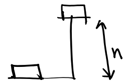
Heat: Energy in transit → Occurs due to ΔT

Work: Energy " " → No other effect



$$W = \int_1^2 p\,dV$$ (Only for Reversible processes)

The piston/cylinder arrangement shown in Fig. P4.51 contains carbon dioxide at 300 KPa and 100°C with a volume of 0.2 m³. Weights are added to the piston such that the gas compresses according to the relation $PV^{1.2}$ = constant to a final temperature of 200°C. Determine the work done during the process.

State 1	State 2
$p_1 = 300$ kPa	$p_2 = ?$
$V_1 = 0.2\ m^3$	$V_2 = ?$
$T_1 = 373$ K	$T_2 = 473$ K

$m_{CO_2} = 0.851$ kg

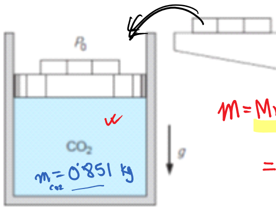


FIGURE P4.51

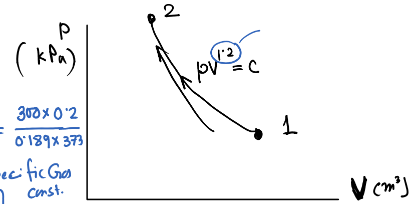
$pV = nRT$

$n = pV/RT$

$m = Mn = \frac{pV}{R_uT} M$ (kg)

$= \frac{pV}{(R_u/M)T} = \frac{pV}{RT} = \frac{300 \times 0.2}{0.189 \times 373}$

↳ Specific Gas const.



$R_{CO_2} = \frac{8.315}{44} = 0.189\ \frac{kJ}{kg \cdot K}$

$R_u = 8.315\ \frac{kJ}{kmol \cdot K}$

Ideal Gas

$pV = nR_uT$

or $pV = mRT$

R = Specific Gas Constant

$$\boxed{R = \frac{R_u}{M}}$$

Polytropic process: $pV^n = C \Rightarrow p = CV^{-n}$

$$_1W_2 = \int_1^2 p\,dV = \int_1^2 C V^{-n} dV$$

$$= \left.\frac{C V^{-n+1}}{-n+1}\right|_1^2 = \left.\frac{pV}{-n+1}\right|_1^2 = \frac{p_2V_2 - p_1V_1}{-n+1}$$

$$\boxed{_1W_2 = \left(\frac{p_1V_1 - p_2V_2}{n-1}\right) = \frac{mR(T_1 - T_2)}{n-1}}$$

ideal

$R_{air} = \frac{8.315}{M_{air}} = \frac{8.315}{28.8} = 0.287\ \frac{kJ}{kgK}$

1 m³ of Air at 10 bar & 600 K,

$m = \frac{10 \times 100 \times 1}{0.287 \times 600}$ kg =

$$_1W_2 = \frac{0.851 \times 0.189\,(373 - 473)}{1.2 - 1}$$

$= -80.42$ kJ

$$\boxed{\text{Find } p_2, V_2}$$

$pV = mRT$ $\qquad pV^{1.2} = C$

For polytropic processes

$pV = mRT$ — Ideal gas eqn

$pV^n = C$ — Process description

(A) $\frac{p_1V_1}{T_1} = \frac{p_2V_2}{T_2}$

÷ (B) $\div\ (p_1V_1^n = p_2V_2^n)$

$V_1^{n-1} T_1 = V_2^{n-1} T_2$

or $\frac{T_2}{T_1} = \left(\frac{V_1}{V_2}\right)^{n-1}$

Also $\left(\frac{V_1}{V_2}\right)^n = \left(\frac{p_2}{p_1}\right)$ $(\because pV^n = c)$

$$\left(\frac{V_1}{V_2}\right)^{n-1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}}$$

$$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}$$

$$\boxed{\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right)^{\frac{n-1}{n}} = \left(\frac{V_1}{V_2}\right)^{n-1}}$$

