اسم المادة : ثرموداينميك 2
اسم التدريسي : أ.م حسن غانم حسن رجبو
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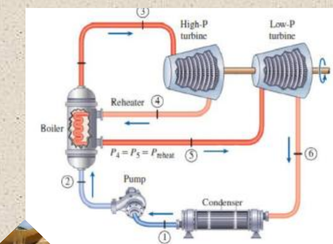
عنوان المحاضرة: مراجعة 2

Thermodynamic II

LECTURE 2
Review I I



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TEMPERATURE AND THE ZEROTH LAW OF THERMODYNAMICS

- **The zeroth law of thermodynamics:** If two bodies are in thermal equilibrium with a third body, they are also in thermal equilibrium with each other.
- By replacing the third body with a thermometer, the zeroth law can be restated as *two bodies are in thermal equilibrium if both have the same temperature reading even if they are not in contact*.

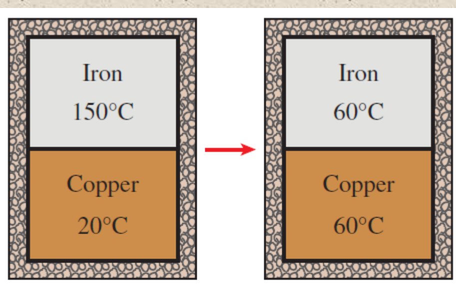


FIGURE 1–34
Two bodies reaching thermal equilibrium after being brought into contact in an isolated enclosure.

Temperature Scales

- All temperature scales are based on some easily reproducible states such as the freezing and boiling points of water: the *ice point* and the *steam point.*
- **Ice point**: A mixture of ice and water that is in equilibrium with air saturated with vapor at 1 atm pressure (0°C or 32°F).
- **Steam point**: A mixture of liquid water and water vapor (with no air) in equilibrium at 1 atm pressure (100°C or 212°F).
- **Celsius scale**: in SI unit system
- **Fahrenheit scale**: in English unit system
- **Thermodynamic temperature scale**: A temperature scale that is independent of the properties of any substance.
- **Kelvin scale** (SI) **Rankine scale** (E)
- A temperature scale nearly identical to the Kelvin scale is the **ideal-gas temperature scale**. The temperatures on this scale are measured using a constant-volume gas thermometer.

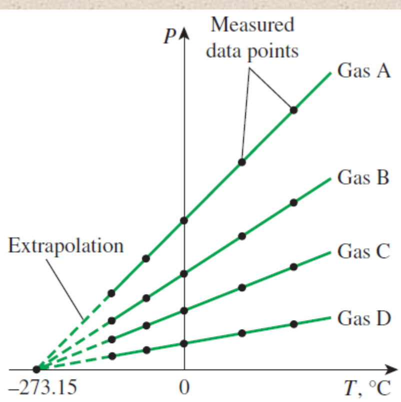


FIGURE 1–35
P versus *T* plots of the experimental data obtained from a constant-volume gas thermometer using four different gases at different (but low) pressures.

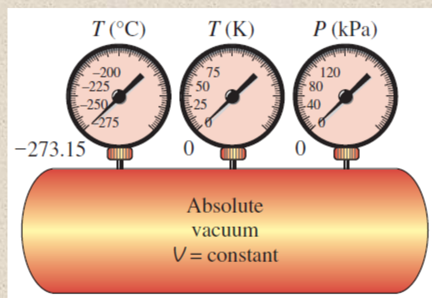


FIGURE 1–36
A constant-volume gas thermometer would read −273.15°C at absolute zero pressure.

$$T(\mathrm{K}) = T(^\circ\mathrm{C}) + 273.15$$

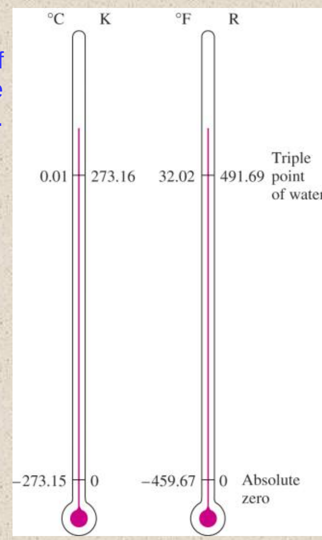
$$T(\mathrm{R}) = T(^\circ\mathrm{F}) + 459.67$$

$$T(\mathrm{R}) = 1.8T(\mathrm{K})$$

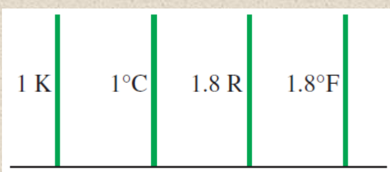
$$T(^\circ\mathrm{F}) = 1.8T(^\circ\mathrm{C}) + 32$$

$$\Delta T(\mathrm{K}) = \Delta T(^\circ\mathrm{C})$$

$$\Delta T(\mathrm{R}) = \Delta T(^\circ\mathrm{F})$$



Comparison of temperature scales.



