Termodinamika

PAF15-216

Hukum 1 Termodinamika

Dosen Pengampu :
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Silabus

PRA UTS	
1	Pendahuluan, Sistem thermodinamika
2	Persamaan Keadaan
3	Kerja & kalor
4	Kuis 1, Hukum I Thermodinamika
5-6	Konsekuensi Hukum I Thermodinamika
7	Perubahan Fase
	UTS

PASCA UTS	
1	Hukum II Thermodinamika
2	Entropy
3-4	Kombinasi Hukum I dan II Thermodinamika
5-6	Kuis 2, Penerapan thermodinamika
7	Teori Kinetik Gas
	UAS

Termodinamika

Kapasitas Kalor, Hukum 1 Termodinamika

Silabus

- Telaah matematis: turunan parsial
- Kapasitas Kalor [spesifik]
- Koefisien ekspansi dan kompresi
- Ekspansi Bebas

REVIEW: Kerja dan kalor

1 mol gas ideal dikompresi pada tekanan konstant 2,0 atm dari 10,0 liter menjadi 2,0 liter. Pada proses ini kalor keluar dari sistem gas dan temperaturnya menurun.

Panas kemudian ditambahkan pada gas pada volume konstan, sehingga tekanan dan temperaturnya menaik. Temperatur naik hingga temperatur semula.

Pada kondisi isothermal volume diekspansi hingga menjadi 10,0 liter kembali.

a. Gambarkan prosesnya dalam diagram PV!
b. Tentukan kalor masuk dan kalor keluar
c. Hitunglah kerja total dari sistem siklik tersebut!

PERUBAHAN DIFFERENSIAL KEADAAN

$$f(x, y, z) = 0$$

$$x = f(y, z)$$

$$dx = \left(\frac{\partial x}{\partial y}\right)_z \mathrm{dy} + \left(\frac{\partial x}{\partial z}\right)_y dz$$

$$y = f(x, z)$$

$$dy = \left(\frac{\partial y}{\partial x}\right)_z \mathrm{dx} + \left(\frac{\partial y}{\partial z}\right)_x dz$$

$$dx = \left(\frac{\partial x}{\partial y}\right)_z \left[\left(\frac{\partial y}{\partial x}\right)_z \mathrm{dx} + \left(\frac{\partial y}{\partial z}\right)_x dz\right] + \left(\frac{\partial x}{\partial z}\right)_y dz$$

$$dx = \left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial x}\right)_z \mathrm{dx} + \left[\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x + \left(\frac{\partial x}{\partial z}\right)_y\right] dz$$

$$dx = \left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial x}\right)_z \mathrm{dx} + \left[\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x + \left(\frac{\partial x}{\partial z}\right)_y\right] dz$$

$dz = 0; dx \neq 0$

$$\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial x}\right)_z = 1$$

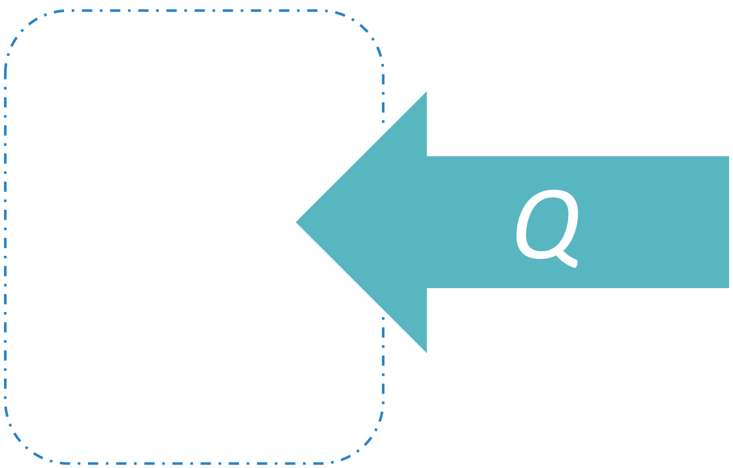
$$\left(\frac{\partial x}{\partial y}\right)_z = \frac{1}{\left(\frac{\partial y}{\partial x}\right)_z}$$

