Temperature

- **Temperature** - the measure of average kinetic energy (KE) of a gas, liquid, or solid. KE is *energy of motion*.
- KE = \( \frac{1}{2} mv^2 \) where \( m \)=mass and \( v \)=velocity (speed)
Temperature

- All molecules have KE whether solid, liquid, or gas
- KE can be rotational, vibrational, or displacement (ex. moving from A to B)
- In solids, molecules are “locked” but can rotate and vibrate
- In liquids, molecules can move slightly but are “weakly tethered” to other molecules
- In gases, molecules are freely moving about
Temperature

• For **air and other gases** (in the troposphere only), it is common to consider the KE to be proportional to the **number of molecular collisions**.
• More collisions means higher temperatures while less collisions means lower temperatures.

Cool gas, fewer and less energetic collisions

Hot gas, more and more energetic collision

Bolte, Waters, Wilden
- Kelvin scale is called the *absolute temperature scale* because it is the only scale that directly measures KE.
- There are negative temperatures on the other two scales and it is impossible to have a negative KE.

\[
\begin{align*}
°F &= 1.8(C) + 32 \\
°C &= (F - 32) \div 1.8 \\
K &= C + 273
\end{align*}
\]
• Weather observations are plotted on a station model (circle)

• Air temperature (T) is plotted in the upper left

• Dew Point temperature (T_D) is plotted in the lower left

• No units ever appear on station circle
• Heat is a measure of the **TOTAL** kinetic energy

• Function of the KE per molecule (T) and the number of molecules

• Think of heat as being equal to $T \times \# \text{ of molecules}$ (fake equation that makes the correct point)
• **Conduction** - heat that is transferred via molecule to molecule contact

• **Convection** - heat that is transferred by moving air or water

• **Radiation** - heat that is transferred by wave-like energy (ex. photons) without any molecular contact and with no air movement involved
• **Radiation** - Earth is warmed by the sun via radiation

• **Conduction** - Surface air is heated by touching the warmer surface of the earth

• **Convection** - Warm air rising into the atmosphere transfers heat from the lowest levels to above
The environmental lapse rate (ELR) is the rate of change of temperature with height between two altitudes in a layer of atmosphere.

ELR is assumed to be constant between those two points.

To calculate the ELR, one needs two temperatures at two different altitudes (heights). Use the formula \((T_2 - T_1)/(H_2 - H_1)\) where T is temperature and H is height.

Answers must always be reduced to °F/1,000 ft.
Temperature

\[ ELR = \frac{(T2 - T1)}{(H2 - H1)} \]

Example:

The air at 2,000 feet is 40 °F while the air at 6,000 feet is 10 °F. Calculate the ELR.

- Jot down the two points being considered:
  \[ T1 = 40 \, ^\circ F, \, H1 = 2,000 \, ft, \, T2 = 10 \, ^\circ F, \, H2 = 6,000 \, ft \]

- Use the formula: \( (10^\circ F - 40^\circ F)/(6,000ft - 2,000ft) \)

- Result = -30°F/4,000ft.

- Divide top and bottom by 4 to reduce the ratio to °F/1,000 ft.

- Answer: -7.5°F / 1,000ft.
Temperature

$$ELR = \frac{(T_2 - T_1)}{(H_2 - H_1)}$$

Example:

- The previous ELR means that the air temperature is cooling 7.5°F for each 1,000 feet of elevation

- One can use this ELR value to estimate any temperature between 2,000 and 6,000 feet

- Ex., if one wanted to estimate the temperature at 4,000 feet, the ELR shows that there should be a decrease of 15°F (2 x 7.5°F) moving from 2,000 feet to 4,000 feet

- Because the air at 2,000 feet is 40°F, the air at 4,000 feet is 25°F (40°F – 15°F)
The atmosphere is divided into four distinct regions based on how temperature changes with height (ELR).
**Temperature**

**TROPOSPHERE**

**T change with height?**  
Cooling (-ELR)

**Why?**  
Ground is heat source

- Contains most of the atmosphere even though it is very shallow.
- Gravity causes the air to be concentrated in this layer.
- The normal environmental lapse rate (ELR) is negative (cooling with increasing height) because the ground is the heat source.
- Note: a temperature inversion may exist in a shallow region within troposphere which results in a positive ELR (warming with height).
Temperature

STRATOSPHERE

T change with height?  Warming (+ELR)

Why?  Ozone absorbs sun’s uv rays
Temperature

MESOSPHERE

T change with height? Cooling (-ELR)

Why? Moving away from both heat sources
THERMOSPHERE

T change with height? Warming (+ELR)

Why? Few, fast-moving molecules, high KE

In reality, the air is not "hot to the touch" because there is so little air present one would not feel anything.
Temperature

- **Adiabatic process** describes a rising or sinking air parcel and the temperature changes associated with that motion
- As an air parcel rises it moves into an area of lower pressure aloft
- This lower pressure causes the air parcel to expand
- The expansion allows more room for the air molecules inside the parcel to move about
- More room means fewer collisions between the molecules
- Fewer collisions means less average KE
- Less average KE means cooler temperatures
- Therefore, **RISING AIR ALWAYS COOLS**
**Adiabatic process** describes a rising or sinking air parcel and the temperature changes associated with that motion.

- As an air parcel sinks it moves into an area of higher pressure below.
- This higher pressure causes the air parcel to be compressed (shrinks).
- The compression allows less room for the air molecules inside the parcel to move about.
- Less room means more collisions between the molecules.
- More collisions means greater average KE.
- Greater average KE means warmer temperatures.
- Therefore, **SINKING AIR ALWAYS WARMS**.
The rate of warming or cooling is constant and is known as the *adiabatic lapse rate (ALR)*. The ALR = 5.5°F/1,000 ft or 10°C/1 Km

- **Rising air** causes *cooling*
- Cooling water vapor in air leads to clouds and precipitation = **wet conditions**

- **Sinking air** causes *warming*
- Warming water vapor prevents clouds from forming = **dry conditions**