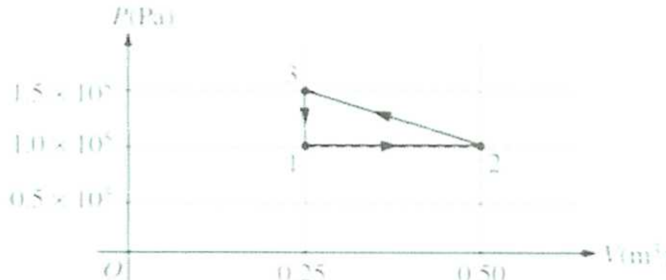
Thermal Exam Review

Directions – Complete the following problems to help prepare you for the upcoming test.

2006 AP® PHYSICS B FREE-RESPONSE QUESTIONS



5. (10 points)

A cylinder with a movable frictionless piston contains an ideal gas that is initially in state 1 at 1×10^5 Pa, 373 K, and 0.25 m^3. The gas is taken through a reversible thermodynamic cycle as shown in the PV diagram above.

P_1 T_1 V_1

(a) Calculate the temperature of the gas when it is in the following states.

i. State 2

$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ $\quad T_2 = \frac{V_2 T_1}{V_1} = \frac{(.50\text{ m}^3)(373\text{K})}{.25\text{ m}^3} = 746\text{K}$

ii. State 3

$\frac{P_1 V_1}{T_1} = \frac{P_3 V_3}{T_3}$ $\quad T_3 = \frac{T_1 P_3}{P_1} = \frac{(373\text{K})(1.5\times10^5\text{Pa})}{1.0\times10^5\text{ Pa}} = 560\text{K}$

(b) Calculate the net work done on the gas during the cycle.

① $W_{1\to2} = -P\Delta V = -(1.0\times10^5\text{ Pa})(.50\text{m}^3 - .25\text{ m}^3) = -2.5\times10^4\text{ J}$

② $W_{2\to3} = -P_{avg}\Delta V = -(1.25\times10^5\text{Pa})(.25\text{m}^3 - .50\text{m}^3) = 3.1\times10^4\text{ J}$

③ $W_{3\to1} = -P\Delta V = 0\text{ J}$

④ $W_{total} = W_{12} + W_{23} + W_{31} = -2.5\times10^4\text{ J} + 3.1\times10^4\text{ J} = +6000\text{ J}$

OR $\Sigma W = $ Area Triangle $= \frac{1}{2}bh = \frac{1}{2}(.25\text{ m}^3)(.5\times1$ … $= +6250\text{ J}$ (counterclockwise is + W)

(c) Was heat added to or removed from the gas during the cycle?

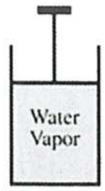
____ Added ✓ Removed ____ Neither added nor removed

Justify your answer.

$\Delta U^{\,0} = Q + W$

$Q = -W$

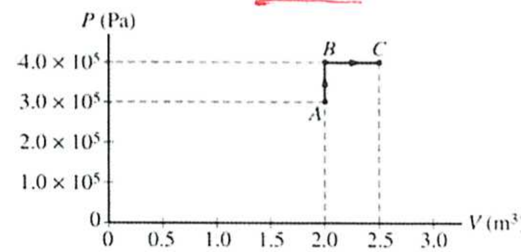
- $\Delta U = 0\text{ J}$ because cycle is complete at returns to same temp so same U.
- Q must be removed to balance out / counteract the work being done on gas



4. (10 points)

The cylinder represented above contains 2.2 kg of water vapor initially at a volume of 2.0 m^3 and an absolute pressure of 3.0×10^5 Pa. This state is represented by point A in the PV diagram below. The molar mass of water is 18 g, and the water vapor can be treated as an ideal gas.

m, V_1, P_1, M



(a) Calculate the temperature of the water vapor at point A.

$PV = nRT$

① $m = nM$, $n = \frac{m}{M} = \frac{2.2\text{kg}}{18\times10^{-3}\text{kg}} = 122 \text{ mol}$

② $T = \frac{PV}{nR} = \frac{(3.0\times10^5\text{Pa})(2.0\text{m}^3)}{(122\text{ mol})(8.31\text{ J/mol·K})} = 590\text{K}$

The absolute pressure of the water vapor is increased at constant volume to 4.0×10^5 Pa at point B, and then the volume of the water vapor is increased at constant pressure to 2.5 m^3 at point C, as shown in the PV diagram.

$P_2 = P_3$, V_3

(b) Calculate the temperature of the water vapor at point C.

$\frac{P_1V_1}{T_1} = \frac{P_3V_3}{T_3}$

$T_3 = \frac{P_3V_3T_1}{P_1V_1} = \frac{(4.0\times10^5\text{Pa})(2.5\text{m}^3)(590\text{K})}{(3.0\times10^5\text{Pa})(2.0\text{m}^3)} = 980\text{K}$

OR

$PV = nRT$

$T = \frac{PV}{nR} = \frac{(4.0\times10^5\text{Pa})(2.5\text{m}^3)}{122\text{mol}(8.31\text{ J/mol·K})} = 986\text{K}$

(c) Does the internal energy of the water vapor for the process $A \to B \to C$ increase, decrease, or remain the same?

__✓__ Increase ____ Decrease ____ Remain the same

Justify your answer.

ΔU proportional to ΔT, since the temperature increases the internal energy increases

(d) Calculate the work done on the water vapor for the process $A \to B \to C$.

$W_{AB} = -P\Delta V = 0\text{J}$

$W_{BC} = -P\Delta V = -(4.0\times10^5\text{Pa})(.5\text{m}^3) = -2.0\times10^5\text{J}$

$W_{tot} = -2.0\times10^5\text{J}$

W = Area = b·h = $(.5\text{m}^3)(4.0\times10^5\text{Pa})$ = -2.0×10^5 J

(clockwise is −)