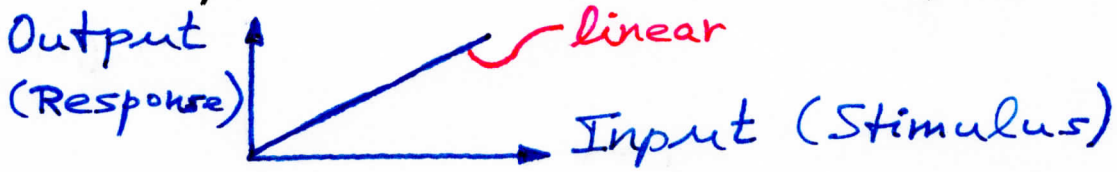
Superposition principle

⇒ Superposition principle applies to linear systems

What is a linear system?

* Output ∝ Input (Response ∝ Stimulus or Effect ∝ Cause)
* Output depends linearly on input
* Double input ⇒ Double output



Superposition principle: In a linear system having multiple sources (V or I sources) the total effect of the sources is the sum of the effects of each source.

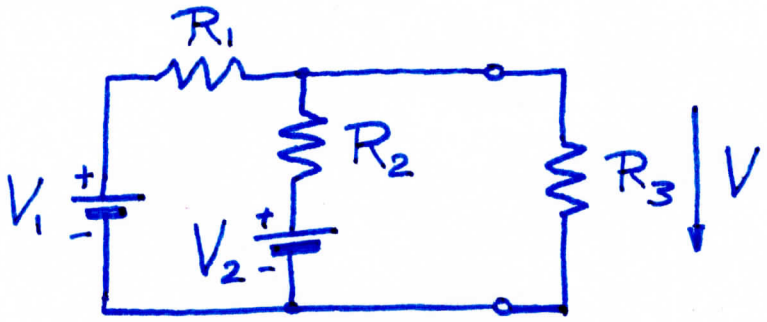
Recall:  Ideal V source ⇒ R = 0

 Ideal I source ⇒ R = ∞

Q: Is a resistor a linear system?

Q: Is a diode a linear system?

1ST example



Effect of V_1

Ohm: $I_{R1} = V_1 / R_1 + (R_2 \parallel R_3)$

$$\Rightarrow V = V_1 - I_{R1} R_1$$

$$= V_1 - \frac{V_1}{R_1 + (R_2 \parallel R_3)} R_1$$

Effect of V_2

Ohm: $I_{R2} = V_2 / R_2 + (R_1 \parallel R_3)$

$$\Rightarrow V = V_2 - I_{R2} R_2$$

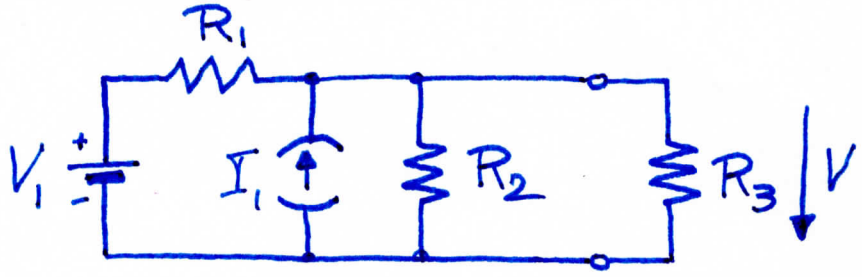
$$= V_2 - \frac{V_2}{R_2 + (R_1 \parallel R_3)} R_2$$

Superposition

$$V = V_1 - \frac{V_1 R_1}{R_1 + (R_2 \parallel R_3)} + V_2 - \frac{V_2 R_2}{R_2 + (R_1 \parallel R_3)}$$

↳ Superposition

2ND example



Effect of V_1

Ohm $\quad I_{R1} = \dfrac{V_1}{R_1 + (R_2 \parallel R_3)}$

$$\Rightarrow V = V_1 - I_{R1} R_1$$

$$= V_1 - \frac{V_1}{R_1 + (R_2 \parallel R_3)} R_1$$

Effect of I_1

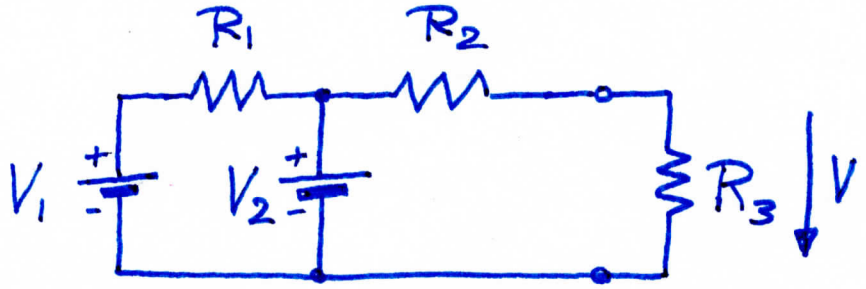
$$V = V_{R3} = I_1 \left(R_1 \parallel R_2 \parallel R_3\right)$$

Superposition

$$V = V_1 - \frac{V_1 R_1}{R_1 + (R_2 \parallel R_3)} + I_1 \left(R_1 \parallel R_2 \parallel R_3\right)$$

↳ Superposition

3RD example



Consider the superposition principle.

Will V_1 have any effect on V ?

Does V depend on V_1 ?

Answers: No. Why ?

