

**Problem 3.32** Three point charges are located as shown in Fig. 3.38, each a distance  $a$  from the origin. Find the approximate electric field at points far from the origin. Express your answer in spherical coordinates, and include the two lowest orders in the multipole expansion.

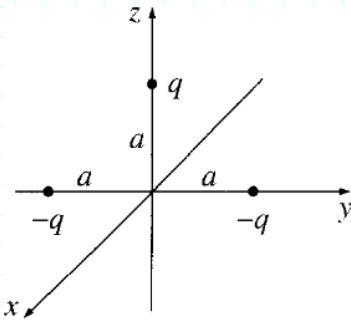


Figure 3.38

**Problem 4.5** In Fig. 4.6,  $\mathbf{p}_1$  and  $\mathbf{p}_2$  are (perfect) dipoles a distance  $r$  apart. What is the torque on  $\mathbf{p}_1$  due to  $\mathbf{p}_2$ ? What is the torque on  $\mathbf{p}_2$  due to  $\mathbf{p}_1$ ? [In each case I want the torque on the dipole *about its own center*. If it bothers you that the answers are not equal and opposite, see Prob. 4.29.]

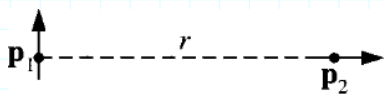


Figure 4.6

**Problem 4.9** A dipole  $\mathbf{p}$  is a distance  $r$  from a point charge  $q$ , and oriented so that  $\mathbf{p}$  makes an angle  $\theta$  with the vector  $\mathbf{r}$  from  $q$  to  $\mathbf{p}$ .

- What is the force on  $\mathbf{p}$ ?
- What is the force on  $q$ ?

**Problem 4.12** Calculate the potential of a uniformly polarized sphere (Ex. 4.2) directly from Eq. 4.9.

## BONUS:

### Problem 4.29

- (a) For the configuration in Prob. 4.5, calculate the *force* on  $\mathbf{p}_2$  due to  $\mathbf{p}_1$ , and the force on  $\mathbf{p}_1$  due to  $\mathbf{p}_2$ . Are the answers consistent with Newton's third law?
- (b) Find the total torque on  $\mathbf{p}_2$  *with respect to the center of*  $\mathbf{p}_1$ , and compare it with the torque on  $\mathbf{p}_1$  *about that same point*. [Hint: combine your answer to (a) with the result of Prob. 4.5.]

**Problem 4.15** A thick spherical shell (inner radius  $a$ , outer radius  $b$ ) is made of dielectric material with a “frozen-in” polarization

$$\mathbf{P}(\mathbf{r}) = \frac{k}{r} \hat{\mathbf{r}},$$

where  $k$  is a constant and  $r$  is the distance from the center (Fig. 4.18). (There is no *free* charge in the problem.) Find the electric field in all three regions by two different methods:

- (a) Locate all the bound charge, and use Gauss's law (Eq. 2.13) to calculate the field it produces.
- (b) Use Eq. 4.23 to find  $\mathbf{D}$ , and then get  $\mathbf{E}$  from Eq. 4.21. [Notice that the second method is much faster, and avoids any explicit reference to the bound charges.]