• Please read the Chapter in Ahrens. I think the text is relatively clear
• You are responsible for all the material covered in the text
• In class, I will only go over the most important points
• The main focus of class time will be on
  – Explanation of more difficult concepts
  – Covering quantitative material
• Question:
  – What are the physical quantities that define the property of air?
    • What can we measure that can tell us about the property of air around us?
Properties of Air

• Density of air
  – Density = mass per unit volume
  \[ \rho = \frac{M}{V} \]  
  Stull (1.7)

  • S.I. unit: kg/m\(^3\)
  • Near sea level, air density \( \sim 1.2 \text{ kg/m}^3 \)
  • Density of liquid water \( \sim 1000 \text{ kg/m}^3 \)

  – Question for thought: What is the total mass of air in this room?
• Air pressure
  – Pressure = force per unit area

\[ P = \frac{F}{A} \quad \text{Stull (1.5)} \]

• Force? – weight of the atmosphere above
  – Weight of atmosphere = mass x gravity
• S.I. unit of pressure: Pa (Pascal) = 1 N/m²
• Average pressure at sea level – 101325 Pa
• Popular unit: hPa = 100 Pa = 1 mb; kPa = 1000 Pa
  – Average sea level pressure in these units:
    1013.25 hPa = 1013.25 mb = 101.325 kPa
• (Other units: 29.92 in. Hg; 14.7 psi)
Hydrostatic Equilibrium

• Question for thought: Gravity constantly pulls the atmosphere towards the Earth’s surface. What keeps the entire atmosphere from collapsing to the surface?

• Answer: The pressure gradient force:
  – Pressure is different at different altitude
  – Analogy: the offensive and defensive lines in a football game
Net upward force = \text{downward force due to gravity}

\[ [P - (P + \Delta p)] \times A = mg = \rho \times A \times \Delta z \times g \]

Hence \[ \Delta p = -\rho g \Delta z \] -- Hydrostatic equation  Stull (1.17)

Near earth’s surface: \[ \Delta p \sim -12 \text{ Pa for each m (or 12 hPa per 100 m)} \]
Classwork Example

• Using the hydrostatic equation, calculate the pressure exerted by mercury with a depth of 1m. Note that the density of mercury is about 13600 kg/m³.
  \[ \Delta p = -\rho g \Delta z = -13600 \times 9.81 \times (-1) = 133416 \text{ Pa} \]

• What is the standard atmospheric pressure at sea level?
  \[ 1013.25 \text{ hPa} = 101325 \text{ Pa} \]

• What depth of mercury will exert the same pressure as the standard atmosphere?
  Rewrite hydrostatic equation, we get: \[ \Delta z = -\frac{\Delta p}{\rho g} \]
  \[ \text{Hence } \Delta z = -\frac{101325}{13600/9.81} = -0.759 \text{ m} \]

• If the liquid is water instead of mercury (density of water is about 1000 kg/m³), do we need a taller or shorter column of water to exert the same pressure? Why?
  Water is less dense than mercury, hence same depth of water exerts less pressure compared with mercury, thus we need a taller column of water to exert the same pressure.
• **Temperature**
  – Measures how fast air molecules move
    • Is proportional to the average *kinetic energy of random motion* of air molecules
  – S.I. unit: K (Kelvin)
  – Other popular units: °C (Celsius); °F (Fahrenheit)
    • $T_K = T_C + 273.15$
    • $T_F = T_C \times \frac{9}{5} + 32$
    • $T_C = (T_F - 32) \times \frac{5}{9}$
  – Water freezes at $0^\circ$C = 273.15K = 32°F
  – Water boils at $100^\circ$C = 373.15K = 212°F
Numerical examples

• Express 35 °C in terms of absolute temperature:
  – $T_K = T_C + 273.15 = 35 + 273.15 = 308.15$ K

• Express 35 °C in terms of °F
  – $T_F = T_C \times \frac{9}{5} + 32 = 35 \times \frac{9}{5} + 32 = 95$ °F

• Express 59°F in terms of °C
  – $T_C = (T_F - 32) \times \frac{5}{9} = (59 - 32) \times \frac{5}{9} = 15$ °C
Atmospheric Layers

Layers are defined by whether average air temperature is increasing or decreasing with altitude:
- Troposphere – decreasing
- Stratosphere – increasing
- Mesosphere – decreasing
- Thermosphere – increasing

These layers are separated by the tropopause, stratopause, and mesopause.