December 3, 2010 Physics 121 Prof. E. F. Redish

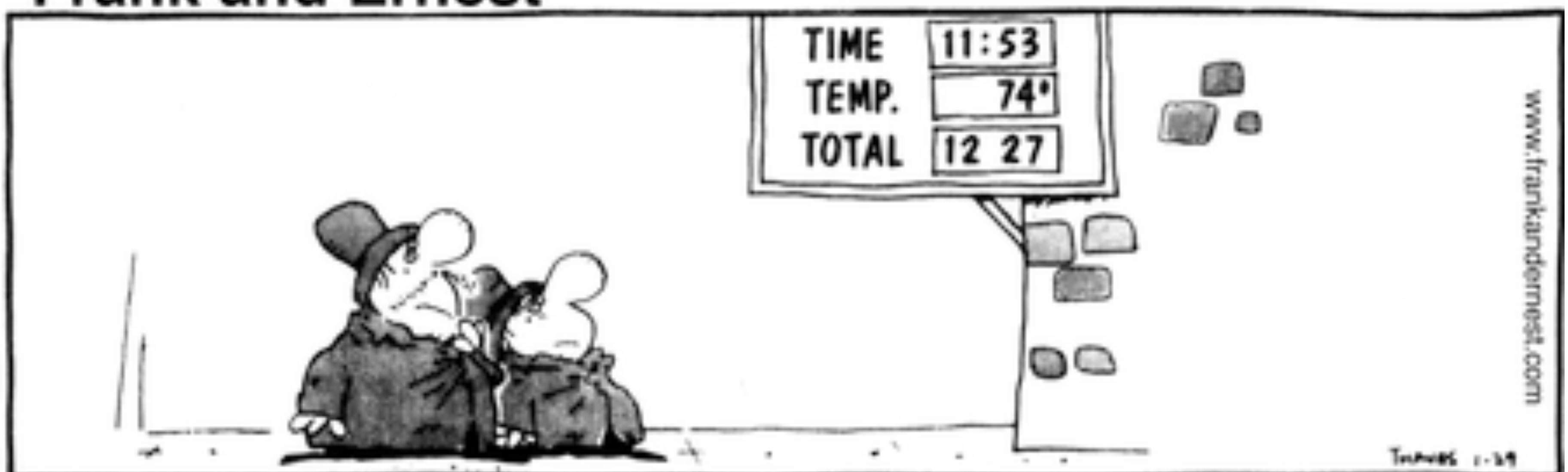
- **<u>Theme Music:</u> Ella Fitzgerald**

