

(PC.L2.1) Familiarize Stage

Thursday, March 29, 2018 8:34 PM

Thermodynamic Processes and Cycles (PC)

Familiarize Stage:

Pre-lecture 2: PV Diagrams, Processes

Reading

1. Read

Lecture Videos

1. Watch

Example Problems

1. Watch

Simulations

1. Sim

Other Suggested Content

1. Check out

Practice

1. Try

Homework

PC.L2.1-01

Description: Work and a PV-diagram

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: How is the magnitude of work related to a PV-diagram?

- | |
|--|
| (1) Multiplication of pressure and volume |
| (2) Slope of the PV curve |
| (3) Area under a PV curve |
| (4) Nothing, work can be found from a PT-diagram |

Answer: (3)

PC.L2.1-02

Description: Sign of work

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Consider a gas that expands. During this process, what is the sign of the work for the gas system?

- | |
|-------------------------|
| (1) Positive |
| (2) Negative |
| (3) Zero |
| (4) Unable to determine |

Answer: (2)

PC.L2.1-03

Description: Zero work processes

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Which of the following processes involve zero work?

- | |
|----------------|
| (1) Isochoric |
| (2) Isothermal |
| (3) Isobaric |
| (4) Adiabatic |
| (5) Isomorphic |

Answer: (1)

PC.L2.1-04

Description: Zero heat processes

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Which of the following processes involve zero heat?

- | |
|----------------|
| (1) Isochoric |
| (2) Isothermal |
| (3) Isobaric |
| (4) Adiabatic |
| (5) Isomorphc |

Answer: (4)

PC.L2.1-05

Description: Zero change in internal thermal energy processes

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Which of the following processes involve zero change in internal thermal energy?

- | |
|----------------|
| (1) Isochoric |
| (2) Isothermal |
| (3) Isobaric |
| (4) Adiabatic |
| (5) Isomorphc |

Answer: (2)

PC.L2.1-06

Description: Infographic quiz thermal process isobaric - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Consider a thermodynamic process

(a) Match each term in the equation with the correct description from the following list. (1) Pressure, (2) Work, (3) Change in volume

The diagram shows the equation $W = -P\Delta V$. Above the equation, there are three horizontal lines labeled (a), (b), and (c). Arrows point from (a) to W , from (b) to P , and from (c) to ΔV .

Answer: (a) Work, (b) Pressure, (c) Change in volume

(b) Which of the following thermodynamic processes is the work equation in the figure relevant?

(1) Isochoric

(2) Isothermal

(3) Isobaric
(4) Adiabatic
(5) Isomorphic

Answer: (3)

PC.L2.1-07

Description: Infographic quiz thermal process isothermal - label matching

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Consider a thermodynamic process.

(a) Match each term in the equation with the correct description from the following list. (1) Boltzmann's constant, (2) Number of particles, (3) Work, (4) Volume final, (5) Temperature, (6) Volume initial

The diagram shows the equation $|W| = Nk_B T \left| \ln \frac{V_f}{V_i} \right|$. Labels (a) through (f) are placed above and below the equation with arrows pointing to specific terms:

- (a) points to $|W|$
- (b) points to T
- (c) points to V_f
- (d) points to N
- (e) points to k_B
- (f) points to V_i

Answer: (a) Work, (b) Temperature, (c) Volume final, (d) Number of particles, (e) Boltzmann's constant, (f) Volume initial

(b) Which thermodynamic process is the work equation in the figure relevant?

- | |
|-----------------|
| (1) Isochoric |
| (2) Isothermal |
| (3) Isobaric |
| (4) Adiabatic |
| (5) Isomorphich |

Answer: (2)

PC.L2.1-08

Description: processes on a PV diagram

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Which comparison of adiabatic and isothermal processes is correct?

- | |
|--|
| (1) The two processes are the same. There is no change in heat content in either process. |
| (2) In adiabatic processes, temperatures vary without heat transfer into or out of the system. In isothermal processes temperature does not change, but the system can transfer heat. |
| (3) In adiabatic processes, no heat transfer occurs so the temperature cannot change. In isothermal processes heat transfer can occur, but does not alter temperature. |
| (4) In adiabatic processes, temperature does not change, but heat can be transferred. In isothermal processes, the system cannot transfer heat so there is no change in the temperature of the system. |

Answer: (2)

PC.L2.1-09

Description: Adiabatic versus isothermal PV curves

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Both adiabatic and isothermal processes involve curvy lines on a PV-diagram. What is different between the two?

