CH365 Chemical Engineering Thermodynamics

Lesson 1
Introduction and Fundamentals 1

Professor Andrew Biaglow

Classroom and Computer Etiquette Reminders

The following behaviors are UNSAT:

- Working on assignments for other classes during CH365.
- Printing documents on the classroom printer *while I am speaking*.
- Consuming food of any kind in the classroom.
- Chewing gum.
- Sleeping.
- Not having a textbook.

If you see a computer floor plate open, please replace it.

Don’t leave documents hanging in the print queue. If you print a document, please either collect it or cancel the print job.

Please bring any printer issues to the attention of your instructor.

Please sign out of lab computers when leaving.

USMA Chemical Engineering Mission

The mission of the chemical engineering program is to prepare commissioned leaders of character who possess the intellectual capital to leverage new and emerging technologies.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Revised by Firsties and Advisory Board in AY2024.

Chemical Engineering Program Educational Objectives

During a career as commissioned officers in the United States Army and beyond, program graduates:

- Demonstrate effective leadership by leveraging chemical engineering expertise and precise technical communication.
- Contribute to the solution of complex problems in a dynamic environment.
- Apply disciplined technical expertise to succeed in advanced study programs.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Revised by Firsties and Advisory Board in AY2024.

Firsties provide input to development of PEOs during the program briefing in January.

Chemical Engineering Student Outcomes

Program Student Outcome 8

The chemical engineering curriculum closely tracks the topics in the Fundamentals of Engineering Exam

On completion of the chemical engineering program, our graduates demonstrate an ability to understand …

- Chemistry
- Material and energy balances
- Safety and environmental factors.
- Thermodynamics of physical and chemical equilibria
- Heat, mass, and momentum transfer
- Chemical reaction engineering
- Continuous and staged separation processes
- Process dynamics and control
- Modern experimental and computing techniques
- Process design.

Published in the USMA Redbook (Part 2 – Disciplinary Offerings)

Red designates course emphasis; Black designates heavy usage in course; Gray designates minor emphasis

Student Outcomes, cont.

The Chemical Engineering Major contains the student outcomes recommended by ABET.

On completion of the chemical engineering program, our graduates demonstrate an ability to …

Published in the USMA Redbook
(Part 2 – Disciplinary Offerings)

- Identify, formulate, and solve complex engineering problems by applying principles of engineering, science, and mathematics.
- Apply engineering design to produce solutions that meet specified needs with consideration of public health, safety, and welfare, as well as global, cultural, social, environmental, and economic factors.
- Communicate effectively with a range of audiences.
- Recognize ethical and professional responsibilities in engineering situations and make informed judgments, which must consider the impact of engineering solutions in global, economic, environmental, and societal contexts.
- Function effectively on a team whose members together provide leadership, create a collaborative and inclusive environment, establish goals, plan tasks, and meet objectives.
- Design and conduct appropriate experimentation, analyze and interpret data, and use engineering judgment to draw conclusions.
- Acquire and apply new knowledge as needed, using appropriate learning strategies.

Red designates course emphasis; Black designates heavy usage in course; Gray designates minor emphasis

Redbook

3.0 Credit Hours (BS=0.0, ET=3.0, MA=0.0)

Prerequisites: MA364, ME301, CH364, CH363

Lessons: 40 @ 55 min

Labs: 0 @ 0 min

This course is on [CANVAS]

Assessment AY2026-1

count	event	points ea.	points	percent
1	TEE	500	500	21.01
1	Capstone	300	300	12.61
1	IPR	0	0	0.00
3	WPRs	200	600	25.21
66	Problems	10	660	27.73
1	SIS Quiz	60	60	2.52
1	MMA Quiz	60	60	2.52
1	Resume	200	200	8.40
	Total		*2380*	*100.00*

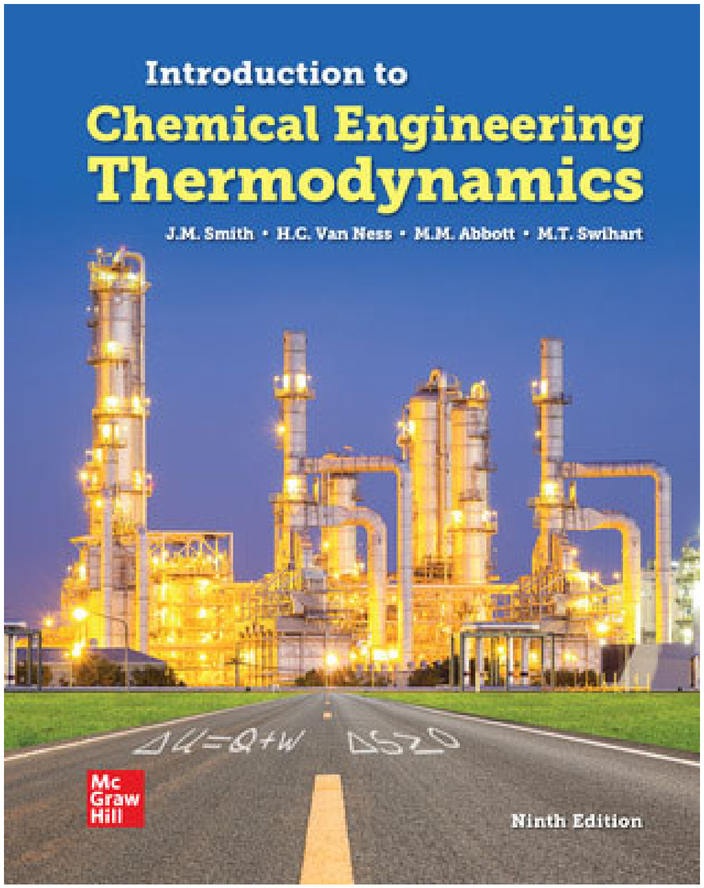
Notes:
Problems are 10 points each and collected as *Problem Sets*
Problem Sets are entered in AMS and the point value varies from 30 to 100 points.

