Thermodinamika

PAF15-216

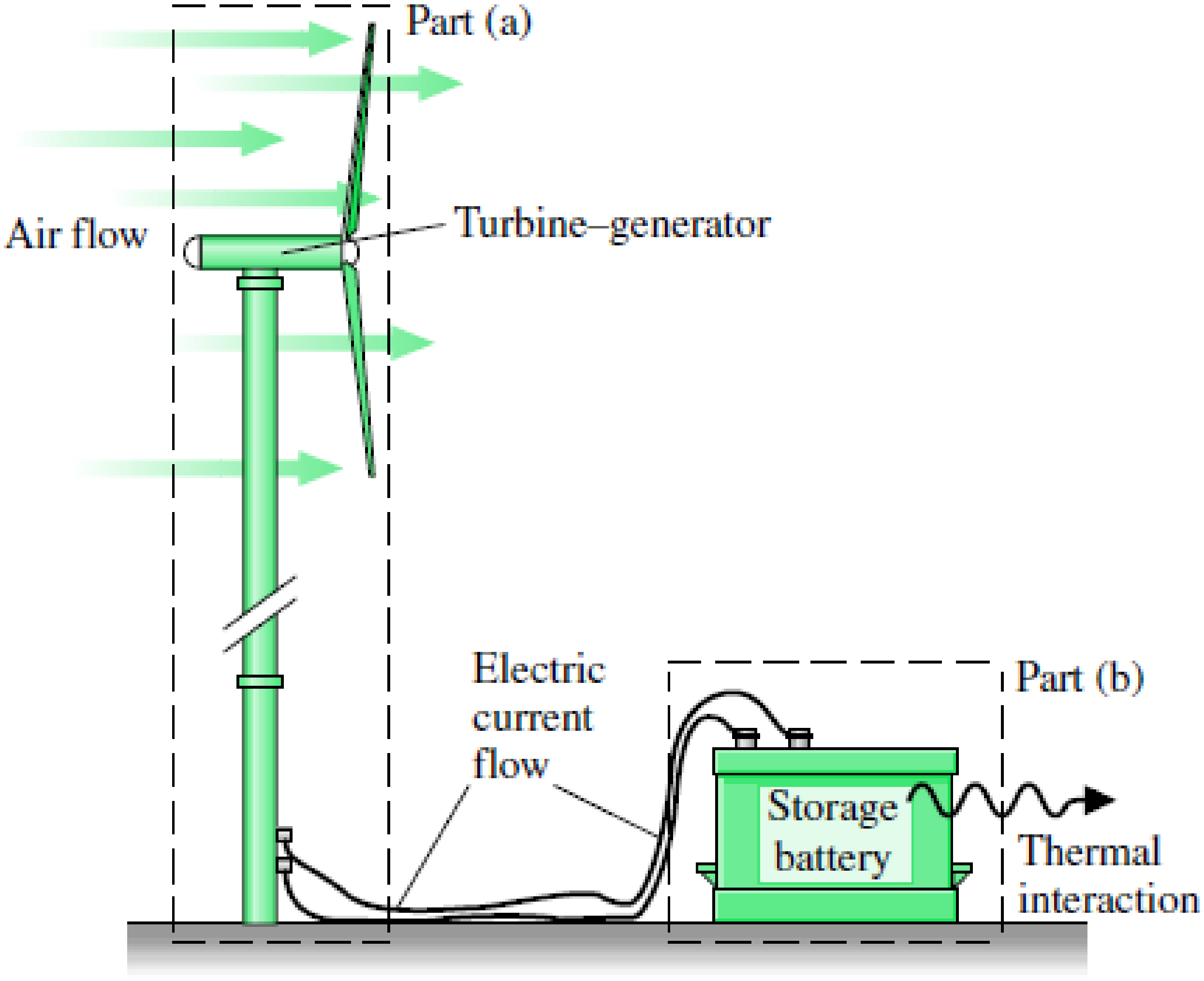
Kerja & Kalor

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

Review: Tentukan sistem, dinding dan lingkungannya!



Perbedaan A dan B

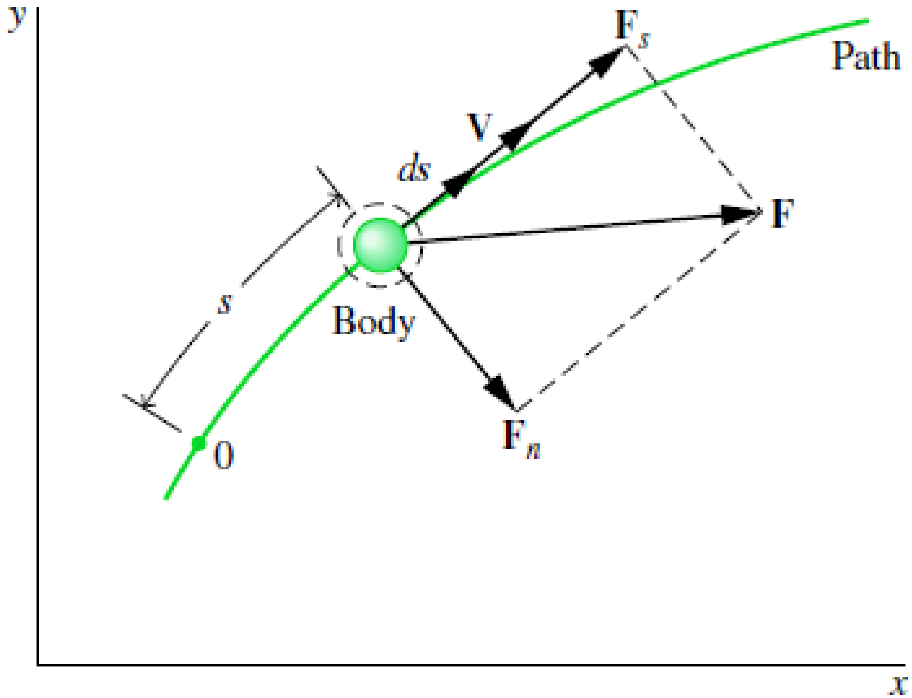
SISTEM A

SISTEM B

Silabus

- Kerja
- Kerja yang bergantung lintasan
- Kalor
- Telaah matematis: turunan parsial
- Koefisien ekspansi dan kompresi

KONSEP: ENERGI



Review: Energi Mekanik

$$F_s = m\frac{dV}{dt}$$

$$F_s = m\frac{dV}{ds}\frac{ds}{dt}$$

$$F_s = mV\frac{dV}{ds}$$

$$F_s\,ds = mVdV$$

$$\int_{s_1}^{s_2} F_s\,ds = \int_{V_1}^{V_2} mVdV$$

$$\int_{s_1}^{s_2} F_s\,ds = \frac{1}{2}m\left(V_2^{\,2} - V_1^{\,2}\right) = \Delta E_K$$

$$\int_{s_1}^{s_2} F_s \, ds = \frac{1}{2} m \left(V_2^2 - V_1^2 \right) = \Delta E_K$$

