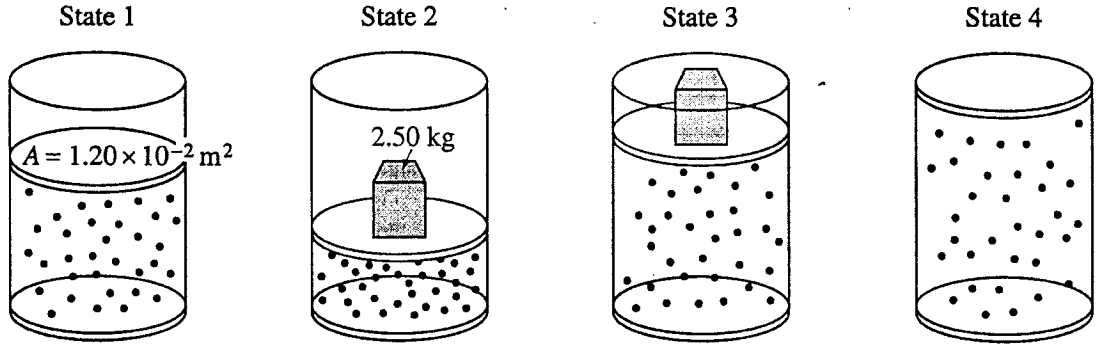
AP® Physics B
2001 Sample Student Responses

These materials were produced by Educational Testing Service (ETS), which develops and administers the examinations of the Advanced Placement Program for the College Board. The College Board and Educational Testing Service (ETS) are dedicated to the principle of equal opportunity, and their programs, services, and employment policies are guided by that principle.

The College Board is a national nonprofit membership association dedicated to preparing, inspiring, and connecting students to college and opportunity. Founded in 1900, the association is composed of more than 3,900 schools, colleges, universities, and other educational organizations. Each year, the College Board serves over three million students and their parents, 22,000 high schools, and 3,500 colleges, through major programs and services in college admission, guidance, assessment, financial aid, enrollment, and teaching and learning. Among its best-known programs are the SAT®, the PSAT/NMSQT™, the Advanced Placement Program® (AP®), and Pacesetter®. The College Board is committed to the principles of equity and excellence, and that commitment is embodied in all of its programs, services, activities, and concerns.



Note: Figures not drawn to scale.

6. (10 points)

A cylinder is fitted with a freely moveable piston of area $1.20 \times 10^{-2}\,\text{m}^2$ and negligible mass. The cylinder below the piston is filled with a gas. At state 1, the gas has volume $1.50 \times 10^{-3}\,\text{m}^3$, pressure $1.02 \times 10^5\,\text{Pa}$, and the cylinder is in contact with a water bath at a temperature of 0°C. The gas is then taken through the following four-step process.

- A 2.50 kg metal block is placed on top of the piston, compressing the gas to state 2, with the gas still at 0°C.
- The cylinder is then brought in contact with a boiling water bath, raising the gas temperature to 100°C at state 3.
- The metal block is removed and the gas expands to state 4 still at 100°C.
- Finally, the cylinder is again placed in contact with the water bath at 0°C, returning the system to state 1.

(a) Determine the pressure of the gas in state 2.

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

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

$$P = \frac{(2.5\,\text{kg})(9.8\,\text{m/s}^2)}{1.2 \times 10^{-2}\,\text{m}^2}$$

$$P = 2040\,\text{Pa} + 1.02 \times 10^5\,\text{Pa} = 1.04 \times 10^5\,\text{Pa}$$

(b) Determine the volume of the gas in state 2.

$$P_1 V_1 = P_2 V_2$$

$$(1.02 \times 10^5\,\text{Pa})(1.5 \times 10^{-3}\,\text{m}^3) = (1.04 \times 10^5\,\text{Pa})(V_2)$$

$$V_2 = 1.47 \times 10^{-3}\,\text{m}^3$$

GO ON TO THE NEXT PAGE.

(c) Indicate below whether the process from state 2 to state 3 is isothermal, isobaric, or adiabatic.

___ Isothermal ✓ Isobaric ___ Adiabatic

Explain your reasoning.

It is isobaric, because temperature increases and volume increases, but pressure remains constant.

$$\frac{P_3V_3}{T_3} = \frac{P_2V_2}{T_2}$$

(d) Is the process from state 4 to state 1 isobaric? ✓ Yes ___ No

Explain your reasoning.

From states 4 to 1, volume decreases as does temperature, but pressure again remains constant.

$$\frac{P_1V_1}{T_1} = \frac{P_4V_4}{T_4}$$

(e) Determine the volume of the gas in state 4.

