Electromagnetic Fields & Waves

- To understand that electric and magnetic fields are interdependent. There’s just a single EM field that presents different faces, in terms of E and B, to different observers.
- EM fields obey four general laws = Maxwell’s equations.
- EM fields can exist without source charges or currents in the form of a self-sustaining EM wave.
- Maxwell’s equations predict that all EM waves travel at the same speed.
- EM waves can be polarized.

**Gauss’ Law with electric fields:**

\[ \mathbf{E} = \frac{1}{4\pi\epsilon_0} \oint \mathbf{E} \cdot d\mathbf{A} \]

There is a net electric flux through this surface that encloses a charge.

---

**Announcements**

- Help sessions
  - W 9 - 10 pm in NSC 119
- MasteringPhysics
  - Hwk #5 due Fri., May 4
- Final Exam available Friday, May 4 from Mrs. Wellsand.

---

**Questions:**

Is there a magnetic equivalent to this law? If so, what does it say?
Charged particles moving through electric fields feel a force given by:

\[ \vec{F}_{\text{elec}} = q \vec{E} \]

Charged particles moving through magnetic fields feel a force given by:

\[ \vec{F}_{\text{mag}} = q \vec{v} \times \vec{B} \]

What happens in regions with both electric and magnetic fields?

Vectorally add the forces together.

**Lorentz Force**

This force is nothing new -- we’re just giving it a name now.

Worksheet Problem #2

Determine the magnitude and direction of the electric field required to allow the charge to pass through a region of space with uniform magnetic field of strength 0.010 T at a speed of \(2.0 \times 10^7\) m/s.

Worksheet Problem #3

Sharon moves with charge \(q\) at velocity \(v\). In her frame, she sees no \(B\) field. Bill, at rest, sees a moving charge, thus a \(B\) field. Who’s right? How do we resolve this conundrum.

Worksheet Problem #4a

Sharon moves with charge \(q\) at velocity \(v\). Bill, at rest, sees a moving charge, through a \(B\) field that should experience a force. But to Sharon, the charge is at rest -- no force. Who’s right? How do we resolve this one?

Worksheet Problem #4b
By adding an electric field in the stationary frame, we get the completely general transform for the electric field in a frame moving with a charge:

\[ \mathbf{E}' = \mathbf{E} - \frac{\mathbf{v} \times \mathbf{B}}{c^2} \]

Let's now get the transformation for the magnetic field in the moving frame, starting with a charge at rest in the stationary frame.

Let me rewrite this B field in the moving frame:

\[ \mathbf{B}' = \mathbf{B} - \frac{\mathbf{v} \times \mathbf{E}}{c^2} \]

Biot-Savart Law of moving charge = transformed Coulomb field of stationary charge.

The permeability of free space and the permittivity of free space are related. Their product has units of inverse speed squared. And no ordinary speed….

Calculate v.  Worksheet Problem #5
Let me rewrite the EMF (potential) in terms of work, since And electrical work is given by:

Putting it all together, I now get:

1) Electric fields originate on + and end on –.
2) Magnetic field lines always form closed loops.
3) Varying magnetic fields induce electric fields.
4) Magnetic fields are generated by moving charges.