Steve Smith Tuition: Physics Notes

Explain Questions

Contents

Prerequisites

None.

Notes

None.

Document History

Date	Version	Comments
13th January 2015	1.0	Initial creation of the document.
12th January 2017	1.1	Cosmetic changes only.
10th March 2017	1.2	Adding more question types and examples.

Part I

The Different Types of *Explain* Question

1 Introduction

Students often find calculation questions in physics exams easier than the longer *explain* questions. This document has been written to try and help you answer those explain-type questions.

There are a number of different question types that fall into this explain-type category; each will be addressed separately:

- Explain a phenomenon, principle, process or definition
- Reasoning from provided information
- Describe an experiment to...
- Discussion of experimental errors or improvements

This is the order in which we will tackle these various question types. That's because I've just had a quick look at Edexcel A-level Physics exams from January 2009 to June 2015, and I've made a tally of how many marks were awarded in each unit for each of the above question types. The results are shown in Table 1.

Question Type	Unit 1	Unit 2	Unit 4	Unit 5	Totals
Explain a phenomenon, principle, process or definition	214	277	229	191	**911**
Reasoning from provided information	68	74	51	40	**233**
Describe an experiment to...	21	19	10	20	**70**
Discussion of experimental errors or improvements	22	7	6	0	**35**
Totals	**325**	**377**	**296**	**251**	**1249**

Table 1: Edexcel Exams : Question Types, January 2009 to June 2015

I haven't gone through this process for AQA and OCR exams yet, but I'm assuming that the general theme will be followed in those exams too.

Explain a phenomenon, principle, process or definition
By far and away the most common type of *explain* question is the one where they are asking you to explain the definition of something (e.g. "Explain what is meant by compressive strain"), a phenomenon (e.g. "Explain what is meant by the photoelectric effect"), a principle (e.g. "Explain what is meant by Newton's Third Law"), or a process (e.g. "Explain why the transfer of energy from potential to kinetic can never be 100% efficient").

Reasoning from provided information
Next most common is the type of question where they present you with some information and ask you to deduce something from it. For example, "Explain what would happen in this electrical circuit [containing a thermistor] if the ambient temperature increases".

Describe an experiment to...
This is a straightforward one to understand: e.g. "Describe an experiment to measure the acceleration due to gravity by a free-fall method".

Discussion of experimental errors or improvements
Physics is an experimental science, and analysing your results is important. So, in exams you get, for example: "Explain how you would reduce the error in measuring the cross-sectional area of the wire", or "Why should you repeat the measurements of the length of the tube".

2 Explain a Phenomenon, Principle, Process or Definition

2.1 Definitions

Here are a couple of examples of having to explain a definition. Definitions of terms can be found in your textbook. If you look in the syllabus for your course, it will tell you what definitions you need to learn.

Define *Electric Field* An electric field is a region of space where a force acts on a charged particle.

State What is Meant by *Laminar Flow* and *Turbulent Flow* Laminar flow is where a fluid flows along uniform smooth lines. At any given place, the the fluid velocity is constant over time. Turbulent flow is where fluid velocity in a particular place changes over time, often in an unpredictable manner.

2.2 Explain a Phenomenon, Principle or Process

This is the most common type of *explain* question. You will have to do a lot of this! So it pays to be prepared and have a strategy ready. And you can practice this sort of question during your revision by making up questions to ask yourself. It's really not hard to do that: just pick a topic. Capacitors, say. Alright. Think of an explain question. What about "Explain what happens when a capacitor is charged"? See what I mean? It's really easy to ask the questions. Answering them on the other hand...

So, how do we answer this kind of explain question? Well, I think what you have to do is to think of your answer as being a little essay. And if you remember what you were taught about writing essays, then you should *plan* the essay before you write it. That means you should get a piece of scrap paper and make notes on it before you write anything on the answer paper. In an exam, just put up your hand immediately the exam starts and ask for scrap paper. You can be doing that while you read all the questions[1].

So what is your plan? Well, I think that you should do the following three things during your plan:

- brainstorming
- organising
- telling the story

2.2.1 Brainstorming

Brainstorming is the act of thinking about everything that you can imagine that might be relevant to answering the question. As soon as you think of something, write it down. You could use bullet points.

How many things do you need to think of? Well, that depends on how many marks are available for the question. If the question is only worth three marks, then you probably need at least three ideas. For six marks, you probably need at least six ideas. I say *at least* because you can never be sure that something you think is relevant is what they want (so you get a mark for it). So I cover myself by trying to think of more things than the number of marks, if I can.

2.2.2 Organising

The aim of this game is to tell a little story about the phenomenon. Good English the story should use, innit? And you have to spell stiff corructly. Particularly physics *key words*. So if you don't know how to spell *photoelectric* or *interference*, etc, then learn them! Mark schemes specifically state that marks will be docked for spelling errors.

