*In the name of God*

# Modelling biological systems

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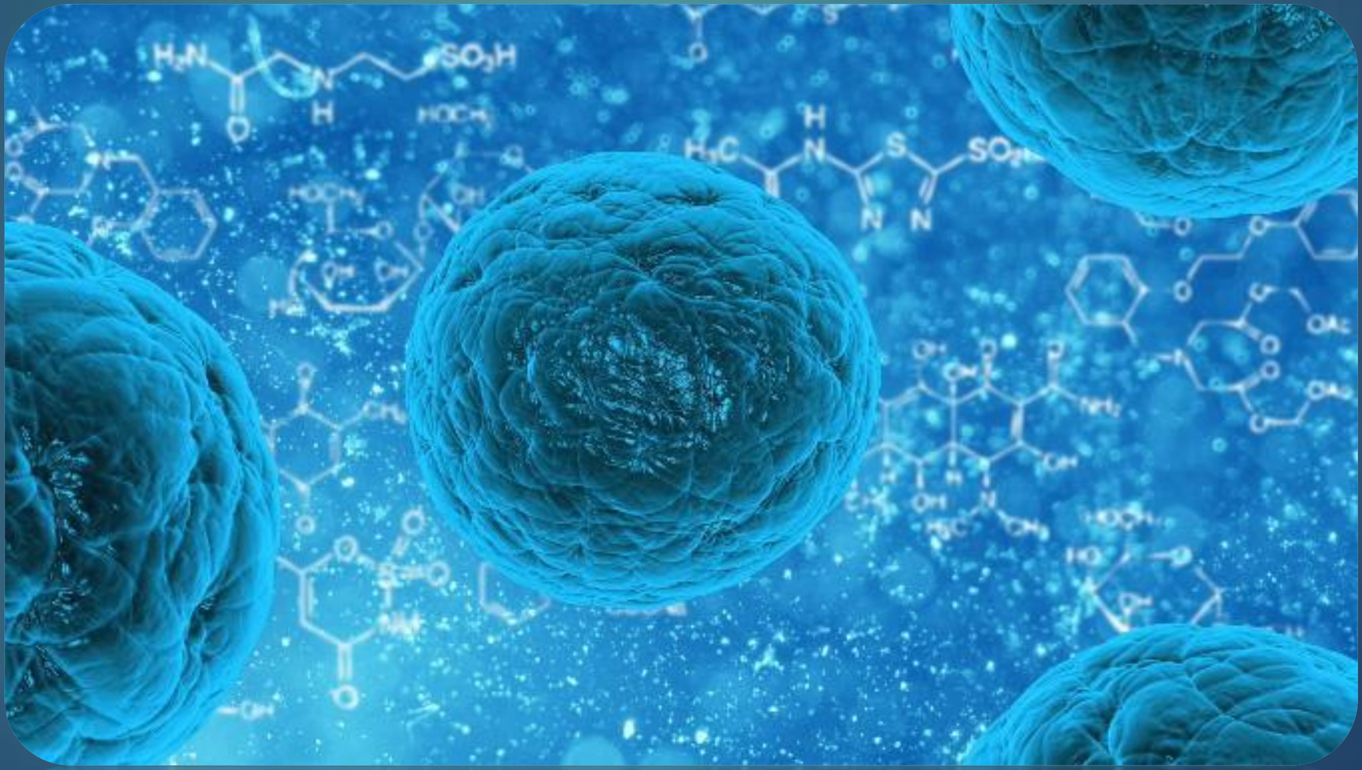
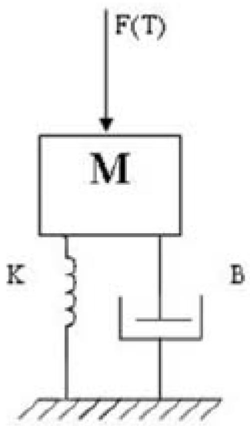


## Translational

- **Example :**

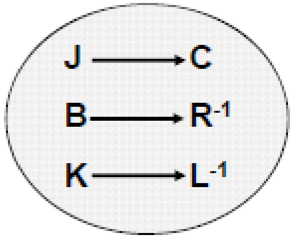
**Write the mathematical model and plot the electrical model**



# Rotational

- Primary variables
  - Longitudinal variables : torque
  - Transverse variables : angular velocity

- Secondary variables
  - Damper : $T_B = B.\Delta w$
  - Spring : $T_K = K\Delta\theta = K\int \Delta w dt$
  - Momentum Inertia : $T_J = J.\dfrac{dw}{dt}$

# Hydraulic

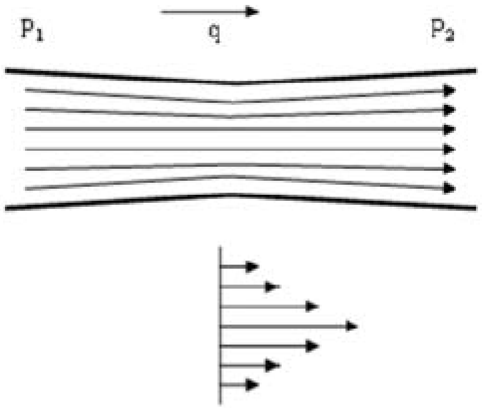
- Primary variables
  - Longitudinal variables : volume flow (or mass flow)
  - Transverse variables : pressure

