Physics 132- Fundamentals of Physics for Biologists II

INTRO
Welcome!

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Who is This Guy?!?

**Elementary School**
- Tore apart a lot of TVs, radios, typewriters – attempted to put them back together (largely unsuccessful)
- Played with chemistry set, electronics kits, model rockets

**High School** – Into science
- Read lots
- Tore more stuff apart Actually repaired some things
- WAY too many computer games

**College**
BS (Physics) 1992
MS (Applied Physics) 2005

**Career**
Delone Catholic High School (1992)
Holton-Arms School (1997)
University of Maryland (2008)
Course Philosophy
What’s different about this class?

- PHYS 131/132 is designed to respond to calls from biology researchers and medical schools to prepare students with the skills to take full advantage of the amazing new tools of 21st century biology and medicine.
• Both the content and pedagogy have been modified
• Class is part of a development and education research project funded by HHMI and NSF
Key aims of 132

- Learning to think scientifically
  - Build model
  - Solve math
  - Interpret solution
  - Evaluate System

- Learning physics relevant for understanding the living world

Usual focus of intro physics class
Learning physics relevant for understanding the living world

**What’s in**
- Energy
- Entropy
- Free Energy
- Charges in Fluids
- Light/Matter Interactions

**What’s out**
- Magnetism
What do I mean by learning physics?

I do NOT mean being able to memorize an equation

I mean the ability to apply your physics knowledge to build an equation or model in order to solve a new problems.

How do our brain tackle new problems?
Try it in your own brain!
Memorize these numbers

[Note to instructor: see ppt notes below]

3 5 2 9 7 4 3 1 0 4 8 5

1 4 9 2 1 7 7 6 2 0 1 4
How does our brain tackle new problems?

- The mind works on two levels: unconscious and conscious.
- Memory is not simply based on recall of information (computer memory is...) but based on partial recall of pieces connected by “plausible” links.
- Our brain appears wired to link any new task to our existing knowledge.
Aim of Phys132 Pedagogy: Building a web of knowledge

- How do we build a reliable web of knowledge?
  - Knowledge of Basic Principles (called foothold ideas in 131): In this class we will build experience with basic physics principles we can count on in a wide variety of circumstances
  - Experience in how to connect the basic principles: Finding coherence in how you solve multiple solutions
Course Logistics
Surveys and Permissions (Vashti Sawtelle)

You should have received emails for two online surveys (for credit)
Your Tasks (for points)

For details see our website:
www.physics.umd.edu/courses/Phys132/spring2014/

Reading: Read a few wiki-pages (we replaced the textbook with a wiki) before each class. Summarize 2-3 of these pages and write one question about them.

Weekly Homework: Working together in course center (Physics Building Rm 0208) is encouraged. You must prepare solutions yourself. Will be submitted on webassign. One to two PAPER problems due at BEGINNING of class on THURSDAY.

Labs: Two week labs with group work START WEEK OF FEBRUARY 3

Weekly Quizzes (lowest score dropped)

Two Midterm Exams (with Makeup possibility)

Final Exam (without Makeup possibility)

1/30/2014
Course Topics

Thermodynamics and Statistical Physics
- How do the basic laws of physics and the laws of probability conspire to give temperature, pressure, heat, entropy, etc.

Electricity
- What are the forces on charges, what governs the flow of charge through matter?

Oscillations and Waves
- Why do things go boing? How do waves transport energy?

Light
- What is interference, how are images formed?

Quantum Mechanics
- Sometimes it’s a wave, sometimes it’s a particle!
Topic 1: Thermodynamics and Statistical Physics
Reviewing Potential Energy

- What is a potential energy curve
- For the given potential energy curve, draw force as a function of position
  (positive force defined here as repulsive, negative force defined as attractive)
Forces from Potential Energy (PE)

- For conservative forces, PE can be defined by
  \[ \vec{F} \cdot \Delta \vec{r} = -\Delta U \]

- If you know \( U \), the force can be gotten from it via
  \[ F_{\parallel} = -\frac{\Delta U_{\text{type}}}{\Delta r} = -\frac{dU_{\text{type}}}{dr} \]

- In more than 1D need to use the gradient
  \[ \vec{F}_{\text{type}} = -\vec{\nabla} U_{\text{type}} \]

- The force always points down the PE hill.
Reviewing Potential Energy

- What would a body with a given total energy do in this potential energy well
Molecular forces

http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-0.html
You know that two atoms that are far apart are barely interacting. How is this represented visually in the PE diagram?

