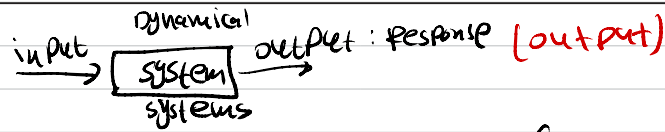
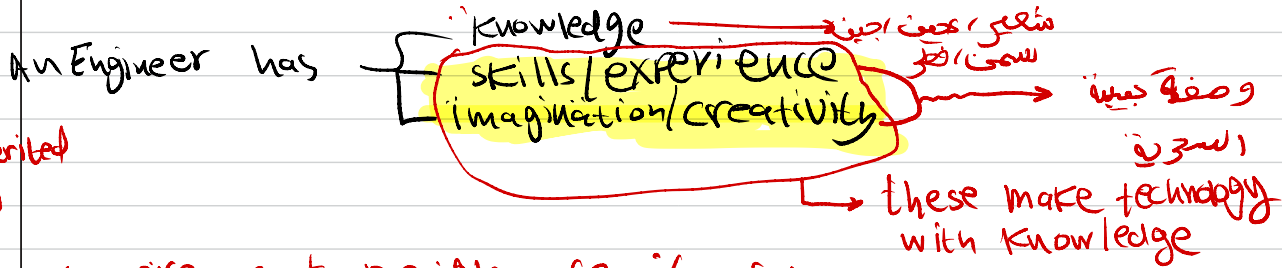


Lecture ①

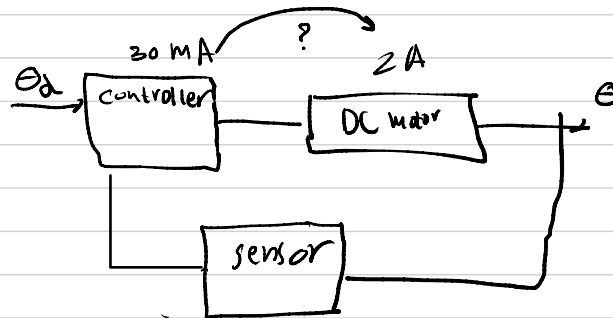


* Dynamical systems have characteristics: (performance, stability, disturbance effects)

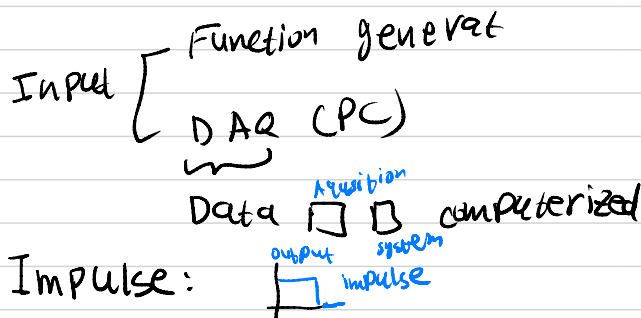


Technology is inherited and never given

* Experiment design (20% of the mark)

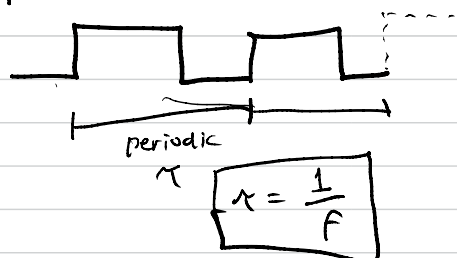


نظري مشهور
output { oscilloscope
DAQ

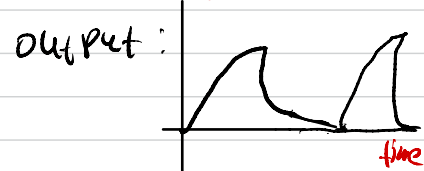


Impulse:

Step:



output = response
 $y(t)$

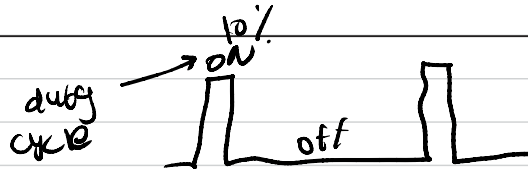


* Synchronization Problem

input will be a series of signals
≡ periodic inputs

* Use simulation: simulink on matlab to create this

if the first is not synchronized to the other signal
 Why periodic? signal $\rightarrow$ synchronization



impulse duty cycle must be as minimum as possible

$\rightarrow$ what about the frequency

* To create an impulse: we reduce frequency and make duty cycle smaller

sampling time: processing time to read and give output: this is 1ms: there is no sensor that gives continuous signal

