

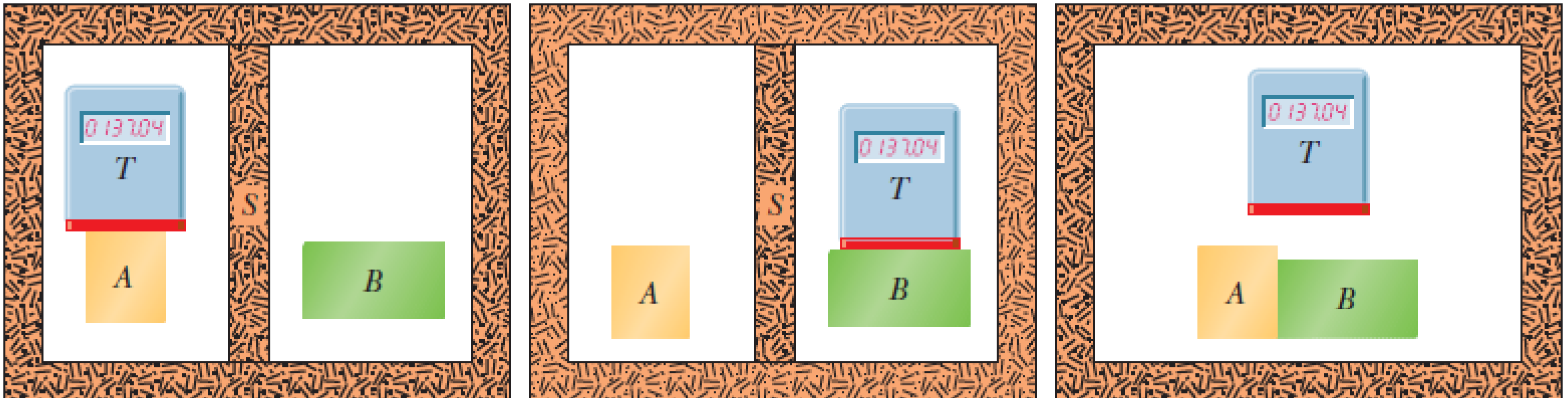
Hukum Termodinamika (1)

Hukum 1 Termodinamika, isobarik, isokorik,
isotermal dan adiabatik

Zeroth Law of Thermodynamics

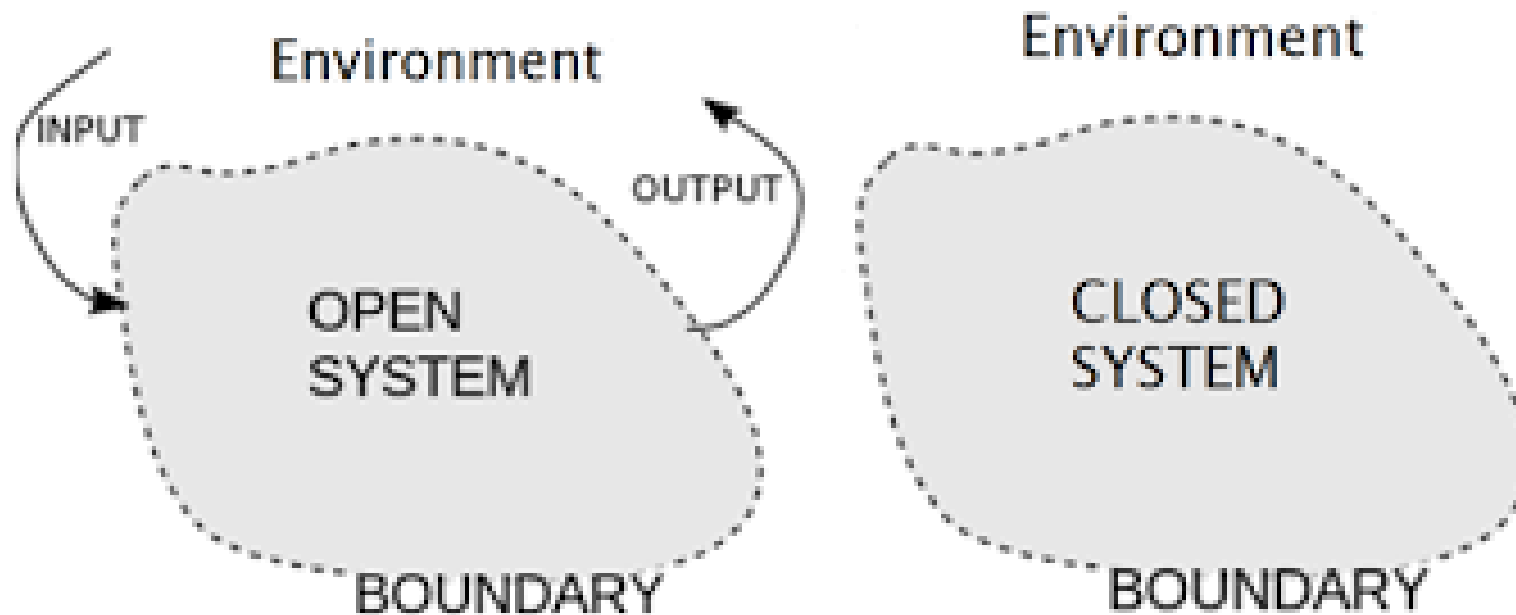
Every object has a temperature.

