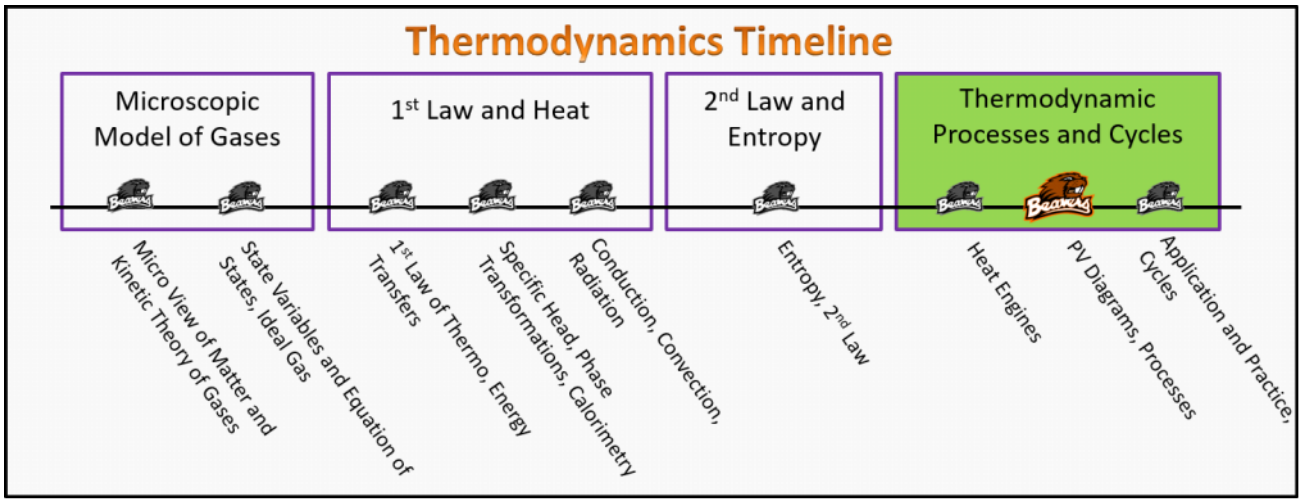
PC.2.L2 - Solutions

Thursday, March 29, 2018 8:34 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

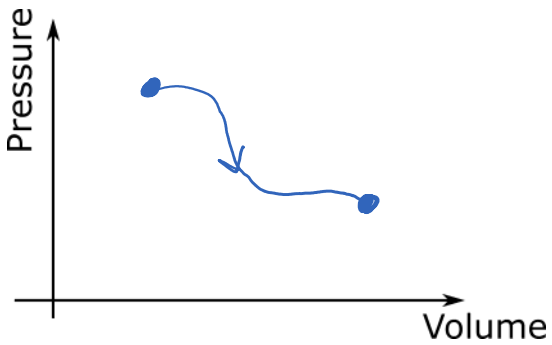
Warm up

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)

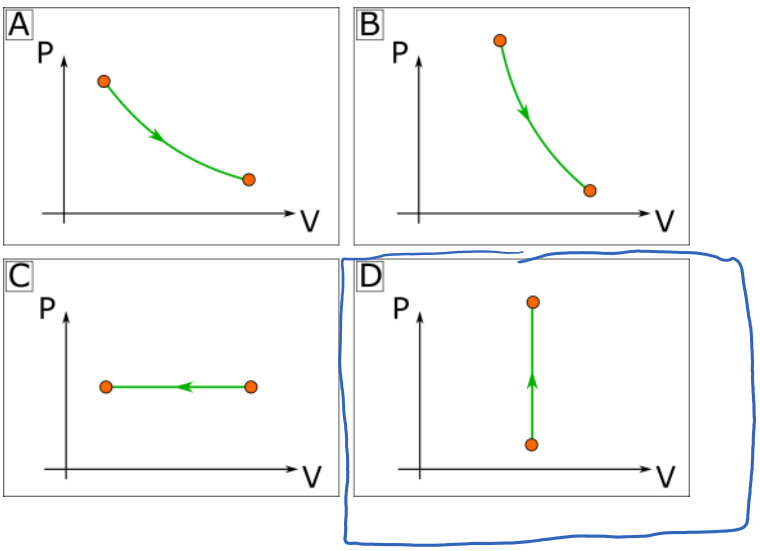
Learning Objectives: [1, 12, 13]

Problem Statement: Consider the 4 PV diagrams below.

(a) Which diagram shows an isochoric process?

iso - const

choric - volume



(b) What are the other diagrams called?

A - isothermal

B - adiabatic

C - isobaric

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 by?

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

$PV = nRT$

$\frac{V}{nR} = \frac{T}{P} \rightarrow \frac{4T}{4P}$

Const ⇒ Const

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?

