2025

AP® Physics 2: Algebra-Based

Sample Student Responses and Scoring Commentary

Inside:

Free-Response Question 2

- ☑ **Scoring Guidelines**
- ☑ **Student Samples**
- ☑ **Scoring Commentary**

Question 2: Translation Between Representations (TBR) — 12 points

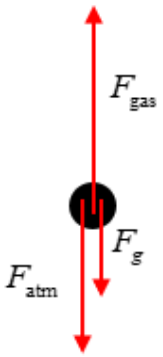
A

For drawing an appropriately labeled arrow downward to represent the direction of the force F_g of gravity that is exerted on the piston — **Point A1**

For drawing an appropriately labeled arrow downward to represent the direction of the force F_{atm} of the atmosphere that is exerted on the piston — **Point A2**

For drawing an appropriately labeled arrow upward to represent the direction of the force F_{gas} of the gas that is exerted on the piston — **Point A3**

Example Response



B

For a multistep derivation that includes $U = \frac{3}{2}nRT$, $U = \frac{3}{2}Nk_BT$, $PV = nRT$, $PV = Nk_BT$, $\vec{a}_{\text{sys}} = \frac{\sum \vec{F}}{m_{\text{sys}}} = \frac{\vec{F}_{\text{net}}}{m_{\text{sys}}}$, $\sum \vec{F} = 0$, $P = \frac{F_\perp}{A}$, an equation that is equivalent to one of the equations listed, or a relevant equation — **Point B1**

Scoring Note: Vector notation is not required for this point to be earned.

For correctly relating the internal energy of the gas to $PV = nRT$ or $PV = Nk_BT$ (e.g., $U = \frac{3}{2}PV$) — **Point B2**

Scoring Note: This point can be earned if the response refers to a generic pressure instead of an absolute pressure.

For an expression for **one** of the following: — **Point B3**

- The correct absolute pressure P of the gas (e.g., $PA - P_{\text{atm}}A - Mg = 0$ or $P = P_{\text{atm}} + \frac{Mg}{A}$).
- The absolute pressure of the gas that is consistent with an incorrect diagram provided in part A.

For an expression for the internal energy of the gas that is consistent with the expression for the pressure P of the gas that is derived for point B3 (e.g., $U = \frac{3}{2}\left(P_{\text{atm}} + \frac{Mg}{A}\right)V_0$) — **Point B4**

Scoring Note: A correct, isolated, final expression earns points B2, B3, and B4.

Example Response

$$\vec{a}_{\text{sys}} = \frac{\sum \vec{F}}{m_{\text{sys}}} = \frac{\vec{F}_{\text{net}}}{m_{\text{sys}}}$$

$$\Sigma \vec{F} = 0$$

$$P = \frac{F_{\perp}}{A}$$

$$PA - P_{\text{atm}}A - F_g = 0$$

$$PA - P_{\text{atm}}A - Mg = 0$$

$$P - P_{\text{atm}} - \frac{Mg}{A} = 0$$

$$P = P_{\text{atm}} + \frac{Mg}{A}$$

$$U = \frac{3}{2}nRT$$

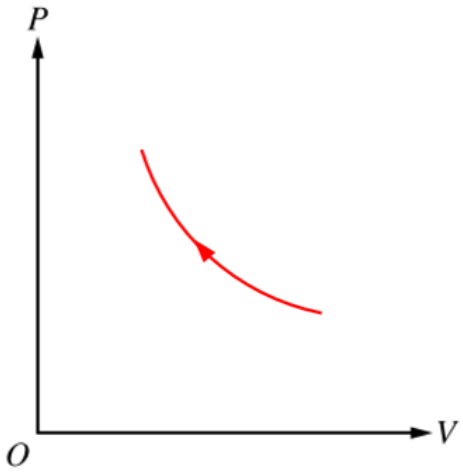
$$PV = nRT$$

$$U = \frac{3}{2}PV$$

$$U = \frac{3}{2}\left(P_{\text{atm}} + \frac{Mg}{A}\right)V_0$$

C	For drawing a line or curve that connects a point in the lower right region of the diagram to the upper left region of the diagram	**Point C1**
	For drawing a curve that is concave up	**Point C2**
	For drawing an arrow that points from a greater to a lesser volume or from a lesser to a greater pressure	**Point C3**