(1) Adiabatic curves are steeper than isothermal curves

(2) Adiabatic curves are less steep than isothermal curves

(3) Nothing, both are processes are identical so their PV curves are identical

Answer: (1)

PC.L2.1-01

Description: xx

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: xx

Answer: xx

PC.L2.1-01

Description: xx

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: xx

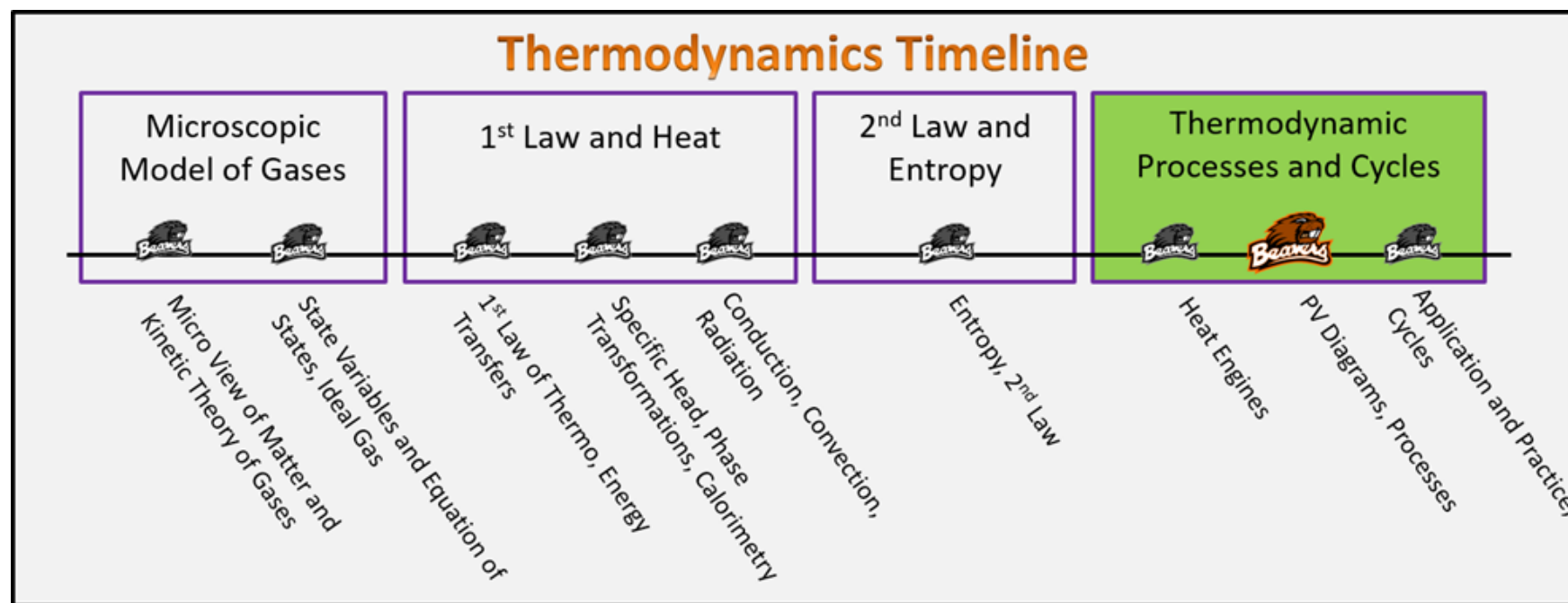
Answer: xx

(PC.2.L2.sols) Foundation Stage Solutions

Monday, January 22, 2018 5:44 PM

Thermodynamics Foundation Stage (PC.2.L2)

Lecture 2 PV Diagrams, Processes



Textbook Chapters (* Calculus version)

- **BoxSand** :: KC videos ([Processes and PV-Diagrams](#))
- **Knight** (College Physics : A strategic approach 3rd) :: 12.3
- ***Knight** (Physics for Scientists and Engineers 4th) :: 18.7 ; 19.2

