Theoretical Question 1

This is essentially a question in special relativity. The core of the question is part (b) which involves a simulated experiment. It requires students to combine the concepts of gravitational red shifts, resonance absorption, Doppler shifts and the graphical interpretation of data.

Overall the question appears to have met its objective of allowing nearly all students to gain a few marks from part (a). A suprisingly large number of students were able to obtain essentially the correct solution to part (b) using the appropriate straight-line graph. Part (c) also produced many basically correct solutions with some of the best students simplifying their soloution to the logical limit. One student managed to obtain the correct answer making use of the 4-momentum. The very best answers to this question were almost flawless and demonstrated a very high level of conceptual understanding and the ability to synthesise ideas from a number of different areas.

Theoretical Question 2

This question is concerned with the propagation of waves in a medium with a varying refractive index and the different modes of propagation which occur. The responses to this question mirrored the marks distribution shown in Figure 1 for the overall theory results. A number of students gained near-perfect marks while an equivalent number gained very few. The most interesting part of the marking arose in connection with part (a), where the arc radius R specified in the question needs to be established. The marking team encountered four distinguishable and valid approaches to establishing the result for R.

Part (c) proved to be a useful discriminator between those students who either did, or did not, realise that a seris of paths, or modes, exists from the source to the receiver. The numerical estimates in part (d), and intended to assist the markers, required some care in marking according to the way in which students treated the issue of significant figures during the calculation. Part (e), which led to the conclusion that the ray with the smallest calue of initial angle will arrive first, was a useful discriminator.

Theoretical Question 3

This question is essentially a problem in mechanics with elements of hydrostatics. It involves the concepts of Archimedes' Principle, small oscillations and rotational dynamics applied to an interesting geometry.

One common mistake of interpretation noted by the examiners was to set the length of the rod equal to the radius rather than to the diameter of the cylinder. In line with the policy on marking, students were only penalised once for this mistake provided that the rest of their analysis was consistent with this assumption. The clever aspect of the problem was in part (d) where some students attempted to estimate the solution to the transcendental equation $\alpha - \sin\alpha\cos\alpha = 1.61\sin\alpha$, rather than simply checking that $\alpha \simeq 1.57(\pi/2)$ gave a reasonable result. Students from two teams used numerical methods to obtain a more precise value for α. One student who correctly applied Newton's method to solve the equation for α received the special prize for mathematics.

Experimental Question 1

This question was concerned with the motion of small objects (cylinders) in a viscous medium, and was designed to test as wide a range of experimental skills as possible. In particular the question aimed to test:

- understanding of the concept of terminal velocity.

- experimental technique; the experiment required careful hand-eye coordination to reduce systematic effects (for example by dropping the cylinders each time with the same orientation and using multiple timings to reduce the scatter in the results).

- the ability to graph and interpret data including the use of logarithmic and linear plots and the interpretation of slopes and intercepts.

- estimation of uncertainties in the results.

The experiment generally worked as expected. Experimental techniques were uniformly good, and the students demonstrated excellent manipulative skills. Their main weakness was in the handling of the determination of the density of the glycerine from the graph of fall time as a function of the density of the cylinders. Students in general did not measure the intercept on the density axis but calculated the density from the intercept on the fall time axis and the slope of the graph.

Experimental Question 2

This question made use of a laser pointer to carry out several experiments in optics. The first task concerned the use of a metal ruler as a diffraction grating. In this experiment the diffraction pattern was formed by reflection with the incident laser beam at nearly normal incidence to the ruler. (This geometry is rather different from the more common demonstration where the incident beam is at close to grazing incidence.) A number of students had difficulty with this geometry and failed to obtain a convincing pattern.

The second experiment investigated the reflection and transmission of light through transparent media. The main difficulty with the measurements was that changes in intensity had to be estimated by eye using a set of calibrated transmission discs. This was much more demanding than using, for example, a photodiode and multimeter as it required the exercise of considerable experimental judgement. It therefore provided an excellent test of a student's experimental technique.

The final experiment was concerned with the scattering of light from a translucent material formed by adding a few drops of milk to water. The amount of scattering and the reduction in the transmitted intensity were measured as a function of the concentration of milk. Students had considerable difficulty with this experiment with some not recognising the phenomena they were meant to be observing. However the best students were still able to obtain convincing results. The exercise therefore provided good discrimination between the most able students.