Control Engineering I - 21/22

Bachelor's Degree in Industrial Technologies Engineering. Group 39

Lecture 0. Intro & Physical systems

Theory – Group 39 (Classroom 2.3.D04/Tuesday 9:00-11:00h)
Exercises - Group 39 (Classroom 2.3.D04/Friday 9:00-11:00h)

Theory: Prof. David Martín Gómez dmgomez@ing.uc3m.es

Exercises: Prof. Irene Pérez Encinar ipencina@ing.uc3m.es

	Monday	Tuesday	Wednesday	Thursday	Friday			
	February					Theory	Exercises	
Week 1	31	1	2	3	4			
		T1			P1	0 Intro. /1 Mathematical tools theory	P1-Physical systems	
Week 2	7	8	9	10	11			
		T2			P2	2 System Modeling	P2-Laplace transforms	
Week 3	14	15	16	17	18			
		T3			P3	3 Introduction to time domain analysis	P3-Linearization & Transfer function	
Week 4	21	22	23	24	25			
		T4			P4	4 First and second order systems	P4-Block Diagrams	
	March							
Week 5	28	1	2	3	4			
		T5			P5	5 Error Calculation	P5-Stability analysis P5-Time domain analysis	
Week 6	7	8	9	10	11			
		T6			P6	6 Root locus, inverse root locus and frontier of the roots	P6-Steady-state errors exercises P6-Root locus exercises	Homework 1
Week 7	14	15	16	17	18			
		EP1	PR-1		PR-1	First midterm	Laboratory Class 1	
Week 8	21	22	23	24	25			
		T7			P7	7 Controllers	P7 Root locus exercises / Inverse root locus exercises	
	28	29	30	31	1			
		T8			P8	8 Análisis frecuencial - Bode	P8 Exercises of controllers	
	April							
Week 9	4	5	6	7	8			
		T9	PR-2		PR-2	9 Frequency Domain analysis - Nyquist	Laboratory Class 2	
Week 10	11	12	13	14	15			
Week 11	18	19	20	21	22			
		T10			P9	10 Nyquist / Frequency Domain Controller Design	P9 Bode Exercises	Homework 2
Week 12	25	26	27	28	29			
		P10	PR-3		PR-3	P10 Nyquist Exercises I	Laboratory Class 3	
	May							
Week 13	2	3	4	5	6			
		EP2			P11	Second Midterm	P11 Nyquist Exercises II	
Week 14	9	10	11	12	13			
		P12			P13	P12 Exams from previous years	P13 Exams from previous years	

Evaluation

Continuous evaluation:

- First and second midterms: 15% + 15%
- Final Exam: 50%
  - **Minimum grade 4/10**
- Labs: 10%
- Exercises: 10%

Recommended Bibliography and software

- **Norman S. Nise, “Control Systems Engineering”, Seventh Edition, Ed. Wiley**

https://www.wiley.com/en-us/Control+Systems+Engineering%2C+7th+Edition-p-9781118800638

- **Ogata, K., “Modern Control Engineering”, 5th Edition, Ed. Prentice-Hall**

https://www.pearson.com/us/higher-education/program/Ogata-Modern-Control-Engineering-5th-Edition/PGM100186.html

- **Software Matlab: Control System Toolbox**

https://www.youtube.com/watch?v=NfSPmBwD71g&t=306s

- **Matlab Online**

https://www.mathworks.com/products/matlab-online.html

Lecture 1

Mathematical modeling of physical systems

System model

- Model: Represents or substitutes a system or physical reality in some aspects

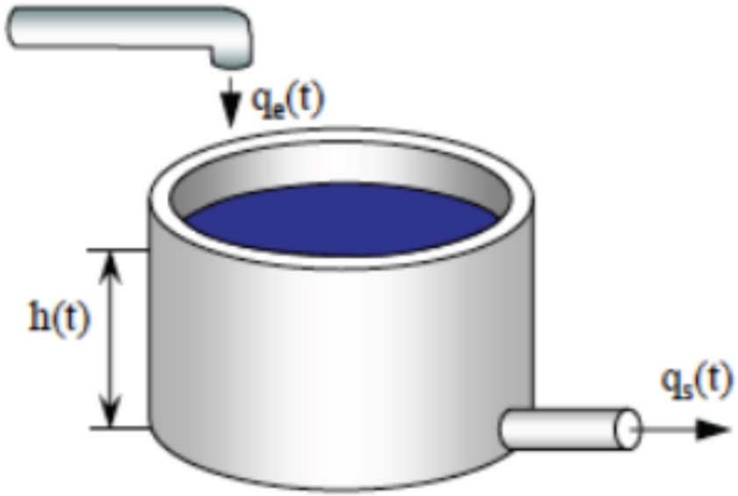
- Mathematical model of a system: set of equations that represents the dynamics of a system with reasonable precision