Documentation Policy

Documentation and Acknowledgment of Academic Work (DAAW), June 2024

- Assignments
  - Cover sheets are required for all graded events.
  - Must be completed in accordance with instructions in App B
  - Assignments will not be accepted without a cover sheet.
  - Example cover sheet for individual paper submission, App B1
  - A fillable cover sheet pdf form is linked to the web site
  - Problem sets are documented, page 22 and App B
  - Document all assistance and collaboration, p. 15 and App A
  - Document Internet and AI sources, App D
  - E-submissions – **where possible, bundle into signed pdf**
- Formal groups are by assignment.
  - Definition: see p. 5
- BLUF – Give credit where credit is due

Textbook – Paper or Electronic Copy



First edition in 1949; very influential book.

ISBN: 978-1-260-72147-8

Instructor is using 1st printing

Parts of the Course

Where we are going - roadmap

- Chapter Coverage
  - Chapter 1 – Fundamentals
  - Chapter 2 – First Law

  review, but presentation and key details are different

  - Chapter 3 – Properties of Pure Fluids
  - Chapter 4 – Heat Effects
  - Chapter 5 – Entropy
  - Chapter 6 – Real Fluids
  - Chapter 10 – Solution Thermodynamics
  - Chapters 12 and 13 – Phase Equilibria
- Chemical Engineering Perspective

What you will learn in this course

Where you are going – end state

- How are physical properties calculated?
- How does the CHEMCAD suggest thermodynamics?
- What is an activity coefficient? Fugacity?
- What is an equation of state? How many are there? Which one is best?
- How does an equation of state allow calculation of properties like enthalpy and entropy?
- How are the properties of a solution calculated?

Critical chemical engineering questions addressed in this course.

Admin Questions?