(1) ΔE^{TH} (+) , **W** (+) , **Q** (+)
(2) ΔE^{TH} (+) , **W** (0) , **Q** (+)
(3) ΔE^{TH} (+) , **W** (0) , **Q** (-)
(4) ΔE^{TH} (-) , **W** (-) , **Q** (-)
(5) ΔE^{TH} (-) , **W** (0) , **Q** (-)

Process	ΔE^{TH}	W	Q
Isochoric increase in temp	+	0	+
Isochoric decrease in temp	−	0	−
Isothermal expansion			
Isothermal compression			
Adiabatic expansion			
Adiabatic compression			
Isobaric expansion			
Isobaric compression			

a) isochoric ⇒ no work done

b) increase in T ⇒ $\Delta E_{th} > 0$

c) $\Delta E_{th} = W + Q$

⇒ if $\Delta E_{th} > 0$, $Q > 0$

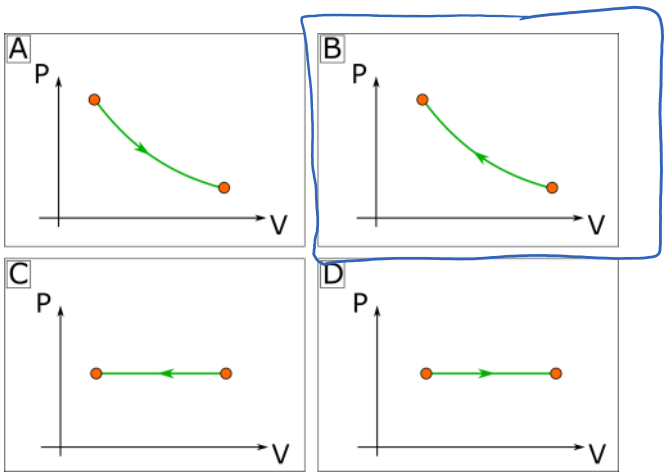
Act II: Isothermal

PC.2.L2-5:

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

Learning Objectives: [1, 12, 13]

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



volume decreasing

PC.2.L2-6:

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

Learning Objectives: [1, 12, 13]

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

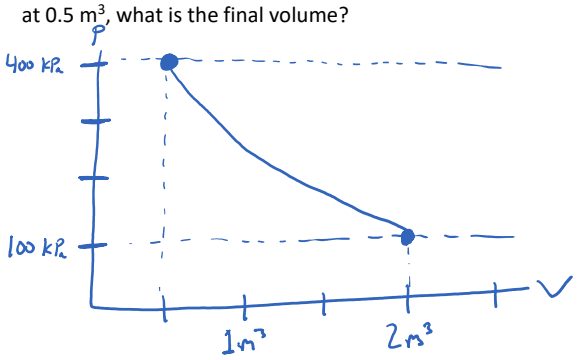
(a) How is the pressure related to the volume?

(1) Linear
(2) Quadratic
(3) Inversely
(4) Inverse squared
(5) No relation

$PV = nRT$ (const)

$P = (\text{const})\frac{1}{V}$

(b) The pressure starts at 400 kPa and goes to 100 kPa. If the volume started at 0.5 m^3, what is the final volume?



$PV = nRT$ (const) $\Rightarrow$ $P \downarrow_4 \Rightarrow V \uparrow^4$

$V_f = 2\ m^3$

PC.2.L2-7:

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 isothermal compression?

(1) ΔE^{TH} (+) , **W** (+) , **Q** (+)
(2) ΔE^{TH} (+) , **W** (-) , **Q** (-)
(3) ΔE^{TH} (0) , **W** (+) , **Q** (-)
(4) ΔE^{TH} (0) , **W** (+) , **Q** (+)
(5) ΔE^{TH} (0) , **W** (-) , **Q** (+)

Process	ΔE^{TH}	W	Q
Isochoric increase in temp	+	0	+
Isochoric decrease in temp	−	0	−
Isothermal expansion	0	−	+
Isothermal compression	0	+	−
Adiabatic expansion			
Adiabatic compression			
Isobaric expansion			
Isobaric compression			

