Problem 5.19 A square loop placed as shown in Fig. 5-44 (P5.19) has 2-m sides and carries a current $I_1 = 5$ A. If a straight, long conductor carrying a current $I_2 = 10$ A is introduced and placed just above the midpoints of two of the loop's sides, determine the net force acting on the loop.

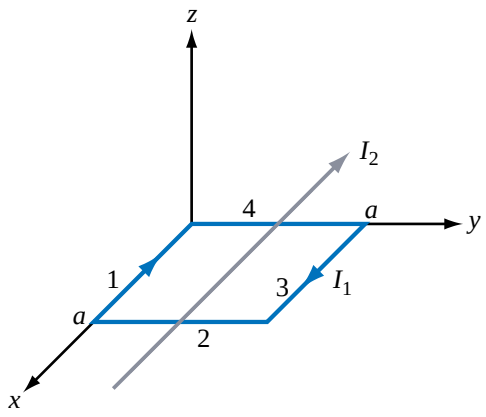

Figure P5.19: Long wire carrying current I_2, just above a square loop carrying I_1 (Problem 5.19).

Solution: Since I_2 is just barely above the loop, we can treat it as if it's in the same plane as the loop. For side 1, I_1 and I_2 are in the same direction, hence the force on side 1 is attractive. That is,

$$\mathbf{F}_1 = \hat{\mathbf{y}} \frac{\mu_0 I_1 I_2 a}{2\pi(a/2)} = \hat{\mathbf{y}} \frac{4\pi \times 10^{-7} \times 5 \times 10 \times 2}{2\pi \times 1} = \hat{\mathbf{y}} 2 \times 10^{-5} \text{ N}.$$

I_1 and I_2 are in opposite directions for side 3. Hence, the force on side 3 is repulsive, which means it is also along $\hat{\mathbf{y}}$. That is, $\mathbf{F}_3 = \mathbf{F}_1$.

The net forces on sides 2 and 4 are zero. Total net force on the loop is

$$\mathbf{F} = 2\mathbf{F}_1 = \hat{\mathbf{y}} 4 \times 10^{-5} \text{ N}.$$