- Giancoli (Physics Principles with Applications 7th) :: 15-2

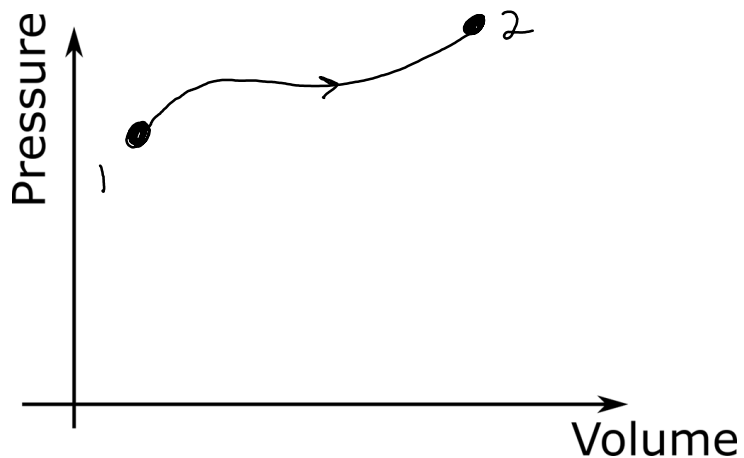
Warm up

PC.2.L2-1:

Description: Sketch any process that starts at one equilibrium state and ends at another.

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 any process that takes an ideal gas from one equilibrium state to a new equilibrium state. Basically, how are equilibrium states represented on a PV diagram and how are processes represented?



Selected Learning Objectives

1. Coming soon to a lecture template near you.

Key Terms

- Thermodynamic process
- Isochoric process
- Isothermal process
- Adiabatic process
- Isobaric process

Key Equations

Key Concepts

- Coming soon to a lecture template near you.

Questions

Act I: Isochoric

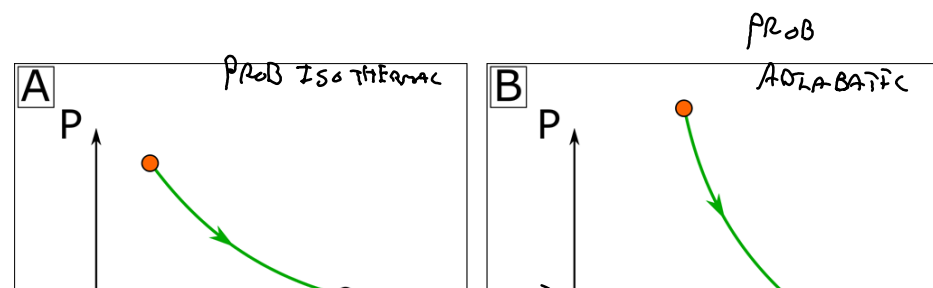
PC.2.L2-2:

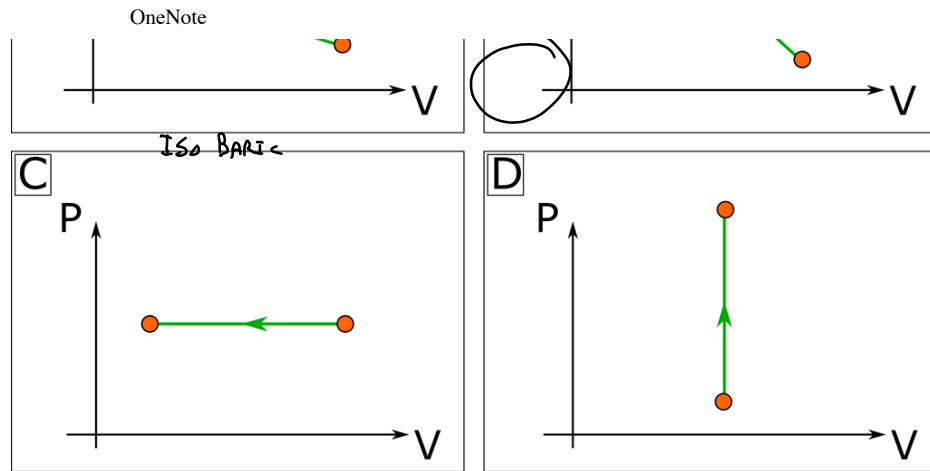
Description: Identify which PV diagram represents an isochoric process. (2 minutes + 2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider the 4 PV diagrams below.

(a) Which diagram shows an isochoric process?





(b) What are the other diagrams called?