Function generator

Cassie lab

Ground to connect devices

Frequency, Amplitude, duty cycle

DAQ

can be used as input

and output

Function

$\downarrow$

DAQ

DAQ

$\downarrow$

DAQ

Analog Plant simulator

Input from where
output to from

$$K_p \equiv g_{zi}^n$$

How to calibrate PID

calibration depending on
the first order system
equation given

$V = I V$? to not confuse signal

$$f = 0.1 \text{ Hz} = 100 \text{ mHz}$$

Simulink
matlab
block diagram
bode diagram

* How to calibrate? Change $K \rightarrow$ gain initially = 1, then the gain was changed to gain = 4

how to convert
to simulink

* Why is calibration important? , this experiment is solving a first order eq.

it can be solved by matlab

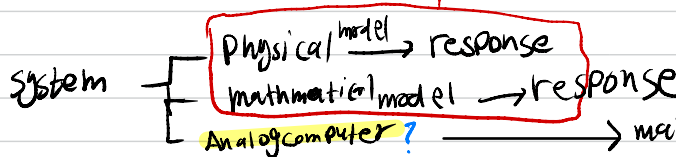
Voltage and other data can be coded as a table

* Analog computer

differential eq.

System dynamics

Differential equation
solve using analog
computer



Analog electrical circuits

make electrical circuits $\Delta V \rightarrow \Delta P$
 $I \rightarrow Q$

Differential equations
represent the
system $\rightarrow$ we are
to solve that equation

Differential equations are solved:

Analytically
Numerically

$$a \frac{dy(t)}{dt} + b y(t) = f(t) \quad \text{Linear coefficient first order}$$

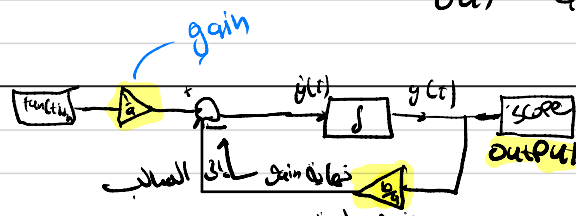
can be solved by (euler, runge kutta, ...)

$$\frac{dy}{dt} + \frac{b}{a} y(t) = \frac{1}{a} f(t) \quad \text{using integrating factor analytically}$$

$$\dot{y}(t) = \frac{1}{a} f(t) - \frac{b}{a} y(t) \quad a > 0$$

Function generator is $f(t) \equiv \text{input}$?
DAQ

- 1) Analytically
- 2) Numerically (euler, Runge kutta)
- 3) Analog



DAQ $\rightarrow$ 1ms

$\rightarrow$ 1ms orig

What is the gain? , in PID controller

5

$$\frac{2.5}{5} = \frac{1}{2}$$

gain $\rightarrow$ gain 11 50 ج 11

DAQ Limit voltage is 10

ogata
Franklin
vande vegate

$$y(t) + \frac{b}{a} y(t) = \frac{1}{a} f(t) \quad \text{let } f(t) = \text{constant} = \text{unit step}$$

let $a=0.2$ $y(t) + 0.4 y(t) = 5f(t)$

unit step $f(t)=1$

$$\frac{A}{s+1} \quad y(t) = \frac{1}{s}$$

step input? , impulse? , ramp?

why must the function be periodic?

For synchronization

$$0.2 \dot{y}(t) + 0.1 y(t) = 5f(t)$$

what kind of input is this and what kind of output will it produce?