Kerja dapat mentransfer energi

$$W = \int_{s_1}^{s_2} F_s \, ds$$

$$W = \Delta E_K$$

Teorema kerja - energi

$$P = \dot{W} = \int_{t_1}^{t_2} \dot{W} \, dt = \int_{t_1}^{t_2} F.V \, dt$$

Power / Daya

- Energi yang ditransfer oleh kerja W
- Satuan daya = J/s

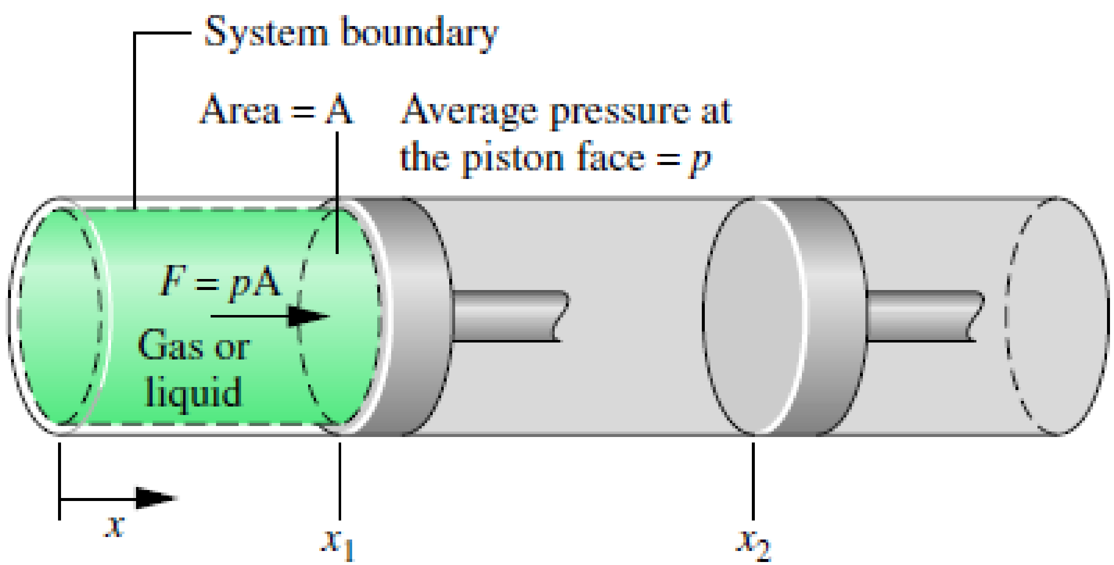
Kerja pada Gas atau Liquid:
Kerja Ekspansi dan Kompresi

$$W = \int_{s_1}^{s_2} F_s \, ds$$

$$W = \int_{x_1}^{x_2} F \, dx$$

$$W = \int_{x_1}^{x_2} pA \, dx$$

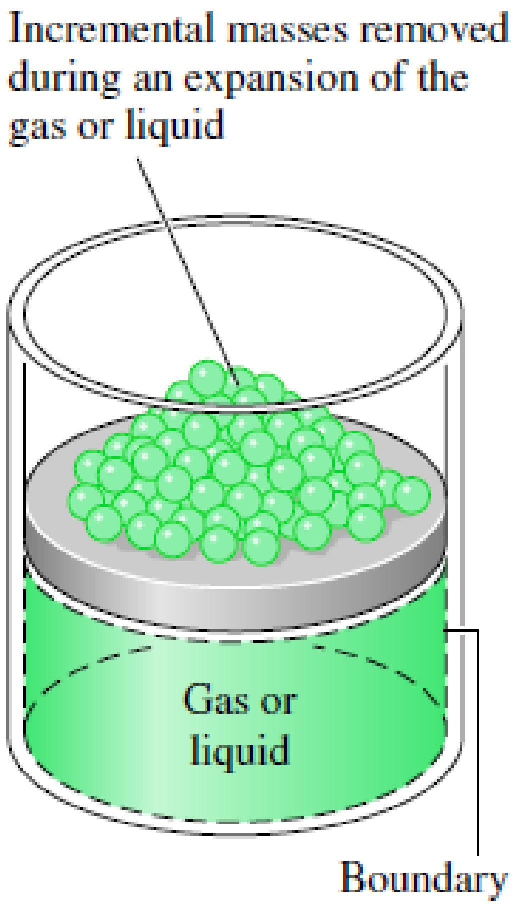
$$\boxed{W = \int_{V_1}^{V_2} p \, dV}$$

