Thermal & Statistical Physics

PHYS 343

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What is Temperature?

- **It is the measurement of the AVERAGE kinetic energy of the particles of matter.**

Temperature

- We associate the concept of temperature with how hot or cold an object feels
- Our senses provide us with a qualitative indication of temperature
- Our senses are unreliable for this purpose
- We need a reliable and reproducible method for measuring the relative hotness or coldness of objects
- We need a technical definition of temperature

Thermal Contact

- **Two objects are in thermal contact with each other if energy can be exchanged between them**
  - **The exchanges we will focus on will be in the form of heat or electromagnetic radiation**
  - **The energy is exchanged due to a temperature difference**

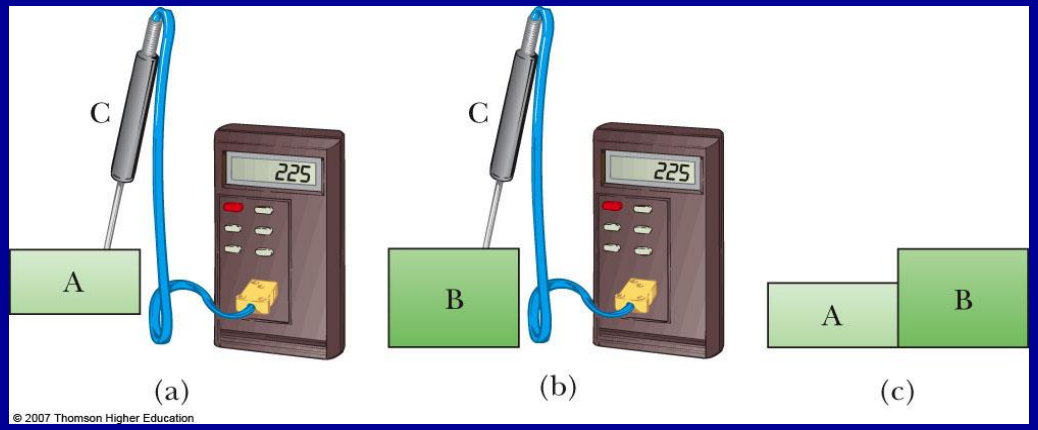
Thermal Equilibrium

- **Thermal equilibrium is a situation in which two objects would not exchange energy by heat or electromagnetic radiation if they were placed in thermal contact**
- **The thermal contact does not have to also be physical contact**

Zeroth Law of Thermodynamics

- **If objects A and B are separately in thermal equilibrium with a third object C, then A and B are in thermal equilibrium with each other**
  - **Let object C be the thermometer**
  - **Since they are in thermal equilibrium with each other, there is no energy exchanged among them**

Zeroth Law of Thermodynamics, Example



- Object C (thermometer) is placed in contact with A until they achieve thermal equilibrium
  - The reading on C is recorded
- Object C is then placed in contact with object B until they achieve thermal equilibrium
  - The reading on C is recorded again
- If the two readings are the same, A and B are also in thermal equilibrium

Temperature

- **Temperature can be thought of as the property that determines whether an object is in thermal equilibrium with other objects**
- **Two objects in thermal equilibrium with each other are at the same temperature**
  - **If two objects have different temperatures, they are not in thermal equilibrium with each other**

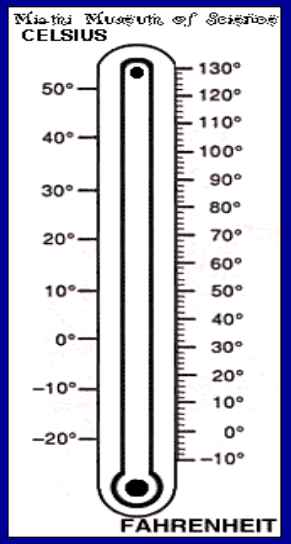
Temperature Scales

- Celsius
- Kelvin
- Fahrenheit
- Rankine

- ***The 3 main temperature scales***
  - **Fahrenheit**
  - **Celsius**
  - **Kelvin**

Celsius Scale

- The fixed points on which this scale was created, were the Boiling and Freezing point of water.
- Original scale had boiling point = 100
- And the freezing point = 0



