

28, Sources of Magnetic Field

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- How are magnetic field created?
- We will study permanent magnets and electromagnets(both sources of magnetic fields) in details

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A magnetic field exerts force only on a *moving* charge. Similarly, we will see that only *moving* charges *create* magnetic fields. We will begin with a single moving point charge that create a magnetic field. We can use this to determine the

1 Magnetic field of a moving charge

A single point charge q is moving with a constant velocity \vec{v} . We call the location of the moving charge at a given instant the **source point** and the point P where we want to find the field, the **field point**.

The field point a distance r from a point charge q , the magnitude of the *electric* field \vec{E} caused by the charge is proportional to the charge magnitude $|q|$ and to $\frac{1}{r^2}$, and the direction of \vec{E} (for a positive q) is along the line from source point to field point. The corresponding relationship for the magnetic field \vec{B} of a point charge q moving with a constant velocity has some similarities and some interesting differences.

Experiments show the magnitude of \vec{B} is also proportional to $|q|$ and to $\frac{1}{r^2}$. **But** the *direction* of \vec{B} is not along the line from the source point to the field point. Instead, \vec{B} is perpendicular to the plane containing this line and the particles velocity vector \vec{v} . The field magnitude B is also

proportional to the particles speed v and the sine of the angle θ .
Therefore, the magnetic-field magnitude at the point P is:

$$B = \frac{\mu_0}{4\pi} \frac{|q|v \sin \theta}{r^2}$$

Where μ_0 is the magnetic constant.

Moving charge: vector magnetic field

We can combine both the magnitude and direction of \vec{B} into a single vector by using the vector product. To avoid having to say "the direction from the source q to the field point P", we introduce a *unit* vector \hat{r} . This vector points from the source point to the field point. The unit vector is equal to the \vec{r} from the source to the field point, divided by its magnitude.