PC.2.L2-3:

Description: Proportional reasoning with ideal gas law. (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider one mole of an ideal monatomic gas that undergoes an isochoric process from one equilibrium state to another. If the pressure is increased by a factor of 4, by what factor does the temperature change?



- (1) 1/16
- (2) 1/4
- (3) 1
- (4) 4
- (5) 16

$$PV = nRT$$

w/ $n, + V$ const

$$P \propto T$$

$$\text{IF } P \rightarrow 4P$$

$\Delta H_{FW} \rightarrow \Delta T$

PC.2.L2-4:

Description: Determine signs of first law quantities. (5 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Which of the following are the correct signs for an isochoric increase in temperature?

$\begin{matrix} + & 0 & + \\ - & 0 & - \end{matrix}$

~~(1) $\Delta E^{TH} (+)$, $W (+)$, $Q (+)$~~
~~(2) $\Delta E^{TH} (+)$, $W (0)$, $Q (+)$~~
~~(3) $\Delta E^{TH} (+)$, $W (0)$, $Q (+)$~~
~~(4) $\Delta E^{TH} (-)$, $W (-)$, $Q (-)$~~
~~(5) $\Delta E^{TH} (-)$, $W (0)$, $Q (-)$~~

IDEAL GAS WORK
 $PV = Nk_B T$ $\Delta W = P \Delta V$

Process	ΔE^{TH}	W	Q
Isochoric increase in temp			
Isochoric decrease in temp			
Isothermal expansion			
Isothermal compression			
Adiabatic expansion			
Adiabatic compression			
Isobaric expansion			
Isobaric compression			

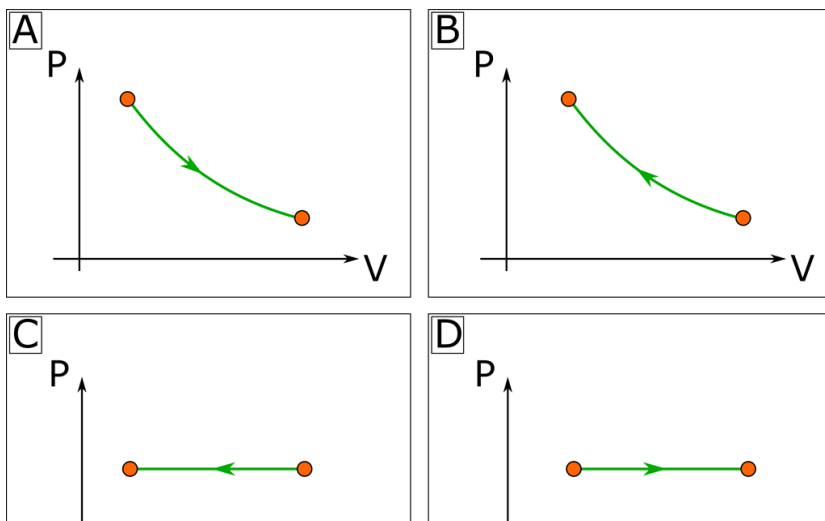
Act II: Isothermal

PC.2.L2-5:

Description: Identify which diagram represents an isothermal process. (2 minutes) Emp COMP: 887.02

Learning Objectives: [1, 12, 13]

Problem Statement: Which of the following P-V diagrams represents an isothermal compression?





PC.2.L2-6:

Description: Proportional reasoning with ideal gas law. (2 minutes + 4 minutes)

Learning Objectives: [1, 12, 13]

○

$$w/ P \rightarrow \frac{1}{4} P$$

Problem Statement: Consider one mole of an ideal monatomic gas that undergoes an isothermal process from one equilibrium state to another.

$$V \rightarrow 4V$$

$$PV = nK_bT$$

(a) How is the pressure related to the volume?

- (1) Linear
- (2) Quadratic
- (3) Inversely $\frac{1}{V}$
- (4) Inverse squared
- (5) No relation

(b) The pressure starts at 400 kPa (and goes to 100 kPa). If the volume started at 0.5 m³, what is the final volume?

