Physics 132- Fundamentals of Physics for Biologists II

Instructors:

Thomas M. Antonsen - MWF 10:00-10:50 010X

David C. Buehrle - Tu-Th 12:30 - 1:45 020X

Wolfgang Losert - on call

Plus a host of others

Course Logistics

Course website:
http://www.physics.umd.edu/courses/Phys132/spring2014

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 Friday

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)

Course Mechanics - for details go to Course web site
http://www.physics.umd.edu/courses/Phys132/spring2014

Readings (on web)
Classes (here)
Recitations
Labs

Grade Components

2 - 50 minute exams	200
Quizes	100
Final Exam	200
Homework	200
Lab	150
Participation	75
Pre-Class and Pre-Lab reading	75
Total	1000

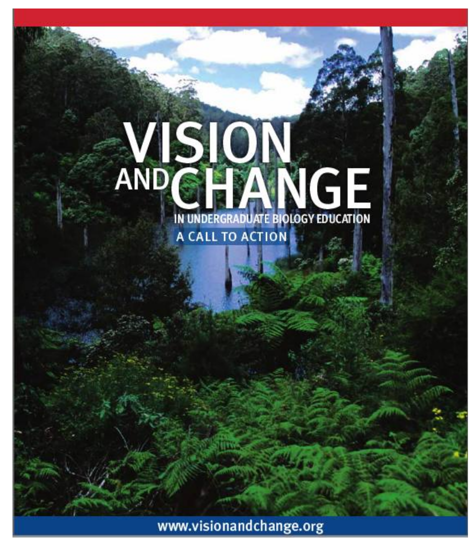
Surveys and Permissions (Vashti Sawtelle)

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

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.
- Class is part of a development and education research project funded by HHMI and NSF



***Scientific Foundations for Future Physicians Report* (2009)**

- Both the <u>content</u> and <u>pedagogy</u> have been modified

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

Active Learning

Group Activities - Lectures, recitations, labs

Lectures are not simply me telling you things you can read.

Clarification
Testing concepts

Key aims of 132

- Learning to think scientifically
  - Build model
  - Solve math ← **Usual focus of intro physics class**
  - Interpret solution
  - Evaluate System

- **Learning physics relevant for understanding the living world**

Aim of Phys132 Pedagogy: Building a web of knowledge

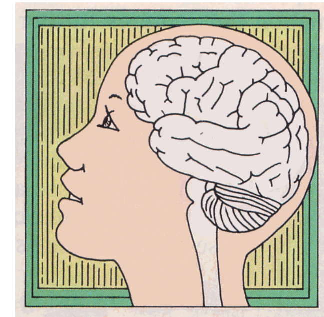
- How do we build a reliable web of knowledge?
  - **Knowledge of Basic Principles (called foothold ideas in 131):** In this class we will build experience with basic physics principles we can count on in a wide variety of circumstances
  - **Experience in how to connect the basic principles:** Finding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

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 does our brain tackle new problems?**

Try it in your own brain!
Memorize these numbers



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?

- 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**

Pantry Analogy

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!

Let's Get Acquainted

Me: Thomas M. Antonsen Jr.

Professor of Physics and Electrical and Computer Engineering

University of Maryland College Park

3339 AV Williams Bldg.

antonsen@umd.edu

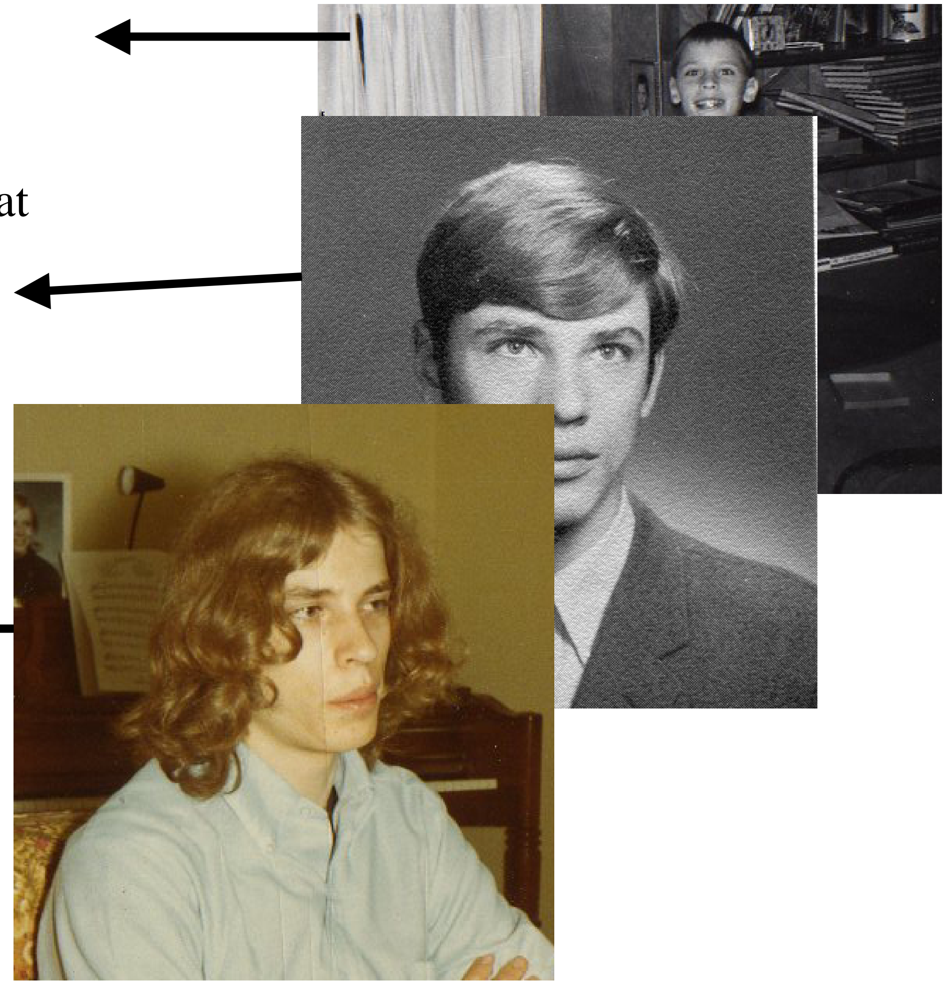
How Did I Get Here?

Middle School
-Played with chemistry set - only one "successful" explosion
-Amazed by a computer that played tic-tac-toe at 1964 World's Fair

High School - Became a nerd
-Math club
-Chemsitry club
-Electronics Lab (had my own oscilliscope)

