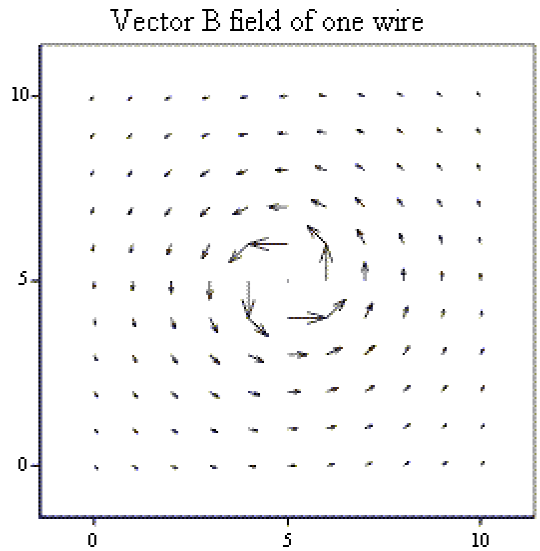
Magnetic field of parallel wires



(MX, MY)

At right is a plot of the vector magnetic field around one wire. If there are two wires, the currents can be in the same direction or the opposite direction. If the currents are in the same direction, the fields far from the wires will add but they will subtract in the region between the wires. If the currents are changed to antiparallel, then the field inside the wires will add but the fields at a distance will subtract. We can see this in vector plots.

The B field of one wire

If a straight wire is in the z direction, then the B field is in the θ direction. The x component of a unit vector in the θ direction is -y/r and the y component is x/r. The x and y components of the vector magnetic field are (-y/r) B_θ and (x/r) B_θ. We know that $B_\theta = \mu I / 2\pi r$. Let's pretend that μ is one so our answers are not in scientific notation.

$\mu_0 := 1$ (This variable is created by typing a period between the μ and the 0.)

$I := 5$ is the current.

The vector X will contain the starting x,y coordinates for the line:

Our vector coordinate is $X := \begin{pmatrix} 1 \\ 1 \end{pmatrix}$ X_0 is x, X_1 is y

In terms of the components of X, the radius is $r(X) := \sqrt{(X_0)^2 + (X_1)^2}$

The θ component of B is $B\theta(X) := \text{if}\left[(r(X)) \neq 0, \dfrac{\mu_0 \cdot I}{2 \cdot \pi \cdot r(X)}, 10^{-4}\right]$

An IF statement has been used so that we don't get a singularity at r = 0.

$Bx(X) := \dfrac{(-X)_1 \cdot B\theta(X)}{r(X)}$ $By(X) := \dfrac{X_0 \cdot B\theta(X)}{r(X)}$

We will put Bx and By into matrices MX and MY with the subscripts i and j indicating the distance in the x and y directions, respectively.

Define i and j, the subscripts of an answer matrix.

$i := 0, 1 .. 10 \qquad j := 0, 1 .. 10$

Our wire is at the origin in the x,y plane, so we will want our plot to go from -5 to +5 along both x and y. The subscript i will go from 0 to 10 and we will subtract 5 from i to get x. Thus x will go from -5 to +5.

