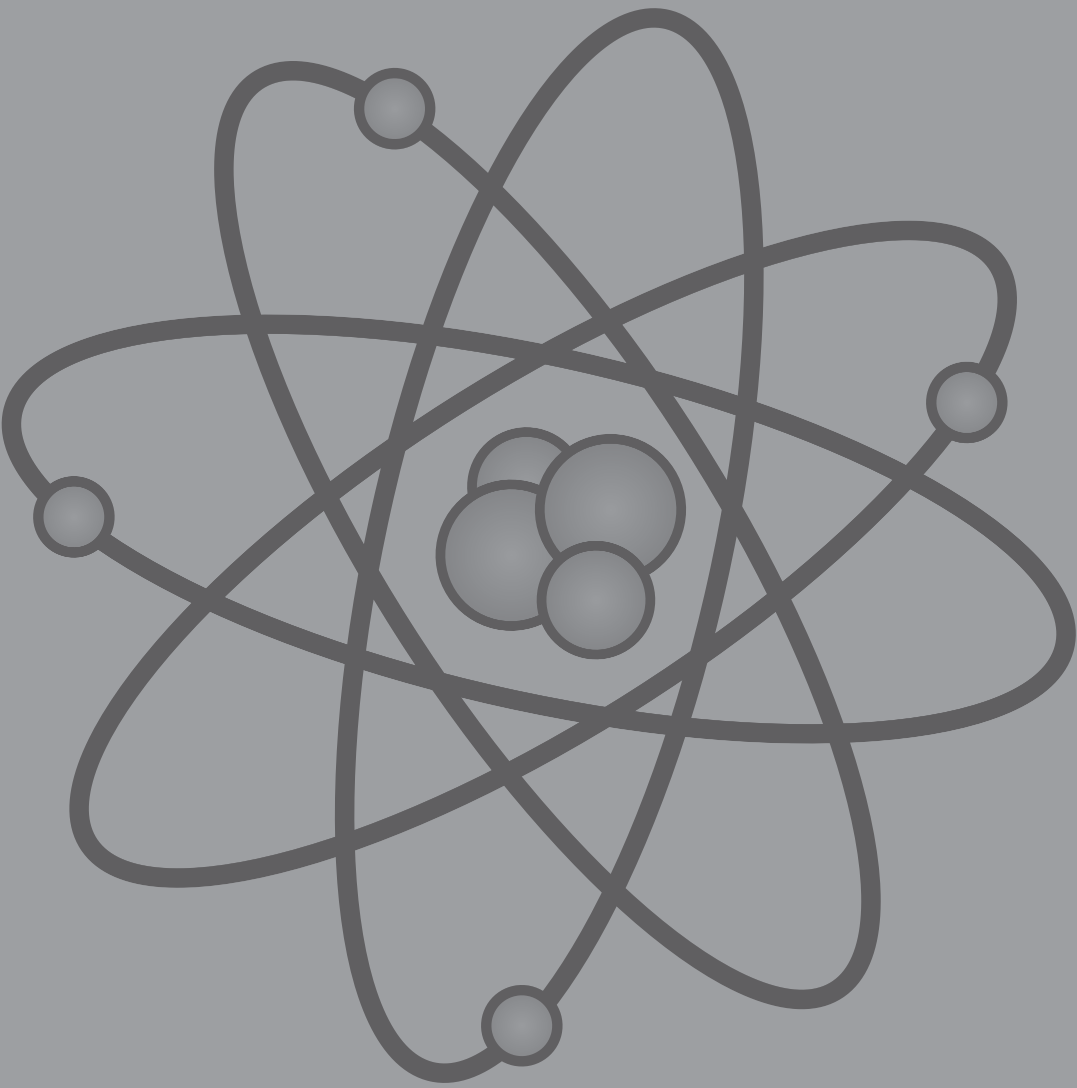

Mission Invisible

YEAR NINE TEACHER NOTES

QGC | FUTUREMAKERS | QUEENSLAND MUSEUM NETWORK | Queensland Government

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Group activity

Watch a video

This resource has been developed to support the touring exhibition *Hadron Collider: Step Inside the World's Greatest Experiment*, created by the London Science Museum, and installed at the Queensland Museum and Sciencentre from 9 December 2016–25 April 2017. The exhibition was made possible through the support of presenting partner, QGC.

For further information on the creation of the exhibition visit: London Science Museum

To discover the latest findings, and research more about the Hadron Collider visit: CERN

Overview and Curriculum Links

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<tr><th>Year 9 Curriculum focus</th><th>Activity</th><th>Notes</th></tr>
<tr><td>Science Understanding

Chemical sciences
All matter is made of atoms that are composed of protons, neutrons and electrons; natural radioactivity arises from the decay of nuclei in atoms (ACSSU177)</td><td>Detector Experiments: the Large Hadron Collider
Web Quest: Detecting the invisible</td><td>A journey beyond the Planetary Model</td></tr>
<tr><td>Science as Human Endeavour

Nature and development of science
Scientific understanding, including models and theories, is contestable and is refined over time through a process of review by the scientific community (ACSHE157)
Advances in scientific understanding often rely on developments in technology and technological advances are often linked to scientific discoveries (ACSHE158)

Use and influence of science
People can use scientific knowledge to evaluate whether they should accept claims, explanations or predictions and advances in science can affect people’s lives, including generating new career opportunities (ACSHE160)</td><td>LHC Exhibition: Detecting the smallest particles</td><td>Visit the LHC to find out more about small particle detection.</td></tr>
<tr><td>Science Inquiry Skills

Questioning and predicting
Formulate questions or hypotheses that can be investigated scientifically (ACSIS164)

Planning and conducting
Plan, select and use appropriate investigation methods, including field work and laboratory experimentation, to collect reliable data; assess risk and address ethical issues associated with these methods (ACSIS165)
Select and use appropriate equipment, including digital technologies, to systematically and accurately collect and record data (ACSIS166)

Processing and analysing data and information
Analyse patterns and trends in data, including describing relationships between variables and identifying inconsistencies (ACSIS169)
Use knowledge of scientific concepts to draw conclusions consistent with evidence (ACSIS170)

Evaluating
Evaluate conclusions, including identifying sources of uncertainty and possible alternative explanations, and describe specific ways to improve the quality of the data (ACSIS171)

Communicating
Communicate scientific ideas and information for a particular purpose, including constructing evidence- based arguments and using appropriate scientific language, conventions and representations (ACSIS174)</td><td>Mission Invisible Challenge: What’s in the box?</td><td>Discovering the nature of particles using detectors: a challenge for all ages.</td></tr>
</table>

Detector Experiments: Large Hadron Collider

A journey beyond the Planetary Model of the Atom

Your Mission

You are about to take a journey through a series of activities that will further develop your ideas about Atomic Theory beyond the Planetary Model of the atom.

The processes of detection of sub-atomic particles are introduced by looking at some historical methods that Scientists have used to discover more about matter and the universe. You will then move on to look at current technologies to find out what Scientists are learning from the Large Hadron Collider experiments.

Learning from what Scientists are doing, you will have the skills to finally undertake an investigation of your own, using detector instruments to find evidence of the nature of particles in a sealed container.

Key Questions

- How can we see the invisible?
- How can Scientists detect the invisible to find out more about matter and the universe?

These focus questions will guide the learning activities that follow.

They could also be used to ascertain students' pre-knowledge of the topic though.

Some example responses Q1:

Student examples of real world objects would most likely include solids and liquids because they consist of many particles and atoms.

Some example responses Q2:

- Gases unless they have colour
- Particles that make up liquids or solids
- Very small particles such as molecules, atoms, neutrons, protons, electrons, bacteria, viruses
- We can’t see them because the particles they are made of are so tiny and the atoms are spaced further apart (e.g. when comparing gases to solids)

Some example responses Q3:

- We know they exist as we see the effects when they interact with other things.

Some example responses Q6:

- We see smaller particles by using detectors that improve our vision such as glasses, hand lens, or microscope. Detectors to see inside things are x-rays or ultra-sounds. Detectors to see into outer-space are telescopes or radio waves. Detectors to see inner Earth are seismic waves or core samples.

THE UNSEEN WORLD

What do you already know about particles that you can’t see?

In small groups, or as a class, discuss answers to these questions:

1. What type of objects can we normally see? Why?
2. What type of objects can’t we normally see? Why?
3. How do we know these invisible things exist?
4. What is the largest object we can see?
5. What is the smallest particle that we can see?
6. How could we see smaller particles?

HOW HAVE SCIENTISTS MADE DISCOVERIES ABOUT THE ATOM?

Key Question

What are some more ways scientists might use to detect the invisible?

Your teacher will advise you which videos or parts of videos you should view to help answer these questions.

Watch the videos as directed by your teacher and complete the table below.

What was detected?	Detector used	What was detected?
X-rays		
Radiation		
Cathode rays		
Nucleus of the atom		
Sub-atomic particles		

Note:
Continued from previous page

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It is recommended that teachers assess the following videos to ascertain which are suitable for their students.