College
BS (Electrical Engineering) 1973
MS/PhD (Plasma Physics) 1976

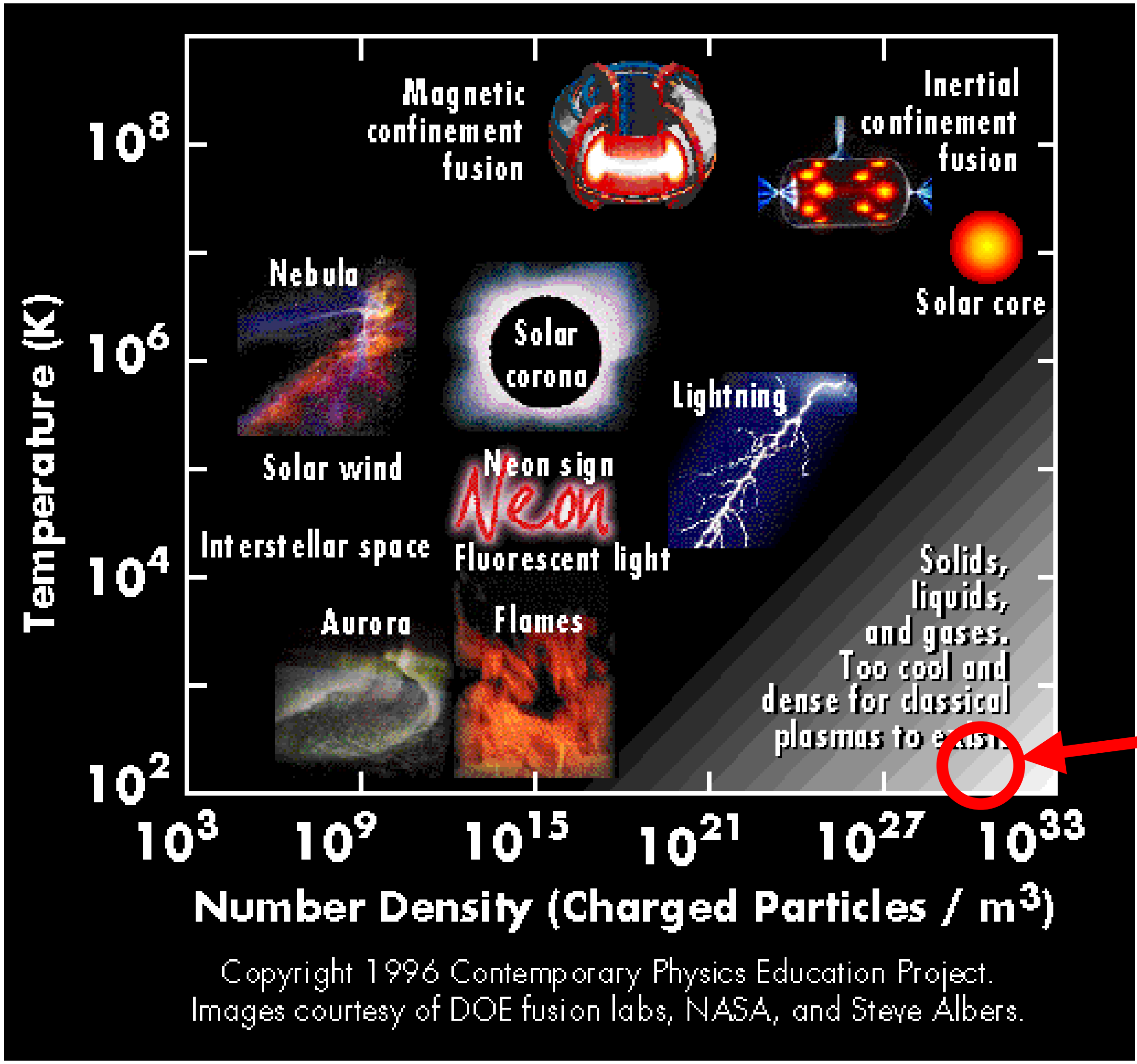
Career
Post Doc Naval Research Lab 1 year
Research Scientist (MIT 3 years)
Joined University of Maryland in 1980



Maybe some day I'll get a real job.

1969-2013 43/44 years at a University

Plasma Physics



Plasma is the fourth state of matter (solid, liquid, gas, plasma)

Most of the visible universe is plasma

You are here: the most important part of the visible universe.

http://FusEdWeb.pppl.gov/

Topic 1: Thermodynamics and Statistical Physics

Announcements

Deadline for reading assignment will be extended to Thursday 1/30/14 10 PM

Questions so far:

If electrons can penetrate barriers, have quantized energy levels and can be in multiple states at once, how can we use the laws of physics to examine the motion and interactions of a single electron like we have with other objects? **
Under what conditions would the kinetic energy really be negative for an electron, and what would that appear like? **

+ many more ….

One of the things that we learned was that our macroscopic mechanical energy -- kinetic plus potential -- was only conserved if resistive forces (friction, viscosity, drag) could be ignored. If they could not be ignored, the total mechanical energy we drained -- lost as the motion went on. And from considerations of examples with a rapid loss of mechanical energy, we concluded that the lost energy actually went somewhere -- into raising the temperature of the interacting matter.

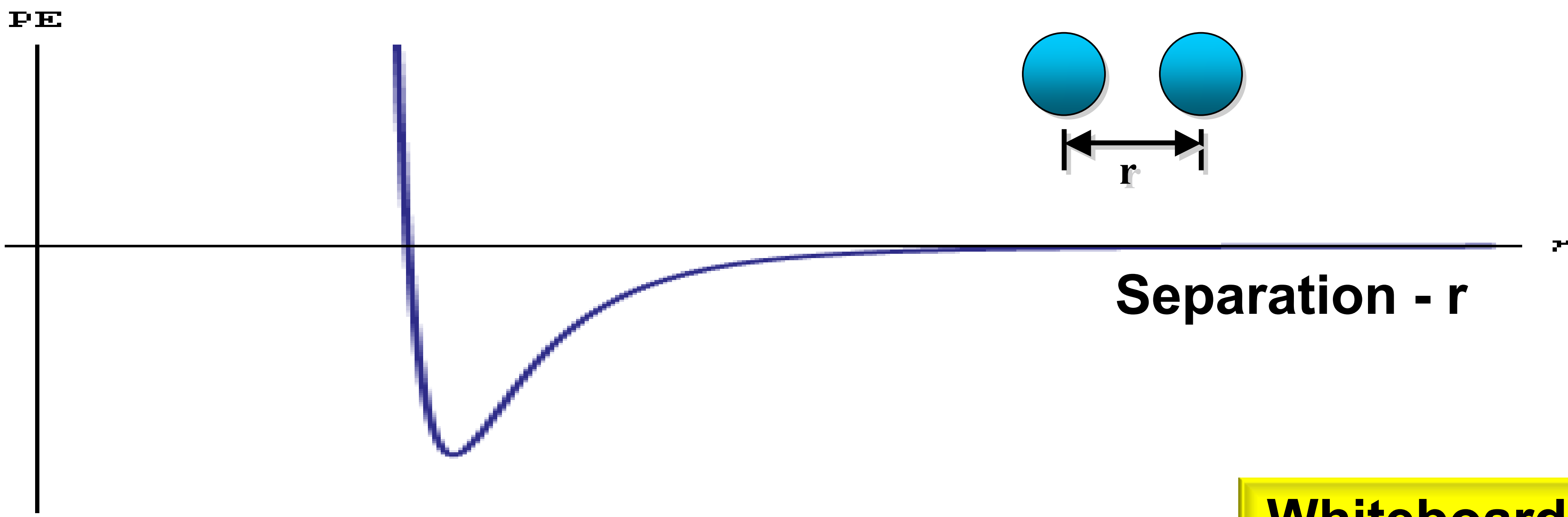
Question

I know that heat is the transfer of energy. If resistive forces increase the KE of the matter via temperature increases, how is the energy "lost" via heat (when the article talks about the KE of the matter increasing with resistive forces) ? How is it "losing" the energy?

