Question 5

10 points total **Distribution of points**

(a)

(i) 2 points

From the ideal gas law, $PV/T =$ a constant

Points A and B are on the isothermal, so they are at the same temperature.

Therefore, $P_B V_B = P_A V_A$

$P_B 2V_0 = P_A V_0$

For the correct answer 1 point

$\frac{P_B}{P_A} = \frac{1}{2}$

For a correct justification (such as the reasoning shown above) 1 point

(ii) 2 points

Points C and B are at the same pressure.

Therefore, $\frac{P_C}{P_A} = \frac{P_B}{P_A}$

For the correct answer 1 point

$\frac{P_C}{P_A} = \frac{1}{2}$

For a correct justification (such as the reasoning shown above) 1 point

(iii) 2 points

Points A and B are on the isothermal, so they are at the same temperature.

For the correct answer 1 point

$\frac{T_B}{T_A} = 1$

For a correct justification (such as the reasoning shown above) 1 point

Question 5 (continued)

Distribution of points

(a) (continued)

(iv) 2 points

Points C and A are at the same volume.

Therefore, from the ideal gas law $\frac{P_C}{P_A} = \frac{T_C}{T_A}$.

$\frac{P_C}{P_A} = \frac{1}{2}$, which was determined in part (ii) above

For the correct answer 1 point

$\frac{T_C}{T_A} = \frac{1}{2}$

For a correct justification (such as the reasoning shown above) 1 point

(b) 1 point

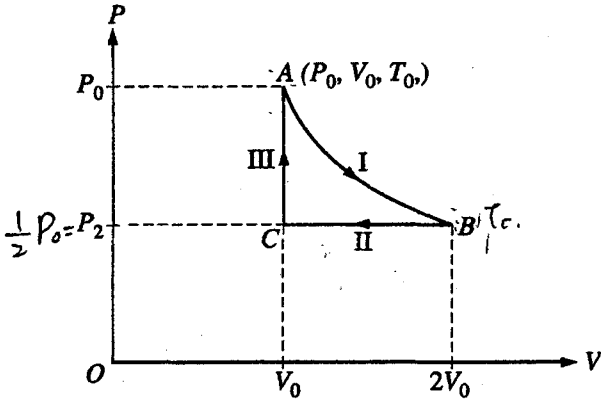
For a correct explanation 1 point

Internal energy depends only on the temperature. Since step I is isothermal there is no change in temperature and thus no change in internal energy

(c) 1 point

For a correct explanation 1 point

$W = -P\Delta V$. In step III there is no change in volume, and thus no work done.



5. (10 points)

A sample of ideal gas is taken through steps I, II, and III in a closed cycle, as shown on the pressure P versus volume V diagram above, so that the gas returns to its original state. The steps in the cycle are as follows.

I. An isothermal expansion occurs from point A to point B, and the volume of the gas doubles.

II. An isobaric compression occurs from point B to point C, and the gas returns to its original volume.

III. A constant volume addition of heat occurs from point C to point A and the gas returns to its original pressure.

(a) Determine numerical values for the following ratios, justifying your answers in the spaces next to each ratio.

i. $\frac{P_B}{P_A} = \frac{1}{2}$

$PV = nRT = \text{const.}$ (P doubles, V halves) (∵ because $P \cdot V$ = constant, if V doubles, P halves)

$P_2 = \frac{1}{2}P_0$

$\frac{P_B}{P_A} = \frac{\frac{P_0}{2}}{P_0} = \frac{1}{2}$

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ii. $\frac{P_C}{P_A} = \frac{1}{2}$

$\frac{P_C}{P_A} = \frac{\frac{P_0}{2}}{P_0} = \frac{1}{2}$

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iii. $\frac{T_B}{T_A} = 1$ in isothermal expansion, temperature does not change.

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iv. $\frac{T_C}{T_A} = \frac{1}{2}$

$PV = nRT$

$\frac{V \downarrow \text{halves}}{T \downarrow \text{halves}} = \text{Const.}$ (∵ because $\frac{V}{T}$ = constant, if V halves, T halves)

$T_C = \frac{1}{2}T_0$

$\frac{T_C}{T_A} = \frac{\frac{T_0}{2}}{T_0} = \frac{1}{2}$

GO ON TO THE NEXT PAGE.

(b) During step I, the change in internal energy is zero. Explain why.

$Q = \Delta U - W$

$= \frac{3}{2} nR\Delta T - P\Delta V$

$\Delta T = 0$

∴ change in internal energy $(\Delta U) = \frac{3}{2} nR\Delta T$, because $\Delta T = 0$, there is no change in internal energy.

