Synoptic Physics

Annabel Cartwright

School of Physics and Astronomy, Cardiff University, UK

Abstract

A new course has been introduced in the second year of undergraduate Physics studies at Cardiff University. Aimed at addressing problem solving, team working and communication, the course has been very well received by students, with exceptional levels of attendance and engagement. Students also displayed an increased level of enthusiasm for the degree and enhanced self-confidence. The structure and content of the course are outlined.

Keywords: group work, applied physics, problem solving

Introduction

Synoptic Physics is a new 10-credit module offered in the second half of the second year and taken by all undergraduate students studying Physics at Cardiff. It was delivered for the first time in the academic year 2012/13.

The course was conceived as part of a revision of the entire curriculum, with the intention of incorporating more problem solving and giving opportunities for group work. The aim was to bring together the physics which the students had learned over the previous eighteen months, and challenge them to use this knowledge to tackle unseen problems. Where possible, these problems were drawn from real-life applications or current research, and were introduced by visiting speakers directly involved with the subject.

Group structure

Students were organised into teams of four, then allocated to one afternoon (three-hour) session per week, with no more than nine teams in any

Corresponding author:

Annabel Cartwright, School of Physics and Astronomy, Cardiff University, UK
Email: Annabel.Cartwright@astro.cf.ac.uk

session. One group consisted of students studying the Astronomy/Astrophysics options. Despite reservations about the perils of teamwork, no problems were encountered concerning group membership, and only one complaint arose, on one particular week, about a team member failing to pull their weight.

Weekly problems

After an introductory session in the first week, nine weekly challenges were set. Problems were designed to incorporate a range of physics learned over the first half of the BSc course, with several components that could be worked on in parallel by different members of the team. The problems for the non-Astro groups included:

- calculating the thickness of a copper or aluminium layer necessary to protect an Airbus from lightning strike, and recommendation as to which metal is lighter;
- working out the size and construction of balloon required to launch the BLAST telescope to 25,000m above Antarctica, and estimation of time from launch to cruising altitude;
- assessing the feasibility of deploying magnetic nanoparticles as a way of killing brain tumours.

Astronomy and Astrophysics problems included:

- determining whether there is a material strong enough to build a space elevator;
- planning a mission to Mars using a simple transfer orbit. Identifying the next potential launch window and calculating the mass of hydrogen fuel required to boost each kilogram of payload.

As a team, students were asked to prepare for a session by completing unmarked 'preparation' homework, which reminded them of any key principles of physics which would be needed. They were then given the problem itself for the first time in the afternoon session, introduced in a 5-10 minute presentation by the module organiser, or guest speaker. They were asked to solve it, as a team, handing in their solution as a written report by the deadline of 5p.m., which usually gave them 2.5 hours.

The class worked in our Computer Lab where there were sufficient PCs for each student to log on. We anticipated that these would be used to write the document, perform calculations or do computer modelling, and to access the Internet to research the problem. Interestingly, they were also used to communicate between team members, efficiently sharing information with one another and keeping people aware of deadlines.

In the first four weeks a team captain was assigned by the module organiser, each student having the chance to lead their team for a week, dividing up the work and monitoring progress. Thereafter the teams decided for themselves who would be in charge or, indeed, whether anyone should be in charge at all. During the session the module organiser was available, keeping an eye on the students and helping if they were completely stuck. This became less necessary as the weeks progressed. At 5p.m. they were expected to hand in a written report, properly structured and word processed, all equations and figures numbered, all references included. Late submissions were permitted, until 9a.m. the following morning, but with a 10% penalty.

Presentations

Each week, one team was allocated the further task of taking the week's problem and researching and completing the work in more depth. They then presented their solution of the problem to the rest of the group at the beginning of the next session, often with the addition of very interesting extension research around the subject. This was marked by their peers, with written feedback, as well as being marked by the module organiser.

Reflective Statement

The final piece of assessed coursework was a reflective statement by each student, in which they reflected on their own and their team's performance in the tasks, and the skills acquired. This was the least popular part of the course, when they were told about it, but was completed to a very high standard.

Importance of the choice of problems

The success of the course hinged on setting interesting problems with plenty of physics to think about, and with several different tasks to accomplish in parallel.