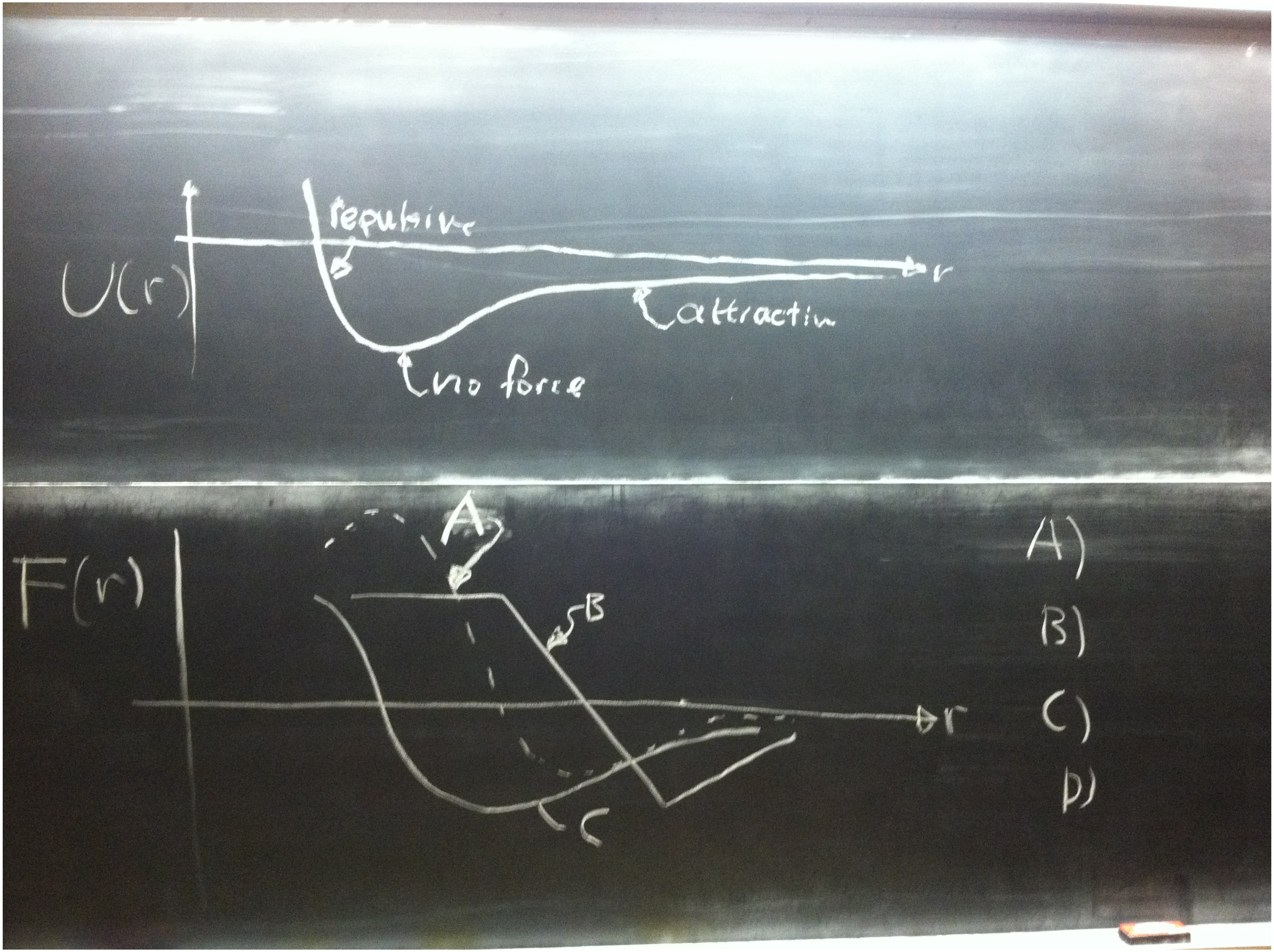
Reviewing Potential Energy

- 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)

Potential Energy - U (r)



Whiteboard, TA & LA



U(r)
repulsive
attractive
no force
r
F(r)
A
B
C
r
A)
B)
C)
D)

Forces from Potential Energy (PE)

- For <u>conservative</u> forces, PE can be defined by

$$\vec{F} \cdot \Delta\vec{r} = -\Delta U$$

- If you know *U*, the force can found via

$$F_{\parallel}^{type} = -\frac{\Delta U_{type}}{\Delta r} = -\frac{dU_{type}}{dr}$$

- In more than 1D need to use the *gradient*

$$\vec{F}^{type} = -\vec{\nabla} U_{type}$$

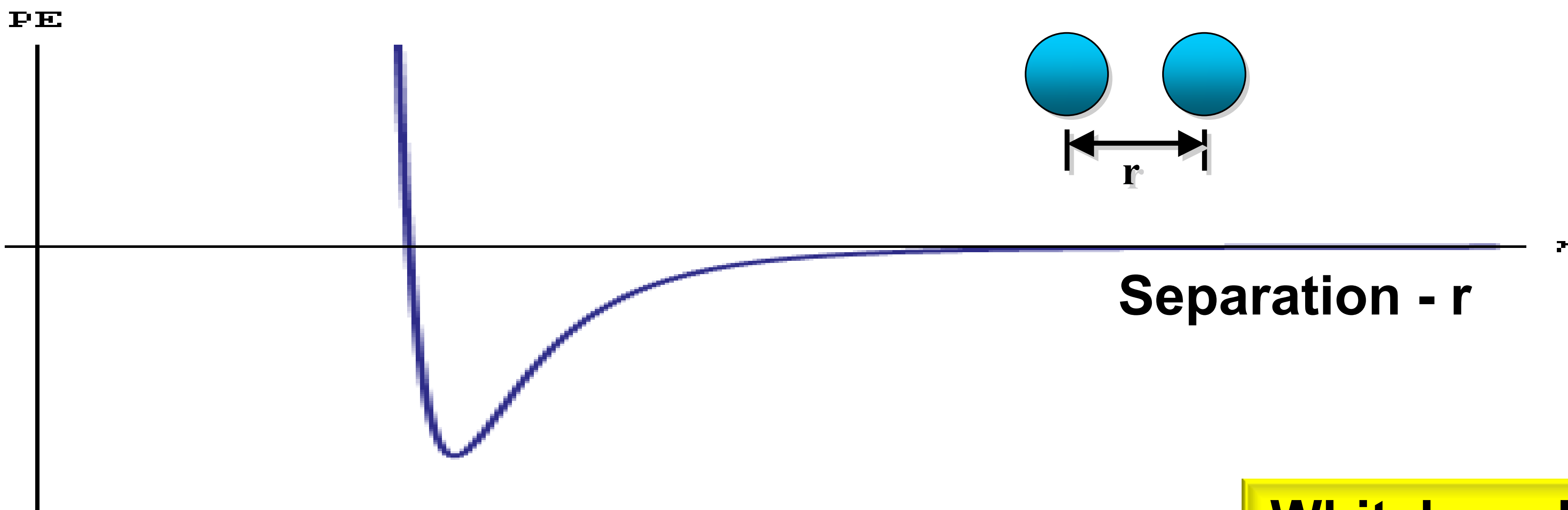
- The force always points <u>down</u> the PE hill.