If two thermodynamic systems are both in thermal equilibrium with a third system, then the two systems are in thermal equilibrium with each other



System and environment

- **System** : the part of the universe that is being studied
- **Environment** : the remainder of the universe that lies outside the boundaries of the system.



Thermodynamic Process

- a thermodynamic change in the state of from one initial state to another

Work and Heat in Thermodynamic Processes

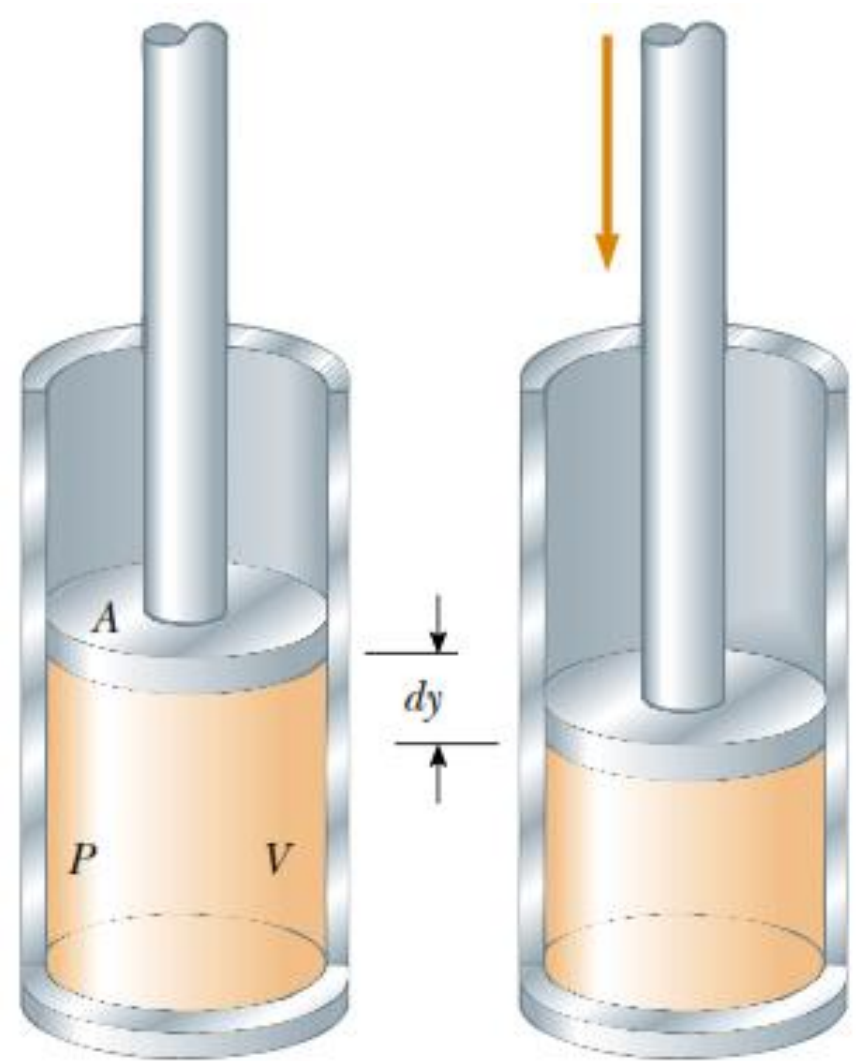
state variables

- the state of a system using such variables as **pressure, volume, temperature, and internal energy**
- It is important to note that a macroscopic state of an **isolated system** can be specified only if the system is in **thermal equilibrium** internally.

