$$
\begin{aligned}
P(\text{Error}) &= \int_0^\infty \Phi\left(-\sqrt{2\gamma}\right) \frac{1}{\gamma_0} e^{-\gamma/\gamma_0} d\gamma \\
&\quad (\text{Let } u(\gamma) = \Phi\left(-\sqrt{2\gamma}\right) \text{ and } v(\gamma) = -e^{-\gamma/\gamma_0}. \\
&\quad \text{ Apply } \int u \cdot dv = u \cdot v| - \int v \cdot du.) \\
&= \Phi\left(-\sqrt{2\gamma}\right)\left(-e^{-\gamma/\gamma_0}\right)\Big|_0^\infty - \int_0^\infty \left(-e^{-\gamma/\gamma_0}\right)\left(-\frac{1}{\sqrt{2\gamma}}\frac{1}{\sqrt{2\pi}}e^{-\gamma}\right) d\gamma \\
&= \frac{1}{2} - \int_0^\infty \frac{1}{\sqrt{4\pi\gamma}} e^{-\gamma(1+1/\gamma_0)} d\gamma \quad (x = \gamma(1+1/\gamma_0)) \\
&= \frac{1}{2} + \frac{1}{\sqrt{1+1/\gamma_0}} \int_0^\infty \left(-\frac{1}{\sqrt{4\pi x}} e^{-x}\right) dx \quad (\text{This is exactly } u'(x).) \\
&= \frac{1}{2} + \frac{1}{\sqrt{1+1/\gamma_0}} \Phi\left(-\sqrt{2x}\right)\Big|_0^\infty \\
&= \frac{1}{2} - \frac{1}{2\sqrt{1+1/\gamma_0}}
\end{aligned}
$$