a) $\Delta T = 0 \Rightarrow \Delta E_{th} = 0$

b) expansion ⇒ negative work done on the gas

c) $\Delta E_{th} = W + Q$
$0 = - +$

Act III: Adiabatic

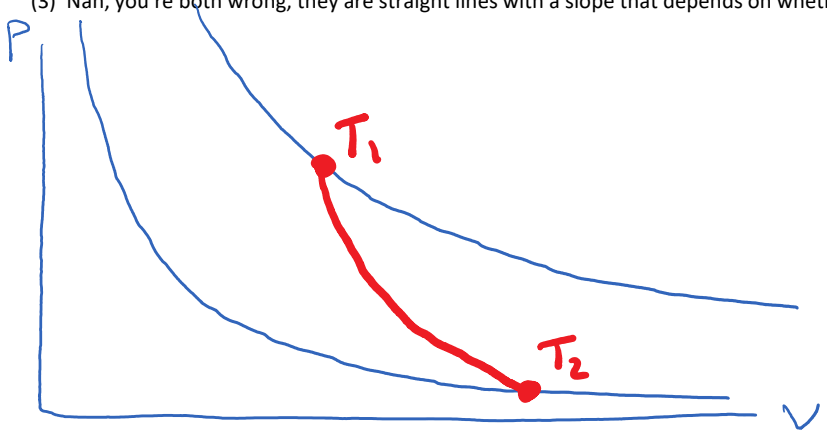
PC.2.L2-8:

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.



PC.2.L2-9:

Description: Identify proportionality for adiabatic process. (3 minutes)

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/$\mathbf{V}^{0.5}$
(3) Pressure is proportional to 1/$\mathbf{V}^{1.5}$ ← steeper than $\frac{1}{V}$
(4) 42

PC.2.L2-10:

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 adiabatic expansion?

(1) ΔE^{TH} (+) , **W** (+) , **Q** (+)
(2) ΔE^{TH} (0) , **W** (-) , **Q** (+)
(3) ΔE^{TH} (-) , **W** (-) , **Q** (0)
(4) ΔE^{TH} (+) , **W** (-) , **Q** (0)
(5) ΔE^{TH} (+) , **W** (+) , **Q** (0)

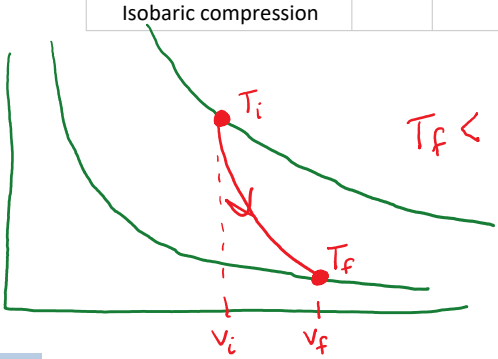
a) $Q = 0$ (adiabatic)

b) expansion ⇒ negative work

c) $\Delta E_{th} = W + Q$
$\uparrow \quad = \quad \uparrow \quad \uparrow$
$- \quad = \quad - \quad 0$

or

Process	ΔE^{TH}	W	Q
Isochoric increase in temp	+	0	+
Isochoric decrease in temp	-	0	-
Isothermal expansion	0	-	+
Isothermal compression	0	+	-
Adiabatic expansion	-	-	0
Adiabatic compression	+	+	0
Isobaric expansion			
Isobaric compression			



$T_f < T_i \Rightarrow \Delta E_{th} < 0$

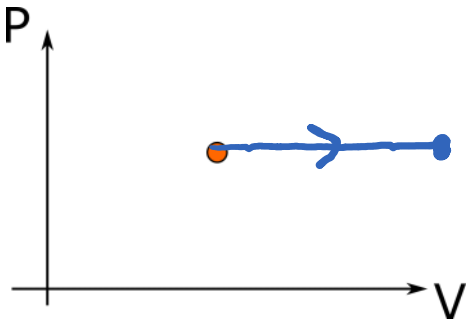
Act IV: Isobaric

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.



PC.2.L2-12:

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

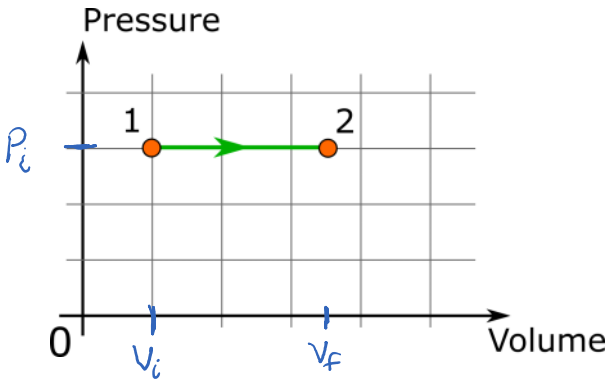
Learning Objectives: [1, 12, 13]

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

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

$PV = nRT$

$\frac{P}{nR} = \frac{T}{V} \rightarrow \frac{3.5T}{3.5V}$



$V_f = 3.5\,V_i$

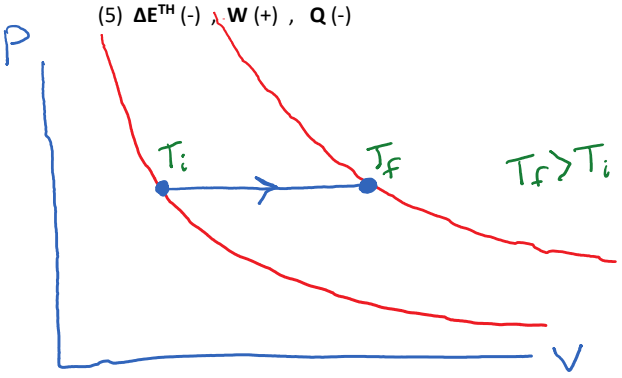
PC.2.L2-13:

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 isobaric expansion?

