The QCAA requires students to complete a research investigation in Unit 4 Physics. In preparation for Unit 4, teachers may choose to assign a similar assessment task in Unit 1, as suggested by the QCAA in their assessment guidance.

The research investigation assessment task requires students to investigate a claim, by drawing on secondary evidence from scientific texts. Students use research conventions to analyse and interpret the evidence to reach a justifiable conclusion about the claim. The research requires students to locate and use information beyond the scope of their knowledge and data they have been given.

The research investigation requires students to gather secondary evidence on a research question. Students must work individually to develop and investigate their research question based on a number of possible claims the teacher provides.

Evidence must be obtained by researching scientifically credible sources, such as scientific journals, books, websites of governments, universities, independent research bodies or science and technology manufacturers. The research investigation constitutes 20% of the total assessment in Unit 4 Physics.

A summary of the objectives and marking for the research investigation (Unit 4) are shown in the following table.

Research investigation may be presented in:
- written form (e.g. scientific report), 1500–2000 words, or
- multimodal presentation form (e.g. poster presentation), 9–11 minutes.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Assessment objectives</th>
<th>Demonstrated by</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Research and planning</td>
<td>- Apply understanding.</td>
<td>- a considered rationale showing how the research question was developed from the claim</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>- Plan an investigation.</td>
<td>- a research question that is specific and relevant</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- collected sources that are sufficient and relevant</td>
<td></td>
</tr>
<tr>
<td>Analysis and interpretation</td>
<td>- Analyze the evidence sourced during the research.</td>
<td>- collection of sufficient and relevant sources</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>- Interpret the research evidence.</td>
<td>- detailed and careful coverage of relevant trends, patterns and relationships</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- detailed and careful coverage of the evidence’s limitations</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- justified scientific arguments based on evidence</td>
<td></td>
</tr>
<tr>
<td>Conclusion and evaluation</td>
<td>- Interpret the evidence from the research.</td>
<td>- a conclusion that is justified and addresses the research question</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>- Evaluate the processes, claims and conclusions within the research.</td>
<td>- insightful examination of the evidence’s quality</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- extension of investigation findings that are credible</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- consideration of possible improvements and extensions to the investigation that are relevant to the claim</td>
<td></td>
</tr>
<tr>
<td>Communication</td>
<td>- Present the research findings, including arguments and conclusions.</td>
<td>- scientific language and representations that are concise and fluent</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td></td>
<td>- suitable use of genre conventions</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>- appropriate referencing conventions to acknowledge sources</td>
<td></td>
</tr>
</tbody>
</table>

Total 20

The scientific inquiry is not a linear process. Scientists will not necessarily complete these steps in the stated order and some steps may need to be repeated or altered in order to more accurately address the research question.
1.11 Developing the research question from a claim

BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO

- analyse a claim to identify scientific concepts, variables and measurable terms within the claim.
- develop a research question or hypothesis from a claim.

The research question should specifically address one of the concepts associated with the claim. It should clearly state the relevant variables. All the research conducted for the research investigation will be directly related to the research question. Therefore, the process begins with the claim and then develops, based on the concepts addressed by the claim.

UNDERSTANDING THE CLAIM

The syllabus defines a claim as 'an assertion made without any accompanying evidence to support it'. The assertion or claim can be a sentence, a statement within a sentence, the title of an article, a quote, or anything published in any form. Your research question will focus your investigation, necessitating evidence to be gathered so that the claim can be evaluated. An example of a claim is shown in the title of an article in Figure 1.11.

![Figure 1.11 - Article with a claim in the title](image)

So how is a research question formed from a claim that is not supported by evidence? The claim itself has to be analysed and understood. Within the claim, identify one or more of:

- known scientific concepts
- variables
- measurable quantities
- ideas related to concepts
- quantities that are claimed to influence another.

CHAPTER 1 | PHYSICS SKILLS AND ASSESSMENT TOOLKIT
You should record all the information you collect during the investigation in a journal, including the process of developing a research question from a claim. This will be used in your research investigation report to address ISMG characteristics about developing a research question from a claim. Write down all the elements found in the claim and try to categorise them using the above list. Each element within the claim may suit more than one category. Table 1.11.1 outlines an example of analysing and categorising elements of a claim.

