Non-subject difficulties in A-level physics questions

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Candidates often do not fully understand what an examination question is asking. What are the reasons for this?

I started to research into the effect of the wording of examination questions when I observed students being unable, during lessons, to answer questions concerning aspects of physics that they had apparently understood. While doing the initial part of my research I found that in examination questions there are difficulties that are not subject-specific. Candidates have to solve such difficulties in order to respond to a question correctly, but the solution of these 'non-subject' difficulties is not a subject-specific skill.

The research

The research was in four parts. The first part consisted of an initial analysis of past physics A-level papers of London Examinations/Edexcel, finding the types and numbers of non-subject difficulties occurring in these papers. These difficulties were categorised and the variation of their occurrence over six years was examined.

The second part of the research consisted of altering the wording of some past A-level questions and trialling the effect of the altered wording on future examination candidates. Examination classes were split into two groups, with an equal split of sexes and ability, so that, for example, half the girls in a class were in a group using the altered questions as part of their mock examination and half were in a group using the unaltered questions. Such trials took place on six separate occasions with three different cohorts and the numbers in the groups ranged from 12 to 20.

The third part of the research involved interviewing future examination candidates immediately after a mock examination. Individual interviews of half an hour were conducted, allowing the students to talk over problems they had encountered and have a second look at the questions in a non-examination situation. Twenty interviews with two different cohorts were carried out. Two group interviews involving a total of 28 future exam candidates were also carried out.

The fourth part of the research involved using examiners' responses to unexpected problems encountered by examination candidates. These responses were obtained from public feedback meetings organised by the exam board over 12 years, from examiners' comments to the London Standing Joint Committee and the examiners' published comments produced after every examination. Six years' comments were considered.

ABSTRACT
This article describes the responses of examination candidates to A-level physics questions. It looks at the effect the wording of the question has on the candidates' chances of successfully solving the question. It also examines the different ways in which questions are internalised by those who read them, that is candidates, teachers and examiners.

Difficulty type 1: ellipsis

Ellipsis is when words are left out of written texts in books and articles or, as considered here, examination questions. The omission is in order to make the text flow more smoothly, leaving the reader to 'fill in' what is missing. In some physics questions, ideas, intentions and instructions are omitted. The experienced examination question reader easily 'inserts' the missing words or parts of diagrams, and is then able

to understand what the question is asking. This insertion occurs so easily that readers do not realise that they have understood ideas or images that have only been implied.

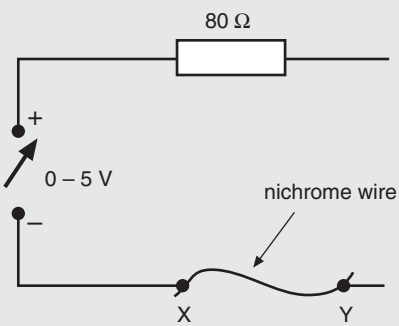
The disadvantage of ellipsis is that the inexperienced reader is uncertain about the intended meaning. In physics questions ellipsis can lead to difficulty in deducing the examiner's intentions. An example of ellipsis is given in Box 1. What the examiner had intended, in the first part of this question, was that candidates would complete the circuit so that the experimenter mentioned could measure the resistance of the wire. The difficulty was that the examiner had not actually asked the candidates to do this. (The question also did not state that the circuit should be able to give values of current and voltage that were on a graph in a later part of the question.)

A literal interpretation of the question would simply be to join the two ends with a line representing a connecting wire. What the examiner was expecting was that the candidates would put an ammeter and a voltmeter in the circuit. Knowing where to put ammeters and voltmeters in a circuit is a very low-level skill for an A-level candidate. However, as reported by the examiner at a teachers' feedback meeting, 10–12% of candidates did not, or were not able to, do this part of the question. (Feedback meetings are held by Edexcel after some of their AS and A2 (formally A-level) exams to discuss the examiners' questions and the candidates' responses with subject teachers.)

Box 1 Edexcel A-level physics June 1999 PH1 question 8

A student is asked to measure the resistivity of the alloy nichrome given a nichrome wire known to have a resistance of about two or three ohms. The wire is mounted between two copper clamps, X and Y, near the ends of the wire. The power supply is a variable power supply of output 0–5 V. The series resistor is 80 ohms.

Complete the following circuit.



The 80 Ω series resistor ensures that the current is kept small. Explain why this is important.

The London Standing Joint Committee (LSJC), in their annual report, asked the Edexcel examiner to explain why the question had not made clear exactly what was required of the candidate. The reply of the examiner was: '*The task of the candidate was clearly stated*.' (The LSJC consists of members of teachers' unions. Teachers send to the committee comments on Edexcel questions. After consideration by the committee the comments are sent to the exam board. The replies of the examiners are sent by the board to all examination centres.)

