Report on B5 (General Relativity and Cosmology) 2013

124 students took the B5 exam. The average mark was about 66% which was the target average, with a standard deviation of about 13%. Almost all students chose to answer the first two questions. These are the GR questions and what I think this shows is that the students are much more geared to the more mathematical GR part of the course than the cosmology. We should consider, in future years, rebalancing the exam so that he first three questions are mostly about GR.

Question 1 (mean 67%, uptake of 110 students):

Excellent uptake. I feared that this question would be too easy but it ended up having exactly the right spread of difficulty without being off-putting.

Question 2 (mean 69%, uptake of 108 students):

Excellent uptake but a difficult question to mark. Almost all students got full marks on the first third and very few were able to answer the final third. Which means that, although the average is fine the spread of marks is tightly centred around the mean. Few students could figure out the observational consequences of this space time which, I believe, means they are focusing too much on the math and not so much on the interpretation.

Question 3 (mean 62%, uptake of 19 students):

the first cosmology question with a low uptake. The question is quite easy yet quite a few of the students found it difficult to answer the middle section to my satisfaction. Again, I think the students are turning to the GR questions, hence the low turnout.

Question 4 (mean 72%, uptake of 11 students):

the second cosmology question with a very low uptake. Somewhat surprising given that students who did answer this question did so moderately well. Might be explained by the fact that the statistical mechanics aspect of cosmology was condensed in the last few lectures even though it is part of the syllabus.

Report on B6 (Condensed-Matter Physics) 2014

170 Candidates sat the exam. The unscaled mean mark was 56%, with a standard deviation of 13%

Marking this exam was a somewhat depressing experience. Many students cannot reproduce standard derivations (e.g. Debye and Fermi Temperatures), restate standard definitions (lattice, basis, structure etc.), or comprehend that both electrons and holes carry current in a semiconductor. I do think we need to evaluate why this is the case. The standard, on the whole, was poor. Some who tutor this third year course believe that there is still far too much material in it, leaving students rushed, and without the necessary time to assimilate simple information, and internalise some basic physical principles.

An additional general comment is that often our students do not know how to answer a physics question: what one generally receives is a stream of formulae with no words, definitions, or linking sentences whatsoever. One has to guess what is in the mind of the undergraduate. I believe it is worth tutors passing on the message to students that such a stream of consciousness does not attract full marks. Perhaps there should be a lecture (maybe at the start of the first year, or each year) on "How to answer questions on physics papers". The "How" concentrating on style, layout, definitions, etc., and giving examples of both a 'good' and 'bad' answer, with both actually proceeding to the correct final formula or number.

Question 1: Attempts 151, Mean mark 14.6, Standard Deviation 3.

The main aim of this question was to test whether students understood the underlying reason for 'missing reflections' in the face-centred and body-centred cubic conventional unit cells. From the responses received, it is fair to say that the vast majority do not. One wonders if they have ever been taught that missing reflections (due to lattice type) are only there because we choose a conventional rather than primitive cell, and that all reflections are allowed in a primitive cell.

More worryingly, the majority of students do not know how to define fundamental terms in crystallography (i.e. *lattice*, *basis*, and *structure*). The number of times a student had written "a lattice is a structure" was legion.

The diagrams of the fcc crystal, even before compression, were scrappy, poor, and difficult to interpret. In all, fewer than 10 students managed to work out the Miller indices of the planes in the bcc crystal resulting from compression of the fcc crystal. Of these, a minority correctly remarked that compressing the crystal will not alter the physically allowed reflections, only the nomenclature.

Overall one gets the impression that they have learnt certain bits of book-work (e.g. which reflections are allowed in the conventional cell nomenclature, and how to derive the rules from the geometric structure factor formula), but have either not been taught, or not picked up, relevant understanding of basic crystallography.

Question 2: Attempts 106, Mean mark 13.5, Standard Deviation 5.