**Example 1**

<table>
<thead>
<tr>
<th>Claim</th>
<th>It is well known that panes of stained glass in old European churches are thicker at the bottom because glass is a slow-moving liquid that flows downwards over centuries.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source and context of claim</td>
<td>An article from the New York Time in July 2008 referred to the unclear nature of glass and whether it was a solid or a liquid.</td>
</tr>
</tbody>
</table>
| Elements in the claim | • Glass is thicker at the bottom than at the top  
• Viscosity  
• Melting point  
• Entropy |

**Classifying elements of the claim**

| Glass | • known concept: solid or a liquid  
• uses entropy to determine when it should melt  
• structure of glass not well understood |
| Viscosity | • measurable known concept  
• related to thickness and resistance to motion |
| Melting point | • can be measured for a simple solid  
• not constant for glass |
| Entropy | • a measure of the randomness of the glass  
• causes fluctuations in many measurable quantities  
• could explain the unusual nature of glass |

**Example 2**

<table>
<thead>
<tr>
<th>Claim</th>
<th>Cold fusion could provide a limitless supply of energy to the world.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Source and context of claim</td>
<td>Journal article from an established science journal states that nuclear fusion can be created by room temperature sources.</td>
</tr>
</tbody>
</table>
| Elements in the claim | • Nuclear fusion  
• Energy production  
• Heat source and temperature required  
• Electrolytic cell |

**Classifying elements of the claim**

| Nuclear fusion | • known scientific concept  
• not achieved yet on Earth  
• source of energy created when smaller nuclei collide and join to make a heavier nucleus  
• needs small nuclei such as hydrogen or helium |
| Energy production | • produces vast amounts of energy per kilogram of matter via Einstein’s equation $E = mc^2$ |
| Heat source | • fusion requires tens to hundreds of millions of Kelvin to start and sustain  
• natural fusion occurs in the cores of stars  
• very limited success on Earth with the use of magnetic bottles to contain the material |
| Electrolytic cell | • a known method of producing electricity via a chemical reaction  
• not known to produce a nuclear reaction but does produce a chemical reaction |

If you unpack the claim into elements such as related terms and concepts, variables and measurable quantities, you can formulate questions.
FORMING A QUESTION

A research question needs to be formed from the claim because the variables stated in the claim may not be measurable or directly observable, and therefore they may not be scientific.

After extrapolating and expanding the claim further into possible scientific elements, each of these elements can be used to form a question (Table 1.11.2). It is best to formulate a number of questions related to the claim and write them all down in the journal. Each question must enable a response that will evaluate the validity or the reliability of the claim.

When phrasing the research question you will need an understanding of the dependent and independent variables and the relationship between the variables. The claim must identify the dependent variable and may also specify the independent variable. If the independent variable is not in the claim, it will be elsewhere in the material about the claim.

Some guidelines to help form a question include:
1. finding the dependent variable in the claim, or refining it by rephrasing it into something measurable
2. choosing an element of the claim to become the independent variable, or identifying it in the material
3. phrasing a question to ask if the independent variable will influence, cause or correlate with the dependent variable
4. writing a few different questions. Usually the questions improve as you write more, which allows the formulation of a more developed research question.

Read through Table 1.11.2 to see examples of questions formed from the elements of the claims from Table 1.11.1.

<table>
<thead>
<tr>
<th>Example 1</th>
<th>Claim</th>
<th>It is well known that panes of stained glass in old European churches are thicker at the bottom because glass is a slow-moving liquid that flow downwards over centuries.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements of the claim</td>
<td>Viscosity</td>
<td>• thinner at top • measurable, related to thickness and resistance to motion</td>
</tr>
<tr>
<td>Formulated questions</td>
<td>a) Can the viscosity of glass be measured? b) How does gravity affect the viscosity of a liquid? c) Is there a relationship between the thickness variation of a pane of glass and its age?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Example 2</th>
<th>Claim</th>
<th>Cold fusion could provide a limitless supply of energy to the world.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Elements of the claim</td>
<td>Electrolytic cell</td>
<td>• it is a known method of producing electricity via a chemical reaction</td>
</tr>
<tr>
<td>Formulated questions</td>
<td>a) Does the rate of energy production from an electrolytic cell depend on its temperature? b) How much mass is lost during an electrolytic cell's operation?</td>
<td></td>
</tr>
</tbody>
</table>

REFINING THE RESEARCH QUESTION

It is possible that one of the questions you write in your journal, from the elements in the claim, will become your research question. As you conduct research into the concepts underpinning the independent and dependent variables, new information will refine the question.
The process to develop a research question is often cyclical, as shown in Figure 1.11.2.

**FIGURE 1.11.2** A chart of a common process for developing a research question. This cycle can be repeated as many times as necessary until a feasible question is formulated.

It is important to record your development of conceptual understanding and the knowledge you gain about the relationships between variables. The research investigation requires evidence of the development from the claim to the research question, as stated in the ISMG.

During the research, continue to record your findings in the journal and make note of any ideas that may arise related to the question. As your knowledge and understanding about the variables develops, refine the question to be more specific.

The goal is to develop the research question to a point where exact data or evidence can be found regarding the variables in the question. It will develop into a research question when evidence from research can answer the question. Table 1.11.3 compares formulated research questions that were refined.

