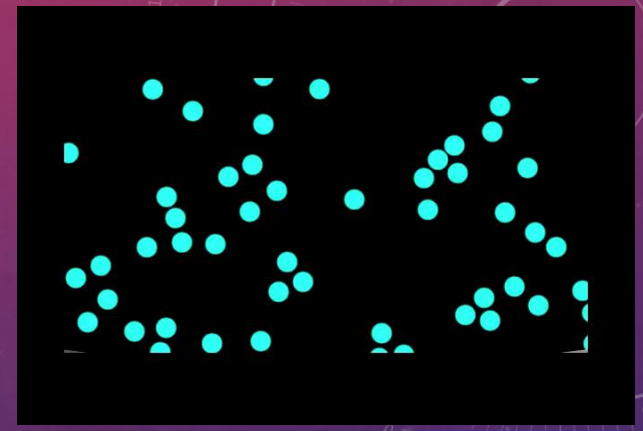
GAS LAWS

PES 1000 – PHYSICS IN EVERYDAY LIFE

MACRO VARIABLES OF A GAS



The state of gas can be completely described by three parameters:

- Volume: The amount of space the particles occupy
  - The variable is usually V.
  - The SI units are m^3 .
- Pressure: The combined force per unit area of all the particles on a surface
  - The variable is often P.
  - The SI unit is the *Pascal* (Pa). 1 Pascal = 1 Newton/m^2.
- Temperature: The average kinetic energy of all of the particles
  - The variable used is generally T.
  - The SI unit is the *Kelvin* (K).

Changes to one of these parameters usually influence both of the others. We would like to know how one parameter changes another while holding the third parameter constant.

CHARLES' LAW (THE LAW OF PRESSURE)

- Jacques Charles (1746 – 1823) studied the relationship between Volume and Temperature while keeping Pressure constant.
  - He found that if Temperature increased, Volume increased, as well.
- Example: Balloons
  - Charles was a balloonist.
  - A balloon is under a constant external pressure of one atmosphere, or 101,000 Pa.
  - As the air in the balloon is heated, the balloon expands, increasing the volume.
  - Two equations that shows this relationship are:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2} = constant \qquad V_2 = \frac{T_2}{T_1} V_1$$

Temperature ↑ Volume ↑

GAY-LUSSAC'S LAW (THE LAW OF VOLUME)

- Joseph Gay-Lussac (1778 – 1850) studied the relationship between Temperature and Pressure while keeping Volume constant.
  - He found that if Temperature increased, Pressure increased, as well.
- Example: A hair spray can thrown into a fire (*Don't Do This!*)
  - The steel can maintains a constant volume.
  - As the contents heat up, the pressure increases.
  - Eventually, the can ruptures and flies out of the fire like a rocket!
  - Two equations that shows this relationship are:

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} = constant \qquad P_2 = \frac{T_2}{T_1} P_1$$

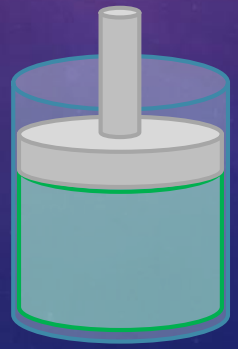
Temperature ↑ Pressure ↑

BOYLE'S LAW (THE LAW OF TEMPERATURE)

- Robert William Boyle (1627 -1691) studied the relationship between Pressure and Volume while keeping Temperature constant.
  - He found that if Pressure increased, Volume *decreased*.
- Example: Compressed air
  - A compressor takes in air at atmospheric pressure.
  - Inside, a piston exerts extra pressure, compressing the air into a smaller volume.
  - Two equations that shows this relationship are:

$$P_1 * V_1 = P_2 * V_2 = constant$$

$$V_2 = \frac{P_1}{P_2} V_1$$



Pressure ↑ Volume ↓

IDEAL GAS LAW

- We can combine all three of these laws into one, which is called the *Ideal Gas Law*.
- The three gas laws are here. The each equal a constant.
- The combination PV/T is, therefore, also a constant.
- That constant is sometimes called *nR*, which depends on the type of gas.
- With a little algebra, we get the usual form of the Ideal Gas Law:
  - $PV = nRT$
- The Ideal Gas Law is useful when you know two of the three variables and you want to calculate the third.
- Example: If I know *nR* for the hair spray gas inside the room-temperature can, and I know the volume of the can, I can calculate the pressure inside.

