(PC.L3.1) Familiarize Stage

Thursday, March 29, 2018 8:34 PM

Thermodynamic Processes and Cycles (PC)

Familiarize Stage:

Pre-lecture 3: Application and Practice, Cycles

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.L3.1-01

Description: Calculations involving processes

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

Problem Statement: 5 J of heat is added to an ideal gas in an isothermal process. How much work does the gas do *on the environment* during this process?

(1) -5 J
(2) 0 J
(3) 5 J
(4) 10 J

Answer: (3)

PC.L3.1-02

Description: Calculations involving processes

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

Problem Statement: 10 J of work is done to compress a gas in an adiabatic process. What is the change to the internal energy of the gas in this process?

(1) 10 J
(2) 0 J
(3) -10 J
(4) 20 J

Answer: (1)

PC.L3.1-03

Description: Cyclic processes and state variables

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

Problem Statement: What is a cyclic process?

(1) A process in which the system follows the same path for every cycle
(2) A process in which the system follows a different path for every cycle
(3) A process in which the system returns to its original state at the end of the cycle
(4) A process in which the system does not return to its original state at the end of the cycle

Answer: (3)

PC.L3.1-04

Description: Internal energy for a cyclic process

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

Problem Statement: What is the change in internal energy for a complete cycle of a cyclic process?

(1) 0 J
(2) 5 J
(3) 10 J

Answer: (1)

PC.L3.1-05

Description: Calculations involving processes

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

Problem Statement: A gas does 10 J of work in a cyclic process. What is the net heat transfer into the system?

(1) -10 J
(2) 0 J
(3) 10 J
(4) 20 J

Answer: (3)

