SYSTEMS OF UNITS, ENGINEERING DESIGN & ANALYSIS

MEG 212 Week 2 Lecture

Lecture Learning Outcomes

At the end of this lecture, you will be able to,

- Discuss the need for a system of units
- Identify two major systems of units used by engineers
- Discuss the differences primary and secondary dimensions with examples
- Identify the three key intensive properties in engineering thermodynamics
- Discuss the steps involved in engineering design and analysis of thermodynamic systems

Why do we need a System of Units?

- Engineers perform calculations to carry out their design and analysis

- These calculations give outputs in numerical values.

As a result, engineers need to be concerned with the units of physical quantities

A unit of measurement is a definite magnitude of a quantity

Things to Note about Units

- A unit of measurement is defined and adopted by convention
- That is, it is used as a standard for measurement for the same kind of quantity

For example, meters, centimeters, kilometers, feet, inches, and miles are all units of length

Seconds, minutes and hours are units of time

Primary and Secondary Dimensions

- **What is the difference between a dimension and a unit?**

- A unit is the standard used to quantify a dimension

For example, meters and feet are both units used to quantify the dimension of length

Seconds, minutes and hours are units used to quantify the dimension of time

Primary and Secondary Dimensions

- **Primary Dimensions**

Independent dimensions from which all other dimensions can be obtained.
They are mass (M), length (L), and time (T)

- **Secondary Dimensions**

Dimensions expressed in terms of the primary (also called fundamental) dimensions

Can you give examples?

System of Units: SI Units

Units for Mass, Length, Time, and Force

	SI	
Quantity	Unit	Symbol
mass	kilogram	kg
length	meter	m
time	second	s
force	newton $(= 1\ \text{kg} \cdot \text{m/s}^2)$	N

- **Legally accepted system in most countries**
- **Conventions of the SI are controlled by an international treaty organization**

SI base unit of length is meter (m)

The length of the path traveled by light in a vacuum during a specified time interval

SI base unit of time is seconds (s)

The duration of 9, 192,631,770 cycles of the radiation associated with a specified transition of the cesium atom

SI base unit of mass is kilogram (kg)

The mass of a particular cylinder of platinum-iridium alloy kept by the International Bureau of Weights and Measures near Paris

Practice Exercises: The Use of SI Units

- **Determine the weight in Newton of an object whose mass is 1000 kg at a place on the earth's surface where the acceleration due to gravity equals a standard value defined as $9.80665\ m.s^{-2}$.**

- **If the object were on the surface of a planet at a point where the acceleration of gravity is one-tenth of the value used above, would the mass change? How does this new value of the acceleration of gravity affect the weight?**

- **What type of unit is the Newton?**

System of Units: English Engineering Units

English	
Unit	Symbol
pound mass	lb
foot	ft
second	s
pound force ($= 32.1740\ \mathrm{lb \cdot ft/s^2}$)	lbf

- Many segments of the engineering community, for example, in the United States, regularly use other system of units
- One of such system of units is the English Engineering Units
- Is the English Engineering Unit the same as the Imperial system of units

EEU base unit of length is foot (ft)

Defined in terms of meter as

$1\ ft = 0.3048\ m$

Or

$12\ in. = 1 ft$

EEU base unit of mass is pound mass (Ib) or (Ibm)

Defined in terms of kilogram as

$1\ Ib = 0.45359237\ kg$

SI base unit of force is the pound force (Ibf)

Force required to accelerate one pound mass at

$32.1740\ ft.s^{-2}$

Which is the standard acceleration of gravity

Important Intensive Properties

- There are three measurable intensive properties that are particularly important in engineering thermodynamics.
- They are, specific volume, pressure and temperature
- From the macroscopic view of thermodynamics, the description of matter is simplified by assuming that it is distributed continuously throughout a region to be studied
- This is known as the **continuum hypothesis**

