Queueing Formulas

\( \lambda \): Arrival rate per time unit.

\( \mu \): Service rate (1/service time)

**Poisson Arrival Exponential Service (M/M/s)**

<table>
<thead>
<tr>
<th>Description</th>
<th>One Server</th>
<th>Two Servers</th>
</tr>
</thead>
<tbody>
<tr>
<td>( P_0 ) Probability of no customers in system</td>
<td>( 1 - \frac{\lambda}{\mu} )</td>
<td>( \frac{2\mu - \lambda}{2\mu + \lambda} )</td>
</tr>
<tr>
<td>( P_w ) Probability of waiting for service</td>
<td>( \frac{\lambda}{\mu} )</td>
<td>( \frac{\lambda^2}{\mu(2\mu + \lambda)} )</td>
</tr>
<tr>
<td>( L_q ) Average number of customers in line</td>
<td>( \frac{\lambda^2}{\mu(\mu - \lambda)} )</td>
<td>( \frac{\lambda^3}{\mu(4\mu^2 - \lambda^2)} )</td>
</tr>
<tr>
<td>( L ) Average number of customers in system</td>
<td>( \frac{\lambda}{\mu - \lambda} )</td>
<td>( \frac{4\mu\lambda}{4\mu^2 - \lambda^2} )</td>
</tr>
<tr>
<td>( W_q ) Average time spent in line</td>
<td>( \frac{\lambda}{\mu(\mu - \lambda)} )</td>
<td>( \frac{\lambda^2}{\mu(4\mu^2 - \lambda^2)} )</td>
</tr>
<tr>
<td>( W ) Average time spent in system</td>
<td>( \frac{1}{\mu - \lambda} )</td>
<td>( \frac{4\mu}{4\mu^2 - \lambda^2} )</td>
</tr>
</tbody>
</table>

**Poisson Arrival General Service (M/G/1)**

\[
\begin{align*}
  P_0 &= 1 - \frac{\lambda}{\mu} \\
  P_w &= \frac{\lambda}{\mu} \\
  L_q &= \frac{\lambda^2 \sigma^2 + \left(\frac{\lambda}{\mu}\right)^2}{2(1 - \frac{\lambda}{\mu})} \\
  L &= L_q + \frac{\lambda}{\mu} \\
  W_q &= \frac{L_q}{\lambda} \\
  W &= \frac{L}{\lambda}
\end{align*}
\]