Reviewing Potential Energy

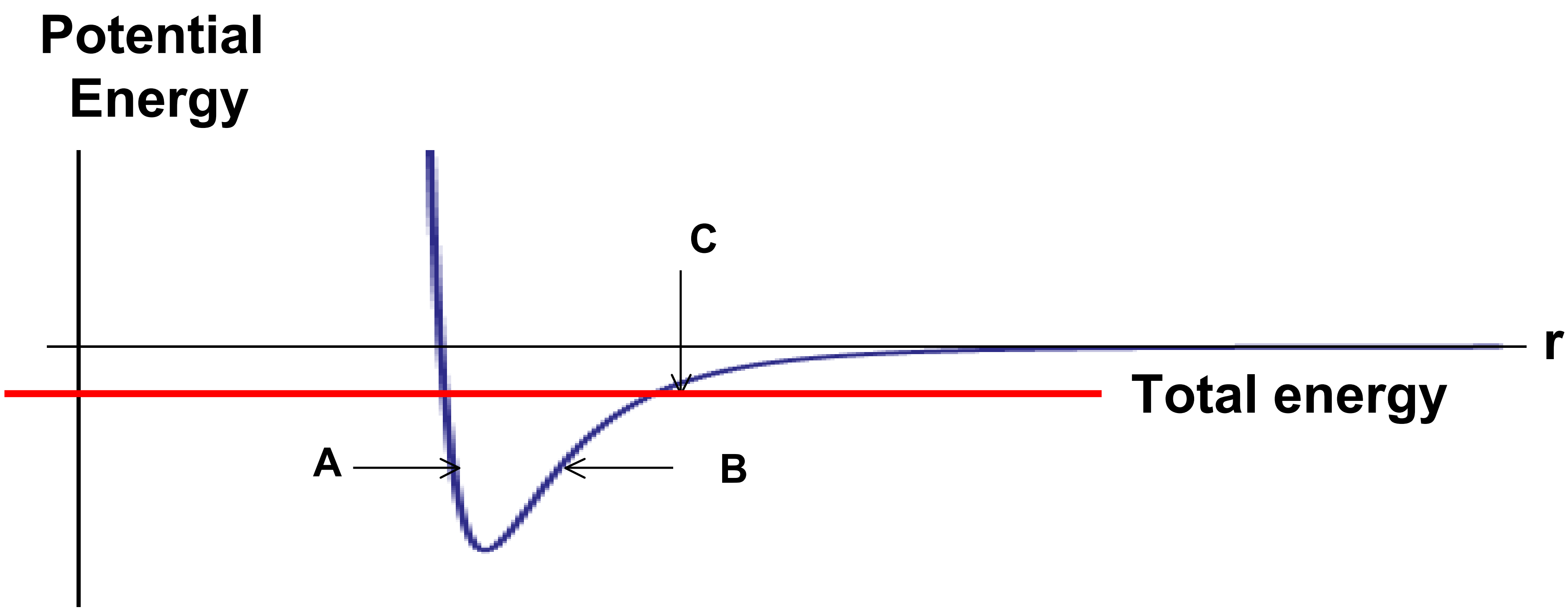
- What would a pair of bodies with a given total energy do in this potential energy well ?

A. E-Total > 0
B. E-Total < 0

Potential Energy - U (r)



Whiteboard, TA & LA



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**

Whiteboard, TA & LA

Announcements 1/31/14

Quiz in class on Monday

HW #1 due Friday 2/7, should appear on website today.
WebAssign + paper hand-in

For paper HW to be handed in to class
single sided - name on each numbered page
no dog ears, staples, spiral binding crinckles, or coffee stains

I plan to be in the course center (0208) MW 11:00 - 12

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Under what conditions would the kinetic energy really be negative for an electron, and what would that appear like? **

+ many more ….

<u>Classical</u> versus <u>Quantum</u> Mechanics

What you have learned so far is referred to as Classical Mechanics

- Particles have <u>definite positions</u> and <u>definite velocities</u>
- Positions and velocities are governed by <u>Newton's Laws</u>

Until about 1900 it was believed that this described the world we live in. But, there were some problems….

Emergence of Quantum Mechanics

-1903 Einstein posited that light was both a wave and a particle. This explained two puzzling experimental observations. Spectrum of Blackbody Radiation & Photoelectric effect

-1913 Bohr model of atom

- 1924 de Broglie posited that if light could be both a wave and a particle, then maybe matter particles (like electrons) could also be wave like.

-1926 Shrodinger posed a wave equation to describe matter waves. A consequence of this equation is barrier penetration or "tunneling".

-1927 Davisson and Germer were conducting an experiment with electrons that gave a strange result, that could be explained of electrons were also wave-like.

Photon's and matter particle's motion is described by a wave field that governs the probability of observing the particle at some point or with some property.

It's weird !!!

To make predictions for measurements we need to make two steps.

1. Solve for the values of the wave field (wave function).

2. Use the wave function to calculate the probability of finding our particle somewhere. We can't say for sure where it will be.

"God does not play dice with the universe." A. Einstein(1926)

So far as we know he does.

Why are we still teaching Classical Mechanics ?

Under many circumstances it's a good approximation to Quantum Mechanics.

You have to crawl before you can run.

Our understanding of things is influenced by our "classical upbringing."

Tunneling

Particles can penetrate classically forbidden regions.

Sounds exotic!

Examples of Tunneling

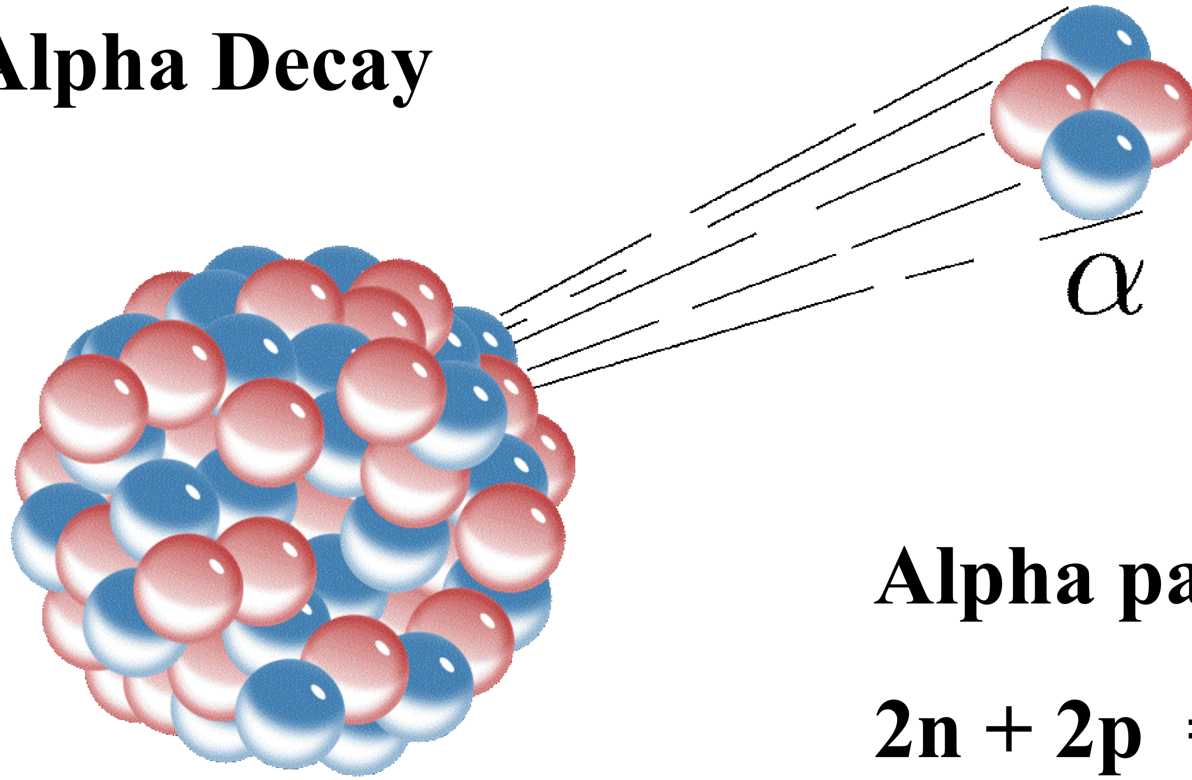
Radioactivity (alpha decay) - in your smoke detector