Example Response



D	For indicating $T_{\text{new}} > T_0$ or an indication that is consistent with incorrect features of the diagram in part A, an incorrect derivation in part B, or incorrect features of the graph in part C	**Point D1**
	For **one** of the following: • A correct justification that indicates that the pressure of the gas has increased for the same volume using features of the diagram in part A, the derivation in part B, or features of the graph in part C • A correct justification that indicates that the volume of the gas has increased for the same pressure using features of the diagram in part A, the derivation in part B, or features of the graph in part C • A justification that is consistent with incorrect features of the diagram in part A, an incorrect derivation in part B, or incorrect features of the graph in part C	**Point D2**

Scoring Notes:

- If the justification is consistent with incorrect features of the diagram in part A, an incorrect derivation in part B, or incorrect features of the graph in part C, and the justification is consistent with an incorrect selection, points D1 and D2 are earned.
- If the justification is consistent with incorrect features of the diagram in part A, an incorrect derivation in part B, or incorrect features of the graph in part C, but the justification is not consistent with an incorrect selection, only point D2 is earned.
- If the justification is not consistent with incorrect features of the diagram in part A, an incorrect derivation in part B, or incorrect features of the graph in part C, but $T_{\text{new}} > T_0$ is selected, only point D1 is earned.

Example Responses

Using the representation from part A if the response considers the volume of the gas at time t_0 and the final volume of the gas after the process described in part D

- *For the piston to remain in equilibrium, the increase in weight from the block would require a greater force, and, therefore, pressure, from the gas on the piston. Because the two volumes are equal, a greater pressure will correspond to a greater temperature. Therefore, $T_{\text{new}} > T_0$.*

Using the representation from part B

- *According to the derivation in part B, if volume increases while pressure remains constant, the internal energy of the gas increases, and, therefore, the temperature will increase. Therefore, $T_{\text{new}} > T_0$.*
- *According to the derivation in part B, the added mass on the piston when the volume is back to the original volume increases the internal energy of the gas. Thus, the temperature increases. Therefore, $T_{\text{new}} > T_0$.*

Using the representation from part C if the response considers the volume of the gas at time t_f and the final volume of the gas after the process described in part D

- *Looking at the graph, if the volume is increased at constant pressure, from the end of the curve that I drew, the product of pressure and volume, and therefore, temperature, will be greater at the end of this process than at the beginning. Therefore, $T_{\text{new}} > T_0$.*

Using the representation from part C if the response considers the volume of the gas at time t_0 and the final volume of the gas after the process described in part D

- *According to the graph in part C, the pressure of the gas at the end of the process in part C is greater than that at the beginning of the process. For the gas to occupy the original volume (at time t_0), the final gas pressure must be greater than the original gas pressure. Therefore, $T_{new} > T_0$.*
- *According to the graph in part C, if the pressure is increased by the added block, and the volume is the same from the beginning of the curve that I drew, the product of pressure and volume, and, therefore, temperature, will be greater at the end of this process than at the beginning. Therefore, $T_{new} > T_0$.*

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART A

PART B

$U = \frac{3}{2} nRT$ $\quad PV = nRT$

$U_{gas} = \frac{3}{2} P_{gas} V_0$

$F_{gas} = F_g + F_{atm}$ $\quad F_\perp = PA$

$P_{gas} A = Mg + P_{atm} A$

$P_{gas} = \frac{Mg}{A} + P_{atm}$

$U_{gas} = \frac{3}{2} \left(\frac{Mg}{A} + P_{atm} \right) V_0$

Question 2: Version J continues on the next page.

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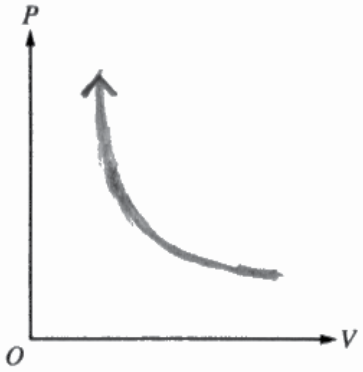
Question 2: Version J

PART C



PART D

✓ $T_{new} > T_0$ ____ $T_{new} < T_0$ ____ $T_{new} = T_0$

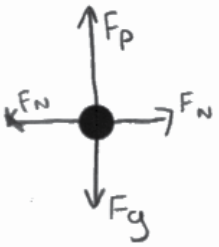
As seen in part A, both the force of the weight of the piston and atmosphere are pushed back against by the force of the gas. If the weight now increases, F_{gas} must increase. $F_{gas} = P_{gas} A$; since the area of the piston did not change, the gas pressure must increase. Since $P \propto T$, increasing the temperature would increase the gas pressure, increasing F_{gas} and allowing the volume to return to V_0.

Go to Question 3 in Bluebook when you're done with this question.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART A



F_P = force of pressure (gas) on piston

F_g = force of gravity on piston

F_N = normal force of container walls on piston

PART B

$U = 3/2\ nRT = 3/2\ Nk_bT$

$PV = nRT$

$K_{avg} = 1/2\ mv^2$

$U = 3/2\ PV_0$

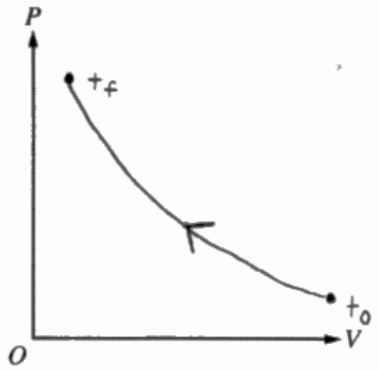
$U = 3/2\ P_{atm} V_0$

Question 2: Version J continues on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART C



PART D

✓ $T_{new} > T_0$ ____ $T_{new} < T_0$ ____ $T_{new} = T_0$

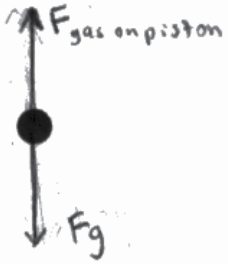
T_{new} must be greater than T_0, as the gas is able to expand with the added weight of the block. This is known to be true based on Part C, which sees the gas condensed as more weight is added. Thus, to raise the piston back up, something external must excite the gas, which is done via raising temperature.

Go to Question 3 in Bluebook when you're done with this question.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART A



PART B

$\Delta U = Q + W$

$\Delta U = mc\Delta T - P\Delta V$

$U = \frac{3}{2}nRT$

$PV = nRT$

$U = \frac{3}{2}(PV)$

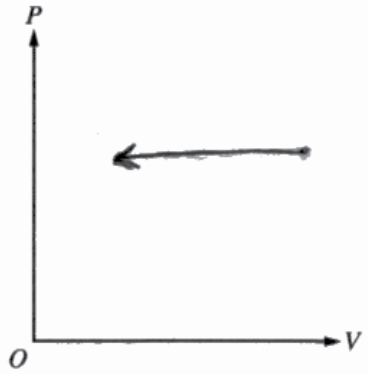
$U = \frac{3}{2}P_{atm}V_0$

Question 2: Version J continues on the next page.

Use a pencil or a pen with black or dark blue ink. Do NOT write your name. Do NOT write outside the box.

Question 2: Version J

PART C



PART D

___ $T_{new} > T_0$ ___X___ $T_{new} < T_0$ ___ $T_{new} = T_0$

The new temperature must be less than the original temperature. This is because the volume of the container the gas is in was decreased, as per my answer in part C. The pressure of the system has not changed, since the piston is movable. Because the volume had decreased, but then is back in its original position after the temperature change, the volume has increased. This means temperature would have had to decrease since they are inversely related, and pressure did not change.

Go to Question 3 in Bluebook when you're done with this question.

Question 2

Note: Student samples are quoted verbatim and may contain spelling and grammatical errors.

Overview

NEW for 2025: The question overviews can be found in the *Chief Reader Report on Student Responses* on AP Central.

Sample: 2A
Score: 12

Part A earned all three points. The first point (A1) was earned because the response indicates that the force of gravity is exerted downward on the piston. The second point (A2) was earned because the response indicates that the force of the atmosphere is exerted downward on the piston. The third point (A3) was earned because the response indicates that the force of the gas is exerted upward on the piston.

