

Thermal Physics

Temperature

Thermometers

Thermal Expansion

Definitions

- Thermal Contact – if energy can be exchanged between two objects, then they are in thermal contact
- Thermal Equilibrium – if two objects are in thermal contact and there is no exchange of energy, then they are in thermal equilibrium

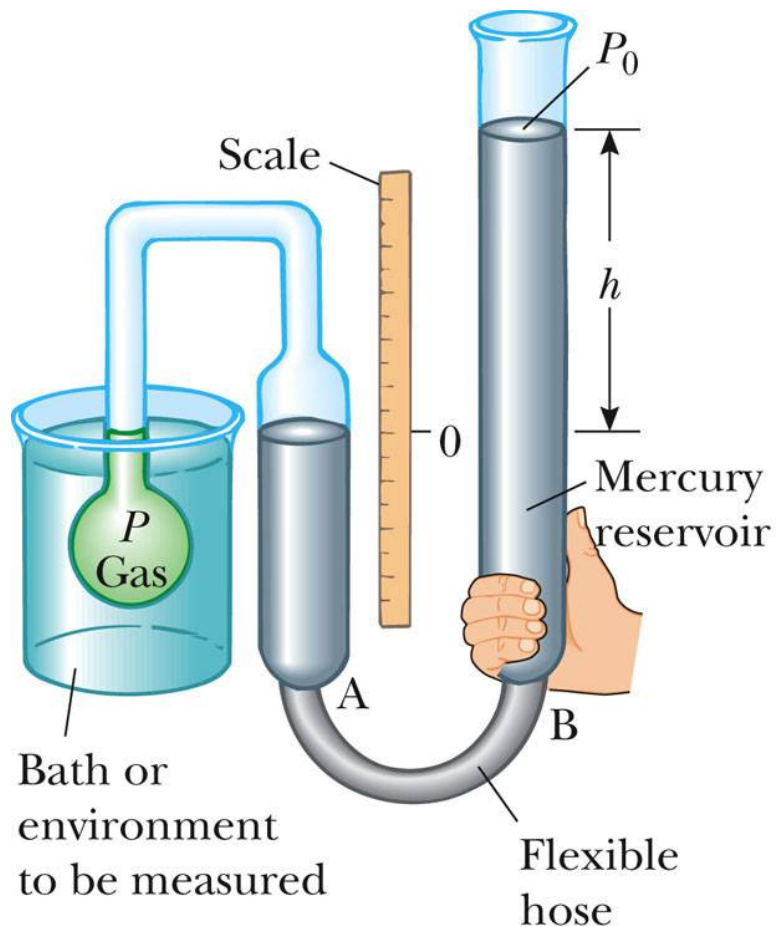
The Law of Equilibrium

- Zeroth Law of Thermodynamics
 - If objects A and B are separately in thermal equilibrium with object C, then A and B are in thermal equilibrium with each other

Definition of Temperature

- If objects A and B are in thermal equilibrium, then they are at the same temperature.

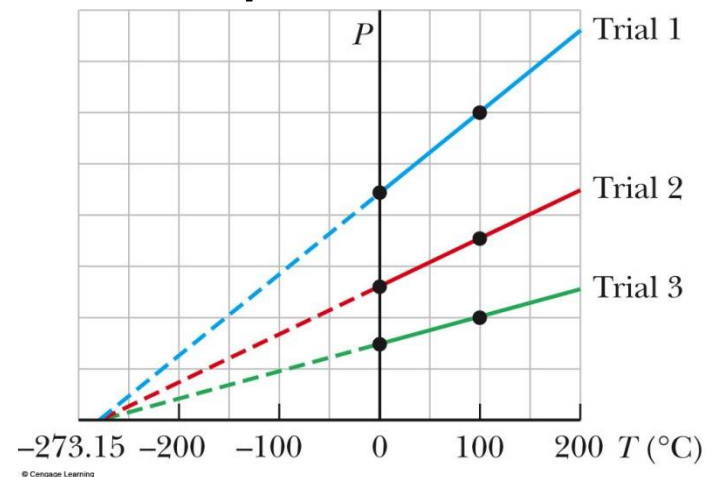
Constant V Gas Thermometer



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Fig. 10.3, p.324

- Reference points
 - 100°C for boiling water
 - 0°C for freezing water
- Extrapolate graph to zero pressure to find absolute zero temperature



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Fig. 10.5, p.325

Temperature Scales

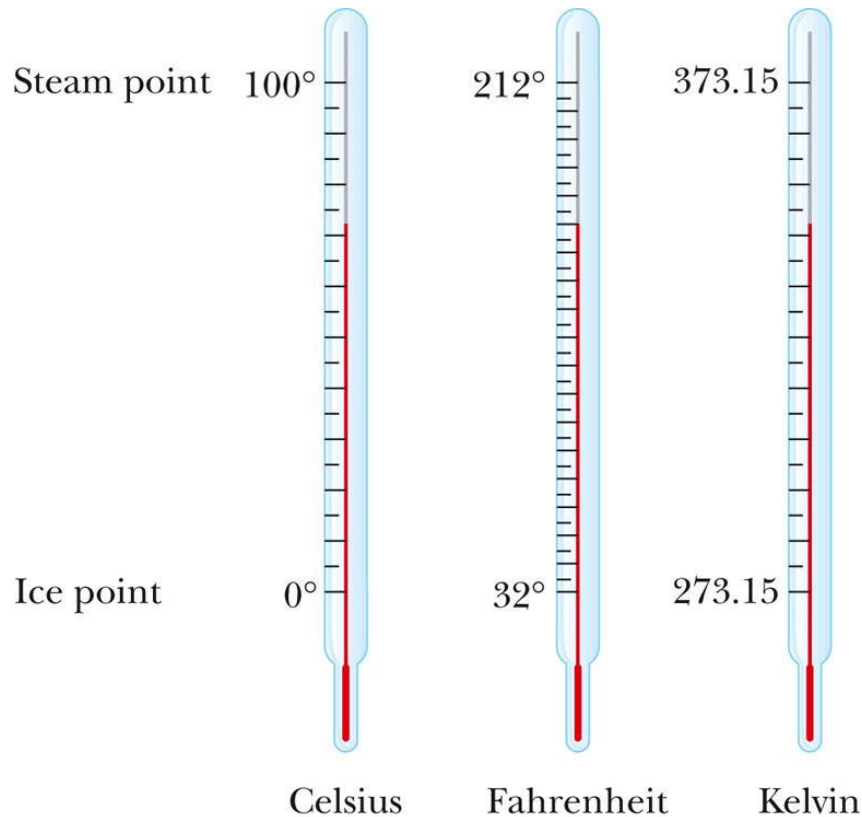


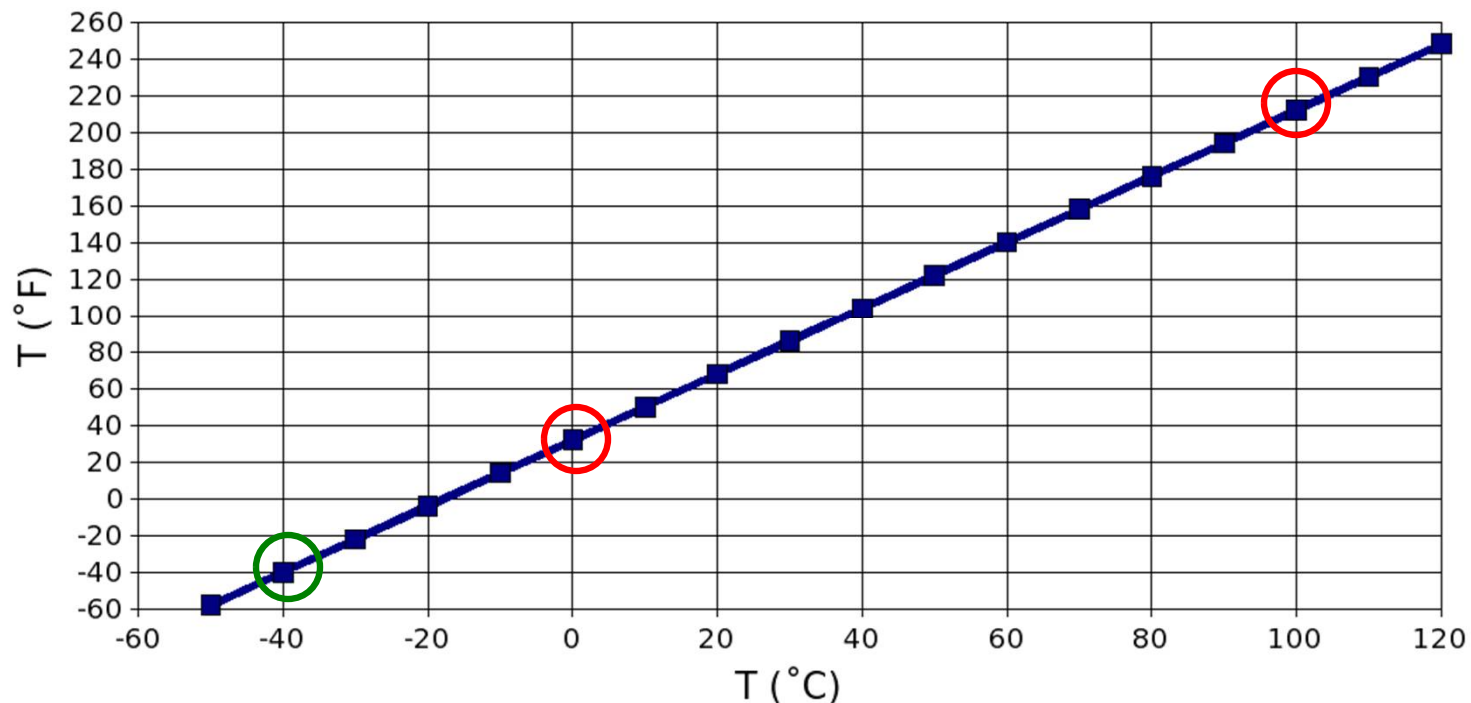
Fig. 10.7, p.326

- Column of fluid changes height in response to warmth or coolness of surroundings
- Numbers assigned to the height establishes the *temperature scale*
- Each division in the scale is called a *degree*

Temperature Scales

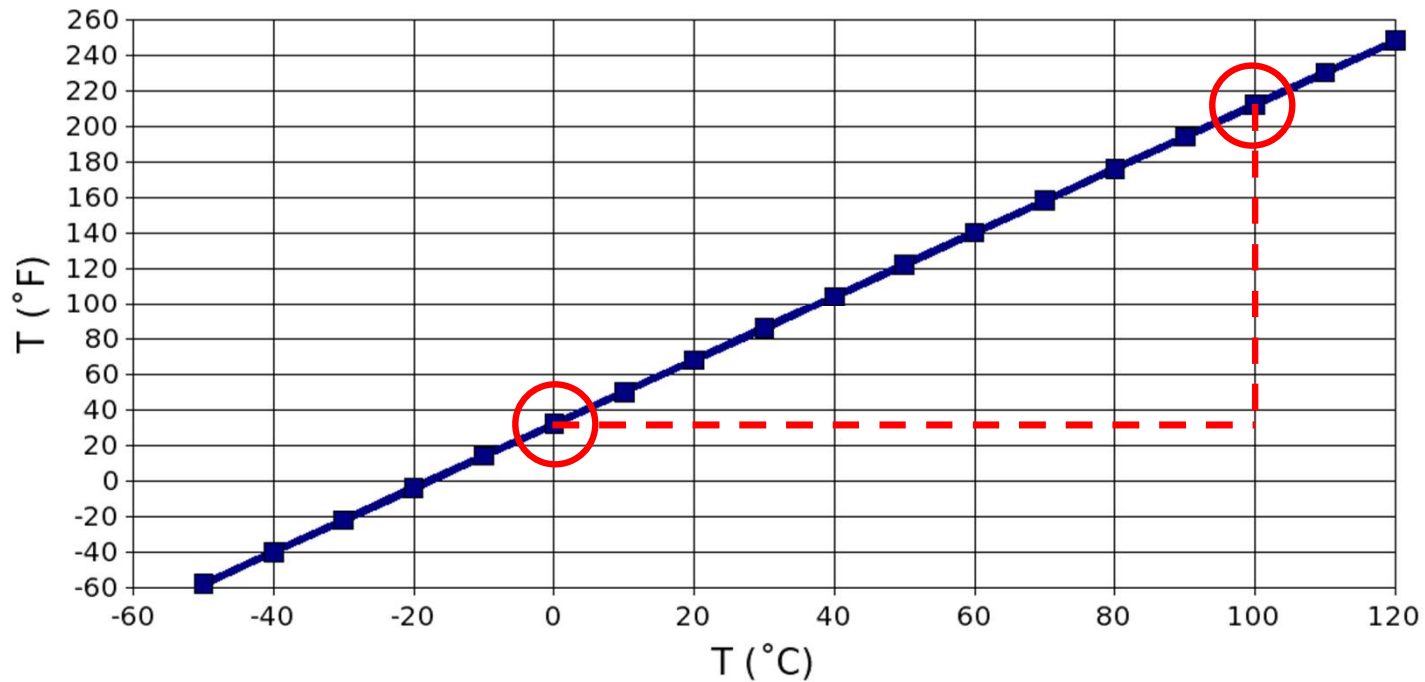
- Defined by:
 - Height of column when water freezes ($0^{\circ}\text{C} = 32^{\circ}\text{F}$)
 - Height of column when water boils ($100^{\circ}\text{C} = 212^{\circ}\text{F}$)
- Note: $-40^{\circ}\text{C} = -40^{\circ}\text{F}$

