Problem 1
In Fig. 1 is shown a simple hydraulic system with a pressure source, an orifice and a constant volume.

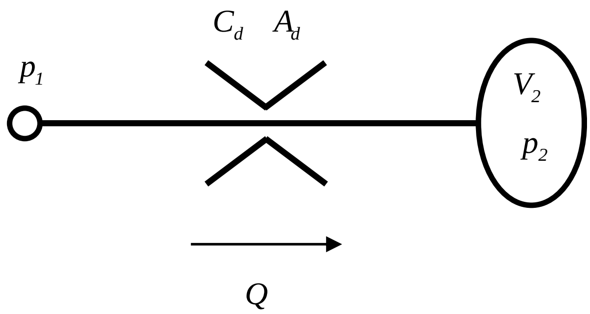
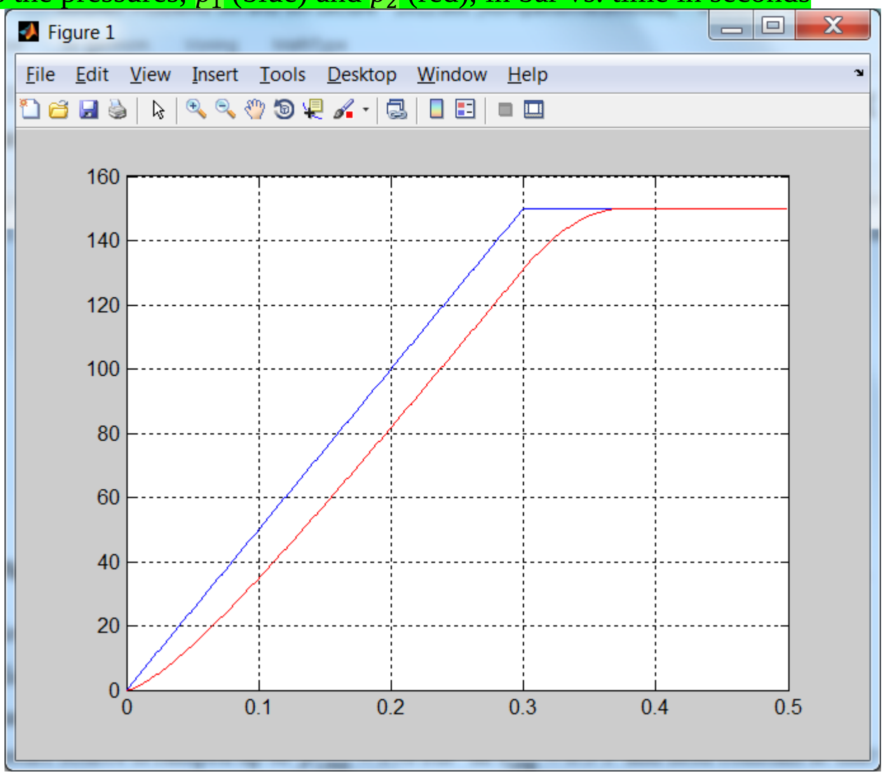


Figure 1 Hydraulic system consisting of a pressure source, an orifice and a volume.

The following data is given for the fluid: density $\rho = 850\ \frac{kg}{m^3}$ and oil stiffness $\beta = 900\ \frac{N}{mm^2}$.
The orifice discharge data: $C_d = 0.55$ and $A_d = 3\ mm^2$.
The volume: $V_2 = 2000\ cm^3$ and initial pressure $p_2^{(init)} = 0\ bar$.
The pressure source is ramped up from no pressure to $p_{1,max} = 150\ bar$ in $t_{ramp} = 0.3\ s$ and held constant.

Simulate the system for a period of 0.5 seconds and plot p_1 and p_2 as a function of time.

Solution as the pressures, p_1 (blue) and p_2 (red), in bar vs. time in seconds



Problem 2

In Fig. 2 is hydraulic system with a pressure source, an orifice and a cylinder supporting a payload.

