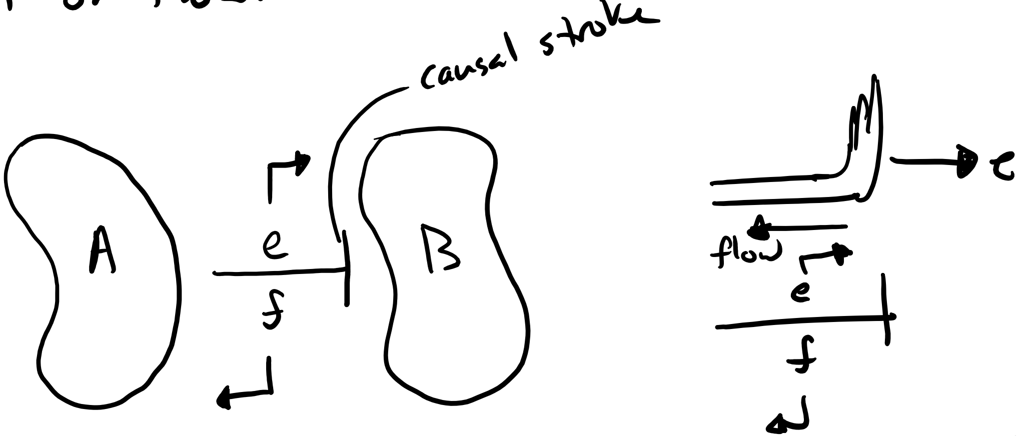
Causality

It is only possible to specify (control, dictate) effort **OR** flow at a bond, not both.

If you apply a force → velocity occurs.

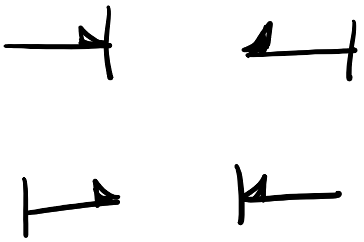
If you specify a velocity → force is required to make that motion

"Causality" describes if something is caused by an effort or flow.



Causality is independent of the power sign convention!

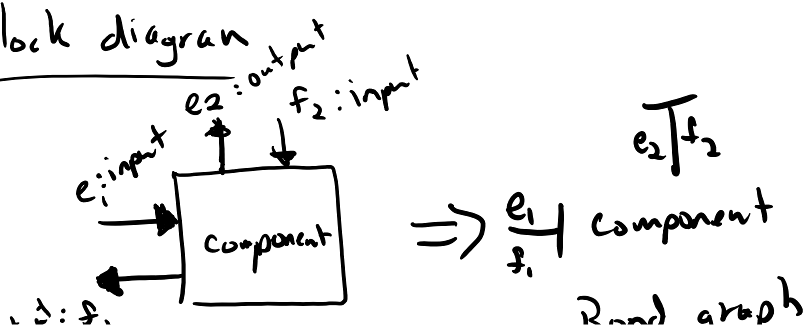
All are valid!

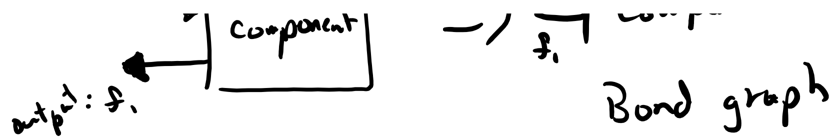


half arrow: direction of positive power flow

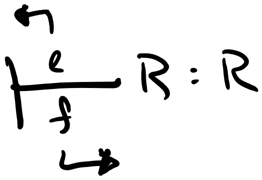
Vertical line: effort or flow is causation of power exchange

Block diagram



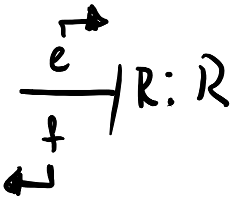


The causal stroke tells us what the inputs and outputs of the related mathematical functions.



