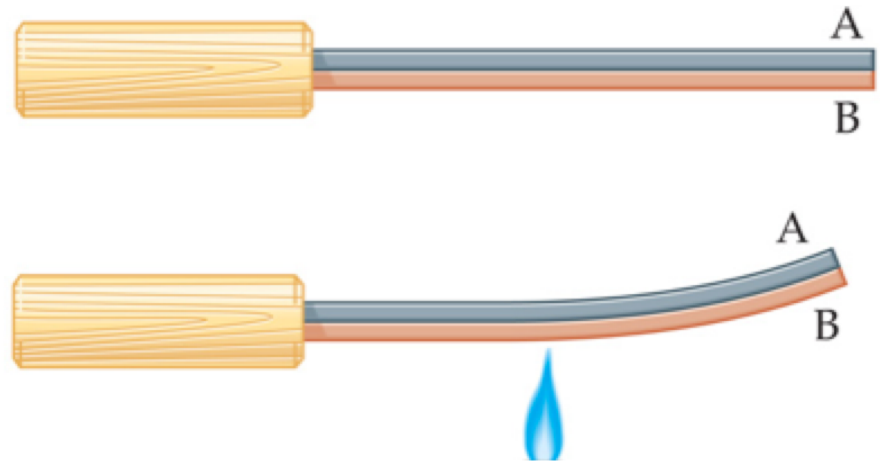
Physics 115
General Physics II

Session 6



Heat
Temperature
Thermal expansion

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- Home page: http://courses.washington.edu/phy115a/

Lecture Schedule (up to exam 1)

Date	Day	Lect.	Topic	readings in Walker
31-Mar	Mon	1	Introduction, Preview	
1-Apr	Tues	2	Density & Pressure	15.1-15.3
3-Apr	Thurs	3	Static Fluids, Buoyancy	15.4-15.5
4-Apr	Fri	4	Fluid Flow, Bernoulli	15.6-15.8
7-Apr	Mon	5	Viscosity, Flow, Capillaries	15.9
8-Apr	Tues	6	Temperature, expansion	16.1-16.3
10-Apr	Thurs	7	Heat, Conduction	16.4-16.6
11-Apr	Fri	8	Ideal gas	17.1-17.2
14-Apr	Mon	9	Heat, Evaporation	17.4-17.5
15-Apr	Tues	10	Phase change	17.6
17-Apr	Thurs	11	First Law Thermodynamics	18.1-18.3
18-Apr	**Fri**		**EXAM 1 Ch 15,16,17**	

Today

Check the course home page
courses.washington.edu/phy115a/
for possible updates once per week.

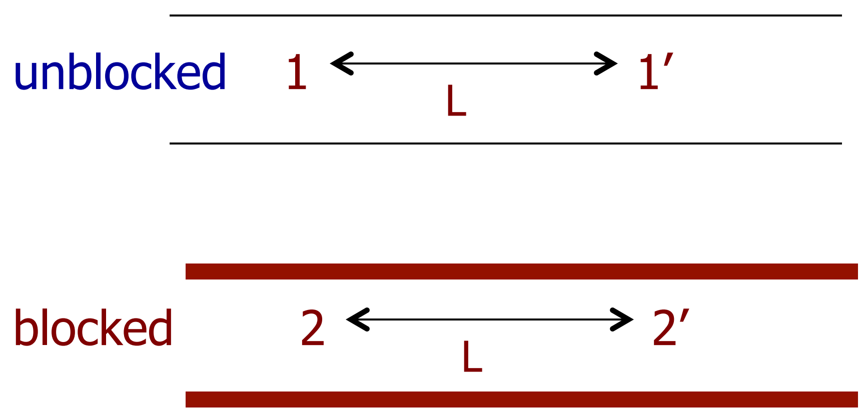
Announcements

- Homework 1 is due tomorrow night (Weds 11:59pm)
- Clicker quiz results will be posted on Friday
  - Check to make sure your clicker is being recorded
  - Roster was updated yesterday
- Early warning: Exam 1 is one week from Friday (4/18)
  - Covers all material discussed in class from chapters 15, 16, 17
  - Formula sheet will be provided
  - Simple calculator is all you need
  - No use of phones, laptops, pads allowed during exam
- Volunteers wanted to take exam at 2:30 instead of 1:30
  - We'd like to balance numbers between sections A/B, for exams
  - If you want to take the exam later, with section B, please go to https://catalyst.uw.edu/quickpoll/vote/wilkes/8858
  - First 38 volunteers will be accepted