$dx = 0; dz \neq 0$

$$\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x = -\left(\frac{\partial x}{\partial z}\right)_y$$

$$\left(\frac{\partial x}{\partial y}\right)_z \left(\frac{\partial y}{\partial z}\right)_x \left(\frac{\partial z}{\partial x}\right)_y = -1$$

KAPASITAS KALOR



- Jika sistem mengalami perubahan temperatur selama perpindahan kalor, maka *kapasitas kalor:*

$$C = \lim \frac{Q}{T_f - T_i}$$

$$C = \frac{dQ}{dT}$$

$$C_V = \left(\frac{dQ}{dT}\right)_V$$

$$C_P = \left(\frac{dQ}{dT}\right)_P$$

Koefisien Ekspansi & Kompresi

Koefisien ekspansi : β

$$\bar{\beta} = \frac{V_2 - V_1}{V_1(T_2 - T_1)}$$

$\bar{\beta}$ adalah fraksi pertambahan volume terhadap perubahan temperatur

$$\beta = \frac{dV}{VdT}$$

$$\beta = \frac{1}{V}\frac{(dV)_P}{(dT)_P}$$

$$\beta = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_P$$

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$$

$$\left(\frac{\partial v}{\partial T}\right)_P = \beta v$$

Koefisien ekspansi gas ideal

$$Pv = RT$$

$$v = \frac{RT}{P}$$

$$\left(\frac{\partial v}{\partial T}\right)_P = \frac{R}{P}$$

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$$

$$\beta = \frac{1}{v}\frac{R}{P}$$

$$\beta = \frac{1}{T}$$

Koefisien Ekspansi Gas Van der Waals

$$\left(P+\frac{a}{v^2}\right)(v-b)=RT$$

$$\beta=\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$$

$$\left(\frac{\partial v}{\partial T}\right)_P=\ldots$$

$$\left(\frac{\partial v}{\partial T}\right)_P\left(\frac{\partial T}{\partial P}\right)_v\left(\frac{\partial P}{\partial v}\right)_T=-1$$

$$\left(\frac{\partial v}{\partial T}\right)_P=\frac{\left(\frac{\partial P}{\partial T}\right)_v}{\left(\frac{\partial P}{\partial v}\right)_T}$$

Koefisien Ekspansi Gas Van Der Waals

$$\left(P+\frac{a}{v^2}\right)(v-b)=RT$$

Koefisien Ekspansi Gas Van Der Waals

$$\left(P+\frac{a}{v^2}\right)(v-b)=RT$$

$$P=\frac{RT}{(v-b)}-\frac{a}{v^2}$$

$$\left(\frac{\partial P}{\partial T}\right)_v=\frac{R}{v-b}$$

$$\left(\frac{\partial P}{\partial v}\right)_T=-\frac{RT}{(v-b)^2}+\frac{2a}{v^3}$$

