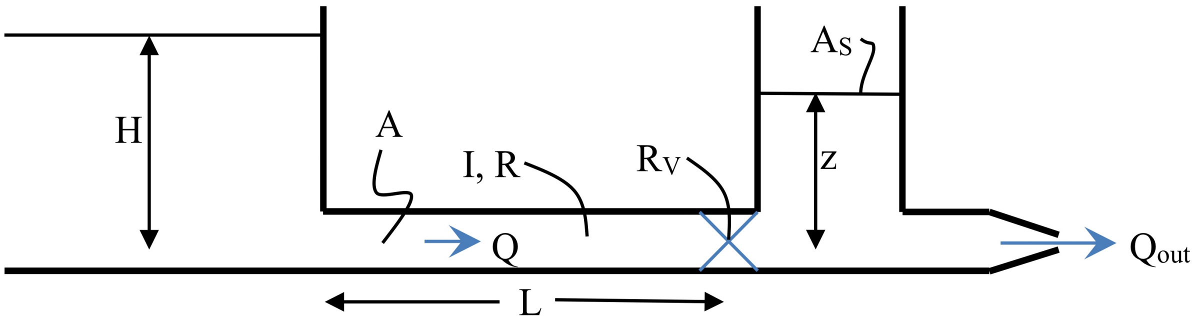
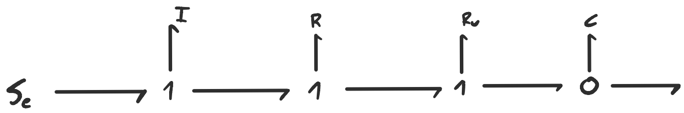
TEP4240
System simulation
Exercise 6

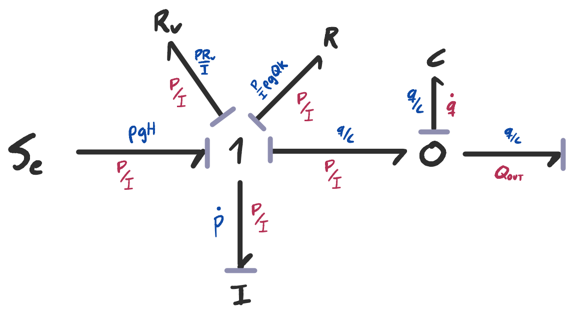
Problem 1



Raw Bond Graph:



Modified Bond Graph:



$\Rightarrow$

$$\begin{cases} \dot p = \rho g H - \frac{q}{C} - \frac{p}{I}(R_v + \rho g Q k) \\ \dot q = \frac{p}{I} - Q_{out} \end{cases}$$

b) Steady state equation: $\dot p = \dot q = 0$

$$\rho g H - \frac{q}{C} - \frac{p}{I}(R_v + \rho g Q k) = 0$$

Substitute $Q_{out} = \frac{p}{I}$, and use mass balance: $Q = Q_{out}$

$$\rho g H - \frac{q}{C} - Q(R_v + \rho g Q k) = 0$$

Also we have $\frac{q}{C}$ = Pressure @ R_v = $\rho g z$

$$\rho g (H - z) - Q R_v - \rho g Q^2 k = 0$$

$$\Rightarrow R_v = \frac{\rho g}{Q}(H - z - kQ^2)$$

c) When simulating:

$C = \frac{A_s}{\rho g}$, $I = \frac{\rho L}{A}$

c)

```
clc
close all
clear all
```

convertVariables Class

```
classdef convertVariables
    % Converting from [p,q] to [Q,z]
    properties
        H = 100;
        Qout
        k = 0.01;
        A = 0.1;
        As = 0.2;
        z0 = 90;
        L = 50;

        rho = 1000;
        g = 9.81;

        I
        C
        Rv
    end

    methods
        function obj = convertVariables(Qout)
            obj.Qout = Qout;
            obj.I = obj.rho * obj.L / (obj.A);
            obj.C = obj.As / (obj.rho * obj.g);
            obj.Rv = obj.rho * obj.g * (obj.H - obj.z0 - obj.k * obj.Qout^2) / obj.Qout;
        end
    end

    methods(Static)
        function [Q, z] = state2real(p, q, obj)
            Q = p / obj.I;
            z = q / obj.As;
        end

        function [p, q] = real2state(Q, z, obj)
            p = Q * obj.I;
            q = z * obj.As;
        end
    end
end
```

