Advanced Particle Physics 2014
Dr David Colling and Dr Morgan Wascko - Course Outline

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Email is the best option if you need to contact us.

Office Hours
Monday 12:30 to 13:30 - Dr Wascko, Blackett 525, Dr Colling, Blackett 529b

Books

• *Modern Particle Physics* Mark Thompson, Cambridge University Press
• *Elementary Particle Physics in a Nutshell* Chris Tunnell, Princeton University Press
• *Introduction to Elementary Particles* David Griffiths, Wiley
• *Quarks and Leptons* Halzen and Martin, Wiley (Good but a little outdated)

These are other books at about the right level which would also be useful.
2. Bowler, “Femtophysics”

Papers
We will also provide a research paper on each of the topics so that you gain an appreciation of how this is done. These will be a mixture of theoretical and experimental papers.

Lectures
The lectures are organised as follows:

• **Course Overview and Basics (1 Lecture; Dr Colling):**

• **Experiments and Detectors (2 Lectures; Dr Colling):**

• **The Dirac Equation (3 Lectures; Dr Colling):**
  Relativistic wave equation for all the matter (fermion spin 1/2) particles. Solutions; spin, helicity, antiparticles.

• **The Electromagnetic Force (5 Lectures; Dr Wascko):**
  The photon wavefunction and Maxwell’s equations. Photon-electron coupling; in the Dirac equation (minimal substitution), in Maxwell’s equations (as a conserved current) and as a Feynman diagram. Massless, implying infinite range, Yukawa couplings. Lagrangians, U(1) gauge invariance and Nöther’s theorem. Decays, Fermi’s Golden Rule, phase space, cross-sections. Reactions; \( \mu^- e^- \rightarrow \mu^- e^- \), \( e^+ e^- \rightarrow \mu^+ \mu^- \).
• **The Strong Force (3 Lectures; Dr Wascko):**
  QCD; SU(3) gauge invariance. Massless but not infinite range; gluons carry their own charge; “confinement” and “asymptotic freedom”. Colourless hadrons as bound states of quarks; baryons, mesons, multiplets. Reactions, $e^+e^- \rightarrow q\bar{q}$, $ep \rightarrow eX$ and $p\bar{p} \rightarrow X$, hadronisation and jets.

• **The Weak Force (6 Lectures; Dr Colling):**
  C and P violation, CPT conservation. Neutral Current interactions; Charged Current Interactions. $W^\pm$, $Z^0$ massive force bosons, spontaneously broken symmetry, left handed coupling. Approximate (Yukawa) point interaction, $G_F$. V-A structure and Dirac equation LH coupling, neutrinos. Handedness and helicity. Muon decay; tau decay; pion decay. CKM matrix, $K^0$, $B^0$ mixing. $K^0$ and $B^0$ CP violation.

• **Electroweak Theory and the Higgs (3 Lectures; Dr Colling):**
  Mixing with hypercharge U(1) gives $Z^0$ and photon. Reactions, $e^+e^- \rightarrow Z^0$. The Higgs and mass generation. Spontaneous symmetry breaking.

• **Neutrinos and Beyond the Standard Model (3 Lectures; Dr Wascko):**

**Problem Sheets:**
There will be a set of problems handed out roughly every two weeks. These form an integral part of the course; there is not enough time in lectures to go through the details of many of the topics, so the problem sheets will fill in the gaps. It will be very hard to pass the exam without having done the problems.

**Rapid Feedback** Details to be confirmed.