Right. So, after brainstorming you will have a set of bullet points. The next thing to do is to put them into some kind of order. You want to organise them so that there is a nice logical flow from beginning to end that you will be able turn into your story, using good grammar and spelling.

2.2.3 Telling the Story

This is now the easy part: just write your story onto the answer sheet.

[1]See my exam techniques guide for more on this!!

3 Reasoning from Provided Information

This is one of those questions where they may show you an experimental setup, and then say something like "What would happen to the reading on the voltmeter, if you increased the intensity of the light falling on the thermistor?".

In this type of question, it's important to produce a logical sequence of steps that lead from the experimental change to the result. Each step needs to be a *simple* and *direct* consequence of the last.

So your answer should look something like this

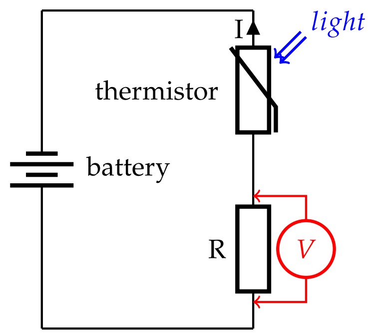
$$\begin{aligned} & \text{the experimental change} \\ \Rightarrow\ & \ldots \\ \Rightarrow\ & \ldots \\ \Rightarrow\ & \text{the result.} \end{aligned}$$

3.1 A Reasoning Question, Involving an Electrical Circuit

3.1.1 The Question

In the circuit shown in Figure 1, light is falling on the thermistor. Explain what happens to the reading on the voltmeter V when the intensity of the light falling on the thermistor increases.

Figure 1: Simple Circuit



3.1.2 The Answer

Here is the logical flow of the argument:

$$\begin{aligned} & \text{the intensity of the light falling on the thermistor increases} \\ \Rightarrow\ & \text{the resistance of the thermistor decreases (1)} \\ \Rightarrow\ & \text{the current in the circuit increases (2)} \\ \Rightarrow\ & \text{the potential difference across the resistance } R \text{ increases (3)} \\ \Rightarrow\ & \text{the reading on the voltmeter } V \text{ increases. (4)} \end{aligned}$$

Notes:

- (1) Thermistors are designed so that their resistance goes *down* as the light intensity falling on them goes *up* [2].
- (2) If the resistance of the thermistor goes *down*, the total resistance of the circuit will go *down*, so the current flowing in the circuit I will go *up*, by Ohm's Law.
- (3) If the current flowing through the fixed resistor R goes up, the potential difference across it will go up, by Ohm's Law.
- (4) If the potential difference across the fixed resistance R goes up, then the reading on the voltmeter V will go up.

[2] At least, most thermistors have this property. There are some thermistors that are designed such that their resistance goes *up* as the light intensity falling on the thermistor goes up, but at A-Level, we're not concerned with those.

4 Describe an Experiment To...

Physics is an experimental subject, after all, and if you become a professional physicist, then you will either be a theoretician, or an experimenter. If you become an experimenter, you will need to describe your experiments in sufficient detail for other physicists around the world to repeat your experiments. If they do, and they get the same results as you, then your work is corroborated. That lends a great deal of credibility to your discoveries.

So, when you want to describe an experiment, what do you need to include? Well, how about this for a list:

- The aim of the experiment (the *Aim*);
- A list (or diagram) of the equipment used (the *Equipment*);
- How you used the equipment, what measurements you took, and how you took them (the *Method*);
- What data was obtained (the *Results*);
- What was the outcome of the experiment (the *Conclusion*);
- How you could make the expeiment better, if you were to do it again (the *Evaluation*).

I'll now go through each of these ideas in turn, thinking about what we would need to consider when writing an answer to this "describe an experiment to..." type of question.

4.1 The Aim of The Experiment

In a proper experimental write-up, this is a very important part of the report. It's very important to say *why* you are doing an experiment. After all, what's the point in doing something, if you can't explain why you are doing it?

But in an exam question where you are describing an experiment, you won't need this bit. So that's one thing out of the way already. Phew!

4.2 The Equipment Used

Now this *is* important to discuss in this type of question. And you have two choices. You can either:

- make a list of the equipment you are going to use, or
- draw a labelled diagram of all the things you will use.

There's nothing wrong with drawing a picture as part of an exam answer. In fact, since a picture is said to be worth a thousand words, it's often a *very* good idea. And in my head, it's better to draw a picture than it is to write a list. The reason I think that is that as you continue to think about what you would do during the experiment, you can keep looking at your diagram to see if you have included your latest thought.

For example, you are asked to describe an experiment to determine the value of the acceleration due to gravity, g. Your idea is to drop something, measure the length of the drop, and the time taken for the drop. Your equipment list consists of a ruler and a stopwatch. But what is it you are going to drop? The stopwatch?

