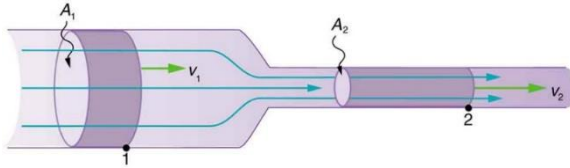


Part 1 - Multiple choice

Question 1



$$v_2 = 5 \text{ m/s}$$

$$D_1 = 5 \text{ cm}$$

$$D_2 = 1 \text{ cm}$$

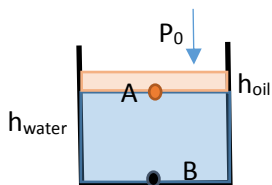
$$A_1 = \pi \frac{D_1^2}{4}$$

$$A_2 = \pi \frac{D_2^2}{4}$$

Continuity equation: $A_1 v_1 = A_2 v_2$

$$\frac{v_1}{v_2} = \frac{A_2}{A_1} = \left(\frac{D_2}{D_1}\right)^2 \Rightarrow v_1 = v_2 \left(\frac{D_2}{D_1}\right)^2 = 5 \frac{\text{m}}{\text{s}} \left(\frac{1 \text{ cm}}{5 \text{ cm}}\right)^2 = 0.2 \frac{\text{m}}{\text{s}}$$

Question 2



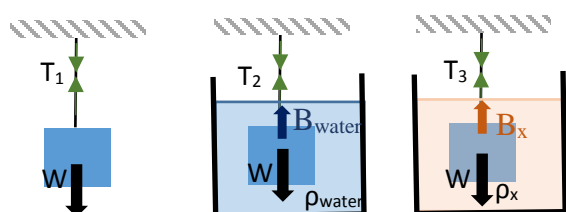
$$P_A = P_0 + \rho_{\text{oil}} g h_{\text{oil}}$$

$$P_B = P_A + \rho_{\text{water}} g h_{\text{water}}$$

$$\text{Gauge pressures: } P_A' = P_A - P_0 = \rho_{\text{oil}} g h_{\text{oil}} = 550 \frac{\text{kg}}{\text{m}^3} \times 9.8 \frac{\text{m}}{\text{s}^2} \times 0.255 \text{ m} = 1375 \text{ Pa}$$

$$P_B' = P_A' + \rho_{\text{water}} g h_{\text{water}} = 1375 \text{ Pa} + 1000 \frac{\text{kg}}{\text{m}^3} \times 9.8 \frac{\text{m}}{\text{s}^2} \times 0.350 \text{ m} = 1375 \text{ Pa} + 3430 \text{ Pa} = 4805 \text{ Pa}$$

Question 3



$$T_1 = mg$$

$$T_2 = mg - B_{\text{water}} = mg - \rho_{\text{water}} Vg \rightarrow \rho_{\text{water}} Vg = T_1 - T_2 \quad (*)$$

$$T_3 = mg - B_x = mg - \rho_x Vg \rightarrow \rho_x Vg = T_1 - T_3 \quad (**)$$

$$(*), (**) \Rightarrow \frac{\rho_x}{\rho_{\text{water}}} = \frac{T_1 - T_3}{T_1 - T_2}$$

$$\rho_x = \frac{T_1 - T_3}{T_1 - T_2} \times 1000 \frac{\text{kg}}{\text{m}^3} = \frac{60.3\text{N} - 28.6\text{N}}{60.3\text{N} - 30\text{N}} 1000 \frac{\text{kg}}{\text{m}^3} = \frac{31.7\text{N}}{30.3\text{N}} 1000 \frac{\text{kg}}{\text{m}^3} = 1046 \frac{\text{kg}}{\text{m}^3}$$

Question 4

A system undergoes an adiabatic process in which its internal energy increases by 20 J. Which of the following statements is true?

- A) the system lost 20 J of energy as heat
- B) 20 J of work was done by the system
- C) the system received 20 J of energy as heat
- D) 20 J of work was done on the system**
- E) none of the above are true

Question 5

$$n = \frac{m}{M} = \frac{2.00 \text{ kg}}{18 \times 10^{-3} \text{ kg/mol}} = 111 \text{ mol}$$

Question 6



$$\Delta L = \alpha L \Delta T = \alpha L \Delta T$$

$$L_1 = L/3 \rightarrow \Delta L_1 = \alpha L_1 \Delta T = \alpha \frac{L}{3} \Delta T$$

$$L_2 = 2L/3 \rightarrow \Delta L_2 = \alpha L_2 \Delta T = \alpha \frac{2L}{3} \Delta T$$

$$\frac{\Delta L_2}{\Delta L} = \frac{\alpha \frac{2L}{3} \Delta T}{\alpha L \Delta T} = \frac{2}{3}$$

Question 7

The limiting low temperature of a physical object is 0K

Question 8



$$R = 0.022 \text{ m}$$

$$m = 10.5 \text{ kg}$$

The weight of the piston creates the pressure on the gas.

$$P = \frac{F}{\text{Area}} = \frac{W}{\text{Area}} = \frac{mg}{\pi R^2} = \frac{10.5 \text{ kg} \times 9.8 \text{ m/s}^2}{\pi (0.022 \text{ m})^2} = 0.67 \times 10^5 \text{ Pa}$$

QUESTION 9

The speed of efflux is $\sqrt{2gh}$, where h is the distance of the hole below the surface of the fluid.