transfer variables

- These variables are zero unless a process occurs in which energy is transferred across the boundary of the system.
- Transfer variables are characteristic of a process in which **energy is transferred between a system and its environment.**

At equilibrium, the gas occupies a volume V and exerts a uniform pressure P on the cylinder's walls and on the piston. If the piston has a cross-sectional area A , the force exerted by the gas on the piston is $F = PA$. Now let us assume that we push the piston inward and compress the gas quasi-statically, that is, slowly enough to allow the system to remain essentially in thermal equilibrium at all times.

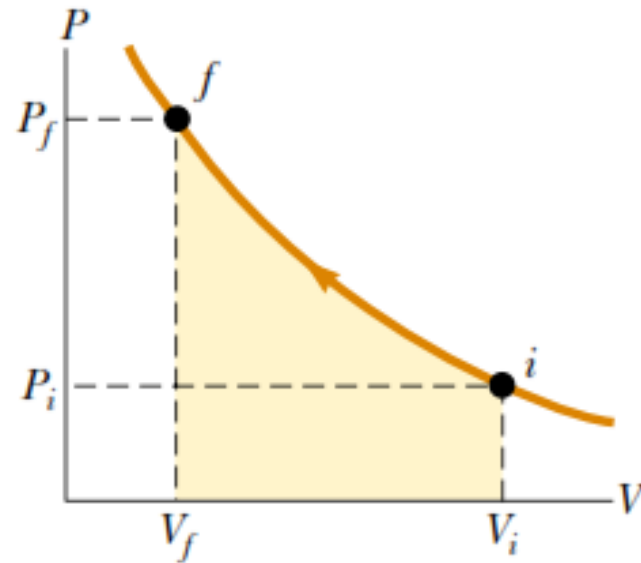


the work done on the gas (compression) is

$$dW = F dr = F dy = P A dy$$

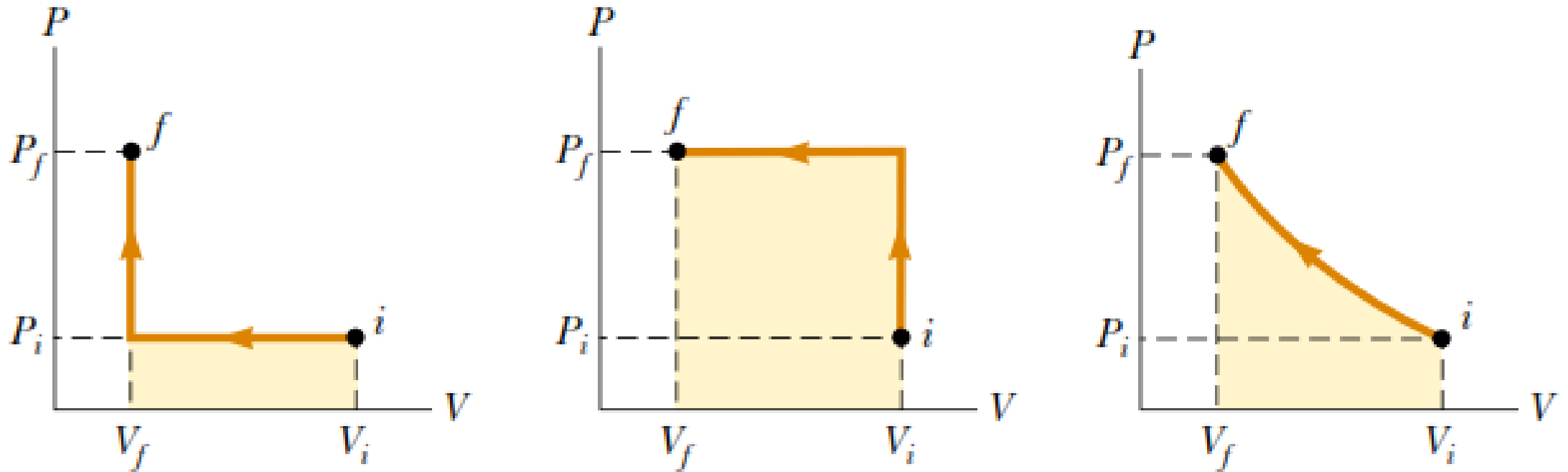
$$dW = PdV$$

$$W = - \int_{V_i}^{V_f} P dV$$



PV diagram

The work done on a gas as it is taken from an initial state to a final state depends on the path between these states.



energy transfer by heat, like work done, depends on the initial, final, and intermediate states of the system.