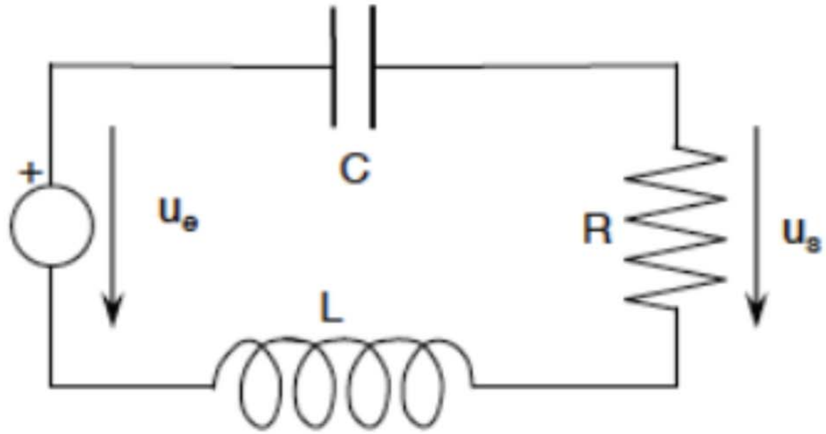
- The dynamics of a system is often described using differential linear equations.
  - Example.

$$3\frac{d^2x}{dt^2}+\frac{dx}{dt}\frac{dy}{dt}+2=0$$

  - Variables are continuous time signals.

Concept of Model of a System





$$q_e(t) - q_s(t) = A\frac{dh(t)}{dt}$$

$$q_s(t) = k\sqrt{h(t)}$$

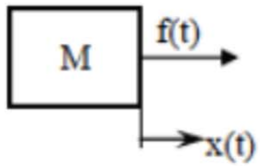
$$u_e(t) = \frac{1}{C}\int i(t)dt + u_s(t) + L\frac{di(t)}{dt}$$

