2.1

\[ \Delta u = \frac{\Delta u}{\Delta t} - v \rightarrow u' \]

\[ a_x = \frac{\Delta u}{\Delta t} \]

\[ \Delta v + uv \Delta t \]

\[ a_y = \frac{\Delta v}{\Delta t} + uv \rightarrow v' + vv \]

2.2 \[ p = q = 0, \quad N = I_{22} \nu \leftrightarrow \tau = I \alpha \]

2.3 (Derivation)

2.4 \[ [I_c] = \begin{bmatrix} I & 0 & 0 \\ 0 & I & 0 \\ 0 & 0 & I \end{bmatrix} \]

no products of inertia, equal principal moments of inertia

\[ [H] = [I_c][\omega] = \begin{bmatrix} I w_x \\ I w_y \\ I w_z \end{bmatrix} = I [\omega] \]

\[ \therefore \tau = I \ddot{\omega} = I \ddot{\alpha}, \quad I \text{ is a scalar.} \]
2.5 \( p = r = 0, \quad q \neq 0, \quad v = 0, \quad u \neq 0, \quad w \neq 0 \)

\[
X = m (\dot{u} + q \cdot \dot{w}) \\
Z = m (\dot{w} - q \cdot \dot{u}) \\
M = I_{yy} q
\]

2.6 \( \ddot{v} - \Omega \dot{w} = \ddot{v} + \Omega^2 v = 0 \)

\[
v = V_0 \sin (\Omega t + \phi) \\
\ddot{v} = -\Omega^2 V_0 \sin (\Omega t + \phi) \\
\therefore \quad \ddot{v} + \Omega^2 v = 0
\]

\( V_0 \) = velocity amplitude  
vector velocity is constant in space

The y-axis spins around with angular velocity \( \Omega \) so the y-component varies sinusoidally.
FIGURE 2.1
Standard coordinate system for vehicle dynamic quantities.
FIGURE 2.2
Bond graph representation of inertial relations for linear and angular momentum.
FIGURE 2.3
General bond graph for a rigid body with body-fixed coordinate frame variables.
FIGURE 2.4
Four-port representation of rigid body dynamics when heave velocity ($W$) and pitch velocity ($q$) are zero.