The First Law of Thermodynamics

- The first law of thermodynamics is a special case of the law of conservation of energy that encompasses changes in internal energy and energy transfer by heat and work.

Energy transfer by heat Q to the system occurs, and work W is done on the system.

Although Q and W both depend on the path, the quantity $Q + W$ is independent of the path.

$$\Delta E_{\text{int}} = Q + W$$

When a system undergoes an infinitesimal change in state in which a small amount of energy dQ is transferred by heat and a small amount of work dW is done, the internal energy changes by a small amount dE . Thus, for infinitesimal processes we can express the first law as

$$dE_{\text{int}} = dQ + dW$$

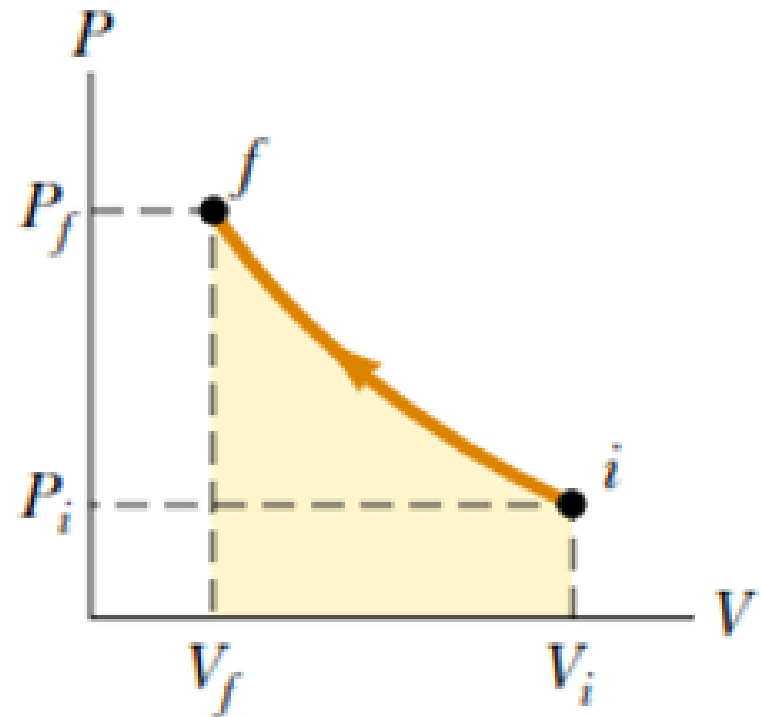
Consider the case of a system (one not isolated from its surroundings) that is taken through a cyclic process—that is, a process that starts and ends at the same state. In this case, the change in the internal energy must again be zero, because E is a state variable, and therefore the energy Q added to the system must equal the negative of the work W done on the system during the cycle. That is, in a cyclic process

$$\Delta E_{\text{int}} = 0 \quad \text{and} \quad Q = -W \quad (\text{cyclic process})$$

Adiabatic process

An adiabatic process is one during which no energy enters or leaves the system by heat—that is, $Q = 0$ (thermally insulated).

