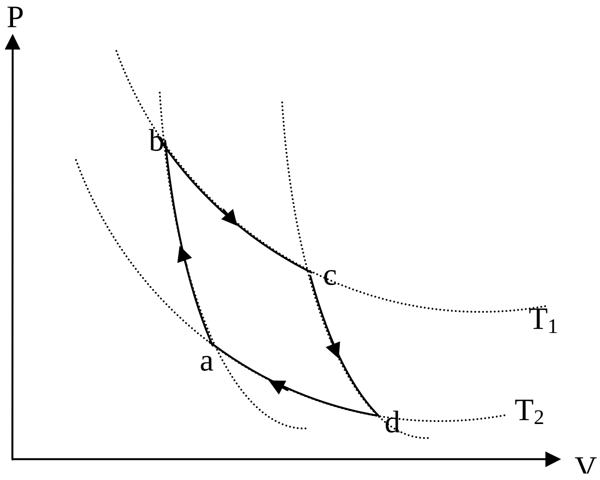
Solusi Soal Ujian Kedua Termodinamika

1. a. Syarat-syarat proses reversible:
    - Proses harus berlangsung kuasistatik
    - Tidak terjadi disipasi energi
    - Tidak melanggar Hukum Termodinamika Kedua (berikan penjelasan secukupnya!)

   b. Siklus Carnot



    - ab: Proses adiabatik, tidak ada pertukaran kalor dan tidak perlu RK
    - cd: Proses adiabatik, tidak ada pertukaran kalor dan tidak perlu RK
    - bc: Proses isotermal, hanya perlu satu RK, suhu tetap T_1
    - da: Proses isotermal, hanya perlu satu RK, suhu tetap T_2
      Jadi, dalam siklus Carnot hanya perlu dua buah RK, gesekan antara dinding dan piston dapat dibuat sedemikan sehingga gesekannya minimal, sehingga proses Carnot mendekati proses reversible.

2. Energi dalam U=U(P,V)

   a. Energi dalam dari gas:
    - Energi kinetik translasi molekul-molekul / partikel-partikel gas
    - Energi kinetik rotasi molekul-molekul / partikel-partikel gas
    - Energi vibrasi (getaran) atom-atom / molekul-molekul / partikel-partikel gas yang terdiri dari energi kinetic getaran dan energi potensial.

   b. U=U(P,V) ; maka:

$$du = \left(\frac{\partial u}{\partial P}\right)_V dP + \left(\frac{\partial u}{\partial V}\right)_P dV$$

   Hukum ke-1:

$$đQ = du + P\,dV$$

$$đQ = \left(\frac{\partial u}{\partial P}\right)_V dP + \left(\frac{\partial u}{\partial V}\right)_P dV + PdV$$

Jadi,

$$đQ = \left(\frac{\partial u}{\partial P}\right)_V dP + \left[\left(\frac{\partial u}{\partial V}\right)_P + P\right] dV$$

3. a. Persamaan keadaan gas ideal PV = nRT

$$d(PV) = d(nRT)$$

$$\frac{1}{PV}\, x\, \underline{PdV + VdP = nRdT} \;\Rightarrow\; \frac{dV}{V} + \frac{dP}{P} = \frac{nR}{PV}dT$$

$$\frac{nR}{PV} = \frac{1}{T} \;\Rightarrow\; \frac{dV}{V} + \frac{dP}{P} = \frac{dT}{T}$$

Jadi,

$$\frac{dP}{P} = \frac{dT}{T} - \frac{dV}{V}$$

b. Persamaan gas dalam proses adiabatik: $PV^{\gamma} = C$

maka: $P_i V_i^{\gamma} = P_f V_f^{\gamma} = C$

Usaha adiabatik:

$$W_{ad} = \int_i^f PdV = \int_i^f \frac{C}{V^{\gamma}} dV = \int_i^f CV^{-1} dV$$

$$= \frac{C}{-\gamma+1} V^{-\gamma+1}\Big|_i^f = \frac{C}{-\gamma+1}\left[V_f^{-\gamma+1} - V_i^{-\gamma+1}\right]$$

$$= \frac{CV_f^{-\gamma+1} - CV_i^{-\gamma+1}}{-\gamma+1} = \frac{P_f V_f^{\gamma} V_f^{-\gamma+1} - P_i V_i^{\gamma} V_i^{-\gamma+1}}{-\gamma+1}$$

$$= \frac{P_f V_f - P_i V_i}{-\gamma+1}$$

$$= \frac{P_i V_i - P_f V_f}{\gamma - 1}$$

Jadi, $W_{ad} = \dfrac{P_i V_i - P_f V_f}{\gamma - 1}$

c. $P(V-b) = RT \;\Rightarrow$ memuai Isotermal : T = 300 K

$V_i = (4+b)$ liter dan $V_f = (8+b)$ liter

$$R = 0{,}08\frac{atm.liter}{mol.K}$$

$$W = -\int PdV = -RT\int \frac{dV}{(V-b)} \;; \qquad y = V - b, \quad dy = dV$$

$$W = -RT\int \frac{dy}{y} = -RT\ln y = -RT\ln(V-b)\Big|_{V_i}^{V_f}$$

$$W = -RT\left[\ln(V_f - b) - (V_i - b)\right]$$
$$W = -RT\left[\ln(8 + b - b) - (4 + b - b)\right]$$
$$W = -RT\ln 2$$
$$W = -16{,}632 \ \ Joule$$

