Solusi Tutorial 9 Fisika Dasar 1A ITB

oleh : Wawan K

A. Pertanyaan

① PV^{γ} = konstan (proses adiabatik)

dengan $\gamma > 1$

menurut hukum 1 termodinamika.

$$Q = \Delta U + W$$

$$0 = \Delta U + W$$

$$\Delta U = -W$$

$\Delta U = \Delta E$ dalam

$$E_{dalam} = n C_V T$$

$$dE_{dalam} = n C_V dT = -W \rightarrow dT = \frac{-PdV}{nC_V}$$

$$W = PdV = nRT$$

turunkan total kedua ruas, menjadi

$$PdV + VdP = nRdT$$

$$PdV + VdP = -\frac{R}{C_V} PdV \qquad R = C_P - C_V$$

$$PdV + VdP = -\left(\frac{C_P - C_V}{C_V}\right) PdV$$

kita bagi dengan PV

$$\frac{dV}{V} + \frac{dP}{P} = -\left(\frac{C_P - C_V}{C_V}\right)\frac{dV}{V}$$

$$\frac{dV}{V} + \frac{dP}{V} = \left(1 - \frac{C_P}{C_V}\right)\frac{dV}{V}$$

(1)

$$\frac{dV}{V} + \frac{dP}{P} = (1-\gamma)\frac{dV}{V}$$

$$\frac{dp}{p} + \gamma \frac{dV}{V} = 0$$

Integral kan kedua ruas,

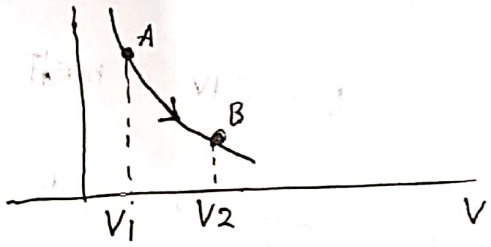
$$\ln P + \gamma \ln V = 0$$

$$\ln P + \ln V^{\gamma} = 0$$

$$\ln(PV^{\gamma}) = 0$$

Sehingga (PV^{γ}) = konstan.

untuk soal no 1, gas mengembang berarti $V_2 > V_1$, maka



ΔV (positif)

$$\Delta U = -W$$
$$= -P\Delta V$$

$$nC_V \Delta T = -P\Delta V$$

ΔT = (negatif)

Sehingga suhunya turun atau mendingin

(2) kita hitung keadaan tiap titik,

•) Titik 1

$P_1 = 2 atm = 2 \times 10^5 \ Pa$

$T_1 = 600 \ K$

$V_1 = 2L = 2 \times 10^{-3} \ m^3$

$$n = \frac{P_1 V_1}{R T_1} = \frac{2 \times 10^5 \times 2 \times 10^{-3}}{8{,}31 \times 600} = 0{,}08 \ mol$$

$$N = n N_A = 0{,}08 \times 6{,}02 \times 10^{23}$$

$$N_1 = 4{,}8 \times 10^{22} \ partikel$$

•) Titik 2

$P_2 = 4 atm = 4 \times 10^5 \ Pa$

$T_2 = 300K \ , \ V_2 = 2L = 2 \times 10^{-3} \ m^3$

$$n = \frac{P_2 V_2}{R T_2} = \frac{4 \times 10^5 \left(2 \times 10^{-3}\right)}{8{,}31 \times 300} = 0{,}32 \ mol$$

$$N = n N_A = 0{,}32 \times 6{,}02 \times 10^{23}$$

$$N_2 = 1{,}93 \times 10^{23} \ partikel$$

•) titik 3

$P_3 = 2 atm = 2 \times 10^5 \ Pa$

$T_3 = 300 \ K$

$V_3 = 4L = 4 \times 10^{-3} \ m^3$

$$n = \frac{P_3 V_3}{R T_3} = \frac{2 \times 10^5 \left(4 \times 10^{-3}\right)}{8{,}31 \times 300}$$

