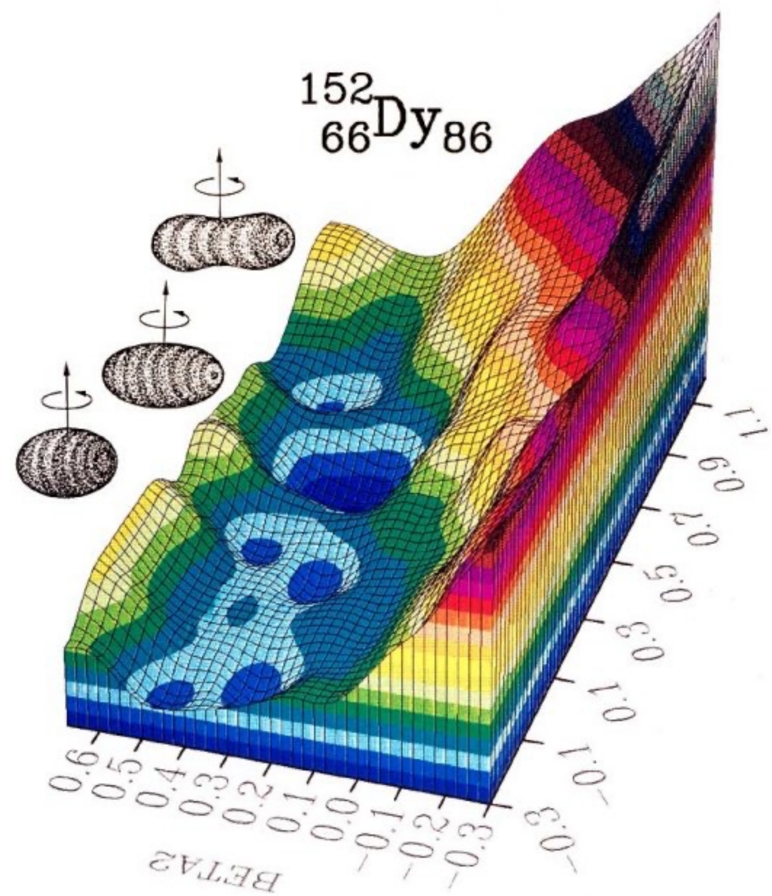
Physics 141.
Lecture 11.



Nuclear potential energy as function of deformation.

Europhysics News (2003), Vol. 34, No. 5

Physics 141.
Lecture 11.

- Course Information:
  - Homework set # 5.
  - Exam # 2.

- Concept Test

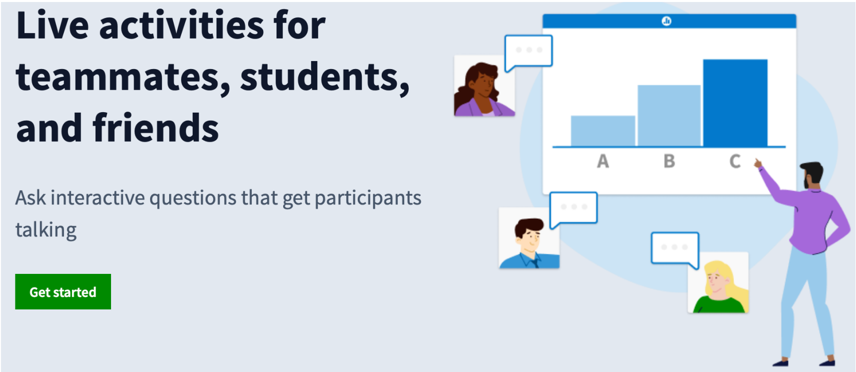
- Discussion of Chapter 7:
  - Focus on thermal energy.

Physics 141.
Course information.

- Homework:
  - Homework set 5 will be due on Friday 10/13 at 12 pm.
- Exam # 2:
  - Exam # 2 will take place on Tuesday October 24.
  - The material covered on this exam is Chapter 4 – 7.
  - The format of the exam will be similar to the format of exam # 1.