(1) ΔE^{TH} (+) , **W** (+) , **Q** (+)
(2) ΔE^{TH} (-) , **W** (-) , **Q** (+)
(3) ΔE^{TH} (-) , **W** (-) , **Q** (-)
(4) ΔE^{TH} (+) , **W** (-) , **Q** (+)
(5) ΔE^{TH} (-) , **W** (+) , **Q** (-)



Process	ΔE^{TH}	W	Q
Isochoric increase in temp	+	0	+
Isochoric decrease in temp	−	0	−
Isothermal expansion	0	−	+
Isothermal compression	0	+	−
Adiabatic expansion	−	−	0
Adiabatic compression	+	+	0
Isobaric expansion	+	−	+ +
Isobaric compression	−	+	− −

a) expansion ⇒ negative Work

b) picture ⇒ $T_f > T_i$ ⇒ $\Delta E_{th} > 0$

c) $\Delta E_{th} = W + Q$
$+ = - \quad ++$

Act III: Other processes

PC.2.L2-14:

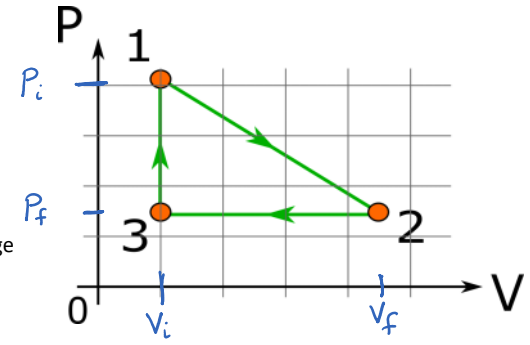
Description: Identify the process type. Proportional reasoning with ideal gas law. (2 minutes + 4 minutes + 2 minutes + 1 minute)

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



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

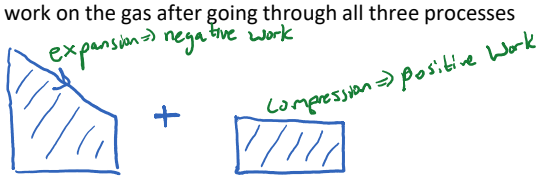
(1) 3/8
(2) 9/5
(3) 27/16
(4) 9/2

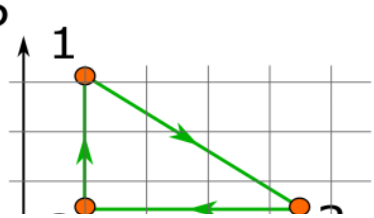
$PV = nRT$

$$\Rightarrow \frac{T_f}{T_i} = \frac{P_f V_f}{P_0 V_0} = \left(\frac{1.5}{4}\right)\left(\frac{4.5}{1}\right) = \left(\frac{3}{8}\right)\left(\frac{9}{2}\right) = \frac{27}{16}$$

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

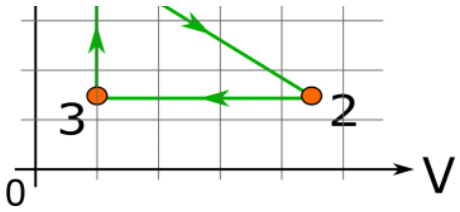
(1) Positive
(2) Negative
(3) Zero





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

(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

Same $P, V, T \Rightarrow \Delta E_{th} = 0$

PC.2.L2-15:

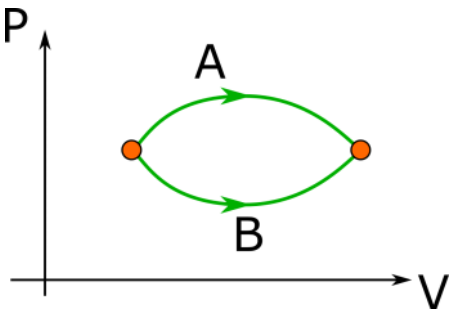
Description: Determine which processes has a larger value of heat flowing into system. (2 minutes + 2 minutes + 3 minutes)

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) $Q_A = Q_B$

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

$\Delta E_A = (-\text{large}) + (+\text{large})$ ← Q_A

$\Delta E_B = (-\text{small}) + (+\text{small})$ ← 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.