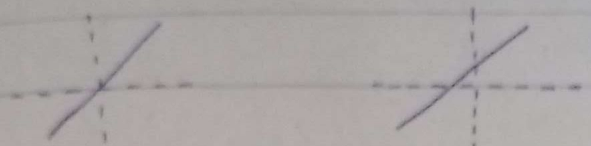
07/Jan/2025

* We will deal only with linear system in I&C.



Linear $y = mx$ | Non linear $y = mx + c$

* Linearity is the relationship b/w input & output
* Time is known as a third component, Graphs b/w input or output vs time won't be linear.

Capacitor $\longrightarrow$ eqn : $i_c = C \dfrac{dv_c}{dt}$ $\longrightarrow$ linear relationship

* Jo change input mai aye wahi output mai aaye usay linear system kahngy.

$y = 2x$

$\because x = 2$

$\boxed{y = 4}$

Now ; $x = 2+1$

$\boxed{y = 6}$

Linear eqns mai jitna x increase hoga utna effect y par ayga.

Input & output are linear

$y = 2x + c$ $\quad \because \boxed{c = 1}$

$\because x = 2$

$\boxed{y = 5}$

Now ; $x = 2+1$

$\boxed{y = 13}$

Non linear mai jitna x increase hoa utna y mai increase nhi aya

Input & output are non linear.

bcz it has intercept (c) & 3rd component

07/Jan/2025

$F(s) = \frac{5s^2+6s+9}{(s+2)(s+8)}$ → Proper function → bcz order of num & denom are same.

$F(s) = \frac{(s+2)}{s^2+9s+2}$ → Strictly proper function → bcz order of num one less than denom

$F(s) = \frac{s^2+5s+2}{(s+5)}$ → Improper function → bcz order of num is more than denominator

$F(s) = \frac{Y(s)}{R(s)}$ → Output
→ Input

Ex:

$F(s) = \frac{Y(s)}{R(s)} = \frac{1}{s^2+5s+6}$

$Y(s) = \frac{1}{s^2+5s+6} \times R(s)$

$Y(t) =$

$Z = a + bi$

$S = \delta + j\omega$ → At initial condition (δ) is zero.
then $\boxed{S = j\omega}$

*- Hum mech. system ka methamatical model always initial condition mai find karngy

*- Roots of numerator are called zero's (O)

*- Roots of denominator are called ...

Degree → no. of integrators (1/s).
→ no. of poles in system is called degree at origin

Transfer functions helps to find:-

① Order ② ~~Degree~~ Type ③ no. of locations of poles ④ No. of location of zero's ⑤ Stability ⑥ Response Curve ⑦ Speed ⑧ Dominant pole.

Mathematical Model → Transfer function (SISO) → S domain representation of a system
Mathematical Model → State Space Representation (MIMO) → Time domain Representation of a system

How to find degree:

$$f(s) = \frac{(s+9)}{s^2(s+5)(s+10)(s+100)}$$

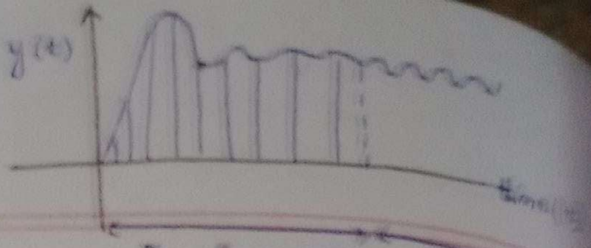
s^2 → 0 0, $(s+5)$ → −5, $(s+10)$ → −10, $(s+100)$ → −100

↓

2 ~~Degree~~ Type system (Jitnay zero denominator mai utna hi degree hoga).

* Degree of system ka numerator k zero se koi taalug nahi hai

04/Jan/2022.