Fahrenheit and Celsius Scales



Conversions

Fahrenheit and Celsius Scales



Slope:
$$\frac{\Delta T_F}{\Delta T_C} = \frac{212^\circ\text{F} - 32^\circ\text{F}}{100^\circ\text{C} - 0^\circ\text{C}} = \frac{180^\circ\text{F}}{100^\circ\text{C}} = \frac{9}{5}$$

Intercept = 32°F

Conversions

	From °C to °F	From °F to °C
Temperature Reading	$T_F = \frac{9}{5}T_C + 32^\circ$	$T_C = \frac{5}{9}(T_F - 32^\circ)$
Temperature Change	$\Delta T_F = \frac{9}{5}\Delta T_C$	$\Delta T_C = \frac{5}{9}\Delta T_F$

Absolute Zero and Kelvin Scale

- Temperature is in units called kelvins (K)
- $T = 0 \text{ K}$ is called absolute zero
- Represents the temperature at which an ideal gas:
 - Has zero volume (at constant pressure)
 - Has zero pressure (at constant volume)

$$T = T_C + 273.15 \text{ K} \qquad \Delta T = \Delta T_C$$

Thermal Expansion

- For solids and liquids:
 - Energy increase via heat input
 - Atoms vibrate with greater amplitude
 - Average separation increases
- Leads to macroscopic expansions

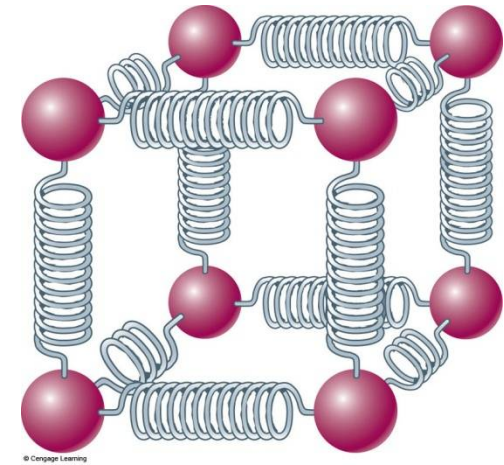


Fig. 9.1, p.269



(a)

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(b)