(a) $v_3 A_3 = \sqrt{2g(y_1 - y_3)} A_3 = \sqrt{2(9.80 \text{ m/s}^2)(8.00 \text{ m})(0.0160 \text{ m}^2)} = 0.200 \text{ m}^3/\text{s}.$

(b) Since p_3 is atmospheric pressure, the gauge pressure at point 2 is

$$p_2 = \frac{1}{2} \rho (v_3^2 - v_2^2) = \frac{1}{2} \rho v_3^2 \left(1 - \left(\frac{A_3}{A_2} \right)^2 \right) = \frac{8}{9} \rho g (y_1 - y_3), \text{ using the expression for } v_3 \text{ found above.}$$

Substitution of numerical values gives $p_2 = 6.97 \times 10^4 \text{ Pa}.$

QUESTION 10

This cycle involves adiabatic (ab), isobaric (bc), and isochoric (ca) processes. ca is at constant volume, ab has $Q = 0$, and bc is at constant pressure.

For a constant pressure process $W = p\Delta V$ and $Q = nC_p \Delta T$. $pV = nRT$ gives $n\Delta T = \frac{p\Delta V}{R}$, so $Q = \left(\frac{C_p}{R}\right)p\Delta V$.

If $\gamma = 1.40$ the gas is diatomic and $C_p = \frac{7}{2}R$.

For a constant volume process $W = 0$ and $Q = nC_V \Delta T$. $pV = nRT$ gives $n\Delta T = \frac{V\Delta p}{R}$, so $Q = \left(\frac{C_V}{R}\right)V\Delta p$. For a diatomic ideal gas $C_V = \frac{5}{2}R$. $1 \text{ atm} = 1.013 \times 10^5 \text{ Pa}$.

(a) $V_b = 9.0 \times 10^{-3} \text{ m}^3$, $p_b = 1.5 \text{ atm}$ and $V_a = 2.0 \times 10^{-3} \text{ m}^3$. For an adiabatic process $p_a V_a^\gamma = p_b V_b^\gamma$.

$$p_a = p_b \left(\frac{V_b}{V_a}\right)^\gamma = (1.5 \text{ atm}) \left(\frac{9.0 \times 10^{-3} \text{ m}^3}{2.0 \times 10^{-3} \text{ m}^3}\right)^{1.4} = 12.3 \text{ atm}.$$

(b) Heat enters the gas in process ca , since T increases.

$$Q = \left(\frac{C_V}{R}\right)V\Delta p = \left(\frac{5}{2}\right)(2.0 \times 10^{-3} \text{ m}^3)(12.3 \text{ atm} - 1.5 \text{ atm})(1.013 \times 10^5 \text{ Pa/atm}) = 5470 \text{ J}. \quad Q_H = 5470 \text{ J}.$$

(c) Heat leaves the gas in process bc , since T decreases.

$$Q = \left(\frac{C_p}{R}\right)p\Delta V = \left(\frac{7}{2}\right)(1.5 \text{ atm})(1.013 \times 10^5 \text{ Pa/atm})(-7.0 \times 10^{-3} \text{ m}^3) = -3723 \text{ J}. \quad Q_C = -3723 \text{ J}.$$

(d) $W = Q_H + Q_C = +5470 \text{ J} + (-3723 \text{ J}) = 1747 \text{ J}$.

$$(e) \quad e = \frac{W}{Q_H} = \frac{1747 \text{ J}}{5470 \text{ J}} = 0.319 = 31.9\%.$$

$$\text{Volume}=300\text{cm}^3$$

$$T_i=80^\circ\text{C}$$

$$m_{\text{ice}}=50\text{g}$$

$$\text{The mass of coffee is: } m_c = \rho_{\text{water}} \times \text{Volume} = \frac{1000\text{Kg}}{\text{m}^3} \times 300\text{cm}^3 = 300\text{g}$$

$$\text{Heat absorbed by ice: } Q_I = L_f m_i + m_i c_w (T_f - 0)$$

$$\text{Heat given away by the coffee is } |Q_c| = m_c c_w (T_i - T_f)$$

$$\text{Setting } Q_I = |Q_c|$$

$$T_f = \frac{m_w c_w T_i - L_f m_i}{c_w (m_i + m_c)} = \frac{300\text{g} \times 4190 \frac{\text{J}}{\text{kg} \cdot \text{C}} \times 80^\circ\text{C} - 334 \frac{\text{J}}{\text{g}} \times 50\text{g}}{4190 \frac{\text{J}}{\text{kg} \cdot \text{C}} (50\text{g} + 300\text{g})} = 57.2^\circ\text{C}$$

$$\text{The coffee has cooled down by: } 80^\circ\text{C} - 57.2^\circ\text{C} = 22.8^\circ\text{C}$$

BONUS QUESTION

The condition that the energy lost by the beverage can be due to evaporation equals the energy gained via radiation exchange implies

$$L_v \frac{dm}{dt} = P_{\text{rad}} = \sigma \varepsilon A (T_{\text{env}}^4 - T^4).$$

The total area of the top and side surfaces of the can is

$$A = \pi r^2 + 2\pi r h = \pi(0.022 \text{ m})^2 + 2\pi(0.022 \text{ m})(0.10 \text{ m}) = 1.53 \times 10^{-2} \text{ m}^2.$$

With $T_{\text{env}} = 32^\circ\text{C} = 305 \text{ K}$, $T = 15^\circ\text{C} = 288 \text{ K}$, and $\varepsilon = 1$, the rate of water mass loss is

$$\begin{aligned} \frac{dm}{dt} &= \frac{\sigma \varepsilon A}{L_v} (T_{\text{env}}^4 - T^4) = \frac{(5.67 \times 10^{-8} \text{ W/m}^2 \cdot \text{K}^4)(1.0)(1.53 \times 10^{-2} \text{ m}^2)}{2.256 \times 10^6 \text{ J/kg}} [(305 \text{ K})^4 - (288 \text{ K})^4] \\ &= 6.82 \times 10^{-7} \text{ kg/s} \approx 0.68 \text{ mg/s}. \end{aligned}$$