The Queensland Museum Hadron Collider video associated with the Hadron Collider exhibition can be used as an introduction or an overview at the end.

Röentgen– X-rays

View from 1 min to 4 min 45 sec.
Source: Milestones of Science.
X-Rays by Wilhelm Conrad Röntgen.
Uploaded Mar 2, 2010.
Total length 7 min 17 sec.

Becquerel – Curie Radiation

View from 2 min 10 sec to 4 min 05 sec. Source: TransTel Cologne. Radioactivity ~ Henri Becquerel, Marie & Pierre Curie. Published Apr 29, 2013. Total length 14 min 50 sec.

JJ Thomson – Cathode rays

View from Start to 3 min 35 sec
Source: Tyler DeWitt (Socratic.org). Discovery of the Electron: Cathode Ray Tube Experiment. Published Nov 27, 2012. Total length 11 min 07 sec.

JJ Thomson – Cathode rays

View all of: Source: D C Hummer. Demo 10H Chem - Cathode Ray Tube. Uploaded Oct 1, 2008.
tal length 2min 48sec.

Rutherford – Atomic nucleus

Source: Backstage Science.
Rutherford Gold Foil Experiment.
Uploaded Apr 14, 2011.
Total length 4 min 05 sec.

These questions will focus the students on important ideas to explore during a visit to the Large Hadron Collider Exhibition. Alternatively, the Queensland Museum's Hadron Collider video could be used to explore answers.

CERN resources to help teachers interpret information for students:

Source: CERN, all links below are made available through CERN's Open Source Learning Resources

Particle accelerators

Using electrostatics to accelerate small (invisible) particles

Particle beam

Using magnets to focus the beam of moving particles.

Particle detectors

Looking at detectors, there are number of types of detectors used, depending on what is being detected.

The most significant discovery so far made using the Large Hadron Collider in CERN has been the discovery of the Higgs Boson. This is one of the fundamental building blocks of matter and the universe.

Higgs Boson

Introducing the Large Hadron Collider

What is the smallest particle that can be detected?

Scientists working at the Large Hadron Collider are researching and seeking answers to this question.

You will now take a journey to their research laboratory which is based on a large underground collider ring that collides particles at close to the speed of light!

The collider was set up to look for evidence of the smallest particles. Among them is the Higgs Boson which is considered as a fundamental particle.

But is it the smallest? Let's find out.

Large Hadron Collider Exhibition at the Queensland Museum

Visit the museum or watch the Queensland Museum Hadron Collider Exhibition videos to find answers to the following questions:

Key questions

1. What types of particles are Scientists looking for, and what have they found so far?
2. Why are they looking for these particles?
3. How do scientists accelerate the particles in the Large Hadron Collider, and how does this principle work?
4. Why are several detectors needed?
5. Why do scientists do more than one experiment (e.g. more than one particle collision?)
6. Do you think Scientists will keep finding smaller particles? Why? This is a big question and will take some thought and explanation to give a good response.

You are now ready to take on the Mission Invisible Challenge!

Note:
Continued from previous page

Students will have little knowledge of quarks, so this fundamental particle may need to be introduced and discussed.

If visiting the Hadron Collider exhibition at the Queensland Museum, other resources can be used to help with concepts and as an introduction. If unable to visit the exhibition, also refer to the Queensland Museum Hadron Collider video

Teacher resources

(recommend that teachers assess suitability for their students)

Higgs Boson animated introduction:

View from Start to 2 min 26 sec

Source: Wyatt Johnson, Alex Johnson and Ellen Knealing. The Higgs Boson Simplified Through Animation. Published Mar 25, 2014. Total length 3 min

What is a Higgs Boson?

View from start to 2 min 55 sec as this video was produced pre-discovery, but facts still relevant.

Source: Fermilab. What is a Higgs Boson? Uploaded Jul 7, 2011. Total length 3 min 26 sec

The Large Hadron Collider, Higgs Boson and Higgs Field

View from 1 min 25 sec to 3 min 35 sec

Source: Veritasium (Produced for ABC's 'Catalyst'). What Now For The Higgs Boson? Published Oct 17, 2012. Total length 8 min

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Mission Invisible Challenge Teacher Instructions

The contents of the sealed box can vary according to level of difficulty appropriate for the students. This allows for differentiated learning in the classroom with by adjusting the level of challenge by altering the combinations of objects and types for different groups.

The range of objects listed in the set up notes is suggested and not prescriptive.

A range of detectors can also be varied and used as a means of differentiating learning. The range of detectors can also be used to simulate the idea that Scientists have to deal with the limitations of available technology. It is important that limitations of the available detection equipment also reinforce the idea that there is no "right" answer. For example if using a bamboo probe in the box the probe should be limited in length so that it does not extend too far inside the box and can't probe to every corner.

