Theme Music: Count Basie & his Orchestra
The Party’s Over
Cartoon: Bill Amend
FoxTrot

EvalUM

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

- Please also do the survey for the Colorado-Wisconsin visitors.
  [https://www.surveymonkey.com/s/NJNRMFD](https://www.surveymonkey.com/s/NJNRMFD)
For the final!

- Final exam: Wednesday 12/18, 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.

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.
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 minimum of the Potential Energy curve.
- With this definition, in a gas of these molecules, ON AVERAGE the energy is the same for both potential and kinetic energy.

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)
**Temperature** in any object

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**: $\frac{1}{2} k_B T$
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**.

\[
C = mc
\]
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 $m\Delta T$.

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 $Q = \pm mc\Delta T$. 