PHY 113 A General Physics I
9-9:50 AM MWF Olin 101

Plan for Lecture 30:

Chapter 20: First law of thermodynamics

1. Concept of internal energy
2. Examples of thermodynamic processes
3. Note: We will not stress energy transfer processes in this class

22	10/29/2012	Kepler's laws and satellite motion	13.4-13.6	13.28, 13.34	10/31/2012
	10/31/2012	Review	10-13,15		
	11/02/2012	Exam	10-13,15		
23	11/05/2012	Fluid mechanics	14.1-14.4	14.8, 14.24	11/07/2012
24	11/07/2012	Fluid mechanics	14.5-14.7	14.39, 14.51	11/09/2012
25	11/09/2012	Temperature	19.1-19.5	19.1, 19.20	11/12/2012
26	11/12/2012	Heat	20.1-20.4	20.3, 20.14, 20.24	11/14/2012
27	11/14/2012	First law of thermodynamics	20.5-20.7	20.26, 20.35	11/16/2012
28	11/16/2012	Ideal gases	21.1-21.5	21.10, 21.19	11/19/2012
29	11/19/2012	Engines	22.1-22.8	22.3, 22.62	11/26/2012
	11/21/2012	*Thanksgiving Holiday*			
	11/23/2012	*Thanksgiving Holiday*			
	11/26/2012	Review	14,19-22		
	11/28/2012	Exam	14,19-22		
30	11/30/2012	Wave motion	16.1-16.6		12/03/2012
31	12/03/2012	Sound & standing waves	17.1-18.8		12/05/2012
	12/05/2012	Review	1-22		
	12/13/2012	Final Exam -- 9 AM			

iclicker question:

Concerning review session for Exam 3 ??

A. yes

B. no

Thermodynamic processes:

Q: heat added to system (Q>0 if $T_E > T_S$)
W: work done on system (W>0 if system expands

$$Q = \int_{T_i}^{T_f} C(T)\,dT$$

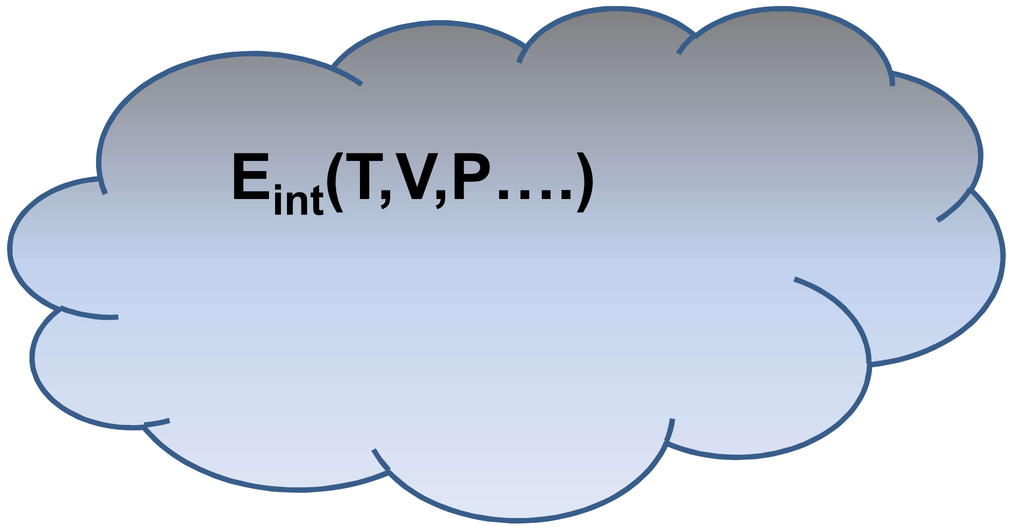
$$W = -\int_{V_i}^{V_f} P\,dV$$

iclicker question:

What happens to the "system" when Q and W are applied?