You may give students the option to design and use one more piece of detection technology after they have explored and made inferences from the available detectors.

It is important that the boxes never be opened to find out if the students were 'right', as the aim of the investigation is to find the best description of the nature of the particles (objects) inside the box based on the evidence of detection. This aims to highlight the nature of scientific work in this area.

Students should describe their objects in terms of properties and should not be attempting to identify what it is by name. For example: a soft spherical object that is lighter than the other objects in the box; it does not appear to have any electrical or magnetic properties but rolls under the influence of gravity.

Materials

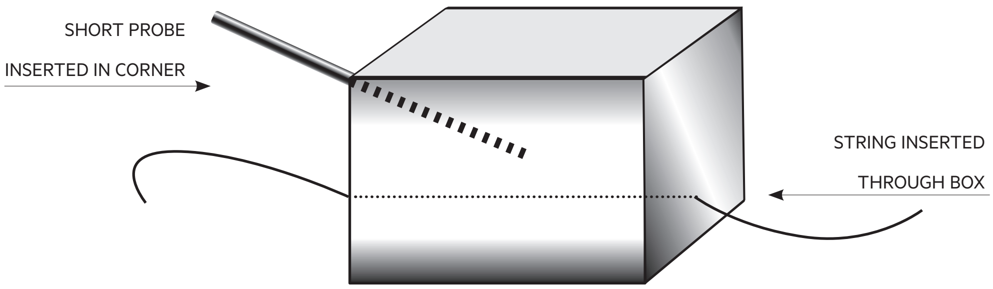
1. **Suitable box which can be sealed**
    - Sealed shoe box
    - Post pack box
2. **Test box (one for the class)**
    - Identical to sealed box except open
    - Samples of objects that could be in sealed box (position in a central location in the class for students to access)
3. **Objects (examples)**

- Spheres
    - Golf ball
    - Practice golf ball
    - Table tennis ball
    - Squash ball
    - Ball with paper clip attached to outer shell
    - Ball bearing

- Prisms
  - Eraser
  - Toy block
  - Toy cylinder
  - Magnet
  - Foam cylinder
- Combination objects (Advanced)
  - Shapes joined by string or springs
  - Magnet with another magnetic material

4. Detectors (examples)

- String threaded through centre of box
- Short probe that can be inserted in one corner of the box
- Magnet or compass
- Scales
- Sound analyser (if available e.g through phone app)
- Electric resistance could be measured if you allow conducting probes to penetrate the box. Use with care as an option.



Setup

Place a ombination of objects into a box and seal it completely. Place a range of sample objects and detectors in a central location for students to access.The composition of sealed box depends on level of challenge required.

Combinations of types will depend on resources available and the level of differentiation required.

Some suggestions:

- Try 3 different shapes with different materials
- Place an open box, similar to the sealed box in a central location with the detectors so students can test how they might use the detectors.

Remember:

The level of complexity needs to be tailored to suit the learning needs of the students.

The sealed box must never be opened to find out if the students were “right”. Doing so would destroy the whole point of the activity: What is your best guess of what is inside based on the evidence you have collected?

Adjust the task demands according to your student needs.

- Hand out sealed boxes to student groups and leave on the desk.
- Ask students to try and guess what is inside.
- Allow students to manipulate the boxes and make another guess.
- Ask students to justify their guesses. Guesses should be based on the results of the manipulations.
- What senses did they use? Think about what senses can be used to detect what is in the box.

Mission Invisible Challenge: What is in the box?

Your challenge is to find out the nature of the particles inside a sealed box, as these particles give the box special properties when moved. You must work out a way to detect the particles inside the box so they can be described. You cannot open the box to see inside, instead you must rely on all your senses and other powers of detection.

To complete your mission you will need to identify what you think is inside the box by describing:

a. Number of particles in the box
b. The shape of the particles
c. The mass of the particles
d. The hardness of the particles

Getting started

- Your teacher will give your group a sealed box.
- Do not attempt to open or look inside the box!
- Use your senses to make a best guess of the number and nature of the particles inside the box. Write down your best guess.
- Discuss your thinking with other members of your group.
- Record your predictions here:

Be prepared to share your ideas with the whole class.

In your group discuss answers to the following questions:

- How can you better detect what is inside the box?
- What senses can you use?
- Can you use other detectors to help us make a better guess? What detectors will you use?

Using the Test Box

- Your teacher will provide you with an open box similar to the sealed box that will allow you to perform some tests on sample particles.
- Your group needs to devise some experiments on the sample particles in the test box to obtain data that might help you identify the unknown particles in the sealed box.

Test procedure

- Decide how your group will perform your experiments and keep this procedure the same for all experiments on both the opened test box and the sealed box.
- Place one object in the test box and perform the first experiment. You will need to observe what the object is doing and then describe what you notice using senses other than your eyes.

Example test data:

Test	Test particle	What did you do?	Describe what happened?
Shape	*Squash ball*	*Placed the ball at one end and then tilted the box.*	*The ball rolled slowly to the other end making a rolling sound before hitting the end with a soft clunk.*
Shape	*Squash ball*	*Placed the ball at one end and then tilted the box at a very slight angle.*	*The ball started to move slowly. We could hear when it started to move.* *It took more than 3 seconds to reach the other end of the box.*

Hardness can be described in terms of hard or soft. The evidence is simply the sound as it either rolls, slides or collides with other particles or the sides of the box.

Students may be able to feel the difference of impact on the side of the box between hard and soft.

Enter your data:

Data Table

Test	Test particle	What did you do?	Describe what happened?

Repeat the Test Procedure

You should use the same procedure as before except this time you will work backwards from the "Describe what happened" to try and match it to one of your test particles. Good luck as this step is the most important.

Remember to think about your data obtained from your experiments with the test box, and how it helps you make better guesses about the particles in the sealed box.

Also remember:

1. Investigate one property at a time. For example, shape.
2. You are not trying to identify the object by name (e.g. Squash ball) only its properties. (e.g. Sphere).

What detectors will you use this time?

Having performed the range of tests in the test box, and had an initial "play" with the sealed box, the students should now be in a position to make a first guess or prediction about what they think is in the sealed box.

Recording results

Key questions you are trying to answer:

1. How many objects in the box?
2. What is the shape of each object? (Sphere, Cylinder, Cube or Prism)
3. What is the mass of each object? (Heavy, Medium, Light)
4. What forces can the object detect? (Magnetic, Gravitational, Electric, etc.)

Record your results about the types of particles you identify are in the sealed box in the tables below:

Data table

1. How many OBJECTS in the box?

What did you do?	Describe what happened?	Number of objects?	Why do you think this?

2. What is the SHAPE of each object?

What did you do?	Describe what happened?	Shape of objects?	Why do you think this?

Data tables

3. What is the MASS of each object? (Heavy, Medium, Light). Predictions:

What did you do?	Describe what happened?	Mass of objects?	Why do you think this?

Data tables

4. What FORCES can the object detect? (Magnetic, Gravitational, Electric, etc.)

Predictions:

What did you do?	Describe what happened?	Number of objects?	Why do you think this?

Reminder:

Do not open the box for students to see if they are "right". This is not about right or wrong as the students must realise that the Scientists cannot just open a box to find the answer.

Students should emulate the Scientist's process of expressing their confidence in their findings.

CONCLUSION

What did you find out?

Mission Accomplished?

Now write a paragraph which describes your findings and conclusion

- Think about what you have found out and what you now believe to be in the box.
- Remember you have to describe the particles in terms of their shape, the number, mass and hardness. Do not identify them as a particular type of ball or toy.
- Did your findings match your predictions? Can you explain why/why not?

It is important that students reflect on the confidence they have in their results. This may need to be adjusted to suit learning needs of students.

Scientists also judge their confidence level by assigning a percentage based on their degree of confidence. This has been particularly evident during the Climate Change debate.

Confidence is the degree to which there is agreement with others performing the same tests as well as the robustness of the evidence.

Students with very high confidence will need to feel that others can reach the same conclusions if they use the same tests or they will need to justify their conclusions against other points of view based on their evidence.

The important point is that students realise that there is no right answer and they can only have a level of confidence in their results.

CONFIDENCE IN RESULTS

Confidence scale

This identifies the confidence that you have in your results.

Your confidence is based on what others who perform the same tests will find.

How confident are you that:

- They will make the same conclusions that you did, or
- You will be able to argue that your results are better?

Very high confidence	90%
High confidence	70% - 90%
Medium confidence	40% - 70%
Low confidence	20% - 40%
Very low confidence	<20%

Then record your answers to the following questions:

1. Using the above scale, what level of confidence would you give your best guess now? Why do you think this?

____

____

____

2. To improve this confidence level, what detector would you like to have to use for more tests? How would this detector help you make a better guess?

____

____

____

3. Scientists would not rate their confidence at 100%. Why do you think this is so?

____

____

____

4. Then discuss your results with the rest of your class.