Department of Physics & Astronomy
Module Report
Semester 1, 2017-18

Course Title: Particle Physics
Module: PHY304
Lecturer(s): Chris Booth
Number of students: 128 (excluding those not present for exam)

General Comments: There were no major changes to the course this year. Extra detail was added to the printed course booklet including more quantum mechanical background on hermitian operators, and the topic of quark symmetry in baryons further expanded. 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: The small whiteboards in the Diamond, one of which was partially covered by the screen, were far from ideal. Students also did not like them.

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 only 1 of the 5 homeworks, and another 5 did only 2. A few students handed work in late and were penalised. The average mark overall was good, at 74%.

Exam Performance:
Exam performance was very similar to recent 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. Some students decided to reproduce homework exercises instead of answering the questions as set!

Question 1 (compulsory short answers) – most sections were well answered. When describing baryons and mesons, the same information was often given twice – e.g. the fact that they are made of quarks and are composite objects were not considered separate properties. Few people were able to give the cross section for annihilation to produce hadrons, given the value for producing muon at the same energy. The question was probably too easy, with average mark 14.4 out of 20 (72%).

Question 2 (quark symmetry, allowed reactions) – a surprisingly popular question. Many people confused the symmetry of baryons with that of the quarks that make them up. The second section was often answered poorly, with students not considering the two identical quarks in each case. Many of the purported wave-functions included all 3 quarks, and had incorrect symmetries. In contrast, the final part on allowed interactions was done very well, with many perfect attempts. Average 8.5/15 (57%) for 97 attempts.

Question 3 (Virtual particles, evidence for 3 generations) – not a very popular question. Definitions of virtual particles were often incomplete, though space-like and time-like cases were well-described. Some good descriptions of the experimental evidence, though some didn't explain what was actually measured and others talked about something irrelevant! Average 7.3/15 (48%) for 40 answers.

Question 4 (Weak interactions). Characteristics of the weak interaction were reasonably well described, though some people listed the same thing twice, and some included properties which

were not directly observable (like the bosons being massive). The logic behind requiring boson exchange with massive particles was sketchy. Few people said how Ws were *first* produced and even fewer how they were observed. The kinematic calculation was generally done well, though some people made it extremely complicated. Average 8.0/15 (53%) for 56 answers.

Question 5 (Form factor). The bookwork part was done very well, and many people completed the calculation well. Some people did a 1-D integral, rather than a volume integral, to normalise the charge density. A number could not write down the linear expression, and a surprising number ignored the information in the question and just reproduced a homework calculation. (This earned no marks!) Average 8.4/15 (56%) for 63 answers.

Overall average 61.5% on exam, 63.3% including homeworks; 4 students failed; 45 first class marks.

Answers to numerical and similar questions

1 e) b quark has spin ½, isospin 0, charge $-{}^{1}/_{3}$ and b quantum number –1.

1 f) Quark content $u\bar{c}$.

1g) Hadron cross section 40 nb.

1h) Gluons are massless, electrically neutral, spin 1 and carry composite colour (colour-anticolour).

1i) Weak interaction, as strangeness changes.

1j) Strong and electromagnetic interactions are invariant under C.

2c)i) Strong – hadrons involved, all qu. nos. conserved.

2c)ii) Forbidden – μ lepton number not conserved.

2c)iii) Weak – change of strangeness by 1 unit.

2c)iv) Forbidden – baryon number not conserved.

2c)v) Electromagnetic – photons involved (all qu. nos. conserved).

2c)vi) Electromagnetic (electroweak at high energy). Charged leptons involved.

2c)vii) Strong – hadrons involved, all qu. nos. conserved.

2c)viii) Forbidden – change of strangeness by 2 units.

4 c) Energy of D was 3739 MeV.

5c) $F(\underline{q}) = \frac{12\hbar^3}{q^3R^3}\left(2\frac{\hbar}{qR}\left(1-\cos\frac{qR}{\hbar}\right)-\sin\frac{qR}{\hbar}\right)$ $F(0)=1$.

Responses to Questionnaire comments

Satisfaction with the module is generally high, with many positive comments on the handout material, homeworks and feedback, and the support provided for individual questions, which is very gratifying. It is gratifying to know that many students found this an interesting topic.

As in previous years, there was a mixed response to the homeworks. Many found the programme of 5 problems to be a useful way to develop skills in solving questions on kinematics. Others felt there was too much work, though if you took on board the feedback and specimen answers from previous homeworks, each exercise should not have taken a lot of time. (It was disappointing to see that many marked homeworks were never collected.) Some people complained that the homeworks were not closely linked to lecture material. This was deliberate, and was advertised! After introductory material in early lectures, the homeworks were intended to be an almost self-contained course to teach a parallel aspect of the topic. (The Teaching Committee is looking into replacing the coursework with non-assessed but compulsory problems classes. If space can be found in the timetable, this is something I would support.)

The other area of complaint was the quality and size of the whiteboards in the Diamond. I agree with the criticism, and have passed this on to our timetable officer.

Planned Revisions for next session: The course book may be expanded to include more material currently only presented in lectures. This may include more kinematics.

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	26th Sep.	3rd Oct.	10th Oct.
Homework 2	10th Oct.	17th Oct.	24th Oct.
Homework 3	24th Oct.	31st Oct.	14th Nov.
Homework 4	14th Nov.	21st Nov.	28th Nov.
Homework 5	28th Nov.	5th Dec.	12th Dec.

C N Booth
23rd January 2018