Consider a Simpson drive automatic transmission. Its arrangement is:

![Diagram](image)

*Figure 6.37. A schematic of a Simpson drive.*

And its gear ratio application modes are:

<table>
<thead>
<tr>
<th>Selector</th>
<th>Gear</th>
<th>Front Clutch</th>
<th>Rear Clutch</th>
<th>Front Band</th>
<th>Rear Band</th>
<th>Over-Running Clutch</th>
</tr>
</thead>
<tbody>
<tr>
<td>D—Drive</td>
<td>First</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
<td>Holds</td>
</tr>
<tr>
<td></td>
<td>Second</td>
<td>Off</td>
<td>On</td>
<td>On</td>
<td>Off</td>
<td>Overruns</td>
</tr>
<tr>
<td></td>
<td>Third</td>
<td>On</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
<td>Overruns</td>
</tr>
<tr>
<td>2—Drive</td>
<td>Second</td>
<td>Off</td>
<td>On</td>
<td>On</td>
<td>Off</td>
<td>Overruns</td>
</tr>
<tr>
<td></td>
<td>First</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
<td>Off</td>
<td>Holds</td>
</tr>
<tr>
<td>1—Low</td>
<td>First</td>
<td>Off</td>
<td>On</td>
<td>Off</td>
<td>On</td>
<td>Holds</td>
</tr>
<tr>
<td>Reverse</td>
<td>First</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>On</td>
<td>No Movement</td>
</tr>
<tr>
<td>Neutral</td>
<td>—</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>Off</td>
<td>No Movement</td>
</tr>
</tbody>
</table>

Note that the sun gear is shared in common between the two gearsets. Note that the ring gear of the rear gearset and the planetary carrier of the front gearset are both splined to the output shaft.
and always rotate at the output shaft speed. The sun gear is free to rotate around the output shaft and is not connected to it directly, but it is connected to the casing that can be braked by the front band. Let both gearsets have 65-tooth rings and 31-tooth suns. Find the gear reductions in D-Drive for 1\textsuperscript{st}, 2\textsuperscript{nd}, and 3\textsuperscript{rd}, and for Reverse, for this Simpson drive. Note that the connections for each of the gear ratios are as follows:

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure638.png}
\caption{Power flow in first gear, Simpson drive.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure639.png}
\caption{Power flow in second gear, Simpson drive.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure640.png}
\caption{Power flow in third gear, Simpson drive.}
\end{figure}

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{figure641.png}
\caption{Power flow in reverse, Simpson drive.}
\end{figure}
Solution

Drive, 1\textsuperscript{st} gear:
Overall input is input-side ring-gear speed (front clutch closed). Overall output speed is input-side carrier speed (output shaft is splined to it). Planetary rule (equation) gives the sun-gear speed (both input-side and output-side sun-gear speeds are the same because they are on the same hollow shaft).

\[
\omega_{\text{in}} = \omega_{\text{front,ring}}
\]
\[
\omega_{\text{out}} = \omega_{\text{front,carrier}}
\]

\[
\frac{N_{\text{sun}}}{N_{\text{ring}}} = \frac{\omega_{\text{in}} - \omega_{\text{out}}}{\omega_{\text{sun}} - \omega_{\text{out}}}
\]

\[
\omega_{\text{sun}} = -\frac{N_{\text{ring}}}{N_{\text{sun}}} \omega_{\text{in}} + \omega_{\text{out}} \left( \frac{N_{\text{ring}}}{N_{\text{sun}}} + 1 \right)
\]

On the rear set, output-side carrier speed is zero. The overrunning clutch is between the rear planetary carrier and the housing (ground). It acts like a one-way version of the rear band, and locks the rear planetary carrier to ground under forward drive. [This does not lock the rear planetary carrier to the rear planetary ring, as one might think from looking at the figure – this would lock up the whole rear planetary, thus locking the front, and make the whole gearbox 1:1.] The output-side ring-gear speed is the overall output speed (splined to it). The planetary rule (equation) gives the sun-gear speed.

\[
\omega_{\text{rear,carrier}} = 0
\]
\[
\omega_{\text{rear,ring}} = \omega_{\text{out}}
\]

\[
\frac{N_{\text{sun}}}{N_{\text{ring}}} = \frac{\omega_{\text{out}}}{\omega_{\text{sun}}}
\]

\[
\omega_{\text{sun}} = -\frac{N_{\text{ring}}}{N_{\text{sun}}} \omega_{\text{out}}
\]

Set the two sun speed equations equal and solve

\[
\frac{\omega_{\text{in}}}{\omega_{\text{out}}} = \frac{N_{\text{sun}}}{N_{\text{ring}}} + 2 = \frac{31}{65} + 2 = 2.48
\]

Drive, 2\textsuperscript{nd} gear:
Overall input speed is the input-side ring-gear speed. The sun-gear speed is zero. Overall output speed is the input-side carrier speed. The planetary rule (equation) solves the ratio directly.
\( \omega_{in} = \omega_{front,ring} \)
\( \omega_{sun} = 0 \)
\( \omega_{out} = \omega_{front,carrier} \)
\[
\frac{N_{sun}}{N_{ring}} = \frac{\omega_{in} - \omega_{out}}{-\omega_{out}}
\]
\[
\frac{\omega_{in}}{\omega_{out}} = \frac{N_{sun}}{N_{ring}} + 1 = \frac{31}{65} + 1 = 1.48
\]

**Drive, 3rd gear:**
Overall input is input-side ring-gear speed. Overall input is input-side sun-gear speed. Overall output is input-side carrier speed. Since the ring and sun rotate together, the carrier must also. The planetary rule gives 0/0 – an indeterminate result. But since overall input = overall output, the ratio is 1.

**Reverse**
Overall input is the sun-gear speed. Overall output is the output-side ring-gear speed. Output-side carrier speed is zero. The planetary rule (equation) solves the ratio directly.

\( \omega_{in} = \omega_{sun} \)
\( \omega_{out} = \omega_{rear,ring} \)
\( \omega_{rear,carrier} = 0 \)
\[
\frac{N_{sun}}{N_{ring}} = \frac{\omega_{rear,ring}}{\omega_{rear,sun}} = \frac{\omega_{out}}{\omega_{in}}
\]
\[
\frac{\omega_{in}}{\omega_{out}} = -\frac{N_{ring}}{N_{sun}} = -\frac{65}{31} = -2.10
\]