$$u_s(t) = R \cdot i(t)$$

Modeling of Mechanical Systems

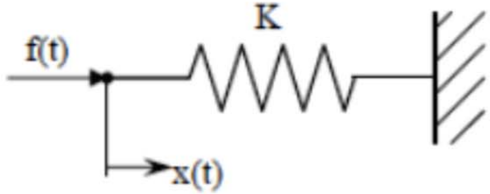
Translational

mass



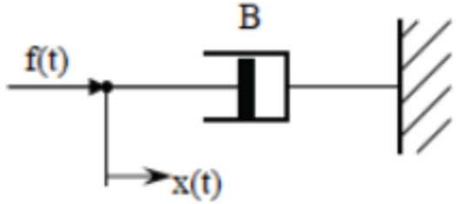
$$F(t) = M\frac{d^2}{dt^2}x(t)$$

spring



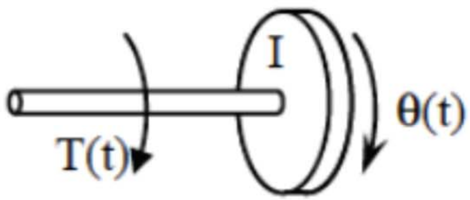
$$F(t) = K \cdot x(t)$$

damper

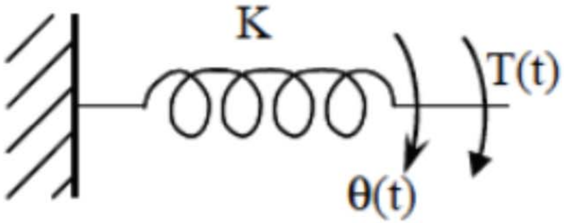


$$F(t) = B\frac{d}{dt}x(t)$$

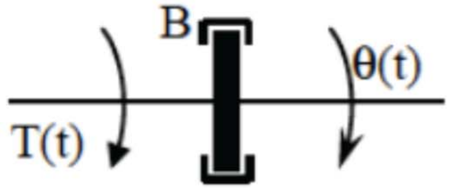
Rotational



$$T(t) = I\frac{d^2}{dt^2}\theta(t)$$



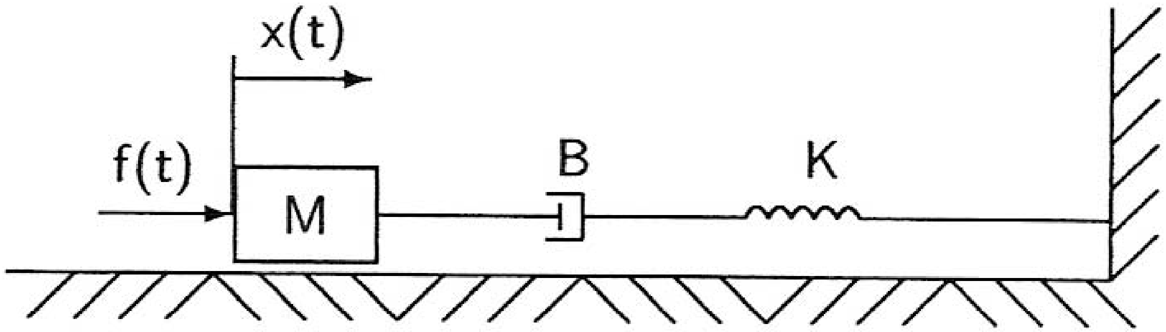
$$T(t) = K \cdot \theta(t)$$



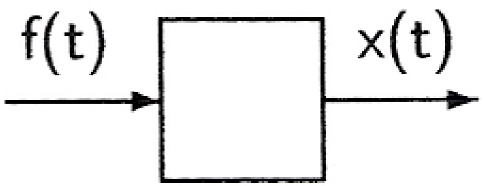
$$T(t) = B\frac{d}{dt}\theta(t)$$

Mechanical systems modeling

Linear movement