Odefun function

(made this before I made the class. Therefore: constants directly inserted)

```
function dydt = odefun_ex6(t, y, Qout)
    % Extract variables from the y vector
    p = y(1);
    q  = y(2);

    %From exercise text
    H = 100;
    k = 0.01;
    A = 0.1;
    As = 0.2;
    z0 = 90;
    L = 50;

    rho = 1000;
    g = 9.81;

    I = rho*L/A;
    C = As/(rho*g);
    Rv = rho*g*(H-z0-k*Qout^2)/Qout;

    % Define the system of ODEs
    p_dot = rho*g*H - q/C - p/I*(Rv + rho*g*(p/I)*k);
    q_dot = p/I - Qout;

    % Pack the derivatives into a column vector
    dydt = [p_dot; q_dot];
end
```

Setting the initial condition

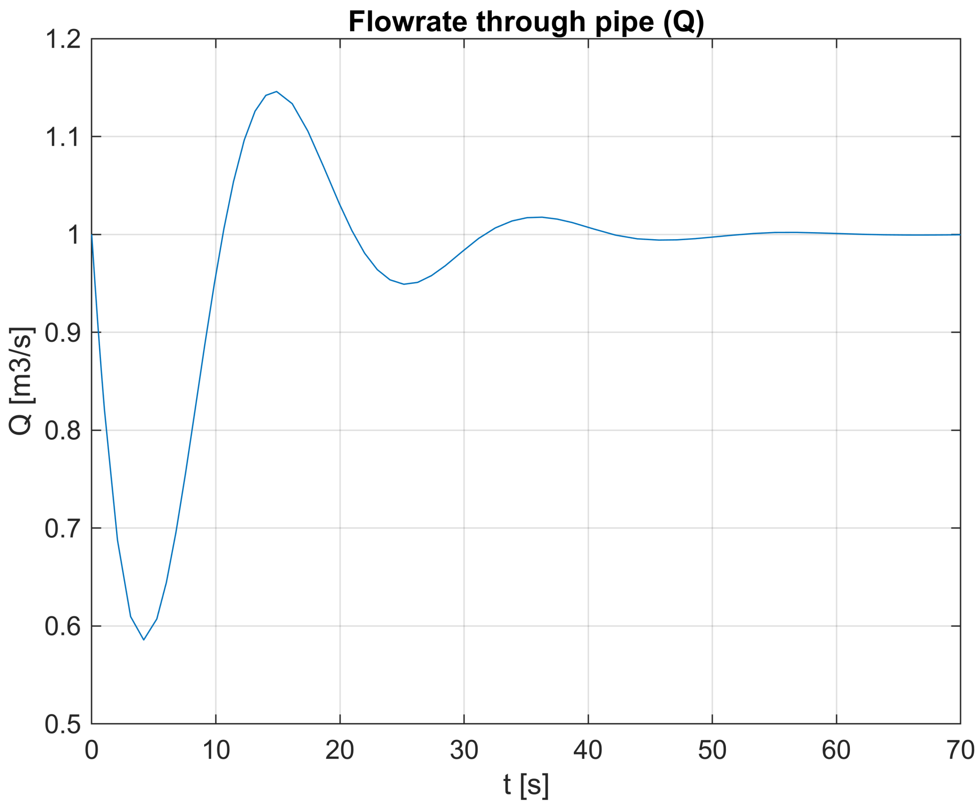
```
Q_start = 1;
z_start = 100;

Qout = 1;
converter = convertVariables(Qout);

[p_start, q_start] = convertVariables.real2state(Q_start, z_start, converter);  % Call the meth
```

