PHYS 30121 INTRODUCTION TO NUCLEAR AND PARTICLE PHYSICS

Revision materials

Course web pages (linked from my home page and Blackboard)

- lecture summaries, with textbook references
- virtual handouts on Feynman diagrams, angular momentum, discrete symmetries, . . .
- all examples sheets with solutions
- last four years' exam papers, with bottomline answers

Textbooks: Martin, Martin and Shaw, Perkins are all available as ebooks from the libary

Blackboard: my visualiser notes, but only if you missed a lecture (see under "Current students only")

Podcasts: ditto

This course is rather different from most others:

- no complicated algebra or fiddly derivations
- instead, you need to be able to recognise patterns
- and to use logical thinking to fit these together and draw conclusions

Different skills from other courses but, if you don't develop them, the material will collapse into a pile of disconnected facts!

And the best way to develop these skills is by using them to solve problems

Example of an important pattern: three generations of fermions

			Q
u	c	t	$+\frac{2}{3}$
d	s	b	$-\frac{1}{3}$
ν_e	ν_μ	ν_τ	0
e^-	μ^-	τ^-	-1

- each consists of a pair of quarks and a pair of leptons
- members of each pair linked by weak interactions with $W^\pm$
- generations (flavours) conserved by strong, EM and Z^0
  mixed in interactions with $W^\pm$ (eg $c \to d + W^+$ and $s + W^+$)

$\rightarrow$ determines whether processes are allowed or forbidden

Don't expect you to remember

- the semi-empirical mass formula

$$M(A,Z) = Z\,M(^1\mathrm{H}) + (A-Z)M_n - a_v\,A + a_s\,A^{2/3} + a_c\,\frac{Z^2}{A^{1/3}} + a_a\,\frac{(A-2Z)^2}{A} - \delta_p$$

  (given at top of exam paper)

- the detailed ordering of levels in the nuclear shell model

  $1s_{1/2} \,\Big|\, 1p_{3/2}\, 1p_{1/2} \,\Big|\, 1d_{5/2}\, 2s_{1/2}\, 1d_{3/2} \,\Big|\, 1f_{7/2} \,\Big|\, 2p_{3/2}\, 1f_{5/2}\, 2p_{1/2}\, 1g_{9/2} \,\Big|$

But do expect you to know what assumptions lead to these, and how to use them

Don’t expect you to be intimately familiar with all 36 light hadrons

But you should know what symbols mean (values of B and S) for the ground-state octets of mesons and baryons, and the Ω^-

Tell you where the particles fit into the hexagonal weight diagrams

Other properties and quark structures follow from these patterns

Three apparently simple ideas that can cause confusion

- angular momenta are vectors
  so magnitude of sum satisfies a triangle rule:

$$J = |J_1 - J_2|, \ldots, J_1 + J_2 \quad \text{in steps of } 1$$

- parity of an orbital wave function is

$$P = (-1)^L$$

  L: orbital angular momentum of one particle in a spherical potential or relative orbital angular momentum of two particles
- C-parity of a particle-antiparticle state is

$$C = (-1)^{L+S}$$

  NB: state must be completely neutral (no charge, baryon number, flavour, ...) otherwise not an eigenstate of $\hat{C}$

Review

Basic constituents of matter: quarks and leptons (3 generations)
Fundamental forces: strong, EM, weak
Feynman diagrams
Continuous symmetries: baryon and lepton number, flavour numbers
Discrete symmetries: parity, charge conjugation, *CP*
Weak interaction: parity violation, flavour mixing (quarks)
Quark model of hadrons: mesons, baryons (multiplets)
Hadron masses and decays
Nuclear forces: range, charge symmetry, saturation
Nuclear sizes: charge radii
Nuclear (atomic) masses: semi-empirical mass formula, line of stability
Nuclear decays: α and β
Nuclear structure: shell model (independent particle)

Exam

Standard format

- compulsory Q1: short parts, covering whole course
- choice of two longer problems (out of three)

Format was slightly different for years 2009/10 to 13/14
but syllabus the same (more emphasis now on discrete symmetries)
so old questions still relevant (but no purely essay ones like 12/13 B5)