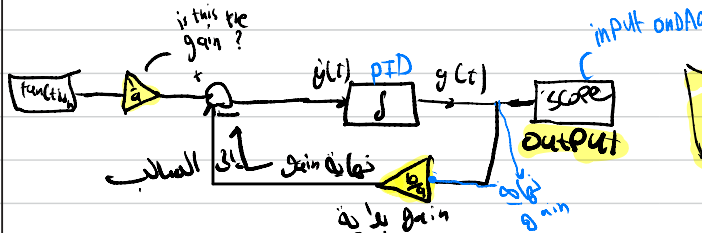
0.5 V

operational amplifier
Summing functions
Differentiate
integral
regular amplifier

how to do calibration

$$\dot{y}(t) = 2 - 3y(t)$$

input
gain



$$\dot{y}(t) = 5 - 2y(t)$$

input = voltage
 $K=2$
response and output
gain

Block diagram

From FOS $\rightarrow$ get output

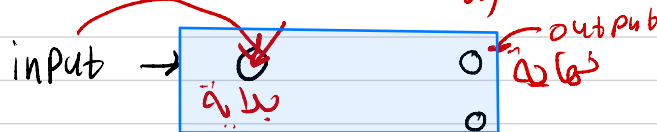
What is the output?

experimental vs theoretical

First order system using analog plant simulator $\rightarrow$

how is a first order equation solved normally and how is it solved using analog plant?

the first step to solving the differential equation was the calibration of the gain (what is the gain physically) (why?)



how to get y ? plug into PID $\rightarrow$ why?
do we solve for $y(t)$? or $\dot{y}(t)$?

input = $\dot{y}$
output = y

Input voltage

The output is
(current?)
(capacitance?)
(Torque?)
(Power?)
(Voltage on another thing?)

"First order system"

FOS equation $\rightarrow$ it has again :

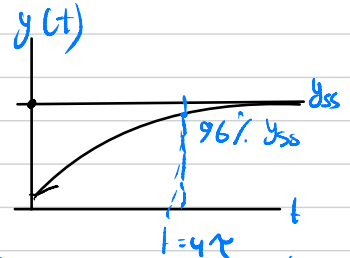
First order system review

* what is the differential equation governing the first order ?

- Differential equation
- Laplace transform
- steady state
- time constant

Transfer function
Input
Output
The response

$$\dot{x} + \frac{1}{\tau} x = 0$$



What is the system in the control lab what the input and what is the output?

equation $y(t) = A e^{-t/\tau}$

$G(s) = \frac{K}{\tau s + 1}$ (1) $\rightarrow$ 2 or constant K?

$y(t) = 1 - e^{-t/\tau}$
 $\frac{Y(s)}{R(s)} = \frac{1}{s} \cdot \frac{1}{\tau s + 1}$ — Transfer Function

$T(s) = \frac{K}{\tau s + 1}$
 $\mathcal{L}^{-1}(T(s)) = \mathcal{L}^{-1}\left[\frac{K}{s} \cdot \frac{1}{\tau s + 1}\right]$
 $= K e^{-t/\tau}$
 $\tau = RC$

Understanding Part

simulink

Analytical solution

- 1 - First order system characteristics, block diagram, output and/or response
- 2 - Analog computer: connections and gain
- 3 - PID controller and gain and input and output

- what is the gain? where is it in the curve?
- what is the difference between black and red curves
- what should I expect from the response? , and what do expect of the theoretical part (Analytical, simulink)

$y(t) = 5 - 2y(t)$ what would happen if this was positive and how to solve this differential equation?

Report Part

Cover page
Objectives
Abstract

Introduction: theory and background
Procedure

- data observed
- data calculated
- discussion
- conclusion

$1 \dot{y}(t) + 2y(t) = 5$ input

$y(t) = 1 - 5e^{-t/4}$

$R \frac{dh}{dt} + A h(t) = \frac{dh}{dt}$

Rate of change between kinetic and potential energy? is this the natural frequency?

$$y(t) = 5 - 2y(t)$$

$$a \frac{dy}{dt} + b y(t) = f(t)$$

system is represented
by this differential
equation, how can it be
solved?

