Orange Sticky Note

Write 1 positive feedback

e.g. something you learned well
something you like about teaching style
something I should keep doing
etc

Pink Sticky Note

1 negative feedback

e.g. something you don't understand well
something I can improve
etc

- HW #2 due Tuesday Jan 21
- Attend 2 of 3 labs before Jan 24th
- Absent on Jan 23 next (thursday), no lecture

Transformer

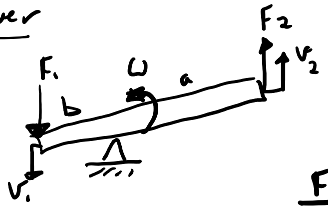
$$\xrightarrow[f_1]{e_1} \overset{m}{\ddot{TF}} \xrightarrow[f_2]{e_2}$$

$$e_1 = m e_2$$

$$m f_1 = f_2$$

Examples

Lever



$$\left.\begin{array}{l} \omega b = v_1 \\ \omega a = v_2 \end{array}\right\} \frac{v_1}{b} = \frac{v_2}{a} \Rightarrow \frac{a}{b} v_1 = v_2$$

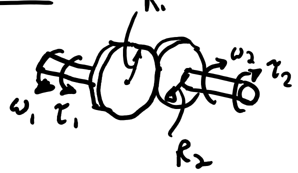
$$\xrightarrow[v_1]{F_1} \overset{a/b}{\ddot{TF}} \xrightarrow[v_2]{F_2}$$

$$F_1 = a/b \, F_2$$

$$\Downarrow$$

$$bF_1 = aF_2$$

Gears



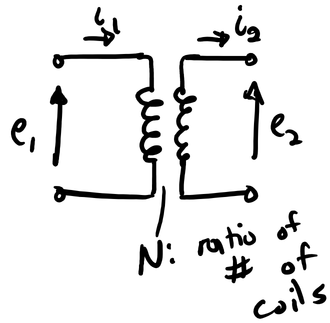
$$\omega_1 R_1 = R_2 \omega_2$$

$$\frac{R_1}{R_2} \omega_1 = \omega_2$$

$$\xrightarrow[\omega_1]{\tau_1} \overset{R_1/R_2}{\ddot{TF}} \xrightarrow[\omega_2]{\tau_2}$$

$$\tau_1 = \frac{R_1}{R_2}\tau_2 \Rightarrow R_2\tau_1 = R_1\tau_2$$

Magnetic field produced by coils

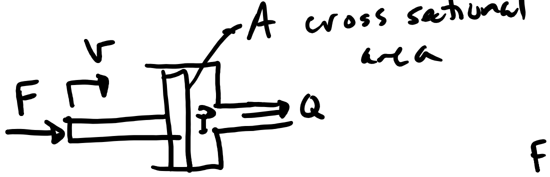


$e_1 = N e_2$

$N i_1 = i_2$

$$\xrightarrow[i_1]{e_1} \overset{N}{\ddot{TF}} \xrightarrow[i_2]{e_2}$$

Hydraulic piston (connects two energy domains) "transducers"



$$\xrightarrow[v]{F} \overset{A}{\ddot{TF}} \xrightarrow[Q]{P}$$

$\frac{F}{A} = P \Rightarrow F = AP$

$Av = Q$

2 Port Gyrator

$$\xrightarrow[f_1]{e_1} \overset{r}{\ddot{GY}} \xrightarrow[f_2]{e_2}$$

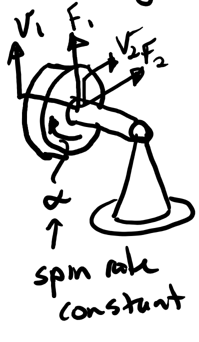
$e_1 = r f_2$

$r f_1 = e_2$

effort $\propto$ flow

Examples

Gyroscope

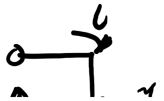


$F_1 = r V_2$

$r V_1 = F_2$

$$\xrightarrow[V_1]{F_1} \overset{r}{\ddot{GY}} \xrightarrow[V_2]{F_2}$$

DC Motor (wound permanent magnetic)