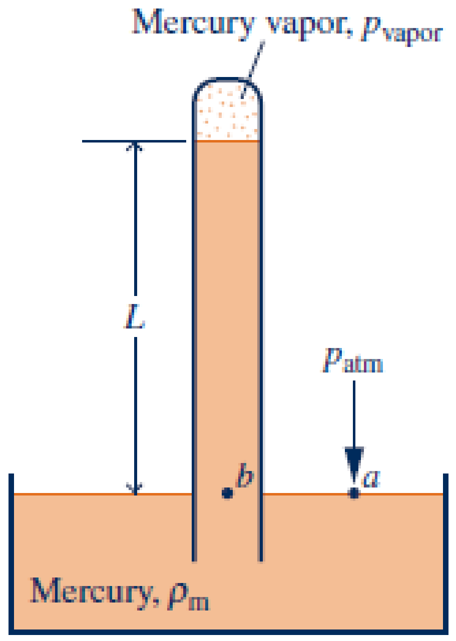
Specific Volume

The reciprocal of density, which is volume per unit mass.

$$v = \frac{1}{\rho}$$

Pressure

Unless otherwise stated refers to absolute pressure which is pressure with respect to zero pressure of a complete vacuum



Pressure measured using a barometer

$$p = p_{atm} + \rho g L$$

Important Intensive Properties

Temperature

Rooted in the notion of 'hotness' or 'coldness'.

It cannot be accurately gauged by human touch.

An objective understanding of equality of temperature can be achieved by using the fact that when the temperature of an object changes, other properties also change

Zeroth Law of Thermodynamics

When two objects are in thermal equilibrium with a third object, they are in thermal equilibrium.

This law is tacitly assumed in every measurement of temperature.

If you want to know if two objects are at the same temperature, all you need to do is to check if they are in thermal equilibrium with a third object.

The third object is usually a thermometer

Important Intensive Properties

Thermometers

An object with at least one measurable property that changes as its temperature changes can be used as a thermometer

This property is called thermometric property and the substance that exhibits this kind of property is called a thermometric substance.

(a) Is a liquid-in-glass thermometer
(b) is an electrical-resistance thermometer
(c) Is an infrared-sensing ear thermometer

(a) (b) (c)

