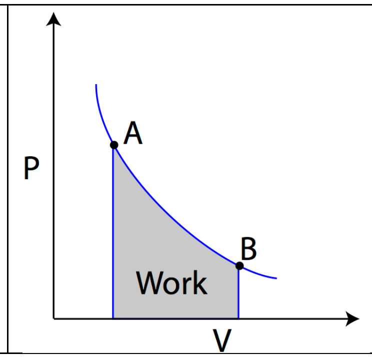
Thermodynamics

5a – Ideal Gas Processes

PV Diagrams

- A pressure vs. volume Graph.
- Represents an ideal gas.
- Each point on a PV diagram represents a triplet of Values (P, V, T).

$$PV = nRT$$

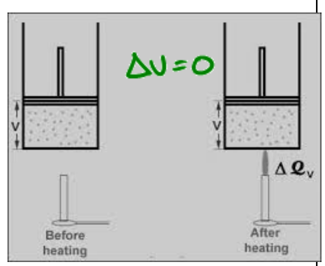


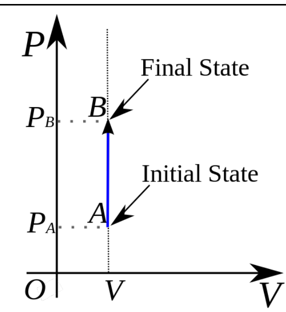
4 Processes – **Iso**choric, **Iso**baric, **Iso**thermal, and Adiabatic

Remember… **Iso** = SAME!

Isochoric Process

- Constant volume process.
- While volume is constant… pressure is *not*!
- The gas is confined in a rigid container ($V_i = V_f$)





Example:
A certain Gas of volume 0.40 m^3, pressure of 4.5 bar and temperature of 1300 ^{o}C is heated to in a cylinder to 9.0 bar when the volume remains constant. Calculate the temperature (in Kelvin) at the end of the process. (1 bar = 100,000 Pa)

$P_1V_1 = n_1RT_1$ $\quad$ $P_2V_2 = n_2RT_2$

$\frac{V_1}{n_1} = \frac{RT_1}{P_1}$ $\quad$ $\frac{V_2}{n_2} = \frac{RT_2}{P_2}$

Since $V_1 = V_2$ and $n_1 = n_2$ …

$$\frac{RT_1}{P_1} = \frac{RT_2}{P_2}$$

$$T_2 = \frac{T_1P_2}{P_1} = \frac{(1573.15K)(900,000Pa)}{450,000Pa}$$

$$T_2 = 3146K = 3100K$$

Example:
On a cold morning the pressure inside a car tire is 28.0 psi when the temperature is 2.0 ^{o}C. As the sun comes out the tire warms the black tire and the temperature reaches 28 ^{o}C. What is the tire pressure (in psi) at this temperature. (1 atm = 14.7 psi)

$P_1V_1 = n_1RT_1$ $\quad$ $P_2V_2 = n_2RT_2$

$\frac{V_1}{n_1} = \frac{RT_1}{P_1}$ $\quad$ $\frac{V_2}{n_2} = \frac{RT_2}{P_2}$

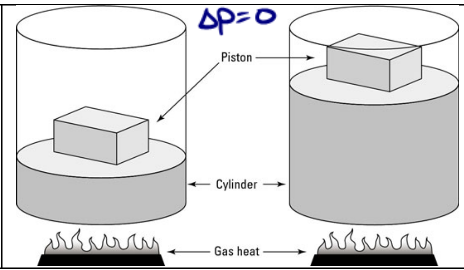
$$\frac{RT_1}{P_1} = \frac{RT_2}{P_2}$$

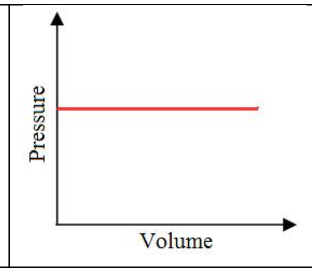
$$P_2 = \frac{P_1T_2}{T_1} = \frac{(301.15K)}{(275.15K)}(28.0 PSI)$$

$$P_2 = 30.6 PSI$$

Isobaric Process

- Constant pressure process. ($P_i = P_f$)
- Constant pressure can be achieved with a piston when heat is applied to the gas.





Example:
A movable piston is placed on a 3.0 L cylinder containing a gas at 60.0 °C. The gas is then cooled until the final temperature is 20 °C. What is the final volume that the gas occupies?

