# AP® PHYSICS 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 $10 \text{ m/s}^2$ 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 5

**10 points total** — **Distribution of points**

(a) 3 points

| Process | $W$ | $Q$ | $\Delta U$ |
|---|---|---|---|
| $A \rightarrow B$ | 0 | + | + |
| $B \rightarrow C$ | – | + | 0 |
| $C \rightarrow A$ | + | – | – |

For correctly identifying the signs of all three variables $(W, \Delta U, Q)$ for process $A \rightarrow B$ — 1 point

For correctly identifying the signs of all three variables $(W, \Delta U, Q)$ for process $B \rightarrow C$ — 1 point

For correctly identifying the signs of all three variables $(W, \Delta U, Q)$ for process $C \rightarrow A$ — 1 point

(b) 4 points

For a correct explanation of why zero work is done on the gas — 1 point

Examples of correct responses include:

- There is no area under the graph/curve.
- There is no volume change.
- The piston does not move.
- $W = -P\Delta V$, where $\Delta V = 0$ .
- $W = 0$ by definition in an isochoric/isovolumetric process.

For a correct explanation of why $\Delta U$ is positive — 1 point

Examples of correct responses include:

- For a fixed number of moles of a sample, an increase in pressure at constant volume implies an increase in temperature, and an increased temperature implies an increase in internal energy ( $\Delta U$ is positive).
- State *B* is on a higher isotherm than state *A*.
- $U = \frac{3}{2}nRT$ ; since $T$ increases, $\Delta U$ is positive.
- $U = \frac{3}{2}PV$ ; since $P$ increases at a constant $V$, $\Delta U$ is positive.
- A correct use of the first law of thermodynamics leading to $\Delta U$ being positive ( $\Delta U = Q + W$ , but $W = 0$ so $\Delta U = Q$ ; since $Q$ is positive, $\Delta U$ must be also).

For a correct explanation of why $Q$ is positive — 1 point

Examples of correct responses include:

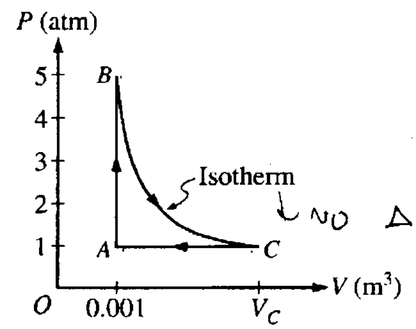
- If pressure increases *and* volume is constant, heat must be added to system.
- If temperature increases *and* volume is constant, heat must be added to system.
- A correct use of the first law of thermodynamics leading to $Q$ being positive ( $\Delta U = Q + W$ , but $W = 0$ so $\Delta U = Q$ ; since $\Delta U$ is positive, $Q$ must be also).

For stating the first law of thermodynamics, whether used correctly or not, OR for correctly explaining all three variables without reference to the first law of thermodynamics — 1 point

**Question 5 (continued)**

| | **Distribution of points** |
|---|---|
| (c) 3 points | |
| For correctly relating states $B$ and $C$ at a constant temperature, using either the ideal gas law or Boyle's Law | 1 point |
| $\dfrac{P_B V_B}{T_B} = \dfrac{P_C V_C}{T_C}$ or $P_B V_B = P_C V_C$ | |
| For the correct substitution of the appropriate values | 1 point |
| $V_C = \dfrac{P_B}{P_C} V_B = \left(\dfrac{5\text{ atm}}{1\text{ atm}}\right)\left(0.001\text{ m}^3\right)$ | |
| For the correct answer including units | 1 point |
| $V_C = 0.005\text{ m}^3$ | |
| *Alternate solution* | *Alternate points* |
| *For correctly relating states A and B at a constant volume, using the ideal gas law, to determine the temperature $T_B$* | *1 point* |
| $\dfrac{P_A V_A}{T_A} = \dfrac{P_B V_B}{T_B}$ | |
| $T_B = \dfrac{P_B}{P_A} T_A = \left(\dfrac{5\text{ atm}}{1\text{ atm}}\right)(400\text{ K}) = 2000\text{ K}$ | |
| *For realizing that $T_C = T_B$ and correctly relating states A and C at constant pressure, using the value of $T_B$ and the ideal gas law or Charles' Law to calculate $V_C$.* | *1 point* |
| $\dfrac{P_A V_A}{T_A} = \dfrac{P_C V_C}{T_C}$ or $\dfrac{V_A}{T_A} = \dfrac{V_C}{T_C}$ | |
| $V_C = \dfrac{T_C}{T_A} V_A = \dfrac{T_B}{T_A} V_A = \left(\dfrac{2000\text{ K}}{400\text{ K}}\right)\left(0.001\text{ m}^3\right)$ | |
| *For the correct answer, including units* | *1 point* |
| $V_C = 0.005\text{ m}^3$ | |

