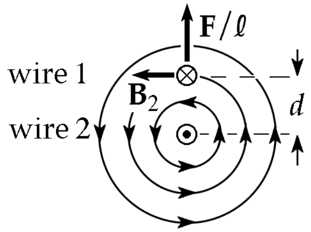
45. A wire with a weight per unit length of 0.080 N/m is suspended directly above a second wire. The top wire carries a current of 30.0 A and the bottom wire carries a current of 60.0 A. Find the distance of separation between the wires so that the top wire will be held in place by magnetic repulsion.

Solution

In the sketch at the right, it is assumed that the current in the lower wire (wire 2) is coming out of the page toward the reader. Then, the magnetic field lines due to the current in wire 2 are circular and centered on this wire. At the location of wire 1, the magnetic field due to the current in wire 2 is horizontal and toward the left with a magnitude of $B_2 = \mu_0 I_2/2\pi d$. Here, $I_2 = 60.0$ A is the current in wire 2 and d is the distance separating the two wires.



If wire 1 is to be suspended in the magnetic field B_2, the magnetic force per unit length, F/ℓ, exerted on it by the field must be directed upward and its magnitude must equal the weight per unit length of wire 1 (i.e. $F/\ell = 0.080\ \mathrm{N/m}$.)

Note that if this force is to be directed upward as needed, the current in wire 1 must flow into the page as indicted in the sketch. The magnetic force exerted on a conductor of length ℓ carrying current I_1 perpendicularly to a field of magnitude B_2 is $F = B_2 I_1 \ell$. Thus, the magnetic force per unit length acting on wire 1 is

$$F/\ell = B_2 I_1 = \left(\frac{\mu_0 I_2}{2\pi d}\right) I_1$$

Therefore, if wire 1 is to be suspended, it is necessary that

$$\mu_0 I_2 I_1 / 2\pi d = 0.080\ \mathrm{N/m}$$

The distance between the wires must be

$$d = \frac{\mu_0 I_2 I_1}{2\pi(0.080\ \mathrm{N/m})} = \frac{\left(4\pi\times10^{-7}\ \mathrm{N/A^2}\right)(60.0\ \mathrm{A})(30.0\ \mathrm{A})}{2\pi(0.080\ \mathrm{N/m})}$$

or $$d = 4.5\times10^{-3}\ \mathrm{m} = 4.5\ \mathrm{mm}$$ ◊