Simulate to *tmax*

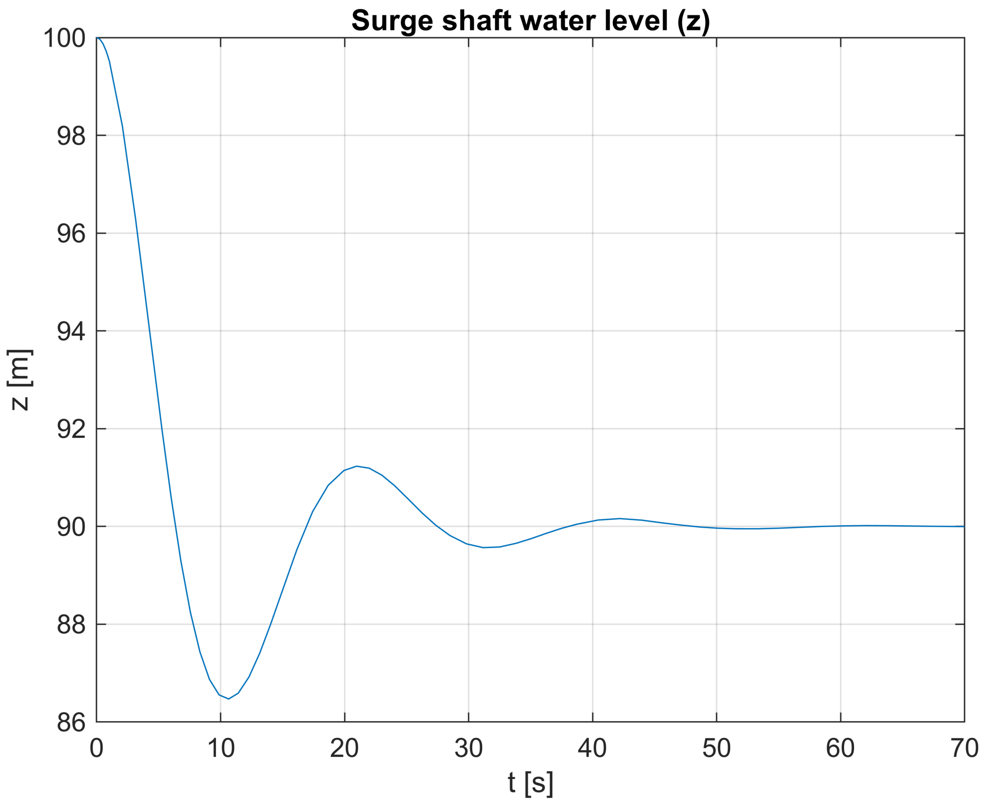
```
tmax = 70;
[t, Y] = ode45(@(t, y) odefun_ex6(t, y, Qout),[0 tmax], [p_start q_start]);
p = Y(:,1);
q = Y(:,2);

[Q, z] = convertVariables.state2real(p, q, converter);  % Call the method with the instance
```

Plots

```
plot(t,Q)
title("Flowrate through pipe (Q)")
xlabel("t [s]")
ylabel("Q [m3/s]")
grid on
```




```
plot(t,z)
title("Surge shaft water level (z)")
xlabel("t [s]")
ylabel("z [m]")
grid on
```



d)

The initial conditions now reads the steady state values from c)

```
Q_start = 1;
z_start = 90;
```

Change the Qout value in the *converter* instance (from *convertVariables* class) to 90% of it original value $\left(0.9\ \frac{m^3}{s}\right)$. Does not make a new instance of the class, because we assume that Rv resistance is the same as before, i.e designed for z0 = 90m.

```
Qout = 0.9;
converter.Qout = Qout;

[p_start, q_start] = convertVariables.real2state(Q_start, z_start, converter);
```

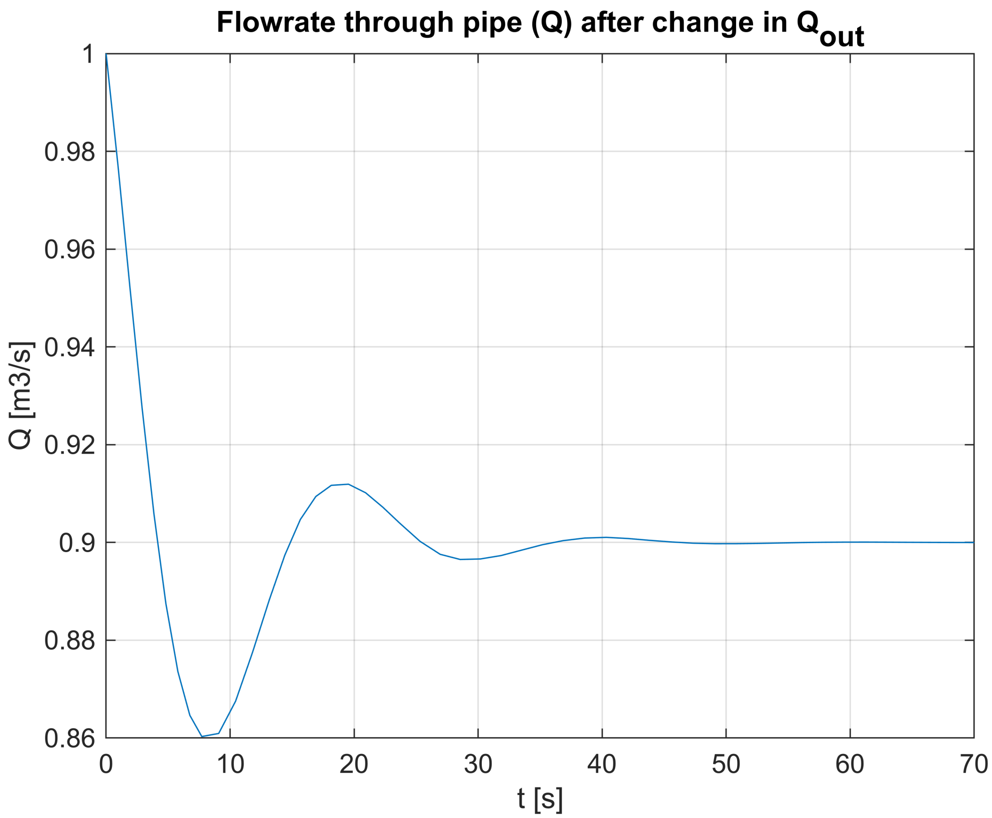
Simulate to *tmax*

```
tmax = 70;
[t, Y] = ode45(@(t, y) odefun_ex6(t, y, Qout),[0 tmax], [p_start q_start]);
p = Y(:,1);
q = Y(:,2);
```

