PHYS 3200: Fields, particles, and symmetries (Fall 2022)

Introduction to relativistic quantum fields, the foundational entities of the standard model of particle physics.

[Classical physics (i.e. non-quantum) may be difficult but is conceptually straightforward; one understands the nature of the entities one is dealing with. Newtonian mechanics deals w/ particles or collections of particles, electromagnetism deals w/ electric + magnetic fields, the only problem is to determine how these evolve in time. We can make a chart.]

phenomena	matter		light	(gravity)
classical description	particles		EM waves	grav. waves
	↕	wave-particle duality	↕	
quantum description	matter waves		photons	gravitons

[How do we encompass everything in a single conceptual framework?]

[Let's make another chart.]

<u>theories</u>

classical mechanics (CM) 1) Newtonian 2) Lagrangian 3) Hamiltonian	classical field theory (CFT) 1) scalar 2) vector (Maxwell) 3) tensor (Einstein) 4)
quantum mechanics (QM) 1) Schrödinger picture 2) Heisenberg picture	quantum field theory (QFT) (particles) 1) spin-0 (e.g. Higgs boson) 2) spin-1 (photons, gluons) 3) spin-2 (gravitons) 4)

[But what about matter? That too is described by a field]

[Add to chart above:]

4) spinor (Dirac)
4) spin-$\frac{1}{2}$ (electrons, quarks)

The fundamental entity describing everything [pace gravity] <u>relativistic quantum field.</u>

[gravity?]

Symmetries

- time and space translations (shifts)
- Lorentz transformations (boosts & rotations)

} Poincaré

these constrain the laws of nature

- internal symmetries (global, eg charge, isospin)
  (local, ie "gauge symmetry")

these constrain interactions among particles

Spontaneous-broken (or hidden) symmetries

Higgs mechanism (responsible for masses of W, Z)
massive spin-1 fields

Suggested follow ups

Tong
Srednicki
Peskin & Schroeder
Schwartz
Coleman

Motto of the course

Omnia disce, videbis postea nihil esse superfluum

Hugh of St. Victor of Paris (1096-1141)

Learn everything; you will find nothing superfluous