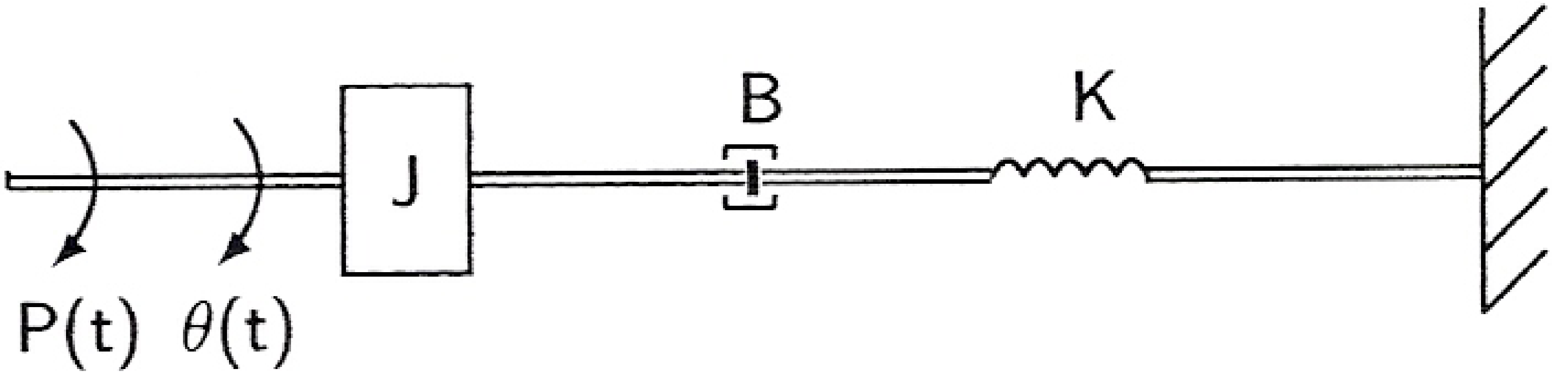


$$M\ddot{x}(t) = f(t) - B\dot{x}(t) - Kx(t)$$

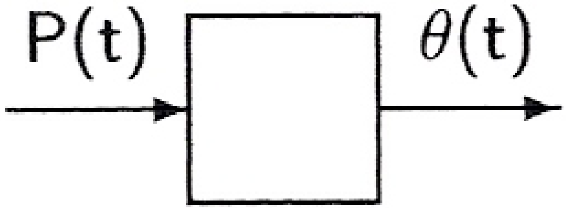


Mechanical systems modeling

Rotational movement

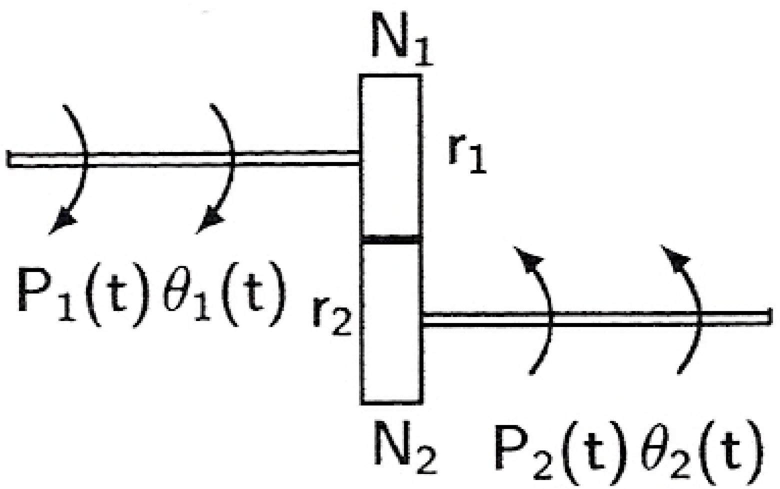


$$J\ddot{\theta}(t) = P(t) - B\dot{\theta}(t) - K\theta(t)$$



Mechanical systems modeling

Multiple gears

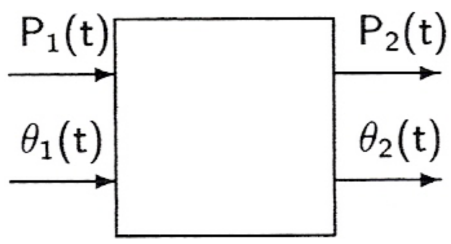


$$\frac{N_1}{N_2} = \frac{r_1}{r_2}$$

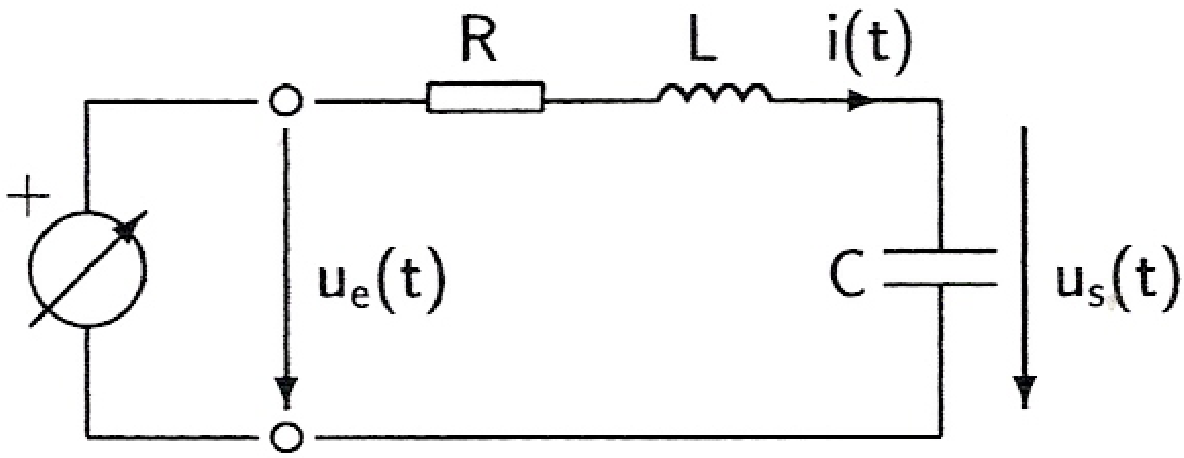
$$r_1\theta_1(t) = r_2\theta_2(t)$$

$$P_1(t)\theta_1(t) = P_2(t)\theta_2(t)$$

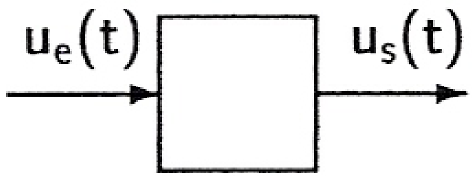
$$\frac{\theta_2(t)}{\theta_1(t)} = \frac{N_1}{N_2} = \frac{P_1(t)}{P_2(t)}$$