Comparison of magnitudes of various temperature units.

- The reference temperature in the original Kelvin scale was the ***ice point***, 273.15 K, which is the temperature at which water freezes (or ice melts).
- The reference point was changed to a much more precisely reproducible point, the ***triple point*** of water (the state at which all three phases of water coexist in equilibrium), which is assigned the value 273.16 K.

PRESSURE

Pressure: A normal force exerted by a fluid per unit area

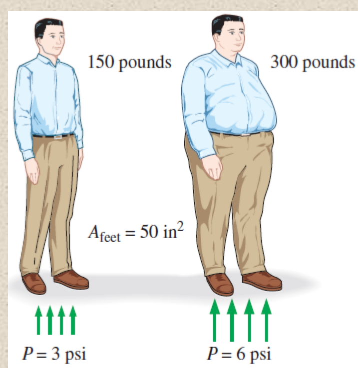
$$1\ \mathrm{Pa} = 1\ \mathrm{N/m^2}$$

$$1\ \mathrm{bar} = 10^5\ \mathrm{Pa} = 0.1\ \mathrm{MPa} = 100\ \mathrm{kPa}$$

$$1\ \mathrm{atm} = 101{,}325\ \mathrm{Pa} = 101.325\ \mathrm{kPa} = 1.01325\ \mathrm{bars}$$

$$1\ \mathrm{kgf/cm^2} = 9.807\ \mathrm{N/cm^2} = 9.807 \times 10^4\ \mathrm{N/m^2} = 9.807 \times 10^4\ \mathrm{Pa}$$
$$= 0.9807\ \mathrm{bar}$$
$$= 0.9679\ \mathrm{atm}$$

Some basic pressure gages.



$$P = \sigma_n = \frac{W}{A_{feet}} = \frac{150\ \mathrm{lbf}}{50\ \mathrm{in}^2} = 3\ \mathrm{psi}$$

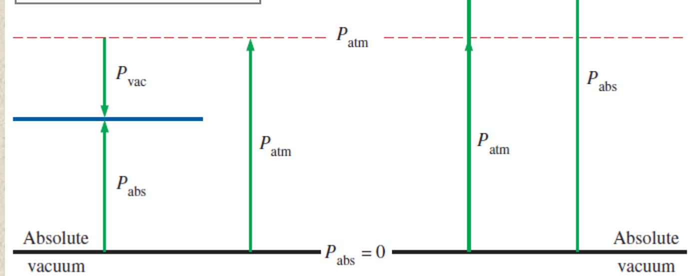
FIGURE 1–39
The normal stress (or "pressure") on the feet of a chubby person is much greater than on the feet of a slim person.

- **Absolute pressure**: The actual pressure at a given position. It is measured relative to absolute vacuum (i.e., absolute zero pressure).
- **Gage pressure**: The difference between the absolute pressure and the local atmospheric pressure. Most pressure-measuring devices are calibrated to read zero in the atmosphere, and so they indicate gage pressure.
- **Vacuum pressures**: Pressures below atmospheric pressure.

Throughout this text, the pressure ***P*** will denote ***absolute pressure*** unless specified otherwise.

$$P_{gage} = P_{abs} - P_{atm}$$

$$P_{vac} = P_{atm} - P_{abs}$$



Variation of Pressure with Depth

$$\Delta P = P_2 - P_1 = \rho g\, \Delta z = \gamma_s\, \Delta z$$

$$P = P_{atm} + \rho g h \quad \text{or} \quad P_{gage} = \rho g h$$

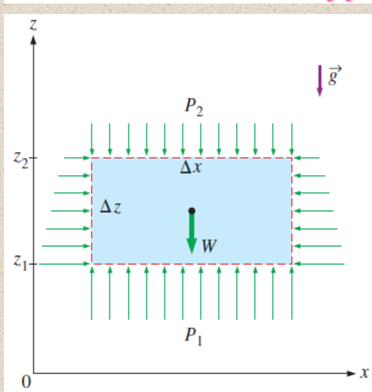


FIGURE 1–43
Free-body diagram of a rectangular fluid element in equilibrium.

