Begin your response to **QUESTION 1** on this page.

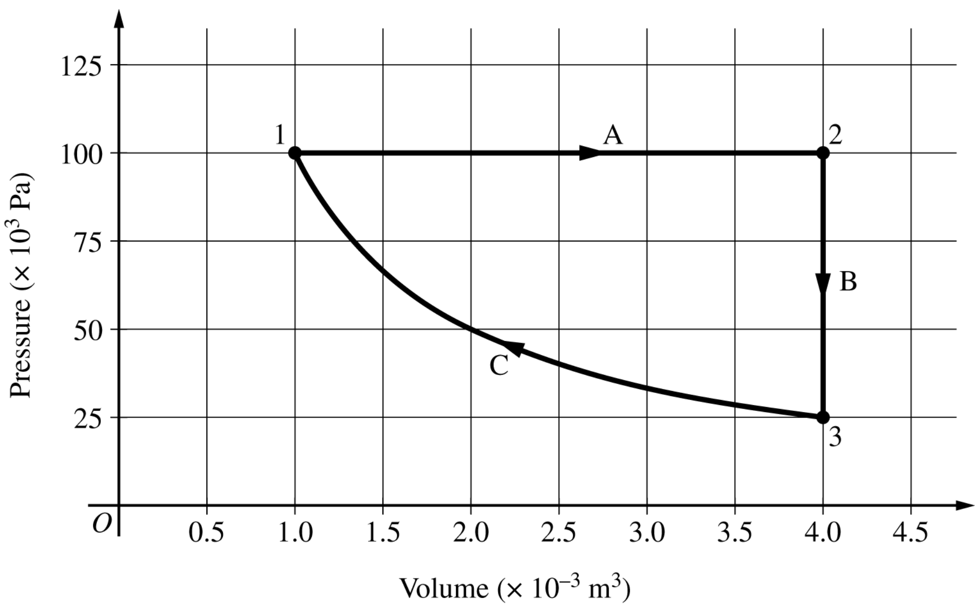
PHYSICS 2

SECTION II

Time—1 hour and 30 minutes

4 Questions

Directions: Questions 1 and 4 are short free-response questions that require about 20 minutes each to answer and are worth 10 points each. Questions 2 and 3 are long free-response questions that require about 25 minutes each to answer and are worth 12 points each. Show your work for each part in the space provided after that part.



1. (10 points, suggested time 20 minutes)

A sample of ideal gas is taken through the thermodynamic cycle shown above. Process C is isothermal.

(a) Consider the portion of the cycle that takes the gas from state 1 to state 3 by processes A and B. Calculate the magnitude of the following and indicate the sign of any nonzero quantities.

- The net change in internal energy ΔU of the gas
- The net work W done on the gas
- The net energy Q transferred to the gas by heating

GO ON TO THE NEXT PAGE.

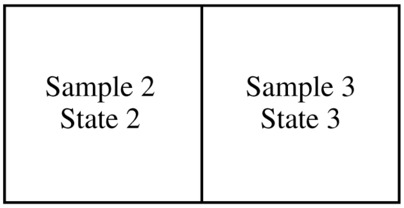
Use a pencil or pen with black or dark blue ink only. Do NOT write your name. Do NOT write outside the box.

Continue your response to **QUESTION 1** on this page.

(b) Consider isothermal process C.

i. Compare the magnitude and sign of the work W done on the gas in process C to the magnitude and sign of the work in the portion of the cycle in part (a). Support your answer using features of the graph.

ii. Explain how the microscopic behavior of the gas particles and changes in the size of the container affect interactions on the microscopic level and produce the observed pressure difference between the beginning and end of process C.



(c) Consider two samples of the gas, each with the same number of gas particles. Sample 2 is in state 2 shown in the graph, and sample 3 is in state 3 shown in the graph. The samples are put into thermal contact, as shown above. Indicate the direction, if any, of energy transfer between the samples. Support your answer using macroscopic thermodynamic principles.

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Question 1: Short Answer — 10 points

(a)		For indicating that $\Delta U = 0$ J	**1 point**
		For correctly calculating the net work done during the two processes with correct units $W = -P\Delta V = -\left(100 \times 10^3 \text{ Pa}\right)\left[(4-1)\left(\times 10^3 \text{ m}\right)\right] = -300 \text{ J}$ **Scoring note:** The answer must either have the negative sign or indicate that the work is done by the gas.	**1 point**
		For substituting ΔU and W into the first law of thermodynamics to obtain a value for Q OR for applying the first law to show that Q is equal in magnitude to W but opposite in sign	**1 point**
		Example response for part (a) *The change in internal energy is zero because the initial and final temperatures are the same at points 1 and 3. The work done on the gas is -PΔV = -300 J. Because the work is negative, 300 J of energy must be transferred to the gas by heating in order for the internal energy of the gas to remain constant.*	
		Total for part (a)	**3 points**
(b)	**i.**	For indicating that the work is less than in part (a), with a reference to less area under the curve	**1 point**
		For indicating that the work is positive or opposite the sign indicated in part (a), with a reference to the sign of the change in volume or the direction of the process as indicated in the graph	**1 point**
		Example response for part (b)(i) *The magnitude of the work done is less than the work in part (a) because there is less area under the curve. The work is also the opposite sign from part (a) because the volume decreases, as shown by the direction of the arrow.*	
	ii.	For stating that there is no change in average kinetic energy/speed of gas molecules	**1 point**
		For indicating a change that is relevant to the collision rate **Scoring note:** Acceptable responses include volume, surface area, time to traverse the container.	**1 point**
		For indicating that there are more collisions with the walls of the container; thus, more force per area (must refer to the walls)	**1 point**
		Example response for part (b)(ii) *Temperature does not change, so the speed of the molecules and the force of collisions with the walls of the container stays the same. Volume decreases, so the density of the gas molecules increases, and they collide more frequently. This means more net force due to collisions with the container walls. The smaller volume also means less surface area.*	
		Total for part (b)	**5 points**
(c)		For indicating that the temperature in state 2 is higher than in state 3	**1 point**
		For indicating that energy flows from the state indicated as hotter to the state indicated as cooler	**1 point**
		Example response for part (c) *The temperature of the gas in sample 2 is higher than the temperature of sample 3. Energy goes from hot to cold, so energy will transfer from sample 2 to sample 3.*	

Total for part (c)	**2 points**
Total for question 1	**10 points**