- Secondary variables
  - Hydraulic resistance : valve $\longrightarrow$ $R_H$
  - Hydraulic capacitor : tank $\longrightarrow$ $C_H$
  - Hydraulic inductor : Fluid inertia $\longrightarrow$ $L_H$

## Hydraulic Resistance

- Laminar flow

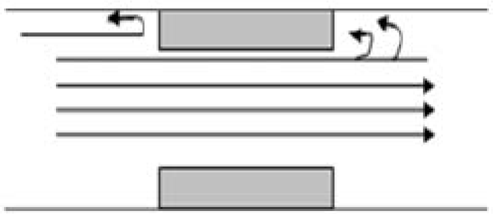
$$\Delta P = R_H . q$$



# Hydraulic Resistance

- Turbulent flow

$$q = g_H \sqrt{\Delta P}$$



**For linearization:**
**(a+x)^0.5=a^(1/2)+1/2/a^(1/2)*x-1/8/a^(3/2)*x^2**

$g_H$ is hydraulic conduction

# Hydraulic Inductor (Inertance)

- Different forces at the both sides produce acceleration for the fluid

$$\Delta P = L_H \frac{dq}{dt}$$

$$L_H = \frac{\rho l}{A}$$

**Notice that:**

$$F_1 - F_2 = m\frac{dv}{dt}$$

$$P_1A - P_2A = (\rho V)\frac{dv}{dt}$$

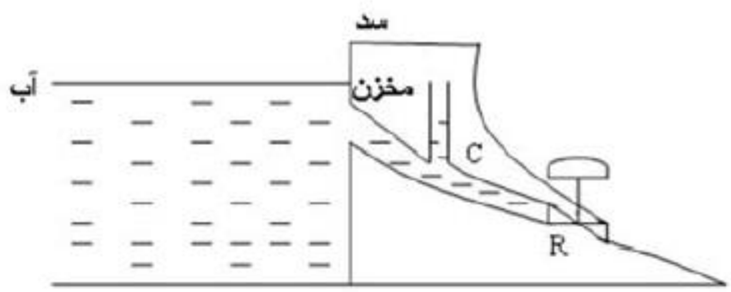
$$\frac{dV}{dt} = \frac{A.dl}{dt} = A.v$$

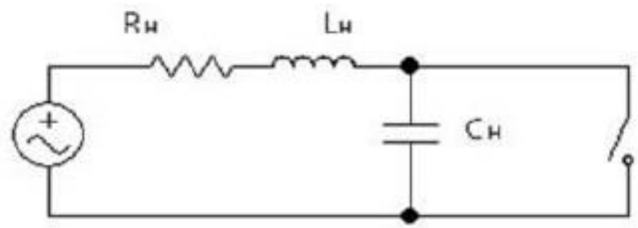
$$q = \frac{dV}{dt} = v.A$$

$$\frac{dq}{dt} = A\frac{dv}{dt}$$

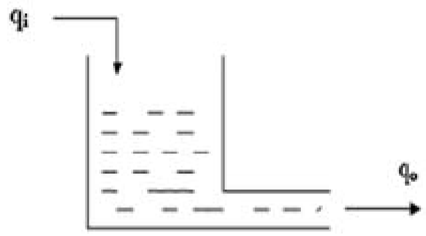
**Fluid with movement couldn't stop suddenly**
**=**
**current of inductor couldn't change suddenly**

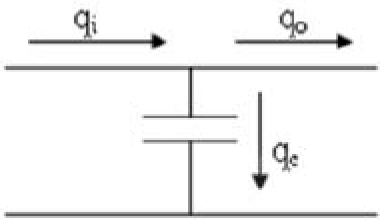
# Surge/Water hammer



# Hydraulic Capacitor




$$q_c = q_i - q_o = A\frac{dh}{dt} = \frac{A}{\rho g}\frac{dp}{dt}$$

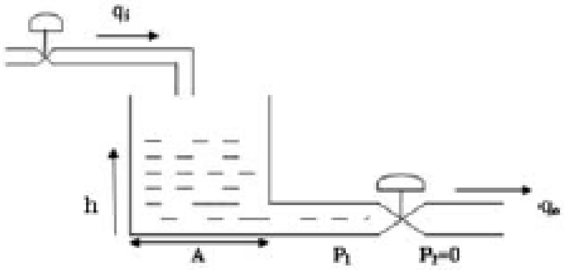
$$P = \frac{Mg}{A} \quad = \frac{\rho A h g}{A} = \rho h g$$

capacitor

$$i = c\frac{dv}{dt} \quad \text{vs} \quad q_c = \frac{A}{\rho g}\frac{dp}{dt}$$

# Example of Hydraulic system

- Draw the electrical model for this system




- solution

$$\begin{cases} q_c = q_i - q_o \\ V = A.h \end{cases} \Rightarrow q_c = q_i - q_o = \frac{dV}{dt} = A\frac{dh}{dt}$$

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obrigado
Dank U
Merci
mahalo
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Grazie
Thank you
mauruuru
Takk
Gracias
Dziękuję
Děkuju
danke
Kiitos