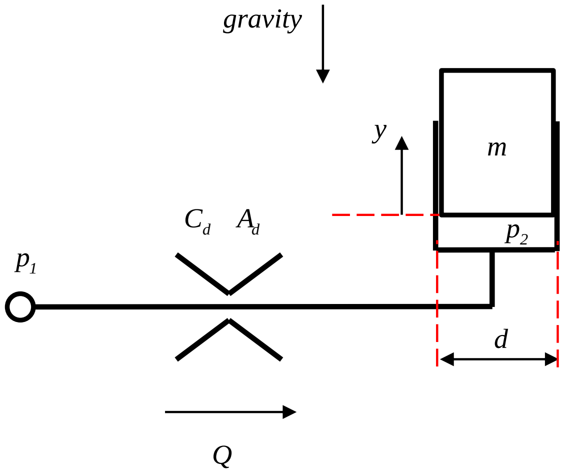
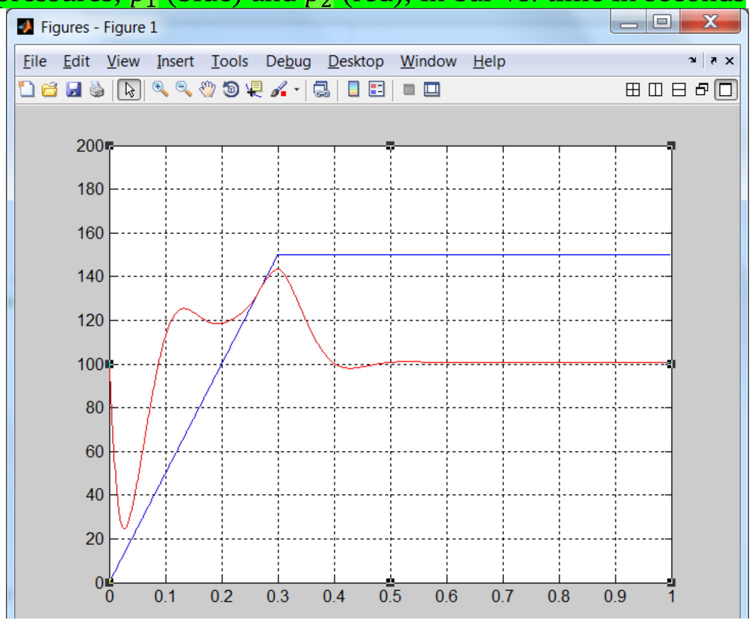


Figure 2 Hydraulic system consisting of a pressure source, an orifice and a payload.

The following data is given for the fluid: density $\rho = 850\ \frac{kg}{m^3}$ and oil stiffness $\beta = 900\ \frac{N}{mm^2}$.
The orifice discharge data: $C_d = 0.55$ and $A_d = 15\ mm^2$.
Piston/payload data: diameter $d = 63\ mm$ and $m = 3200\ kg$.
The volume of the cylinder chamber is variable. It is a function of the piston travel $V_2 = V_{2,min} + A \cdot y$, where $V_{2,min} = 2000\ cm^3$ and the piston area is referred to as A.
The initial pressure $p_2^{(init)}$ holds the payload in static equilibrium and the payload starts from rest at $y = 0\ mm$.
The pressure source is ramped up from no pressure to $p_{1,max} = 150\ bar$ in $t_{ramp} = 0.3\ s$ and held constant at that value.

Simulate the system for a period of 1 second and plot p_1 and p_2 as a function of time.

Solution as the pressures, p_1 (blue) and p_2 (red), in bar vs. time in seconds



Problem 3

A hydraulic-mechanical system is shown in Fig. 3. It consists of a flow source Q_0, four fixed orifices $A_{d1..4}$, and two double acting cylinders. Each cylinder is attached to a payload that they push horizontally. Gravitational loads can be neglected.

The cylinders are identical, and they are fixed to the ground. Inside each cylinder is a piston with diameter $d = 42\,mm$. The pistons are connected to a piston rod with diameter $d_r = 30\,mm$. The maximum piston travel is $L_0 = 1600\,mm$

The mass of the piston and the piston rod can be neglected. The mass of the two payloads are $m_1 = 3000$ kg, and $m_2 = 5000$ kg.