Important Intensive Properties

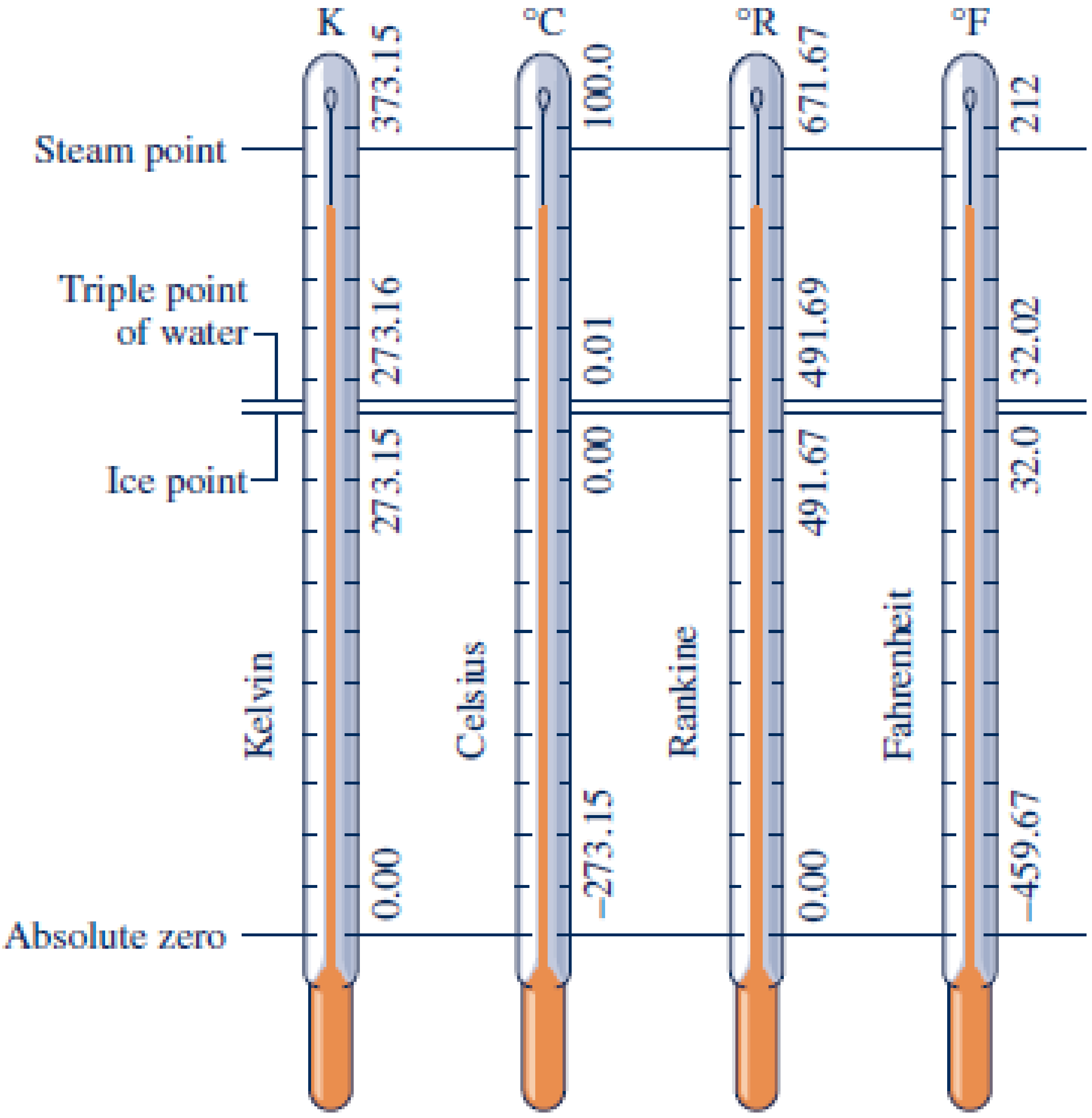
Temperature Scales

The tendency of the liquid in a liquid-in-glass thermometer to freeze at low temperatures imposes on it a lower limit on the range of temperature it can measure

Also, at high temperatures, liquids vaporize and as a result there are limits to empirical means of measuring temperature

In view of these limitations, there is a need to have a procedure for assigning temperatures values that do not depend on class of substances called

