GAUSS' LAW

20.5. DISCOVERING GAUSS' LAW IN FLATLAND

How is the flux at a closed surface related to the enclosed charge? Let's pretend we live in a two-dimensional world in which all charges and electric field lines are constrained to lie in a flat two-dimensional space—of course, mathematicians call such a space a plane.[1]

For this project you will need:

- 1 computer
- 1 Coulomb software simulation[2]

Recommended Group Size:	2	Interactive Demo OK?:	N

Open the Coulomb program on the computer again and set it to sketch lines for some nutty, creative mix of charges. Don't be *too* creative or the lines will take forever to sketch out. You should do the following:

1. Open the Coulomb simulation and place some positive *and* negative charges at different places on the screen. Then start the program to calculate and display the electric field lines in two dimensions.
2. Either sketch or print out the screen configuration showing the charges and the associated "E-field" lines.
3. Draw arrows on each of the lines indicating in what direction a *small* positive test charge would move. **Note:** "Small" means that the test charge does not exert enough forces on the charge distributions that create the E-field to cause the field to change noticeably.
4. Figure out what the two-dimensional equivalent of a "closed surface" ought to look like and draw several "closed surfaces" on your diagram.

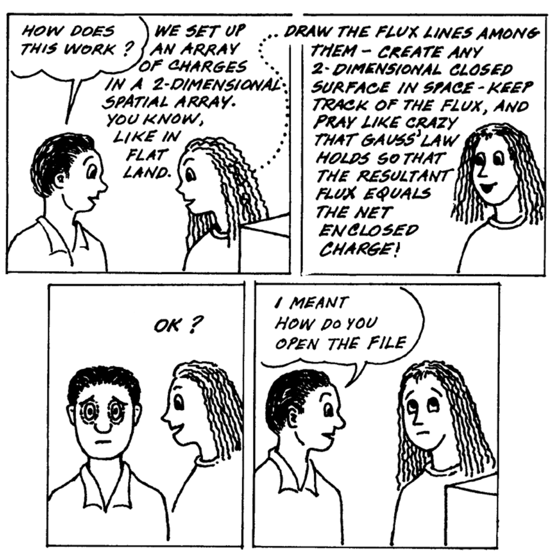

Fig. 20.4.

[1] If you haven't already read it, we recommend that you read E. A. Abbot's book entitled *Flatland; A Romance of Many Dimensions* (Dover, New York, 1952). It's a delightful piece of late nineteenth-century political satire in the guise of a mathematical spoof.

[2] In a two-dimensional map of flux lines it is not possible to assign a fixed number of lines to a charge and to assign spacings between coming from infinity unambiguously. Thus, the line densities may not look proper in some of the Coulomb software plots. This should not matter to students completing this exercise.

Having done all of this preparation, you should be ready to discover how the flux (graphically represented by the net number of electric field lines passing through a surface) is related to the net charge enclosed by the surface.

20.5.1. Activity: Gauss' Law in Flatland

a. Place a replica of the charge configuration you designed and the associated field lines in the space below.

b. Draw some two-dimensional closed "surfaces" in pencil in the space above. Some of them should enclose charge, and some should avoid enclosing charge. Count net electric field lines passing through each "surface." **Note:** Consider lines coming out of a surface as positive and lines going into a surface as negative. The *net number of lines* is defined as the number of positive lines minus the number of negative lines.

	Charge enclosed by the arbitrary surface			Lines of flux in and out of the surface		
	Total Positive Charge (Arbitrary Units)	Total Negative Charge (Arbitrary Units)	q^{net}	Φ_{out}	Φ_{in}	Φ^{net}
1						
2						
3						

c. What is the apparent relationship between the net flux and the net charge enclosed by a two-dimensional "surface"?

b. If the conductor has excess charge and it can't be inside the Gaussian surface according to Gauss' law, then what's the only place the charge can be?

c. Given the fact that as like charges, the excess charges will repel each other, is the conclusion you reached in part b. above physically reasonable? Explain. **Hint:** How can each unit of excess charge that is repelling every other unit of excess charge get as far away as possible from the other excess charges on the conductor?

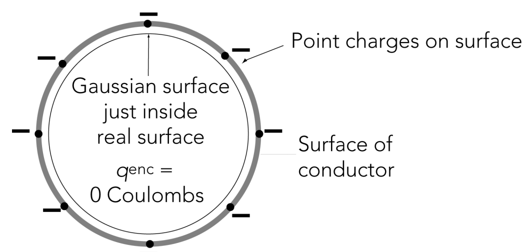

Fig. 20.6.

20.7. EXPERIMENTAL CONFIRMATION OF GAUSS' LAW

You used Gauss' law to predict that excess charge in a conductor would move to the outside surface of the conductor. Let's check this prediction. We can do this using:

- 1 soup can (a surrogate ice pail)
- 1 black plastic rod
- 1 piece of fur
- 1 metal-coated, threaded ball (with low mass)
- 1 electroscope with gold leaves (optional)

Recommended Group Size:	4	Interactive Demo OK?:	N

The test of Gauss' law that you are about to perform is attributed to Benjamin Franklin but is usually referred to as the Faraday Ice Pail Experiment. How did Faraday get credit for this one?

20.7.1. Activity: The Faraday Ice Pail Experiment

a. Suppose that a plastic rod that has been rubbed with fur is used to charge a metal-coated ball. Mark the sign of the charges on the ball in the following diagram.