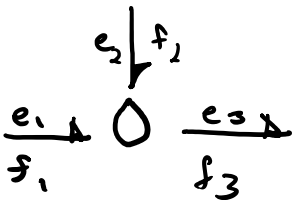


### 3 Ports

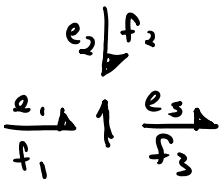
Common effort ( $\emptyset$  junction)



$$e_1 = e_2 = e_3$$

$$f_3 = f_1 + f_2 \quad \text{or} \quad 0 = f_1 + f_2 - f_3$$

Common flow (1 junction)



$$f_1 = f_2 = f_3$$

$$e_3 = e_1 + e_2 \quad \text{or} \quad 0 = e_1 + e_2 - e_3$$

### Bicycle

dynamics equations

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

not constant

$\delta(t), \beta(t)$

$\omega(t)$

$\theta(t)$

$\psi(t)$

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

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

State variables

$$\bar{X} = \begin{bmatrix} \omega \\ \theta \\ \psi \end{bmatrix} \quad \text{roll rate } \dot{\bar{X}} = \begin{bmatrix} \dot{\omega} \\ \dot{\theta} \\ \dot{\psi} \end{bmatrix}$$

roll angle  
heading angle

Inputs

Constant Parameter Vector

$$\bar{p} = \begin{bmatrix} m \\ g \\ h \\ a \\ b \end{bmatrix}$$

mass kg 87 kg  
acc. due to grav. m/s<sup>2</sup> 9.81  
height to com m 1m  
dist. to front wheel 0.5m  
dist to rear wheel 1m

Inputs ✓

$$\bar{r} = \begin{bmatrix} \delta \\ \dot{\beta} \end{bmatrix} \begin{array}{l} \text{steer angle rad} \\ \text{steer rate rad/s} \end{array}$$

$$\begin{bmatrix} b \\ v \\ I \end{bmatrix} \begin{array}{l} \text{dist to rear wheel k m} \\ \text{Speed } 5 \text{ m/s} \\ \text{roll moment of inertia } 3.28 \text{ kg m}^2 \end{array}$$