$pV^n = C$

$p^{\frac{1}{n}} V = D$

$pV^n = C$

$p^{\frac{1}{n}} V = D$

$\frac{T_2}{T_1} = \left(\frac{p_2}{p_1}\right) = \left(\frac{V_1}{V_2}\right)$

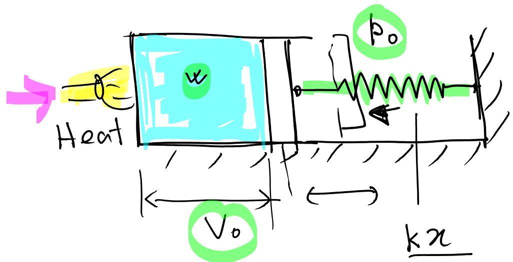
$\frac{473}{373} = \left(\frac{p_2}{300}\right)^{\frac{0.2}{1.2}} = \left(\frac{0.2}{V_2}\right)^{0.2}$

p_2

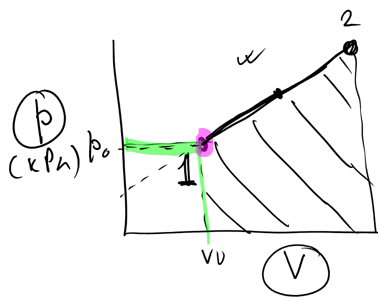
V_2

$\boxed{p = C V^{-n}}$

$p = f(V)$



$\frac{kx}{A}$



$p = f(V)$

$\boxed{p = aV + b}$

$W = \int p\,dV =$

C_p

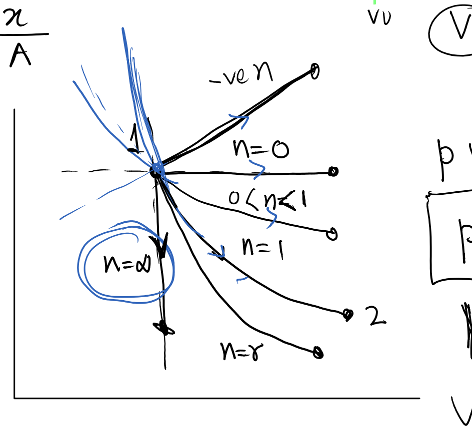
& C_v

Adiabatic process (No Heat Trans)

$\boxed{pV^\gamma = C}$ $\gamma_{He} = 1.67$

$\boxed{\gamma = \frac{C_p}{C_v}} \rightarrow \gamma = 1.4$

$\gamma_{CO_2} = 1.3$



$pV^0 = C \Rightarrow p = C$

$\boxed{pV^1 = C} \Rightarrow T = C$

$pV^\infty = C \Rightarrow V = C$

$W = \int F\,ds = \int p\,dV$

$n = 1$

$W = \frac{p_1V_1 - p_2V_2}{n-1}$

$n = \infty$
$n = 1$ X

$W = p_1V_1 \ln\frac{V_2}{V_1}$

or $p_2V_2 \ln\frac{V_2}{V_1}$

or $mRT_1 \ln V_2/V_1$ or $mRT_1 \ln\frac{p_1}{p_2}$

or $mRT_2 \ln V_2/V_1$

$p_2V_2 = p_1V_1$

A piston/cylinder arrangement shown in Fig. P4.64 initially contains air at 150 kPa and 400°C. The setup is allowed to cool to the ambient temperature of 20°C.

a. Is the piston resting on the stops in the final state? What is the final pressure in the cylinder?

b. What is the specific work done by the air during the process?

$p_1 = 150\,kPa$ $\quad p_2 = 150\,kPa$

$T_1 = 673\,K$ $\quad T_2 = ?$

$V_1 = V$ $\quad V_2 = V/2$

$\frac{\cancel{p_1} V_1}{T_1} = \frac{\cancel{p_2} V_2}{T_2} \Rightarrow T_2 = T_1 \times \frac{V_2}{V_1} = T_1/2$

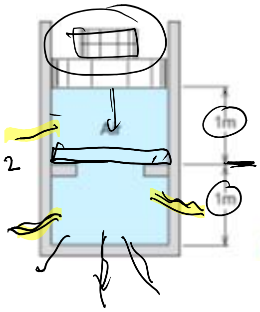


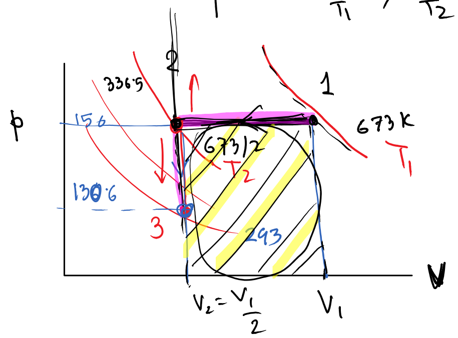
FIGURE P4.64

Polytropic $= n$?