Scope of Thermodynamics

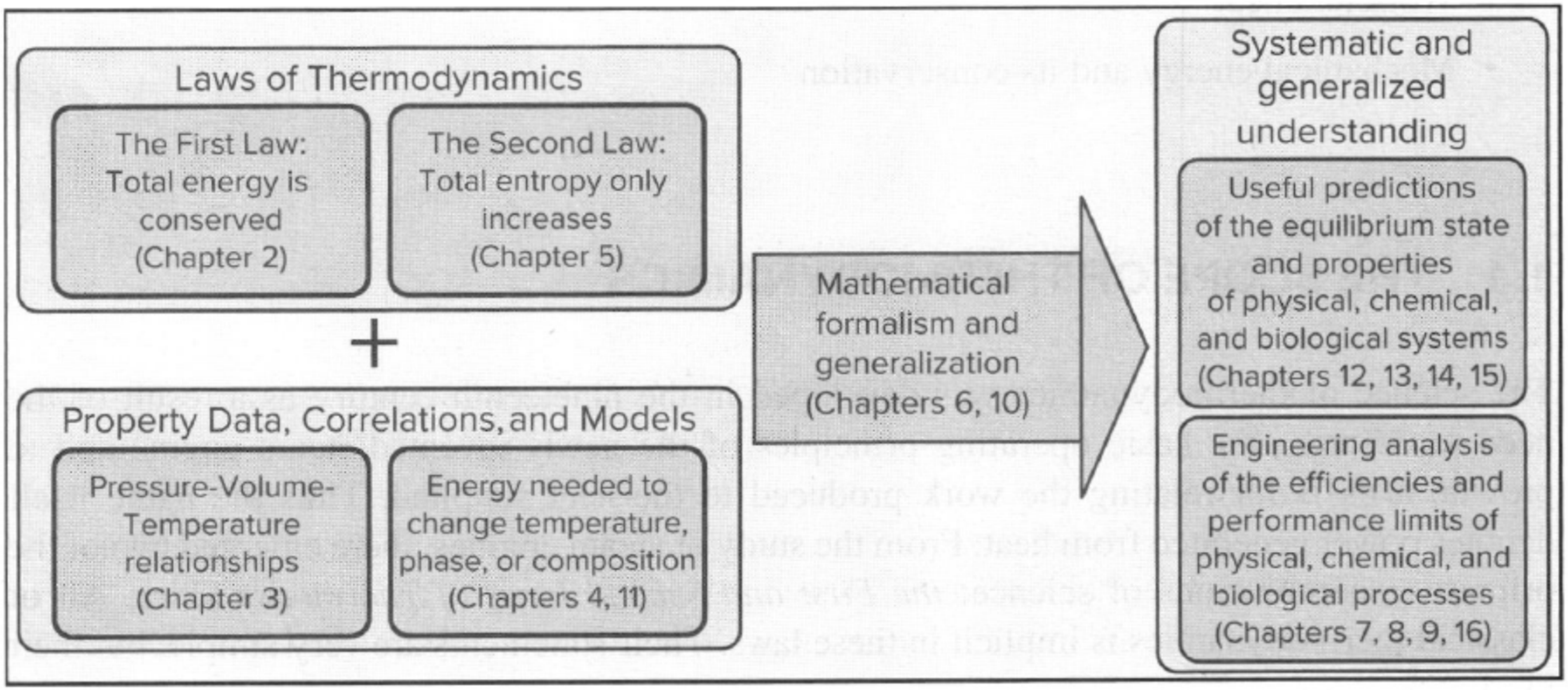


Figure 1.1: Schematic illustrating the combination of the laws of thermodynamics with data on material properties to produce useful predictions and analyses.

- Originally – how much work from heat
- Chemical systems - how much product can I make?
- Physical and chemical processes involving “rate” →No

Scope of Thermodynamics

- Originally – how much work (or power) from heat
  - “Primitive laws” (no contrary experience)
  - Derivation of a general mathematical framework.
- Chemical systems - how much product can I make?
  - Heat and work requirements for physical and chemical processes
- Determination of properties when data are unavailable

Dimensions and Units

1 second

duration of 9,192,631 cycles of radiation emitted from the hyperfine transition in the ground state of cesium-133

1 meter

distance light travels in vacuum in 1/299,792,458 of a sec

1 kilogram

mass of platinum-iridium cylinder at the International Bureau of Weights and Measures at Sevres, France

1 kelvin

1/273.16 of the triple point of water

English units – use conversion factors – App A, pp 661-662

1 ft = 0.3048 m   1 lb_m = 0.45359237 kg   1 lb-mol = 453.59237 mol

Measures of Amount or Size

- mass, m
- moles, n
- total volume, V^t

note the “t”

$$n = \frac{m}{M} \text{ or } m = nM$$

M = molar mass

molar volume $$V = \frac{V^t}{n} \text{ or } V^t = nV$$

note the plain V

specific volume $$V = \frac{V^t}{m} \text{ or } V^t = mV$$

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

Force

1 Newton is the amount of force which when applied to a mass of 1 kg creates an acceleration of 1 m s^{-2}

$$\text{force} \,[=]\, \text{N} \quad \text{and} \quad 1\,\text{N} \equiv 1\,\frac{(\text{kg})(\text{m})}{\text{s}^2}$$

1 lb_f is the amount of force, when applied to a mass of 1 lb_m , produces an acceleration of 32.1740 ft s^{-2}

$$\text{force} \,[=]\, \text{lb}_f \quad \text{and} \quad 1\,\text{lb}_f \equiv 32.1740\,\frac{(\text{lb}_m)(\text{ft})}{\text{s}^2}$$

Gravitational Conversion, g_c

Both EE and SI systems use it

$$F = \frac{1}{g_c} ma$$

$$F = ma$$

English Engineering Units:

If force is in lb_f:

$$1(lb_f) = \frac{1}{g_c} \times 1(lb_m) \times 32.1740(ft)(s^{-2})$$

$$g_c = 32.1740 \frac{(ft)(lb_m)/s^2}{lb_f}$$

SI Units:

If force is in N:

$$1(N) = \frac{1}{g_c} \times 1(kg) \times 1(m)(s^{-2})$$

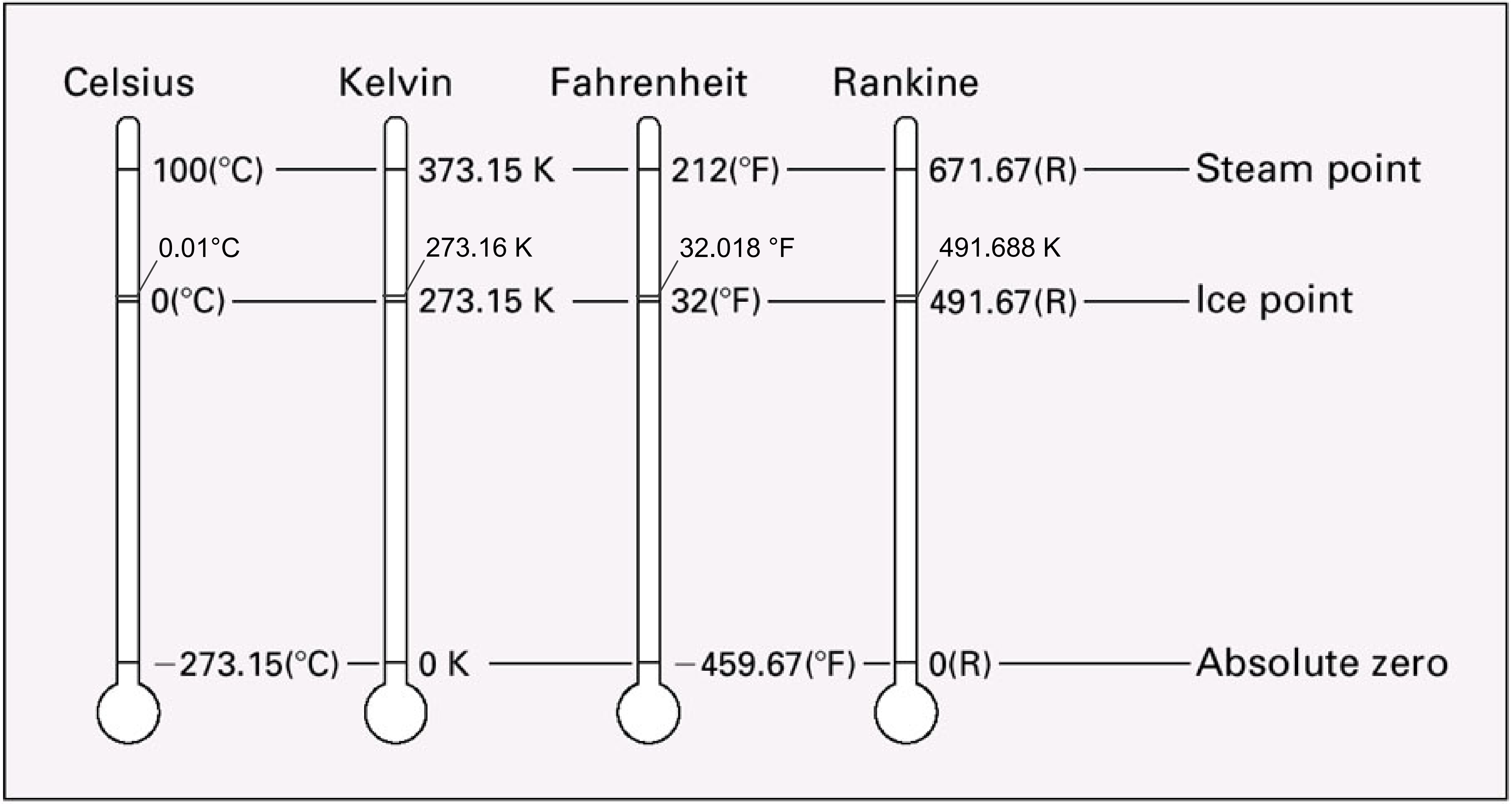
$$g_c = 1 \frac{(kg)(m)/s^2}{N}$$

Example Problem

What is the value of g_c and what are its units in a unit system in which the second, the foot, and the pound-mass are the "primitives" (p. 4), and the unit of force is the poundal, defined as the force required to give 1 lb_m an acceleration of 1 ft/s^2?

The poundal is the unit of force in the foot-pound-second (FPS) system of units.
The symbol for the poundal is pdl.