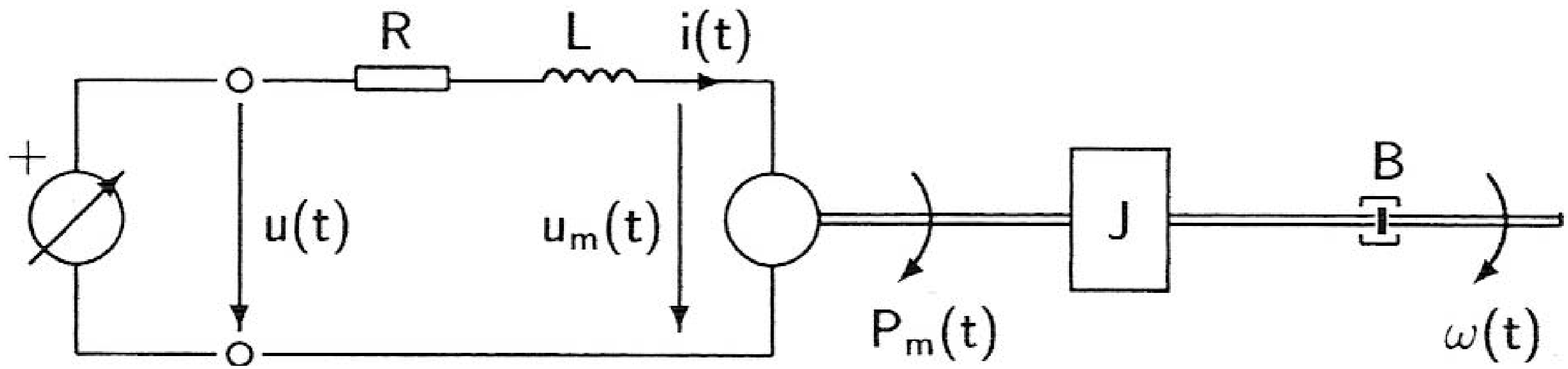
Electrical systems modeling



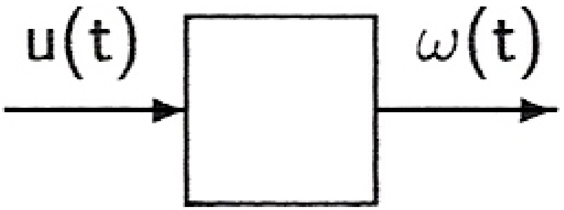
$$\left.\begin{aligned} u_e(t) &= Ri(t) + L\frac{di}{dt} + u_s(t) \\ u_s(t) &= \frac{1}{C}\int_0^t i(\tau)d\tau \end{aligned}\right\} \Longrightarrow u_e(t) = RC\dot{u}_s(t) + LC\ddot{u}_s(t) + u_s(t)$$



Electro-mechanical systems modeling



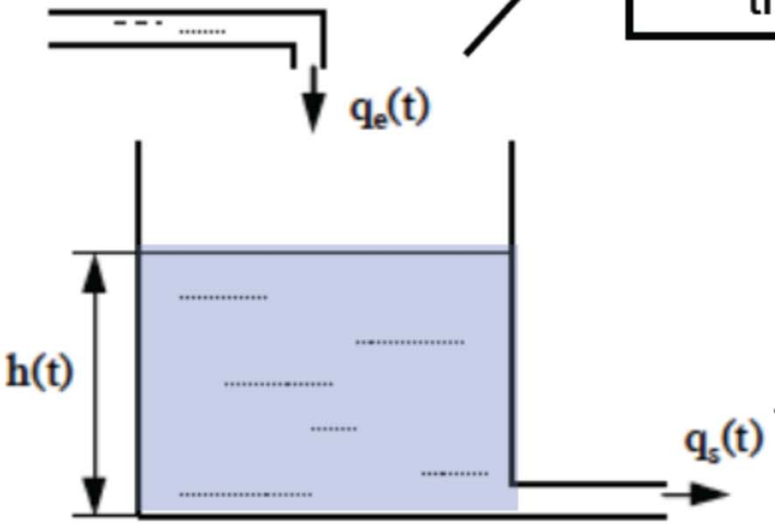
$$
\begin{cases}
u(t) = Ri(t) + L\frac{di}{dt} + u_m(t) \\
u_m(t) = K_b w(t) \\
P_m(t) = K_p i(t) \\
J\dot{w}(t) = P_m(t) - Bw(t)
\end{cases}
$$



Modeling of Hydraulic Systems

Flow rate into the tank

Height of water in the tank



Flow rate out of the tank

Constant related to the flow rate into the tank.

