: Thursday 10:30–12:00, 2:00–3:00, 4:00–5:00, Friday 10:30–12:00, 3:00–5:00

This will be a timed, closed book, take-home examination. You are to complete the exam in one continuous sitting lasting no more than 90 minutes. The only materials that you may use are those that I provide: copies of the inside covers of your text, photocopies of the figures representing differential volume elements in cylindrical and spherical coordinates, and the attached equation sheet. The exam will be due on Monday, November 24.

The main focus of the exam will be material from Griffiths Chapter 5, 6.1.1–6.1.2, Chapter 7 (through 7.3.3), and 9.2.1–9.2.2 (with a little bit of supporting material from earlier parts of Chapter 9), although you are still responsible for the "old" material in the sense that you might have to use some basic ideas to solve a problem of current interest.

The exam questions will be similar to the homework problems you have already done in problem sets #16 to #21, and to the worked examples in the text.

You should be able to:

- Find magnetic forces on moving charges and/or current distributions (**I**, **K**, **J**) in known fields.
- Find magnetic fields from known current distributions. (Use Biot-Savart Law, Ampere's Law, and superposition as appropriate.)
- Calculate magnetic moments from known current distributions.
- Determine approximate magnetic fields far away from localized current distributions.
- Find forces and torques on magnetic moments in known fields.
- Calculate motional emfs.
- Use Faraday's Law to calculate "induced" electric fields.
- Use Ampere's Law with Maxwell's "fix" (displacement current) to calculate "induced" magnetic fields.

- Calculate mutual inductances in simple configurations of wires.
- Derive the wave equation for electromagnetic waves.
- Test whether a given vector wave is a solution of the electromagnetic wave equation.
- Given a description of an electromagnetic wave in words, write down mathematical expressions for **E** and **B**.
- Given mathematical expressions for **E** and **B** in an electromagnetic wave, describe the properties of the wave in words (direction of propagation, frequency, wavelength, plane of polarization, etc.).
- Use Taylor's theorem to expand expressions in powers of small quantities.

Equations

$$\mathbf{B}(\mathbf{r}) = \frac{\mu_0}{4\pi} I \int \frac{d\mathbf{l}' \times \hat{\mathscr{r}}}{\mathscr{r}^2} \longleftrightarrow \frac{\mu_0}{4\pi} \int \frac{\mathbf{K}(\mathbf{r}') \times \hat{\mathscr{r}}}{\mathscr{r}^2}\, da' \longleftrightarrow \frac{\mu_0}{4\pi} \int \frac{\mathbf{J}(\mathbf{r}') \times \hat{\mathscr{r}}}{\mathscr{r}^2}\, d\tau'$$

$$\mathbf{I} = \lambda \mathbf{v}$$

$$\mathbf{K} \equiv \frac{d\mathbf{I}}{dl_\perp} \longrightarrow \sigma \mathbf{v}$$

$$\mathbf{J} \equiv \frac{d\mathbf{I}}{da_\perp} \longrightarrow \rho \mathbf{v} \longleftrightarrow I = \int \mathbf{J} \cdot d\mathbf{a}$$

$$\mathbf{F} = q\left[\mathbf{E} + (\mathbf{v} \times \mathbf{B})\right]$$

$$\mathbf{F}_{\text{mag}} = \int I(d\mathbf{l} \times \mathbf{B}) \longleftrightarrow \int (\mathbf{K} \times \mathbf{B})\, da \longleftrightarrow \int (\mathbf{J} \times \mathbf{B})\, d\tau$$

$$\mathbf{m} = I \int d\mathbf{a}$$

$$\mathbf{B}_{\text{dip}}(\mathbf{r}) = \frac{\mu_0 m}{4\pi r^3}\left(2\cos\theta\, \hat{\mathbf{r}} + \sin\theta\, \hat{\boldsymbol{\theta}}\right) = \frac{\mu_0}{4\pi r^3}[3(\mathbf{m} \cdot \hat{\mathbf{r}})\hat{\mathbf{r}} - \mathbf{m}]$$

$$\mathbf{N} = \mathbf{m} \times \mathbf{B}$$

$$\mathbf{F} = \boldsymbol{\nabla}(\mathbf{m} \cdot \mathbf{B})$$

$$\mathbf{J} = \sigma \mathbf{E}$$

$$\mathcal{E} \equiv \oint \mathbf{f}_s \cdot d\mathbf{l} \longrightarrow \oint (\mathbf{f}_{\text{elec}} + \mathbf{f}_{\text{mag}}) \cdot d\mathbf{l}$$

$$\Phi \equiv \int \mathbf{B} \cdot d\mathbf{a}$$

$$\mathcal{E} = -\frac{d\Phi}{dt}$$

$$\oint \mathbf{E}\cdot d\mathbf{l} = -\frac{\partial}{\partial t}\int \mathbf{B}\cdot d\mathbf{a} \longleftrightarrow \nabla \times \mathbf{E} = -\frac{\partial \mathbf{B}}{\partial t}$$

$$\oint \mathbf{B}\cdot d\mathbf{l} = \mu_0 \left(I_{\text{enc}} + \epsilon_0 \frac{\partial}{\partial t}\int \mathbf{E}\cdot d\mathbf{a} \right) \longleftrightarrow \nabla \times \mathbf{B} = \mu_0 \mathbf{J} + \mu_0 \epsilon_0 \frac{\partial \mathbf{E}}{\partial t}$$

$$\mathbf{J}_d \equiv \epsilon_0 \frac{\partial \mathrm{E}}{\partial t}$$

$$\Phi = LI \qquad \text{and} \qquad \Phi = MI$$

$$\mathcal{E} = -L\frac{dI}{dt}$$

$$W = \frac{1}{2}LI^2$$

$$\nabla^2 \mathbf{E} = \mu_0 \epsilon_0 \frac{\partial^2 \mathbf{E}}{\partial t^2} \qquad \nabla^2 \mathbf{B} = \mu_0 \epsilon_0 \frac{\partial^2 \mathbf{B}}{\partial t^2}$$

Traveling Plane Wave Solutions:

$$\mathbf{E}(\mathbf{r},t) = E_0 \cos(\mathbf{k}\cdot\mathbf{r} - \omega t + \delta)\,\hat{\mathbf{n}} \qquad \mathbf{B}(\mathbf{r},t) = \frac{E_0}{c}\cos(\mathbf{k}\cdot\mathbf{r} - \omega t + \delta)\,(\hat{\mathbf{k}} \times \hat{\mathbf{n}}) = \frac{1}{c}\,\hat{\mathbf{k}} \times \mathbf{E}(\mathbf{r},t)$$

$$\tilde{\mathbf{E}}(\mathbf{r},t) = \tilde{E}_0 e^{i(\mathbf{k}\cdot\mathbf{r} - \omega t)}\,\hat{\mathbf{n}} \qquad \tilde{\mathbf{B}}(\mathbf{r},t) = \frac{1}{c}\,\tilde{E}_0\, e^{i(\mathbf{k}\cdot\mathbf{r} - \omega t)}\,(\hat{\mathbf{k}} \times \hat{\mathbf{n}}) = \frac{1}{c}\,\hat{\mathbf{k}} \times \tilde{\mathbf{E}}(\mathbf{r},t)$$