AP® PHYSICS B (Form B)
2008 SCORING GUIDELINES

General Notes About 2008 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 1 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.

AP® PHYSICS B
2008 SCORING GUIDELINES (Form B)

Question 6

10 points total **Distribution of points**

(a) 4 points

Apply the ideal gas law to pairs of points, recognizing that *nR* is the same at all three points.

For example, comparing points 1 and 2 and points 1 and 3

For correct use of the ideal gas law at points 1 and 2, with correct substation of values — 1 point

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}\text{, with } V_1 = V_2$$

$$T_2 = \frac{T_1P_2}{P_1} = \frac{(300\text{ K})\left(500\times 10^3\text{ Pa}\right)}{100\times 10^3\text{ Pa}}$$

For the correct temperature at point 2 — 1 point

$T_2 = 1500\text{ K}$

For correct use of the ideal gas law at points 1 and 3, with correct substitution of values — 1 point

$$\frac{P_1V_1}{T_1} = \frac{P_3V_3}{T_3}\text{, with } P_1 = P_3$$

$$T_3 = \frac{T_1V_3}{V_1} = \frac{(300\text{ K})\left(6.0\times 10^{-4}\text{ m}^3\right)}{1.0\times 10^{-4}\text{ m}^3}$$

For the correct temperature at point 3 — 1 point

$T_3 = 1800\text{ K}$

(b) 2 points

Approach 1: Calculate the area enclosed by the triangular path

For recognition that the magnitude of the work done on the gas in one cycle is equal to the area enclosed by the triangular path — 1 point

$$W_{tot} = \frac{1}{2}(V_3 - V_1)(P_2 - P_1)$$

For the correct answer — 1 point

$$W_{tot} = \frac{1}{2}\left[(6.0 - 1.0)\times 10^{-4}\text{ m}^3\right]\left[(500 - 100)\times 10^3\text{ Pa}\right]$$

$W_{tot} = 100\text{ J}$

Question 6 (continued)

Distribution of points

(b) (continued)

Approach 2: Calculate the work done on the gas in each of the three processes and take the sum

For recognition that the work done on the gas is equal to the sum of the work done in each of the three processes

1 point

$W_{tot} = W_{1\to2} + W_{2\to3} + W_{3\to1}$

For a correct computation of the numerical value

1 point

$W_{1\to2} = -P_1\left(V_2 - V_1\right)$, but $V_2 = V_1$, so $W_{1\to2} = 0$

$$W_{2\to3} = -\frac{\left[(500 + 100)\times 10^3\ \text{Pa}\right]}{2}\left[(6.0 - 1.0)\times 10^{-4}\ \text{m}^3\right] = -150\ \text{J}$$

$$W_{3\to1} = -P_3\left(V_1 - V_3\right) = -\left(100\times 10^3\ \text{Pa}\right)\left[(1.0 - 6.0)\times 10^{-4}\ \text{m}^3\right] = +50\ \text{J}$$

$W_{3\to1} = +50\ \text{J}$

$W_{tot} = W_{1\to2} + W_{2\to3} + W_{3\to1} = 0 - 150\ \text{J} + 50\ \text{J} = -100\ \text{J}$

Note: The minus sign was not necessary since the question asks only for the amount of work; the sign is asked for in part (c).

(c) 1 point

For indicating that the work done on the gas in one complete cycle is negative

1 point

(d) 3 points

For an application of the first law of thermodynamics to process $1 \to 2$, recognizing that the work done from point 1 to point 2 is zero

1 point

$\Delta U = Q + W$

$Q = \Delta U - W$

$Q = \Delta U$

For a correct expression for Q from point 1 to point 2, with correct substitution of values

1 point

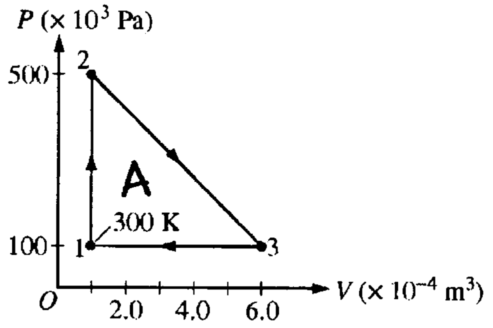
$$Q = \frac{3}{2}nR\Delta T = \frac{3}{2}(0.0040\ \text{mol})(8.31\ \text{J/mol}\bullet\text{K})(1500\ \text{K} - 300\ \text{K})$$

For the correct answer

1 point

$Q = 60\ \text{J}$

B6A



6. (10 points)

A 0.0040 mol sample of a monatomic gas is taken through the cycle shown above. The temperature T_1 of state 1 is 300 K.

$\frac{PV}{T}$ = constant throughout the cycle

(a) Calculate T_2 and T_3.

$$\frac{P_1}{T_1} = \frac{P_2}{T_2} \qquad T_2 = \frac{P_2 T_1}{P_1} = \frac{(500\times10^3\,Pa)(300\,k)}{(100\times10^3\,Pa)} = 1{,}500\,K$$

$$\frac{V_1}{T_1} = \frac{V_3}{T_3} \qquad T_3 = \frac{V_3 T_1}{V_1} = \frac{(6.0\times10^{-4}m^3)(300\,k)}{(1.0\times10^{-4}m^3)} = 1{,}800\,K$$

(b) Calculate the amount of work done on the gas in one cycle.

$$W_{on} = -P\Delta V = -A = -\frac{1}{2}bh = -\frac{1}{2}(6.0\times10^{-4}m^3 - 1.0\times10^{-4}m^3)(500\times10^3\,Pa - 100\times10^3\,Pa)$$

$$W_{on} = -100\,J$$

(c) Is the net work done on the gas in one complete cycle positive, negative, or zero?

