December 6, 2010 Physics 121 Prof. E. F. Redish

- **Theme Music:** **Manuel de Falla**
  Ritual Dance of Fire *played by Ruth Laredo*
- **Cartoon:** **Jeff Mallett**
  Frazz

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Surveys

- Campus evaluation (login at upper right)
  - https://www.CourseEvalUM.umd.edu
    (or from BlackBoard)
- In tutorial next week
  - Post-instruction concept survey (5 pts)
- On line
  - Post-instruction attitude survey (5 pts)
    http://perg-surveys.physics.umd.edu/MPEX2post.php

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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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Thermal Energy is NOT Temperature

- Even if the masses are the same, the temperature does not wind up halfway between.
- Each kind of material translates thermal energy into temperature in its own way.

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

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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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Scales and Units

- 1 cal = the amount of thermal energy needed to change the temperature of 1 gm of water by 1 degree C (from 14.5^o to 15.5^o) (by definition)
- 1 Cal = 1000 cal
- 1 Cal = 4184 J

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Reinterpreting Our Results

- When two objects at different temperature are put together, thermal energy flows from the hotter body to the colder body until their temperatures are the same. (0^{th} Law)

$$Q = m_1c_1\Delta T_1 = m_1c_1(T_f - T_1^i)$$
$$-Q = m_2c_2\Delta T_2 = m_2c_2(T_f - T_2^i)$$
$$m_1c_1(T_f - T_1^i) = -m_2c_2(T_f - T_2^i)$$
$$m_1c_1(T_f - T_1) = m_2c_2(T_2 - T_f)$$
$$T_f = \frac{m_1c_1T_1 + m_2c_2T_2}{m_1c_1 + m_2c_2}$$
$$T_f = \left(\frac{m_1c_1}{m_1c_1 + m_2c_2}\right)T_1 + \left(\frac{m_2c_2}{m_1c_1 + m_2c_2}\right)T_2$$

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Foothold ideas: 2

- When two objects of <u>different</u> 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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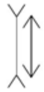
Real-World Intuition 1: Reconsidered

- 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 cloth part of your chair and the metal part, which feels warmer?



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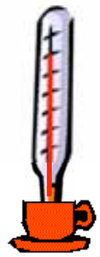
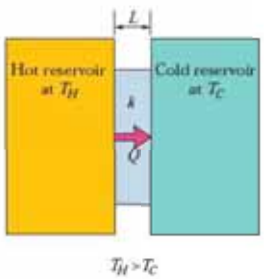
ILD 7



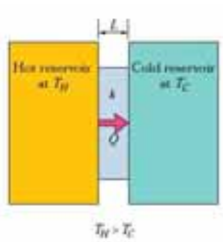
Heat Flow by Conduction

- 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?



The Heat Flow Equation

$$\Delta T = Z\Phi$$

- 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 → $\phi = \frac{\Phi}{A}$

Thermal conductance → $k = \frac{1}{\rho}$

- The equation then becomes

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

$$\Delta T = R\phi$$

Thermal resistance (R-value) → R

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Some thermal conductances

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

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