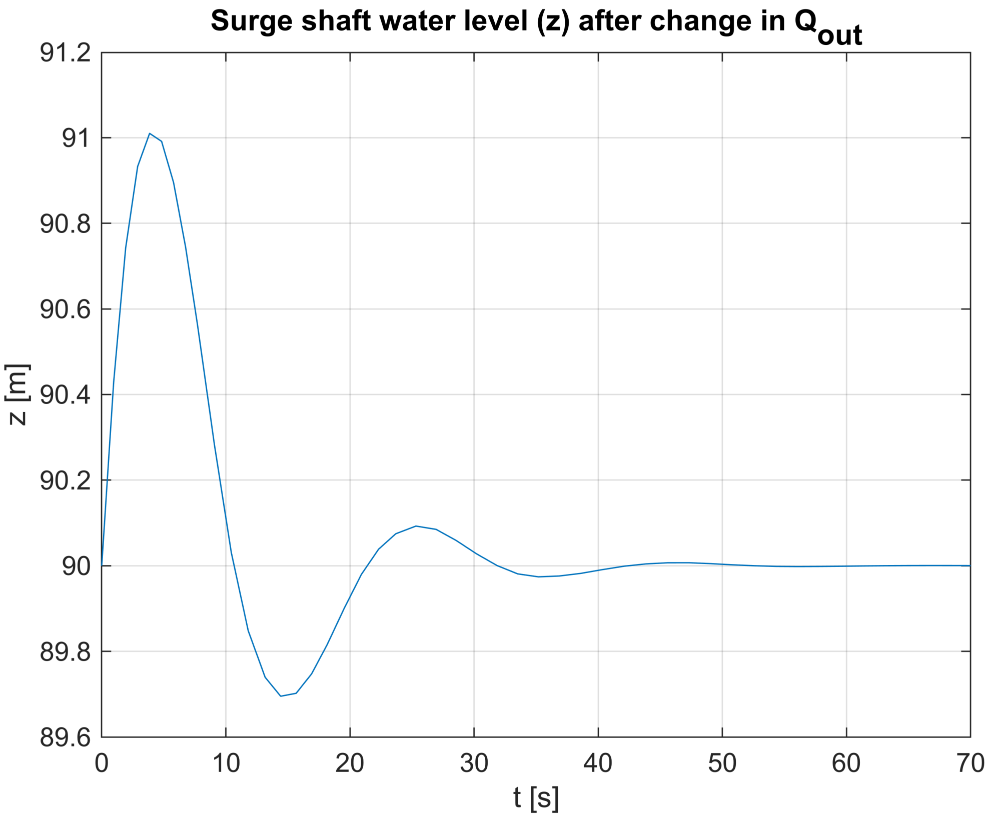
```
[Q, z] = convertVariables.state2real(p, q, converter);
```

Plots

```
plot(t,Q)
title("Flowrate through pipe (Q) after change in Q_{out}")
xlabel("t [s]")
ylabel("Q [m3/s]")
grid on
```




```
plot(t,z)
title("Surge shaft water level (z) after change in Q_{out}")
xlabel("t [s]")
ylabel("z [m]")
grid on
```



The results make sense because when the Qout suddenly drops, then Q>Qout will fill the surge shaft, and after a while, the Q value will drop low enough to Q = Qout to obtain mass balance. Then water level will drop to the level the resistance Rv was initially designed for.

e)

:)