

Lab 1 due by midnight  
 HW 3 due Monday

Weekly feedback sticky notes

Red negative note

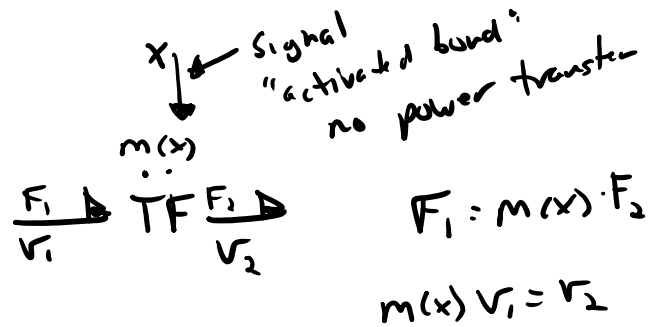
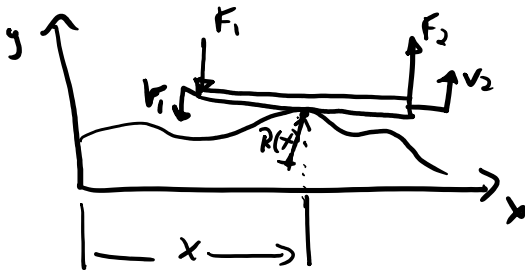
- something you don't understand
- something I should spend more time on
- something you would like me to change

Yellow positive note

something you like  
 what you understand best  
 I should keep doing

Modulated Transformers and Gytrators

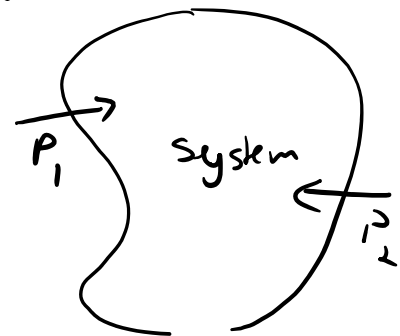
Ex



$$F_1 = m(x) \cdot F_2$$

$$m(x) V_1 = V_2$$

environment



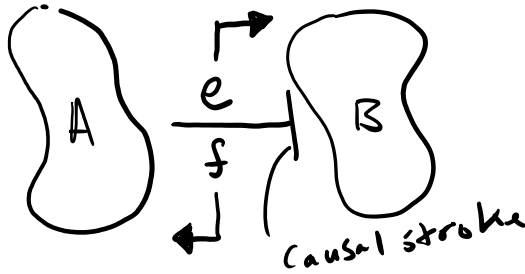
Causality

It is only possible to specify  
 (control, dictate) either OR flow at  
a bond, not both.  
 across the system boundary

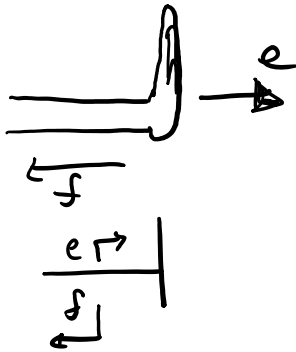
If you apply a force  $\rightarrow$  velocity occurs

If you specify a velocity  $\rightarrow$  force is required to make that motion

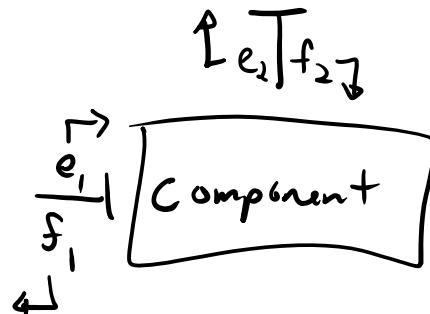
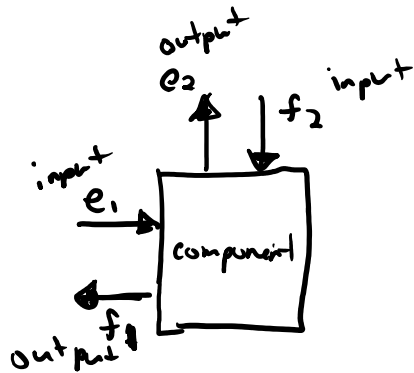
Causality describes if something is caused by an effort or a flow. We use the causal stroke to describe this idea.



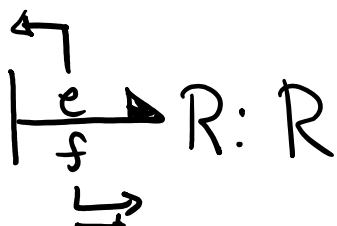
$e$  is input to B  
 $f$  is input to A  
 $f$  is an output of B  
 $e$  is an output of A



Causality is independent of the sign convention for power.

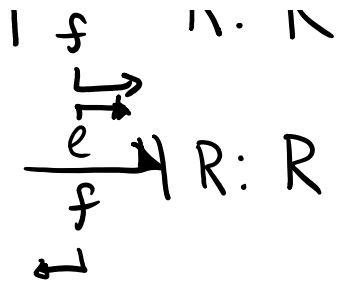


The causal stroke tells us what the inputs and outputs are of the mathematical relationships.



output  $\swarrow$  input  $\searrow$   
 $e = R f$   
 , output  $\swarrow$

flow is input  
 causes output effort



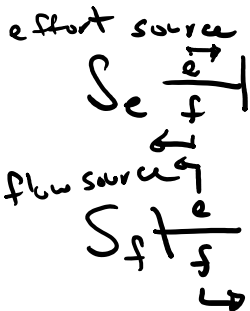
$$f = \frac{1}{R} e$$

output ← input

effort is input  
causes flow output

## Causality for Ports

### Sources



This is the causality of the sources always.

## Capacitance

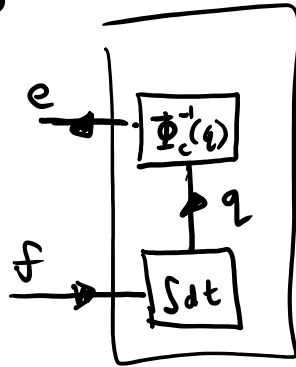
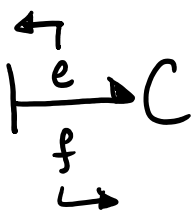
$$e = \Phi_c^{-1}(q) \Rightarrow e = \Phi_c^{-1}(\int f dt)$$

output ← input

$$q = \Phi_c(e) \Rightarrow f = \frac{d}{dt} \Phi_c(e)$$

↑ output      ↑ input

## Integral Causality

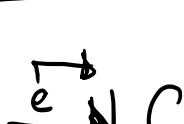


$$e = \Phi_c^{-1}(\int f dt) \text{ non-linear}$$

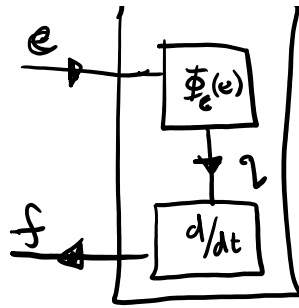
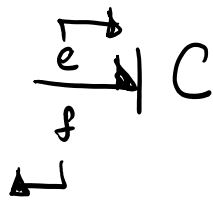
$$e = \frac{1}{C} \int f dt \text{ linear}$$

↑ output      ↑ inputs

## Derivative Causality



$$f = \frac{d}{dt} (\Phi_c(e)) \text{ non-linear}$$



$$f = \frac{d}{dt} (\Phi_c(e)) \quad \text{non-lin}$$

$$f = C \frac{de}{dt} \quad \text{lin}$$