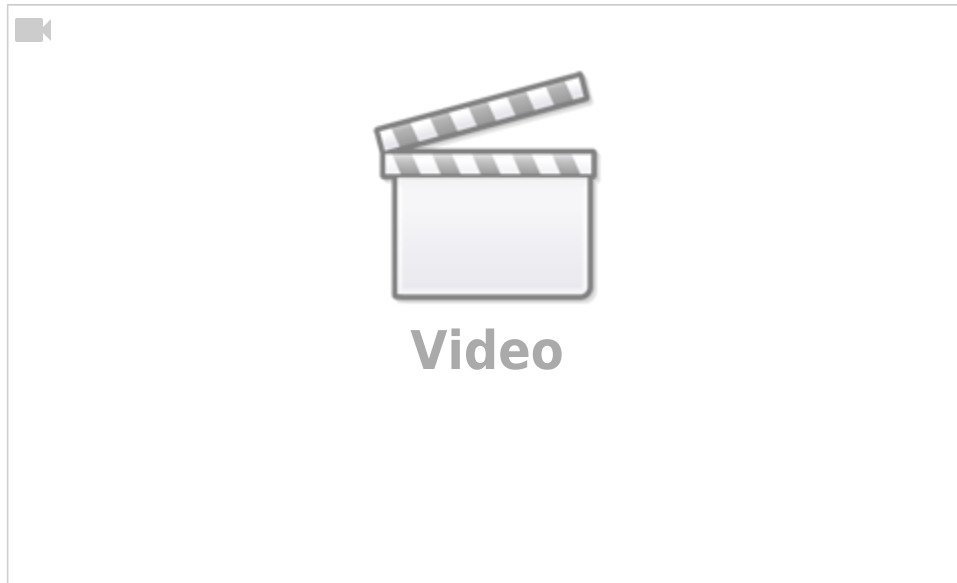


Conceptual Electronics Videos

The series manages to start from scratch and work its way up to Electromagnetism pretty much without math. One thing they could have improved though is the labelling. So while you watch this next video, keep in mind that:

- Red particles are **positive** charges
- Blue particles are **negative** charges
- Purple arrows are **electric** fields
- Green arrows are **magnetic** fields.



The videos can seem pretty overwhelming, with all these fields creating each other, but there's really only four rules that govern it all:

Name	Math	Description
Gauss' Law	$\vec{\nabla} \cdot \vec{E} = \frac{\rho}{\epsilon_0}$	An electric charge (right) creates an electric field that points away from the charge and “disperses” to infinity (left)
Gauss' Law of Magnetism	$\vec{\nabla} \cdot \vec{B} = 0$	A magnetic field (left) can not “disperse” to infinity the way an electric field can. In other words: “magnetic charges” don't exist the way electric charges do.
Faraday's Law of Induction	$\vec{\nabla} \times \vec{E} = -\frac{\partial \vec{B}}{\partial t}$	A changing magnetic field (right) creates a “curly” electric field (left) and vice-versa.
Ampere's Law	$\vec{\nabla} \times \vec{B} = \mu_0 \left(\vec{J} + \epsilon_0 \frac{\partial \vec{E}}{\partial t} \right)$	An electric current and/or a changing electric field (right) creates a “curly” magnetic field (left)

Together, these four equations (known as  **Maxwell's Equations**) account for all the electromagnetic phenomena we observe:

- [4:00] Magnetic fields exerts a force on moving charged particles because a moving charged particle creates curly magnetic field around it (Ampere's Law) so the particle behaves like a magnet. This is the principle behind old Cathode Ray Tube TVs: send electrons flying toward a screen that can image them, and adjust

their deflection using a magnetic field.

- [4:16] A charged particle moving in a loop creates a magnetic field (Ampere's Law) which is the same for a spinning electric charge, which is the what permanent magnets are made of. Notice how the magnetic field lines form closed loops (Gauss' Law of Magnetism).
- [5:20] Magnetic fields can be created by a current through a wire (first part of Ampere's Law), which is how electric motors function.
- [7:08] Electric fields can be created by a magnetic field which is changing in time (Faraday's Law of Induction), which is how alternators function.
- [10:15] Magnetic fields can also be created by a changing electric field (second part of ampere's law). Together with the other three laws, these can lead to a feed back loop where a changing magnetic field creates a changing electric field, which creates a changing magnetic field, and so on. This is how electromagnetic waves are created.