$n = 0{,}32 \ mol$

$$N = n \times N_A = 0{,}32 \times 6{,}02 \times 10^{23}$$

$$N_3 = 1{,}93 \times 10^{23} \ partikel$$

(2) -) titik 4

$P_4 = 4\ atm = 4 \times 10^5\ Pa$

$T_4 = 600k$

$V_4 = 2L = 2 \times 10^{-3}\ m^3$

$$n = \frac{P_4 V_4}{RT_4} = \frac{4 \times 10^5 \times 2 \times 10^{-3}}{8{,}31 \times 600} = 0{,}16\ mol$$

$$N_4 = n\, N_A = 0{,}16 \times 6{,}02 \times 10^{23} = 9{,}6 \times 10^{22}\ partikel$$

Jadi, urutannya adalah 2 dan 3, 4, 1

(3) Laju kalor Induksi

$$\frac{Q}{t} = kA \frac{dT}{dx}$$

$$\frac{Q}{t} = kA \left| \frac{\Delta T}{L} \right|$$

Dari grafik, dapat kita lihat hubungannya

$$\text{gradien} \approx \frac{kA}{L}$$ (karena Sumbu $y = \frac{Q}{t}$ dan Sumbu $x = \Delta T$)

Sehingga Urutan gradien, gradien A > gradien B > gradien C

dan urutan panjangnya, $L_C > L_B > L_A$

(4) a) Isotermal →

ekspansi Volume.

$Q = \Delta U + W$

$Q = 0 + W$

$PV = nRT$

$P = \frac{nRT}{V}$

$W = \int P\,dV$

$= \int \frac{nRT}{V}\,dV$

$= nRT \int \frac{dV}{V}$

$W = nRT \ln\left(\frac{V_2}{V_1}\right)$

b) Isotermal.

$W = \int P\,dV$

$= nRT \int \frac{dV}{V}$

$W = nRT \ln\left(\frac{V_2}{V_1}\right) = nRT \ln\left(\frac{P_1}{P_2}\right)$

$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

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

c) Isobar, $W = \int P\,dV = P\,\Delta V$

d) Volume konstan (Iso Volume), $W = 0$

Karena, Usaha pada gas negatif, maka → dilakukan pada gas

urutannya adalah dari yang terbesar :

b, d, a, c

(5) $Q = E_{dalam} + W$

$dQ = dE_{dalam} + dW$

$dQ = dE_{dalam} + PdV$ ← $PV = nRT \rightarrow P = \frac{nRT}{V}$

$dQ = n C_V dT + nRT \frac{dV}{V}$

$\frac{dQ}{T} = n C_V \frac{dT}{T} + nR \frac{dV}{V}$

Sehingga $S = \int \frac{dQ}{T}$

maka: $\int \frac{dQ}{T} = \int n C_V \frac{dT}{T} + nR \int \frac{dV}{V}$

$S = n C_V \ln\left(\frac{T_2}{T_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$

a) Saat Isotermal, $T_1 = T_2$

maka: $S = n C_V \ln(1) + nR \ln\left(\frac{V_2}{V_1}\right)$

$= 0 + nR \ln\left(\frac{V_2}{V_1}\right) = nR \ln\left(\frac{V_2}{V_1}\right)$

b) $S = n C_V \ln\left(\frac{T_2}{T_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$

$= n C_V \ln(1) + nR \ln\left(\frac{V_2}{V_1}\right)$

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

(5) b)

$$P_1V_1 = P_2V_2$$

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

maka: $S = nR \ln\left(\frac{V_2}{V_1}\right)$

$$S = nR \ln\left(\frac{P_1}{P_2}\right)$$

(c) Tekanan konstan, $P_1 = P_2$

$$S = nC_V \ln\left(\frac{T_2}{T_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$$

$$= nC_V \ln\frac{T_2}{T_1} + nR \ln\left(\frac{V_2}{V_1}\right)$$

$$= n\left(\frac{3}{2}R\right) \ln\left(\frac{V_2}{V_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$$

$$S = \frac{5}{2}nR \ln\left(\frac{V_2}{V_1}\right)$$

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

Jadi, urutannya

c, a, b

oleh : Wawan K

B. SOAL

① a) $Q = mc\,\Delta T$

$= mc(T_f - T_i)$

$$c = \frac{Q}{m(T_f - T_i)} = \frac{325}{30\times10^{-3}(45-25)} = 541{,}7\ J/kg\cdot K$$

b) panas jenis molar :