$$\overset{\text{output}}{e} = R\overset{\text{input}}{f}$$

flow is the input and causes the effort



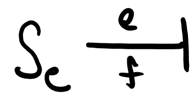
$$\overset{\text{output}}{f} = \frac{1}{R}\overset{\text{input}}{e}$$

effort is the input and causes output flow

Causality of ports

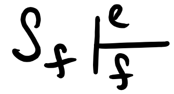
Sources

effort



These always have this causality!

flow



Capacitance

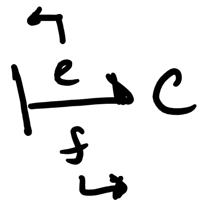
causality indicates whether we use the functional relationship or its inverse

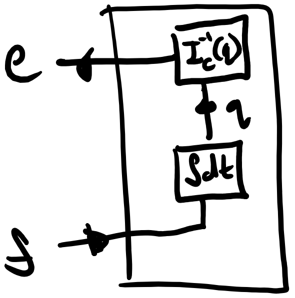
$$\overset{\text{output}}{e} = \Phi_c^{-1}(\overset{\text{input}}{q}) \Rightarrow \overset{\text{output}}{e} = \Phi_c^{-1}(\overset{\text{input}}{\int f dt})$$

$$q = \Phi_c(e) \Rightarrow \overset{\text{output}}{f} = \frac{d}{dt}\Phi_c(\overset{\text{input}}{e})$$

Integral causality

Integral causality





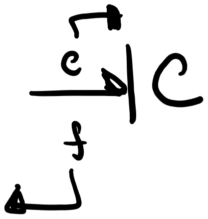
$e = \Phi_c^{-1}\left(\int f\,dt\right)$ non-linear

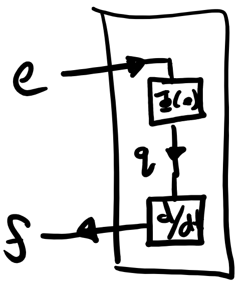
$e = \frac{1}{C}\int f\,dt$ linear

outputs

input

Derivative causality





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

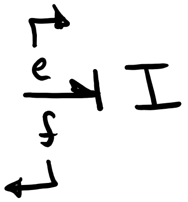
input

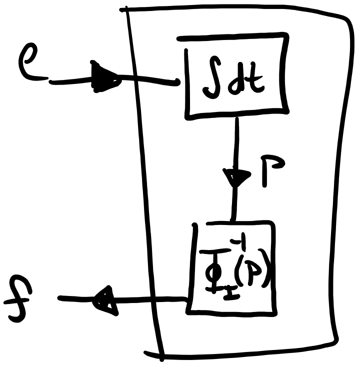
$f = C\frac{de}{dt}$ linear

output

Inertia

Integral causality

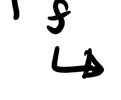


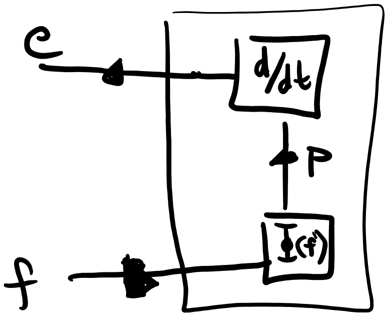


$f = \Phi_I^{-1}\left(\int e\,dt\right)$ non-lin

$f = I\int e\,dt$ linear

Derivative causality



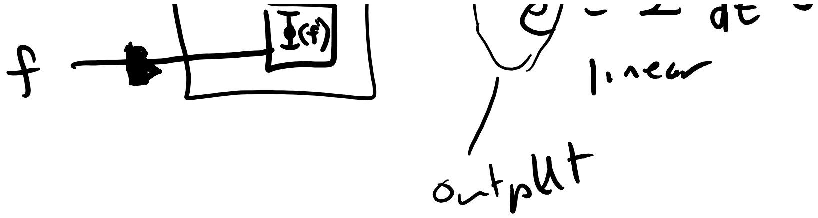


non-linear

$e = \frac{d}{dt}\left(\Phi_I(f)\right)$

$e = I\frac{d}{dt}f$ — inputs

linear


f
I(f)
at
linear
output