$$\beta=\frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P$$

$$\beta=\frac{Rv^2(v-b)}{RTv^3-2a(v-b)^2}$$

Koefisien Kompresi : κ

$$\bar{\kappa} = -\frac{V_2 - V_1}{V_1\left(P_2 - P_1\right)}$$

$$\kappa = -\frac{dV}{VdP}$$

$$\kappa = -\frac{1}{V}\frac{dV}{dP}$$

Isothermal

$$\kappa = -\frac{1}{V}\left(\frac{dV}{dP}\right)_T$$

$$\kappa = -\frac{1}{v}\left(\frac{dv}{dP}\right)_T$$

$$\left(\frac{dv}{dP}\right)_T = -\kappa v$$

κ untuk gas ideal dan Van der Waals

$$\kappa = -\frac{1}{v}\left(-\frac{RT}{P^2}\right) = \frac{1}{P}$$

$$\kappa = \frac{v^2(v-b)^2}{RTv^3 - 2a(v-b)^2}$$

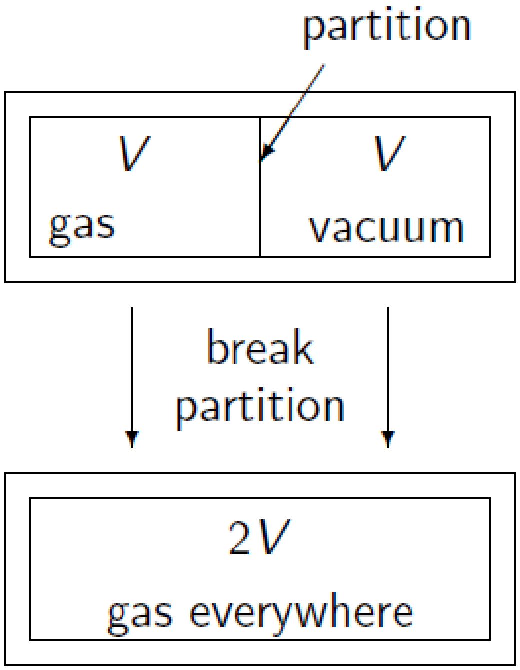
Hubungan β dan κ

$$\beta = \frac{1}{v}\left(\frac{\partial v}{\partial T}\right)_P \qquad \kappa = -\frac{1}{v}\left(\frac{\partial v}{\partial P}\right)_T$$

$$\left(\frac{\partial P}{\partial T}\right)_v = -\frac{\left(\partial v/\partial T\right)_P}{\left(\partial v/\partial P\right)_T}$$

$$\left(\frac{\partial P}{\partial T}\right)_v = -\frac{\beta v}{-\kappa v} = \frac{\beta}{\kappa}$$

Ekspansi bebas



Tidak ada kerja, tidak ada kalor

$$U_i = U_f$$

Gas ideal:

$$U=U(T)$$

$$T_i = T_f$$

Real gas:

$$U=U(T,V)$$

$$T=T(U,V)$$

Koefisien joule; ekspansi bebas

$$
\begin{aligned}
dT &= \left(\frac{\partial T}{\partial V}\right)_U dV + \left(\frac{\partial T}{\partial U}\right)_V dU \\
&= \left(\frac{\partial T}{\partial V}\right)_U dV \\
&= \mu_J dV
\end{aligned}
$$