When the variation of density with elevation is known

$$\Delta P = P_2 - P_1 = -\int_1^2 \rho g\, dz$$

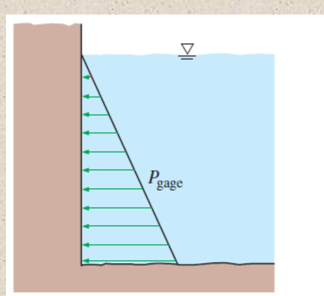


FIGURE 1–42
The pressure of a fluid at rest increases with depth (as a result of added weight).

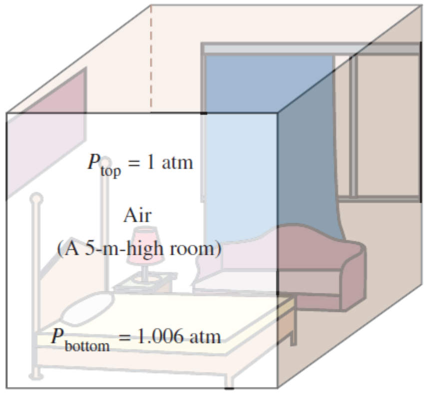


FIGURE 1–44
In a room filled with a gas, the variation of pressure with height is negligible.

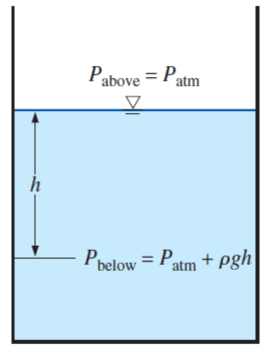


FIGURE 1–45
Pressure in a liquid at rest increases linearly with distance from the free surface.

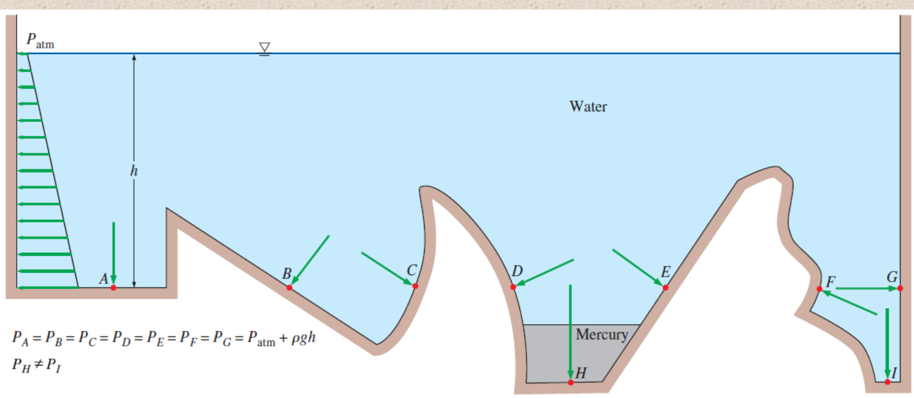


FIGURE 1–46
Under hydrostatic conditions, the pressure is the same at all points on a horizontal plane in a given fluid regardless of geometry, provided that the points are interconnected by the same fluid.

Pascal's law: The pressure applied to a confined fluid increases the pressure throughout by the same amount.

$$P_1 = P_2 \quad \rightarrow \quad \frac{F_1}{A_1} = \frac{F_2}{A_2} \quad \rightarrow \quad \frac{F_2}{F_1} = \frac{A_2}{A_1}$$

The area ratio A_2/A_1 is called the *ideal mechanical advantage* of the hydraulic lift.

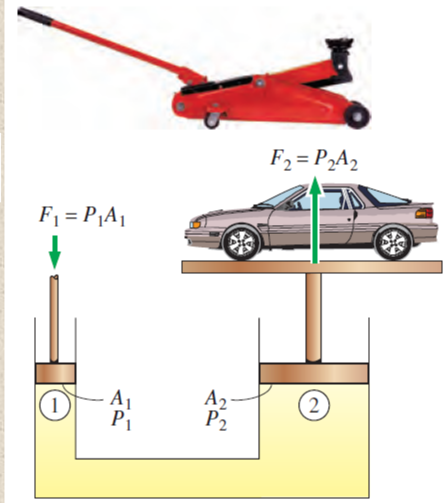


FIGURE 1–47
Lifting of a large weight by a small force by the application of Pascal's law. A common example is a hydraulic jack.