**TABLE 1.11.3** Development of the original formulated questions into research questions

<table>
<thead>
<tr>
<th>Claim</th>
<th>Formulated questions</th>
<th>Refined research question</th>
</tr>
</thead>
<tbody>
<tr>
<td>It is well known that panes of stained glass in old European churches are thicker at the bottom because glass is a slow-moving liquid that flows downward over centuries.</td>
<td>a. Can the viscosity of glass be measured?</td>
<td>b. How does gravity affect the viscosity of a liquid?</td>
</tr>
<tr>
<td>a. Is the viscosity of glass measurable using equipment found in a high school physics laboratory?</td>
<td>b. What is the relationship between the acceleration due to Earth's gravitational field and the viscosity of a liquid?</td>
<td></td>
</tr>
<tr>
<td>Cold fusion could provide a limitless supply of energy to the world</td>
<td>a. Does the rate of energy production from an electrolytic cell depend on its temperature?</td>
<td>b. How much heat is lost during an electrolytic cell's operation?</td>
</tr>
<tr>
<td>a. Does the temperature of an electrolytic cell increase the rate of energy production?</td>
<td>b. What is the relationship between the duration of energy production from an electrolytic cell to the total mass lost by the cell?</td>
<td></td>
</tr>
</tbody>
</table>
In your research investigation report, the research you recorded in your journal will be used to write the considered rationale for the research question, displaying its clear development from the claim. This will be achieved by using the research in your journal to outline its step-by-step development, justifying the steps using scientific concepts, knowledge and understanding, as shown in Figure 1.11.2.

The syllabus defines specific (required by the research investigation ISMG) as ‘clearly defined or identified; precise and clear in making statements or issuing instructions; explicit’ and relevant as ‘bearing upon or connected with the matter in hand; to purpose; applicable and pertinent; having a direct bearing on’. Therefore, a specific research question must explicitly identify the dependent and independent variables. The research question must be connected to the considered rationale and the topic of study.

### 1.11 Review

**SUMMARY**

- A claim is an assertion made without any accompanying evidence to support it.

- Research questions and hypotheses can be developed from claims by identifying the underlying scientific concepts and variables of a claim.

**KEY QUESTIONS**

**Retrieval**

1. Define claim.
2. Identify what a research question should explicitly state.

**Comprehension**

3. Explain why the research question should be refined.

**Analysis**

4. Outline the relationship between research and understanding, and the research question that is relevant to the ISMG.
5. Formulate a research question and then a hypothesis for the following claims.
   a. Aluminium foil stops gamma radiation.
   b. Magnetic fields have medicinal benefits.
   c. High-voltage power lines emit dangerous radiation.
1.12 Finding and choosing suitable resources

By the end of this module, you should be able to:

- distinguish between primary and secondary sources
- locate a range of primary and secondary sources
- determine the validity and reliability of a source.

When gathering scientific evidence for the research investigation, use reputable publications including:

- scientific journals—research papers and scientific reviews
- scientific articles written by organisations that apply scientific research to their industry
- commercial articles such as those in science magazines, newspapers and some websites.

The research investigation must include a reference list of cited resources. The resources used should be sufficient and relevant. The syllabus defines sufficient as 'enough or adequate for the purpose' and relevant as 'bearing upon or connected with the matter in hand, in the purpose pertinent, applicable and pertinent, has direct bearing on'. Figure 1.12.1 points out the features of sources deemed 'sufficient' and 'relevant'.

![Diagram showing features of sources suitable for the research investigation](image-url)
SOURCING INFORMATION
Consider whether the information you use is from a primary or secondary source.

Primary and secondary sources
Primary sources of information are written by the observer or witness of an event or the scientist who conducted the research. The original observer has only processed the information. Therefore, it is the least biased of all available sources of information. However, even primary sources may be biased, as the observer or researcher had to make choices related to the observation, control of variables, use of instruments and choices for processing data.

Secondary sources of information are not eye-witness accounts but interpretations of events by other people. As second-hand information, accuracy and reliability may be reduced, and events may be interpreted through the writer’s perception and bias. You should aim to use a wide range of data sources when using secondary data, to cross-check for accuracy, reliability and validity of information.

When searching for information and evidence, follow these guidelines:
1. Determine if it is a primary or secondary resource
2. Confirm it is valid:
   - Is the information specifically related to the claim?
   - Is the evidence and information relevant to the variables in the research question?
3. Assess its reliability:
   - Is it current information?
   - Is it up-to-date in its understanding of relationships?
   - Is the evidence equivalent to that from other sources?
   - Does the author have credible qualifications and expertise?
   - Is the methodology valid and were the variables controlled or measured?