PC.L3.1-01

Description: xx

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

Problem Statement: xx

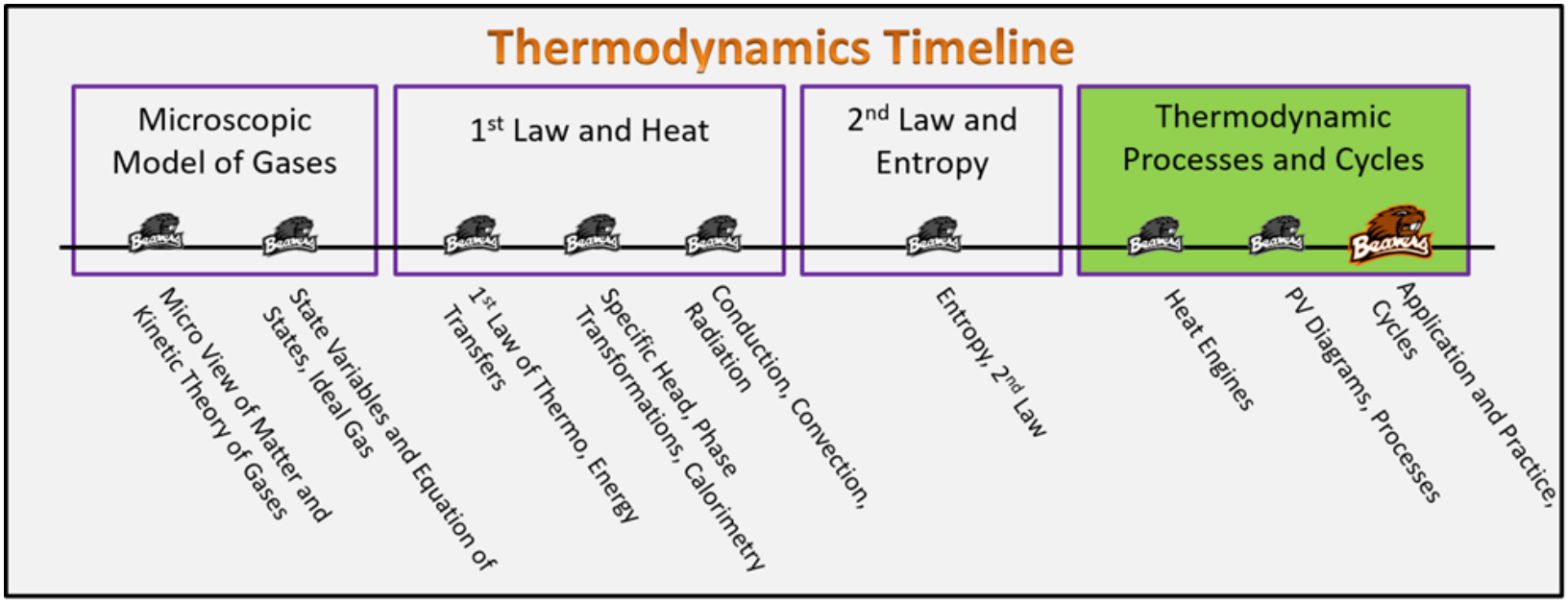
Answer: xx

(PC.2.L3.sols) Foundation Stage Solutions

Thursday, March 29, 2018 8:34 PM

Thermodynamics
Foundation Stage (PC.2.L3)

Lecture 3
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

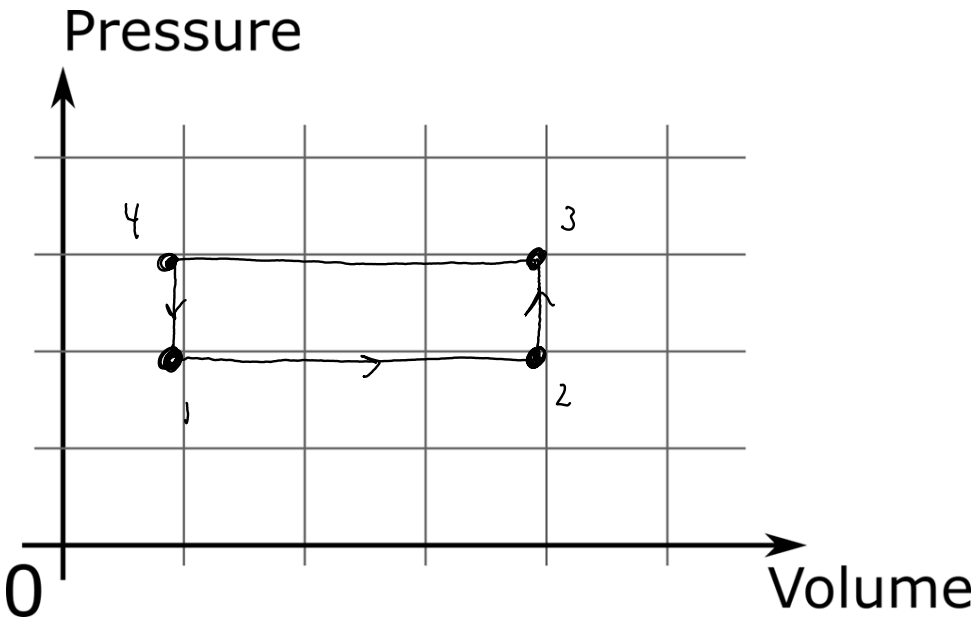
Warm up

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

Act I: Isochoric

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.

$\frac{1}{2}(0.2-0.1)(40000-20000)\ Pa\ m^3$

(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·m^2/s^2

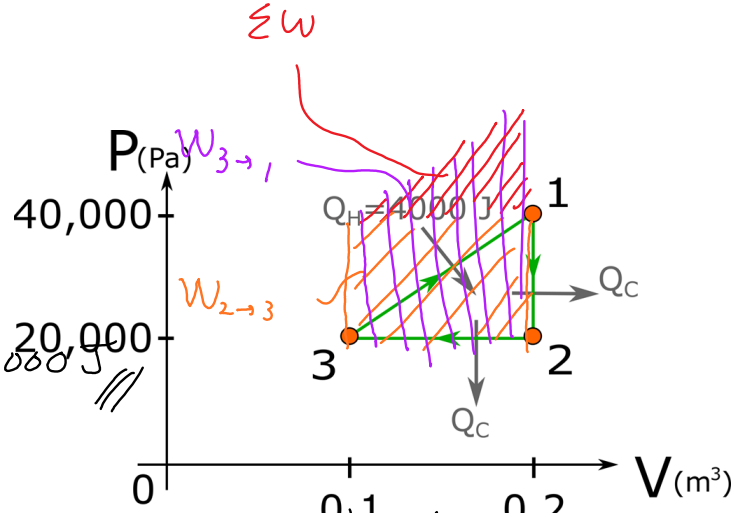
$W_{2\to3}$ (+) small area

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

$W_{3\to1}$ (−) large area

(1) Positive

$\Sigma W = -1000\ J$



(2) Negative
(3) Zero

$\Sigma W (-)$ so Engine

$e = \frac{NET}{PAY} = \frac{|\Sigma W|}{Q_{IN}}$

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

(d) What is the efficiency of this cycle?