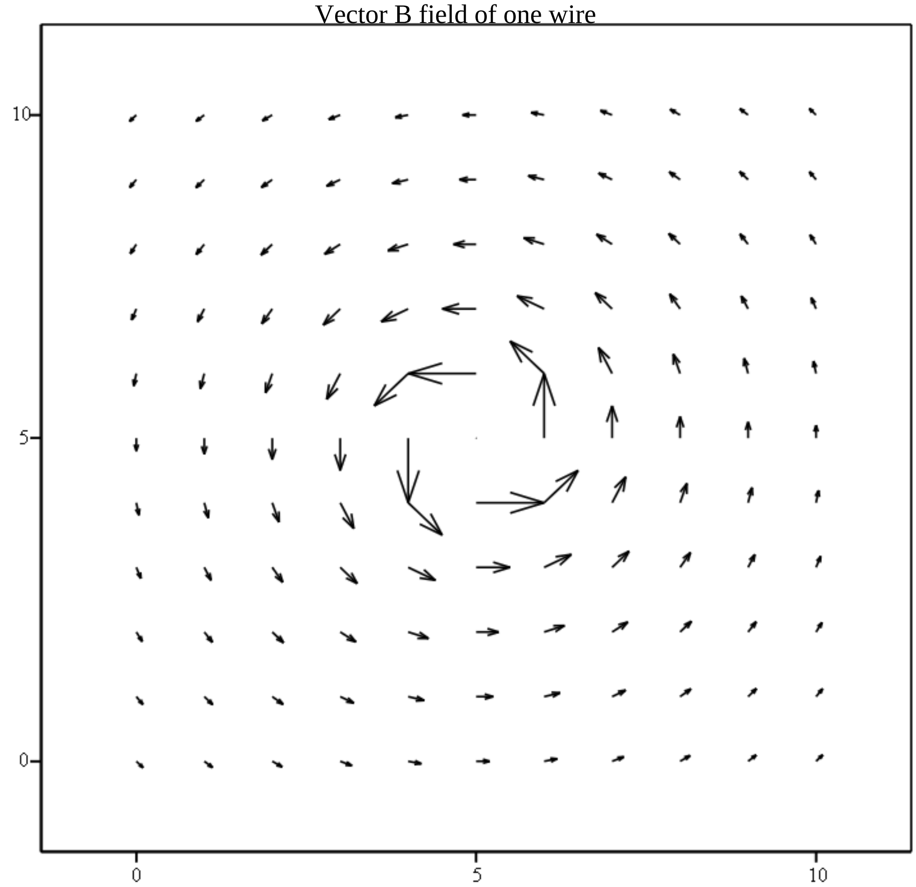
$$MX_{i,j} := Bx\left(\begin{pmatrix} -5 + i \\ -5 + j \end{pmatrix}\right)$$

distance along x is -5+i
distance along y is -5 + j

$$MY_{i,j} := By\left(\begin{pmatrix} -5 + i \\ -5 + j \end{pmatrix}\right)$$

Use a vector plot to show the x and y components of B in the matrices MX and MY

Vector B field of one wire



(MX, MY)

The two arguments MX and MY must be in parentheses.

Field of parallel wires with parallel currents

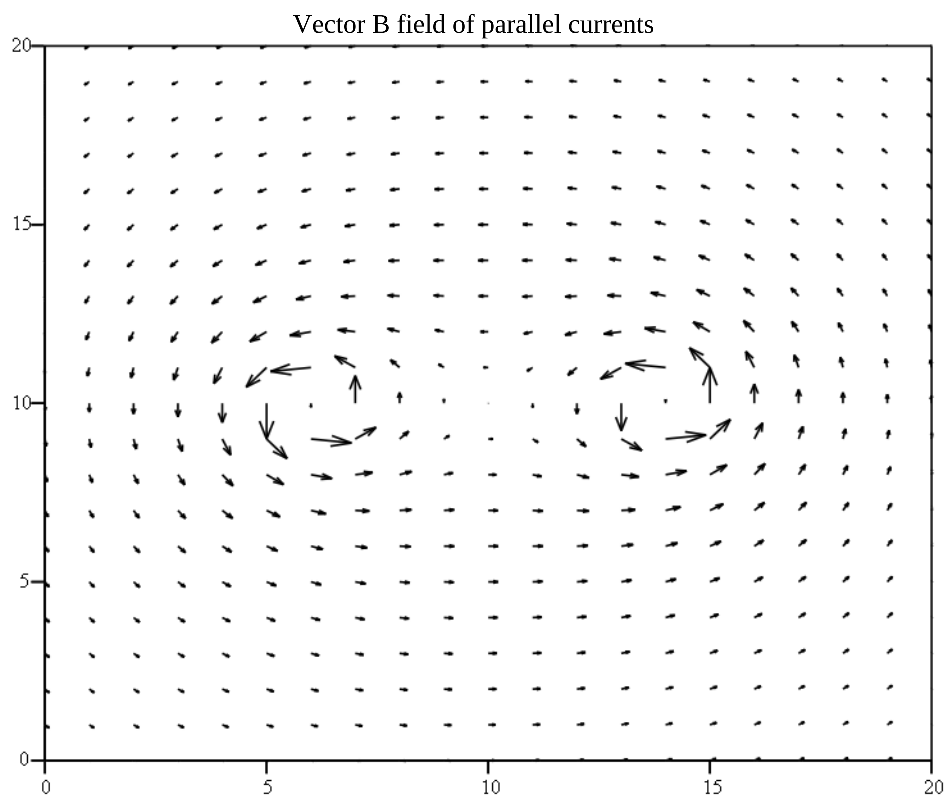
Here we plot the sum of the fields of two wires. One wire is shifted 4 units to the left and the other is shifted 4 units to the right.