$$C_m = \frac{Q}{n(T_f - T_i)}$$

$$= \frac{325}{0{,}60\,(45-25)}$$

$$= 27\ J/mol\cdot K$$

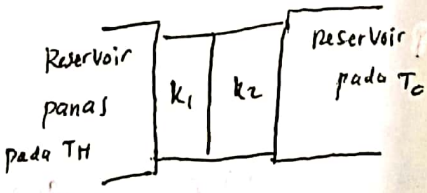
n = jumlah mol

$$n = \frac{m}{Mr} = \frac{30\times10^{-3}\ kg}{50\times10^{-3}\ kg/mol}$$

$n = 0{,}60$ mol

c) $$n = \frac{m}{Mr} = \frac{30\times10^{-3}\ kg}{50\times10^{-3}\ kg/mol} = 0{,}600\ mol$$

② untuk kasus misalnya ada 2 k,



maka laju kalor konduksi,

$$P_{kon} = \frac{Q}{t} = \frac{k_2 A(T_H - T_x)}{L_2} = \frac{k_1 A(T_x - T_c)}{L_1} \quad \ldots 1)$$

maka : $$T_x = \frac{k_1 L_2 T_c + k_2 L_1 T_H}{k_1 L_2 + k_2 L_1}$$

Substitusi T_x ke pers (1)

(2) maka : $P_{cond} = \frac{A\,(T_H - T_C)}{L_1/k_1 + L_2/k_2}$

atau $P_{cond} = \frac{A\,(T_H - T_C)}{\Sigma(L/k)}$ ..... 2)

Dengan menggunakan pers (2) pada permasalahan ini, diperoleh :

$$\frac{T_H - T_C}{L_1/k_1 + L_2/k_2 + L_3/k_3} = \frac{\Delta T_2}{(L_2/k_2)}$$

$$\frac{45^\circ C}{1 + \frac{7,5}{9} + \frac{3,5}{8}} = \frac{\Delta T_2}{\frac{7,5}{9}}$$

$$\frac{45^\circ C}{1 + 0,83 + 0,9375} = \frac{\Delta T_2}{0,83}$$

$$\Delta T_2 = 0,83\left(\frac{45^\circ C}{2,2708}\right)$$

$$\Delta T_2 = 16,45^\circ C$$

(3) $PV = nRT$

$$n = \frac{PV}{RT} \rightarrow \frac{m}{Mr} = \frac{PV}{RT} \rightarrow m = \frac{PVMr}{RT} = \frac{100 \times 1,01 \times 10^5 \; 50 \times 10^{-3} \left(4 \times 10^{-3}\right)}{8,31 \times 288}$$

$$m = 0,84 \text{ kg}$$

④ a) $PV = nRT$ atau $PV = NkT$

$V = 5{,}6 \times 10^3$ cc $= 5{,}6 \times 10^3$ Cm^3

atau $V = 5{,}6 \times 10^3 \times 10^{-6}$ m^3

$V = 5{,}6 \times 10^{-3}$ m^3

$P = 29$ Psi

$= 29 \times 6{,}9 \times 10^3$ Pa

$P_{gauge} = 2 \times 10^5$ Pa

maka banyaknya gas,

$P_{gauge} = P_{mutlak} - P_0$

$N = \frac{PV}{kT} = \frac{(3 \times 10^5)(5{,}6 \times 10^{-3})}{1{,}381 \times 10^{-23}(300)}$

$P_{gas} = P_{gauge} + P_0$

$= 3 \times 10^5$ Pa

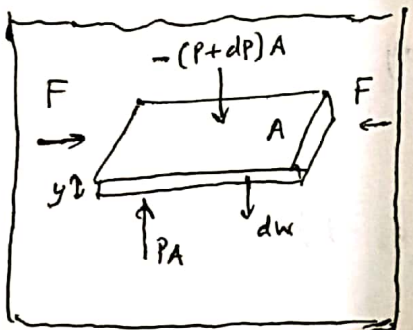
$N = 4 \times 10^{23}$ partikel //

b) $\frac{P_1 V_1}{T_1} = \frac{P_2 V_2}{T_2}$ (asumsi Volume konstan)

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

$\frac{3 \times 10^5}{300} = \frac{P_2}{320} \rightarrow P_2 = 3{,}2 \times 10^5$ Pa $= 3{,}2 \times 10^5$ N/m^2.