$$\frac{P}{T} = constant$$

$$\frac{V}{T} = constant$$

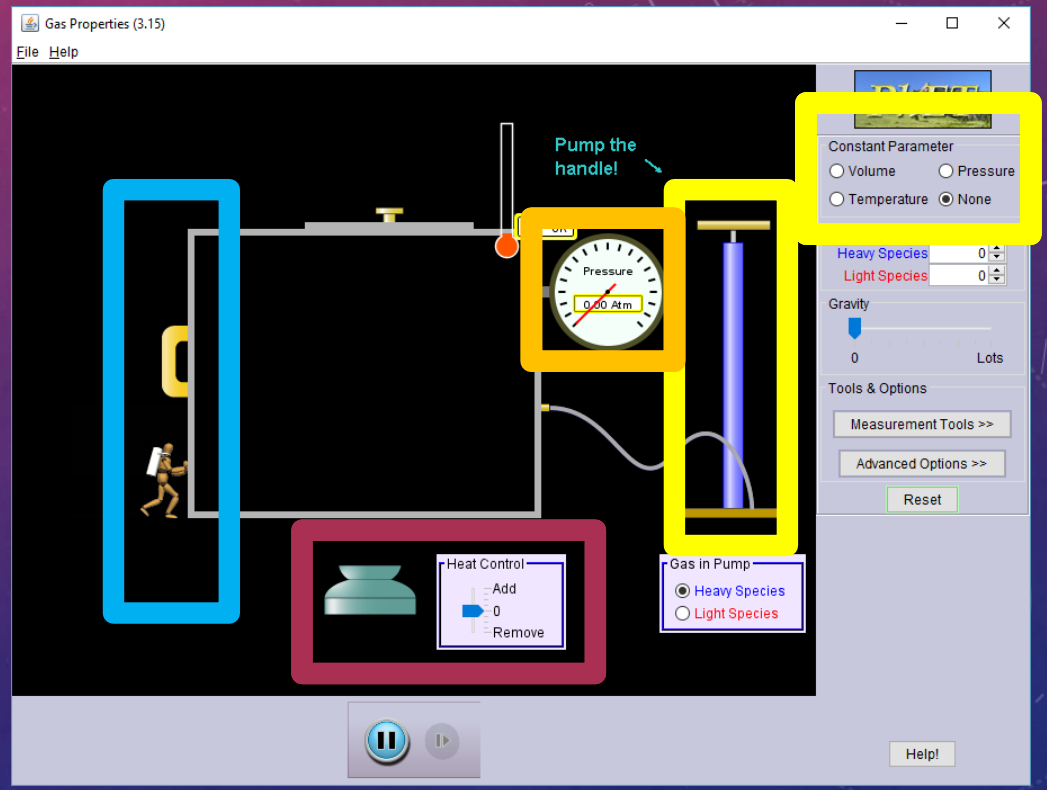
$$PV = constant$$

$$\frac{PV}{T} = nR$$

IDEAL GAS SIMULATION

- Link to simulation: https://phet.colorado.edu/en/simulation/legacy/gas-properties

- Things to do:
  - Pump some gas into the chamber.
  - Select ‘Pressure’ as the Constant Parameter.
    - Add heat, and watch the volume go up.
  - Now select ‘Volume’ as the Constant Parameter.
    - Add heat, and watch the pressure go up.
  - Finally, select ‘Temperature’ as the Constant Parameter.
    - Slide the left side of the chamber to the right, decreasing the volume, and watch the pressure go up.



CONCLUSION

- Three variables can be used to describe the state of a sample of gas.
  - Pressure, Temperature, and Volume
- There are three gas laws, each assuming one of these variables is constant and relating the other two variables.
  - Charles' Law – Pressure is constant.
  - Gay-Lussac's Law – Volume is constant.
  - Boyle's Law – Temperature is constant.
- The three gas laws can be combined into the Ideal Gas Law, which relates all three variables.
  - $PV = nRT$