Ekspansi bebas real gas ;
volume berubah dari V_1 menjadi V_2

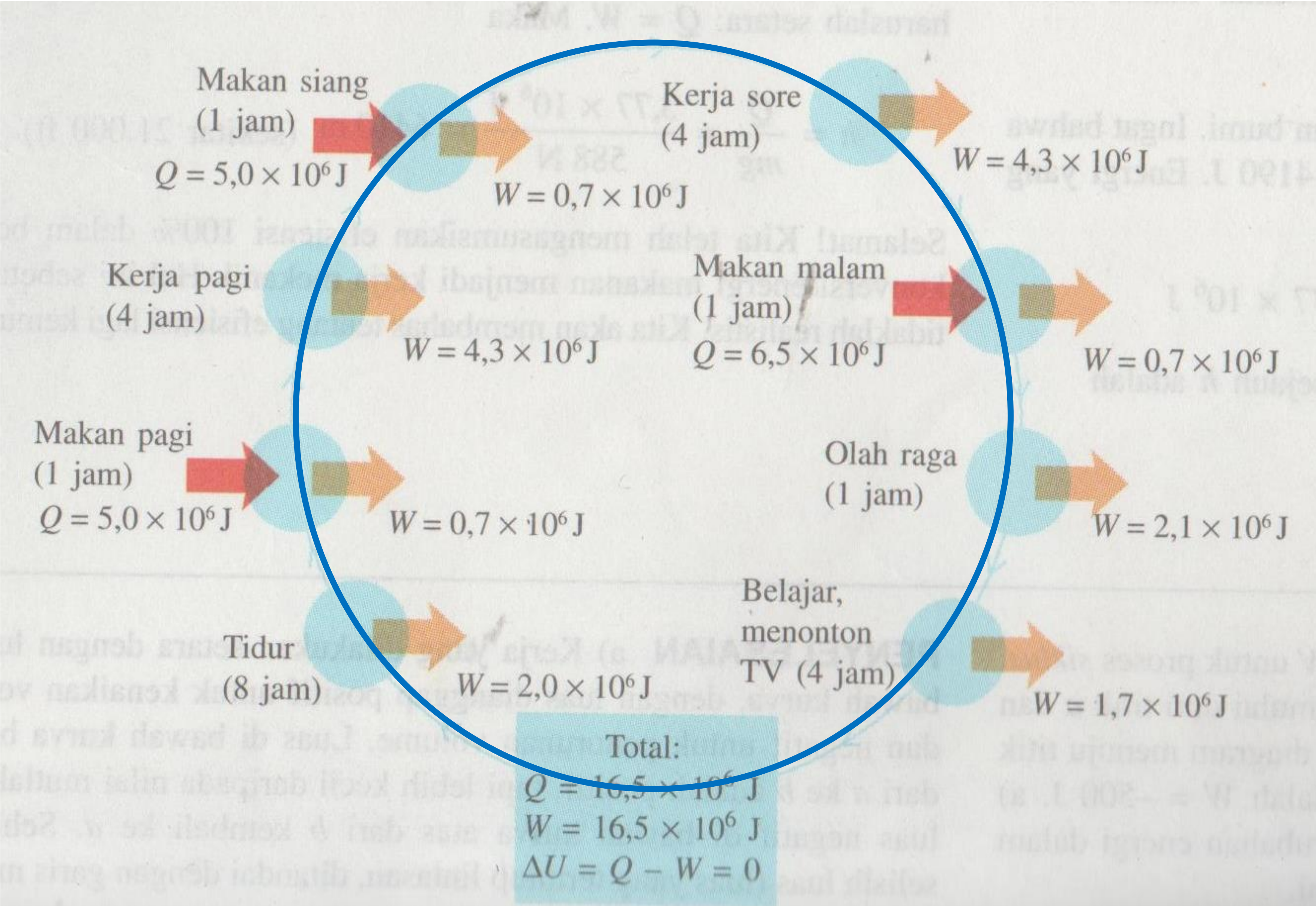
$$dT = \mu_J dV$$

$$\int dT = \int \mu_J dV$$

$$\Delta T = \int_{V_1}^{V_2} \mu_J dV$$

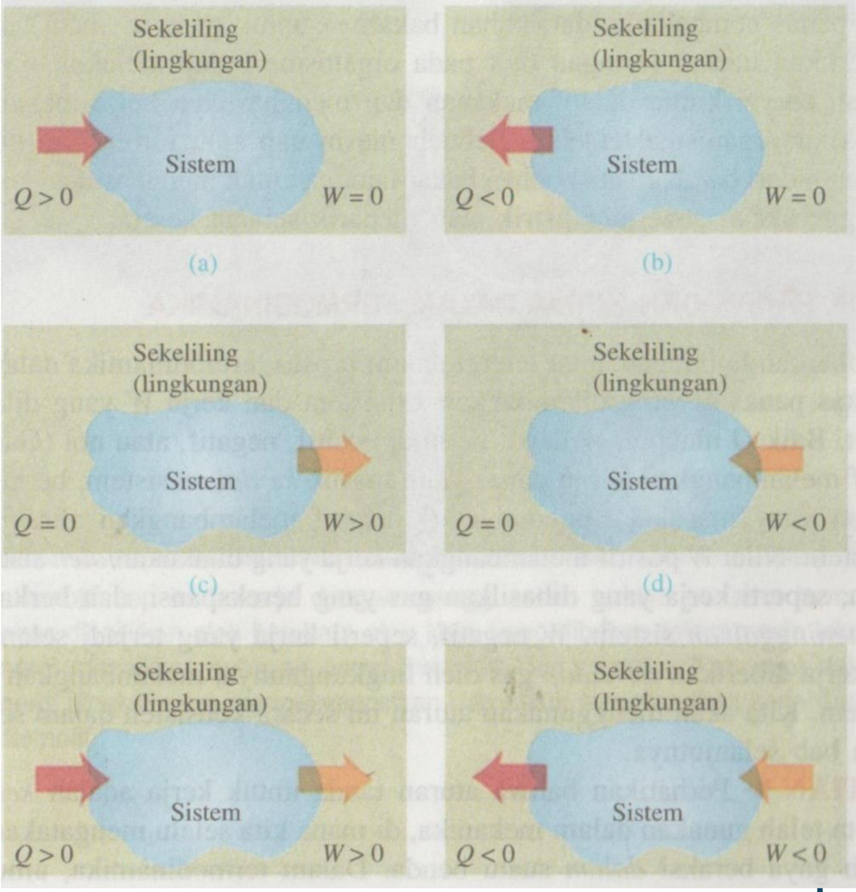
Hukum 1 Thermodinamika

$$\Delta U = Q - W$$

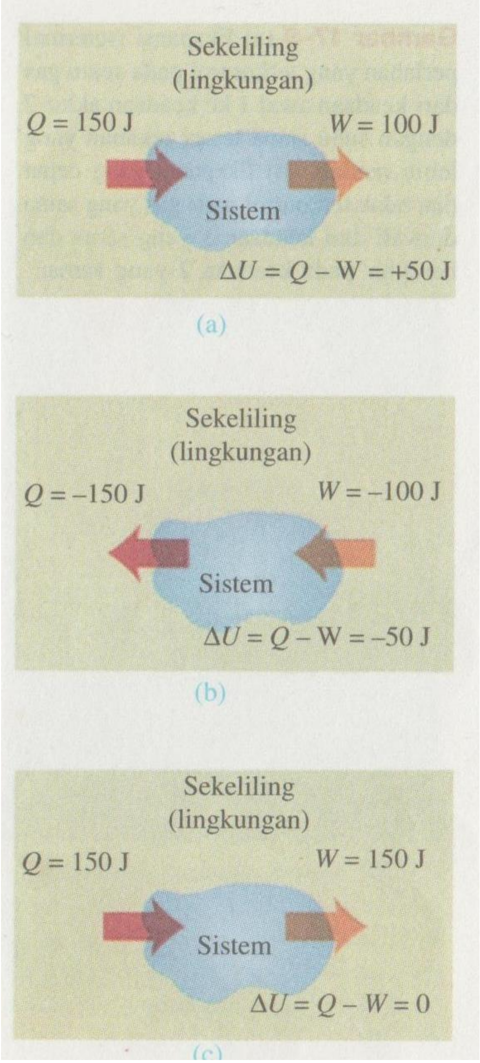

Makan siang
(1 jam)
Q = 5,0 × 10⁶ J
W = 0,7 × 10⁶ J
Kerja sore
(4 jam)
W = 4,3 × 10⁶ J
Kerja pagi
(4 jam)
W = 4,3 × 10⁶ J
Makan malam
(1 jam)
Q = 6,5 × 10⁶ J
W = 0,7 × 10⁶ J
Makan pagi
(1 jam)
Q = 5,0 × 10⁶ J
W = 0,7 × 10⁶ J
Olah raga
(1 jam)
W = 2,1 × 10⁶ J
Tidur
(8 jam)
W = 2,0 × 10⁶ J
Belajar,
menonton
TV (4 jam)
W = 1,7 × 10⁶ J
Total:
Q = 16,5 × 10⁶ J
W = 16,5 × 10⁶ J
ΔU = Q − W = 0

Pertukaran energi: panas & kerja

- Panas [Q] yang ditambahkan ke sistem dan kerja [W] yang dilakukan oleh sistem.
- Q
  - + : aliran panas masuk ke sistem
  - - : aliran panas keluar sistem
- W
  - + : kerja yang dilakukan oleh sistem terhadap lingkungan
  - - : kerja yang diberikan oleh lingkungan