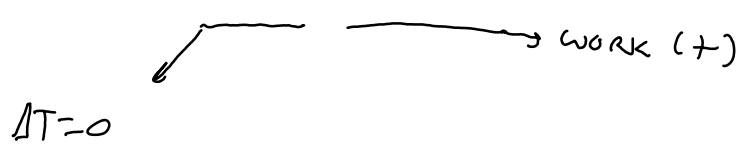
so

$$V_f = (0.5 \text{ m}^3) \times \frac{400 \text{ kPa}}{100 \text{ kPa}} = 2 \text{ m}^3$$

PC.2.2-7:

Description: Determine signs of first law quantities. (5 minutes)

Learning Objectives: [1, 12, 13]



so
 $\Delta E^{th} = 0$

0 - +
 0 + -

$\Delta E^{th} = W + Q$

Problem Statement: Which of the following are the correct signs for an isothermal compression?

$0 = W + Q$
 (+) (-)

$|W| = |Q|$

- (1) $\Delta E^{TH} (+)$, $W (+)$, $Q (+)$
- (2) $\Delta E^{TH} (+)$, $W (-)$, $Q (-)$
- (3) $\Delta E^{TH} (0)$, $W (+)$, $Q (-)$
- (4) $\Delta E^{TH} (0)$, $W (+)$, $Q (+)$
- (5) $\Delta E^{TH} (0)$, $W (-)$, $Q (+)$

Process	ΔE^{TH}	W	Q
Isochoric increase in temp			
Isochoric decrease in temp			
Isothermal expansion			
Isothermal compression			
Adiabatic expansion			
Adiabatic compression			
Isobaric expansion			
Isobaric compression			

TTT
O

x

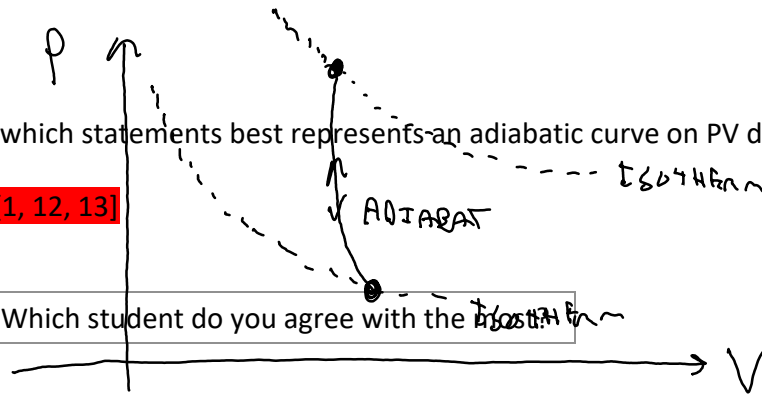
Act III: Adiabatic

PC.2.L2-8:

Description: Identify which statements best represents an adiabatic curve on PV diagram (3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Which student do you agree with the most?



- (1) I think adiabatic PV lines are curvy and less steep than isotherms.
- (2) I agree that they are curvy, but they are more steep than isotherms, right?
- (3) Nah, you're both wrong, they are straight lines with a slope that depends on whether the gas is expanding or contracting.

TTT
O

()

F

— MORE STEEP THAN $\frac{1}{V}$

PC.2.L2-9:

Description: Identify proportionality for adiabatic process: (3 minutes)
 $PV^{3/2} = \text{CONST.}$

Learning Objectives: [1, 12, 13]

Problem Statement: Which of the following statements could be true for monatomic ideal gases that go through an adiabatic process?

- (1) Pressure is proportional to $1/V$
- (2) Pressure is proportional to $1/V^{0.5}$
- (3) Pressure is proportional to $1/V^{1.5}$
- (4) 42



PC.2.L2-10:

Description: Determine signs of first law quantities. (5 minutes)

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

+	-	0
-	+	0

Learning Objectives: [1, 12, 13] (-)

Problem Statement: Which of the following are the correct signs for an adiabatic expansion?

$$\Delta E^{TH} = W$$

- (1) $\Delta E^{TH} (+)$, $W (+)$, $Q (+)$
- (2) $\Delta E^{TH} (0)$, $W (-)$, $Q (+)$
- (3) $\Delta E^{TH} (-)$, $W (-)$, $Q (0)$
- (4) $\Delta E^{TH} (+)$, $W (-)$, $Q (0)$
- (5) $\Delta E^{TH} (+)$, $W (+)$, $Q (0)$

Process	ΔE^{TH}	W	Q
Isochoric increase in temp			
Isochoric decrease in temp			
Isothermal expansion			
Isothermal compression			
Adiabatic expansion			
Adiabatic compression			
Isobaric expansion			
Isobaric compression			