Example: partially blocked artery

- Blood flows through an artery whose diameter is reduced by 15% by a blockage, but volume flow rate of blood through the artery remains the same
  - By what factor has ΔP across the length of this artery changed? (pressure drop increased)
  - "by what factor?" → ratio of blocked to unblocked
  - Must take into account viscosity of blood: use Poiseulle's eqn

Tube of length L, area A has P difference $\Delta P = 8\pi\eta \frac{vL}{A}$



$$\frac{\Delta P_1 \pi r_1^4}{8\eta L} = \frac{\Delta P_2 \pi r_2^4}{8\eta L} \Rightarrow \frac{\Delta P_2}{\Delta P_1} = \frac{r_1^4}{r_2^4}$$

$$r_2 = 0.85 r_1$$

$$\frac{\Delta P_2}{\Delta P_1} = \frac{r_1^4}{(0.85 r_1)^4} = 1.92$$

So: 15% diameter change causes X2 change in P difference

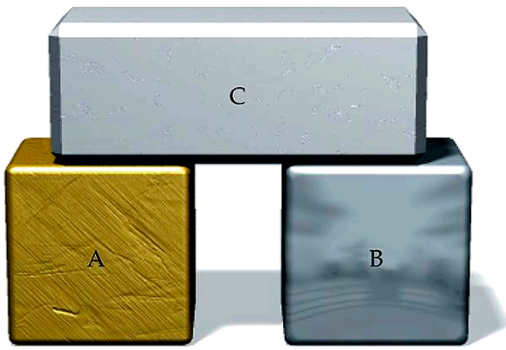
Temperature and Heat

- Heat = energy transferred between bodies due to a difference in temperature

  (Heat transfer = thermodynamics)

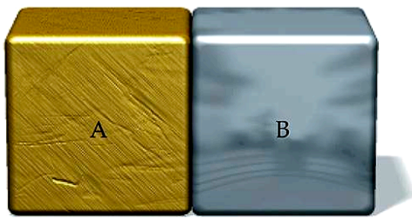
  – Bodies are in thermal equilibrium if no heat transfer occurs
    - Thermal equilibrium → No temperature difference

The "Zeroth" Law of Thermodynamics:
If two objects are in thermal equilibrium with a third object, then all three of the objects are in thermal equilibrium with each other.



(a)

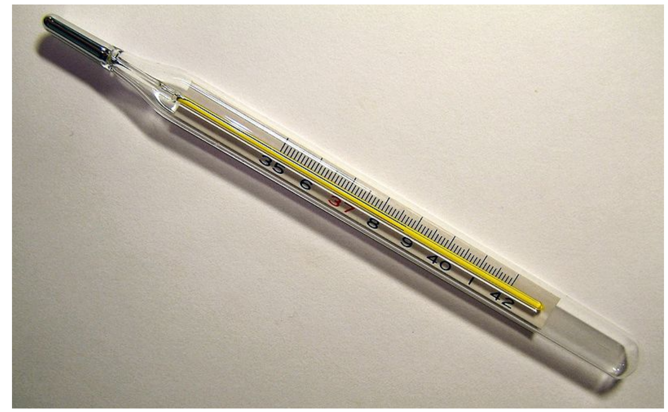
  – Two bodies are defined to be at the *same temperature* if they are in thermal equilibrium.



(b)

Temperature scales

- Celsius scale – science, and everywhere but USA
- Fahrenheit scale – USA



Water Ice point
 = normal freezing point of water
 = 0°C = 32°F.

Steam point
 = boiling point of water at P=1 atm
 = 100°C = 212°F.

40°C

$$\Delta t = t_s - t_i = 100°C = 180°F \quad \text{so} \quad \frac{\Delta t(C)}{\Delta t(F)} = \frac{100}{180} = \frac{5}{9}$$

$$\boxed{t_C = \tfrac{5}{9}\left(t_F - 32°F\right) \quad \text{and} \quad t_F = \tfrac{9}{5} t_C + 32°F}$$

Note that the readings match when $t = -40°F = -40°C$, so:

$$\boxed{t_C = \tfrac{5}{9}\left(t_F + 40°F\right) - 40°C \quad \text{and} \quad t_F = \tfrac{9}{5}\left(t_C + 40°C\right) - 40°F}$$

Converting Fahrenheit & Celsius Temperatures

The temperature in Marrakech is measured with a Celsius thermometer to be 40°C. An American tourist asks "What is that in Fahrenheit?"