Esaki (Tunnel) Diode -Circuit device

Scanning Tunneling Electron Microscopes - Let's you "image" very small things

One of the steps of photosynthesis - Just ask Professor Losert

Alpha Decay



Alpha particle:

$$2n + 2p = He^4$$

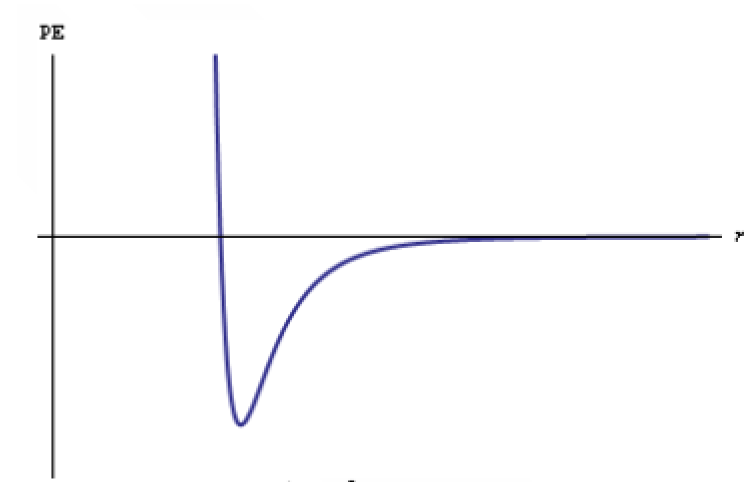
Typically 5 MeV

Too Heavy Nucleus

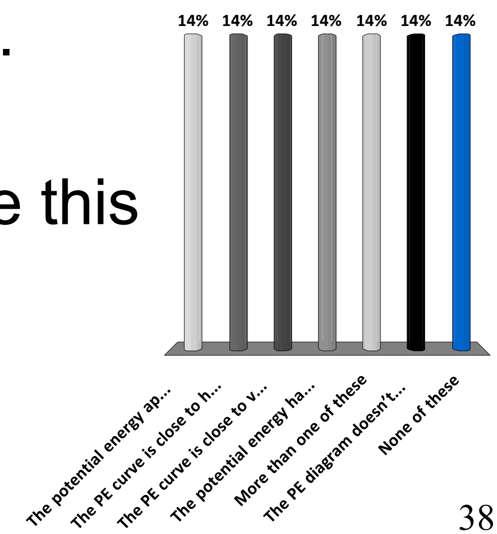
(Americium-241)

Wikimedia Commons.

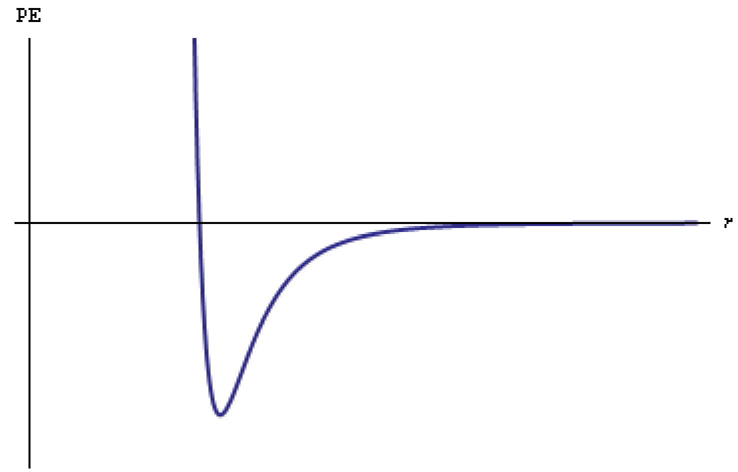
You know that two atoms that are far apart are barely interacting. How is this represented visually in the PE diagram?



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?



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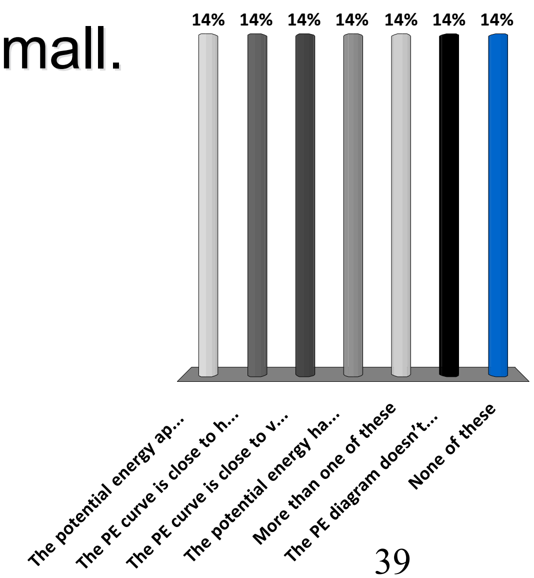
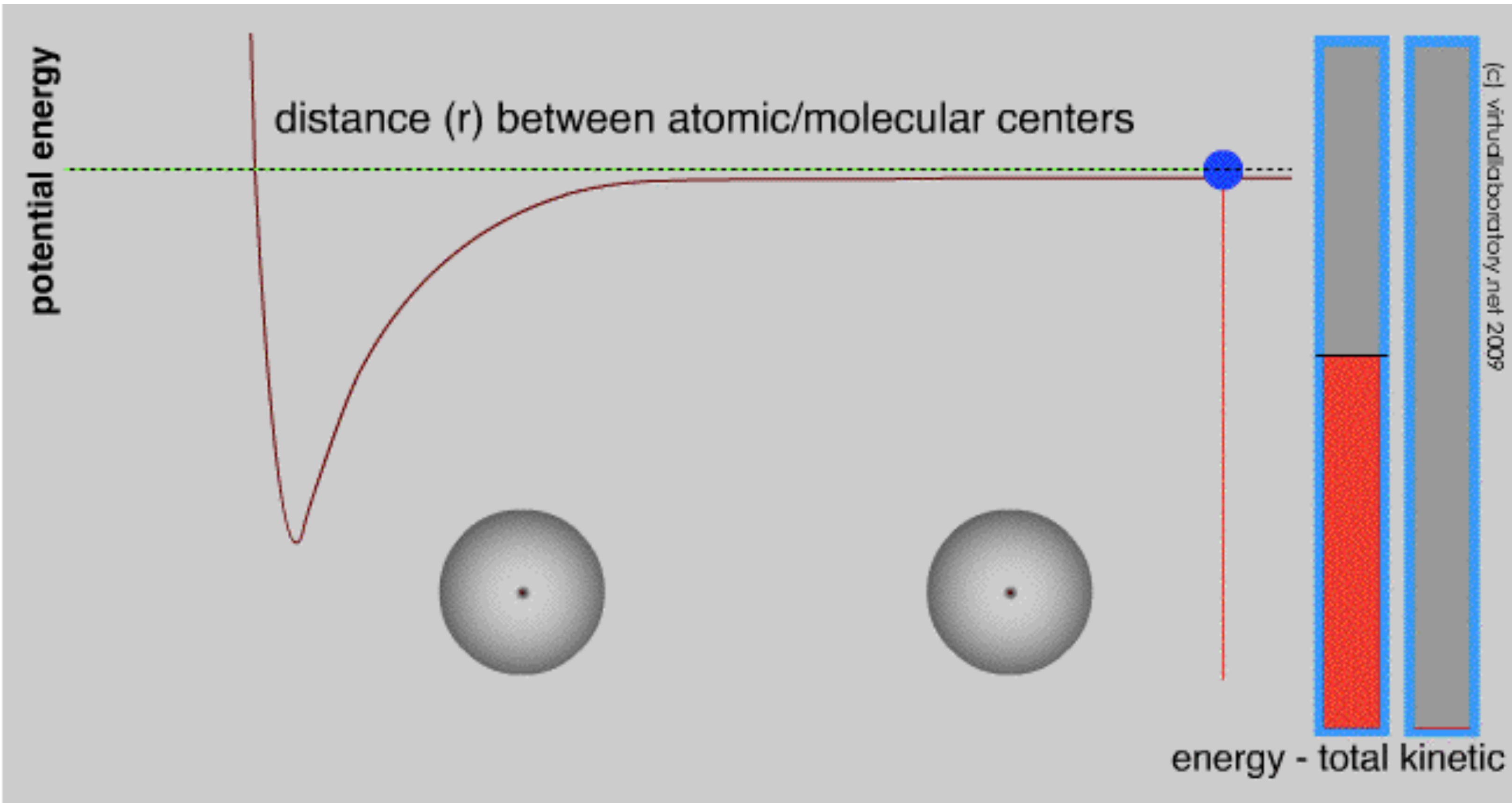


