Magnetic Materials

Recall that **atoms and molecules**, having both positive (i.e., protons) and negative (i.e., electron) charged particles can form **electric dipoles**.

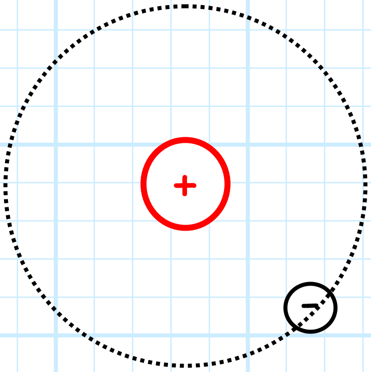
We find that atoms and molecules also can also form **magnetic dipoles**!

Q: *How??*

A: Recall a magnetic dipole is formed when current flows in a **small loop**. Current, of course, is **moving charge**, therefore charge moving around a small loop forms a magnetic dipole.

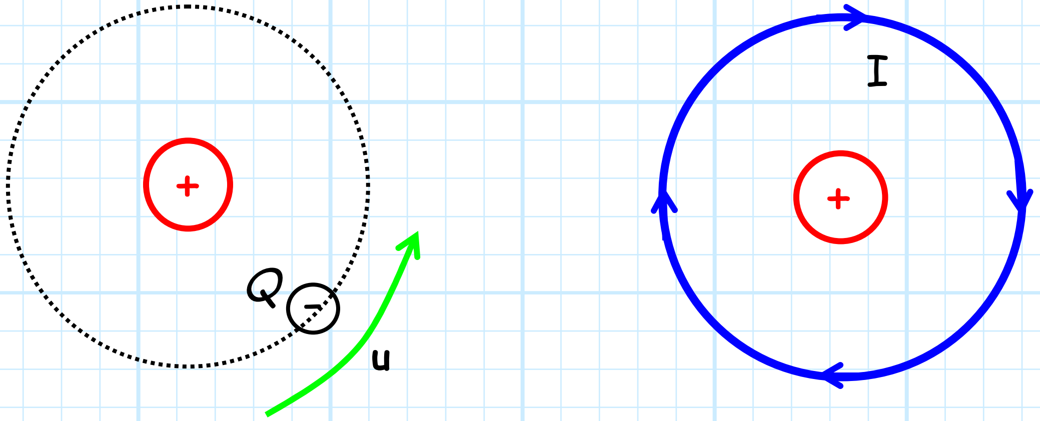
Molecules and atoms **often** exhibit electrons moving around in small loops!

Again, we use our **ridiculously** simple model of an atom:



⊖ = electron
(negative charge)

⊕ = nucleus
(positive charge)

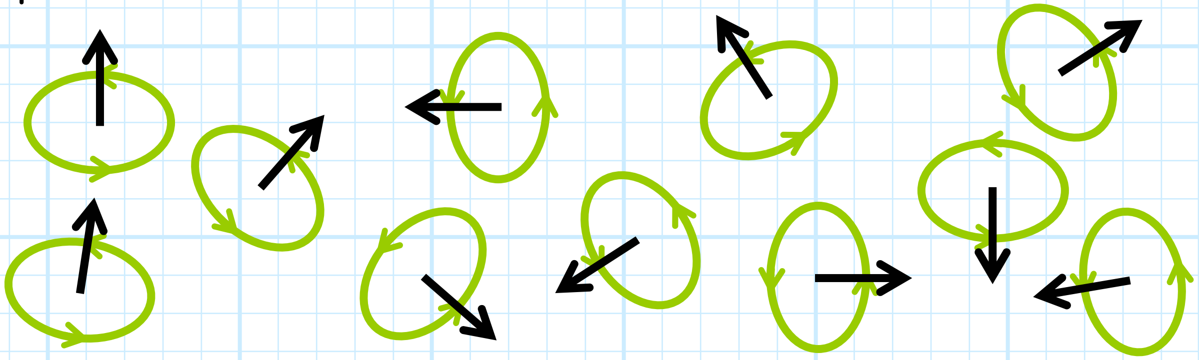


An electron with charge Q orbiting around a nucleus at velocity **u** forms a **small current loop**, where $I = Q|\mathbf{u}|$.

This forms a **magnetic dipole**!

This is a **very simple** atomic explanation of how magnetic dipoles are formed in material. In actuality, the physical mechanisms that lead to magnetic dipoles can be **far** more complex. For example, **electron spin** can also create a magnetic dipole moment.

Typically, the atoms/molecules of materials exhibit either **no** magnetic dipole moment (i.e., $\mathbf{m} = 0$), or the dipole moments of each atom/molecule are **randomly oriented**, such that the **net** dipole moment is **zero**.



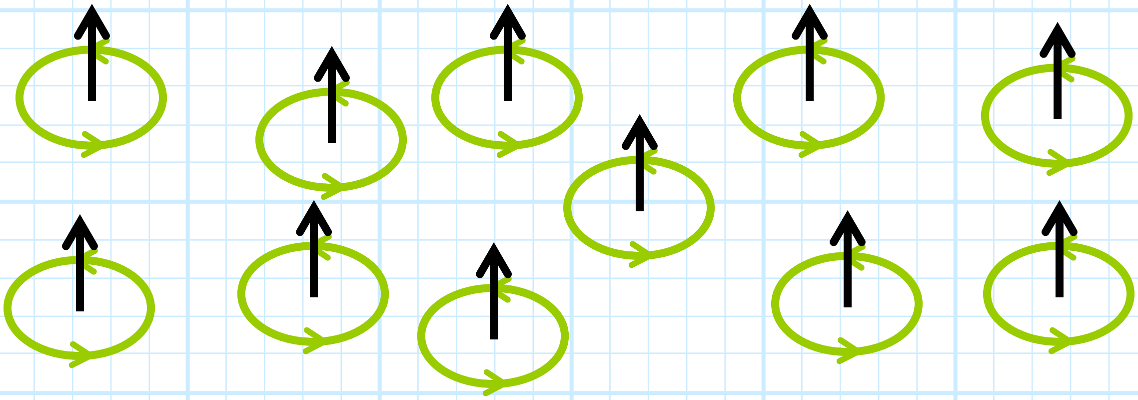
Therefore, if we have N randomly oriented magnetic dipoles $\mathbf{m}_n$, we find there average value will be zero:

$$\frac{1}{N}\sum_n \mathbf{m}_n = 0$$

Similarly, we find that the **total** magnetic flux density created by these magnetic dipoles is **also zero**:

$$\sum_n \mathbf{B}_n(\bar{r}) = 0$$

However, we find that sometimes the magnetic dipole moment of each atom/molecule is **not** randomly oriented, but in fact are **aligned**!



In this case, total magnetic flux density created by these dipoles is **non-zero**!

$$\sum_n \mathbf{B}_n(\bar{r}) \neq 0 .$$

Q: ***Why** would these magnetic dipoles be aligned?*

A: **Two** possible reasons:

1) the material is a **permanent magnet**.

2) the material is immersed in some **magnetizing field** $\mathbf{B}_m(\bar{r})$.