Department of Physics & Astronomy
Module Report
Semester 1, 2015-16

Course Title: Particle Physics
Module: PHY304
Lecturer(s): Chris Booth
Number of students: 95 (excluding those not present for exam)

General Comments: There were no major changes to the course this year. The printed course booklet was again produced, instead of using separate handouts for each topic. The expanded topic of quark symmetry in baryons was continued. There were 21 lectures plus two revision & problem classes, one just before the exam. Five assessed homeworks were set fortnightly, with unassessed problem sheets in the intervening weeks. The use of a feedback sheet for each homework, discussing common problems and errors, was continued.

Problems Experienced: None.

Coursework Performance: (5 homeworks) This was generally performed well. Students appeared to appreciate that it gave them practice in kinematic calculations, in particular. Most students attempted all questions, though one handed in no homeworks, three did only 1 or 2 of the 5 and another 11 omitted 1 or 2 homeworks. A few students handed work in late and were penalised. The average mark overall was good, at 70.3%.

Exam Performance:
Exam performance was similar to previous years'. The main weaknesses displayed were inadequate explanations (mentioning a few facts without explaining any connections) and faulty logical reasoning, e.g. in explaining the relationship between observations and theories.

Question 1 (compulsory short answers) – most sections were reasonably well answered but with a lack of precision or detail. Fermions were often described as fundamental particles, and were said to have "antisymmetric wave-functions" without mentioning the exchange of identical particles Many got the parity of the ϕ wrong, either ignoring the $(-1)^l$ term, incorrectly combining the two kaon parities or assuming the initial isolated particle had orbital angular momentum! Feynman diagrams sometimes required bosons with very odd properties, and did not describe the reaction at the quark level. The explanation of the term *jet* was particularly poor, with no description of either cause or appearance of the produced particles. Average 13.1 out of 20 (65%).

Question 2 (quantum numbers, baryon multiplets and decay kinematics) – a very popular question. Some good answers. Definition of the quantum numbers was poor, with many only saying isospin was "a vector in arbitrary space" or "connected with charge". For part (c), most people simply stated that the decuplet contained the Δ while the octet contains the nucleons with no explanation of why, or confused isospin and spin. Almost everyone completed the kinematic calculation correctly. Average 8.4/15 (56%) for 85 attempts.

Question 3 (virtual particles, Yukawa potential) – a less popular question. Many definitions of virtual particles were rather imprecise. The (bookwork) derivations of Yukawa potential and propagator were generally done well. Many ignored the 1% change in cross section, or took it to be the value rather than the change! (The marks for sections (c) and (d) were not correctly aligned with the questions. The mark weighting was therefore treated flexibly to ensure no-one was penalised by this.) Average 7.8/15 (52%) for 23 answers.

Question 4 (flavour decays, allowed interactions) – a very popular question. The first section was usually done very well or very badly! The fact that a charged current ($W^{\pm}$) was needed was missed by most. Many gave completely inadequate explanations, even if the decay chain was correct. The categorisation of allowed/forbidden reactions was done much better. Average 8.1/15 (54%) for 74 answers.

Question 5 (Anomalous magnetic moment and *g*–2, decay kinematics) – A very unpopular question with several incomplete answers. Very little detail was given for the experiment, and almost nothing on how results were used to find *a*. The kinematic calculation was done very well. Average 8.4/15 (56%) for 8 answers.

Overall average 59.0% on exam, 60.8% including homeworks; 9 students failed; 27 first class marks.

Answers to numerical and similar questions

1d) $K^+ = u\bar{s}$; $K^- = s\bar{u}$.

1f) Electromagnetic interaction, as photons are involved.

1h) Neutrino energy is 29.8 MeV.

2d) Kaon energy is 585 MeV.

3d) Boson mass is greater than 70.7 GeV/c^2.

4c)i) Forbidden – violation of tau and muon lepton numbers.

4c)ii) Weak – involvement of neutrinos.

4c)iii) Forbidden – change of strangeness by 2 units.

4c)iv) Weak – change of strangeness by 1 unit.

4c)v) Forbidden – Baryon number not conserved.

4c)vi) Strong – hadrons involved, all QN conserved.

4c)vii) Forbidden – change of strangeness by 2 units.

4c)viii) Electromagnetic (electroweak at high energy) – charged leptons involved.

5c) Maximum neutrino momentum 2116 MeV/c.

Responses to Questionnaire comments

Satisfaction with the module is generally high, with many positive comments on the handout material, homeworks and feedback, which is very gratifying. (2 people did indicate that feedback was poor or very poor. Since all work was returned within one week with detailed comments and model answers, I would be interested to know what these two students wanted in addition.)

One person objected to doing kinematic problems in "what is supposed to be a qualitative module". I don't know where they got the impression that the module was purely qualitative – though some parts of the material are dependent on advanced theory which cannot be covered in the course, where quantitative explanations are possible they are and should be given!

There was a suggestion that more could be said about applications of particle physics. This will be considered for the future.

It is true that the lecture notes contain gaps in derivations or explanations. This is deliberate and is actually highlighted at the appropriate points in the notes, as I believe it aids the learning and remembering of mathematical material when it is presented fresh in lectures with personal notes being taken.

There was a complaint that coursework marking was harsh. However, it was repeatedly stressed that full marks required proper explanations, not just correct numerical values, and this was frequently missing. (The fact that the overall homework mark averaged over 70% indicates that actually I was over-generous in this respect!)

Planned Revisions for next session: Minor revisions to the course booklet.

Course work deadlines and return of marked work

All work was handed out and required on the dates indicated at the start of the semester on the Third Year timetable. Each piece of work was returned with comments one week after being handed in.

Feedback was provided by comments written on the marked scripts, a specimen solution for each question and a "feedback sheet" containing comments on common errors, easier approaches etc.

Work	Given out	Handed in	Returned to students
Homework 1	29th Sep.	6th Oct.	13th Oct.
Homework 2	13th Oct.	20th Oct.	27th Oct.
Homework 3	27th Oct.	3rd Nov.	17th Nov.
Homework 4	17th Nov.	24th Nov.	1st Dec.
Homework 5	1st Dec.	8th Dec.	15th Dec.

C N Booth
8th February 2016