$$\Delta E_{\text{int}} = W \quad (\text{adiabatic process})$$



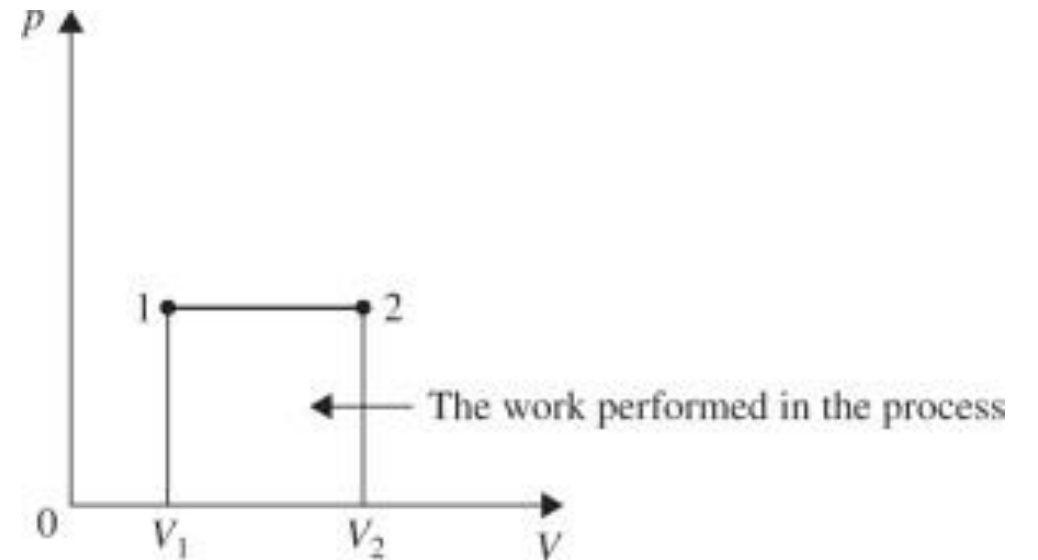
Isobaric process

A process that occurs at constant pressure is called an isobaric process.

In such a process, the values of the heat and the work are both usually nonzero.

$$W = -P(V_f - V_i) \quad (\text{isobaric process})$$

where P is the constant pressure.



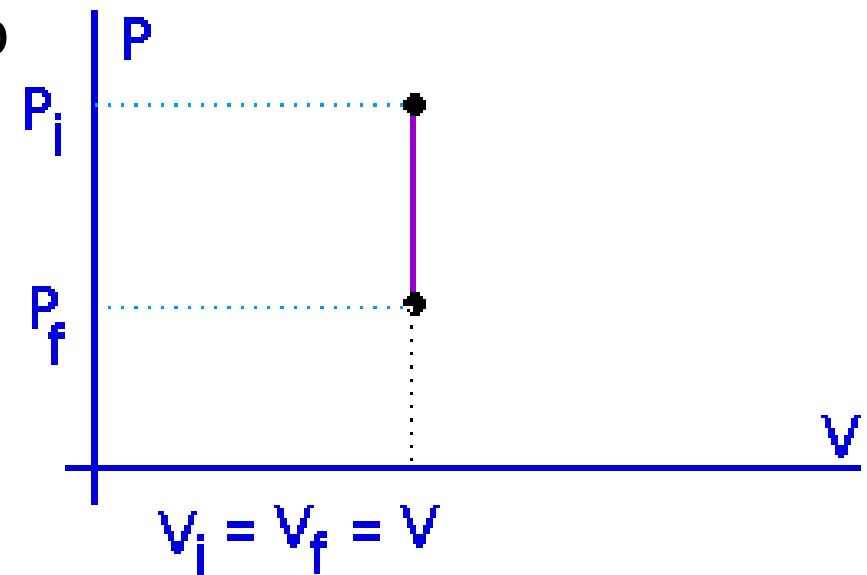
Isovolumetric/isokhorik process

A process that takes place at constant volume is called an isovolumetric process.

$$\Delta E_{\text{int}} = Q \quad (\text{isovolumetric process})$$

In such a process, the value of the work done is zero because the volume does not change.

Hence, from the first law we see that in an isovolumetric process, because $W = 0$,



Isothermal Expansion of an Ideal Gas

A process that occurs at constant temperature is called an isothermal process.

$$PV = nRT$$

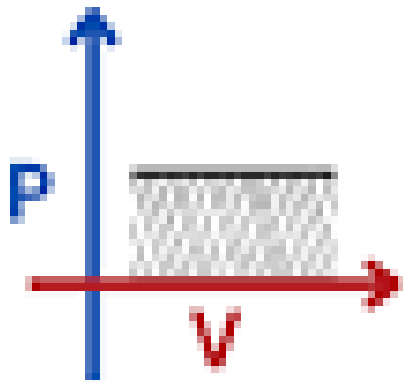
$$W = - \int_{V_i}^{V_f} P dV = - \int_{V_i}^{V_f} \frac{nRT}{V} dV$$

