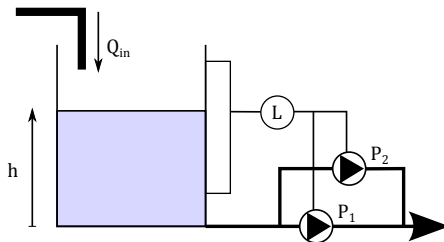


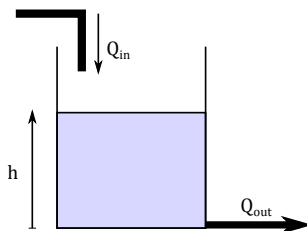
## 1 Wastewater pumps

Wastewater vertical cylindrical tank has a diameter of 4 m and a height of 5 m. Water is pumped out of the tank with two pumps: the main pump  $P_1$  and an auxiliary pump  $P_2$ , both pump up  $54 \text{ m}^3/\text{h}$ . Pump  $P_1$  is placed in service at  $h = 3 \text{ m}$  and out at  $1 \text{ m}$ . Pump  $P_2$  at levels  $4 \text{ m}$  and  $2 \text{ m}$ , respectively.



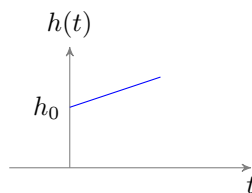
Initial conditions are: wastewater level  
 $h = 2 \text{ m}$ ,  
inflow  $Q_{in} = 0.5 \text{ m}^3/\text{min}$ ,  
 $P_1$  is ON.

Starts to rain, and rain water with a constant inflow fills sewage tank with  $Q_{in,r} = 1.5 \text{ m}^3/\text{min}$ . Rain lasts for  $3/4$  hours. How does the wastewater level change in the tank in time  $h(t)$ , and how do pumps  $P_1$  and  $P_2$  work during this time?



$V = h \cdot A$  - fluid volume,  
 $\frac{dV}{dt} = Q_{in} - Q_{out}$  - volume flow rate.

$$\Rightarrow \frac{dh}{dt} = \frac{Q_{in} - Q_{out}}{A} \quad (5.1)$$



$$h = \int \frac{Q_{in} - Q_{out}}{A} dt + h_0$$

- not interested in the past ( $Q_{in}, Q_{out}, h$  with  $(t < 0)$ )
- initial condition:  $h(t = 0) = h_0$
- if  $Q_{in}$  and  $Q_{out}$  are constant, then  $h(t)$  is a line segment

$$A \cdot \Delta h = (Q_{in} - Q_{out}) \cdot \Delta t$$

Graph consists of several line segments.

## 2 Level control

In a vertical cylindrical tank ( $d = 1.5 \text{ m}$ ,  $h = 3.5 \text{ m}$ ) with two-position controller level  $h$  is kept as close as possible to the value of  $h = 3.0 \text{ m}$ . This is done by switching the pump with inflow  $Q_{in} = 36 \text{ m}^3/h$ . Outflow of the vessel can vary from  $100 \dots 500 \text{ l/min}$ . The pump switching period should be not less than 5 min. Calculate the pump ON-OFF levels  $h_1$  and  $h_2$  ( $\Delta h$ ).

$$\Delta h = F(T, A, Q_{in}, Q_{out}),$$

where  $T = t_1 + t_2$  is a pump switching period.

Does slowly changing outflow cause the level  $\Delta h$  fluctuations?

### Some notes: ON-OFF level control

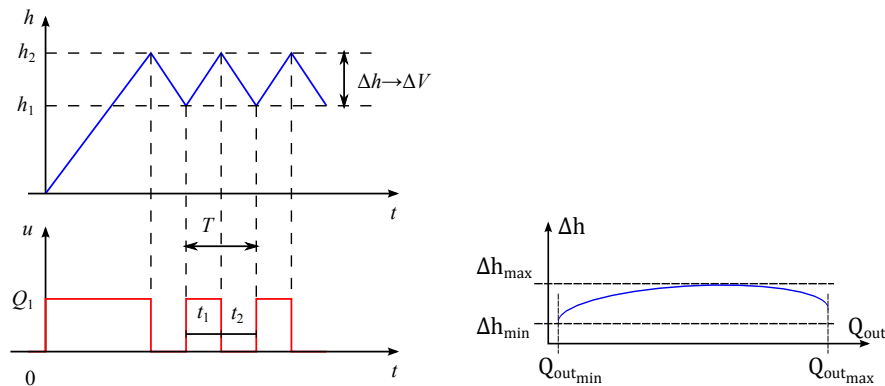


Figure 5.1: ON-OFF Control