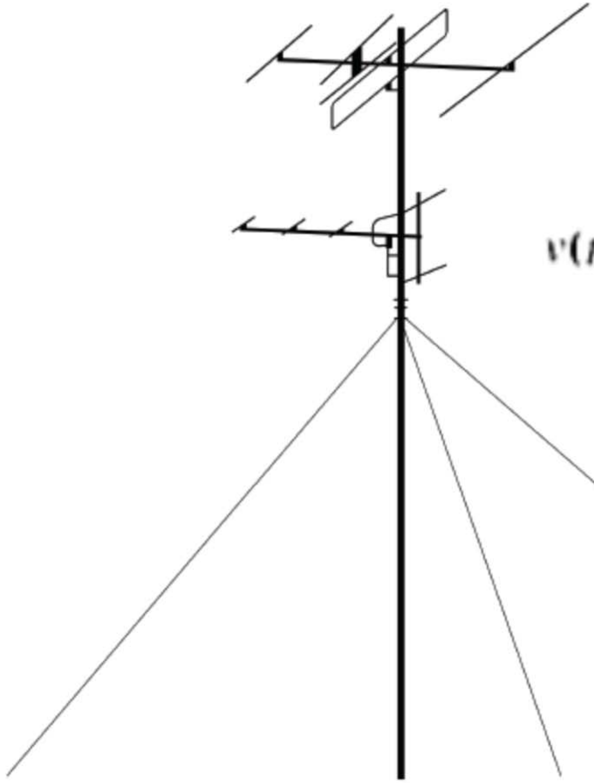
$$q_e(t) - q_s(t) = A\frac{dh(t)}{dt}$$

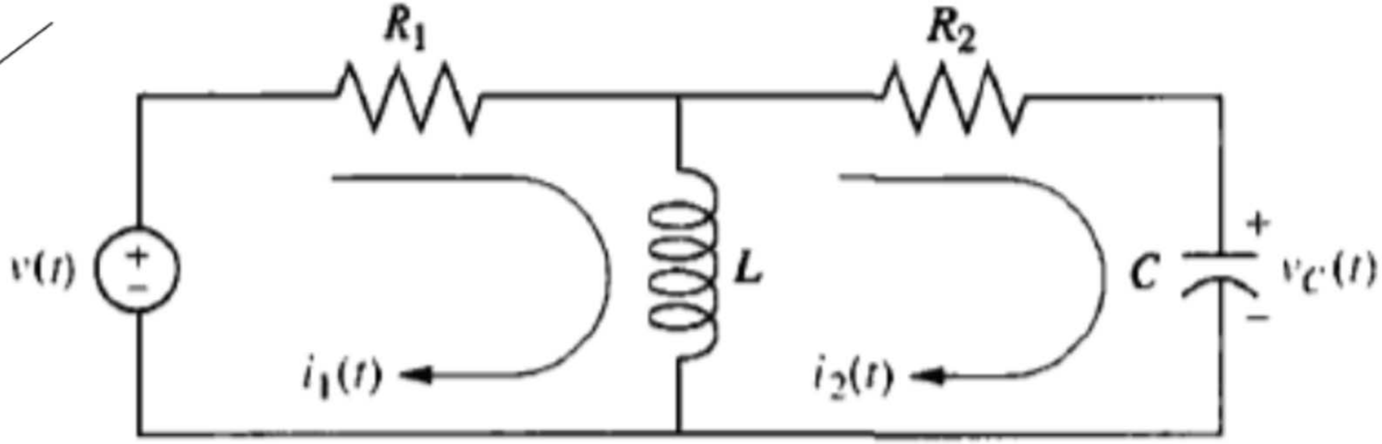
$$q_s(t) = k\sqrt{h(t)}$$

Cross-sectional area of the tank.