The 'protection of aircraft against lightning' problem was a good example, introduced by a former student now working in this field for Airbus. The students immediately could relate to the importance of the topic and were excited and interested. The topic broke down neatly into three areas of research (lightning characteristics, the size and surface area of an Airbus, and the density, thermal and electrical characteristics of copper and aluminium). There was also a tricky bit of fairly complicated Ohm's law to work out, and then they plugged in the specific and latent heats of the metals in order to work out the thickness of metal required to conduct away the electricity without vaporising an area larger than 10cm in diameter.

Hilarious problems arose along the way, one team finding that a layer of copper 100m thick would be required. Usually this was a problem with algebra, easily identified by dimensional analysis. Eventually, the clear recommendation by all teams in terms of weight (and some also looked into cost) was aluminium. However, the team who then analysed the problem in more depth were able to show the following week that problems arise with aluminium interacting galvanically with the carbon fibre, so copper is used in practice.

Student performance and feedback

The students were able to achieve a very high standard of work, and were soon automatically using quite advanced methods such as dimensional analysis to check their algebra, all four simultaneously working on a single document, setting up Python worksheets to perform calculations, and producing the reference list as they wrote the document.

They also became far more adept at using internet search engines to speed up the research phase, and were more critical and aware of the quality and reliability of the different types of source documents. We made a point of spoon-feeding them as little as possible: having been given the problem it was up to them to identify the information they needed and then to go and find it.

The students' ability to work as a team also developed over the term. They were pleased that they all had the opportunity to lead the team, even those who were then happy to hand that responsibility to someone else. The element of time pressure, and the small groups, meant that there was no opportunity for anyone to opt out. Everyone had to be doing something and if anyone was getting bogged down, the rest of the team had to step in and help. They all wanted their team to do as well as possible every week, and took real pride in the professionalism of their work.

The students also thoroughly enjoyed applying physics to 'real' problems, which incorporated aspects of every course they had undertaken so far. This opened their eyes to just how much they already knew and, in some cases, to potential career opportunities. Remarks such as 'it is really interesting, just talking about the physics', were overheard, to the delight of the teaching staff.

The feedback from the course was exceptionally good. Many students commented on how much they had enjoyed the experience and their reflective statements also showed that they realised the value of what they had learned. Even some aspects which were initially unpopular, such as having to work in teams, make presentations, and work against the clock, were appreciated as having stretched them and given them useful experience.

'Communication skills' is usually taken to mean the ability to write a document or give a presentation. Our students learned to identify the importance of other, less tangible communication skills: realising whether someone understands what you are saying; noticing and then intervening to help someone who is struggling; getting a team back on task when they are distracted; making sure that everyone in a meeting has an opportunity to contribute; not pushing your own solution to a problem before you have listened to everyone else, but, equally, not allowing yourself to be talked over when you have something important to contribute. All of these were specifically mentioned in reflective statements.

Conclusion and future plans

Synoptic Physics will be repeated this year in almost exactly the same format. We will offer a similar range of problems with a few new ones, and exactly the same format and timings. Repetition was extremely successful - students learned from their mistakes one week and improved the next - but the course would not work without effort going into producing really interesting and varied problems.

I particularly recommend having a single team reporting back to the class on what was attempted the previous week. The fact that all class members are familiar with the problem makes them a well-informed, interested and critical audience. Many commented on how much they learned from critically assessing all the other presentations as well as their own. A small prize was given to the team whose presentation achieved the highest mark from their peers, and this was keenly contested.

Some things that did not work so well will be improved. Many of the students did not bother to do the preparation homework, preferring to rely on the one studious person in their team. This preparation will now be obligatory, to be done on-line with all students obtaining individual marks for completion.

I can thoroughly recommend the introduction of a course along these lines - to quote one of the students, "all Physics students should have to do a course like Synoptic Physics". I hope that the detail I have provided as to exactly how the course was designed will assist others in planning something similar. To summarise, the key components, which I believe contributed to the course being so successful, were:

1. use of real-world problems that incorporate lots of different physics;
2. making it a real-time challenge so everyone is busy;
3. being demanding – it is amazing how much they can achieve;
4. having one team report back the following week with a more detailed analysis;
5. including reflective statements at the end, so students realise how much they have learned.

Acknowledgements

I was greatly assisted in the delivery of this course, and in the design of some of the problems, by Professor Steve Eales and Dr Sam Ladak, of Cardiff University, Rhys Phillips of EADS/Airbus and Dr Dave Nutter of EDF Energy.