Future candidates who had done this paper as their mock PH1 exam were encouraged during individual interviews to talk through how they had understood the questions during the mock examination. The interviews each lasted half an hour. A schedule of open-ended questions was used and the interviews were taped, with the permission of the pupils. They saw their marked papers for the first time at their interview, which took place the day after their mock examination. The pupils had achieved different levels of success in the first part of this question, '*Complete the following circuit*.' When asked '*What does this mean? What is the purpose of the circuit?*' their responses included:

- Failing to see that part of the examination question:

  '*I thought it was just a diagram for me to look at, but I kept thinking why is this circuit not complete'*, said Sam. I then asked him to redo the question and he put the meters in the correct places. Richard also missed this question when he did the paper: '*Missed it, totally missed it*' he stated. He, unlike Sam, was not able to solve the question during the interview. '*What's in it? ... I thought everything was here ... they haven't said anything about measuring*', he complained.

- Successfully doing the question but not realising how they had done so:

  Brian had considerable trouble in working out at the interview how he had been able to do the question. He thought that it had been made clear that the diagram represented the circuit referred to: '*No, it doesn't tell you … I presumed … as you were measuring resistivity*', he said. His reply is interesting, as it makes clearer that candidates do

not realise how they successfully tackle questions containing ellipsis, by unconsciously filling in missing information.

- Not able to understand the ellipsis:

  Louise was not able to fill in the missing information but she could find and fill in something from her experiences: '*I realised that it had to be a square or rectangular shape*' and '*I knew you had to put an ammeter in ... that was obvious*'. Phillipa did not find it so obvious: '*I didn't really see what it wanted ... it didn't say you needed an ammeter or voltmeter*'. She added that, '*If you want to measure resistance they might be quite useful*'.

The same question was given to another class to complete under test conditions. In a group feedback session we discussed any problems that they had encountered. One of them, Nick, would not wait for the feedback and shouted out during the test: '*What the hell are we supposed to write?*' During the feedback session he added more moderately, '*In an exam you don't have the time to read and reread to enable you to understand the examiner's intention*.'

The physics requirement of this question is to find out whether a candidate knows how to connect an ammeter and a voltmeter correctly in a circuit. This could have been put in a much simpler question and one without ellipsis. It is possible that, in the actual examination, it was realising that there was a question and understanding the ellipsis that decided whether or not a candidate was successful.

Difficulty type 2: separated information

Another difficulty associated with interpreting the text of examination questions is separated information. This is when important information, vital to the correct solving of the question, has been placed in a position that is difficult for the candidate to access. The candidates, while reading, are starting to formulate the problem in their heads. They have enough information to start and even finish the problem, but unfortunately the information is not complete. By the separation of some of the required information or the placing of some vital requirement of the question at the end of the question, or in an insufficiently obvious position, the candidate is put under the mistaken impression that they possess all that is necessary to solve the question.

Separated information was one of the difficulties that was investigated by trialling with examination candidates. This involved altering the wording of some examination questions to make the intention of the examiner clearer. Examination classes were split into two, with the same representation of ability and sex in each half. Pupils did the questions under test conditions, one half using questions with altered wording and the other half using questions with unaltered wording.

A question taken from January 1997 PH1 was used in one of the trials (Box 2). The examiner at the feedback meeting stated that many candidates in the original exam missed the words *starting from rest* and gave an incorrect answer. Candidates had thought that the glider was travelling with a constant speed. For the trials the first sentence of the question was altered by moving that phrase so that the wording now read:

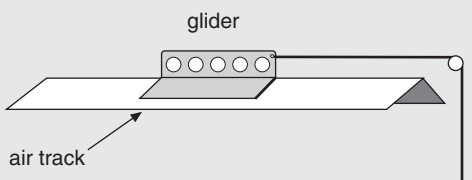
> *A student finds that when a glider starts from rest it takes 1.13 s to move a distance of 90 cm.*

On average those doing the unaltered question had about a 50% lower mark than those who did the altered question.

Separation of information is also likely to occur in questions with several parts. The candidate concentrates on the information required to answer the first part of the question. This concentration on the first part of the question leads some candidates to forget that the information relevant to solving later parts of the question may already have been read. Putting a picture between the information and the question may have a similar effect. An example is given in Box 3.