THERMODYNAMIC TEMPERATURE SCALES



Important Intensive Properties

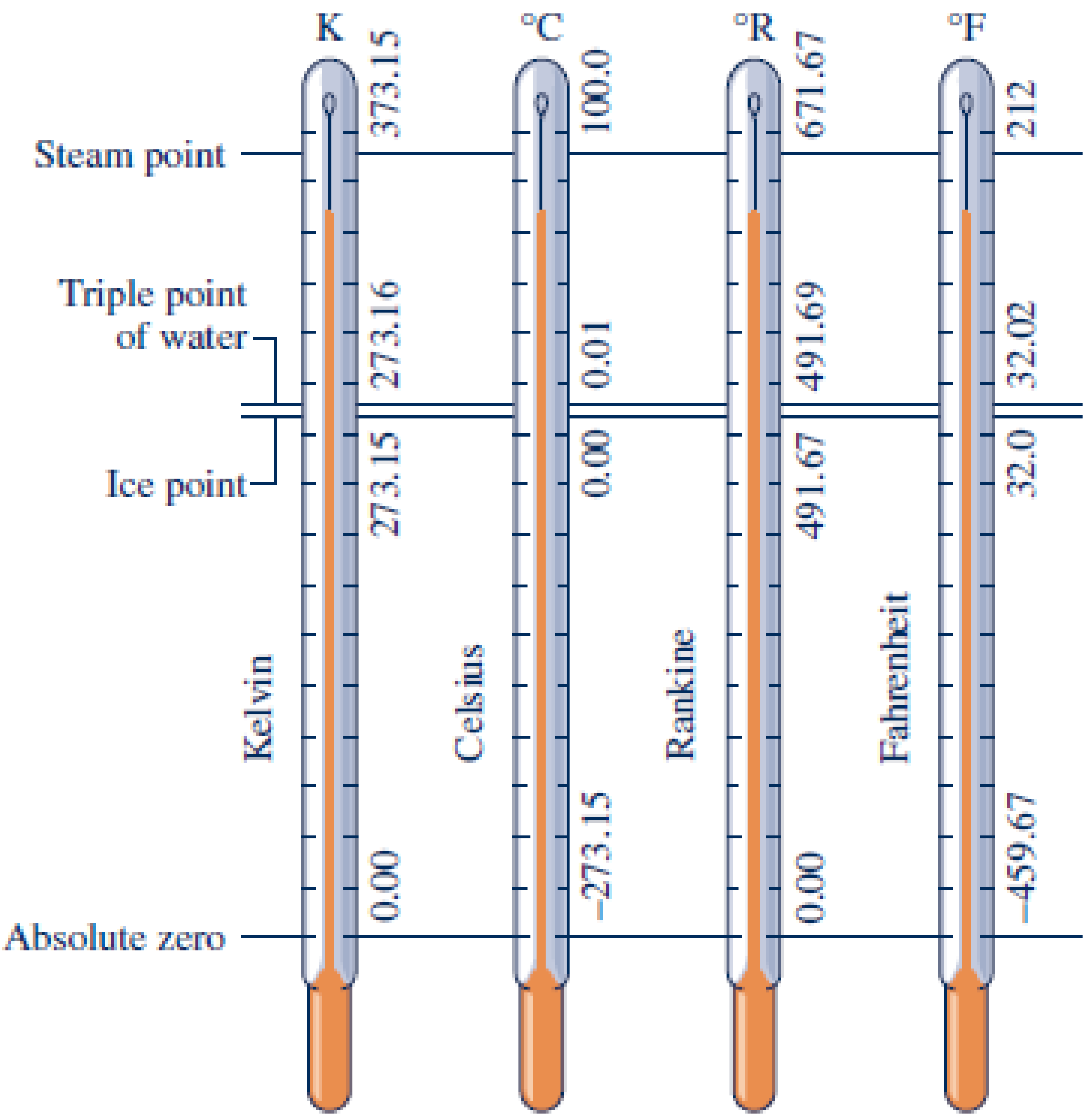
Kelvin Scale

Is an absolute thermodynamic temperature scale that provides a continuous definition of temperature, valid over all ranges of temperature.

Kelvin is an SI base unit for temperature

The Kelvin scale is developed using the conservation of energy principle and the second law of thermodynamics