$e = \frac{1000\ J}{4000\ J} = 0.25$

1ST LAW

$\Delta E^{TH}_{TOTAL} = W_{TOTAL} + Q_{TOTAL}$ ($\Delta E^{TH} \to 0$)

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

$0 = W_{TOTAL} + Q_H + Q_C$

$0 = -1000 + 4000$

$Q_C = -3000\ J$

so $|Q_C| < |Q_H|$

PC.2.L3-3:

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

Learning Objectives: [1, 12, 13]

~ MONATOMIC GASES

~ 1ST LAW

~ IDEAL GAS

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

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

PC.2.L3-4:

Description: Cycle problem. (30 minutes)

ISO THERM

Learning Objectives: [1, 12, 13]

ISO BARIC

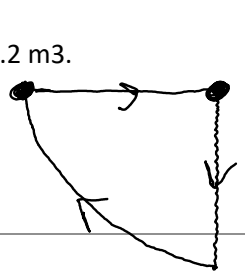
ISOCHORIC

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

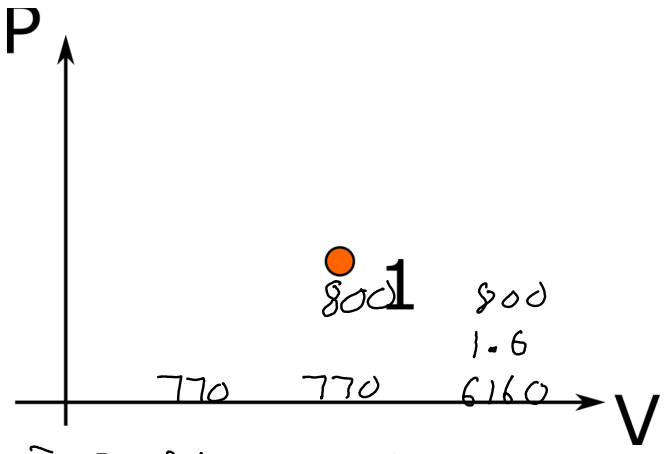
Process **1** → **2** :: Compression with **P V** = Constant, from P_1 = 100 kPa , V_1 = 1.6 m3 to V_2 = 0.2 m3.

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

Process **3** → **1** :: Constant volume with $E_1 - E_3 = -1680$ kJ



(a) Use the **PV** to the right to sketch this cycle.



(b) Is this a power or refrigeration cycle?

$P_1V_1 = nRT_1 \qquad T_1 = \frac{P_1V_1}{nR} \approx 770\ K$

$T_1 = T_2$ B/C on Isothermal

$1 \to 2$ $\quad V \propto \frac{1}{P} \qquad V \to \frac{1}{8}V$

So $P \to 8P$

$P_2 = P_3$ B/C Isobaric

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

$2 \to 3$ $\quad T \propto V \qquad V \to 8V$

So $T \to 8T$

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

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

0 1680 0

−1120

2800 −1680

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

$\Sigma \Delta E^{TH} = 0$

(f) Which of the following quantities are zero?

(1) $\Delta E^{TH}_{1\ to\ 2}$

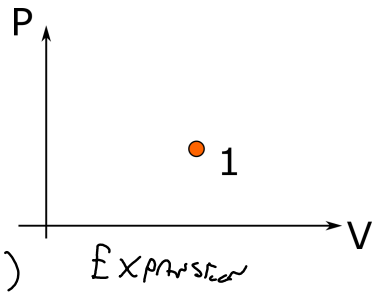
(2) $\Delta E^{TH}_{2\ to\ 3}$

(3) $\Delta E^{TH}_{3\ to\ 1}$

(4) ΔE^{TH}_{Total}

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (kJ)		$\Delta E^{TH} = 0 + 0$	−1680	
W (kJ)				
Q (kJ)				