Effect of V_1

$V = 0$

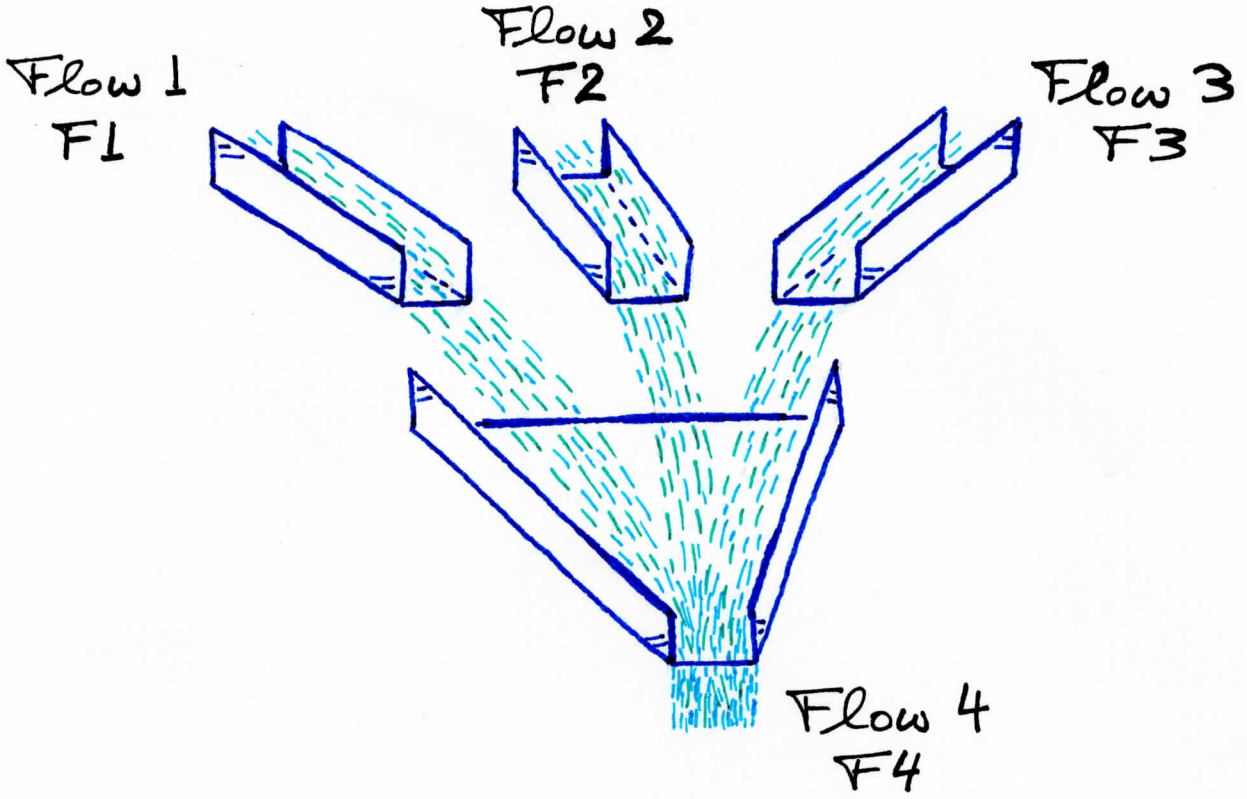
Effect of V_2

$$V = V_2 \frac{R_3}{R_2 + R_3}$$ (voltage divider)

Superposition

$$V = \underbrace{0}_{\text{Superposition}} + V_2 \frac{R_3}{R_2 + R_3} = V_2 \frac{R_3}{R_2 + R_3}$$

Superposition principle ⇒ Mechanical analog



Linear system: $F4 = F1 + F2 + F3$

$$\text{Effect} = \Sigma \text{ Causes}$$

Q: Starting with the above-shown linear mechanical system, how can we modify the system to make it a non-linear mechanical system ?

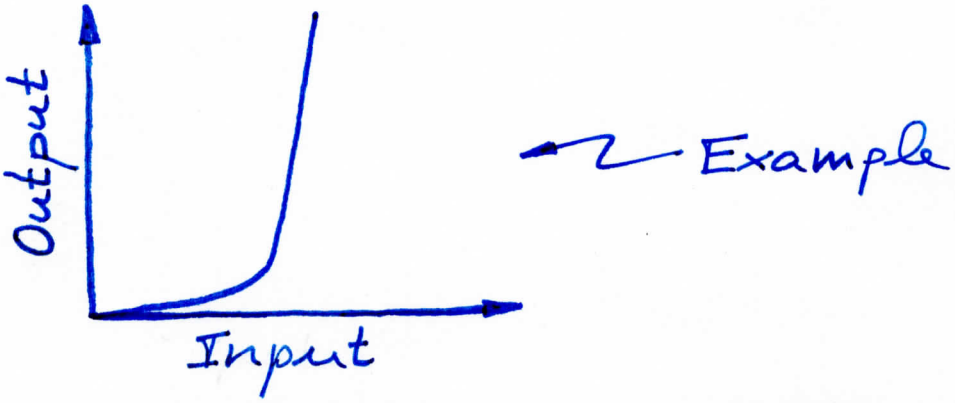
⇒ Name two modifications !

Q: Can you give other examples of mechanical or electrical or acoustic or optical systems ?

Q: Is our ear an acoustic system ?

Q: Are most systems linear or non-linear systems ?

Input-output characteristic of non-linear system:



Note: All systems can be linearized in a small range of operating conditions.