PUPIL
RESEARCHER
INITIATIVE

Hunting the Quark

Setting the Scene

You will be working as either a physicist applying for a research post to study the origin of the Universe or a member of the panel interviewing the applicants for the post. To prepare yourself for the interview, either as interviewee or interviewer, you will need to know about the structure of the atom and the Big Bang theory.

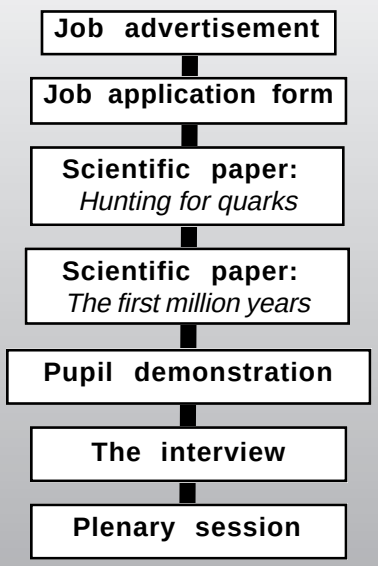
Pupil Research Brief

Study Guide

Syllabus Targets *Science you will learn about in this Brief*

- ❑ 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



Outcome Checklist

You will either be interviewed or interview, for the post of a research physicist in the field of particle physics. Guidelines for candidates and interview panels, along with two scientific papers and a demonstration model help prepare you for the interview process. You should make sure you produce the following items as you work through the Brief.

Job application form

- ❑ completed form

Guidelines for candidates

- ❑ notes on how the interview went

Guidelines for interview panels

- ❑ notes on what you learned from the interview situations

Scientific papers and demonstration model

- ❑ notes and questions for the interview

Interview assessment form

- ❑ comments on candidates' knowledge and skills

University of Redstone

Physics Department

RESEARCHER
£15-20K

The successful applicant will work on an exciting project to understand more about the moment the Universe was created.

Candidates must be:

- familiar with the latest theories about the structure of the atom and the origin of the Universe
- able to work well in a team
- experienced investigators.

An excellent package of benefits is available, including 35 days leave.

Post funded by the Research Council

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Research post application

Please write clearly in block capitals

Name **Mr/Miss/Ms**

Address **Telephone Number**

Date of Birth **Nationality**

School / College **Subjects Studied**

Teamwork Ability *(How well do you work in a team? Give an example.)*

Research Experience *(List any investigations you have done.)*

Hobbies and Interests *(Give a brief list.)*

I confirm that the information given is correct

Signature **Date**

For office use only *Date Received*

The University of Redstone is an equal opportunities employer

GUIDELINES FOR CANDIDATES

For this job application you will:

- complete an application form
- have a 10 minute interview.

To get the job you have to show the interview panel that you meet the job requirements better than the other candidates.

Completing your application form

First impressions count. Ensure you make a good impression by completing the form carefully and neatly. The selection panel will be looking in particular at your:

- ability to work in a team
- research experience (doing investigations).

Preparing for your interview

What you say in the interview reveals more about you than an application form can. So spend time preparing for the questions. The panel will be finding out what you know about the latest theories on:

- the structure of the atom
- the origin of the Universe.

You can learn more about these theories by reading the documents you've been given:

- 'Hunting for quarks'
- 'The first million years'

Making notes will help you remember and understand the main points. You can practise for the interview by imagining some questions you could be asked, and then trying to answer them.

Coping with the interview

During the interview you should:

- try to stay calm and relaxed
- think for a moment before answering the question
- ask the interviewer to repeat the question if you don’t understand it
- give full answers if you can.

Learning from the experience

In the interview, what went well?

What went badly?

How could you improve?

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Assessment form

Post: Researcher
Dept: Physics

Candidate ----------

Requirements	Comments
Has knowledge of atomic structure the origin of the Universe	
Teamwork ability	
Research experience	

Signed ---------- Date ----------

GUIDELINES FOR INTERVIEW PANELS

It's up to you to decide who gets the job. The candidate you pick will be the one that you think meets the job requirements best. To collect information about the candidates you will:

- interview them for 10 minutes each
- study their application forms.

Preparing questions for the interviews

Use the interview to out find what candidates know about the latest theories on:

- the structure of the atom
- the origin of the Universe.

To help you prepare questions about the structure of the atom:

- read the document 'Hunting for quarks', which describes an experiment
- try out the model of the particle accelerator, which the professor will demonstrate to you
- devise no more than 4 or 5 questions about how the model relates to the experiment (you'll have the model in the interview).

To help you prepare questions about the origin of the Universe:

- read the document 'The first million years'
- make a list of the important points yourself
- choose 4 or 5 points as a panel and turn them into questions.

Don't make your questions too difficult, or the candidates won't be able to answer at all.

Studying the application forms

The application forms give you information about each candidate's:

- research experience (doing investigations)
- teamwork ability.

You can then complete these sections on the assessment forms.

Conducting the interviews

In planning or conducting the interview :

- decide who will chair the interview panel
- decide who's going to write comments on the assessment form (take turns in doing this)
- divide the questions between the other members of the panel
- introduce yourself and other panel members to the candidate
- be friendly to all the candidates and ask them about their hobbies first (to help them relax)
- decide who will demonstrate the model of the particle accelerator to the candidate
- keep to the 10 minutes allowed.

Making your decision

Working as a panel:

- take one job requirement at a time
- write down the candidates in order of how well they meet that job requirement
- decide overall who meets the job requirements best.

After the interview

Be sensitive when you let the candidates know your decision. If there's time, give each one some feedback on the interview, by telling them:

- what they did well
- how they could improve - be positive.

Learning from the experience

What have you learned that will help you in an interview situation?

Hunting for quarks

This is an extract from a scientific paper written in 1974 describing how scientists discovered quarks. You could also read Frank Close's article 'Inside the Atom' in issue 1 of PRISM, the PRI journal (September 1996).

Introduction

As we look into the atom, we discover hidden worlds inside. First we find electrons in the space around the nucleus. Then, probing into the nucleus, we find that it is made of particles - protons and neutrons. Can we probe any further? Many scientists now believe we can. A new theory says that protons and neutrons are made up from even smaller particles called 'quarks'. The experiment described in this paper provides evidence for the existence of these quarks.

Method

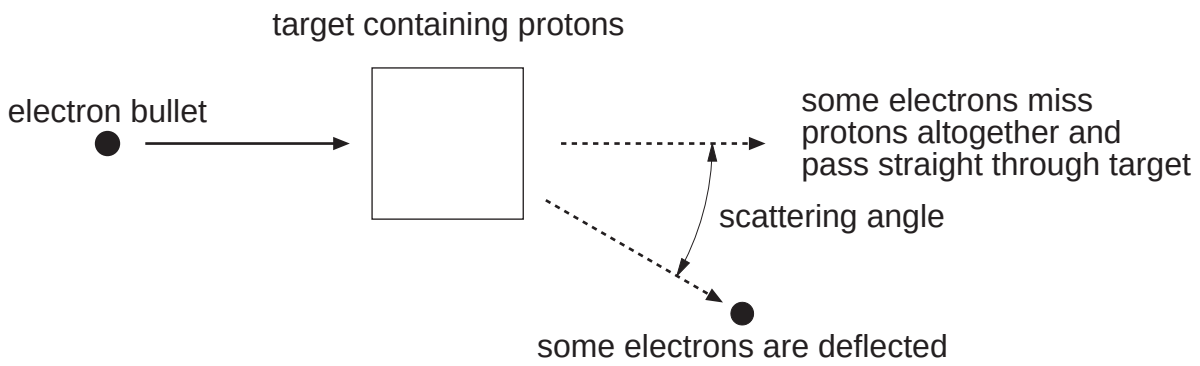
Our idea was simple. By firing electron 'bullets' at protons we hoped to find out more about them. Scientists discovered the nucleus by a similar experiment in the early part of this century.

We chose electrons as bullets, because they are much smaller than protons. But for the electrons to get right inside the protons they would have to be travelling at close to the speed of light. A machine, called a particle accelerator, has just been built that will accelerate electrons to this enormous speed. It is basically a tunnel 3 kilometres long. Electrons are fed energy in the form of radio waves and they accelerate from one end of the tunnel to the other in a fraction of a second.

For our experiment, we fired the beam of electrons from the particle accelerator at a target containing protons. What we wanted to know was how much the electrons would be deflected by whatever the protons were made from?

To see where the electrons came out, and how much they were deflected we used special detectors which we could move around the target. For each electron bullet we measured the angle through which it was deflected. This is called the 'scattering angle'.

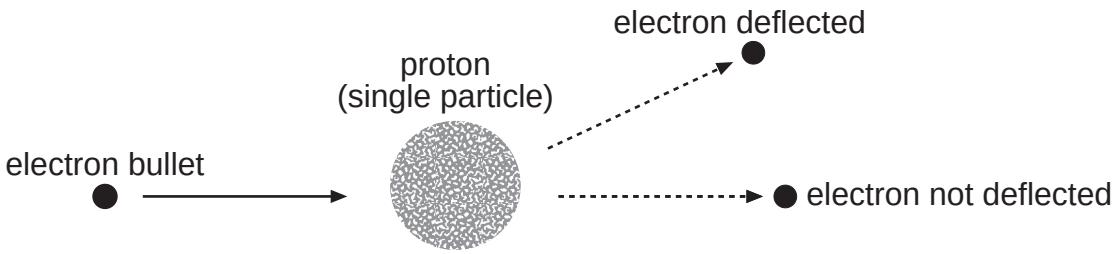
Figure 1. Particle accelerator fires electrons at a target containing protons



Predictions

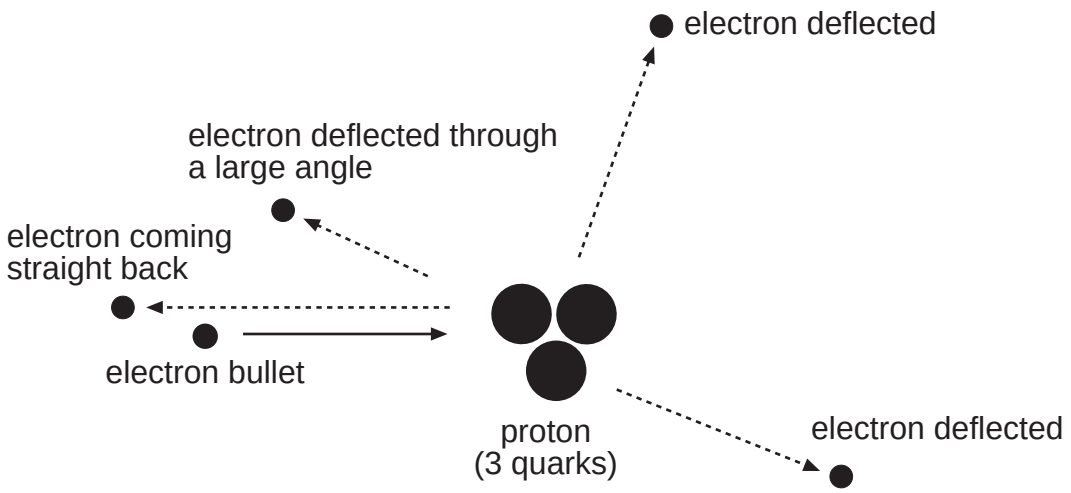
If the proton is a single particle we can imagine that its charge and mass are spread thinly throughout its volume, like a cloud. If this theory is correct, then when we fired electrons at the particle cloud, they would only be slightly deflected. So the single particle theory would predict small scattering angles.

Figure 2. The single particle theory



However, the new theory proposes that the proton is made up of 3 small particles called quarks. In this case the electrons, being of much smaller mass than the quarks, would be deflected much more. A few of the electrons might even come straight back. So the quark theory predicts much larger scattering angles.

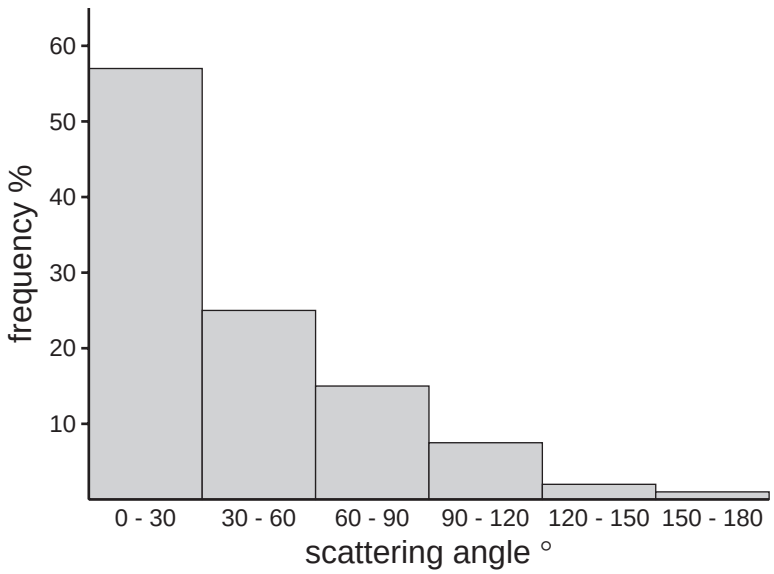
Figure 3. The quark theory



We would also expect a lot of the electrons to go straight through the metal target, completely missing the protons.

Results
We measured the scattering angles of the electron bullets over a long period of time. We then drew a frequency diagram.

Figure 4. Frequency diagram showing scattering angle of electrons



Conclusion
The frequency diagram shows that many electrons went straight through the metal target, as we expected. But many of them were scattered through large angles and some of them came straight back. These results can only be explained if the theory is correct: protons are made of even tinier particles called quarks.

Not only does this discovery tell us more about the atom, it helps us understand the origins of the Universe. By accelerating electrons to close to the speed of light, we have actually recreated the conditions in the Universe when it was only 1/100 of a second old.

The first million years

A violent birth

Scientists have a vision of creation, known as the 'Big Bang'. This theory says that the Universe began with an almighty explosion, about 15 billion years ago. Ever since then it has been expanding and cooling, as the energy from the Big Bang becomes more dispersed.

Today the Universe is teeming with giant structures like galaxies and stars. But what was the Universe like when it was very young?

Scientists have tried to answer this question by simulating the conditions that existed a tiny fraction of a second after the Big Bang. They have recreated temperatures of billions of degrees right here on Earth, by accelerating particles to nearly the speed of light and making them collide. We now have a glimpse of the Universe as it was growing up.

After the Big Bang

In the first few moments of the Big Bang, the Universe was a seething mass of high energy particles, smaller than a fist, (see *Figure 1* on the next page). These tiny particles included electrons and quarks, the building blocks of atoms. There were so many particles that light couldn't travel far without bumping into one. So the Universe was opaque.

Within a second the quarks had begun to cluster together making protons and neutrons. Three minutes later, when the early Universe was still as hot as the inside of the Sun, the protons and neutrons came together to make small nuclei such as helium.

Then, for about three hundred thousand years, the Universe just kept on expanding and cooling. Eventually when the temperature had dropped to about 3 000 K, electrons were moving slowly enough to be captured by the nuclei, making complete atoms.

Without free electrons racing around, light could now travel vast distances. The Universe had become transparent.

After millions of years of expansion the first big structures started to emerge. In little pockets of space where the atoms were closer gravity began to make matter clump together. These pockets were the birthplaces of the first stars and galaxies.

Mind over matter

In order to understand the Big Bang more fully we need to create conditions where electrons are accelerated to even higher speeds. However, eventually our technology will reach a limit. We'll never be able to recreate the temperatures of the Big Bang itself in the laboratory.

But there is another way. Many scientists believe that all the forces we know are just different aspects of one 'superforce'. One force is causing them big problems, and that is gravity.When scientists finalise the superforce theory they will be able to understand fully what happened at the moment of creation.

This will be the ultimate challenge: to explain how the Universe suddenly came into existence 15 billion years ago.

Figure 1. History of the Universe