Although the first ten marks of this question were allotted for pure bookwork (deriving the Fermi and Debye temperatures), many students still lost marks. This was one of the questions where on many occasions one was met with a stream of formulae with no explanation at all. Factors of 2 (say for spin) or 3 (for dimension or polarisation) were inserted without any reasoning whatsoever, and then often in the wrong place. In deriving the Debye temperature many students went into auto-pilot mode as if they were deriving the Debye-T^3 law, wasting an inordinate amount of time. Even with a formula before them in the question, calculating the Fermi and Debye temperature frequently resulted in errors, either by using the speed of light instead of sound, or by forgetting that there are 4 lattice points (and hence atoms/electrons for a monovalent metal) in the conventional cell. As a result, students could quite happily come up with ridiculous temperatures (like 10^{15} Kelvin) without seemingly batting an eyelid. It seems that many students have very little physical feel for what a typical Debye or Fermi temperature should be. Less than half could reason why an electron's wavevector cannot change significantly in magnitude during a scattering event.

Encouragingly a few students did mention that λ was analogous to the Compton wavelength of an electron, with the speed of sound replacing the speed of light. However, they were then unable to say with any conviction what a Compton-like wavelength represented.

Question 3: Attempts 38, Mean mark 12.4, Standard Deviation 3.5.

This was the least popular question, and garnered the fewest marks. Most students could make a good stab at discussing the basics, such as the difference between an intrinsic and extrinsic semiconductor, and the definition of mobility and effective mass, but most were unaware as to why, in most cases, electrons are more mobile than holes.

Furthermore, when it came to making some very trivial calculations, chaos ensued. Despite all candidates writing in the first section that an intrinsic semiconductor has an equal number of electrons and holes, only 3 of the 38 candidates then correctly deduced an equal number density of these carriers from the mobilities and resistivity provided for the sample of pure Germanium. Although a good fraction of the candidates correctly calculated the drift velocity of the electrons and holes in the Germanium, very few then realised they could use conservation of current to deduce the drift velocity of the electrons in the metal.

Overall, it appears that the candidates have a poor understanding of very simple concepts such as conductivity of a pure semiconductor, mobility, and how both electrons and holes carry current.

Question 4: Attempts 44, Mean mark 14.8, Standard Deviation 5.

Answers to this quite straight-forward question attracted the most marks (just), but also the largest standard deviation. How well candidates fared was mainly a function of whether they understood the basics of ferromagnetism—a sizeable minority were unaware of the fundamental physics that it is a Coulomb energy due to exchange that causes spins to align in a ferromagnet. Marks were also lost by candidates who could not remember how the field from a dipole scales with distance. Although almost all candidates could derive Curie's law for a simple paramagnet, many came unstuck in attempting to derive a formula for the susceptibility above the ferromagnetic transition temperature.

Report on C1 (Astrophysics) 2014

Whole paper: raw mean = 58.8; SD = 12.0; 27 candidates

Q1: Pulsars: $n = 22$, $\bar{x} = 16.5$, $\sigma = 4.7$
A question on how well the magnetic dipole model describes radio pulsars. A very popular question involving a descriptive part and culminating with the derivation of an estimate for the magnetic field of magnetars. The question was very well answered in general, but the mean was brought down by three very low scores.

Q2: Supernovae: $n = 26$, $\bar{x} = 14.3$, $\sigma = 3.4$
The most popular question of the paper, attempted by all bar one candidate. The first part of the question, dealing with the description of core collapse supernovae and up to the derivation of the total orbital angular momentum of the binary in the merger model of SN 1987A was correctly answered by most students. However, very few managed to estimate the mass loss and come up with sensible observations which could be used to confirm/refute the model.

Q3: Black hole: $n = 14$, $\bar{x} = 14.9$, $\sigma = 3.6$
A reasonable uptake on this question, with most of the students able to answer the first half (up to and including the calculation of the distance to the black hole) correctly. The second half gave rise to more mixed results, in particular for the discussion of the role played by non-circular stellar orbits.

Q4: Essay - unified models of active galaxies: $n = 9$, $\bar{x} = 12.8$, $\sigma = 4.4$
A fair uptake on the essay question, in line with past exams. The outcome was a bit disappointing however, most candidates losing themselves in the description of secondary details rather than outlining the main characteristics of the unified model. A couple of very poor attempts also brought down the mean.

Q5: Planetary nebulae: $n = 5$, $\bar{x} = 8.2$, $\sigma = 5.8$
Strangely enough, this question did not look appealing to the students, even though it was very similar to a problem given in tutorial classes. The results show a bimodal distribution, with half of the candidates doing reasonably well (especially on the descriptive part of the question and the derivation of the intensity ratio of the lines) and the other half doing very poorly.