⑤ kita kembali ke fluida (karena udara dapat kita asumsikan fluida)



kesetimbangan gaya :

$\Sigma F_y = 0$

$F_a - My - F_{hidrostatis} = 0$

$PA - mg - (P+dP)A = 0$

atau : $PA - (P+dP)A - mg = 0$

$PA - (P+dP)A - \rho V g = 0$

$PA - (P+dP)A - \rho (A\,dy) g = 0$

$P - (P+dP) = \rho g\, dy$

$-dP = \rho g\, dy$

$\frac{dP}{dy} = -\rho g$ ------(1)

hukum gas ideal :

$PV = nRT$

$PV = \frac{m}{Mr} RT$

$\frac{m}{V} = \frac{PMr}{RT}$

$\rho = \frac{PMr}{RT}$

maka ρ substitusi ke pers (1)

$\frac{dP}{dy} = \frac{-\rho Mr}{RT} g$

$\int \frac{dP}{P} = \frac{-Mg}{RT} \int_{y_1}^{y_2} dy$

$\ln \frac{P_2}{P_1} = -\frac{Mg}{RT} (y_2 - y_1)$

(5) $\frac{P_2}{P_1} = e^{-M g (y_2 - y_1)/RT}$

$P_2 = P_1 e^{-M_1 g (y_2 - y_1)/RT}$

jadi, terbukti tekanan sebagai fungsi ketinggian (y).

(6) $Q = E_{dalam} + W$

$dQ = dE_{dalam} + dW$

$dQ = dE_{dalam} + PdV$

$dQ = nC_V dT + nRT \frac{dV}{V}$

bagi dengan T,

$\frac{dQ}{T} = nC_V \frac{dT}{T} + nR \frac{dV}{V}$

$S = \int \frac{dQ}{T}$, maka $S = nC_V \int \frac{dT}{T} + nR \int \frac{dV}{V}$

$S = nC_V \ln\left(\frac{T_2}{T_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$

Volume tetap, $V_2 = V_1$

maka: $S = nC_V \ln \frac{101}{100} + nR \ln\left(\frac{V_1}{V_1}\right)$

$= 1\left(\frac{3}{2}\right)(8{,}31) \ln(1{,}01) + 0$

$S = 0{,}124$ J/K

(7) Proses tekanan tetap.

dengan rumus yang telah diketahui,

$$S = nC_V \ln\left(\frac{T_2}{T_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$$

karena tekanan konstan, maka

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

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

$N = nN_A$

$n = \frac{N}{N_A}$

Sehingga : $S = n\left(\frac{3}{2}R\right) \ln\left(\frac{V_2}{V_1}\right) + nR \ln\left(\frac{V_2}{V_1}\right)$

$$= 2{,}5\, nR \ln\left(\frac{V_2}{V_1}\right)$$

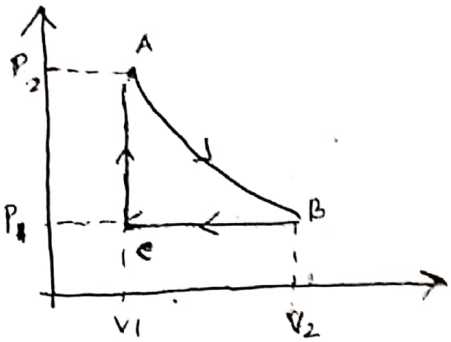
$$= 2{,}5 \frac{N}{N_A} R \ln\left(\frac{V_2}{V_1}\right)$$

$$S = \frac{2{,}5NR}{N_A} \ln\left(\frac{V_2}{V_1}\right)$$

$N_A = 6{,}62 \times 10^{23}$ partikel

$R = 8{,}314\ J/mol \cdot K$

(8) a)



b) $W_{total} = W_{AB} + W_{BC} + W_{CA}$

$= nRT \ln\left(\frac{V_2}{V_1}\right) + \left(\int P\,dV\right) + 0 = nRT \ln\left(\frac{2V_1}{V_1}\right) + 1\times10^5\,Pa\,(V - 2V_1)$

$= nRT \ln 2 + 10^5\,(-2\times10^{-3})$

$= 8{,}31\,nT \ln 2 - 200$

$W_{total}\ (5{,}76\,nT - 200)\ J$

c) $\Delta U_{total} = \Delta E_{int\ total} = 0$ (untuk siklus)

(9) a) Prosesnya Isovolume kemudian Isobar.

