Physics 1501

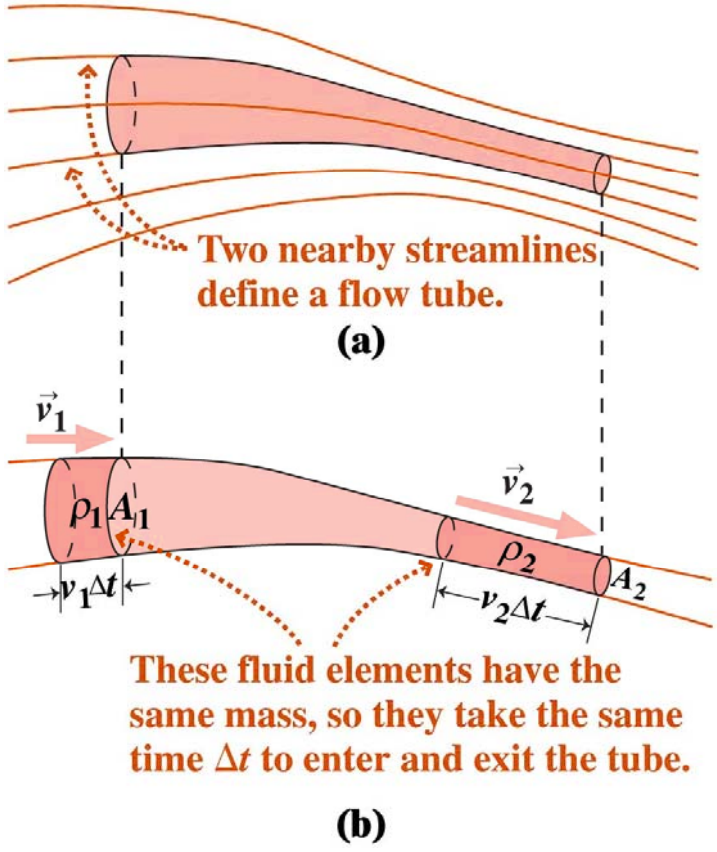
Fall 2008

Mechanics, Thermodynamics, Waves, Fluids

Lecture 28: Temperature and heat

Recap: the continuity equation

- The **continuity equation** expresses conservation of mass in a moving fluid.
  - It follows from considering a **flow tube**, usually an imaginary tube bounded by nearby streamlines.
    - The flow tube may also be an actual physical tube or pipe.
- The continuity equation reads
  $\rho v A$ = constant
  - Here ρ is the density, v the flow speed, and A the cross-sectional area; the quantities are evaluated at points along the same flow tube.
  - The quantity $\rho v A$ is the mass flow rate.
  - For incompressible fluids, density is constant and the continuity equation reduces to vA = constant.
    - Here vA is the volume flow rate.

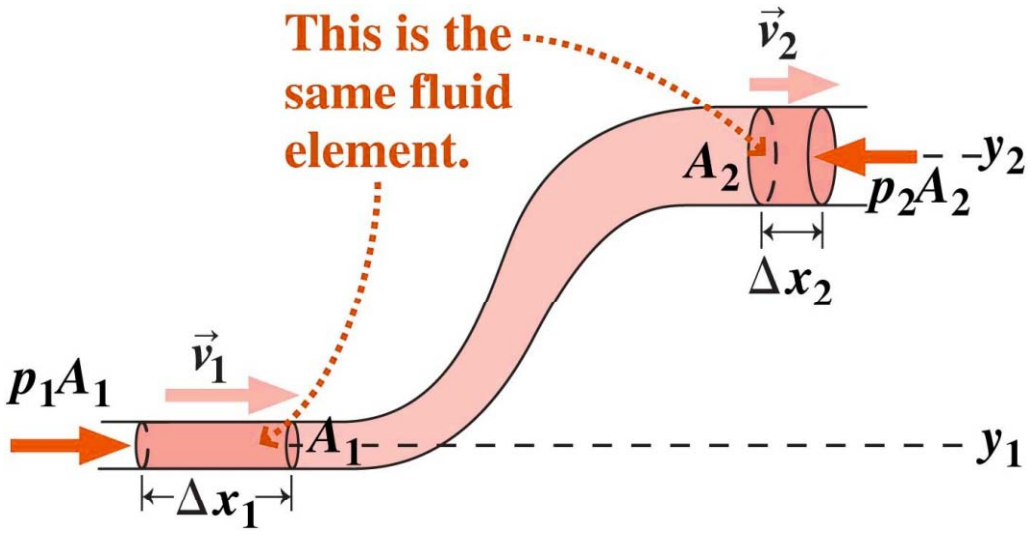


Recap: Bernoulli's equation

- Considering the work done as a fluid moves along a stream tube leads to **Bernoulli's equation**, a statement of energy conservation in a fluid.
  - Neglecting fluid friction (viscosity) and in the absence of mechanical pumps and turbines that add or remove energy from the fluid, Bernoulli's equation reads

$$p + \tfrac{1}{2}\rho v^2 + \rho g h = \text{constant}$$

where the quantities are evaluated along a flow tube.