A. Its energy increases
B. Its energy decrease
C. Its energy remains the same
D. Insufficient information to answer question

Internal energy of a system

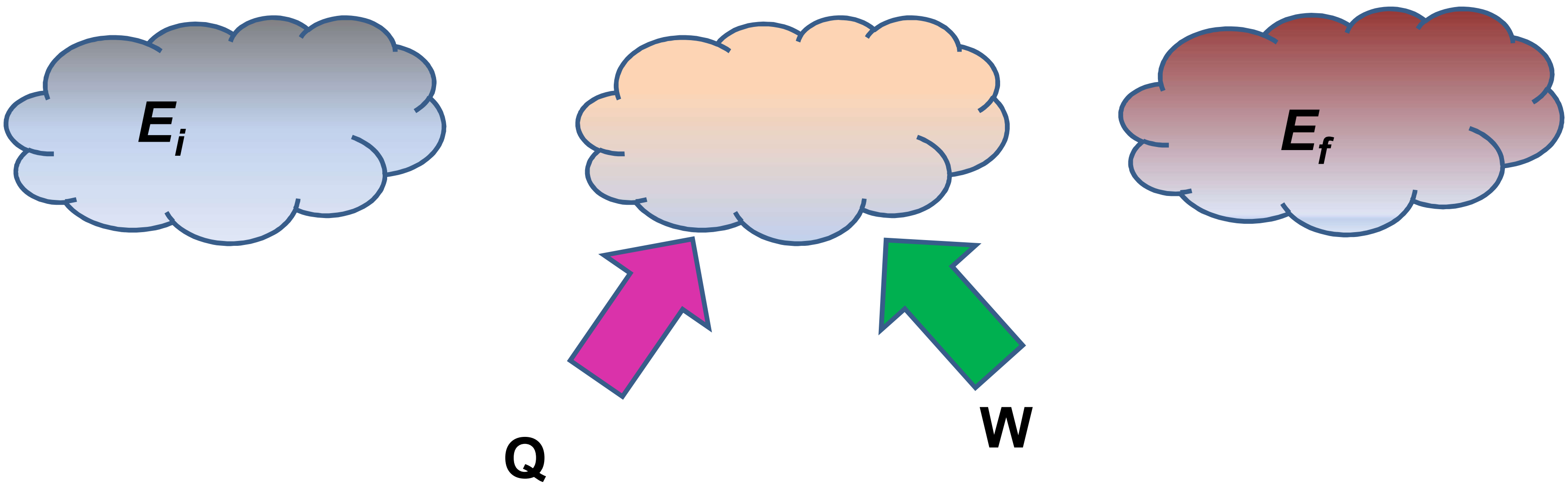


The internal energy is a "state" property of the system, depending on the instantaneous parameters (such as T, P, V, etc.). By contrast, Q and W describe path-dependent processes.

$$\Delta E_{\text{int}} = E_{\text{int}}(T_f, V_f, P_f) - E_{\text{int}}(T_i, V_i, P_i)$$

First law of thermodynamics:

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



Applications of first law of thermodyamics

System → ideal gas

8.314 J/(mol K)

$$PV = nRT$$

temperature in K

volume in m^3

# of moles

pressure in Pascals

Ideal gas -- continued

$$\text{Equation of state:} \quad PV = nRT$$

$$\text{Internal energy:} \quad E_{\text{int}} = \frac{1}{\gamma - 1} nRT = \frac{1}{\gamma - 1} PV$$

$$\gamma = \text{parameter depending on type of ideal gas}$$

$$= \begin{cases} \frac{5}{3} & \text{for monoatomic} \\ \frac{7}{5} & \text{for diatomic} \\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots & \end{cases}$$

iclicker question:

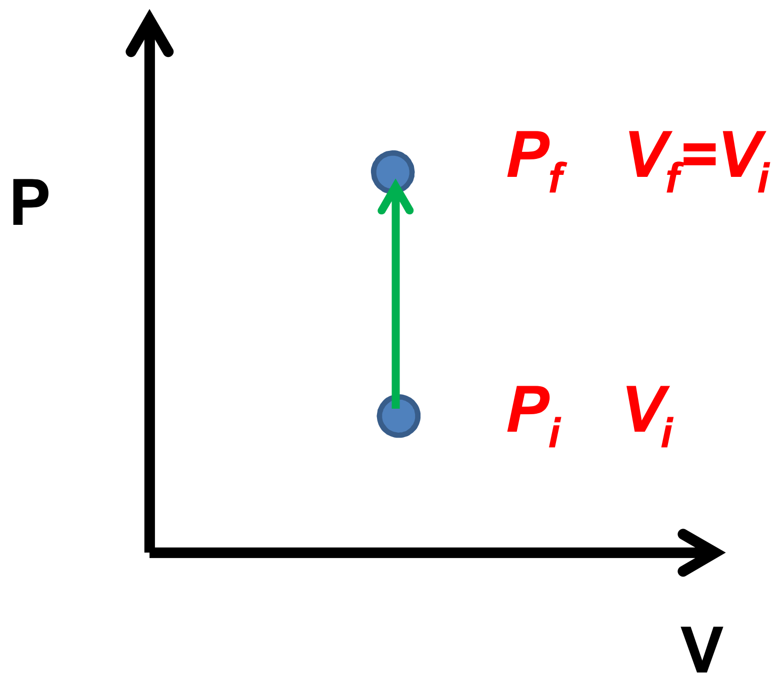
We are about to see several P-V diagrams. Why is this helpful?

A. **It will help us analyze the thermodynamic work**
B. **Physicists like nice graphs**
C. **It is not actually helpful**

Constant volume process on an ideal gas

Equation of state: $PV = nRT$

Internal energy: $E_{int} = \frac{1}{\gamma - 1} nRT = \frac{1}{\gamma - 1} PV$



$$W = 0$$

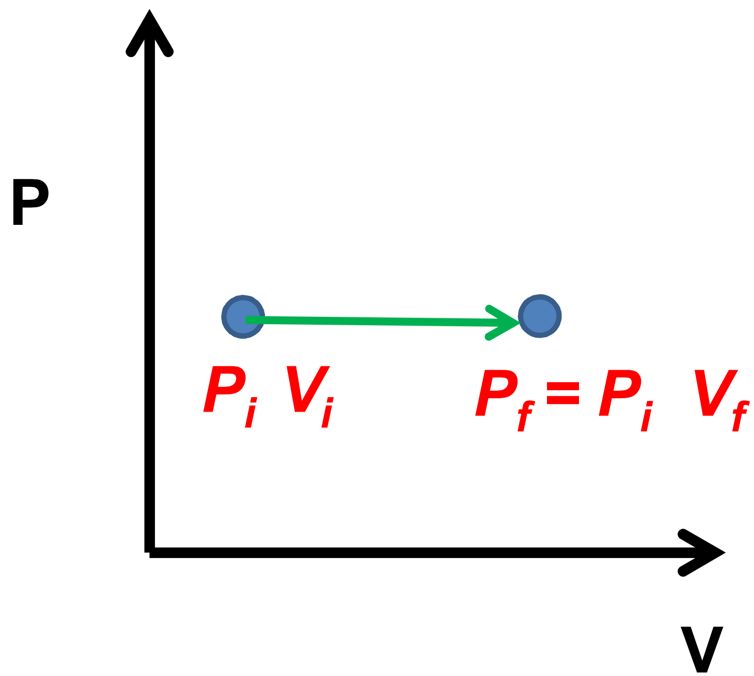
$$\Delta E_{int} = Q$$

$$= \frac{(P_f - P_i)V_i}{\gamma - 1}$$

Constant pressure process on an ideal gas

Equation of state: $PV = nRT$

Internal energy: $E_{\text{int}} = \frac{1}{\gamma - 1} nRT = \frac{1}{\gamma - 1} PV$



