$$
\begin{aligned}
\left(\int_{-\infty}^{\infty} e^{-x^2}\,dx\right)^2 &= \int_{-\infty}^{\infty}\int_{-\infty}^{\infty} e^{-(x^2+y^2)}\,dx\,dy \\
&= \int_{0}^{2\pi}\int_{0}^{\infty} e^{-r^2} r\,dr\,d\theta \\
&= \int_{0}^{2\pi}\left[-\frac{e^{-r^2}}{2}\right]_{r=0}^{r=\infty} d\theta \\
&= \pi.
\end{aligned}
$$