A. The potential energy approaches zero as r gets large.
B. The PE curve is close to horizontal as r gets large.
C. The PE curve is close to vertical as r gets small.
D. The potential energy has a minimum.
E. More than one of these
F. The PE diagram doesn’t demonstrate this information
G. None of these
These two atoms can exist in a stable bound state. How is this represented visually in the PE diagram?

A. The potential energy approaches zero as r gets large.
B. The PE curve is close to horizontal as r gets large.
C. The PE curve is close to vertical as r gets small.
D. The potential energy has a minimum.
E. More than one of these
F. The PE diagram doesn’t demonstrate this information
G. None of these
Questions…

- Is the statement that "Electrons . . . have to be thought of as being capable of being in multiple places and states at the same time" meant to be taken literally? Can electrons literally exist in more than one spot?**
- How are electrons, protons and neutrons wave-like?**
- How do atoms transfer energy? I saw this in the MCAT, but I'm still confused. How do waves transfer energy to something? Does this mean different wavelengths and frequencies in the visible light spectrum transfer different energies?**
- Why is zero potential energy ok but not zero kinetic energy?
- Why cant a specific position or time be associated to a molecule in quantum physics?
- What do they mean when they say a region where KE would be negative?**
And more questions…

- I am having difficulty understanding the Lennard-Jones potential in the follow-on reading. Can you please explain how the Lennard-Jones model relates to the PE curves we discussed in-class? What happens to the Lennard-Jones potential when electron orbitals are modified/shared?

- Is the "zero" potential energy line an arbitrary term? Does it have to be related to where the atoms are far apart and at rest?**

- Are these the forces that can be quantitatively modeled by Coulomb's law?

- In what instances can we get an unstable equilibrium?**

- What does a negative potential energy signify? How can a potential energy be negative? **

- Why does a "minimum" on the graph where the KE is the greatest refer to a stable bond? If the KE is the greatest wouldn't that mean that the atoms are moving the most when they are bound? According to the simulation this does not seem to be the case.
1) What is the **force** at point A, B, C? Consider both magnitude and direction! **Draw the vectors on the whiteboard**

2) Draw $r$ vs $t$

3) Draw $v$ vs $t$
Identifying thermal energy in a Pair of Atoms

- Let’s define the zero of potential energy as the minimum of the Potential Energy Curve.
- With this definition, energy is ON AVERAGE the same for both potential and kinetic energy.
Temperature

- **Temperature**: Measures the amount of energy in each atom or interaction – the key concept is that thermal energy is on average equally distributed among all these possible “bins” where energy could reside.

- **Note**: Potential energy of each bin is here defined relative to each minimum of the Potential Energy Curve.
Thermal Energy

- **Thermal energy of object A**: Measures the TOTAL energy in the whole object. Depends on temperature and the number of “bins” where energy could reside.
- Energy in each bin: $\frac{1}{2} kT$
Assume you have a mix of the two molecules blue and red
If the molecules are mixed, where is the energy level of molecule B?

1. 1
2. 2
3. 3

1/30/2014  Physics 132
Spheres numbered 1, 2, and 3 all “stick” when added one at a time. Which is more tightly bound?

1. Sphere 1 (when 2 and 3 are NOT there)
2. Sphere 3 (when 1 and 2 ARE there)
3. They will be the same.

The Gauss gun

![Image of steel spheres with a strong magnet]
The Gauss gun

When sphere 0 is released it is attracted to the magnet and begins to speed up. What do you think will happen when it hits the magnet?

1. Sphere 0 will stick. Nothing else will happen.
2. Sphere 3 will be kicked off at the same speed that sphere 0 hit with and will slow down to a stop – reversing what 0 did as it approached. They will be the same.
3. Something else will happen. (What?)
The Gauss gun
When sphere 0 is released it is attracted to the magnet and begins to speed up. What do you think will happen when it hits the magnet?

The molecule started in the blue state in thermal equilibrium. The green state has the same temperature as the blue state.

- **How can we tell that the two states are at the same temperature?**
- **Is the potential energy different in blue and green state?**
- **What would you call such a reaction chemistry?** (write name on whiteboard)