ESO 201A: Thermodynamics

2016-2017-I semester

Energy Analysis of Closed Systems: part 2

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Learning objective

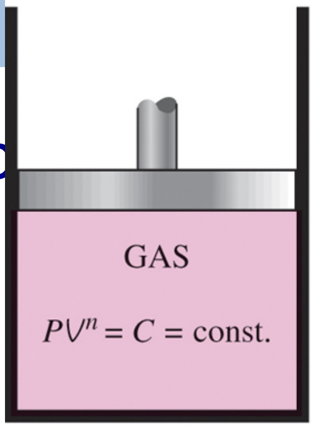
- Examine the moving boundary work or $P\,dV$ work commonly encountered in reciprocating devices such as automotive engines and compressors.
- Identify the first law of thermodynamics as simply a statement of the conservation of energy principle for closed (fixed mass) systems.
- Develop the general energy balance applied to closed systems.
- Define the specific heat at constant volume and the specific heat at constant pressure.
- Relate the specific heats to the calculation of the changes in internal energy and enthalpy of ideal gases.
- Describe incompressible substances and determine the changes in their internal energy and enthalpy.
- Solve energy balance problems for closed (fixed mass) systems that involve heat and work interactions for general pure substances, ideal gases, and incompressible substances.

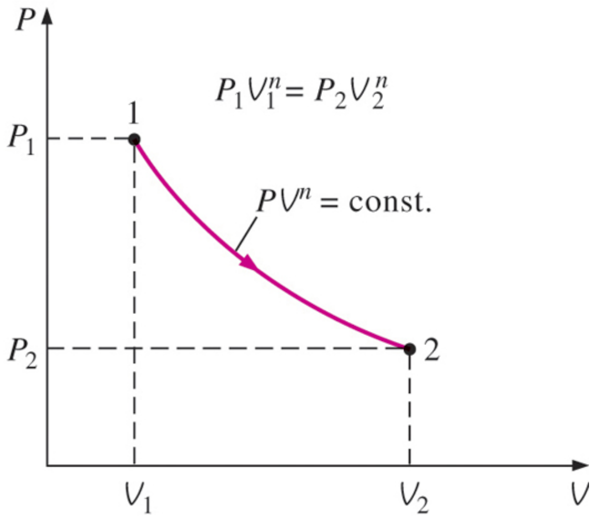
Polytropic process

During actual expansion/compression process o

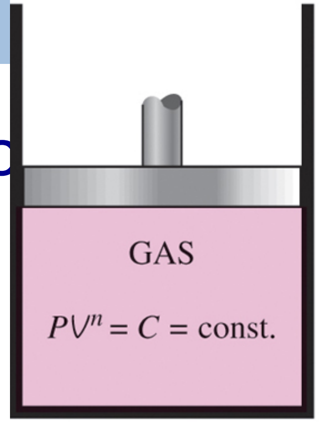
gases P and V often are related to $P = CV^{-n}$

Polytropic process: *C*, *n* (polytropic exponent) constants





Polytropic process



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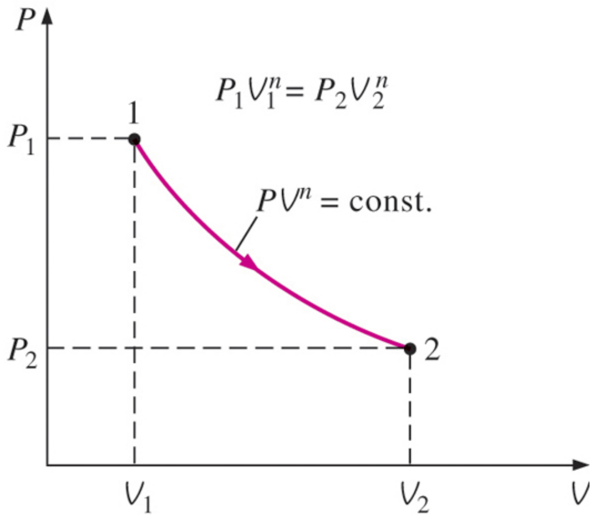
Polytropic process: *C*, *n* (polytropic exponent) constants

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-n}\,dV = C\,\frac{V_2^{-n+1} - V_1^{-n+1}}{-n+1} = \frac{P_2V_2 - P_1V_1}{1-n}$$

Ideal gas: PV=mRT

$$W_b = \frac{mR(T_2 - T_1)}{1-n} \qquad n \neq 1$$



Polytropic process

PV=C

When n = 1(isothermal process)

$$W_b = \int_1^2 P\,dV = \int_1^2 CV^{-1}\,dV = PV\ln\left(\frac{V_2}{V_1}\right)$$

