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(a)

$$1 = \langle\psi(0)|\psi(0)\rangle = \frac{|A|^2}{6} + \frac{1}{6} + 1 + \frac{1}{4}$$

So, it seems that for any value of A systems state is not renormalizable. Instead of $|\psi(0)\rangle$ we use $|\psi_N(0)\rangle$.

$$|\psi_N(0)\rangle = \sqrt{\frac{12}{19}}\left(\frac{1}{\sqrt{6}}|\phi_1\rangle + \frac{1}{\sqrt{6}}|\phi_2\rangle + |\phi_3\rangle + \frac{1}{2}|\phi_4\rangle\right)$$

(b)

$$|\psi_N(t)\rangle = e^{-i\hat{H}t}|\psi_N(0)\rangle = \sqrt{\frac{12}{19}}\left(\frac{1}{\sqrt{6}}e^{\frac{-iE_1t}{\hbar}}|\phi_1\rangle + \frac{1}{\sqrt{6}}e^{\frac{-iE_2t}{\hbar}}|\phi_2\rangle + e^{\frac{-iE_3t}{\hbar}}|\phi_3\rangle + \frac{1}{2}e^{\frac{-iE_4t}{\hbar}}|\phi_4\rangle\right)$$

(c)

$$P = |\langle\phi_2|\psi_N(t)\rangle|^2 = \left|\frac{1}{\sqrt{6}}e^{\frac{-iE_2t}{\hbar}}\right|^2 = \frac{1}{6}$$

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