19. An unusual message delivery system is pictured in Figure P19.19. A 15-cm length of conductor that is free to move is held in place between two thin conductors. When a 5.0-A current is directed as shown in the figure, the wire segment moves upward at a constant velocity. If the mass of the wire is 15 g, find the magnitude and direction of the minimum magnetic field that is required to move the wire. (The wire slides without friction on the two vertical conductors.)

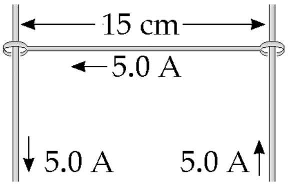

Figure P19.19

Solution

For the wire to move upward at constant velocity, the net force acting on it must be zero. Thus, the magnetic force must be directed upward and have a magnitude equal to the weight of the wire, $F = w = mg$. In general, the magnitude of the magnetic force acting on a current carrying conductor is $F = BI\ell\sin\theta$, where B is the magnitude of the field, I is the current in the conductor, ℓ is the conductor's length, and θ is the angle between the directions of the current and the magnetic field. Therefore, to move the wire at constant velocity, the magnitude of the field needed is

$$B = \frac{mg}{I\ell\sin\theta}$$

If B is to be a minimum, it is necessary for $\sin\theta$ to have its maximum value (1.0).

Thus, $$B_{\min} = \frac{mg}{I\ell} = \frac{\left(15\times10^{-3}\ \text{kg}\right)\left(9.8\ \text{m/s}^2\right)}{(5.0\ \text{A})\left(15\times10^{-2}\ \text{m}\right)} = 0.20\ \text{T}$$ ◊

To find the direction of this minimum magnitude field, realize that if $\sin\theta = 1.00$, then $\theta = 90°$ and the field is perpendicular to the current. Using Figure P19.19 and right-hand rule #1, hold your right hand flat with the palm upward (the required direction of the magnetic force), and the thumb pointing to the left (the direction of the current). You should find that your fingers are pointing out of the page toward you. This is the required direction of the magnetic field. ◊