PH108

Why Electricity and Magnetism?

Pradeep Sarin
Department of Physics, 220F

email: pradeepsarin@iitb.ac.in

please put PH108 in the subject line of any course related email
Use course Moodle site for general questions/clarifications

… because every IIT graduate must know

How to change a light bulb

How long does it take to light a bulb?

Man walks into a dark room (bulbs are OFF)

Turns the light switch ON

How long does it take for charge to go from switch to bulb ? (copper wire is ~ 10m long)

Pick the answer you think is closest to correct:

1) ~ 0.1 second
2) ~ 1 second
3) ~ 1 minute
4) ~ 1 hour
5) ~ 1 day
6) ~ 1 week

!

What is electricity? Current ?

Let's say the wire connecting switch to bulb is ~ 10m

Let's say charge → electrons

Electrons are sent from switch make the bulb light up

We need to calculate the average speed of electrons in wire

How much charge is needed?

Charge moving through a conductor

1 Coulomb / second = 1 Ampere (A)

Let's say your bulb needs 0.1 A to light up

1 electron charge = 1.6 * 10^{-19} C/electron

$$i = \frac{0.1\ C/sec}{1.6\times10^{-19}\ C/electron} = 6.25 \times 10^{17}\ \text{electrons/sec}$$

How much charge is available?

Let's say the conductor is pure Copper (Cu)

Molar mass of Cu = 0.064 kg / $N_A \rightarrow 9.41*10^{24}$ Cu atoms/kg

Density of Cu = $9*10^3$ kg/m^3, Each Cu atom gives 1 electron

$$\boldsymbol{\rho} = 9.41 * 10^{24} \frac{atoms}{kg} \times 9 * 10^3 \frac{kg}{m^3} = 8.47 \times 10^{28} \text{ electrons/m}^3$$

How fast do the electrons move?

Typical Cu wire diameter ~ 1 mm

$\rightarrow A = 8 * 10^{-7}\ m^2$

Speed of electrons $= \frac{i}{\rho A} = \frac{6.25 * 10^{17}\ \text{electrons/sec}}{8.47 * 10^{28}\ \text{electrons/m}^3 \times 8 * 10^{-7}\ \text{m}^2}$

$v = 9.22 \times 10^{-6}\ m/sec$

How long for the bulb to light?

Approximate length of Cu wire ~ 10m

$$t = \frac{10\ m}{v} = \frac{10\ \text{m}}{9.22 \times 10^{-6}\ \text{m/sec}} = 1{,}084{,}598\ sec$$

$$= 18{,}076\ min$$

$$= 301\ hours$$

$$= 12\ days$$

Reality check:

…zzzzzz

Man walks into room

Turns switch ON, Bulb goes on *immediately*

What is electricity? redux

There are some charges *here* – at the light switch

There are some charges *there* – at the bulb

These charges exert a force on *those* charges

These charges create an electric field

Turning the switch ON disturbs the field

The field disturbance travels at close to speed of light and affects *those* charges

The light bulb turns ON

Electromagnetism is a theory of **fields**

Electric and magnetic **FIELDS**

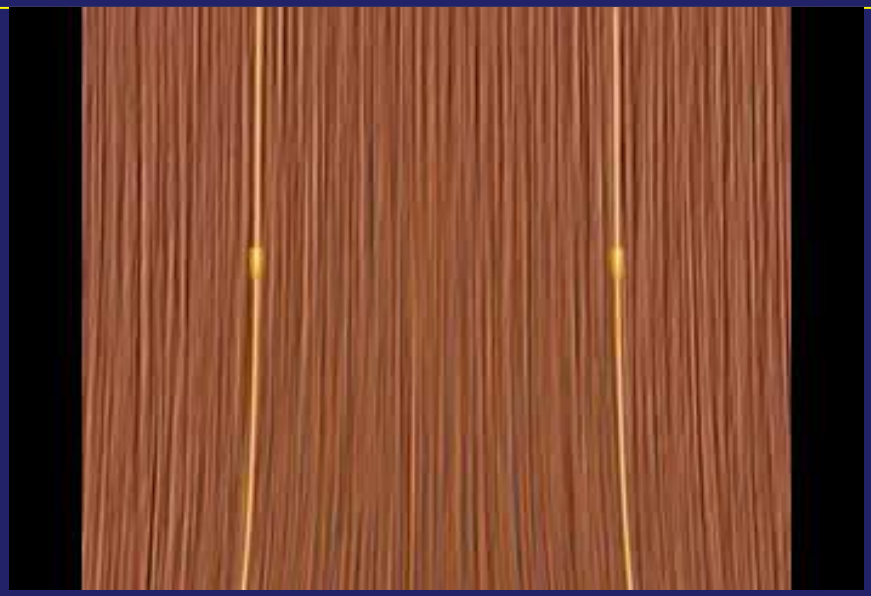
Fields are VECTOR functions

To each point in space, we attach a vector.
Vector has magnitude and direction.

We calculate how these vector functions are created by charge distributions

As charges move, fields change: relationship between field at one point and a nearby point → derivatives, integrals etc

Vector fields (can be) beautiful



This is a representation of the electric field between two parallel plates with opposite charge.

A point charge is introduced from the bottom – it disturbs the field – indicated by bending of the field lines

Video courtesy of the MIT TEAL animation studio – it takes ~ 5 hour computation to generate this 20 sec clip

What do you know about vector functions?

Choose from the following:

1) I know basic differentiation and integration $\frac{df}{dx}$, $\int f(x)dx$

2) I have heard of divergence $\nabla \cdot \vec{E}$, gradient ∇f , curl $\nabla \times \vec{E}$ but don't know how to calculate them

3) I can calculate div, grad, curl but don't know how to **plot** them

4) I know everything, why am I even here?

Logistics of PH108

- 80 % minimum attendance is compulsory
  We will cross-check biometric attendance occasionally – any absentees present will get DR

- Tutorials (and the heavy stuff) start next week

- No DX grade (except in exceptional circumstances)
  Minimum pass mark is 35/100

Questions , Comments ?