4.3 The Method

This is very important, too. In fact, this is the main bit. Here you have to describe the experiment. And essentially that will consist of:

- how you set up the equipment,
- what measurements you are going to take, and
- how you are going to take them.

It will also include standard experimental technique, such as:

- taking repeated readings, and
- drawing a straight-line graph of your data.

4.3.1 What Measurements are Taken...and How They are Taken

You need to spell out which measurements you are going to take, and how you are going to take them.

For example, I'm going to measure the height through which a ball bearing drops (this will be the distance from the drop point to a light gate, h) with a meter ruler, and the time for the drop using the light gate to determine the precise time when the ball bearing has fallen through h.

4.3.2 Taking Repeated Readings

In any experiment, you should always (if possible, that is) take a particular reading many times, and then find the average value of all your readings. That way you are trying to reduce some errors that might creep into the process.

4.3.3 Drawing Straight-Line Graphs

When you are carrying out an experiment, a great experimental technique to take advantage of is that of processing your data in such a way that you can draw a straight-line graph of the data in the results section. See Section 4.4.1 for more details.

4.4 The Results

The results you present are of course determined by the measurements you take, and the way you present them is determined by an initial analysis of the theory...

4.4.1 Data Analysis and Visualisation of the Data

Now in the experiment to measure the acceleration due to gravity by dropping a ball bearing, the equation we are going to use for our theory is this one:

$$s = \frac{1}{2}gt^2$$

which is a *SUVAT* equation ($s = ut + \frac{1}{2}at^2$) with an initial velocity of zero ($u = 0$). That means we need to drop the ball bearing so that it has an initial velocity of zero.

Now if we compare this equation to the general equation of a straight line,

$$\begin{array}{ccccccc} s & = & \frac{1}{2}g & t^2 & + & 0 \\ y & = & m & x & + & c \end{array}$$

then you can see that if we drew a graph of s up the y-axis and t^2 along the x-axis, then we would get a straight line, with a gradient of $\frac{1}{2}g$ and a y-intercept of 0.

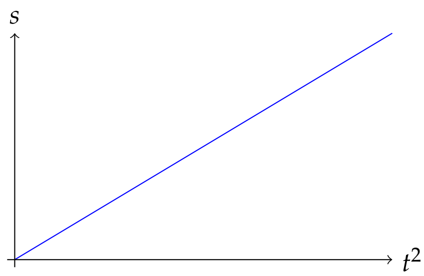
So the way to present our data would be in a table of values that would look like Table 2, and a graph such

Table 2: Table of Values

s	t^2
...	...
...	...

as that in Figure 2. And so if we are going to present the data this way (so that the gradient of the graph gives us $\frac{1}{2}g$), then *this determines our experimental method!*

Figure 2: Graph of Data



4.5 The Conclusion

A vital part of an experimental write-up, but not required in this type of exam question. Yesss!

4.6 The Evaluation

Again: a vital part of an experimental write-up, but not required in this type of exam question. Result!!

4.7 Summary

So: how do you go about answering this type of question? Here's the routine.

On a separate piece of scrap paper, plan your answer. The plan should include (1) your analysis, and (2) what your answer will contain.

4.7.1 Do the Analysis

The first part of the plan involves an analysis of the theory. Ask yourself two questions:

- Which equation am I going to use to base the experiment on?
- How can I draw a straight-line graph of the data?

4.7.2 Plan the Answer

Once you have decided these things, you start to do the following:

- make a list of equipment, or draw a diagram of the equipment to be used;
- explain the method, which will include what measurements to take, and how to take them. The method will be determined by the analysis of the theory. Don't forget to take repeated readings of a given measurement, and if possible, take sufficient measurements to plot a straight-line graph;
- explain how you would get the required value from the data (or the graph).

And that's it!

5 Discussion of Experimental Errors or Improvements

Usually, these are easier to answer than the types of questions we've experienced so far. They are typically only worth a mark or two, and the test is more about your knowledge of practicals than it is about how well you can put sentences together to tell a story.

Ensuring accuracy of measured quantities usually boils down to one of the following:

- take repeated readings and find a mean.
- use specialised equipment to take a measurement: so you should use light gates rather than a stop-watch to measure a time, for example; or take a video so that distances can be measured accurately.
- constructing your experiment so that the quantity you measure is as large as possible (so that the error in measuring it is as small as possible).
- ensuring that you would get the same measurements if you repeated the experiment. See 5.4, for example.
- elimination of systematic errors. See 5.5, for example.
- the use of straight-line graphs in obtaining useful information from an experiment, and the elimination of random errors in individual measurements. See 4.4.1.

Here are some examples.

5.1 Edexcel January 2009 Physics the Go, Q15 (b)

The Question
[You are asked to determine the acceleration of free fall at the surface of the Earth, g, using a free fall method in the laboratory...]

