Small Group Teaching in Undergraduate Science

Higher Education Learning Project (Physics)

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INDIVIDUAL STUDY
IN UNDERGRADUATE SCIENCE

SMALL GROUP TEACHING
IN UNDERGRADUATE SCIENCE

PRACTICAL WORK
IN UNDERGRADUATE SCIENCE

STUDENTS' REACTIONS
TO UNDERGRADUATE SCIENCE
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General preface

The Higher Education Learning Project is a working alliance of teachers in higher education, initially of physicists. We began in 1972 with a group drawn from the Universities of Birmingham, Surrey and Sussex; Birkbeck College, Chelsea College and Royal Holloway College in the University of London; and from Liverpool Polytechnic. Over the next four years we were joined by teachers from a considerable number of other Universities and Colleges.

The activities of the project fell into four areas:

Individual Study: experimenting with, and looking into the value of methods of teaching which placed less reliance on the lecture.

Tutorial Teaching: investigating the problems of small group teaching in science, and trying out new materials for tutors to use.

Laboratory Teaching: investigating the problems of laboratory work, and the advantages and difficulties of a variety of kinds of innovation.

Motivation: a large scale study, interviewing students at many universities, with a view to understanding better the problems of learning as they see them.

Many departments of physics helped in the work of the project. We are grateful to the Department of Physics, University of Birmingham, for providing facilities for Barbara Hodgson; to Chelsea College for facilities for the co-ordinator, the project secretary, Martin Harrap and Dietrich Brandt; to the Institute for Educational Technology, University of Surrey, for providing facilities for Will Bridge and for releasing Sid O'Connell part-time; to the School of Mathematical and Physical Sciences, University of Sussex, for releasing Peter Unsworth part time; and to the Physics Department, Liverpool Polytechnic, for releasing Roy Lawrence part time.

Much of the work of the project has been done by people who gave freely of their time, without reward. The project is particularly grateful to Lewis Elton, who organised the
individual study activities of the project, and to Joan Bliss who developed the
motivation interview, trained physicists in interviewing, and organised the
whole study.

The project owes its thanks to the very many teachers, in a large number of
departments, who involved themselves in the work. Their names appear in the
publications with which they were particularly associated. We are also grateful
to the many students who have talked to us, and who have been at the receiving
end of various innovations.

We also wish to thank the Director and Trustees of the Nuffield Foundation for
their support; and the members of the Advisory Committee, notably the
chairman Dr Gavin, for their continued advice and help.

Finally, everyone concerned in the project is in debt to Paul Black. He played a
major role in initiating the project, acted in all but name as joint co-ordinator,
and gave generously of his time, energy and insight to every aspect of its work.

We began as a group of physicists, but it was never our intention to concern
ourselves solely with problems of teaching physics. We have had useful
discussions with teachers in a number of other scientific disciplines, and this
experience is the basis for the belief that these books will interest many besides
physicists. Nothing would please us more than to have made some contribution
to the discussion of teaching problems in the academic community at large.

Jon Ogborn

Co-ordinator
Preface to this volume

This book has grown slowly over the last few years. During those years, our ideas for changes in tutorial teaching, thoughts about what is involved in teaching in small groups, and investigations into some of the problems, have developed. Many people have been involved in the work in many ways. Some tried things for us, some suggested things to us, some offered valuable criticism. Some, and to these we are especially indebted, let us inside their tutorials either by being observed, by being recorded, or by writing us personal accounts of what happened as they saw it. The whole book depends upon all these contributions.

Throughout, the direction we hoped to take was towards a greater flexibility and variety in small group teaching, and better use of its potential. Material accumulated: some was welcomed, but much was developed out of finding that the help offered to others was inadequate or incomplete. We are grateful to those who attended meetings and made clear to us deficiencies in the content and balance of what we had to say.

The work offered here is by no means complete. Even the exercise of writing this book has crystallised many ideas which, when it was planned, were not foreseen. So we ask the reader to be somewhat tolerant, and hope that further progress will be made as a result of public discussion and criticism, and by its being taken up by others.

We wrote the book together, and every part of it has benefited by contributions or criticisms from the other authors. The main responsibilities for the various chapters are, however:

- chapters 1 to 4  Paul Black
- chapter 5  Jon Ogborn and Peter Unsworth
- chapters 7 and 8  Jon Ogborn
- chapters 9 and 10  Paul Black, Barbara Hodgson, Jon Ogborn, Peter Unsworth

Joan Bliss
We are not, however, the sole authors. Many others have provided material which is incorporated in the book, and we wish here to acknowledge the essential part they have played in its development. They are, including some whose contribution has been to be overheard teaching students:

Dr D Bailin    Dr E M Forgan
Dr R G Bennetts Dr W Gelletly
Mr D Boud      Dr A D C Grassie
Dr N B Cryer   Dr J A R Griffiths
Mr B Davies    Dr R G Harris
Dr E R Davies  Dr S M Kay
Dr A P Dorey   Dr A Leggatt
Dr D Evans     Mr W B Powell
Dr C Finn      Dr E M Wray
Dr R W Whitworth

Finally, we wish to thank those who made it possible for us to work together: the Trustees of the Nuffield Foundation, and the many helpful and tolerant members of our respective universities. The experience has changed us all.

Paul Black
Joan Bliss
Barbara Hodgson
Jon Ogborn
Peter Unsworth

NOTE

The book includes transcripts of recorded tutorials, and from material collected in the course of a series of interviews with students for a companion volume. The latter is the source of the comments from students which are quoted in the book.
Part one:

What are the problems?
1. Can a book help?

1.1 JOHN'S PEN

This book has been written to help the work of teaching and learning in small
groups. Although many of those who have to give tutorials find the task
difficult, it is not obvious that the difficulties can be tackled by reading a book.
Much of the existing literature on groups does not seem to help because it tends
to be remote: one cannot see oneself in it; it does not connect with the problems
one has in struggling to help students to better achievements in physics.

One way to help might be to bring the discussion of these problems into
closer contact with reality. This can only be done by first describing or exposing
the reality, by making public the private world of the tutor with his students so
that we can begin to share and, hopefully, to understand the problems that arise.
Consider the following description of the beginning of a tutorial:

Dr Smith steered books and papers to one edge of his desk, piling up the
sheets where he had just been writing.

'Sit down John', he said. The student had interrupted him by arriving
punctually - he always did. And one couldn't complain as John sat there,
on his own, glancing up occasionally from his habitual study of the
desk.

John spoke: It was today ...' 'Oh yes - I was just trying to finish...' The
reassurance tailed off - Smith fussed with the chairs. His thoughts
refused to focus on first year undergraduate physics. Also he had to fill
in time before the others arrived - not easy with John.

'How are things this week John?' 'Oh, alright'. The smile was weak, but
covered a determination to avoid the lead. Alec and Simon brought
relief, noise and movement. John relaxed. Dr Smith opened again - and
Alec responded readily.

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'We all had this bug in hall. It started on Friday evening and by Saturday...'. This part was easy whenever Alec turned up. Something had always happened to him. But it took time and somehow the discussion had to be steered around to physics.

'I suppose the illness made it difficult to think about work this week?' He'd put it clumsily. 'Well yes...'. Alec's recoil was too obvious, but Smith hadn't intended to halt him with sarcasm. Smith had to restore things.

'Are you alright now?' That seemed to help. 'Well perhaps we can ask Simon and John whether they have anything they want to ask about first'.

John had shifted and opened a notebook, but his gaze kept down. Simon met the enquiring look but turned from it.

It was a familiar silence but the embarrassment was just as pressing as if it had been new. Smith tried again. 'Let's take the Optics course for example. Has anything come up there that has given you trouble?'

The silence was as long again, but this time Simon broke it 'He did a long calculation about diffraction from a slit using \( j \omega t \) and things would we have to remember that for an examination?'

Smith's mind started to race on two levels. On one level this discussion had to be propped up, whilst on the second level he began to sort and compose ideas about diffraction. On neither level was he at ease. Questions about examinations were dodgy.

He spoke cautiously. 'Did he say that he would not expect you to learn them?' 'He didn't say anything about it' said Simon. 'Then you'll have to assume that you're supposed to know it'. Smith noted Simon's dissatisfaction, but he couldn't make an empty promise, or undertake to shift the Optics lecturer.

'Was there anything else in Optics?' No, apparently there was nothing else in Optics. 'Well perhaps we should talk about the single slit calculation you've just asked about'.

The second level had come up with something. John took out his pen
The experienced tutor who does not see in Dr Smith some small part of himself and his own dilemmas may not need this book, and may instead be invited to prepare his contribution to the second edition!

For the rest, it may be useful to start by re-reading and thinking about the episode. It clearly describes an unsatisfactory beginning, and it is equally clear that the rest of the tutorial is unlikely to go well. But why did it start badly, and why can one foresee that it might not get better? Many reasons may be perceived: Dr Smith was not prepared; John steered his tutor towards giving a lecture in order to protect himself; Dr Smith could not provide the interpretation of his colleague's or his department's examination requirements that his students needed; and so on. A full analysis of this episode is not given in this chapter but it may help the reader at this stage to make his own analysis, considering the various features of the episode grouping them under several categories, such as:

- the tutor's preparation and expectations; his personality and status.
- the students' preparation and expectations.
- the tutor/student interactions and the pressures they exert on one another.
- the effect of the context; for example, the norms of the department in which the tutorial occurs.

The lack of any preparation by the tutor is one clear feature of the tutorial, and the passage may be useful in illustrating that the task of simultaneously selecting a topic for discussion, coping with the physics, and developing personal relationships between group members is so demanding that any way of relaxing the requirements ought to be considered carefully. One such way is for the tutor to come to the tutorial prepared with material and with ideas about methods of running it.

1.2 A STRATEGY TO COPE

Many tutors have found it helpful to discuss episodes like the one presented above. Even experienced tutors respond with relief and release to the presentation of evidence which shows that we all share similar difficulties in trying to run tutorial groups. A collection of such episodes should help to expose problems in a way that can make the discussion of
them both more open and more realistic. This is the purpose of the first part of this book. Chapters 2, 3, and 4 present and discuss episodes which have been selected and arranged in order to focus attention on three issues in turn: those of reacting on the spot in a spontaneous tutorial; those concerned with preparation; and those concerned with personal relationships. The grouping is to be regarded as a rough convenience, and not as a stereotyped labelling.

The discussion of evidence could be endless, and the episodes confirm and amplify the impression which anyone will gain in going over and over an account of what happened in a group: that the interactions and outcomes are complex. However, some common themes do emerge in Chapters 2, 3, and 4. Thus the first part of the book can help to establish the nature of the problems, but a more systematic and analytic discussion is needed if we are to understand them. This is the purpose of the second part of the book in which the aims of tutorials; the way people behave in groups; the language of tutorials and the use of questions are considered in detail.

The third part of the book sets out to draw useful lessons and provide practical help. A new kind of group work (skill sessions) is described, and the practical problems and possibilities of preparing tutorials are explored. For both of these topics, the chapters end with a collection of prepared outlines, most of which have been used in physics courses An encouraging feature of the work of the project has been the readiness with which some tutors have taken up the prepared outlines, have reported a relatively high rate of success with them, and have contributed further ideas of their own. The final chapter summarises the practical lessons which can be drawn from the book as a whole.

1.3 WHAT IS A TUTORIAL?

The scope of a book on tutorials partly depends upon the definition of a tutorial which its authors adopt. We have assumed for much of this book that we are talking about a regular meeting of a number, greater than one and less than ten, of students with a tutor. Much of it is equally relevant either to tutorials connected to a particular course, or to tutorials in which a tutor helps with all of the work of his students. However, some ideas and problems are relevant only to the latter alternative. There has been no attempt to debate the relative merits of these two forms of organisation although much of the material for such a debate may be found here.
In Chapter 9, however, the discussion turns to a method involving a class of about sixteen students with one tutor, organised with a different and specific purpose, that of training in certain skills. This has been included both because this work is a novel development which several departments have taken up with enthusiasm and success, and because it illustrates some of the problems and possibilities of the smaller group tutorial. However, a serious excursion into this area would require a task of collecting and analysing evidence about the variety of problem or example classes which are organised in many courses. This has not been attempted in our work, and in this respect Chapter 9 raises issues which are not tackled in this book.

1.4 PHYSICS ONLY?

The book reports the results of developments and investigations which have been conducted almost wholly amongst, for, and by physicists. This does not mean that the results are only of value to physicists, for there may be truth in the paradox that the best way to learn lessons of general value is to investigate the particular.

It has been our experience in this work that most of it has aroused interest and comment from many quarters, particularly from scientists in other disciplines. Almost all of the book could be read by non-physicists, and some explanatory material to help such readers is included where appropriate. Much of the exemplary material will lose some of its significance for the reader who is a non-scientist, but the general principles underlying the discussion of this material and most of the analysis of part 2 have relevance outside the natural sciences.

1.5 USING THE BOOK

Although we believe that the sequence of presentation adopted will be the most suitable one for most readers, the book is not tightly structured and much of it could be read out of sequence. For example, those interested in prepared materials and ideas could go first to chapters 9 and 10, while a reader with a particular interest in problems of language could study chapters 7 and 8, and so on.

It is hoped that many will find it a working handbook, to be looked at and

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dipped into on several occasions as ideas and experiences arise from their own tutorials which complement or challenge the printed ideas. The book is seen by its authors as a first essay, more an account of a journey of exploration than an atlas, to be carried in the knapsack by future expeditions rather than left at home for the detached study of the armchair. If it stimulates more rewarding journeys, and so leads to better exploration in the future, it will have achieved its purpose.
2. Take what comes

2.1 THREE CHAPTERS OF EPISODES FROM TUTORIALS

The aim of chapters 2, 3 and 4 is to illustrate and define some of the main problems about small group teaching, by looking at what happens in real life. The chapters are built around nine 'episodes' from actual tutorials, given by six different tutors. All the names have been changed.

Seven of the episodes were written by the tutors involved. In these, the events are seen through their eyes (though each writes of himself in the third person). Such episodes must be thought of as like short stories; as selected aspects of the truth told to bring out one person's view of it. To look at them critically is to ask both, 'Why did this happen?', and also, as an outsider, to ask, 'Why did this tutor report events with this particular emphasis?'. Each is authentic, in that it took place in a tutorial given in the course of normal undergraduate teaching; and each writer has tried to be honest.

Two of the episodes are seen through a colder, less interpreting eye: that of the camera and tape recorder. They are verbatim transcripts from video tape, again from real tutorials, though space prevents more than a fraction of the tutorial being given. Their authenticity is different; the events they record are more objective, and for that reason both more and less valuable than the portraits painted by the tutor. The tutor's thoughts and feelings now have to be inferred, but what happens is not reflected in the potentially distorting mirror of those thoughts and feelings; a distortion that is at once troublesome, and the very thing it is worth discussing.

Each episode has a commentary. The reader will find it useful to consider also his own reactions to each episode, since the reported experiences have a validity which no analysis can claim, and they may have lessons for the reader which the commentaries overlook.

Any such commentary might look at an episode from a multitude of points of view. The commentaries in chapters 2, 3 and 4 ask of each episode three main kinds of question:
'What happened?' - the main sequence of events, and the physics involved;

'What did the tutor do?' - his decisions, his attitudes, and their effects on the meeting;

'What did the students do?' - this question including what arises from their relationships with the tutor.

Other questions could be asked. Those above include aspects of the question, 'Who is doing what to whom?', but leave out any extensive thought about the consequential question, 'How are they doing it?'. This more subtle question belongs to chapters 6, 7, and 8, and the episodes may offer useful data to turn back to in the light of those chapters.

Because the tutorials are real, they present a difficulty for the reader who does not know much about the subjects discussed in them, so brief notes are offered which may help in this respect.

2.2 TUTORIALS WHICH TAKE WHAT COMES

The three episodes in the present chapter are all about tutorials for which there was no prepared plan. Whether he has a plan or not, any tutor has at times to take decisions on the spot: reacting to students, or dealing with silence and lack of response, for example. These decisions have cumulative effects which are hard to foresee. Where there is no plan, everything has to be settled on the spot in this way. So these episodes may help to expose some of the links between immediate reactions and decisions, and their long term effects.

2.3 DR WHITE AND DIELECTRICS

Many tutorials are treated as a clinic. The consultant, the tutor, listens to the patient's symptoms, and can attempt to provide treatment. This first episode, about a tutorial with first year students, illustrates some of the problems of finding and applying the right sort of medication.

Dr White's tutorial group consisted of three students, Anne, Richard, and Steve, all in the middle of their second term.
When asked how the present set of problems was coming along, Anne said she had trouble with number 1.

The problem was about the capacitance of a plate lying inside an earthed box.

Anne said 'It's part (iii) I'm stuck with, where there is a dielectric in the lower gap and not in the upper one.'

'Can either of the others of you do this?', asked Dr White. Steve responded at once. 'I can remember a similar problem in vacuo from last term. The p.d. is the same across both parts so it is like two capacitors in parallel.

'Splendid.' Dr White amplified the point for the benefit of the others. He had intended to spend much of the session on dielectrics if nothing else pressing arose, so he decided to carry on from here. 'This is really a very simple geometry, and splitting it into two capacitors, while it is a good way of solving this problem, does not teach us much about the fields. Shall we try considering some slightly less simple cases?'

No response, so he went on. 'Here is a coaxial cylinder capacitor like that in your problem 2, and half the volume is filled with wax coated on the inner cylinder. If I melt the wax so that it fills the lower half, will that change the capacitance?'

The physics here is about calculating capacitance $C = Q/V$. The problem reduces to calculating the electric field of the charge $Q$, and getting $V$ from that. The tutorial is about using Gauss' theorem to obtain the field. Gauss' theorem involves integrating over a closed surface. When the field (here the displacement $D$) varies over the surface, the integral cannot be done by multiplying the total surface area by the value of $D$ at one place; an obvious point but one missed by students here, who will often have dealt with cases where $D$ does not vary. The variation of $D$ is quite subtle, since it is defined so that its component normal to the surface of a dielectric does not change at the boundary of that surface.

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'Does melting change the dielectric constant?', asked Richard. 'We will let it solidify again', he replied 'And we can go on to consider what happens if we put the wax on the outer cylinder, or break it up into a loose powder to fill the whole space.'

'Now, how can we tackle this sort of thing?'

Richard started at once. 'Well, $D$ will be the same in all cases.' 'Just a moment', interjected Dr White, 'How have you set it up? Is there a constant charge on the centre cylinder or is it at a constant potential?'. With a little discussion they agreed to assume constant charge $\lambda$ per unit length.

With help Richard clarified his assertion: '$D$ is the same in all cases, and is a function of $r$ only.' Even under some pressure they all agreed to this, but as Dr White continued to press the point, Steve began to show a worry about the $D$ field parallel to the boundary in case 2.

Dr White made encouraging noises, but it was left to him to say in effect 'If the $D$ field is the same at $A$ and $B$, then the $E$ fields are in the ratio $\varepsilon_r$, but we know that tangential components of $E$ are the same, so we've gone wrong somewhere. It is the point you made, Steve, at the beginning, that the p.d. must be the same across the air and dielectric So, where have we gone wrong?'

Silence. 'Well, I think Richard's point started from $\int D ds = \lambda$. Is that right? 'Yes' 'Well what is the next step?'

Silence. 'I think you argue $D \cdot 2\pi r = \lambda$ so that $D = \frac{\lambda}{2\pi r}$.'
which is a function of \( r \) only. Is that right?’ Richard agreed. ‘But that leads to \( E_A \) not being equal to \( E_B \), so where have we gone wrong?’

Silence. ‘Well is \( \int D.ds = \lambda \) correct?’ Richard wondered about some difficulty with the dot product, but they agreed \( D \) was parallel to \( ds \) and nothing was wrong there. They accepted \( \int D.ds = \lambda \) as correct; in effect one of Maxwell’s equations. ‘So where have we gone wrong?’

A long silence. Dr White determined not to tell them. Tutorials, he thought to himself, have recently been too much like lectures from me. So he thought up an analogy about a lamp bulb in a spherical room. \( \int I.ds \) was the power of the bulb, but we know that the light does not necessarily fall uniformly on the walls. This took up a few minutes, but got nowhere.

Eventually Richard said, ‘I think the difficulty is in the way the lecturer presents it. We only ever deal with parallel plate situations’. Dr White knew this to be untrue and queried it. They agreed that they had seen spheres between parallel plates and similar awkward cases where the field lines were bent by the medium.

At this point Dr White noted that Anne was almost falling asleep, and realised she had said nothing for (he glanced at his watch) it must have been 30 minutes at least!

Steve now came in with a speculation that they were integrating over the wrong surface, and Dr White had to explain that they could choose any surface. Perhaps the cylinder of radius \( r \) was not going to solve their problem, but what was wrong with the argument they had used to deduce that \( D \) was a function of \( r \) only?

After a long pause, ‘I think Gauss’s theorem gives only an average value of \( D \)’ commented Richard.

Dr White realised they might get there at last, but he must be careful that they didn’t misinterpret the point and waste all the time they had spent, so he said, ‘Do you mean that in \( \int D.ds = \lambda \) you only insert an average value of \( D \)?’ ‘Oh no’, replied Richard. The \( D \) there is the actual value through \( ds \).’ Dr White accepted this and explained that it was in writing \( D.2\pi r = \lambda \) that they had assumed \( D \) was uniform.

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He went into a short summary of the way to handle calculations of this kind, and realised the hour had almost gone.

He felt that Anne might easily have let out a long snore, and could he have blamed her?

2.3.1 COMMENTARY ON DR WHITE AND DIELECTRICS

What happened? Here is one way of looking at the events.

Anne raised a specific problem, and Steve gave a solution. The tutor accepted the solution, and used it as an opening into other aspects of the problem, which he thought important. He had a general issue in mind, and proposed four problems to illustrate it. Soon the discussion closed in on a particular paradox; one put up by Dr White to challenge Richard's incorrect answer. The various ways out of the paradox sought by students were not to the point, and a clue given by an analogy did not lead them to the right way. Finally, out of a valid point made by Richard, the tutor built an explanation of how to deal with the class of problems he had proposed.

The summary makes clear that the tutor tried to control events. The episode makes clear that he was not happy with all his choices of direction. Briefly and unkindly: he had a line and they couldn't follow it.

Was it a success? Despite Dr White's own dissatisfaction, there was a good deal achieved. Indeed, he glosses over several achievements: the initial problem was dealt with; they were thinking ('even under some pressure they all agreed'); they could cope with tricky detail ('they agreed that $D$ was parallel to $ds$'); and connections were built up ('they agreed that they had seen spheres'). Useful and important lessons were there to be learned: an example showing that learning rules for Gauss' theorem or for $D$ and $E$ could take one astray; and a chance to rehearse several ideas, including dot products, surface integrals, field directions altered by a medium, and so on. Few of these things would have emerged (as Dr White saw) from a simple straight answer to Anne's problem.

Dr White could have expounded the issues instead of proposing his four problems. In the end, he did expound them. Was the intervening struggle worth while; was his determination not to tell them reasonable?

The crucial move, to expand a particular question into an exploration of general issues, makes good sense. Less satisfactory is that this attempt boiled down to a struggle with one special paradox. The means to the end, namely the putting up of four examples,
did not wholly work. Dr White ran too far ahead of the students; indeed his question, 'Now how can we tackle this sort of thing?' demands a generalised answer; a strategy. A student, not knowing the subject well enough to stand back in this way, could be forgiven for feeling confused and scared by the examples.

Dr White's choice of examples required all his academic expertise. At the 'paradox' stage, one might with hindsight argue that it would have been better to go back to simpler geometries (parallel plates). But that depends on realising what could be brought out in this way (relations between $D$ and $E$, potential difference and surface charge, and boundary conditions) and what could not (cylindrical fields, less trivial cases of Gauss' theorem). Dr White's case brings out just how much quick, expert thinking tutors must be capable of. Because he is reacting on the spot, Dr White can give himself perhaps up to ten seconds at a time for such thoughts and planning.

The episode contains two conversations: the public one with students, and the private one inside Dr White. Perhaps it would have been easier if the private thinking had been made more public. Dr White might at several points have said, 'Let's list all the points we might need, things we need for this problem, whether you're clear about them or not'. This might have told him more than he could work out for himself about the students; have shown them by the way a valuable tactic in solving problems; and have given everyone, including himself, time to think.

Looking at the episode in another way, one can ask, 'Who was doing what to whom?'

At a general level, Dr White made the decisions, and, albeit gracefully, imposed them. Nor were the reasons for his strategy explained in more than bare outline. The students' main job was to wait for a demand, and to try to react correctly to it, though they could join in on their own account.

At a more detailed level, what happened when they responded or joined in? On one occasion the tutor was positive ('splendid', to Steve); but often his reaction was negative or blocking. For example, Richard's question about melting was blocked, not answered; and his start on an answer was interrupted ('Just a moment, how have you set it up?') when he might have explained some more. (Is it fair to point out that Richard didn't set it up).

Each of these reactions is, in itself, not hard to defend. But taken together, they could
easily put Richard on the defensive. It could seem to him that Dr White (who is not) is a prickly customer, who does not tolerate any flaws in what one is struggling to say.

There could be effects on the personal relationships between students and tutor. We do not in everyday conversation feel very comfortable with a person of superior status who often blocks or challenges our nervous attempts to contribute, and who insists on the validity of his own point of view.

Finally, it should be noted that this tutor's account would not serve as a piece of fiction for general reading. The main personal touch is a concern for Anne. That apart, it is a physics story with few of the feelings of the tutor and none of the feelings of the students playing any part in it. To point this out is not to criticise what is after all an account of a physics tutorial by a physics tutor. But it does suggest that there could be important things going on which have a good deal of influence on events, which tend to be hidden from us.

2.4 DR SMITH AND IONISATION

Dr White, in the previous episode, had difficulty in getting the nature of a difficulty clear. In the next episode, so does Dr Smith.

'There was something in yesterday's lecture about ionisation, that I didn't understand', said Alec. 'Go on' said Dr Smith. His tone was encouraging, though cool, hiding the fact that he was pleasantly surprised to have a definite request for help so early in the term - and on something he understood.

'Well, in the experiment in the lecture with the Bunsen between the parallel plates, the Bunsen flame gave conduction but was it the ions or the heat that did it?'

The episode concerns a first year tutorial with three students. It followed a lecture about ionisation potentials. In the lecture, a hot Bunsen flame had been demonstrated conducting electricity, and so to contain ions. The absence of ions in air at room temperature (which arises because too few molecular collisions are energetic enough to cause ionisation), and ionisation produced by collisions between electrons and atoms in a gas filled triode (thyatron) led to evidence about the order of magnitude of ionisation potentials.
The words were no more than clues to the trouble. I'm not sure I understand your difficulty. Could you try saying a little more about it, or explain it another way? The answer might help diagnosis, it might, in itself, be therapeutic. At the least it would give him time to think.

'Well, there are ions there because of the gas burning. But would a hot wire have done?' Again, Smith resisted the temptation to answer. So he asked, 'What made you think of a hot wire?' 'In the other experiment with the thyatron you got ionisation and that had only a hot wire in it'.

It was sometimes hard to believe that it was not perversity that put the facts together in these off-beat ways. Still, this looked like an easy and well defined job and he could foresee useful ways of broadening it.

'What was the hot wire for in the thyatron?', he asked. Alec's face showed that he had got the message, that he was in a muddle over the thyatron, but that he could not deduce much from the hint. The silence made Dr Smith aware of Simon and John, but glances at them confirmed that they were hoping to look on.

'Well, this is a gas-filled valve isn't it?' Heads nodded obediently. 'And it gives very little current until you apply about 12 volts to it. What does the 12 volts do - why does it have to be there?' 'It speeds up the electrons'. Simon had come in, 'And then they ionise by collision .. .' He went on, competently. He cleared up Alec's confusion, and actually talked to Alec in so doing.

'I see' said Alec finally. 'So a hot wire couldn't ionise on its own'. Smith drew out that an answer would need knowledge of the energies of atoms in a heated gas, and that such energies could be obtained from the kinetic theory of gases. He asked what relationship from the theory would help, and got $pV=RT$ from John. 'Well, that's correct - but it does not have anything in it about atoms or molecules'.

Silence. 'I mean, it's a perfectly good experimental, macroscopic law. But what we need is a microscopic explanation from a theory about atoms'. Smith's pleasure in phrasing the distinction was qualified - did it mean anything to them? The silence gave no reassurance.

'Well didn't you discuss and read about equations like $p = \frac{1}{3} \rho c^2$ which can be turned into numbers and masses of individual molecules to give $pV = \frac{1}{3} Nmc^2$?'

He wrote it on a sheet of paper and turned it round. 'My notes and the book have two different equations', said John, 'the book has
\[ p = \frac{1}{3} N \overline{mc^2} \]. I can't see why they are different. 'Write it down under this first one' said Smith.

As John did so Smith looked at the other two. 'Can either of you clear up his problem? Why the difference between the two? Can they both be right?' A pause, then John: 'I think I see it now'. 'Explain it to the others'. John did so, pointing out the two different meanings of \( N \), but they had clearly been very close to seeing it for themselves.

'Now that does it for us' said Smith, changing gear. 'We can write it as

\[ pV = \frac{2}{3} N \left( \frac{1}{2} \overline{mc^2} \right) \]

and then re-write the left-hand side to get

\[ \frac{1}{2} \overline{mc^2} = \frac{2}{3} \frac{R}{N} T \]

from John's first equation'.

He scribbled, then turned the paper round to them. 'Now I think you were told that at room temperature this energy \( \frac{1}{2} \overline{mc^2} \) was only a fraction of an electron volt, nothing like enough to ionise. Now what is the temperature in a Bunsen flame?'

There was a long, blank pause. 'About 200?', ventured Alec. 'No, 2000', he tried, as Smith's face fell. Smith made sure they knew that it was absolute temperatures that were involved, and asked again about the temperature of gas in a Bunsen flame.

More silence. 'Any idea at all?'. No, no idea. Smith embarked on a monologue about dull red heat, bright red heat, tin melting, iron melting, white heat, and tungsten filaments, ending up with a story about a room mate of his who once let a kettle boil dry and melted it all over the stove. This brought out that the temperature, perhaps 1500 K, was only a few times room temperature, while the ionisation energy was more than a hundred times the kinetic energy of a molecule at room temperature.

'But do we need them all to be at the full energy?', said Alec. 'Can't just a few do?' 'A good question Alec - you've been reading about velocity distributions, have you?' Whether he had or not, it was a good point for bringing their textbook into the scene. Smith fetched the book and opened it. 'There - I think you meant that there would be a few in this tail here with velocities much bigger than the mean. So if we wanted much more energy than the mean there might be very few - but say it was only one in a million, would that fraction be enough to give a measurable ionisation current?'
He knew as he said it that it was a daft question - too vague, too difficult. Simon started to write on a piece of paper, purposefully but privately.

'I suppose we could get the number and compare it with the number of charges flowing in the wire of the circuit?', Alec suggested. 'Well, how could we relate a number of ions to a current?' Smith spotted some promising symbols amongst Simon's scribble. 'Is that what you are calculating, Simon?'

Simon explained: his uncertainty about the electronic charge was a gift for Smith, who talked for a few minutes about fundamental constants, and drew attention to the table on the book's inside cover. Talking about the current, he ended, '... so, say $10^{-7}$ amperes, which gives us $10^{12}$ electrons per second. But we then have to relate that, which is a rate of production, to the number of atoms with enough energy that we need'.

Time was running out and he was just beginning to realise that there was more to this line of argument than he had anticipated. 'So that would be a quite involved calculation', he said.

That was his opinion, but it gave the misleading impression that he was speaking from confident insight. To correct this a little, he added, 'I don't know the answer to the question about the flame and the ions - but I do know that a hot wire is supposed to work although it certainly gives a smaller effect'.

They went out, satisfied, talking, alert. They'd covered a lot of useful ground, thought Smith, even though in the end, the answer to Alec's opening question had turned out to be, 'I don't know'.

2.4.1 COMMENTARY ON DR SMITH AND IONISATION

What happened in Dr Smith's tutorial? At the level of what was done, a student raised a specific point, which gave little hint of what might lie behind it, and the tutor chose to explore a number of related background ideas. For several of the main questions in this exploration, all important, the students could contribute little. Even so, the discussion seemed profitable, and could be seen as an example of the way to explore a problem. It also
revealed, in the end, that the tutor did not know the answer to the initial question.

What about Dr Smith's tactics: the detailed way he handled things? They seem to have been generally effective. Incidentally, Alec was encouraged to talk around his difficulty, and this provided a number of clues and leads for the tutor to build on. Smith might have been tempted to press Alec for the exact nature of his difficulty, which, since Alec's difficulty was not clear to Alec himself, could have been less effective.

Where a question produced no response, the tutor had a range of reactions available: to give more information, to vary the question, or to take up and use an incomplete contribution. So the tutorial, though it had its stops and starts, could proceed fairly smoothly, with the level and pace being varied to suit the need of the moment. Had the tutor not been able to do this, his strategy of choosing an aim, choosing a route to that aim, and finding suitably small steps along that route, would have been less viable.

It is worth noting that the tutor knew the students' course well (as did Dr White in 2.3). He knew the content and motive of the lecture, and had he not, the initial question would have made less sense. Had he not known what to assume they knew, about kinetic theory for example, he would have found it much harder to pick suitable questions or topics.

A small but significant detail is the use of the textbook. The tutor knew the book, had it to hand, and recognised and used an opportunity to bring it into the discussion.

What about Dr Smith's strategy: his plan for how things should go? His remark following Alec's explanations, that he could 'foresee useful ways of broadening', could be unkindly translated as, 'make out of the student's need the kind of tutorial I want to give'. The group may well have got value from the result, but given the chance might have settled on something else.

The important choice, to explore the background to the initial question, was a private one. No ripple of it appears visible to the students. One result was that, although there were chances for students to take the initiative (Simon used them to effect), the chances were local and isolated. The chances could be taken because the control the tutor exercised was played fairly lightly. For example, the digression on the two versions of the equations shows respect and care, so that John gets his chance and takes it.
Like Dr White (2.3) Dr Smith needs a ready grasp of the subject. Without it he could not plan ahead, or produce suitable tactics. It should be emphasised that this is not the same as knowing the answer; indeed he turned out not to know the answer. That it was so was in many ways a bonus, because it helped his strategy of 'come with me, and I will show you how a physicist can think around a problem like this'. Indeed, in his 'daft question' the physicist jumped ahead of the teacher, and in that question lay the seeds of his realisation that he did not know all the answers.