Lower temperatures than $0\ K$ are not defined



Important Intensive Properties

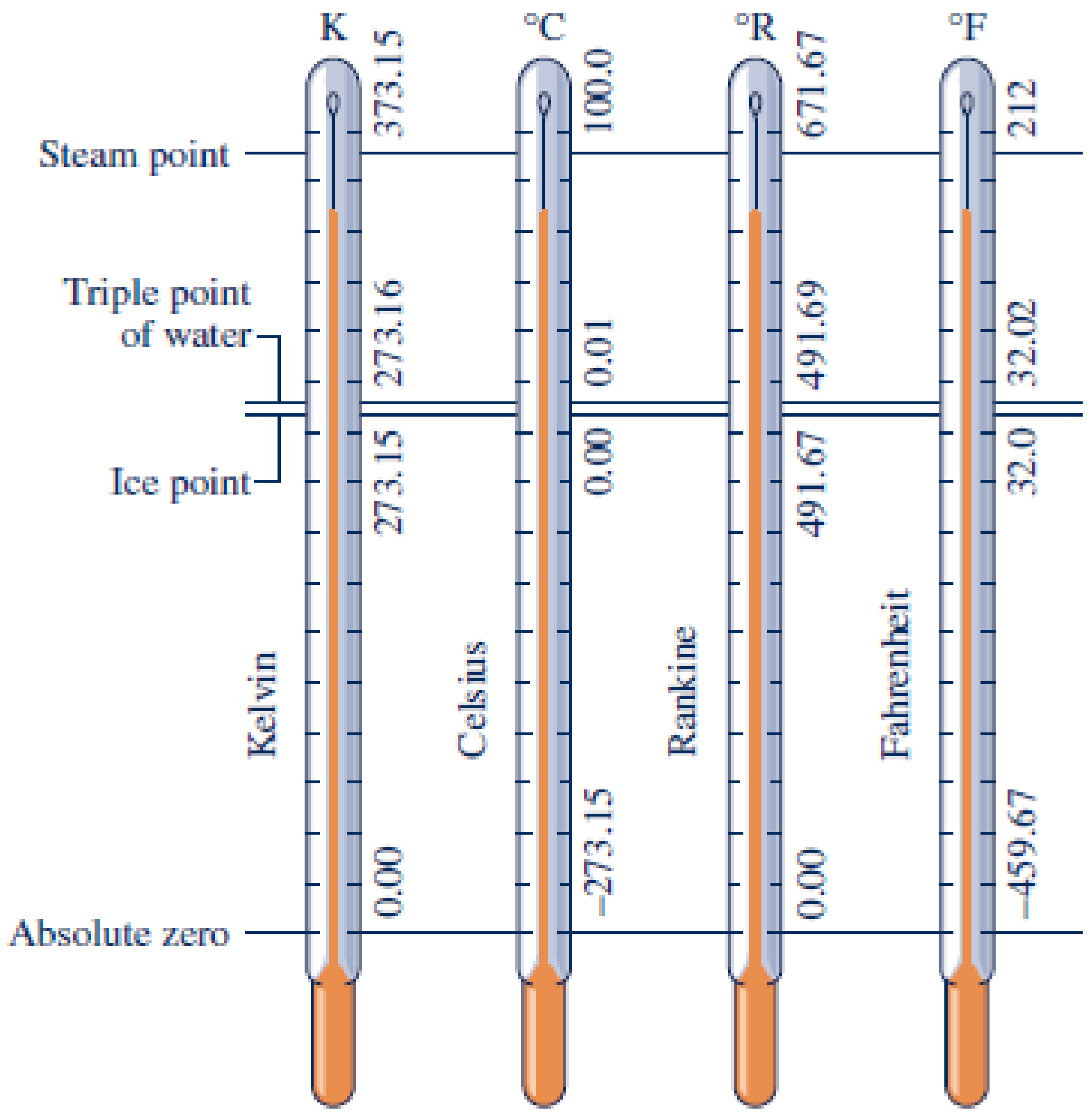
Rankine Scale

Is proportional to the Kelvin scale according to,

$$T(°R) = 1.8\,T(K)°$$

It is also an absolute thermodynamic scale with an absolute zero that coincides with the absolute zero of the Kelvin scale

In thermodynamic relationships, temperature is always in terms of Kelvin or Rankine scale unless specifically stated otherwise