Give one precaution you would take to ensure the accuracy of your measurements.

The Answer
So, for example: Repeat the measurements of the time it takes the object to drop the certain distance, and find a mean.

5.2 Edexcel January 2009 Physics the Go, Q19 (d) (i)

The Question
Explain the advantage of using a video camera over making observations by eye.

The Answer
Using a video camera allows each frame of the video to be analysed. As each frame is taken at a precise time, it is possible to use the video to measure distances accurately at precise times. Something you can't do by eye very easily.

Video is great for determining the exact time (at least it pins down the time to within two consecutive frames) when something happens: precisely when an object gets to its highest point when thrown up into the air, for example. So it can eliminate human reaction time errors in using stopwatches, etc.

5.3 Edexcel January 2011 Physics the Go, Q12

The Question
Explain why the wire used when measuring the Young Modulus of copper in a school laboratory is long and thin.

The Answer
This is one of those questions where they want you to construct your experiment so that the quantity you measure is as large as possible (so that the error in measuring it is as small as possible).

In a Young's Modulus experiment, we will be hanging weights on (that is, applying stretching forces to) a wire, and we want to measure how much the wire stretches for a given force. So we want to design our experiment to get the biggest stretch for a given weight.

The wire will stretch more if the wire is thin. That's because stress $= \frac{\text{force}}{\text{area}}$, so to get a large stress, we want the cross-sectional area of the wire to be small. That also means that we don't need as large a force to stretch the wire. That's another benefit of having a thin wire.

We want a long wire because the strain $= \frac{\text{extension}}{\text{original length}}$, so for a given stress, we will get a longer extension the longer the wire.

5.4 Edexcel June 2011 Physics the Go, Q13 (b)

The Question
The student thinks that the stopwatch method is less reliable than the ICT method. Discuss what makes using a stopwatch less reliable.

The Answer
There will be human error in operating the stopwatch, which doesn't occur when using ICT.

When conducting an experiment, you want to remove the possibility that you will get different results in different circumstances. If you use humans to measure times using a stopwatch, you will probably get different results from the same experimental setup if (i) you use different humans (as different humans have different reaction times), and (ii) if you use the same human but at different times (such as when they are fresh, and when they are tired).

5.5 Edexcel January 2013 Physics the Go, Q13 (a) (ii)

The Question
[A student carries out an experiment to find the acceleration of free fall. In this experiment the student releases a small steel ball in front of a metre rule and uses a video camera to record its motion. The camera captures 30 images per second, which may be played back one image at a time.]

Describe a systematic error which could arise.

The Answer
Systematic errors occur when there is a consistent error in all measurements of a particular type. For example, if you were measuring the lengths of tables with a tape measure, and you had made lots of measurements before you realised that the first five centimetres of your tape had been cut off, then all your measurements would be five centimetres too big!

The possible sources of systematic error in this would be:

- the ball might not be released exactly when a given frame of the video is shot. So you don't know precisely when (between one frame and another) the ball was released.
- the ruler measuring vertical height might not be vertical.
- the video camera might be faulty: it might be running too fast, or too slow.
- there might be line-of-sight issues: the line from camera to ball to meter ruler might not give you an accurate value of the distance the ball has dropped at different times.

Part II

Example Answers to *Explain* Questions

This part gives a few more examples of some of the question types that were outlined in Part I.

6 Explain a Phenomenon, Principle, Process or Definition

6.1 A Question About Standing Waves

Here's a question about *standing waves*. It's Question 20 from the May 2009 Edexcel paper "Physics at Work".

6.1.1 The Question

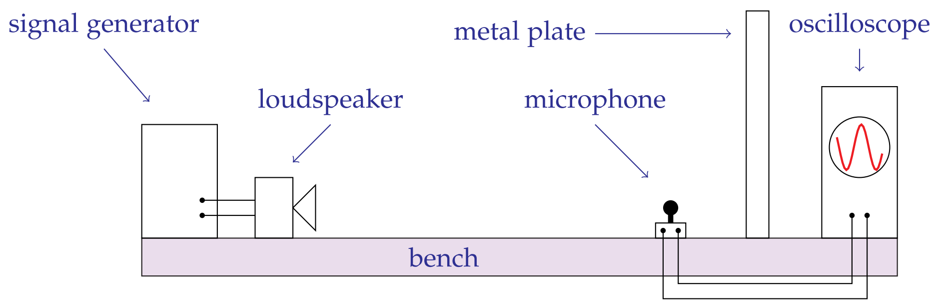


Figure 3: An Experiment with Sound Waves

Figure 3 shows an experiment with sound waves. A loudspeaker is connected to a signal generator. A microphone is connected to an oscilloscope. Sound waves reach the microphone directly from the loudspeaker and after reflection from the metal plate. As the microphone is moved towards the loudspeaker, the amplitude of the wave displayed on the oscilloscope varies through a series of maxima and minima.

