Syllabus for Phys.624
Introductory Quantum Field Theory
Fall, 2002

Dr. R. N. Mohapatra

Text Book: "A First Book of Quantum Field Theory" by A. Lahiri and P. B. Pal, CRC Press, Washington D. C.

Other books: "Quantum Field Theory" by F. Mandl and G. Shaw; "Introduction to Quantum Field Theory" by M. Peskin and V. Shroeder (Addison-Wesley); "Quantum Field Theory: A Modern Introduction" by M. Kaku (Oxford).

Topics to be covered are Chapters 1-12 of Lahiri and Pal. There will be three midterm exams: Sept. 30, Oct. 23, Nov. 18 and a final exam on the date in the college schedule i.e. December 18, 8:AM.

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

My office hours are wednesday 2-4; at other times, 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.

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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, 2002
Due September 11, wednesday

1. Radiation field inside a cubic enclosure, which contains no charges, is specified by the 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. Show that replacing the Lagrangian density $\mathcal{L}(\phi, \partial\phi)$ by $\mathcal{L} + \partial_\alpha\Lambda^\alpha$, where Λ^α are arbitrary functions of the fields ϕ does not alter the field equations.

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. The Lagrangian for a particle of mass m and charge e moving in an electromagnetic field, is given by

$$\mathcal{L}(\mathbf{x}, \frac{d}{dt}\mathbf{x}) = \frac{1}{2}m(\frac{d\mathbf{x}}{dt})^2 + \frac{e}{c}\mathbf{A}\cdot\frac{d\mathbf{x}}{dt} - e\phi$$

.

(i) Obtain the canonical momentum; (ii) Derive the field equations for the particle in terms of the electric and the magnetic fields. (iii) Derive the corresponding Hamiltonian and use it to check your answers to the problems in (i) and (ii).