Waves and Fields (PHYS 195): Week 8

Spring 2009 v1.0

"I was standing on the edge of my toilet hanging a clock, the porcelain was wet, I slipped hit my head on the edge of the sink, and when I came to, I had a revelation, a vision, a picture in my head, a picture of this (points to the flux capacitor). This is what makes time travel possible, the Flux Capacitor."
-Doc in *Back to the Future*

Intro:
We continue to develop of the theory of electric fields. Before break I introduced the electric potential, electric flux, and in what amounts to a re-phrasing of Coulomb's law, Gauss's Law. After break we will study moving charges and an application of electric forces, simple circuits. Once you set charges in motion there is a very rich set of phenomenon even if you confine your attention to circuits. We will only investigate simple elements including resistors, capacitors, and batteries. We'll also see that moving charges give rise to another vector field, the magnetic field.

The Motor Kits will be distributed the week after break!

Due Wednesday, April 1

Reading: (the reading so far for our study of electric fields)

- HRW 21
- HRW 22 sections 1 - 6, 8, 9 (we skip section 7)
- HRW 23 sections 1 - 8 (we skip section 9)
- HRW 24 sections 1 - 8, 10 - 12 (we skip section 9)
- Now, **for Monday, March 30**: HRW 25.2 - page 660, 25.4 - 25.5
- Wednesday: HRW 26.1 - 26.7
- Friday: HRW 27
- Monday: HRW 28

Physics Topics:

- Electric dipole field
- Electric potential
- Electric flux
- Gauss's Law
- Circuits

Math Topics:

- Gradients e.g. $\mathbf{E} = -\nabla \mathbf{V}$
- Line integrals e.g. $V = -\int \mathbf{E} \cdot \mathbf{d}\ell$

Problems:

(1) In a plane the electric field is constant and points in the $+y$ direction so that $\mathbf{E} = E_o\hat{\mathbf{j}}$. Find the potential

$$V = -\int \mathbf{E} \cdot d\ell$$

at (d, d) in two ways:

(a) Integrate along a path from (0,0) to $(0, d)$ and then from $(0, d)$ to (d, d).

(b) Integrate directly from (0,0) to (d, d).
(c) Must your two answers be equal?
In both cases assume the potential is zero at (0,0).

(2) **Please re-do this Week 7 problem 6 quantitatively.** You have two charges of $+4q$ each and one -q charge.
(a) How would you place them along a line so that there is no net force on any one of the charges?
(b) What is the nature of this equilibrium (stable, neutral, or unstable) for the $-q$ charge? Be sure to clearly state the conditions you use to find the solutions for a and b.

(3) Carefully sketch the electric field lines for problem 2.

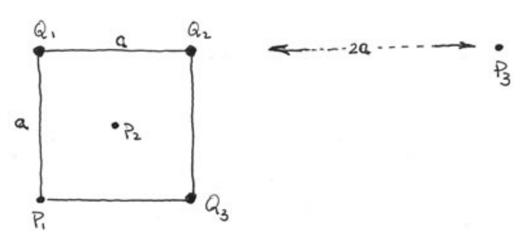
(4) HRW **QUESTION** 1 of Chapter 22

(5) HRW 22.50

(6) A fixed ring of radius R carries a uniformly distributed charge of magnitude $-Q$.
(a) What is the electric field on a point on the axis of the ring z away from the center? (You can just state the result as it is in the reading and we derived it in class.)
(b) A positive charge q is confined to move along the axis of the ring. If it is placed at the center of the ring then displaced slightly ($z \ll R$), show that the charge will undergo simple harmonic motion.
(c) If the charge has mass m, what is the period of the motion?

(7) **3D electric fields!** Find a PC computer. Dowload the zipped folder ModelBuilder from the Phys 195 website. Load application GLUIModelBuilder then the “BigDipoleModel” configuration and add about 25 field lines per charge. Try out the rotation knob so you can (virtually) see the field lines in 3D!
Now load the quadrupole configuration.
(a) Sketch the field lines in 2D
(b) Write down the charges in multiples of a basic charge q
(c) Write a brief description of the differences between the 2D and 3D field lines
Feel free to explore this program further. You can design your own configurations by modifying one of the text files.

(8) Point charges Q_1, Q_2, and Q_3 sit on three corners of a square with sides of length a. A point P_3 is $2a$ away from Q_2 as in the figure.
(a) What is the electric potential at P_2 and P_3? Be sure to choose a reasonable zero.
(b) Check out “SethsSquare” using the E-field Model Builder. Use about 32 lines per charge. Sketch the electric field lines in the plane of the square. (Hint: A large sketch is often easier)
(c) Using E-field Model Builder see if you can find the surface where $V = 0$ around charge number 2. Add this equipotential to your sketch.
In the final step of all your quantitative solutions substitute the values $a = 1$m, $Q_1 = +5\mu$C, $Q_2 = -1\mu$C, and $Q_3 = +2\mu$C.



(9) HRW 23.6

(10) HRW 24.4

(11) **Bonus Kelvin Water Dropper**: The "mysterious" Kelvin Water Dropper which, as demonstrated in lecture, is capable of creating a large electrical potential difference between the conducting cups. When high enough, this potential difference caused electrical breakdown in the gap. This occurred at roughly regular intervals as the water flowed. Explain this phenomenon. *Hints: Assume an initial slight asymmetry of charge between the two cups. Carefully draw the electric field lines around the cylinder as a drop forms. Follow what you expect to happen as the drop forms and falls. Explain how the large electric fields are generated. Water is a good conductor.*

Lab:

E-Field Mapping

A look ahead...

Next week we start studying magnetic fields. Quiz II is coming up the week of April 6.