Table 1.12.1 summarises the characteristics of primary and secondary sources. Sometimes the same type of resource may be classified as both a primary and a secondary source, depending on when and by whom it was written. For example, a scientist’s journal article on a how a gamma ray laser can be used to measure tiny cracks in metals is a primary source, while a general magazine article about gamma rays written by a journalist and referring to the scientific study is a secondary source.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Primary sources</th>
<th>Secondary sources</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>first-hand records of events or experiences</td>
<td>interpretations of primary sources</td>
</tr>
<tr>
<td></td>
<td>written at the time the event happened</td>
<td>written by people who did not see or experience the event</td>
</tr>
<tr>
<td></td>
<td>original documents</td>
<td>use information from original documents but rework it</td>
</tr>
<tr>
<td>Examples</td>
<td>results of experiments</td>
<td>textbooks</td>
</tr>
<tr>
<td></td>
<td>scientific journal/magazine articles</td>
<td>biographies</td>
</tr>
<tr>
<td></td>
<td>reports of scientific discoveries</td>
<td>newspaper articles</td>
</tr>
<tr>
<td></td>
<td>photographs, experiments, maps and artefacts</td>
<td>magazine articles</td>
</tr>
<tr>
<td></td>
<td>interviewed with experts</td>
<td>radio and television documentaries</td>
</tr>
<tr>
<td></td>
<td>websites (if they meet the criteria above)</td>
<td>websites that interpret the scientific work of others</td>
</tr>
<tr>
<td></td>
<td></td>
<td>podcasts</td>
</tr>
</tbody>
</table>
Articles in scientific journals

Peer-reviewed scientific journals are excellent sources of information. Journals are a collection of scientific reports written by the scientists who conducted the research. The reports and articles found in scientific journals are published primary sources, meaning they are the results of the experiments (Figure 1.12.2).

Ram-pressure feeding of supermassive black holes

Bianca M. Poggianti, Yara L. Jaffé, Alessia Moretti, Marco Guillemin, Mario Radovich, Stephanie Tonnesen, Jacopo Fritz, Daniela Betttoni, Benedetto Volonteri, Giovanni Fasano, Callum Bellhouse, George Hau & Alessandro Omizzolo

Affiliations
Contributions
Corresponding author

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When a supermassive black hole at the centre of a galaxy accretes matter, it gives rise to a mighty energetic phenomenon: an active galactic nucleus. Numerous physical processes have been proposed to account for the funneling of gas towards the galactic centre to feed the black hole. There are also several physical processes that can remove gas from a galaxy, one of which is ram-pressure stripping by the hot gas that fills the space between galaxies in galaxy clusters. Here we report that six out of a sample of seven 'jellyfish' galaxies—galaxies with long 'tentacles' of material that extend for dozens of kiloparsecs beyond the galactic disk—host an active nucleus, and two of them also have galactic-scale ionization cones. The high incidence of nuclear activity among heavily stripped jellyfish galaxies may be due to ram pressure causing gas to flow towards the centre and triggering the activity, or to an enhancement of the stripping caused by energy injection from the active nucleus, or both. Our analysis of the galactic position and velocity relative to the cluster strongly supports the first hypothesis, and puts forward ram pressure as another possible mechanism for feeding the central supermassive black hole with gas.

FIGURE 1.12.2 An extract of an article from a scientific journal of a research report written by scientists. The article follows a strict structure: a pertinent title, names of authors, an abstract, and the report, which uses the convention of introduction, method, results, analysis, conclusion and a reference list.
Access to scientific journals can be restricted, as many journals require subscriptions or membership at a financial cost, although some are free. Figure 1.12.3 provides ideas for accessing scientific journals. NASA ADS is another service that allows access to physics and astronomy abstracts.

**Figure 1.12.3** Suggestions and information on accessing scientific journal articles

Scientific articles are excellent sources of information, but they also have their drawbacks as sources for the research investigation. Table 1.12.2 outlines some advantages and disadvantages of sourcing and using articles in scientific journals for the research investigation.

**Table 1.12.2** Advantages and disadvantages of scientific articles

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• written by experts</td>
<td>• information is complex and challenging</td>
</tr>
<tr>
<td>• authoritative information (peer-reviewed)</td>
<td>• to understand, with complex language and</td>
</tr>
<tr>
<td>• most current information</td>
<td>• advanced processing and analysis of data</td>
</tr>
<tr>
<td>• logical organised layout</td>
<td>• require an understanding of scientific</td>
</tr>
<tr>
<td>• content is relevant to the topic</td>
<td>• literacy, language and numeracy</td>
</tr>
<tr>
<td>• contain an abstract that summarises all</td>
<td>• may be time-consuming to read and</td>
</tr>
<tr>
<td>information in the article (if you don’t</td>
<td>• analysis</td>
</tr>
<tr>
<td>find the information in the abstract, the</td>
<td>• do not have recently published articles</td>
</tr>
<tr>
<td>article is not relevant)</td>
<td>• about well-established concepts</td>
</tr>
<tr>
<td>• primary source</td>
<td>• may be difficult to locate</td>
</tr>
</tbody>
</table>

**Books and physical publications**

Secondary sources such as good science magazines and books are valuable sources of secondary information.