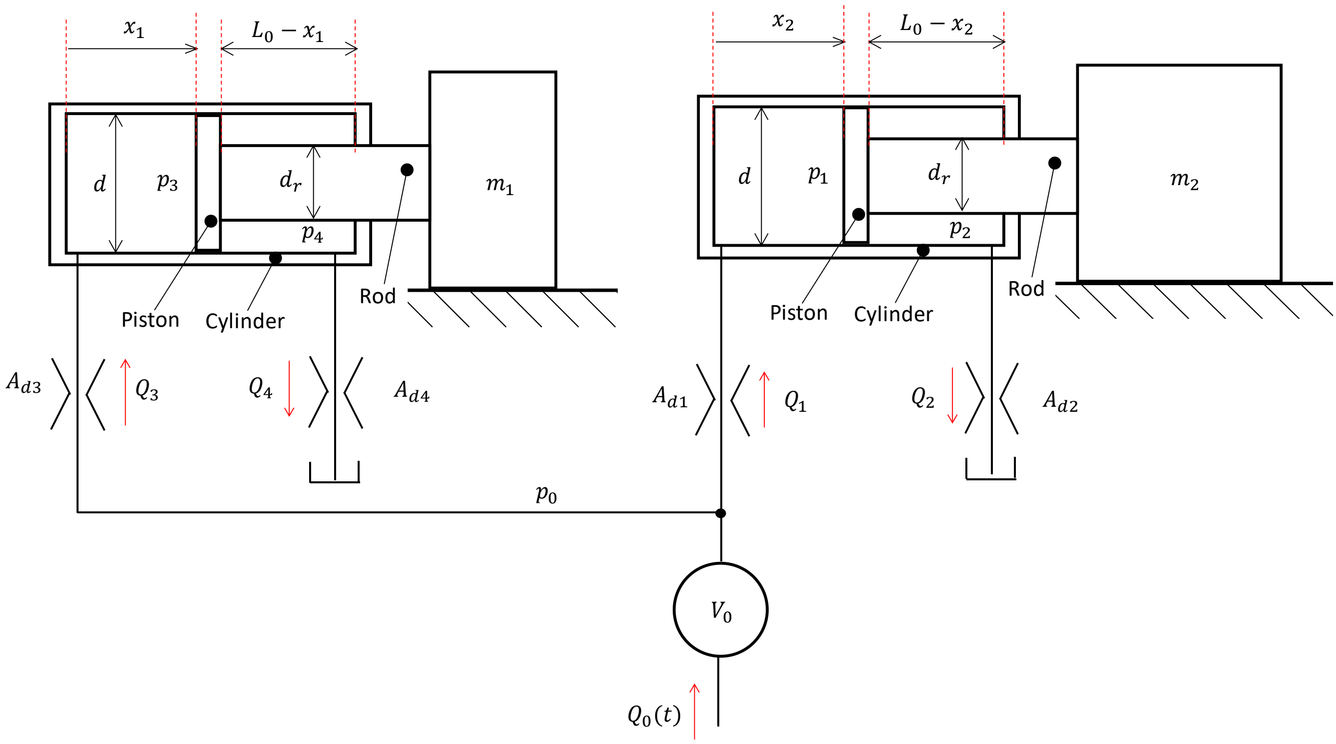


Figure 3 Hydraulic-mechanical system.

Both masses are subject to a friction force which can be modeled as a function of the speed, see Fig. 4:

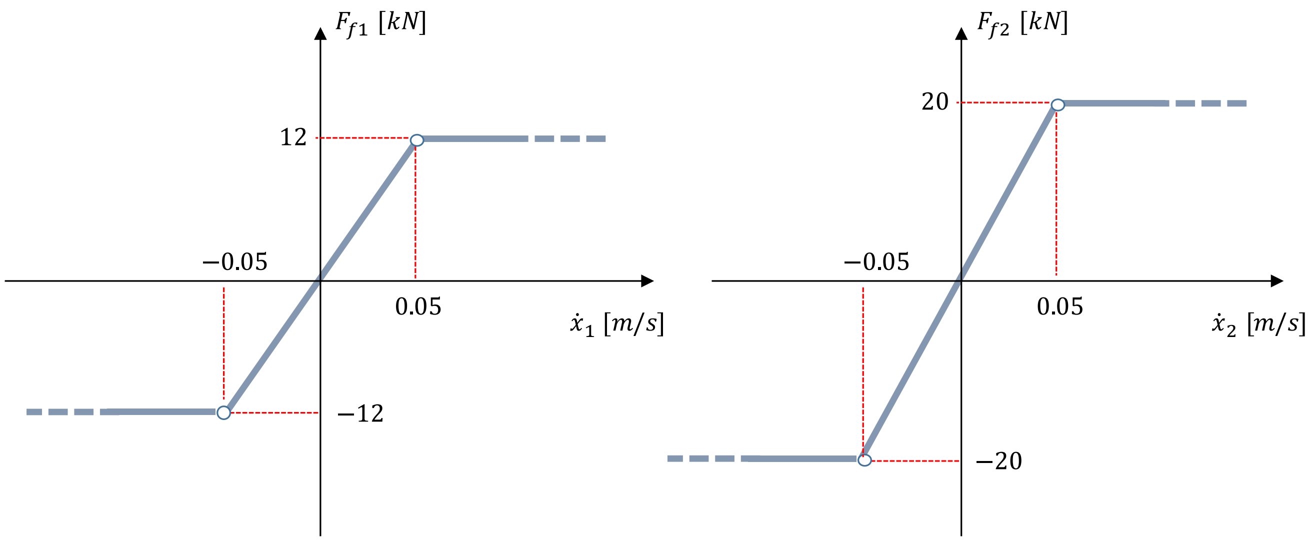


Figure 4 Variation of friction forces vs piston speed.

