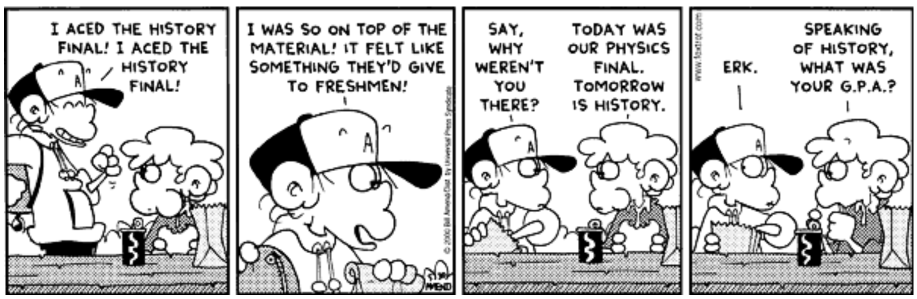
December 12, 2013 Physics 131 Prof. E. F. Redish

- **Theme Music:** **Count Basie & his Orchestra**

  The Party's Over

Cartoon: Bill Amend

FoxTrot



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EvalUM

- As of this morning , we only have about 30% participation! Please do this!
  https://CourseEvalUM.umd.edu

- Please also do the survey for the Colorado-Wisconsin visitors.
  https://www.surveymonkey.com/s/NJNRMFD

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For the final!

- Final exam: Wednesday12/18, 6:30-10:30 PM, in Chemistry 1407.
- Review slides will soon be posted as a link on the Schedule page (12/18 date).
- Grades for Readings, Clickers, and HW will be updated and posted in the next few days.
- Sample problems (including many from last year's final) have been posted on ELMS
- Q&A session, T 4-6 OK?
- Do you want office hours next week?

Research Experience

OPEN Spring 2014: three credit course
Quantitative Biology and Biophysics Research Experience - Physics299L

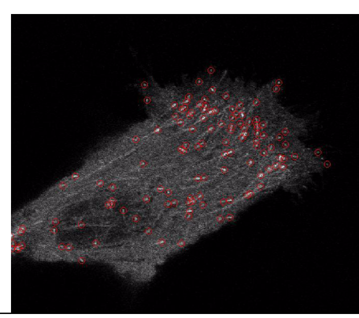
Admission is by permission of the instructor.
We have 24 slots for the 240 Phys131 students

For questions, or to apply, email me
wlosert@umd.edu I need:

1) Name
2) Univ ID,
3) ***One paragraph explaining what you hope to learn from this Research Experience, and how it will help your career.***

Topic: Intracellular Dynamics During Cell Division

NIH Postdocs as Co-Instructors
1-2 visits to NIH for experiments
Skills from 131:
- *Image/motion analysis*
- *Tackling tough problems in groups*



"The kind of motion we call heat"

- We have a natural sense of hot and cold.
- In the 19th century it was learned that the warmth of an object was a measure of a kind of random internal motion of the object's atoms.
- It was found that there was a surprisingly large amount of "hidden" energy that objects possessed as a result of their temperature – and that under the right conditions, this energy could be put to work.

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Definitions: Thermal energy

- Our model of matter as composed of many small moving particles allows us to extend energy conservation to include resistive forces.
- The energy associated with the motion of a macroscopic is ***coherent***; all parts of the object) move in the same way. The object has a net momentum associated with its kinetic energy.
- The internal energy of an object is ***incoherent***. The molecules of the object are moving in all directions randomly. Although the individual molecules have kinetic energy and momentum, the net momentum of the object as a result of its thermal energy is zero.
- The key idea in understanding thermal energy is ***equipartition*** – the equal sharing of energy any place it can go.

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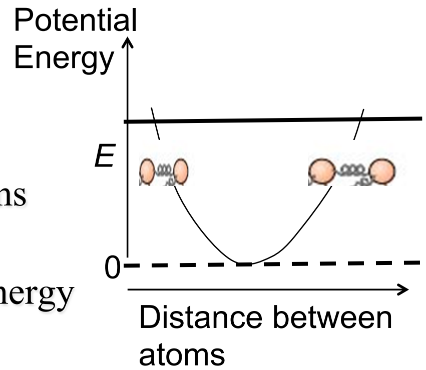
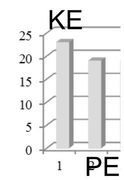
Energy in a 2-Atom Molecule