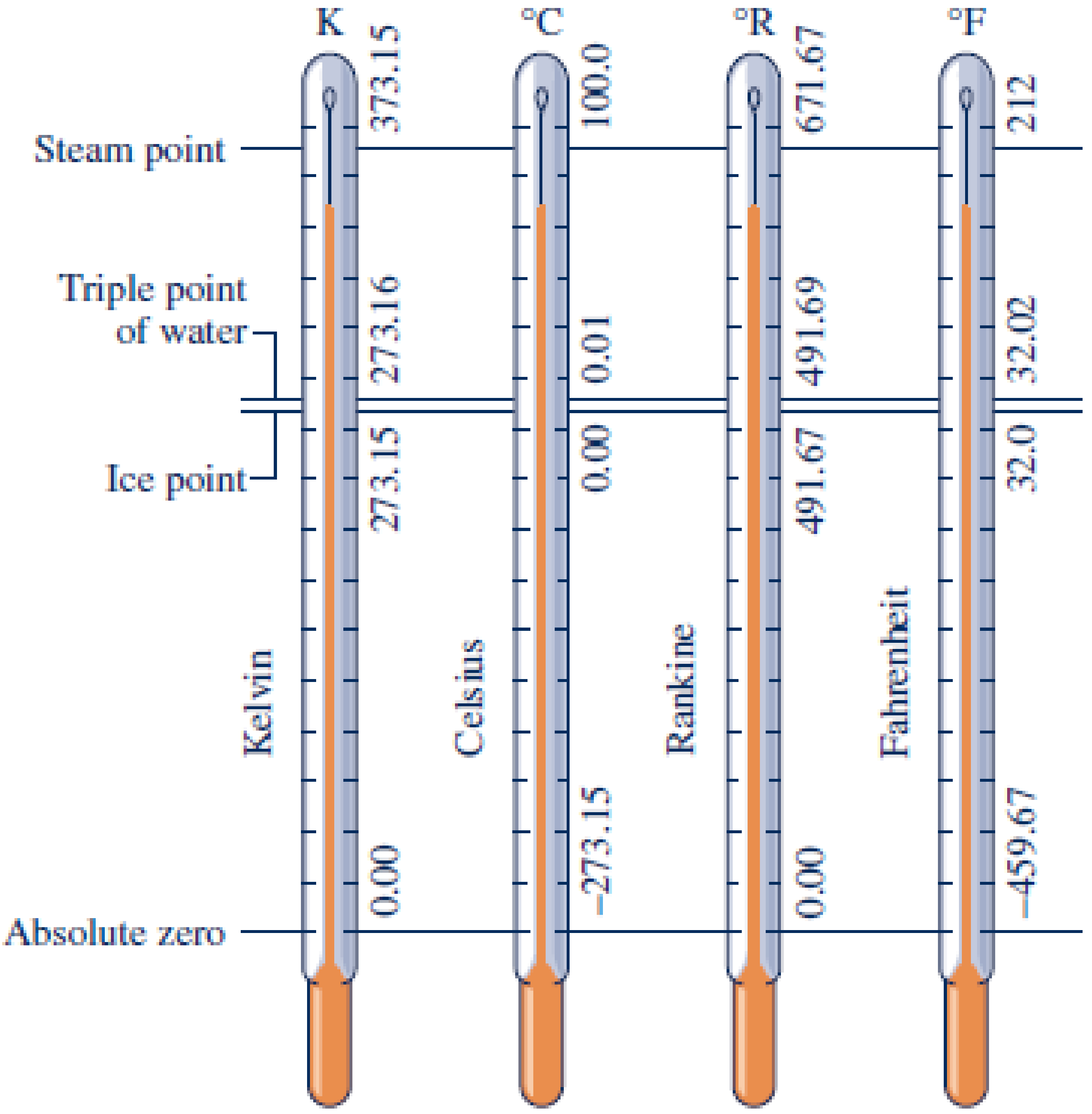
Important Intensive Properties

Celsius and Fahrenheit Scales

The relationship between the Kelvin, Rankine, Celsius and Fahrenheit scales are shown in the figure based on temperature at three fixed points.

The points are, the triple point, ice point and steam point.

By international agreement, temperature scales are defined by the numerical value assigned to the triple point of water, i.e. the state of equilibrium among steam, ice and liquid water.



Engineering Design and Analysis

The word ENGINEER comes from a Latin word which means INVENTION

Invention is the key function of an engineering discipline having many aspects ranging from developing new devices to addressing complex social issues using technology

Engineers are the “go to people” when there is a need for design and analysis of devices required to meet human needs

Engineering Design and Analysis

What is Design?

Engineering design is a decision making process in which principles drawn from engineering and other fields such as economics and statistics are applied iteratively, to devise a system, system component or process

What are the fundamental elements of design?

- Establishment of objectives
- Synthesis
- Analysis
- Construction testing
- Evaluation
- Redesign (if necessary)

Engineering Design and Analysis

Where do Design Projects originate from?

Recognition of a need or an opportunity (which initially might not be fully understood)

Before birthing solutions to these needs, design objectives need to be defined first

What to consider for workable designs

- Lowest cost
- Highest efficiency
- Smallest size
- Lightest weight
- Reliability
- Manufacturability
- Maintainability
- Marketplace considerations

Engineering Design and Analysis

Why Engineering Analysis?

If, for example, we have a proposed design for a fire-protection system in our classrooms, what components would we need to put together for this system?

Major Components

- Overhead piping network for water
- Numerous sprinkler heads

How do we decide the specific sizing of the pipes, pipe material, the number of sprinklers, etc.?

ENGINEERING ANALYSIS

Engineering Design and Analysis

Why Engineering Analysis?

Engineering analysis ensures that all components of a design form a smoothly working whole while meeting the relevant cost constraints, engineering codes and standards

Laws that govern thermodynamic system analysis

- Conservation of mass principle
- Conservation of energy principle
- Second law of thermodynamics

Engineering Design and Analysis

Thermodynamic System Analysis

- Define the system
- Identify relevant interaction with the surroundings
- Pay attention to the physical laws and relationships that describe the behavior of the system

- Present your engineering model based on the first 3 bullet points

The engineering model is a simplified representation of the system behavior for the purpose of analysis

Methodology for Solving Thermodynamic Problems

- State briefly what is known (Read the problem carefully)
- State what needs to be determined
- Draw a sketch of the system and label it with the given information
- State all your assumptions (This can also be found in the problem description)
- Using all the information given with the simplified model, state all the governing equations and relationships needed to obtain the desired result
- Solve the problem and interpret the results

SUMMARY

1. System of Units
2. Types of Dimensions
3. Important Intensive Properties
4. Temperature Scales
5. Engineering Design & Analysis
6. Solving Thermodynamic Problems

Next Lecture

- Reading assignment: pages 39 to 60
- Work and kinetic energy
- Potential energy
- Conservation of energy
- Sign convention and notation
- Power, Modeling expansion and compression work in actual processes