The strategy, however, pays a price. The whole discussion could have been disposed of much more briefly, and not every digression need have been pursued by questioning. That might have made more time to deal with other matters. Whether or not the price was worth it is one of the basic questions about the aims of small group teaching. The usefulness of the clinical analogy used in introducing Dr White's tutorial (2.3) is called in question. Dr Smith chooses, at least some of the time, to get the students to express and talk around their ideas. Although he uses the result to guide his planning, it may be that the act of expressing ideas, however confusedly, is a much more positive part of learning than a mere matter of letting the tutor know what to do. Incisive questions or short sharp relevant information may save time, but may teach less than one supposes.

Returning to details, there are some further interesting features. The tutor wrote on paper and pushed it around to the others, rather than standing up at the blackboard. It may be that this encouraged Simon to make a tentative contribution by way of a private scribble.

The respect noted before shows in several responses to what students say: interest in Alec's problem; following up John's digression about two different equations; and the recognition of students' attempts ('Well, that's correct.....; 'Now that does it for us.....; 'Is that what you are calculating?'). Similarly, Dr Smith jumps at people rather less than Dr White reports himself as doing, and can surely be forgiven (perhaps praised) for his face falling at an absurd estimate of temperature. These, and other touches like the personal anecdote about the kettle, all suggest that he takes some care to develop and keep in good repair personal relationships with his students. Perhaps as a result, they seem to feel free to offer at least some very tentative answers in areas where they know they are confused. Whatever the reason, the discussion benefited from these contributions.
The third and last episode in this chapter finds a tutor posing a general question for discussion, and then having to deal on the spot with consequences that are not according to plan. There are three students, this time in their final year.

There were still twenty minutes left and Gordon felt encouraged to launch into something he had been thinking about on the train the previous evening.

'Since we don't seem to have any pressing problems I thought that we might take a look at quantum mechanics from a slightly different point of view.' Gordon hesitated. 'You have had several courses on atomic physics and quantum mechanics now and we have been rushing along - solving equations; doing these complicated ladder operator problems, and so on. But it occurred to me that we had never really discussed any of the fundamentals of the subject. So let me pose as the man in the street and ask, “What is different about quantum mechanics ?”.'

After about ten seconds of silence, he took it up again. 'That was rather vague. Perhaps we might look at a specific situation. Imagine we have a beam of plane polarised photons and we introduce some kind of polariser in front of it. What does quantum mechanics tell us we will observe on the other side, and how does it differ from classical mechanics?'

Tony responded quietly: 'Is it something statistical?' Gordon thought, good - he clearly has the essence of it. My woolly introduction didn't put him off. Graeme jumped in: 'You will get a distribution on the other side'. 'Distribution? I'm not quite clear what you mean - distribution in energy or intensity or what?', "Distribution in energy. The uncertainty principle prevents you from knowing the energy precisely once you make this measurement."

The problem Gordon poses has to do with the fact that when a polarised beam of light passes through a polariser, with an angle $\theta$ between the plane of polarisation of the beam and the polarising plane of the material, the beam emerges polarised along the direction of the polariser, with its intensity reduced by a factor $\cos^2\theta$. This result is easily understood using classical wave theory. The problem is to show how the concepts and rules of quantum theory, applied to a photon model of light, produce the same result. Experts will know that the matter ultimately has considerable depth, but these deeper difficulties are not germane to the discussion here.
Pandora's box was open, as usual, and Gordon struggled with how to get back to the ideas he wanted to touch on. He was also conscious of Linda's silence. Obviously she was not following, but how was she to be brought in? He continued, 'What does quantum mechanics tell us about this? Does it predict the energy distribution? What physical mechanism is involved?' Tony answered again. 'I don't agree. There will be a spread in the polarisation after the filter'.

The long silence was broken by Gordon. 'Why does that happen?' 'Well', said Tony, 'it is because you can write down a wave function for the system before the filter, and you can write a wave function for the system after the filter, but there is no connection between them'.

'Our man in the street would probably like to ask whether quantum mechanics is of any use then. If everything is totally unrelated to what goes before why bother with quantum mechanics?' 'The statistical thing means that the system behaves arbitrarily; you cannot tell what happens afterwards', replied Tony.

Gordon could feel the time running out. 'We have had several suggestions now without pursuing them too far and without homing in on one. It is possible energy has a distribution, or polarisation varies'.

Graeme interrupted, 'I was confused earlier. I thought we were talking about diffraction - I don't think that there will be an energy distribution here'. Gordon nodded. 'So the question at issue is a simple one. We have a single one of our plane-polarised photons approaching the polariser and we want to know what quantum mechanics will say happens to it'.

'It's a statistical thing', said Tony. 'It will tell us the probability that the photon passes through'. 'And if we talk about the whole beam?' 'Mm same thing - it will give us the average intensity of the beam on the other side of the filter'. 'What will the probability be if the polariser is at angle \( \theta \) to the beam?' Graeme came in again, 'Zero probability almost'.

'Do you two agree?' Vague nods of assent from Tony and Linda. 'You have been looking pretty doubtful about all this, Linda. Do you think that is what you would
'What about you, Tony?' "Well, I know some light gets through'. 'That is a bit different from Graeme's suggestion'. 'Yes'. 'What number would quantum mechanics give?' Tony again: 'Is it cos²θ ?'

The time was almost gone. Gordon took the lead offered. 'Yes, you are right'. 'We can say that the incoming photon is in a state ψ with components cosθ and sinθ. The action of the filter is to force the photon into one state or the other, with probability cos²θ for the fraction that gets through. Clearly, if they are all polarised at 90⁰ to the polariser they won't get through, and vice versa'.

Linda still looked unhappy but Tony nodded vigorously and Graeme seemed happy.

'Unfortunately we have run out of time again. I have the feeling we got a bit lost in the middle there. Perhaps we should take it up again next time. I had wanted to discuss the Stern-Gerlach experiment with you. It is closely related to this situation we have just discussed, and it was a favourite oral exam topic for our last external examiner. You should look at it before next week'.

As he tidied up he was nagged by familiar doubts. Why was it so hard to get through to the fundamentals? Looked at the right way everything is so simple and clear, but the clear view always seemed to elude them. With a bit of help Tony and Graeme were getting there but Linda was sinking fast. She would drown completely if something wasn't done. He had better arrange some remedial tutorials on her own. His conscience silenced by the thought of positive action to be taken he turned to the research paper he was trying to write.

2.5.1 COMMENTARY ON POLARISATION AND QUANTUM MECHANICS

What happened to Gordon and his group? The tutor started with a general issue intended to provoke discussion, and was quickly forced to narrow it down to a much smaller one. The new question produced several confused responses, and the confusion increased rather
than decreased with each new question, until a very definite focus was provided (The question at issue is a simple one...'). Then a step by step quiz made positive progress, and led to a short exposition of the main point.

At the end, Gordon drops a hint about matters that external examiners like to discuss. Whether for this motive or for another, it makes good sense for Gordon to try to use his small group for the discussion of important matters in general terms, and if the relative failure is at all characteristic, doubts must arise about whether what went on in earlier tutorials was as helpful as it might have been, in this direction.

The students are quite good at technical matters, and can do calculations about rather advanced ideas, but, although at least two or them know about the essential general ideas, such as the uncertainty principle, wave functions, and a probabilistic interpretation, they cannot use this knowledge in any general way, appropriately and with discrimination. They can operate within a tight framework, but not find their own framework. Such a state of affairs is common enough.

The confusions (as with earlier episodes) need considerable knowledge on the tutor's part if they are to be probed and dealt with. By the final year, it cannot always be taken for granted that the special problems implied in what students raise will all fall into the areas of the tutor's special expertise. 'Pandora's box' sums up this feature, and few tutors would feel easy about an impromptu attempt to unravel the web of confusions and implied confusions that Gordon is presented with.

What kind of questions did Gordon ask, and what was their effect? The opening question may have helped create confusion, by appearing at once to invite any relevant contribution, but at the same time suggesting that there is one narrowly defined answer ('What is...? and next, 'What does...?'). Something like, 'How many differences can we think of?' might have had a form better fitted to its general intention. As it was, the students may have felt they were having to guess what the tutor wanted, and this may explain why the issues were narrowed down more and more under pressure of silence.

That the tutor did have something in mind is clear ('how to get back to the ideas he wanted to touch on'). And with these ideas in mind, he bypassed the Pandora's box of confusion, and drove the discussion back to them, with closely defined questions. More generally, the danger inherent in both previous episodes, that what the tutor has in mind may not be what the students need, is sharper here. A natural anxiety to finish what one has
started may be as strong a driving force as are efforts, like Pandora's, to close the lid of the box again.

There is something paradoxical about the episode. The tutor expresses a clear concern and care for the students, and is anxious that they should get value from the discussion. But nearly everything said is about subject matter, rarely an enquiry about whether a student is worried, lost or in a difficulty. It may be that the tutor had a view of their needs which centred on getting through to something definite and clear, and perhaps the trouble is that this is not the whole truth.

Similarly the tutor reports his own anxiety, and uncertainty about how to deal with what emerges; a point not confined to the present episode. It might have been better to say so, rather than to keep digging at the physics. A general exploratory chat, starting from the point that the tutor does not know how best to respond, could perhaps prepare the ground for more constructive work in that or a later tutorial. Even Linda could have said something about what she did or did not understand. As it was, she may have been keeping quiet so as not to be asked a question she couldn't answer, and Gordon may not have done her a service by being so kind as to refrain.

2. 6 CONCLUSIONS?

One advantage of using descriptions of real tutorials as a starting point, is that the temptation to make easy generalisations is readily resisted. What emerges are issues and problems, not diagnoses or solutions.

But it does become clear that a major part of the task of responding to problems raised by students is finding out a good deal about what those problems are; more than is caught by thinking in terms of the 'exact nature of the difficulty'. It is all too easy to deal with a clear but irrelevant difficulty, and never get to grips with the actual, but more diffuse or concealed one.

Questions about deciding the agenda for the tutorial also clearly arise. It is not easy to ensure that the topic itself, or the pace and level of its treatment, are helpful. It is hard to know when to press on, and when to abandon a well-meant but ineffective plan; and not easy even to get the information needed to help the decision.

It is curious that, in a chapter about impromptu teaching, the natural titles for at least two
episodes should have seemed to take the form, 'Dr X on...'. At least, it ought to be asked whether such titles are good ones. Does the tutor take over the direction of events, mainly using his knowledge of a topic to determine what happens? Without doubt, the tutor's knowledge is an essential part of his qualifications for the job. But when should he use it to guide students on a magical mystery tour? And does the magic always justify the mystery; indeed does it need the mystery at all?
3. Preparation

3.1 TUTORIALS WITH SOME PREPARED BASIS

Can some basis of prepared work improve the quality of small group teaching? In particular, can it help with the difficulties, illustrated by episodes in chapter 2, which arise when the tutor relies on impromptu, on the spot reaction?

The episodes in this chapter are concerned with tutorials which are in various senses prepared. They will not resolve questions about the value of preparation, but they may bring out some issues involved in trying to resolve them for oneself.

3.2 DISCUSSING NEWTON'S LAWS

This episode is from a first year tutorial with five students. They had agreed the week before to discuss Newton's laws of motion at the next meeting. The tutorial was held in a university video-recording studio, and appears (unlike previous episodes) as a verbatim transcript of parts of the recording.

T Newton's laws of motion. Can anyone tell me what the first law is? Come on.
S1 Every body continues in a state of rest or uniform motion unless accred on

The discussion turns on the meaning and status of Newton's laws of motion. The problem is a deep and difficult one, but arises because to advance into further mechanics (especially relativity) there is a need to examine the basis of what the student has previously learned. At an elementary level, one can learn laws like 'force = mass x acceleration', but it then turns out that some of these laws can be seen as defining their own terms (force, for example). Behind that is an even subtler point. Looking at a law as a defining relation may seem to rob it of its importance, so that the work of genius of finding the right conceptual framework comes to look like an arbitrary and trivial deciding of meanings.
by an impressed force.

T  O.K. Now what does that mean? (five second pause)
S2 With absolutely no force acting on it whatsoever, and you give it
a gentle push, it'll start moving at a constant velocity - and it'll stay
moving at that velocity unless something causes it to slow down. I
suppose - that's in the opposite direction or in some other direction to stop - to
alter it doing that.

T  O.K. Is this really a law as such or is it - is it a definition? If it's
- if it's a definition what's defined? What are the things which sort of
come in?

S2 It defines a force really. It defines - you could say it defines a
force as something which alters the motion of a particle or object.
(five second pause)
S1 It is a law really because it's a fact. (laughter)
T Well somebody says it's a definition and somebody says it's a
law. It's a definition because it defines what we mean by force,
and it's a law, sort of - a law because it's - it's a fact.
S2 Well if you're going to call that a law what would you say a force
was? (five second pause)
S1 You don't really define it somehow. (laughter)
S3 Surely a lot - plenty of laws define things.
S2 Yes, but it's a matter of whether the law is strictly a law, or
whether it's strictly a definition. In other words could you manage -
could you manage without a law - without using the law as a
definition or could you not?
S3 Can you split laws and definitions (pause) into such firm
categories?
S2 Yes, some anyhow - because one form of Newton's Laws -
Newton's second law is \( F=ma \). That - with the first law that is not
necessarily a definition.
S3 Of force?
S2 Yes. (2 and 4 start speaking together)
S2 Sorry, go on.
S4 Isn't it a definition and the application of it becomes a law?
S2 That's a point, yeah. In that case are you - would you say
Newton's first law was a definition and the second was a law or
what?
S4 Which are we calling the second? (laughter)
S3 \( F=ma \)
S4 On that one (five second pause) That's a law I think.
S2 So the first's a definition.
S4 Yes.

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S2 Well of course if you ignored the first you could say the second was a definition and the first law was a law. (laughter)
T You've got yourselves into a nice tangle.
S4 I think this is the wrong department for that sort of thing
T Is it so obvious in fact, let's come back to the point, about it being a fact; is it so obvious that it's a fact? (six second pause) Or have you been conditioned into thinking, accepting -
S4 It's one of those things I think because you (pause) sort of take that as given and then introduce friction and such forces to explain why it doesn't hold absolutely, so er -
S5 Well it wasn't obvious in Newton's time was it?
T It wasn't.
S5 No.
T No.
S5 That's why it was such a new thing.
S3 Well is it obvious now, I mean just because we know about it, is it so obvious?

In the next page of transcript, Student 2 drew a parallel with other ideas, and argued that the law seemed obvious because it had been drilled into one. Student 3 pointed out that it would not be obvious if he had not heard of it before. The tutor closed off this discussion by summarising their feelings, and asked:

T What about the second law? Is there - is there a definition involved in there? (four second pause)
Say \( F = ma \).
S2 Yes there is.
T What?
S2 Mass, I think.
S3 Why?
S2 Because, well how do you define mass otherwise? (laughter) It's a measure of inertia. It distinguishes mass and weight.
S3 Yes - but you might as well say it defines acceleration. You're just picking one of the three.
S2 Acceleration - not, not really. That's not so fundamental as mass.
Mass is fundamental, acceleration isn't, you see.
S4 Yes but force isn't - force is a combination of a lot of things.
S2 But I mean it's fundamental in the sense that you sort of measure it directly. Acceleration you don't.
S4 Mm.

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T Does the definition of acceleration depend on Newton's second law? (pause) Is there another definition which is independent of Newton's second law - of, let's say, acceleration?
S2 Well I've always been brought up with the idea that acceleration is the rate of change of velocity. I've never heard it described as a law.
T Well I think that is a definition. I think the first law is rather more than just a definition because as (S1) says it does illustrate an experimental fact which, when you look at it, is very difficult to demonstrate experimentally, because uniform motion in fact is a rare bird indeed. But acceleration doesn't really depend on Newton's second law. Is there anything in the $F=ma$ part of it which really does depend on, on its, so to speak, existence for (eleven second pause) - for the second law? What do you say force, for instance is? Is that defined elsewhere other than the second law?
S2 Yes, in the first law, I would say. It's perhaps more than a definition but part of it is certainly a definition (pause) but the force is the thing that alters the motion of something or other. (five second pause)
T Is that a complete definition of force? Don't you need anything else to complete the definition? (eight second pause)
S1 The first law doesn't tell you what it is in terms of other quantities. The second tells you what a force is in terms of mass and the acceleration.
T Always assuming that you've got - you know what the mass and what the acceleration -
S1 Yes.
T In other words what you're saying is that the effective unit of force hasn't been defined in the first law.
S2 In other words the first law's qualitative and the second law's quantitative.
T Possibly, yes. In fact to make it quantitative we need units for acceleration, and units for mass. Now you've got a unit for $\frac{dv}{dt}$.

T What about the unit for mass?
S2 Haven't got one. (eight second pause)
T You see the problem now? We've got three quantities and we can fix - in order to get the third one we need to fix two of them. At the moment we can only definitely fix one. (six second pause) Now which of the others do we fix?

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The tutorial went on to a discussion of mass and weight, of ways to measure or compare mass, to the idea of inertia and to the third law and momentum.

3. 2. 1 COMMENTARY ON THE DISCUSSION OF NEWTON'S LAWS

The reader will probably have been struck by the rambling and incoherent appearance of the discussion. It is necessary to emphasise, for readers unaccustomed to looking at transcribed conversations, that this is the impression all of them give at first sight (see chapter 7). In speech, one does break off when it appears that the listener has got the point, and one does change direction in mid-sentence if it appears that he has not.

That said, the discussion is in fact rambling. Various labels such as 'law', 'definition', and 'fact' are tried out for the status of the first law; then for both first and second laws; after which the 'obviousness' of the first law is put in question. Then the tutor turns attention to the second law, which is again compared with the first, before at the end of the extract, the problem about the second law begins to be clearly formulated.

It is not obvious whether the fitful, hesitant nature of the discussion is regrettable or not; whether the tutor ought to have let it wander unclearly around, or not. At least one tutor's reaction to seeing the videotape was that it was a painful and uncomfortable waste of time, and that the time would have been much better spent on a clear exposition.

The nature of the discussion can be looked at from two points of view: whether it reflects the degree of preparation, and whether it reflects the way the tutor handled it.

First, then, were the students prepared? They had in fact been given an exposition of the issues in a recent lecture, and they did expect to discuss them, as is clear from the way the discussion gets underway without introduction. It is also clear that this preparation did not bring each student to the meeting with a set of clear and consistent views to put forward, so that one reaction could be that the preparation had been ineffective.

But in a different sense, the students were prepared. On inspection, many of the things they say are attempts to formulate, not ideas about Newton's laws, but ideas about
their own difficulties with the problem. When one student puts a suggestion, another frequently responds by trying to say how far he agrees or differs (the incidence of 'I think that...' and 'But what do you say to...?' as compared with assertions about physics is quite high for a physics tutorial). They have come prepared to consider their own difficulties, and to compare them with those of others.

It could be argued that the tutor was exploiting the unique opportunity offered by small group teaching, for students to become aware of their difficulties, first by expressing ideas, and second by having those ideas contrasted with those of others. If grasping a concept is more than knowing what is right, but also involves getting straight about what is wrong, such discussion could be seen as indispensable. It is at least significant, with regard to thinking about the aims of tutorial teaching, that the episode can produce such sharply conflicting views about its potential value.

Secondly, what did the tutor do, which influenced the form of the discussion? To begin with, he acted more or less as chairman, repeating or contrasting things which had been said, to focus the next stage of discussion on a particular issue. When he put his own views, they were comments on the students, not on the subject ('You've got yourselves in a nice tangle'). He invited self-reflection ('have you been conditioned...?') No student was told he was wrong, and the tutor only worked gently and indirectly to put things right. Then, at the end, he changed tactics, and began to intervene much more, putting in a series of new, specific questions of his own, which lead to some measure of clarification of the issues. He was now acting as guide, instead of as chairman and commentator.

The description of what the tutor did raises questions about roles the tutor can play (see chapter 6). These questions must concern both the appropriateness of various roles for different purposes, and the need to change roles as a tutorial develops.

Finally, the transcript is by no means the whole reality. It can be seen from it that student 2 made much of the running, but not that he leaned back in his chair in a confident, even provocative manner. It can be seen from it that student 5 joined in only once, but not that he looked withdrawn and unresponsive. Actions speak as loudly as words, so that the visual record contains some important information. Chapter 6 discusses what the tutor can learn by observing such things.
This episode is concerned with another kind of preparation: with the tutor coming prepared with ideas for activities. One of them he calls, 'It's all happening'. This was his version of an idea which appears in chapter 10. The group consisted of six first year students.

Ogilvy had come to this first meeting with his first-year tutorial group with some ideas about what to do. They had as yet had no lectures in the atomic physics course, and the main thing, he thought, was to get to know them, and to get them talking.

'Let's get to know one another - I'm Bill Ogilvy - I know some of your last names, but I don't know who is who yet'.

Ogilvy looked at the student who had sat beside him when they had put two tables together and arranged chairs round them. 'MacEwen'. 'What do your friends call you? Your first name?' 'Oh - Ian'. Ogilvy wrote, getting the home address and telephone number too.

It went on round the table, until Ogilvy had all six names and the other details down. Ogilvy's next idea was something he had thought of on his way there.

'I think we ought to get used to talking about what we find hard or confusing - everyone has some kind of difficulty. Maybe we could go round the table, and each say something - anything at all - he always finds baffling, or tricky. It's also a way to get to know each other'.

The student sitting beside him - Ian - started off straight away, without a pause. Ogilvy reflected that that itself told him something about the chap - he wondered quite what.

'I always found mechanics easy, but I didn't get on with atomic physics things like that'. Ogilvy thought of asking, 'What do you mean - can you be more precise?', but decided not to. He looked at his list of names and then at the next student. 'Jim ?'

Jim took a visible breath. 'Oh - RC circuits, integrating and differentiating, I couldn't get that. I knew what they did - you know - but why they did it - I couldn't understand. 'Ogilvy felt the need for some kind of reply. 'I think a lot of people have trouble with AC theory.'
He turned to the next student, who was riffling through the material handed out for the course the day before, and who said, 'I can't understand this thing in the notes. Avogadro's hypothesis. I mean I know what it is, but how could you prove it?' Ian replied at once: 'It's only a hypothesis, after all, you can't prove it, you just accept it as a hypothesis - that's how I think about it, anyway'. Nods all round, except from the one who had asked.

Ogilvy wondered what to do. Avogadro had been put in at the start of the course because they often had trouble with it. Ogilvy had already given some thought to a way of talking about it. He decided to go on with his game of 'say what you don't understand'. Without thinking much, he replied to Ian: 'That sounds to me like a bit of a get-out. I mean, it's fantastic, absurd - how could any gas at all have the same number of molecules in the same volume? I know it's true, but I remember finding it very hard to see why. Anyway, how would you count them?'

No one said anything, including Ian, who had sounded rather certain of himself. Ogilvy pushed on. 'Anyway, that's something we must talk about soon'. He checked the list for the names, and asked for the next contribution.

The game went on. AC theory came up again, and produced a bit of an argument about Nuffield courses. Some had done the Nuffield course, others had heard of it, and opinions were about equally divided. Most of them had something to say, when Ogilvy enquired if they had any impressions. 'Well, there's obviously room for disagreement about Nuffield', he said.

The discussion stopped, and Ogilvy found himself back in the driving seat. He thought again about Avogadro. Launch into that? He had intended to try another game, 'It's all happening'. He'd never done it before, and was curious to know how it would go. The students sat waiting for him to make a move.

'The Avogadro thing is important, and we'll come back to it. Just now I want to try something else ....' Ogilvy got underway with his explanation of, 'It's all happening'. He asked them to write down all the things that might be going on between the filament and the screen of a television set. They began writing down ideas. Then they stopped, and waited.

Ogilvy consulted the list of names again. 'Peter, would you collect the ideas, and

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you and the others sort them out a bit - see which are the same and which are different? I've got this book here which has a bit in it written by Avogadro himself, and I want to look at it to see if there is anything there which might help'.

Ogilvy turned to his book, but listened. He heard Dave, who had been rather quiet, insist that the question, 'What are electrons anyway?' must go in. Peter started to read his list.

'The first thing we've got is electrons coming out of metals'. Ogilvy looked round and asked, 'What do you think of as happening inside the metal?' 'The electrons carry away energy from the filament'. 'How do you mean, they take energy from the filament?', asked Ogilvy. He pursued it a little, and then they worked down the list, Ogilvy restating items or questioning them.

Everyone talked to him, not to each other, with rare exceptions. It was hard to get something definite and clear out of each point.

He looked at the clock - five minutes left. The feeling of wanting something definite won. He cut short the discussion. 'OK, let's finally go back to Avogadro, and then do some more on him next time. Ogilvy talked rapidly, skimming through the idea he had had about making sense of Avogadro.

Decidedly past the hour, he stopped. Five of them went out hurriedly. Ian stayed behind and helped put the chairs and tables back into rows facing the blackboard.

'What do you have next?' 'Electricity, over the road.' 'You'd better go or you'll be late.' Ian went, saying over his shoulder, 'Anyway, thanks for the coffee'.

3.3.1 COMMENTARY ON THE FIRST MEETING

What happened at the first meeting? In brief, the tutor found out the names of the six students, tried two ways of getting them talking, and finally gave a hurried talk about something raised by one of them at the beginning. They did talk, but in isolated small exchanges, without any real flow of discussion around any one of the topics.

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The episode is not one about physics, but about the way a tutor handled a group of six students on a special occasion, using at least partly planned tactics. That physics was not the main item on the agenda can be seen as a weakness, or as a strength. The tutor was trying to build up relationships for the future, but whether he did it well is another question.

In some respects, he was thoughtful and skillful. He wrote down the names, established the intention to use first names, and used the list so as to address students by name, so beginning the job of learning them. He made sure he could get in touch with them if necessary, by taking addresses and telephone numbers. He had arranged the chairs specially. On this occasion at least, he provided coffee.

The tutor showed signs of being observant, noticing one student's forwardness and another's hesitancy. He sometimes got students to talk just by looking round, rather than by picking on one, so as to put less pressure on them. Some of the tactics are deft: getting them to write down ideas and sort them out on their own, with one student asked to be "chairman" for a few minutes, for example.

But such praise needs considerable qualification. It is not clear that he has much more than goodwill to offer as the reason for his 'games'. What is supposed to come out of them is by no means clear, and when almost by accident the first one ended, he abandoned any attempt to get something more useful out of it, and dived into the next idea. Indeed, reading between the lines, it looks as if he had been learning a little about handling groups, and that he demonstrates the well-worn truth that a little learning is a dangerous thing.

At all events, although the tutor has some prepared ideas, he betrays some unsureness of touch in deciding what to do with them. The second 'game' probably needs more time than he allowed: two good ideas may be worse than one.

How did he appear to the students? Better, perhaps, than he might have. He could have rejected Ian's very first, very vague effort; and he did sympathise with Jim about AC circuits. But he also may have seemed other than he would have wished. He squashed Ian: it is not easy for a tutor to remember what superior fire-power he deploys. More seriously, he put so much effort into wondering what to do, and trying out assorted ideas, that he may have come over as a games player. While the initial message may have come over as, 'he is interested in us and what we think', in the end it may have looked more like, 'he plays games with us and does what he wants, not what we want'.

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So, oddly enough, an episode in which a tutor tried too hard to get the students involved, ends up as one which reinforced his apparent determination to stay in control, whether he wished it to or not. Prepared ideas do have this danger, especially when the point of them has not been discussed openly.

3.4 A PROBLEM ABOUT BLACK-BODY RADIATION

The kind of preparation with which this episode is concerned is a common one: students coming having attempted to solve set problems, prepared to discuss their answers.

The episode is again a transcript from a recording. Before the extract begins, the tutor and his two students had mentioned several problems they had tried, and the tutor had settled on the question below.

Calculate the frequency at which the radiated intensity is maximum for a black-body at (i) 6000 K (ii) 300 K. What relevance has this result to the statement that the infra-red astronomer faces a problem comparable to that of an optical astronomer working in a lighted dome with a luminescent telescope?

If two stars, one of radius r and the other of radius 2r, radiate total intensities of visible (and near-visible) radiation in the ratio of 4 to 1, what is the ratio of the temperatures of the two stars?

Which star would appear brighter when viewed with far infrared radiation, and by how much?

The episode starts with a question about the second paragraph.

T: I mean the middle part of the question, it says two stars, one is twice the radius of the other - and they emit -

The answer to the second paragraph of the question depends on knowing that the intensity radiated per unit area of a surface varies as the fourth power of the temperature. The answer to the third paragraph depends on knowing how the intensity is distributed over various parts of the spectrum, and on knowing that, although the distribution changes with temperature, the intensity at any one place in the spectrum is always higher if the temperature is higher.
S1 The ratio of the temperatures, I make 1.4 to 1
S2 I got it 8 to 1
T (to S 1) That being root two -?
S1 Um (three second pause) Yes.
T Presumably.
S2 I got a lower temperature for the star that's brighter.
T Yeah, I don't think that's right actually. Would you like to show us how you did it? (S2 goes to blackboard)
S2 If I can remember, What I did was to consider the two stars as these. (Draws circles on board) One has a radius of \( r \) and the other one had a bigger radius of \( 2r \). I'm not sure that's relevant yet. So the area of this one would be 1 unit, and the area of that one would be 4 units, presumably. And I worked it out using this formula
\[
I_1 = \sigma T_1^4 \quad I_2 = 4\sigma T_2^4
\]
S1 What does that signify?
S2 This? That's the -
T Ah, yes, that's supposed to be the smaller star.
S2 \( T_2 \) leads to \( 4\sigma T_2^4 \) That's \( T_1 \) and that's \( T_2 \). The temperatures of each star are different.
S1 Do you know how you got those?
S2 What, these two formulas? (surprised) Well -
S1 What, why -
S2 This the radiation emitted per unit of surface area.
S1 Is it?
S2 Yeah.
S1 That's where I went wrong, 'cos I disregarded the radiiuses, I thought no matter what the size of the object you got I equal to \( \sigma T^4 \). So that's where I went wrong.
T Yeah, I mean, you can see that's - um (two second pause) don't you find that a bit surprising?
S1 What, what I thought?
T Yeah.
S Yeah, I did.
T I mean, you can see that that's a property of the quality of surface, right? I mean... you'd expect that it would depend upon its temperature, but plainly the temperature doesn't depend on how big it is - O.K.? But the total amount actually put out would surely have to depend on - that's what you're talking about, how much the total thing gives out.
S1 I knew there was something odd, but my I was equal to what was called the spectral intensity. I used the spectral intensity per unit area.
Right, O.K. You're fine - carry on.

Shall I go on from there?

The tutor then checked that student 2 could complete the calculation.

The bit that I found a bit more difficult was when I looked at that as $T$ increases - I mean goes up - the frequency increases.

Which bit is this? The last bit, you meant?

Yeah.

What is the ratio - you found the ratio of the temperature of the two stars and you are asking now which would appear brighter when -

In the infra-red.

When viewed in the infra-red, I see.

You've used a different problem,

Let's understand what his problem was, first of all.

So, I mean that seems reasonable to me.

As temperature increases - frequency increases -

And from the formula before, $2.82kT/h$. I mean, if you put $T$ up the frequency goes up, the maximum frequency. So it seemed to me that, the second star would have been more in the infra-red anyway unless it was very low.

Hm, I don't think that I quite understand. Do you (S1) understand what....?

I think you are wrong in saying that as $T$ increases $f$ increases.

What do you mean? Yes, what do you mean by $f$? Do you mean the maximum frequency?

Yeah, the maximum frequency.

Yeah, at maximum intensity. O.K. now I understand what you are saying.

Yeah, 'cos when you have got the formula before that $f_{max}$ is equal to $2.82kT$ over whatever it is.

Yeah, I see.

It seems to me that if you put the $T$ up, the $f$ goes up as well.

True, but - (turning to S 1) why don't you say what you just said?

I just say that $f_{max}$ is not the only thing you are thinking about.

That's right. What we are saying is that that is just $f_{max}$ - that's what the spectrum peaks at, right? But we are saying, to hell with that, we are actually going to look at the damn thing with an infra-red telescope or something.

Oh - yes - yes.
We are just using that particular frequency which may or may not happen to be $f_{max}$

Student 2 then explained how he had done the calculation, and that he had copied a formula out of a book, at which they all laughed. Student 1 objected to his calculation, and student 2 replied:

S2 ...I didn't know what to do with that... I was a bit worried about it really.
T You should have been, yes!

Later, after exploring both students' ideas, the tutor asked:

T Right. But have you done this in the lectures?
S1 No.
T Have you done the, what's that called, Wien's radiation law or what is it?
S1 We didn't do that either.
T You didn't do that either. I see.
S1 I can't remember it.
S2 I got those out of a book.
S2 I work more out of a book these days than lectures.
T Well, fair enough, yeah. Are you happy about the way they are derived, did you follow the derivation?
S2 Yes, I read through the whole passage until I got to the bit I needed, so I mean I read through the derivation, but how much notice I took of it is a different matter altogether.

3.4.1 COMMENTARY ON THE DISCUSSION OF A BLACK-BODY PROBLEM

The tutor would doubtless report simply that they had discussed the solutions to a problem from an examples sheet.

A fuller description would include the facts that the two students explained the ways they had thought about the problem; that they argued with each other; and that the tutor did not go through the solution, but stopped when he thought the approach was clear. It would be reasonable to say that there was some genuine discussion.

The tutor took a background role in more than one sense. The subject of discussion was always the students' ideas, rather than his own. Further, the tutor presented himself as trying to understand them, not as trying to get them to understand him.
He was able to adopt such a role because both students spoke freely, and themselves added fuel to the discussion without prompting. They exposed their failures and doubts as readily as their confident ideas. It is very striking that the episode (including the parts summarised) contains no question from the tutor which remains unanswered, or which produces a long silence.

The tutor did, however, strongly influence the form of the discussion. He might be said to have acted as the 'conductor'. The entries of the instruments were clearly signalled: 'Would you like to show us how?', and 'Why don't you say what you've just said?'. When he did intervene, he returned the control firmly and explicitly: 'Right, OK. You're fine carry on'. He kept things clear by holding a student back if necessary: 'Let's understand what his problem was, first of all', but made sure that the point came out later.

The tutor's own points were inserted briefly and with directness: 'I don't think that's right, actually'; 'But we are saying, to hell with that...'; and 'You should have been (worried), yes!'. But his positiveness is not overwhelming, perhaps because his remarks belong to dialogue rather than monologue: 'I would have thought that...'; 'Don't you find that a bit surprising?'; and 'I don't think I quite understand'. Many tutors would have continued after the last remark with something like, 'Do you mean that... ?', whereas this tutor turns to the other student, and asks if he understands. In short, he takes their ideas seriously.

It is important to note that none of this implies any softness or unclarity of attitude. Indeed, the tutor comes across as a forceful character, but one who reacts directly and intelligibly. He conducts with a brisk baton, and the players respond. The students behave confidently ('I think you are wrong...'), and this confidence must be related both to the relationship with the tutor, and to the fact that they had come prepared with material to talk about.