The first source you should use is your textbook. The language and concepts are presented specifically for high school students. In addition, the textbook addresses the syllabus objectives. Non-fiction books and magazines will probably be commonly used resources for the research investigation. Common commercial science magazines you might find in your school library include *New Scientist*, *Commom*, *Scientific American* and *The Hub* (Figure 1.12.4).
Table 1.12.3 outlines some advantages and disadvantages of non-fiction books as sources for your research.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>• may be written by experts</td>
<td>• may not have been published recently</td>
</tr>
<tr>
<td>• potentially authoritative information</td>
<td>• visible to only one person at a time</td>
</tr>
<tr>
<td>• logical, organised layout</td>
<td>• may have more bias than primary sources</td>
</tr>
<tr>
<td>• content is relevant to the topic</td>
<td>• not easily located in libraries</td>
</tr>
<tr>
<td>• contain table of contents and index to help find relevant information</td>
<td>• written in language that is understandable</td>
</tr>
</tbody>
</table>

**Searching online**

Online sources include online scientific organisations such as CSIRO, AIP (Australian Institute of Physics), IOP (Institute of Physics), NASA, and other university publications and presses. Many government and privately funded science organisations publish material along with non-for-profit scientific organisations. Websites may direct you to magazines and scientific journals, such as those described above, the news, podcasts, blogs and videos (institutional, company and personal).

Information located on the internet requires very careful scrutiny. The openness and ease of publishing on the internet means information may not be valid and reliable. Use the guidelines above to help you evaluate sources. Table 1.12.4 outlines advantages and disadvantages of locating and using information online.

When searching for relevant information you need appropriate search terms to enter into a search engine. These tips can help your search:

• Break your search statement into concepts and key words:
• Find synonyms, other related terms and concepts that apply to the topic:
• Create concepts of 1–3 words to enter into the search engine:
• Try different combinations of terms:
• Don’t settle for the first sites on the first or your first attempt and look beyond the first page of results:
• Look through the results for sites from science organisations and research institutions (e.g. CSIRO, NASA, .gov, .org), universities (.edu) and science journals and magazines.

**Overview of resources**

Your textbook should be your first source of reliable information. Other information should be consistent with this. Articles published in journals and magazines often present findings of new research, which may or may not be confirmed later. Be careful not to treat such sources of information as established fact. Scientific journals are peer-reviewed (critically reviewed by other specialist scientists), which gives them more credibility than other sources.
## Evaluating sources for validity and reliability

Determining the validity and reliability of a source can be a challenging task. For some sources it is easy to find details about the author, evidence and concurrency, while others contain content and do not offer any other details. Another difficulty is that when learning about a new topic or concept you are all novice learners; so it can be challenging to tell if a source is valid or not.

These tables outline examples of evaluating a resource step-by-step, for a claim about the ability of sound waves to levitate polystyrene foam particles.

**SOURCE EVALUATED:** Three-dimensional mid-air acoustic manipulation by ultrasonic phased arrays. Scientific research article [http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0097390](http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0097390)

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Decision</th>
<th>Support/Justification</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Primary or secondary?</strong></td>
<td>Primary</td>
<td>Research article published in PLoS Research results published in article</td>
</tr>
<tr>
<td><strong>Validity</strong></td>
<td>Does it contain information that is specifically related to the claim?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Is the evidence and information pertinent to the variables in the research question?</td>
<td>Yes</td>
</tr>
<tr>
<td><strong>Reliability</strong></td>
<td>Is it current/recent information?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Is it up-to-date in its understanding of relationships?</td>
<td>Yes</td>
</tr>
<tr>
<td></td>
<td>Is the evidence equivalent to other sources?</td>
<td>Mostly</td>
</tr>
<tr>
<td></td>
<td>Check credibility and consider the author’s qualifications and expertise</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Try to find the sample size</td>
<td>Unknown</td>
</tr>
<tr>
<td></td>
<td>Try to establish what variables were controlled or measured</td>
<td>Known</td>
</tr>
</tbody>
</table>

A judgement could be made about this source such as:

The information and evidence was published by experts in a peer-reviewed journal article that is current and with variables of experimentation known and directly related to the claim and research question. The results are new but are not yet substantiated, therefore affecting the reliability of the evidence. This resource is both valid and reliable.

*continued over page*
**Skillbuilder continued**

SOURCE EVALUATED: Scientists levitate small objects.