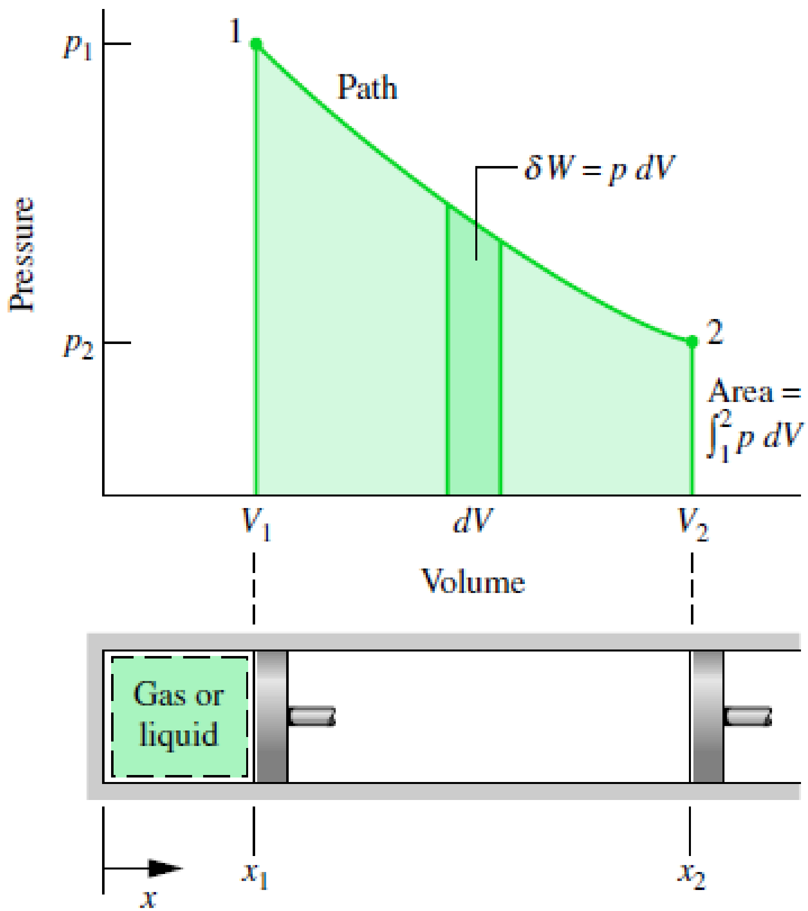


$$\delta W = p \, dV$$

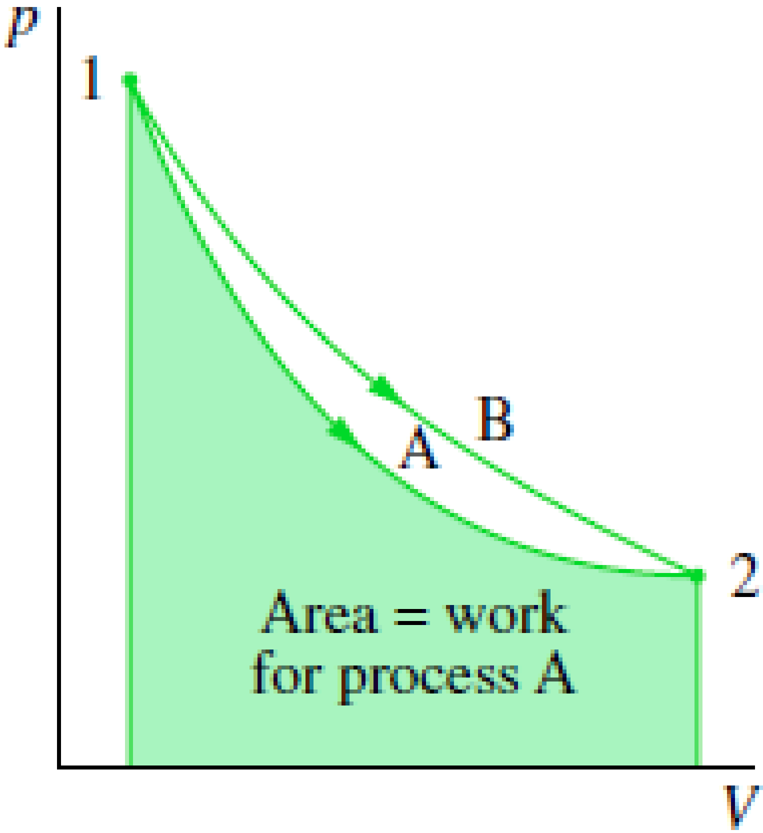
$$W = p\left(V_2 - V_1\right)$$

Kerja pada proses *quasistatik*



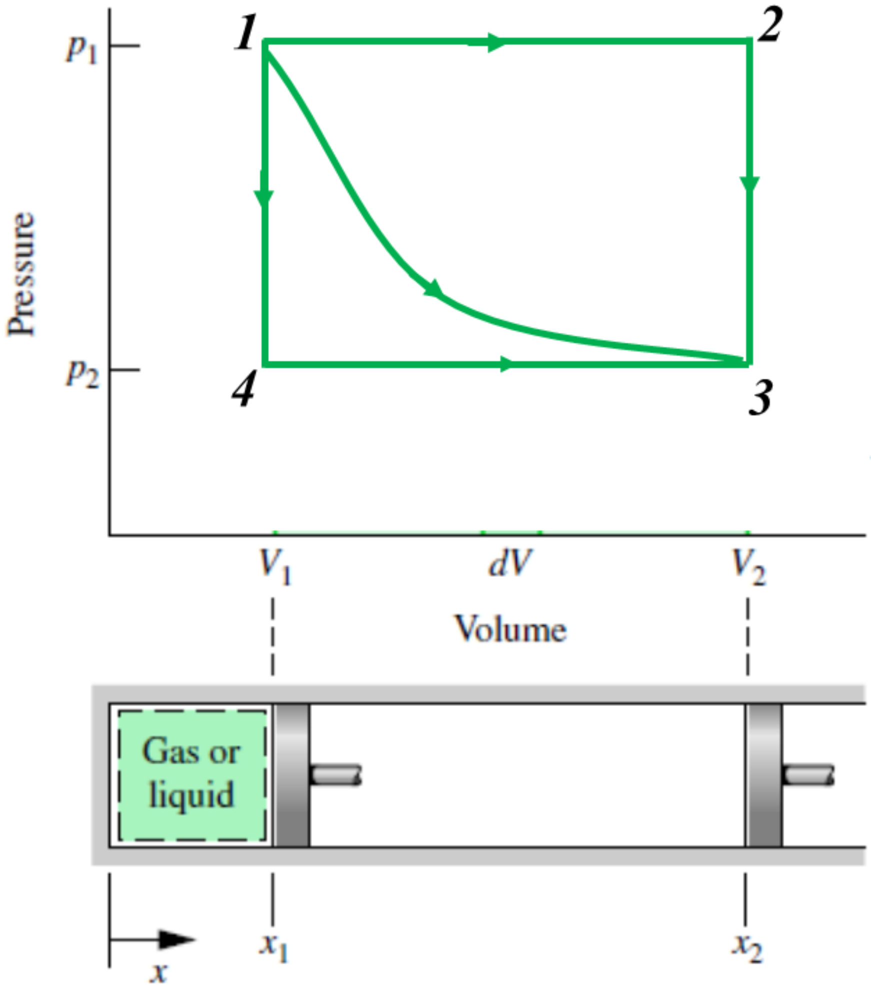


Kerja bergantung lintasan proses



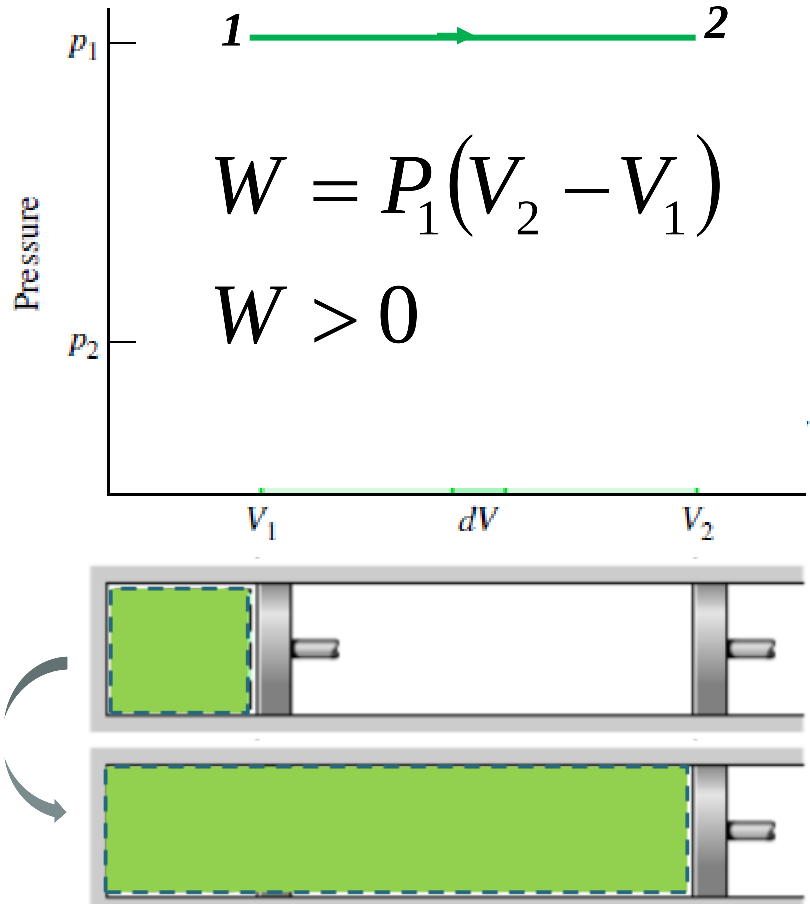
Sebuah proses thermodinamika terjadi sbb:

