Thermodynamics
Foundation Stage (PC.2.L3)

Lecture 3
Application and Practice, Cycles

Thermodynamics Timeline

| Microscopic Model of Gases | 1st Law and Heat | 2nd Law and Entropy | Thermodynamic Processes and Cycles |

Micro View of Matter and Kinetic Theory of Gases
State Variables and States, Ideal Gas Equation of
1st Law of Thermo, Energy Transfers
Specific Head, Phase Transformations, Calorimetry
Conduction, Convection, Radiation
Entropy, 2nd Law
Heat Engines
PV Diagrams, Processes
Application and Practice, Cycles

Textbook Chapters (* Calculus version)

- ○ **BoxSand** :: KC videos (Thermodynamic Cycles)
- ○ **Knight** (College Physics : A strategic approach 3rd) :: N/A
- ○ ***Knight** (Physics for Scientists and Engineers 4th) :: 21.2 ; 21.3 ; 21.4 ; 21.6
- ○ **Giancoli** (Physics Principles with Applications 7th) :: N/A

Warm up

PC.2.L3-1:

Description: Sketch the curves on a PV diagram given the type of process.

Learning Objectives: [?] - Can you identify the objectives from the previous lecture, and this lecture, that this question is relevant to?

Problem Statement: On the PV diagram below, sketch a curve that represents an ideal gas taken through an isobaric process that doubles the volume from one equilibrium state to another equilibrium state. After the gas is at this new equilibrium state, then sketch the curve that represents taking the gas thorough an isochoric doubling of pressure to a third equilibrium state. Finally, the gas is taken back to its original equilibrium state via one more isobaric compression and isochoric decrease in temperature.
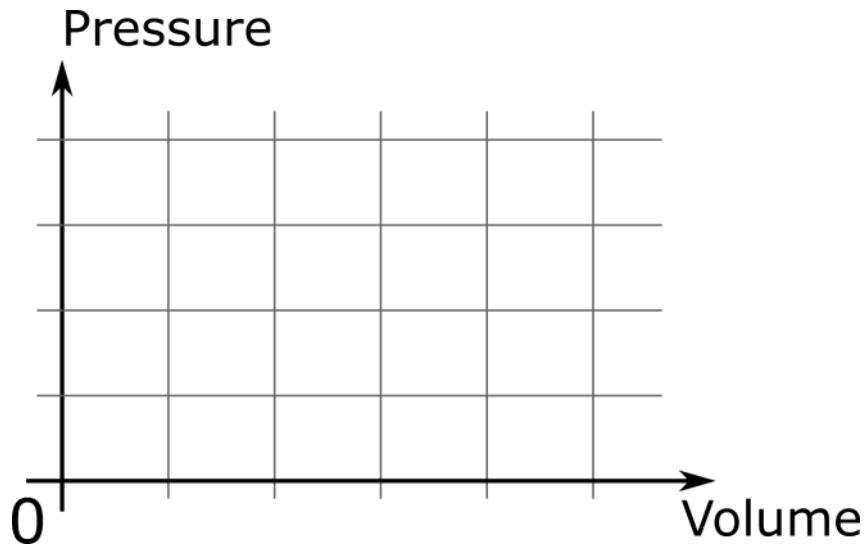
Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

○ Thermodynamic cycle
○ Efficiency

Key Equations

Key Concepts

○ Coming soon to a lecture template near you.

Questions

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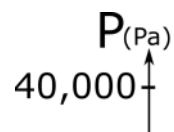Act I: Isochoric

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PC.2.L3-2:

Description: Use a PV diagram to determine net work for a cycle. Determine efficiency given net heat in. (4 minutes + 2 minutes + 2 minutes + 3 minutes + 3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider the PV diagram shown below.

(a) What are the units of the area enclosed by the cycle? Hint: Pressure is force per area.
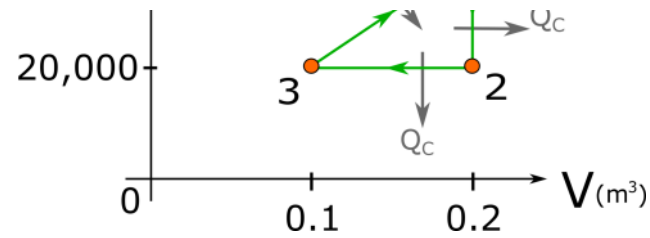
(1) 1,000 N·m

(2) 1,000 J
(3) 1,000 kg·m²/s²

(b) What is the sign of the net work?

(1) Positive
(2) Negative
(3) Zero

(c) Is this a heat pump or a heat engine?

20,000

3   2

Q_C

Q_C

0

0.1   0.2 V (m³)

(d) What is the efficiency of this cycle?

(e) Is there more total heat entering or exiting the system in a complete cycle?

