Question 2: Version J

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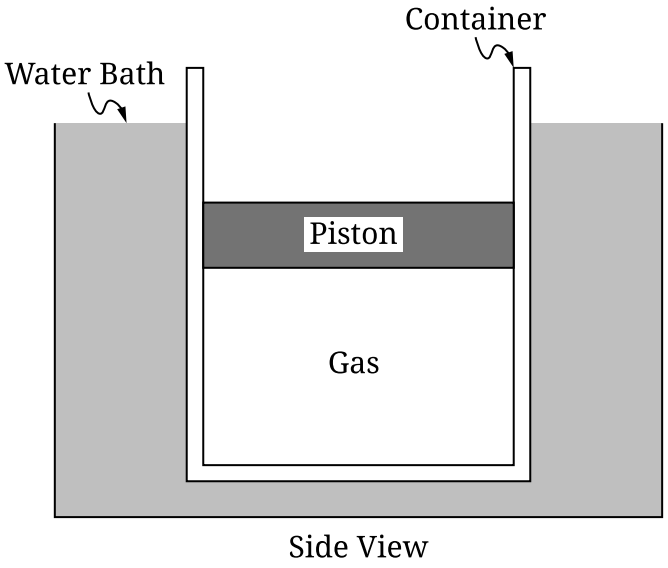
2. A sample of a monatomic ideal gas is sealed in a thermally conducting container by a movable piston of mass M and area A. The container is in a large water bath that is held at a constant temperature T_0. The piston is free to move with negligible friction. At the instant shown, the gas is in thermal equilibrium with the water bath, the piston is at rest, and the gas occupies volume V_0. The pressure of the air above the piston is P_{atm}.



Note: Figure not drawn to scale.

A. On the dot shown, representing the piston, **draw** and **label** the forces that are exerted on the piston. Each force must be represented by a distinct arrow starting on, and pointing away from, the dot.

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

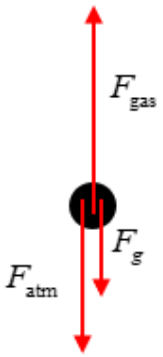
A

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.