- Dimulai dari keadaan kesetimbangan 1 menjadi keadaan akhir 2
- A dan B adalah kurva proses; berbeda
- Besarnya kerja bergantung pada proses yang terjadi, ***bukan*** pada keadaan awal dan akhir

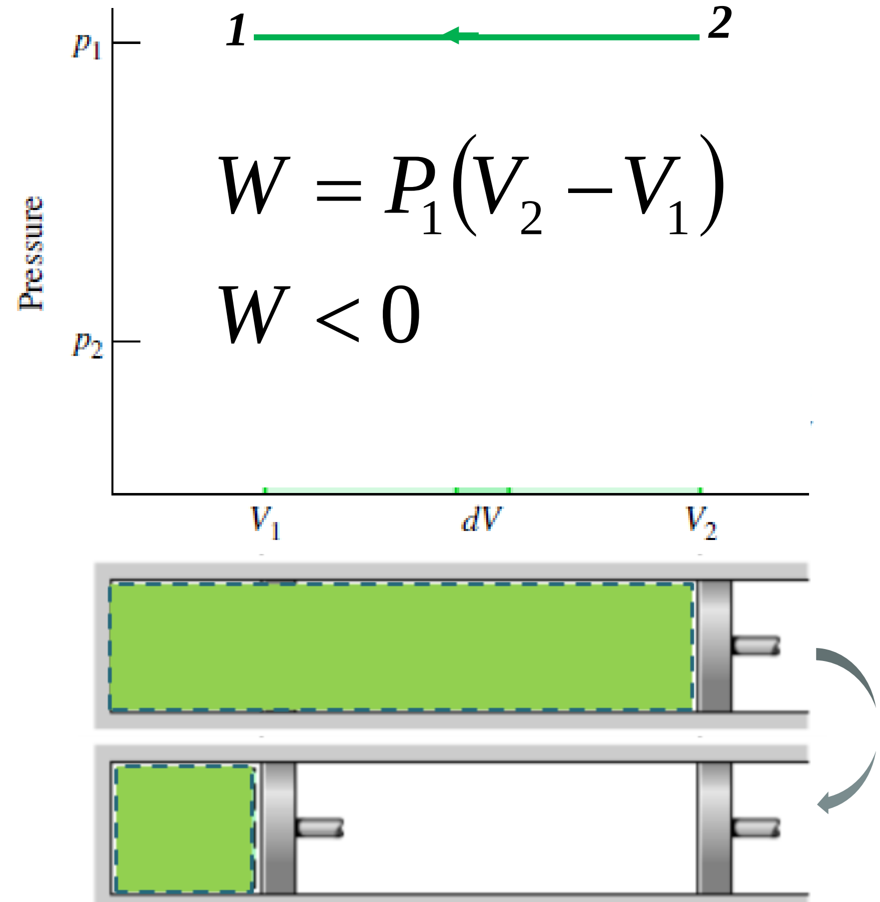


- Tentukan alternatif proses untuk mengubah sistem dari keadaan 1 menjadi 3!
- Tentukan kerja masing-masing proses!

Kerja Ekspansi & Kompresi

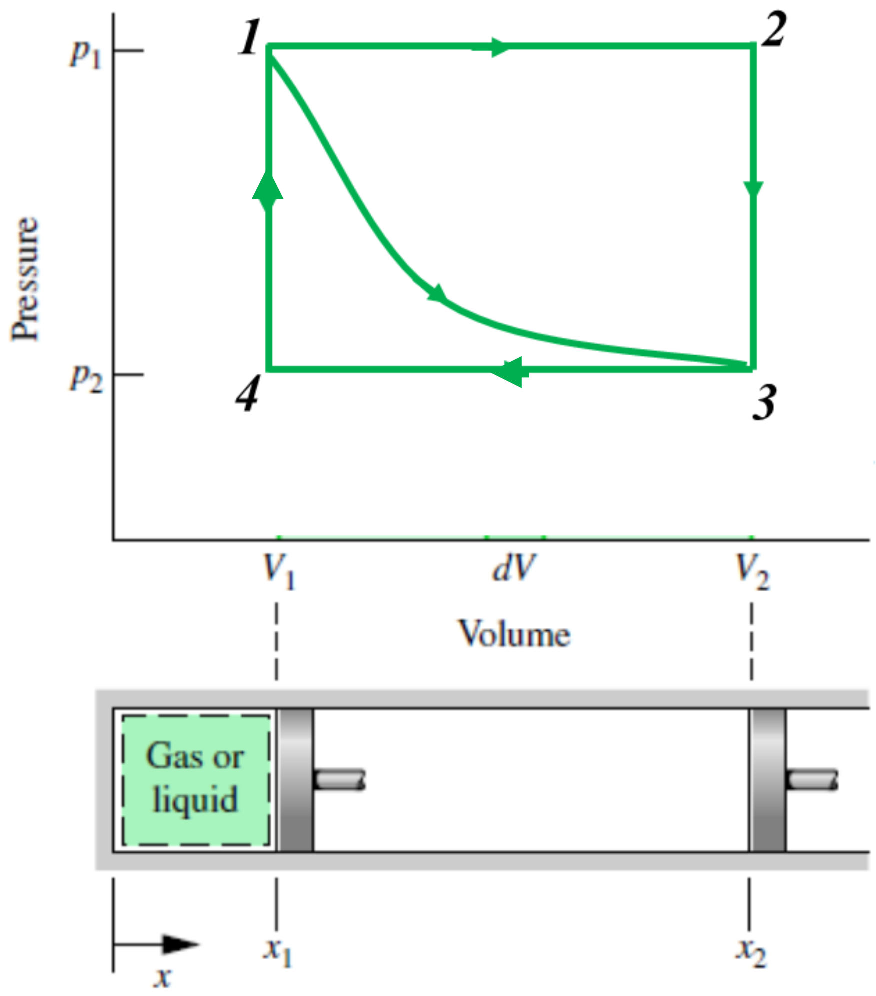


$$W = P_1\left(V_2 - V_1\right)$$
$$W > 0$$



$$W = P_1\left(V_2 - V_1\right)$$
$$W < 0$$

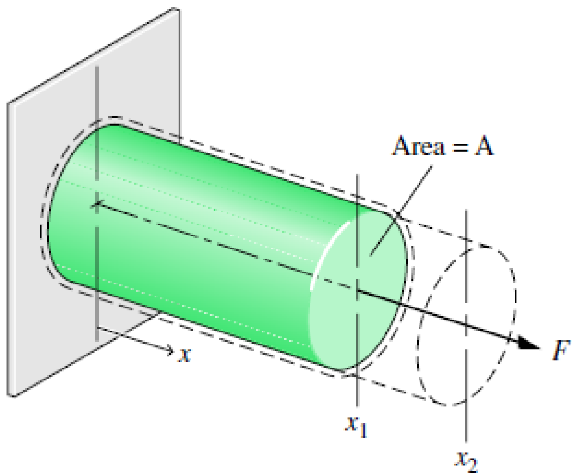
Tentukan mana proses kerja ekspansi dan kompresi