Part B earned all four points. The first point (B1) was earned because the response indicates a multistep derivation that includes a correct expression for internal energy, the ideal gas law, other relevant equations, and relevant subsequent work. The second point (B2) was earned because the response correctly relates the internal energy of the gas to the ideal gas law. The third point (B3) was earned because the response correctly indicates an expression for the pressure that is consistent with part A. The fourth point (B4) was earned because the response indicates an expression for the internal energy of the gas that is consistent with the expression in B3.

Part C earned all three points. The first point (C1) was earned because the response indicates a line or curve that connects a point in the lower right region of the graph to the upper left region of the graph. The second point (C2) was earned because the response indicates a curve that is concave up. The third point (C3) was earned because the response indicates an arrow that is pointing from a lesser to a greater pressure/from a greater to a lesser volume.

Part D earned both points. The first point (D1) was earned because the response indicates that T_{new} is greater than T_0, and the response is consistent with parts A and B. The second point (D2) was earned because the response indicates that the pressure of the gas has increased for the same volume or that the volume of the gas increases for the same pressure using relevant features from parts A and B. The force directions are referenced in connection with how the derivation in part B is related to the correct selection.

Question 2 (continued)

Sample: 2B
Score: 9

Part A earned two out of three points. The first point (A1) was earned because the response indicates that the force of gravity is exerted downward on the piston. The second point (A2) was not earned because the response does not indicate that the force of the atmosphere is exerted downward on the piston. The third point (A3) was earned because the response indicates that the force of the gas is exerted upward on the piston. The label defines F_{p} as the force of the gas on the piston.

Part B earned two out of four points. The first point (B1) was earned because the response indicates a multistep derivation that includes a correct expression for internal energy, the ideal gas law, and other relevant expressions. The second point (B2) was earned because the response correctly relates the internal energy of the gas to the ideal gas law. The third point (B3) was not earned because the response does not indicate an expression for the pressure that is consistent with part A. The fourth point (B4) was not earned because the response does not indicate an expression for the internal energy of the gas that is consistent with the expression in B3.

Part C earned all three points. The first point (C1) was earned because the response indicates a curve that connects a point in the lower right region of the graph to the upper left region of the graph. The second point (C2) was earned because the response indicates a curve that is concave up. The third point (C3) was earned because the response indicates an arrow that is pointing from a lesser to a greater pressure/from a greater to a lesser volume.

Part D earned both points. The first point (D1) was earned because the response indicates that T_{new} is greater than T_0, and the justification is consistent with part C. The second point (D2) was earned because the response indicates that the volume of the gas increases for the same pressure using relevant features from part C.

Question 2 (continued)

Sample: 2C
Score: 5

Part A earned two out of three points. The first point (A1) was earned because the response indicates that the force of gravity is exerted downward on the piston. The second point (A2) was not earned because the response does not indicate that the force of the atmosphere is exerted downward on the piston. The third point (A3) was earned because the response indicates that the force of the gas is exerted upward on the piston.

Part B earned two out of four points. The first point (B1) was earned because the response indicates a multistep derivation that includes a correct expression for internal energy, the ideal gas law, and other relevant expressions. The second point (B2) was earned because the response correctly relates the internal energy of the gas to the ideal gas law. The third point (B3) was not earned because the response does not indicate an expression for the pressure that is consistent with part A. The fourth point (B4) was not earned because the response does not indicate an expression for the internal energy of the gas that is consistent with the expression in B3.

Part C earned one out of three points. The first point (C1) was not earned because the response does not indicate a line or curve that connects a point in the lower right region of the graph to the upper left region of the graph. The second point (C2) was not earned because the response does not indicate a curve that is concave up. The third point (C3) was earned because the response indicates an arrow that is pointing from a greater to a lesser volume.

Part D did not earn either point. The first point (D1) was not earned because the response does not indicate that T_{new} is greater than T_0, and the response does not indicate a selection that is consistent with parts A, B, or C. The second point (D2) was not earned because the response incorrectly indicates that volume and temperature are inversely related. Furthermore, the response does not acknowledge the information described in part D of the free-response question.