* ~~Bond graph~~
* ~~linear graph~~

09/10/19

I) Introduction:

1.1) Mechatronics = study of devices that simultaneously combine at least two fields of engineering science that keep interacting together.

- Mechanical eng (continuum mechanics, fluid..., solid)
- Electrotechnical Eng (electrical, electronics, magnetism)
- Process Eng (chemistry, thermodynamics, thermal, energy)
- Science and technology for information and communication
  - ↳ ~~control~~
  - ↳ ~~computer science~~
  - ↳ ~~internet of things~~
  - ↳ ~~network~~
  - ↳ binary / logic

1.2) Tendancy:

↳ needs for mechatronic systems are ↑ a lot

- Smart sys
- autonomous sys
- connected objects / Internet of Things
- increase the number of functionalities
- ↑ performances (control).

All theses aspects lead to including AI

- Systems able to learn.

1.3) · Aim / Goal:

Find equilibrium / trade-off / optimal behavior at the

general level (mechatronic) and not at the local level.
⇒ how to find the good balance?

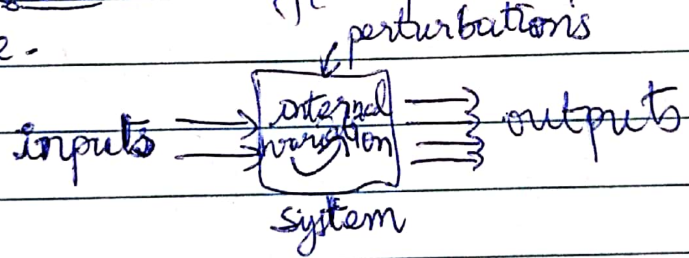
[Def] Modelling:

Model = mathematical representation of the real behavior of a device. It corresponds more or less to the reality. There has to be a trade-off between the complexity and the trueness.

Interest in modelling ⇒ understanding the behavior
⇒ explanation of a behavior
⇒ predict behavior

} Modelling and Control

[Def] Systems = Set of components combined for a given purpose.



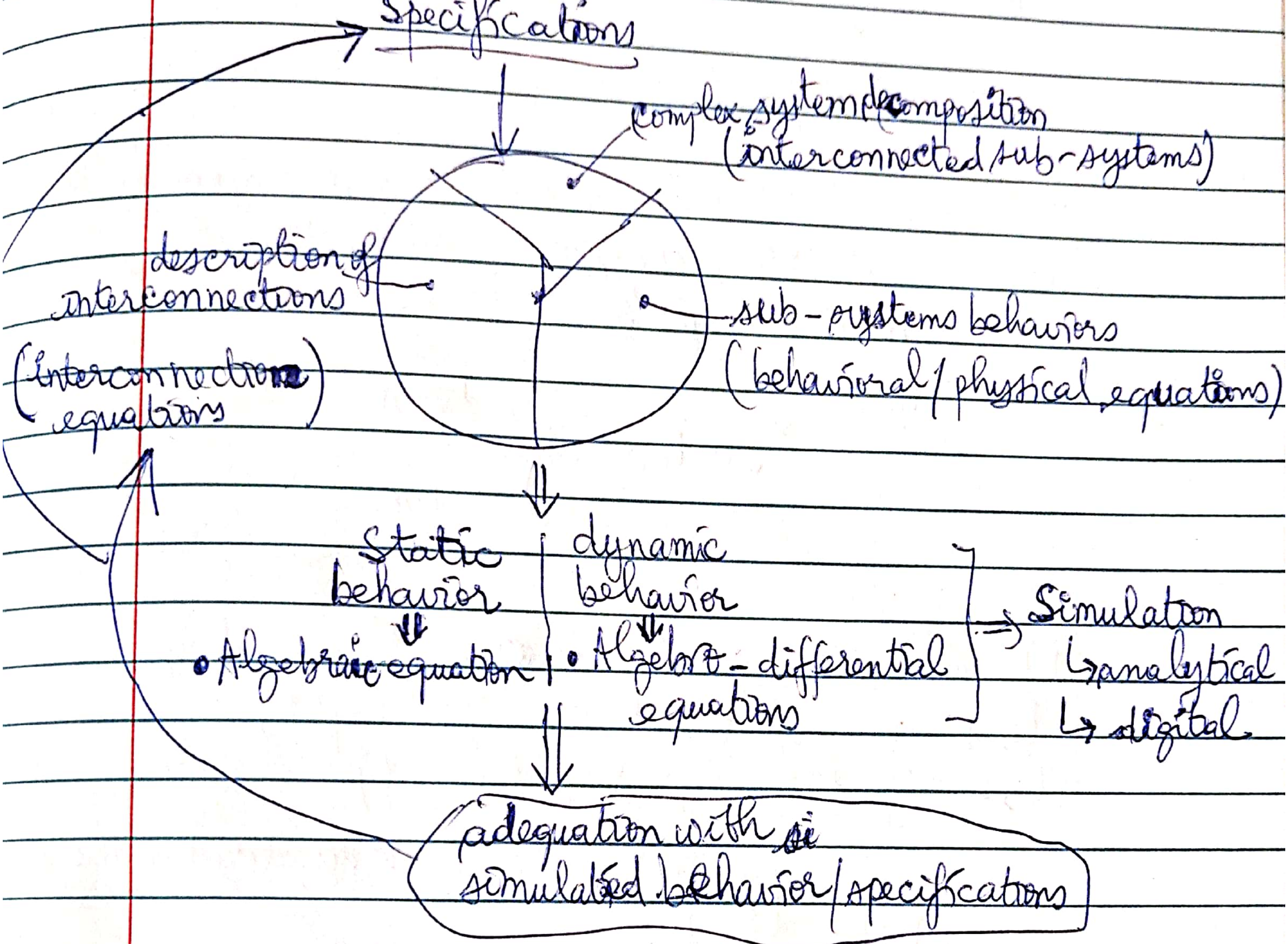
- the behavior of every component can be described by general laws (mech, elect, thermodynamics, ...) that link the different physical quantities