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Decision</th>
<th>Support/justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary or secondary</td>
<td>Secondary</td>
<td>General information with photos</td>
</tr>
<tr>
<td>Validity</td>
<td>Mostly</td>
<td>Effect of levitation on insects</td>
</tr>
<tr>
<td>Does it contain information that is specifically related to the claim?</td>
<td>Yes</td>
<td>Levitation and weight</td>
</tr>
<tr>
<td>Is the evidence and information pertinent to the variables in the research question?</td>
<td>Mostly</td>
<td>November 2006</td>
</tr>
<tr>
<td>Reliability</td>
<td>Unknown</td>
<td>Researchers not listed, however correlates with other sources</td>
</tr>
<tr>
<td>Is it current/recent information?</td>
<td>Mostly</td>
<td>Equivalent to other sources</td>
</tr>
<tr>
<td>Is it up-to-date in its understanding of relationships?</td>
<td>Yes</td>
<td>Author is a science journalist</td>
</tr>
<tr>
<td>Is the evidence equivalent to other sources?</td>
<td>Yes</td>
<td>Author is a science journalist</td>
</tr>
<tr>
<td>Choose credibility and consider the author's qualifications and expertise.</td>
<td>Unknown</td>
<td>Not published</td>
</tr>
<tr>
<td>Try to find the sample size.</td>
<td>Unknown</td>
<td>Not published</td>
</tr>
<tr>
<td>Try to establish what variables were controlled or measured.</td>
<td>Unknown</td>
<td>Not published</td>
</tr>
</tbody>
</table>

**Test the skill**

In researching about the claim 'Objects that can travel faster than light', the article, 'These four cosmic phenomena travel faster than light' at https://www.sciencesalert.com/these-4-cosmic-phenomena-travel-faster-than-the-speed-of-light, was found. Evaluate this source in relation to its usefulness in investigating the claim. Use the table to make a judgement of the validity and reliability of the source.

SOURCE EVALUATED: These four cosmic phenomena travel faster than light.
https://www.sciencesalert.com/these-4-cosmic-phenomena-travel-faster-than-the-speed-of-light

<table>
<thead>
<tr>
<th>Criteria</th>
<th>Decision</th>
<th>Support/justification</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary or secondary</td>
<td>Secondary</td>
<td>General information with photos</td>
</tr>
<tr>
<td>Validity</td>
<td>Mostly</td>
<td>Effect of levitation on insects</td>
</tr>
<tr>
<td>Does it contain information that is specifically related to the claim?</td>
<td>Yes</td>
<td>Levitation and weight</td>
</tr>
<tr>
<td>Is the evidence and information pertinent to the variables in the research question?</td>
<td>Mostly</td>
<td>November 2006</td>
</tr>
<tr>
<td>Reliability</td>
<td>Unknown</td>
<td>Researchers not listed, however correlates with other sources</td>
</tr>
<tr>
<td>Is it current/recent information?</td>
<td>Mostly</td>
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</tr>
<tr>
<td>Try to establish what variables were controlled or measured.</td>
<td>Unknown</td>
<td>Not published</td>
</tr>
</tbody>
</table>

Solution: Source is valid and reliable.
1.12 Review

SUMMARY

• Scientific evidence for the research investigation can be sourced from numerous publications including scientific journals, scientific articles and commercial articles.

• A primary source is written by the observer/witness of an event, or the scientist who conducted the research.

• A secondary source is a document that refers to or analyses a primary source.

KEY QUESTIONS

Retrieval
1. Decide whether each of the following is a primary or a secondary source.
   a. a newspaper article about global warming
   b. an experiment to investigate chemical changes when mixing combinations of chemicals
   c. an interview with a forensic scientist about using science to track criminals
   d. a website with information about interplanetary travel by humans

Comprehension
2. Explain the difference between a primary and a secondary resource.

Analysis
3. You are learning about orbits of planets in other solar systems, and are searching for facts about how the mass of the central star affects the shape of an orbit. From the list below, identify which one would be the best resource to use. Explain your answer.
   B. an article in the prestigious journal Astronomy and Astrophysics, published in June 2017
   C. the website Exoplanet.eu, accessed on 6 June 2017
1.13 Research: taking and organising notes

BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO

- use your scientific journal to take and organise notes, and to refine experimental procedures.
- paraphrase information found in primary and secondary sources.

As previously mentioned, a journal should be maintained in which you record all the ideas, research and developments of the research investigation. Once all the work is complete, the information in the journal should form the basis of your response. There is no need to produce new work as it is already completed in the journal.

Scientists organise their journal notes with the following general features:

- date of journal entries
- journal entries for:
  - ideas, observations, proposals and questions
  - research background information for ideas, observations, proposals and questions
  - refinements
  - personal explanations of information, concepts, ideas, observations, proposals and questions (this often includes diagrams)
- results, data and evidence
- origin of information (recording sources).

RECORDING DATE OF JOURNAL ENTRIES

Always place the date at the start of each day you record in your journal. This is done by professionals worldwide to catalogue and file information. When trying to find previously completed work, most people search their memory as to when they completed the work. They think “I’m sure I did the research of X after I found the information on X last week”. So the date of your research will become a simple yet effective filing system.

RECORDING JOURNAL ENTRIES

Each journal entry should follow a cataloguing system; most typically this is the date and a title. A reference point or cataloguing system helps you to find information when you are searching for it later.

