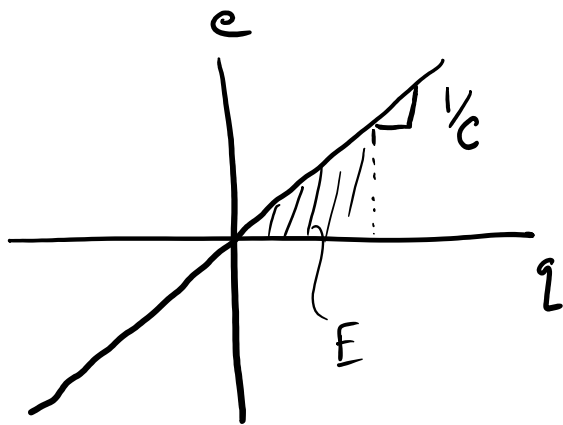


- Matlab session right after class (4:10 - 5:00 CME 1.6)
- Keins OH M 1-2 pm TB 207 Rm 110 (in addition to labs)
- HW #2 due Monday

Forgot linear capacitance

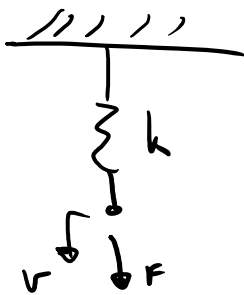


$$E = \int e dq = \int \frac{1}{c} q dq = \frac{1}{c} \frac{q^2}{2}$$

$$e = \frac{1}{c} q$$

$$q = C e$$

$$q = \int i dt$$

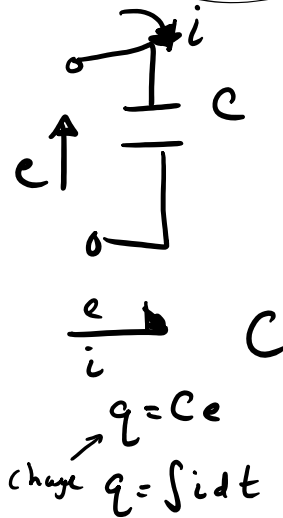


$$C: \frac{1}{k}$$

$$E = k \frac{x^2}{2}$$

$$x = \frac{1}{k} F$$

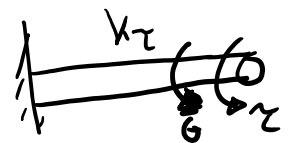
$$x = \int v dt$$



$$q = C e$$

$$\text{charge } q = \int i dt$$

Torsional Spring

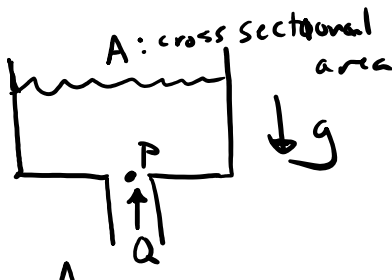


$$\theta = \frac{1}{k_\tau} \tau$$

$$\theta = \int \omega dt$$

$$\frac{\tau}{\omega} \rightarrow C: \frac{1}{k_\tau}$$

Small volume tank of fluid



$$C_T \approx \frac{A}{\rho g} \uparrow \uparrow Q$$

$$V = C_T P$$

$$V = \int Q dt$$

$$\frac{P}{Q} \triangle C : C_T$$

↑  
hydraulic  
capacitance  
of tank

1 port inertia: relates flow and momentum

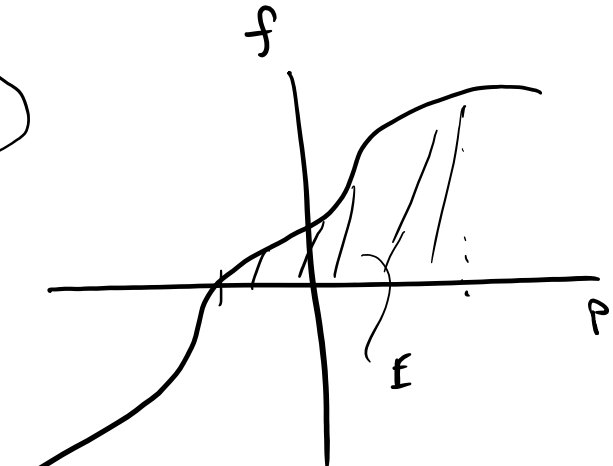
$$\frac{e}{f} \triangle I$$

$$p = \Phi_I(f)$$

$$f = \Phi_I^{-1}(p)$$

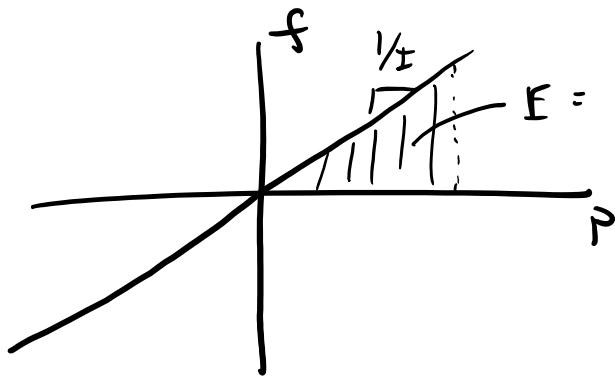
$$\frac{dp}{dt} = e \Rightarrow p = \int e dt$$

$e^+, f^+ \rightarrow$  positive power into the inertia, store "kinetic" energy  
conserves energy!