Clearly, this tutorial avoided many of the problems revealed in earlier episodes. But it should be noted that the range of discussion was limited to the task defined by the problem. The nature of related problems was not raised, for example, indeed, Dr White (2.3) reports in a line or two, what may have been an equally effective discussion of a problem, and goes on to show how trouble arose in trying to generalise from it.

There was no discussion of general related issues, such as were clearly prompted by the question. Dr Smith (2.4) and the tutor in 3.2 found difficulties there.
Two of the hardest parts of the tutor's task, to establish priorities and locate unrecognised difficulties, have been removed from the job by sticking to the set problem and its solution. The task has been made easier by being made more modest. The issue is whether a modest success is worth more than a more ambitious partial failure.

3.5 SUMMARY

There are several kinds of preparation, including an agreement to discuss an issue (3.2), prepared tactics in the tutor's mind (3.3), and prepared work by students (3.4). In general, all these kinds of preparation reduce the extent to which the tutor has to improvise not just a subject for discussion, but also the plan for the discussion, and his reactions to problems students bring up. Also, students may be able more easily to see the point of work which has derived from their own efforts.

It is also clear that preparation is not enough. The last episode shows how important are the relationships between tutor and students (not to mention the advantage of dealing with only two).

Some pitfalls of preparation have also emerged. It is dangerous, but tempting, to stick to one's plan, in spite of evidence of more pressing needs. Students can be bewildered or frustrated if the plan is not made clear to them. If the prepared plan is narrowly defined, all sorts of needs may never emerge. In these respects, the problems of prepared tutorials have a good deal in common with those discussed in chapter 2.

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4. Working together

4.1 EPISODES ABOUT WORKING TOGETHER IN GROUPS

In chapters 2 and 3, a number of differences between ways tutors and students do, or do not, work together, emerged. In this chapter, attention is focussed on whether these differences matter: on short and long term effects of different ways of working; on the value to be attached to them; and on how they relate to the purpose the tutorial has.

Not all the differences seen before were intended. The context matters: first year or third, the size of the group, the personalities of teacher and students. Some seem almost inevitable. Does the tutor have much choice about how he works with students?

In order to focus on such issues, the episodes have been shortened, from those originally written by the tutor, by selecting one passage which characterises the style of the work.

Three short episodes are presented, one after the other, in sections 4.2, 4.3, and 4.4. They are all discussed in section 4.5.

4.2. CONFUSION ABOUT ENERGY LEVELS

This episode concerns six first year students, and the problem raised by one of them about understanding how the energy levels of an atom are related to the frequencies of the spectral lines it emits.

Norton had begun, as on the previous week, by collecting and writing down the things the students wanted to have clarified from their work that week. They started on the points about spectral lines. Bill led off:

"This spectrum (it was a Balmer spectrum), is this $n=1$ or what?" He started to draw
in pencil and leaned forward towards Norton. Norton gave him a felt pen so that they could all see, and pushed his own chair back so that Bill couldn't talk only to him.

'You have, say, this (bottom) line here. Call that line 1, O.K.? Norton wondered what was coming, and tried hard to listen carefully. 'Call this next (top) line 2. These lines are in this space here between them are they?'

'Tell me what the lines are, Bill.' 'Levels or frequencies, this is \( n=1 \), this is \( n=2 \) ...' Bill began to repeat himself. Norton gathered himself for an explanation about levels, differences between levels, photon energies and so on.

'Right, the first thing is to...' Peter came in as the words formed themselves. 'I don't see how a line can be just \( n=1 \), it's got nowhere to jump to'. Jim and Clive looked puzzled - Norton felt sympathy with them. Alan sat calm and silent.

Martin put his oar in. 'This formula (the Balmer equation again) how did they get that? I mean, where does this \( n \) come from? I don't see that at all.' Jim answered him. 'It's all a big cheat, I reckon. They say you can get wavelengths - wavenumbers - whatever it is, out of it but to get the equation they had to put the wavelengths in the first place. That's what I think, anyway.'

Martin looked at Norton. 'Is that right?' Norton, who secretly fancied himself as a bit of a philosopher, found that he had leapt at the point. He held forth about empirical formulae, and made up a fanciful tale about guitar players who knew nothing of standing waves, but who worked out an equation for the overtones of a string, with whole numbers in it that they thought were nice, but peculiar. When he finished, they began again. Norton kept hearing new fragments of partial nonsense as he tried to think about the one that had last floated by.

'....these frequency levels....' '.....this line at an energy \( n=3 \) ....' '.....the Balmer jumps to level 1....' '.....a line at the level \( n=1 \), doesn't make sense to me....'

Somehow or other, Norton patched together some explanations. He never really felt
that he had got to grips with any one student's difficulty, though. Everything each student offered gave only the faintest clues as to the trouble, and time and again Norton was driven back, not to answering the question, but to explaining the whole thing from start to finish. He tried to listen, but found it hard to make sense of almost every question.

As it went on, he became aware of how things had developed. Bill, Martin, and Peter, sometimes joined by Jim and Clive, spoke to him alone so that he was conducting three or four individual tutorials in parallel. Each fairly often broke in on another during a pause, raising a different issue. Two or three times, Norton had to ask one of them to stop and wait - realising afterwards that some of these points had never been returned to.

4.3 CHARGE ON CONDUCTORS

The previous episode might have been called, 'Norton loses his grip'. In the next, the tutor decidedly does not. It is from a first year tutorial with three students. One student had asked about why the text book said that, when finding the force on a charge due to several others, the other charges should be at rest. The point is that a charge put near a conductor will cause free charges in the conductor to move until the resultant field parallel to the surface of the conductor is zero. This point was not mentioned in the book. The tutor proposed, without giving reasons, an example to discuss.

'Let's look at a simple example - a positive charge is brought up near a flat metal surface - the metal is earthed.' Dr Austin sketched on a piece of paper, and turned it round towards the trio. 'What happens?'

Mary answered after a short silence. 'You get induction - charge flows from earth.' 'Why?' asked Dr Austin. 'The positive charge attracts it', said Mary. 'How much charge does it attract?'

No answer from anyone. Austin had to try again. 'When will it stop piling up negative charge?' The silence, if anything, was more profound. Austin was only partly discomfited: the other part was savouring the challenge.
'Will it just go on piling up negative charge until there is infinite charge there?' They all smiled nervously - not surprising in view of the question - but the rhetorical device had worked and he tried to go further. 'What determines what happens - how much charge, how the charge is distributed, and so on? What controls things?'

David had a go. 'It has to be equipotential'. 'Yes - go on', encouraged Austin. David couldn't go on, but Austin pressed the point. 'You say it has to be equipotential - what does that mean? What can you deduce from it?'

David thought. Austin looked at Mary. Mary had her try: 'There will be uniform charge on the plate. ' 'Do you agree with that David?' David agreed. 'Does it make sense to you Alan?' It made sense to Alan too.

Austin realised that he was in it up to his neck, but he didn't mind. It would be fun getting them to see the point of this lot. He began to plan. First he must dig at the identification of uniform potential with uniform charge. He tried an oblique angle.

'How can the plate be at earth potential if it has a negative charge?' Silence and blank faces showed that the angle was too oblique. He changed tack.

'Mary, why did you agree that it had to be equipotential?' 'Well near a sheet of charge you have equipotentials all parallel to it.' She sketched, plausibly. 'Yes, good', said Dr Austin, 'and what about the field?' 'It's at right angles - like this', David interposed, and drew appropriate lines. 'Yes, why?' 'Fields are at right angles to equipotentials.'

Austin hesitated, but decided not to press for a real explanation - it could wait. 'That's only true', he said, 'for a sheet of charge on its own, isn't it? Here we have this other charge close by. '

'Very close to the metal', said David, 'its charge has the biggest effect, so its just like a metal surface on its own.'

'That's a good argument. . . ' said Dr Austin, despite a nagging doubt about it. What it was eluded him; anyway he must press on.

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Austin did press on, and by the end of the hour had got the main point out: that the charges moved until there was no net force on them.

4.4 NUCLEAR MODELS

In this episode, the tutor and three third year students talk about the shell model of the nucleus. The problem is that a shell model arises naturally in a system like a hydrogen atom in which there is a central force, but for a collection of nucleons it is not obvious why there could be any kind of central force.

'All in all', said Jackson, 'the shell model is a very odd thing.' 'What do you mean?', Brian demanded.

'Do you not think that it is very strange that it exists at all, or at least that it works? We can easily see why it works in an atom. The nucleus sits in the middle and provides the strong central force which dictates the form of the potential and leads to the familiar electron shells. It's a bit different in the nuclear case. There isn't anything in the middle to produce the central potential yet we still have the shell model.'

It was clearly a question, and John responded to it. 'The problem is the picture. It is very difficult to picture the nucleus. Maybe there is something in the middle. Maybe it is denser in the middle, and the dense bit in the middle acts as a sort of nucleus for the nucleus. That would give a nuclear potential well, wouldn't it?'

'That would mean that the particles in the middle bit weren't in shells, but there is evidence that even the deep-lying nucleons are in shells.' As he spoke, Jackson had drawn a picture of John's nucleus on the sheet of paper in front of him.

Brian leaned forward and added to the picture. 'Perhaps the nucleons pair off on each side of the centre like this, and the force between them will pull them towards the centre.' 'What about an odd one on the outside?', asked Peter. 'It wouldn't have anything to pull it towards the
centre.' 'Well it would feel the average pull from the other nucleons', replied Brian.
Jackson prodded gently: 'There's a glimmer of an idea there. One thing you haven't mentioned are the forces involved. We know that the Coulomb force will tend to blow the protons apart, but what about the nuclear force?' 'Oh, that holds things together', interjected Peter.

The tutor then asked about the size of nuclei, and the range of nuclear forces. The students competently and with gusto went through the estimation of the range of nuclear forces from the mass of a pion and the uncertainty principle. The tutor then asked:

'What do these numbers we have worked out imply?'

Peter was quick to respond. 'It means that each one is only pulled by the neighbouring nucleons. N is not affected by those on the other side of the nucleus.' He hesitated, then; 'Does that mean that on average they get pulled more towards the centre just because they are only pulled by neighbouring nucleons, and on average there are more nucleons towards the centre?'

'Good', said Jackson, 'You have hit the nail on the head.' This group always seemed to get there. At least two of them would make just as good physicists as himself. They already knew more than he did in some areas.

'The only problem', he continued, 'is the fact that the nucleons are all moving in their orbits, and will continually be scattered when they encounter another nucleon. Why doesn't that destroy the regularity of the shell structure?'

After a brief pause Peter suggested, 'Perhaps all the other orbits are filled so there is no orbit to scatter into.' 'Why can't it go into one of the filled orbits?' Brian had been following too. 'The nucleons are fermions, so they have to obey the Pauli exclusion principle.'

'Very good. The nucleons feel this average nuclear force which gives a central potential and the nucleons don't scatter out of their orbits because the Pauli principle prevents them being scattered into adjacent orbits.'

Jackson's eye caught the clock. 'As usual, we have run over time, and I have another class. We might see where all this leads, next week.'
They filed out. Not for the first time, Jackson wondered whether there was any point in having tutorials with a group like this. They would probably get along quite happily under their own steam. Still, there was no time for such musings; he had better hurry or he would be late for the next class.

4.5 COMMENTARY ON EPISODES 4.2, 4.3, and 4.4

The three episodes above present several contrasts, so far as different ways of working together are concerned.

Jackson's final thought exposes the catch 22 of tutorials: if the students understand, they can discuss a point, but what then is the point of the discussion? Norton and Austin reveal the other side of the catch: if the students do not understand, either the tutor cannot understand their confusion (Norton), or he himself decides what is best for them, and has to force them to keep to his line of thought (Austin).

The error in this argument is that it too strongly polarises understanding and not understanding. Jackson may be wrong, for his students may have been helped to organise their ideas, and may have gained confidence from revisiting known but not yet completely familiar territory. Norton's students may at least have become aware that they were confused - a by no means trivial step. Austin's students at least knew that his chain of argument existed, even if the links in it had to be put in place for them, and may even now have escaped them.

The three groups have different kinds of agenda. In Norton's, the students dictate the agenda (literally as well as metaphorically, since he writes down items they suggest). Austin and Jackson both decide their own agendas. Austin does it strongly but implicitly: out of a suggested difficulty he produces a problem which seems only distantly related to it, as if it was obvious that this was the proper starting point. Austin does this several times, planning but not revealing his plans, while Jackson puts things up for discussion more openly.

Such differences relate to the way the tutor does, or does not, maintain control. Norton withdraws control to the extent of letting the group run wild. But he does try to be receptive, and the students do respond by talking about their problems. Austin, by contrast, remains totally in control. Even when things go wrong, the students wait for his next question. His control works, because the questions are carefully formulated; indeed at
times he reminds one of a chess master playing multiple chess with a group of beginners. Jackson proposes rather than disposes; his authority is expressed through rewards like, 'Very good', or 'You have hit the nail on the head'.

Further differences emerge if it is asked who is putting pressure on whom. The students press Norton for individual attention, each competing for 'air time'. Austin presses individual students for clear, precise answers. He expects, and gets, no response when such an answer cannot be found, preferring to try another question. Jackson is more varied than either of the others in his reactions, joining in as well as questioning.

What does each tutor really care about, and does what he cares about matter? Austin cares for the physics involved, and that something clear and definite should emerge. He is concerned that they should understand a difficult matter as well as possible, and shows respect in pitching the level of his questions. Austin's will be judged a success story by many.

Norton cares for the students in a different way, wanting to get their problems to work on. But he may not care for them enough; he perhaps ought to try to help them to work together better, and to show more respect for each other and for him. Norton's story will be seen as a failure by not a few.

Jackson's story suggests that judgements about the other two ought not to be made too quickly. His students talk to him, putting up ideas, in just the way Norton tries to encourage and Austin may unconsciously discourage. He shows, though, a respect which Norton does not manage, in accepting what they say and giving something in return (John was given a serious counter-argument, rather than being told he was wrong).

It cannot be said flatly that one such tutorial is good or bad. But it might be said that if Norton goes on as he did, his students will come to think that he may care about what their problems are, but that he does not care about dealing with them. And it might be said that if Austin went on often in the same way, his students would think that he cared only about dealing with problems of his own choosing, and that what should have been a help had turned into a viva-voce examination.

None of these things can be considered without looking at the wider context. Norton's group is a large one, and this in itself may have made difficulties. Indeed, Jackson may have been fortunate in this respect, and in having third year students; it is easy
to have a discussion which keeps to the point with a few people who also know pretty well what they are talking about, and are not too unequal in status.

Norton and Austin have different ways of trying to help their less mature first year students. Austin provides a tight framework, and is skilled at avoiding irrelevance. As a result, something definite is achieved, which may help to build confidence, at a time when it can be needed. He also demonstrates the level of argument he expects, at a time when students may be unsure about standards. Norton tries to offer an atmosphere in which personal difficulties can emerge, and in which individual, but wrong, contributions can be valued. For a discussion like Jackson's to be possible, something of both may be needed, but too much of either may well destroy the very thing it is trying to develop.

4.6 THREE CHAPTERS OF EPISODES - ANY CONCLUSIONS?

This section summarises briefly some of the main issues raised in this first part of the book, and relates these to the chapters to come.

Many points made in the episode commentaries have represented wisdom after the event, suggesting alternative ways of doing better. Some such suggestions have been about better ways of achieving the same ends, but others, by suggesting different aims for the work, have called in question the aims actually being pursued. It should be clear that a diversity of aims is involved ('occasionally one might well...','but if one always worked this way then...'). The need for discussion of aims (chapter 5) has been lurking in the background throughout.

Another issue that has been emphasised has been the character and extent of student contribution to and involvement in, tutorials. This depends partly on the responsibility felt by students for the work, whether by way of negotiation and preparation, or by way of general loyalty to a set of friends. It is also influenced by the relationship of the pace and level of the work to their own capabilities, and by the relevance of the topics to their own felt needs. It further depends on the friendliness and personal encouragement that tutors may offer in response to student’s contributions.

These and related issues are looked at in chapter 6. Whilst the importance of them for successful work in a group hardly needs stressing, the commentaries have also
suggested that there may be reciprocal and cumulative interactions between the
development of personal relationships and the methods, both of work, and of
approach to the development of understanding, adopted in the group. Many
features of importance here have been touched upon in brief attempts to look at
the episode transactions in detail. More will be said in the analyses offered in
chapter 7 and 8, where some features of the language used in tutorials, and
particularly the types of question used, are looked at.

The case for tutors having access to a range of ideas which they can use
to prepare tutorials, or call on in need, has been sufficiently made to justify
chapters 9 and 10, which attempt to offer help of this kind.

Before leaving the episodes, it should be emphasised again that they and
their kind contain more than can be extracted here or in later chapters. The
reader is more likely to benefit from seeing in them some reflection of himself,
than he is to profit from the commentaries of others.

Indeed, and on a more personal note, those who have been involved in
writing episodes about their own teaching, or in looking at video tapes of
themselves and others in action, have learned many things, not all of them
welcome, about their own work. It may well be that the greatest value of these
three chapters of episodes is to suggest that the reader might himself reflect on
the evidence he could obtain, by writing for himself the story of one or two
tutorials of his own, or, with more trouble, recording and listening to them. The
material in these chapters would then serve the only purpose for which they
could decently be said to be adequate - as first reference points for a further
exploration of the territory.

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Part two:

Understanding the problems
5. What is tutorial teaching for?

5.1 GETTING OUTSIDE THE PROBLEM

In Part One, we began where the work of the project itself began, with day-to-
day needs, worries and difficulties felt by tutors. These problems do, however, 
need to be seen in a larger perspective. We need to stand back from them, so as 
to see them in relation to what tutorial teaching might be attempting to achieve. 
That is the function of this chapter.

5.1.1 TUTORIALS AND THE AIMS OF THE UNIVERSITY

Answers to the question, 'What are the aims of the university?' are apt to be 
both diffuse and inflated. Yet they cannot be avoided if any account of the role 
of tutorial teaching is to be given. It may at least sharpen the issues to conjure 
up images of things which are highly valued.

One such image will surely be that of the deeply knowledgeable man 
telling others what he knows, and being listened to for what he has to say. 
Another image will be more lonely; an image of the scholar engaged in private 
and lengthy struggle with what is not known. A third, though it will take many 
forms, will certainly be one of people involved in close and reasoned argument. 
A fourth may perhaps be represented by an image of degree day; a time when 
hopes for the handing on of what is valued are symbolised.

Such values are expressed in many of the activities of the university, 
often in all, but in some more particularly than in others. Lectures, private 
study, seminars, tutorials, marking and examining; all carry one or more 
messages about where the values of the university lie. Yet these values, and 
these activities, are in competition as well as in collaboration with one another. 
In this light, the fundamental question about tutorial teaching is one about the 
value to be attached to the last two images: discussion and talk as it relates to 
students becoming members of the community of scholars.

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There will be those who find this high-sounding verbiage. They may prefer to look at the matter more coolly and more technically, asking perhaps whether tutorial teaching is a cost-effective part of a system for producing graduates.

To this one might respond at two levels. First, on its own terms, it really is difficult to see how a system without a strong personal ingredient could do the job. Research groups take it for granted that discussion between members of the group is essential. In industry, where cost is rarely ignored, matters which are new or difficult are ordinarily sorted out in small group discussion; indeed the interest of the business world in small groups is at least as strong as that of the teaching world. Just because learning is a new, difficult, and personal affair, talking things through is a practical necessity. So one justification for this book is its attempt to develop ways of doing better what must in any case be done.

But there is also a response at a deeper level. It might be objected that to think solely of tutorial teaching as a technique which may be more or less efficient, is to refuse to take the purpose of the enterprise seriously enough. To view the university as a production line is, in our view, wrong. It must concern itself with what is of personal and social value to those whose lives it affects. This concern must be outward-looking, seeing the values of the university as important for the individual student in later life, and for the community at large. There must also be an inward-looking concern, with whether the university is what it ought to be; in Newman’s vision:

'... an Alma Mater, knowing her children one by one, not a foundry, or a mint, or a treadmill.'

This book, then, is also based on the view that tutorial teaching can play a unique part in working gradually towards teaching with more humanity. But ambitions do not guarantee achievements; what counts is hard, detailed work. Much of the book, therefore, is close to the ground, attentive to practical detail, but in a way which tries not to lose sight of the goal.

5.1.2 TUTORIALS IN SCIENCE AND IN OTHER SUBJECTS

It seems worth asking how the place of the tutorial in the work of a science student differs from work in another subject, say history. For the history student, the week's work is likely to be an essay, to be discussed with his tutor at a meeting which is in some respects
the focus of the whole week. The tutorial is an essential part of the definition of what his work is.

For better or worse, the week's work for a student of the sciences is very different: several lecture courses to be followed as they progress through an organised development of ideas; laboratory work to be done and written about; and sets of examples to be attempted. Work for him does not focus on one theme, or on one discussion, but on many things each at a different stage at any one moment. Here at once we have the source of many of the problems of the science tutorial: problems of finding a focus for discussion; and problems of achieving any consistent level of discussion.

The comparison brings into focus some dilemmas of the science tutorial. The history tutorial is an end in itself, a major means through which what it is to do history is communicated. It is not an ancillary to lectures (rather the reverse, in fact). By contrast, the science tutorial serves many masters, and is subject to their competing and conflicting demands.

The response, we think, must both accept present necessities, and look towards ways of changing them. For example, the episodes in chapters 2 and 4 are about understanding what can go wrong, so as to avoid repeating mistakes; while the skill session material of chapter 9 describes a new, but practicable, way of teaching in small groups. Some tutors will be more interested in one aspect than in the other. It is our hope only to bring these issues, and the question of the proper balance between them, into the debate every tutor has to conduct with himself about what it is best to do.

5.1.3 TUTORIALS: NECESSITY OR LUXURY?

Tutorial teaching is something of a British eccentricity. Poorer countries cannot afford it. Others, as well or better off than ourselves, are not so highly selective in admitting students to university, and so have larger classes than ourselves, within which tutorial work is at least very difficult, though increasingly in demand.

As more and more people come to expect a university education, tutorial teaching becomes increasingly harder to provide. Our tutorial tradition is a thing of value whose survival ought to be fought for. If tutorial teaching is not done well, it will become harder.
and harder to argue the case for it. Worse, it could become devalued if its contribution to personal care came to be seen as a myth, notable mainly for the expense of perpetuating it.

5.2 AIMS AND VALUES OF TUTORIAL TEACHING

A difficulty in discussing the aims of tutorial teaching, is an uncertainty whether some feature ought to be seen as an aim, or as a side effect which may also have value. For example, one student said:

'It's very good because you get to know people in your ...tutorial, gradually, and so you make friends.'

Is this an aim for first year tutorials, or just a happy outcome? The answer will depend on two things: on the importance one attaches to the outcome, and on whether other ways are provided which may do the same job as well or better. 'Making friends' is just such an intermediate case, which some will regard as central and others will not. Few aims are totally clear cut (not even 'learning physics'), so universal agreement is not to be expected. The selection which follows can only be one of several ways of looking at the matter.

5.2.1 TEACHING BY EXAMPLE

'... by talking about it, it comes. He...talks about the whole thing... does it through again... and you say, "I see where that goes", whereas you didn't before.'

It is not too difficult to plan a lecture course in, say, electromagnetic theory, because one can analyse it into steps. It is very difficult to plan a lecture series on, say, solving problems, because one has little idea of how to describe the whole, part by part. Such things, many of which are rather like crafts, are taught on the apprenticeship model: learning by seeing the expert do it, and by trying for oneself under his guidance and protection.

The tutorial can provide just such a situation. The tutor can function as a model of competent performance; can criticise particular instances of attempts by students to do it themselves.

Many matters in science teaching are of this kind. The approach to a problem is
one. Learning to be appropriately critical is another. Yet others include making
good hypotheses, thinking of alternative explanations, making sensible
approximations, putting ideas into quantitative or algebraic form, judging
sensibly the precision needed in an experiment, selecting important information
to record, and so on. Not all of the things best taught by example fall to the
tutor, but many do.

5. 2.2 MAKING TEACHING MORE RESPONSIVE

There is a very real sense in which the tutor is there to learn from the students.
The tutorial has a function as part of the flow of information back to individuals
and to the department, which can be used to modify and improve teaching.

But what the tutor learns ought to make a more immediate difference, as
well. The tutorial is the place where teaching can be a response to an immediate
need, being shaped not by a plan but by the demands of the moment.

Several issues emerge. It is not possible to respond without
understanding the need, and much of chapters 6, 7, and 8 concern difficulties of
finding out what the trouble is. What students need can be very varied, and if
the tutor is to encourage and allow them to influence what is done, he himself
must have a wide variety of resources. It is no use finding out what is needed,
or letting students ask for what they want, if one has no way to deliver the
goods. Chapter 10, for this reason, suggests a variety of things a tutor can do.

What happens when the tutor cannot respond effectively is well known
to all who have every tried tutoring. Here is how one student saw it:

'You'd come in, and he'd say, "Any questions?" - "Oh". Then... he'd sort
of pick up the last lecture notes... and start asking questions on them,
explaining bits that weren't even difficult. If you asked him a question,
then he'd wander on and on and on... he'd go past the question and then
go on and on.'

5.2.3 FEEDBACK TO STUDENTS

'You got feedback on what you were doing. He was always there to
encourage you, or to tell you when you were way out of line.'

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People cannot learn very much without information about how they are doing. The tutorial is an important addition to other channels, for several reasons. Feedback from a tutorial discussion can come soon after the event; sooner than it can through tests or examinations. The information can be of a subtler and more detailed kind, because it is got through the to-and-fro of argument or question and answer. It can be the information the student actually asks for, rather than that which someone else has decided he should have. Also, however, it can be information the student would never have realised the need for if left to himself; information about a subtle confusion, for example.

Another quite different kind of feedback is too easily forgotten. People can only learn who and what they are by having reactions from other people. It is in this way that they learn how clever, how nice, how hard-working, and how acceptable they are. Many things are involved here: confidence (note how the student quoted above links feedback to encouragement); learning how hard one needs to work; and, above all, coming to a realistic assessment of oneself.

Much - probably most - of such information does not come directly from the tutor, but from other students. The tutor is an influence in so far as what he does is the context for reactions of the others, and in so far as he helps by inviting contributions and reactions, and by clarifying them.

5.2.4 INDEPENDENCE AND MATURITY

Those whose aim it is that students should arrive at greater maturity and independence cannot afford to neglect the personal kind of feedback we have just been discussing. To be at all independent must mean being able to work out how one is doing, and that cannot be done reliably by people who are not fairly clear about their own qualities, standing, and wishes.

University courses to a great extent force a student to learn on his own. It is in the tutorial that difficulties in dealing with the demands made by this freedom can be brought out into the open. To do this at all, the tutor must have the trust of students. The following student's description brings out well what this means:

'...an intelligent bloke talking to you more or less as equals - someone you...
can feel is a friend; not a deep friend, but at least somebody you can come to... you felt that this bloke cared about you - he established a sort of friendly attitude, then built on that - I mean, it was never anyone you could take a liberty with, but at least he was an interesting person.’

Students’ attitudes to and feelings about work may need exploring at a whole variety of levels. Sometimes an open discussion of doubts about the reasonableness of the course may be necessary. A student may, after all, have goals of his own which are not to do with becoming a physicist, and may well need help in sorting out a sensible attitude to a course which makes different assumptions.

Often though, attitudes will be formed by the way the tutor and other students discuss work; by what they take seriously. Here is another argument for working in groups, rather than one-to-one. There is good evidence that people are rather little influenced in their attitudes by being told, and are much more influenced by working them out in discussion.

5.2.5 LEARNING HOW TO WORK

What it is to be a scholar, or to be on the way to becoming one, involves more than attitudes to work. There are particular things to learn, too. For example, students need to be able to make effective notes, as a part of learning the subject. Scholars need to be able to find and use references, and this is something to be learned. Students becoming scholars need to learn both kinds of thing; nor can the division be drawn at all sharply.

The tutorial could play a particularly valuable part in some of these things, and in so doing, contribute in its own right to learning in the university.

The tutorial could have a special role in things like discussing essays students have written, talking through what good examination answers or practical reports might be like, preparing and giving short talks, and all the things which are involved in developing a green-fingered approach to dealing with problems.

Others, of which using the library and being able to find references are an example, could be dealt with in other ways, but often are not. Just because tutorial teaching is
flexible, it can accommodate them most easily.

5.2.6 UNDERSTANDING THROUGH DISCUSSION

The reader may by now suspect that the writers have forgotten that understanding physics is, after all, a central aim of tutorial teaching. Far from it. The tutorial can help students to move from knowledge as something remembered to it as something understood and usable. One way it can do this is by getting students to say what they know. Having to tell ideas to others is a powerful means of reaching a deeper understanding. Teachers all recognise how much more they learned when they first had to teach a topic. Anyone doing research knows how essential it is to talk through ideas with people; and how much of what one then learns is due not so much to what the others say, as to the act of having had to formulate one’s ideas for them.

There is also a second aspect. For at least some students, science can sometimes lose significance and meaning, so that it looks like a jumble of equations and technical terms. Here, explaining things to other people can sometimes help, and this student catches that aspect as well as the previous one:

"There was this homework a girl had to do... it appeared to me to be important, because she couldn't do it... I could see through the difficulty, and tried to explain at least where the difficulty was. Until then... I had sort of done it, but it hadn't been very important, and suddenly it became quite important. And I could reflect on it myself after that, and it became part of my store of knowledge. It achieved significance through being significant to somebody else."

5. 2.7 DEALING WITH PARTICULAR DIFFICULTIES

For many, dealing with special problems and difficulties is the main, and often the only acknowledged purpose of the tutorial. For that reason it deserves a section of its own, even though much of what needs to be said has been said in earlier sections.

Several of the episodes in chapters 2, 3 and 4, show how hard it often is to pinpoint an exact difficulty, and how many difficulties are turned up by any careful exploration of students’ thinking.

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The tutor has no option but to accept that he cannot deal with more than a tiny fraction of students' difficulties. It is therefore important to sort out the reasons for devoting time to it. One such reason can have to do with confidence: for a student to find that he can understand one thing can help him to try harder to understand another. A second reason has to do with the approach: students may be able to learn by example what kind of thought and self-examination is needed in order to get out of a confusion or get past a blockage.

However, to use a medical analogy, it may need to be recognised that diagnosis, prescription and remedy are different functions. The doctor usually makes the diagnosis, but does not attempt to mix or administer the medicine in the surgery. Similarly, tutors may need to recognise that the 'cure' cannot always be achieved within the tutorial. Otherwise, the tutorial may end up only dealing with the most trivial of maladies.

5.2.8 LEARNING TO WORK TOGETHER

Much of physics is solitary, but a good deal is not. It would be a narrow view of a life in science which ignored the importance of getting advice from and giving advice to others, working effectively in a research or development group, and working out future plans. The ability to put one's views, to listen to and grasp those of others, and to help keep such discussions in focus without letting issues become too personalised, all have some importance.

The tutor, by the way he conducts discussions, insists on letting several people have their say, and tries to clarify what is at issue, can at least aim to set a standard of discussion. Such a standard can provide a framework within which students can exercise the powers of discussion they already possess, and it can express the values implicit in the way the scientific community conducts its affairs.

5.2.9 PERSONAL CARE

Students, like everyone else, have all sorts of problems, which shade imperceptibly from tricky points in the subject to very private and deep problems.
Some tutors will be inclined to think that they are there to help with physics, and would be embarrassed by any outburst of feeling. Nor perhaps do they feel adequate to deal with anything but the subject they know. In this they may be to some extent correct, because a clumsy treatment of a private problem may be worse than nothing.

Such a view will not entirely do, however. Any group of people is bound to throw up such things sooner or later. They will emerge even in the coolest, most impersonal contexts, when it becomes plain, for example, that the student does not understand about state vectors because he is miserable. Learning physics cannot be wholly divorced from deeper feelings, and the problem cannot be neatly divided between the physics tutorial and the counselling or advisory services.

Indeed, most questions of personal care will be simpler, more practical and immediate, having to do with such things as getting behind with work, being worried about a difficult course, or just being depressed about a difficult set of examples. What is important here is probably mainly to have developed a reasonable atmosphere in the tutorial, within which such things can be accepted. Often, just saying how one feels helps as much as anything, as long as it is not rejected or brushed aside. Personal care in this modest but important sense may be more important than any attempt to go deeper.

5.2.10 INDIVIDUALITY

Much of science teaching is devoted to ensuring that students all become the same: that everyone knows the same things. In so far as the tutorial is devoted to filling in gaps and clearing up problems, it serves the same end.

It is not, however, obvious that this is the best use of all the time spent with an individual tutor. The tutorial could also be an opportunity to develop individual interests and strengths; a place where people become interestingly different. Ways in which this can be done, which may deserve attention, include essays written and discussed, talks by students prepared and given, and discussions around a theme in which the tutor and students are both interested. Time which is free to be spent as one pleases is often important:

'I feel very happy when I'm in a tutorial. I can sit there - I can think about something, and talk about it for a while and there's no rush to get through a
certain amount of work in such a time. We can spend half an hour on one question, talking about it, and that makes me feel really good.’

Just as important, the tutor is an individual too. He will be very good at a few things, competent in others, and unsure in at least some areas; both in his knowledge and in his skill as a tutor. There seems good reason to suggest that the tutorial ought to exploit his strengths, whatever they happen to be. Not least amongst the arguments which should influence a choice of one aim rather than another, is what one is good at.

5.3 THE TUTORIAL IN CONTEXT

Although in the previous section, aims and values more or less particular to tutorial teaching were explored, it would be wrong to suppose that the tutorial functions in isolation. Much else of what goes on determines what it can reasonably try to achieve. So two things are involved: knowing what is going on, which is the context in which the tutorial must operate; and working out a strategy for the best use of small group teaching, which meets the demands of that context, and functions within its constraints.

5.3.1 KNOWING WHAT IS GOING ON

By and large, university teaching is done by experts who rightly teach what, and how, they think fit. Too often, perhaps, this independence extends to a lack of information on the part of each about the others. Yet for the tutor, information is crucial. Without it, he may spend all the time he has in the tutorial finding out what has and has not been done, leaving none for following through the consequences. Some means of obtaining such information is vital.

What else students have to do is also important. The time when they have to write a major laboratory report is not the best one to choose to set an essay or ask for a talk to be prepared. Even the timing of the tutorial may be important. Tutors may know rather little about the work-load and work-pattern of students.

What a tutor finds out about the whole context of other work may give him pause for thought. Not every lecture course is clear, not every laboratory is free from tedium or
frustration, and not every administrative arrangement is seen as fair or sensible. Not every syllabus is short enough to be learned for understanding in the time available.