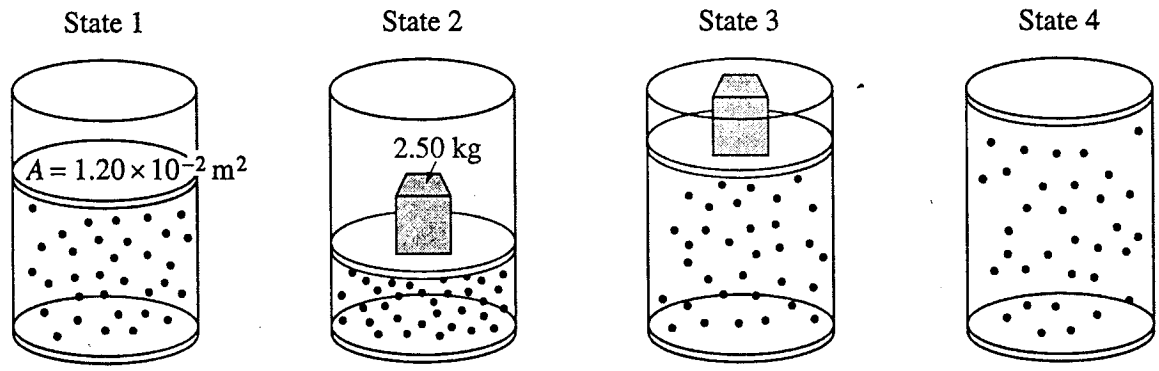
$$\frac{V_4}{T_4} = \frac{V_1}{T_1}$$

$$V_4 = \frac{V_1T_4}{T_1}$$

$$V_4 = \frac{(1.5\times10^{-3}\ m^3)(373K)}{(273K)}$$

$$V_4 = 2.05\times10^{-3}\ m^3$$

GO ON TO THE NEXT PAGE.



$T_1 = 0°C$
$V_1 = 1.50 \times 10^{-3}\ m^3$
$P_1 = 1.02 \times 10^5\ Pa$

$T_2 = 0°C$

$T_3 = 100°C$

$T_4 = 100°C$

Note: Figures not drawn to scale.

6. (10 points)

A cylinder is fitted with a freely moveable piston of area $1.20 \times 10^{-2}\ m^2$ and negligible mass. The cylinder below the piston is filled with a gas. At state 1, the gas has volume $1.50 \times 10^{-3}\ m^3$, pressure 1.02×10^5 Pa, and the cylinder is in contact with a water bath at a temperature of 0°C. The gas is then taken through the following four-step process.

- A 2.50 kg metal block is placed on top of the piston, compressing the gas to state 2, with the gas still at 0°C.
- The cylinder is then brought in contact with a boiling water bath, raising the gas temperature to 100°C at state 3.
- The metal block is removed and the gas expands to state 4 still at 100°C.
- Finally, the cylinder is again placed in contact with the water bath at 0°C, returning the system to state 1.

(a) Determine the pressure of the gas in state 2.

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

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

$$P = \frac{(2.50\ kg)(9.8\ m/s^2)}{(1.20 \times 10^{-2}\ m^2)}$$

$$P = 2041\ Pa$$

$$P = 1.02 \times 10^5\ Pa + 2041\ Pa$$

$$P = 1.04 \times 10^5\ Pa$$

(b) Determine the volume of the gas in state 2.

$$\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$$

$$\frac{(1.02 \times 10^5\ Pa)(1.50 \times 10^{-3}\ m^3)}{273\ K} = \frac{(1.04 \times 10^5\ Pa)(V_2)}{273\ K}$$

$$(273)(1.04 \times 10^5)\ V_2 = (1.02 \times 10^5)(1.50 \times 10^{-3})(273)$$

$$V_2 = 1.47 \times 10^{-3}\ m^3$$

GO ON TO THE NEXT PAGE.

(c) Indicate below whether the process from state 2 to state 3 is isothermal, isobaric, or adiabatic.

___ Isothermal ✓ Isobaric ___ Adiabatic

Explain your reasoning.

The process is isobaric because the volume increases and the temperature increases. Therefore, using $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$, the pressure is constant.

(d) Is the process from state 4 to state 1 isobaric? ✓ Yes ___ No

Explain your reasoning.

It is isobaric because the temperature decreases and the volume decreases there pressure is constant.

(e) Determine the volume of the gas in state 4.

$PV = nRT$ $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$ $(1.02\times10^5\ P_a)(1.50\times10^{-3}\ m^3) = n(R)(273\ K)$

$n =$

It fills the container,

GO ON TO THE NEXT PAGE.