Problem 1

A mechanical system consists of a mass, an incline, a linear spring and a nonlinear damper, see Figure 1. The mass slides on the incline. The friction between mass and incline can be modeled with a hyperbolic tangent friction (Eq. 2.10 in the notes) with $\mu_k = 0.2$ and $v_{tnh} = 0.02\ \frac{m}{s}$.

A linear spring and a nonlinear (impact) damper are positioned as shown in Figure 1.

The following data is given: Mass $m = 200\ kg$, incline angle $\theta = 30°$, undeformed length of spring $L_0 = 50\ mm$, spring stiffness $k = 150\ kN/m$, damping constant $b = 4000\ \frac{N\cdot s}{m\cdot\sqrt{m}}$.

The nonlinear damper gives an impact damping force according to:

$$F = \begin{cases} b \cdot \sqrt{\Delta} \cdot \dot{\Delta} & \Delta \geq 0 \\ 0 & \Delta < 0 \end{cases}$$

where Δ is the compression of the linear spring.

At time $t = 0\ s$ the position of the mass is $x = 150\ mm$ and the velocity is $\dot{x} = 0\ \frac{mm}{s}$.

Make a simulation model of the mechanical system and simulate from $t = 0\ s$ to $t = 3\ s$.

Plot the position and velocity of the mass x, as a function of time. Report the maximum magnitude of x and $\dot{x}$. Also report the RMS value of these two quantities.

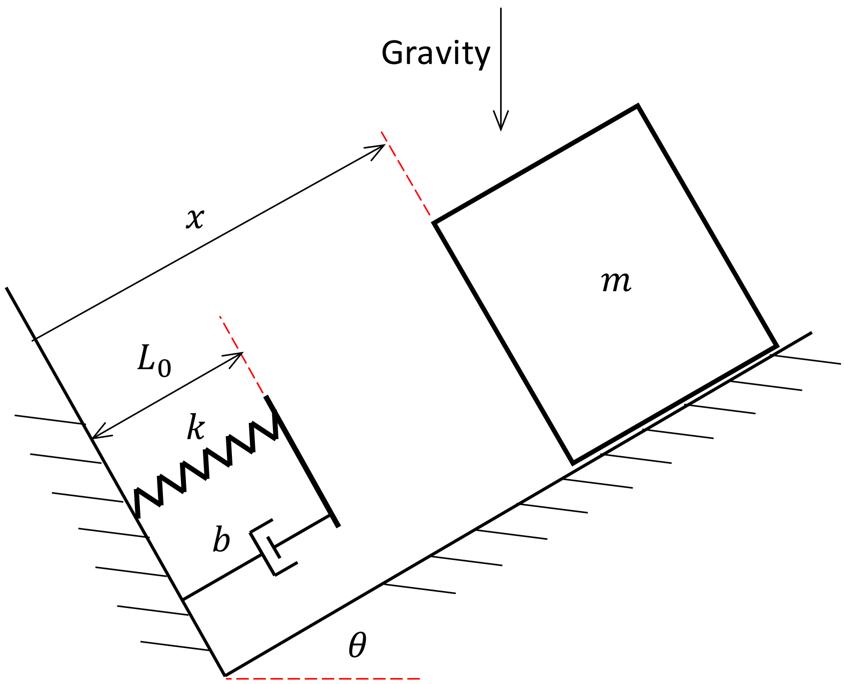
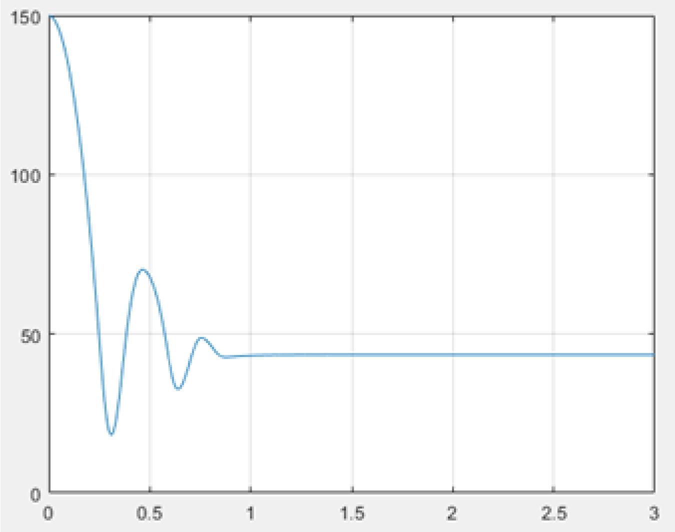
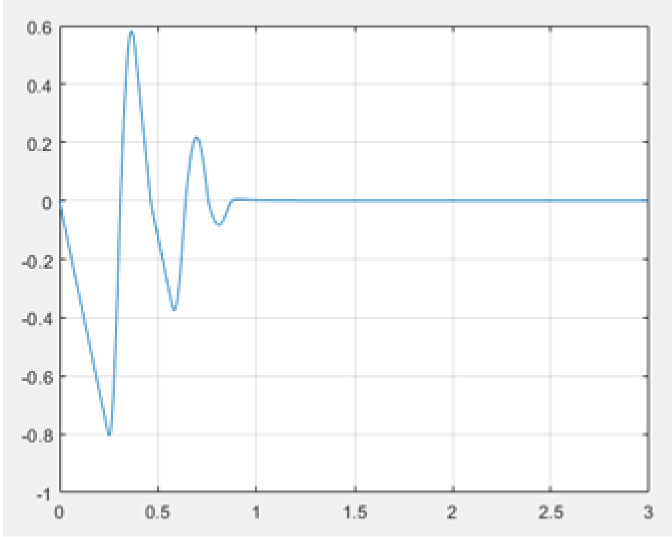