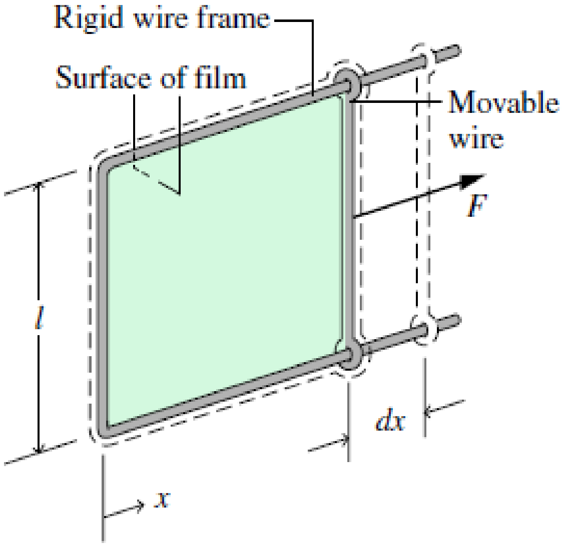
Kerja pada proses-proses thermodinamika

No	Proses	Kerja
1	Isobarik	$W = \int_{V_2}^{V_1} PdV = P(V_2 - V_1)$
2	Isothermal	
3	Isokhorik	
4	Adiabatik	

Kerja sistem lainnya

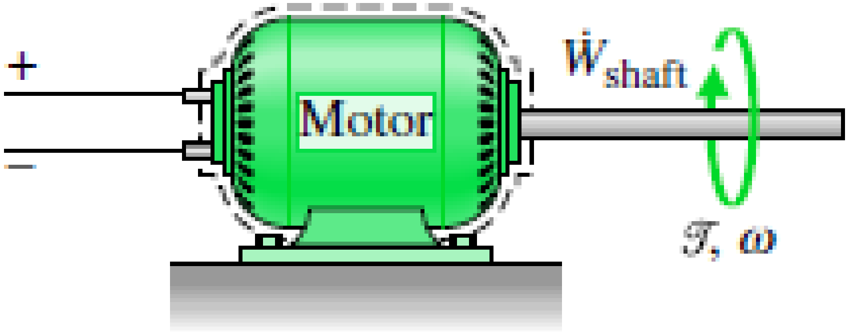


$$W = -\int_{x_1}^{x_2} \sigma A \, dx$$



$$W = -\int_{A_1}^{A_2} \tau \, dA$$

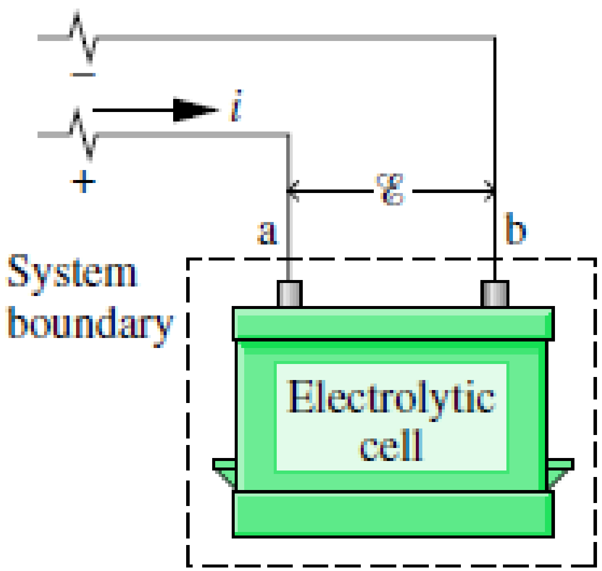
$$F = 2l\bar{\tau}$$



$$\mathcal{T} = F_t R$$

$$V = R\omega$$

$$\dot{W} = F_t V = (\mathcal{T}/R)(R\omega) = \mathcal{T}\omega$$



$$\dot{W} = -\mathcal{E}i$$

$$\delta W = -\mathcal{E}\, dZ$$

Kerja yang dipindahkan dari medan elektrik seragam yang diberi material dielektrik:

$$\delta W = -\mathbf{E} \cdot d(V\mathbf{P})$$

P: momen dipole per-satuan volume

Kerja yang dipindahkan dari medan magnet ketika polarisasi bertambah:

$$\delta W = -\mu_0 \mathbf{H} \cdot d(V\mathbf{M})$$

H: kuat medan magnet sistem
M: momen dipole magnetic per-satuan volume

intensif

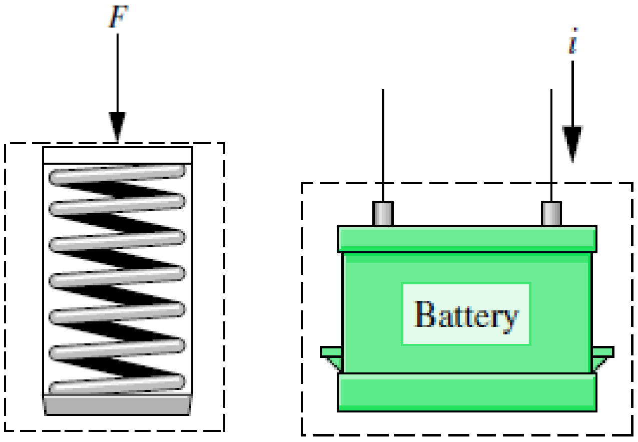
$$\delta W = p\,dV - \sigma d(\mathrm{A}x) - \tau\,d\mathrm{A} - \mathcal{E}\,dZ - \mathbf{E}\cdot d(V\mathbf{P}) - \mu_0\mathbf{H}\cdot d(V\mathbf{M}) + \cdots$$

Differensial ekstensif

ENERGI

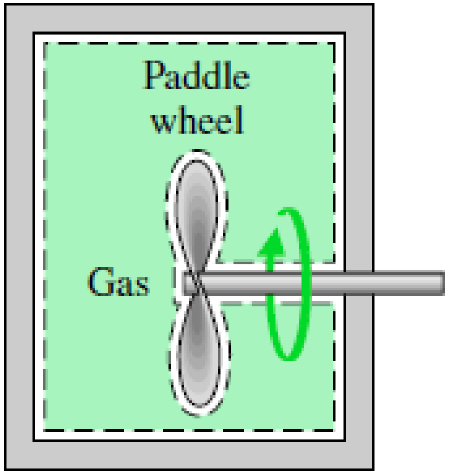
Kalor

Kerja - Energi



- Ketika kerja dilakukan untuk mengkompres pegas, maka energy akan tersimpan

- Ketika batrei diberi muatan, maka energy yang tersimpan akan bertambah



- Gas (liquid) dalam sistem tertutup dalam keadaan setimbang. Ketika wadah terisolasi di aduk, sistem akan mencapai kesetimbangan akhir. Energi gas akan bertambah.