Temperature Units

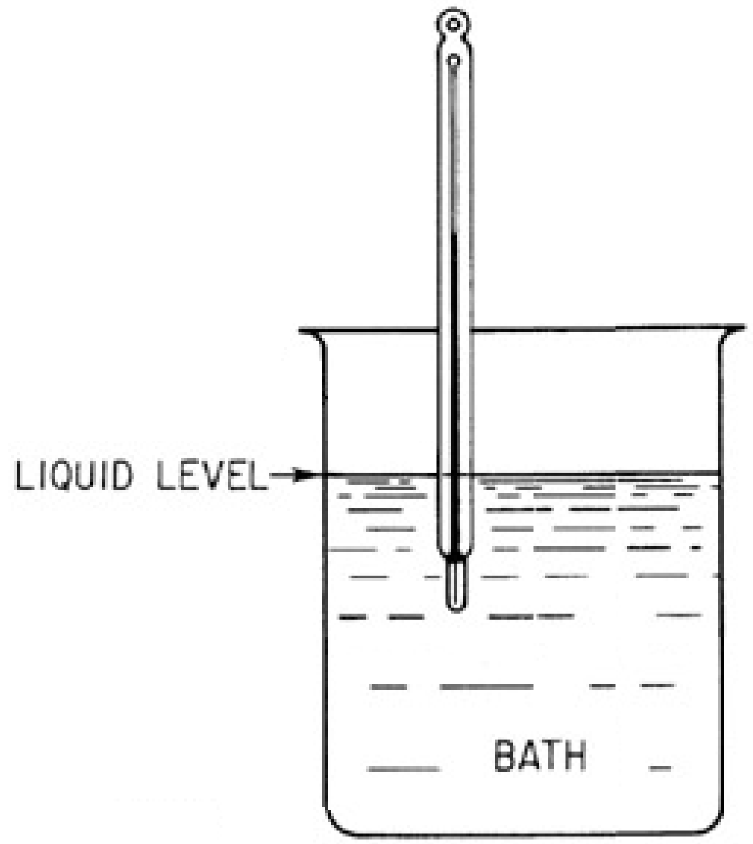


$$^{o}C = K - 273.15 \qquad ^{o}F = 1.8^{o}C + 32$$

$$^{o}F = R - 459.67 \qquad R = 1.8K$$

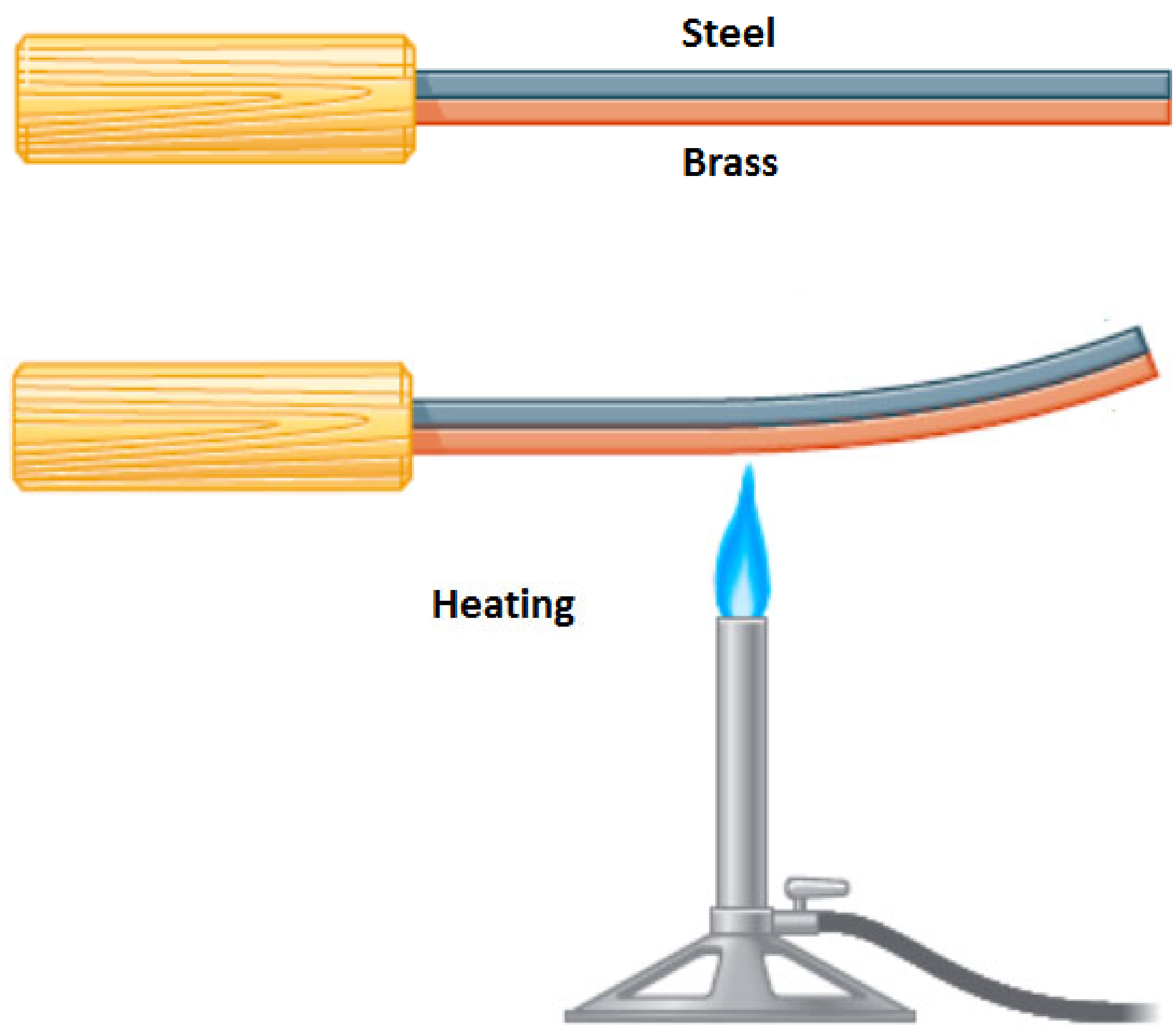
Temperature Measurement

Liquid-in-glass
Bimetallic strips
Thermocouples
Resistance thermometers
Thermistors
Pyrometers
Infrared