Celsius Scale …

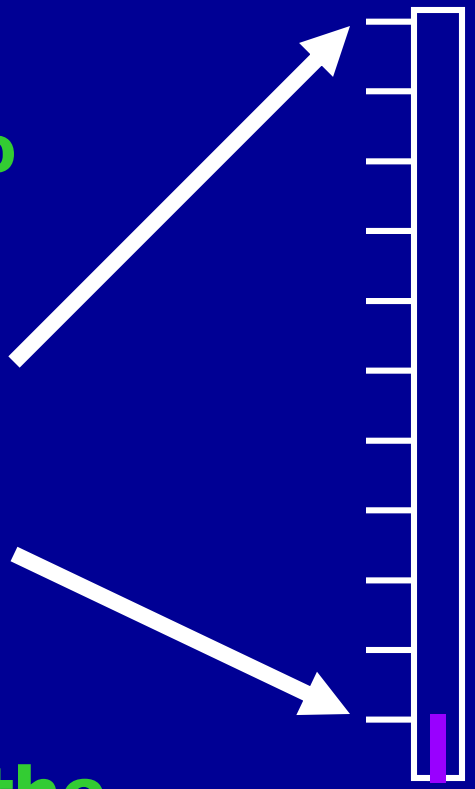
- **The ice point of water is defined to be 0 ^{0}C**
- **The steam point of water is defined to be 100**
- **The length of the column between these two points is divided into 100 increments, called degrees**

Celsius Scale…

- **These were later reversed so the**

➢ ***Boiling Point*** **= 100 ^{0}C**

➢ ***Freezing Point*** **= 0 ^{0}C**



- **The original name was the CENTIGRADE scale**

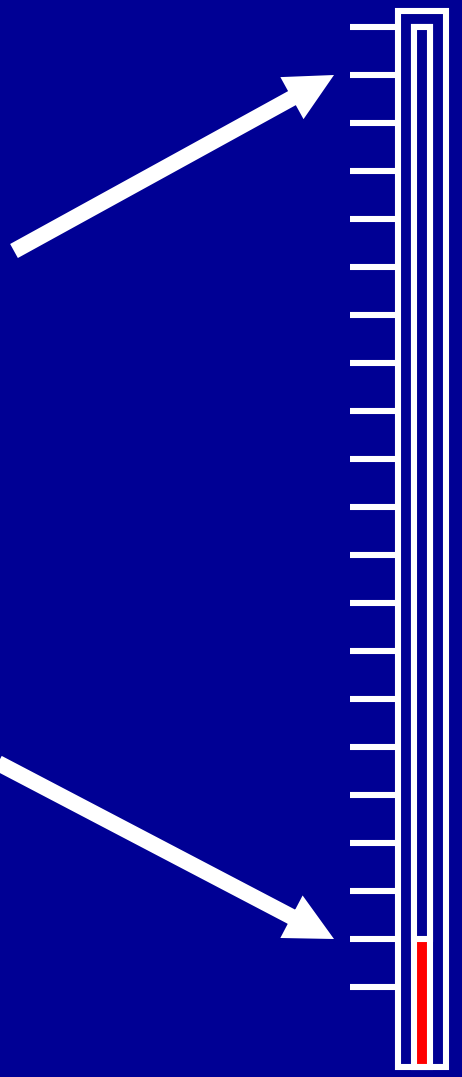
Fahrenheit Scale

- Named for Daniel Fahrenheit
- Temperature of the ice point is $32^{o}F$
- Temperature of the steam point is $212^{o}F$
- There are 180 divisions (degrees) between the two reference points

The Fahrenheit Scale

- **Boiling point**
- **became =** 212 ^{0}F

- **Freezing point**
- **became =** 32 ^{0}F



Absolute Temperature Scale

- **Absolute zero is used as the basis of the absolute temperature scale**
- **The size of the degree on the absolute scale is the same as the size of the degree on the Celsius scale**

Absolute Temperature Scale…

- **The absolute temperature scale is now based on two new fixed points**
  - **One point is absolute zero**
  - **The other point is the triple point of water**
    - **This is the combination of temperature and pressure where ice, water, and steam can all coexist**

