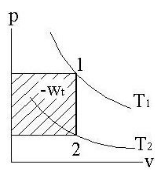
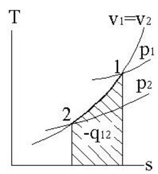
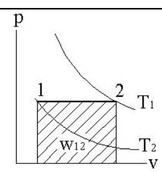
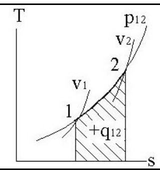
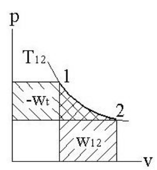
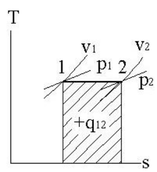
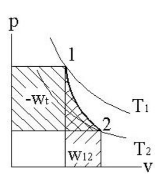
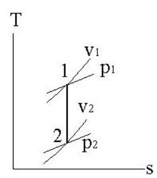
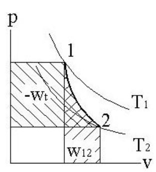
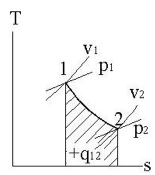
Thermodynamic Processes

(All Equations are Mass-Specific, Simplifications for Perfect Gas, Reversible Process)

TD Process	Work-Diagram	Heat-Diagram	Thermodynamic State Quantities			Heat Transfer	Mechanical (Expansion) Work (Closed System)	Technical Work (Open System)	Change in Entropy	Change in Internal Energy
$\left(pv^n = const\right)$	pv-diagram	Ts-diagram	$\frac{T_2}{T_1}$	$\frac{p_2}{p_1}$	$\frac{v_2}{v_1}$	$\Delta q = q_{12}$ $\left(= \int du + \int pdv = \int dh - \int vdp\right)$	$w_{m12} = \int_1^2 pdv$	$w_{t12} = -\int_1^2 vdp$	$\Delta s_{12} = s_2 - s_1 = \int_1^2 \frac{dq}{T}$	$du = c_v dT$
Isochoric v = const ($n = \infty$, i.e. $p^{1/n} v = const$)			$= \frac{p_2}{p_1}$	$= \frac{T_2}{T_1}$	$= 1$	$= u_2 - u_1 = \int_{T_1}^{T_2} c_v dT$ $= c_v\left(T_2 - T_1\right)$ $= c_p\left(T_2 - T_1\right) - v\left(p_2 - p_1\right)$	$= 0$	$= -v\left(p_2 - p_1\right)$	$= c_v \ln \frac{T_2}{T_1}$ $= c_v \ln \frac{p_2}{p_1}$	$du = c_v dT$ $\Delta u = c_v\left(T_2 - T_1\right)$
Isobaric P = const ($n = 0$)			$= \frac{v_2}{v_1}$	$= 1$	$= \frac{T_2}{T_1}$	$= h_2 - h_1$ $= c_p\left(T_2 - T_1\right)$ $= c_v\left(T_2 - T_1\right) + p\left(v_2 - v_1\right)$	$= p\left(v_2 - v_1\right)$ $= R\left(T_2 - T_1\right)$	$= 0$	$= c_p \ln \frac{T_2}{T_1}$ $= c_p \ln \frac{v_2}{v_1}$	$du = c_v dT$ $\Delta u = c_v\left(T_2 - T_1\right)$
Isothermal T = const ($n = 1$)			$= 1$	$= \frac{v_1}{v_2}$	$= \frac{p_1}{p_2}$	$= w_{12}$ $= RT \ln \frac{p_1}{p_2}$ $= RT \ln \frac{v_2}{v_1}$ $\left(RT = p_1 v_1 = p_2 v_2\right)$	$= q_{12}$ $= RT \ln \frac{p_1}{p_2}$ $= RT \ln \frac{v_2}{v_1}$ $\left(RT = p_1 v_1 = p_2 v_2\right)$	$= -w_{12}$	$= R \ln \frac{v_2}{v_1}$ $= R \ln \frac{p_1}{p_2}$ $\left(= -R \ln \frac{p_2}{p_1}\right)$	$du = 0$ $\Delta u = 0$
Isentropic s = const $dq = 0$ ($n = \gamma$)			$= \left(\frac{v_1}{v_2}\right)^{\gamma - 1}$ $= \left(\frac{p_2}{p_1}\right)^{\frac{\gamma - 1}{\gamma}}$	$= \left(\frac{v_1}{v_2}\right)^{\gamma}$ $= \left(\frac{T_2}{T_1}\right)^{\frac{\gamma}{\gamma - 1}}$	$= \left(\frac{T_1}{T_2}\right)^{\frac{1}{\gamma - 1}}$ $= \left(\frac{p_1}{p_2}\right)^{\frac{1}{\gamma}}$	$= 0$	$= -\left(u_2 - u_1\right)$ $= c_v\left(T_1 - T_2\right)$	$= -\left(h_2 - h_1\right)$ $= -\gamma \cdot w_{12}$ $= -\gamma \cdot c_v\left(T_2 - T_1\right)$ $= -c_p\left(T_2 - T_1\right)$	$= 0$	$du = c_v dT = -w_{12}$ $\Delta u = c_v\left(T_2 - T_1\right) = \frac{R}{\gamma - 1}\left(T_2 - T_1\right)$