$$W = - nRT \int_{V_i}^{V_f} \frac{dV}{V} = - nRT \ln V \Big|_{V_i}^{V_f}$$

$$W = nRT \ln \left(\frac{V_i}{V_f} \right)$$

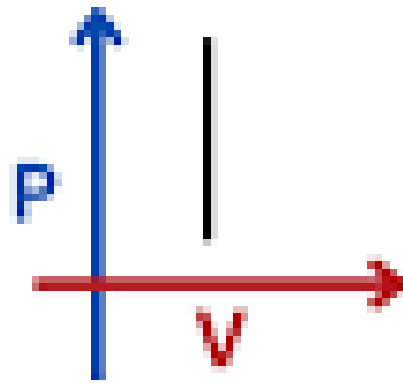
Thermodynamic process

Isobaric



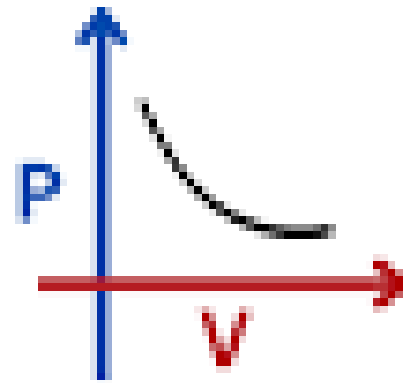
$$W = P \times \Delta V$$

Isochoric



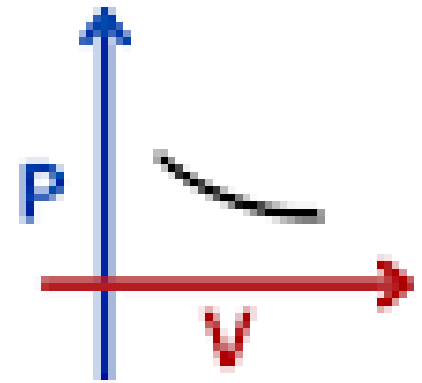
$$W = 0$$

Isothermal



$$\Delta U = 0$$

Adiabatic



$$Q = 0$$

Example 1

A 1.0-mol sample of an ideal gas is kept at 0.0°C during an expansion from 3.0 L to 10.0 L.

- (A) How much work is done on the gas during the expansion?
- (B) How much energy transfer by heat occurs with the surroundings in this process?
- (C) If the gas is returned to the original volume by means of an isobaric process, how much work is done on the gas?

a. $W = nRT \ln \left(\frac{V_i}{V_f} \right)$

$$= (1.0 \text{ mol})(8.31 \text{ J/mol}\cdot\text{K})(273 \text{ K}) \ln \left(\frac{3.0 \text{ L}}{10.0 \text{ L}} \right)$$

$$= -2.7 \times 10^3 \text{ J}$$

b. $\Delta E_{\text{int}} = Q + W$

$$0 = Q + W$$

$$Q = -W = 2.7 \times 10^3 \text{ J}$$

c. $W = -P(V_f - V_i) = -\frac{nRT_i}{V_i} (V_f - V_i)$

$$= -\frac{(1.0 \text{ mol})(8.31 \text{ J/mol}\cdot\text{K})(273 \text{ K})}{10.0 \times 10^{-3} \text{ m}^3} \\ \times (3.0 \times 10^{-3} \text{ m}^3 - 10.0 \times 10^{-3} \text{ m}^3)$$

$$= 1.6 \times 10^3 \text{ J}$$

Example 2


Suppose 1.00 g of water vaporizes isobarically at atmospheric pressure (1.013×10^5 Pa). Its volume in the liquid state is $V_i = V_{\text{liquid}} = 1.00 \text{ cm}^3$, and its volume in the vapor state is $V_f = V_{\text{vapor}} = 1\,671 \text{ cm}^3$. Find the work done in the expansion and the change in internal energy of the system. Ignore any mixing of the steam and the surrounding air—imagine that the steam simply pushes the surrounding air out of the way.