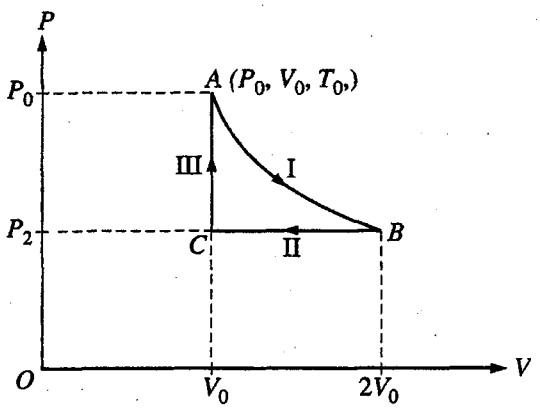
(c) During step III, the work done on the gas is zero. Explain why.

$Q = \Delta U - W$

$= \frac{3}{2} nR\Delta T - P\Delta V$

Work done on the gas $(W) = P\Delta V$, because $\Delta V = 0$, there is no work done on the gas

GO ON TO THE NEXT PAGE.



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I. An isothermal expansion occurs from point A to point B, and the volume of the gas doubles.

II. An isobaric compression occurs from point B to point C, and the gas returns to its original volume.

III. A constant volume addition of heat occurs from point C to point A and the gas returns to its original pressure.

(a) Determine numerical values for the following ratios, justifying your answers in the spaces next to each ratio.

i. $\frac{P_B}{P_A} = \frac{1}{2}$ isothermal ⇒ constant temperature
pV = constant
$P_1V_1 = P_2V_2$ or $P_AV_0 = P_B(2V_0)$
$\Rightarrow \frac{P_B}{P_A} = \frac{V_0}{2V_0} = \frac{1}{2}$

ii. $\frac{P_C}{P_A} =$ from B to C

iii. $\frac{T_B}{T_A} = 1$ because AB is an isothermal expansion, so temperature does not change

iv. $\frac{T_C}{T_A} = \frac{1}{2}$ from B to C, volume is halved
$\frac{V_1}{T_1} = \frac{V_2}{T_2}$

GO ON TO THE NEXT PAGE.

(b) During step I, the change in internal energy is zero. Explain why.

$\Delta U = nR\Delta T$

the change in temperature is zero (isothermal)

$\Rightarrow \Delta U$ is zero

↑ change in internal energy

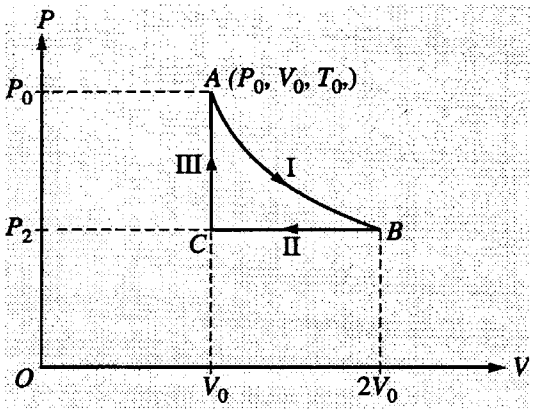
(c) During step III, the work done on the gas is zero. Explain why.

$W = -P\Delta V$

the change in volume is zero (isochoric)

$\Rightarrow W$ is zero

↑ work done on gas



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I. An isothermal expansion occurs from point A to point B, and the volume of the gas doubles.

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III. A constant volume addition of heat occurs from point C to point A and the gas returns to its original pressure.

(a) Determine numerical values for the following ratios, justifying your answers in the spaces next to each ratio.

i. $\frac{P_B}{P_A} = \frac{1}{2}$

because $PV_B = PV_A \Rightarrow \frac{P_B}{P_A} = \frac{V_A}{V_B}$

ii. $\frac{P_C}{P_A} = 2$

$\frac{P_C}{T_C} = \frac{P_A}{T_A} \Rightarrow \frac{P_C}{P_A} = \frac{T_C}{T_A}$

iii. $\frac{T_B}{T_A} = 2$

because it's isothermal

iv. $\frac{T_C}{T_A} = 2$

because it must get an additional heat to return to P_0

GO ON TO THE NEXT PAGE.

(b) During step I, the change in internal energy is zero. Explain why.

(c) During step III, the work done on the gas is zero. Explain why.

because it is isovolumetric

$W = P\Delta V$ since ΔV is 0 $W = 0$

AP® PHYSICS B
2006 SCORING COMMENTARY (Form B)

Question 5

Sample: B5A
Score: 10

In part (a)(iv) the student does not use the fact that states *A* and *C* have the same volume. Instead, the temperature is determined using the fact that states *B* and *C* have the same pressure.

Sample: B5B
Score: 8

The only credit lost was for part (a)(ii), where no solution is attempted. The student takes the same approach to part (a)(iv) described above.

Sample: B5C
Score: 3

Part (a) only earned credit for the correct answer to (i). Part (b) earned nothing, and part (c) received full credit.