Transient system → by the time system changes

Steady state → by the time system remain constant

$$G_1(s) = \frac{s+2}{s(s+5)(s+4)} \rightarrow z_1 = -2$$

$s_1 = 0,\ s_2 = -5,\ s_3 = -4.$

$$G_2(s) = \frac{s(s+6)(s+8)}{s^2(s^2+9s+4)(s+10)} \rightarrow z = 0, -6, -8$$

$s_{1,2} = 0,\ s_3 = -10,\ s_3 = -8.53,\ s_4 = -1.46$

$$G_3(s) = \frac{1}{(s^2+36)(s+8)} \rightarrow \text{No zero's } (0)$$

$s_1 = -8,\ s_2 = \pm 6j$

$$G_4(s) = \frac{s}{(s^2+2s+3)} \rightarrow z = 0$$

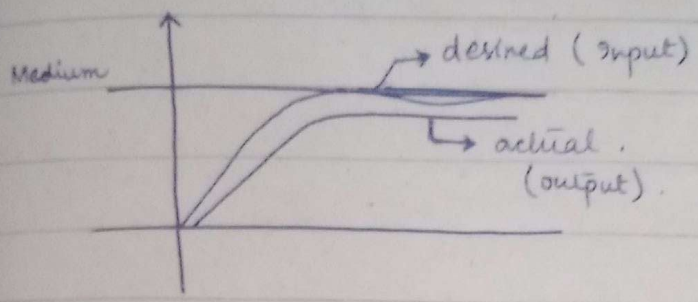
$s = -1 \pm 1.414j$

<u>Graphs:-</u>

08/Jan/2025.

BIBO system,

Bounded Input bounded output stable system.



Input and output shape same ho to BIBO system kahngy.

* A system is said to be stable if and if all the poles of the system are negative i.e lies on the left side of the s-graph.

Dominant poles- →(response curve or speed btata hai)

The pole which is near or closest to origin is called dominant pole of the system but if there are complex pole in the system they will always be the dominant pole of the sy.

Ex:

$$G(s) = \frac{s}{(s^2+2s+3)(s+0.5)}$$

$s = -1 \pm 1.414j$ $\quad$ $s_2 = -0.5$

system mai complex number ajay to ab wo O.P Kahlyga.

D.P (dominant pole).

08/Jan/2025

① **Speed:-**

The system of D.P which is far from origin is called and has higher speed altough the system of D.P which is near to origin has slowest speed.

Types Of poles:

① Real & Distinct → $G(s) = \dfrac{1}{(s+5)(s+10)(s+8)(s+2)}$ → over damped

$\underbrace{-5,\ -10,\ -8,\ -2}$

all are real & Distinct.

② Real & Equal → $G(s) = \dfrac{1}{(s+4)^2(s+9)(s+15)}$ → critical damped.

$\underbrace{-4,-4}_{\text{equal}},\ -9,\ -15$

equal and all are real.

③ Complex Conjugate → $G(s) = \dfrac{1}{(s+8)(s^2+2s+3)(s+1)}$ → under damped

$(-8),\ \underbrace{-1 \pm 1.41j}_{\text{complex}},\ -1$

$\boxed{0.1 - 0.9}$

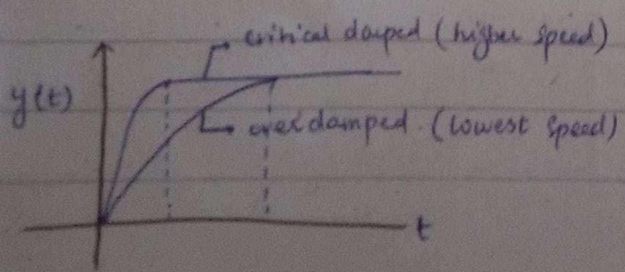
overshoot ziada range

overshoot kam range

④ Imaginary Poles → $G(s) = \dfrac{1}{(s+8)(s+2)(s^2+144)}$ → undamped

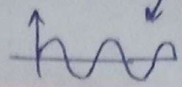
$-8,\ -2\qquad \underbrace{\pm 12j}_{\text{Imag.}}$

no real part.