5.3.2 WORKING OUT A STRATEGY

In what has gone before, it may have seemed as if the tutorial should have fixed aims; some one selection from the many possibilities. That could not be so: students develop and their needs change; correspondingly the emphasis on different aims and on different kinds of work must vary continually.

One part of developing a strategy must be to think out priorities for all the many possible activities, such as helping with problems, dealing with difficulties from lectures, talking through important ideas, working on particular skills including those involved in studying effectively, getting students to talk themselves, and so on.

Another part involves forming some idea of how students are themselves changing; perhaps lacking confidence at first, and certainly at that time busy finding out what is expected of them, both in word and in fact. Later, perhaps, interest flags, and they may also get involved in many desirable but non-academic activities. Later still, things like project work make new demands, final examinations may loom large, all at a time when courses often reach their most difficult level.

The working out of a strategy is necessarily an individual affair, but one which ought to be informed by a view about what is being aimed at. Any discussion of aims necessarily looks idealistic. Hard-headed practical people (amongst whom the writers count themselves) often react against such discussions, as over-ambitious and out of touch with reality. Against this, it has to be argued that to react to the pressures of the moment, without any guiding sense of purpose, is often to drift into courses of action about which the best one can say is that they seemed inevitable at the time. It is to permit the urgent to drive out the important.

What is certain, however, is that to try to attain all the things discussed in this chapter, in a total of perhaps a hundred one-hour tutorials over three years, given by several people, is out of the question. Rather, the problem is one of choice; of choosing those aims which are both more important than others, and which the tutor himself finds to be best suited to his own powers and limitations.
The choice cannot be an abstract one. It will depend on what the tutor knows about the particular students he has. And, above all, it must depend on having ideas about how to realise various aims in practice. It is no use having an aim and no idea about how to achieve it. Only in so far as other parts of this book offer at least some help of this last kind, can it claim to make sense for those for whom the problem about tutorial teaching is that they have to get on and do it, rather than sit back and think about it.
6. People in groups

6.1 THINKING ABOUT PEOPLE IN GROUPS

'... he usually starts off by saying, "What would you like to discuss today?" That's when you get your first long silence. Then he probably suggests something, and starts to question us on it, and - well, nobody is very forthcoming.'

Tutors and tutorial groups do have their problems. Many of these problems are particular to the science tutorial, but many are ones which arise whenever human beings work in groups.

The problems will be approached from two points of view: people as individuals, and people in groups. From the first point of view, the questions are about how the tutor as a person influences students, and how they as persons have effects on what does happen or can happen. From the second point of view, the questions are about the special consequences of being in a group; about things which happen because the individuals are together and not alone.

Human beings are complicated, and much of what can be said is only tentative. Equally, human beings know a good deal about each other anyway, and much of what can be said is common-sense. The aim of this chapter is, tentatively, to try to organise that common-sense around a number of ideas, which may be useful in thinking about tutorial groups. Section 6.1 outlines and illustrates these ideas. Because most of the ideas derive from common-sense, it is natural and convenient to introduce them first in familiar situations.

Section 6.2 develops further ideas about people as individuals, while section 6.3 develops those concerned with people in groups.

6.1.1 KNOWING ABOUT INDIVIDUALS

To discover what other people are like is rewarding but difficult. For example, when one
takes a new job in a new town, one often feels a little daunted by the task of getting to know a number of new people, and of finding friends amongst them. How is it done? How, again, does a new lecturer find out who on the staff is influential, is helpful, or is worth talking to about particular things?

Much of it is done by observation, conscious or not. At a staff meeting, the way people say things reveals something about them; perhaps an inclination to dominate others, or to persuade and manoeuvre them. Even where and how people sit may be relevant, distinguishing those who are deeply involved from those who are not. Attitudes to others can be revealed, amongst other things, by the way people listen to others, or by the way they draw others into the discussion.

Such knowledge of others is indispensable, as is shown by the great difficulties anyone has in working with unknown people. For the tutor, the problem of getting to know his students is a difficult one. He will probably meet them only once a week for an hour, and that is a short time in which to find out very much. Their personal histories, difficulties and problems may remain hidden from him.

Many tutors do something about it: inviting students home for a meal or a drink, for example, and also using information available from other sources in the University. Such knowledge can be very helpful. A student who is, for example, often absent from lectures or laboratories, and who seems distant and cut-off in tutorials, may - and may be thought to be - unconcerned about work. But his behaviour may have other causes; family problems - a dying parent, for instance. Inevitably there are many such matters which come to light too late, if at all, after they have had serious repercussions on work.

It is easier to forget the reverse process, that students need to get to know their tutors. They use this knowledge to decide what sort of problems to bring to him, and it influences how they behave towards him. Whether or not they see him as a real person with interests and feelings may be quite important:

'The nice thing about him was that he used to tell us he wasn't feeling so good - because of a hangover - he'd been out the night before. What he doesn't realise is that even when he's got a hangover, he is still very good at helping us.'
6.1.2 THINGS THAT HAPPEN IN GROUPS

Although individuals often go their own ways, what they do when they are part of a group is often strongly influenced by the group. A group is more than a collection of individuals.

One thing that influences people in groups is what others expect. At a party, there is an expectation of lively, amusing talk, so that when one person tells a joke another is likely to cap it, and so on; behaviour which would be unduly forward in a different context.

Also, being in a group leads people to adopt roles. Again, at a party, there are those who talk and those who listen, and the listeners are as essential as the talkers. From time to time, of course, people change roles.

The notion of role is simple but important. We all have very clear, but often implicit, ideas about patterns of behaviour which feel appropriate to particular situations. A chairman (one type of group role) should, for example, be firm but not take sides. That is, behaviour in a particular role conforms to a set of mutual normal expectations which are constant and stable enough to define, however implicitly, what is normal or not.

A group has a recognisable character: students and tutor in a tutorial, or four people playing bridge, are recognisably groups, where half a dozen people in a 'bus queue usually are not. Groups develop a certain cohesion: that is, members act together in concert. It is not only the chairman, but also other committee members who contrive to silence someone who keeps on introducing irrelevancies. The stronger the cohesion, the greater the pressure the group can exert on its members; pressure either to maintain roles, or to push individuals into or out of particular roles.

As groups tend to have norms, cohesion can grow either through the willingness of individuals to conform to them, or through group pressure to conform. For example, conformity may be necessary to achieve a task: a member of a research group cannot simply not turn up when the group has been allocated time on a machine, or he defeats the group’s task.

Group pressure is one mechanism for doing things to people, but not the only one. Another is negotiation, important because of its relationship to efficient functioning. Negotiation can be explicit, as when a committee decides the priority of items on the agenda, or implicit, as it often is when one faction on the committee look around amongst each other to find the one who will speak for them.
Belonging to a group often, though not always, can involve an individual being dependent on the group: that is, it offers him something he cannot obtain without it. Much dependency is reasonable: the status obtained from membership of a professional group; the achievement from working in a team building a bridge. Some dependency is not so good for the person: depending on a group for one's opinions, or on an authority for reasons for doing things, can be examples.

6.1.3 DIFFERENT KINDS OF GROUPS

It will not have escaped the reader that the things mentioned above are by no means automatic or inevitable. People can always opt out. Much here depends on the extent of their commitment to the group. A useful, if rough, distinction can be drawn between types of group in which personal commitment is important, and those in which it is not. It is just because the level of commitment of students to a tutorial group may be in doubt that it is worth looking at these different kinds of group.

Groups involving personal commitment include, for example, task groups and social groups. By a task group is meant one formed to do a definite job: research groups, boards of examiners, and so on. By contrast, social groups like youth clubs or debating societies have their value for individuals in the shared activity they provide.

The tutorial does not fit neatly into either category. It has a task, but the task may not always be clear. It has something to do with the shared activity of talking and thinking together in an intellectual milieu, but it lacks the voluntary nature of, for example, late-night talking about issues.

Groups where personal commitment is not so important are have-to groups and arbitrary groups. Have-to groups are those to which people belong out of duty rather than desire; not a few academic committees are of this kind. Arbitrary groups are those made up of people thrown together (as they see it) by accident; for example, passengers stranded on a broken down train. In both kinds, negotiation - whether explicit or implicit - is especially important because roles have to be found and accepted, and sometimes redefined.

Where does the tutorial fit into this picture? So far as the tutor is concerned, it is something of a have-to group; a part of his job. So he may start with good intentions, but if
the group bores him or is difficult to handle, he is likely to reduce the effort he puts into it. At least, he may feel it a struggle to keep trying.

For the students, the tutorial is to some extent an arbitrary group. They find themselves with others they have not chosen, and, even if attendance is not required, it appears as something expected of them. In consequence, they naturally wait to find out whether it seems valuable or not, and defer decisions about how much effort to invest in it.

6.1.4 AUTHORITY AND THE TUTORIAL

The context of the tutorial is very well defined. It has a special purpose, and it takes place in a situation which clearly defines roles such as teacher and student. In such a context, the tutor cannot escape the role he is given, by the institution, by his colleagues, and by the students. He is an authority, by virtue of his knowledge and position. The role of a leader with authority is by no means a bad one, and is often necessary and helpful. Students usually appreciate someone who knows what he is doing:

'He makes us work....but you don't mind working for him. I don't know whether it is his personality, or the way he treats tutorials, but I don't mind saying something and being wrong in his, but I do in others.'

Thus authority is an inescapable issue. But to say this does not mean that the nature of the tutor's authority is unalterable. The arbitrary nature of the group means that students will at first play, and expect the tutor to play, anticipated roles, unless and until the roles are challenged. This is the way relationships between tutor and students are almost bound to begin, but they can develop and change. Just because of the tutor's authority, the initiative for such change will almost always have to come from him.

Several kinds of role are open to the tutor, within these limits. For example, he can act as chairman, fixing and overseeing the agenda without directing it or himself making direct contributions. Other examples are discussed later (6.3). None remove the tutor's authority, but they can use it more flexibly and reasonably, within the constraints of what can and ought to be done.
Because a tutorial is an arbitrary and a have-to group, cohesion often
develops slowly and uncertainly. Without a prior commitment, there is some
uncertainty about what the group is going to do, and how it will do it. In
addition, the relative shortness and infrequency of tutorial meetings adds to the
uncertainty and makes cohesion more difficult, because students and tutor may
not get to know each other well enough.

More deeply, there may be uncertainty about what learning physics is to
mean in a tutorial context. It may look ad hoc:

'He said that if we had nothing to ask him, he had nothing to tell us. I
took that to mean we didn't have to come unless we asked something.
But then he ticked us off for not coming...He said, “Well, I have got to
fill these periods somehow, so you must all give a talk.”.'

Students may not expect the same things: some looking for help with
problems, others for personal guidance, and others for immediate contact with a
scientist. The tutor may have his own ideas, too. It is hard for a group to get
anywhere if its aims are unclear. Too many forces compel it in different
directions. Somehow, it has to work out what it is trying to do, if it is to
function effectively.

The tutor can try to impose his view of the purpose of the group.
Because of its nature, students are likely to acquiesce in, rather than to commit
themselves to, his purposes. More positively, the tutor's authority does at least
allow him to propose what should or could be done, and to bring into the open
unhelpful currents that may be running under the surface.

Nothing of what has been said here is ineluctable. Individual characters
can always make important differences. An individual can buck the trend, but
what has been described here is the kind of trend he is likely to find himself
bucking.

6.2 INDIVIDUALS IN GROUPS

'...I have a natter about the problem sheet...and somebody brings another
problem, and we sit around and discuss it for a while. And we realise, if
somebody has got a problem about that, that we didn't realise, that we
can unravel it between us. '

For this student, the tutorial proceeds comfortably along satisfactory
lines. Behind the scenes, it is very likely that the tutor contributed a good deal
to its success by how he

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acted. He may have made the students feel comfortable - how can one do this? He may have been good at guessing who to encourage - how can that be done? He may have been careful to impose himself at one time, and not at another - how does he decide? This section is concerned with a discussion of such matters.

6.2.1 ROOMS, TABLES AND CHAIRS

An observer might have made the following notes about the physical setting of a tutorial:

Held in tutor's study - rather small. 5 students present. Blackboard behind tutor's desk. Chairs stacked in a corner to save space. A chair behind the desk, and a large easy chair for visitors in front. Students arrive and place stacked chairs in a row in front of the desk. Tutor comes round desk, and gets them to put chairs in a semi-circle - rather cramped. Tutor left with easy chair. Room soon becomes hot. Tutor often uses the blackboard nobody else does. Students make notes on knee pads.

Points which emerge from such a description are:

choice of room: familiarity, size, comfort.
arrangement of chairs: who sits where.
writing: use of blackboard; making notes.

CHOICE OF ROOM: FAMILIARITY, SIZE, COMFORT

When one comes into an unfamiliar room, it takes a little time before one settles down in it, but when a room is regularly used for a certain job, it is easy to get down to the job without delay. So a regular meeting place has its importance.

If the meeting place is the tutor's study, it may have a welcoming and personal feeling. His books, his pictures, and the notes pinned to the wall all have his personal stamp on them, and make the room feel lived in. The tutor can feel secure too, with what he needs at hand.

On the other hand, the telephone is likely to ring, and people may drop in. A notice on the door can help the latter, but the former is harder to deal with.

Tutor's studies are often small, and a small room can get hot and stuffy, so that it is hard to
concentrate. In a cramped space it is not easy to make notes, or to relax and listen. In too large a room, though, it is easy to feel lost, and not at home.

It is not always easy to do anything about such matters, but where there is a choice, they deserve thought. It is all too easy to think of such things as facts of life, and to imagine that they cannot be as important as all that.

ARRANGEMENT OF CHAIRS: WHO SITS WHERE

A circle, semi-circle or square is often a good arrangement of chairs: because everyone can see the others, it is easy to address anyone else or hear them without straining or moving. A straight row of chairs is more awkward - and notice how one immediately assumes that the tutor will be sitting in front of the row.

Left to themselves, students will often arrange chairs according to habit or expectation. It is useful and thoughtful of the tutor to arrange the chairs beforehand for the first meeting, and at later meetings to encourage students to put them out in the same way, explaining why.

It is not usually an accident that the tutor tends to be left with the largest or most comfortable chair. There are advantages in having all the chairs alike, so that the tutor can more easily be flexible about whether he is the focus of attention or not at any moment, and can more easily encourage students to participate.

It may be worth noticing where particular students sit. Those who need reassurance may sit next to friends, while those who do not want to be involved often look for an out-of-the-way place, or one near the door. The following imaginary observer's notes suggest similar observations:

Four students, 3 men and a woman, sitting around a table in the tutor’s study. Short, fair man sits as always opposite tutor. He talks a lot, and emphasises points with gestures. Dark-haired man sits as usual next to the tutor. He is quiet, but makes rather penetrating points from time to time. He doesn't always respond when the tutor tries to bring him in. The other man seems to annoy the tutor: sometimes he says nothing, but fidgets restlessly; sometimes he keeps contradicting people over small things. The girl seems to listen, and often says things which add a bit to what someone else has said, or agrees with them, but she doesn't interrupt.

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The seating plan was:

Fair man <-> Other man
Girl <-> Dark-haired man
Power <-> Power
Safety <-> Safety
Tutor <-> Tutor

Sitting opposite the tutor can mean several things. It can be a place for the self-assured; for someone like the fair man who does not mind facing the tutor squarely, and has plenty to say. From this position also, he can easily catch the tutor's attention, which could be why he is able to be so talkative. It is harder for the tutor to notice when students sitting beside him might join in, and more of an effort to turn to them to bring them in.

Sitting beside the tutor offers more security. The dark-haired man may be shy, and only want to talk when he chooses. This can also be a place for someone who safely (instead of riskily) gets a position of importance by agreeing with the tutor, aligning himself with him. Yet again, a student who depends on the tutor and wants to talk only to him, may choose such a place.

Too much should not be made of such interpretations. People often sit in the same places out of comfortable habit. But noticing where people sit, including the place the tutor tends to find or be left, can tell one something about the roles students want to play, or want the tutor to play.

WRITING: USE OF BLACKBOARD; MAKING NOTES

In a science tutorial it is often necessary to write things down. A circle of chairs, especially low ones, is useful for a general group discussion, but awkward for writing.

A blackboard is often the answer. But people do tend to sit in rows facing a blackboard, and this makes discussion very difficult. If there are up to (say) four students, sitting at a table is often better. Writing can be done on sheets of paper, using felt pens, and turned or passed round so that everyone can see. For a larger group, the passing around of paper becomes absurd.

For a discussion, however, sitting around a table can be a good solution for a larger group. Students can make private notes easily, and books and papers can lie easily to hand.
A table also offers security: it can be leant on, and it both unifies the group while providing a safe barrier between people. If the tutor wants to leave the group for a short time, to give them time to think, he can easily and naturally do so, even just by edging away from the table a little. Withdrawing from a group sitting in a circle is clumsier and less natural.

When a blackboard is needed, either for the tutor or for a student to write on while addressing the group, a semi-circle facing the blackboard works well, as it also permits discussion. The best place for the tutor is usually at one end of the semicircle. From that place he can see people most easily, and does not divide the group, in two if he sits in the middle, or cutting out a few if he sits near one end. If he sits in the middle, he can also too easily become the main focus of attention. The end seat, however, is one from which the temptation to leap to the blackboard may need to be resisted.

Writing on the blackboard, and talking at the same time, is not an easy task for a student:

'... if you are writing on the blackboard so that everyone can see, you can't see all that you are writing yourself, and if you are trying to work things out at the same time, it doesn't work. So... I don't realise what I'm writing... and everything goes wrong - goes haywire ... It is as if you were facing an impossibility... he is asking you to do it on the blackboard so that others can see, but also so he can see how your mind is working.'

One useful way of getting students used to the situation is to ask one student to write what another is talking about. The responsibility is then shared, and the student talking can give his full attention to what he is saying. The situation can help students to listen carefully and communicate clearly, because mistakes or failures of communication show up readily.

6.2.2 TALKING WITHOUT WORDS

It was suggested in the previous section that the positions chosen by students have some relation to what kind of people they are, and to how they are feeling. Where a person sits, how he sits, and how he behaves, all say something about him.

What such actions mean is rarely completely clear. One tutor might notice a student looking glum and saying little, and guess that he might be upset, while another might make a quite
different guess, on the same evidence. A student who fidgets may be nervous, and one who never looks at anyone else may be shy and retiring. But single clues like this are not enough. The more one knows about a person, the better one's guesses are likely to be (husbands and wives, or close friends, can tell a lot at a glance). The less one knows the students, the more at a loss one is likely to be.

Particular actions are an essential part of communication. For example, looking directly at someone after asking a question, tells him that he is expected to reply. He finds it hard not to do so, and everyone else waits for him to speak. Similarly, deliberately looking around a group at each person in turn invites someone to reply. Looking at students like this can be used as a device to get them to talk, but of course it can be over-used. If it is, students will be found looking at the floor or out of the window whenever one asks a question!

OBSERVING ACTIONS

What can a tutor learn by noticing what students do?

One kind of action, and a powerful one, is silence. In the imaginary tutorial described above (section 6.2.1) one student fidgets, and is silent except to interrupt others.

He could be in an aggressive mood. Refusing to join in can be a safe but very effective form of aggressive action. Even supposing that this is the reason, the tutor needs to know more before he can guess whether the student is doing it because, for instance, he resents the tutorial as a waste of time, or perhaps because he feels that the tutor has been unkind or dismissive.

Equally, silence could indicate that the student is shy, or that he is hoping to avoid being asked things he cannot cope with. The same action can have many meanings.

The way a person sits says something, too. A person with something to say will often bring his chair forward a little, or lean forward. If he wants to make a point strongly, he will often lean forward towards the person he is addressing, and is more likely to use gestures. If others feel this to be too assertive, they can often be seen leaning backwards, or turning away. But people also lean backwards when they feel, or when they wish that they felt, confident.

Not only can the same action have many meanings, but also the same feeling can be
expressed in many ways. Of three students all of whom are interested in what is being said, one may look hard at the speaker, another may nod and smile, and a third may even look withdrawn if he is thinking hard about what is being said. How people show what they feel depends on what they are like, and again, knowledge is necessary for any good guess to be made about what is going on.

So, actions do speak loudly, but the code is hard to crack. What they say is often ambiguous, and is sometimes deliberately concealed. Even so, the habit of noticing how students are behaving, and speculating about what it might mean, is one worth cultivating.

A TUTOR’S ACTIONS

Students keep a careful eye on their tutors. Indeed, they have been watching teachers closely for a long time, and before that, their parents.

What they see tells them a good deal. It tells them how the tutor is likely to react, and what sort of things he expects. Doing this is a human necessity, so that one can anticipate what will happen and think about how to react. But it is not always reliable: people tend to label each other in a limited or stereotyped way. These labels can be unfair and powerful in their effect, and hard to alter. For example, one student said, possibly quite wrongly, of his tutor:

'I don't think this particular chap would be interested... all these dull students asking stupid questions....'

A tutor does have to think about what his actions seem to mean.

6.2.3 ENCOURAGING TALK AND DISCUSSION

'The more I thought, "I must say something, sometime", the more I didn't, and just closed up like a clam. I know once I was on the edge of being reduced to tears... I was so clamped up... he said something like, "Oh, rubbish"... I'd said something, and it was sat on. At first I was upset, and then afterwards I was angry... I think he ought to have realised that I was making a contribution.'

The example is an extreme one, but it does direct attention to the fact that students can find it hard to talk in a tutorial.

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One reason is that it is difficult to express, in newly learned special terms, new and difficult ideas. Another is that, by comparison with the tutor, the student is much less fluent and confident with the ideas, and so may not risk joining in. Both these matters are looked at in more detail in chapter 7.

TIME TO THINK

Every tutor knows the silence that so often follows a question. Evidence in chapter 7 and from similar work suggests that ten seconds, often less, is the longest time a student gets to answer, before the worrying silence makes the tutor feel compelled to rephrase the question. Silence is, however, a very reasonable response to many questions. One does need time to think, to work out what the question means, what lies behind it, and what would make an acceptable answer. All this can easily need more than a few seconds.

The fact that silence may be a good and a necessary thing does not make it any easier to cope with. It can be awkward, and it can be ambiguous, leaving one unsure whether the cause is in the question, in the need for thought, or perhaps in tiredness or loss of interest.

The problem, then, is to find relaxed and productive ways of using silence. One way is to ask each student to write down anything he can about the answer. This can remove the sense of unease (it is reasonable to be quiet while writing or while thinking what to write). It also involves every student, and bypasses a natural preoccupation with hoping that someone else will answer first.

Another way to help is to leave the students alone together for a short time. They can be left to work out a solution, to list difficulties, or to clarify what they want to know. They will often then talk more freely, and problems that they might not have raised, fearing them to be trivial, may well emerge.

KEEPING PEOPLE TALKING

How can one help students to talk, when they find it difficult? Everyone knows the answer: we talk freely to people who seem responsive and interested, and not to those who do not.

Any recording of a conversation reveals a quite remarkable amount of response by the listener, in the form of things like, 'Mm', 'Yes', 'Uh-huh', 'Ah', and so on. Indeed, nothing is more unsettling than talking to a totally silent person who stares at you with a fixed expression.
These sounds, and facial expressions too, tell the speaker of the hearer's interest and desire to hear more, and signal his understanding or acceptance. The hearer uses them to tell the speaker, and the speaker himself uses them to decide, whether to speed up or slow down; whether to fill in detail or to skip it; and whether to defend his views or to assume that they will pass.

The following extract from a tape-recorded tutorial shows some of these things at work:

T Could you - could you give any - sort of basic reason for your objection - why you think that couldn't happen, if you do think it couldn't happen, now?
S Well, just taking d.c.
T Mm
S to start with. If you double the current coming in here, you can double the current in both those (parallel arms of a circuit).
T Um - yes
S The ratio will - will stay constant
T Yes
S but - um - both the currents in - um - those two (pause) elements will be double.
T That's fine - that's right - yes
S So you think (pause) you know, if you take in a. c., as - er as the current increases - um - the current in both the two - er elements will increase (pause) the same. (long pause)
T Ah' (laughs gently)
S You know - the ratio will be the same.
T I think I would buy all that if we were only talking about resistances in parallel.

The 'ums' and 'ers' are irritating to read, but are here essential to the point. They reveal some of the difficulty the student has in keeping going, a striking example being the selection of the necessary general term 'element', before which he pauses noticeably on both occasions. Chapter 7 contains further examples of what can be learned from such hesitancy.

Notice how often the tutor intervenes, and that the interventions are positive, even though the student is in fact exposing an error in his thinking. Indeed, this shows that 'yes' does not here signal agreement, but rather, 'I get your point - go on'. Its opposite is not 'no', but things like 'eh?' or 'what?'

Another valuable device is the repetition of the last word or two, which is a remarkably effective encouragement to continue. It says, 'I'm listening - what comes next?'. If something has been said hesitantly, it can help to repeat it without the pauses and
changes of direction, saying also that the point is taken, accepted, or understood. And discussion can be helped along by saying that one is recapitulating so that the others can think about the point.

It is often tempting to go further, and to try helpfully to correct mistakes or fill in omissions. While this may be necessary, it has its dangers; used too often it may make students feel inadequate, when the deficiencies in what they say are exposed again and again as soon as they utter anything.

Similarly, feeding in further information may also be necessary, but can also be overdone. The tutor can see that it is needed, but only if the students can see how to use it will it usually help. Otherwise, it can easily create yet another silence. Perhaps Dr White, in chapter 2 (section 2.3) offers a case in point. He silences his group with some information about the implications for the tangential component of the field, which it seems they could not cope with.

Another problem is to decide whether a question would help things along. It may, but it is worth remembering that it may force the student into an answer which breaks his train of thought. The following recorded extract shows how powerful is the effect of interposing a question:

T ... does it matter which side of the filament you join your h. t. battery?
S Not really, but you're better off if you connect the negative end of that (points to circuit) to the positive terminal.
T (after a pause) Can you explain the argument as to why it is?
S Yes - it's the force on the electrons... (he continues)
T Yes, so what would you say about the energy of the electrons arriving at the anode, then?
S (pause) Well it's - they're not all the same, depending on where they come from.

The student gives a confident first answer, and the tutor, rather than saying 'Mm?', as if expecting more, asks if he can explain. So the student has to say 'Yes' (he can) before going on. Then the tutor asks another helping and prodding question, and the student starts with 'Well, it's', referring to the word 'energy' in the question, before returning to his own line of thought about the particles. One such case makes little difference, but it could be an unfortunate habit to develop, even admitting the times when there is need to check and correct.
6.3 ROLES AND PATTERNS OF GROUP BEHAVIOUR

This section concerns the way people work together in groups. It uses ideas introduced in section 6.1: that people play roles; that groups have both covert and overt mechanisms for controlling the people in them; and that groups differ in their behaviour according to their nature. These ideas are used to illustrate some of the problems and possibilities of the science tutorial group, and to offer a number of suggestions for tutors.

Thinking about a tutorial group involves thinking about the role played by the tutor. He has by no means a free choice of role, for several reasons. First, his position as a member of staff, and the things that are expected of a tutor, determine much of what he can be like. Second, even if he tries to alter his role, the group itself may, for good reasons or bad, limit or modify any change of role. Third, the particular students he has, their strengths and weaknesses, and the demands made by particular courses or tasks, make some courses of action more reasonable than others.

Finally, the tutor is himself. Playing a role is not a matter of acting, but of living a role, because each role involves accepting the values and feelings that go with it. One is better advised to play any role that comes naturally, than one which is calculated, but which one cannot live up to consistently. Students are more likely to respect and understand, even if they do not necessarily like, a tutor whose behaviour is at least consistent and in accord with his own personality.

6.3.1 MECHANISMS

Some aspects of the behaviour of a group, and the roles played in it, are decided openly; when things are negotiated, when people agree to co-operate, and when they get themselves organised. But much is also done covertly, often because what is unseen can be more powerful. Thus a group can exert pressure on someone to behave as it expects; people can collude with one another, as in avoiding a difficult topic; and they can develop a dependency on others which can inhibit discussion or criticism.

But again, these covert mechanisms are as often useful as dangerous. It may be entirely right for the students in a group to exert pressure on their tutor to, for example, deal with work for examinations when he fancies a free-ranging discussion, if that is what worries them.
Several such mechanisms of group interaction are discussed below. The covert ones are worth becoming aware of, because their power depends upon their being hidden. A tutor who sees what is going on below the surface, and brings it into the open, can thereby considerably weaken its force, and so open the way towards finding a more reasonable or effective way of working.

By contrast, the overt mechanisms, like negotiation, are often the stronger for being discussed openly. So again, moving towards a more satisfactory kind of group can be aided by using them in a direct way. Ways of encouraging them to function are therefore suggested.

In what follows, various of these mechanisms are discussed. Within them, the possible roles that tutors might adopt, and some of the difficulties of doing so, are indicated.

6.3.2 PRESSURE

There will be times when the tutor chooses to adopt the role of instructor: to give information that he considers necessary. Indeed, being able to choose more flexibly how to use one's authority does not necessarily mean using it less, but also means knowing and judging when to use it more.

Students' and colleagues' expectations may put pressure on the tutor to adopt such a role, or not to, and such pressure can be hard to resist.

What students expect may or may not be clear. Some will sometimes see their tutor as essentially present to solve set problems, or go over course work, and can force him into the role of instructor by only asking questions of this kind, or by staying silent until he - perhaps in desperation - starts to talk.

At times, such pressure is perfectly appropriate. The students may, for example, need to hear some ideas over again before they are ready to discuss them, or they may need immediate help with a worrying problem.

At other times, the tutor may try to play some other role, and be faced by contrary expectations. The student who said:

'Supervisions were depressing... they're supposed to be a great help, but they aren't really... If you asked a question you tended to let yourself into trouble.. .'
reveals what may have been pressure exerted both ways; on the tutor to deliver just one kind of help, and by the tutor to get them to contribute to something else.

However, some students may have totally different ideas about what the tutorial is for:

'I thought it would be like where you could sit down and have a cup of coffee... you could relax. O.K., you would have some work to do, but you would discuss what goes on... When he just comes in and spouts words, you lose interest.

Such expectations can demand of the tutor that he be a person of many skills: not only able to solve problems, but able to discuss general issues, able to help with personal problems, able to create interest, and so on, not to mention being able to provide liquid refreshment. The tutor may neither feel able or willing to meet all these expectations, but may find himself unhappy faced with students' pressure on him to do so, often exerted through not co-operating with what he does offer.

Pressure comes from outside too, from colleagues and from the organisation of teaching. If an examination requires extensive coverage of material, and if tutorial teaching is seen as complementing lectures in getting through it, the aims of the tutorial are implicitly settled in advance. The instructor role is expected, and the tutor will be largely obliged to adopt it.

Pressure is also exerted between students. For example, a student who cannot cope with a problem may well not mention the fact if he has reason to think that all the others can. As well as not liking to appear not to know something they all understand, they may show boredom or impatience if he asks. A little such treatment exerts strong pressure on him to keep quiet, so that that becomes the only way out.

Equally, one student amongst three or four others who want to talk about some difficulty which he finds trivial or boring, is not very likely to oppose the discussion. In general, it is easier to go along with what most others in the group want, even if it is not to one's own advantage, so as not to have them turn against one. Because important things can be left out in this way, a tutor may need to be on the look-out for it. Doing so is not easy, because it involves knowing a good deal about the individual students, and dealing with it involves using this knowledge so as tactfully to bring the excluded person into the discussion.
There are two kinds of reaction to pressure. One is to bring it into the open, asking why it is difficult to do what one wants to. This can sometimes be the only way to break a fixed pattern. The other is to use other overt mechanisms against it, for example proposing and negotiating what should be done.

6.3.3 DEPENDENCY

It is easy for students to come not just to accept the tutor as instructor, but to rely on it. Such dependency can lead to their not being critical, with things not understood not being questioned, and with things they need not being thought about- or asked for. Further, the reliable flow of information can become too comfortable and secure, so that the anxieties of working alone on problems can tend to be avoided. In the end, students can stop coming with their own problems, and come expecting the tutor to do all the work.

Another role the tutor can play is that of a model, himself exemplifying the standards of thought of his discipline, so that students can discover what it is like to think and talk like, for example, a physicist. This can be a good kind of dependency. On the other hand, the tutor's performance can be too brilliant, and so intimidating, with students feeling that ideas they have cannot match his standards. The need is to find ways of discussing ideas at a standard acceptable to the tutor and accessible to the students.

Similarly, students can come to depend on each other. They may tend to wait for the boldest to begin, so that he ends up laying down the line of discussion. Or one student may reliably always have something to bring up, leading the others not to bother.

Dependency is particularly difficult to detect, partly because it often exploits the things people are good at, and so is seen in a favourable light. One response to it is to deliberately spread and assign responsibilities. It may help, for example, to be systematic about going round the group asking for ideas or problems, so that everyone comes to know that their turn will arrive. The tutor may be able to reduce dependency on himself by explicitly indicating that he has said enough, and by inviting any other ideas, especially about what has been left out or was not clear. The tactic, mentioned before, of giving the group a job to do, and withdrawing, can also be useful.
6.3.4 COLLUSION

In a group, people often collude with one another to get what they want or to avoid what they do not want, as in this instance:

'... the tutor can't be expected to know everything. So it means harder work for us trying to find something for him to do in 50 minutes, to stop him setting us work that we don't want to do.'

It is not clear how the tutor was kept busy, but the students may have learned more about the art of making people do things than they did about physics. Not all the students in the group need have been so cynical, but even so, if they found tutorials of little value, or resented the lack of help, they may have colluded by not taking part.

Tutor and students can sometimes collude with one another. Suppose, for instance, that a particular course is well known not to be well taught. The students, feeling large areas of ignorance, but knowing them to be common, may avoid questions about it so as to keep off a topic on which they feel insecure. The tutor may be tempted to go along with this, and not ask about the course, perhaps because it would be awkward to have to handle criticisms of the teaching, or be forced to make them, or perhaps because he can anticipate the large amount of time it would take to do anything about it.

Collusion often works by making what ought to be questioned or thought about seem normal, ordinary, and safe. Thus it can be that the tutor is pushed into talking all the time, because he is then doing something familiar, and students treat it as such. When, in chapter 1, the tutor launches forth on the only topic he can find, and John takes out his pen, we have an example of it.

In a sense, of course, much collusion is both necessary and good; a group cannot forever be talking about why it is doing one thing rather than another. So where the group works together on physics, without question, or where one student helps another who is floundering, it would be absurd to be concerned. But where important things are being tacitly avoided, it may be necessary to ask why.