Perubahan Energi total sistem:

- Energi kinetik : gerakan sistem
- Energi potensial: posisi sistem, medan gravitasi
- Energi internal

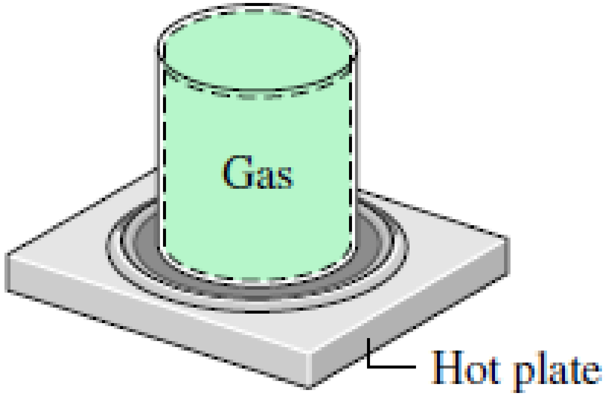
$$E_2 - E_1 = (\mathrm{KE}_2 - \mathrm{KE}_1) + (\mathrm{PE}_2 - \mathrm{PE}_1) + (U_2 - U_1)$$

$$\Delta E = \Delta\mathrm{KE} + \Delta\mathrm{PE} + \Delta U$$

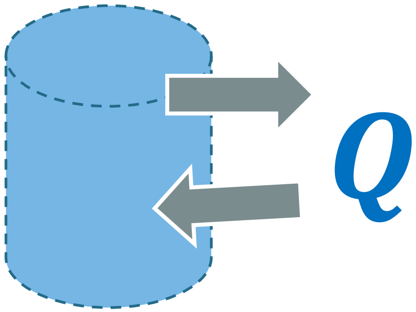
Interpretasi mikroskopik:
ENERGI INTERNAL

- Energi berhubungan dengan gerakan-gerakan dan konfigurasi-konfigurasi dari molekul-molekul individu, atom, dan partikel subatom yang membentuk materi di dalam sistem
- Setiap partikel gas bergerak, saling bertumbukan dengan partikel lain – dengan dinding di dalam sistem
- Energi tersimpan pada ikatan-ikatan kimia diantara atom-atom pembentuk molekul, keadaan orbital elektron, spin inti, dan gaya ikat dalam inti.

Energi yang ditransfer oleh kalor



- Gas dalam sistem tertutup dapat berinteraksi dengan kalor
- Energi gas akan bertambah meskipun tidak ada kerja



- Q>0 : kalor ditransfer **ke** lingkungan
- Q<0 : kalor ditransfer **oleh** lingkungan

Laju transfer kalor & flux kalor

$$Q = \int_1^2 \delta Q$$

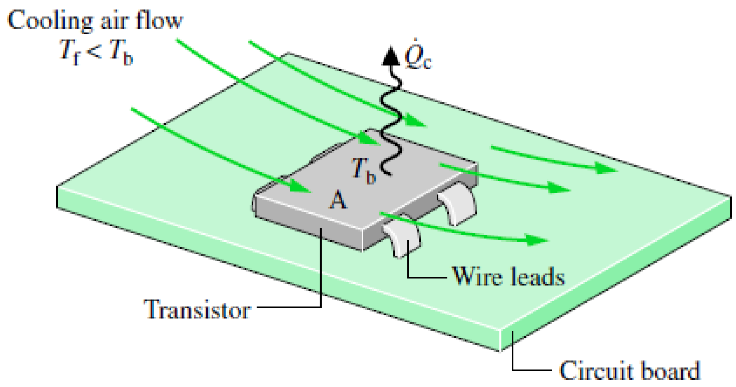
Konduksi: $$\dot{Q}_x = -\kappa A \frac{dT}{dx}$$ *Fourier's law*

$$Q = \int_{t_1}^{t_2} \dot{Q}\, dt$$

Radiasi: $$\dot{Q}_e = \varepsilon \sigma A T_b^4$$ *Stefan-Boltzmann law*

$$\dot{Q} = \int_A \dot{q}\, dA$$

Konveksi: $$\dot{Q}_c = hA(T_b - T_f)$$



Applications	h (W/m^2 · K)
Free convection	
Gases	2–25
Liquids	50–1000
Forced convection	
Gases	25–250
Liquids	50–20,000

Kesetimbangan dalam sistem tertutup

$$\left[\begin{array}{c}\textit{change} \text{ in the amount} \\ \text{of energy contained} \\ \text{within the system} \\ \text{during some time} \\ \text{interval}\end{array}\right] = \left[\begin{array}{c}\textit{net} \text{ amount of energy} \\ \text{transferred } \textit{in} \text{ across} \\ \text{the system boundary by} \\ \textit{heat} \text{ transfer during} \\ \text{the time interval}\end{array}\right] - \left[\begin{array}{c}\textit{net} \text{ amount of energy} \\ \text{transferred } \textit{out} \text{ across} \\ \text{the system boundary} \\ \text{by } \textit{work} \text{ during the} \\ \text{time interval}\end{array}\right]$$