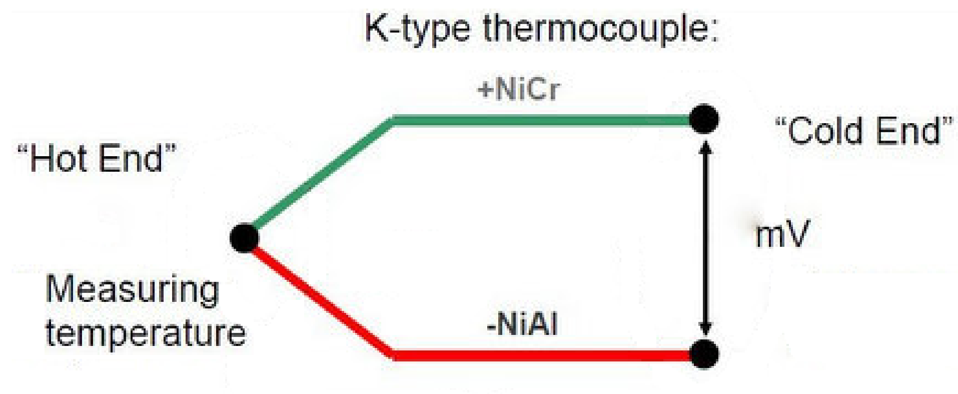
Temperature Measurement

Liquid-in-glass
Bimetallic strips
Thermocouples
Resistance thermometers
Thermistors
Pyrometers
Infrared



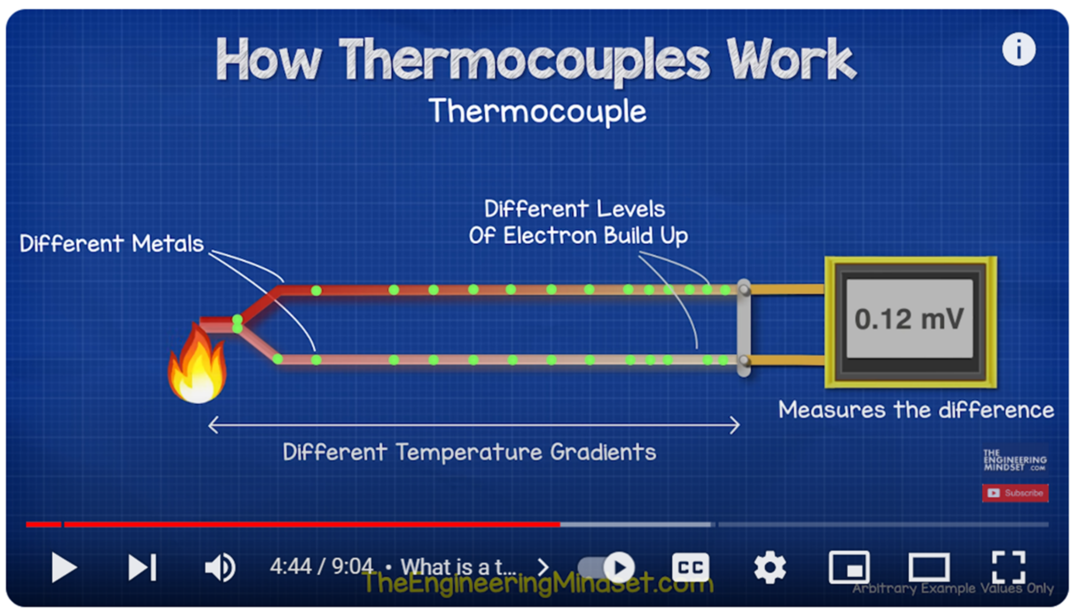
Temperature Measurement

Liquid-in-glass
Bimetallic strips
Thermocouples
Resistance thermometers
Thermistors
Pyrometers
Infrared



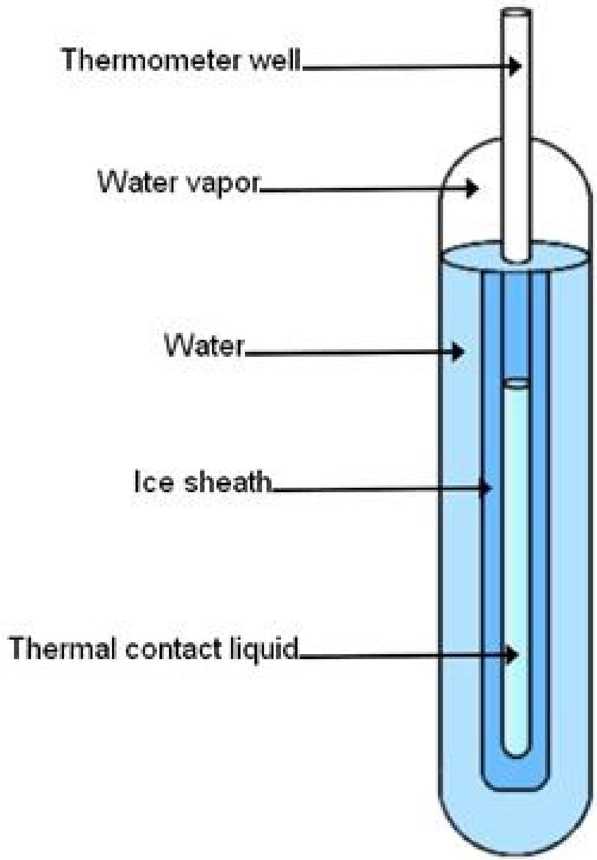
Here is a link to an excellent video on how thermocouples work: https://www.youtube.com/watch?v=v7NUi88Lxi8