Energi dalam dan Hukum I termodinamika



$$U_2 - U_1 = \Delta U = Q - W$$

$$dU = dQ - dW$$

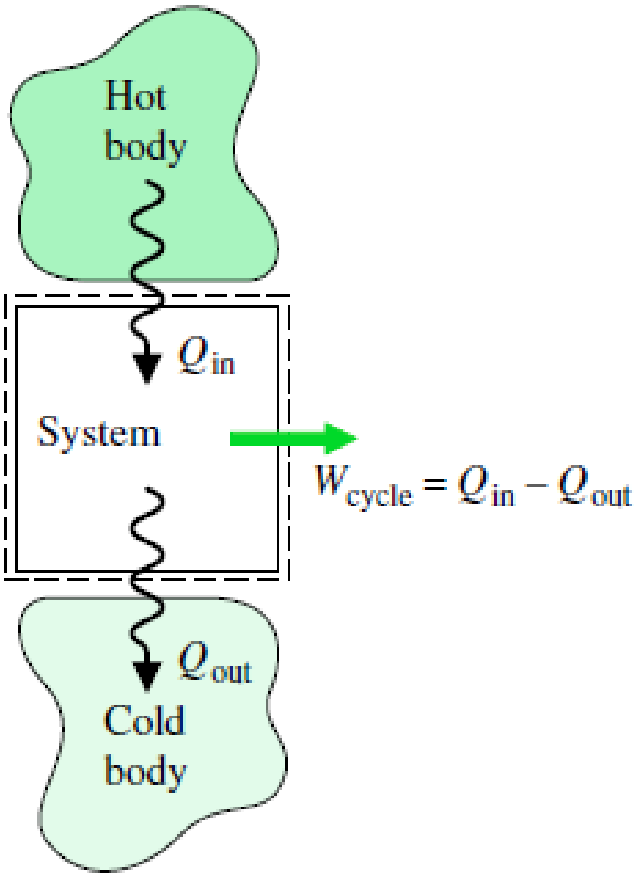
PROSES TERMODINAMIKA

Proses	*Apa yang konstant?*	*Prediksi Hukum I :* $\Delta U = Q - W$	
Isothermal			
Isobarik			
Isokhorik			
Adiabatis			

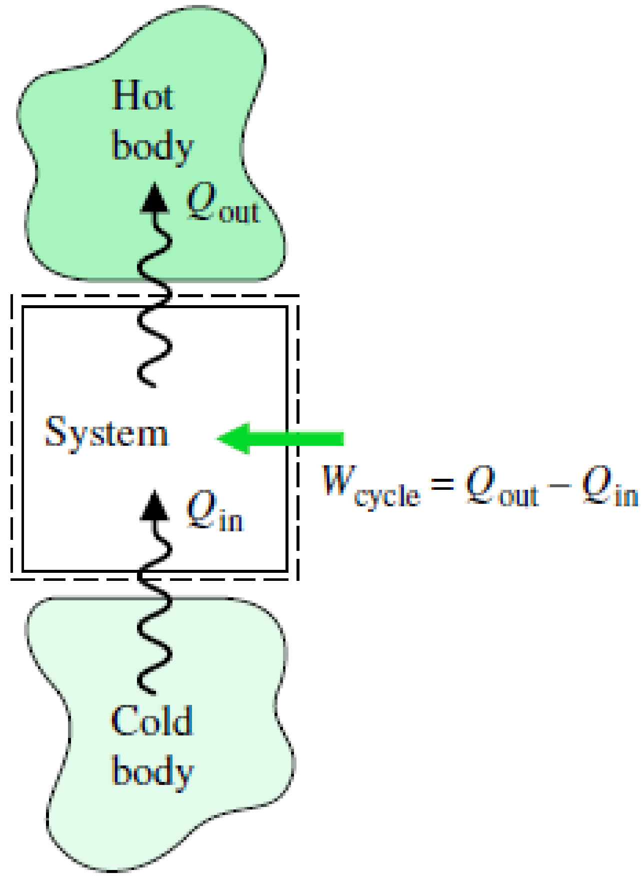
Mesin Kalor & Pendingin

Mesin kalor & Refrigerator

Power cycles.



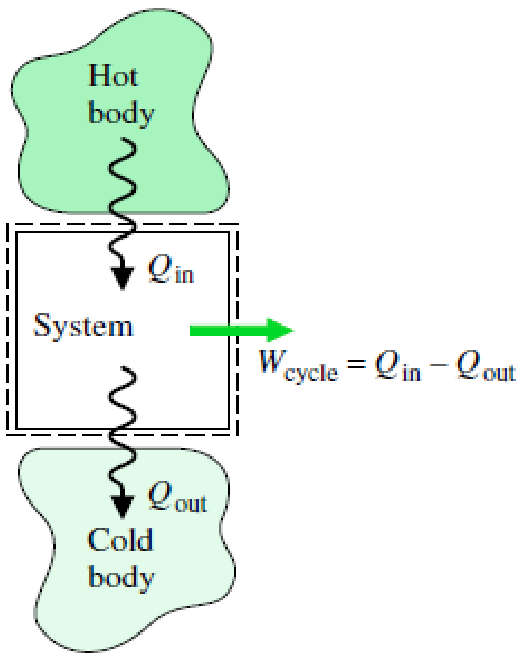
Refrigeration and heat pump cycles.



