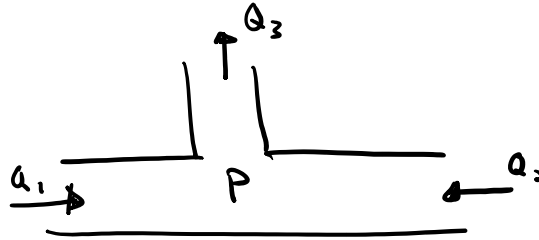
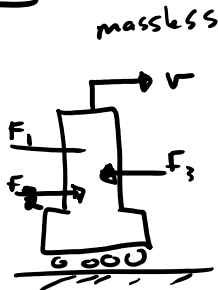


Office hours: Weds, Thurs 1:10-2:00 PM
Bairner 2015

3 Ports



$F_2 \downarrow v$
 $F_1 \rightarrow \quad \left| \quad F_3 \rightarrow$
 $v \quad \quad \quad v$
 common flow
 velocities are
 the same
 one junction
 $F_1 + F_2 = F_3$

$P \uparrow Q_3$
 $\frac{P}{Q_1} \rightarrow \quad \left(\right) \quad \leftarrow \frac{P}{Q_2}$
 $Q_1 \quad \quad \quad Q_2$
 common effort
 pressure is the
 same
 zero junction
 $Q_1 + Q_2 = Q_3$

Generalized Form of Basic Components

1 port resistance (relates effort and flow)

$\frac{e}{f} \rightarrow R$ represents

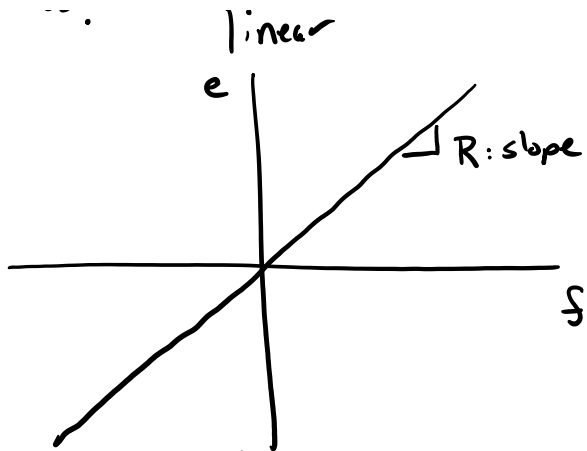
$e = \Phi_R(f)$
 $f = \Phi_R^{-1}(e)$

Non-linear

Sign convention
 if e^+ , f^+ then power
 into the resistance, R ,
 and the energy will
 be dissipated
 non-conservative
 process!



linear
e |



resistance

$$e = R f$$

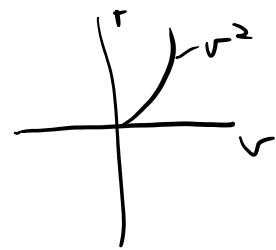
$$f = \left(\frac{1}{R}\right) e$$

conductance

electrical
 $v = R i$
 Ohm's Law

$$\frac{e}{f} \rightarrow R: R$$

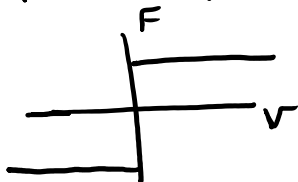
ω
Bond
Symbol



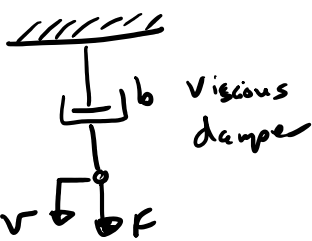
slope of the line

Common Resistances

$$F = \mu N_f \text{sgn}(v)$$



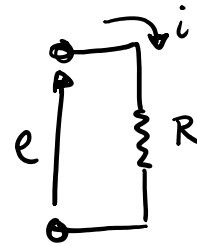
Coulomb friction
 is a non-linear
 resistor



viscous
 damper

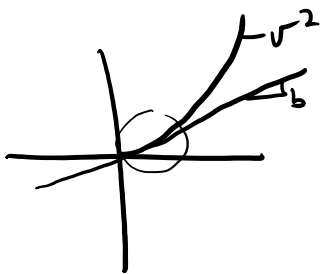
$$F = b v$$

$$\frac{F}{v} \rightarrow R: b$$

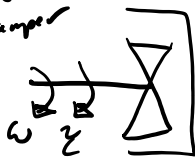


$$e = R i$$

$$\frac{e}{i} \rightarrow R: R$$



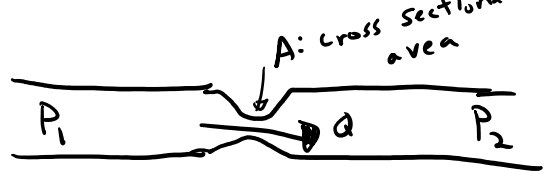
rotational
 viscous
 damper



$$\tau = b_t \omega$$

$$\frac{\tau}{\omega} \rightarrow R: b_t$$

hydraulic flow restrictor



$$\Delta P = P_1 - P_2$$

pressure
 drop

$$\Delta P = \frac{e}{2A} Q |Q|$$

non-linear

$$\frac{\Delta P}{Q} \rightarrow R$$

1 port Compliance (capacitance)

relates effort and displacement

$$\frac{e}{f} \rightarrow C$$

if $e^+, f^+ \Rightarrow$ store energy in capacitor

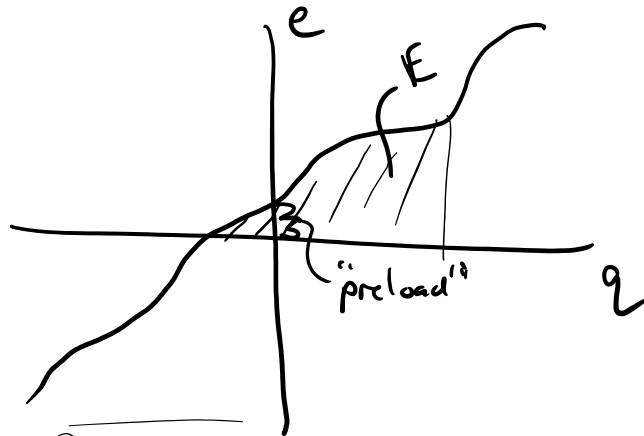
$$E = \int e f dt \quad \left. \begin{array}{l} \text{energy} \\ \text{and} \\ f dt = dq \\ q = \int f dt \end{array} \right\} E = \int e dq \quad \left. \begin{array}{l} \text{displacement} \\ \text{effort} \end{array} \right\}$$

Compliance store "potential" energy and return it with no loss \rightarrow conservative wrt energy

$$e = \Phi_c^{-1}(q)$$

$$q = \Phi_c(e)$$

non-linear

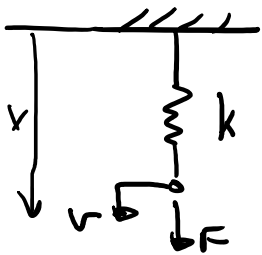


$$q = \Phi_c(e)$$

$$q = \int f dt$$

Examples

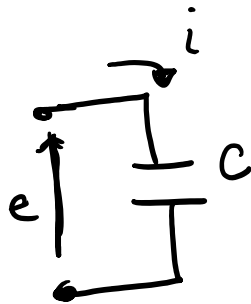
springs



$$F = kx$$

$$x = \int v dt$$

$$\frac{F}{v} \rightarrow C = 1/k$$



$$q = Ce$$

charge

$$q = \int i dt$$

$$\frac{e}{i} \rightarrow C: C$$