what is an impulse response

Contents map

developed content units	taxonomy levels
Dirac delta	u1, e1
impulse response	u1, e1

| prerequisite content units	taxonomy levels
superposition principle	u1, e1
Euler backwards discretization	u1, e1
LTI RR	u1, e1

Main ILO of sub-module "what is an impulse response"

> **Describe** what the impulse response of an LTI system is in practice

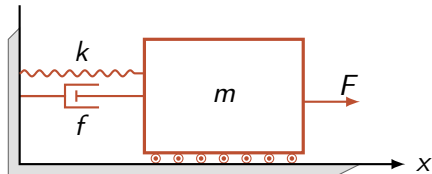Impulse response ↔ superposition principle ↔ LTI system

talking about the impulse response of a nonlinear system is such
a big mistake that may make you fail the exam on the spot

Practical example: spring-mass system
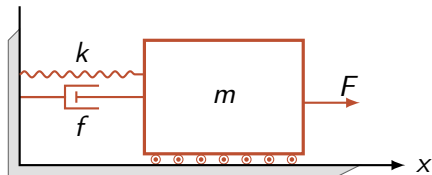
- output = position
- input = force (in Newtons)

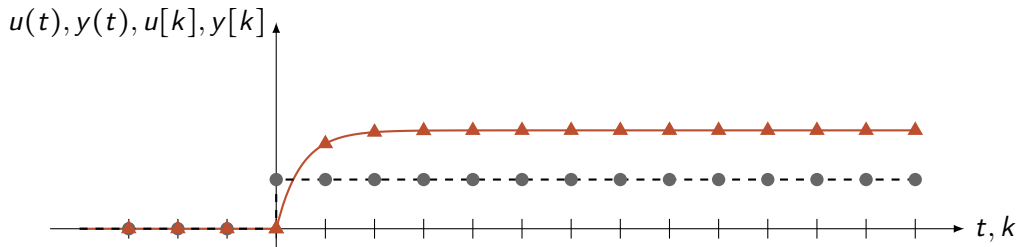# Discretizing the spring-mass system with a Euler backwards scheme
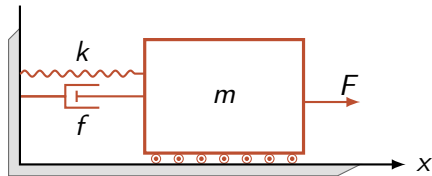

$$\text{Newton} \mapsto \ddot{y}(t) + a_1\dot{y}(t) + a_0y(t) = b_0u(t)$$
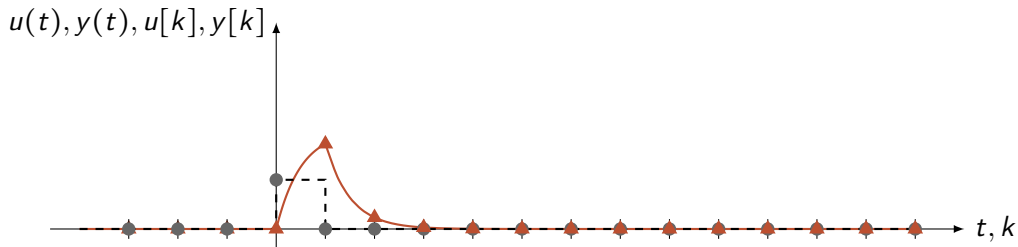
becomes, with Euler,
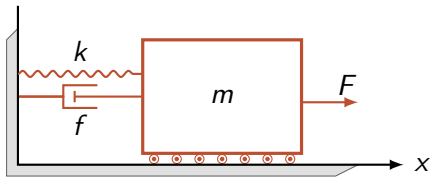
$$y^{++} + \alpha_1 y^{+} + \alpha_0 y = \beta u$$

What does it mean to apply a control signal $u[k] = \text{step}$?
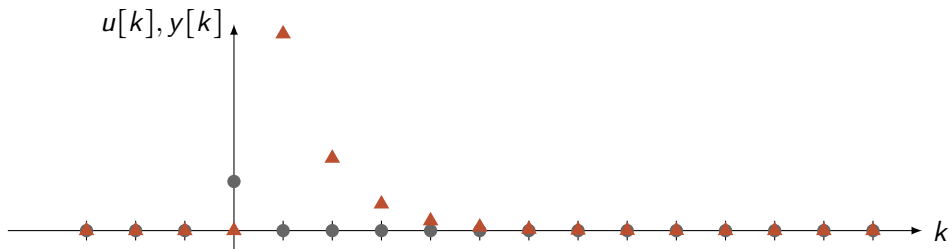
And $u[k] = 1$ only for $k = 0$, and 0 otherwise?

(i.e., $u[k] = \delta[k]$)

The impulse response for DT LTI systems

Discussion

Where would you draw $\delta[k-4]$?
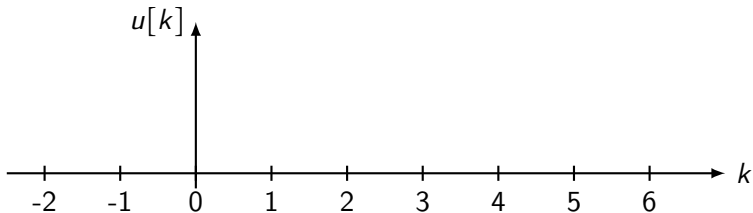
Summarizing

> **Describe** what the impulse response of an LTI system is in practice

- an opportune behavior of the response of a LTI system to a discrete Dirac's delta

Most important python code for this sub-module

Important libraries / methods

- `https://docs.scipy.org/doc/scipy/reference/generated/scipy.signal.impulse.html`
- `https://python-control.readthedocs.io/en/latest/generated/control.impulse_response.html`

Self-assessment material

Question 1

What is the impulse response of an LTI system?

Potential answers:

  I: The output of the system when the input is a discrete Dirac's delta.

 II: The output of the system when the input is a step function.

III: The output of the system when the input is a sinusoidal signal.

IV: The output of the system when the input is a random signal.

 V: I do not know

Question 2

Why is the impulse response meaningful only for LTI systems?

Potential answers:

   I: Because nonlinear systems do not have outputs.

  II: Because the impulse response relies on the superposition principle, which is valid only for LTI systems.

 III: Because the impulse response is only defined for continuous-time systems.

 IV: Because the impulse response is too complex for nonlinear systems.

  V: I do not know

Question 3

What happens to the impulse response of a discrete-time LTI system if the input is $\delta[k-4]$?

Potential answers:

   I: The impulse response becomes zero.
  II: The impulse response is shifted by 4 time units.
 III: The impulse response is scaled by a factor of 4.
  IV: The impulse response becomes nonlinear.
   V: I do not know

Question 4

What is the practical significance of the impulse response in analyzing LTI systems?

Potential answers:

- I: It allows us to ignore the system's initial conditions.
- II: It characterizes the system's behavior and can be used to determine the output for any input.
- III: It ensures the system response is always sinusoidal.
- IV: It makes the system response independent of the input.
- V: I do not know

Question 5

In the context of a spring-mass-damper system, what does the impulse response represent?

Potential answers:

   I: The steady-state position of the mass.

  II: The displacement of the mass over time after an instantaneous force is applied.

 III: The force required to keep the mass at rest.

 IV: The frequency of oscillation of the mass.

  V: I do not know

Recap of sub-module "what is an impulse response"

- impulse responses are directly connected to step responses
- actually this connection is valid only if the system is LTI

?