$A \rightarrow B \rightarrow C$ (B→C: Isobar; A→B: Isovolume)

misalkan $C_V = 21\ J/mol \cdot K$

maka $C_P = C_V + R$

$= 21 + 8{,}31$

$= 29{,}3\ J/mol \cdot K$

$Q_{total} = Q_{AB}\ (Isovolume) + Q_{BC}\ (Isobar)$

$= nC_V\Delta T + nC_P\Delta T$

$= n\left(21\ J/n\,k\right)(T_B - T_A) + n\left(29{,}3\ J/n\,k\right)T_C - T_B$

$= 4{,}8\,(21)\,(T_B - T_A) + 4{,}8\,(29{,}3)\,(T_C - T_B)$

$n = \frac{PV}{RT}$

$= \frac{2\cdot10^5 \cdot 5\cdot10^{-3}}{8{,}31 \cdot 250}$

$= 4{,}8\ mol$

Pada proses A-B (Isovolume)

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

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

$$\frac{2\ atm}{250} = \frac{4\ atm}{T_B}$$

$$T_B = 500K$$

proses B-C (Isobar)

$$\frac{V_B}{T_B} = \frac{V_C}{T_C}$$

$$V_C = \left(\frac{T_C}{T_B}\right) V_B$$

$$= \left(\frac{650}{500}\right) 5.10^{-3}$$

$$V_C = 6,5 \times 10^{-3}\ m^3$$

Maka :

a) $Q_{total} = Q_{AB} + Q_{BC}$

$= 4,8(21)(500-250) + 4,8(29,3)(650-500)$

$= 25200 + 21096$

$= 46,296\ kJ$

$Q_{total} = 46\ kJ$

b) C ⟶ D gas didinginkan pada Volume tetap. $(V_C = V_D) = 6,5 \times 10^{-3}\ m^3$

$P_D = P_A = 2.10^5\ Pa$

D → A (tekanan tetap)

$Q_{selama\ pendinginan} = Q_{CD} + Q_{DA}$

$= n C_V (T_D - T_C) + n C_P (T_A - T_D)$

(9) b) proses C → D (Iso Volume)

$$\frac{P_C V_C}{T_C} = \frac{P_D V_D}{T_D}$$

$$\frac{P_C}{T_C} = \frac{P_D}{T_D}$$

$$\frac{4\,atm}{650} = \frac{2\,atm}{T_D}$$

$$T_D = \frac{1}{2}(650) = 325\,K$$

maka :

$$Q = Q_{CD} + Q_{DA}$$

$$= 4{,}8\,(21)\,(325 - 650) + 4{,}8\,(29{,}3)\,(250 - 325)$$

$$= -32.760\,J - 10.548\,J$$

$$= -43{,}3\,kJ$$

$$Q = -43\,kJ$$

c) W total siklus = $W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$$= 0 + W_{BC} + 0 + W_{DA}$$

$$= W_{BC} + W_{DA}$$

$$= P_1 (V_C - V_B) + P_2 (V_A - V_D)$$

$$= 4.10^5 \left(6{,}5 \times 10^{-3} - 2.10^{-3}\right) + 2.10^5 \left(2.10^{-3} - 6{,}5 \times 10^{-3}\right)$$

(9) c) $W_{total\ siklus} = 1800 - 900 = 900\ J$

(10) Efisiensi kulkas Carnot adalah

$$\eta = 1 - \frac{T_2}{T_1}$$

$$= 1 - \frac{200}{350} \times 100\%$$

$$\eta = 0{,}428 = 42{,}8\%$$

$$\eta = 0{,}43$$

$$\frac{1}{3} \times 0{,}43 = \eta_{kulkas}$$

$$\eta_{kulkas} = 0{,}14$$

$$\eta_{kulkas} = \frac{W}{Q_H} = \frac{Q_H - Q_C}{Q_H}$$

$$0{,}14 = \frac{Q_H - 500}{Q_H}$$

$$0{,}14 Q_H = Q_H - 500$$

$$-0{,}86 Q_H = -500$$

$$Q_H = 581\ J$$

Good luck