ζ → damping factor. (Dying out of oscillation)

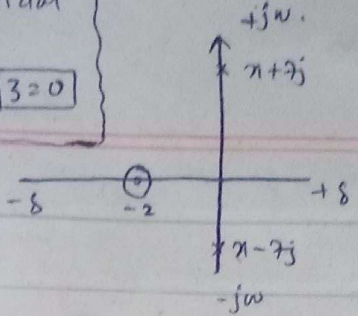
If ζ = 0 → system is synosoidal



$\boxed{\zeta = 0}$

11/Jan/2025

For $G_1(s)$:-



$$G_1(s) = \frac{(s+2)}{(s^2+49)(s+1)}$$

= −2 $\boxed{\text{undamped}}$

$\boxed{\zeta = 0}$

Dp $\boxed{\pm 7j}$, −1

$\boxed{\text{zero}}$ → 0, $-0.5 \pm \frac{\sqrt{11}}{2}j$

$\boxed{\text{underdamped}}$

For $G_2(s)$:

$$G_2(s) = \frac{s(s^2+s+3)}{(s^2+s+9)(s+6)(s+2)}$$

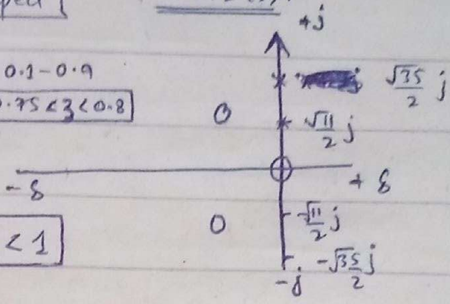
ζ → 0.1 − 0.9

Recommended → $\boxed{0.75 < \zeta < 0.8}$

poles → $\boxed{-0.5 \pm \frac{\sqrt{35}}{2}j}$, −6, −2

D.P

$\boxed{\zeta < 1}$



$\boxed{\text{critical damped}}$

For $G_3(s)$:

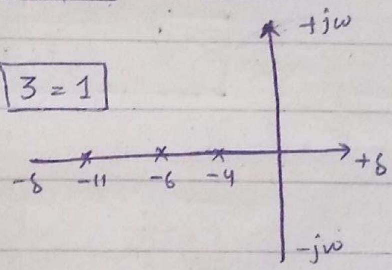
$$G_3(s) = \frac{1}{(s^2+8s+16)(s+6)(s+11)}$$

fastest system bcz Dp are far from origin.

$\boxed{-4, -4}$, −6, −11.

Dp

$\boxed{\zeta = 1}$



$$G_4(s) = \frac{s(s+8)}{(s+0.1)(s+2.5)(s+6)}$$

For $G_4(s)$:

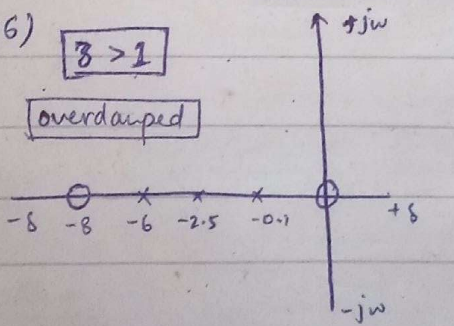
Slowest system bcz Dp is very near from origin.

$\boxed{-0.1}$, −2.5, −6

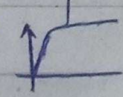
D.P

$\boxed{\zeta > 1}$

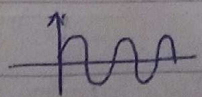
$\boxed{\text{overdamped}}$



*- If system is smooth then the system is Critical damped and it has faster response.

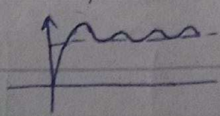


- ±7j → means undamped →



→ $\boxed{\zeta = 0}$

- underdamped →



→ $\boxed{0.1 \zeta < 0.9}$ $\boxed{0.1 \text{ to } 0.9}$

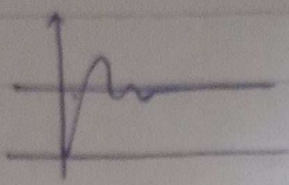
*- overshoot jiada to zeta (ζ) ki value kam

*- overshoot kam to zeta (ζ) ki value jiada.

$\boxed{\text{Damper} \rightarrow \text{Increasing resistance}}$

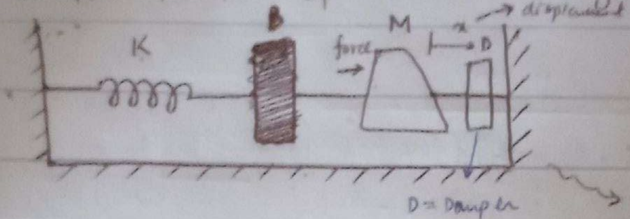
28/Jan/2025 Tuesday

If system has $0.75 < \zeta < 0.8$ then it has less overshoot.



* Damping factor effect speed and overshoot in a system.

* Find out the transfer function of Mechanical system.



$\int dt \rightarrow \frac{1}{s}$

$\frac{d}{dt} \rightarrow s$

SISO system ha hey aik force pr aik outcome aarha ha
Ex. force lagy gi to displacement hoga sirf

Spring $\longrightarrow$ $F = -kx$

Damper $\longrightarrow$ $F = Bv \Rightarrow B . dx/dt$

Mass $\longrightarrow$ $F = ma \Rightarrow m . \frac{dv}{dt} = M\frac{d^2x}{dt^2}$

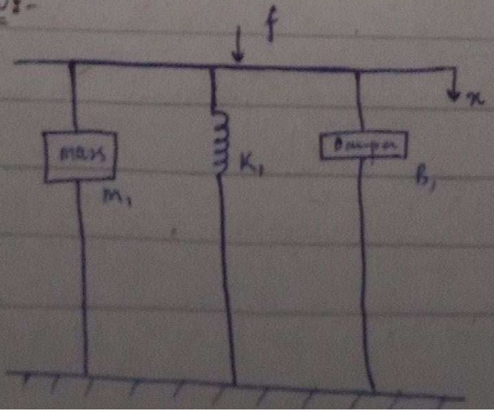
S-Domain Representation:-

Spring $\rightarrow$ $F(s) = k\,x(s)$

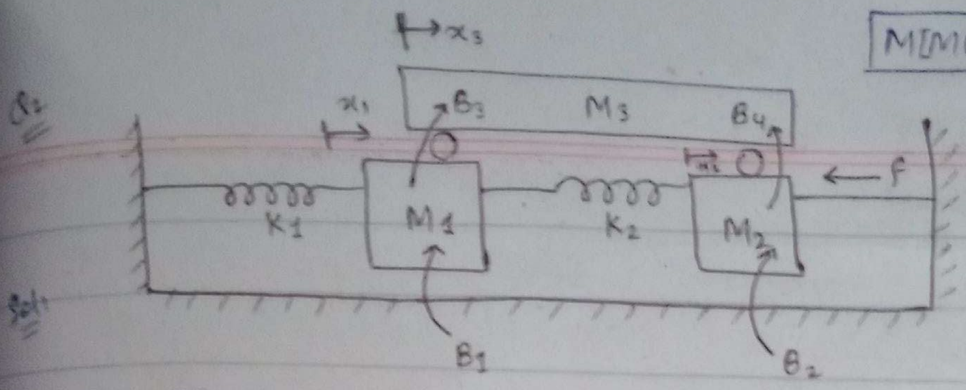
Damper $\rightarrow$ $F(s) = Bv(s) = BS\,x(s)$

Mass $\rightarrow$ $F(s) = Ma(s) = MSv(s) = MS^2x(s)$.

