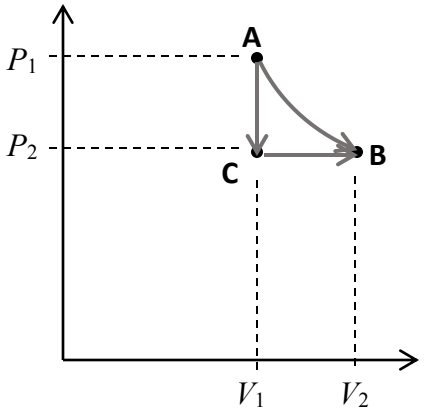
Name: Key

Physics Quiz 1

1. 2.0 moles of a monatomic ideal gas initially are at state **A**, with a pressure of $P_1 = 3.0 \times 10^5$ Pa and volume of $V_1 = 6.0 \times 10^{-2}$ m^3. The gas can be taken directly to state **B** by the constant-temperature path **A**—**B** depicted, or stepwise through state **C**, by path **A**—**C** followed by path **C**—**B**.



   a. The path **A**—**B** is carried out at constant temperature. The word for a constant temperature process is isothermal.

   b. The path **A**—**C** is carried out at constant volume. The word for that is isochoric.

   c. The path **C**—**B** is carried out at constant pressure. The word for that is isobaric.

   d. What is the temperature of the gas at state **A**?

   Ideal gas $PV = nRT$, so $T = PV/(nR) = \dfrac{(3\times10^5\ \text{J/m}^3)(6\times10^{-2}\ \text{m}^3)}{(2\ \text{mol})(8.314\ \text{J/(mol K)})} = 1082.5$ K

   This seemed high to me, so I made the online version 4 mol gas, making the temperature half as much, or 541.3 K.

   e. What is the internal energy of the gas at state **A**?

   Monatomic ideal gas $U = 3/2\ nRT = 3/2\ PV = 3/2(3\times10^5\ \text{J/m}^3)(6\times10^{-2}\ \text{m}^3)$
   $= 27\times10^3$ J = 27 kJ

   f. The volume of the gas at state **B** is $V_2 = 9.0 \times 10^{-2}$ m^3. What is the pressure P_2 at state **B**?

   $PV = nRT$ and T is unchanged, so $P_1V_1 = P_2V_2$ thus $P_2 = P_1V_1/V_2$
   $= (3\times10^5\ \text{J/m}^3)(6\times10^{-2}\ \text{m}^3)/(9\times10^{-2}\ \text{m}^3) = 2\times10^5\ \text{J/m}^3 = 2\times10^5$ Pa

   g. What is the internal energy of the gas at state **B**?

   Same temperature as state A, so same $U = 27$ kJ.

   h. What is the internal energy *change* of the gas along path **A**—**B**?

   Zero.

i. What is the sign (+, –, 0) of the work done by the gas along path **A**—**B**?

The gas expands, so it does work on the surroundings. (+)

j. What is the work done by the gas along path **A**—**B**?

Work done by an ideal gas in an isothermal step:

$W = nRT \ln(V_2/V_1) = (18\text{ kJ}) \ln(9/6) = (18\text{ kJ})(0.4055) = 7298\text{ J}$

k. What is the sign (+, –, 0) of the heat absorbed by the gas along path **A**—**B**?

Here, $Q = W$ (Why?) so (+)

l. What is the heat absorbed by the gas along path **A**—**B**?

$Q = W$, so $Q = 7298$ J.

m. What is the sign (+, –, 0) of the work done by the gas along path **A**—**C**?

0

n. What is the work done by the gas along path **A**—**C**?

0

o. What is the temperature of the gas at state **C**?

$PV = nRT$ and here V is constant so $V = V_1 = nRT_A/P_1 = nRT_C/P_2$. Then $T_C = T_A\ P_2/P_1 = (1082.5\text{ K})(2/3) = 721.7\text{ K}$.

If there are 4 moles of gas, the temperature is half this, 360.9 K.

p. What is the internal energy of the gas at state **C**?

$U = 3/2\ nRT = 3/2\ P_2\ V_1 = 3/2\ (12\text{ kJ}) = 18\text{ kJ}$

q. What is the internal energy *change* of the gas along path **A**—**C**?

$\Delta U = U_C - U_A = 18\text{ kJ} - 27\text{ kJ} = -9\text{ kJ}$

r. What is the sign (+, –, 0) of the heat absorbed by the gas along path **A**—**C**?

Zero work, decrease in U, so negative Q. (–)

s. What is the heat absorbed by the gas along path **A**—**C**?

$\Delta U = Q - W$, so $Q = \Delta U + W = -9$ kJ + 0 = –9 kJ.

t. What is the sign (+, –, 0) of the work done by the gas along path **C**—**B**?

Expansion, so the system does work. (+)

u. What is the work done by the gas along path **C**—**B**?

For an isobaric process, $W = P\Delta V = (2\times10^5\ \text{J/m}^3)(3\times10^{-2}\ \text{m}^3) = +6$ kJ

v. What is the change in the internal energy of the gas along path **C**—**B**?

$\Delta U = U_B - U_C = 27$ kJ – 18 kJ = +9 kJ

w. What is the sign (+, –, 0) of the heat absorbed by the gas along path **C**—**B**?

+

x. What is the heat absorbed by the gas along path **C**—**B**?

$\Delta U = Q - W$, so $Q = \Delta U + W = 9$ kJ + 6 kJ = 15 kJ

2. The First law of thermodynamics can be written $\Delta U = Q - W$.

a. What is U in this formula? What does it mean?

Internal energy, the total molecular kinetic and intermolecular potential energy.

b. What is Q in this formula? What does it mean?

Heat absorbed by the system.

c. What is W in this formula? What does it mean?

Work done by the system.