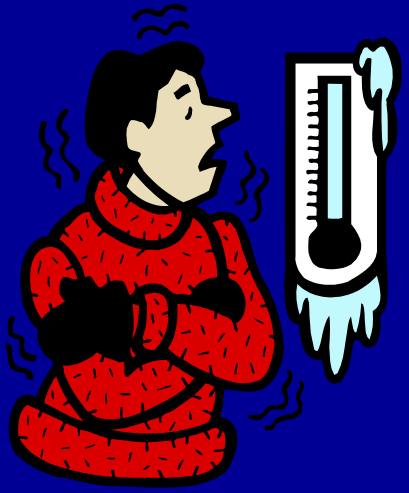
Kelvin Scale

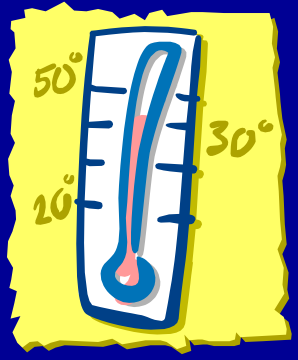
- **This temperature is known as**

  - **ABSOLUTE ZERO**

- **Absolute Zero = 0 K**
- **Boiling point of water = 373 K**
- **Freezing point of water = 273 K**

Comparison of Temperature scales





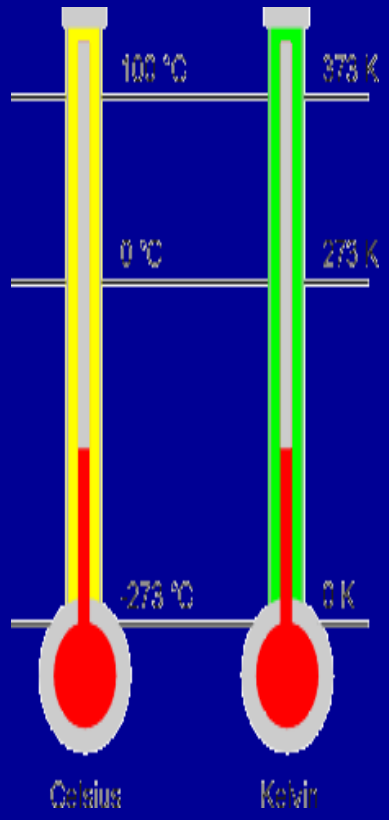
Temperature CONVERSION

Celsius to Kelvin:

K = C + 273

Kelvin to Celsius:

C = K - 273



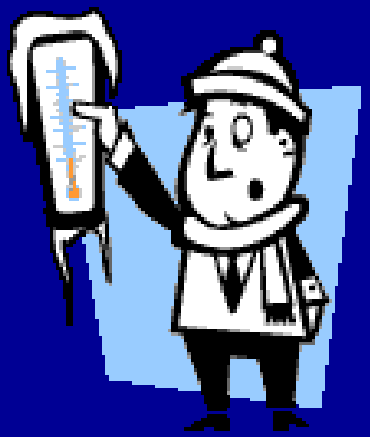
Temperature CONVERSION…

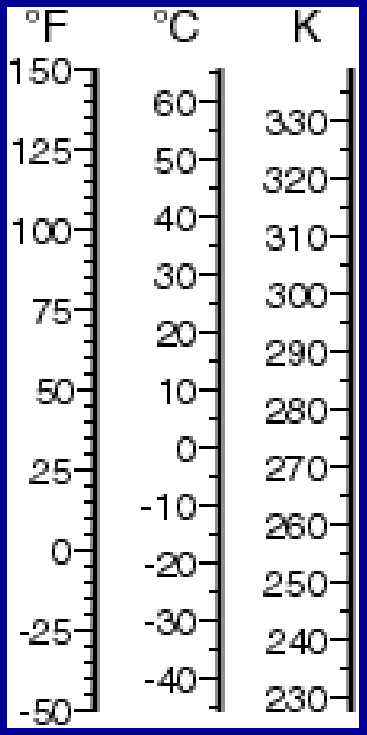
°F = 9/5(°C) +3

°C = 5/9[(°F) –32]

