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.

-> Reoganize 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

<u>Example: Electrical Transport</u>

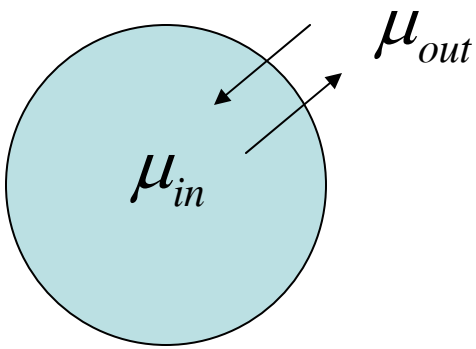
H-R Curriculum: Definition of EMF, Ohm’s Law, Equivalent Resistance, Kirchhof’s Laws, “Circuit Drill”.

Electrical circuits in water: short-circuit.

Electrical potential of a cell in water.

Chemical potential of ion.

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



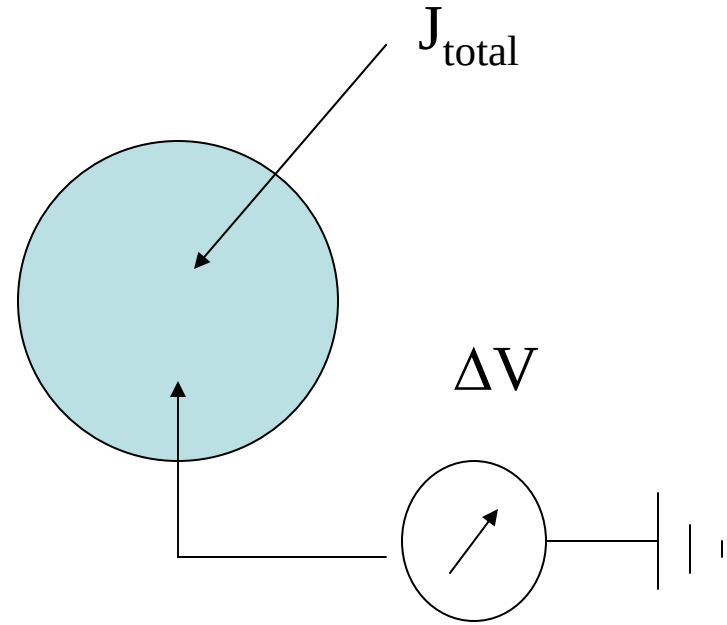
Second Law of Thermodynamics:

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

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

Ohm's Law: current density of ion i:

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



Conservation of Electrical Charge:

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

For a cell: must vanish under steady state conditions.
Membrane potential:

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

- four fundamental physical principles!
- Can an undergraduate physics curriculum be constructed that does support the Life-Science currciulum ?
- 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,..).

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.