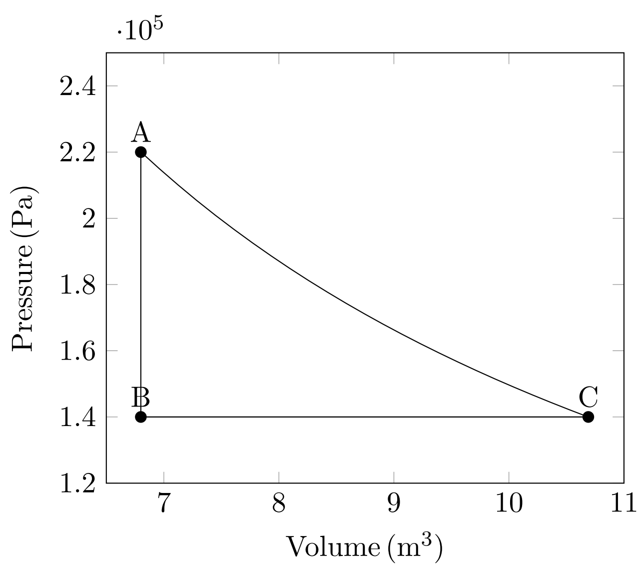
Physics 151: Accelerated Physics I—Mechanics and Thermodynamics
First Law of Thermodynamics

Problem 1: A monatomic ideal gas is initially at state "A", with a volume of $6.80\,\mathrm{m}^3$, pressure 2.20×10^5 Pa, and temperature 300 K. The pressure is then reduced at constant volume to state "B," with a pressure of 1.40×10^5 Pa. Next, it is expanded at constant pressure to state "C," where the temperature returns to 300 K. Finally, it is compressed at constant temperature back to state "A."

Fill in the missing entries in the following tables:

State	p **(Pa)**	V **(m^3)**	T **(K)**
A	2.20×10^5	6.80	300
B	1.40×10^5	6.80	
C	1.40×10^5		300

Process	**Q (J)**	**W (J)**	**Δ U (J)**
$A \to B$			
$B \to C$			
$C \to A$			
$A \to B \to C \to A$			



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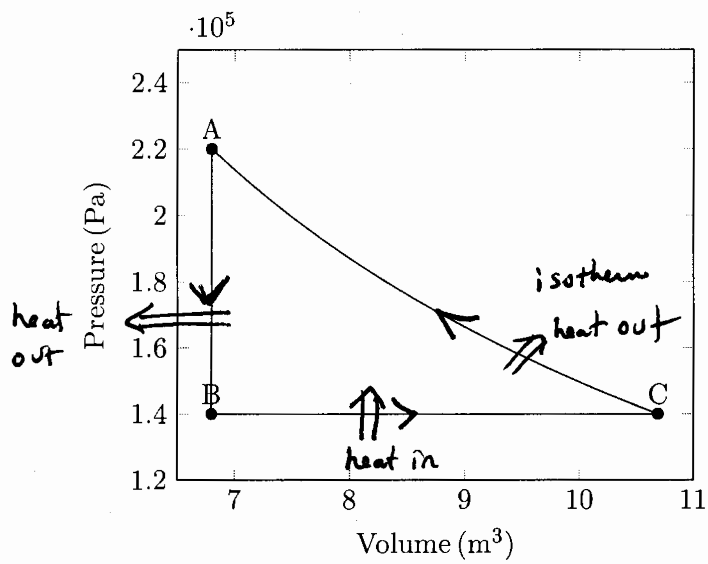
Problem 1: A monatomic ideal gas is initially at state "A", with a volume of $6.80\,\mathrm{m}^3$, pressure $2.20 \times 10^5\,\mathrm{Pa}$, and temperature $300\,\mathrm{K}$. The pressure is then reduced at constant volume to state "B," with a pressure of $1.40 \times 10^5\,\mathrm{Pa}$. Next, it is expanded at constant pressure to state "C," where the temperature returns to $300\,\mathrm{K}$. Finally, it is compressed at constant temperature back to state "A."

Fill in the missing entries in the following tables:

State	p (Pa)	V (m^3)	T (K)
A	2.20×10^5	6.80	300
B	1.40×10^5	6.80	190.9
C	1.40×10^5	10.69	300

Process	Q (J)	W (J)	Δ U (J)
$A \to B$	−816,100	0	−816,100
$B \to C$	1,360,700	544,600	816,100
$C \to A$	−677,000	−677,000	0
$A \to B \to C \to A$	−132,400	−132,400	0



Fill in 1st table:

$$\frac{p_A V_A = nRT_A}{p_B V_B = nRT_B}$$

$$T_B = T_A \frac{p_B}{p_A} = 190.9\ \mathrm{K}$$

$$\frac{p_B V_B = nRT_B}{p_C V_C = nRT_C}$$

$$V_C = \frac{V_B T_C}{T_B} = 10.69\,\mathrm{m}^3$$

Processes:

A → B: $W = \int p\,dV = 0$

$\Delta U = n C_v \Delta T$ what is n? $n = \frac{p_A V_A}{R T_A} = 599.8$ moles

or symbolically, recall $C_v = \frac{3}{2} R$, so

$$\Delta U = \left(\frac{p_A V_A}{R T_A}\right)\left(\frac{3}{2} R\right)\left(\Delta T\right) = \frac{3}{2} p_A V_A \frac{\Delta T}{T_A} = -816{,}068\text{ J}$$

$Q = \Delta U + W = \Delta U = -816{,}068\text{ J}$

B → C $W = \int p\,\Delta V = p_B (V_c - V_B) = 544{,}600\text{ J}$

$\Delta U = n C_v \Delta T = (599.8\text{ moles})\left(\frac{3}{2}R\right)(300 - 190.9)$

$\Delta U = 816\,100\text{ J}$

$Q = W + \Delta U = 1{,}360{,}700\text{ J}$

C → A

$W = \int p\,dV = ?$ p varies, but T is constant.

Use $p = nRT/V$

$$W = \int_C^A \frac{nRT}{V}\,dV = nRT_c \int_c^A \frac{dV}{V} = nRT_c \ln\left(\frac{V_A}{V_c}\right)$$

or $W = p_c V_c \ln\left(\frac{V_A}{V_c}\right) = -677{,}000\text{ J}$

$\Delta U = n C_v \Delta T = 0$ (isothermal).

$Q = W + \Delta U = -677{,}000\text{ J}$

Full cycle: $\Delta U_{ABCA} = n C_v \Delta T_{A \cdot A} = 0.$

(Totals are sensitive to round-off.)