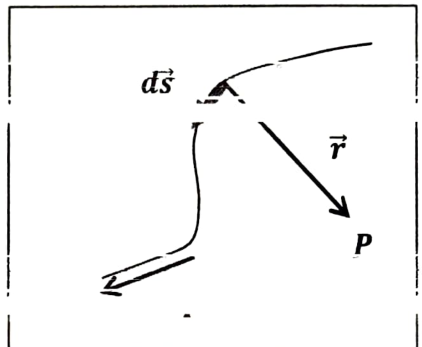
Section	Group	Name	Signature

Grade

	Jacob H[illegible]	[illegible]

Materials: • *none*

After this activity you should know: *• Biot-Savart law • the direction and magnitude of the magnetic field created by a long straight thin current • be able to calculate magnetic field due to multiple currents.*

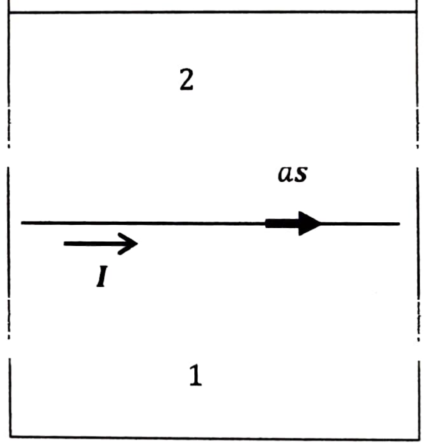


Magnetic fields are generated by moving charges or currents. Even a permanent magnet can be thought of as a large collection of current loops on an atomic scale.

Biot-Savart Law: The Biot-Savart law gives the magnetic field $d\vec{B}$ at point P due to a small segment $d\vec{s}$ of a wire carrying a current I:

$$d\vec{B} = \frac{\mu_0 I}{4\pi}\frac{d\vec{s}\times\hat{r}}{r^2}$$

of $d\vec{s}$ is the same direction as the current at position on the wire



1. A long straight thin wire carries current as shown. Use the Biot-Savart law and the right hand rule to determine the direction of the magnetic field at the points shown.

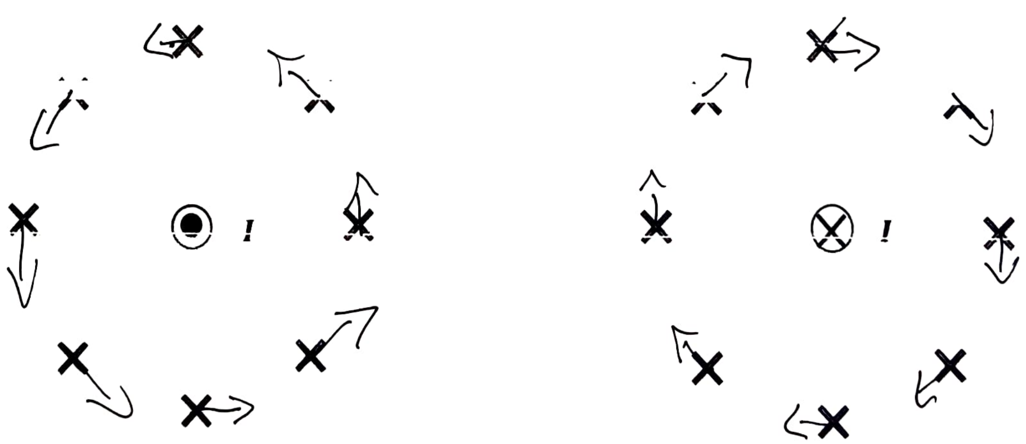
   a. What is the direction of the magnetic field at point 1 (left/right/in/out/top/bottom/zero)? *Hint: pick a small length $d\vec{s}$ of the current and draw the vector $\vec{r}$ from $d\vec{s}$ to point 1.*

      In

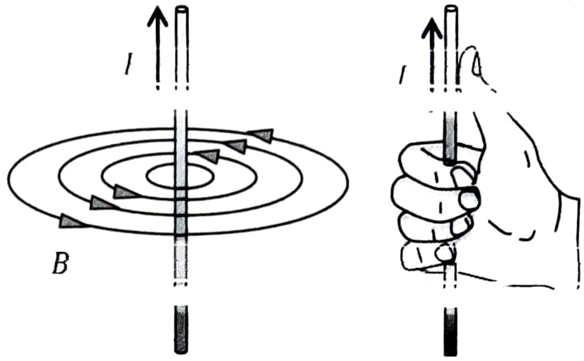
   b. What is the direction of the magnetic field at point 2 (left/right/in/out/top/bottom/zero)?

      out

   c. Turn the long wire so the current is coming straight out of the page (shown on the diagram on the left). Draw arrows at each point x showing the direction of the magnetic field at that point. Repeat for the diagram on the right which shows the current going into the page.

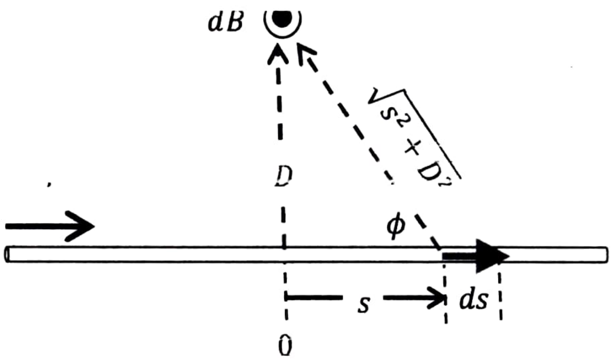


Right hand rule for magnetic field due to a long straight current: Magnetic field lines are a way to graphically represent the magnetic field. The direction of $\vec{B}$ at any point is tangent to the field line and the magnitude of B is proportional to the density of field lines. For the long straight wire, the magnetic field lines form circles around the wire.