(a) Explain why the amplitude of the sound varies in this way. [4]

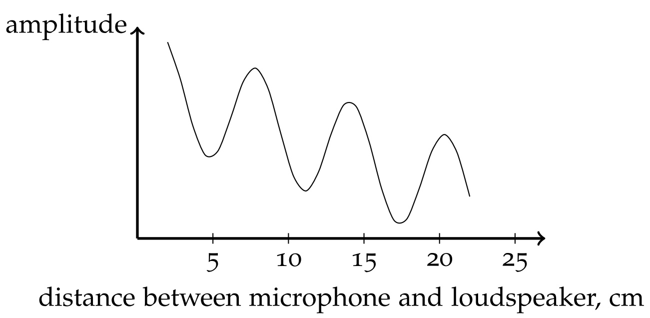


Figure 4: Amplitude versus Distance

(b) ...

(c) The microphone is placed close to the loudspeaker and gradually moved towards the metal plate. Figure 4 shows how the amplitude of the wave displayed on the oscilloscope varies with the position of the microphone.

(i) Explain why the minima never have a zero value. [2]

(ii) As the microphone is moved towards the metal plate, the amplitudes at the minima gradually decrease. Suggest why this happens. [2]

6.1.2 Thinking About Part (a)

(a) In the mark scheme for this question it says: *The answer must be clear, organised in a logical sequence and uses specialist vocabulary*.

To do this it's a really good idea to prepare your answer on a piece of scrap paper before you write anything on the answer sheet. That's so that you can *brainstorm*: gather your thoughts together, thinking about about anything that might be relevant, and making sure that you use *specialist vocabulary*, and that *you spell things correctly*.

Once you've thought of as much as you can, put it into some kind of order so that you can tell a story. You can *organise* your answer before you commit anything to the answer paper.

Then you *tell the story* by writing it onto the answer paper.

Here goes.

Brainstorming So - what is relevant here? Think of anything you can about what's happening in the experiment. The question mentions two waves arriving at the microphone: one directly from the loudspeaker, and one which has been reflected off the metal plate. And we're going to have to explain these maxima and minima. So that means we must have

1. combining of the two waves
2. superposition of the two waves
3. interference between the two waves
4. when you get a direct and a reflected wave passing though each other you often get standing / stationary waves (aha! that will explain the maxima and minima!)
5. with standing waves there must be nodes and anti-nodes
6. the nodes are where the two waves interfere constructively, the anti-nodes are when the two waves interfere destructively
7. two waves will interfere constructively if their phase difference is $n\lambda$, and they will interfere destructively if their phase difference is $\left(n + \frac{1}{2}\right)\lambda$.

I can't hink of anything else!

Organising Right. Now, points (1), (2) and (3) are all really the same thing, so I'll just talk about "interference" of the two waves. Nodes and anti-nodes - point (5) - is the same thing as talking about maxima and minima, so I'll leave the nodes and anti-nodes out, as they referred to maxima and minima in the question.

But everything else can go in!

Telling the story The story will just be my answer! So, see the next bit for that!

6.1.3 My Answer to Part (a)

When the ("original") wave from the loudspeaker reflects back off the metal plate, the "reflected" wave interferes with the original wave.

The two waves will have the same frequency and wavelength, similar amplitudes, and a constant phase difference between them. These are the conditions for stationary waves to be produced, and an interference pattern is set up consisting of maxima (where the waves interfere constructively: here the phase difference between the waves is $n\lambda$) and minima (where the waves interfere destructively: where the phase difference between the waves is $\left(n + \frac{1}{2}\right)\lambda$).

6.1.4 Thinking About Part (c)

Well the first thing to do here is to try and understand what's happening with this amplitude-distance graph (Figure 4). Particularly regarding the minima (which is what the question is asking about).

Brainstorming The x-axis is the distance between the loudspeaker and the microphone. Let's call this d, so we can talk about it. So the graph is saying that when d is small (the microphone is close to the loudspeaker), then the minima have quite a big amplitude. The destructive interference is nowhere near cancelling the two waves out.

But as d gets larger, so the microphone is close to the metal plate, then the minima do get close to zero amplitude. In that case the two waves are close to cancelling each other out.

So what can account for this? The conditions for complete destructive interference are: (1) the waves have to have a phase difference of half a wavelength, but also (2) *they have to have the same amplitude*. So: what can account for the two waves (original and reflected) having similar amplitudes near the metal plate (large d), and very different amplitudes near the loudspeaker (small d)?

Ah! If we were to walk away from the loudspeaker, and keep walking, then the sound level (i.e. the amplitude) would continue to drop the further we walked away. So the further away from the loudspeaker the wave is, the smaller its amplitude will be! Right: so when the original wave and the reflected wave are close to the metal plate, their amplitudes will be similar, as the distance they have each travelled will be similar. But near the loudspeaker, the original wave has gone very little distance, but the reflected wave has gone all the way to the metal plate and back, so its amplitude will be a lot less that the original wave! That's it!!

