

Teaching Physics for Pre-Medical Students at UCLA.

Undergraduate Curriculum

- General science requirements:
 - Math with calculus: three quarters (freshman)
 - Physics with calculus: same (sophomore)
 - General Chemistry: same
 - Organic Chemistry: same

Heavy course load

- Life-Science requirements:
 - Biochemistry
 - Molecular, Cell and Developmental Biology
 - Genetics
 - Physiology

*Acceptance by UCLA medical school: requires average of A-

Students

- 20 % First time exposure to Physics.
 - 30-40% “Algebra-based” Physics in high school.
 - 30-40% Advanced Placement physics class with some calculus.
- Student quality and preparation: **very heterogeneous pool.**
 - Top 15% compares well with physics and engineering majors.

Physics 6

- 1, 100 - 1, 500 students per year; more than 2/3 pre-med.
- Typical class size: 200 - 300.
- **Last physics-based class for life-science student. No biophysics!**
- Major “service-class” of UCLA Physics Department.

Standard Format

- Three contact hours per week + one hour recitation session. Homework problems + “equation drill”. Weekly lab class.
- Physics 6A: Mechanics
 - 6B: Electricity and Magnetism
 - 6C: Waves, Optics, Modern Physics
- * Soft version of “Halliday-Resnick” general physics.
- Taught by mixture of ladder faculty (often HEP) and “soft-money” instructors.

1994: Dean Roberto Peccei:

- Reform of General Science Requirements.

-> Reorganize Physics 6 to reflect needs of Life-Science students.

Life Science faculty: dissatisfied about General Science curriculum.
No consensus about content for an appropriate physics class.

- Department and Dean supported hiring Biological Physics faculty.

Why should Life-Science students have to take a physics class?

- Essential part of scientific literacy. Foundation of a rational, scientific analysis of nature. “Lewis Thomas argument”

But how does “equation drill” serve that purpose?

- Life science students practically never **use** an equation of Physics 6 in the remaining Life Science curriculum. Only rarely as MD’s or as career Life Science professionals.
- Physics is imbedded in the “protocols” for experimental procedures or operation of equipment (NMR, Xray, laser, ultrasound, ..)

Existing Physics 6 could be dropped from the Life Science curriculum without serious negative impact.

- What **concepts** will Life-Science students encounter in their **Life Science required classes** that require physics for a serious understanding?
- * Can the Halliday-Resnick curriculum be updated to achieve this?

Physiology and Animal Anatomy (“Marieb”)

- Mechanics:

- Forces on skeleton. (“Biomechanics”)
- Physics of senses: Vision, Hearing, & Speech.
- Hydrostatics and Hydrodynamics:
 - Blood pressure.
 - Blood circulation. Laplace Law.
 - Swimming and Flight.

- Thermodynamics:

- Metabolism.
- Thermoregulation.
- Osmotic Pressure.

- Electricity.

- Transport of Nervous Signals

Molecular Biology and Biochemistry (“Alberts”, “Stryer”).

- Macromolecule Interaction
(hydrophobic interactions, van der Waals, ...)
- Electrophoresis.
- Sedimentation.
- X-ray crystallography and NMR.
- Thermodynamics of Energy Transfer.
- Membrane Electrical Potential.

Can the H-R curriculum be upgraded? Add problem sets and/or extra chapters. (Giancoli, Serway, ..)

- Time-constraint Problem. Extra material is dropped.
- “Wrong Physics” Problem

Example: Electrical Transport

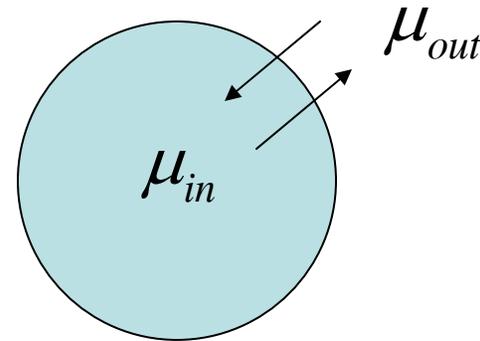
H-R Curriculum: Definition of EMF, Ohm’s Law, Equivalent Resistance, Kirchhof’s Laws, “Circuit Drill”.

Electrical circuits in water: short-circuit.

Electrical potential of a cell in water.