There is a right hand rule for the direction in the magnetic field lines go around the wire. Grasp the wire with your thumb in the direction of the current. The direction your fingers wrap around the wire is the direction that the B field lines go around the wire. Check that this agrees with your analysis of the long straight wire from the previous problem.

Magnitude of magnetic field due to a long straight current: The magnitude of the magnetic field at a distance D due to a very long straight wire carrying current I can be derived from the Biot-Savart law:



$$dB = \frac{\mu_0 I\, ds \sin\phi}{4\pi(s^2+D^2)} = \frac{\mu_0 I D\, ds}{4\pi(s^2+D^2)^{3/2}}$$

where we used $\sin\phi = D/\sqrt{s^2+D^2}$. The magnitude of the magnetic field due to a very long (infinite) wire is

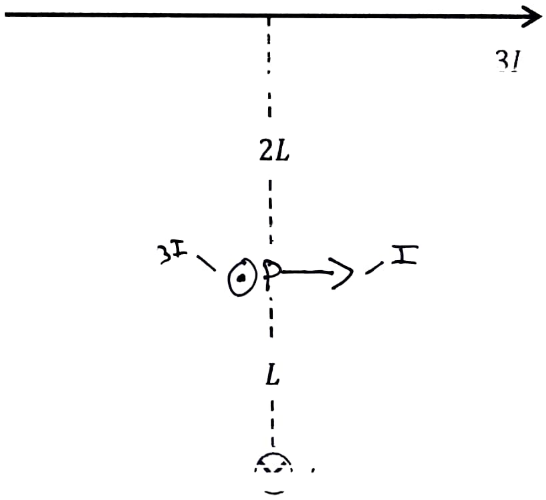
$$B = \int dB = \frac{\mu_0 I D}{4\pi}\int_{-\infty}^{\infty}\frac{ds}{(s^2+D^2)^{3/2}} = \frac{\mu_0 I}{2\pi D}$$

This is an important relationship that we use often.

2. Two very long straight wires (treat as infinite) carry currents in the direction shown.

   a. Draw arrows (or write $\odot$ or $\otimes$) for the magnetic field at point P due to (i) the current I and (ii) the current $3I$.

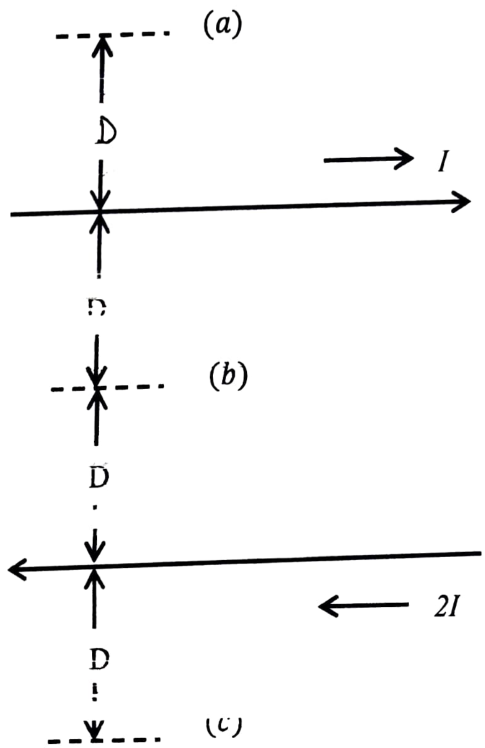
   b. Determine the magnitude of the magnetic field at point P.



$I = \frac{\mu_0 I}{2\pi L}$

$3I = \frac{3\mu_0 I}{4\pi L}$ $= \frac{7\mu_0 I}{4\pi L}$

3. Two very long parallel wires carry the currents shown. Determine the magnitude and direction of the magnetic field (left/right/top/bottom/in/out/zero) at each point (a), (b) and (c). *Hint: at each point, determine the magnetic field due to each wire and add the contribution as vectors.*



a. *Direction* = In

$$\frac{\mu_0 I}{2\pi D} - \frac{2\mu_0 I}{8\pi D} = \frac{2\mu_0 I}{8\pi D}$$

Magnitude = $\frac{\mu_0 I}{4\pi D}$

b. *Direction* = out

$$\frac{\mu_0 I}{2\pi D} + \frac{2\mu I}{2\pi D} = +\frac{3\mu_0 I}{2\pi D}$$

Magnitude = $\frac{3\mu_0 I}{2\pi D}$

c. *Direction* = In

$$\frac{2\mu_0 I}{2\pi D} - \frac{\mu_0 I}{8\pi D} = \frac{7\mu_0 I}{8\pi D}$$

Magnitude = $\frac{7\mu_0 I}{8\pi D}$

d. What is the direction and magnitude of the magnetic field at point (b) if the direction of the bottom $2I$ current was to the right instead of to the left?

In $\frac{\mu_0 I}{2\pi D}$