$$W = -P_i\left(V_f - V_i\right)$$

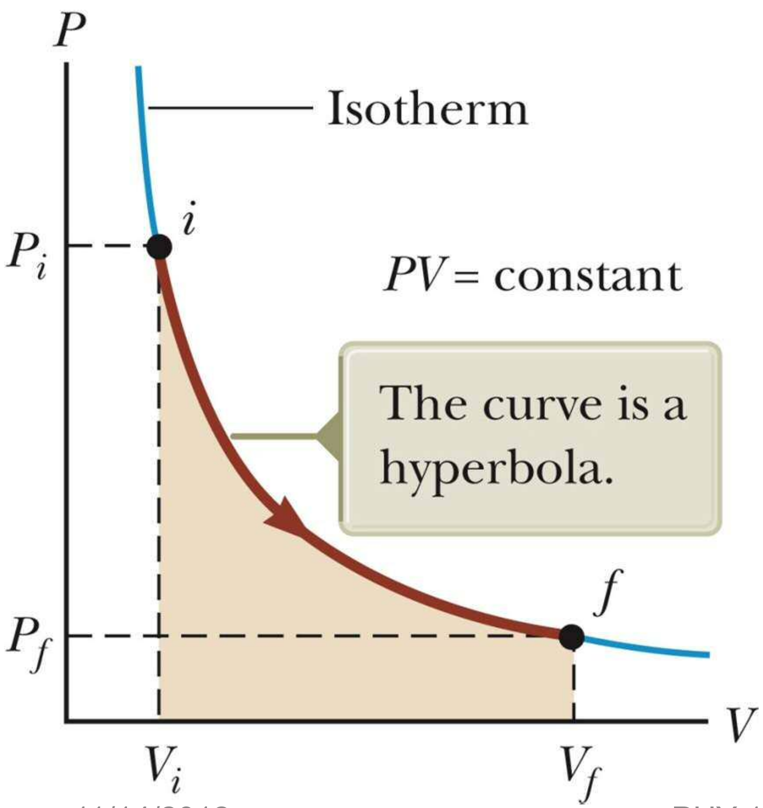
$$\Delta E_{\text{int}} = \frac{P_i\left(V_f - V_i\right)}{\gamma - 1}$$

$$Q = \frac{\gamma P_i\left(V_f - V_i\right)}{\gamma - 1}$$

Constant temperature process on an ideal gas

Equation of state: $PV = nRT$

Internal energy: $E_{\text{int}} = \frac{1}{\gamma - 1} nRT = \frac{1}{\gamma - 1} PV$