$$E = \int e f dt = \int f dp$$

linear case



$$f = \frac{1}{I} p$$

$$p = I f$$

$$E = \int f dp$$

$$= \int \frac{1}{I} p dp = \frac{p^2}{2I}$$

$$\frac{e}{f} \triangle I : t$$

linear motion

$$m v = p$$

$$E = \frac{m^2 v^2}{2m} = \frac{m v^2}{2}$$

$$\begin{aligned} p &= I f \\ p &= \int e dt \end{aligned}$$

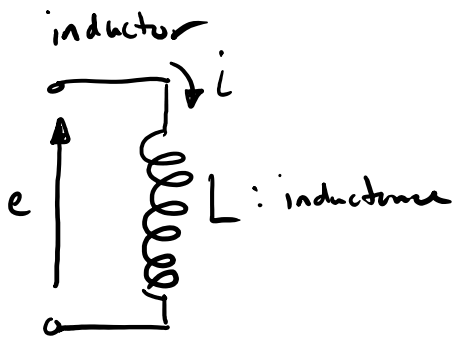
### Examples

inductor  
→ i

mass  
→ v

rotating distributed mass

→ ω



$$I: L$$

$$\lambda = Li$$

momentum  
for  
electric

$$\lambda = \int e \, dt$$

Mass

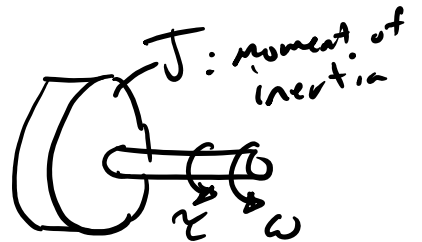


$$F \rightarrow I: m$$

$$p = mv$$

$$p = \int F \, dt$$

rotating distributed mass



$$\tau \rightarrow I: J$$

ang. momentum  $h = J\omega$   
 $h = \int \tau \, dt$

non-linear example mass moving close to speed of light

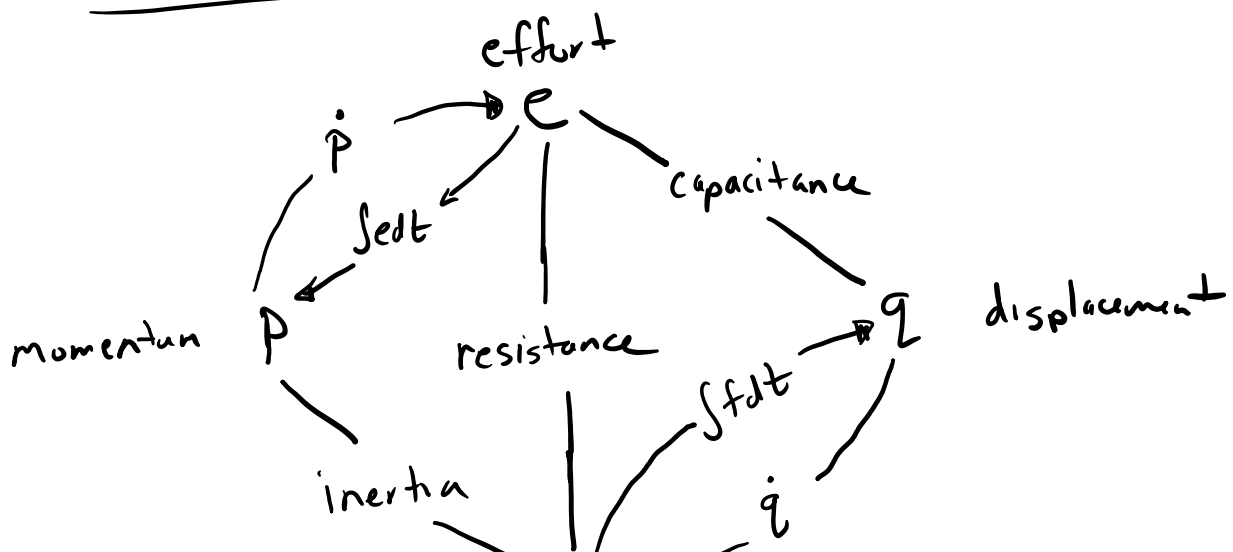
$$p \neq mv$$

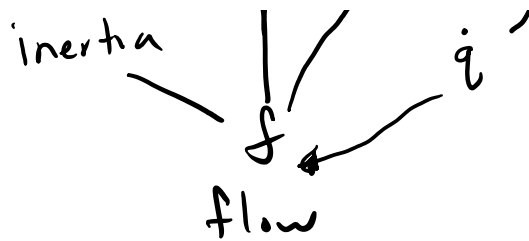
$$p = \frac{mv}{\left(1 - \frac{v^2}{c^2}\right)^{1/2}}$$

Speed of light

Relationships of the 1 ports and variables

Tetrahedron of State





1 ports effort/flow sources (inputs)

$S_e \rightarrow$  supplies specified effort, "draws" needed flow

$S_f \rightarrow$  supplies specified flow, "draws" needed effort

Example: battery  $e: S_e \rightarrow$

supplies specified constant voltage, draws needed amperage

Example: gravity at earth's surface

supplies specified constant force, draws needed velocity

$mg: S_e \rightarrow$

Example: road input from lab 1

supplies specified velocity, draws needed force

$v_{in}: S_f \rightarrow$