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Fig. 10.8, p.329

Expansion Coefficients

$$\Delta L = \alpha L_0 \Delta T \quad [10.4]$$

Linear Expansion – 1D

$$\Delta A = \gamma A_0 \Delta T \quad [10.5]$$

Area Expansion – 2D

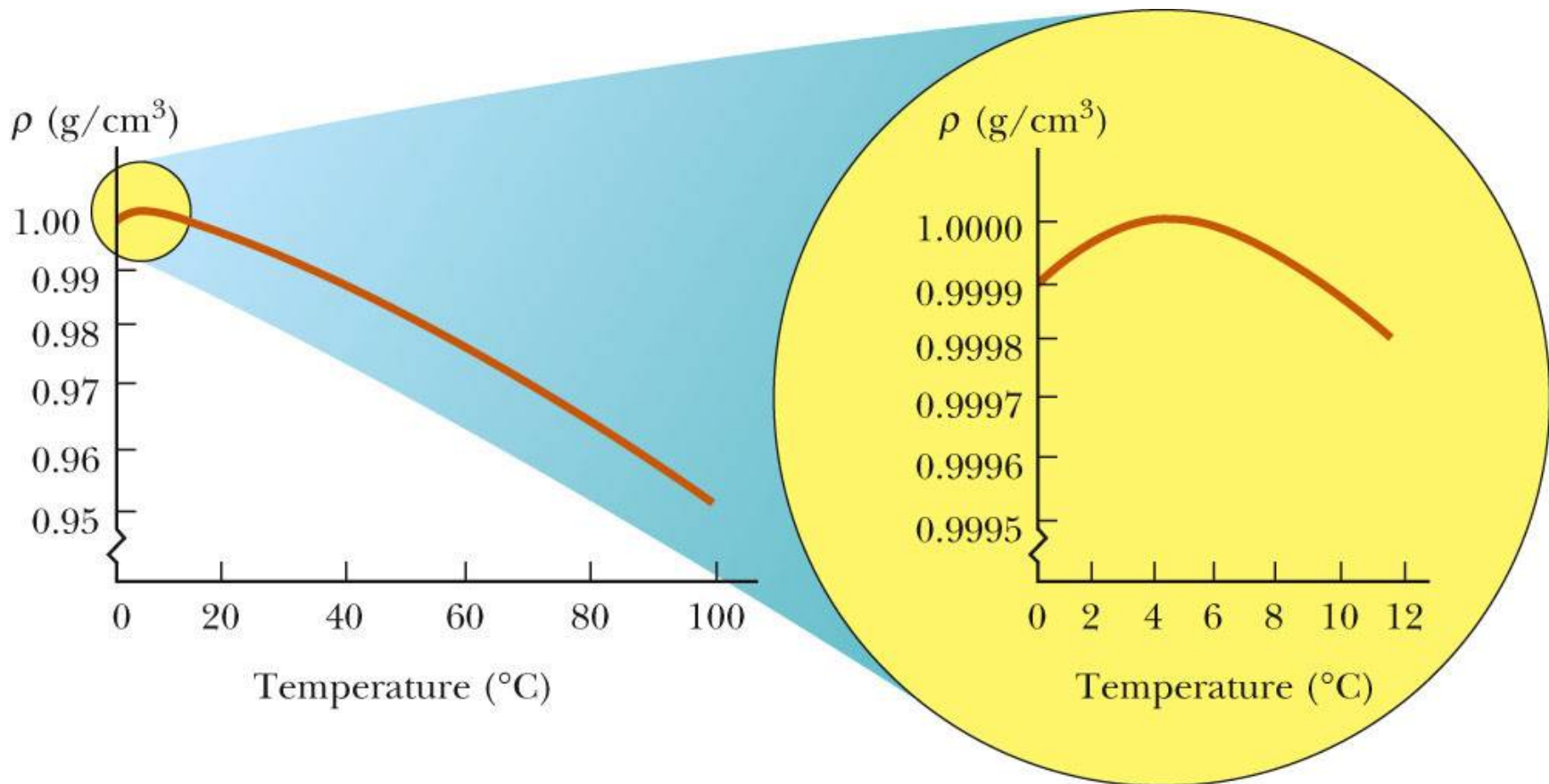
$$\Delta V = \beta V_0 \Delta T \quad [10.6]$$

Volume Expansion – 3D

If α is the same in all directions then

$$\gamma = 2\alpha \qquad \beta = 3\alpha$$

No Life Without Water



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Fig. 10.11, p.334

As water cools, it first contracts, but then expands near freezing