28, Sources of Magnetic Field

January 30, 2020

- 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. Similarily, 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 similarites and some interesting differences.

Experiments sjpw 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 my it's magnitude.