$$E_2 - E_1 = Q - W$$

$$\Delta \mathrm{KE} + \Delta \mathrm{PE} + \Delta U = Q - W$$

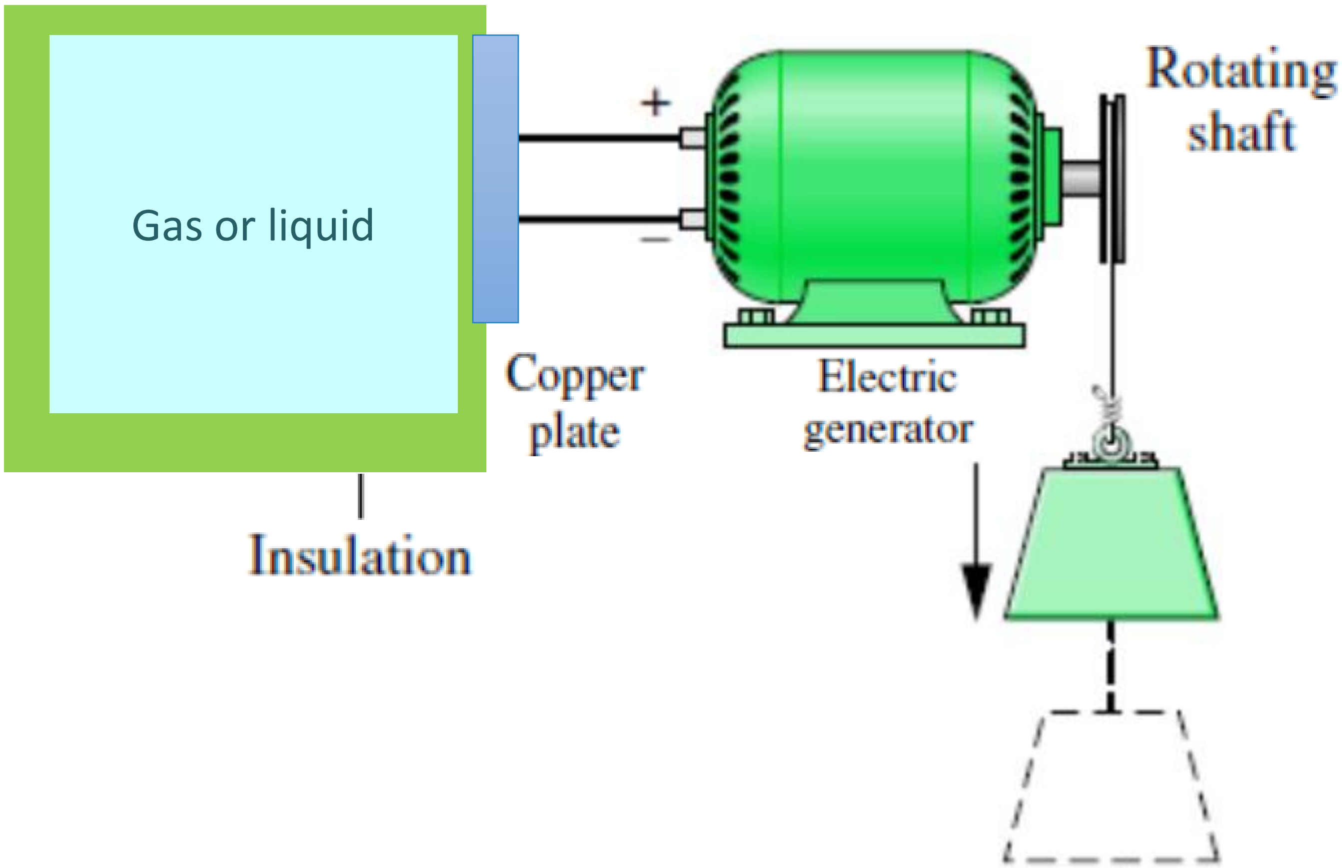
Laju Perubahan Energi

$$\begin{bmatrix}\text{time } \textit{rate of change} \\ \text{of the energy} \\ \text{contained within} \\ \text{the system } \textit{at} \\ \textit{time } t\end{bmatrix} = \begin{bmatrix}\text{net } \textit{rate} \text{ at which} \\ \text{energy is being} \\ \text{transferred in} \\ \text{by heat transfer} \\ \textit{at time } t\end{bmatrix} - \begin{bmatrix}\text{net } \textit{rate} \text{ at which} \\ \text{energy is being} \\ \text{transferred out} \\ \text{by work } \textit{at} \\ \textit{time } t\end{bmatrix}$$

$$\frac{dE}{dt} = \dot{Q} - \dot{W}$$

$$\frac{d\mathrm{KE}}{dt} + \frac{d\mathrm{PE}}{dt} + \frac{dU}{dt} = \dot{Q} - \dot{W}$$

Pemilihan batas / dinding

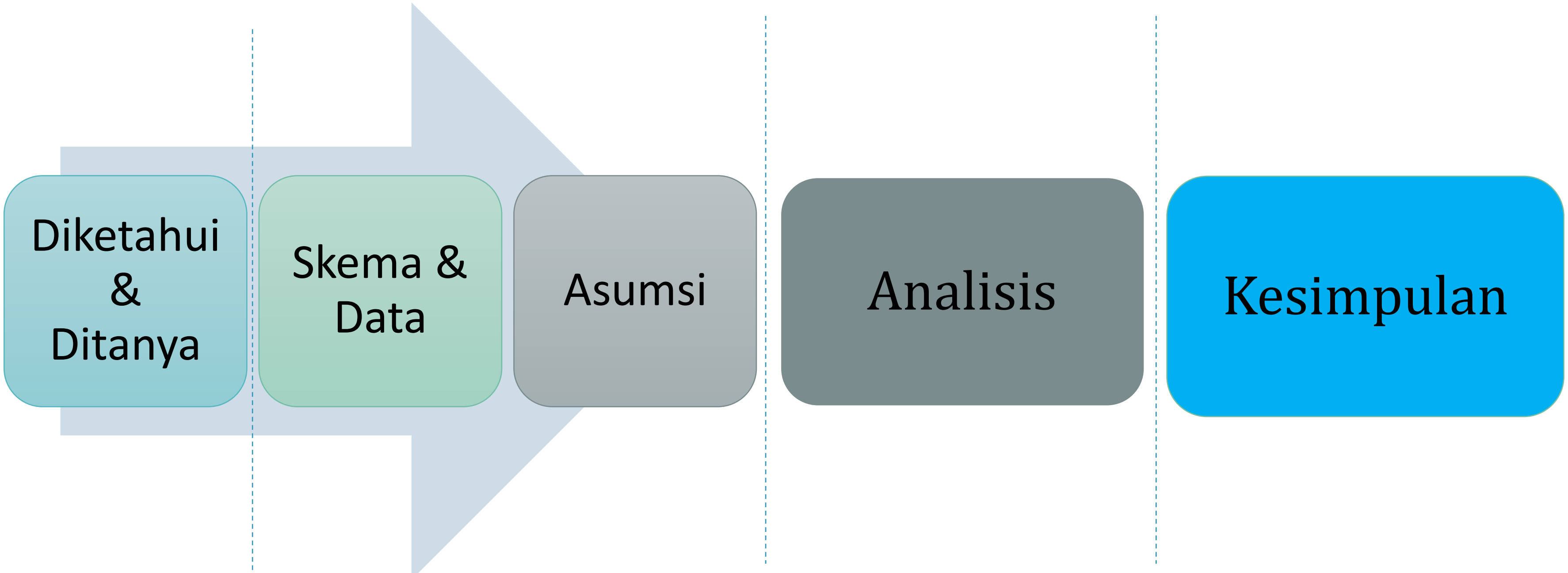


PENERAPAN

Four kilograms of a certain gas is contained within a piston–cylinder assembly. The gas undergoes a process for which the pressure–volume relationship is $PV^{1,5}$=*constant*

The initial pressure is 3 bar, the initial volume is 0,1 m^3, and the final volume is 0,2 m^3. The change in specific internal energy of the gas in the process is u_2-u_1= 4.6 kJ/kg. There are no significant changes in kinetic or potential energy.

Determine the net heat transfer for the process, in kJ.


