Physics 102:
Introduction to Physics

- Same course procedures as Physics 101

- Labs start next week

- Lectures by Ed Groth

- Electromagnetism-Waves-Optics-Quantum-Nuclear

- Course web page is
  http://physics.princeton.edu/~groth/phys102s02/
Electric Charges

- Electric charge is a conserved property of matter
  - Charge can be moved from one body to another
  - The smallest unit of charge appears to be the proton charge. The electron charge is \(-e\)
- Opposite charges attract each other, and like charges repel each other.
- Coulomb’s Law: 
  \[ F = \frac{kq_1q_2}{r^2} \]
  with \( k = 8.99 \times 10^9 \text{ Nm}^2 / \text{C}^2 \)
  note similarity to Newton’s law of Gravity.
Two uniformly charged spheres are firmly fastened to and electrically insulated from frictionless pucks on an air table. The charge on sphere 2 is three times the charge on sphere 1. Which force diagram correctly shows the magnitude and direction of the electrostatic forces:

A

B

C

D

E

F

G none of the above
Charging

Charges move freely through conductors (e.g., copper, gold, …) but stay where they are placed on insulators (e.g., wood, rubber, …).

- Charging by contact
  - a charged rod is brought into contact with a conductor, and
  - charges are transferred to the conductor

- Charging by induction
  - a charged rod is brought near a conductor
  - the conductor is grounded
  - the charged rod is removed.
Kelvin Generator

How do electroscopes get charged?

Hint: imagine that one drop starts out with a small charge on it.
The Electrophorus

- First the rubber (insulator) is negatively charged by friction.
- When the metal plate (conductor) is brought near, a charge separation is induced, then negative charge flows to ground from top of plate.
- When the plate is removed, it has a net positive charge.
Conductors

If we place charge onto a conducting surface, where does it reside?

Why?
The Electric Field

- The electric field is the force per unit charge on a test charge: \( E = \frac{F}{q} \)
- It is a vector, pointing in the direction a positive charge would be accelerated.
- The field at a point is the (vector) sum of the fields due to each charge.

- Field lines begin at positive charges and end at negative charges.
- The electric field is tangent to the field lines at all points.
- The density of field lines is proportional to the strength of the field.
The electric field induces charges on the grains which in turn produce torques that align the grains with the field.
A point charge attracted to a conducting copper sphere. The charge on each is the same.

The point charge is initially moving away from the sphere but does not have enough energy to escape.

The green lines show the electric field

From http://web.mit.edu/jbelcher/www/
An electric field points to the right as shown.

If the charge is negative, which of the paths is possible?

A) 1, 2
B) 3
C) 4
D) 2
E) 6
Gravitational and Electric Potential Energy

- Recall that the work done against gravity is the change in gravitational potential energy:
  \[ W_{AB} = mgh_A - mgh_B = \text{GPE}_A - \text{GPE}_B \]

- We also do work moving a charge in an electric field (force is \( F = qE \)):
  \[ W_{AB} = \text{EPE}_A - \text{EPE}_B \]
  (change in electric potential energy)
Voltage

- The voltage of an object tells you its

  Electrical potential energy per unit charge

  \[ \Delta V = \frac{\Delta EPE}{q_0} \quad \text{Units are J/C} \]

- Just as for gravitational potential energy, we can sense only \textit{differences} in electrical potential energy --OR VOLTAGES.

- Zero is arbitrary: far away (infinite separation) or in lab, “ground”.


The Van de Graaff Generator
The Human Electroscope