Ideas, observations, proposals and questions

You may be surprised how often simple ideas, observations, proposals and questions influence, direct and help your research days or weeks later. Your ideas, observations, proposals and questions could be related to:

- the variables or concepts involved in your investigation
- new terms you were exposed to and do not understand
- data or evidence you do not currently comprehend but is important to a part of the investigation
- statistics about significance in the analysis of some information
- ideas and proposals about possible future research and questions.
Record all of these in your journal. Later they may:

- save you time by:
  - ensuring you do not research the same idea twice
  - helping you to link ideas from one day or week to the next when you return to your work
  - suggesting guidance and pathways for research and queries that are related
  - provide links between concepts in the future that are currently unknown
  - provide answers (or partial answers) to future issues, conceptual blocks and questions
  - develop understanding of unrelated concepts that become pertinent later.

The content and recordings in your journal will not be in a logical conceptual order, as are your class notes or a textbook. This is because you are researching unfamiliar knowledge and you won't know how it all fits together until the research is complete. The journal will contain all you need to complete the report later.

Before you add an entry to your journal make sure you have recorded the date and provided your own title for the entry. As you take notes from different sources, always record the source information, such as the title, web address, author and page. Figure 1.3.1 is an example of a journal entry.

![Journal Entry Example](image)

**Figure 1.3.1** A journal entry with the journal entry date, titles and information. There will be numerous journal entries on any given date, and most likely with their own titles. The same titles will appear on different entry dates as research continues on that topic.
**Research background information**

Information taken from a source should be rewritten or summarised in your own words in the journal. Avoid copying information verbatim so you are not tempted to plagiarise when you write up the research investigation.

It can be difficult sometimes to rewrite sources into your own words, especially if it is already expressed well and concisely. Before you write and record the research information, read the material and grasp its understanding. Without referring back to the source, write notes in your journal, in your own words. Use multiple sources and a dictionary as references for information. The notes in your journals should be detailed with extended explanations that you will fully comprehend when you refer back to them at a future date.

**Worked example 1.13.1**

RE-WORDING INFORMATION FROM SOURCES

A resource for information states that:

'It can be expected that the days will be warm and the nights will be cool over the next three days due to the high-pressure system moving across the region.'

Rewrite this information into your own words.

<table>
<thead>
<tr>
<th>Thinking</th>
<th>Working</th>
</tr>
</thead>
<tbody>
<tr>
<td>Swap the order of information so that the reason (high-pressure system) comes before the object (the warm days and cool nights).</td>
<td>Due to the high-pressure system moving across the region, the days will be warm while the nights will be cool.</td>
</tr>
<tr>
<td>Change numerous words such as adjectives, verbs, adverbs and nouns.</td>
<td>It has been predicted that during the daytime it will be warm while the evenings will be cool for about 3 days, as a high-pressure system travels over the region.</td>
</tr>
<tr>
<td>Gather more data so you can elaborate on the information to explicitly outline explanations.</td>
<td>The weather forecast expects (made a prediction based on computer simulations) that the temperature during the day will be warm (22-25°C) and the evenings will be cool (below 12°C) due to a high-pressure system (weak high-pressure system), which dissipates clouds and allows direct sunshine to warm Earth's surface; however, in the evenings this system brings cool air from higher altitudes that is no longer warmed by the Sun.</td>
</tr>
</tbody>
</table>

**Try yourself 1.13.1**

RE-WORDING INFORMATION FROM SOURCES

A resource for information states that:

'It can be expected that days will be cooler and there will be more rain over the next three days due to the low-pressure system moving across the region.'

Rewrite this information into your own words.
Personal explanations and interpretation

The journal is a valuable tool that is personal to you. As such, it should be written and displayed in formats that you understand and that make meaning of information to produce the research investigation report. It can include writing, drawings and schematics (e.g. flow charts).

Sometimes, one form of recording information provides more details than others, and details are not just facts, it can be the order of events, their location or their physical orientation. Therefore, use a variety of ways to record or present the information to encapsulate more comprehensive details. Figure 1.13.2 presents the same information in a few different ways.

Newton's Law of Universal Gravitation relation that every mass in the universe attracts every other mass:

\[ F = \frac{G m_1 m_2}{d^2} \]

- \( m_1 \) = mass of planet
- \( m_2 \) = mass of Sun
- \( d \) = distance between them
- Force on planet from Sun
- Force on Sun from planets
- Small planets must pull
- a pull on the Sun

![Diagram of Sun and small planet with distance labeled]

**Figure 1.13.2**  (a) Sample page from a journal explaining Newton's law of universal gravitation in the claim that small planets exert a pull on the Sun. (b) Sample page from a journal explaining Newton's Law of Universal Gravitation in a flow chart as a schematic to unpack the above claim. (c) Sample page from a journal explaining Newton's law of universal gravitation in a diagram.
RESULTS, DATA AND EVIDENCE

When you find scientific results in a resource, it is important to record the values or reproduce them in the journal. Your notes about the results, data or evidence should include:

- specific details and your own interpretation of significant values
- the trend or pattern
- the comparison or difference between one set of values and another
- the statistics used to establish significance and also the author's interpretation
- notes written in your own words.

