Course Project
Motion of a Pendulum Attached to a Spring
Deadline Friday 17th of Bahman

- **Project Objective**

In this project, you will study the **motion of a pendulum that is attached to a spring**, using:

1. **Analytical equations (MATLAB)**
2. **Multibody simulation (SimScape, Adams)**

The goal is **not to design** the system, but to:

- Understand how the motion happens,
- Compare mathematical modeling with simulation results.

This project strengthens your understanding of:

- Kinematics and kinetics
- Coupled motion (translation + rotation)
- Use of engineering simulation tools

- **System Description (Physical Meaning)**

The system consists of:

- A **mass (m)** hanging from a **spring (k)**
- The spring is attached to a fixed ceiling
- The mass can:
  - **Swing like a pendulum**
  - **Move up and down as spring stretches**

So the motion is **two-dimensional** and **coupled** (Fig.1.).

Two motions happen at the same time:

1. **Angular motion** → pendulum swinging
2. **Radial motion** → spring stretching and compressing

This makes the system more interesting than a simple pendulum.

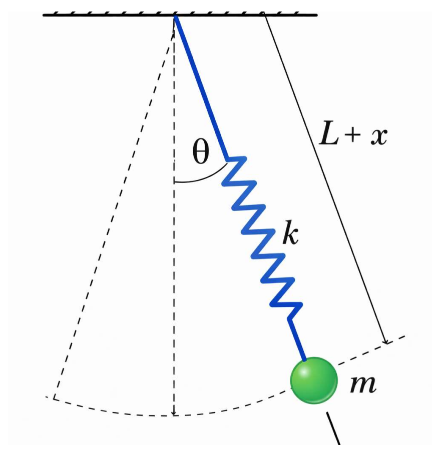

Fig.1. Problem Schematics

- **Variables You Will Use**

Symbol Meaning

$x(t)$	Extension of the spring
$\theta(t)$	Swing angle
m	Mass of the bob
k	Spring stiffness
L	Natural length of spring
g	Gravity

- **What You Are Expected to Do**

Part 1 — Analytical (MATLAB)

Coordinate systems used in this problem are shown in Fig.2. $\overrightarrow{a_1}$ and $\overrightarrow{a_2}$ are the unit vectors of the inertial coordinate, while $\overrightarrow{b_1}$ and $\overrightarrow{b_2}$ are rotational local unit vectors attached to the pendulum.

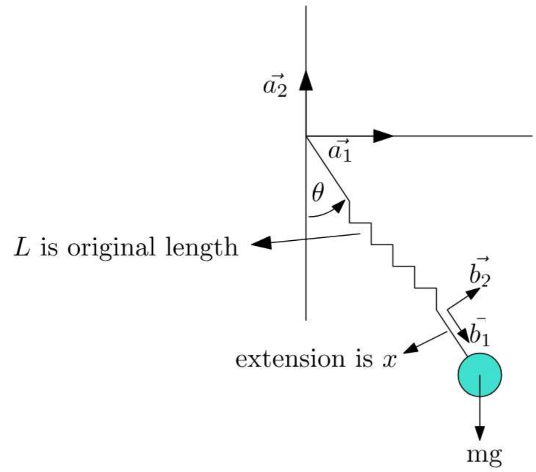

Fig.2. Coordinates

Your task is to:

1. Knowing the pendulum position vector at any instant is $\vec{r} = (L + x)\,\overrightarrow{b_1}$, derive the equations for the velocity and acceleration vectors.
2. Use Newton's law and derive the equations of motion (two ODEs) for x and θ.
3. Let initial conditions be:
   - $L = 1\ (m), k = 1\ \left(\frac{N}{m}\right), m = 1\ (kg)$
   - $x(0) = 0.1\ (m), \dot{x}(0) = 0\ \left(\frac{m}{s}\right), \theta(0) = 20°, \dot{\theta}(0) = 0\ (\frac{rad}{s})$
4. Implement the equations in MATLAB
5. Solve them numerically using ode45
6. Plot:
   - Spring extension vs time $(x - t)$
   - Swing angle vs time $(\theta - t)$
   - Motion of the mass (x–y trajectory)

Part 2 — Simulation

Create the model in ADAMS using the inputs from Part1. Each model includes:

- A pivot
- A spring
- A mass
- Gravity

Your tasks:

1. Run the simulation
2. Extract:
   - Spring extension
   - Angle of motion
   - Position of the mass
3. Plot the same quantities as in Part1.

Optional Bonus (20%): Simulation in SimScape and extracting the same outputs.

Part 3 — Comparison & Discussion

You will compare:

Quantity	**MATLAB**	**Adams**	**SimScape**
Spring extension	✓	✓	✓
Swing angle	✓	✓	✓
Energy	✓	✓	✓
Motion shape	✓	✓	✓

Then answer:

- Are the results similar?
- Why are small differences expected?

- **What You Must Submit**

1 Report (max 10 pages)

Include:

- System description
- Plots (with labels)
- Comparison table
- Explanation of differences

2 MATLAB Files

- ODE code
- Plotting script

3 Simulation Results

- Screenshots or exported plots from Adams and SimScape