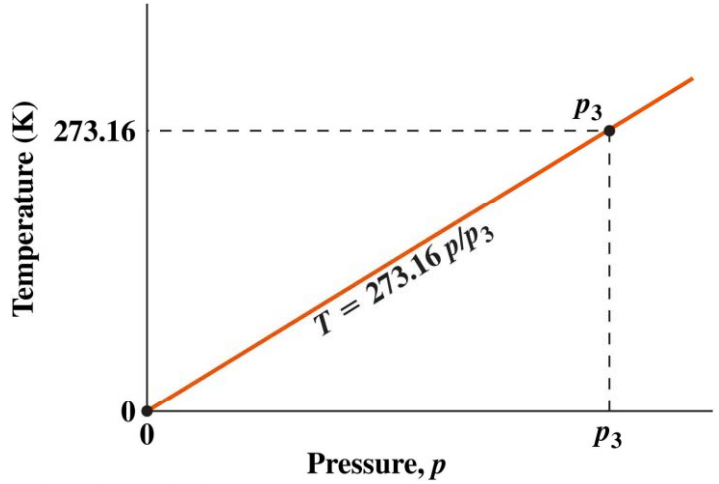


Thermodynamic equilibrium and temperature

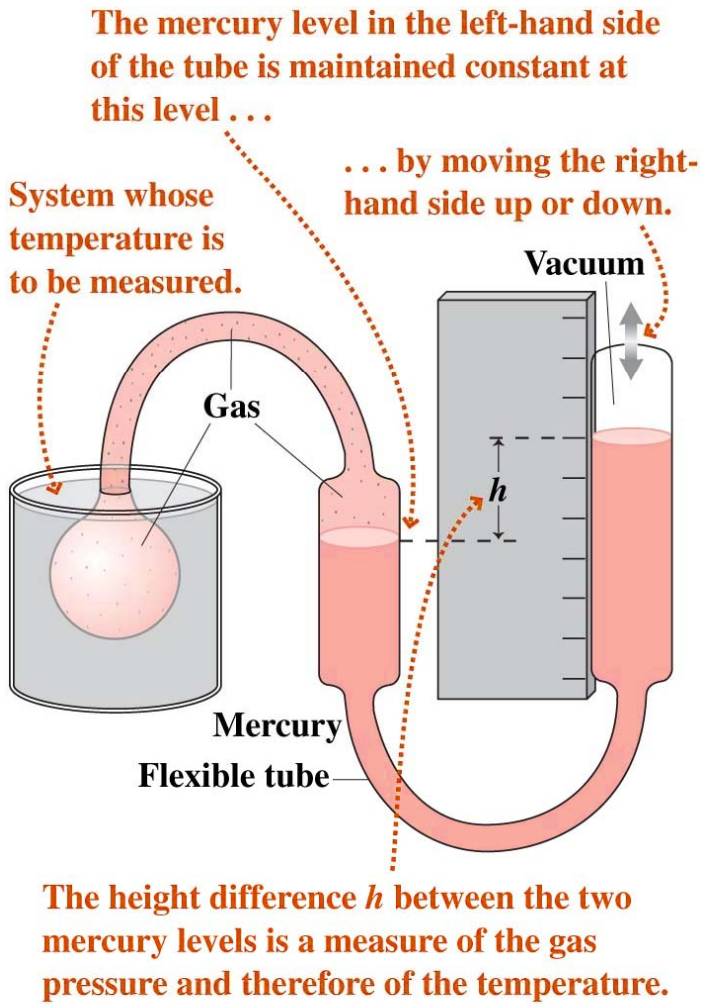
- Two systems placed in contact may undergo changes in macroscopic properties like length, pressure, electrical resistance, etc.
- When such macroscopic changes cease, the two systems are in **thermodynamic equilibrium.**
- By definition, systems in thermodynamic equilibrium are at the same **temperature.**
- Any convenient macroscopic property can be used as a measure of temperature.
  - A **thermometer** is a small system with some macroscopic property whose value is used as an indication of temperature.

