PROBLEM SOLVING Electrostatics: Electric Forces and Electric Fields

Solving electrostatics problems follows, to a large extent, the general problem-solving procedure discussed in Section 4–9. Whether you use electric field or electrostatic forces, the procedure is similar:

1. **Draw** a careful **diagram**—namely, a free-body diagram for each object, showing all the forces acting on that object, or showing the electric field at a point due to all significant charges present. Determine the **direction** of each force or electric field physically: like charges repel each other, unlike charges attract; fields point away from a + charge, and toward a − charge. Show and label each vector force or field on your diagram.
2. **Apply Coulomb's law** to calculate the magnitude of the force that each contributing charge exerts on a charged object, or the magnitude of the electric field at a point. Deal only with magnitudes of charges (leaving out minus signs), and obtain the magnitude of each force or electric field.
3. **Add vectorially** all the forces on an object, or the contributing fields at a point, to get the resultant. Use **symmetry** (say, in the geometry) whenever possible.

Let us see how this Problem Solving Box can be applied to Example 16–9, part (*b*).

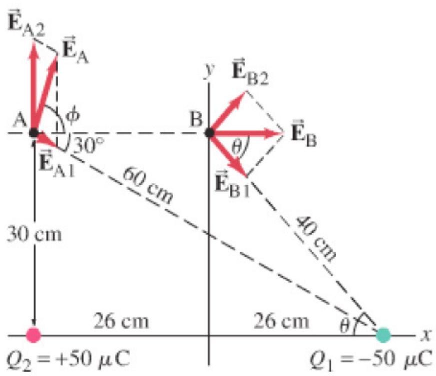


FIGURE 16–28 (repeated) Calculation of the electric field at points A and B for Example 16–9.

EXAMPLE 16–9 Repeated. Calculate the total electric field at point B in Fig. 16–28 due to both charges, Q_1 and Q_2.

APPROACH and SOLUTION

1. **Draw** a careful **diagram**. The **directions** of the electric fields $\vec{E}_{B1}$ and $\vec{E}_{B2}$, as well as the net field $\vec{E}_B$, are shown in Fig. 16–28. $\vec{E}_{B2}$ points away from the positive charge Q_2; $\vec{E}_{B1}$ points toward the negative charge Q_1.
2. **Apply Coulomb's law** to find the magnitudes of the contributing electric fields. Because B is equidistant (40 cm by the Pythagorean theorem) from the two equal charges, the magnitudes of E_{B1} and E_{B2} are the same; that is,

$$E_{B1} = E_{B2} = \frac{kQ}{r^2} = \frac{(9.0 \times 10^9\,\mathrm{N\cdot m^2/C^2})(50 \times 10^{-6}\,\mathrm{C})}{(0.40\,\mathrm{m})^2}$$
$$= 2.8 \times 10^6\,\mathrm{N/C}.$$

3. **Add vectorially**, and use **symmetry** when possible. The y components of $\vec{E}_{B1}$ and $\vec{E}_{B2}$ are equal and opposite. Because of this symmetry, the total field E_B is horizontal and equals $E_{B1}\cos\theta + E_{B2}\cos\theta = 2\,E_{B1}\cos\theta$. From Fig. 16–28, $\cos\theta = 26\,\mathrm{cm}/40\,\mathrm{cm} = 0.65$. Then

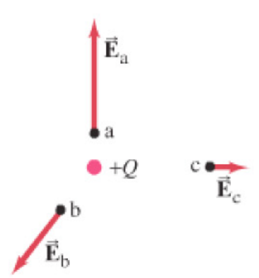
$$E_B = 2E_{B1}\cos\theta = 2(2.8 \times 10^6\,\mathrm{N/C})(0.65)$$
$$= 3.6 \times 10^6\,\mathrm{N/C},$$

and the direction of $\vec{E}_B$ is along the $+x$ direction.

NOTE Part (*a*) of Example 16–9 exhibited no useful symmetry.

16–8 Field Lines

FIGURE 16–29 Electric field vector, shown at three points, due to a single point charge Q. (Compare to Fig. 16–23.)



Since the electric field is a vector, it is sometimes referred to as a *vector field*. We could indicate the electric field with arrows at various points in a given situation, such as at a, b, and c in Fig. 16–29. The directions of $\vec{E}_a$, $\vec{E}_b$, and $\vec{E}_c$ are the same as for the forces shown earlier in Fig. 16–23, but the lengths (magnitudes) are different since we divide F by q to get E. However, the relative lengths of $\vec{E}_a$, $\vec{E}_b$, and $\vec{E}_c$ are the same as for the forces since we divide by the same q each time. To indicate the electric field in such a way at *many* points, however, would result in many arrows, which would quickly become confusing. To avoid this, we use another technique, that of field lines.