Chemical potential of ion.

$$\mu = \mu_0 + eV + k_B T \ln c$$



Second Law of Thermodynamics:

Thermal equilibrium: $\mu_{in} = \mu_{out}$

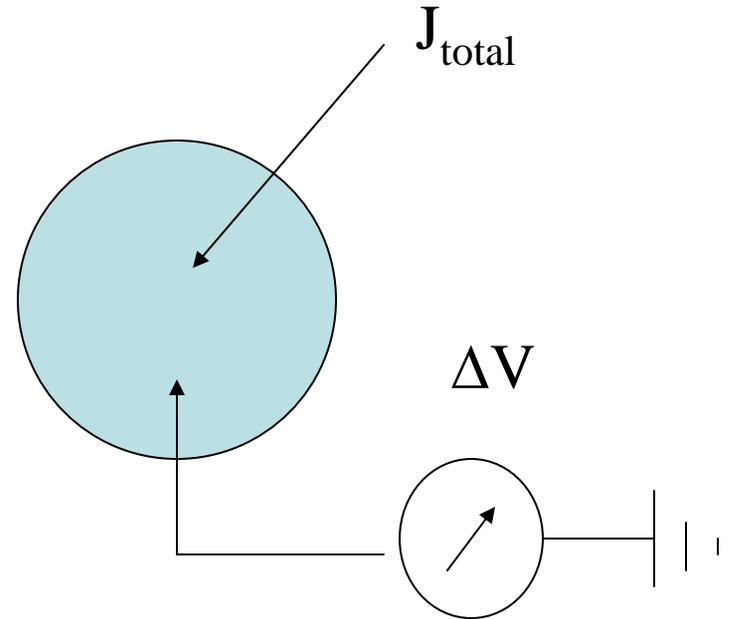
$\Delta V_{eq} \cong (k_B T / e) \ln(c_{in} / c_{out})$ Universal voltage scale (about 20 mV)

Ohm's Law: current density of ion i :

$$J_i = g_i (\Delta V - \Delta V_{eq}^i)$$

Conservation of Electrical Charge:

$$J_{total} = \sum_{ion\ species} J_i$$



For a cell: must vanish under steady state conditions.

Membrane potential:

$$\Delta V = \frac{\sum_i g_i \Delta V_{eq}^i}{\sum_i g_i}$$

- four fundamental physical principles!
- Can an undergraduate physics curriculum be constructed that does support the Life-Science curriculum ?
- Is relevant undergraduate material even available?

1996-1999:

- * Wrote lecture notes for Physics 6A, B, &C
Published by a custom publishing house (Hayden-McNeill)
(teaching relief from Dean). Aim: book form.
- * Lab reconstruction (funded by Dean and NSF).
- * Pilot classes 50-100 students.
Students response to new lectures was very positive. Did better
in MCAT exams
- * Problems with new labs (mechanics arm, heat diffusion,..).

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dynamics



1999-2001: Full Scale

Growing problems

- Faculty members not comfortable with new material. TA's could not deal with problem sets involving new material (example: hydrodynamics). Faculty communicated negative attitude to TA and soft-money instructors.
- Faculty Angst: “Students ask me questions about photon absorption in eye by retinal molecules (“cis-trans isomerisation”) that I am teaching. They know more than me about subject!”
- Violation of “Social Contract”: “It is 11 pm. I have to prepare next day's class. I don't want to learn about membrane potentials. This is a large class which already takes a lot of my time”

Dean Peccei: suggests a teaching manual to assist faculty.

2001: Faculty votes to return to the old format.

2003: Physics 6 is *split*:

- * Regular series: “old” format.

- * Honors series: “new” format.

Maximum class size: 100 students, taught by

Biological Physics/Soft Matter faculty

(three experimentalists, two theorists).

2005: Biophysics Major at UCLA.

2006: New edition of Hayden-McNeill notes.

Regular series: *Revitalized* (by Katshushi Arisaka). Student seminars on topics like special relativity, black holes, super nova's.....

Conclusions

- Teaching physics appropriate for a Life Science curriculum **in a research-based institution** requires faculty members with research programs in Biophysics or Biological Physics.
- The graduate students of these faculty members are the “natural” TA’s of the class.
- Offering a *choice* to the Life-Science student about the type of Physics class they can take works well for a large, heterogeneous student body.
- “Top-down” teaching reforms may run into faculty resistance.