  Too Darn Hot

- **<u>Cartoon:</u> Bob Thaves**

  Frank & Ernest

Frank and Ernest

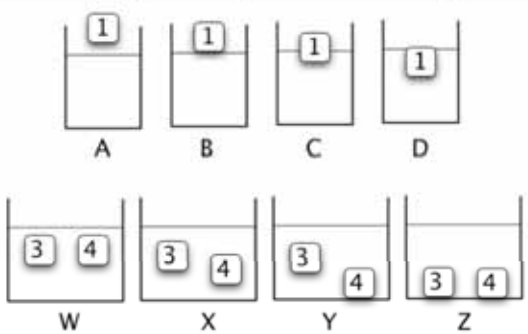


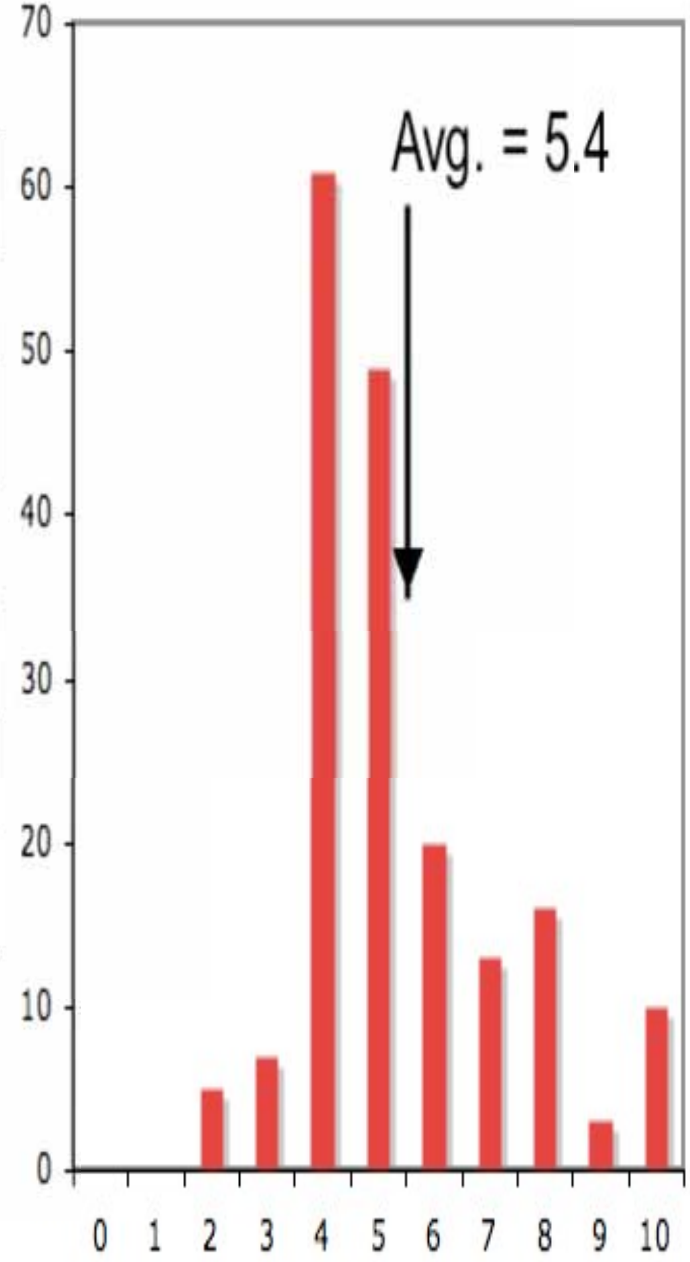
Outline

- Go over Q10
- What do we mean by temperature?
- Thermal Energy is not Temperature
  - Heat Capacity and Specific Heat
  - Heat of Transformation
- Heat Capacity and Specific Heat
- Summary: Heat and Temperature
- ILD 7 (start if time)

Quiz 10

	10.1		10.2		10.3		10.4
BX	21%	A	94%	D>U>L=R	27%	SAME	19%
BY	4%	B	3%	D>L=R>U	24%	DIFF	81%
CX	39%	C	3%	D=L=R>U	2%		
CY	3%			U>L=R>D	14%		
CZ	20%			D=L=R=U	5%		
				U>D=L=R	2%		





Surveys

- Campus evaluation (login at upper right)
  - *https://www.CourseEvalUM.umd.edu*
- In tutorial next week
  - Post-instruction concept survey (5 pts)
- On line
  - Post-instruction attitude survey (5 pts)

  http://perg-surveys.physics.umd.edu/MPEX2.php

"The kind of motion we call heat"

- For the last two weeks of the class we will consider the topic of heat and temperature.
- We have a natural sense of hot and cold.
- In the 18th 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 surpisingly 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.

Real-World Intuition 1

- 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?

Real-World Intuition 2
How do objects exchange hot and cold?

- When two amounts of water at different temperatures are combined, they come to a temperature somewhere in between.
- We expect that the amount of each kind of water determines the final temperature.
- Try it!
  - Case 1: Equal amounts of water
  - Case 2: Different amounts of water

Two Objects of the Same Kind but Different Temperatures

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

the changes in
temp are opposite—
one goes up
the other goes down

$$m_1(T_f - T_1) = m_2(T_2 - T_f)$$

$$m_1 T_f - m_1 T_1 = m_2 T_2 - m_2 T_f$$

$$m_1 T_f + m_2 T_f = m_1 T_1 + m_2 T_2$$

$$T_f = \frac{m_1 T_1 + m_2 T_2}{m_1 + m_2} = \left(\frac{m_1}{M}\right) T_1 + \left(\frac{m_2}{M}\right) T_2$$

Implications

- From the equation $m_1 \Delta T_1 = -m_2 \Delta T_2$
  - it looks like something is being transferred from the hot object to the cold object
  - it looks like temperature is kind of a "density of hotness." You have to multiply by the mass to get the "amount of hotness" transferred.
- We will call the thing being transferred "thermal energy."
  (We will see later that it can be transformed into other kinds of energy.)

What if we have different kinds of stuff?

- What happens if we have equal masses of water and something else — a copper cylinder, say?
- What's your intuition here?
  – Will the temperature settle down to halfway between?
  – Will it be closer to the water's temperature?
  – Will it be closer to the copper's temperature?
- Try it!

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.

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

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.

$$C = mc$$

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

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. (0th Law)

$$Q = m_1 c_1 \Delta T_1 = m_1 c_1 (T_f - T_1^i)$$

$$-Q = m_2 c_2 \Delta T_2 = m_2 c_2 (T_f - T_2^i)$$

$$m_1 c_1 (T_f - T_1^i) = -m_2 c_2 (T_f - T_2^i)$$

$$m_1 c_1 (T_f - T_1) = m_2 c_2 (T_2 - T_f)$$

$$T_f = \frac{m_1 c_1 T_1 + m_2 c_2 T_2}{m_1 c_1 + m_2 c_2}$$

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 $m\Delta T$.

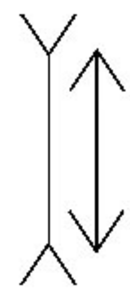
Foothold ideas: 2

- 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 $Q = \pm mc\Delta T$

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?



ILD 7