PRESSURE MEASUREMENT DEVICES

The Barometer

- Atmospheric pressure is measured by a device called a **barometer**; thus, the atmospheric pressure is often referred to as the ***barometric pressure***.
- A frequently used pressure unit is the *standard atmosphere*, which is defined as the pressure produced by a column of mercury 760 mm in height at 0°C (ρ_{Hg} = 13,595 kg/m^3) under standard gravitational acceleration (g = 9.807 m/s^2).

$$P_{atm} = \rho g h$$

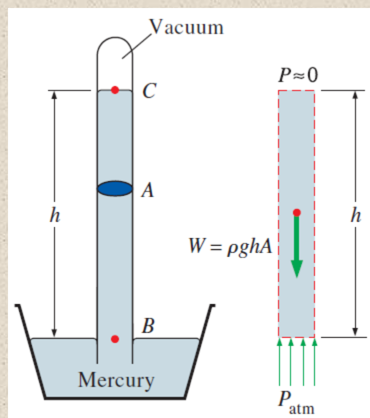


FIGURE 1–48
The basic barometer.

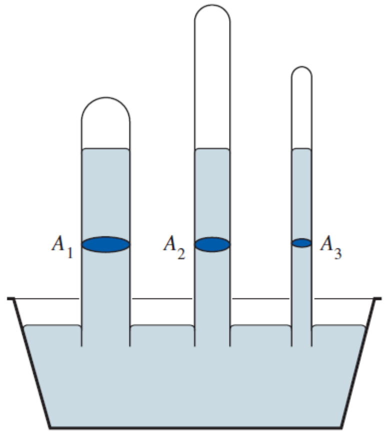


FIGURE 1–49
The length or the cross-sectional area of the tube has no effect on the height of the fluid column of a barometer, provided that the tube diameter is large enough to avoid surface tension (capillary) effects.

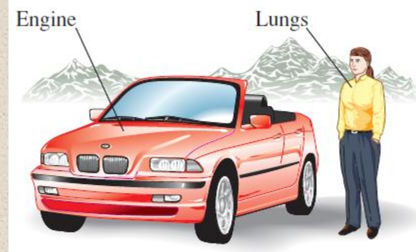
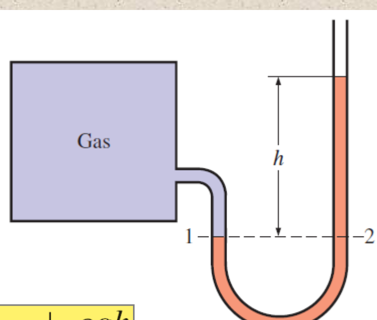


FIGURE 1–50
At high altitudes, a car engine generates less power and a person gets less oxygen because of the lower density of air.

The Manometer

It is commonly used to measure small and moderate pressure differences. A manometer contains one or more fluids such as mercury, water, alcohol, or oil.



$$P_2 = P_{atm} + \rho g h$$

FIGURE 1–55
The basic manometer.

FIGURE 1–54
A simple U-tube manometer, with high pressure applied to the right side.

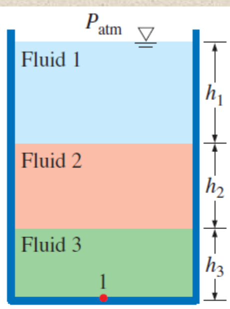


FIGURE 1–57
In stacked-up fluid layers at rest, the pressure change across each fluid layer of density ρ and height h is ρgh.

$$P_{atm} + \rho_1 gh_1 + \rho_2 gh_2 + \rho_3 gh_3 = P_1$$

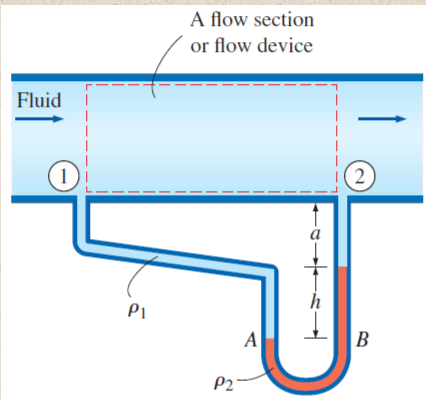


FIGURE 1–58
Measuring the pressure drop across a flow section or a flow device by a differential manometer.

$$P_1 + \rho_1 g(a + h) - \rho_2 gh - \rho_1 ga = P_2$$

$$P_1 - P_2 = (\rho_2 - \rho_1)gh$$

Other Pressure Measurement Devices

- **Bourdon tube**: Consists of a hollow metal tube bent like a hook whose end is closed and connected to a dial indicator needle.
- **Pressure transducers**: Use various techniques to convert the pressure effect to an electrical effect such as a change in voltage, resistance, or capacitance.
- Pressure transducers are smaller and faster, and they can be more sensitive, reliable, and precise than their mechanical counterparts.
- **Strain-gage pressure transducers:** Work by having a diaphragm deflect between two chambers open to the pressure inputs.
- **Piezoelectric transducers**: Also called solid-state pressure transducers, work on the principle that an electric potential is generated in a crystalline substance when it is subjected to mechanical pressure.

