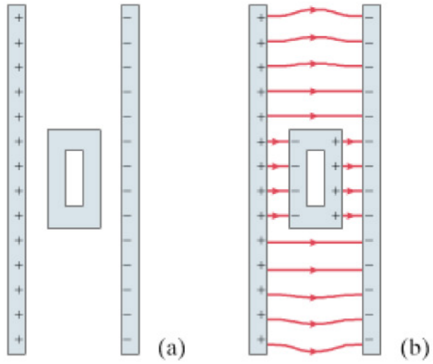

FIGURE 16–35 Example 16–10.

FIGURE 16–36 A strong electric field exists in the vicinity of this "Faraday cage," so strong that stray electrons in the atmosphere are accelerated to the KE needed to knock electrons out of air atoms, causing an avalanche of charge which flows to (or from) the metal cage. Yet the person inside the cage is not affected.

CONCEPTUAL EXAMPLE 16–10 **Shielding, and safety in a storm.** A neutral hollow metal box is placed between two parallel charged plates as shown in Fig. 16–35a. What is the field like inside the box?

RESPONSE If our metal box had been solid, and not hollow, free electrons in the box would have redistributed themselves along the surface until all their individual fields would have canceled each other inside the box. The net field inside the box would have been zero. For a hollow box, the external field is not changed since the electrons in the metal can move just as freely as before to the surface. Hence the field inside the hollow metal box is also zero, and the field lines are something like those shown in Fig. 16–35b. A conducting box used in this way is an effective device for shielding delicate instruments and electronic circuits from unwanted external electric fields. We also can see that a relatively safe place to be during a lightning storm is inside a car, surrounded by metal. See also Fig. 16–36, where a person inside a porous "cage" is protected from a strong electric discharge.

PHYSICS APPLIED
Electrical shielding

* 16–10 Gauss's Law

An important relation in electricity is Gauss's law, developed by the great mathematician Karl Friedrich Gauss (1777–1855). It relates electric charge and electric field, and is a more general and elegant version of Coulomb's law.

Gauss's law involves the concept of **electric flux**, which refers to the electric field passing through a given area. For a uniform electric field $\vec{\mathbf{E}}$ passing through an area A, as shown in Fig. 16–37a, the electric flux Φ_E is defined as

$$\Phi_E = EA\cos\theta,$$

where θ is the angle between the electric field direction and a line drawn perpendicular to the area. The flux can be written equivalently as

$$\Phi_E = E_\perp A = EA_\perp, \tag{16–7}$$

where $E_\perp = E\cos\theta$ is the component of $\vec{\mathbf{E}}$ perpendicular to the area (Fig. 16–37b) and, similarly, $A_\perp = A\cos\theta$ is the projection of the area A perpendicular to the field $\vec{\mathbf{E}}$ (Fig. 16–37c).

Electric flux has a simple intuitive interpretation in terms of field lines. We mentioned in Section 16–8 that field lines can always be drawn so that the number (N) passing through unit area perpendicular to the field $(A_\perp)$ is proportional to the magnitude of the field (E): that is, $E \propto N/A_\perp$. Hence,

$$N \propto EA_\perp = \Phi_E, \tag{16–8}$$

so the flux through an area is proportional to the number of lines passing through that area.

FIGURE 16–37 (a) A uniform electric field $\vec{\mathbf{E}}$ passing through a flat area A. (b) $E_\perp = E\cos\theta$ is the component of $\vec{\mathbf{E}}$ perpendicular to the plane of area A. (c) $A_\perp = A\cos\theta$ is the projection (dashed) of the area A perpendicular to the field $\vec{\mathbf{E}}$.