Figure 1 Mass on incline.

Solution as plot of $x(t)$ in mm vs time in seconds (left) and $\dot{x}(t)$ in m/s vs time in seconds (right).





Problem 2

Two masses are connected via a rope that goes around a sheave, see Figure 2. The inertia of the rope and sheave can be neglected and there is no friction between the mass and the ground or inside the sheave.

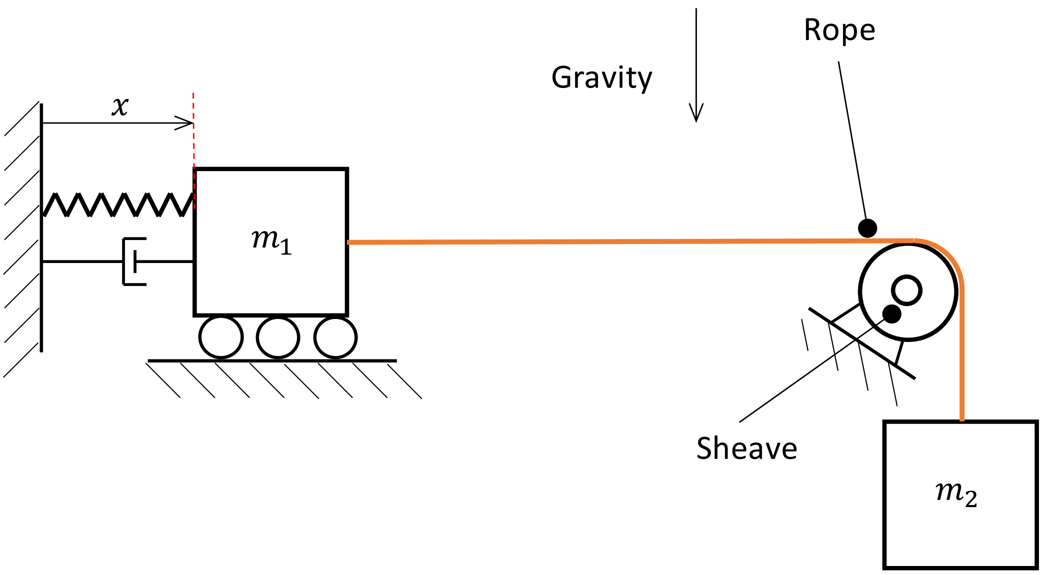


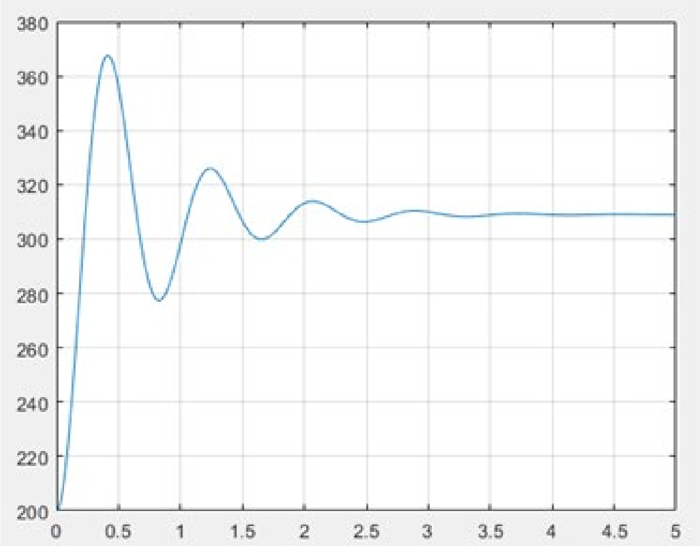
Figure 2 Two masses connected via a rope.

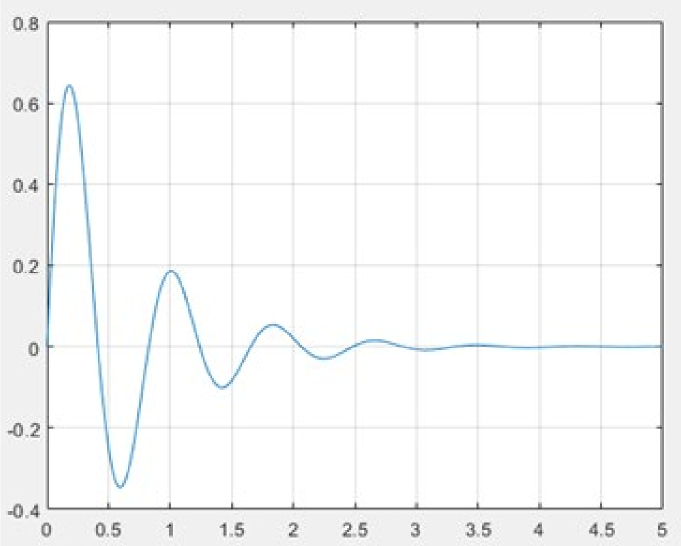
The spring is linear and can work in both compression and tension. The damper is linear. The following data is given: Masses $m_1 = 100\ kg$ and $m_2 = 200\ kg$, undeformed length of spring $L_0 = 200\ mm$, spring stiffness $k = 18\ kN/m$, damping constant $b = 900\ \frac{N \cdot s}{m}$.

At time $t = 0\ s$ the spring is unstretched $x = 200\ mm$ and the velocity is $\dot{x} = 0\ \frac{mm}{s}$.

Make a simulation model of the mechanical system and simulate from $t = 0\ s$ to $t = 5\ s$.
Plot the position and velocity of the mass x, as a function of time.

Solution as plot of $x(t)$ in mm vs time in seconds (left) and $\dot{x}(t)$ in m/s vs time in seconds (right).





Problem 3

In Figure 3 is shown a power transmission that consists of a motor, a gear box and a drum. Attached to the drum is a wire that holds a vertically translating payload.