The friction forces should always act against the direction of motion.

All four orifices have the same discharge coefficient $C_d = 0.6$. The discharge areas of the fixed orifices are $A_{d1} = A_{d3} = 9\ mm^2$ and $A_{d2} = A_{d4} = 5\ mm^2$.

The liquid has density $\rho = 875 \frac{kg}{m^3}$ and bulk modulus (stiffness) $\beta = 830\ MPa$. The flow source delivers a time dependent flow as shown in Figure 5.

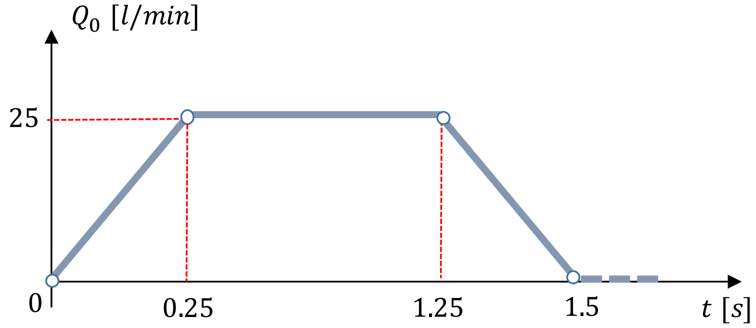


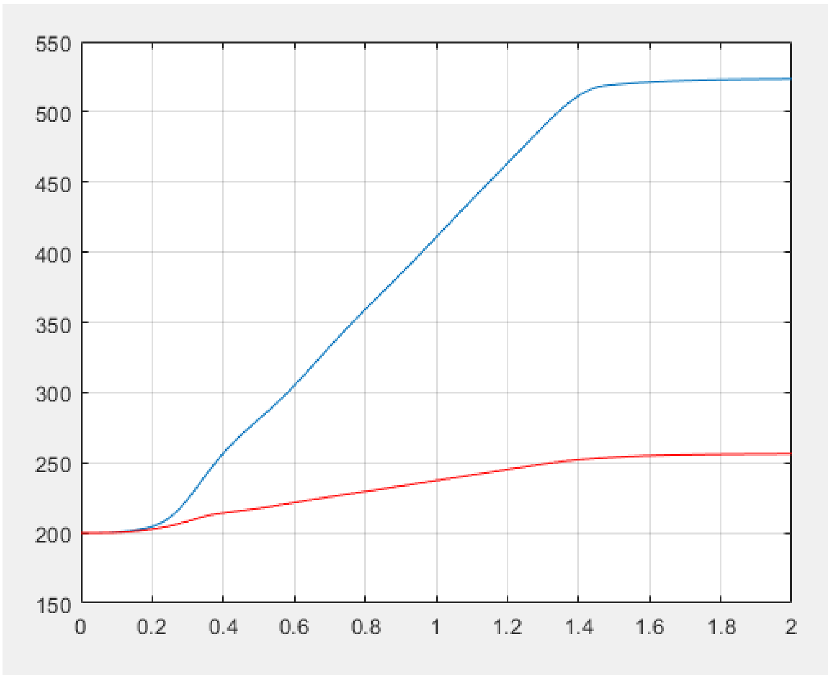
Figure 5 Variation of source flow vs time.

The inlet can be modeled as a constant volume, $V_0 = 1.0\ dm^3$.

At time $t = 0\ s$ the positions of the pistons are, $x_1 = x_2 = 200\ mm$ and $\dot{x}_1 = \dot{x}_2 = 0\ mm/s$. At time $t = 0\ s$ all the five pressures are $p_{0..4} = 0\ bar$.

Make a simulation model of the hydraulic-mechanical system and simulate from $t = 0\ s$ to $t = 2\ s$.
Plot the positions of the pistons, x_1 and x_2, as a function of time.
Plot the pressures p_0, p_3, and p_4 as a function of time.

Solution as the piston positions, x_1 (blue) and x_2 (red), in mm vs. time in seconds



Solution as the pressures, p_0 (blue), p_3 (red), and , p_4 (green), in bar vs. time in seconds