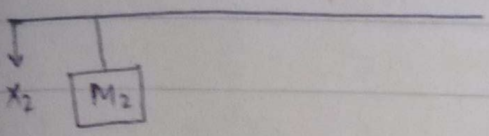
Free Body Diagram:-



MIMO System



Free Body Diagram:



Making Eqn for X_2:

$$M_2 \frac{d^2}{dt}(x_2-0) + k_2(x_2-0) + B_3 \frac{d}{dt}(x_2-0) + B_2 \frac{d}{dt}(x_2-x_1) = f_1.$$

$$M_2 \frac{d^2}{dt} x_2 + k_2 x_2 + B_3 \frac{d}{dt} x_2 + B_2 \frac{d}{dt} x_2 - B_2 \frac{d}{dt} x_1 = f_1.$$

$$X_2(s) \cdot \left[M_2 s^2 + (B_2+B_3)s + k_2\right] - X_1(s) B_2 s = F_1(s).$$

$$-X_1(s) B_2(s) + \left[M_2 s^2 + (B_2+B_3)s + k_2\right] \cdot X_2(s) = F_1(s) \quad (1)$$

Making Eq for X_1:-

15/Jan/2025.

Solving Q # 01

$F = ma$

$F = m \frac{dv}{dt}$

$$\boxed{F = M d^2x/dt^2}$$

$G(s) = \frac{X(S)}{F(S)} = ?$

$$M_1 \frac{d^2}{dt^2}(x-0) + K_1(x-0) + B_1 \frac{d}{dt}(x-0) = f.$$

$$M_1 \frac{d^2}{dt^2}(x) + K_1(x) + B_1 \frac{d}{dt} x = f$$

Convert into time domain:-

$$M_1 \frac{d^2}{dt^2} x(t) + k_1 x(t) + B_1 \frac{d}{dx} x(t) = f(t).$$

$$M_1 S^2 X(S) + K_1 (x)(S) + B_1 s (x)(S) = f(S)$$

$$X(S)\left[M_1 s^2 + K_1 + B_1 s\right] = f(S)$$

$$\frac{X(S)}{F(S)} = \frac{1}{M_1 S^2 + B_1 s + K_1}$$

$$\boxed{\frac{X(S)}{F(S)} = \frac{1/M_1}{S^2 + \frac{B_1 S}{M_1} + \frac{K_1}{M_1}}}$$

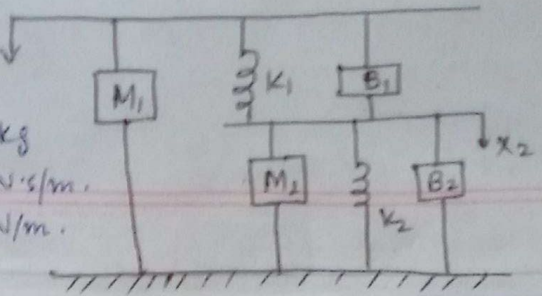
$\boxed{Mass = Ms^2(x)}$

Given,

$M_1 = M_2 = 2kg$

$B_1 = B_2 = 1 N\cdot s/m.$

$K_1 = K_2 = 3 N/m.$



$\boxed{\text{MIMO sys}}$

~~$M_1 s^2 + (B_1+B_2)s + K_1$~~

① $G_1(s) = X_1(s)/F(s) = ?$

② $G_2(s) = X_2(s)/F(s) = ?$

For x_1,

$$M_1 s^2 (x_1 - 0) + K_1 (x_1 - x_2) + B_1 s (x_1 - x_2) = F(s).$$

$$M_1 s^2 x_1(s) + K_1 x_1(s) - K_1 x_2(s) + B_1 s x_1(s) - B_1 s x_2(s) = F(s)$$

$$X_1(s)\left[M_1 s^2 + B_1 s + K_1\right] - \left[B_1 s + K_1\right] X_2(s) = F(s) \text{ — Ⓐ}.$$

For x_2,

$K_2(x_2 - x_1) = 0$

$$M_2 s^2 (x_2 - 0) + K_2 (x_2 - 0) + B_2 s (x - 0) + B_1 s (x_2 - x_1) +$$

$$-(B_1 s + K_1) X_1(s) + \left[M_2 s^2 + (B_1 + B_2)s + (K_1 + K_2)\right] X_2(s) = 0 \text{ — Ⓑ}$$