$\frac{p_2 V_2}{T_2} = \frac{p_3 V_3}{T_3}$

$\frac{p_2}{T_2} = \frac{p_3}{T_3}$

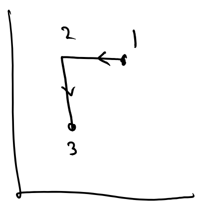
336.5 $\quad \rightarrow 293$



$p_3 = p_2 \times \frac{293}{336.5} = 130.6\,kPa$

$W = \int p\,dV = (-)\, 150 \times \frac{V_1}{2}$

Sp. work done $= w = \frac{W}{m} = -\frac{p_1 V_1}{2} = -\frac{RT_1}{2} = -\frac{0.287 \times 673}{2}\ \frac{kJ}{kg}$ $\quad m = \frac{p_1 V_1}{RT_1}$

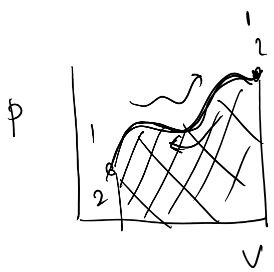


$W = \int^3 p\,dV =$

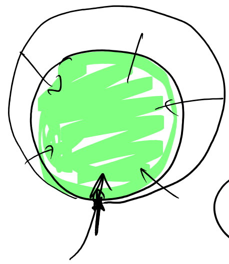
$= \int_1^2 p\,dV + \int_2^3 p\,\cancel{dV} \rightarrow 0$

$= 150 \times (V_2 - V_1) + 0$

$= 150 \times (-V_1/2)$

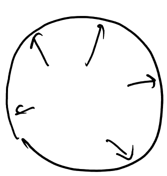


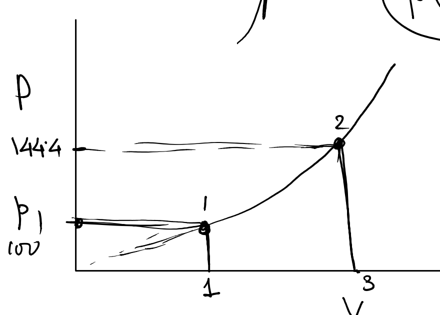
A balloon behaves so that the pressure is $P = C_2 V^{1/3}$ and $C_2 = 100$ kPa/m. The balloon is blown up with air from a starting volume of 1 m³ to a volume of 3 m³. Find the final mass of air, assuming it is at 25°C, and the work done by the air.



$pV^{-1/3} = C$

$\boxed{W = F \times \text{displ.}}$





Here, we should be careful to interpret what we mean by "work done by air." If we simply calculate W=∫pdV, we get an answer of +250 kJ. But then the question is work done by which air? Since there is mass of air entering into the balloon, we need to clearly delineate what our system is. After you have done the calculations you will realize that initially, the balloon has 1.17 kg of air, and the final mass of air inside the balloon is 5.05 kg, meaning that 3.88 kg has entered the balloon in the process. **So our system here is a given mass of air (5.05 kg).**

$p_1 = 100 \times 1 = 100\,kPa$

Final condn. $\quad T_2 = 298\,K$

you will realize that initially, the balloon has 1.17 kg of air, and the final mass of air inside the balloon is 5.05 kg, meaning that 3.88 kg has entered the balloon in the process. **So our system here is a given mass of air (5.05 kg), which initially occupies 1 m³ (the balloon) + 3.31 m³ (the air outside the balloon, identified by a hypothetical system boundary).** The task here is to compress this entire volume into 3 m³. The system boundary therefore shrinks from 4.31 m³ to 3 m³. The boundary pressure is 100 kPa (since it remains outside the balloon). Hence the work done is W=100x(3-4.31) kJ= -131 kJ. **This negative work means the work you need to push the air inside the balloon.**