TD Process	Work-Diagram	Heat-Diagram	Thermodynamic State Quantities			Heat Transfer	Mechanical (Expansion) Work (Closed System)	Mechanical Work (Open System)	Change in Entropy	Change in Internal Energy
$\left(pv^n = const\right)$	pv-diagram	Ts-diagram	$\frac{T_2}{T_1}$	$\frac{p_2}{p_1}$	$\frac{v_2}{v_1}$	$\Delta q = q_{12}$ $\left(= \int de + \int pdv = \int dh - \int vdp\right)$	$w_{12} = \int_1^2 pdv$	$w_{t12} = -\int_1^2 vdp$	$\Delta s_{12} = s_2 - s_1 = \int_1^2 \frac{dq}{T}$	$du = c_v dT$
Polytropic ($n = n$; typically $1 < n < \gamma$)			Identical to isentropic process, replace γ by n.			$= c_v \frac{n-\gamma}{n-1}\left(T_2 - T_1\right)$ $= c_n\left(T_2 - T_1\right)$	$= -\left(e_2 - e_1\right)\frac{\gamma - 1}{n-1}$ $= c_v \frac{\gamma - 1}{n-1}\left(T_1 - T_2\right)$ $= \frac{1}{n-1}\left(p_1 v_1 - p_2 v_2\right)$ $= \frac{p_1 v_1}{n-1}\left(1 - \frac{T_2}{T_1}\right)$ $= \frac{p_1 v_1}{n-1}\left[1 - \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}\right]$ $= \frac{p_1 v_1}{n-1}\left[1 - \left(\frac{v_1}{v_2}\right)^{n-1}\right]$ $\left(p_1 v_1 = RT_1\right)$	$= -\left(h_2 - h_1 - q_{12}\right)$ $= -n \cdot w_{12}$	$= c_v \ln\frac{T_2}{T_1} + R\ln\frac{v_2}{v_1}$ $= c_v \frac{n-\gamma}{n-1}\ln\frac{T_2}{T_1}$ $= c_n \ln\frac{T_2}{T_1}$ $= c_p \ln\frac{T_2}{T_1} - R\ln\frac{p_2}{p_1}$ $= c_v \ln\frac{p_2}{p_1} + c_p \ln\frac{v_2}{v_1}$	$du = c_v dT$ $\Delta u = c_v\left(T_2 - T_1\right)$

1st Law of Thermodynamics:

Closed System: $du = \delta q - \delta w = \delta q - pdv; w_{m12} = \int_1^2 pdv$

Open System: $dh = \delta q - \delta w_t = \delta q + vdp; w_{t12} = -\int_1^2 vdp$