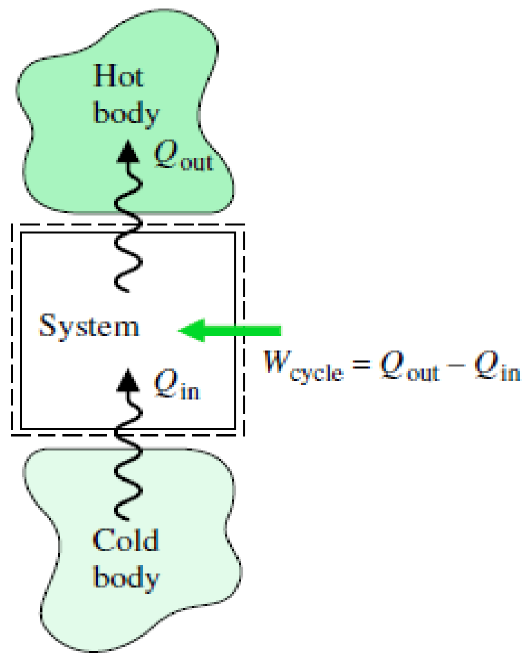
$$\Delta E_{\text{cycle}} = Q_{\text{cycle}} - W_{\text{cycle}}$$

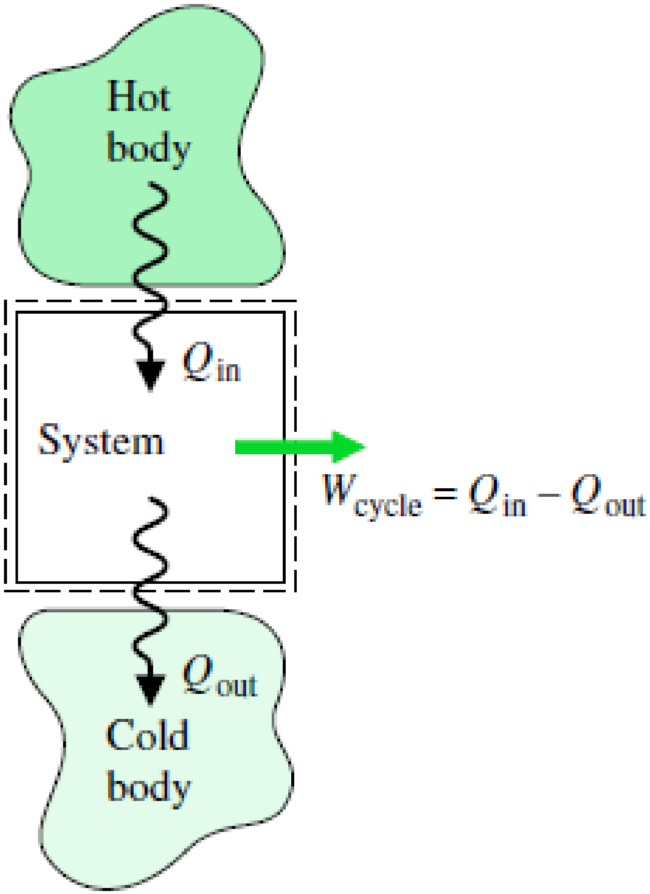
Ketika sistem kembali ke keadaan semula: $Q_{cycle} = W_{cycle}$

Power cycles.



Refrigeration and heat pump cycles.

