PHYS 3310 – Electrostatics and Magnetostatics
PHYS 3320 – Electrodynamics and Electromagnetic waves + special relativity

This semester: will cover Chap. 1~6 of Griffiths
Next semester: likely use a different textbook (Marion & Heald).

Reading assignment this week: Griffiths "Advertisement", Sec. 1.1-1.3.

Where does E&M fit into the grand scheme of physics?

We know of 4 fundamental forces: (weakest to strongest)

— Gravity	1
— Weak nuclear	10^{35}
— Electromagnetic	10^{38}
— Strong nuclear	10^{40}

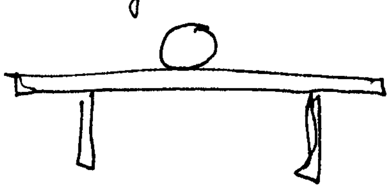
Most "ordinary" phenomena:

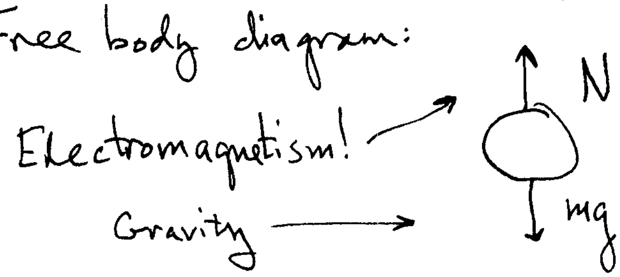
Weak int. is too weak to be noticed
Strong int. operates on too short distances to matter
Gravity "should" be irrelevant, except:
- it's always attractive, so no cancellations
- We happen to be right next to a very large mass and mass is the "charge" of gravity

<u>Electromagnetism causes</u> almost <u>any</u> phenomenon you encounter that's not obviously gravitational in nature!

Of course, it's often well disguised:

Rock sitting on a table. Free body diagram:





What causes the "normal force" that keeps me from falling through the floor?

→ EM forces keep atoms intact

→ EM forces between atoms form molecules

→ EM forces between molecules hold materials together

→ These forces are strong enough to counteract my weight on the floor

A bit of history:

- Pre mid-19th century:
  3 fundamental forces: Gravity, Electric, Magnetic

- Maxwell unified E&M ~1860s ⇒ Electromagnetic

- Nuclear forces discovered, described first in early-mid 20th century: 4 "fundamental" forces now known.

- Weinberg, Abdus, Salam proposed unification of E&M with Weak force in 1970s, confirmed 1984. Now only 3 fundamental forces (though at ordinary energies still behaves as 4):
  Gravity, Electroweak, Strong

- Much current work attempts to unify Electroweak & Strong
  Not a complete success yet.

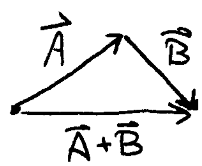
- Strings attempt to do it all!

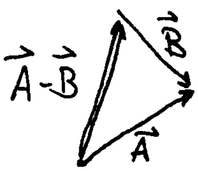
E&M is still the most successful field theory in physics.

Most physics courses start with a math lesson. We will spend most of a week on vector calculus. Should be review!

Vectors: have a magnitude & direction, addition & scalar multiplication properties:

Typography: $\vec{A}$ handwritten $\longleftrightarrow$ typeset $\mathbf{A}$ no arrow, bold, roman (not italic)





Scalar (dot) product:

$$\vec{A}\cdot\vec{B} = |A|\,|B|\cos\theta_{AB}.$$

$$= \vec{B}\cdot\vec{A} \qquad \text{(commutative)}$$

Vectors are represented in components defined by a set of orthogonal unit vectors $(\hat{x},\hat{y},\hat{z})$ or $(\hat{r},\hat{\theta},\hat{\phi})$ or $(\hat{\rho},\hat{\phi},\hat{z})$ or...

$$\left.\begin{array}{l} \text{so} \quad A_x = \vec{A}\cdot\hat{x} \quad A_y = \vec{A}\cdot\hat{y} \quad A_z = \vec{A}\cdot\hat{z} \\ \text{and} \quad \vec{A} = A_x\hat{x} + A_y\hat{y} + A_z\hat{z} \quad \text{often written } (A_x, A_y, A_z) \end{array}\right\}(*)$$

Orthogonal vectors have zero dot product: $\hat{x}\cdot\hat{y} = 0$.

Can show equivalence of lines in (*) using distributive property $\vec{A}\cdot(\vec{B}+\vec{C}) = \vec{A}\cdot\vec{B} + \vec{A}\cdot\vec{C}$:

$$\vec{A}\cdot\hat{x} = \hat{x}\cdot\vec{A} = \hat{x}\cdot\left(A_x\hat{x} + A_y\hat{y} + A_z\hat{z}\right)$$

$$= A_x\hat{x}\cdot\hat{x} + A_y\cancel{\hat{y}\cdot\hat{x}}_{0} + A_z\cancel{\hat{z}\cdot\hat{x}}_{0} = A_x$$

Component-based dot product:

$$\vec{A}\cdot\vec{B} = \left(A_x\hat{x} + A_y\hat{y} + A_z\hat{z}\right)\left(B_x\hat{x} + B_y\hat{y} + B_z\hat{z}\right)$$

$$= A_xB_x\,\hat{x}\cdot\hat{x} + A_xB_y\,\underbrace{\cancel{\hat{x}\cdot\hat{y}}}_{0} + \underbrace{\cdots}_{0} + A_yB_y\,\hat{y}\cdot\hat{y} + \underbrace{\cdots}_{0} + A_zB_z\,\hat{z}\cdot\hat{z}$$

$$= A_xB_x + A_yB_y + A_zB_z$$

Also recall that $|\vec{A}|^2 = \vec{A}\cdot\vec{A}$.

Another very useful identity: $|\vec{A}+\vec{B}|^2$

$$|\vec{A}+\vec{B}|^2 = (\vec{A}+\vec{B})\cdot(\vec{A}+\vec{B})$$

$$= \vec{A}\cdot\vec{A} + \vec{B}\cdot\vec{B} + \vec{A}\cdot\vec{B} + \vec{B}\cdot\vec{A}$$

$$= |\vec{A}|^2 + |\vec{B}|^2 + 2\,\vec{A}\cdot\vec{B}$$

$\longrightarrow$ often seen in E&M as

$$\mathscr{r}^2 = |\vec{r}-\vec{r}\,'|^2$$
$$= r^2 + r'^2 - 2\,\vec{r}\cdot\vec{r}\,'$$
$$= r^2 + r'^2 - 2rr'\cos\theta_{rr'}$$