General Notes About 2009 AP Physics Scoring Guidelines

1. The solutions contain the most common method of solving the free-response questions and the allocation of points for this solution. Some also contain a common alternate solution. Other methods of solution also receive appropriate credit for correct work.

2. Generally, double penalty for errors is avoided. For example, if an incorrect answer to part (a) is correctly substituted into an otherwise correct solution to part (b), full credit will usually be awarded. One exception to this may be cases when the numerical answer to a later part should be easily recognized as wrong, e.g., a speed faster than the speed of light in vacuum.

3. Implicit statements of concepts normally receive credit. For example, if use of the equation expressing a particular concept is worth one point and a student's solution contains the application of that equation to the problem, but the student does not write the basic equation, the point is still awarded. However, when students are asked to derive an expression it is normally expected that they will begin by writing one or more fundamental equations, such as those given on the AP Physics Exam equation sheet. For a description of the use of such terms as "derive" and "calculate" on the exams, and what is expected for each, see "The Free-Response Sections—Student Presentation" in the *AP Physics Course Description*.

4. The scoring guidelines typically show numerical results using the value $g = 9.8 \text{ m/s}^2$, but use of 10 m/s^2 is of course also acceptable. Solutions usually show numerical answers using both values when they are significantly different.

5. Strict rules regarding significant digits are usually not applied to numerical answers. However, in some cases answers containing too many digits may be penalized. In general, two to four significant digits are acceptable. Numerical answers that differ from the published answer due to differences in rounding throughout the question typically receive full credit. Exceptions to these guidelines usually occur when rounding makes a difference in obtaining a reasonable answer. For example, suppose a solution requires subtracting two numbers that should have five significant figures and that differ starting with the fourth digit (e.g., 20.295 and 20.278). Rounding to three digits will lose the accuracy required to determine the difference in the numbers, and some credit may be lost.

Question 4

10 points total | **Distribution of points**

(a) 3 points

For any attempt to use the ideal gas equation of state, i.e., by attempting to substitute values into the equation (simply writing the equation did not earn this point) — 1 point

$PV = nRT$

$T = PV/nR$

For correctly calculating the number of moles — 1 point

$n = 2.2\ \text{kg}/18 \times 10^{-3}\ \text{kg/mol} = 122\ \text{mol}$

For substituting the correct values for pressure, volume, and the universal gas constant into the ideal gas equation — 1 point

$T_A = \left(3.0 \times 10^5\ \text{Pa}\right)\left(2.0\ \text{m}^3\right)/(122\ \text{mol})(8.31\ \text{J/mol•K})$

$T_A = 590\ \text{K}$

(b) 1 point

$T = PV/nR$

$T_C = \left(4.0 \times 10^5\ \text{Pa}\right)\left(2.5\ \text{m}^3\right)/(122\ \text{mol})(8.31\ \text{J/mol•K})$

For the correct answer, with the correct unit — 1 point

$T_C = 980\ \text{K}$

Note: An alternate solution uses the ratios $P_A V_A/T_A = P_C V_C/T_C$ to obtain $T_C = 5T_A/3$. The point could be earned if the answers in parts (b) and (a) were in the ratio $5/3$ and the temperatures were in Kelvin.

(c) 3 points

For indicating that the internal energy increases — 1 point

For a correct justification, with no incorrect statements — 2 points

For example: internal energy is proportional to the temperature, which increases as the gas is taken from *A* to *C*.

One point could be earned for an incomplete justification or one that would be complete and correct but for an incorrect physical statement.

(d) 3 points

W = area under the curve = $-P\,\Delta V$ (the minus sign is not needed for this point) — 1 point

$W = -\left(4.0 \times 10^5\ \text{Pa}\right)\left(0.5\ \text{m}^3\right)$

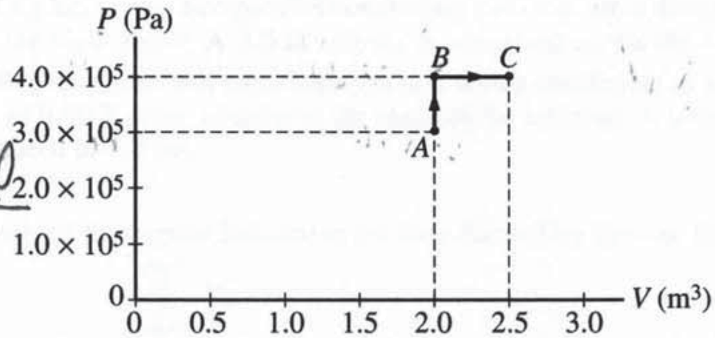
For an answer having the correct magnitude, including the correct unit — 1 point

For the negative sign on the answer — 1 point

$W = -2.0 \times 10^5\ \text{J}$

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.



$= \frac{2.2\,kg\,H_2O}{} \Big| \frac{1\,mol\,H_2O}{18\,g\,H_2O}$

$= 122.2\ mol\ H_2O$

$Pa = \frac{N}{m^2}$

$V = m^3$

$\frac{N}{m^2} \Big| m^3 = J$

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

$PV = nRT$

$T = \frac{PV}{nR} = \frac{3.0E5\,Pa \,|\, 2.0\,m^3}{} \Big| \frac{}{122.2\,mol} \Big| \frac{mol \cdot K}{8.31\,J}$

$T_A = 590.85\ K$

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.