Organising So here we want to talk about the *difference* in amplitudes of the two waves near the metal plate, and near the loudspeaker. We also have to explain that because the difference in amplitudes of the two waves are different in the two positions, they will cancel out near the metal plate, but they won't near the loudspeaker. And just for emphasis I want to mention that complete destructive interference occurs when the phase difference is half a wavelength.

Telling the story The story will just be my answer! So, see the next bit for that!

6.1.5 My Answer to Part (c): Both (i) and (ii)

For two waves to completely destructively interfere, their amplitudes have to be the same. The amplitude of a sound wave will reduce the further it goes.

Near the metal plate, the original wave and the reflected wave have travelled roughly the same distance, so their amplitudes will be similar, and they will be close to cancelling each other out where the phase difference is half a wavelength.

But near the loudspeaker, the original wave has travelled almost no distance, and the reflected wave has travelled all the way to the metal plate and back. So the amplitude of the reflected wave will be reduced much more that the original wave, and total destructive interference will not occur, even when the phase difference is half a wavelength.

6.2 A Question About Rutherford's α-Particle Scattering Experiment

Here's a question about Rutherford's famous α-particle scattering experiment. It's Question 8 from the January 2010 Edexcel paper "Physics on the Move".

6.2.1 The Question

Rutherford designed an experiment to see what happened when alpha particles were directed at a piece of gold foil. Summarise the observations and state the conclusions Rutherford reached about the structure of gold atoms. [5]

6.2.2 My Thinking

Before we start, I want to say that this α-particle scattering experiment by Rutherford and his mates is such an important experiment in the history of modern physics that you should know it inside out. It's *very* likely to come up.

Brainstorming OK, so let's try and think of as many things as possible that might have something to do with this experiment. There are five marks available for this question, so I need at least five things to say. Probably more!

Now the question is in two parts: (1) summarise the observations, and (2) explain the conclusions. So let's tackle the observations first.

1. α-particles are emitted from certain radioactive nuclei.
2. α-particles are helium nuclei, so they consist of two protons and two neutrons. They have a charge of $+2$.
3. The gold foil has to be really thin.
4. Most of the α-particles go straight through the thin foil, without being deflected.
5. A few α-particles have their trajectories slightly deflected as they pass through the foil.
6. Very occasionally, α-particles have their trajectories deflected through very large angles.

Now let's think about the conclusions.

a An atom is mostly empty space.
b The nucleus is positively charged.
c There is a nucleus(!) which is tiny compared to the size of the atom as a whole.
d The nucleus has almost all of the mass of the atom.

Organising Right. I don't think we need (1). The only bit of (2) that we need is that α-particles are positively charged. (3), (4) and (5) are definitely necessary.

And I like all the conclusions!

Telling the Story The story will just be my answer! So, see the next bit for that!

6.2.3 My Answer

Observations α-particles were fired at thin gold foil. Most of the α-particles go straight through the thin foil, without being deflected. A few α-particles have their trajectories slightly deflected as they pass through the foil. Very occasionally, α-particles have their trajectories deflected through very large angles by the gold foil.

Conclusions Rutherford concluded that the structure of an atom was that almost all the mass and all the positive charge was concentrated in a tiny nucleus in the center of the atom, and that the rest of the atom was empty space, apart from the electrons that orbited the nucleus.

7 Reasoning from Provided Information

7.1 A Question from Fluids

This question was Question 17 on the Edexcel June 2009 "Physics on the Go" paper.

7.1.1 The Question

A science centre houses a display with tall, transparent tubes of different liquids. Visitors can pump air into the bottom of the tubes to create bubbles that rise to the top at different steady speeds.

(b) (ii) If the weight of the air in the bubble is ignored, the steady upwards speed [of a bubble once it has attained terminal velocity] is given by

$$v = \frac{2\rho r^2 g}{9\eta}$$

where ρ is the density of the liquid, r is the radius of the bubble and η is the coefficient of viscosity of the liquid. Explain what happens to the speeds of the observed bubbles if the temperature of the liquid increases. [2]

7.1.2 The Answer

(b) (ii) So, we have to reason from the initial information to the end conclusion. That means our logic should look something like this:

the temperature of the liquid increases
⇒ ...
⇒ the speed v will ...?

OK. So where do we start on this one? Well, we have a formula for v, and it depends on other variables: ρ, r, g and η. So I suppose we need to figure out what affect increasing the temperature of the liquid would do to each of these variables.

$\boldsymbol{\rho}$ Fluids don't expand or contract much if their temperature changes, so I'm going to assume that the density of the fluid won't change much.