CONST. PRESSURE



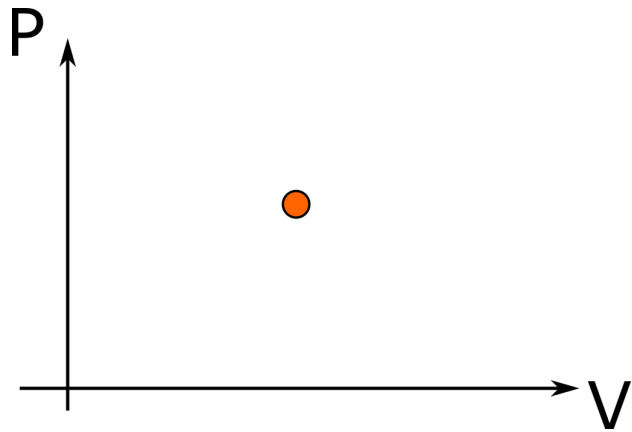

Act IV: Isobaric

PC.2.L2-11:

Description: Sketch an isobaric process. (2 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Use the provided PV diagram and initial equilibrium state to sketch an isobaric expansion.



$$PV = nRT$$

$$V \propto T$$

①

$$V_i = V$$

$$V_f = \frac{?}{?} V_i$$

$$V_f = 3.5V = \frac{7}{2}V$$

PC.2.L2-12:

V 2V 3V 4V

Description: Proportional reasoning with ideal gas law. (4 minutes)

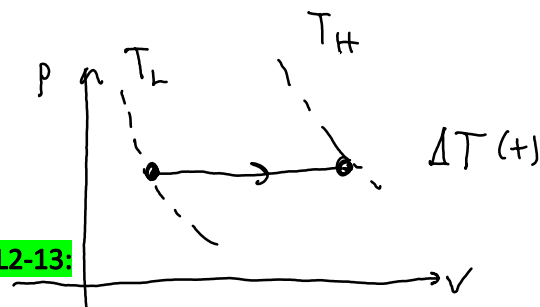
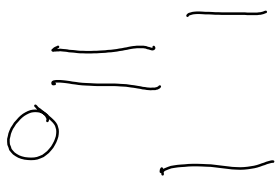
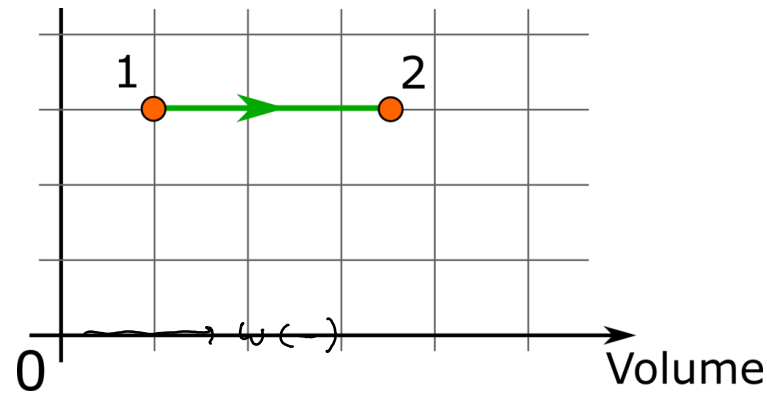
Learning Objectives: [1, 12, 13]

Problem Statement: Below shows an isobaric process. By what factor does the temperature change?

- (1) 1/2.5
- (2) 2/3

Pressure
↑

- (3) 1
- (4) 3/2
- (5) 2.5
- (6) 7/2



PC.2.L2-13:

Description: Determine signs of first law quantities. (5 minutes)

Learning Objectives: [1, 12, 13]

ΔU^*
 $(+)$ $(-)$ $(+)$

$|Q| > |W|$

+	0	+
+	0	+
+	+	+
+	+	+
+	+	+

Problem Statement: Which of the following are the correct signs for an isobaric expansion?

