Physics 131- Fundamentals of Physics for Biologists I

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Molecular Dynamics Simulations
http://www.youtube.com/watch?v=hT0c6Q4DLbk

Outline

Review Quiz 10

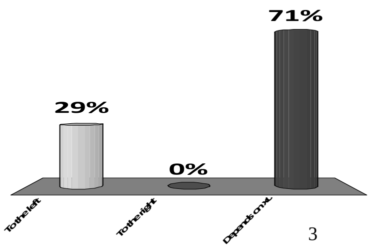
Heat Capacity

Extending energy Conservation: The first law of thermodynamics

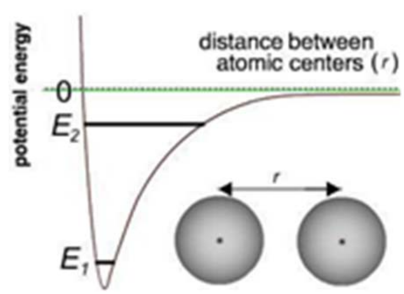
Lets assume that an object is at position x_0 and the x-axis points to the right . If instead I place it at $-x_0$

X-axis

1. To the left
2. To the right
3. Depends on x_0

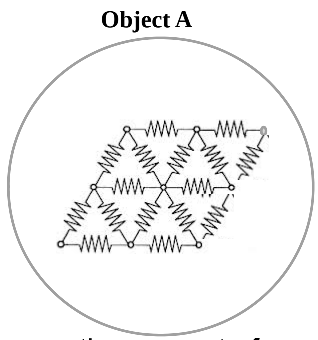


Quiz 10
Average: 6.7



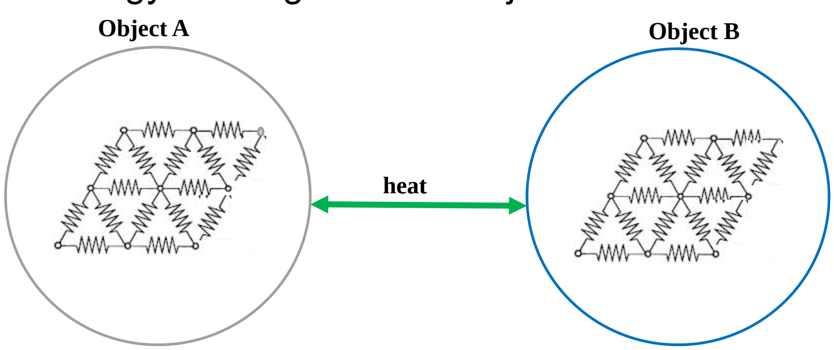
CORRECT	AC	C	BD	B
other	*E*		*EF*	*A*

Temperature and 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 locations where energy could reside.
- **Energy of object A :** Measures the TOTAL energy in the whole object. Depends on temperature and the number of locations where energy could reside.

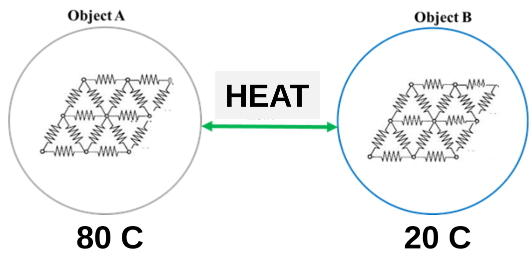
- Energy Sharing between objects



- All internal “stores” of energy have – on average the same thermal energy.

Critical Experiment 1

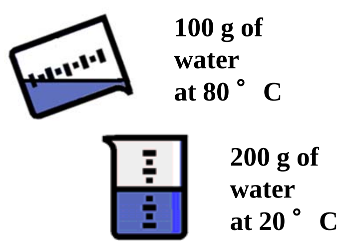
If we have equal amounts of the same kinds of materials at different temperatures and put them together, what happens?



1. pretty close to 50 C
2. pretty close to 80 C
3. pretty close to 20 C
4. greater than 80 C
5. less than 20 C

Critical Experiment 2

If we have unequal amounts of the same kinds of materials at different temperatures and put them together, what happens?



1. pretty close to 40 C
2. pretty close to 80 C
3. pretty close to 20 C
4. greater than 60 C
5. something else

- How does the thermometer know where the hot molecules in the water are?

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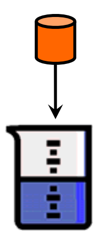
Critical Experiment 3

If we have equal masses of different kinds of materials at different temperatures and put them together, what happens?