$\boldsymbol{r}$ If the temperature of the liquid goes up, then the temperature of the air in the bubble will go up, and so the pressure and volume will probably go up. So I reckon r will go *up*.

$\boldsymbol{g}$ Unless we go to another planet, or high up in the atmosphere, then the acceleration of gravity won't change.

$\boldsymbol{\eta}$ The viscosity of the liquid will go *down* if the temperature goes up. This is a common idea in fluids.

So, if the numerator of the fraction will go up (because r goes up and ρ and g stay the same), and the deniminator goes down (because η goes down), then v will go up.

Here's my answer then:

the temperature of the liquid increases
⇒ the radius of the bubble will increase and the viscosity of the liquid decreases
⇒ the speed v of the bubble will increase.

7.2 A Question from Projectiles

This question was Question 14 on the Edexcel June 2013 "Physics on the Go" paper.

7.2.1 The Question

(c) A projectile would have a greater range on the Moon than the Earth because of the lower gravitational field strength and because of a lack of an atmosphere. Explain how each of these factors would increase the range of the projectile. [3]

7.2.2 The Answer

(c) So again, we want to provide an answer that looks like this:

the gravitational field strength on the moon is less
⇒ ...
⇒ the range of the projectile will be greater.

But in this case we have *two* things to cosider: the gravitational field strength, and the atmosphere. So we really want *two* little sequences of logic. Let's look at gravitational field strength first. What effect does this have on projectiles?

Well, the gravitational field strength, g, determines the downward acceleration of the projectile after it has been launched. So if g is smaller, the projectile will fall slower. So it will take longer to fall. So the time of flight will be greater. Ah! So if flight time is greater, then it can go further horizontally!! Yes!!

Now the atmosphere. How will the lack of an atmosphere affect the motion of the projectile? Well clearly if there is no atmosphere, there will be no air resistance, so the horizontal motion will not be reduced, as it is on Earth, by the air the projectile passes through.

All we have to do now then is to assemble our answers:

the gravitational field strength on the moon is less
⇒ the projectile will take longer to fall to the ground
⇒ the projectile flight time is longer
⇒ the range of the projectile will be greater.

And:

the atmosphere is absent on the Moon
⇒ the air resistance is less
⇒ the range of the projectile will be greater.

7.3 A Reasoning Question, Involving a Capacitor

Not all reasoning questions involve a logical series of steps from one piece of knowledge to another. Sometimes you have to analyse a given situation, or compare things. Here's an example of this kind of thing. It's Question 8 from the June 2012 Edexcel paper "Physics on the Move".

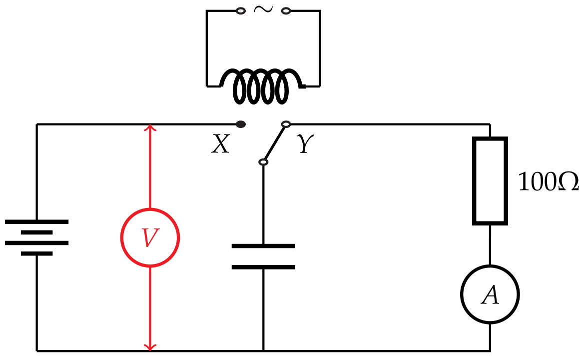
7.3.1 The Question

A student is investigating capacitors. She uses the circuit in Figure 5 to check the capacitance of a capacitor labelled 2.2 μF which has a tolerance of $\pm 30\%$.

The switch flicks between contacts, X and Y, so that the capacitor charges and discharges f times per second.

(a) The capacitor must discharge fully through the 100Ω resistor.
(i) Explain why 400 Hz is a suitable value for f.

Figure 5: A Circuit with a Capacitor



7.3.2 The Answer

This question must be something to do with *time* as it's talking about a frequency f of 400Hz. So, what *time*-thing does a capacitor have? Oh yeah: the *time constant*. Now the time constant is the time it takes for the voltage across the capacitor to go down to about 37% of its initial value. So how long will it take to discharge completely? Difficult question to answer!

So, what do we do? Well, we could first of all compare the time constant with the time that the switch is in one position. Let's do that.

The time the switch is in one position will be

$$t_{\mathrm{X\ or\ Y}} = \frac{1}{f} = \frac{1}{400} = 2.5 \times 10^{-3}\ \mathrm{s}$$

And the time constant for the resistor-capacitor combination will be

$$t_{RC} = RC = 100 \times 2.86 \times 10^{-6} = 2.86 \times 10^{-4}\ \mathrm{s}$$

(setting the value of the capacitor to its highest possible value of $2.2 \times 10^{-6} + 30\% = 2.86 \times 10^{-4}$s). Right, so the capacitor can be discharging through

$$\frac{2.5 \times 10^{-3}}{2.86 \times 10^{-4}} = 8.74$$

time constants before the switch flicks and it starts charging up again. Discharging through 8.74 time constants would leave the voltage across the capacitor being $0.37^{8.74} \approx 2 \times 10^{-4}$ of what it was at the start of the discharging process. I would say that would be fully discharged enough!

