Graduate Seminar in Electricity and Magnetism
Lecture 1

Based on Purcell, Chapter 1

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Electric Charge

- From the Rigvedic rishis who commented upon lightening, to Ampere Farady and Maxwell, electricity appeared as an extraordinary phenomenon.
- In classical electromagnetism, we deal with charges, forces on charges, forces exerted by charges and the generated electric fields in the ambient surroundings.
- Apart from the very microscopic domain which needs a quantum theoretic description, for the mesoscopic domain classical electromagnetism sufficed for a long time.
- Nevertheless charge itself is microscopic and experiments such as with the Leyden jar confirmed its existence.

Electric Charge - II

- When the motion of charges is not explicitly considered, the study is called electrostatics.
- Herein snapshots are studied which can be analyzed under the static assumption.
- Just as a wave has a trough and a crest, or depression and expression, high and low, similarly charges are also existent in two primary flavors - positive and negative.
- We could ask if intermediate signed charge types also occur and if not why?
- Alternately, we could ask why the transition from charge $= 0$ units to some positive value and on the other hand to some negative value, involving moving in two opposing directions, cannot be treated more continuously?

Electric Charge - III

- For example, if instead of positive and negative being treated as two opposing directions, they were treated as two orthogonal directions?
- Then, we could have vector charges such as $\vec{a} = (+3, -2)$.
- Here the charge $\vec{a}$ is not simply 1 unit of positive charge, since the angle is also important.
- The question would then be how would we utilize this angular degree of freedom?
- It could encode some other property, such as spin, if the charge also spun on some axis, or it could encode the dynamics of the charge.
- Since a charge in a specific dynamics generates a specific magnetic field, this angle could then represent the magnetic field, though that would be cumbersome.

Electric Charge - IV

- Another sensible allocation would be to represent the mass of the charged body by the angle using a conformal mapping.
- Recall that conformal mappings map the real line to a finite interval like $[0, 2\pi]$.
- Such a construction would be useful in joint studies of electromagnetism and general relativity, for example.
- Given this sensible representation and its simplicity, one can ask why the early physicists stuck to separate studies of gravitation and charged bodies.
- It may be because even though this construction gives a vector for each physical charge, instead of a scalar, vector operations were not widely understood and possibly their applications were not widely understood.