*Another method is to use the ideal gas law to calculate $T_B$, set $T_C = T_B$, and once again use the ideal gas law to calculate $V_C$.*




No $\Delta$ Temp

5. (10 points)

$W = -P\Delta V$

A 0.03 mol sample of helium is taken through the cycle shown in the diagram above. The temperature of state $A$ is 400 K.

$\uparrow P = +$

(a) For each process in this cycle, indicate in the table below whether the quantities $W$, $Q$, and $\Delta U$ are positive (+), negative (–), or zero (0). $W$ is the work done on the helium sample.

| Process | $W$ | $Q$ | $\Delta U$ |
|---|---|---|---|
| $A \to B$ | 0 | + | + |
| $B \to C$ | – | + | 0 |
| $C \to A$ | + | – | – |

$PV = nRT$
$\downarrow \quad \downarrow$

(b) Explain your response for the signs of the quantities for process $A \to B$.

I) $W = -P\Delta V$
and since $\Delta V = 0$
$W = 0$

II) since $P\uparrow$ and $V$ is constant,
Temp $\uparrow$
as $PV = nRT$
$\therefore$ since $\Delta U \propto T$,
$U$ (+)

III) $\Delta U = W + Q$
$(+) = 0 + \underline{Q}$
$\therefore$
$Q$ has to be (+) for equation to work

(c) Calculate $V_C$.

Point B
$PV = nRT$
$T_B = \frac{PV}{nR}$
$T_B = \frac{(5.0 \times 10^5) \cdot \times (0.001)}{(0.03)\ \ (8.31)}$
$T_B = 2005$ K

II) $V_C$
$T_B = T_C$ b/c isothermal process $B \to C$
So Temp does NOT $\Delta$

(sv) $PV = nRT$
$V = \frac{nRT}{P}$
$V = \frac{(0.03)(8.31)(2005)}{1 \times 10^5}$
$\boxed{V = 0.005\ m^3}$

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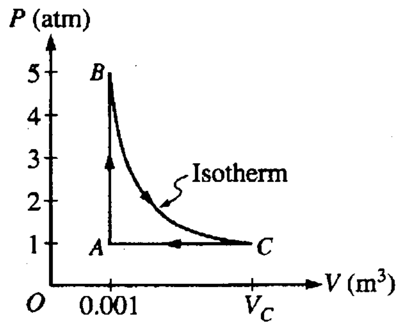


5. (10 points)

A 0.03 mol sample of helium is taken through the cycle shown in the diagram above. The temperature of state *A* is 400 K.

(a) For each process in this cycle, indicate in the table below whether the quantities *W*, *Q*, and $\Delta U$ are positive (+), negative (–), or zero (0). *W* is the work done on the helium sample.

| Process | $W$ | $Q$ | $\Delta U$ |
|---|---|---|---|
| $A \to B$ | 0 | – | – |
| $B \to C$ | – | + | 0 |
| $C \to A$ | + | – | + |

$\Delta U = Q + W$

$W = -P\Delta V$

(b) Explain your response for the signs of the quantities for process $A \to B$.

