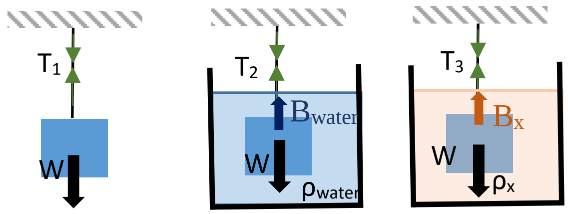
Part 1 - Multiple choice

Question 1



T_1=mg

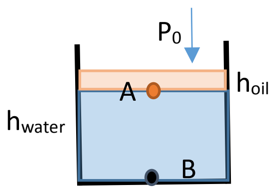
T_2=mg –B_{water} =mg- $\rho_{water}Vg$ ➔ $\rho_{water}Vg=T_1-T_2$ (*)

T_3=mg –B_x =mg- $\rho_x Vg$➔ $\rho_x Vg= T_1-T_3$ (**)

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

$$\rho_x = \frac{T_1 - T_3}{T_1 - T_2} \times 1000\,\frac{kg}{m^3} = \frac{41.9N - 15.8N}{41.9N - 25N}\,1000\,\frac{kg}{m^3} = \frac{26.1N}{16.9N}\,1000\,\frac{kg}{m^3} = 1544\,\frac{kg}{m^3}$$

Question 2



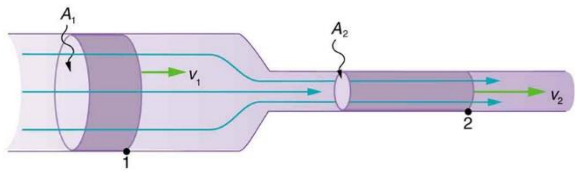
$P_A=P_0+\rho_{oil}\, g\, h_{oil}$

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

Gauge pressures: $P_A' = P_A - P_0 = \rho_{oil}\, g\, h_{oil} = 550\,\frac{kg}{m^3} \times 9.8\,\frac{m}{s^2} \times 0.155\, m = 835\, Pa$

$P_B' = P_A' + \rho_{water}\, g\, h_{water} = 835\, Pa + 1000\,\frac{kg}{m^3} \times 9.8\,\frac{m}{s^2} \times 0.280\, m = 835\, Pa + 2744\, Pa = 3580\, Pa$

Question 3



v_2=3 m/s
D_1=3cm
D_2=1cm

$$A_1 = \pi \frac{{D_1}^2}{4}$$
$$A_2 = \pi \frac{{D_2}^2}{4}$$

Continuity equation: $A_1v_1= A_2v_2$

$$\frac{v_1}{v_2} = \frac{A_2}{A_1} = \left(\frac{D_2}{D_1}\right)^2 => v_1 = v_2\left(\frac{D_2}{D_1}\right)^2 = 3\frac{m}{s}\left(\frac{1\ cm}{3cm}\right)^2 = 0.33\frac{m}{s}$$

Question 4

R=0.013m

m=8.7kg

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

$$P = \frac{F}{Area} = \frac{W}{Area} = \frac{mg}{\pi\ R^2} = \frac{8.7\ kg \times 9.8\ m/s}{\pi(0.013m)^2} = 1.60 \times 10^5 Pa$$

Question 5

$$n = \frac{m}{M} = \frac{1.00\,kg}{18 \times 10^{-3} kg/mol} = 55\,mol$$

Question 6

The limiting low temperature of a physical object is 0K

Question7

Δ L=αLΔT=$\alpha L \Delta T$

L_1=L/3 ➔Δ L_1=αL_1ΔT=$\alpha \frac{L}{3} \Delta T$

L_2=2L/3➔Δ L_2=αL_2ΔT= $\alpha \frac{2L}{3} \Delta T$

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

Question 8

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

A) 20 J of work was done on the system

B) 20 J of work was done by the system

C) the system received 20 J of energy as heat

D) the system lost 20 J of energy as heat

E) none of the above are true

Question 9

Volume=130cm^3
T_i=80ºC
m_{ice}=12g

The mass of coffee is: $m_c = \rho_{water} \times Volume = \frac{1000Kg}{m^3} \times 130cm^3 = 130g$

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

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

Setting $Q_I = |Q_c|$

$$T_f = \frac{m_w c_w T_i - L_f m_i}{c_w (m_i + m_c)} = \frac{130g \times 4190 \frac{J}{kg \cdot C} \times 80℃ - 334 \frac{J}{g} \times 12g}{4190 \frac{J}{kg \cdot C} (12g + 130g)} = 66.5℃$$

The coffee has cooled down by: $80℃ - 66.5℃ = 13.5℃$

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

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

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

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

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

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

(d) $W = Q_{\text{H}} + Q_{\text{C}} = +5470\text{ J} + (-3723\text{ J}) = 1747\text{ J}.$

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

QUESTION 11

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

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

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

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

$$A = \pi r^2 + 2\pi rh = \pi(0.022\text{ m})^2 + 2\pi(0.022\text{ m})(0.10\text{ m}) = 1.53\times10^{-2}\text{ m}^2\,.$$

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

$$\frac{dm}{dt} = \frac{\sigma\varepsilon A}{L_V}(T_{\text{env}}^4 - T^4) = \frac{(5.67\times10^{-8}\text{ W/m}^2\cdot\text{K}^4)(1.0)(1.53\times10^{-2}\text{ m}^2)}{2.256\times10^6\text{ J/kg}}\left[(305\text{ K})^4 - (288\text{ K})^4\right]$$
$$= 6.82\times10^{-7}\text{ kg/s} \approx 0.68\text{ mg/s.}$$