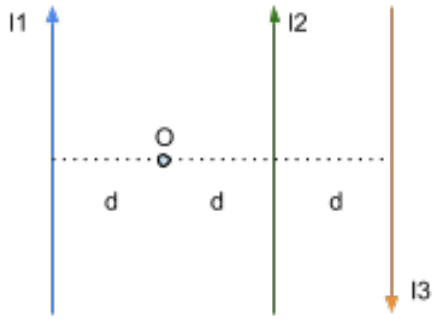
Ampere's Law Example (magnetic fields due to three straight current wires)

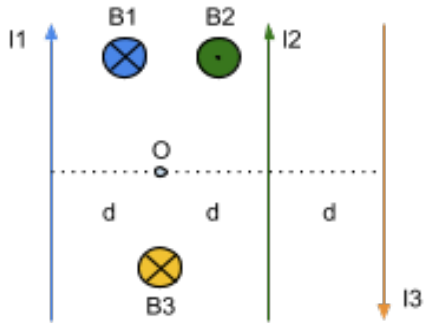
Compute the total magnetic field at point O.



Solution

Step 1: Determine the direction of the magnetic field at point O due to each current-carrying wire.

Using the right-hand rule on each of the wires, we see that wire 1 and 3 create magnetic fields that point into the page in the region of interest, whereas wire 2 creates a magnetic field that is pointing out of the page.



Step 2: Write an expression for the total magnetic field.

Since magnetic field is additive, the total magnitude of B at point O is: $B_O = B1 - B2 + B3$ where the negative accounts for the opposite direction of B2 compared with that of B1 and B3.

Step 3: Calculate the total magnetic field at O.

Using the relationship: $\mathrm{B} = \frac{\mu_o I}{2\pi r}$ and noting that $r_1 = r_2 = d$ while $r_3 = 2d$ we obtain:

$$B_O = B1 - B2 + B3 \quad \Rightarrow \quad \boldsymbol{B_O = \frac{\mu_o I1}{2\pi d} - \frac{\mu_o I2}{2\pi d} + \frac{\mu_o I3}{2\pi(2d)} = \frac{\mu_o}{2\pi d}\left(I1 - I2 + \frac{1}{2}I3\right)}$$