

PHYS 514
Practice Questions Set-1

Q.1

Briefly explain the following three basic Josephson-Junction Qubits. (Draw energy band diagram and state the basic working principle of each)

- (a) Charge qubit
- (b) Flux Qubit
- (c) Phase Qubit

Q.2

Show that $\langle E \rangle = 0$ and $\langle E^2 \rangle \neq 0$ for a Fock state $|n\rangle$. Find the electric field uncertainty ΔE for the Fock state $|7\rangle$.

Q.3

Consider the following superposition of two Fock states, $|\psi\rangle$ in the cavity

$$|\psi\rangle = \sqrt{0.20}|10\rangle + \sqrt{0.80}|40\rangle$$

- (a) What is the average number of photon in the cavity?
- (b) If you annihilate a photon by the acting annihilation operator $\hat{a}$ on this state, then how many photons remain in the cavity ?

Q.4

The ‘dressed states’ eigenstates associated cavity-qubit system is given by

$$|n, -\rangle = \cos(\theta_n)|g\rangle|n+1\rangle - \sin(\theta_n)|e\rangle|n\rangle$$

$$|n, +\rangle = \sin(\theta_n)|g\rangle|n+1\rangle + \cos(\theta_n)|e\rangle|n\rangle$$

- (a) Rewrite down the above states when qubit frequency ω_q is equal to cavity frequency ω_c
- (b) What is the energy eigen states of dressed states when $\omega_q = \omega_c$
- (c) Briefly discuss the condition in which $\theta_n = 0$. Rewrite down the down the dressed states for θ_n and briefly explain this state of the cavity-qubit system.

Q.5

In the presence of driving pulse of frequency ω_d , the state of qubit can be expressed as

$$|\psi(t)\rangle = C_g(t)e^{+i\frac{\omega_q}{2}t}|g\rangle + C_e(t)e^{-i\frac{\omega_q}{2}t}|e\rangle$$

Where

$$C_g(t) = \frac{e^{-i\frac{\Delta_d}{2}t}}{\Omega_R} \left(\Omega_R \cos\left(\frac{\Omega_R}{2}t\right) + i\Delta_d \sin\left(\frac{\Omega_R}{2}t\right) \right)$$

$$C_e(t) = i \frac{Ae^{+i\frac{\Delta_d}{2}t}}{\Omega_R} \sin\left(\frac{\Omega_R}{2}t\right)$$

With $\Delta_d = \omega_q - \omega_d$ and $\Omega_R = \sqrt{A^2 + \Delta_d^2}$, $A = Ed$

- (a) Drive the expression for population of qubit in excited state, $P_e(t)$
- (b) Under what condition maximum value of $P_e(t) = 1$
- (c) From answer (a) write down the expression for Rabi frequency
- (d) Write down the factors that can change the Rabi frequency
- (e) Write down some uses/applications of the Rabi frequency information in qubit processing

Q.6

- (a) What do you mean by the quality factor of a cavity and CPW. Briefly explain how do you measure the quality factor of a cavity/CPW
- (b) What is the difference between Rabi measurements and Ramsi measurements
- (c) Briefly explain the T1 and T2 measurements of a qubit