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

Plan for Lecture 32:

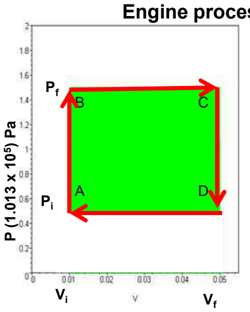
Chapter 22: Heat engines

1. **Thermodynamic cycles; work and heat efficiency**
2. **Carnot cycle**
3. **Otto cycle; diesel cycle**
4. **Note – in this class, we will not focus on entropy and the second law of thermodynamics**

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
9	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			

Thermodynamic cycles for designing ideal engines and heat pumps http://auto.howstuffworks.com/engine1.htm

Engine process:

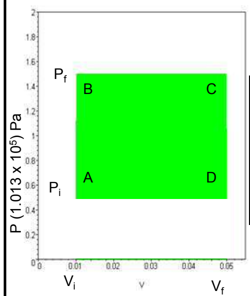


Work of engine : $W_{eng} = -W$

Heat input to system : $Q = |Q_{in}| - |Q_{out}|$

Efficiency : $\varepsilon \equiv \frac{W_{eng}}{Q_{in}}$

Examples process by an ideal gas:

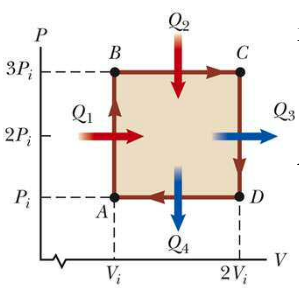


	A→B	B→C	C→D	D→A
Q	$\frac{V_i(P_f-P_i)}{\gamma-1}$	$\frac{\gamma P_f(V_f-V_i)}{\gamma-1}$	$\frac{-V_f(P_f-P_i)}{\gamma-1}$	$\frac{-\gamma P_i(V_f-V_i)}{\gamma-1}$
W	0	$-P_f(V_f-V_i)$	0	$P_i(V_f-V_i)$
ΔE_{int}	$\frac{V_i(P_f-P_i)}{\gamma-1}$	$\frac{P_f(V_f-V_i)}{\gamma-1}$	$\frac{-V_f(P_f-P_i)}{\gamma-1}$	$\frac{-P_i(V_f-V_i)}{\gamma-1}$

Efficiency : $\varepsilon \equiv \frac{W_{eng}}{Q_{in}}$

$$\varepsilon = \frac{(P_f - P_i)(V_f - V_i)}{Q_{AB} + Q_{BC}}$$

Example from homework



Efficiency : $\varepsilon \equiv \frac{W_{eng}}{Q_{in}}$

$$\varepsilon = \frac{(P_f - P_i)(V_f - V_i)}{Q_{AB} + Q_{BC}}$$

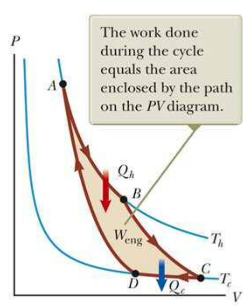
Also : $-W = W_{eng} = Q = Q_{in} - |Q_{out}|$

$$\varepsilon = \frac{Q_{in} - |Q_{out}|}{Q_{in}} = 1 - \frac{|Q_{out}|}{Q_{in}}$$

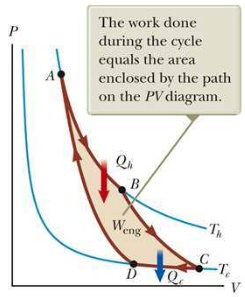
$$\varepsilon = 1 - \frac{|Q_{CD} + Q_{DA}|}{Q_{AB} + Q_{BC}}$$

Most efficient thermodynamic cycle -- Carnot

Sadi Carnot 1796-1832



Carnot cycle:



A→B Isothermal at T_h
B→C Adiabatic
C→D Isothermal at T_c
D→A Adiabatic

Efficiency of Carnot cycle

$$\varepsilon = \frac{Q_{in} - |Q_{out}|}{Q_{in}} = 1 - \frac{|Q_{out}|}{Q_{in}}$$

$$\varepsilon = 1 - \frac{T_c}{T_h}$$

***iclicker exercise*:**
We discussed the efficiency of an engine as

$$\varepsilon = \frac{Q_{in} - |Q_{out}|}{Q_{in}} = 1 - \frac{|Q_{out}|}{Q_{in}}$$

Is this result
A. Special to the Carnot cycle
B. General to all ideal thermodynamic cycles

***iclicker exercise*:**
We discussed the efficiency of an engine running with hot and cold reservoirs as

$$\varepsilon = 1 - \frac{T_c}{T_h}$$

Is this result
A. Special to the Carnot cycle
B. General to all ideal thermodynamic cycles

Note that for a Carnot cycle:

$$\frac{|Q_{out}|}{|Q_{in}|} = \frac{|W_{AB}|}{|W_{CD}|} = \frac{nRT_c \ln(V_C/V_D)}{nRT_h \ln(V_B/V_A)}$$

For adiabatic process

$$T_h V_B^{\gamma-1} = T_c V_C^{\gamma-1}$$

$$T_h V_A^{\gamma-1} = T_c V_D^{\gamma-1}$$

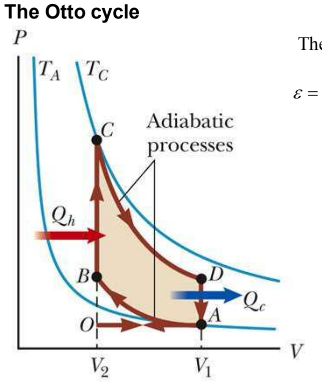
$$\Rightarrow V_C/V_D = V_B/V_A$$

$$\Rightarrow \frac{|Q_{out}|}{|Q_{in}|} = \frac{T_c}{T_h}$$

iclicker exercise:
Why should we care about the Carnot cycle?

A. We shouldn't
B. It approximately models some heating and cooling technologies
C. It provides insight into another thermodynamic variable -- entropy

The Otto cycle



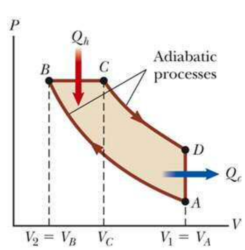
Theoretical efficiency :

$$\varepsilon = 1 - \left(\frac{V_2}{V_1}\right)^{\gamma-1}$$

The Diesel cycle

Theoretical efficiency:

$$\varepsilon = 1 - \frac{1}{\gamma}\left(\frac{T_D - T_A}{T_C - T_B}\right)$$



−/0 points | My Notes | SerPSE8 22.P.006.

A multicylinder gasoline engine in an airplane, operating at 2.55×10^3 rev/min, takes in energy 7.90×10^3 J and exhausts 4.53×10^3 J for each revolution of the crankshaft.

(a) How many liters of fuel does it consume in 1.00 h of operation if the heat of combustion of the fuel is equal to 4.03×10^7 J/L?

_____ L/h

(b) What is the mechanical power output of the engine? Ignore friction and express the answer in horsepower.

_____ hp

(c) What is the torque exerted by the crankshaft on the load?

_____ N · m

(d) What power must the exhaust and cooling system transfer out of the engine?

_____ W

Engine vs heating/cooling designs