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

$PV = nRT \quad T = \frac{PV}{nR} = \frac{4.0E5\,Pa \,|\, 2.5\,m^3}{} \Big| \frac{}{122.2\,mol} \Big| \frac{mol \cdot K}{8.31\,J}$

$T_C = 984.75\ K$

$\Delta U = Q + W$

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

_↑_ Increase ____ Decrease ____ Remain the same

Justify your answer.

It is not a cycle therefore it would not stay the same, and it generate a positive slope indicating an increase in P and V = Internal Energy.

(d) Calculate the work done on the water vapor for the process $A \xrightarrow{0W} B \rightarrow C$.

$W = -P\Delta V$

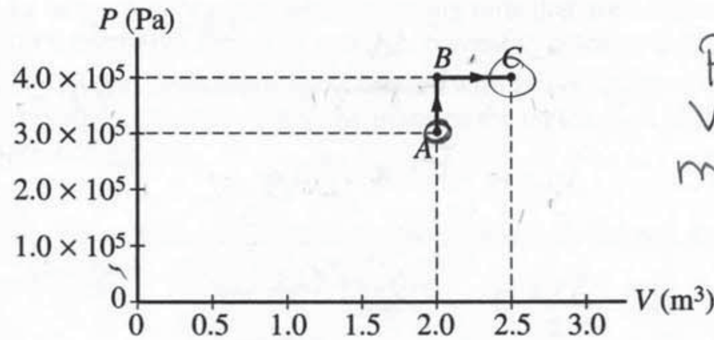
A→B
0 work

B→C
$W = -4.0E5\,Pa\,(2.0 - 2.5)$ −.5m³

$W = 200{,}000\,J$

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.



P
V
m

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

$n = \frac{2200g}{1} * \frac{1 mol\ H_2O}{18g} =$ ~~122~~ $\frac{1100}{9}$ mol

$PV = nRT$

3.0×10^5 Pa = 3.0×10^5 atm

$(3.0 \times 10^5)(2.0) = \left(\frac{1100}{9}\right) 8.314\, T$

$T_A = 590.46$ 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.

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

$P = 4 \times 10^5$

$V = 2.5$

$PV = nRT$ $n = \frac{1100}{9}$ mol H_2O

$(4 \times 10^5)(2.5) = \frac{1100}{9}(8.314)\, T$

$T_c = 984.10$ 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 __X__Decrease ____Remain the same

Justify your answer.

because when going from ~~the~~ A → C the T increases meaning heat is given off ∴ the internal energy of the water decreases.

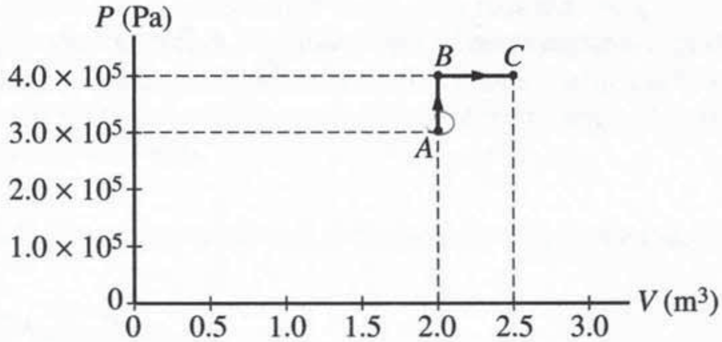
(d) Calculate the work done on the water vapor for the process $A \to B \to C$.

$W = -P\Delta V$ $\Delta V = 2.5 - 2 = .5$

$W = -200{,}000\ Pa \cdot m^3$ $P = 4 \times 10^5$

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.



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

$PV = nRT$

$(3.0 \times 10^5)(2.0) = (18)(8.31)T$

$T = \frac{600000}{149.58} = \boxed{4011.23\ K}$

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.

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

$PV = nRT$

$(4.0 \times 10^5)(2.5) = (18)(8.31)T$

$T = \frac{1000000}{149.58} = \boxed{6685.39\ K}$

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

____Increase   _X_Decrease   ____Remain the same

Justify your answer.

$\Delta U = Q + W \qquad W = -P\Delta V$

$\Delta U_c = 6685.39 + (-4.0\times10^5)(.5) = -193314.61$

$U_A = 4011.23 + (-3.0\times10^5)\,0 = 4011.23$

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

$W = -P\Delta V$

Question 4

Overview

This question assessed students' mastery of thermodynamics, specifically the ideal gas law, internal energy, and the concept of work.

Sample: B-4A
Score: 9

The response earned the full 3 points in part (a), 1 point in part (b), and 3 points in part (c). The only part of the response where a point was lost was part (d), where the answer does not have the required negative sign. The student does explicit work in parts (a) and (b) to determine that the units do indeed cancel properly to yield Kelvin.

Sample: B-4B
Score: 7

Parts (a), (b), and (d) earned the maximum number of points available for those parts. Part (c) earned no points because the student marks the wrong choice ("Decrease").

Sample: B-4C
Score: 4

Part (a) earned only 2 points since the student does not correctly calculate the number of moles. The calculation in part (b) is consistent with part (a), and the answers are in a $5/3$ ratio, so the point was earned. Part (c) earned no points since the wrong choice is picked. In part (d) work is correctly identified as $-P\,\Delta V$, so 1 point was earned.