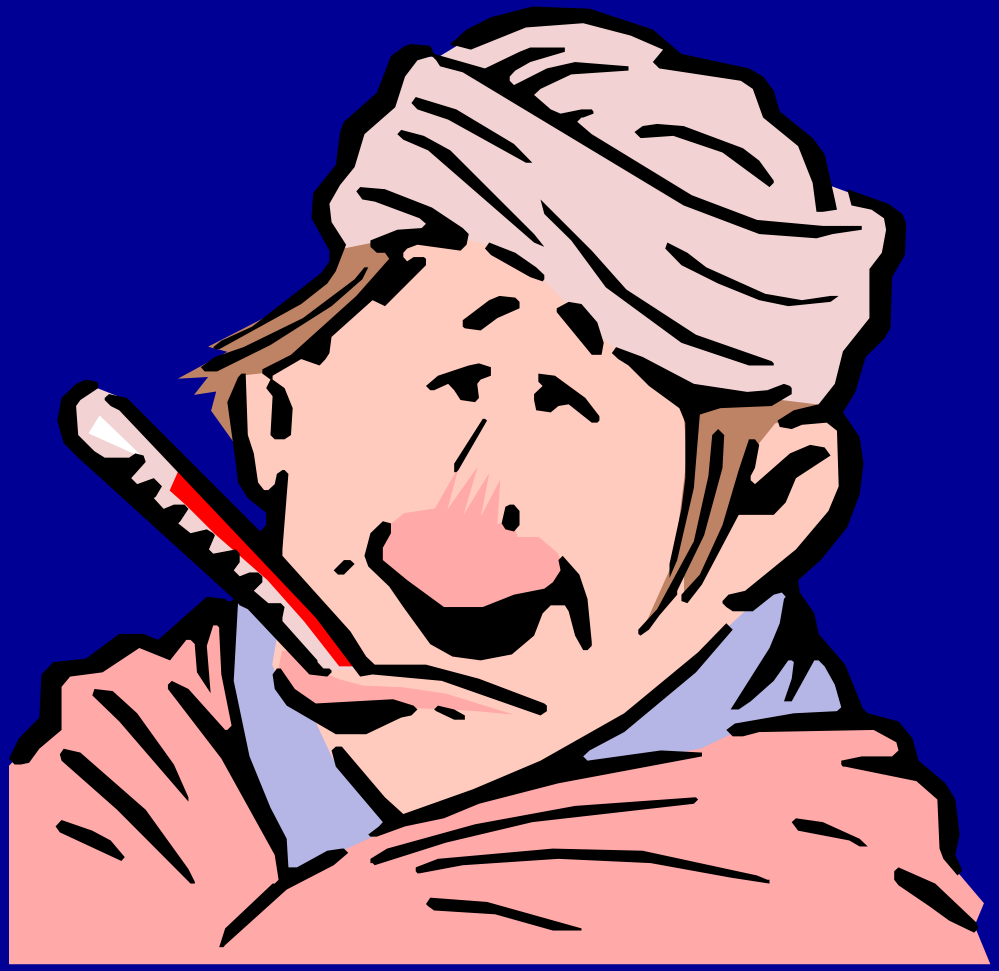
°F = °R – 459.67

°C = K – 273.15





Thermometers



Thermometers

- A **thermometer** is a device that is used to measure the **temperature** of a system
- Thermometers are based on the principle that some **physical property of a system changes as the system's temperature changes**