- define → constituents of the sys
→ interactions with its environment

- holistic approach (decomposition of complex systems into simpler ones / study the behavior of a general system knowing the behavior of elementary components.)

1.2) Mechatronics based on system modelling:

Approach for the design ⟶ control.



Systems can be classified into two main categories:

* lumped parameters systems ⇒ equations are finite and differential (finite dimensional sys). The sys is described by a finite number of signals. Sys evolution only depends on time.

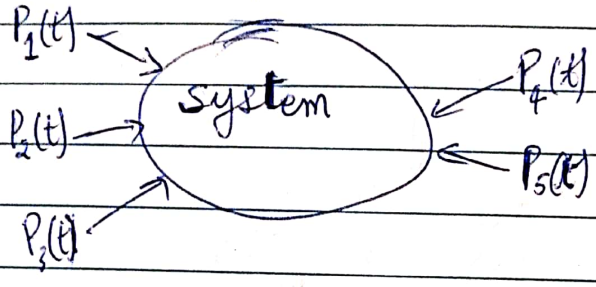
* Distributed parameters systems
Equations are partial differential (infinite dimensional sys).

Sys is described by an infinite number of signals. Sys evolution depends on time + space.

II.) Energy Based Approach :

① General approach :

"ideal point of view" ⇒ a sys exchange energy with its environment (other sub-sys in interaction with) through a finite number of ports.



$P(t)$ represents power flow across the boundary
↳ ~~+ if brought into the sys (input)~~
↳ ~~− if taken / removed (output)~~

$$P(t) = \frac{d\,\mathcal{E}(t)}{dt}$$

$\mathcal{E}(t)$ ← instantaneous energy stored in the sys

↳ effort variable × flow variable

Variables can be split into two groups :

* variable whose change induce a flow

ex : Force / Torque / Current / Volume / Volume flow rate
$F(t)$ $(C(t))$ $I(t)$ $V(t)$ $Q(t)$

They are associated with their variations.

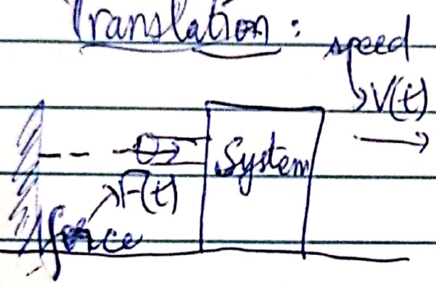
ex : charge $q(t) \Rightarrow i(t) = \frac{dq(t)}{dt}$

linear momentum $p(t)$ $\Rightarrow F(t) = \frac{dp(t)}{dt}$

* Variables whose change induce an effort
↳ potential of...
ex: electrical potential
↳ potential difference
ex: Voltage $= V_A - V_B$

② Mechanical systems:

Translation:



potential energy

$$P(t) = F(t) \times V(t) = \frac{dE(t)}{dt}$$

$$V(t) = \frac{dx(t)}{dt}$$

$$\Rightarrow P(t) = F(t) \times \frac{dx(t)}{dt} = \frac{dE(t)}{dt}$$

$$\Rightarrow F(t) = \frac{dE(t)}{dx(t)}$$

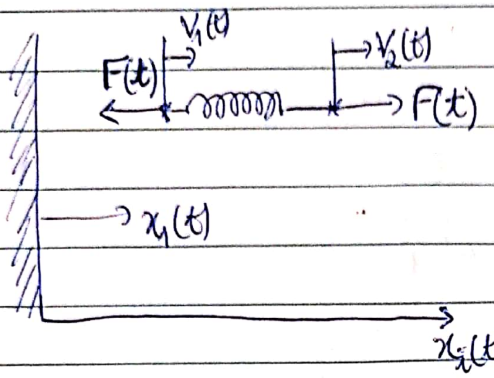
~~thus~~ change of position ⇒ change of energy