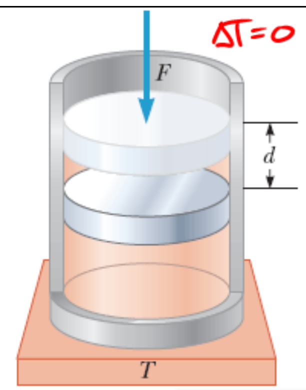
$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

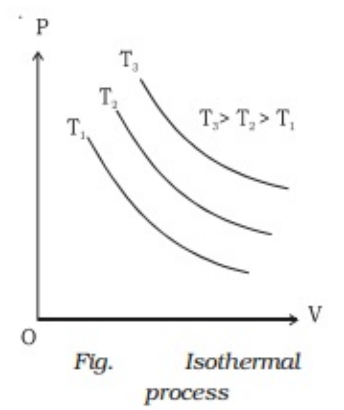
$$V_2 = \frac{T_2}{T_1} \cdot V_1 = \left(\frac{293.15K}{333.15K}\right)(3.0L) = \boxed{2.6\ L}$$

Isothermal Process

- Constant Temperature process. ($T_i = T_f$)
- Can be achieved by using a heat reservoir.

Heat Reservoir: (or Heat Sink) is a thermodynamic system with a **heat** capacity that is large enough that when it is in thermal contact with another system of interest or its environment, its temperature remains effectively constant. *Remember the rock in the Atlantic Ocean?*





Example:
A south pacific pearl diver takes a deep breath at the surface of the ocean. She fills her lungs with 4.5 L of air, and then dives to a depth of 6.0 m. At this death what is the volume of air occupied by the pearl diver's lungs? *Wait… do we need to remember something from the previous unit? Classic Flawson…*

Umm… Depth!

$$P_1 = 1.01 \times 10^5\ Pa$$

$$P_2 = P_0 + \rho_w g d = 1.01 \times 10^5\ Pa + (1030)(9.8)(6.0) = 1.62 \times 10^5\ Pa$$

$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2} = \frac{(1.01 \times 10^5\ Pa) \times (4.5L)}{(1.62 \times 10^5\ Pa)} = \boxed{2.8\ L}$$

Isothermal expansion occurs when the gas expands and does work on the surroundings.

Isothermal contraction occurs when the gas contracts and the surroundings does work on the gas.

Adiabatic Process

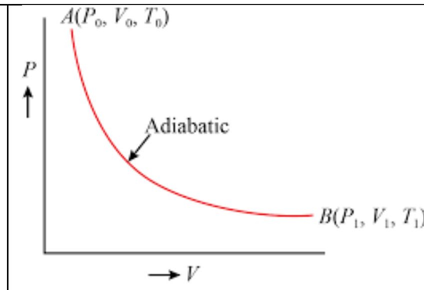
- Constant HEAT process. (Q = 0)
- Change in P, V, and T!
- Therefore… from the 1st Law simplifies

$$\Delta U = W + \cancel{Q}$$

An adiabatic expansion lowers the temp of the gas.

An adiabatic compression raises the temp of the gas.

This process allows one to use Work instead of Heat to change the temperature of a gas.



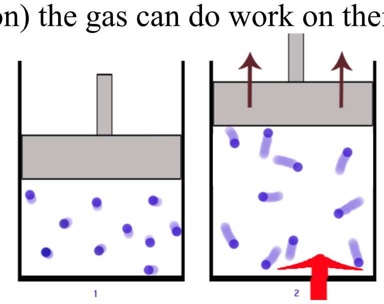
(P–V Diagram)

Thermodynamics

5b – Thermodynamics of an Ideal-Gas Process

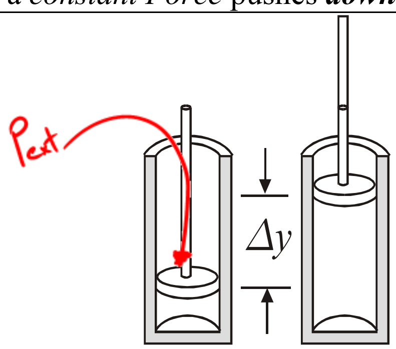
Remember that Heat and Work are just two different ways to add energy to a system.

When a gas expands (an expanding piston) the gas can do work on their surroundings.



due to P_{ext}

When a *constant Force* pushes ***down*** on a piston object Work can be calculated….

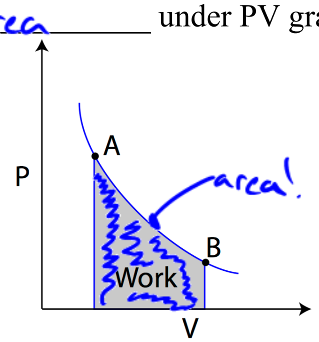


$W = F \cdot d$ $P_{ext} = \frac{F}{A}$ $F = P_{ext} \cdot A$

$W = (P_{ext} \cdot A)d = P_{ext} \cdot A \cdot \Delta y$

$W = P \cdot \Delta V$ → whoa…

And equally important…. Work is the area under PV graph between V_i and V_f. (ΔV)



Ok… A couple of important details