1st Law



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

(5) $W_{1 \text{ to } 2}$ $-(800000)(1.6-0.2)$

(6) $W_{2 \text{ to } 3}$

(7) $W_{3 \text{ to } 1}$

(8) W_{Total}

(9) $Q_{1 \text{ to } 2}$

(10) $Q_{2 \text{ to } 3}$

~~(11)~~ $Q_{3 \text{ to } 1}$

(12) Q_{Total}

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

$-1120\,000$ J

1ST LAW $\Delta E_{TH} = W + Q$ $\quad 1680 = -1120 + Q \quad \rightarrow Q = 2800$

0	1680		0
333	-1120	0	-787
-333	2800	-1680	787

w/ $PV = nRT$

(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) $-P\,V \ln(V_f/V_i)$

$-(100000)(1.6)\ln\left(\frac{.2}{1.6}\right)$

$+333\,000$ J

(+) COMPRESSION

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

1ST LAW $\Delta E_{TH} = W + Q$ ($\Delta E_{TH} = 0$)

$Q = -W$

$\Sigma W = 333 - 1120 = -787$ kJ

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

1ST LAW $\Delta E_{TH} = W + Q$ ($\Delta E_{TH} = 0$) OR ΣQ

$-333 + 2800 - 1680 = 787$ kJ

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE_{TH} (kJ)			-1680	
W (kJ)				
Q (kJ)				

$Q = \Delta E_{TH} - W$

(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) $-P\,V \ln(V_f/V_i)$

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

$e = \frac{\text{GET}}{\text{PAY}} = \frac{|\Sigma W|}{Q_H} = \frac{787}{2800} \approx \boxed{0.281}$

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

(o) Finish the table of energies.

(p) Calculate the efficiency of this cycle.

Conceptual questions for discussion

1. Coming soon.

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.

(PC.L3.3) Practice Stage

Thursday, March 29, 2018 8:34 PM

Thermodynamic Processes and Cycles (PC)

Practice Stage:

Post-lecture 3: Application and Practice, Cycles

Reading
1. none

Lecture Videos
1. none

Example Problems
1. none

Simulations
1. none

Other Suggested Content
1. none

Practice
1. none

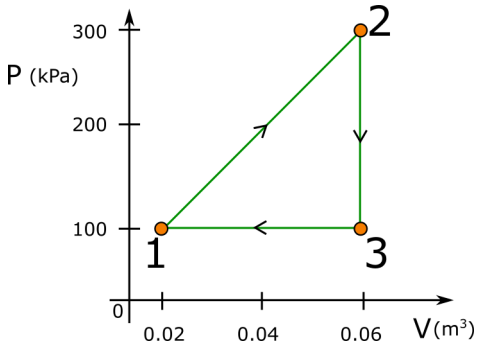
Homework

PC.L3.3-01a

Description: Features of non-uniform circular motion

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

Problem Statement: 1.202 moles of a monatomic gas is taken through the cycle shown below. Which of the following tables correctly describes the pressure, volume, and temperature at each of the three states?



(1)

	1	2	3
P (Pa)	100,000	300,000	100,000
V (m^3)	0.02	0.06	0.06
T (K)	200	600	200

(2)

	1	2	3
P (Pa)	100,000	300,000	100,000
V (m^3)	0.02	0.06	0.06
T (K)	200	600	600

(3)

	1	2	3

P (Pa)	100,000	300,000	100,000
V (m^3)	0.02	0.06	0.06
T (K)	200	1800	1800

(4)

	1	2	3
P (Pa)	100,000	300,000	100,000
V (m^3)	0.02	0.06	0.06
T (K)	200	1800	600

Answer: (4)

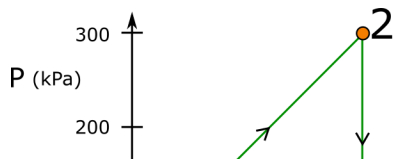
PC.L3.3-01b

Description: Features of non-uniform circular motion

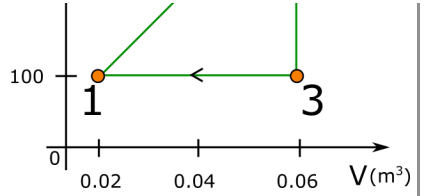
Learning Objectives: [x,xx,…] Put the learning objective numbers here

Problem Statement: 1.202 moles of a monatomic gas is taken through the cycle shown below. We wish to eventually fill out the table below. Which of the following quantities are zero?