Concept test lecture 10.
PollEv.com/frankwolfs050

- The concept test today will have three questions.
- I will collect your answers electronically using the Poll Everywhere system.
- You will first answer the question yourself. The I will give you time to talk to your neighbors and possibly change your answer.



Chapter 7.
Energy in macroscopic systems.

- The focus of Chapter 7 is macroscopic systems and how to calculate the energy of such systems.

- If the system is isolated from its environment, the system energy will be conserved (we must make sure that all forms of energy are taken into consideration when we determine the energy of the system).

- If the system is interacting with its environment, we must determine the flow of energy in order to determine the net energy balance. Important interactions to consider:
  - Thermal interactions.
  - Air resistance.
  - Friction.

Energy in macroscopic systems.

- In order to determine the energy of a macroscopic system we must know how to:
  - Calculate the particle energy of each particle:

$$E = \frac{mc^2}{\sqrt{1 - v^2 / c^2}} = mc^2 + K$$

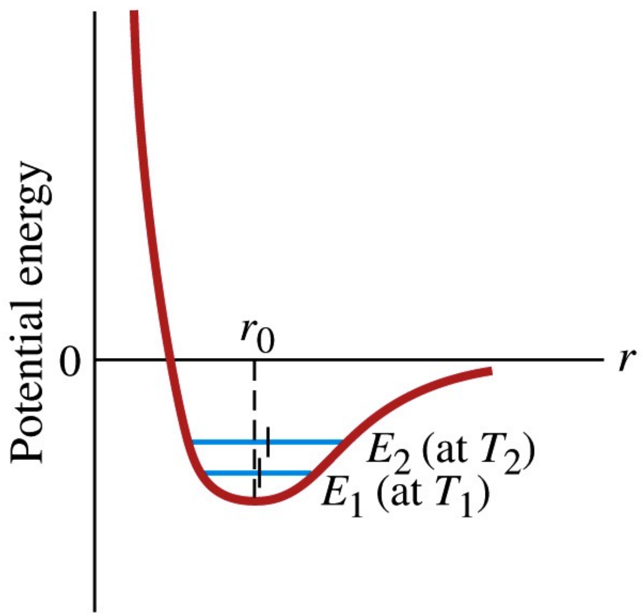
  - Calculate the work done by the forces acting on the particles during the assembly of the system.

$$U\left(\vec{r}\right) = U\left(\vec{r}_0\right) + \Delta U = U\left(\vec{r}_0\right) - \int_{\vec{r}_0}^{\vec{r}} \vec{F} \bullet d\vec{r}$$

  - Calculate the work done by the external forces that may act on the system. These force may include conservative and non-conservative forces:
    - Thermal interactions.
    - Air resistance and drag.
    - Friction.

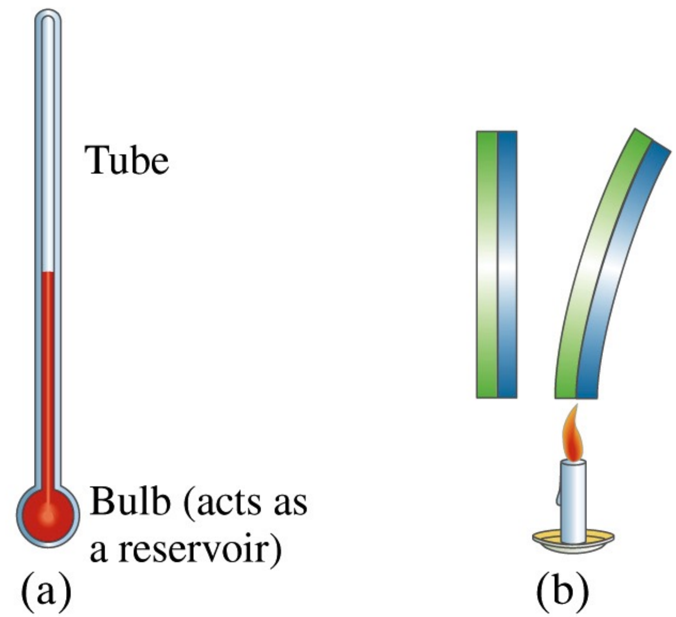
Thermal energy.