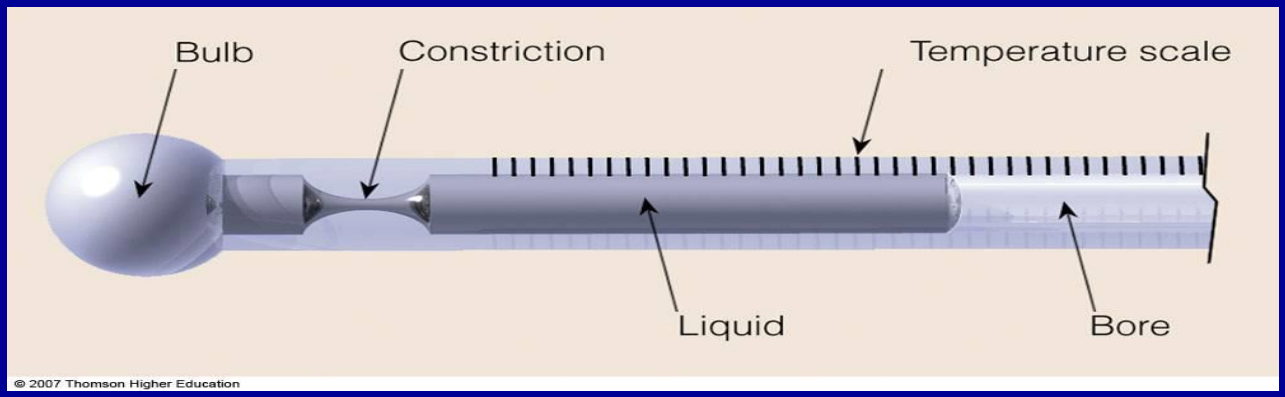
Thermometers, cont

- **These properties include:**
  - **The volume of a liquid**
  - **The dimensions of a solid**
  - **The pressure of a gas at a constant volume**
  - **The volume of a gas at a constant pressure**
  - **The electric resistance of a conductor**
  - **The color of an object**
- **A temperature scale can be established on the basis of any of these physical properties**

Calibrating a Thermometer

- A thermometer can be calibrated by placing it in contact with some natural systems that remain at constant temperature
- Common systems involve water
  - A mixture of ice and water at atmospheric pressure Called the ice point of water
  - A mixture of water and steam in equilibrium Called the steam point of water
- Once these points are established, the length between them can be divided into a number of segments

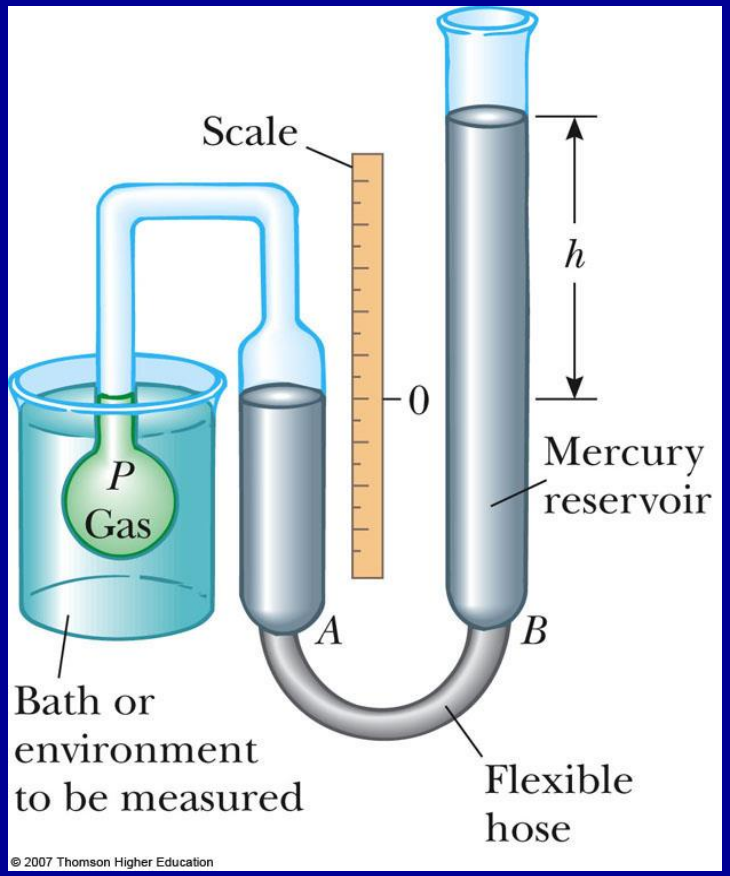
Liquid in glass



Liquid-in-glass thermometer: glass tube filled with liquid (often mercury or alcohol) that expands/contracts with air temperature

Constant-Volume Gas Thermometer

- The physical change exploited is the variation of pressure of a fixed volume gas as its temperature changes
- The volume of the gas is kept constant by raising or lowering the reservoir B to keep the mercury level at A constant

