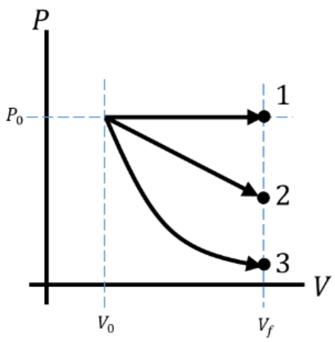
THERMODYNAMICS: PROCESS TYPES

Process Types:

Any thermodynamic event can be described by one or more of the process types listed below. Classification of an event allows for assumptions to be made that simplify the problem-solving process. A P-V diagram is used to showcase three different processes:



	Distinction	Type	Meaning	Work formula
1	n = 1	Isobaric	Constant pressure	$W = P(V_2 - V_1)$
2	n = 0	Isothermal	Constant temperature	$W = P_1V_1 \ln\left(\frac{V_2}{V_1}\right)$
3	$n \neq 0 \neq 1 \neq k$	Polytropic	$PV^n = Constant$	$W = \frac{P_2V_2 - P_1V_1}{1-n}$
	n = k = $\frac{C_p}{C_v}$	Isentropic	Constant entropy	

Knowing the ideal gas law, $PV = RT$, where R is universal gas constant:

$$R = 8.314 \frac{kJ}{kmol \cdot K} = \frac{\bar{R}}{m_{molar}} = R$$

- Isobaric:

$$W = \int_{V_1}^{V_2} PdV = P\int_{V_1}^{V_2} dV = \boldsymbol{P(V_2 - V_1)}$$

- Isothermal:

$$W = \int_{V_1}^{V_2} PdV = \int_{V_1}^{V_2} \frac{RT}{V}dV = RT\int_{V_1}^{V_2} \frac{1}{V}dV = RT \cdot [\ln(V_2) - \ln(V_1)] = RT \cdot \ln\left(\frac{V_2}{V_1}\right) = \boldsymbol{P_1V_1 \cdot \ln\left(\frac{V_2}{V_1}\right)}$$

- Polytropic:

$n \neq 0 \neq 1 \neq k$ yields $PV^n = constant$ such that $P_1V_1^n = P_2V_2^n$

$$\frac{P_2}{P_1} = \left(\frac{V_1}{V_2}\right)^n \qquad \frac{T_2}{T_1} = \left(\frac{P_2}{P_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$$

$$W = \int_{V_1}^{V_2} PdV = C\int_{V_1}^{V_2} V^{-n}dV = \frac{P_2V_2 - P_1V_1}{1-n} = \boldsymbol{\frac{mR(T_2 - T_1)}{1-n}}$$

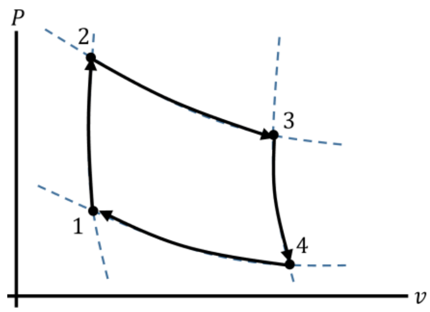
- Ideal gas:

$$n \neq 1: W = \frac{m_{tot}R(T_2 - T_1)}{1-n} = \frac{m_{tot}\bar{R}(T_2 - T_1)}{m_{molar} \cdot (1-n)}$$

$$n = 1: W = mRT \cdot ln\left(\frac{V_2}{V_1}\right)$$

A PV diagram is also useful in understanding compression/expansion that occurs in a thermodynamic event. The curves can be classified based on their changes in pressure and volume.

Below is an example of a thermodynamic cycle that occurs in a 4-stroke engine:



Event	*Process Type*	*Reaction*	*Stage of Engine cycle*
$1 \rightarrow 2$	Adiabatic + isentropic	Compression	Compression
$2 \rightarrow 3$	Isothermal	Expansion	Intake
$3 \rightarrow 4$	Adiabatic +isentropic	Expansion	Combustion
$4 \rightarrow 1$	Isothermal	Compression	exhaust

For more information, visit a tutor. All appointments are available in-person at the Student Success Center, located in the Library, or online. Adapted from Moran, M. J., Shapiro, H. N., Boettner, D. D., & Bailey, M. B. (2014). *Fundamentals of Engineering Thermodynamics.* Hoboken, NJ: Wiley.