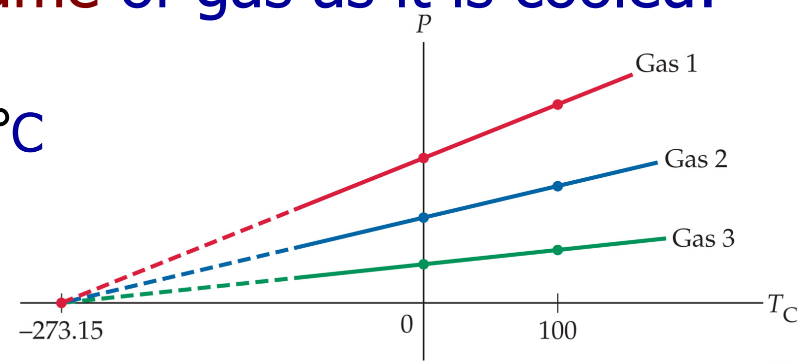
$$T_F = \tfrac{9}{5} T_C + 32°F$$
$$= \tfrac{9}{5}\left(40°C\right) + 32°F$$
$$= 72°F + 32°F = 104°F$$

The thermometer in a grocery store beer cooler reads 40 °F. A European tourist asks "what is that in Celsius?"

$$T_C = \tfrac{5}{9}\left(T_F - 32°F\right) = \tfrac{5}{9}\left(8°F\right) = 4.4°C$$

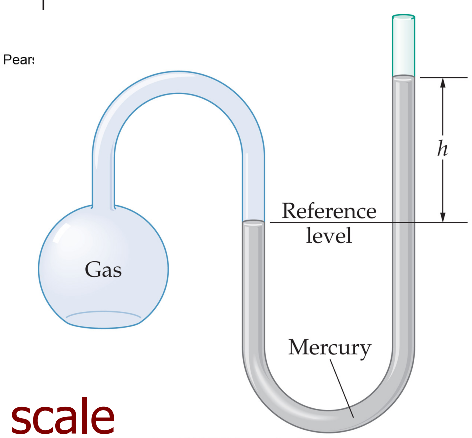
Lowest limit on T

- Experiments show there is a lower limit to temperature
  - We will see: T measures molecular speeds, eventually v=0 !
  - We find: P in a given volume of gas is proportional to its T
- Measure P of a constant volume of gas as it is cooled:
  - Result: all kinds of gases tend toward P=0 at same T: –273 °C



How can we measure P for a constant volume of gas?

- Use a U-tube manometer
- As P gets smaller, adjust amount of fluid so that left side is always same height



Kelvin temperature scale: $\boxed{T_K = T_C + 273.15°C}$

Absolute zero = –273.15 °C = 0 K (zero kelvins)

1 K (kelvin) has same size as 1°C, just shifted origin of scale

Quiz 3

- Two objects in physical contact with each other are in thermal equilibrium. Then

  A. No heat is being transferred between them

  B. They have the same temperature

  C. Both A and B are true

  D. Neither A or B is true

Thermal expansion

- Most materials expand when heated
  - Basis of simple liquid thermometers
  - Approximately linear with T

$$\Delta L \propto \Delta T \rightarrow \Delta L = (const)\Delta T = \alpha L_0 \Delta T$$

- L_0 = original length of object
- Coefficient of linear expansion α : units = 1/°C (or 1/K)

