1. Forces in electrostatic systems with conductors
2. Current
3. Equation of continuity

Reading: Chapter 4.1, 4.2
BEFORE CLASS: risk of electrocution/freezing

SET TIME FOR FIRST HOUR EXAM:
   WEEK OF FEB 19 EVENING? MON, THURS?

DO WARM-UP PROBLEMS BEFORE RECITATIONS THIS WEEK

4th HOMEWORK ASSIGNMENT IS DUE IN CLASS NEXT MONDAY

class web site
http://www.physics.rutgers.edu/ugrad/272
Back to the charge $Q$ a height $h$ above a grounded infinite conducting sheet...

We know how to find $\phi(\vec{r})$ everywhere.

**New question: what is the force on the point charge?**

The electric force from the charge distribution on the plane.

Connect this to $U(h)$: $F(h)=-\frac{dU}{dh}$

See Problem 3.11 and its solution for more on this.
A charge $Q$ a distance $D$ from a grounded conducting sphere

What is the force on the point charge?
The electric force from the charge distribution on the sphere

Outside

Inside at the center

Inside off center

See Problem 3.13 for method of images solution
Parallel plate capacitor with A, h; charge Q (σ = Q/A)

What is the force on the upper plate?

E field outside is zero, E field inside is -σ/ε₀
F = Q Eₐᵥ = -Q σ/(2ε₀) = -Q²/(2Aε₀)

(why Eₐᵥ? Regard the layer of surface charge as the limit of a slab as the thickness goes to zero – see p. 30-32 in Purcell)

Connect this to U(h) (hold lower plate fixed)
U(h) = (1/2) (Ah) ε₀ E² = (1/2) Q² h /(Aε₀)
F(h) = -dU(h)/dh = -Q²/(2Aε₀)
Up to now we have been considering systems where the arrangement of charges is fixed, studying the electric field produced and its description by a potential function. “electrostatics”

Rules include
“Electric field inside a conductor is zero”

Now we allow charges to move:
New quantities: current, resistance…
New rules: Ohm’s law…
The systems we consider have large numbers of charged particles moving together  
Density \( n \) = number per volume  
Velocity \( v \)  
Analogy to fluid flow  

mass flow rate = mass that passes through surface per time  
= increase in mass on the far side of the surface per time  

Mass flow rate can be positive or negative  
negative if mass is moving FROM far side TO near side
The systems we consider have large numbers of charged particles moving together
Density \( n = \text{number per volume} \)
Analogy to fluid flow

mass flow rate = mass that passes through surface per time
= increase in mass on the far side of the surface per time

**Electric current** = NET charge that passes through surface in a given time
= increase in charge on the far side of the surface per time
Electric current =
NET charge that passes through surface per time unit
1 C/s = 1 A (Ampere)

A number (not a vector)
Can be positive or negative

Positive if net charge on the far side is increasing

Negative if net charge on the far side is decreasing
**Current** = NET charge that passes through surface per time
= change in net charge on “far” side of the surface per time

Scalar: positive or negative
Positive charges move to far side: current is positive
Positive charges move from far side: current negative
Negative charges move to far side: current negative
Negative charges move from far side: current positive
Of the following four situations in which positive and negative charges move horizontally through a surface at rates shown in the figure, in which situation does the current have the smallest magnitude?
Of the following four situations in which positive and negative charges move horizontally through a surface at rates shown in the figure, in which situation does the current have the smallest magnitude?
Mostly we consider charges moving in metal wires. The number density $n$ of free charges is a property of the metal (Cu, Al, etc) – behaves like an incompressible fluid.

A wire is like a pipe for charge.
Consider systems with “steady current”
Current doesn’t change with time.
no buildup or depletion of charge at any point

Analogy with fluids:
equation of continuity
i is the same for all
cross sections of the wire

Split wire: net flow at junction is zero
\[ i_{in} = i_{out}; \quad i_0 = i_1 + i_2 \]

Current is NOT a vector
Steady currents flow in the wires shown. What is the magnitude and direction of the current $i$?
(a) Zero
(b) 2 A, into the junction
(c) 2 A, out of the junction
(d) 8 A, into the junction
(e) 8 A, out of the junction