NATIONAL UNIVERSITY OF SINGAPORE

PC4246 Quantum Optics

(Semester I: AY 2018-19)

Time Allowed: 2 Hours

INSTRUCTIONS TO STUDENTS

1 Please write your student number only on the answer book. Do not write your name.

2 This assessment paper contains 2 questions and comprises 2 printed pages (including this page).

3 Students are required to answer ALL questions.

4 The answers are to be written with ink pen only (no pencil).

5 This is a CLOSED BOOK examination.

6 Students should write the answers for each question on a new page.

7 The total mark is 30.

8 Mark for each question is shown in square bracket.

9 Programmable calculators are NOT allowed.

Q1.[15 Marks]

Alice repetitively prepares two-photon states:

$$|\psi\rangle = 1/\sqrt{2}(|1\rangle_H |1\rangle_V + |1\rangle_V |1\rangle_H),$$

where H and V denotes the horizontal and vertical polarization of the photons, respectively. After preparation, she sends one out of the two photons to Bob. Bob has no knowledge about the basis in which the states are prepared but he knows that the photons are prepared in a pure state. Based on this information answer the following:

A. Without having any information about the basis in which the state $|\psi\rangle$ has been prepared, Bob performs a measurement with a horizontal analyzer (or polarizer). Derive the mean photon number (expectation value of the number operator) that Bob will observe.

B. Show by derivation that it is possible for Bob to know whether the state that Alice prepared is a separable state or not.

C. If Bob measures in $|L/R\rangle$ basis would his result in [B.] be affected? Justify your answer.

D. Explain the experimental setup that Bob needs in order to implement [B.].

Q2.[15 Marks]

Consider an atom placed inside an optical cavity. The atom is effectively a two-level system. Consider strong coupling and no loss of excitation from the cavity or the atom.

A. Starting from the Hamiltonian, derive the eigenstates and eigenvalues of the system.

B. Consider that the atom-cavity coupling strength is 50 kHz and the cavity is detuned from the atomic resonance by -5 MHz. Restricting to single excitation of the system, derive and explain the changes in the eigenvalue spectrum of the system.

C. How would the results change if the cavity is detuned by $+5$ MHz?

D. Explain qualitatively the possible loss mechanisms in an atom-cavity system and how these losses affect the system.

END OF PAPER

[MM]