4. $$\left(\frac{\partial B}{\partial P}\right)_T = \left(\frac{\partial}{\partial P}\right)_T \left[\frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P\right] = -\frac{1}{V^2}\left(\frac{\partial V}{\partial P}\right)_T\left(\frac{\partial V}{\partial T}\right)_P + \frac{1}{V}\frac{\partial^2 V}{\partial P \partial T} \quad \ldots\ldots\ (*)$$

$$\left(\frac{\partial k}{\partial T}\right)_P = \left(\frac{\partial}{\partial T}\right)_P \left[-\frac{1}{V}\left(\frac{\partial V}{\partial P}\right)_T\right] = \frac{1}{V^2}\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial V}{\partial P}\right)_T - \frac{1}{V}\frac{\partial^2 V}{\partial T \partial P} \quad \ldots\ldots\ (**)$$

$$-\left(\frac{\partial k}{\partial T}\right)_P = \frac{1}{V^2}\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial V}{\partial P}\right)_T + \frac{1}{V}\frac{\partial^2 V}{\partial T \partial P} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ (***)$$

karena:

$$\frac{\partial^2 V}{\partial P \partial T} = \frac{\partial^2 V}{\partial T \partial P}$$

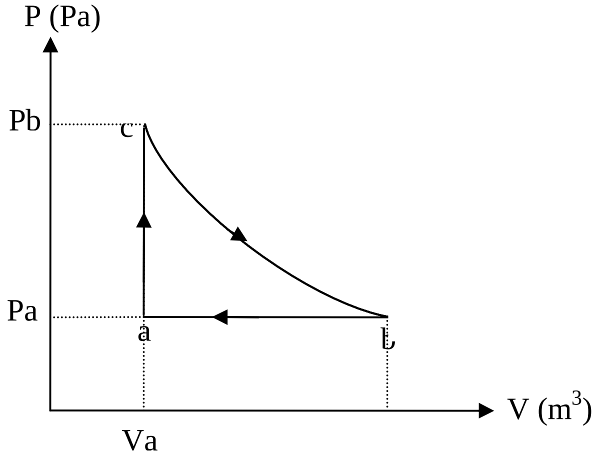
maka, dari (*) dan (***); nampak bahwa:

$$\left(\frac{\partial B}{\partial P}\right)_T = -\frac{1}{V^2}\left(\frac{\partial V}{\partial P}\right)_T\left(\frac{\partial V}{\partial T}\right)_P + \frac{1}{V}\frac{\partial^2 V}{\partial P \partial T}$$
$$-\left(\frac{\partial k}{\partial T}\right)_P = \frac{1}{V^2}\left(\frac{\partial V}{\partial T}\right)_P\left(\frac{\partial V}{\partial P}\right)_T + \frac{1}{V}\frac{\partial^2 V}{\partial P \partial T}$$

Jadi:

$$\left(\frac{\partial B}{\partial P}\right)_T = -\left(\frac{\partial k}{\partial T}\right)_P$$

5.



Ta = 1.10^5 Pa
Pb = 3.10^5 Pa
n = 1 mol
R = 8,31 J/mol.K
Dit: Efisiensi siklus tersebut?

Jawab:

$$efisiensi = \eta = \frac{|W|}{|Q_m|}$$

Wabc = [Luas Va – b – c – Vc] – [Luas Va – a – c – Vc]
Hitung dulu: Va dan Vb

- Di b : $P_b V_a = nRT$ $\Rightarrow$ $V_a = \frac{nRT}{P_b} = \frac{1.8,31.300}{3.10^5} = 8,31.10^{-3} m^3$
- Di c : $P_a V_c = nRT$ $\Rightarrow$ $V_c = \frac{nRT}{P_a} = \frac{1.8,31.300}{10^5} = 24,93.10^{-3} m^3$
- b – c : $W_{bc} = -\int PdV = -\int_{V_a}^{V_c} C\frac{dV}{V} = -nRTlnV\Big|_{V_a}^{V_c}$

$$= -1.8,31.300.[\ln V_c - \ln V_a]$$

$$= -8,31.300.\ln\frac{24,93.10^{-3}}{8,31.10^{-3}}$$

$$= 2738,84 \text{ Joule}$$

$$|W_{ab}| = 2738,84 \text{ Joule}$$

- c – a : W_{ca} = Luas V_a – a – c – V_c = 10^5 (24,93-8,31).10^{-3}
  = 16,62.102 = 1662 Joule

$$|W_{ca}| = 1662 \text{ Joule}$$

maka:

$$|W_{abc}| = |W_{bc}| - |W_{ca}|$$

$$= (2738,84 - 1662) \text{ Joule}$$

Kalor yang masuk = $|Q_m| = Luas V_a.V_b.V_c = 2738,84$ Joule

Jadi:

$$\eta = \frac{1076,84}{273,84} x 100\% = 39,317\%$$