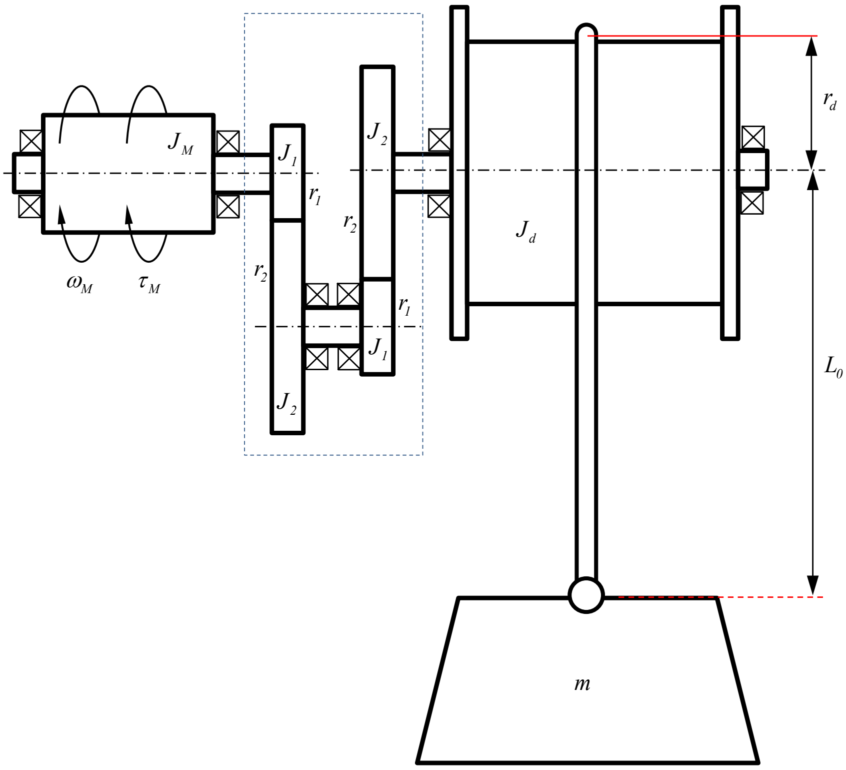


Figure 3 Payload connected via a wire to a drive train that consists of a motor, a gearbox and a drum.

The following inertia data is given: $J_m = 0.8\ kg \cdot m^2$, $J_1 = 0.1\ kg \cdot m^2$, $J_2 = 1.5\ kg \cdot m^2$, $J_d = 8\ kg \cdot m^2$ and $m = 10000\ kg$.

The following geometry data is given: $r_1 = 80\ mm$, $r_2 = 480\ mm$, $r_d = 600\ mm$ and $L_0 = 10\ m$.

The torque provided by the motor is a function of the motor speed. During hoisting, see Figure 4.

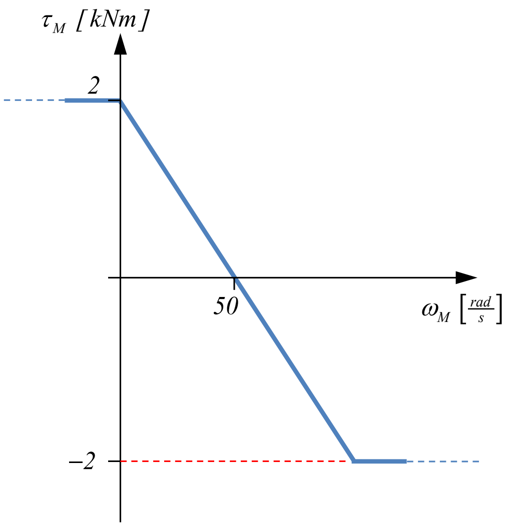
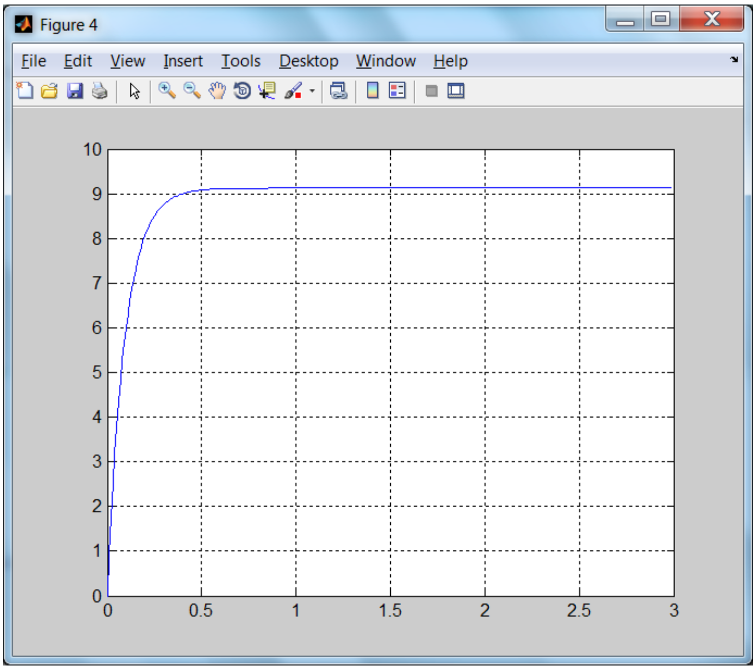


Figure 4 Motor torque-speed characteristics during hoisting.