- For small displacements around the bond length, the PE of a pair of bound atoms can be modeled as a spring.
- Define the zero of potential energy as the <u>minimum</u> of the Potential Energy curve.
- With this definition, in a gas of these molecules, ON AVERAGE the energy is <u>the same</u> for both potential and kinetic energy



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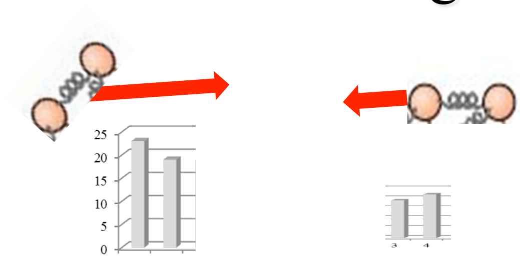
Interaction between two pairs of molecules in a gas



- **After many random collisions, energy is ON AVERAGE the same for**
  - **Kinetic energy of motion of both pairs of atoms**
  - **Kinetic energy of vibration of atom pair**
  - **Potential energy of interaction (relative to potential minimum)**

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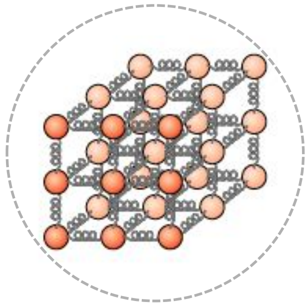
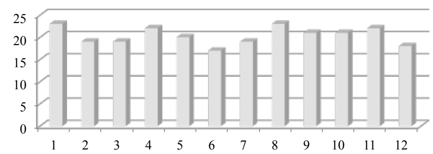
Temperature in any object

Object A



Object contains MANY atoms (kinetic energy) *and* interactions (potential energy)



- **Temperature:** Measures the amount of energy in each atom or interaction – thermal energy is **on average** equally distributed among all these possible "bins" in which energy could reside.
- **Note: Potential energy of each bin is here defined relative to each minimum of the Potential Energy Curve.**

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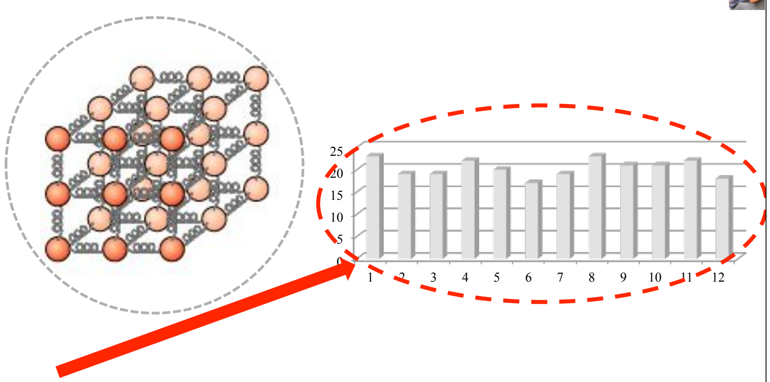
Thermal Energy in an object

Object A



- **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: ½ $k_B T$

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Thermal Energy is NOT Temperature

- Even if the masses are the same, the temperature does not wind up halfway between.
- There are different numbers of places to put the energy in water and copper!
- Each kind of material translates thermal energy into temperature in its own way.

$$Q = m_1 c_1 \Delta T_1 = -m_2 c_2 \Delta T_2$$

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Specific Heat and Heat Capacity

- The amount of thermal energy needed to produce one degree of temperature change is an object is called its heat capacity.

$$Q = C\Delta T$$

- The amount of thermal energy per unit mass needed to produce one degree of temperature change in an object is called its specific heat.

$$C = mc$$

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Foothold ideas: 1

- Temperature is a measure of how hot or cold something is. (We have a natural physical sense of hot and cold.)
- When two objects are left in contact for long enough they come to the same temperature.
- When two objects of the same material but different temperatures are put together they reach an average, weighted by the fraction of the total mass.
- The mechanism responsible for the above rule is that the same thermal energy is transferred from one object to the other: Q proportional to $m\Delta T$.

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Foothold ideas: 2

- When two objects of different materials and different temperatures are put together they come to a common temperature, but it is not obtained by the simple rule.
- Each object translates thermal energy into temperature in its own way. This is specified by a density-like quantity, c, the specific heat.
- The heat capacity of an object is $C = mc$.
- When two objects of different material and different temperatures are put together they reach an average, weighted by the fraction of the total heat capacity.
- When heat is absorbed or emitted by an object $Q = \pm mc\Delta T$

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