PC.2.L3-3:

Description: Identify the most commonly used physics when analyzing a cycle problem. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: As an up-and-coming thermal engineer you decide to get a few tattoos regarding thermodynamic cycles. Which of the following equations/concepts would you get on your sleeve if you plan to attend Thermo U?

(1) $\Delta E^{TH} = 3/2\ N\ k_B\ \Delta T$

(2) $\Delta E^{TH} = W + Q$

(3) $P\ V = N\ k_B\ T$

(4) **Work** = ± **area** under PV curve

(5) $Q/\Delta t = k\ A\ \Delta T\ /\ L$

(6) $Q/\Delta t = e\ \sigma\ A\ T^4$

Description: Cycle problem. (30 minutes)

Problem Statement: 25 moles of an ideal monatomic gas undergoes a thermodynamic cycle consisting of three processes:

Process **1 → 2** :: Compression with (**P V**) = Constant, from P_1 = 100 kPa , V_1 = 1.6 m3 to V_2 = 0.2 m3.

Process **2 → 3** :: Constant pressure to $V_3 = V_1$.

Process **3 → 1** :: Constant volume with $E_1 - E_3$ = -3549 kJ.

(a) Use the **PV** diagram to the right to sketch this cycle.
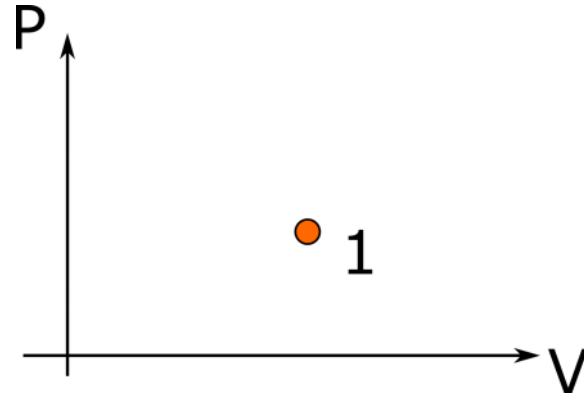
(b) Is this a power or refrigeration cycle?

(c) Given P_1, V_1, and **n**, what is T_1?

n = 25 moles	1	2	3
P (kPa)	100		
V (m³)	1.6	0.2	
T (K)			

(d) What is the pressure at equilibrium state **2**?

(e) What is the temperature at equilibrium state **3**?

(f) Which of the following quantities are zero?

(1) $\Delta E^{TH}_{1\ to\ 2}$
(2) $\Delta E^{TH}_{2\ to\ 3}$
(3) $\Delta E^{TH}_{3\ to\ 1}$
(4) ΔE^{TH}_{Total}

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (kJ)			-3549	
W (kJ)				
Q (kJ)				

(g) What is the change in thermal energy from **2** to **3**?

(5) $W_{1\,to\,2}$
(6) $W_{2\,to\,3}$
(7) $W_{3\,to\,1}$
(8) W_{Total}
(9) $Q_{1\,to\,2}$
(10) $Q_{2\,to\,3}$
(11) $Q_{3\,to\,1}$
(12) Q_{Total}

(g) What is the change in thermal energy from **2** to **3**?

(h) What is the heat transfer from **3** to **1**?

(i) Which function would you use to calculate the work from **2** to **3**?

    (1) $P\,\Delta V$
    (2) $-\,P\,\Delta V$
    (3) $n\,R\,T\,\ln(V_f/V_i)$
    (4) $-\,n\,R\,T\,\ln(V_f/V_i)$
    (5) $P\,V\,\ln(V_f/V_i)$
    (6) $-\,P\,V\,\ln(V_f/V_i)$

(j) Is the work from **2** to **3** positive or negative?

(k) Calculate the heat from **2** to **3**.

(l) Which function would you use to calculate the work from **1** to **2**?

    (1) $P\,\Delta V$
    (2) $-\,P\,\Delta V$
    (3) $n\,R\,T\,\ln(V_f/V_i)$
    (4) $-\,n\,R\,T\,\ln(V_f/V_i)$
    (5) $P\,V\,\ln(V_f/V_i)$
    (6) $-\,P\,V\,\ln(V_f/V_i)$

(m) Is the work from **1** to **2** positive or negative?

	$1 \to 2$	$2 \to 3$	$3 \to 1$	**Complete Cycle**
ΔE^{TH} (kJ)			-3549	
W (kJ)				
Q (kJ)				

(n) Calculate the heat from **1** to **2**.

(o) Finish the table of energies.

(p) Calculate the efficiency of this cycle.

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Conceptual questions for discussion

    1. <mark>Coming soon.</mark>

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Hints

PC.2.L3-1: No hints.

PC.2.L3-2: No hints.

PC.2.L3-3: No hints.

PC.2.L3-4: No hints.