Simulate the first three seconds of a hoisting situation. The motor starts from rest and the payload hangs $L_0 = 10\ m$ below the centerline of the drum.

Solution as plot of $\dot{\theta}(t) = \omega_M(t)$ in radians pr. second vs time in seconds.



Problem 4

Two masses are connected via a rope and two sheaves, see Figure 5. The inertia of the rope and sheaves can be neglected and there is no friction between the mass and the ground or inside the sheaves.

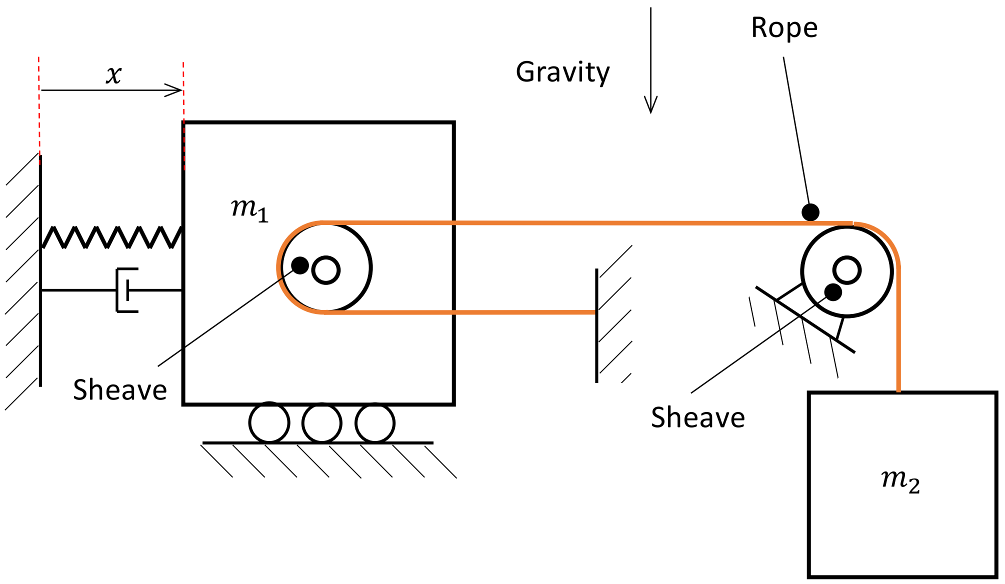


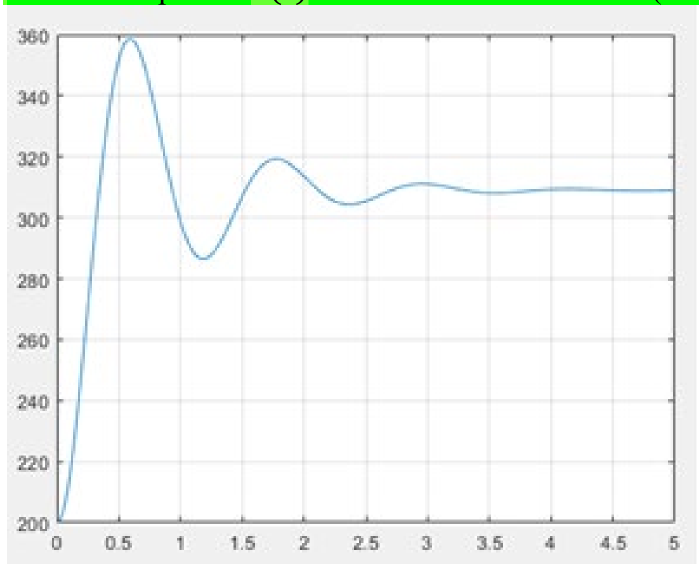
Figure 5 Two masses connected via a rope and a sheave-pulley system.