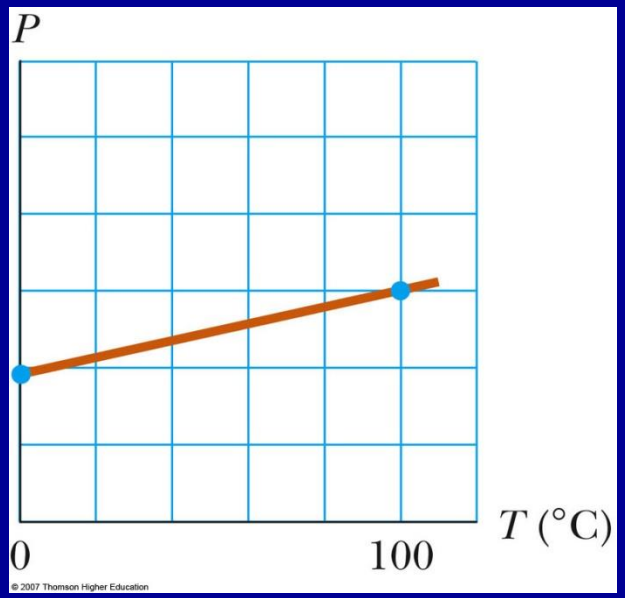


Constant-Volume Gas Thermometer, cont

- **The pressure is indicated by the height difference between reservoir B and column A**
- **The thermometer is calibrated by using a ice water bath and a steam water bath**
- **The pressures of the mercury under each situation are recorded**
  - **The volume is kept constant by adjusting A**
- **The information is plotted**

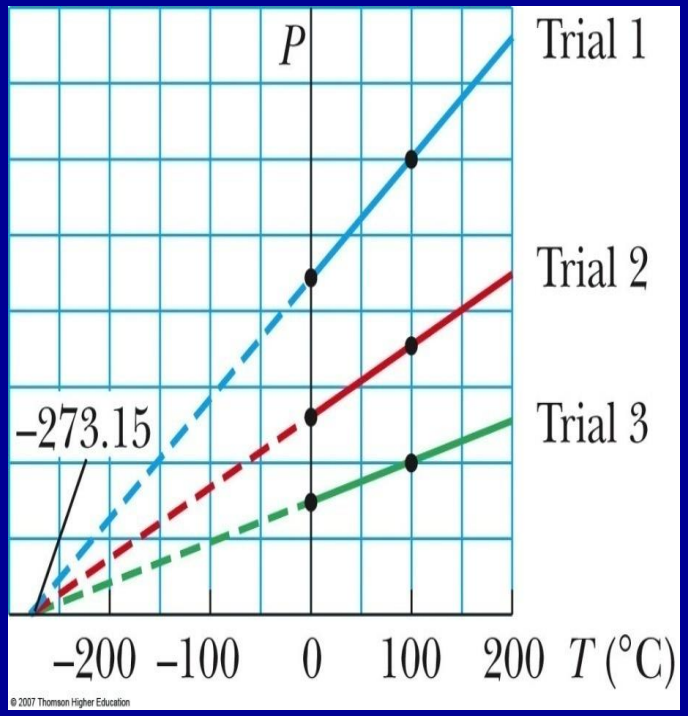
Constant-Volume Gas Thermometer, final

- To find the temperature of a substance, the gas flask is placed in thermal contact with the substance
- The pressure is found on the graph
- The temperature is read from the graph



Absolute Zero

- The thermometer readings are virtually independent of the gas used
- If the lines for various gases are extended, the pressure is always zero when the temperature is 273.15° C
- This temperature is called absolute zero



Some ideas…..

- **Calculations in physics usually use the "absolute" or "Kelvin" scale of temperature**
- **In "real life" we mostly use the Celsius scale**
- **1K is the same "size" as 1°C, only the zero of the scale is different**
- **Calculations involving temperature differences can be done with either Celsius or Kelvin units**
- **For all other calculations, we must convert Celsius temperatures to Kelvin (add 273 to Celsius temp.)**

	BP of helium	*BP of nitrogen*	*MP of water*	*BP of water*
Kelvin Temp	4.2K	77.3K	273.2K	373.2K
Celsius Temp.	-269°C	-196°C	0°C	100°C