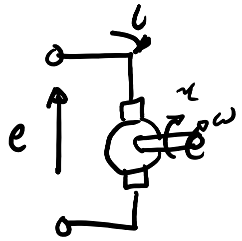


$e = T\omega$

T - motor constant

$$\xrightarrow{e} \overset{T}{\ddot{GY}} \xrightarrow{\tau}$$

ψ - motor

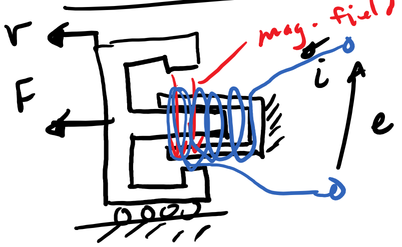


$e = T\omega$

$Ti = \tau$

$\xrightarrow[i]{e} \dot{G}\dot{Y} \xrightarrow[\omega]{\tau}$

Voice Coil



βl — mag. flux of field — length of wire

$\xrightarrow[i]{e} \dot{G}\dot{Y} \xrightarrow[v]{F}$

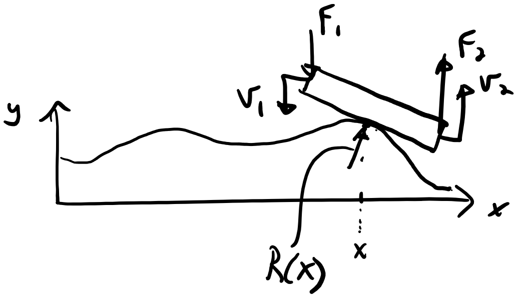
Lorentz effect

$e = \beta l v$

$\beta l F = i$

Modulated transformers and gyrators

Ex



$x \downarrow$ – no power flow "active bond"

$m(x)$

$\xrightarrow[v_1]{F_1} \dot{T}\dot{F} \xrightarrow[v_2]{F_2}$

3 (or more) Ports

common effort 0 junction (port)

$$\begin{tikzcd} & {} \arrow[d, "e_2"', "f_2"] & \\ {} \arrow[r, "e_1", "f_1"'] & 0 \arrow[r, "e_3", "f_3"'] & {} \end{tikzcd}$$

$e_1 = e_2 = e_3$

$f_1 + f_2 - f_3 = 0$

$-f_1 - f_2 + f_3 = 0$

$f_3 = f_1 + f_2$

Common flow 1 junction (port)

$$\begin{tikzcd} & {} \arrow[d, "e_2"', "f_2"] & \\ {} \arrow[r, "e_1", "f_1"'] & 1 \arrow[r, "e_3", "f_3"'] & {} \end{tikzcd}$$

$f_1 = f_2 = f_3$

$e_3 = e_1 + e_2$

$$e_1 + e_2 - e_3 = 0$$

arrows dictate the signs in the summations!

Simple Balance Model of a Bicycle

System dynamic equations (set of 1st order ODEs)

$$\dot{\theta} = \omega$$

$$\dot{\omega} = \frac{mgh\theta - \frac{mh}{b}(av\beta + v^2\delta)}{I + mh^2}$$

$$\dot{\psi} = \frac{v}{b}\tan(\delta)$$

States (time varying)

$$\bar{x} = \begin{array}{cl} \begin{bmatrix} \omega(t) \\ \theta(t) \\ \psi(t) \end{bmatrix} & \begin{array}{l} \text{roll rate} \\ \text{roll angle} \\ \text{heading angle} \end{array} \end{array}$$

State vector

Inputs (may be time varying)

$$\bar{r} = \begin{array}{cl} \begin{bmatrix} \beta(t) \\ \delta(t) \end{bmatrix} & \begin{array}{l} \text{steer rate} \\ \text{steer angle} \end{array} \end{array}$$

input vector

$$\beta = \dot{\delta}$$

Constant parameters

$$\bar{p} = \begin{array}{cl} \begin{bmatrix} m \\ g \\ h \\ a \\ b \\ v \\ I \end{bmatrix} & \begin{array}{l} \text{bicycle + rider mass} \\ \text{acc. due to gravity} \\ \text{height of mass center} \\ \text{Wheel base} \\ \text{distance to mass center} \\ \text{speed} \\ \text{roll moment of inertia} \end{array} \end{array}$$

Controller (input function)

$$\delta = k_p \theta$$

$$\beta = k_p \omega$$

proportional controller