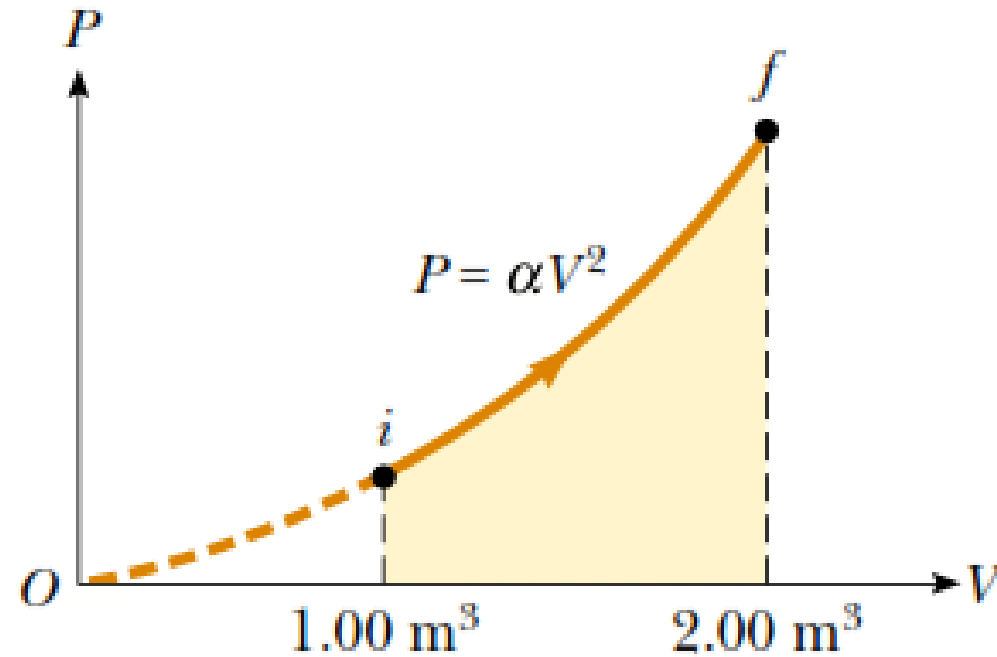
$$\begin{aligned}W &= -P(V_f - V_i) \\ &= -(1.013 \times 10^5 \text{ Pa})(1.671 \times 10^{-6} \text{ m}^3 - 1.00 \times 10^{-6} \text{ m}^3) \\ &= -169 \text{ J}\end{aligned}$$

$$Q = mL_v = (1.00 \times 10^{-3} \text{ kg})(2.26 \times 10^6 \text{ J/kg}) = 2260 \text{ J}$$

$$\Delta E_{\text{int}} = Q + W = 2260 \text{ J} + (-169 \text{ J}) = 2.09 \text{ kJ}$$

Example 3

 A sample of ideal gas is expanded to twice its original volume of 1.00 m^3 in a quasi-static process for which $P = \alpha V^2$, with $\alpha = 5.00 \text{ atm/m}^6$, as shown in Figure P20.23. How much work is done on the expanding gas?



$$1 \text{ atm} = 1,013 \times 10^5 \text{ Pa}$$

$$W_{if} = -\int_i^f P dV$$

The work done on the gas is the negative of the area under the curve $P = \alpha V^2$ between V_i and V_f .

$$W_{if} = -\int_i^f \alpha V^2 dV = -\frac{1}{3} \alpha (V_f^3 - V_i^3)$$

$$V_f = 2V_i = 2(1.00 \text{ m}^3) = 2.00 \text{ m}^3$$

$$W_{if} = -\frac{1}{3} \left[(5.00 \text{ atm/m}^6) (1.013 \times 10^5 \text{ Pa/atm}) \right] \left[(2.00 \text{ m}^3)^3 + (1.00 \text{ m}^3)^3 \right] = \boxed{-1.18 \text{ MJ}}$$