Ideal gas: PV=mRT

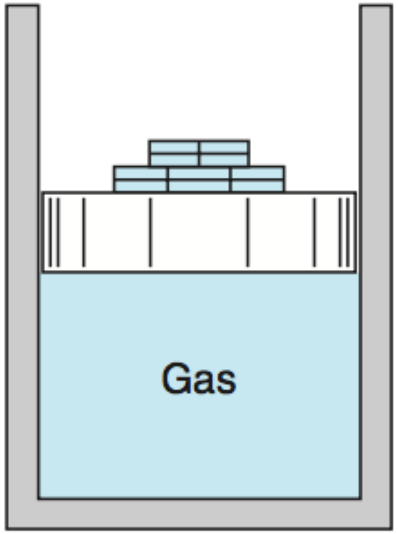
$$W_b = \int_1^2 P\,dV = P_0 \int_1^2 dV = P_0(V_2 - V_1)$$

Constant pressure process

What is the boundary work for a constant-volume process?

Example

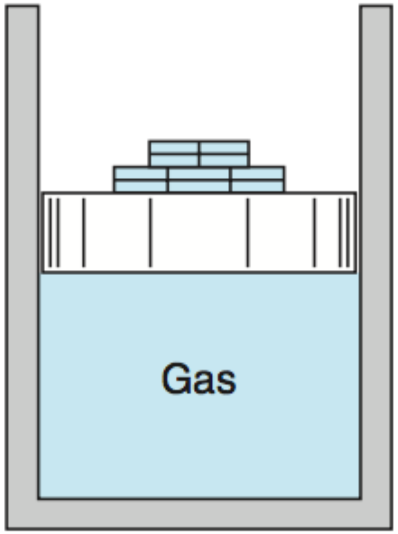
Consider as a system the gas in the cylinder shown in Figure. The cylinder is fitted with a piston on which a number of small weights are placed. The initial pressure is 200 kPa, and the initial volume of the gas is 0.04 m^3.



a) Let a Bunsen burner be placed under the cylinder, and let the volume of the gas increase to 0.1 m^3 while the pressure remains constant. Calculate the work done by the system during this process.

Example

B) Consider the same system and initial conditions, but at the same time that the Bunsen burner is under the cylinder and the piston is rising, remove weights from the piston at such a rate that, during the process, the temperature of the gas remains constant.

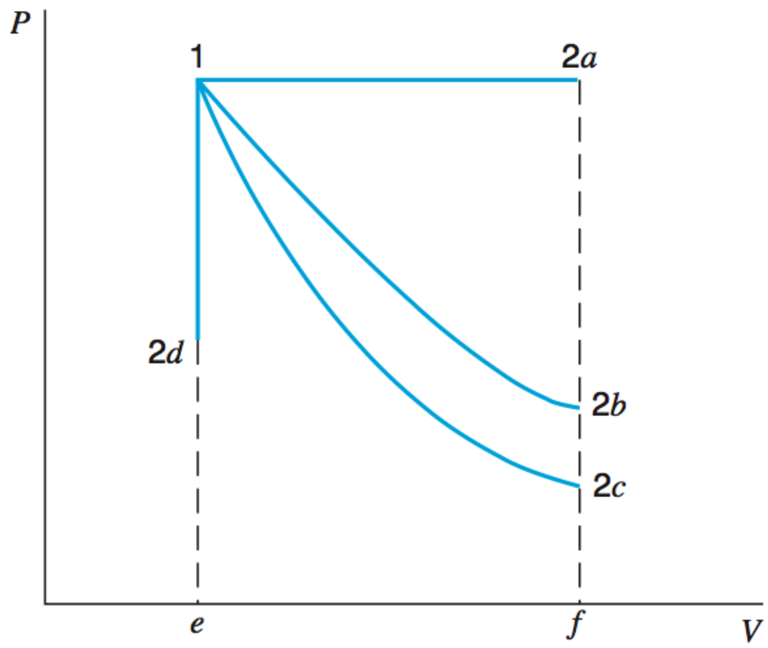


Example

C) Consider the same system, but during the heat transfer remove the weights at such a rate that the expression $PV^{1.3}$ = constant describes the relation between pressure and volume during the process. Again, the final volume is 0.1 m^3. Calculate the work.

Example

D) Consider the system and the initial state given in the first three examples, but let the piston be held by a pin so that the volume remains constant. In addition, let heat be transferred from the system until the pressure drops to 100 kPa. Calculate the work.



Next lecture

- Examine the moving boundary work or $P\,dV$ work commonly encountered in reciprocating devices such as automotive engines and compressors.
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