Exercise 1

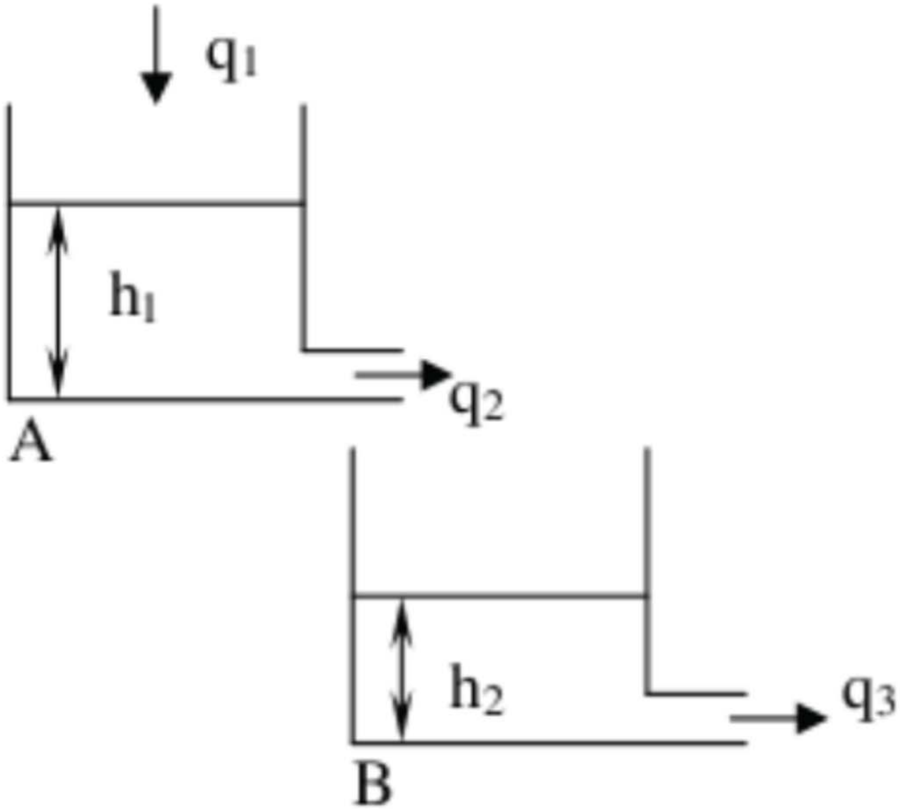
Obtain the equations of the following electrical system.





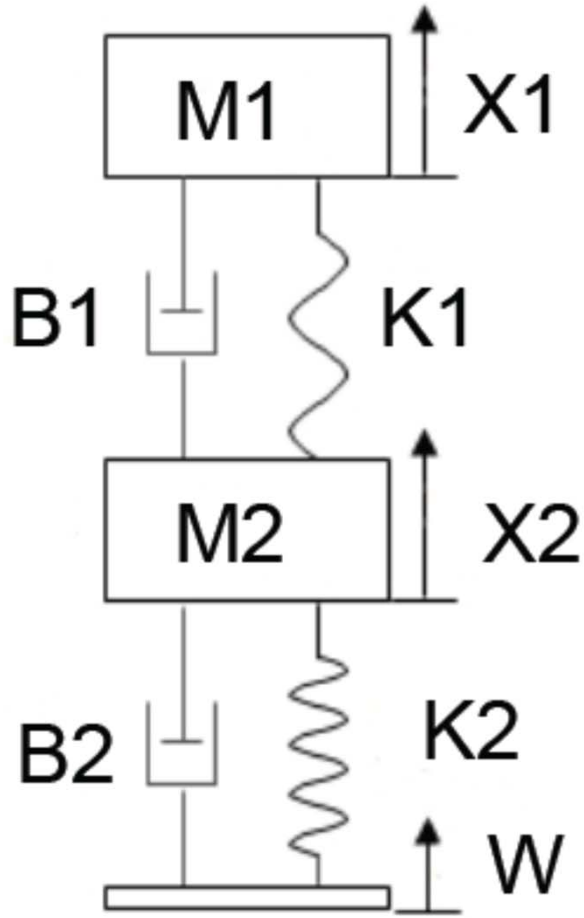
Exercise 2

Obtain the equations of the following hydraulic system.



Exercise 3

Obtain the equations of the following mechanical translational system.



Exercise 4

Obtain the equations of the following rotational system.