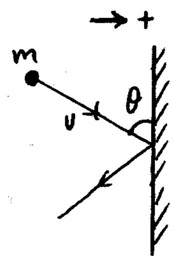
PHYS 262 — Homework 7 (Ch21) — Spring '03

1. (SB3) force on stone during collision $= \frac{\Delta p}{\Delta t}$



$\Delta p =$ change in momentum of stone

$= m(-v)\sin\theta - mv\sin\theta$

$= -2mv\sin\theta$

$F =$ total force on window $= -\frac{\Delta p}{\Delta t} = \frac{2mv\sin\theta}{t} N$

$P =$ Pressure on window $= Nm\frac{2v\sin\theta}{At}$

$m = 5g$, $t = 30s$, $N = 500$, $A = 0.6m^2$, $\theta = 45°$, $V = 8ms^{-1}$

$\therefore$ $F = 0.943$ N

$P = 1.57$ Pa $\#$

2. (SB11) (a) $\bar{K} = \frac{3}{2}k_BT$ $(\because T = (150+273)K = 423K)$

$= 8.76 \times 10^{-21}$ J $\#$

(b) $\bar{K} = \frac{1}{2}m(v_{rms})^2$ where m is the mass of one atom

$v_{rms} = \sqrt{\frac{2\bar{K}}{m}}$

for He, $m = \frac{\text{molar mass of helium}}{N_A} = 6.64 \times 10^{-24} g$

$\therefore$ $v_{rms} = 1.62 \times 10^3 ms^{-1}$ $\#$

for Ar, $m = \frac{\text{molar mass of Ar}}{N_A} = 6.63 \times 10^{-23} g$

$\therefore$ $v_{rms} = 514 ms^{-1}$ $\#$

3. (SB16) (a) $\because V =$ constant

$\therefore W = 0 J$

$\Rightarrow \Delta E_{int} = Q - W$

$= 209 J$ $\#$

(b) $V =$ constant $\Rightarrow W = 0 J$ $\#$

(c) $\Delta E_{int} = Q = nC_v\Delta T$

Given $n = 1$, $Q = 209 J$

C_v for ideal monatomic gas $= \frac{3}{2}R$

$\therefore \Delta T = 16.8 K$

hence, final temperature $= 317 K$ $\#$

4. (SB24) (a) For adiabatic process

$P_iV_i^{\gamma} = P_fV_f^{\gamma}$

$\frac{V_f}{V_i} = \left(\frac{P_i}{P_f}\right)^{\frac{1}{\gamma}}$

$= 0.118$ $\#$

(b) $\frac{T_f}{T_i} = \frac{P_fV_f}{P_iV_i}$ $(\because PV = nRT)$

$= 2.35$ $\#$

(c) adiabatic $\Rightarrow Q = 0 J$ $\#$

Given $T_i = 27°C = 300K$, $n = 0.06$

$\Delta T = T_f - T_i = 1.35\, T_i$

$\gamma = 1.4 \Rightarrow \frac{C_p}{C_v} = 1.4 \Rightarrow \frac{C_v + R}{C_v} = 1.4, \therefore C_v = \frac{5}{2}R$

$\Delta E_{int} = n C_v \Delta T$ (for constant volume process)

$= 135\,J$ #

Finally, by the first law of thermodynamics,

$\Delta E_{int} = Q - W$

$W = -135\,J$ #

5. (SB26) P_0 = atmospheric pressure = 101.3 kPa

(a) $V_i = \pi r^2 h$ ($r = (0.5)(2.5\,cm)$, $h = 50\,cm$)

$P_i = P_0$

$P_f = P_0 + 800\,kPa$ (recall the definition of gauge pressure)

$P_i V_i^{\gamma} = P_f V_f^{\gamma}$ ($\gamma = 1.4$)

$V_f = 5.15 \times 10^{-5}\,m^3$ #

(b) $T_i = 27\,°C = 300\,K$

$$\frac{P_i V_i}{T_i} = \frac{P_f V_f}{T_f}$$

$$T_f = \frac{P_f V_f}{P_i V_i} T_i$$

$= 560\,K$ #

(c) assume the pump is made of iron. let the final temperature be T

density of iron = ρ_{Fe}

specific heat of iron = C_{Fe}

thickness of pump wall = δ

$P_i V_i = nRT_i \Rightarrow n = 9.97 \times 10^{-3}$ mol of air

$\gamma = 1.4 \Rightarrow C_v = \frac{5}{2}R$

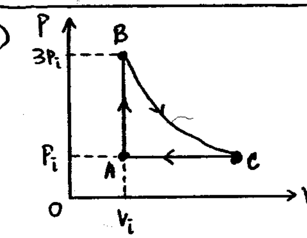
$m_{Fe} = \pi[(r+\delta)^2 - r^2] h \rho_{Fe}$

then, $n C_v (T_f - T) = m_{Fe} C_{Fe} (T - T_i)$

$\Rightarrow T = 302.24\,K$

$\therefore$ increase in wall temperature = 2.24 K #

6. (SB30) (a)



$\gamma = 1.4 \Rightarrow C_v = \frac{5}{2}R$

$C_p = \frac{7}{2}R$

(b) $P_B V_B^{\gamma} = P_C V_C^{\gamma}$

$$V_C = \left(\frac{P_B}{P_C}\right)^{\frac{1}{\gamma}} V_B$$

$= 2.19\, V_i$ #

(c) $\frac{P_A}{T_A} = \frac{P_B}{T_B}$ ($\because$ V is constant for $A \to B$)

$$T_B = \frac{P_B}{P_A} T_A$$

$= 3T_i$ #

(d) after one cycle, $T = T_A = T_i$ #

(e) For one complete cycle,

$\Delta E_{int} = Q - W = 0$

$\therefore W = Q = Q_{AB} + Q_{BC} + Q_{CA}$

$Q_{AB} = n C_v (T_B - T_A) = 5nRT_i$

$Q_{BC} = 0$

$Q_{CA} = n C_p (T_A - T_C)$

$= n \frac{7}{2} R \left[T_i - \frac{P_i (2.19 V_i)}{nR}\right]$

$= -4.17\, nRT_i$

So, $W = 0.83\, P_i V_i$ # ($\because P_i V_i = nRT_i$)