- One form of energy that is frequently present in mechanics problems, but often ignored, is the thermal energy.
- Thermal energy is associated with the temperature of a system; a change in thermal energy correspond to a change in temperature.
- An increase in the temperature of a material will increase the amplitude of the inter-atomic vibrations, and increase the average distance between atoms (due to the fact that the potential energy is not symmetric around its minimum).

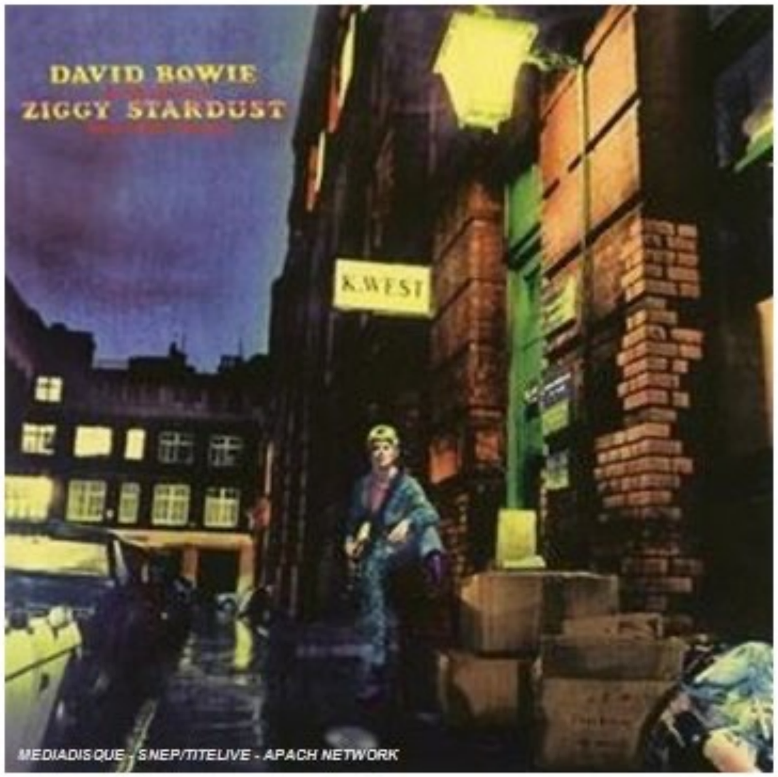


Temperature.

- Since the thermal energy of a system is related to its temperature, we need to be able to measure the temperature of our system.
- Properties of many bodies change as their thermal environment is altered. For example, thermal expansion or contraction, pressure changes, etc.
- We can use these changes in properties to develop a tool that allows us to measure temperature: the **thermometer.**



2 Minute 58 Second Intermission.



- Since paying attention for 1 hour and 15 minutes is hard when the topic is physics, let's take a 2 minute 58 second intermission.
- You can:
  - Stretch out.
  - Talk to your neighbors.
  - Ask me a quick question.
  - Enjoy the fantastic music.
  - Go asleep, as long as you wake up in 2 minutes and 58 seconds.

Measuring temperature.

- In order to measure the temperature of a system, we need to bring the thermometer in contact with the system.
- We must wait long enough to ensure that the thermometer and the system are in thermal equilibrium (have the same temperature).
- This approach relies on the **zeroth law of thermodynamics**:

  Temperature is a property of a body, and two bodies are in thermal equilibrium if their temperatures are equal.

- If the thermometer initially has a different temperature than the system, energy will flow to provide thermal equilibrium and the temperature of both systems will change!