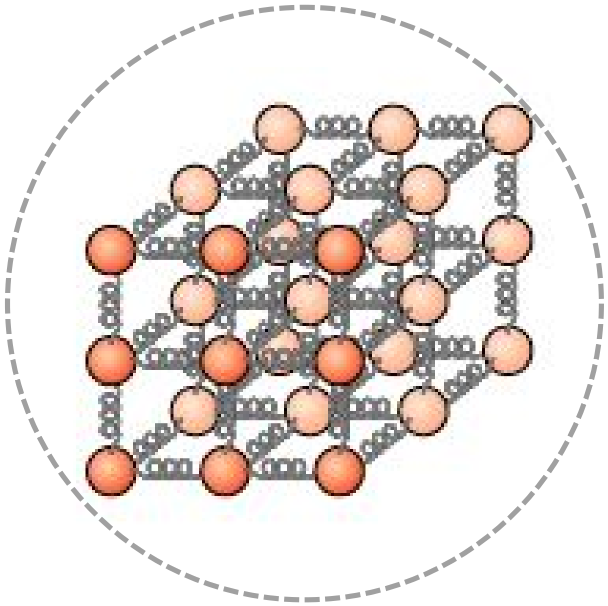
Molecular forces



http://besocratic.colorado.edu/CLUE-Chemistry/activities/LondonDispersionForce/1.2-interactions-0.html

Thermal Energy

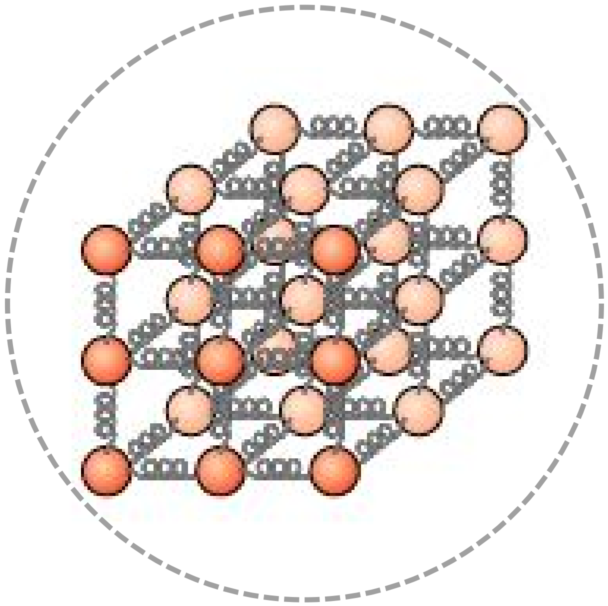
Object A



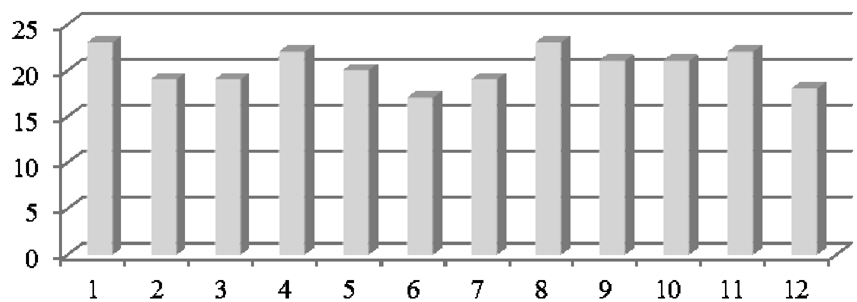
- **Thermal energy of object A :** Measures the TOTAL (internal) energy in the whole object. Depends on temperature and the number of “bins” where energy could reside.

Temperature

Object A

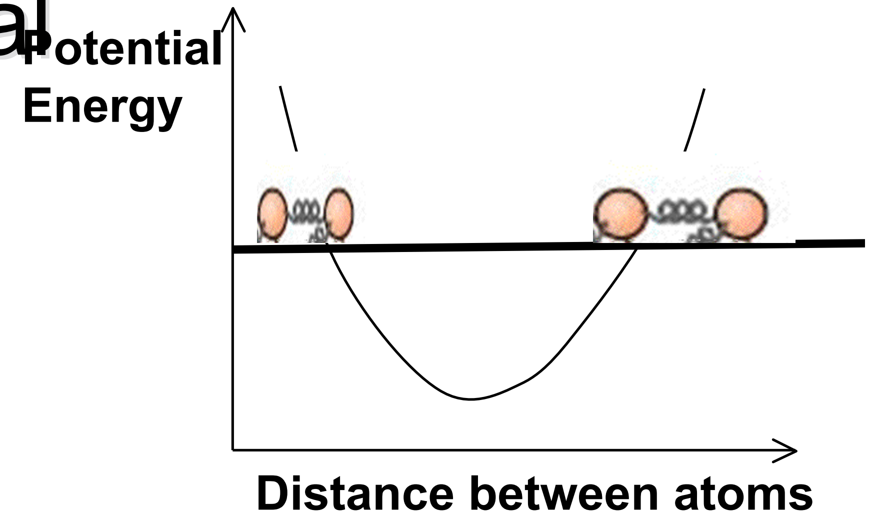


Object contains MANY **atoms (kinetic energy)** *and* **interactions (potential energy**)

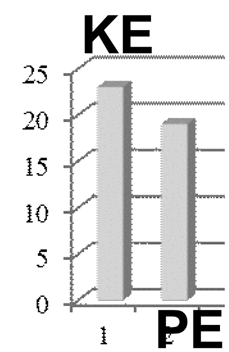


- **Temperature:** Measures the amount of energy in each atom or interaction – the key concept is that thermal energy is **on average** equally distributed among all these possible "bins" where energy could reside.
- Average Energy in each bin: 1/2 kT k - Botlzmann's const

