To prepare for second part of Chapter 15, we will use a different coordinate system for each gear.

For example:

Gear A:

\[ \text{e}_{A1} \times \text{e}_{A2} = k \text{ (out of plane)} \]

\[ k \times \text{e}_{A1} = \text{e}_{A2}, \text{ etc.} \]

Gear B:

\[ \text{e}_{D_1} \times \text{e}_{D_2} = k \]

\[ k \times \text{e}_{D_1} = \text{e}_{D_2}, \text{ etc.} \]

Fly (or spider) wheel:

\[ \text{e}_{A} \times \text{e}_{A} = k \]

\[ k \times \text{e}_{A} = \text{e}_{A}, \text{ etc.} \]

At the instant we are solving this problem, \( \text{e}_{D_1}, \text{e}_{A1}, \text{ and } \text{e}_{A} \) are all aligned in the same direction — Thus equal.

Same is true for \( \text{e}_{A2}, \text{e}_{A2} \) and \( \text{e}_{D_2} \).

They will not be aligned in the next second; i.e., they all may have different derivatives.

\[ \text{E} \]

\( \{ \text{Gear} \) E is stationary, so \( \dot{V}_{E} = 0 \)

\( \dot{V}_{A} = 0 \)

We go from A \( \rightarrow \) F on 2 different rigid bodies, using 2 coordinate systems

Then we will take derivative to find \( \omega_D \)!
\[ W_A = -w_0 e_z \quad \text{given} \]
\[ W_D = w_D e_z \quad \text{unknown} \]
\[ W_S = -w_S e_z \quad \text{unknown} \]

\[ \sum F = 0 \]
\[ \sum F_x = 0 \]
\[ \sum F_y = 0 \]
\[ \sum F_z = 0 \]

\[ \sum F = \sum A - R e_{A_1} - 2 R e_{D_1} \]
\[ V_F = V_A - R w_A e_{A_1} - 2 R w_D e_{D_1} \]
\[ V_C = V_A - R (-w_0 e_A) - 2 R w_D e_{D_1} \]
\[ 0 = 0 + R w_0 e_{A_2} - 2 R w_D e_{D_2} \quad \text{note: right now } e_{D_2} = e_A \]
\[ \Rightarrow w_D = \frac{w_0 e_z}{2} \Rightarrow \]
\[ w_D = \frac{w_0 e_z}{2} \]

What about \( V_D = ? \)
\[ \sum F = \sum A - R e_{A_1} - R e_{D_1} \Rightarrow V_D = V_A - R (-w_0 e_A) - R \left( \frac{w_0 e_z}{2} \right) e_{D_2} \]
\[ V_D = \frac{R w_0 e_{A_2} - R w_0 e_{D_2}}{2} = \frac{R w_0 e_{D_2}}{2} = V_A \quad \text{going to D using the spider!} \]

What is \( w_S = ? \)
\[ \sum F = \sum A - 2 R e_{S_1} \]
\[ V_D = V_A - 2 R w_S e_{S_1} \Rightarrow \]
\[ \frac{R w_0 e_{D_2}}{2} = -2 R w_S e_{S_1} \Rightarrow \]
\[ w_S = -\frac{w_0}{4} e_z \Rightarrow \]
\[ w_S = -\frac{w_0}{4} e_z \]

He assumed \( t > 0 \) got a negative answer.

For accelerations, points F, H on gear D

We need to go to them on the disk/gear D! First, what is \( A_D = ? \)

D is pinned, so it is one physical point, has one velocity \( v \) and acceleration (technically, F, H, \( e_z \) each are 2 points, one on each gear in contact, having the same velocity \( v \) and tangential acceleration but not normal!)

D is on the spider-wheel, so \( \sum F = \sum A - 2 R e_{S_1} \) as well
\[ v_D = v_A - 2Rw_5 \leq x e_{s1} \]
\[ a_D = \frac{a_A}{R} - 2Rw_5 \leq x (w_5 \leq x e_{s1}) \]
\[ a_D = 0 - 2Rw_5 \leq x (e_{s2}) = 2Rw_5 e_{s1} = a_D \]

Points F, G! Using gear D & get to Them
\[ \Gamma_F = \Gamma_D + R_{eD1} \rightarrow \frac{v_F}{v_D} = 1 + \frac{Rw_5}{R} \leq x (e_{s1}) \]
\[ a_F = a_D + \frac{Rw_5}{R} \leq x (e_{s1} \leq x e_{s1}) \]
\[ a_F = a_D - \frac{Rw_5}{R} e_{s1} = 2Rw_5 e_{s1} - Rw_5 e_{s1}, e_{s1} \equiv e_{s1} \]
\[ a_F = R \left( \frac{2w_5}{16} - \frac{w_5}{4} \right) e_{s1} \rightarrow \frac{a_F}{R} = \frac{Rw_5}{8} e_{s1} \]

\[ \Gamma_D = \Gamma_D - R_{eD1} \quad \text{Taking 2 derivative, exactly} \]
\[ \text{as with point F} \]

\[ a_H = 2Rw_5 e_{s1} + Rw_5 \leq x e_{s1} \]
\[ \frac{a_H}{w_5, w_5} \leq x e_{s1} \]
\[ a_H = \frac{3Rw_5 e_{s1}}{8} \]

Note: The Big point here is that, depending how you get from one point to another, you need to be careful about unit vectors. For example, both \( \Gamma_D \) are correct.

\[ \Gamma_D = \Gamma_A - R_{eA1} - R_{eD1} \leftarrow \text{using gear A, then gear D} \]
\[ \Gamma_D = \Gamma_A - 2R e_{s1} \leftarrow \text{using spider wheel & get to D} \]

Right now, \( e_{s1}, e_{s1} \) are equal, but have different derivation \( w_5 + w_5 \neq w_5 \). If you are careful in taking derivation, both equations give you the right answer!