Measuring temperature.

- In order to measure temperature we must:
  - Agree on a standard reference point to which we assign a certain temperature.
  - Agree on a unit.
  - Agree on a standard thermometer against which all other thermometers can be calibrated.
- The unit of temperature will be the Kelvin (K).
- The standard reference point is the triple point of water (T = 273.16 K).

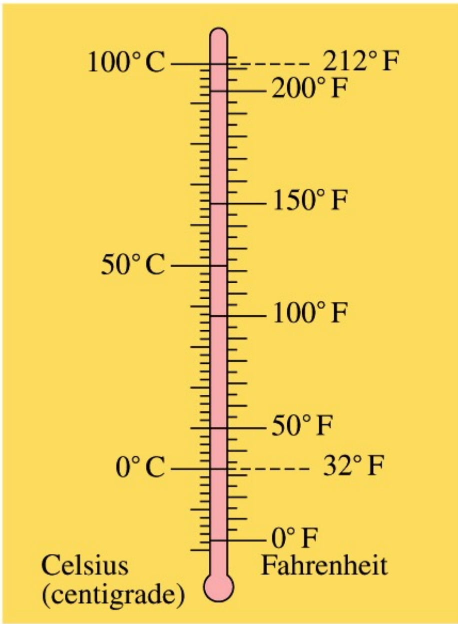
http://www.fluke.fr/common/prod_pages/pages/hart/products/tpw.htm

Measuring temperature. Temperature scales.

- The Kelvin is not frequently used in our daily life.

- More common temperature scales are the Celsius scale:
  - 0° is defined as the freezing point of water.
  - 100° is defined as the boiling point of water.

  and the Fahrenheit scale:
  - 32° is defined as the freezing point of water.
  - 212° is defined as the boiling point of water.

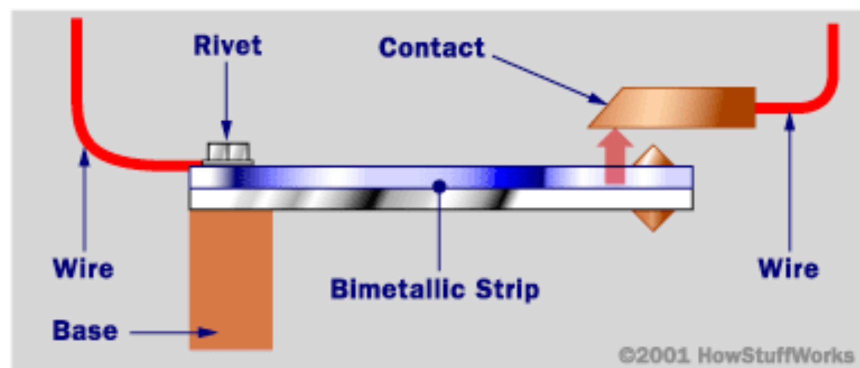


Measuring temperature. Thermometers.

- Thermometers exist in many different forms.
- The design of a thermometer depends on how they are going to be used, and the range of temperatures to be measured.
- All thermometers rely on using macroscopic changes to measure temperature.
- For example, in the mercury thermometer, expansion or contraction of the mercury is used to measure temperature.

Measuring temperature. Thermometers.