Thermal Energy can be either Kinetic or Potential

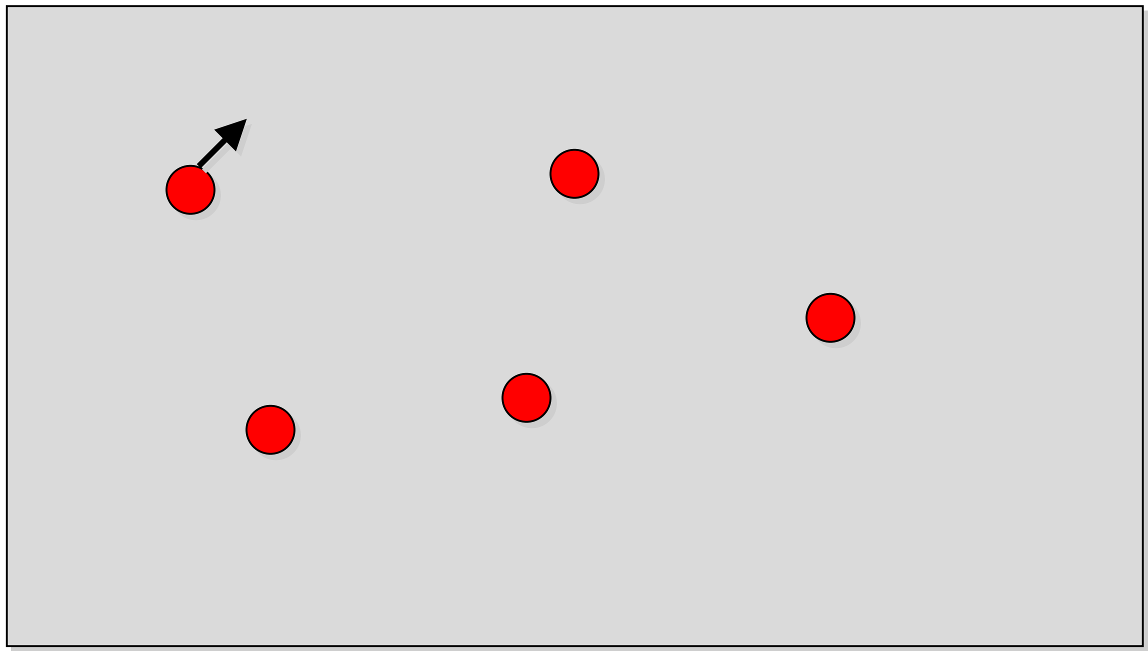


- **Let's define the zero of potential energy as the minimum of the Potential Energy Curve.**
- **With this definition, energy is ON AVERAGE the same for both potential and kinetic energy**



