AP® PHYSICS B
2007 SCORING GUIDELINES

General Notes About 2007 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 and 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 5

10 points total | **Distribution of points**

(a) 2 points

Using the relationship between pressure and force
$P = F/A$

For correctly determining the area of the piston — 1 point

$A = \pi R^2 = \pi(0.20\ \text{m}/2)^2$

$F = P_{abs}A = P_{abs}\pi R^2$

For correct substitution of values for pressure and area (or for correct answer in the absence of explicitly showing the substitution) — 1 point

$F = (4.0 \times 10^5\ \text{Pa})\pi(0.20\ \text{m}/2)^2$

$F = 1.3 \times 10^4\ \text{N}$

(b) 2 points

Using the ideal gas law
$PV = nRT$

$V = \dfrac{nRT}{P}$

For correct substitution of at least three numerical values — 1 point

$V = \dfrac{(2.0\ \text{mol})(8.31\ \text{J/mol}\bullet\text{K})(300\ \text{K})}{4.0 \times 10^5\ \text{Pa}}$

For the correct answer — 1 point

$V = 1.2 \times 10^{-2}\ \text{m}^3$

(c) 2 points

Using the expression for the work done <u>on</u> the gas
$W_{\text{on}} = -P\,\Delta V$

The work done <u>by</u> the gas has the opposite sign
$W_{\text{by}} = P_{abs}\,\Delta V$

For a correct expression for the change in volume — 1 point

$\Delta V = Ax = \pi R^2 x$

$W_{\text{by}} = P_{abs}\pi R^2 x$

For substituting the correct pressure and a change in volume — 1 point

$W_{\text{by}} = (4.0 \times 10^5\ \text{Pa})\pi(0.20\ \text{m}/2)^2(0.15\ \text{m})$

$W_{\text{by}} = 1.9 \times 10^3\ \text{J}$

Question 5 (continued)

Distribution of points

(c) (continued)

Alternate solution — *Alternate points*

$W = Fx$

For substituting the value of force from part (a) — *1 point*

For substituting the correct value for the distance — *1 point*

$W = (1.3 \times 10^4 \text{ N})(0.15 \text{ m})$

$W = 1.9 \times 10^3 \text{ J}$

Note: One point was deducted for any indication that the final value of the work done by the gas is negative.

(d) 3 points

For correctly indicating that heat is transferred to the gas. — 1 point

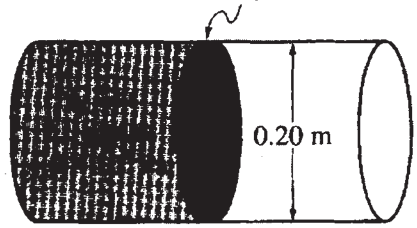
For any indication that because the expansion occurs under constant pressure, the temperature or internal energy of the gas increases. — 1 point

For correctly applying the first law of thermodynamics to explain why heat is transferred to the gas. For example: Since the internal energy goes up while the gas loses energy by doing work, heat must be added. — 1 point

Units point

For including correct units in at least two of the answers in (a) through (c) — 1 point

Note: If a substitution was made using a value with units other than those given in the problem or in the Table of Information, the units used had to be explicitly stated. An exception was part (b), where the commonly used values of pressure in atmospheres and R in $(liter)(atmospheres)/(moles)(K)$ were acceptable.



5. (10 points)

The figure above shows a 0.20 m diameter cylinder fitted with a frictionless piston, initially fixed in place. The cylinder contains 2.0 moles of nitrogen gas at an absolute pressure of 4.0×10^5 Pa. Nitrogen gas has a molar mass of 28 g/mole and it behaves as an ideal gas.

(a) Calculate the force that the nitrogen gas exerts on the piston.

$P = \frac{F}{A}$ $\quad A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2$

$F = PA = 4.0 \times 10^5\ \text{Pa} \cdot \pi \cdot (.10\ \text{m})^2$

$F = 1.3 \times 10^4\ \text{N}$

(b) Calculate the volume of the gas if the temperature of the gas is 300 K.

$PV = nRT$

$V = \frac{nRT}{P} = \frac{2.0\ \text{mol} \cdot 8.31 \frac{\text{J}}{\text{mol K}} \cdot 300\ \text{K}}{4.0 \times 10^5\ \text{Pa}} = 0.012\ \text{m}^3$

(c) In a certain process, the piston is allowed to move, and the gas expands at constant pressure and pushes the piston out 0.15 m. Calculate how much work is done by the gas.

$W_{by} = P\Delta V = PAd = Fd$

$= 1.3 \times 10^4\ \text{N} \cdot .15\ \text{m}$

$= 1950\ \text{J}$

GO ON TO THE NEXT PAGE.

(d) Which of the following is true of the heat energy transferred to or from the gas, if any, in the process in part (c)?

__✓__ Heat is transferred to the gas.

_____ Heat is transferred from the gas.

_____ No heat is transferred in the process.

Justify your answer.

$\Delta U = Q_{to} - W_{by}$ $PV = nRT$ $\Delta U = \frac{3}{2} nk\Delta T$

Since the product PV increases, T increases proportionally, and so does U. Since ΔU is positive and so is W_{by}, Q must be positive (and larger than W_{by}) ∴ heat has been added to the gas.

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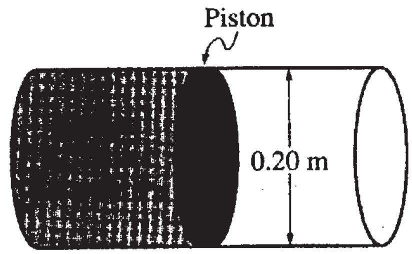

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The figure above shows a 0.20 m diameter cylinder fitted with a frictionless piston, initially fixed in place. The cylinder contains 2.0 moles of nitrogen gas at an absolute pressure of 4.0×10^5 Pa. Nitrogen gas has a molar mass of 28 g/mole and it behaves as an ideal gas.

(a) Calculate the force that the nitrogen gas exerts on the piston.

$P = \frac{F}{A}$

$F = PA = P(\pi r^2)$

$F = 50265 N$

$F = 50{,}000 N$

$P = 4.0 \cdot 10^5 Pa$
$A = \pi r^2$
$r = 0.20 m$

(b) Calculate the volume of the gas if the temperature of the gas is 300 K.

$PV = nRT$

$V = nRT/P$

$V = 0.01246 m^3$

$V = 0.012 m^3$

$T = 300 k$
$n = 2.0 mol$
$P = 4.0 \cdot 10^5 Pa$
$R = 8.31 J/molk$
$V = ?$

(c) In a certain process, the piston is allowed to move, and the gas expands at constant pressure and pushes the piston out 0.15 m. Calculate how much work is done by the gas.

$W = -P\Delta V$

$\Delta V = \pi r^2 \cdot d$
$\Delta V = 1.88 \cdot 10^{-2}$

$r = 0.20 m$
$d = 0.15 m$
$P = 4.0 \cdot 10^5 Pa$

$W = -7539.82 J$

$W = -7500 J$

GO ON TO THE NEXT PAGE.

(d) Which of the following is true of the heat energy transferred to or from the gas, if any, in the process in part (c)?

__✓__ Heat is transferred to the gas.

_____ Heat is transferred from the gas.

_____ No heat is transferred in the process.

Justify your answer.

In order to expand at constant pressure, energy must be added.

$PV = nRT$

With P, n, and R remaining constant, T must increase in order for V to increase.

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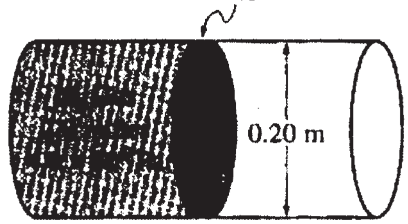

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(a) Calculate the force that the nitrogen gas exerts on the piston.

$P = \frac{F}{A}$

$F = (4.0 \times 10^5 Pa)(\pi(2.0 m)^2)$

$F = 5.0 \times 10^4 N$

(b) Calculate the volume of the gas if the temperature of the gas is 300 K.

$PV = nRT$

$(4.0 \times 10^5 Pa) V = n (300 K)(8.31 \frac{J}{(mol \cdot K)})$

$V = 6.2 \times 10^{-3} m^3$

(c) In a certain process, the piston is allowed to move, and the gas expands at constant pressure and pushes the piston out 0.15 m. Calculate how much work is done by the gas.

$W = -P\Delta V$

$= (-4.0 \times 10^5 Pa)(-6.2 \times 10^{-3} m^3 + 7.1 \times 10^{-3} m^3)$

$= -360$

GO ON TO THE NEXT PAGE.

(d) Which of the following is true of the heat energy transferred to or from the gas, if any, in the process in part (c)?

______ Heat is transferred to the gas.

__/__ Heat is transferred from the gas.

______ No heat is transferred in the process.

Justify your answer.

The heat is transferred from the gas because the work is negative which denotes the release of heat.

Question 5

Overview

This 10-point question was designed to measure students' understanding of thermodynamics. A specified amount of an ideal gas was confined at constant pressure. In part (a) students were asked to calculate the force exerted by the gas on a piston of specified diameter, and in part (b) to calculate the volume occupied by the gas, given a specified temperature. A constant-pressure expansion was described in part (c), and students were required to calculate the work done by the gas. In part (d) they had to decide whether heat energy was transferred to or from the gas (or not at all) and to justify their choice.

Sample: 5A
Score: 10

The student uses the alternate method for solving part (c). The last part uses a convention for the first law of thermodynamics in which W is the work done by the system.

Sample: 5B
Score: 7

In part (a) the diameter is used instead of the radius, so only the substitution point was earned. Part (b) is correct. In part (c) the student was not penalized again for the wrong value for area, so 2 points could have been earned, but one was deducted for the negative sign. The units point was also earned. Part (d) has the correct choice and an explanation of the increase in temperature, so 2 points were earned.

Sample: 5C
Score: 3

In part (a) the diameter is used instead of the radius, so only the substitution point was earned. In part (b) the student has three values correct and earned the substitution point. However, the number of moles is not substituted, so the answer is incorrect. In part (c) 1 point was earned for the substitutions, since the correct pressure and some attempt at a change in volume are used, but that point was deducted because of the negative answer. The units point was earned for parts (a) and (b). Part (d) earned nothing.