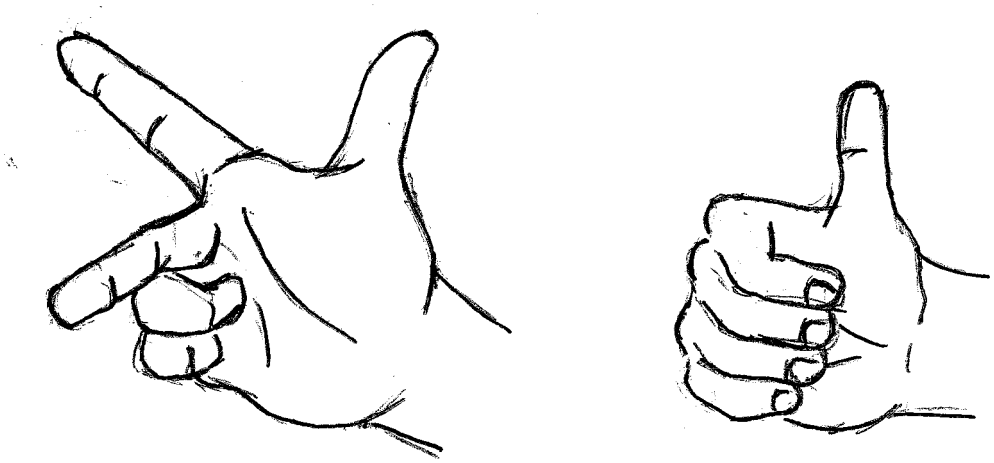
Vectors and Right Hand Rules in Magnetism

Drawing 3D Vectors on a 2D Page

When working with magnetism, we will often have to deal with different vectors pointing in all three directions in space, since we are using the cross product extensively. Since not everyone is an artist and perspective views tend to mask, rather than illuminate, the important features of a diagram, there is a convention for expressing vectors that leave the plane of the page. Vectors lying within the plane of the page are drawn normally. For a vector that is to point *out* of the plane of the page towards the viewer, we use a circle with a dot in the center (as if you were looking head on into an arrow). For vectors going *into* the page, the vector is represented as a circle with an X through it (as though you were looking head on at the feathered tail of an arrow.

"out of page" "into page"

Configurations of the Right Hand



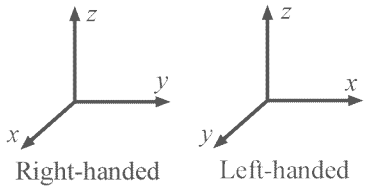
Configuration 1 Configuration 2

In configuration 1, the vectors will point in the thumb, index finger, and middle finger directions. To simplify writing, we will refer to the triplet of quantities (a,b,c) to mean "a points in the direction of the thumb, b points in the direction of the index finger, and c points in the direction of the middle finger."

In configuration 2, the vectors or currents will point in the direction of the thumb or curl around in the direction of the fingers.

Right Handed Coordinate Systems

In magnetism, we will want to use *right-handed coordinate systems*. A right-handed coordinate system is one in which the coordinates have a definite order. For cartesian coordinates the order is (x,y,z) while for cylindrical the order is (r, θ, z). The ordering is such that, in configuration 1 above, the first coordinate is the thumb, the second is the index finger, and the third is the middle finger. If we switch the order of any two coordinates, we are left with a left-handed system. If we cyclically permute the coordinates (for instance, to (y,z,x) or (z,x,y)), then the system is still right-handed.



Applications

The Cross Product

Use configuration 1. If $\mathbf{A} \times \mathbf{B} = \mathbf{C}$, then the direction of **C** is determines from the directions of **A** and **B** by using the tripled (**A**, **B**, **C**) in configuration 1.

Force on a Moving Charge or Current

Use configuration 1. The force on a charge in a magnetic field is $\mathbf{F}=q(\mathbf{v} \times \mathbf{B})$. For a *positively* charged particle, then the triplet used in configuration 1 will be (v, B, F). For a *negatively* charged particle, then the triplet used in configuration 1 will be (v, B, -F). If we are looking at the force on a current, then we use the tripled (direction of current, B, F).

Magnetic Field from a Straight Wire

Use configuration 2. Your thumb is the direction of the current and your curled fingers point in the direction of the magnetic field circling the current.

Magnetic Field from a Loop of Wire

Use configuration 2. Your curled fingers will curl in the direction of the current and your thumb will point in the direction of the magnetic field at the center of the current.

Area Vector for an Open Surface

An open surface has a loop of some sort as its boundary. Give this boundary a direction (clockwise or counterclockwise). Use configuration 2. Your fingers curl around in the direction of this orientation, and your thumb will point in the direction of the area vector.

Direction of Induced Current

Use configuration 2. Your thumb points in the direction of *changing* magnetic field and your fingers curl in the direction that the induced current will follow.