$P_1 = 100 \times 1 = 100$ kPa

Final cond^n. $T_2 = 298$ K

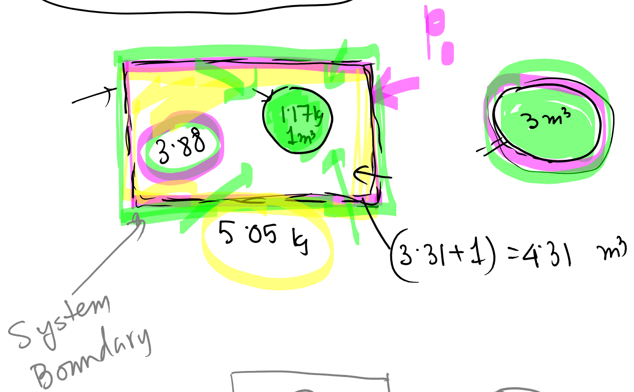
$$m_2 = \frac{P_2 V_2}{R_{air} T_2} = \frac{144.4 \times 3}{0.287 \times 298} = 5.05 \text{ kg}.$$

$$m_1 = \frac{100 \times 1}{0.287 \times 298} = 1.17 \text{ kg}.$$

$\boxed{\Delta m = 3.88}$

$W = \Delta m RT$

Work = Boundary work →



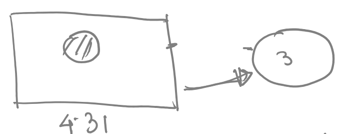
$$V_{outside} = \frac{3.88 \times 0.287 \times 298}{100}$$

$= 3.31$ m³

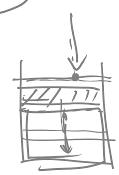
$W = P_0 \times \Delta V$

$= 100 \times (3 - 4.31)$

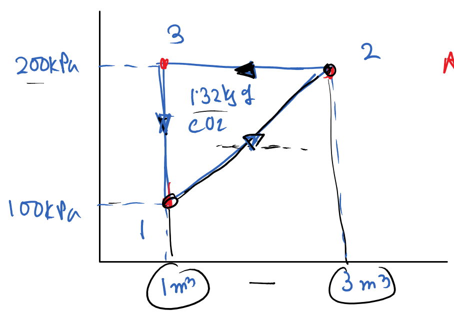
$= -131$ kJ



Boundary work



$\int p\,dV$



Find T_1, T_2, T_3 ←

Also find W_{12}, W_{13}, W_{31} &

Net work produced by the cycle

$_1W_2 = +300$ kJ

$_2W_3 = -400$ kJ

$_3W_1 = 0$

$W_{net} = -100$ kJ

A 400-L tank, *A* (see Fig. P4.32), contains argon gas at 250 kPa and 30°C. Cylinder *B*, having a frictionless piston of such mass that a pressure of 150 kPa will float it, is initially empty. The valve is opened, and argon flows into *B* and eventually reaches a uniform state of 150 kPa and 30°C throughout. What is the work done by the argon?

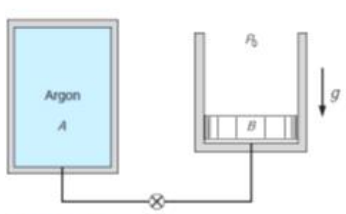
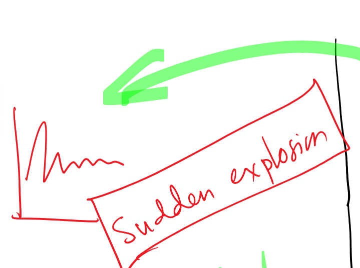
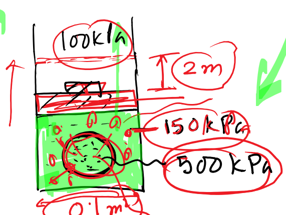


FIGURE P4.32





W = ?

$W = \int p\,dV$

$\int F\,dx$

$m \times g = \Delta p \times A$

$= 50 \times 0.1$ kN

$= 5$ kN

FIGURE P4.32

$W = \int F\, dx$

$= 50 \times 0.1$ kN

$= 5$ kN

$W = mgh = 5 \times 2$ kJ

$= 10$ kJ