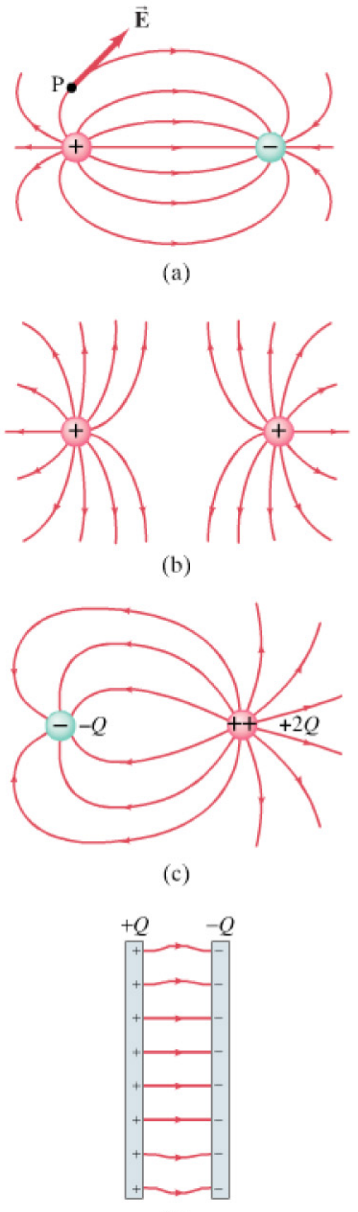
(a) (b)

FIGURE 16–30 Electric field lines (a) near a single positive point charge, (b) near a single negative point charge.

Electric field lines

To visualize the electric field, we draw a series of lines to indicate the direction of the electric field at various points in space. These **electric field lines** (sometimes called *lines of force*) are drawn so that they indicate the direction of the force due to the given field on a positive test charge. The lines of force due to a single isolated positive charge are shown in Fig. 16–30a and for a single isolated negative charge in Fig. 16–30b. In part (a) the lines point radially outward from the charge, and in part (b) they point radially inward toward the charge because that is the direction the force would be on a positive test charge in each case (as in Fig. 16–26). Only a few representative lines are shown. We could just as well draw lines in between those shown since the electric field exists there as well. We can draw the lines so that the *number of lines starting on a positive charge, or ending on a negative charge, is proportional to the magnitude of the charge*. Notice that nearer the charge, where the electric field is greater $(F \propto 1/r^2)$, the lines are closer together. This is a general property of electric field lines: *the closer together the lines are, the stronger the electric field in that region*. In fact, field lines can be drawn so that the number of lines crossing unit area perpendicular to $\vec{\mathbf{E}}$ is proportional to the magnitude of the electric field.

FIGURE 16–31 Electric field lines for four arrangements of charges.



(a) (b) (c) (d)

Figure 16–31a shows the electric field lines due to two equal charges of opposite sign, a combination known as an **electric dipole**. The electric field lines are curved in this case and are directed from the positive charge to the negative charge. The direction of the electric field at any point is tangent to the field line at that point as shown by the vector arrow $\vec{\mathbf{E}}$ at point P. To satisfy yourself that this is the correct pattern for the electric field lines, you can make a few calculations such as those done in Example 16–9 for just this case (see Fig. 16–28). Figure 16–31b shows the electric field lines for two equal positive charges, and Fig. 16–31c for unequal charges, $+2Q$ and $-Q$. Note that twice as many lines leave $+2Q$ as enter $-Q$ (number of lines is proportional to magnitude of Q). Finally, in Fig. 16–31d, we see the field between two parallel plates carrying equal but opposite charges. Notice that the electric field lines between the two plates start out perpendicular to the surface of the metal plates (we'll see why this is true in the next Section) and go directly from one plate to the other, as we expect because a positive test charge placed between the plates would feel a strong repulsion from the positive plate and a strong attraction to the negative plate. The field lines between two close plates are parallel and equally spaced in the central region, but fringe outward near the edges. Thus, in the central region, the electric field has the same magnitude at all points, and we can write

$$E = \text{constant.} \qquad \left[\begin{array}{l}\text{between two closely spaced,}\\ \text{oppositely charged, parallel plates}\end{array}\right] \quad \textbf{(16–6)}$$

The fringing of the field near the edges can often be ignored, particularly if the separation of the plates is small compared to their size.[†]

[†] The magnitude of the constant electric field between two parallel plates is given by $E = Q/\epsilon_0 A$, where Q is the magnitude of the charge on each plate and A is the area of one plate. We show this in the optional Section 16–10 on Gauss's law.