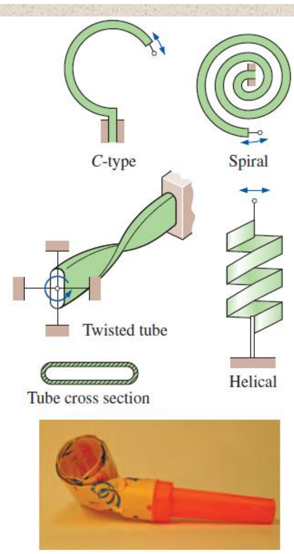


FIGURE 1–60
Various types of Bourdon tubes used to measure pressure. They work on the same principle as party noise-makers (bottom photo) due to the flat tube cross section.

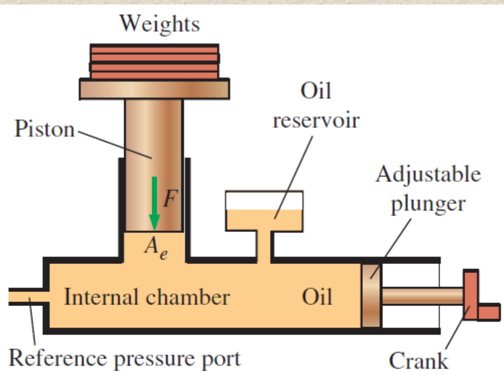


FIGURE 1–61
A deadweight tester is able to measure extremely high pressures (up to 10,000 psi in some applications).

PROBLEM-SOLVING TECHNIQUE

- Step 1: Problem Statement
- Step 2: Schematic
- Step 3: Assumptions and Approximations
- Step 4: Physical Laws
- Step 5: Properties
- Step 6: Calculations
- Step 7: Reasoning, Verification, and Discussion

EES (Engineering Equation Solver) (Pronounced as ease):
EES is a program that solves systems of linear or nonlinear algebraic or differential equations numerically. It has a large library of built-in thermodynamic property functions as well as mathematical functions. Unlike some software packages, EES does not solve engineering problems; it only solves the equations supplied by the user.

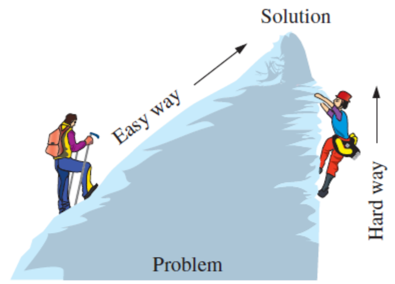


FIGURE 1–62
A step-by-step approach can greatly simplify problem solving.

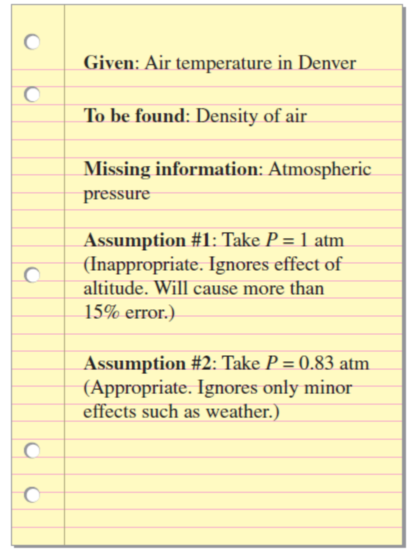


FIGURE 1–63
The assumptions made while solving an engineering problem must be reasonable and justifiable.

Summary

- Thermodynamics and energy
  - ✓ Application areas of thermodynamics
- Importance of dimensions and units
  - ✓ Some SI and English units, Dimensional homogeneity, Unity conversion ratios
- Systems and control volumes
- Properties of a system
  - ✓ Continuum
- Density and specific gravity
- State and equilibrium
  - ✓ The state postulate
- Processes and cycles
  - ✓ The steady-flow process
- Temperature and the zeroth law of thermodynamics
  - ✓ Temperature scales
- Pressure
  - ✓ Variation of pressure with depth
- The manometer
  - ✓ Other pressure measurement devices
- The barometer and atmospheric pressure
- Problem solving technique

Any Questions???