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
7	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

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

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

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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

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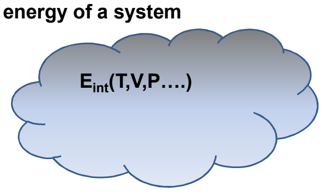
Internal energy of a system



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.

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

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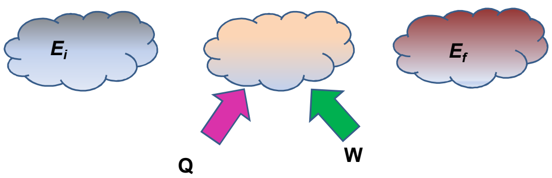
First law of thermodynamics:

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



Applications of first law of thermodyamics

System ➔ ideal gas

$$PV = nRT$$

- P: pressure in Pascals
- V: volume in m^3
- n: # of moles
- R: 8.314 J/(mol K)
- T: temperature in K

Ideal gas -- continued

Equation of state: $PV = nRT$

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

γ = parameter depending on type of ideal gas

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

iclicker question:

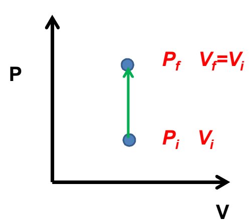
We are about to see several P-V diagrams. Why is this helpful?

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



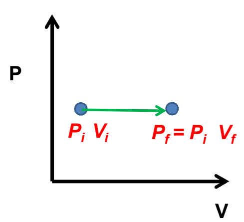
$$W = 0$$

$$\Delta E_{\text{int}} = Q = \frac{(P_f - P_i)V_i}{\gamma - 1}$$

Constant pressure process on an ideal gas

Equation of state: $PV = nRT$

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



$$W = -P_i(V_f - V_i)$$

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

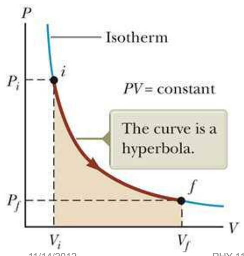
$$Q = \frac{\gamma P_i(V_f - V_i)}{\gamma - 1}$$

Constant temperature process on an ideal gas

Equation of state: $PV = nRT$

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

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



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

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

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

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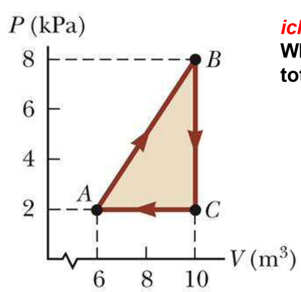
Consider the process described by A→B→C→A



iclicker exercise:

What is the net change in total energy?

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

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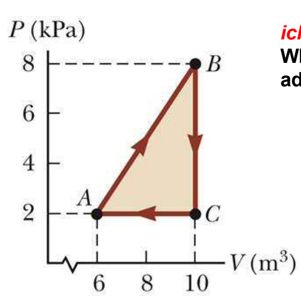
Consider the process described by A→B→C→A



iclicker exercise:

What is the net heat added to the system?

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

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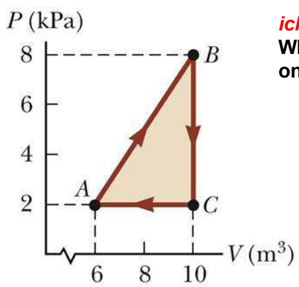
Consider the process described by A→B→C→A



iclicker exercise:

What is the net work done on the system?

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

Webassign problem # 4: