gravitational redshift.

Q.3. (mean 69%, 58 attempts): the first cosmology question, with a reasonable uptake. Albeit quite easy, quite a lot of students were confused about the effect of curvature on the deceleration parameter or how to find a closed expression for the conformal distance. Very few quantitatively explained how the angular diameter distance is affected by curvature.

Q.4. (mean 66%, 9 attempts): the second cosmology question, with a very low uptake: this was 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 B3.VI (Condensed-Matter Physics) 2012

(Candidates: 152; raw mean mark 65.6%, SD 14.3)

The raw mean and the standard deviation were pretty much exactly what was intended. The overall impression from marking the paper was that most students knew their 'book-work' fairly well, and the differences between scores gleaned by candidates resulted from their capacity to respond to questions that either differed slightly from the standard derivation (e.g. derive the number of phonons at low temperature, rather than the total energy), or required them to think a little more deeply (for example comparing volumes of different crystal structures). In this sense, at least from an examiner's point of view, this appears to be a 'fair' paper that successfully enabled students to show their abilities, and had little need for re-scaling.

Q.1. Attempts: 120, Mean Mark: 15.3, STD: 4.2.

This was the most popular question on the paper. That said, very few students picked up marks in the first short section: almost every student simply reproduced the statement that the scattering of electromagnetic radiation was proportional to the number of electrons in an atom, without giving any reason why this is the case (approximately) for X-rays. If the scattering of optical light was simply proportional to the total number of electrons in a given atom, the practicalities of writing this report would be severe indeed. Only two students mentioned the words Thomson scattering (but without explanation), and a few noticed that X-rays were 'high energy' (without comparing that energy with anything). It is clear that students have not been able to transfer what they learnt last year in electromagnetism, and link it to X-ray scattering, inasmuch as they appear not to know that only if the energy of the photon vastly exceeds the binding energy of an electron, then that electron effectively scatters as a free particle. The vast majority of students could take the data and deduce that the lattice type of NaCl was FCC, and determine the lattice parameter, although there were quite a few who used the grating equation rather than Bragg's law, which led to wrong answers. In the second part of the question, where the students were explicitly told that NaCl has a simple cubic lattice under high pressure, a considerable number of the candidates immediately wrote down that it was BCC! There was thus evident confusion amongst a sizable minority of the candidates as to the difference between a structure and a lattice. For the final part of the question, many students forgot that there are 4 lattice points in conventional FCC lattice, compared with 1 in the SC lattice, and this led to erroneous answers for the fractional volumes of the cells (this part of the question was designed to test if they would realize that this must be taken into account).

Q.2. Attempts: 48, Mean Mark: 18.3, STD: 4.7.

As the question was about Debye theory, quite a few candidates decided to derive the Debye T-cubed law for the specific heat capacity of a solid, even though this was not asked for at any stage, and would not lead to the correct answer for the number of phonons present at low temperatures. Of those candidates who did explicitly write down the integral for the number of phonons, most were able to determine correctly the number of phonons present in the nanocube, and to then give good reasoned arguments as to why their approach would break down when the temperature was lowered such that the calculated mean phonon wavelength would exceed the length of the side of the cube. Some students thought that the Debye approach only worked at low temperatures, and hence could not show that it reproduces the high temperature limit correctly.

Q.3. Attempts: 88, Mean Mark: 17.8, STD: 3.8.

The vast majority of the candidates were able to derive the law of mass action - although quite a few of the answers were scrappy or incomplete. The most common omissions in the derivation were to leave off the limits of the energy in the integrals, and, once having derived an expression for the number of electrons in the conduction band, then to hand-wave their way to an answer for the number of holes in the valence band, rather than fully justify their expression. Many marks were lost in the next section, as a sizable fraction of the candidates did not know the hydrogenic model for the binding energy of an electron to a donor - that is to say how to scale the energy from hydrogen by the effective mass ratio and inverse-square of the relative permittivity: this led to estimations of binding energies in the eV range, and in at least one case of MeV!. Most candidates could set up a condition on the np product corresponding to extrinsic behaviour holding up to 750K, and the few marks lost in this section were minor, and due mainly to calculation errors.

Q.4. Attempts: 120, Mean Mark: 14.8, STD: 4.4.

Most students could derive the Fermi wavevector and energy for a 2-D solid, though there were candidates who evidently only knew by-heart the answer for the 3-D case, and wrote that down instead. Factor of two errors (owing to omission of spin degeneracy) were frequent. The most common error on this paper was the drawing of the second Brillouin zone for the 2-D crystal with a rectangular lattice - most thought it to be triangular, rather than a trapezoid, as they did not draw all of the perpendicular bisectors correctly. Many descriptions of how band gap overlaps in a divalent material can lead to insulating or metallic behaviour were poor, with quite a few candidates trying to explain this using a purely 1-D monatomic model (where it does not occur), rather than discussing the relative energies in the relevant parts of the first and second Brillouin zones in the 2-D crystal.

Report on C1 (Astrophysics) 2012

(Candidates: 47 ; raw mean mark 67.2%, SD 16.7)

A good mean, but a relatively broad spread, skewed low.

Q.1. *Early Universe and structure growth.* $n = 5$, mean = 15.2, SD = 7.2. This was an elegant mathematical question but with a low uptake. Several of the answers were near perfect but a couple were fragmentary.

Q.2. *Galaxies, lensing.* $n = 42$, mean = 18.9, SD = 4.5. A hugely popular question, with a clearly very attractive initial section on cluster mass estimation via lensed arcs. Most candidates found the last part challenging, indeed many offered suggestion totally outside the specified topic of X-ray observations. However, at the top end there were some very good descriptions of the difficulties of mass estimation via X-ray methods.

Q.3. *Galaxies, number counts and evolution.* $n = 12$, mean = 14.5, SD = 7.1. A less popular galaxies question with the mean brought down by some fragmentary results but nonetheless there were some excellent answers presented at the top end. One candidate offered a discussion