8 Describe an Experiment To...

8.1 Measure the Acceleration Due To Gravity

8.1.1 Do the Analysis

We will drop a ball bearing. We measure the distance it falls, h, and the time taken for it to fall that distance, t.

What equation will I use to base the experiment on? Here's the maths: the ball bearing falls from rest through a distance h, and it takes a time t to do this. So, using SUVAT, the initial velocity u will be 0; $s = h$; $a = g$; and $t = t$:

$$s = \frac{1}{2}gt^2$$

How can I draw a straight line from this equation? Here's how:

$$h = \frac{1}{2}g \quad t^2 + 0$$

$$y = m \quad x + c$$

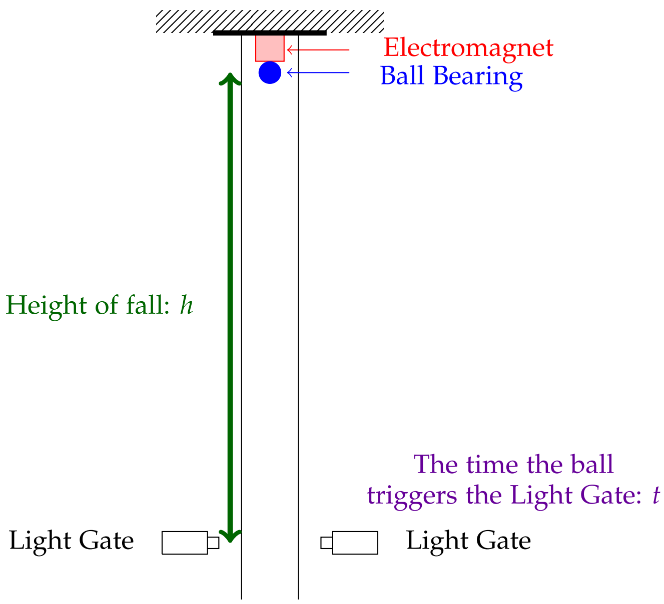
Now we've done the analysis, we can write our answer.

8.1.2 The Answer

The Equipment

Figure 6 is a diagram of the equipment to be used.

Figure 6: Diagram of the Equipment Used



The Method

A ball bearing will be dropped through a height h, and the time taken for it to fall, t will be measured.

h will be measured using a ruler, and t will be measured using a light gate. When the electromagnet is switched off, a timer starts; when the light gate is triggered, the timer stops; the time from the ball bearing being released until it triggers the light gate will be t.

We would then repeat these two measurements many times (to find an average t for each h), for a (large) number of different distances h. Then we tabulate our results, having columns labelled h, t and t^2. Using the data table we next draw a graph of h against t^2. The graph should be a straight line, the gradient of which is a half of g.

8.2 Measure the Internal Resistance and EMF of a Battery

8.2.1 Do the Analysis

What equation will I use to base the experiment on? The equation for the internal resistance r and EMF E of a battery is

$$E = V + Ir \tag{1}$$

where V is the potential difference across the terminals of the battery when there is a current I through it.

How will I get a straight line graph from this equation? We can write Equation (1) as

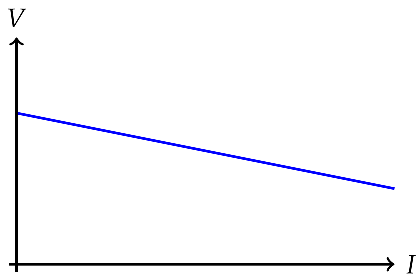
$$V = -rI + E$$

and by comparing this equation to that of the general equation of a straight line,

$$\begin{array}{cccccc} V & = & -r & I & + & E \\ y & = & m & x & + & c \end{array}$$

then a graph of V up the y-axis against I along the x-axis will yield a straight line, whose gradient is $-r$ and the y-intercept will be E. See Figure 7.

Figure 7: V-I Graph



So there's the analysis. That tells me what I need to do...

8.2.2 The Answer

The Equipment

I will set up a circuit containing the battery, an ammeter (to measure the current) and a variable resistor (so that I can change the current), all in series. I then connect a voltmeter in parallel across the terminals of the battery (so that I can measure the potential difference across it).

The Method

Vary the resistance of the variable resistor so that I can get different readings of V and I. For each $V - I$ pair, take several readings of the potential difference V across the battery and the current I in the circuit, and take an average of each.

Draw up a data table containing values of V and I for each setting of the variable resistor.

Draw a graph of V against I from the data in the table. The y-intercept will be E, the EMF of the battery, and the gradient will be $-r$, where r is the internal resistance of the battery.