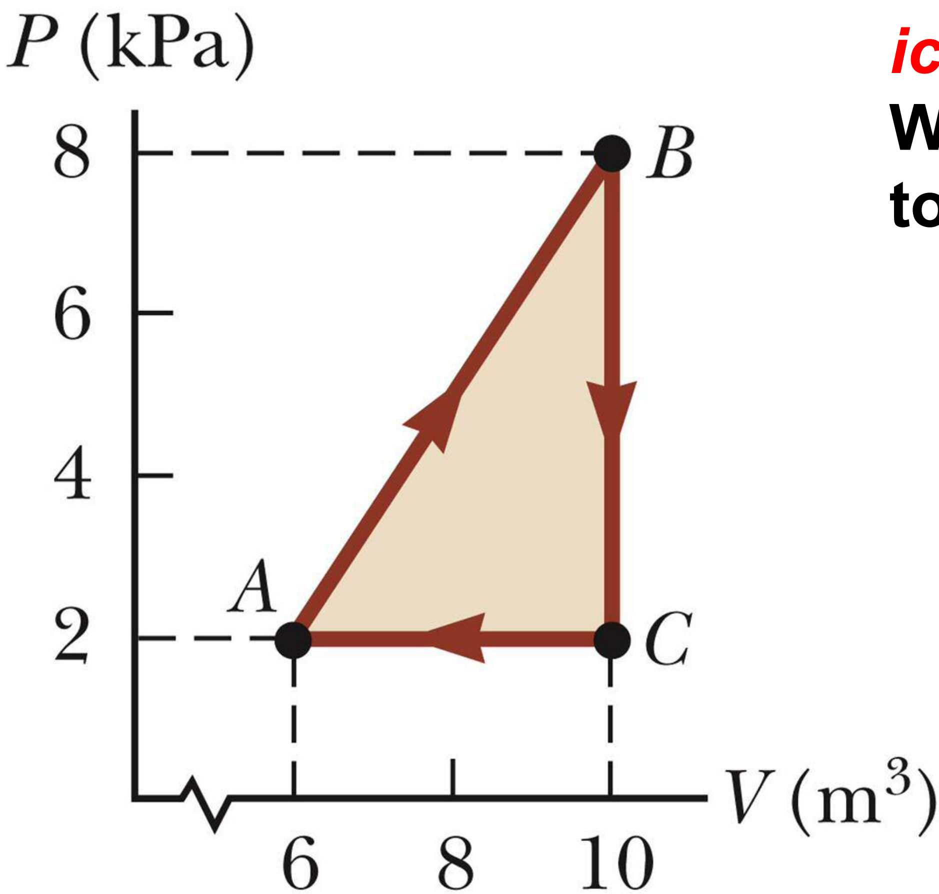
$$\Delta E_{\text{int}} = 0$$

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

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

$$= P_i V_i \ln\left(\frac{P_i}{P_f}\right)$$

Consider the process described by A→B→C→A

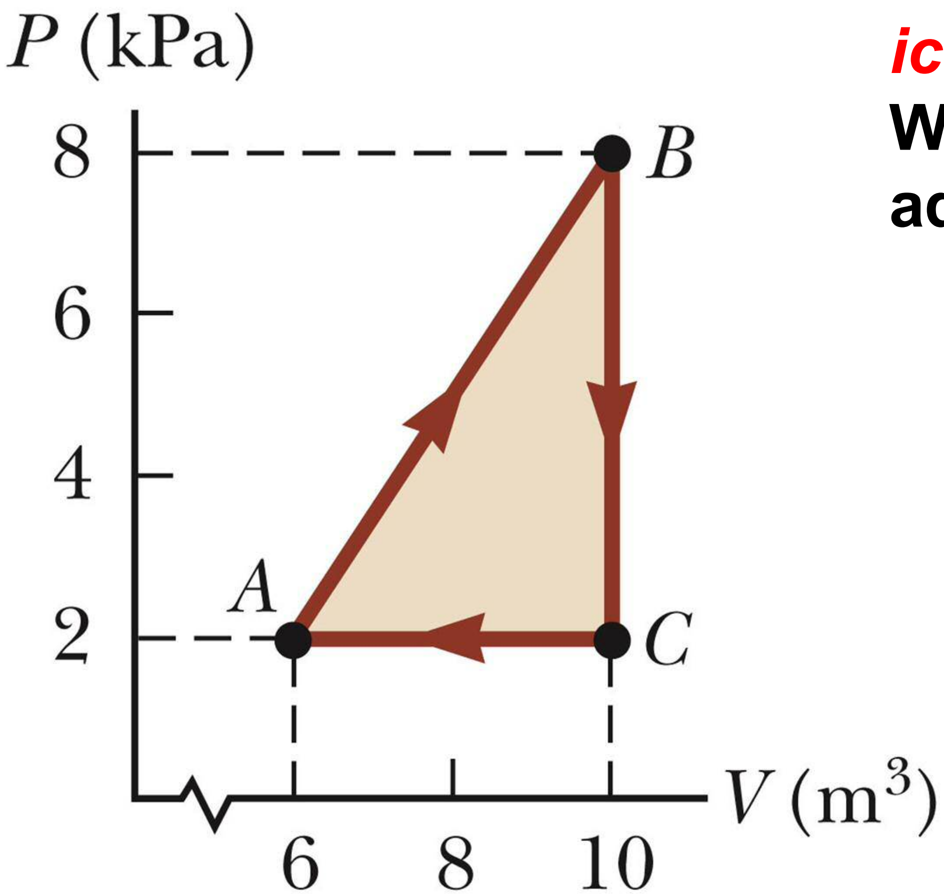


iclicker exercise:

What is the net change in total energy?