In the paragraph above the diagram is 'the scenesetter' and it contains important information. This information concerns which hand pushes and which hand pulls. This method of presenting the required information seems to have the effect of

Box 2 Edexcel A-level physics January 1997 PH1 question 5

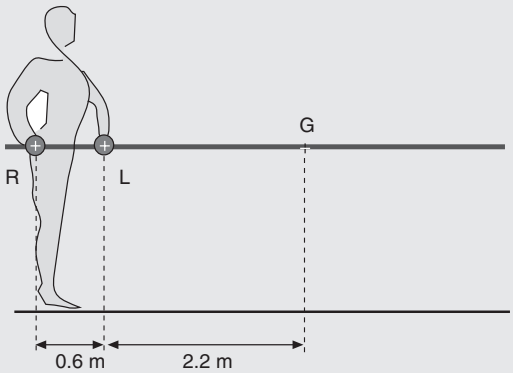


A student finds that the glider takes 1.13 s to move a distance of 90 cm starting from rest.

Calculate the speed of the glider after 1.13 s.

Box 3 Edexcel A-level physics June 1999 PH5 question 3

The diagram shows a pole-vaulter at rest at the start of the runway. His left hand is holding the pole at L; his right hand is pushing down at R to counterbalance the weight of the pole which acts at its centre of gravity G.



a) Draw a free-body force diagram for the pole.

The pole weighs 26 N. Calculate the force which each of the pole-vaulter's hands exerts on the pole.

concealing information. This question was on a paper that a second group of future candidates was interviewed about.

These students were at the beginning of year 13. As described above, the individual interviews were taped and, so that each interviewee considered the same points, the same series of questions were asked of each. However, the interviewees were free to discuss any aspect of the question or of the paper. The interviews were not only a research opportunity but also a feedback session for the students. This enabled them, on an individual basis, to find out where they were going wrong and how to avoid making mistakes in the future. To consider this question the interviewees were asked to reread the first paragraph and pick out the important points. In particular they were asked to consider the word 'counterbalance' ('*Read the first paragraph. What is important in it? What does counterbalance mean?*'):

Laura, having a second chance to read and consider the question, was still of the opinion that: '*It doesn't tell you, no*' (that one hand is holding while the other is pushing). Only on being asked to look again did she see it: '*Yes it does*', was her annoyed response.

Brian also had problems with the same question: '*I missed that it said each hand, and I stopped after working out the first force*', he said.

Graham also missed information in the scenesetter in this question and he was of the opinion that he was not alone: '*A lot of people missed those three lines out … I didn't pay much attention to the first three lines. I only look back if I can't do the question*.' He meant that if he *thought* he could do the question he didn't look back.

Ronald also missed important information in the scenesetter: '*Missed pushing down, I can't believe I've done that, the hand was on top, so was doing the pushing*', was his comment.

In the examiners' comments (published by the exam board, with their mark schemes, after every examination) mention was made of the adjustment that had to be made to the marking scheme to allow some marks to be given to those candidates who had missed or misread the information in the 'scenesetter' and had assumed that both hands performed the same function, whereas one hand was acting as a fulcrum and the other was providing the effort.

Difficulty type 3: mistakes

Another difficulty that may occur is a mistake in the wording of a question. An example of this occurred in the question given in Box 4. To the examiner it did not seem serious. It consisted of asking the candidate, in the stem of the question, to calculate the *resistivity* and at the end of the question, in the space for the answer, asking for the *resistance*.

There was a varied response to this mistake from the students interviewed who were asked the question: '*Resistance instead of resistivity – did this bother you?*':

- Not seeing the mistake:

  '*I didn't notice it said resistance, I should have seen that*', said Cyril. '*Didn't notice resistance, lucky I didn't!*' Brian said.

- Confusion:

  '*It bothered me, which was I calculating, resistance or resistivity? It was confusing*', Donald

Box 4 Edexcel A-level physics June 1999 PH1 question 8

The length of the wire between the clamps is 51 cm. The diameter of the nichrome wire is 0.59 mm. Calculate the resistivity of the nichrome.

Resistance = ...

commented. Sam had, '*Thought I must be wrong and started it again*'. '*I did get a bit confused*', said Phillipa.

- Candidates spotting the mistake and successfully dealing with it (this was the reaction envisaged by the examiner):

  '*This is a misprint, isn't it?*' Richard said. Shaun commented, '*I'd actually realised that they'd made a mistake*'.

It was claimed by the examiner at the feedback meeting and in the examiners' comments that there was no sign in the scripts of the candidates being worried by the mistake. However, it would have been difficult to judge this from the scripts alone.

Difficulty type 4: wrong or idiosyncratic wording

The fourth difficulty observed is wrong or idiosyncratic wording. The examiner may use the wrong word or words or use a word that has more than one meaning.

For example, the word *estimate* is used in different ways by examiners. On some papers it has been used to mean 'guess a missing value'; on other papers it has meant 'there will be lack of sensitivity in the results' or 'accurate results are not expected'. (Sensitivity is taken by Edexcel to mean to how many significant figures the answer can be given. It is different from accuracy in that a measurement can have many significant figures, due to the scale or type of measuring instrument used, but if that instrument is faulty the measurement will be very inaccurate.) In the question in Box 5 it appeared to the students being interviewed that *estimate* had the third meaning of this word, 'accurate results are not expected'. As a consequence, the students were misled as to what method of solving the problem would be accepted by the examiner. To do this question, the students, and the candidates in the actual exam, had to find the area under the irregular-shaped graph. There was no accurate way of finding this but the examiner made it clear at the teachers' feedback meeting, and in the mark scheme, that only a relatively small range of values was acceptable. This was not what the pupils had been led to expect by their interpretation of the wording of the question.

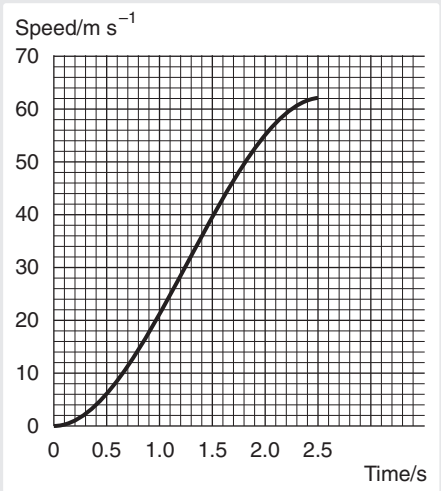
The pupils were asked:

What do you think is meant by '*Use the graph to estimate*'?

'*I thought they just wanted an estimate*', commented Cyril, on getting his area outside the limits. He added '*What did I think when I read "estimate"? Not counting up all the squares, just general*'. Brian was annoyed that his answer had been found wanting: '*Estimate means give a rough answer … then a line is all right!*' This was a reference to the fact that he had approximated the shape of the area under the graph to a triangle. Phillipa had thought about the word a lot: '*Estimate … I was puzzled as to how accurate they wanted it*', she said. Arnold had no doubt about what was required: '*Give a rough answer*' was his interpretation of the word.

This type of difficulty can be overcome by being very specific about the intended meaning of words. Putting a list of words, with the single meaning that each word

Box 5 Edexcel A-level physics June 1999 PH1 question 2



Use the graph to estimate

i) The displacement 1.5 s after the start.

will have on the examination papers, in the syllabus, would help to avoid this difficulty.

Effect on mark schemes

When the majority of the candidates have been unable to answer a question in the way expected by the examiner because of difficulties in interpreting the text, mark schemes have had to be rewritten to accommodate the candidates' mistakes and still be able to award some marks.

Sometimes, when a minority of candidates have been unsuccessful, because of such difficulties, the examiners have used the adverse effect of the difficulty to increase the discrimination of the question. In the examiners' comments, referring to one such occurrence, the examiner said '*Some candidates missed "separate" at the end of the question, but this improved the discrimination of the question*'. However, this discrimination is not based on ability in physics.

Conclusion

The above examples are taken from Edexcel A-level physics papers because these were the papers that the students I taught would be sitting. It is likely that such difficulties occur in the questions for other subjects and of other exam boards.

Why do such difficulties occur in questions? Mistakes are left in as a result of poor proof-reading but the other difficulties require more explanation. The examiners would not intentionally write a question in such a way that it was difficult to comprehend. They do not wish to test any skills other than those of the subject. It could be that these difficulties are inadvertently put into a question and not noticed because the examiners do not themselves consider them to be difficulties. Perhaps owing to the experience and the expertise of the examiners, they are more able than most candidates to insert instructions mentally and to hold in their head information given earlier in a question.

This is true not only of the examiners but of many subject teachers. When I raised the ellipsis difficulty (Box 1) at a feedback meeting, the response from many of the teachers was surprisingly negative. As they had no problem with the ellipsis most of the teachers were unable to see that it would be a problem for the candidates.

An illuminating comment was made by one of my students during his interview when he had had a chance to reread a question. He said '*It was difficult because I got it wrong; if I'd got it right it would have been easy*'. What he meant was that if he had been able to understand correctly what the question was asking, during the exam, he would have been more successful.

The purpose of examination questions is to ascertain the ability of a candidate in a particular subject. For this purpose to be realised it must be possible for all candidates to successfully understand what the questions are asking.

How can we ensure questions set are more accessible and test only *subject* knowledge, understanding and ability? Trialling questions would reveal when they are not answered as expected and so are not suitable to be used, in that form, in an examination. The exam boards already use a kind of trialling where questions that have been successfully answered in an earlier examination are used again in a slightly different form. However, more organised trialling with future candidates, as is at present undertaken for the SATs, would be more effective.

Also, if examiners are aware of what non-subject difficulties are liable to cause problems for candidates, they could take steps to avoid including them in the questions. I hope that my research, of which the above is a sample, will help with this task.

Acknowledgement

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