6.3.5 NEGOTIATION

Like the mechanisms described previously, negotiation in a group can be covert and
implicit. When looking around for an answer, the tutor may avoid looking at one student who is sure to know and at another who is sure to find it difficult, so as to get an answer from someone who he thinks ought to try. Again, a student who wants to make sure of getting his problem dealt with may arrive with papers and notes ready organised, to establish his priority. Many discussions come to an end when the contributions tail off, rather than through any open decision.

No group could work without a good deal of implicit negotiation of this kind. Indeed, because students in a tutorial group are often initially strangers to one another, a good deal of working out of who is who has to go on. The tutor, by being a little sharp with a brash or insistent person, or very patient with a quiet and unconfident one, communicates what sort of behaviour he hopes for. Students can sometimes be seen negotiating who will have the first try, or whether to press the tutor further, just by looking at each other.

On the other hand, there is an important part to be played by overt, explicit negotiation, from time to time.

One example would be when the tutor wished to adopt for a time the role of chairman of the group, with the group working together on a task, and with each student participating.

Here the tutor has to use his authority to take the initiative. Such a task-centred group cannot easily function unless jobs have been worked out and assigned to suitable people. A plan of work needs to be proposed, and to be discussed so that it is accepted. For instance, the tutor might be proposing that all students read a paper beforehand, and discuss it after a talk by one of them. Both the reasons for doing it, and the work required, need to be negotiated, taking account of other things they would like to do or have to do, otherwise, feeling it to have been imposed, the students are likely to do little of what is expected, or feel that the difficulties are unreasonable:

'He gets one person each week to talk... he gave us a list with references... I find this really annoying because some of the references you just don't understand at all... So you write it all up, and you stand there and read it all, and you really don't know what you're talking about, and the others don't understand. It's very infuriating. You feel you could do something much more useful.'

Of course, it is important to make sure that the right resources are available, even though it
is not possible to tell whether this student was exaggerating. The main trouble seems to be that he did not see the point of it, which could only be dealt with by discussing the matter.

This does not mean that students dictate the programme. Rather, they are asked to take responsibility for thinking about what they want. Indeed, often the tutor needs to be the one to inject a note of realism. Also he needs to be realistic about students' capabilities, not allowing them to take on things which would be too much for them.

On a larger scale, there is much to be said for negotiating the programme of tutorial work for a term, or a year (chapter 10 discusses strategies of different kinds).

On a small scale, it can help to have a short explicit discussion of the agenda for a tutorial, rather than starting on the first thing to come up. It may be no more than a matter of listing questions, or it may involve deciding what to give time to. The point of such negotiation is not just to clarify and organise work, but to give everyone a greater sense of responsibility for it. Here, as elsewhere, it is useful for the tutor to write down suggestions. This makes them less easy to forget, and it makes them public property so that people can refer to them and reconsider them. Further, asking for suggestions or ideas with a pen poised to write them down is an effective but reasonable way of putting pressure on to get them.

Roles, as well as activities, may need negotiating. It will not usually be enough for the tutor to announce, for example, that he will merely take the chair, and then- to wait for contributions:

'He sits there saying nothing, just observing, and you begin to feel a bit peculiar. You know he knows, and he knows that he knows, and it all seems a bit odd.'

The student here may be unjust, but may also have been unsure what was expected. The tutor had stepped out of his anticipated role, and it was not clear why. Possibly also he may have gone too far, not taking enough account of the limits on the roles he could adopt.

Nevertheless, the chairman's role, if understood, has its value. Students know that their views are not going to come under question from an authority, and this may make them readier to volunteer contributions. The role has to be played flexibly and tactfully, stepping out of it if needed, perhaps to deal with an argument that is going badly astray.

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6.3.6 CO-OPERATION

Much of learning at university is individual, requiring little co-operation. But working in a group requires at least some co-operation, and, if students are to take any large share in the work, may require a good deal.

People do have to learn how to co-operate. Because he can more easily see a task in perspective, the tutor can help by talking it through with students, suggesting what parts of it are more important than others, for example. He can ensure that work is fairly shared, and that standards are understood. Where students are presenting work, they can often be helped by a private meeting with the tutor beforehand. Confusions and omissions detected at this stage can increase the value of the work, and make students feel that the tutor is being co-operative rather than waiting for them to try and perhaps fail.

Some roles the tutor might adopt require co-operation from students (as well as requiring to be negotiated). One such is to play the role of consultant: that is, the tutor offers resources, but the students have to ask for them, and plan their own work. Clearly, the relationship on offer needs to be well defined. The students need to know what is permitted, and how and to what extent the tutor will control things. Equally, what roles they are to play need negotiating. There may be need for a chairman, for someone to look after books and papers, or for someone to keep notes of difficulties. Where such jobs are unfamiliar they need to be very clearly explained, and they demand a good deal of co-operation. The art of running such groups, which increase in value with the maturity of students and at the same time encourage it, is to ensure that they work while not appearing to direct them.

No less difficult, and needing a different kind of co-operation, is to play the devil's advocate: that is, to take on whatever is offered, and provide objections and counter-arguments. There is obvious value in playing such a role on occasion, because of the stimulus to thought that it can offer. But it requires not only that students feel they want to co-operate and argue back, in a friendly atmosphere, but also great skill. Not least of its difficulties is the great temptation to show off too much.

On a more everyday level, co-operation is needed for a tutorial group to function at all. The most important factor is probably commitment, which has in the science tutorial to be
developed over a period of time. The tutor’s own concern for students is
important here, revealed as it is in many ways; in the effort he puts in; in the
way he talks to students about their work; in his enthusiasm for what they are
doing; in his willingness to talk about his own work and ideas; and so on. All
these communicate the extent to which he cares:

"... people who can inspire enthusiasm in somebody and in work... You
got feedback from him about what you were doing. He was always there
to encourage you, or to tell you when you were out of line... ."

6.3.7 ORGANISATION

Every group needs some organisation, which has to be reasonably clear. This is
especially the case when co-operative work is needed. Here the tutor may need
to exercise his authority rather more, as opposed to rather less, giving a clear
lead in the organisation and planning of work.

Where activities are new or unfamiliar, clear organisation is important. Many such matters are second nature to a tutor, and seem so obvious that they are overlooked. It is easy to forget that a student may not know how to use the library, finding references or looking for an explanation of a point. The tutor may be able to help with the organisation of work; with advice about books; with problems of writing essays and reports; and so on. It is often hard to appreciate just what advice students need, and to give realistic advice. It can be hard to gauge what is required:

'The tutor said, "You must all give a talk. Don't spend more than an hour
preparing it. " So I got hold of something I was interested in... I spent 22
hours on it, I should think... Then at the end he chewed me up... I
complained that I had spent longer than he'd suggested, and he said, "Oh
well, that was just meant to be a guide. You are meant to get interested
and spend longer".'

The tutor needs to organise more mundane matters too. For instance,
getting to know the names of students in a group of more than two or three
takes effort and planning. It is useful to write down names at the first meeting,
and to use the list openly to address students by name. There need be no
embarrassment in doing so; students are likely to value
the effort that is being made. It is also necessary to decide, and perhaps discuss, forms of address. Informality can be aided by using first names, but others will prefer more formal modes, and accept the distance this can introduce.

Time is one of the harder things to organise, in a group discussion. All too often, time runs out and things get left undone, or there is time to spare which has hurriedly to be filled. While arrangements need to be flexible, it may be useful to discuss briefly how long to spend on an item, at least so as to establish its priority.

Perhaps more important than organisation itself is that the tutor appears confident, having a sure touch, and knowing what he is about. There will be times when he feels no such thing, but even then a confident air can sometimes breed the real thing.

6.4 MANAGING PEOPLE

This chapter has been about managing people. In a sense, there is something distasteful about putting it in that way, as if it were a matter of manipulation. On the other hand, there is no escape from the question; as a tutor one is not just doing one's subject, one is necessarily getting along with a group of students, whether well or badly.

However, this chapter is not a collection of techniques for dealing with students. Rather, it has tried to expose the nature of the important issues, to suggest alternative ways of looking at them, and to offer some practical advice on the consequences of various courses of action.

People are complicated, and there are no simple recipes for dealing with them. Even if there were, people are awkward enough to react badly to being manipulated. In the end then, what matters is knowing enough about the students one has to work with to understand them and to be able to treat them reasonably, and to be aware of enough of what is going on between them to provide what is needed and avoid the obvious difficulties.

What the tutor is himself like will decide much of what can or does happen, and nothing in this chapter should be taken as encouraging a tutor to be anything but himself. Indeed, everything of value that people do together is founded on respect, and mutual respect cannot exist without self-respect.

\begin{center}
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\end{center}
7. Talking physics

TWO CHAPTERS ABOUT LANGUAGE

This chapter and the next are about the language of tutorial teaching. Sections 7.1 and 7.2 first illustrate the ideas with material from tape recorded tutorials, and then discuss the background theory. Following sections then each focus on one of a number of particular issues.

Section 7.3 looks at differences between the way tutors and students talk, so as to help understand some of the problems of tutorial discussion.

Section 7.4 examines one particular tutorial, and tries to trace the growth of understanding through discussion. Thus it concerns the relation of language and ideas.

Section 7.5 is about written, not spoken language. It looks at ways in which scientific text books may be hard to follow, which are relevant to a tutor trying to help students to learn from books.

Chapter 8 is devoted to a discussion and analysis of one major tutorial activity: asking students questions.

7.1 NOT WAVING BUT DROWNING

The tutor often finds himself carried along, like a swimmer in a breaking wave, on a flow of language it is hard to understand or control. He has little time to reflect, and can find it hard to make sense of what is going on. Observation of the language of tutorials soon reveals a number of characteristic phenomena.

For example, tutors talk most of the time, and students talk rather little. A page of transcript of a physics tutorial taken at random has as speakers, in turn:

Tutor, student, tutor, student, tutor, student, tutor, student, tutor, student, student, tutor, student, tutor, student, student, tutor, student, tutor, student, tutor.
Only twice do students speak without an intervention from the tutor. The tutor speaks nine times, saying 145 words, while the three students who speak share ten utterances, and between them say 152 words. It is hard to find cases where students talk more, and easy to find ones where they talk less. (On the next page of this transcript the tutor says five times as many words as all the students.) Why does this happen and does it matter?

Again, the pause left for an answer to a question is often very short. The following is typical:

T  What is taken as the energy and momentum of the photon? (two second pause)
T  What's that? (points to blackboard - four second pause)
S  \( \hbar \) over...
S2 \( \hbar \) over \( \lambda \)

Such pauses average perhaps five seconds, and rarely exceed ten, before the tutor feels compelled to rephrase or redirect the question. What makes it so? Would more time help?

Another notable phenomenon concerns the nature of replies:

T  I hope one could quote evidence for a photon having a wave nature and a particle nature. What would you quote for wave nature?
S  Interference?
T  Interference - that's the normal one. And particle nature?
S  (very quietly) Interaction
T  In which form? That's a general.....
S  Absorption
S  Photo-emission
T  Yes. Now, what's the reverse of photo-emission, photo-electric effect? (seven second pause, then tutor explains)

Students' replies are often brief, sometimes just one word. They are also commonly questions, either in the form, 'Is it... ?', or a single word said in a questioning tone, as above. What does this mean? Why are elaborated answers rare?

The questions in these examples also have a common form. Many are 'What is...?' questions; that is, they invite a single expected response. For instance:

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What would be the difference between.....?

or,

What is the mass, roughly, of an alpha particle and an electron?

Like them are 'Is it . . .?' questions, asking for yes or no as a reply:

Is it a quantum phenomenon?

or,

Is it plus or minus?

It is easy to see why such questions arise in science more often than they might in, say, literary studies. But why are they so common, and do they have effects on the discussion of which they are part?

Yet another feature, well known to any tutor, is the difficulty of understanding students' questions. For instance:

Isn't this just like having one energy level (pause) over the other - as a - to compare the difference - different numbers?

or,

I've never understood how that - how that point - you know (indicates a node on a standing wave)

How that point never moves

No, how energy is transferred across that point. It's still baffling even though initially - all right? - you said that a wave going that way and a wave going back. But once superposition occurs, how does it keep going?

Such exchanges are frustratingly frequent. Will laziness or lack of competence serve as sufficient explanation? What do they force tutors into? Are there ways out?

Equally, students may wish that what they are asking could be better understood:

'Whenever I ask him a question, he always likes to answer a question slightly different to the one that I ask - and I never really seem to get to grips with it ...he always seems to go two steps ahead, and seems to think that I know as well - when really I am still at base one, so to speak.'

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7.2 LOOKING AT LANGUAGE

It is not obvious that there is any merit in looking at the language of teaching, nor what 'looking at the language' would be. The present study began from a problem which is well illustrated by the episodes reported in chapters 1 to 4: that in any tutorial a confusing number of different things are all going on at the same time. We found that a number of points of view were needed, and that looking at the language was one useful one.

The aim of the study was not to do linguistics; it was to help tutors (including ourselves). This help can be at several levels. First, just by freezing the speech on the page, it is possible to pay attention to things that otherwise go past too fast to be thought about. These include such things as silences and their causes, the coherence of discussion, and the ways in which questions are posed and answered.

Second, it is possible to offer some useful terms with which to discuss and think about small group teaching. Such terms and ideas may usefully widen the range of things it is possible to think about concerning tutorial teaching.

Third, it seemed important to understand more; to try to get some insight into how the language of tutorial teaching works, and why the talk turns out as it does. This has inevitably been the hardest part of the job, and one as yet only at a primitive stage.

The reason why language offers a valuable, non-trivial framework for thinking about teaching is that this framework is at once sufficiently detailed and sufficiently general. It becomes possible to say things about particular events - a mistake in an argument or a question which did not work as intended and yet still relate these things to the whole form of the tutorial, and the way in which it developed.

Nevertheless, the study has considerable limitations. The data is restricted: transcriptions of 15 tutorials given by 9 tutors, all but three being with first year students. The discussion and analysis deliberately says something about many issues, rather than a great deal about one or two, just because the practical problem is to deal with all issues at once as they arise. Where the ideas offered have any novelty, they are also very tentative.

Clearly, the whole enterprise depended on taking over many ideas from previous work, notably that which deals with language as communication and personal interaction.
A brief, non-technical outline of these ideas is offered below. Some readers may prefer to return to them later, going first to sections from 7.3 onwards, which deal with particular problems. The ideas do, however, inform much of what follows.

7.2.1 IDEAS ABOUT LANGUAGE

The ideas about language used here are rather general, deriving from the linguist Halliday and his school. Firstly, Halliday suggests looking at three different kinds of job* that language is used to do:

- using language to say something; to convey a content.
- using language to affect others; to do something.
- using language to create structures; to make talk or writing hang together into something coherent.

Any actual use of language involves doing all three kinds of job at the same time, not one by one. An example may help:

(The tutor had asked about a problem in which students had wrongly supposed that a force was constant.)
S1   Force is variable
S2   plus the force is.....
T   (interrupts) That's - that’s the thing I was trying to get

The tutor is saying something: that the student has made the point he wanted. But he is also doing several things: interrupting; giving the verbal equivalent of a red tick in a book; and closing off a series of previous suggestions, so also taking back the initiative, intentionally or not. What he says also fits into connected exchanges: it contains a pointer to the last remark but one ('that's') and an implicit reference to what is being talked about ('the thing').

Secondly, there is what determines the form or style of language used in various situations. The contrast of previous spoken material with the surrounding written text will surely have struck the reader. It is also plain that the words quoted above are not from a tutorial in history, and that they are not from a lecture on variable forces.

* Halliday uses the terms ideational, interpersonal, and textual function. See the references and commentary at the end of chapter 8.
Linguists suggest that such differences can be understood by looking at three aspects of the situation* which parallel the three jobs above:

- what it is about (here physics, not history).
- what roles people are playing (here tutor and students)
- what kind of communication is used (here face to face talk)

That is to say, features of these three kinds describe the situation, in so far as it affects the language used. A book for children differs from a physics tutorial in all three ways, a conversation about a film differs from it in two ways, and a tutorial in history is different in only one respect.

Thirdly, the whole point of using language is to convey meanings. Some effective way of representing meanings is crucial.

Meaning cannot usefully be thought of as 'contained in' words, like water in a bucket. There are well known philosophical, psychological, and linguistic difficulties with that idea. Rather, meaning has to do with making one choice rather than another, from a range of possible choices; with having said this, rather than that. For example, beginning a letter with 'Dear Dr Smith' does not convey the same as beginning with 'Dear Smith' or 'Dear Jim', and some choices such as 'Dear Dr Jim' are not admissible at all, meaning nothing. The meaning is understood by seeing what is written as one particular selection from what could have been selected.

Thus to represent a meaning is to show what choice has been made, and what choices could have been made. This is conveniently done using systemic networks. Such networks are used in section 7.4, to handle developing ideas in physics, and in chapter 8, to distinguish different sorts of question. They are introduced briefly below, through an example.

The example is purely an illustration of the idea and the notation. It comes from dynamics, not from linguistics. A dynamical argument can belong either to classical or to quantum dynamics. Such an exclusive choice is represented by a vertical bar, to be read, 'if dynamics, then classical or quantum':

\[
\text{dynamics} \quad \bigg\vert \quad \text{classical} \quad \text{quantum}
\]

*Linguists' terms are: register (the form); varying in field (the subject), tenor (roles), and mode (means of communication).
There can be any number of options.

However, independently of this choice, another can be made between relativistic and non-relativistic dynamics. Such combining options are represented by a bracket:

\[
\begin{aligned}
\text{classical} & \quad \text{quantum} \\
\text{dynamics} & \quad \text{relativistic} \\
& \quad \text{non-relativistic}
\end{aligned}
\]

Newtonian dynamics has two of these features, classical and non-relativistic. A left-facing bracket represents the necessary presence of two or more previous selections:

\[
\begin{aligned}
\text{relativistic} & \quad \text{non-relativistic} \\
& \quad \text{Newtonian}
\end{aligned}
\]

In fact, all four possible pairs of options combine, distinguishing four main kinds of dynamical argument:

The notation, with some minor additions, is summarised at the end of chapter 8, together with references for any who wish to pursue the ideas further.

In addition to these very general ideas about language, some have been taken from other studies of language in teaching, mostly in schools. Several things noted previously
have also been observed in work of this kind, notably the frequent intervention by the teacher, the way students address him and not each other, the use of questions with a known answer, and the short time allowed for an answer.

Readers interested in such work will find a good account of it, and a critical bibliography, given by Sinclair and Coulthard (see references at the end of chapter 8).

7.3 TUTOR-TALK AND STUDENT-TALK

This section attempts to describe differences between the ways tutors and students talk in small group teaching, suggesting reasons for them, and consequences they may have for such work. The discussion will look at the following two samples from different tutorials:

SAMPLE 1

S ...I mean, it'll damp, it must damp eventually...certainly it'll then right?
  - in order to keep it going - right? - in this case (pause) er - er - we've got say a closed or open pipe - you blow at one end, right?
  and - but down the other end things are still happening -you know it has an effect on (pause) what's happening down the other end as well (pause) I can't explain myself, but - er

Later, this student's tutor says:

T But this one here - I mean - the answer (light laugh), the answer is that it just bounces forward - bounce - If you like, the energy bounces backwards and forwards from the end.(pause) If you were to send a wave disturbance against the end - if it's in sound waves - the wave would get - compress all the molecules against this rigid wall, and the - those molecules are compressed up like a spring, so they start to come back again, and that would set the wave going back - and that would go along, you know, until it compresses against that wall there, and it would come back again.

SAMPLE 2

S What about if you're taking a (pause) How can I put this? If you've got this - um (pause) These are the ions, as you put it, (pause) and these

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electrons are moving about - moving about - because there's a measure of the energy up here (points to sketch) - and say yes - and you have these electrons being conducted along or moving about, as you said before, one electron can be here (marks sketch) and this - this is the glue, in other words.

T   Right
S   Now there must be energy levels within the glue
T   Yes
S   Yes? So, if you - if you're taking that small band here (indicates range $dE$) - limiting the energy level to a very small band - then you can consider electrons in here (pause) I'm not quite with this....

Later, this student's tutor said:

T   ...you're talking simultaneously of energy and energy levels. Now (pause) if you said (pause) that in this- in any particular system - let's not take anything real, because it's difficult, but something imaginary - if there were four possible energies - four energy levels then it would certainly be reasonable to say that there are a million in the bottom, a hundred thousand in that one, and ten thousand in that one, and a thousand in that one. You could say how many particles were in each state each particular, definite, possible energy.
S   Oh, this is what confuses me.
T   Then that you could say. And one of the advantages of quantum mechanics is that energies are definite and divided from one another, and you can count. Now the difficulty comes in bridging the gap between that, and the way we usually talk, in which energy is (pause) more or less thought of as continuous.

The two stretches of talk by students are amongst the longest recorded. Both tutors continued beyond the part quoted for at least as long again. Clearly students find it hard to talk at length, and tutors do not. What else can usefully be said about the differences?

7.3.1 THE NATURE OF SPEECH

It is common to find speech thought of as a sloppy version of 'correct' language, with writing seen as the model. On the contrary, speech is a good deal more flexible and subtle than writing: it takes a very good writer to convey what anyone can say in conversation.

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Speech has all the resources of intonation, emphasis, pausing, and repetition, as well as gestures and looks. This is not to say that writing is inferior; the two are different. One important difference is that speech is planned and constructed as it is delivered, and this planning takes account of the live reactions of the hearer and of the speaker.

Speech contains traces of this planning, and from them can be learned something about the speaker. Look, for example, at where the pauses and changes of direction appear in the student speech in the first sample. The chunks of internally cohesive speech between breaks are quite short:

'we've got say a closed or open pipe'
'down the other end things are still happening'

In between them there are pauses, and fillers like 'er' and 'you know'. The chunks are juxtaposed, rather than forming elements of a larger structure. The second sample is much the same, and neither is untypical.

7.3.2 PLANNING AND THINKING

Compare the samples of tutor-talk with student-talk. They too begin with similar short chunks:

'but this one here'
'the answer is that it just bounces forward'

But, immediately after, there is a much longer stretch which hangs together as a whole.

When did these tutors plan this organised speech? It is not likely to be an accident that at first both pause a good deal: they are probably busy thinking ahead. The thinking period lasts perhaps ten seconds - a time longer than students sometimes get to answer a question.

There is reason to think that the students are also thinking. Each fresh start means that what has been said has been considered and rejected or modified. Where the two tutors soon build a plan of what to say, the two students go on struggling. When the second says:

'- and say - yes - and you have these electrons being conducted along or moving about'

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he can almost be heard fitting ideas together. It may be no accident that speech of this kind rarely lasts long, and that both examples end with 'giving up' moves. It is hard work.

7.3.3 AUTHORITY, FLUENCY, AND KNOWLEDGE

It is notable that both students keep checks on what they are saying ('right?', 'yes?'). They are having to think, not just about the subject, but also about the correctness, relevance, and relationship of their thoughts about the subject. And both use the tutor as a reference point, as the implied standard of correctness or adequacy.

The tutors, by contrast, refer for correctness to ideas in their own heads; to some part of physics, not to a person. When the second tutor says:

'and one of the advantages of quantum mechanics'

he not only refers directly to the subject, but the feature of it which he then mentions (discrete levels) is revealed to be what has lain behind the whole plan of his previous remarks.

The way the second student uses things like:

'as you put it'

further illustrates how both speak as if expecting to be stopped if they are wrong; a feature absent from the way the tutors talk. The relationship of the speech to the pattern of authority is clear'

There is another facet of authority worth mentioning. The tutors' speech is notably more fluent, is longer, and is more complex in structure. This makes them difficult people to interrupt; because few chances are offered; because someone working out a train of thought tends to ignore interruptions; and because a fluent speaker comes to occupy a higher place in the discussion pecking order (others do not risk exposing themselves to the comparison). Furthermore, such a speaker sets a fast pace, and the further ahead he has thought, the more anxious he is to get there. The listener cannot have the speaker's plan in his mind, and if the pace is high, has to think hard to get the drift.

Here, if the diagnosis is correct, there is a remedy. The tutor can try hard to talk more slowly, and can try to offer an explicit plan of what he is saying, as well as saying it. The tutor's fluency and command of ideas is still important: how could a student learn to talk more expertly except by talking with an expert?

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It is worth looking at how expertise, or the lack of it, shows. When the first student says:

'a closed or open pipe'

he says it simply in passing, having such a thing as available for thought as things like temperature or time. Other things are clearly not so available, and are produced hesitantly. Lack of expertness also shows up in saying things wrongly, as when the second student says:

'limiting the energy level to a very small band'

which was what led to the whole discussion of discrete levels. This means that encouraging students to talk is doubly important: both to give practice in thinking and to reveal where ideas are not yet clear. Some ways of encouraging talk were discussed in chapter 6.

7.4 WHAT DO YOU MEAN?

This section develops further the idea suggested at the end of the last: that areas of misunderstanding can be revealed by the way students talk. It looks at the way discussion can explore misunderstandings, and develop understanding.

The problem is that of giving a clear account of confusion. It is easy to look at partial understanding as the absence of parts of a full understanding. But partial understanding is more complicated than that. It may involve wrong connections between correct ideas, correct ideas used in the wrong way, and so on.

An attempt is made to trace the growth of ideas in a discussion. From what students say, patterns which try to capture how they are thinking are proposed. For this purpose, the network notation introduced in section 7.2 (and summarised at the end of chapter 8) is used. That is, students' knowledge is represented as the set of meanings they can control and use.

7.4.1 EXPLORING MEANING IN A TUTORIAL

The examples which follow all come from one tutorial, which was concerned with

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difficulties of three first year students in understanding resonant circuits. One student began by asking:

S1 Can you represent (pause) the impedances on the vector diagram? (pause) Because I don't think you can. You see there's a series circuit here - an a.c. series circuit... We are trying to find - it says calculate the value of the impedances of the separate components at the resonant frequency, and represent your answers by a diagram showing the three separate impedances as vectors in the complex plane. Well, the point is, I think here you work out the (pause) impedances for each one

T yes

S1 and you do a simple algebraic expression for them. You just add them together algebraically. What is the point of using a vector diagram since there are no phase lags or leads involved? (pause) Now I thought here - it can't be right - there is another question here, where it seems you have got to work out the angle as well - so it must be a vector diagram in some respect. But I don't see how.

Notice the pauses before the term 'impedance'. Such pauses often indicate difficulty in selecting what follows, and it does turn out that this student has not yet got impedance built into a firm structure of meanings.

The tutor invited him to say more:

S1 ...we need vector diagrams for voltage and current, because one leads or lags depending on whether it's an inductor or capacitor. Right? Now - you have phase angles and the best way to represent these is on the vector diagram... But here, the impedances - they don't - they aren't at (pause) right angles or lead or lag on each other. I would have thought this was just a simple algebraic (pause) equation.

It appears that for this student impedance is a name used for resistance in a.c. circuits, and that ideas about vector addition are disconnected from it. Perhaps the following network catches something of this split:

![Diagram]

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The broken line means that resistance is the normal choice, with impedance being chosen only when the feature a.c., marked with a * is selected. It may be useful to speculate that new meanings are often added in this way, as when students treat relativistic equations as true only at very large velocities.

The network shows vectors as relevant only to current or voltage in a.c. circuits, and not as connected with impedance.

It is interesting that the student uses the form of another set question to infer that it allows something that his pattern of ideas does not, and tries to fit the two together. Note that he cannot simply add new connections to his own ideas: in terms of his present system the new one just makes no sense. Here is a crucial problem in understanding. What to the student makes no sense, is what to the expert is the only thing that does make sense. It is not that the student has only something fuzzy in mind, but that he has a quite definite system of interlinked discriminations which happen to differ from the expert's. A new discrimination sometimes will simply not fit in at all, without extensive repair work elsewhere.

Some later remarks lend support to this view:

S1 ...here you are using vector addition of two resistances (pause) there equivalent to resistance - to impedance -

The failure to handle vector/scalar and resistance/impedance in combination is rather clear. A second student reveals a further, related difficulty:

S2 Current and voltage are vector quantities - can be represented by vectors...because they've got direc impedance is just a scalar, isn't it?

Not surprisingly, the tutor says, 'Oh dear!'.

The tutor then spent some time getting a student to talk through how he thought about the currents in a parallel circuit, finding that he thought that, as in d.c., only the magnitudes of the currents mattered. The dialogue appears in chapter 6, in section 6.2.3, as an example of encouraging students to talk. It is worth noting how little the tutor can find out about these sorts of difficulties, unless he can get them talking.

By now, the tutor has seen that what is at issue is building up a complex set of distinctions and connections between ideas used in d.c. and a.c. circuits. Part of the discussion shows this being done:

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S1 It's because you're always trying to go back to d.c....
T Yes
S1 And when you do that, then it's hard to visualise it changing.....
T Yes... the other feature of d.c. parallel circuits is that you talk
about the
common voltage, and have to work out the distribution of currents.
S1 Yes
T And that you still have to do in a.c...So that part of the argument
still carries through
S1 The only difference...being one sort of (pause) cancels the other.
T Yes
S1 Whereas in the other you've got them all adding up.
T All adding up. They can cancel or add, or do a bit of both, in the
a.c. case.

Notice how the student joins in and practices making sense. Perhaps the
meaning system they are building looks something like this:

That is, the nature (complex or not) of quantities, and some names,
depend on the choice of a.c or d.c. What quantities are combined depends only
on the choice of series or parallel.

It is pleasing to see a student later testing this system:

S3 Is there any situation where you've got more than one of them -
the p.d. or current - being constant?
T Well, I'll make one up shall I? If you ask for trouble you get it.

It is plain that this analysis is a tentative shot in the dark, and that no tutor could
do more than guess at the problems while working with students. But what this
tutor did do was to
make it clear that he wanted to know what they thought, persistently getting them to talk around their ideas, rather than himself jumping to conclusions, as witnessed by things he said like:

'Now can you go back and decide.....?'

'So what you are saying, if I could restate it...'

'I would like to just explore Frank's argument, which went.....'

and, of course,

'What do you mean... ?'

7.5 UNDERSTANDING 'SCIENTISH'

Talking science is not easy, but neither is reading it. This section looks at some of the problems of reading scientific writing. Tutors do have to deal with problems students have in reading books; indeed some of the material for tutors introduced in chapter 10 is addressed to this question. Further, the contrasts between spoken and written may give additional insight into both.

The examples given are not identified. What is important about them is that they are normal and typical. All come from reputable university text books.

7.5.1 WHAT IS 'SCIENTISH' LIKE?

Here is a sentence from a text book:

'Let a positively charged particle of unknown \( \frac{q}{m} \) enter the region between P and P' in fig.2-10(b) with an unknown velocity \( V_x \) along the x-axis.'

It is in a sufficiently specialised variety of English to be called 'Scientish', and it illustrates a number of features often found in this sort of prose.

One such feature is the special use of 'let', to propose a situation for discussion; another use being to assign quantities, as in, 'let v be the velocity...'. More generally, this is an example of the frequent use of the terms of formal argument; writers of Scientish freely 'let', 'assume', 'define', 'derive', 'consider', 'imply', 'compare', and so on.

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An expression like 'of unknown $q/m$ ' has a complex function, meaning something like, 'whose charge to mass ratio, which will shortly be referred to again, probably in an equation so represented symbolically, has a certain value which for the moment we will not, or can not, give numerically'. Note how it is implicit that the writer has selected the right thing for attention - there is no room for the reader to ask why or to whom $q/m$ is unknown.

Much is assumed about the reader's knowledge. Thus, 'with an unknown velocity $V_X$, along the x-axis' assumes ideas about notation, coordinate axes, and vectors. Information is given in diagrams, which function as part of the text, so that what P and P’ are is not even mentioned (nor does the diagram say in fact that they are at once pole-pieces and plates).

Scienthish treats abstract quantities as real objects. In the example, the particle is a mere carrier of the properties $q/m$ and $V_X$.

All this may seem an unwiedy mountain of interpretation to pile on one short sentence. Is there really such a problem? In one sense, there is not: such a sentence is in no way unusual, nor are its difficulties especially formidable. But grasping it quickly and smoothly does involve a good deal; more than might be supposed. A physicist reads it with ease, but a ten-year old makes nothing of it at all. Between the two, there is much learning to be done.

7.5.2 TECHNICAL LANGUAGE AND CODED INFORMATION

Varieties of language differ according to the kind of thing they have to say (see section 7.2). It is the use of technical terms, mathematics, graphs, tables, and diagrams that first strike one in looking at scientific writing. Chapter 9 offers some ideas which may help with this aspect.

Technical terms are necessary. But where they are used on a par with non-technical terms, the inexpert reader feels excluded. For example, the present reader will doubtless feel more excluded by:

'\text{The phonologically component of a grammar converts surface structure into a phonetic representation.}'

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than he will by:

'Sounds carry meanings according to definite rules.'

Worse, he will probably misconstrue the word 'grammar', assuming that it means what it meant at school, when it does not. Such terms abound in scientific texts ('power', 'active', 'linear', for example). English permits such terms to be stacked up, giving things like:

'isotropic linear homogeneous dielectric' or

'one-dimensional infinite-walled potential well'.

It is striking how often students stumble over technical terms in discussion. A good deal of practice is needed to find out how a term can and cannot be used.

Scientific texts talk through equations and diagrams as well as through terms. To the scientist, an equation can almost talk, but to the student it may look like a meaningless jumble, or - worse - a familiar but ill-understood pattern. The problem is the very virtue of mathematics: its extreme economy. So there is much to be said for talking about what equations mean. When one tries, it is surprising how much there is to say. Similarly, graphs, tables and diagrams are densely packed with information, and often bear talking through.

7.5.3 REDUNDANCY

In speaking, but not in writing, things are repeated or said in more than one way. Written scientific text is particularly lacking in redundancy. For example:

'If a vertical line is drawn at some arbitrary chosen pressure, it will intersect the isenthalpic curves at a number of points at which µ may be obtained by measuring the slopes of the isenthalps at these points.'

A lecturer might begin to make the same point by saying:

'Looking at this diagram - the one of temperature and pressure - and at the curves of constant enthalpy - enthalpy $H$ or $U + PV$ right? - we could ask what happens at constant pressure - at every state up a line like this - running vertically at this constant pressure....'

He would have covered the first clause, in about three times as many words, giving explicit
Much of what scientific writing loads on the reader in this way is formal or abstract in character, requiring understanding of formal moves like, 'at some arbitrary chosen pressure'.

A non-redundant text suits the expert well enough. It in one way suits the student by being brief; he has in all conscience plenty to read. But it nevertheless does make considerable demands on him.

7.5.4 TAKEN FOR GRANTED

Varieties of language differ in what is assumed about the people involved. Consider the following pair of extracts:

'Dimensionless numbers are especially interesting. They stimulate thinking.'

'If we divide $e^2$ by $c$ we have the dimensionless quantity or $\alpha = 1 \over 137.04$.'