Diketahui & Ditanya
Skema & Data
Asumsi
Analisis
Kesimpulan

Diketahui & ditanya

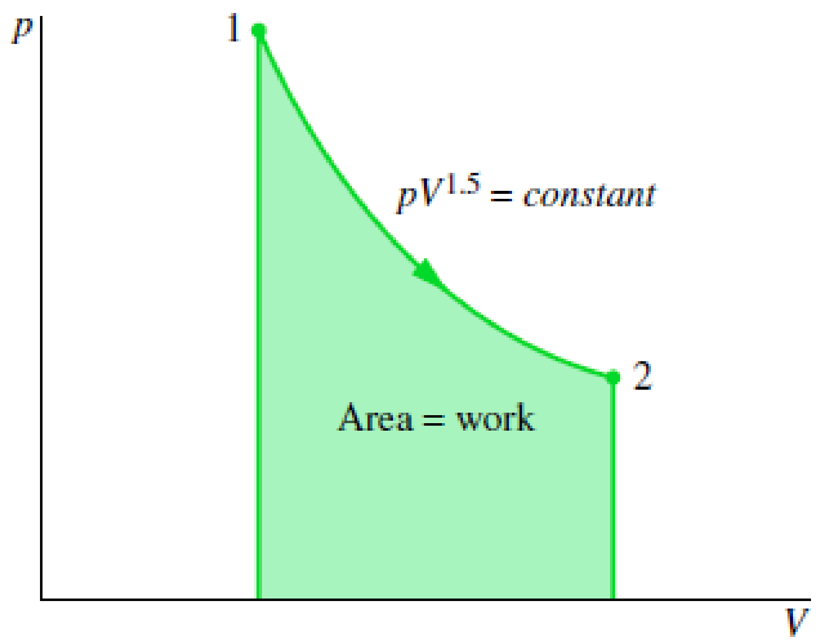
Diketahui:

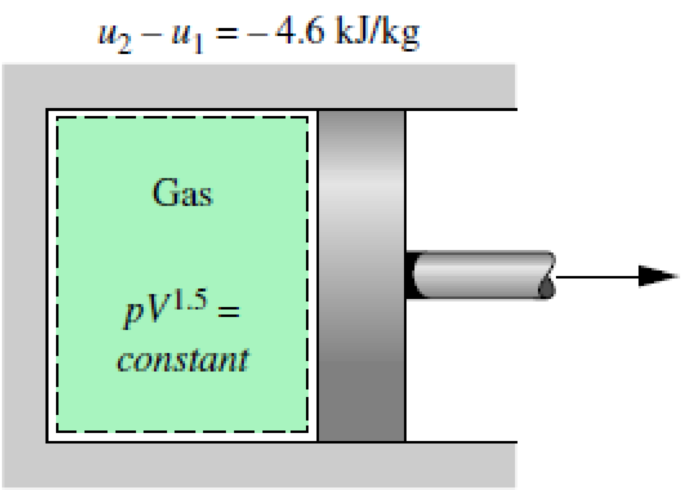
A gas within a piston–cylinder assembly undergoes an expansion process for which the pressure–volume relation and the change in specific internal energy are specified.

Ditanya:

Determine the net heat transfer for the process.

Skema, data, asumsi





Assumptions:

1. The gas is a closed system.
2. The process is described by $pV^{1.5} = constant$.
3. There is no change in the kinetic or potential energy of the system.

Contoh Soal

Air is contained in a vertical piston–cylinder assembly fitted with an electrical resistor.

The atmosphere exerts a pressure of 1 bar on the top of the piston, which has a mass of 45 kg and a face area of 0.09 m2.

Electric current passes through the resistor, and the volume of the air slowly increases by 0.045 m^3 while its pressure remains constant.

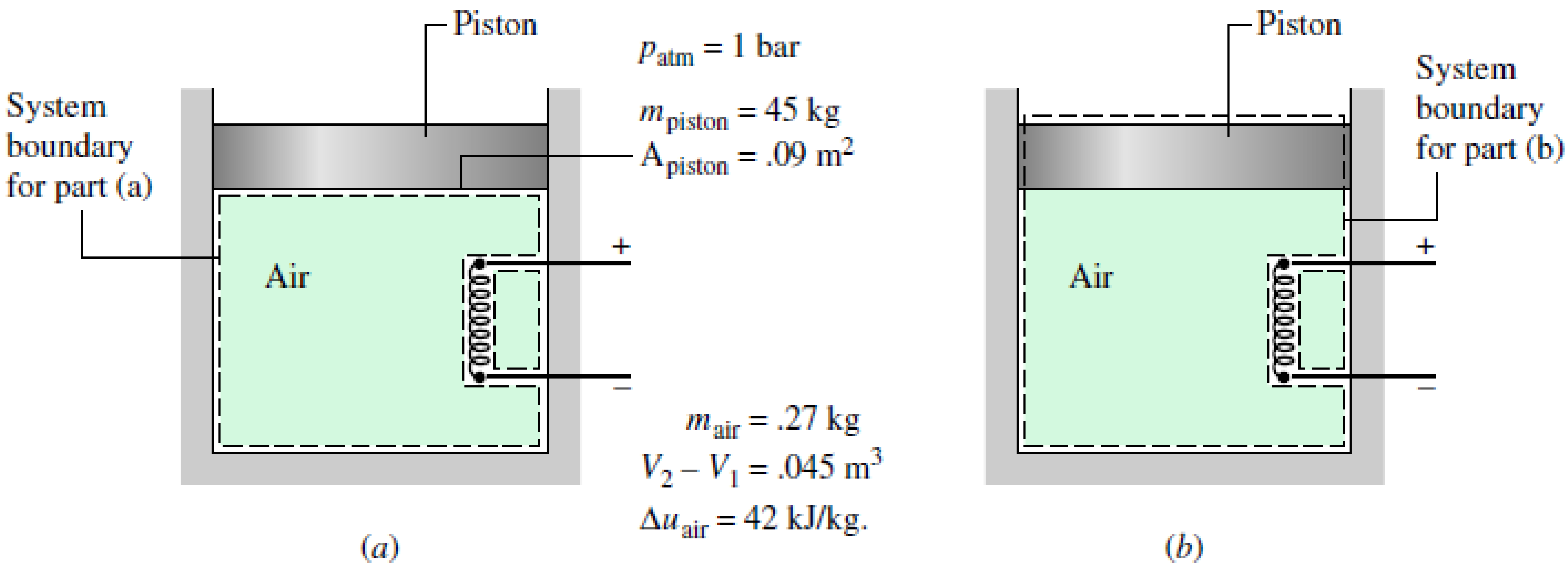
The mass of the air is 0.27 kg, and its specific internal energy increases by 42 kJ/kg.

The air and piston are at rest initially and finally. The piston–cylinder material is a ceramic composite and thus a good insulator.

Friction between the piston and cylinder wall can be ignored, and the local acceleration of gravity is $g = 9.81\ m/s^2$.

Determine the heat transfer from the resistor to the air, in kJ, for a system consisting of **(a)** the air alone, **(b)** the air and the piston.

- ***Known:*** Data are provided for air contained in a vertical piston–cylinder fitted with an electrical resistor.
- ***Find:*** Considering each of two alternative systems, determine the heat transfer from the resistor to the air.



Assumptions:

1. Two closed systems are under consideration, as shown in the schematic.
2. The only significant heat transfer is from the resistor to the air, during which the air expands slowly and its pressure remains constant.
3. There is no net change in kinetic energy; the change in potential energy of the air is negligible; and since the piston material is a good insulator, the internal energy of the piston is not affected by the heat transfer.
4. Friction between the piston and cylinder wall is negligible.
5. The acceleration of gravity is constant; g = 9.81 m/s^2.

RINGKASAN

No	Proses	$\Delta U = Q - W$
1	Isobarik	
2	Isothermal	
3	Isokhorik	
4	Adiabatik	