A. 0
B. 12000 J
C. Who knows?

Consider the process described by A→B→C→A

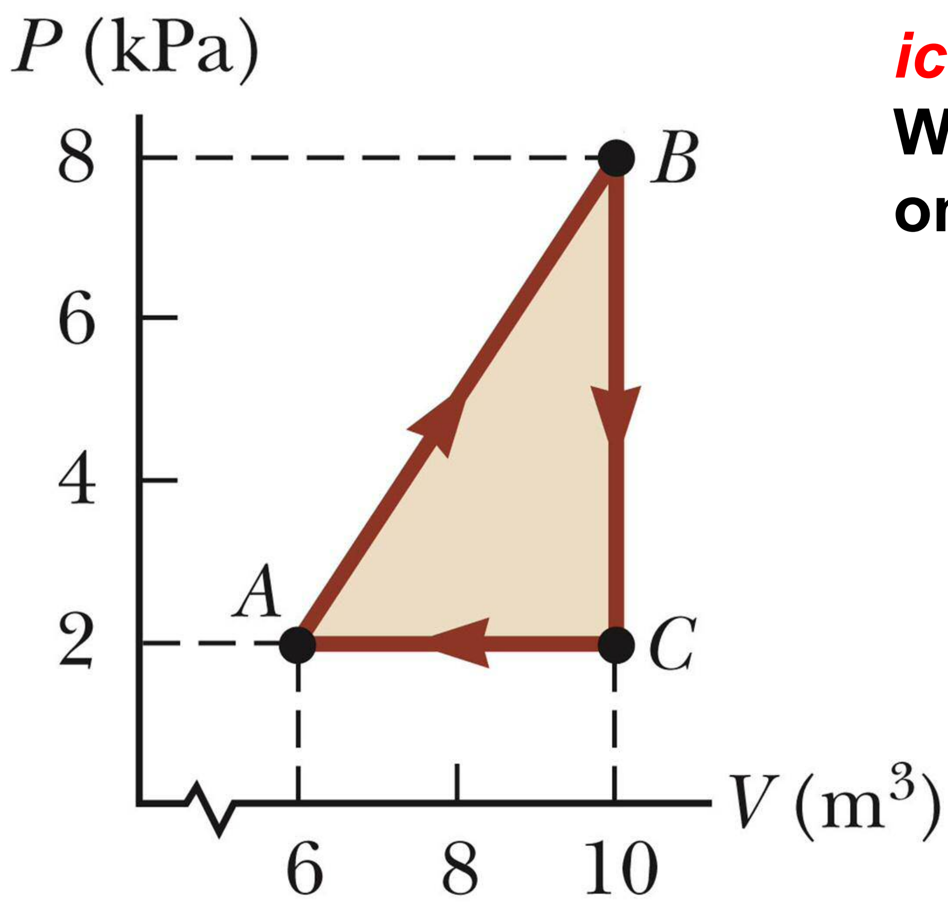


iclicker exercise:

What is the net heat added to the system?

- A. 0
- B. 12000 J
- C. Who knows?

Consider the process described by A→B→C→A



iclicker exercise:

What is the net work done on the system?

A. 0
B. -12000 J
C. Who knows?

Webassign problem # 4: