PUPIL RESEARCHER INITIATIVE

Hunting the Quark

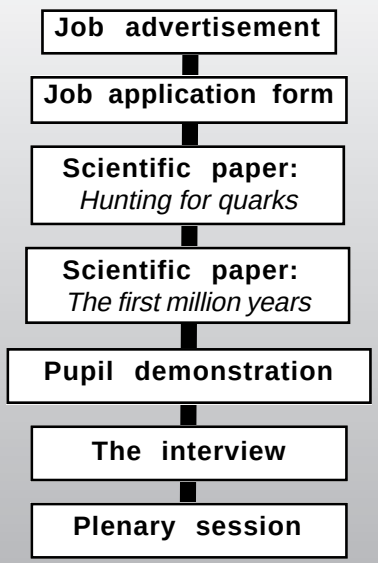
Pupil Research Brief

Teachers' Notes

Syllabus Coverage *Subject Knowledge and Understanding*

- ❑ atoms have a small central nucleus made up of protons and neutrons
- ❑ around the nucleus there are electrons
- ❑ theories of the origin of the Universe suggest that it might have started billions of years ago from one place, with a huge explosion, or Big Bang

Route through the Brief



Introduction

The context for the Brief is a simulation of an interview process. Half the pupils apply for a job as a physics researcher, studying conditions in the early Universe. The other half interview the candidates, working as panels of three, to decide which one meets the job requirements best. Both candidates and interviewers are provided with a sheet of guidelines to help them through the application process.

To meet the job requirements candidates will have to become familiar with the latest theories about the origin of the Universe and the structure of the atom. So, they spend time preparing for the interview by studying an article about the early Universe, and learning about the experiment which discovered the quark. They also complete a short application form. Interviewers need to study the new theories, as they have to devise the interview questions and evaluate the candidates' answers. In your role as professor of the physics department, you demonstrate to the panels a model of the quark experiment, using very basic equipment. The panels use the model in the interviews, as a basis for their questions.

The Brief then moves into the next phase, where panels interview each of the three candidates competing for one job. Using the information they have collected from the interviews and application forms, they reach a decision and inform the candidates. The guideline sheets encourage pupils to evaluate their performance and suggest ways to improve their interview skills for the future.

Pupil Research Brief

Teachers' Notes continued

Prior knowledge

This Brief assumes pupils know that atoms are made of electrons orbiting a nucleus consisting of protons and neutrons. Pupils do not need to be familiar with Red Shift evidence for an expanding Universe to use this Brief.

Running the Brief

Pupil grouping

Each group consists of a panel of up to four interviewers (three is ideal) and three candidates. Suggested groupings are :

Initial briefing	-	whole class; teacher introduces the topic
Job advertisement	-	whole class; teacher sets the scene, allocates pupil groups
Job application form	-	individuals for interviewees or as a panel for interviewers
Scientific papers - 'Hunting for quarks' & 'The first million years'		individuals or pairs; pupils write questions as interviewers or learn salient points as interviewees
Interview	-	individual pupils are interviewed by the panel of 3 or 4 pupils
Plenary session	-	whole class; teacher leads de-briefing session

Timing

This Brief may take about 2 hours of classroom time. One hour for the preparation phase (perhaps with a homework too) and another hour for the interviews, feedback and evaluation.

Activities

The teacher should issue pupils with the **Study Guide** which provides them with a summary of what they should produce as they work through the Brief. It can also act as a checklist for pupils to monitor their own progress. Outline the scenario, in which pupils will learn some of the latest ideas in cosmology and particle physics as well as getting some experience of the interview process. Then show them the **job advertisement**, which is designed to be copied onto overhead transparency. Point out to pupils that they have already had research experience, by doing investigations in previous science lessons.

Next split the class into groups of about six and get pupils to decide who will be the candidates and who the interview panel. Describe the phases of the simulation (see introduction) and give out the **research documents** and the relevant **guideline sheets**. In addition, candidates will need an **application form** and the interview panel several **assessment forms** (one for each candidate in the group).

Finally, set a time limit for candidates to complete their application forms. Twenty minutes should be sufficient, and this will give the interview panel time to study the forms during the same lesson.

Preparation phase

After candidates have completed their application forms, they will become more familiar with the theories on the origin of the Universe and the structure of the atom by studying the two documents:

- *Hunting for quarks* - a simulated scientific paper which describes the experiment which discovered quarks inside protons using particle accelerators
- *The first million years* - an article about conditions in the early Universe

Encouraging candidates to help each other prepare for the interview would reduce the competitive element in this exercise.

Interviewers will begin by reading the **papers** *Hunting for quarks* and *The first million years*. They will want to see the model of the experiment (see below) and then spend the rest of the lesson devising questions and studying the candidates' application forms. As they do so they write comments on the assessment sheets.

Interview phase

Each candidate gets a 10-minute interview during which the panel make notes about the candidate's answers on the assessment form. You might like to think about rearranging the laboratory furniture (if this is possible), so that four panel interviews can take place simultaneously, at a reasonable distance from the other candidates who are still preparing.

After candidates have been interviewed they can complete the 'Learning from experience' section on their guidelines sheet. However, as the first candidate to be interviewed may have to wait up to half an hour until the panel reach their decision, you might

want to prepare an additional task for these pupils. This might be, for example, reading Frank Close's article "Inside the atom", written for the first edition of *PRISM*, the PRI journal.

After the interviews

Depending on how much emphasis you want to put on who gets the job and how much of this is a learning experience, you could have the panels tell the candidates their decision separately or together. Just as with a real interview, it will help the candidates if the panels can give them some individual feedback on their performance.

Finally, if there's time, it would be valuable to have a short plenary session where pupils can share their experiences and reflect on what they have learned. You could also try to brainstorm: 'tips on interview technique'.

Technical details

A model of the 'Hunting the quark' experiment : equipment needed.

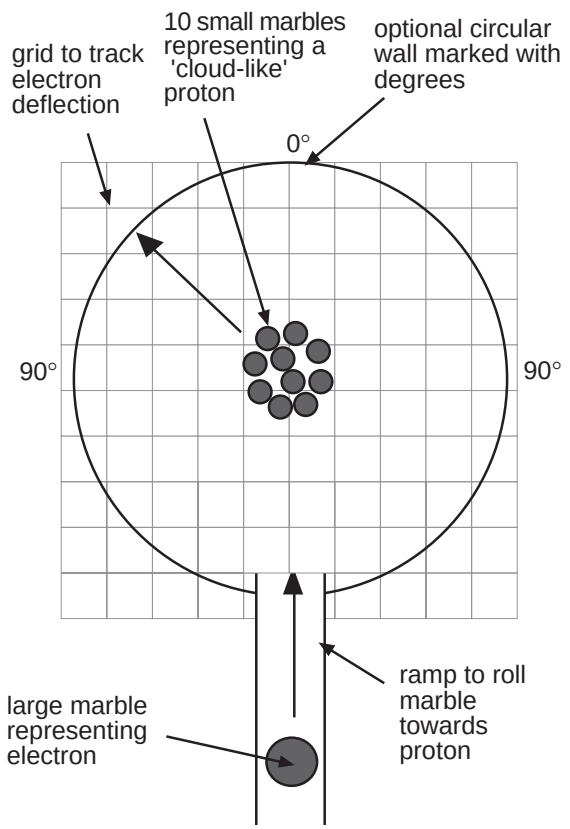
Each group will need a model of the 'Hunting the quark' experiment for the interview. For the model you will need the following equipment:

- 3 large marbles
- 10 small marbles
- a length of plastic track (or similar) with a groove to fit a marble
- a clamp stand
- a drawing board (or the bench)

The bigger the difference in size between the marbles, the better the model works.

The method used to search for quarks inside the proton uses the same principle as the famous experiment which led Rutherford to propose the existence of a nucleus within the atom. Instead of alpha particles, scientists working at the Stanford Linear Accelerator in California (SLAC) in the late sixties used electrons as their 'bullets'. They accelerated the electrons to the enormous velocity needed to penetrate their proton target using a particle accelerator. By investigating how much the electrons were scattered, they were able to show that protons were made of even tinier particles called quarks. See the paper 'Hunting for quarks' for a description of the theory.

You can model this experiment very simply using two different sizes of marbles or ball bearings to represent the particles, and a grooved plastic track which is raised at one end as the particle accelerator. The arrangement is illustrated in the diagram below.



The marble picks up speed as it runs down the ramp, just as electrons do in the accelerator. To investigate the predictions of the 'single particle' theory, use a larger marble as the electron and a collection of ten smaller marbles placed loosely in the centre of the board to represent the cloud-like proton . You will find that most of the time the larger marble is only slightly deflected by its passage through the group of smaller marbles. To investigate the predictions of the quark theory, use a smaller marble as the electron and place three larger ones close together on the board to represent the quarks.

For a class of 24 pupils you will need to construct four models. Although you only need one to demonstrate, each group will need a model for the interview. Demonstrate the model to the interviewers, so that they understand how it relates to the quark-hunting experiment. Then encourage them to come up with questions to test candidates' understanding of the model, e.g. "How would you arrange the marbles to test the predictions of the quark theory?"

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Teachers' Notes continued

Incidentally, you may wish to point out to the pupils that in fact every house probably has its own 'particle accelerator' - i.e. the television set - where a stream of electrons is accelerated across the cathode ray tube by a very high voltage.

Scottish syllabus coverage

Standard Grade Physics - *Health Physic*s

Further pupil research opportunities

Pupils may follow up work on quarks by searching for articles in magazines (such as *New Scientist)* about quarks, anti-matter and any new developments in particle physics. They may also look for any news on the Internet from such places as the CERN Web-site.