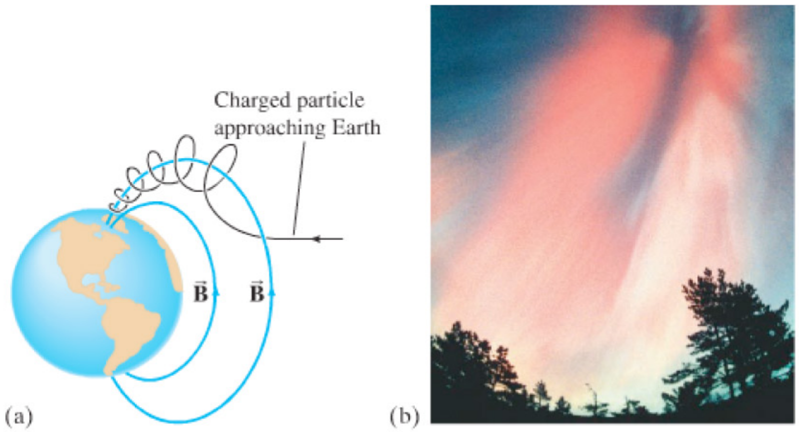

FIGURE 20–18 (a) Diagram showing a charged particle that approaches the Earth and is "captured" by the magnetic field of the Earth. Such particles follow the field lines toward the poles as shown. (b) Photo of aurora borealis.

* Aurora Borealis

PHYSICS APPLIED
The aurora borealis

Charged ions approach the Earth from the Sun (the "solar wind") and enter the atmosphere mainly near the poles, sometimes causing a phenomenon called the **aurora borealis** or "northern lights" in northern latitudes. To see why, consider Example 20–6 and Fig. 20–18 (see also Fig. 20–17). In Fig. 20–18 we imagine a stream of charged particles approaching the Earth. The velocity component *perpendicular* to the field for each particle becomes a circular orbit around the field lines, whereas the velocity component *parallel* to the field carries the particle along the field lines toward the poles. As a particle approaches the N pole, the magnetic field is stronger and the radius of the helical path becomes smaller.

The high concentration of charged particles ionizes the air, and as the electrons recombine with atoms, light is emitted (Chapter 27) which is the aurora. Auroras are especially spectacular during periods of high sunspot activity when the solar wind brings more charged particles toward Earth.

* Vector Product

Equation 20–3 can be written in a vector form that incorporates the right-hand rule:

$$\vec{\mathbf{F}} = q\vec{\mathbf{v}} \times \vec{\mathbf{B}} \tag{20–5}$$

The cross $\times$ implies the right-hand rule: first point your fingers along the velocity vector $\vec{\mathbf{v}}$ so that when you bend them, they point in the direction of the magnetic field $\vec{\mathbf{B}}$. Then your thumb gives the direction of the force $\vec{\mathbf{F}}$. The cross $\times$ also implies the use of $\sin\theta$ for the magnitude of F. Equation 20–5 is a vector equation known as the *vector cross product*.

20–5 Magnetic Field Due to a Long Straight Wire

We saw in Section 20–2, Fig. 20–8, that the magnetic field surrounding the electric current in a long straight wire is such that the field lines are circles with the wire at the center (Fig. 20–19). You might expect that the field strength at a given point would be greater if the current flowing in the wire were greater; and that the field would be less at points farther from the wire. This is indeed the case. Careful experiments show that the magnetic field B due to the current in a long straight wire is directly proportional to the current I in the wire and inversely proportional to the distance r from the wire:

$$B \propto \frac{I}{r}.$$

This relation is valid as long as r, the perpendicular distance to the wire, is much less than the distance to the ends of the wire (i.e., the wire is long).

FIGURE 20–19 Same as Fig. 20–8b, magnetic field lines around a long straight wire carrying an electric current I.