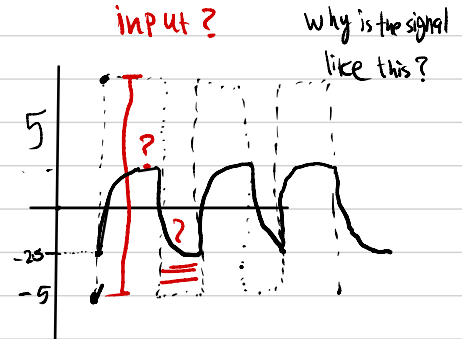
2

what is the gain

$\frac{1}{a}$



What is the gain and what does it mean physically



Analogy starts from $-V_{max}$
(or V_{min}) and the magnitude
is $1/2 V_{max}$

Why is the output
2.5 Volts? it got halved?

$$\text{my zero is } \frac{-2.5}{(-2.5 \rightarrow 2.5) = (0 \rightarrow 5)}$$

L2 22/10/2023

* position control of a DC-motor

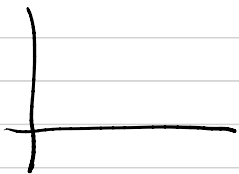
servo-systems: displacement, speed, Torque or combination.

stabilits:

Finite-input

Finite output

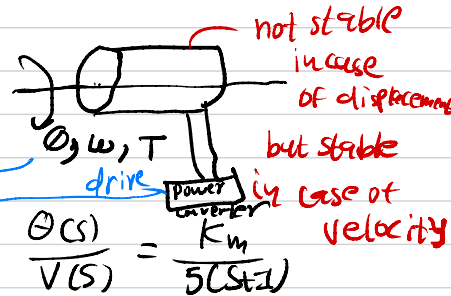
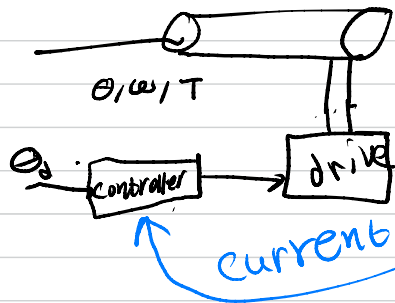
not increasing to infinity



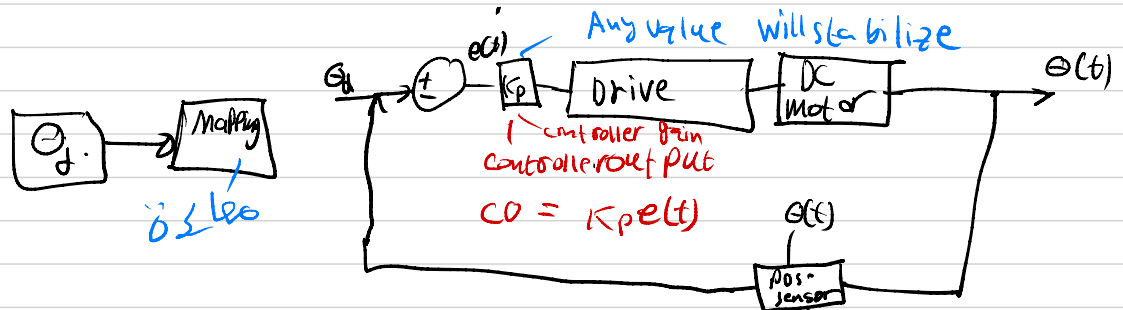
فإنه النظم

أولاً يجب النظام stable
only then do we increase performance

* design of controller : stabilize the system



شروط كل الالة
اتوافق الاشارات نوعاً وكمياً
شروط لاجل الالة الكهربائية
2- الثاني : تعمد في ما يلي



* connection between voltage to position

- voltage based
 - 0 - 5V
 - 1 - 5V
 - 0 - 10V
 - 1 - 10V
 - current based
 - 0 → 24mA
 - 1 → 24mA
- heat exchanger

Mac
Papa Johns
pizzeria
starbucks

لا يكون
اسمك

UK
Jordan
America

at 10 $\rightarrow$ volts
at 5

step input
disturbance

potentio meter

0 $\rightarrow$ 90 will give step
input
step (100%) can be given
by the DAA

mapping

at 0 0.1V
 $\theta = 10$
20
30
40
50
60

change $K_p (1 \rightarrow 100)$

(1, 2) (1, 10)
(3, 4) (15, 25)
(5, 6) (7, 35) (55, 100)

L (4) 29/10/2023

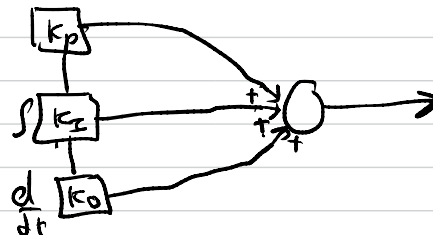
PID controller

Remember: Proportional control and how it stabilized and enhanced the perf.
However, the error wasn't zero. Response time got better faster at
the cost of overshooting

