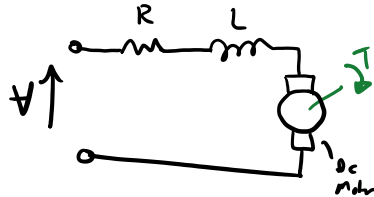


$$F_D = \frac{1}{2} \rho A v^2$$

$$F_R = C_R F_N = C_R mg \cos \alpha$$

$$F_{wR} = mg \sin \alpha$$

$$F_{wR} = mg$$



Newton's Laws  $\Sigma F = ma$

Kinematics

①  $m\dot{v} = F_p - F_D - F_R - F_{wR}$

①  $v = \omega r$

Euler's Law  $\Sigma T = \frac{dH}{dt}$  ang. momentum

②  $\dot{\theta} = \omega$

②  $2J\dot{\omega} = T_m - T_{BF}$   
 $T_m$ : motor torque,  $T_{BF}$ : bearing friction

④  $\dot{s} = v \cos \alpha$

Kirchoff's Voltage Law

⑤  $\frac{di}{dt} L = V(t) - Ri - e_{mf}$

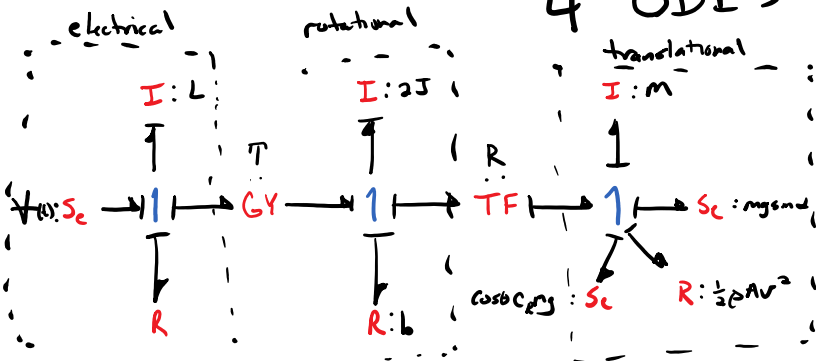
DC Motor motor constant

⑥  $e_{mf} = T \omega$

⑦  $T_m = T i$

equations

Can be reduced to 4 ODES



Block Graph

P → m → P<sub>i</sub>

Bond Graph

$$\dot{P}_2 = S_{e1} - R_3 \frac{P_2}{I_2} - T \frac{P_c}{I_c}$$

$$P_c \left[ \frac{T R_3}{I_2} - R_8 \frac{P_c}{I_c} - R(S_{e11} + R_{12} + S_{e13}) \right]$$


---


$$\left( 1 + \frac{I_{10} R^3}{I_c} \right)$$

2 ODEs  
that describe  
how v/w and  
i change with  
time