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)				



Q (J)				



(1) $\Delta E^{TH}_{1\rightarrow 2}$
(2) $\Delta E^{TH}_{2\rightarrow 3}$
(3) $\Delta E^{TH}_{3\rightarrow 1}$
(4) $\Delta E^{TH}_{complete}$
(5) $W_{1\rightarrow 2}$
(6) $W_{2\rightarrow 3}$
(7) $W_{3\rightarrow 1}$
(8) $W_{complete}$
(9) $Q_{1\rightarrow 2}$
(10) $Q_{2\rightarrow 3}$
(11) $Q_{3\rightarrow 1}$
(12) $Q_{complete}$

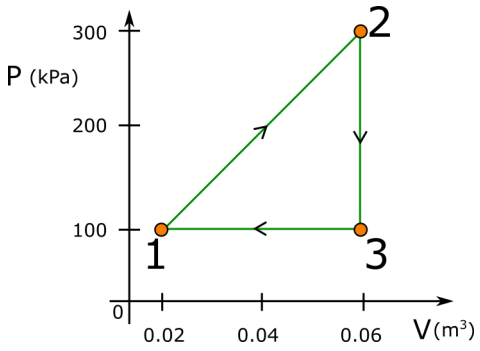
Answer: (4), (6)

PC.L3.3-01c

Description: Features of non-uniform circular motion

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

Problem Statement: 1.202 moles of a monatomic gas is taken through the cycle shown below. We wish to eventually fill out the table below. Which table correctly describes the change in thermal energies between each state and the complete cycle?



(1)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)	24,000	18,000	6,000	0
W (J)				
Q (J)				

(2)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)	24,000	-18,000	-6,000	0
W (J)				
Q (J)				

(3)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)	-24,000	18,000	6,000	0
W (J)				

	Q (J)				

		1 → 2	2 → 3	3 → 1	Complete Cycle
(4)	ΔE^{TH} (J)	-24,000	-18,000	-6,000	0
	W (J)				
	Q (J)				

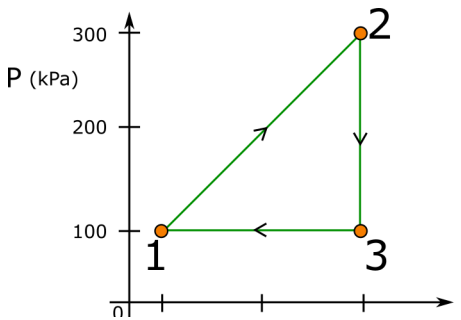
Answer: (2)

PC.L3.3-01d

Description: Features of non-uniform circular motion

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

Problem Statement: 1.202 moles of a monatomic gas is taken through the cycle shown below. We wish to eventually fill out the table below. Which table correctly describes the work done between each state and the complete cycle?



(1)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)	-14,000	0	14,000	0
Q (J)				

(2)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)	14,000	0	14,000	24,000
Q (J)				

(3)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)	-28,000	0	14,000	-14,000
Q (J)				

(4)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)	-14,000	0	-14,000	-28,000
Q (J)				

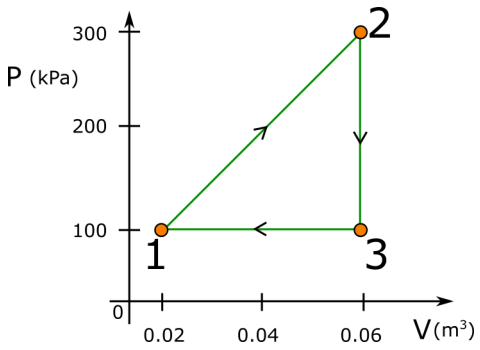
Answer: (3)

PC.L3.3-01e

Description: Features of non-uniform circular motion

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

Problem Statement: 1.202 moles of a monatomic gas is taken through the cycle shown below. We wish to eventually fill out the table below. Which table correctly describes the heat between each state and the complete cycle?



(1)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)				
Q (J)	-4,000	18,000	8,000	22,000

(2)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)				
Q (J)	4,000	18,000	-8,000	14,000

(3)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)				
Q (J)	4,000	-18,000	8,000	-6,000

(4)

	1 → 2	2 → 3	3 → 1	Complete Cycle
ΔE^{TH} (J)				
W (J)				
Q (J)	52,000	-18,000	-20,000	14,000

Answer: (4)