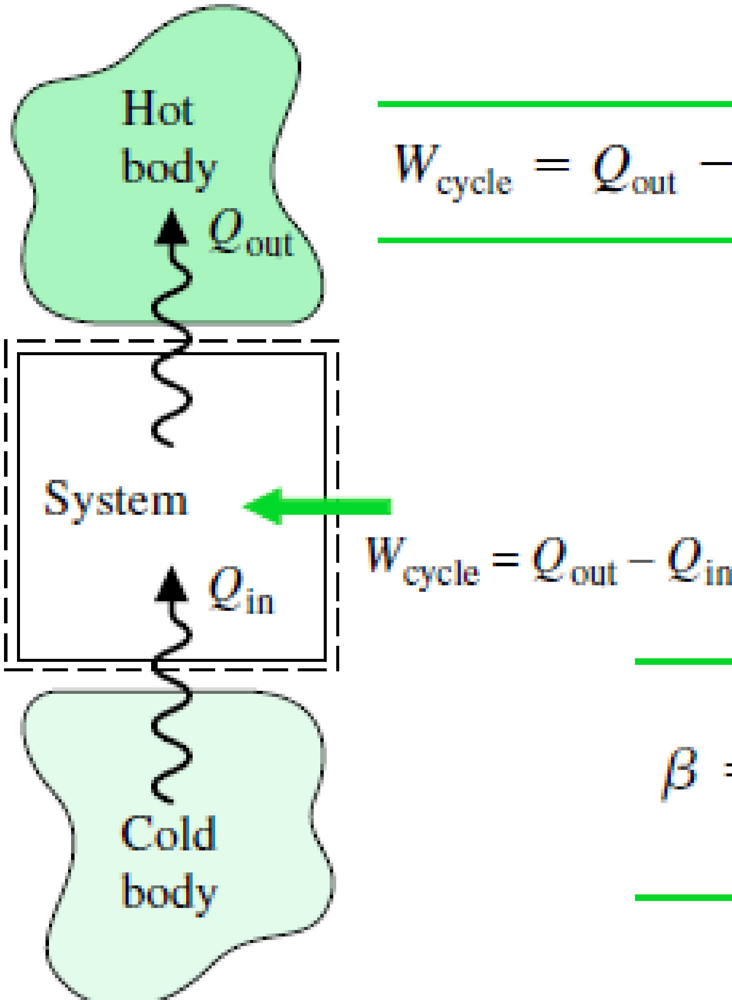




$$W_{cycle} = Q_{in} - Q_{out} \qquad \text{(power cycle)}$$

$$\eta = \frac{W_{cycle}}{Q_{in}} \qquad \text{(power cycle)}$$

$$\eta = \frac{Q_{in} - Q_{out}}{Q_{in}} = 1 - \frac{Q_{out}}{Q_{in}}$$



$$W_{cycle} = Q_{out} - Q_{in} \qquad \text{(refrigeration and heat pump cycles)}$$

$$\beta = \frac{Q_{in}}{W_{cycle}} \qquad \text{(refrigeration cycle)}$$

$$\beta = \frac{Q_{in}}{Q_{out} - Q_{in}}$$

Applying

2.47 The following table gives data, in kJ, for a system undergoing a thermodynamic cycle consisting of four processes in series. For the cycle, kinetic and potential energy effects can be neglected. Determine

(a) the missing table entries, each in kJ.
(b) whether the cycle is a power cycle or a refrigeration cycle.

Process	ΔU	Q	W
1–2	600		−600
2–3			−1300
3–4	−700	0	
4–1		500	700

2.48 A gas undergoes a thermodynamic cycle consisting of three processes:

Process 1–2: compression with $pV = constant$, from $p_1 = 1$ bar, $V_1 = 1.6\ \text{m}^3$ to $V_2 = 0.2\ \text{m}^3$, $U_2 - U_1 = 0$

Process 2–3: constant pressure to $V_3 = V_1$

Process 3–1: constant volume, $U_1 - U_3 = -3549$ kJ

There are no significant changes in kinetic or potential energy. Determine the heat transfer and work for Process 2–3, in kJ. Is this a power cycle or a refrigeration cycle?

2.49 A gas undergoes a thermodynamic cycle consisting of three processes:

Process 1–2: constant volume, $V = 0.028\ \text{m}^3$, $U_2 - U_1 = 26.4\ \text{kJ}$

Process 2–3: expansion with $pV = constant$, $U_3 = U_2$

Process 3–1: constant pressure, $p = 1.4$ bar, $W_{31} = -10.5$ kJ

There are no significant changes in kinetic or potential energy.

(a) Sketch the cycle on a p–V diagram.
(b) Calculate the net work for the cycle, in kJ.
(c) Calculate the heat transfer for process 2–3, in kJ.
(d) Calculate the heat transfer for process 3–1, in kJ.

Is this a power cycle or a refrigeration cycle?