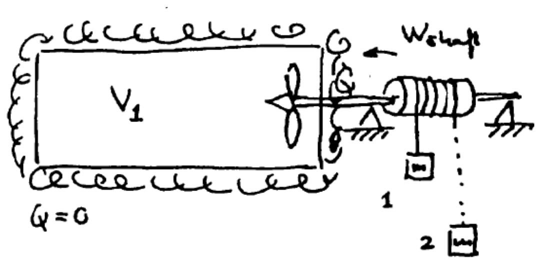
We have seen in class that, in order to restore an irreversible process, we leave a "trace" on the environment and the surroundings of the system (rest of universe). Can we find a criterion for this behavior? Using thermodynamic properties of the system, can we formulate a criterion that makes the distinction between reversible and irreversible processes?

Let's conduct 4 different thought experiments, where all the systems have the same initial state (U_1, V_1) and the processes are all adiabatic.

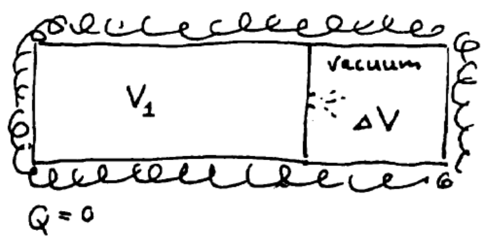
A



$U_2 = U_1 + W_{shaft}$

$V_2 = V_1$

B

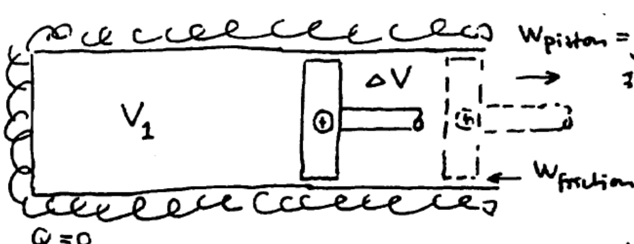


"free expansion"

$U_2 = U_1$ (no work, no heat)

$V_2 = V_1 + \Delta V$

C



$W_{piston} = \int_1^2 P\,dV$

$U_2 = U_1 - \int_1^2 P\,dV + W_{friction}$

$V_2 = V_1 + \Delta V$

D same piston, but no friction ($W_{friction} = 0$)

$U_2 = U_1 - \int_1^2 P\,dV$

$V_2 = V_1 + \Delta V$

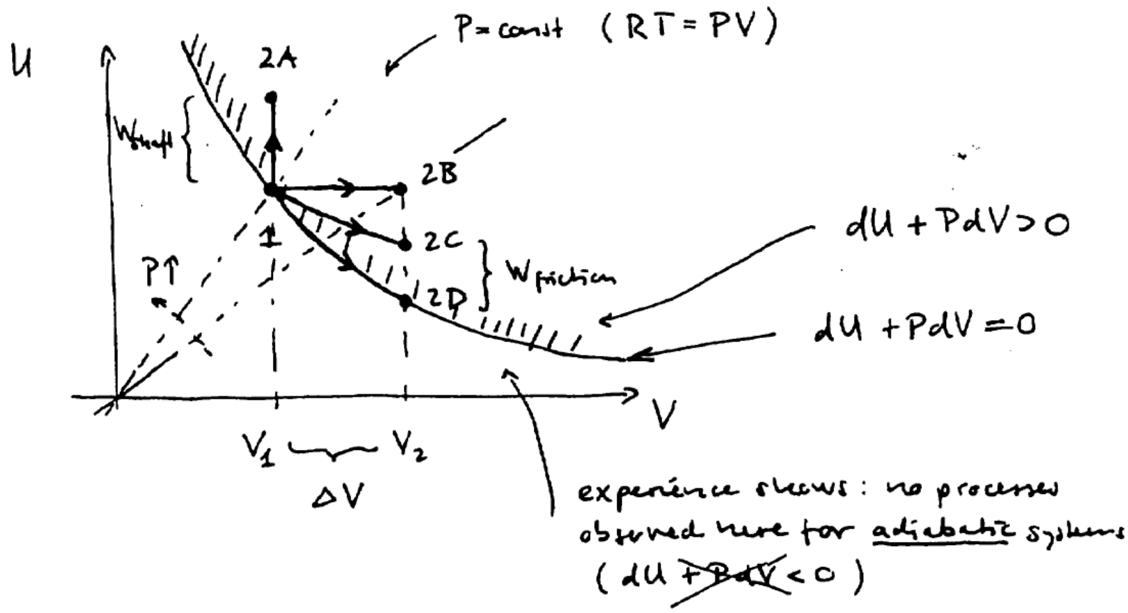
Looking at these processes, what can we say about the reversibility of the processes?

→ A, B, C are all **irreversible** processes – we leave a mark on the environment when returning to initial state

→ D is the only **reversible** process among these adiabatic processes – there is no friction, no dissipation – we don't leave a mark on the environment when returning to initial state

Let us return to the question stated earlier: can we find a criterion that determines whether a process is reversible or irreversible using the thermodynamic properties of the system?

For all the cases above, we looked at the changes in U and V. Let us construct a U-V diagram and draw these processes.



A, B, C : adiabatic, **irreversible** processes ⟶ dU + PdV > 0

D : adiabatic, **reversible** process ⟶ dU + PdV = 0

Can we find an indicator S that has the same behavior as dU + PdV for adiabatic processes (note that there is no heat interaction with the surroundings):

dS > 0	⟶	adiabatic **irreversible**
dS = 0	⟶	adiabatic **reversible**

In addition we would like S to have the following features:

- S should be appropriate for non-adiabatic systems as well
- S should be an extensive property (as are U and V)
- S should not be path dependent

As we will see in Chapter 5, we can indeed find a new property S that we call ***entropy*** (in Greek: εν – τροποσ, where εν means "inside or inner" and τροποσ is "direction"). The definition and behavior of this new property S is what we call the ***Second Law of Thermodynamics***.