- (1) $\Delta E^{TH} (+)$, $W (+)$, $Q (+)$
- (2) $\Delta E^{TH} (-)$, $W (-)$, $Q (+)$
- (3) $\Delta E^{TH} (-)$, $W (-)$, $Q (-)$

Process	ΔE^{TH}	W	Q
Isochoric increase in temp			
Isochoric decrease in temp			

(4) $\Delta E^{TH} (+)$, $W (-)$, $Q (+)$

(5) $\Delta E^{TH} (-)$, $W (+)$, $Q (-)$

Isothermal expansion			
Isothermal compression			
Adiabatic expansion			
Adiabatic compression			
Isobaric expansion			
Isobaric compression			

○

○

$$PV = nRT$$

$$PV \propto T$$

$$\left(\frac{3}{8}P\right)\left(\frac{9}{2}V\right) \leftrightarrow T$$

$$\frac{27}{7}PV \leftrightarrow T$$

$$P_i = 4P \quad P_f = ? P_i$$

Act III: Other processes

$$X = \frac{3}{8}$$

$$P \rightarrow \frac{3}{8}P$$

4P

3P

2P

P

V 2V 3V 4V 5V

$$V_i = V$$

$$V \rightarrow \frac{9}{2}V$$

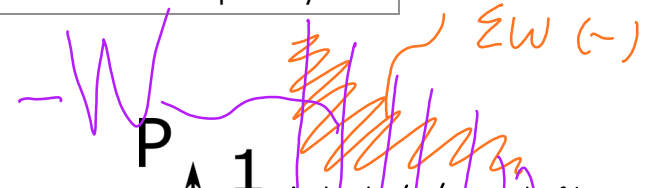
$$V_f = 4.5V = \frac{9}{2}V$$

PC.2.L2-14:

Description: Identify the process type. Proportional reasoning with ideal gas law. (2 minutes + 4 minutes + 2 minutes + 1 minute)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider the PV diagram shown below with 3 processes that form a complete cycle.

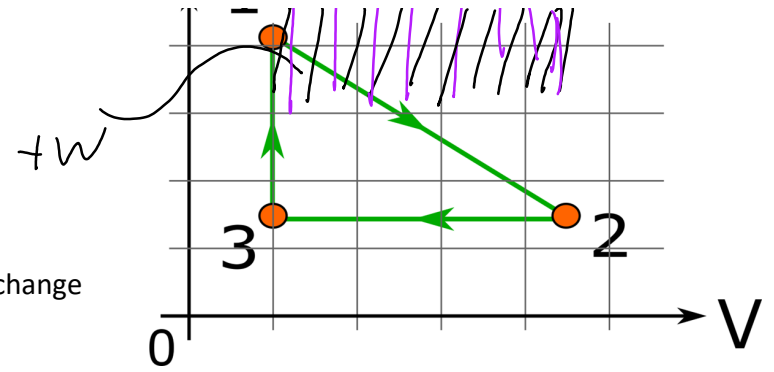


(a) What type of process is represented from equilibrium states 1 → 2 ?

Ⓞ

- (1) Isochoric
- (2) Isothermal
- (3) Adiabatic
- (4) Isobaric
- (5) None of the above

START + STOP @ SAME TEMP
 so $\Delta T = 0$



(b) Considering the stage from 1 → 2, by what factor does the temperature change by? Ⓞ

- (1) 3/8
- (2) 9/5
- (3) 27/16
- (4) 9/2

(c) What is the sign of the net work on the gas after going through all three processes sequentially?

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

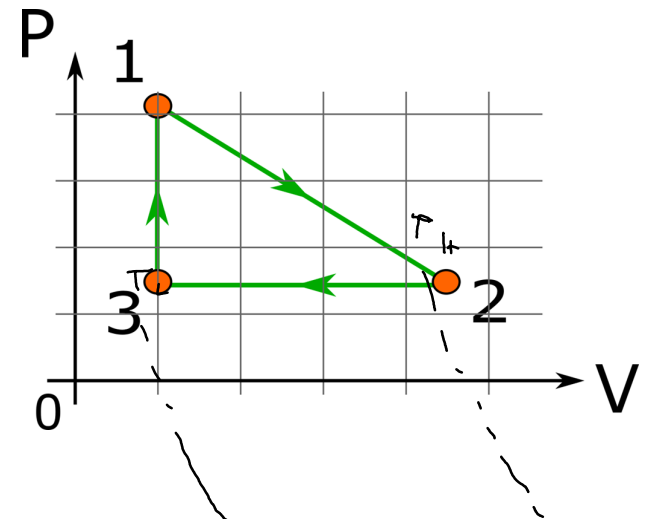
(d) What is the sign of ΔE^{TH} of the gas after going through all three processes sequentially?