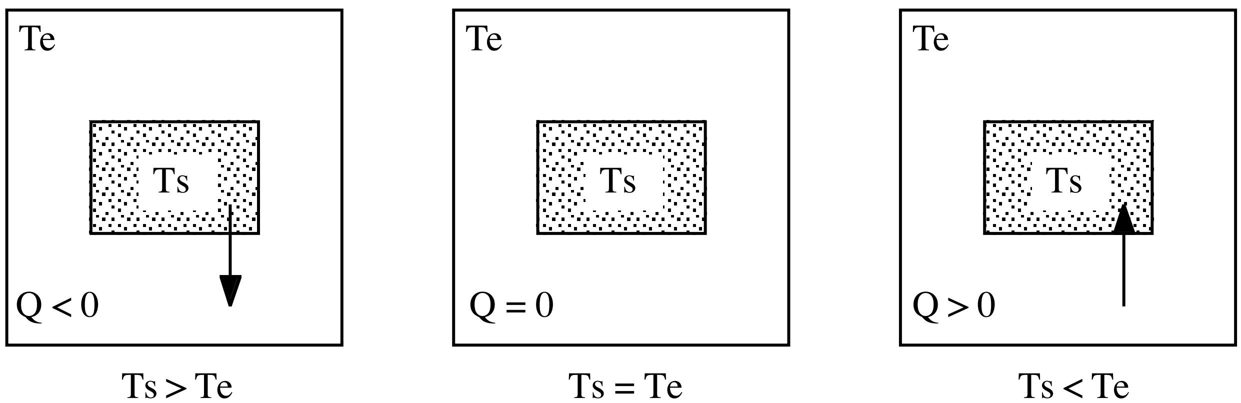
- Many thermometers rely on bimetals. Bimetals strips consist out of two different metals, connected to each other (side by side).
- When the temperature of the metals change, their length will change. If the changes in their lengths are different, the strip will bend.
- The change in shape of the strip can be used to move the dial of the thermometer, or open/close an electric circuit (in a thermostat).



http://home.howstuffworks.com/therm2.htm

Thermal energy and thermal equilibrium.

- When two objects are brought in thermal contact they can achieve thermal equilibrium (equal temperature) via an exchange of thermal energy.
- The exchange of thermal energy (heat, *Q*) will continue until the two objects have the same temperature.
- Thermal energy can also be exchanged if work is done.



Heat (thermal energy).

- We commonly use Q to indicate the amount of heat (thermal energy) transferred.

- Since heat is a form of energy, its unit is the Joule.

- Another commonly used unit for heat is the calorie. One calorie is defined as the mount of heat required to raise the temperature of 1 g of water from 14.5°C to 15.5°C. 1 cal = 4.186 J.

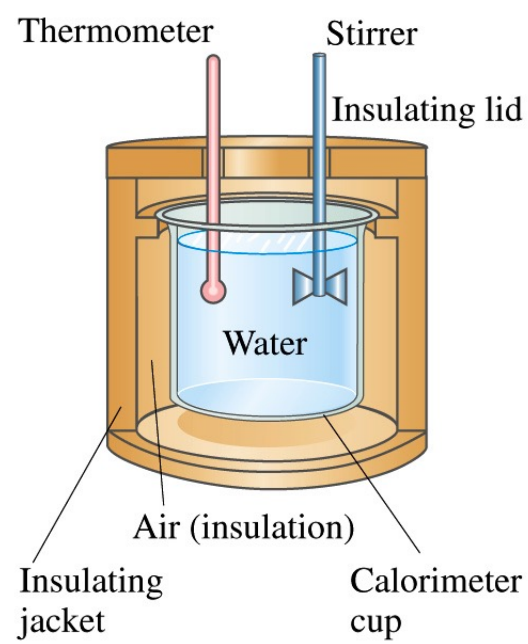
Heat and heat capacity.

- When heat is added to an object, its temperature will increase:

$$Q = C\left(T_f - T_i\right)$$

- The coefficient C is the heat capacity of the object. It depends on the type and the amount of material used.
- In order to remove the dependence on the amount of material, we prefer to use the heat capacity per unit mass c:

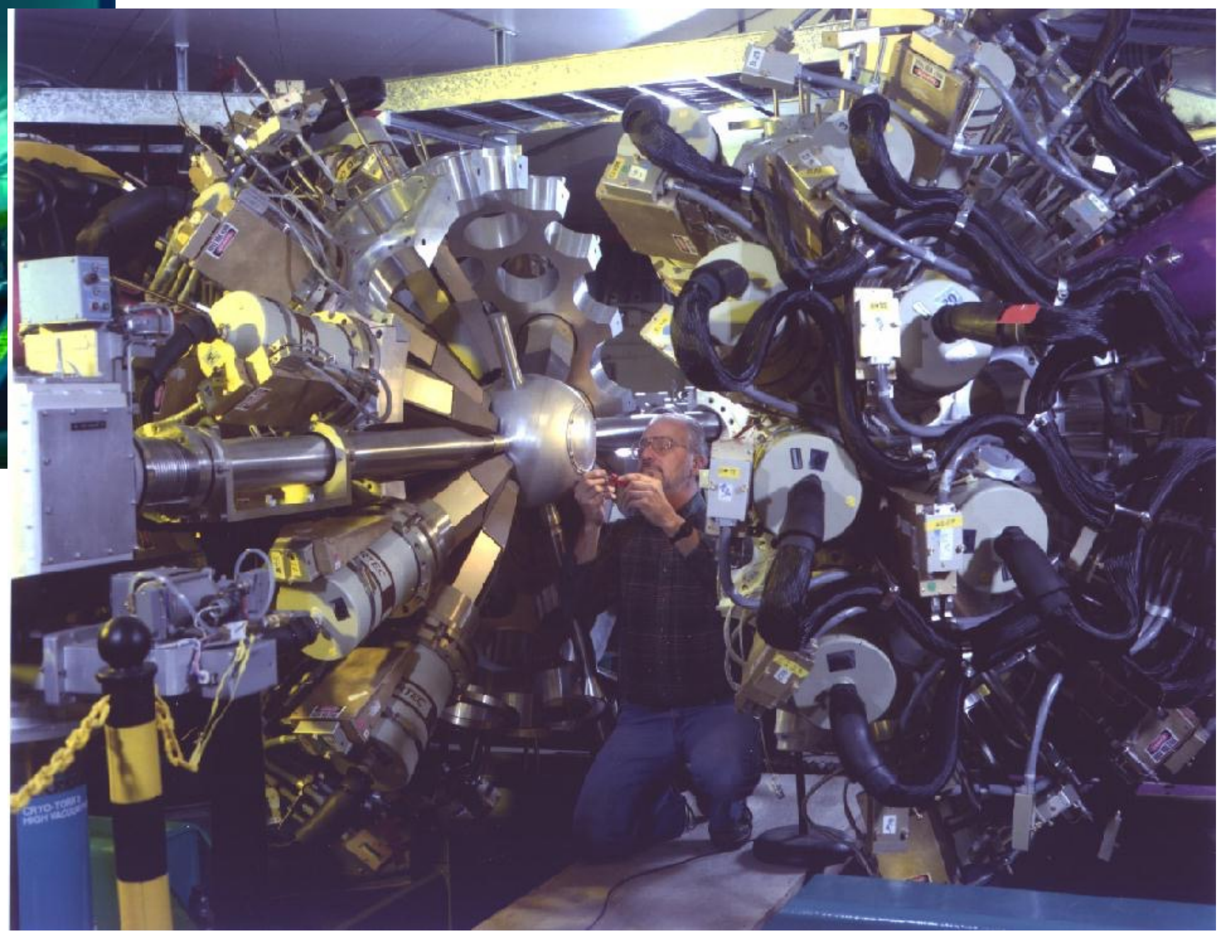
$$Q = cm\left(T_f - T_i\right)$$



Transfer of heat.

- Heat can be transferred in a number of different ways:
  - Conduction: transfer of heat via molecular collisions. Usually the dominant mechanism for heat transfer in metals.
  - Convection: transfer of heat of mass movement of molecules. Usually the dominant mechanism of heat transfer in liquids and gases.
  - Radiation: transfer of heat using electromagnetic radiation (e.g. light).
- We will discuss these mechanisms in more detail towards the end of the course.

Done for today!
Up next: quantization of energy.



http://www.phy.anl.gov/gallery/equipment/