Gas thermometers and the kelvin scale

- The SI temperature scale is defined using the **triple point of water**, the unique temperature where solid, liquid, and gas can coexist.
  - The temperature at the triple point is defined to be 273.16 K.
  - The point of zero pressure in a gas defines a second temperature, namely **absolute zero.**
  - Together, the two defined temperatures establish the kelvin scale.



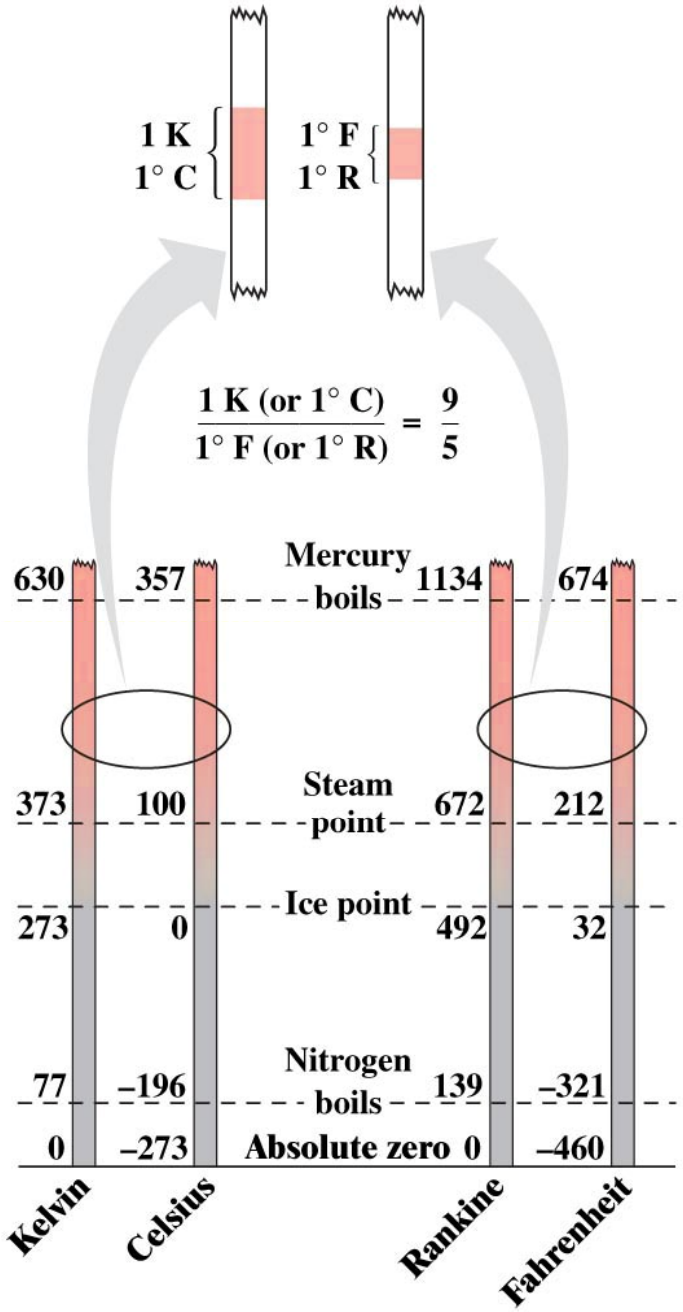
Two points establish the kelvin temperature scale



A constant-volume gas thermometer

Other temperature scales

- One celsius degree is the same size as one kelvin, but the zero of the celsius scale is at 273.15 K —the freezing point of water under normal conditions.
- One Fahrenheit degree is 5/9 the size of a celsius degree, and the zero of Fahrenheit is 32˚F below the freezing point.
    - The Rankine scale has its zero at absolute zero, and its degrees the same size as those on the Fahrenheit scale.



Heat and temperature

- **Heat** is energy being transferred from one object to another because of a temperature difference alone.
  - In SI, heat is measured in joules.
  - An older unit, the calorie, is equal to 4.184 J.
- The **heat capacity** C of an object is a measure of the heat ΔQ required per unit temperature change: $\Delta Q = C\,\Delta T$.
  - The **specific heat** c of a substance is the heat capacity per unit mass: $\Delta Q = mc\,\Delta T$.
  - When two substances at different temperatures are brought into thermal contact without any loss of energy, they come to equilibrium at a temperature determined by their masses and specific heats:

$$m_1 c_1 \Delta T_1 + m_2 c_2 \Delta T_2 = 0$$

Here the ΔT's are the changes from the original temperatures to the final, common equilibrium temperature.

question

- A hot rock with mass 250 g is dropped into an equal mass of cool water. Which temperature changes more, that of the rock or that of the water?

A. The temperature of the rock changes more.

B. The temperature of the water changes more.

C. The temperatures of the water and the rock change equally.