The second, by using the term 'dimensionless quantity' in the flow of the phrase, takes it for granted that the reader knows what such a thing is, and why it might be of interest. The first does not. As it happens, both extracts are from the same text, and the first comes one short paragraph before the second. Readers of Scientish have to cotton-on quickly.

In Scientish, it is also taken for granted that highly generalised situations are normal:

'...suppose there is a cavity in the conductor. A Gaussian surface which does not enclose the cavity can still be shrunk to zero, but......'

Interestingly, it is the actual and concrete which is treated as unusual:

'In 1725 James Bradley started an interesting series of precise observations of an apparent seasonal change in the positions of stars, in particular of a star called $\gamma$-Draconis.'

Scientish, then, treats of an idealised, generalised world inhabited by 'particles', 'masses', or 'conductors', not by bricks, cars, or tin cans. Many of its objects are abstract.
classes of idealised object: harmonic oscillators, pure inductances, and so on. As noted before, the drama they play out is a logical one.

7.5.5 THE WRITER IS ALWAYS RIGHT

The writer of Scientish adopts particular roles. Compare these two passages:

'In what follows, I want to present the thinking and indicate the facts that have led me along the present path, in the hope that the point of view associated with these ideas may prove useful to some other researchers...'

'Einstein postulated that a beam of light consisted of small bundles of energy which are now called light quanta or photons... When a photon collides with an electron... it may transfer its energy to the electron.'

The first is from a translation of the paper in which Einstein proposed the quantisation of radiation. The second is how the first appears in a textbook. To begin with, the textbook does reflect, though palely, the tentativeness of the first, but the tone is soon more assertive. After the initial sentence, nothing suggests any doubt as to the existence of things like photons.

In the first, the reader is invited to join in the argument. The second leads him along a pre-determined path. Remarks like, '...as we saw in section 4.4...', are common. The nature of writing forces such devices on the writer, but the well-structured and unarguable content of Scientish can make them look as if the student is supposed to perform the impossible task of mopping up everything in the text from page 1 on, in sequence.

Scientish does rather put the reader on the spot: it does not persuade or cajole - it tells. Everything is offered as clear and correct, so that it is no surprise to find students anxious that not understanding must be their fault:

'...relief that you can understand it now, whereas you didn't before... I can forget... I needn't worry...'

Hard though it can be, the effort can be worthwhile:

'...suddenly... everything fell into place. I felt relief at having understood it, and marvel at the beauty of the logic that led to it and fell away from it.'

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8. Questions, questions, questions

8.1 INTRODUCTION

Here is a not unusual tutorial question (see 7.1):

'Yes. Now - what's the reverse of photo-emission - photo-electric effect?'

It is not unusual in a number of respects:

it is a 'what is...' question, about physics.

it is initiated by the tutor, who will probably initiate the next.

the tutor knows the answer.

the students know he knows the answer.

if a student answered it, he would address the tutor.

the tutor will evaluate any answer.

it produced silence (seven seconds).

in the end, the tutor answers it.

Tutors ask a great number of questions. For example, one tutor asked more than seventy questions in an hour, of which more than half were questions about physics. Of the remainder, a dozen or so were requests for clarification, about ten were questions about what to do, and about five were general questions such as, 'What do we think about that?'.

This chapter looks at tutorial questions; at features they have, at reasons for their nature, and at effects they may produce. Section 8.2 begins informally, with a number of sketches or caricatures of styles of questioning; of patterns of questioning into which tutors sometimes fall. Section 8.3 attempts to look a little deeper, at how the nature and effects of questions might be better analysed and understood. Finally, section 8.4 draws some more general lessons from the previous discussion.

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8.2 STYLES OF QUESTIONING: SOME CARICATURES

In observing tutorials, familiar patterns of questioning emerged. Gradually, they acquired caricatured descriptions and names, which had some use, if only in being memorable enough to make it possible to see what might be going on before it was too late, and the moment had passed.

8.2.1 THE ALPINE GUIDE, OR 'STEP BY STEP'

Arguments in physics are difficult and intricate. One way of keeping going is to lead step by step by a series of questions. Each step in the argument is turned into a question, and each question expects an answer which will in turn permit the next question. The following invented example may illustrate the style:

\[
\begin{align*}
T & \quad \text{How could we get to the de Broglie relation starting from photons?} \\
S & \quad \text{Start from } E = hf \\
T & \quad \text{Good, } E = hf. \text{ What other relation can we use for } E ? \\
S & \quad E = mc^2 \\
T & \quad \text{Fine. How can we bring in momentum } p \ ? \\
S & \quad \text{Put } p = mc \\
T & \quad \text{What does substituting that give us?} \\
S & \quad E = pc \\
T & \quad \text{We now have } E = pc. \text{ What does } E = hf \text{ now give us?} \\
S & \quad pc = hf, \text{ so } p = h/\lambda, \text{ because } c = f\lambda . \\
T & \quad \text{Excellent. Now then, what } \ldots \ldots \text{ ?}
\end{align*}
\]

The tutor acts rather like an alpine guide putting the feet of his party of amateur climbers carefully into every foothold.

Every question is formed so as to contain the logic of the next step. Every question is supposed to be judged so as to get the required response, while at the same time - for self respect - not being too easy. (The footholds must not be too far apart, nor too close.)

A question which gets no answer, or a wrong answer, is thought of as defective. The tutor feels that he should have asked a different, clearer, or simpler question. (It is the guide’s fault if the climbers fall.)

In reality, attempts to guide students over the alpine rocks of argument are not so simple, and are often more interesting. The previous (invented) example was a guess at

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what was intended in a real example, when the tutor asked how de Broglie obtained the relationship:

S Didn't he rearrange Compton's laws?
T Yes, it does come partly by the Compton - but, of course, we haven't done the laws of Compton anyway.

The student has started to climb the wrong mountain. The tutor asks the question again, getting:

\[ p = \frac{h}{\lambda} \text{ and } E = hf. \]

This student has jumped straight to the top, giving as a starting point the ultimate goal. This the tutor then has to explain. He has \( E = hf \), but wants something else, which they don't seem to know. So he drives in a piton; an artificial foothold:

T It uses actually what is a relativity type expression.
S (several) \( E = mc^2 \)!

A slightly inelegant artificial aid, perhaps, but the climb is on again. Getting momentum in is the next cliff to be scaled:

T ... how does that give you your \( p = h/\lambda \)?

A pause - no climber moves. Try a lower foothold:

T What is \( p \) for a start? Very simple approach to it?
S Momentum
T Momentum - \( mv \). (pause)

The student has put his foot in the wrong hold, one even lower than meant. The tutor has to give a heave with his shoulder and lift the climber a bit, up to momentum being \( mv \).

A student offers \( c = f/\lambda \), and another helps with:

\[ hc/\lambda \text{ is } mc^2 \text{, and then you've got } h/\lambda = mc \]

The climb is now going according to plan. However, not wanting to risk a fall at this stage, the tutor now made a quick solo dash for the top, and finished the argument off himself.

These climbs always turn out to be harder than one thinks. Indeed the amount of planning the tutor must do so as to ask the 'right' question indicates how much thought has to go into the argument. Also, it is by no means obvious that the rough and ready scramble just described was inferior to the skilfully managed ascent with which we began. The very

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'defects' in it may have brought out places where students' understanding was inadequate even for this fairly straightforward task.

8.2.2 GUESS WHAT I'M THINKING

Some questions have, in the mind of the questioner, more clearly specified answers than others. It is a feature of language that the form of a question indicates a good deal about what the questioner will accept as an answer; that in some sense it gives the answer away. This is a very valuable feature: to be able to ask the question one wants saves time. A question like 'What method is the best for... ?' says that there is a best method, in a way that, 'What might be a good method to... ?', does not.

Troubles can ensue when one wants to ask a question without giving away the answer, and the clearer the answer is to the questioner, the harder the task becomes. This can lead to questions which leave the person questioned completely in the dark about what sort of answer might serve. At worst, the question becomes 'Guess what I'm thinking'.

For example, it had become plain to one tutor that some students thought that it was the resistance of the filament of a lamp that was responsible for limiting the rate of increase of current, if a voltage was suddenly applied across it. Searching for a question that did not contain the clue 'inductance', and thinking of solenoids, coils, and then spirals, he asked:

'What does a lamp filament remind you of? Something we've met. '

From the students' point of view, what could he be thinking of? Candles? Wires? Had a student said, 'a spring?', the tutor might well have acknowledged the nature of the game by saying, instinctively, 'good, you're getting warm'. Another sign that it is a guessing game is that a questioning answer feels reasonable.

In another case, a tutor asked,

'What is the OK thing to use? You've met it, you've seen it. You've all got one at home.'

The answer was an amplifier.

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Another example, which comes close to 'Guess what I'm thinking' comes from a third year tutorial:

'How would you really want to do Debye theory? How would you like to calculate the specific heat - of a solid - without somebody waving Debye theory at you - and saying, "well, of course, it's a model - and it's a continuum", things like that?'

One symptom of 'Guess what I'm thinking' is that reasonable, even correct, answers are turned aside. Perhaps this is such a case:

T Can you think of the meaning of potential?... Can you think of another way of talking about potential in the context of potential describing energy?
S It's the work done by
T No. Don't think of potential in that case. It has a more general - I would have thought more in terms of available energy - potential meaning 'it could come out'. You all have latent potential, though whether it comes out or not I don't really know. (laughs)

The phrase, '... in the context of potential describing energy' was perhaps a hint in the desired direction.

It is easy to ask these sorts of questions, and hard to avoid them. They sprout freely in situations where the tutor has a clear idea of the next required step or move. It may be more reasonable to ask questions which permit a variety of answers, such as:

What sort of things affect current and rate of change of current?
How many other ways can we think of for a circuit to affect the current?
What different sorts of meaning does the word potential have in physics and in other things?
What ideas might help us to think about this?

8.2.3 HINTS AND SLOTS

Consider the following concocted series of questions:

'What is the most fundamental aspect of any scattering experiment?'

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Well then, what is the essential thing we always measure?

Think - the beam comes at the target. What happens to it?

Look - suppose there's this incoming particle travelling along, and it's deflected and goes off an an . . . ?

(Ah - angle!)

Good Well, having seen what is the most fundamental aspect of any scattering experiment. ..

It is hard to ask large questions which work, especially if they begin with 'What is... ?', so suggesting that there is one special answer. In an episode reported in chapter 2 the tutor may have fallen into a similar trap by asking, 'What is special about quantum mechanics?'. He too narrows the question down further and further, to one about photons and polarisers.

The last question above is of a special kind, which might be called a 'slot' question. The answer is a filler for a slot in a statement, the slot being for preference near the end so that the form of the statement offers plenty of hints about a suitable filler. Another example is:

... electrons come down this wire, right? ... and join on to silver ions and make ... ?

Silver

Silver atoms

Such questions pop up in dense argument conducted by question and answer:

'Haven't divided by x we now multiply by... ?' 'y'

'Right... '

'And entropy is k times the log of ... ?' 'Omega'.

A related form is that in which the tutor reacts only to the answer which for him slots into place. For example:

(showing a polar plot of diffraction) Have you any idea what is meant by this diagram?... What is represented by the curvy line I've drawn here?
S1 It's the space, and you've drawn a graph at the same time

S2 The intensity

T (to S2) So what is intensity on this diagram now?

In many ways, the first answer is rather nice, but the tutor had a slot in his mind shaped like, 'polar plot of intensity', into which the second answer fitted better.

One danger of such a reaction is that the answer may not get discussed. The tutor accepts it because it fits, but that is not enough reason to suppose that the students see why it is right. In one instance, we recorded seven attempts to answer a question, in several ways, of which the seventh just got the response, 'Right’, and none of the others were examined.

8.3 DIFFERENT KINDS OF QUESTION

Can different kinds of question be analysed in a more systematic way than the caricatures of the previous section? This section offers some tentative steps in this direction.

The point of such an analysis is to try to find a set of ideas which could assist constructive thought and discussion about tutorial questioning. Although the analysis seems to work tolerably well, any further work is certain to modify and extend it, and may well challenge its whole basis. The reader will have to decide for himself whether it offers him a usable set of ideas or not.

The analysis uses the network notation introduced in section 7. 2, which is summarised at the end of this chapter.

8.3.1 NATURE OF THE ANALYSIS

Any question is doing several things at once, which are different in kind, but related. Consider again the question:

'Yes. Now - what's the reverse of photo-emission - photo electric effect ?'

It can be described from four points of view, each corresponding to one of four clusters of related features, into which the analysis below is divided.

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First, although it appears that the speaker wants to know something, he does not. The question is intended to get the student to say something the tutor already knows. In type, it is not an enquiry, but an attempt to elicit something.

Second, the question is talking about physics, and not about, say, what should be done next in the tutorial.

Third, the tutor doing something: here he is taking the initiative, and deciding what will happen.

Fourth, the question has a particular kind of connection with what has gone before. The tutor has just been given an answer which satisfies him, and proposes something new but related. He is not, for example, reacting to something he does not understand.

These three aspects are not all of a kind. The last three relate to the three functions of language discussed in section 7.2: language as saying something; as doing something; and as building connected patterns. The first aspect is nearer the surface, being the way what is going on deeper down comes out.

8.3.2 TYPES OF QUESTION

We distinguish between questions like:

'... what about number twelve - did you get this one out?'

'... can you say why you don't like it?'

in which the tutor is asking something he does not know, and questions like:

'How does that give you your $p = h/\lambda$?'

'What's the momentum of the photon?'

in which both tutor and students expect the tutor to match the reply against one he has in mind. In the second, the tutor may gain knowledge about the student, but not knowledge about the answer. We shall call the first type enquiry, and the second type elicitation; a distinction in the form of a question.

Another distinction which can be made for both these forms concerns how strongly the question itself specifies what would serve as an answer. Both the elicitation questions above constrain the answer rather tightly, compared with, for example:

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'Let's... think about what we know about electrolysis - related to atoms and what's going on - but anything we know about electrolysis.'

Many more kinds of response are open to such a question. Some of those it produced were:

'Faraday' s law s.'

'I don't (know anything about electrolysis)'

'Solution - if you use a solution it's got to be ionic'

We shall say that questions can offer a frame for an answer which is relatively closed or open. The distinction applies to enquiries too. For example:

'Right... and you can't understand why you get the difference ?'

which is rather more closed than:

'Do you have any particular feelings about which of those... discussions might be more useful to you at this point ?'

which in context was clearly not expecting merely 'yes' or 'no' for an answer.

Finally, within elicitations, we shall distinguish those like:

'Is it a quantum phenomenon?'

where the reason for asking the question is implicit, from others like:

'... if we can now go back... There you have those three things in series, right? Now let's recap - what do they have in common - what is common to all of them if the three are in series?' in which the aim of the question is made more explicit.

All these distinctions can be compactly expressed by a network:
8.3.3 KINDS OF THING ASKED ABOUT

Much of what is talked about in a science tutorial is, obviously, the subject, science. But there are other things too. There are questions about procedure, which include asking what to do next, or whether a discussion is complete. There are also general questions which anyone might ask of another person, about such matters as social life, health, or interests.

All of these kinds of questions can ask for more than one sort of reaction. The question may be about facts (what a student has done, or what delayed him, for example): about thoughts (perhaps whether he thinks he knows something); or about feelings (maybe whether he feels confident, or whether he feels bored).

These distinctions form the main structure of the network proposed to describe the content of questions:
Questions about subject matter are frequent, and seem worth dividing into more than one sort.

First, we distinguish questions about the public, objective aspects of the subject; the subject as it exists in books. Contrasted with these are questions about the student's own ideas; about his private, personal and subjective version of things. To give examples of each:

'How much is a mole of - water molecules?'

'... an ionic solution - if you could peer inside, what would it look like do you think? If only you could look inside, what would there be in it - what picture do you see?'

Second, we distinguish between questions like,

'What is the frequency of the emitted radiation?'

to which an answer is scientific information, and ones like,

'Can you recognise any of those terms? (in a wave equation)

to which the answer is some kind of statement about the student's knowledge.

The first have been labelled knowledge, and the second evaluation of knowledge.

8. 3.4 WAYS OF DOING THINGS WITH QUESTIONS

Different sorts of question obviously feel different, but defining the differences is an elusive affair. In part it is elusive because many of the differences are implicit; understood from the way things are put. For example, the question,

'Can you give me any sort of reason for your objection?'

is softer in its effect than is, say,

'What is the resistance, then?' (asked by the tutor)

The second makes more of a demand, while the first is more like an invitation. The following network is an attempt to describe some of these differences:

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The network allows for a question to be asked both for what it is about, and for the effect of asking it; for example, both to find out if a student knows the answer, and also to get that student to say something. That is, the role the tutor adopts concerns both the content of the question, and the involvement of students.

The tutor is said to be taking a participating or a controlling role. For example Dr White, in the episode about dielectrics in chapter 2, is controlling the content of the discussion when he proposes his questions about a new situation (cylinders instead of parallel plates). What we have called Alpine Guide questions (section 8.2.1) often control both involvement and content: they press for a response, and specify what it should be about. The control can be relatively firm or relatively flexible; firm control over involvement was what was called a demand, and flexible control was what was called an invitation.

On occasions, the tutor may be a participant: that is, control over the discussion flows back and forth. For example, the following question was asked by a tutor in the middle of a complicated mutual discussion:

'Now the question is - you could ask - replace - you could talk about a sort of random fluctuation of potential, for instance. (pause) Would you be able to use that - that motion to obtain useful work?'
The question looks like an elicitation, but in the context it was not. Indeed the student replied:

'Ah - well - that's connected with Maxwell's demon - it seems an analogous sort of thing - because what you're suggesting is just an ordinary - classical Maxwell's demon machine, it seems...'

The question was intended, and was treated, as a contribution; as something to be commented on, rather than as a question which must be answered. The questioner may be engaged in the discussion, as here, or he may be being receptive.

All these things may be explicit or implicit. Thus in,

'... You've got first of all this quantity of matter (mass). What exactly do you mean by that?'

the demand for an explanation is implicit in the form of the question (compare 'I think it would help us if you could explain...'). Equally implicit is the tutor's attempt to involve the student addressed (compare, 'I'd like you to go on and say some more about...') The following is more explicit in a number of ways:

'We are going to come back to that in a minute. That's the bit about which I'm saying you are wrong... But before that I would like to explore...'s argument (states it). And the question is... whether or not... it is true for every circuit... always true?'

Paradoxically, implicit control is often stronger in its effect than explicit control. The hearer can treat an explicit expression like,

'That's the bit about which I'm saying you're wrong.

as a proposal to which he could react. But if asked,

'What do you mean by the potential energy?'

it is quite hard for a student to refuse the role given to him, perhaps by saying that what he means isn't the point.
8.3.5 KINDS OF CONNECTION

The function of a question can normally only be understood and described in terms of what went before, and what may follow. Sometimes they form chains. A question may also serve to redirect attention, to simplify another which proved too hard, to clarify a point, and so on. The loop in the network below represents the cyclic process in which some questions arise out of others.

![Network diagram](image)

The network says that if the tutor is in control, he will have reasons for asking the next question, like repeating, modifying, clarifying, redirecting attention, or going on to the next step. If the tutor is participating, what matters is whether the question is acceptable or not. If acceptable, people may ask for things like an expansion of it, while if not acceptable they may ask for it to be re-examined. These last possibilities, and others like them, are not represented here.

It would be foolish to pretend that this is all that is involved. Indeed, understanding how talk between people is organised has proved one of the more intractable problems linguists have tackled. At best, we have here proposed for consideration a few features of possible practical interest.
8.3.6 STATUS OF THE ANALYSIS

This concludes the presentation of the analytic framework. The reader will surely (and rightly) have doubted whether the right features, and the right connections between them, were being proposed. The test must be two-fold: do examples of each set of features ring true; and - more important - does the analysis make it possible to say anything interesting and non-trivial? With some trepidation, the next and final section takes some steps towards confronting the second question.

8.4 QUESTIONING AND TUTORIAL TEACHING

This section considers possible effects on tutorial teaching of different kinds of questioning. The issues involve taste and opinion, and there is plenty of room for disagreement about them. It is hoped that the brief sections which follow will at least suggest issues worth thinking about, whatever position one takes upon them.

8.4.1 THE TUTOR KNOWS THE SUBJECT

Consider what is going on in the following exchanges:

T ... Then we come back to trying to see why we get more p.d. across there than we do across there. (seven second pause) Well, let me put the question another way. Why would you expect to get the same p. d ?
S1 You're taking the p.d. across the same resistance.
T How do you know you're taking it across the same resistance ?
S1 You assume that the resistance in those wires is in series with that.
T Yes - well about how big is this resistance ?
S1 0.01 ohms.
T 0.01 ohms. So when you say virtually zero, what sort of value do you - would you have to make that go ?
S2 Well it'd be a zero resistance, a small resistance - reasonable resistance in that wire
T (interrupts) Very small, yes.

The questions tend to be elicitations, with a closed frame. Why? The tutor is in firm control of the content; indeed, a little later a student says,
'It would have been easier to use one resistance and just a common terminal, rather than using four terminals, surely?'

and the tutor replies,

'Well, let's get on to that later.'

The firm control of content is done by the closed frame given to questions. It is because he is expected to know what he is talking about that the tutor can take control, or have it put upon him. So the questions concern what he is supposed to know: their content is the objective aspects of knowledge of the subject. They are about facts, rather than about private thoughts.

In many respects, the sequence is very reasonable, but one of its consequences is that it is the tutor who is made to break the seven second silence, by modifying his question. The question produces silence for the same reason: only a correct answer looks as if it will do. All this can put a tutor in a difficult position: always having to keep up the initiative. It also reinforces his position of authority, by backing it the authority of the subject itself.

8.4.2 INQUISITION

Those who have investigated teaching in schools have also noticed the tendency towards long strings of questions from teachers, with short answers from pupils, and short pauses allowed for answers. One of them has unkindly called the pattern 'inquisition'.

Such questions firmly control involvement as well as content, so seeming to students like demand after demand. In a small group, this could well lead to students not trying to answer questions after a while, because that forces the tutor into asking easier ones. Also, the hidden and unintended message may get across that it is the tutor alone, and not students, who ought to be asking questions.

8.4.3 LEADING BY QUESTIONING

Tutors, as we have seen, sometimes lead students through an argument by question and answer. Something here may depend on whether the tutor's control is explicit or implicit.
Just because the tutor does know where he is going, he may not explain or express what he is doing in each step, and may leave students with the feeling that they do not see the pattern of the argument.

The tutor below, however, is more explicit:

T  How many vectors are we going to have... first of all?
S 1 Three
T  Three, OK. One for each (of L, R, C). All right? Now, can you start by proposing any of the three to draw in?
S 1 I'll go for the easy one... I'll go for the resistor.
T  The wretch!
S 1 The resistor's in phase with the current, so it'll be along the x-axis (more details brought out)
T  OK. Now let's think about the next one. (pause) Now can anyone propose a different one?
S 2 Well - voltage due to the inductor

There are more invitations, and fewer demands, but also the explicit way the steps in the subject matter are controlled could make it easier for students to say, for example, that they do not see why these should be the steps.

8.4.4 DIGGING INTO DIFFICULTIES

It is often very hard to find out where students are confused or ignorant. Different patterns of questioning may be most suitable in different circumstances. Often, though questions whose job is to evaluate knowledge come out as (mainly) elicitations of knowledge, and may feel more like a test than a helpful diagnosis. The following exchanges offer a contrast:

T  ... very clever of it to do it all (laughs) but it manages it. Is there any question about that (I'd like to check whether you have any problem with that now? (four second pause) Why are you smiling?
S 1 I don't know (pause) it's all right, I suppose. (laughter)
T  Yes
S 2 I don't like it very much
T  Can you - can you say why you don't like it?
S 2 I don't know - I suppose it, I suppose it has to be true. You know, there you're keeping a constant current, therefore the voltage must have changed. There you're keeping a constant voltage so therefore the current must be changed.
The features from several of the networks are now different. The tutor is first inviting, then participating in a receptive way. The content is now what the student thinks and feels, about which the tutor cannot be expert, so the questions are enquiries rather than elicitations. With the tutor participating, the students do more of the work of keeping the discussion going.

It is never easy to decide what sort of way to dig into difficulties, but it is not likely that if the difficulty is a private one, it will emerge from a kind of questioning which is only expressed in the form of eliciting questions about the subject matter.

8.4.5 REVELATIONS

Talking with students, it is often clear that something is not understood. It may be necessary to dig (as above) into what the difficulty really is. In doing so, other difficulties that exist may go unnoticed. Several episodes illustrate the point: a problem the tutor had not guessed at emerges too late, or, just as the problem seems revealed, a student asks something else which reveals a whole Pandora's box of misunderstanding.

The next extract reveals something of the central dilemma posed by what happens when one really begins to get students saying what they do not know.

T (asking about notes)... say the sort of words and ideas that when you look at it, you say I don't understand that...
S1 This bit
S2 Seems to me that
T (to S1) ... right, \( N(E)dE \) ... any more?
S3 The equation (points to \( N(E)dE = C E^{1/2} dE \) )
T OK. I'm writing. Tell me some more ... (four second pause)
S4 The Fermi energy
T The Fermi energy (eleven second pause) You see the point... ?
The conduction electrons haven't been mentioned as something we don't understand. Now if you don't, they ought to be.
S5 Put it in
T You want conduction electrons (six second pause) The point is, if we pick out the things we don't get, we can focus on those (ten second pause)
S6 Um - really extending the Fermi energy - the Pauli excursion (said with effort)
T Exclusion... Pauli exclusion principle ...
S1 This infinite well

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So it went on, yielding, amongst other things:

'quantum mechanical solution'
'this figure here'
'comparison between these equations shows that - it doesn't show that to me'
'what's \( V_O \)?'
'in this diagram, which is metal 1 and which is metal 2 ?'

The open frame questions, and writing down of answers, produced a great deal to discuss. The tutor played a receptive role, and the silences are longer than usual, perhaps too long - one was twenty seconds.

On the one hand, here is an object lesson in getting students to express difficulties; and on the other, an object lesson in getting more than can possibly be talked about in an hour.

8.4.6 KEEPING ON THE RAILS

We have seen how there is some tension between keeping the discussion clearly in focus, so risking not dealing with what matters to students; and encouraging students to talk about things in their own way, so risking never getting anywhere.

Another way to keep things on the rails, apart from eliciting, may be to extend the use of questions about procedure. Questions like,

'We could start on one, and then do the other. Do you have a priority ?'

'Can we come back to that question in a minute. . ? Jean made this proposition and it's coming up again. All right ?'

invite students to help plan the discussion, or at least put a plan openly before them. It is all too easy for the tutor, who knows his way around the subject, to keep the plan he has implicit.

Another part of an answer may be to make clear to students the different sorts of discussion which could be attempted, and the trade-offs involved in each, so that
expectations are more realistic. At least, if the diagnosis does not take the form the patient expects (and it not always does) the doctor might explain why.

8.4.7 DISCUSSING TOGETHER

One common form of discussion is, of course, of attempts to solve exercises from problem sheets. Here it is natural for the discussion to be participatory, rather than controlled strongly by the tutor. The dialogue reported in chapter 4 (section 4.4) may be worth re-examining from this point of view. Its subject matter moves easily between objective facts, knowledge, evaluation of knowledge, and reflections on each. The tutor can be both receptive and engaged. Students both involve themselves, and can be brought in ('Do you understand?'). Control of content is done by remarks about procedure ('Let's understand what his problem was'), as well as by direct questions about knowledge or its evaluation. Few questions are elicitations - that is, the tutor appears as needing to know, not as knowing.

One thing that many tutors would wish to aim for is a mutual discussion of some point in the subject, with everyone joining in on more or less equal terms. What would count as signs of a genuine discussion? One sign is that a student can respond to a question, not by answering it, but by arguing about it. Another sign is that people can change the subject, and take it for granted that the new idea does not have to be excused or justified. For example:

S1       I was just - just trying to apply the same arguments to the - the noisy resistor - I didn't seem to get very far.

S2       If you try and rectify, then I think you do, because the rectifier itself will display - er - probably necessary deflections of the same order.

A further sign of discursive roles is that students appraise their own positions, rather than expecting them to be appraised by the tutor. They say things like

'I should have thought that...'

'No, I know. That's what I was saying'

Nor in discussion is there so much of the tutor correcting and reformulating what has been said, as there is in,
The phase difference between the inductor and the current across the inductor.

Yes - between the p.d. across the inductor, and the current through the inductor, to be precise.

All these things, especially the assumption of the right to correct and reformulate, express authority. A tutor's authority is proper and inescapable. But if its expression is habitual and strong, discussion becomes difficult. The moderating of authority in the above discussion even made it possible for one student to say to the tutor, without condescension or submission:

'I think you're probably right, actually.'

8.5 IN CONCLUSION

In the end then, so what? The discussion of this chapter and the last has ranged across many issues, small and large, from pauses after questions to the tutor as an authority. The issues are all inter-related, so that getting them in order in one's mind is difficult. It follows also that there are few simple recipes to be found: 'Do this' and 'Don't do that' are not the messages to be found here.

Perhaps, though, a study of the language of teaching does offer something, though more belongs to future promise than to present achievement.

First, it looks at what is real; at what happens; and so may be one bridge between the rhetoric of talk about teaching and the business of getting on with the job.

Secondly, it can be complex without descending to the useless level at which everything is an individual difference, and generalisation is vacuous.

Thirdly, it has something to say about style; about differences in style and their consequences. Here the tutor can perhaps become aware of possibilities, and so gain more power to choose for himself what to do.

Lastly, it can begin to suggest how things work; to underpin what often seems either arbitrary or inevitable, with something which may one day deserve the name theory. Teaching will remain an art, not a science, but an art need not wholly be a mystery. Understanding its language is one, though only one, way to begin to penetrate the mystery.

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SUMMARY OF NETWORK NOTATION

- If a then one of b, c, d.
- If a then all of b, c, d.
- If a and b then c.
- If a or b or both then c
- If a and also c elsewhere then b, otherwise nothing.
REFERENCES AND COMMENTARY

Those readers who happen to wish to look more closely into the ideas about language which lie behind chapters 7 and 8 will find the following references a useful beginning. The comments indicate what sort of thing is to be found in each.

A collection of papers of varying interest, containing some classics.

Some early work based on tape recordings of school teaching - much of it science.

The first introductory textbook to systemic linguistics.

A wide-ranging, readable - even witty - but fat textbook, encompassing language, thought, personality, and the behaviour of groups.

A varied collection of papers, both detailed and general, which give a good idea of the variety of the field.

Halliday M A K (1973) Exploration in the functions of language, Edward Arnold.
An excellent exposition of Halliday's ideas, written specially for teachers, though still containing original work. Systemic networks are clearly explained, as is their application to language in practical, social contexts.

page 134
A set of readings which touch - heavily or lightly - on a very large number of
issues.

Sinclair J McH, Coulthard R M (1975) Towards an analysis of discourse,
Oxford.
A report of research into analysing the language of school classroom teaching.
Has an excellent critical bibliography surveying earlier work.

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Part three:

Are there any answers?
9. Skill sessions

9.1 INTRODUCTION:
EXAMPLE OF A SKILL SESSION

A skill session is a kind of group teaching which differs significantly from a conventional tutorial, both in method and content. The idea is first introduced by an example; then section 9.2 describes the method and section 9.3 the selection of content. The outcome of the use of skill sessions in several institutions is considered in section 9.4, and possible developments in 9.5. The remainder of the chapter, section 9.6, is a portfolio of outlines of skill sessions which have been tried.

If one could eavesdrop on a skill session, one might see something as follows:

Sixteen students arrive, and the tutor tells them that they are going to do some order of magnitude estimates, giving as an example working out whether the solar energy falling on the roof of a house could provide all, or a half, or just a tiny part of its energy requirements. He says how useful a physicist finds it to be able to do this kind of thing, and mentions an example from his recent research.

The tutor then writes three problems on the blackboard:

'What is the rate of growth, in metres per second, of your hair?'

'How many words did this morning's lecturer say? How many words are there in your notes?'

'How much fare money does a bus in this town collect in a day?'

He divides the sixteen students into four groups, and makes each group of four sit round its own table, telling them to agree on an answer to the first problem, and to go on to the others only if they finish. One student in each group is told that in half an hour's time he will be asked to tell the rest what his group agreed. All this takes about five minutes.
For the next half hour, the groups work alone, in a buzz of conversation. The tutor stands apart, listening generally but leaving the groups mostly alone. One group falls silent, and he goes over and suggests an idea to them. He hears another group arguing about the exact value of a quantity, and reminds them that a rough value will do.

When the half hour is up, he gets the students to come and sit in front of the blackboard, even though one group is deep in the middle of an argument. One by one, the spokesmen are called up to report (having been reminded about this a little before the groups were stopped).

Two of the answers to the hair-growth problem are about $10^{-8}$ m s$^{-1}$; one is much larger, and one much smaller. On going through the calculations, one contains a slip in working out a power of ten, and another an absurd estimate which is first defended, then abandoned by the group that made it. The tutor has some trouble getting them to agree that answers differing by a factor of two are really the same. One group has tried all three, two have done one and most of the second, and one has barely finished the first problem.

The hour is up before the third problem is discussed, and the tutor sums things up, saying that next time they will try some similar problems with a bit more physics in them. As a parting shot, he suggests that it would be interesting to work out how many atoms are added each second to a growing hair.

The essential features of the method are:

- a set of prepared problems.
- a group large enough to be divided for part of the time into about four sub-groups of about four.
- sub-groups working more or less alone for about half the total time.
- spokesmen to report the work of each sub-group.
- discussion with the whole class based on the reports.

The content can, but need not, be something like making order of magnitude estimates, sketching graphs from an equation, or planning the main outline of an experiment, which can be seen as skills needed by a working scientist.
The problems set do have to be ones that groups of students can get somewhere with in half an hour on their own, and which throw up useful material for discussion.

9.2 A METHOD OF WORKING

As a method of working, skill sessions imply a belief in the value of students discussing problems amongst themselves. To achieve that, attention has to be paid to the structure of the session: to having suitable material; to having a workable organisation of groups; and to using time to the best advantage. These points are expanded on below.

It can be seen as a virtue of the method that it leads to students talking with one another about physics, if such talk develops their ideas and their ability to express them. That the talk is with peers can have several advantages: people often then talk more freely than they do with superiors, and are more receptive and self-critical; in addition the pace and level is kept within students' abilities.

For the discussion to have these virtues, it is essential both that the groups work alone, and that the work set is simple enough to allow participation without seeming trivial or boring. It is not enough just to leave students alone with problems. Experience has shown that this can only be done effectively within a carefully organised framework, so that it is important to pay close attention to the sort of detail given here.

The introductory phase needs to be kept short, to allow time for the rest, and so that the tutor does not seem to dominate. But it does need explicitly to convey what the session is about, and why it is important. It may help to do one example quickly. An instance of the importance of the topic from the tutor's own experience is usually telling.

It is important to appoint spokesmen for each group at the start, and to explain their job. They should be asked to keep notes, and to report on progress, difficulties, agreements, and disagreements, as well as on results. It can be better to have some system for appointing spokesmen in rotation, though some leave the choice to groups.

The same problem can be given to all groups, different problems to each group, or groups can be asked to choose one from a set. The choice depends on the topic: the first plan is best when useful differences may arise between groups which can be exploited in the final discussion; while the other two are better if the value of the topic lies in a variety of
examples. A design problem might be of the first kind, and the interpretation of graphs one of the second.

Students and furniture will need to be moved around during the session. Sub-groups work best round a small table, or round the end of a large one. It is usually necessary firmly to insist on moving chairs and tables; otherwise students stay where they are and try to work while sitting in a row, for example. For the full group discussion at the end, it is again necessary to insist on moving into a circle or arc, around a blackboard or projector screen. The temptation to avoid this seeming fuss, or to mention it mildly without seeing that it is done, is strong and needs to be overcome.

So far as is reasonable, leave the sub-groups alone. If the tutor attempts to help, neither he nor they may discover the real capabilities or problems of a group. At this stage, the tutor's job is to ensure that groups know what they are supposed to be doing, and to give information or advice when asked. It is, however, useful to listen in from a distance, so as to plan the timing, and pick up issues which ought to be brought out in the full group discussion.

The final discussion is the part most tutors find hardest, but is the part where much of the value of the session emerges. The value comes when students have to abandon previously agreed positions, modify agreed views, accept other equally good alternative solutions, and see others getting into the same trouble as they did.

The temptation is always to cut short this part, by letting sub-groups go on with a lively argument, or by letting every group finish all that it is doing. A firm calling of a halt is needed, not less than twenty minutes before the end.

Ideally, in the final discussion, students will challenge one another, ask questions, and get nearer resolving difficulties amongst themselves. In reality, the discussion present the tutor with many dilemmas.

One dilemma is that students make mistakes. Some need correcting at once, but if the tutor corrects or improves on points frequently and immediately, students will soon learn to keep quiet. Often, it is best to make a note of such things, and bring them up later. Quite often, the mistake does get spotted in due course.
Another dilemma is that other groups do not react to the various reports, seeming content to report and leave it at that, despite glaring differences. It may be important to go round insisting on one question from each of the other groups about every report. Done at the first few meetings, this can gather its own momentum in time.

The tutor has two roles in the final discussion: chairman and expert commentator. It is useful to bear them both clearly in mind, saying when one proposes to make a comment before joining in with it.

The tutor as expert has much to offer in the final discussion. Students can see him reacting on his feet to suggestions, and from that learn standards of skillful performance. The dilemma for the tutor is of striking a balance between displaying his skill and encouraging students to contribute. Perhaps the best advice is to have patience, saving up one's own points for a time, and then to give them as a clarification of what has been said.

It is important to sum up at the end, saying what has been achieved, and commenting on unresolved problems. Students easily lose sight of the aim of the exercise, and can be confused and disheartened if it tails off in a tangle of unclear arguments as time runs out.

Despite the above insistence on ground rules, the format can be used flexibly. The cycle of: introduction - work in subgroups - discussion of reports, can be gone round twice in an hour by using shorter tasks, for example. Numbers are less flexible. A subgroup of less than four can easily run out of ideas, or not offer enough criticism, so reaching premature and invalid conclusions. A subgroup larger than four can easily have a silent passenger. If there are more than four subgroups, it takes too long to hear and discuss all the reports. Thus twelve to sixteen seems to be the optimum number.

Staff consistently overestimate what can be achieved by a subgroup in the time available. So problems must be simple and few in number. If they are not, they take time from the final discussion, and the tutor is forced to take it over and rush through it, giving all the comments himself. Indeed, experience suggests that one hour is shorter than the ideal time, so that timetabling which allows sessions to run on can be useful.

Finally, do not expect too much, or try to inject too many ideas. The expert has acquired his skills gradually over many years, to the point where they may seem trivial to him. One hour spent on (say) order of magnitude estimates will not work magic. It can be a
signal that such a skill is valued, and can perhaps help confidence to grow a little. Indeed the tutor may find himself surprised by the frailty of students' skill, and learn useful lessons about what it is reasonable to expect. A flood of expertise may wash away the seedling, where a drop of water might encourage it to grow.

9.3 WHY SKILLS?

The content of sessions described, as distinct from their format, might be called skills: that is, things a working scientist can do which are not directly to do with subject matter. Teaching courses tend to be organised around subject areas, assuming that skills will be developed by the way, in doing problems. The original impetus for skill sessions was a hope that there would be value in something more direct (Black, Griffith, and Powell 1974).

One may, or may not, think that such skill can be analysed into components. But in any case, if such a session is to have a clear focus, some particular skills have to be identified, and suitable work on them devised. Section 9.6 gives a set of such sessions which have been tried. It is not complete or final: new ideas continue to arise, some from thinking about problems of learning in general, and others from experience of difficulties revealed in students' work.

It has proved easy for staff to think of ideas for such sessions, but hard for them to produce clear and suitable work for them. Having such work, usually in the form of specific problems, is crucial, especially if colleagues will have to put the sessions into effect. It is no use just having a general idea for a session.

A range of graded problems is needed, to allow choice according to preference, and to allow adaptation when a chosen problem proves too hard. A good working rule is to include some which seem trivial; often they prove not to be, and if they are, a group disposes of them quickly and little harm is done.

Sessions can with value be arranged in some developing sequence. One might be a series on problem solving, including selecting main principles, formulating a model and an equation, and thinking of alternatives. Another might be related to project work, including orders of magnitude, selecting instruments, and deciding what to measure.
It cannot, of course, be automatically assumed that skill is readily built up in this way, from parts, even though there is evidence enough that students do lack the skills looked at here as components. While the sessions reveal a good deal about students' needs, they do not solve the problem of doing more than a little about them. Experiments with sequences of skills, perhaps culminating in sessions intended to synthesise them, are worth trying, but their success cannot be guaranteed. For this sort of reason, the sessions that exist are based on the instincts and intuitions of practitioners.

9.4 WHAT HAPPENS WHEN YOU TRY SKILL SESSIONS?

An innovation can in part be judged by its hardiness. Skill sessions began and survived in the physics department at the university of Birmingham, and have since been transplanted without withering to other departments and subjects. That is, staff have been satisfied with them, and have not abandoned them.

The results of questionnaires in more than one department show a clear majority of students finding them interesting and valuable, and finding the level of difficulty of sessions in section 9.6 about right. They agreed that the sessions 'help one to think like a physicist', and - an unanticipated spin-off - that they helped them to get to know other students early in the course. They did not accept that tutors gave insufficient help, but did feel that final discussions were too often left 'in the air'. They were not always convinced of their relevance to the rest of the course, or of their value for examinations. One department found that the last opinion shifted when a sequence of sessions was explained, and reflected in specific examination questions. Some students say they gain in self-confidence and ability to solve problems, more from skill sessions than from problem classes or tutorials. Finally, the sessions are clearly enjoyed.

Given adequate outlines, staff have proved willing to run the sessions. Later, many think up their own material. The way they run them varies considerably: some doing in two or three sessions what others do in one; and varying in emphasis, time, and conduct of aspects of the sessions. Personal style is important, and success has been achieved with very diverse styles. In general, tutors comment favourably on the sessions, notably on the active participation of students.
Despite such favourable opinion, there is not - nor could there easily be - any firm evidence that students actually acquire the skills in question. Indeed, realism suggests that in an hour one could hardly hope to do more than focus attention on a skill and the need for it.

9.5 REFLECTIONS AND DEVELOPMENTS

It is a matter for conjecture whether the format of skill sessions can usefully be used for other purposes, such as problem classes, and whether their content could as well, or better, be taught in another fashion, perhaps using written material. The format is certainly usable, and indeed has been used for many purposes before being applied to skill sessions. Ideas from chapter 6 suggest that it strikes a good balance between the various problems that constrain effective small group work.

It can be argued that the format is a good one for the content. Learning new skills may involve a change of attitude, and a degree of self-criticism, for which working with one's peers is likely to be helpful.

Perhaps a good part of the interest of skill sessions is in the way they focus on an important problem of undergraduate courses. They may be seen as a small contribution to fresh thinking about it, and as a way of exposing, if not of disposing of, difficulties of students in this area.

Those who wish to try the sessions will need to consider how to introduce them. In a small department, a few can easily be tried on the whole class, even as an optional extra. In a large department, agreement of colleagues and a timetable slot is necessary. Some have made a trial replacement of some tutorials or problem classes; others have taken time from laboratory work, and concentrated on laboratory skills. The method has been used at levels from the sixth form to the final year at university, and in engineering, zoology, genetics and other subjects.

A trial can be short, and not interfere with other courses. This obvious advantage is offset by the consequence that students may see the work as unrelated to other things. However, it would seem to be wise to try it first and worry about this later, thinking then about the part the sessions should play in the whole teaching programme. Indeed, the debate will acquire a needed vigour when skill sessions compete with other things.
9.6 SKILL SESSION OUTLINES

This section consists of outlines for skill sessions:

1. ESTIMATING ORDERS OF MAGNITUDE
2. SCALING
3. TRANSLATION: WORDS AND GRAPHS
4. TRANSLATION: SYMBOLS AND GRAPHS
5. USING ALGEBRA IN ARGUMENT
6. THE ART OF NEGLIGENCE
7. FIRST STEPS IN PLANNING AN INVESTIGATION
8. DESIGNING AN EXPERIMENT
9. SELECTION OF INSTRUMENTS
10. THINKING OF ALTERNATIVES
11. THINK ABOUT IT FIRST
12. WHAT IS THE PRINCIPLE?
13. WHEN IS IT TRUE?
14. WHAT ARE THE RELEVANT VARIABLES?
15. SPOTTING THE FALLACY

The list of titles is in no way exhaustive, complete, or balanced. The outlines are intended to serve two purposes:

- to provide a starting point; something to try at first, or something to have on hand when time presses.

- to suggest other possibilities by example.

The outlines offered here have, however, been tried in a number of departments by a variety of tutors, and have been modified in the light of that experience. In particular, questions which at first sight look trivial are, in general, found not to be. Indeed, the outlines probably still contain too many problems which are too difficult.

Most of the outlines are written with first year students in mind, because most trial work was done with first year students. Some can easily be adapted to other years, by changing the problems, the session on order of magnitude estimates being an obvious example.

While wanting to encourage tutors to produce their own material, it is important to say that producing successful material is not easy. Most ideas have to be modified after trial.

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Each of the following outlines gives a brief introduction to the idea of the session, and some advice about running it. Then a number of possible problems are suggested, from which the tutor can select a few, or which may suggest to him some similar problems. In general, the first one or two are easy.

9.6.1 ESTIMATING ORDERS OF MAGNITUDE

Problems 1 to 5 are simple, non-physical ones to introduce the idea. For a single session, one can be chosen, followed by another from problems 6 to 12. There is work enough for two sessions, so if time permits, more of the first few questions can be asked in the first session, followed by others in the second. It is useful to start groups on different questions, but to tell them to go on to questions set to other groups.

PROBLEMS

1 What is the rate of growth of your hair, in metres per second? How many atomic layers per second? How many atoms per second per hair?

2 How many bricks are there in Birmingham?

3 How much fare-money does a city 'bus collect in a day?

4 What thickness of your sleeve is worn off by one rub across the table? (Could radioactive tracers detect the wear?)

5 How many words were uttered by this morning's lecturer? How many words are written in your notes?

6 If I give a man 10 joules:
   to heat his coffee, will it scald him?
   in a punch on the nose, will it hurt him?

How much energy in joules is dissipated:
   by burning a match?
   by stopping a car at the traffic lights?

7 How does the cost of a joule of electrical energy from a dry cell compare with the cost of a joule from the mains?

8 Roughly what error is made by using the volume of a block of brass at room temperature, in working out the density of liquid nitrogen from a measurement of the weight of the block immersed in the nitrogen?

9 An anarchist says he has just dissolved one curie of iodine-131 in the city reservoir. Do you laugh it off or raise the alarm? (The half-life of iodine-131 is 8 days, and the maximum dose in the thyroid gland is 0.7 microcurie.)
10 What is the chance that you are now breathing in one of the molecules that Caesar exhaled with his dying breath?

11 What is the recoil velocity of the Earth when a child bounces a ball on the ground?

12 What is the daily consumption of electrical energy in the United Kingdom?

9.6.2 SCALING

Why are things the size they are? Some are determined by intrinsic factors, others by the size of man. Questions of size relate to questions of design how big to make the apparatus - and to the use of scale models. The session includes some practical dimensional analysis.

Questions 1 and 2 are intended to show that there may be problems connected with scale. One might be done as an introductory example. Problem 5 is probably best given to all groups at the same time, since different assumptions lead to different approaches.

PROBLEMS

1 How tall is a flea, and how high can a flea jump? How tall is a horse? So - how high can a horse jump?

2 Which of two teapots keeps the tea warm longer, if one is twice as large in all linear dimensions as the other?

3 What effects would scaling up all the linear dimensions by a factor of two have on the performance of:
   an electric fire?
   a cycle dynamo?
   a telescope?
   a nuclear reactor?
   an apparatus to measure specific heat capacity electrically?

4 Why are
   cameras
   mercury-in-glass thermometers
   chemical balances
the size they are?

5 A man has driven in a small nail with a small hammer. The next nail has twice the linear dimensions of the first, so he picks a hammer of twice the size too. Can he now drive in the nail more, less, or equally quickly?
6 Of two cars with all linear dimensions, including the engine, in the ratio two to one, which has the better power to weight ratio? (Or, could Lilliputians have cars?)

9.6.3 TRANSLATION: WORDS AND GRAPHS

Problems 1 to 4 ask for graphs to be put into words. Problems 5 to 8 ask for graphs to be sketched from a description. The problems are relatively easy, especially 1 to 4, and several can be given. They can be extended by asking for further plots, for example of power against time for problems 3 or 5, and by asking for information contained in slopes, intercepts and areas.

PROBLEMS

1 Describe this journey:

2 Say what it would feel like to pull the wires whose load-extension graphs are as shown:

3 How does the resistance change with p.d. for these curves? What sort of thing might each be?

4 If two people hear the frequency of the whistle of a train going past on a straight track change as shown, what can be said about how far they are from the track?

5-8 Sketch graphs of:

5 current against time, after the normal working p.d. has been suddenly applied across a torch bulb.

6 the temperature of a room against time, from the time the heating is switched on, if the heating is controlled by a thermostat.
7 the net gravitational force against distance, for a moon probe travelling directly from the Earth to the Moon.

8 acceleration against time for a train going from one station to the next.

9.6.4 TRANSLATION: SYMBOLS AND GRAPHS

This session is more difficult than the last. Equations are given, from which graphs are to be sketched. It is advisable to select expressions from recent lectures; even so, prepare to be disappointed! The first question is a simple introductory example.

PROBLEMS

1 Draw the graph of \( E \) against \( v \) if \( E = hv - W \), where \( h \) and \( W \) are positive constants. How does the graph change if \( h \), and \( W \), are made larger?

2 Sketch graphs of amplitude against time for:
   - a travelling wave \( A(t) = A_0 \cos (kx + (or -)\cos \omega t) \)
   - a standing wave \( A(t) = A_0 \cos kx \cos pt \)
   - a modulated sinusoidal oscillation \( A(t) = A_0 (1+b \cos \omega_1 t) \cos \omega_2 t \)
   - a damped harmonic oscillation \( A(t) = A_0 \exp (-\gamma t) \sin \omega t \)

2 Sketch the graph of the Maxwell Boltzmann distribution \( N(u) = u^2 \exp (-\lambda u^2) \)
   if \( \lambda \) is small and positive. Where is the maximum? Which term dominates at large, and at small values of \( u \)?

3 The equation \( \frac{|V_{out}|}{|V_{in}|} = \frac{1}{\sqrt{(1 + \omega^2 C^2 R^2)}} \) gives the ratio of the amplitudes of output and input voltages, when an alternating voltage, angular frequency \( \omega \), is applied to the RC filter shown. Sketch the variation of the ratio with \( \omega \). How does the curve cut the axis at \( \omega = 0 \)?

4 Sketch curves of amplitude against angular frequency \( \omega \) at various values of \( \omega_0, k \) and \( F \), for forced oscillations given by \( A(\omega) = \frac{F}{\sqrt{(\omega^2 - \omega_0^2)^2 + 4k^2\omega^2}} \)

5 Sketch the variation of intensity \( I_r \) with phase difference \( \delta \) for \( 0 < \delta < 4\pi \), for
\[ r = 0.5 \text{ and } r = 0.9, \text{ in a Fabry-Perot interferometer, for} \]

\[ I_r = I_0 \left( 1 + \frac{4r^2}{(1-r^2)^2} \sin^2 \frac{\delta}{2} \right) \]

which:

9.6.5 USİNG ALGEBRA İN ARGUMENT

It is not trivial to produce a quantitative model of a situation, deciding on assumptions, deciding on variables, and getting an equation between the variables. The problems here use only a few simple ideas, so as to focus on the process of setting up a model. It is possible to put numbers in at the end, but this is not the main aim. However, students in difficulties can be advised to try the problem with numbers to start with, to find first how things fit together. Because answers depend on assumptions, it is probably best if all groups have the same task.

PROBLEMS

1 What is the carrying capacity of a motorway in passengers per unit time, in terms of the speed of vehicles, passengers per vehicle, and number of vehicles per unit distance?

2 Suppose that a city centre is a circle of radius \( r \) , with \( n \) people per unit area working in it. They all commute in and out in rush hours lasting for time \( t \), with \( p \) people per unit time able to cross per metre of the perimeter. How are these variables related? Why is there an upper limit to \( r \) ?

3 As skyscrapers get taller, more of the ground space is used up with lifts and stairs, and with thicker supporting columns. Make some assumptions and:
   - express free ground floor space as a function of height.
   - express free floor space on any floor as a function of its height above the ground.
   - express total free floor space in a skyscraper as a function of its height.

4 The sky is dark at night. If there were a uniform distribution of stars in space extending to infinity, show that this would not be so.

5 What can be deduced about nuclear binding energies from simple facts about nuclei (sizes, numbers of protons and neutrons) and knowledge of electrical forces and of simple wave mechanics?

6 Stellar bodies might be formed by accretion. Suppose matter is stuck on to a rotating sphere. If the angular velocity stayed constant, why would bits fly off again when the sphere reached a certain size? Now argue that the angular velocity will not stay constant.

7 If neutron irradiation produces nucleons of a short-lived isotope, at a rate proportional to the neutron flux and to the number of nucleons
being irradiated, how much of the isotope will there be after a long irradiation?

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9.6.6 THE ART OF NEGLIGENCE

Scientists neglect all sorts of aspects of problems they tackle. They approximate, oversimplify, and idealise situations. The difficulty is to do it enough to make a problem tractable, without making it trivial. The problems suggested ask for lists of approximations or simplifications, and for some statements of their consequences.

PROBLEMS

1 List as many approximations as possible, that are made in using
\[ s = ut + \frac{1}{2} gt^2 \]
to find the time of fall of an object under gravity. Explain why they make the problem easier to solve. Suggest at least one case where the answer would be badly wrong.

2 List approximations made in calculating the amplitude of the alternating current I drawn from a signal generator, voltage \( V \), angular frequency \( \omega \), by a parallel plate capacitor, using \( V/l = 1/\omega C \) and \( C = \varepsilon_o A/d \). What effect on the answer do they have?

3 List approximations and simplifications made in calculating the temperature of the Earth from the temperature of the Sun, using the Stefan radiation law and the inverse square law.

4 List as many ways as possible in which one is idealising in making ordinary calculations of the currents and p.d.’s in a network such as:

![Network Diagram]

9.6.7 FIRST STEPS IN PLANNING AN INVESTIGATION

The idea is to decide what one would do first, in starting an investigation of some phenomenon; noting the relevant theory; deciding on relevant factors; and suggesting where to make a start experimentally. For problems like those suggested, students can be asked to imagine that they will start on it next week, so that they now need to select some first ideas to test, and specify what sort of apparatus they need for that.

It may be desirable to use topics actually used in teaching laboratories.

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PROBLEMS

1 The variation of pressure in a rubber balloon as it is blown up.

2 The size of craters made by dropping hard spheres on dry sand.

3 Ionisation in flames.

4 Condensation of liquid from a vapour, on cold walls of a chamber.

5 Variation of conductivity of a semiconductor with temperature.

6 The strength of glued joints.

9.6.8 DESIGNING AN EXPERIMENT

The problems below involve choosing one of several approaches and also making the design quantitative. Students find the latter difficult, and may not attempt it without prompting. Indeed, a full discussion of one of the problems needs more than a hour, so that it may be best to limit them further.

PROBLEMS

1 Design an experiment for a teaching laboratory, to illustrate Fraunhofer diffraction. It should allow patterns from one slit, and changes as further slits are opened, to be seen, so a slit system large enough to have a moving shutter is wanted. Give a quantitative specification for the components and their spacing and dimensions.

2 Design an electric field deflection system for an oscilloscope tube. Assume that the accelerating voltage is about 2 kV. A 20 mm deflection on the screen is to correspond to a 20 V signal across the deflection plates. Details are wanted of the length, width and spacing of the plates, and their position in the tube.

3 Propose a method to detect the deflection of an electron beam under gravity, and work out whether the deflection will be detectable or not.

4 Design an experiment to measure the slowing down of a rifle bullet by air resistance, considering what precision might be needed to detect any change in speed.
9.6.9 SELECTION OF INSTRUMENTS

There are reasons, sometimes conflicting, for preferring one instrument to another. Two aspects matter: the physics behind the choice, and the balance of arguments about the choice. The whole class can discuss an initial example, listing features of for instance a good ammeter, such as range, sensitivity, resolution, accuracy, low resistance, speed of response, cost, size, robustness, and so on. Then sub-groups can make similar lists for other instruments, being asked to identify all important characteristics, not to design or choose the instrument. The groups are likely to go through a good number of instruments, so it is important to leave plenty of time for reporting back.

PROBLEMS

1 A balance including a set of appropriate weights for:
   weighing coins in a bank.
   dispensing dangerous drugs.
   finding the density of oil used in the Millikan experiment.
   determining the density of air.
   weighing rocks on the Moon, without bringing them back to Earth.
   determining the mass (about 1 g) of balls used in a precision measurement of the acceleration of free fall by timing the fall.
   studying corrosion of metal plates left exposed to a corroding environment for several years.

2 A thermometer for:
   obtaining meteorological records in the U.K.
   identifying organic chemicals by measuring their melting points.
   determining molecular weights by measuring the change in freezing point when a substance is added to solvent.
   measuring the temperature drop when a compressed gas is released into a larger volume.
   measuring the specific heat capacity of diamond.
   measuring the thermal conductivity of silver wire.
   measuring the temperature of the melt in a blast furnace so as to be able to control the temperature automatically.

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9.6.10 THINKING OF ALTERNATIVES

This session is about divergent thinking; about having many and varied ideas, not about analysing each. Such an exercise can seem frivolous if pursued for too long, and it may be worth switching to a closer comparison of some of the alternatives, after a time.

PROBLEMS

How many different ways can you think of to:

1 measure the thickness of tissue paper?
2 measure the height of a tower?
3 estimate, or measure, the weight of a bus?
4 measure the duration of the light from a flash bulb?
5 estimate the energy arriving at the Earth from the Sun?
6 estimate the power of an average car engine?
7 measure the acceleration of free fall?
8 measure the speed of rotation of dentist's drill?
9 estimate, or measure, the rainfall in a week?
10 measure the frequency of the alternating mains?

9.6.11 THINK ABOUT IT FIRST

This session is about looking at a problem as a whole, before starting detailed work on particular aspects of it, so as not to waste time working on false assumptions. It can start with a question from an examples sheet, and proceed in two stages. First, a number of particular queries are raised and noted down. For example, if a question involves an electron beam, what is the beam current or the number of electrons per second?

Second, sub-groups are given these queries to answer, while the final discussion is used to check the answers and see how they affect the whole problem.

The point is that in doing many problems, it is necessary to check first on relevant conditions; on such things as whether flow can be assumed to be streamline, whether an effect is in a linear region, whether an effect is negligible, and so on.
9.6.12 WHAT IS THE PRINCIPLE?

It is often hard for students to say what basic principles are involved in something, so that they may give every possible detail, or none at all. The phrase itself seems clear, but very possibly is not. So the task in this session is to analyse phenomena not for the details, but for the basic principles which govern them. Much of the final discussion may need to distinguish principles which are more or are less basic.

PROBLEMS

What physical principles are involved in:

1. the action of a diffraction grating?
2. the Geiger-Marsden experiment, and Rutherford's inferences from it?
3. measuring the Planck constant using the photo-electric electric effect; using electron diffraction?
4. explaining the binding energy of a nucleus?
5. the working of a mass spectrometer?
6. driving cars fast but safely round corners?
7. going to the Moon?
8. the efficiency of a nuclear power station?
9. the working of a powerful electromagnet?
10. a very high vacuum system for an accelerator?

9.6.13 WHEN IS IT TRUE? *

Each group is given a law or laws to discuss, and is asked to produce three statements for each:
what does the law say is generally true?
what circumstances can alter, and the law still be true?
what circumstances invalidate the law, or make it true only with qualifications?

It is useful to start with an example discussed with the whole class.

PROBLEMS

1 Ohm's law.
2 Hooke's law.
3 The laws of electromagnetic induction.
4 The Lorentz transformations.
5 The mass-energy relation.
6 Newton's laws of motion.
7 The uncertainty principle.
8 The inverse square law for gravitation.
9 The inverse square law for electric charge.
10 The inverse square law for a source of light.
11 The gas laws.
12 Conservation of energy.
13 Conservation of momentum.
14 The Boltzmann factor.

9.6.14 WHAT ARE THE RELEVANT VARIABLES?

The task here is to take a phenomenon, and decide, using common sense and simple physical or dimensional arguments, what physical quantities determine the effect, not forgetting those which might do, but in fact do not. The aim is to practice simple verbal physical reasoning.

PROBLEMS

1 The speed of big waves out at sea.
2 The frequency of oscillation of water slopping (in the tilting mode) in a shallow tray.
3 The speed at which a rotating flywheel is torn apart.
4 The time of contact of a golf ball with a golf club.
5 The power that can be obtained from a dynamo.
6 The frequency of oscillation of a steel strip clamped at one end.
7 The radius at which a glass plate bent in a curve snaps.
8 The brightness of a television screen.

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9.6.15 SPOTTING THE FALLACY

Arguments (not least in examination answers) go wrong for several reasons, including: defining a symbol one way and using it differently.

- treating a variable as constant.
- treating a vector as a scalar.
- applying a principle when it does not apply.
- making an assumption and then violating it.
- treating coupled quantities as independent.
- ignoring a relevant effect.
- having a physical quantity equal to unity, and losing it.

Some of these can be introduced, perhaps with examples from recent work. Sub-groups can then be given written arguments containing fallacies, and be asked to identify them. It is best that all groups have the same material, and look at all the examples, even if they cannot do some.

PROBLEMS

1 If the charge \( CV \) on the dome of an electrostatic generator is connected to earth through a resistance \( R \), the current is \( V/R \) and so the charge will be gone in a time

\[ t = \frac{CV}{R} = RC \]

charge will be gone in a time

2 The force on a charged particle moving at right angles to a magnetic field is \( F = BqV \) because:

- the force on a current element, \( F = BI \delta l \)
- the current, \( I = \delta q/\delta t \)
- force
  \[ F = B(\delta q/\delta t) \delta l \]
  \[ F = Bq(\delta l/\delta \tau) \]

\[ F = BqV \]

3 The electric field at point \( P \), due to equal and opposite charges \( +q \) and \( -q \) is

\[ +q/4\pi\epsilon_0 \ r^2 - q/4\pi\epsilon_0 \ r^2 = 0 \]

Similarly, the potential is zero, so that \( E = -\text{grad}V = 0 \).

4 Resistance to the motion of a satellite in a circular orbit reduces the kinetic energy \( T = \frac{1}{2} m v^2 \), and so the speed \( V \). The angular momentum \( J = mvr \) is conserved, so as \( v \) decreases, the radius gradually increases.

5 Since the resolving power of a grating is equal to \( Nn \), the resolution of a spectroscope can be made as large as required by using a grating with the lines ruled more closely.
The Emperor of China refuses to be measured. So $10^8$ Chinamen were asked to guess his height. Their estimates varied from 1.5 m to 1.9 m, the mean being 1.71322 with a standard deviation of about 0.1 m. The standard error of the mean is smaller by the square root of the number of observations, so this method gives the height of the emperor to a precision of 10 microns. (What happens if he has his hair cut?)

REFERENCES

The first reference below describes skill sessions. The others contain questions which may be useful in developing one's own material for sessions.


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10. Preparation and tutorkit

10.1 INTRODUCTION

This chapter contains a number of ideas for tutorials which are prepared in various ways. As the episodes of chapter 3 show, preparation is no panacea. However, it can reduce the range and variety of the challenges to which a tutor has to react on the spot, allowing some decisions to be made more calmly and not under pressure of time.

There are different kinds of preparation:

- a thought out routine or method of working.
- prepared content for the tutorial.
- students prepared with set pieces of work.
- negotiation about a method of working or an agenda.

Sections 10.2 to 10.4 discuss aspects of preparing individual tutorials. Section 10.5 considers strategies of combining different kinds of tutorial in a suitable sequence. Section 10.6 considers how discussion can be prepared. Finally, section 10.7 contains a number of outlines for prepared tutorials; a kit of parts for tutors.

10.2 THE TUTOR IS PREPARED

In some sense a tutor is always prepared for helping with lectures. He has knowledge, experience and understanding of physics. But he also needs to know as much as he can about the students’ course: timetable, syllabus, lecture notes, problem sheets, textbooks, laboratory programme, assessment methods, examination questions, and so on. The point is obvious, but under pressure of work it is often difficult to assemble the information and keep it up to date. It is useful if such things as course textbooks can be to hand in the tutorial room, and if students regularly bring their lecture notes.
With the co-operation of colleagues, it is possible to be more systematic. In one large department, lecturers have issued tutors with short questions for discussion, which focus on key features of their recent lectures. A set of multiple choice questions can serve a similar purpose, and can perhaps scan a wider range of difficulties (see 10.7.1). Often, the problems exposed will outrun the time available, and a tutor can usefully be prepared with references which are particularly good on specific topics (see 10.7.2).

10.3 PREPARED PHYSICS

Besides being prepared for reacting on the spot, a tutor can have prepared content or routines.

One such might be to put a physical situation to the group, and to ask them to list all the issues in physics which might be relevant to it (see 10.7.3). The purpose of this idea might be to help students see how diverse is the range of ideas involved in any concrete example. The way the issues fit into the structure of courses and topics can also be brought out. This sort of idea involves three things: a thought out aim; a way of organising the work; and a particular problem or example.

Similar outlines (see 10.7.4, 10.7.5) are concerned with looking at broader aspects of solving problems and with helping students to think back to fundamental ideas. It is equally possible to use prepared content with more modest and explicit aims: for example, exponential growth and decay in different areas in physics.

Prepared outlines of this kind could be of help to tutors in indicating an approach which they might adopt in working out ideas of their own for prepared tutorials. Experience so far suggests that tutors have no shortage of good ideas but that preparing workable plans is not so easy. Some rules for workable plans are worth suggesting. One simple rule is that the general idea must be worked out in detail: 'Modelling in physics' might be a good initial idea, but, 'Select three examples of models from this term's courses and list features of reality which they (a) emphasise, (b) ignore', can be more helpful because it is nearer to being an actual tutorial activity. This leads to a second rule: that planning is not complete until the gap between vague aspiration and definite things to do has been spanned. This is difficult to do, but a carefully chosen explicit task to start a group thinking and talking is essential to success.
A third rule is that the difficulty is such that collaboration with colleagues in developing ideas is often the best, and may be the only, method. A final rule is that a procedure is needed as well as a topic or problem. Thus one tutor might succeed by stating the task clearly but briefly, getting students to work together whilst he goes away for ten minutes, making them explain their answers on his return, and then basing a discussion on the needs and difficulties that have arisen. The same task, read direct to a group and followed immediately by, 'Any ideas... Come on, somebody start', might achieve rather less. Detail is important, and cannot lightly be changed.

10.4 PREPARATION TO HELP STUDY

It is also possible to organise tutorials in order to help students with their study in general, rather than to clarify some aspect of the subject. Examples of such outlines include short talks by students (10.7.6), essays (10.7.7), examination answers (10.7.8), lecture notes (10.7.9), using the library (10.7.10), learning from books (10.7.11), and putting the laboratory in context (10.7.12).

On topics such as these a general discussion is ineffective. For the student, the generalisations need to be translated into specific examples relevant to his own work. For the tutor, there is a need to make sure that his views are realistic. For both reasons, all of the outlines in this group start from samples of students' own work, so that thinking about it, and getting comments from other students as well as from the tutor, can help to develop self criticism and broaden the approach to work.

Of course, suggestions such as that students should give prepared talks, or that a tutor should discuss examination answers, are hardly novel. However aspects of the way they are done are: for example, the collection and circulation of sample notes and comparison of them with the lecturer's own notes.

10.5 A TUTORIAL STRATEGY

Equipped with a variety of workable ideas for running tutorials to serve various aims, a tutor is then in a position to think also of a long-term plan to encompass a whole series of tutorials. No general strategy for all circumstances can be offered because of the differences between tutors and contexts. However, two brief examples will illustrate the idea.
The first example is for tutorials in the first term for first year students, in a department where the tutorial is designed to support all of the lecture course work, with a tutor seeing a group of four students for an hour each week, and in which separate problem classes meet some of the need to work on problem sheets and matters closely related to the lecture courses. The topics planned for the tutorials in ten successive weeks could be:

**Week 1**

**IT'S ALL HAPPENING (10.7.3):** to get students talking about something definite (not social chat), to arouse interest, and to introduce the aims of the course as a whole.

**Weeks 2 and 3**

**WORK ON LECTURES (10.7.13):** to emphasise early the need to work on and keep up with courses.

**Week 4**

**MAKING EFFECTIVE NOTES (10.7.9):** a first priority, working on notes taken in the second and third weeks, with a deliberate gap so that students have to rely more on the notes than on immediate memory.

**Weeks 5 and 6**

**WORK ON LECTURES (10.7.13):** to keep up momentum.

**Week 7**

**SHORT TALKS BY STUDENTS (10.7.6):** on topics covering main issues from courses, to get thinking going about general themes rather than detail. Essays (10.7.7) might serve a similar purpose.

**Weeks 8 and 9**

**WORK ON LECTURES (10.7.13)**

**Week 10**

**EXAMINATION ANSWERS (10.7.8):** prior to an end of term examination, to discuss samples of answers, taken from previous years.

As soon as an overall plan is mapped out, it is clear that the task of helping students keep

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pace with, and locate and clarify difficulties in lecture courses has to play a large part. The tutorial discussion needs to be effective for this purpose. In addition to the brief remarks in section 10.2, ways in which organising such discussion may be tackled systematically are outlined in 10.7.13.

The second example is a sequence which was used with final year students who had one tutorial a week with a tutor whose job was to help with the nuclear physics part of the courses.

Week 1

IT'S ALL HAPPENING (10.7.1): to revive thinking after the long vacation; to emphasise the overview of the final year; to get to know a new group.

Week 2

ORDER OF MAGNITUDE ESTIMATES (9.6.1): to start the group working together; also of general value besides being relevant to questions in one of the finals papers.

Week 3

SHORT TALKS BY STUDENTS (10. 7.6): on two selected original papers on a topic involving the physics of the course. Students were asked both to discuss the ideas (which they did well) and to criticise the style of presentation (which they did not do well). The exercise was put here partly because an assessed essay was looming.

Weeks 4, 5, and 6

WORK ON LECTURES (10.7.13): students being given questions from past examination papers beforehand.

Weeks 7 and 8

SHORT TALKS BY STUDENTS (10.7.6): this time on laboratory work, meant to help students talk about the way laboratory work fitted with lectures.

Week 9

WORK ON LECTURES (10. 7. 13): an unseen problem prepared by the tutor on a course which a meeting between tutors had shown was giving general difficulty.

The strategies differ, as they should. But they have in common an attempt to do justice to a variety of needs, and to strike a balance between short-term and long-term help. A good strategy will allow students some say too: for example, the students in the above example turned down an offer of a tutorial on the use of the library (10.7.10) intended to help with their essays.
A danger inherent in carefully prepared work is that the students may feel that
the tutorial does not belong to them, so that, not feeling able to put their own
needs on to the agenda, they will not feel responsible for the work, however
interesting and well thought out the exercises are. And yet responsibility for
one’s own work is an important aim which ought not to be missed. Too narrow
an interpretation of the notion of a strategy in section 10.5 could make matters
worse rather than better. There can only be responsibility with choice, so any
planning ought to be discussed with students and modified if necessary; not a
fixed menu, but at least a la carte, and possibly just a larder full of ingredients.

Another way of enhancing responsibility that has been tried is to ask
students to divide amongst themselves the task of reporting to the group on
progress in courses, coming prepared with a brief survey of the main ideas
together with steps in it that have given difficulty. Students then began to talk
responsibly about organising this work, and did not fail to produce it. The tutor
was helped both by the list of topics produced, and by seeing how students saw
them. Ways of organising discussion of this kind are suggested in 10.7.14.

Each tutor has to work out for himself what style of leadership is
appropriate for him and his students, and what aims he wishes to pursue. The
ideas proposed in this chapter should be regarded as a kit of tools: tools which
can be used as needed, but tools which may also alter the craftsman’s view of
the way the job should be done, and even of the type of job he might try to do in
future.

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10.7 TUTORKIT: OUTLINES FOR TUTORIALS

This section consists of a series of outlines for tutorials:

1. MULTIPLE CHOICE QUESTIONS
2. REFERENCES
3. IT'S ALL HAPPENING
4. MAKE THE EQUATIONS TALK
5. THINKING BACK TO FUNDAMENTALS
6. SHORT TALKS BY STUDENTS
7. ESSAYS
8. EXAMINATION ANSWERS
9. MAKING EFFECTIVE NOTES
10. USING THE LIBRARY
11. LEARNING FROM BOOKS
12. PUTTING THE LABORATORY IN CONTEXT
13. HELPING WITH LECTURES
14. SYSTEMATIC DISCUSSION

All the ideas suggested have been tried by physics tutors, and modified as a result. Space prevents all their ideas being included, so the outlines here are just starting points. Tutoring being necessarily an individual affair, that may be all that it is profitable to offer.

The outlines fall into three groups:

1 to 5, which are mainly prepared content.
6 to 12, which are mainly to do with studying.
13 and 14, which are about structuring discussion.

There is no sharp distinction between material here, and skill session material in chapter 9. Skill sessions can be used as material for ordinary tutorial work (though not in the same format), and some tutorkit material could be adapted to skill sessions, by producing suitable tasks (5 and 9 might be examples).
10.7.1 MULTIPLE CHOICE QUESTIONS

Tutorial discussion based on multiple choice questions has a number of advantages:

- a considerable number of topics can be covered.
- topics which do not need attention are passed over quickly.
- the questions can raise issues which might not arise spontaneously, by containing unusual options.
- disagreement between students is brought out clearly by their choice of different answers, so promoting immediate discussion.

A set of suitable questions is needed. Ten or more can be covered in an hour. The technical quality of the questions is not critical, as discussion of ambiguities can be very useful.

Being quick to read, and needing no time to write an answer, a sheet of questions can be given out in the tutorial and done on the spot. Each student is asked to pick an answer, and the tutor goes round the group asking what each chose. If everyone agrees the group can pass to the next question.

Disagreements need to be resolved, starting by asking each student to explain his choice, without revealing the answer the tutor prefers. Very different kinds of problem emerge:

- trivial slips, cleared up quickly.
- not understanding the question, helped by asking for it to be put in another way.
- particular terms not understood, which can then be talked about.
- ideas or topics not understood at all, which may lead to planning a longer future session, or suggesting further work.

Variations can include setting the questions beforehand and basing discussion on questions wrongly answered. More taxing, and allowing much less coverage, is to invite students each to write a multiple choice question. This can be very revealing, but does take a long time in discussion.

In common with other written materials, such questions have the advantage that time to think about them is naturally needed, so that silent pauses for thought are not uncomfortable - as much as half a minute is a quite tolerable silence. With a large group, it may be advisable to divide it into smaller groups.
Every tutor carries in his head books which deal well with particular topics. Just because the tutorial cannot deal with every issue that arises, such references are important. It might be useful to have a more systematic supply, to supplement personal knowledge, not least so as to encourage the notion that a tutor cannot possibly be a source of instant lecturing on any topic.

It is suggested that tutors make out cards with annotated references for areas of special difficulty. This could be done individually, or cooperatively; the latter having the advantage of sharing tutors’ experience of areas of difficulty. Cards could usefully include space for students’ comments: they do not always find references as helpful as expected.

SAMPLE CARD

Complex numbers and a.c. circuits


pp 17-29 : individual study treatment of complex numbers, Argand diagram, $e^{i\theta}$, de Moivre’s theorem. Good examples and diagnostic questions.


Standard treatment like 1. Use sections 7.1 to 7.4.


Appendix A2.2 on sinusoids in circuits elements; A2.3 does $e^{j\omega t}$; A2.4 complex impedance; A2.5 vector representation.

STUDENTS’ COMMENTS

Topics collected from tutors included:

- scalar and vector products.
- scalar and vector fields; div, grad, curl; potential.
- line and surface integrals.
- angular momentum.
- integrating second order differential equations.
- Fourier series.
- wave equations.
wave groups; Fourier integral; phase and group velocity. complex numbers and a.c. circuits.

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Probability distributions, discrete and continuous.
meaning of a wave function; Schrödinger equation.
operators, eigenvalues, eigenfunctions.
orthogonality, normalisation, degeneracy.
cavity radiation.
parity, exchange symmetry.
symmetry in using Gauss' theorem, Ampere's law.
first law of thermodynamics.
reversible and irreversible changes.
functions of state; perfect and imperfect differentials.
statistical and macroscopic views of entropy.
free energy, Gibbs' function.
quantum numbers and spectroscopic notation.
reciprocal space.
noise and statistics.
equivalent circuits of active elements.
Fourier transform.

10.7.3 IT'S ALL HAPPENING

Lecture courses seem to present physics as in separate compartments, but any real process involves ideas from many parts of physics. This can be brought out, and students given the chance to think across topics by a simple exercise, which at the same time yields a lot of material for discussion.

For example, a circuit can be drawn on the board:

Then students are left alone for ten minutes, having been asked to list everything they can think of that is happening after the switch is closed. They are told to put down all the ideas, topics, and problems that would be involved in describing all the physics of what is going on. It is emphasised that they need not know about what they put down; it is just a knowledge shopping list.

After ten minutes, the tutor gets the lists read out, and can then add to the list, organise items on it, or discuss any one issue raised. The last usually adds further things to the list. The variety of issues can be remarkable: here including current growth, exponentials, capacitance, charge conservation, Kirchoff's laws, electrons in metals, magnetic fields, induction, displacement current, and energy conservation.
Suitable problems will depend on the stage students are at, the above example having been used with first year students at the start of the year, to get them talking, and show them that they knew more than they may have thought. As a rule, problems should be simple and concrete.

One valuable use of the idea is to provide an overview of coming courses, with the tutor showing how the items fit into the various topics in the programme.

A variation might be called, WHAT DO I KNOW? Students are paired off, given a topic, one to tell the other anything he can think of that he knows about it in five minutes. The second is told to listen and make notes, but not interrupt except to ask again, ‘What do you know about that?’ Then the roles are reversed, with a new topic. At this stage, the tutor merely calls time, and does not join in. A discussion can then be built around collecting two lists from the whole group: things most know and important things some or all do not know, and what can or must be done about them.

10.7.4 MAKE THE EQUATIONS TALK *

The equations, from which the solution to a problem are obtained, have much to say. They contain information about the whole class of similar problems, about important qualitative features of that class, about its physical interpretation, about interesting limiting cases, and so on.

Too often, all this information remains hidden. If the problem asks for a numerical result, the student obtains but one value out of a whole set which has interesting properties. More may be got out of a problem such as,

'At what angle will a thermal neutron undergo a first-order Bragg reflection from atomic planes of spacing 0.314 nm?'

by starting instead from the physical system in question--here a crystal diffracting thermal neutrons--and asking:

what questions of interest might be asked about this system?

picking one; what can be said qualitatively about the problem?

* Idea taken from a paper by Noah Lerman. See the references at the end of chapter 9.

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what are all the variables?
what are the equations, and what is their solution?
what is the nature of the solution, what graphs can be drawn to display it, and what physical interpretation can be given?
what related problems are there, and what might their solutions look like?

Suppose that in the example it is proposed to look into the relation of diffraction angle and neutron temperature, having usefully canvassed other possibilities.

The next, qualitative step, is what the question setter usually does in private. Such things as the link between temperature, kinetic energy, and so to momentum via mass can emerge. The need to ask whether the spread of speeds matters could arise. Such a discussion makes it harder for absurd answers to go unnoticed later, and emphasises physical insight.

Setting up the variables continues from the last stage, but it becomes necessary to ask which are the best ones to choose - here, is momentum best expressed in terms of speed or energy? The equations then follow, and can be solved, this being the step that is often all the student does in a conventional problem.

Discussing the nature of the solution can be the most valuable step. After inserting numbers, and a dimensional check, it is worth sketching graphs of the relationships revealed. In the example, $\sin \theta$ can be plotted against temperature, for various spacings, and for masses of other particles besides neutrons:

![Graphs](image-url)
The answer to the original problem is the single point marked: on the first graph; the answer here is a family of curves. Such things as the small importance of changes of temperature except at low temperatures, become visible. Limiting cases, such as $T \to 0$ are worth looking into and explaining, and other problems such as what happens when $\sin \theta$ becomes unity arise.

Related problems, such as the spread in angle because of the spread in speeds, can readily emerge, and again demand physical thought. This puts the problem in a larger context, and can develop intuition and insight.

The example is not a special one. A great many others lend themselves to the same treatment.

10.7.5 THINKING BACK TO FUNDAMENTALS

'Show how, from first principles... ?'

'What fundamental physical principles are involved in... ?'

Such phrases appear in examination questions, not least because it is part of the beauty of physics that so much comes from so little. But much of the difficulty of the subject has the same source, and questions like these are not easy.

It is not easy for a student to know what counts as fundamental. So the suggestion is to invent a situation in which it might be reasonable to want to write down just the fundamental ideas for some topic. One such might be a book to go on a space-ship, so that later generations on a distant planet could reconstruct it all for themselves. Another might be a physicist about to be shipwrecked, hastily collecting books so as to be able to go on doing physics alone on a desert island.

The question then becomes, what is the minimum it would be essential to have so as to be able to deduce the rest? Topics might be:

- alpha particle scattering.
- hydrogen energy levels.
- relativistic dynamics.
- resonance.
- rotational motion.
- electromagnetic waves.
A simple example, such as the topic ‘free fall’, can introduce the idea, in which equations like \( s = \frac{1}{2} gt^2 \) would not be needed, being derivative, but a value of \( g \), or better \( F = GMm/r^2 \) and associated things, would be.

The group can first be asked to write down any ideas that occur to them, fundamental or not, leaving them alone for ten minutes to do so. Then the ideas can be collected, and the tutor can help assemble them on the blackboard in sets which are fundamental, derived, are raw data, and so on.

It will be found that students confuse facts, laws, and theories, and the value of the exercise lies in debating where to put items. Lists will be incomplete, but the discussion can produce missing items.

10.7.6 SHORT TALKS BY STUDENTS

There is nothing new in the idea of asking students to give talks in tutorials. The value of it is obvious and varied, including:

- researching a topic from original papers.
- contact with unusual, exciting or modern topics.
- preparing for oral or seminar work; learning to communicate.
- seeing subject matter in a wider context.
- personal involvement in a topic.

There are several things the tutor needs to look after if the exercise is to be a success. The first rule is to discuss with the group the point of doing it, and negotiate what is expected, what time and resources are needed, and how help can be got. Students' willing cooperation is essential, and can only be had by involving them in the planning.

Amongst things to be discussed are the quality and level of talk expected. Talks to be addressed to fellow students need to be very different from talks designed to show the tutor how much one knows, so the aim must be clear. Preparation time needs to be realistically assessed, and it is particularly important to ensure that references are both accessible and intelligible. While original papers can be used with final year students, sources such as Scientific American, Endeavour, Contemporary, Physics, and New Scientist, are often better starting points for first year students. Overall, it is important to remember that students cannot usually just be given topic and references, and be expected

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to cope. Particularly helpful is a brief meeting with the tutor before the talk, at which obvious problems in the student's plan can be ironed out.

In one department, first year students were on one occasion given a free choice of topic. They commented on the way this led them to look through a good deal of the literature. It had the disadvantage that a student could choose an unsuitable topic: either one too hard, or one lacking in detail to discuss. Advice about the choice would seem desirable.

On a second occasion, topics were selected from a list, deliberately related to current courses, including laser fusion, acoustic holography, fibre optics, and the Mössbauer effect, all of which worked well. Not all did: an article on linear induction motors lacked detail, while books on low temperatures contained too much for the time available. Others like wave-particle duality, particle accelerators, and nuclear reactors, tended to be too broad in scope. Perhaps the best topics were those, like the Mössbauer effect, which begin with simple ideas but are nevertheless thought-provoking.

10.7.7 ESSAYS

Like talks, essay writing scarcely belongs to the new ideas department. These notes concern ways in which a tutor could help students to see what is involved, and how they could improve their writing.

What, if anything, the tutor can do will depend on the context: on the role of essays; their assessment; their length, and so on. Not all the ideas here apply to every context, and nor will group discussion always be the best way to help.

Some help can be given by a prior discussion, about such things as planning, reading, depth, different approaches, identifying key issues, structure, and the extent to which the essay can be personal. The value of such prior discussion, especially if led by the tutor, is limited in that inexperienced students make much less sense of it than is hoped. They may not, for example, share the tutor's clear idea of 'structure' in an essay. It may be best to start by getting students to make their own list of what is important in an essay: at least the discussion then starts from their ideas, which may surprise the tutor. Most such points, however, will only be appreciated with experience, and more valuable work can probably be done on samples of actual essays.
More help can be given if essays are discussed in draft. It helps here if, as is sometimes done, the final essay for assessment is a rewritten version of a first attempt. The tutor then has something concrete to talk about, and advice is decoupled from assessment. If essays are being written solely for the tutor, this device can often be introduced. It is important to remember that essays may only be able to be discussed if they are not too long.

When it is possible to discuss actual essays, the difficulty is to get at the large and important issues and yet keep the discussion in focus.

One way of doing this is to select passages from essays which bring out particular issues that seem important, such as the introductions, or examples of varying style, and have just these read and discussed in the tutorial.

Having said what the issue is, the passages are passed round and read by every student, allowing around 15 minutes for this silent reading. As they read, students are asked to jot down notable differences and similarities between the passages. Each ends up with his own work, and discussion can start by asking for each to offer some criticism of it.

One specific example of the use of the method concerned the introductions to essays, which the tutor felt to be the weakest point. Asked if they knew what the essay would then be about, and what kind of thing it would say, students could see ways in which the introductions failed.

Another example concerned summaries: it emerged that not all summaries said clearly what the writer's view was, even when the essay title had been a question.

The audience for the essay was a further issue, explored by asking students to guess for whom the passages were written, or who would understand them. It emerged that essays were inconsistent, switching levels, and at least exposed the problem of writing for a particular audience in the artificial situation of the set essay.

Again, structure can be looked at. Here students were asked to skim each essay quickly, and just note the names of things dealt with, and their sequence. Apart from lack of structure, much of what there was turned out to derive from the references used, because the writer lacked an overall view of his own.

Finally, even style can be discussed by getting the group to try to say why they found
selected passages attractive and clear, or not. Questions like, are sentences
definite with one thing to say?, do the important things stand out?, are the
connections clear?, is the right word for the job used?, and so on, can be
brought out. A good exercise is to ask the writer to say aloud what he meant,
which he usually does much better. Then a written version of what he has just
said can be put on the blackboard, and compared with what he originally wrote.

10.7.8 EXAMINATION ANSWERS

Students never see anyone else's examination answers, nor, given the pressure
on their attention, are they likely to recall much about the processes by which
they arrived at their own. Advice about examination technique thus tends to
lack concrete reference, and may, if it presupposes an unrealistic standard,
increase anxiety.

A tutorial discussion of sample answers is therefore suggested. If the
discussion comes before the examination, samples can be taken from previous
years, or be concocted by putting together characteristics of several answers. If
real answers are used, anonymity must be preserved by having the answer typed
and by removing all identification. The answers should be taken from amongst
fairly good and fairly poor ones (not excellent or disastrous ones) so as to
represent a normal range of actual achievement. Mongrel answers should
represent a similar range.

If the tutorial follows an examination, work of students in the group
could be used, with their consent.

First, give the group copies of the question, and allow time for them to
compile a check list of the things that ought to go into an answer. Explain that
you do not want the answer, but things like, 'a description of...', 'a proof of...,'
and more detailed things like, 'give the approximations'.

Then distribute copies of, say, two answers, and ask each student to
decide which is the better. It may be necessary to dissuade them from working
through the answers in detail; a decision ought to be possible on the general
level and extent of the answers. There may be a need to discuss anomalies: it is
best to let students persuade one another.

Then one can go on to a detailed comparison of the answers, perhaps
again getting lists first to be talked about afterwards, asking:

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what is present in the less good answers, that still deserves credit?

what is missing, even from the better answers?

what are the main differences between them?

Finally, it is only fair to say that the answers were about midway in the better and worse halves of all answers, and to remind the group that few people can bring out all they know in an examination.

In choosing or concocting sample answers, it is best to avoid too much incorrect physics (tempting though that is), and to select them for features like muddled presentation, half finished arguments, misinterpretations, and so on. A good-looking answer which in fact does not answer the question may be useful, and may go undetected for some time in the discussion.

The initial check list, before answers are looked at, is important: otherwise students tend to dive into detail without this framework to go by. Even so, it is necessary to encourage them to use the check list.

10.7.9 MAKING EFFECTIVE NOTES

Suggestions here are directed to using small group discussion to make students, and perhaps the tutor, more aware of the problems of making effective notes. Practice will be the main source of learning, but a little critical self-awareness could help.

It could be argued that the problem is not one for students, but for lecturers; that good lectures yield good notes. Indeed, the exercises here may point to some deficiencies in lecturing. But in real life, students do have to cope with middling lectures, and, more important, what they attend to may not be just what the lecturer emphasises, however well he does it.

In one department, students made carbon copy notes, which the tutor collected and then discussed. What emerged was the selective nature of what students chose to record. Items high on the list below tended to be present, while items low on the list did not:

- equations, diagrams
- approximations
reasons for steps between equations
relevant physical principles
meaning of new symbols
overall structure of argument
examples of applications
relationships with other ideas
historical comments
demonstrations

Discussion of the notes suggested that students often had a 'blow by blow' grasp of the argument, but not of its general nature, direction, or motivation. Where this is so, it must be hard for them to take the necessary decisions about what to select for attention, and how to give their notes structure. Lecturers can be encouraged to give general organising comments; students may need to be persuaded to listen to them.

It seems better to base discussion on specific activities, so as to get at general points by example. One such is to get the group to pick out from notes all the symbols they cannot immediately identify. Another is to choose a step in an argument, and ask why the second line follows from the first. Some are obvious and some are not; perhaps the latter should be noted. Other things such as approximations or boundary conditions can be dealt with in the same way.

The general structure of the argument can be got at by asking the group to suggest headlines for sections of notes: titles which say what the next part is about. Give examples like:

'A consequence of the postulates'

'An experiment which confirms the consequence'

It may be useful to pick out terms from a text book dealing with the same ideas (for example, 'hamiltonian' or 'operator') and ask for an explanation of them which another student could understand. Terms not understood are often not noted, or later get written down without thought.

Students will rightly object that there is no time to note everything. The issue can be confronted by playing back a few minutes of a tape recording of a lecture of which they have notes. Play it several times, asking for different things, such as items missed, items rightly ignored, or important things there was no time to get down.
Books and notes might as well be complementary. Another exercise
could be to compare notes with the relevant pages of a book, and talk about the
differences. How ought they to differ?

Note taking can also be discussed as part of ordinary tutorial work.
When a detailed topic arises, the tutor can appoint one or two students as note-
takers, asking the rest to put pens aside and join in. Then copy the notes for the
next meeting, and spend time discussing them: points not made clear or left out,
for example. It is only fair to let the writer begin the criticism. Afterwards
another student could be asked to produce a final version for everyone.

It is worth pointing out that this tactic could improve discussion too.
Nobody can both talk and write, so if all make notes, the tutor soon finds
himself giving a monologue.

Not all these ideas can be used at one time, but one or two selected on
occasion might be worth trying.

10.7.10 USING THE LIBRARY

The library exercise, part of which appears on the next page, was developed for
tutorial use with first year students of engineering by Dr R.G. Bennetts of the
Department of Electronics, University of Southampton.

The exercise takes students into the library, and shows them how to find
what they want. It takes the form of a questionnaire asking for information of
various kinds. It took 1.5 to 2 hours. Obviously the example needs modifying
for other subjects and libraries.

Besides asking for authors, titles, and classmarks, the questions included
some about newspapers and general periodicals, which seems a feature worth
retaining. The author also included references to one or two of his own
publications, which must have added interest to the work.

There is, of course, no obvious reason why tutorial time should be used
for such an exercise, and a department which wished to could deal with it in
other ways. On the other hand, it is just the flexibility of tutorial teaching which
makes this kind of enterprise possible.

Another time when such an exercise might be worth doing would be
when major projects are just beginning.
INFORMATION RETRIEVAL EXERCISE

BOOKS

Where are Latin dictionaries kept? Level 4.. Case 7...
For Jackson, 'Neither fish, flesh, fowl, or good red herring' what is the classmark, LF809.. and author's initials J A. ?
For J.H.Simpson and R.S.Richards 'Junction transistors' what is the classmark.TK809 and the title of chapter 5 Low frequency equivalent circuits..............

NEWSPAPERS

Where is the International Herald Tribune kept Level 4..

BOUND PERIODICALS

Who wrote the article on page 84 of I.E.E. Electronics Letters, vol.8, no.24, Feb. 1974 R G Bennetts.. ?

CURRENT PERIODICALS

Find the authors and titles of the articles on:
page 284 of Antiquity, vol.67, no.100, 1973
Author E J Kane Title Review of Current sonic boom studies..
Author K Harrison Title The primitive Anglo Saxon calendar..

CONFERENCE PROCEEDINGS

What is the classmark of the proceedings of the Conference on the Mechanics of European Economic Integration, Reading 1967?.. .................................................................

Does the library have the I.E.E.E Computer Society International Symposium on fault-tolerant computing.. no.. ?
If not, how would they get it International lending library office.. ?

ABSTRACTS
Find in INSPEC Computer and Control Abstracts, vol.6, for the paper with reference 1-20097 the following:
Author ..R.G.Bennetts.. Title ..Switching Theory Part 2..?
Journal ..Design Electronics... Year ..1971... ?

GENERAL

What is short loan........................................?
What is restricted loan ..................................?
What may you have Xerox copies of .......................
Do you need written authority .......................?
Cost.......?

-----------------------------------------------

page 179
Chapter 7, section 7.5, looked at some of the reasons why students find learning from books a non-trivial matter, quite apart from difficulties with the subject matter. The suggestions below can be incorporated into the course of ordinary tutorial teaching, whenever there is occasion to consult a text book. Obviously, the tutor needs to know the recommended course texts and to have them to hand.

The point of the suggestions is not to 'train' in using books, but to help students to see what the difficulties are, and that everyone has them, so that confidence is built up a little.

The natural starting point is a discussion of the problems of getting the sense of a paragraph or so. The group can be left for some minutes to read the paragraph, and write down any problems they have in reading it. (That there are problems can be brought out by first reading aloud a few lines from a newspaper.) For example:

'The calculation of the $x$-component of the dipole moment matrix element (10-31) is intimately related to the already familiar calculation of the expectation value, using Postulate V, for the case where the system is in a superposition of pure states $\psi_m$ and $\psi_r$. As a simple example..........................................'

Such a passage contains many technical terms; refers to other parts of the book explicitly and implicitly; uses symbols; assumes that some ideas are understood, and so on. It can easily provide material for 20 minutes of discussion, which may best be planned for the end of the tutorial so as not to take over the whole time.

The discussion can usefully come down to a single sentence, asking each student to rewrite it in his own words, and then to say what it means. This can reveal how active a process reading is: that the reader does not 'take in' the text, but remoulds it to fit what he expects or knows. Such misunderstandings commonly show up when a sentence later on fails to make sense, so that the need to cross-check can be brought out. This is the more necessary because of the compactness of scientific writing.

Graphs and diagrams are worth talking about, getting students to say aloud what they convey.

Finally, words used in special ways (like 'pure' above) are worth attention. What is the writer conveying by using them?
A tutor may be able to help students see more of the relationship of laboratory work to the rest of his courses, either by taking an experiment all have done (easier in later years) and asking for all the bits of physics that are relevant to it, whether or not they are its main point, or by starting from some general principle, and asking what collection of facts makes it reasonable to suppose that it is true (or at least, not yet shown to be false).

The first is akin to IT'S ALL HAPPENING (10.7.3). Lists of all relevant bits of physics can be asked for, collected, and collated. The discussion can touch on problems of design, on side effects which may or may not be negligible, and so on. A way to round it off is to ask: 'Suppose someone who knew no physics wanted to build the apparatus and do the experiment, understanding it all. What would we have to teach him?'. Another is to write down all the tasks a technician would have to do so as to make the experiment work - thus bringing out precautions and the organisation of collecting data.

The second can begin from something like, 'force is mass times acceleration', asking where it comes from. Can it be deduced? If so, from what? Where does that come from? Ultimately, what appeal to experiment must be made? What experiments would be needed? How would one set about really doing them? The discussion could then look at concrete details, and at what experimental skills and techniques would be needed.

The tutor's main job, of course, is helping with lectures. It is a difficult job because it is not easy to know just what went on in lectures, what things are not understood - especially those which are thought to be but are not, and what ideas of their own students may have made out of them, to mention a few.

As has been pointed out before, information is a critical commodity indeed one tutor has made a habit of attending the course he tutors, and says he could not do without the information he gets in that way. Other sources of information are lecture notes, the timetable, question sheets, and so on.

This kind of information need not just be background: sometimes it can be used more directly. Instead of having to think up questions on the spot, it can help to come to the
tutorial with prepared questions, based for example on lecture notes. In this way, the questions can more easily be designed to get at points of general importance, as well as at matters of detail (the frequency of the latter kind was noted in chapters 7 and 8). Questions can also be about the lecture, as well as about the physics, asking why something was done in a certain way, for instance.

One tutor, to give a concrete example, was trying to help with a lecture (for which he had notes) in which the lecturer had approached alpha particle scattering by first speculating about what force could produce such an effect. Gravity, for example, could be ruled out by an order of magnitude estimate, making a point about the need to be quantitative. Thinking about electric forces led to calculations via the potential at the distance of closest approach, which was consistent with a 'size' obtained from a target area got from the chance of large angle scattering. This argument brought out several issues, including the value of energy arguments and the use of a path integral. He had then shown how a more detailed approach could give much better information, by developing from the assumption of a central force the relation of scattering angle and impact parameter.

Whether one likes this line of thought or not, it illustrates features common to many lectures. The lecturer has a variety of purposes, and is at once teaching detailed theory and its wider significance. Had the tutor known only that the lecture was about alpha scattering, he might merely have asked what assumptions were made and how the proof goes, for example.

This tutor, however, designed a varied set of questions to get at a number of points, including:

- what are the main forces in nature?
- of them, why did the lecturer concentrate on the electric force?
- why use an energy argument involving a path integral?
- sketch a graph of potential energy against distance for a head on collision, and an oblique one.
- why must an orbit be symmetrical? (the lecture notes gave and ruled out an unsymmetrical shape).
- what does Kepler's law say about the speed of a comet as it comes nearer to, and swings round, the sun?
- why can the theory neglect the effect of the forces on the nucleus? When ought it not to?
The questions were designed to be used with the lecture notes, and clearly rely heavily on them. Besides raising a variety of issues, they are in a form close to the students' experience of the topic. Another advantage of such prepared questions is that they can be framed with greater care.

Lecture notes then, can help the tutor as much as the students for whom they are normally intended. There is a case for asking lecturers who prefer not to issue notes, nevertheless to offer tutors a half page summary which they can use.

Short set problems can also be used. Each student can be given one to try on the spot (so they must be short), and then be asked to show the others how he did it or where he got stuck. If the questions cover the issues in recent lectures, the procedure offers both some practice and a chance for the tutor to diagnose common difficulties.

10.7.14 SYSTEMATIC DISCUSSION

Often, the tutor tries to find out what should be discussed, and then decides how to discuss it. There may be advantages in involving students more in preparing the discussion, and in going about it in an agreed and organised way. The advantage of an agreed group procedure is that commitment can be greater, and the discussion be more in focus.

One scheme is to agree with the group that each student will bring a summary of one part of the course, and at least one difficulty concerning it.

Help may be needed with the form of such preparation. A series of steps can be suggested*:

- read through notes immediately after lecture; fill in gaps.
- list terms of which you are unsure.
- write down the overall message of the lecture.
- identify the sub-topics and main arguments.
- note the topics or arguments which were most difficult.
- think of one question to ask about each topic.
- ask yourself what use it is to know each topic, for understanding other things.

*based on Fawcett-Hill. See references at the end of chapter 10.
Such a list needs to be provided in written form if it is to be used, though it is worth modifying it in the light of what students say about trying to use it.

A related scheme is agreeing with the group about the form and conduct of the tutorial discussion. One might propose stages such as:

- collecting an agenda.
- settling priorities.
- having a discussion plan.
- moving to the next item.

At the first stage the tutor can offer to write down anything anyone suggests needs attention. He should resist the natural temptation to dispose of small items at once; they often turn out not to be, and something much more important may turn up later which ought to displace them.

The next stage is to ask which are the more important items, and in what order to take them. Here the tutor will have views of his own, and can properly propose them.

It may help to discuss items with some loose structure to the discussion. Perhaps the first thing is to try to get everyone to the same level, by dealing with words and ideas that are not understood. A second step can be to collect opinions about the main reasons for difficulties, which may turn out to need different kinds of treatment.

As important as anything else is to have a way of deciding when to go on to the next item. No discussion can resolve everything, so there is a tendency to go on about one problem and leave others untouched. It is useful, for example, to have a rule that after, say ten minutes on an item, the tutor will ask whether they should move on or not. This at least gives him time to consider the matter too.

REFERENCES


11. Rules for tutors?

Tutoring should be an enjoyable and productive experience, and the whole book has been about how it might be so more often and more easily. Although no-one in his senses would suppose that the whole thing can be reduced to a set of rules, it may nevertheless be helpful to try, if only to focus attention on things worth thinking about. So here are some rules.

Think about questions and answers. Count up to ten after asking a question, before trying again. Don't always ask for 'the answer'; ask sometimes about what they think about things. Remember to ask what they don't know, too.

Make space for thought. Getting them to work alone, and writing things down, can help. Arrange tasks so that several students are involved in each, rather than always posing problems to one at a time.

Think about, and look after, the detail. Just how a problem is put, or work on it is organised, can make a difference to whether it seems difficult or easy, overwhelming or manageable.

Pay attention to the way students behave. Their behaviour can carry much information about how they are reacting. Guess what it might mean, and see if the guess can be confirmed. Watch out for hidden manoeuvring, and try bringing some of it into the open.

Think a little about where you and they might best sit, and try some different arrangements. Notice too where they do put themselves, and if necessary do something about it. Look at them when they are talking to you.

Listen to the talk. The way students talk about physics contains a number of clues about what they know and how they feel about it. Listen to yourself too, and consider it from the point of view of someone less competent in the subject than yourself.

Admit when you can't answer a question, solve a problem, or don't know what to do. Invite them to help.
Consider a plan for the tutorial, and a strategy for several tutorials. Discuss your plans with the group, especially when they involve preparation and work. Change plans when necessary, but don't change them arbitrarily. Occasionally, try something new. But don't forget to explain it. Remember that they may not expect from a tutorial the same as you do.

Think, as well as about facts, about intellectual skills; about such things as the approach to a problem, the form of an argument, and the demands a problem makes on skills.

Try to find ways of reflecting afterwards on what happened. The simplest device is just to think about it for five minutes, or talk to someone about it. Going further, one can try to write the story of the tutorial, which helps a good deal when it is re-read later. Tape-recording a tutorial or two, and listening to them at home, can reveal a good deal. Video-tape is less practicable, but even more informative.

Don't do things which don't suit you: do what you do best. Therefore, as a final rule, break all or any of the above rules whenever it seems sensible to do so.
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