(If you are in a hurry, watch the clip between 4 and 5 minutes)



Temperature Measurement

All calibrated against primary standard:



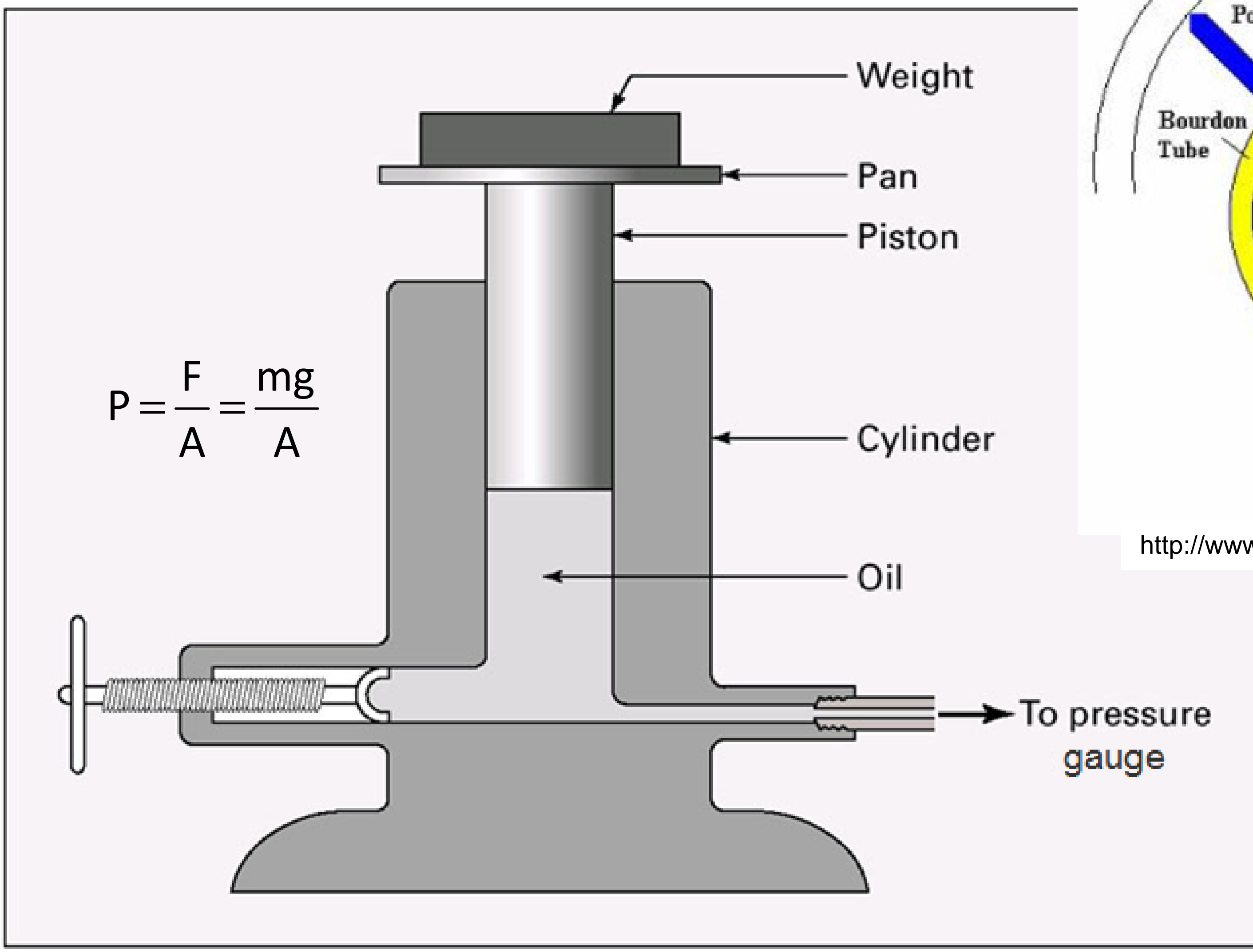
Water Triple Point Cell

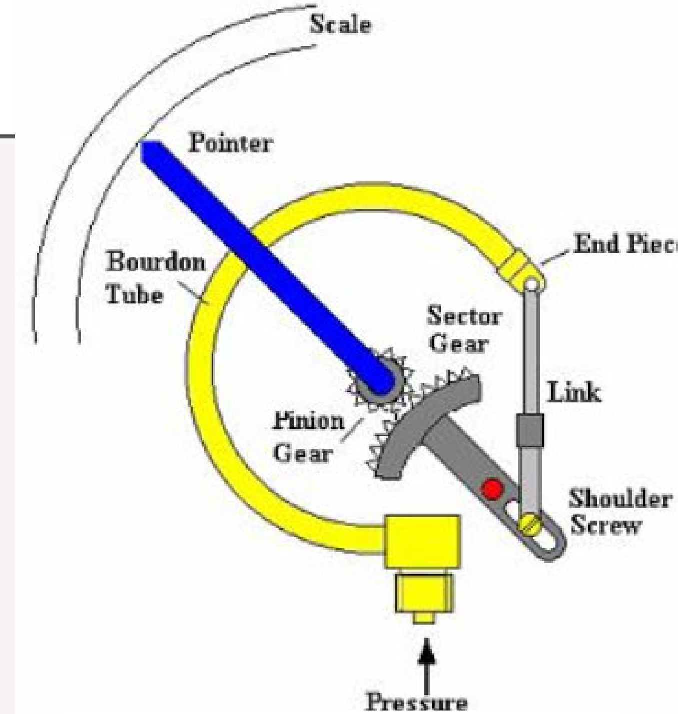
Image from http://aashtoresource.org

Pressure

Fig. 1.2

$$P = \frac{F}{A} = \frac{mg}{A}$$

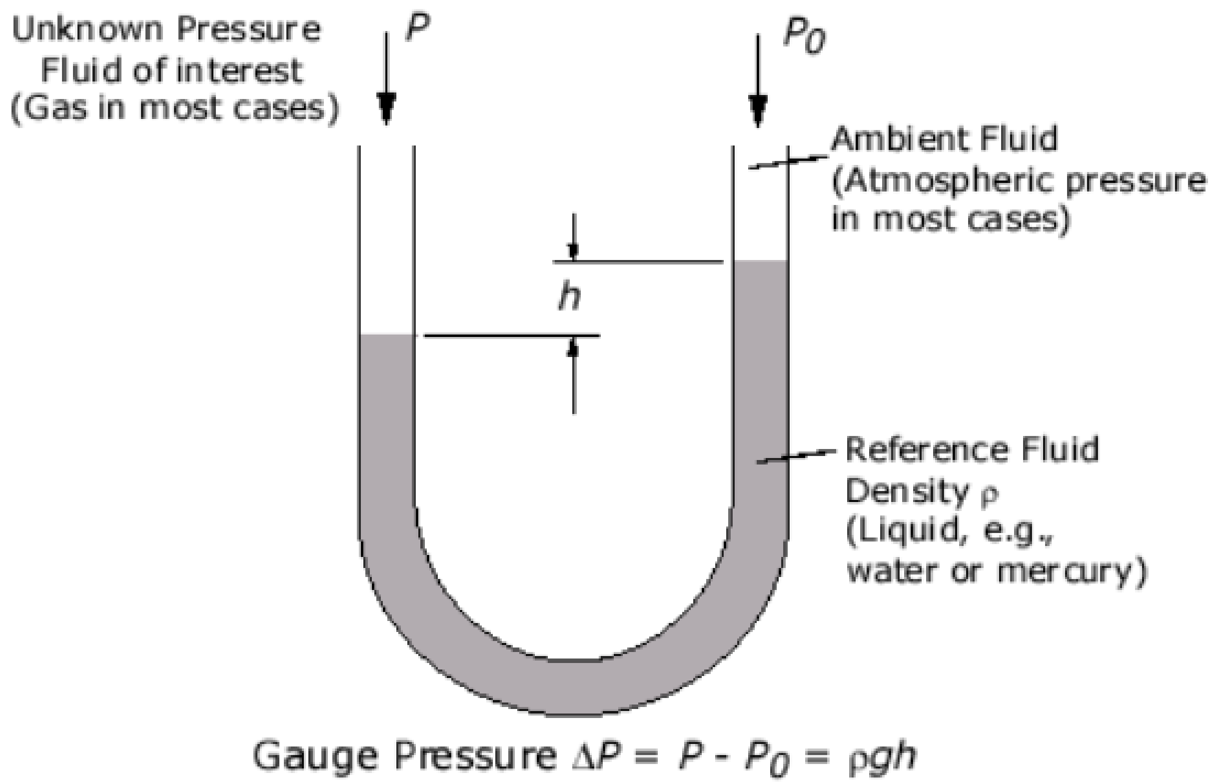




http://www.instrumentationtoolbox.com/

Also: $$P = \frac{F}{A} = \frac{mg}{A} = \frac{Ah\rho g}{A} = h\rho g$$ (manometers)

Manometers


Unknown Pressure
Fluid of interest
(Gas in most cases)
P
P0
Ambient Fluid
(Atmospheric pressure
in most cases)
h
Reference Fluid
Density ρ
(Liquid, e.g.,
water or mercury)
Gauge Pressure ΔP = P - P0 = ρgh

Questions?