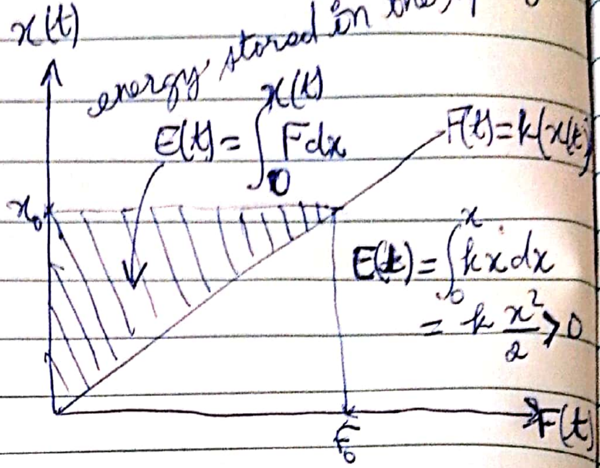
$$F(t) = \frac{dp(t)}{dt} \Rightarrow \underbrace{\frac{dE(t)}{dt}}_{\text{kinetic energy}} = \frac{dp(t)}{dt} \times V(t) \rightarrow V(t) = \frac{dE(t)}{dp(t)}$$

$P(t) = F(t) \times V(t) \Rightarrow$ dissipated energy

* Energy storage element
= element that can store the energy and that can restore it (they can't provide energy to the environment in an infinite way).

- **Spring**:

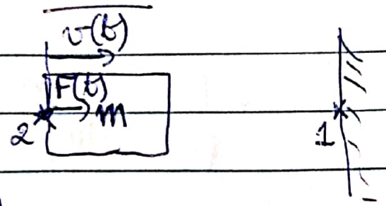


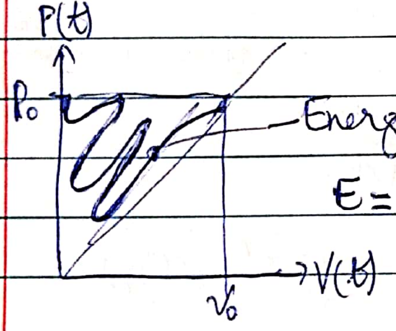


$$E(t) = \int_0^{x(t)} F\,dx$$

$$E(t) = \int_0^{x} kx\,dx = k\frac{x^2}{2} > 0$$

- **Mass**:





Energy stored at V_0/P_0

$$E = \int_0^{P} V(t)\,dp \quad \text{with } V = \frac{P}{m}$$

$$= \int_0^{P} \frac{P}{m}\,dp = \frac{P^2}{2m} > 0 \quad \text{(energy stored)}$$

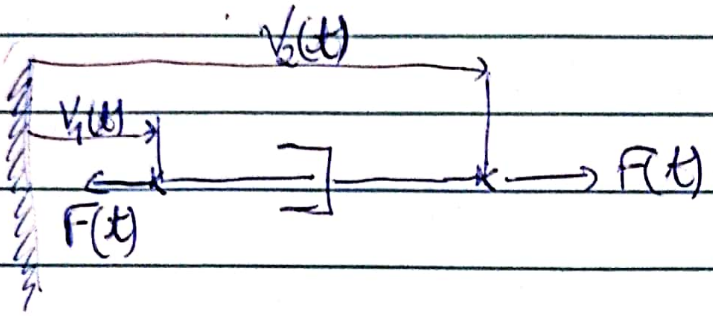
Rq: $P(t) = m \cdot V(t)$

$$\Rightarrow \boxed{F(t) = \frac{dP(t)}{dt} = m\,\frac{dV(t)}{dt}} \leftarrow \text{Newton's law}$$

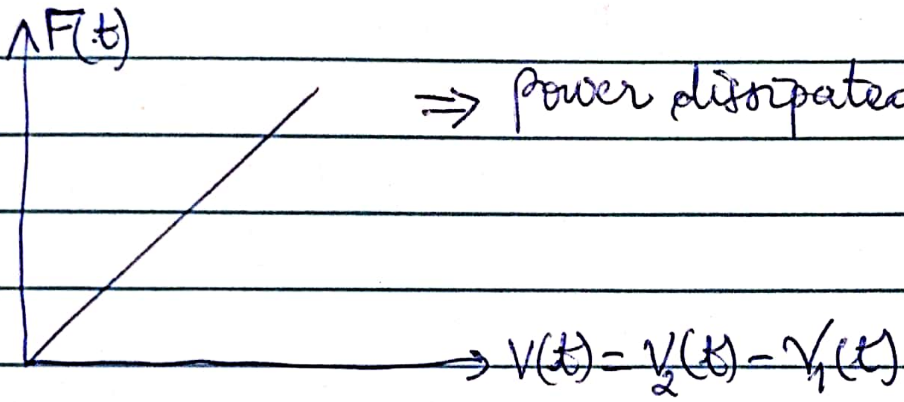
* Energy dissipation elements:

From the energy point of view, energy dissipation element, receive energy (as work force) and transform a part of it into heat. These elements highlight energy lost by a system (~~to~~ be minimized).

- damper



perfect damper $F(t) = \alpha . V(t)$



$\Rightarrow$ power dissipated $P = F . V = \alpha V^2$

* Sources elements

↳ Force sources : a force is generated independantly to the speed $V(t)$. The speed only depends on the system that is connected to this source.

↳ Speed sources : a speed is - - - ... to the force. The force only ———