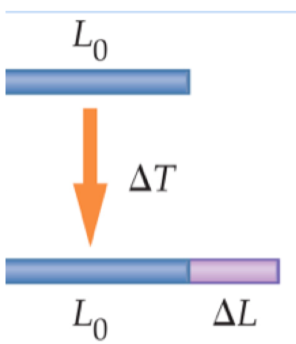
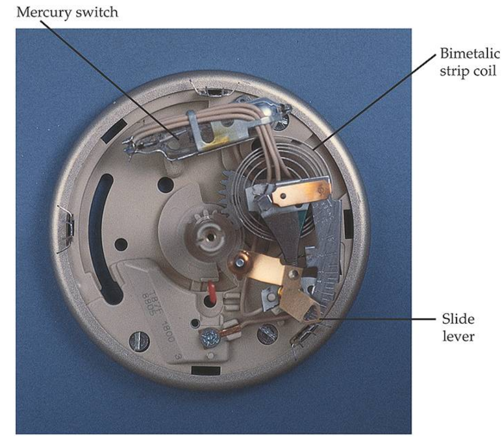


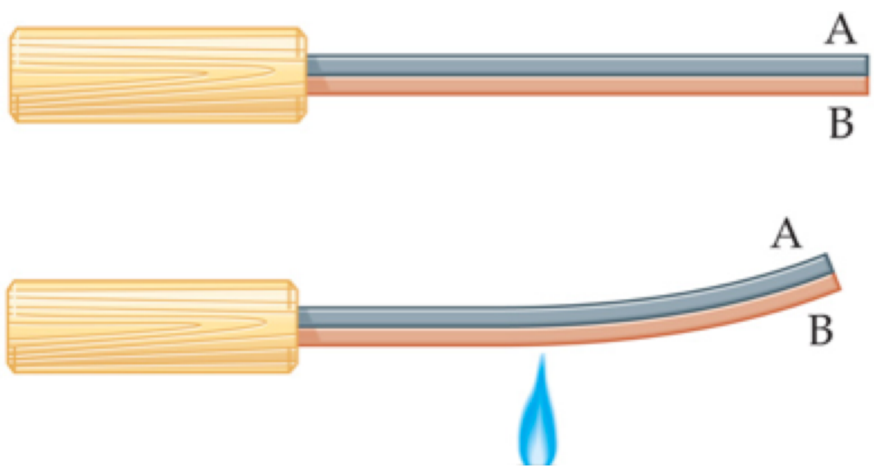
TABLE 16–1 Coefficients of Thermal Expansion near 20 °C

Substance	Coefficient of linear expansion, $\alpha (K^{-1})$
Lead	29×10^{-6}
Aluminum	24×10^{-6}
Brass	19×10^{-6}
Copper	17×10^{-6}
Iron (steel)	12×10^{-6}
Concrete	12×10^{-6}
Window glass	11×10^{-6}
Pyrex glass	3.3×10^{-6}
Quartz	0.50×10^{-6}
Substance	**Coefficient of volume expansion, $\beta (K^{-1})$**
Ether	1.51×10^{-3}
Carbon tetrachloride	1.18×10^{-3}
Alcohol	1.01×10^{-3}
Gasoline	0.95×10^{-3}
Olive oil	0.68×10^{-3}
Water	0.21×10^{-3}
Mercury	0.18×10^{-3}

Linear expansion example: bimetallic strips

- Used in old thermostats and mechanical thermometers
    - Silicon chips are used for this now…
  - Two strips of metals with different α 's
  - Same length at some reference T
  - Increase or decrease T:
    One gets longer than the other: bends





2-Dimensional expansion

- Linear expansion → expansion of area, or volume
  - Area expansion = linear expansion in 2 dimensions

$$A' = \left(L + \Delta L\right)^2 = \left(L_0 + \alpha L_0 \Delta T\right)^2 = L_0^2 + 2\alpha L_0^2 \Delta T + \alpha^2 L_0^2 \Delta T^2$$

$$for \quad \alpha \Delta T << 1, \quad \alpha^2 \Delta T^2 \approx 0 \rightarrow A' \approx L_0^2 + 2\alpha L_0^2 \Delta T = A + 2\alpha A\, \Delta T$$

$$\Delta A = A' - A = 2\alpha A\, \Delta T$$

Notice: not proportional to α^2 , but 2α

  - Volume expansion: same idea, now we get factor 3α

$$V' = \left(L + \Delta L\right)^3 = \left(L_0 + \alpha L_0 \Delta T\right)^3$$

$$for \quad \alpha \Delta T << 1, \quad \Delta V = V' - V = 3\alpha V\, \Delta T$$

    - However, we define a volume coeff of expansion β :

$$\Delta V = \beta V \Delta T \rightarrow \beta \approx 3\alpha$$