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$$|\psi_i\rangle = \sum_i |\phi_i\rangle \langle \phi_i | \psi_i \rangle = |\phi_1\rangle \langle \phi_1 | \psi_i \rangle + |\phi_2\rangle \langle \phi_2 | \psi_i \rangle + |\phi_3\rangle \langle \phi_3 | \psi_i \rangle = \frac{i}{\sqrt{3}} |\phi_1\rangle + \sqrt{\frac{2}{3}} |\phi_2\rangle$$

$$\begin{aligned} |\psi_f\rangle &= \sum_i |\phi_i\rangle \langle \phi_i | \psi_f \rangle = |\phi_1\rangle \langle \phi_1 | \psi_f \rangle + |\phi_2\rangle \langle \phi_2 | \psi_f \rangle + |\phi_3\rangle \langle \phi_3 | \psi_f \rangle \\ &= \frac{1+i}{\sqrt{3}} |\phi_1\rangle + \sqrt{\frac{1}{6}} |\phi_2\rangle + \sqrt{\frac{1}{6}} |\phi_3\rangle \end{aligned}$$

$$\begin{aligned} P = |\langle \psi_f | \psi_i \rangle|^2 &= \left(\frac{1-i}{\sqrt{3}} \langle \phi_1 | + \sqrt{\frac{1}{6}} \langle \phi_2 | + \sqrt{\frac{1}{6}} \langle \phi_3 | \right) \left(\frac{i}{\sqrt{3}} |\phi_1\rangle + \sqrt{\frac{2}{3}} |\phi_2\rangle \right) = \left| \frac{1-i}{\sqrt{3}} \frac{i}{\sqrt{3}} + \sqrt{\frac{1}{6}} \sqrt{\frac{2}{3}} \right|^2 \\ &= \left| \frac{1+i}{3} + \frac{1}{3} \right|^2 = \left| \frac{2+i}{3} \right|^2 = \frac{2^2 + 1^2}{3^2} = \frac{5}{9} \end{aligned}$$

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