* Today we want to eliminate steady state error

* Remember: system type and order

* Controller contains 3 types of control P, I, D



$$C_o = K_p e(t) + K_I \int_0^t e(t) dt + K_D \frac{de(t)}{dt}$$

$$C(s) = K_p E(s) + \frac{K_I}{s} + K_D s E(s)$$

$$\frac{E(s)}{C(s)} = \frac{K_D s^2 + K_p s + K_I}{s}$$

two zeros $\rightarrow$ number of poles increased
system time increased

→ servo motor

$$\frac{\Theta(s)}{V(s)} = \frac{K_m}{s(\tau s^2)} \leftarrow s \cdot s = s^2 \Rightarrow \text{system type 2 when}$$

given step input will give a stable output with zero steady state error

* K_I eliminates error

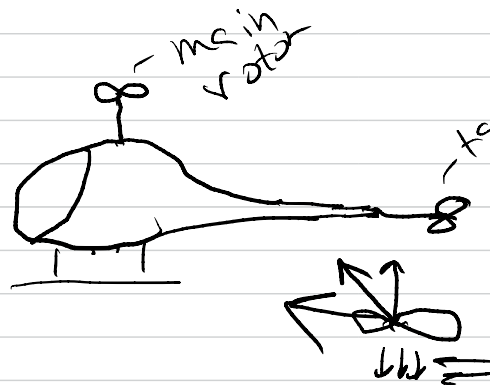
* K_D increases damping

take K_p as factoring component

$$C(s) = \underbrace{(K_p)}_{K_c} \left[1 + \underbrace{\left(\frac{K_I}{K_p} \cdot \frac{1}{s} \right)}_{\frac{1}{T_I}} + \underbrace{\left(\frac{K_D}{K_p} s \right)}_{T_D} \right] \quad \text{Industry usage}$$

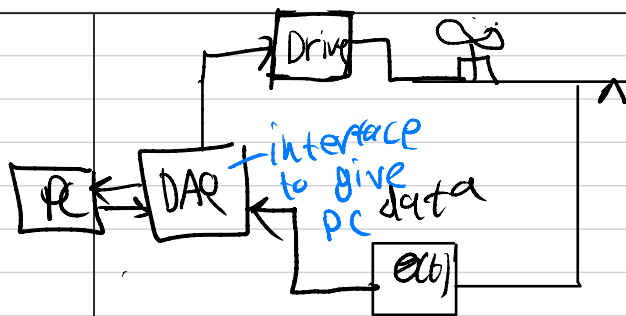
$$\frac{K_D}{K_I} = T_I \quad T_D = \frac{K_D}{K_p} \quad K_c = K_p$$

* Today
We study
the effects of
the controller



Part 1: vertical stability

Part 2: Planar stability



we can control the angle

the concept is PID controller controlling the angle

by changing the velocity we can change the angle. This way we use controller to control velocity

* same connections as before!

P, PI, PID (3 tables)

K_f increases overshoot

K_d eliminates overshoot

Table 1
 $K_c = 40$ constant

T_i changing

$K_p = 40$

$T_d = 0.1, 0.9, 2$

$T_i = 0$

$T_i = 0$ $K_c = 40$

0.1

0.9

2.0

T_i, T_d changing

$K_c = 40, 40$

$T_i = 20, 40$

$T_d = 0.1, 0.9$

$K_c = 40, T_d = 0$

$T_i = 20$

40

50

2 rotors aerodynamic

1DOF: horizontal or vertical

2DOF moving pitch: both horizontal and vertical

*study effects of PID (1DOF, 2DOF

matlab: Trass:

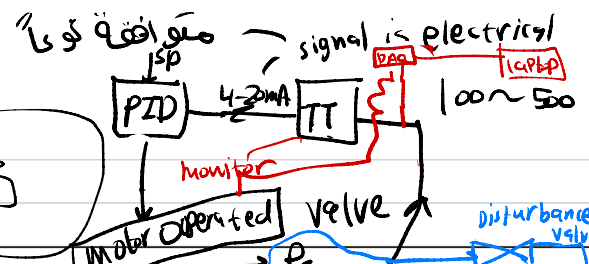
$$K_p = 2 \sim 5$$

$$K_p = 3$$

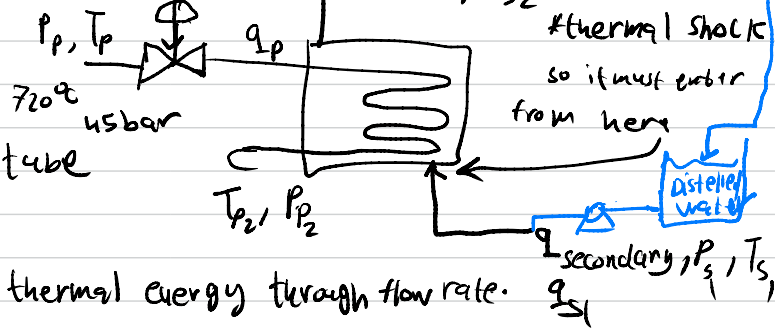
$$\tau_i = 0$$

$$\tau_f = 0$$

lecture 12/11/2023



- * Heat exchanger
 - * Types
 - Plate
 - shell and tube
- * Dwell time controlling thermal energy through flow rate.
- * steam trap $\rightarrow$ To get rid of the condensate and allow only steam.
- * Hunting for what opening should the valve open?



pipe? hose? Tube?

* The controlled variable: what are we trying to control: which the temperature (Temperature)!

this is read through temperature transmitter

compact
easily maintained
easily serviced

Transfers thermal energy without the two fluids mixing together

Primary loop connected to a boiler

Why not start from (0-4 mA)
1- For trouble shooting (0 = open circuit)
(4 = closed circuit)

20 mA since the human can be shocked completely at 30 mA



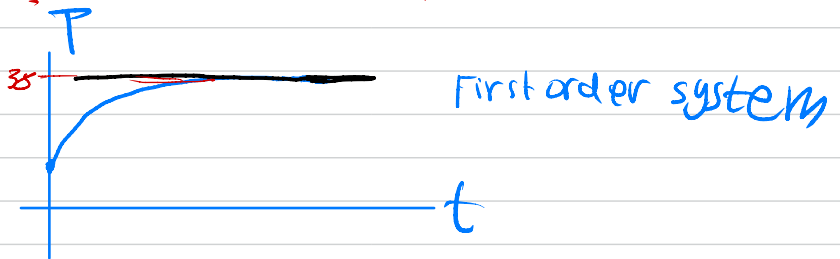
cooling tower!

Handwritten notes in Arabic script.

heat exchanger
fouling

Handwritten notes in Arabic script.

no residue



$$e(t) = sp - T(t)$$

Radiator = plate

$\rightarrow$ heat surface area $\rightarrow$ turbulent flow

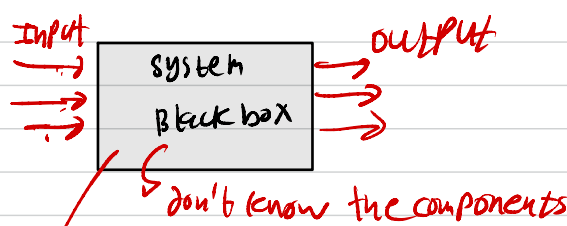
gasket $\rightarrow$ tight fit
 $\downarrow$
to prevent leakage

U6 19/11/202

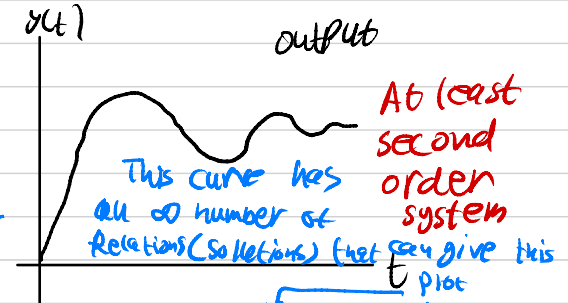
system identification : Reverse engineering

System: collection of components to give a certain output I don't know the system: given that we know inputs and outputs can I

سقطت مسيرة
أمر دحية ورفقت
إيران تسليحاً للكويت



output is a reaction of the input



Mass-spring damper system

Curve fit

$$x^3 + 3x^2 + x^2 + x + 5$$

Can we curve fit with a polynomial [Fourier and Taylor series]

