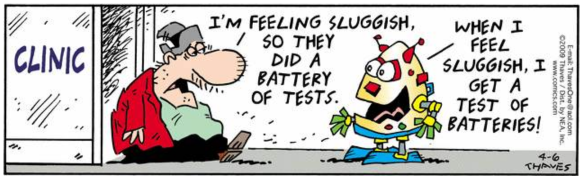
March 13, 2013 Physics 132 Prof. E. F. Redish

- **Theme Music:** The Blue Man Group
  Current
- **Cartoon:** Bob Thaves
  Frank & Ernest



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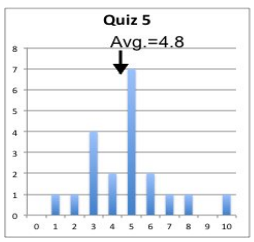
Quiz 5



	5.1
1=2=3	15%
1>2=3	10%
2>1=3	20%
3>1=2	10%
2>1>3	10%
3>2>1	5%
3>1>2	5%
1=2>3	10%
1=3>2	5%
2=3>1	10%

	5.2.1	5.2.2	5.2.3
A	85%	15%	65%
B	0%	20%	35%
C	15%	0%	0%
D	0%	55%	0%
E	0%	10%	0%

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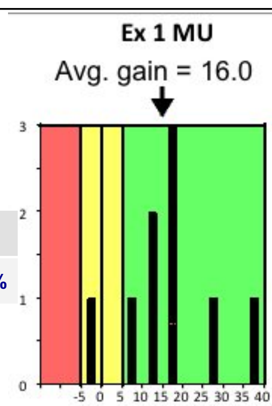
Exam 1 Makeup Results

#1	#2	#3	#4	#5
89%	31%	61%	72%	68%



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Reading question

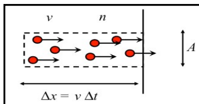
- How does moving charge tend to maintain its volume like an incompressible fluid? Aren't the electrons always repelling each other and scattering around, therefore leading to a lack of defined volume?

Foothold Idea: Local Neutrality

- Most matter is made of of an equal balance of two kinds of charges: positive and negative.
- Since the electric force is very strong, mostly the + and - charges overlap closely and cancel each other. (Entropy!)
- Small imbalances in the cancellation leads to:
  - polarization forces
  - potential drop across a resistance
  - observed electric forces.

Foothold ideas: Currents

- Charge is moving: How much? $$I = \frac{\Delta q}{\Delta t}$$
- How does this relate to the individual charges? $$I = q\,n\,A\,v$$
- Constant flow means pushing force balances the drag force $$ma = F_e - bv$$ $$a = 0 \quad \Rightarrow \quad v = F_e/b$$
- What pushes the charges through resistance? Electric force implies a drop in *V*! $$F_e = qE$$ $$\Delta V = -\frac{E}{L}$$



Ohm's Law

- Current proportional to velocity
- Due to resistance, Electric force proportional to velocity.
- Force proportional to "electric pressure drop" = "electric PE"
- Therefore, current proportional to "electric PE"

$$I = qnAv \quad \Rightarrow \quad v = \frac{I}{qnA}$$

$$qE = bv$$

$$\Delta V = EL \quad \Rightarrow \quad E = \frac{\Delta V}{L}$$

$$\Rightarrow \quad \frac{q\Delta V}{L} = \frac{bI}{qnA}$$

$$\Delta V = I\left(\frac{bL}{q^2 nA}\right) \equiv IR$$

$$\Delta V = IR$$

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Resistivity and Conductance

- The resistance factor in Ohm's Law separates into a geometrical part (L/A) times a part independent of the size and shape but dependent on the material.
- This coefficient is called the *resistivity* of the material (ρ). Its reciprocal (g) is called *conductivity*. The reciprocal of the resistance is called the *conductance* (G).

$$R = \left(\frac{bL}{q^2 nA}\right) = \rho\frac{L}{A} = \frac{1}{g}\frac{L}{A} = \frac{1}{G}$$

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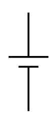
Electric circuit elements

- *Batteries* —devices that maintain a constant electrical pressure difference across their terminals (like a water pump that raises water to a certain height).
- *Resistances* —devices that have significant drag and oppose current. Pressure will drop across them.
- *Wires* — have very little resistance. We can ignore the drag in them (mostly – as long as there are other resistances present).



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Very useful heuristic

- The Constant Potential Trick (CPT)
  - Along any part of a circuit with 0 resistance, then $\Delta V = 0$, i.e., the voltage is constant since in any circuit element

$$\Delta V = IR$$

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Analogy 1: The rope model

- Since like charges repel strongly, there can't be a buildup of charge anywhere in the circuit (unless we make a special arrangement -- capacitance).
- Moving charges push other movable charges in front of them. The electrons move like links in a chain or rope.

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Analogy 2 (Drude model): Ping-pong balls and nail board

- In this analogy, we treat the electrons as small particles that can move freely through the conductor. (ping-pong balls)
- The ions that form the fixed body of the conductor are treated as fixed. (nails)
- The electron move freely between the ions until they hit them. Then they scatter in a random direction.

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Analogy 3: Water flow

- The rope analogy fails because electrons can go either way at a junction. A current can split in a way a rope cannot.
- Water flow is a useful analogy because water
  - can divide
  - is conserved and cannot be compressed.

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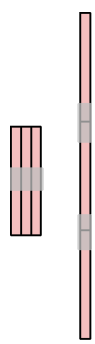
Analogy 4: Air flow

- Pressure is analogous to electric potential.
- Pressure drop produces flow.
- Amount of flow depends on what is connected across a pressure drop.



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