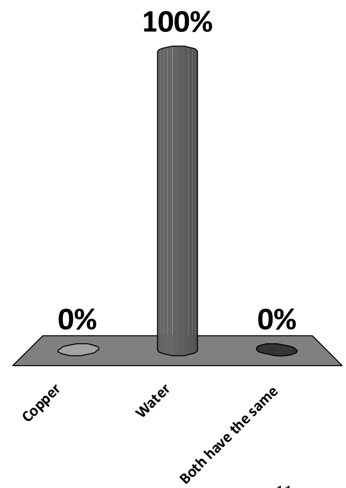
200 g of copper at 80° C

200 g of water at 20° C

1. pretty close to 50 C
2. pretty close to 80 C
3. pretty close to 20 C
4. greater than 80 C
5. less than 20 C

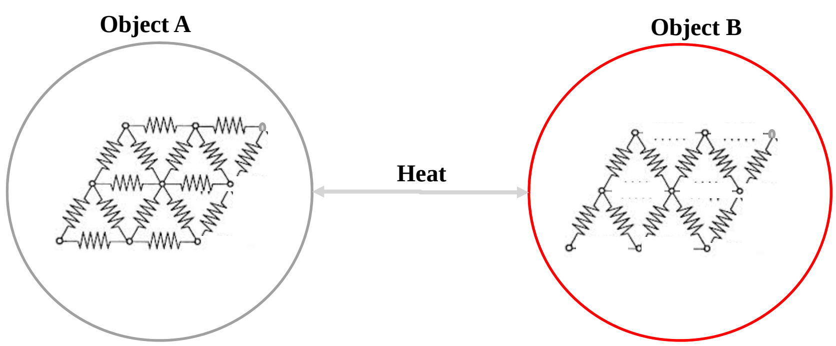
For water and copper of the same mass, does one of them have more internal "stores" of energy

1. Copper
2. Water
3. Both have the same



Interaction between two objects?

<u>When two objects touch they are brought to the same temperature:</u>
There are **fewer** places to store the energy in object B, so to get object B to the same temperature we need **less** energy than for object A



Specific Heat and Heat Capacity

- The amount of thermal energy Q needed to produce one degree of temperature change is an object is called its <u>heat capacity C</u>.

$$Q = C\Delta T$$

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

$$C = mc$$

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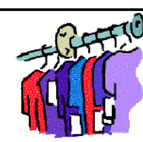
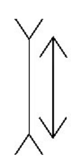
Real-World Intuition 1: Reconsidered



– If we have a cup of hot water and a cup of cold water and we put them aside for a while, what will happen to them?

– If you touch the plastic part of your chair and the metal part, which feels warmer?



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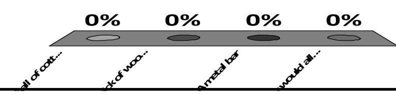
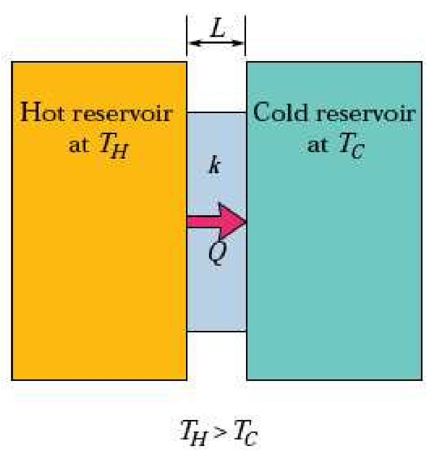
The objects listed in 1-3 below are placed in an oven heated to 90° C and left for a long time. Which object will feel warmest when you touch it?

1. A ball of cotton
2. A stick of wood
3. A metal bar
4. They would all feel the same



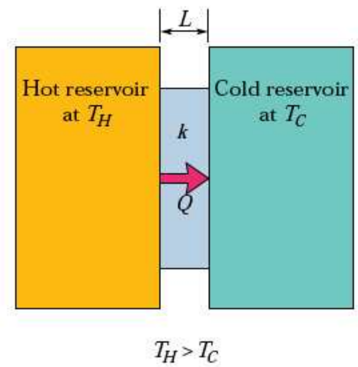
Heat Flow by Conduction

- Simplest case (again)
  - Hot block at T_H
  - Cold block at T_C
  - Connecting block that carries ("conducts") thermal energy from the hot block to the cold.



Creating an equation

- Φ = Flow
  = heat energy/sec
  [Φ] = Joules/s = Watts
- What drives the flow?
- How does the rate of flow depend on the property of the connecting block?



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The Heat Flow Equation

Difference: T_h-T_c

$$\Delta T = Z\Phi$$

- We expect the flow to
  - Be less for a longer block (*L*)
  - Be more for a wider block (*A*)

$$Z = \rho\frac{L}{A}$$

- *ρ* = thermal resistivity – a property of the kind of substance the block is made of

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A more standard form

- We have written the heat flow equation to have it match the HP equation. It is more standardly written this way:

Heat flow per unit area → $\phi = \frac{\Phi}{A}$

$k = \frac{1}{\rho}$ ← **Thermal conductance**

- The equation then becomes

$$\Delta T = Z\Phi = \frac{\rho L}{A}\Phi = \left(\frac{L}{k}\right)\left(\frac{\Phi}{A}\right)$$

$$\Delta T = R\phi$$

R ← **Thermal resistance (R-value)**

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Some thermal conductances

Material	*k* (W/Cm)	Material	*k* (W/Cm)
Steel	12-45	Wood	0.4
Aluminum	200	Insulation	0.04
Copper	380	Air	0.025

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How are P and Z different from the specific heat capacity? In both cases, it seems like they describe how easily an object gains or loses heat.

P and Z are about how FAST a system changes energy, heat capacity tells you how much energy the system needs to change its temperature

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