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

Ⓞ

Both - work

larger area under A





$$\omega / \Delta T_A = \Delta T_B$$

$$\Delta E_A^{th} = \Delta E_B^{th}$$

PC.2.L2-15:

Description: Determine which process has a larger value of heat flowing into system. (2 minutes + 2 minutes + 3 minutes)

Learning Objectives: [1, 12, 13]

Problem Statement: Consider the two different processes shown on the PV-diagram below.

(a) How does the change in temperature compare between process A and process B?

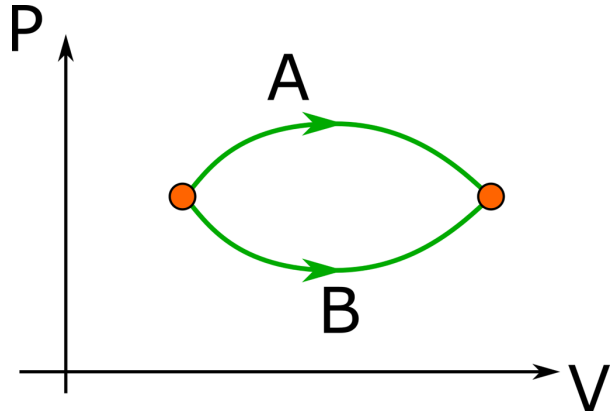
- (1) $\Delta T_A > \Delta T_B$
- (2) $\Delta T_A < \Delta T_B$
- (3) $\Delta T_A = \Delta T_B$

(b) Which process does more work on the environment?

- (1) A
- (2) B
- (3) A and B do equal work on the environment.

(c) Which processes has a larger value of heat?

- (1) $Q_A > Q_B$
- (2) $Q_A < Q_B$



$$(3) Q_A = Q_B$$

Conceptual questions for discussion

1. **Coming soon.**

Hints

PC.2.L2-1: No hints.

PC.2.L2-2: No hints.

PC.2.L2-3: No hints.

PC.2.L2-4: No hints.

PC.2.L2-5: No hints.

PC.2.L2-6: No hints.

PC.2.L2-7: No hints.

PC.2.L2-8: No hints.

PC.2.L2-9: No hints.

PC.2.L2-10: No hints.

PC.2.L2-11: No hints.

PC.2.L2-12: No hints.

PC.2.L2-13: No hints.

PC.2.L2-14: No hints.

(PC.L2.3) Practice Stage

Thursday, March 29, 2018 8:34 PM

Thermodynamic Processes and Cycles (PC)

Practice Stage:

Post-lecture 2: PV Diagrams, Processes

Reading

1. none

Lecture Videos

1. none

Example Problems

1. none

Simulations

1. none

Other Suggested Content

1. none

Practice

1. none

Homework

PC.L2.3-01

Description: Features of non-uniform circular motion

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Consider 1.3 moles of an ideal gas at an initial temperature of 400 K and in a 1.2 m^3 closed container. If the gas goes through an isochoric process to twice the initial temperature, what is the new pressure of the gas?

Answer: 7200 Pa

PC.L2.3-02

Description: Direction of acceleration in non-uniform circular motion

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Consider 1.3 moles of an ideal gas at an initial temperature of 400 K and in a 1.2 m^3 closed container. If the gas goes through an isothermal process to 3.6 m^3 , what is the new pressure of the gas?

Answer: 1200 Pa

PC.L2.3-03

Description: Compare angular acceleration of two objects on the same turntable.

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: Consider 1.3 moles of an ideal gas at an initial temperature of 400 K and in a 1.2 m^3 closed container. If the gas goes through an isobaric process to 3.6 m^3 , what is the new temperature of the gas?

Answer: 1200 K

PC.L2.3-04

Description: Non-UCM kinematics of a car's crankshaft

Learning Objectives: [x,xx,...] Put the learning objective numbers here

Problem Statement: In an adiabatic process, no energy is lost or gained via heat. Which of the following scenarios would best represent an adiabatic process?

- (1) A closed container of gas is placed next to a fire.
- (2) A closed container of gas initially at room temperature has a piston that very slowly compresses the gas.
- (3) A closed container of gas initially at room temperature has a piston that very quickly compresses the gas.
- (4) A closed container of gas is suddenly opened to the environment where the gas escapes to.

Answer: (3)