____ Positive [✓ Negative] ____ Zero

(d) Calculate the heat added to the gas during process 1→2.

constant volume

$$\Delta U = \frac{3}{2}nR\Delta T = \frac{3}{2}(0.0040\,mol)(8.31\,\tfrac{J}{mol.k})(1{,}500\,k - 300\,k)$$

$$= 60\,J$$

$\Delta U = Q + W$ but $W = 0$

$\Delta U = Q$

$Q = 60\,J$

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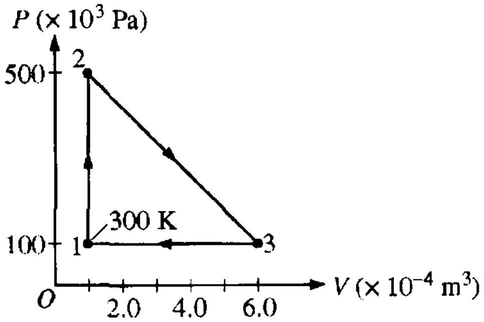

6. (10 points)

A 0.0040 mol sample of a monatomic gas is taken through the cycle shown above. The temperature T_1 of state 1 is 300 K.

(a) Calculate T_2 and T_3.

$PV = nRT \Rightarrow T_2 = \frac{P_2V_2}{nR} = \frac{(500\times10^3)(1\times10^{-4})}{(0.004)(8.31)} = 1504 \sim 1500\ K$

$T_3 = \frac{P_3V_3}{nR} = \frac{(100\times10^3)(6\times10^{-4})}{(0.004)(8.31)} = 1805 \sim 1800\ K$

(b) Calculate the amount of work done on the gas in one cycle.

$W_1 = -P\Delta V_1$, $\Delta V_1 = 0$ on going from $1 \to 2 \Rightarrow W_1 = 0\ J$

$W_2 = -P\Delta V_2 \Rightarrow -(500\times10^3)(5\times10^{-4}) \Rightarrow$ ~~$W_2\ 250$~~ $W_2 = -250\ J$

$W_3 = -P\Delta V_3 \Rightarrow -(100\times10^3)(-5\times10^{-4}) \Rightarrow 50\ J$

$\rightarrow W_T = W_1 + W_2 + W_3 = 0 - 250 + 50 = -200\ J$

(c) Is the net work done on the gas in one complete cycle positive, negative, or zero?

____ Positive _✓_ Negative ____ Zero

(d) Calculate the heat added to the gas during process 1→2.

$\Delta U = Q + W \Rightarrow Q = \overset{0}{\cancel{\Delta U}} - W$
$- (-200)$
$= 200\ J$

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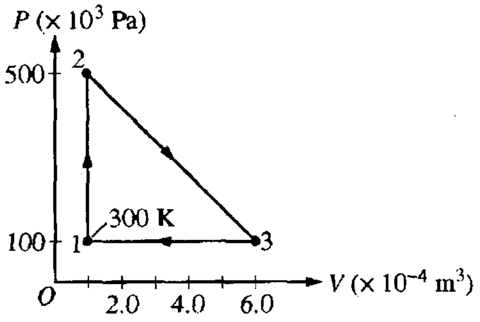

6. (10 points)

A 0.0040 mol sample of a monatomic gas is taken through the cycle shown above. The temperature T_1 of state 1 is 300 K.

(a) Calculate T_2 and T_3.

$$\frac{PV}{T} = \text{constant} = \frac{100\times10^3 \times 1\times10^{-4}}{300} = \frac{1}{30}$$

$$\frac{P_2V_2}{T_2} = \frac{1}{30} = \frac{500\times10^3 \times 1\times10^{-4}}{T_2} \qquad T_2 = 1500\,K$$

$$\frac{P_3V_3}{T_3} = \frac{1}{30} = \frac{100\times10^3 \times 6\times10^{-4}}{T_3} \qquad T_3 = 1800\,K$$

(b) Calculate the amount of work done on the gas in one cycle.

$1800 - (1500 + 300) = 0$

(c) Is the net work done on the gas in one complete cycle positive, negative, or zero?

____ Positive ____ Negative [✓ Zero]

(d) Calculate the heat added to the gas during process 1→2.

$\Delta Q = mc\Delta t$

AP® PHYSICS B
2008 SCORING COMMENTARY (Form B)

Question 6

Sample: B6A
Score: 10

All parts are answered correctly, so full credit was given. The work in part (b) is calculated by finding the area of the triangle in the *PV* diagram.

Sample: B6B
Score: 6

Part (a) is correctly solved using the ideal gas law directly, and all 4 points were awarded. Part (b) uses approach 2, and 1 point was awarded for recognizing that the work done during the cycle is equal to the sum of the work done in each of the three processes. However, the work going from state 2 to state 3 is calculated incorrectly. One point was awarded for the correct choice in part (c). The first law of thermodynamics is applied incorrectly in part (d), so no credit was given.

Sample: B6C
Score: 4

Full credit was given for part (a). No relevant work is performed in parts (b) and (d), and the choice made in part (c) is incorrect.