Putting values of $M_1, M_2, B_1, B_2, K_1, K_2$ in eq Ⓐ & eq Ⓑ :-

eq Ⓐ ⇒ $X_1(s)\left[2s^2 + s + 3\right] - \left[s+3\right] X_2(s) = F(s). \longrightarrow$ ①

eq Ⓑ ⇒ $-(s+3) X_1(s) + \left[2s^2 + 2s + 6\right] X_2(s) = 0 \longrightarrow$ ②.

Applying Cramer's Rule,

$$\begin{array}{cc} x_1 & x_2 \end{array}$$
$$\begin{bmatrix} 2s^2+s+3 & -(s+3) \\ -(s+3) & 2s^2+2s+6 \end{bmatrix} = \begin{bmatrix} F(s) \\ 0 \end{bmatrix}.$$

$$\therefore G_1(s) = \frac{X_1(s)}{F(s)} = ?$$

$X_1, X_2 \longrightarrow 2(x)$ hn mtlb

2^{nd} ~~order ka~~ degree of freedom.

order → no. of mass

given mass → Two

X_1 ke liye numerator ka 1st coloum input se replace karenge.

$$X_1(s) = \frac{\begin{bmatrix} F(s) & -(s+3) \\ 0 & 2s^2+2s+6 \end{bmatrix}}{\begin{bmatrix} 2s^2+2s+3 & -(s+3) \\ -(s+3) & 2s^2+2s+6 \end{bmatrix}}$$

$$X_1(s) = \frac{F(s)\left[2s^2+2s+6\right]}{(2s^2+s+3)(2s^2+2s+6)-(s+3)^2}$$

$$\boxed{\frac{X_1(s)}{F(s)} = \frac{2s^2+2s+6}{4s^2}}$$

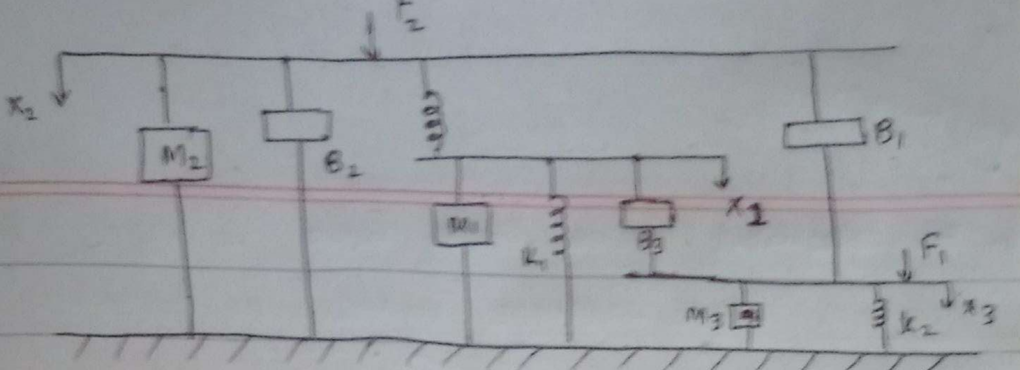
For $G_2(s) = \frac{X_2(s)}{F(s)}$:-

$$X_2(s) = \frac{\begin{bmatrix} 2s^2+s+3 & F(s) \\ -(s+3) & 0 \end{bmatrix}}{\begin{bmatrix} 2s^2+2s+3 & -(s+3) \\ -(s+3) & 2s^2+2s+6 \end{bmatrix}}$$

$$X_2(s) = \frac{F(s)\left[-(s+3)\right]}{(2s^2+s+3)(2s^2+2s+6)-(s+3)^2}$$

middle me minus ata hai cramers rule me

$X_2(s) =$



For x_1:

$$\left[M_1 s^2 + B_3 s + (K_1 + K_3)\right] x_1(s) - K_3 x_2(s) - B_3 s\, x_3(s) = 0 \quad \text{(A)}$$

