Syllabus for Phys.624
Introductory Quantum Field Theory
Fall, 2004

Dr. R. N. Mohapatra

Text Book: "Quantum Field Theory" by F. Mandl and G. Shaw (John Wiley)

"Field Quantization" by W. Greiner and J. Reinhardt (Springer-Verlag)

Topics to be covered are Chapters 1-13 of Mandl and Shaw with supplementary material from Greiner and Reinhardt. I recommend that you get both the books. There will be three midterm exams: Oct. 4, Nov. 3(tentative), Dec.3 (tentative) and a final exam on the date in the college schedule i.e. December 15, 8-10:AM.

There will be homework assignments every week. They will be collected the following week, same day it was assigned. The final grades will be based on all homeworks and the tests.

My office hours are wednesday and Friday 2-3; at other times, (except Tuesday and Thursdays) I will be available with appointment. Do take advantage of the office hours. Quantum Field Theory is a completely new language, although the basic rules are that of Quantum mechanics; knowledge of QFT is essential in all fields of theoretical physics. So you will need help in thoroughly assimilating the rules and techniques of this important topic.

My e-mail: rmohapat@physics.umd.edu My Office: Rm 4124; Tel. 56022.

Homework grading will be done by Prof. Y. S. Kim.

Final grade will be based on 40% from midterms, 40% from final and 20% homework.

Phys. 624 Homework 1
Fall, 2004
Due September 6, Monday

1. Radiation field inside a cubic enclosure, which contains no charges, is specified by the quantum state:

$$|c\rangle = exp(-\frac{1}{2}|c|^2)\sum_{n=0}^{\infty}\frac{c^n}{\sqrt{n!}}|n\rangle$$

where $c = |c|e^{i\delta}$ is any complex number and $|n\rangle$ is the state in which there are n photons. Derive the following properties of $|c\rangle$: (i) $|c\rangle$ is a normalized state; (ii) $a|c\rangle = c|c\rangle$ where a is the annihilation operator as in the case of a simple harmonic oscillator; (iii) $\langle c|\mathbf{N}|c\rangle = |c|^2$, where $\mathbf{N}$ is the number operator.

2. Suppose you have a creation operator $a^\dagger$ and annihilation operator a, which satisfy the following commutation relation

$$aa^\dagger - qa^\dagger a = 1$$

.

Calculate the norm of an n-particle state ${a^\dagger}^n|0\rangle$. For what values of q, is the norm positive. Use the fact that $a|0\rangle = 0$.

3. Consider the case $q = -1$ in problem two and show that no physically admissible state can have two or more quanta of the same particle.

4. Consider a system described by a single set of creation and annihilation operators a and $a^\dagger$ obeying the anticommutation relations $[a, a^\dagger]_+ = 1$ and relations $a^2 = 0$. Prove the relation $[a, a^\dagger] = (-1)^N$, where $N = a^\dagger a$, the number operator.

5. Consider two pairs of creation and annihilation operators: $(a, a^\dagger)$ and $(b, b^\dagger)$ which satisfy the commutation and anti-commutation relations respectively. Suppose the Hamiltonian of the system is given by $H = \omega_a a^\dagger a + \omega_b b^\dagger b$.

(a) Consider an operator $Q = b^\dagger a$ and its hermitean conjugate. Calculate the commutation relation between Q and $a^\dagger$ and anti-commutation relation between Q and $b^\dagger$.

(b) When does Q commute with H ? Calculate the anti-commutator of Q and $Q^\dagger$.