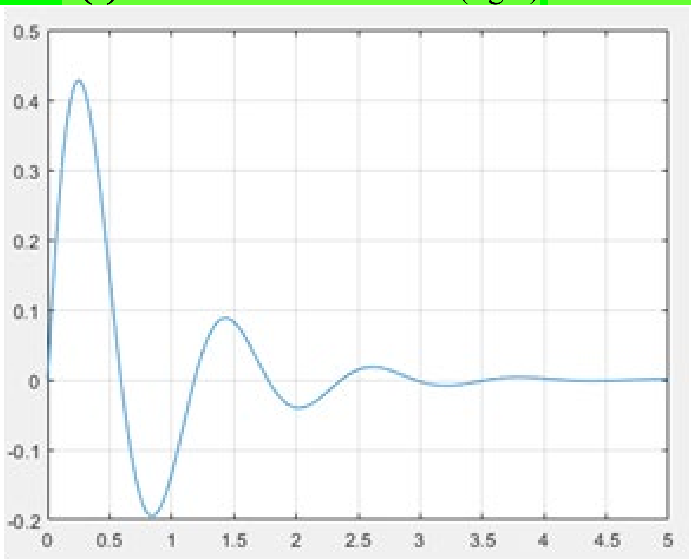
The spring is linear and can work in both compression and tension. The damper is linear. The following data is given: Masses $m_1 = 400\ kg$ and $m_2 = 200\ kg$, undeformed length of spring $L_0 = 200\ mm$, spring stiffness $k = 36\ kN/m$, damping constant $b = 3200\ \frac{N \cdot s}{m}$.

At time $t = 0\ s$ the spring is unstretched $x = 200\ mm$ and the velocity is $\dot{x} = 0\ \frac{mm}{s}$.

Make a simulation model of the mechanical system and simulate from $t = 0\ s$ to $t = 5\ s$.
Plot the position and velocity of the mass x, as a function of time.

Solution as plot of $x(t)$ in mm vs time in seconds (left) and $\dot{x}(t)$ in m/s vs time in seconds (right).





Problem 5
In a more detailed model of the system in problem 3 the flexibility of the wire is taken into account, see Figure 6.

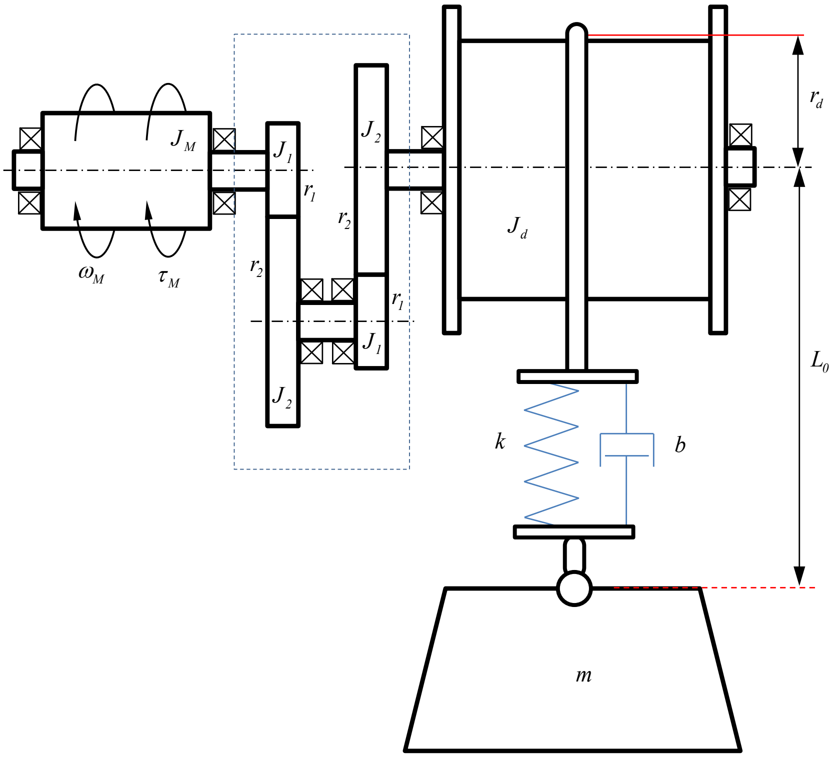


Figure 6 Payload connected via a wire to a drive train that consists of a motor, a gearbox and a drum. The wire is modeled as a spring-damper.

The following data is given for the wire: $k = 10^7 \frac{N}{m}$ and $b = 2 \cdot 10^4 \frac{N \cdot s}{m}$. Simulate the first three seconds of a hoisting situation. Initially, the motor and the payload are both stationary. The wire is stretched so that: $L_0 = 10\, m + \frac{m \cdot g}{k}$.

Solution as plot of $\dot{\theta}(t) = \omega_M(t)$ in radians pr. second vs time in seconds.