For x_2:

$$-K_3 x_1(s) + \left[M_2 s^2 + (B_1 + B_2)s + K_3\right] x_2(s) - B_1 s\, x_3(s) = F_2(s)$$

For x_3:

$$-B_3 s\, x_1(s) - B_1 s\, x_2(s) + \left[M_3 s^2 + (B_1 + B_3)s + K_2\right] x_3(s) = F_2(s)$$

For $G_1(s) = \dfrac{x_3(s)}{F_2(s)} = ?$

x_3 mai $F_1(s)$ arha hai at time $F_1(s)$ ni aega mai

For x_3:

$$x_3(s) = \frac{\begin{array}{ccc} x_1(s) & x_2(s) & x_3(s) \\ \left[\begin{array}{ccc} M_1 s^2 + B_3(s) + (K_1 + K_3) & -K_3 & 0 \\ -K_3 & M_2 s^2 + (B_1 + B_2) + K_3 & 0 \\ -B_3(s) & -B_1 s & F_1 \end{array}\right] \end{array}}{\left[\begin{array}{ccc} M_1 s^2 + B_3 s + (K_1 + K_3) & -K_3 & -B_3 s \\ -K_3 & M_2 s^2 + (B_1 + B_2) + K_3 & -B_1 s \\ -B_3(s) & -B_1 s & M_3 s^2 + (B_1 + B_3)s + K_2 \end{array}\right]}$$

when system is 3rd degree of freedom, then we will leave the solution here.

Ans.

21/Jan/2025

Tuesday

* In electrical system, we have 2 input system called force-voltage system or force-current system

Voltage changed into → force.
Current changed into → force

~~in electrical system~~

when electrical sys. changed by mech. sys.

Force-Velocity System :-

*- $F = ma \Rightarrow F = m\,dv/dt$ → Mass
*- $F = Bv \Rightarrow F = Bv$ → Damper.
*- $F = kx \Rightarrow F = k\int v\,dt$ → Spring.

F-V → force-voltage	F-I → Force-current
V → input	V → output
I → output	I → input
$V = IR$ → Resistor	$I = V/R$.
$V_c = \frac{1}{c}\int i_c\,dt$ → capacitor	$i_c = \frac{c\,dv_c}{dt}$
$V_L = \frac{L\,di_L}{dt}$ → inductor	$i_L = \frac{1}{L}\int V_L\,dt$.

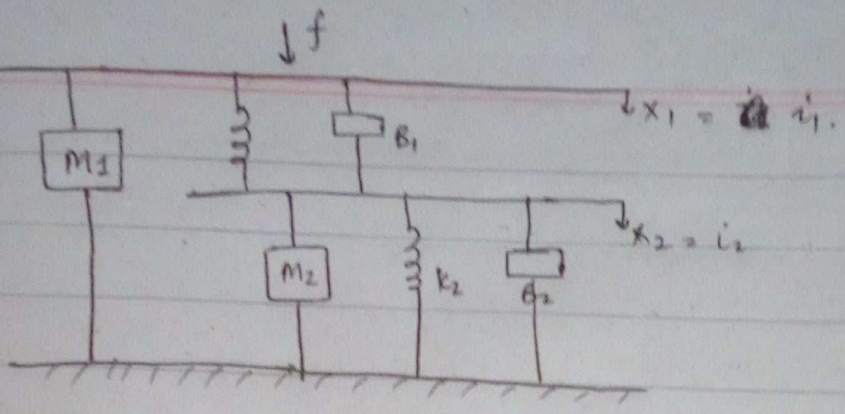
(F-V Analogous)	(F-I Analogous)
F – V	F – I
v – I	v – V
M – L	M – C
B – R	B – 1/R
K – $\frac{1}{C}$	K – 1/L

electrical to mechanical changes

Parallel → voltage same.

Series → current same.

F-V Analogous



electrical circuit,