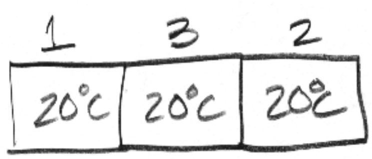
Thermodynamics

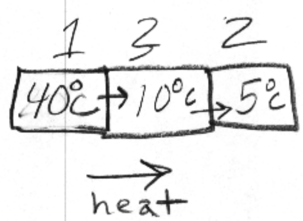
Energy transfers 2 ways

- Work = F × d
- Heat (due to temp. difference)

The Zeroth Law of Thermodynamics

- When two objects of diff. temp. are in contact heat will flow from high to low until equilibrium is reached.



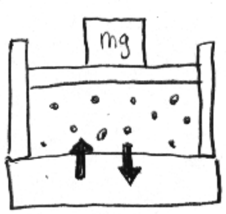


For a closed system

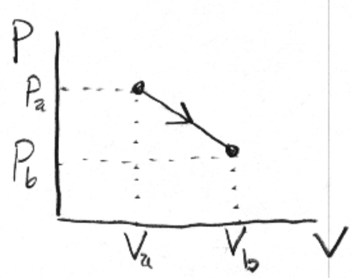
$\Sigma Q = \emptyset$ $Q_1 + Q_2 \ldots = \emptyset$

The First Law of Thermodynamics

- Conservation of Energy (that includes heat)

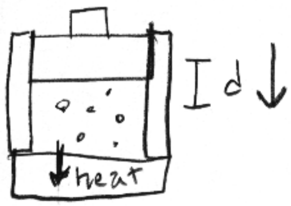


$PV = nRT$
(state of the gas)



P-V diagram
Show how the system is affected as we move from 1 state to another

Work is done on or by the system when the volume of the gas changes.



$$PV = nRT$$

V ↓ if pressure stays constant then T must decrease (Heat removed)

Work done on the gas $W = -Fd$

$F = PA$ so... $W = -PAd$ or $\boxed{W = -P\Delta V}$

$V = Ad$

★ The (+) or (−) sign is disputed. For us

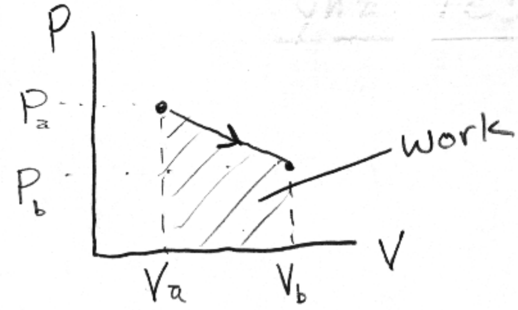
(+) Work indicates work done on the system

(−) Work indicates work done by the system

$$(+)\ W = -P(-\Delta V)$$ volume decreasing $-\Delta V$ (work done on system)

$$(-)\ W = -P(\Delta V)$$ volume increasing ΔV (work done by system)

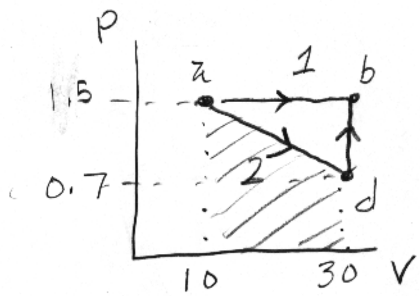
This assumes that the pressure is constant. If P does change then work is area under the curve of P-V diagram.



→ (−) Work

← (+) Work

Work depends on the path between the two states



- Work for path (ab) is $W = -P\Delta V$
- Work for path (adb) is the area under slope (ad). (Path (db) has $\Delta V = \emptyset$ so no work was done.)

$$W = -\frac{1}{2}h(b_1 + b_2)$$ ← area of a trapezoid

$$W = -\frac{1}{2}(\Delta V)(P_a + P_d)$$

However, $(Q + W)$ is not path dependent

internal energy $= U$

1st Law → $\boxed{\Delta U = Q + W}$ regardless of how it gets there

if $\Delta V = \emptyset$ $U = Q = mc\Delta T$

Second Law of Thermodynamics

☆ Heat engines
- Use heat to produce work

We will use cyclic engines so...

$$\Delta U = 0$$

$$\boxed{\Sigma Q = -W}$$

net heat absorbed by system is equal to work performed by the system.

hot source Q_H (−) → cold reservoir Q_c (+)

$$\Sigma Q = Q_H + Q_c$$

−or−

$$\Sigma Q = Q_H - |Q_c|$$

Thermal Efficiency (e)
- ratio of output to input

2nd Law → $$\boxed{e = \left|\frac{W}{Q_H}\right|}$$

$$|W| = \Sigma Q$$

$$\Sigma Q = Q_H - |Q_c|$$

$$e = \frac{Q_H - |Q_c|}{Q_H} = 1 - \frac{|Q_c|}{Q_H}$$

☆ $(Q_c \neq 0)$ therefore no cyclic heat engine can operate at 100% efficiency!