In process $A \to B$, work is zero because there is no change in volume, Q is neg. because as the pressure increases, heat will need to be drawn out of the gas, and $\Delta U$ is neg. because is work is zero then $\Delta U = Q$.

In process $B \to C$, work is neg. because there is a positive change in volume, Q is pos. because during this isothermal process, heat must be added to keep the temp. constant, and $\Delta U$ is zero because an isothermal process has no change in internal energy.

In process $C \to A$, work is positive because there is a neg. change in volume, Q is neg. because heat needs to be removed from the gas, and $\Delta U$ is pos. because the work done is greater than the heat removed.

(c) Calculate $V_C$.

$$\frac{P_B V_B}{\cancel{T_B}} = \frac{P_C V_C}{\cancel{T_C}} \qquad T_B = T_C$$

$$V_C = \frac{P_B V_B}{P_C}$$

$$V_C = \frac{(5\cancel{atm})(.001 m^3)}{1\cancel{atm}}$$

$$\boxed{V_C = 5 \times 10^{-3}\ m^3}$$

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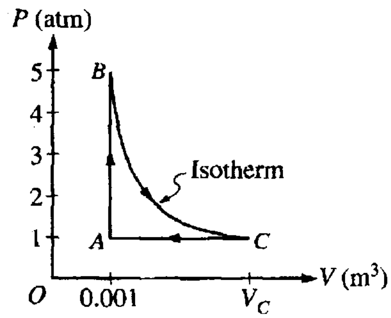


5. (10 points)

A 0.03 mol sample of helium is taken through the cycle shown in the diagram above. The temperature of state *A* is 400 K.

(a) For each process in this cycle, indicate in the table below whether the quantities *W*, *Q*, and $\Delta U$ are positive (+), negative (–), or zero (0). *W* is the work done on the helium sample.

| Process | $W$ | $Q$ | $\Delta U$ |
|---|---|---|---|
| $A \rightarrow B$ | 0 | + | + |
| $B \rightarrow C$ | + | – | – |
| $C \rightarrow A$ | – | 0 | – |

(b) Explain your response for the signs of the quantities for process $A \rightarrow B$.

There is no area under a vertical line so the work is zero.

(c) Calculate $V_C$.

$PV = nRT$

$(1)(V_C) = (.03)(8.31)(400)$

$\boxed{V_C = 99.72\ m^3}$

# AP® PHYSICS B
# 2008 SCORING COMMENTARY

## Question 5

### Overview

The intent of this question was primarily to determine students' ability to interpret a pressure versus volume graph and secondarily to determine their ability to correctly use the ideal gas laws for specific thermodynamic processes. Parts (a) and (b) investigated understanding of different forms of energy and their roles in thermodynamic processes, including understanding of the specific relationships among work, internal energy, and heat. Part (c) focused on the ideal gas law.

**Sample: B5A**
**Score: 10**

Full credit was awarded for each part of this problem. All processes are correctly characterized in part (a). In part (b) it is correctly indicated that no work is done in the isovolumetric process, the change in internal energy is correlated to the increase in temperature, and the first law is used to explain why heat is added. In part (c) the ideal gas law is used to find the temperature at point *B*; this temperature is equated to the temperature at point *C*, allowing the volume at point *C* to be determined, again using the ideal gas law.

**Sample: B5B**
**Score: 6**

Only 1 point was awarded for part (a), as only process $B \rightarrow C$ is correctly characterized. Only 2 points were awarded for part (b), as $W$ is explained correctly, and the 1st law is stated, but the signs for $Q$ and $\Delta U$ are incorrect. Full credit was awarded for part (c), which is solved using the ideal gas law.

**Sample: B5C**
**Score: 2**

Only 1 point was awarded for part (a), as only process $A \rightarrow B$ is correctly characterized. One point was earned in part (b) for correctly explaining why zero work is done, but no additional work is performed. No credit was earned for part (c), as the ideal gas law at state *C* was used with an incorrect temperature; this was a common mistake.