This gives the conditions it must be in the form

* This system is correct in math. However in engineering this is not correct

Solution of the 2nd order system must be in this form since it's a mass-spring system

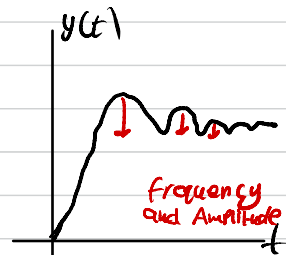
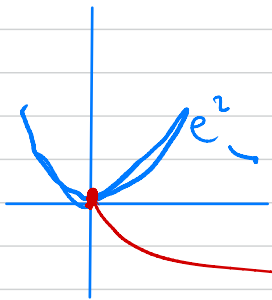
* This boils down to finding (F, ω_n)

(3) Optimization techniques (Advanced but can use

$$J = \sum (y_e(t) - y(t))^2$$

Cost function Error

$J \rightarrow 0$ — This is the point we are looking for
minimum $\rightarrow$ Find (F, ω_n)



to find F (damping ratio)

$$\zeta = \frac{c}{c_r} = \frac{\omega_n}{\omega_d}$$

can be found using

① Log. decrement

Calculus of variation
euler lagrange

Constraint

← subject to (Transfer function $G(s)$)

Find values F, ω_n through readings

Mass
damping
Stiffness

② Equivalent (use Matlab Curve Fitting laplace domain)
 $\omega_d = \omega_n \sqrt{1 - \zeta^2}$

lecture 7 26/11/2023

Elevator control
→ modeling of elevator

- ① Derive the governing diff. eq.
- ② Simulate on matlab/simulink

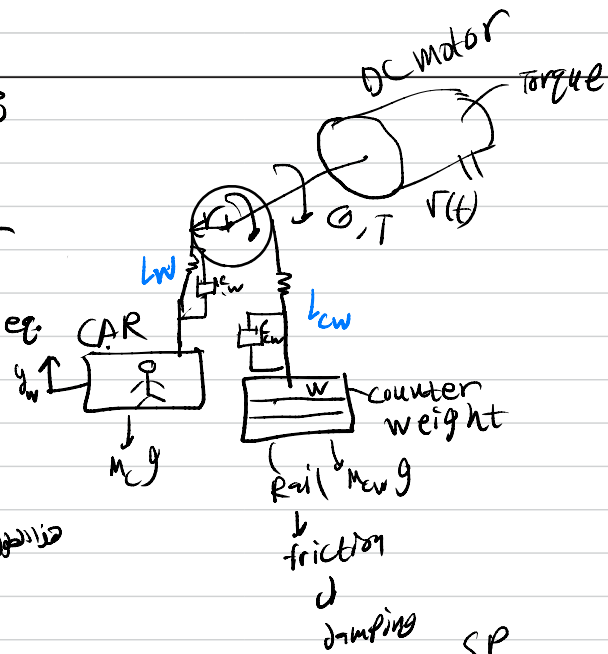
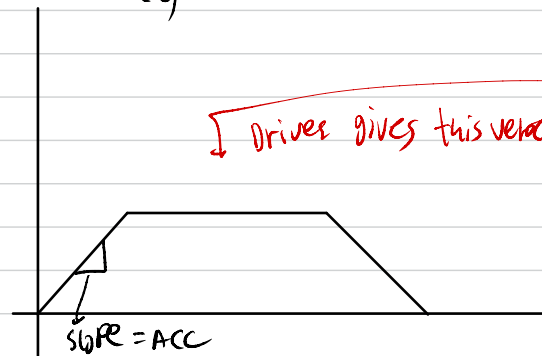
$$L_w + L_{cw} = L \quad \text{cable mass}$$

$$\frac{dL_w}{dt} + \frac{dL_{cw}}{dt} = \frac{dL}{dt}$$

$$G = \frac{K_m}{s(\gamma s + 1)} = \frac{\Theta(s)}{\gamma(s)} \quad \text{limit switch}$$

→ sequence control

$$\omega(s) = \dot{\theta}(s)$$



stiffness
 $K = \frac{EA}{L}$
Rod behaves like a spring

