Oberlin College Physics 411, Electrodynamics, Fall 2021

Assignment 1

Monday, 29 November

Reading: Griffiths chapter 7 on "Electrodynamics". Section 7.1, "Electromotive Force", should be pretty straightforward. Sections 7.2, "Electromagnetic Induction", and 7.3 "Maxwell Equations" bring in more new ideas.

Also *Notes on Electrodynamics* chapter 1, "Welcome", and chapter 2, "Vector Calculus".

Problems: Due Friday, 3 December.

- Additional problem: *Magnetic force between two moving charged particles* Particle 1 of charge q_1 moves with velocity $\vec{v}_1$, and particle 2 of charge q_2 moves with velocity $\vec{v}_2$. They are separated by a distance r_{12} and the unit vector from particle 1 to particle 2 is $\hat{r}_{12}$.

  a. Combine the magnetic force law ($q\vec{v} \times \vec{B}$) and the Biot-Savart law to show that the magnetic force on particle 2 due to particle 1 is
  $$\vec{F}_{\text{on 2 by 1}} = \frac{\mu_0}{4\pi} \frac{q_1 q_2}{r_{12}^2} \vec{v}_2 \times (\vec{v}_1 \times \hat{r}_{12}).$$

  b. Suppose that particle 1 is heading due east, while particle 2, located due north of particle 1, is heading due north. Show that the magnetic force on particle 2 due to particle 1 is finite and points east, whereas the magnetic force on particle 1 due to particle 2 is zero. [This violation of Newton's third law shows that something is wrong with the above derivation. At fault is our use (actually misuse) of the Biot-Savart law, which applies only for steady currents but which we have used for the transient current of a single moving charge. The moral of the story is that the result of part (a), which looks like a perfectly good analog to Coulomb's law, is not true in general.]

  c. (Optional... very difficult.) Integrate the Biot-Savart law around a circuit to show that when two complete circuits interact magnetically, the magnetic force on circuit 1 due to circuit 2 is equal and opposite to the magnetic force on circuit 2 due to circuit 1.

- Griffiths 7.8: *Electric induction*
- Griffiths 7.9: *Apparent oversight in the flux rule*
- Griffiths 7.15: *Solenoid*
- Griffiths 7.25: *Inductance of a hairpin loop*