N oscillators, Thermal Energy = (2/2) N kT

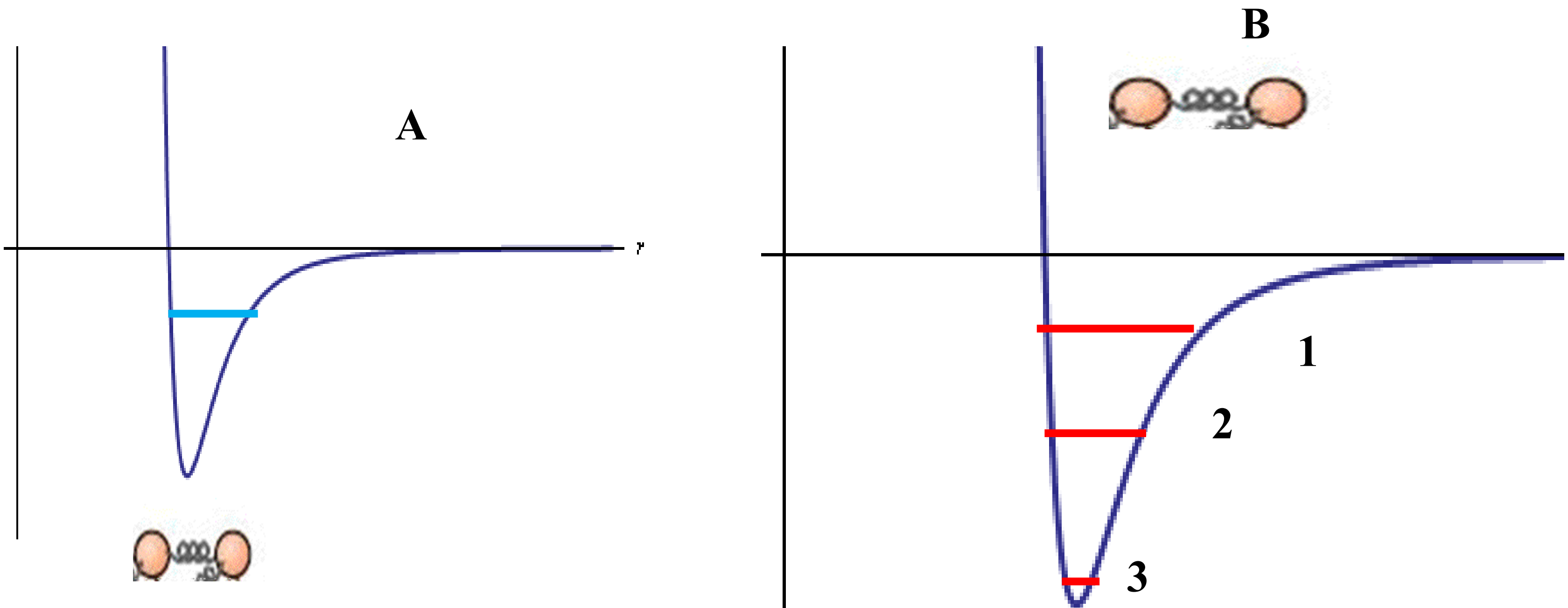
Thermal Energy in an ideal gas



N monatomic molecules, moving in 3D

Thermal Energy = (3/2) N kT

Mixtures of Molecules

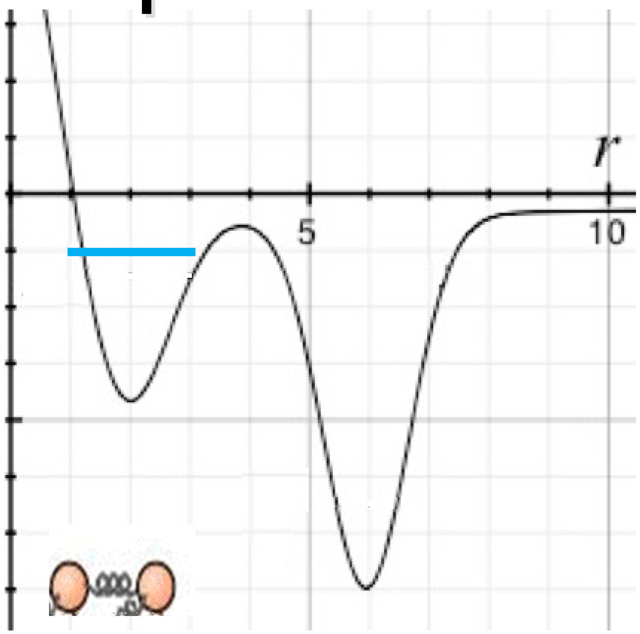


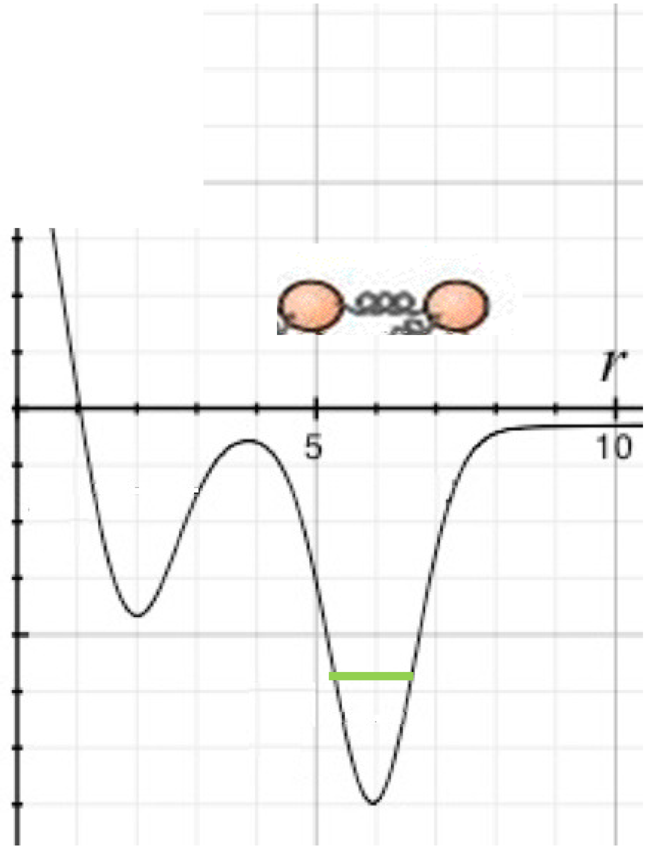
Assume you have a mix of two molecules A and B. The blue line shows the average energy for an A

Red lines are possible average energies for B's **The molecules are mixed, where is the average energy of molecules B?**

1. 1
2. 2
3. 3

Implications of our temperature model



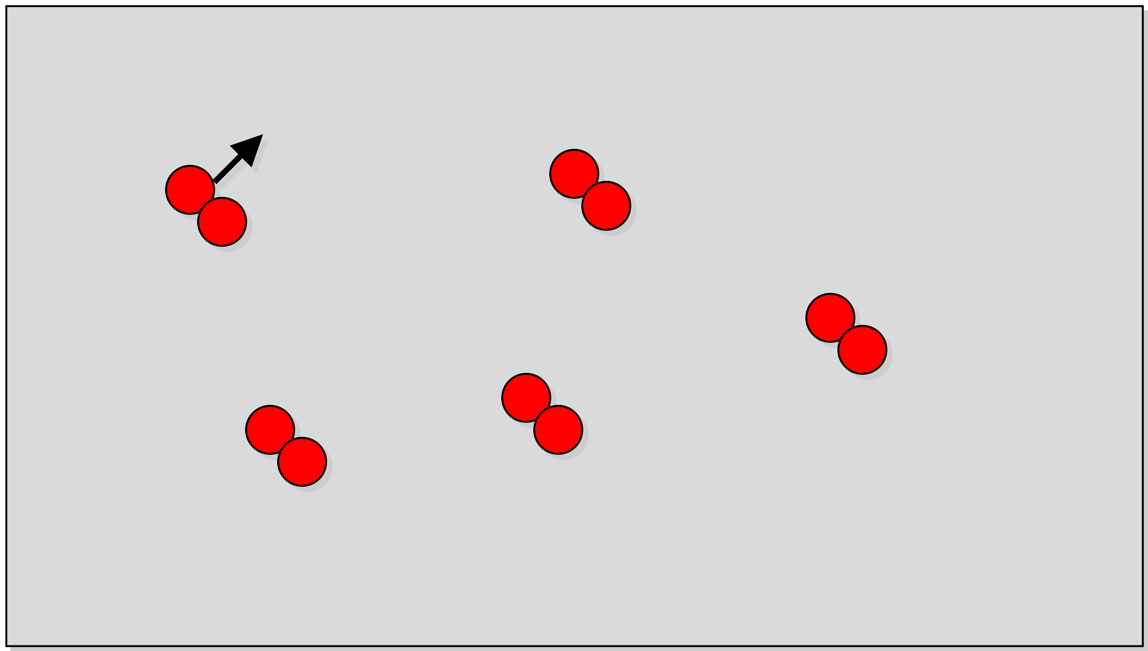


Molecules started in the blue well in thermal equilibrium. The blue line represents the average energy. The green molecules have the same temperature as the blue ones.

- **How can we tell that the two groups are at the same temperature?**
- **Is the potential energy different in blue and green cases?**
- **What would you call such a reaction in chemistry**

Whiteboard, TA & LA

Thermal Energy in gas

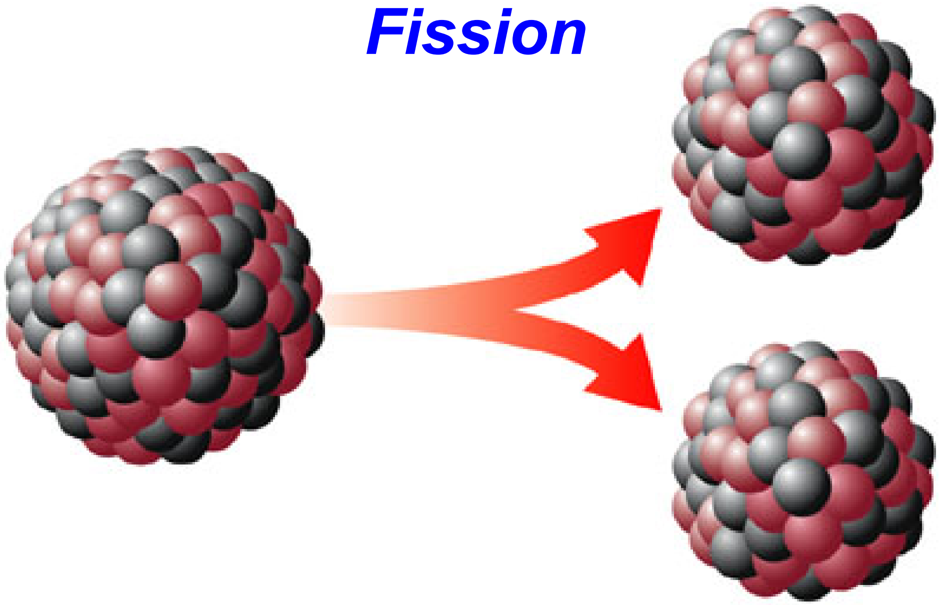


N diatomic molecules, moving in 3D

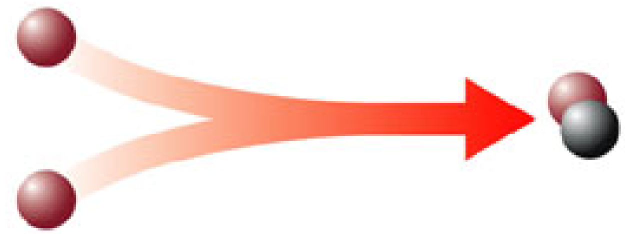
Thermal Energy = (?/2) N kT

Whiteboard, TA & LA

Fission



Fusion



Small nuclei stick together to make a bigger one and releases energy

- Fusion powers all the stars, including the Sun.
- The fuel is hydrogen, but it has to be heated to millions of degrees to ignite and burn
- Power plants based on fusion could supply all our electrical needs. No greenhouse gases.