E E / Mteor / Agron 518
Spring 2008
Problem Set 2
Due Tuesday, January 29, 2008.

Assigned January 22, 2008, updated January 25, 2008.

1. Use the appropriate expression for differential surface area $d\mathbf{s}$ to determine the area of each of the following surfaces. Hint: check your answers by calculating the surface areas using formulas for geometrical shapes. The surface area of an open cone is $\pi r s$ where r is the radius of the base and s is the edge.

   (a) $1 \le r \le 6$; $\pi/2 \le \phi \le \pi$; $z = 0$.

   (b) $0 \le R \le 4$; $\theta = \pi/3$; $0 \le \phi \le 2\pi$.

2. Find the volumes. Hint: check your answers by calculating the volumes using formulas for geometrical shapes. The volume of a cone is $\frac{1}{3}\pi r^2 h$ where r is the radius of the base and h is the height.

   (a) $2 \le r \le 5$; $\pi/2 \le \phi \le \pi$; $0 \le z \le 2$.

   (b) $0 \le R \le 5$; $0 \le \theta \le \pi/3$; $0 \le \phi \le 2\pi$.

3. A vector field $\mathbf{D} = \hat{\mathbf{r}}\, r^3$ exists in the region between two concentric cylindrical surfaces defined by $r = 1$ and $r = 2$, with both cylinders extending between $z = 0$ and $z = 5$. Verify the divergence theorem by evaluating:

   (a) $\oint \mathbf{D} \cdot d\mathbf{s}$, and

   (b) $\int \nabla \cdot \mathbf{D}\, dV$.

4. Use "Faraday's Electromagnetic Lab" on the PHET website (`http://phet.colorado.edu/`) to explore Faraday's law. Play and experiment. Note that the "Indicator" (when available) tells you when current is flowing through the wire. The indicator can either be a light bulb or a galvanometer (voltmeter). The light bulb does not distinguish between positive and negative current: it lights up whenever any kind of current flows. The galvanometer indicates the direction of the electromotive force (emf) or voltage. When the voltage is higher at the red terminal than at the grey terminal, then the galvanometer registers a positive voltage. When the voltage is higher at the grey

terminal than at the red terminal, the galvanometer registers a negative voltage. Recall that the electrons actually move in the *opposite* direction of the current, and that the current through the resistor flows from high to low voltage. I found it convenient to use the "Field Meter" to measure the magnetic field, and especially to determine how the magnetic field is changing in time. I suggest placing the "Field Meter" sensing element right in the loop of the Pickup Coil. Also try using the "Play," "Pause," and "Step" functions at the bottom.

(a) Using either the "Pickup Coil," the "Transformer," or the "Generator" experiment, describe what happens to the voltage when you increase the number of loops on the Pickup Coil. Why? Include in your answer a discussion of the physical relationships discussed in class.

5. Using "Faraday's Electromagnetic Lab," write *and answer* your own homework problem. Illustrate an important physical concept discussed in class.

6. Download the m–file linked to the Thursday 1/17 lecture. This is an example that I wrote to check number 3 from Problem Set 1. Recall that an m–file is just a script, a set of text commands that are executed like a program. When you run an m–file, it is just like typing by hand every command in the m–file into the MATLAB command line. Notice how this m–file works. Also note how I have commented the file (% signs followed by notes). Recall that $y_1(x,t) = 3\cos(20t - 30x)$ and $y_2(x,t) = -3\cos(20t + 30x)$, with both having units of cm.

   (a) What happens when `x=linspace(x_min,x_max,1000)` is changed to `x=linspace(x_min,x_max,10)`? When changed to `x=linspace(x_min,x_max,100)`?

   (b) Reproduce Figure 2 for $y_2(x,t)$ to show how it propagates in the $-\hat{x}$ direction. Name it Figure 3.

   (c) Create a Figure 4 that verifies that the superposition of $y_1(x,t)$ and $y_2(x,t)$ is $y_s(x,t) = 6\sin(20t)\sin(30x)$.

   Always include your m–file in what you hand in for homework!

7. Read "The Power of Induction" using the link on the Thursday 1/24 lecture.

   (a) List one thing that can limit the efficiency of wireless power transmission.

   (b) What do you think about wireless power transmission? Do you have any concerns?