$i := 0, 1 .. 20$ $\qquad$ $j := 0, 1 .. 20$

$$MX_{i,j} := Bx\left(\begin{pmatrix} -10 + i - 4 \\ -10 + j \end{pmatrix}\right) + Bx\left(\begin{pmatrix} -10 + i + 4 \\ -10 + j \end{pmatrix}\right)$$

Note how the shifting right and left is done.

$$MY_{i,j} := By\left(\begin{pmatrix} -10 + i - 4 \\ -10 + j \end{pmatrix}\right) + By\left[\begin{bmatrix} (-10 + i) + 4 \\ -10 + j \end{bmatrix}\right]$$



(MX, MY)

Note that there is an "X point" at the origin.
Can you see that the x point has B = 0, $dB_x/dy > 0$ and $dB_y/dx < 0$?

Field of parallel wires with antiparallel currents.

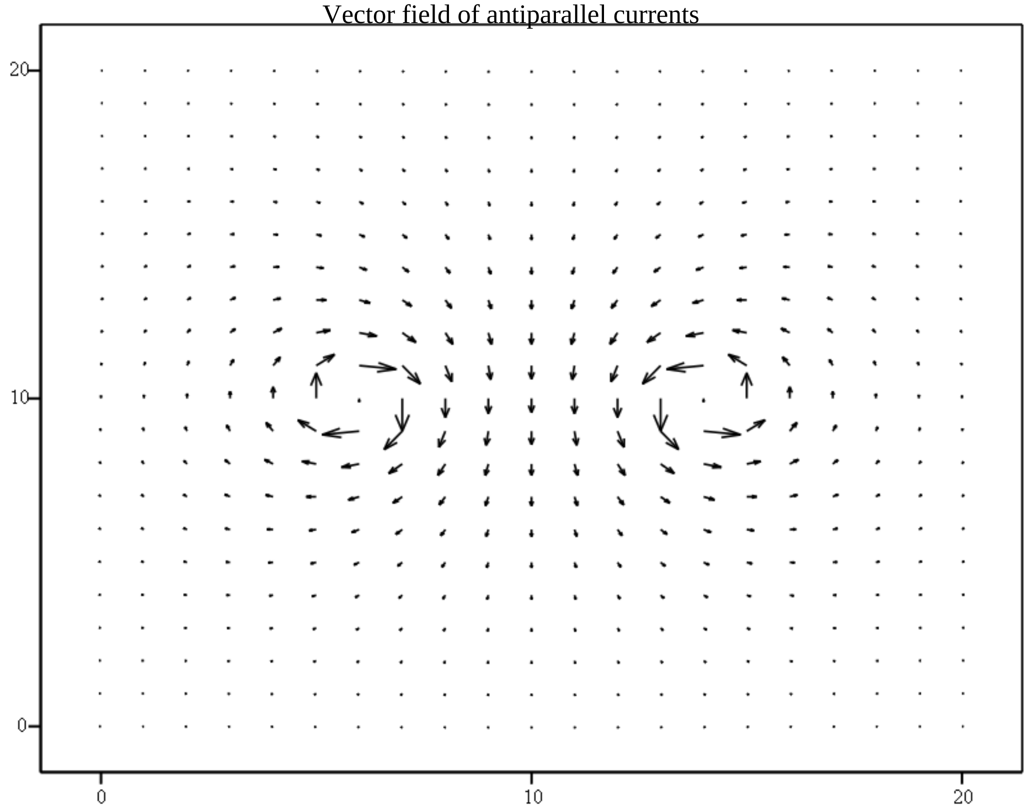
In this case the current of the second wire is subtracted rather than added.

$i := 0, 1 .. 20$ $j := 0, 1 .. 20$

$$MX_{i,j} := Bx\left(\begin{pmatrix} -10 + i - 4 \\ -10 + j \end{pmatrix}\right) - Bx\left(\begin{pmatrix} -10 + i + 4 \\ -10 + j \end{pmatrix}\right)$$

$$MY_{i,j} := By\left(\begin{pmatrix} -10 + i - 4 \\ -10 + j \end{pmatrix}\right) - By\left[\begin{bmatrix} (-10 + i) + 4 \\ -10 + j \end{bmatrix}\right]$$

Vector field of antiparallel currents



(MX, MY)

Try it: What does the field plot look like with four parallel wires located at the corner of a square if the currents are all parallel (+,+,+,+)? If the currents are in alternate directions (+,-,+,-)?