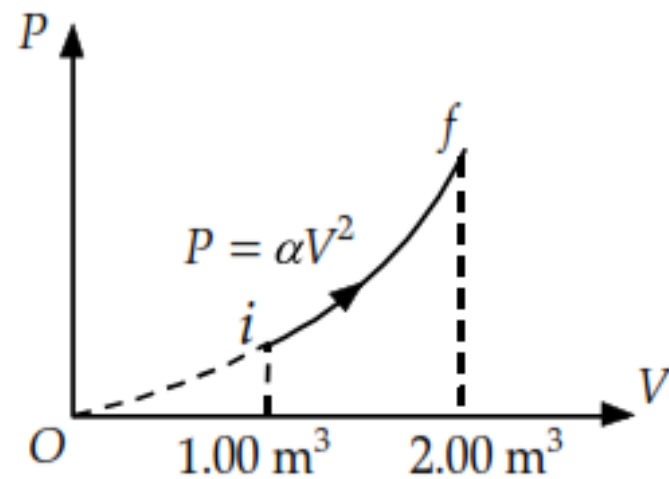


FIG. P20.23

Example 4

(a) Determine the work done on a fluid that expands from i to f as indicated in Figure P20.24. (b) **What If?** How much work is performed on the fluid if it is compressed from f to i along the same path?

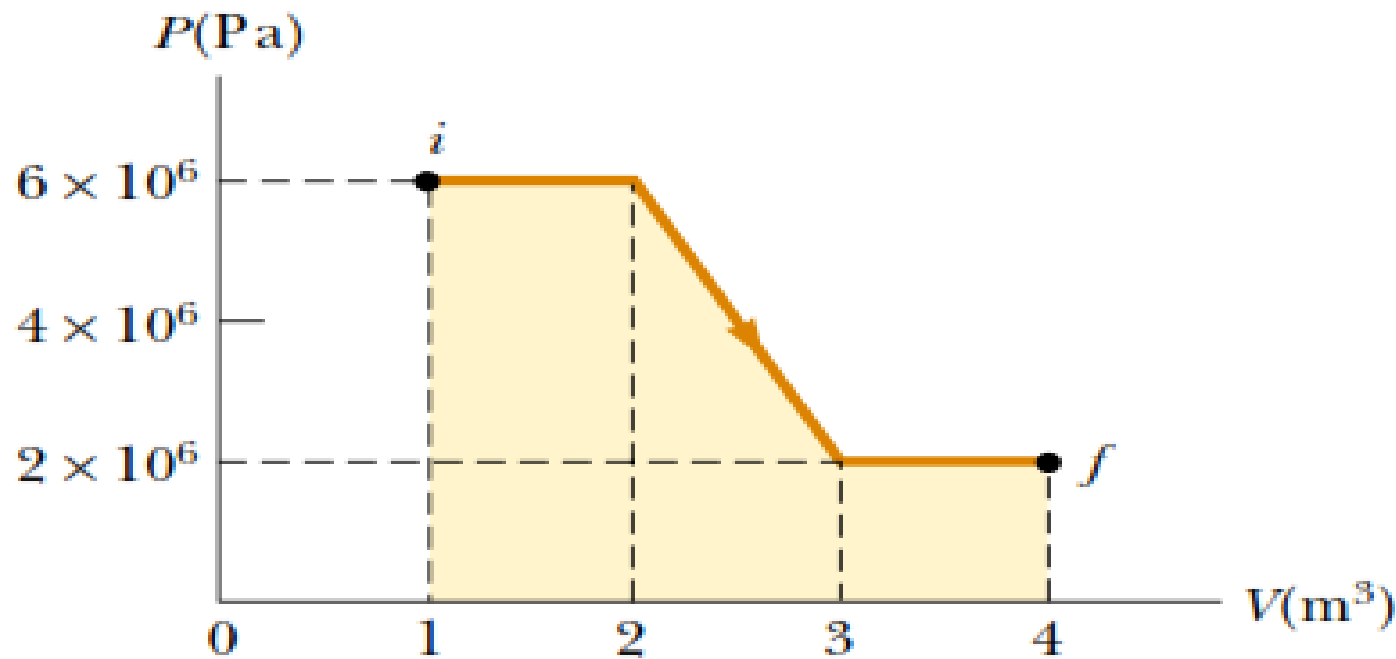


Figure P20.24

(a) $W = -\int P dV$

$$W = -(6.00 \times 10^6 \text{ Pa})(2.00 - 1.00) \text{ m}^3 +$$
$$-(4.00 \times 10^6 \text{ Pa})(3.00 - 2.00) \text{ m}^3 +$$
$$-(2.00 \times 10^6 \text{ Pa})(4.00 - 3.00) \text{ m}^3$$

$$W_{i \rightarrow f} = \boxed{-12.0 \text{ MJ}}$$

(b) $W_{f \rightarrow i} = \boxed{+12.0 \text{ MJ}}$