Figure 13.3 shows examples of research evidence and how they can be reinterpreted for a journal entry. Figure 13.3a is the original evidence the student found through research and Figure 13.3b is the student's notes and interpretation of the evidence.

![Graph showing light curve data](image)

**Figure 13.3** (a) Examples of representing evidence using graphs and statistics. This data is from the light curve of a distant star. The legend shows the time interval. Statistical information is given in the legend, and these anomalies are highlighted in yellow circles. (b) An example of a student's notes and interpretation of the evidence found as the source.
When making journal entries it is important for your understanding and analysis of statistical method (e.g. $R^2$ value), that you express information in your own words. You will most likely have to conduct further research to understand the statistics, their meaning and the author's interpretation of the results, as you will come across new statistical calculations you haven't seen previously.

**Recording the origin of information**

As you conduct your investigation and research, it is important to write down the source of the information. This will enable you to return to the source later to continue researching, collect further information or re-check details. You will also be required to produce a reference list in the report, and it will save time if you have already recorded the source of the information. You could use a table as shown.

<table>
<thead>
<tr>
<th>Books</th>
<th>Online</th>
</tr>
</thead>
<tbody>
<tr>
<td>- Author(s)</td>
<td>- Author(s) or organisation</td>
</tr>
<tr>
<td>- Title</td>
<td>- Title</td>
</tr>
<tr>
<td>- Date of publication</td>
<td>- Date website was written or updated</td>
</tr>
<tr>
<td>- Publisher</td>
<td>- Date website was accessed</td>
</tr>
<tr>
<td>- Place of publication</td>
<td>- Website address (URL)</td>
</tr>
<tr>
<td>- Pages</td>
<td></td>
</tr>
</tbody>
</table>

**1.13 Review**

**SUMMARY**

- There is no single method for taking and organising notes.
- A scientific journal enables scientists to record and organise their notes.
- Scientists continually revise and refine their experiments based on previous experimentation and results.

**KEY QUESTIONS**

**Retrieval**

1. List at least four things you should write down in your scientific journal.

**Comprehension**

2. State how to record information from a source in your journal.
3. Explain the benefit of keeping a scientific journal.

**Analysis**

4. Paraphrase the following:
   a. A group of scientists were using different metals to determine their ability at shielding beta particles coming from a radioactive source in a nuclear reactor. There was no statistically significant difference between the metals and their shielding ability.
   b. A researcher found that by increasing the amount of semiconductor material mixed with conducting material, the resistance of the mixture was drastically reduced. Further experimentation also showed that as the temperature of the mixture was reduced the resistance was even further decreased.
   c. A study found that the mass attached to a freely swinging pendulum bob had little to no effect on the period of the pendulum's motion. The researchers also found that the pull-back distance had little effect on the period of the pendulum.
### Writing a report for the research investigation

**BY THE END OF THIS MODULE, YOU SHOULD BE ABLE TO**

- write a report for your research investigation
- write a literature review for your research investigation.

Different genres can be used to report a research investigation. As a written report, the genres include a literature review, empirical essay and annotated bibliography. The report must be 1500-2000 words. Alternatively, a poster can be used as a multimodal presentation of 9-11 minutes. Even though there are many ways to present your report, it must follow a scientific genre and meet the requirements of the syllabus.

Writing a research investigation report requires scientific communication and will need to follow scientific genre conventions. An explanation of these requirements has been provided in Module 1.10. A report will communicate information in a logical sequence (introduction, body and conclusion) and may contain subheadings. Many of the characteristics of the student experiment are closely related to the research investigation. The focus of the student experiment is on interpreting data collected during a scientific investigation, whereas the focus of the research investigation is to explore a claim.

Characteristics of the genres for presenting the research investigation are summarised in Table 1.14.1. This module will focus on the literature review.

<table>
<thead>
<tr>
<th>Science presentation genre</th>
<th>Brief description</th>
<th>Features</th>
</tr>
</thead>
</table>
| Literature review          | A report that evaluates information found in a publication, related to the selected topic. The report gives a theoretical base for the claim (question), and analyses and interprets information/data related to the claim. The objectives is to point out strengths and weaknesses of the claim. | - Abstract  
- Introduction to topic providing context  
- Discussion of information/data  
- Analysis of data/information  
- Evaluation of information/data  
- Conclusion related back to claim  
- Presented as paragraphs that flow on in a logical development of claim  
- Uses subheadings |
| Empirical essay            | Very similar to a literature review. | |
| Annotative bibliography    | Notes, comments and explanations about articles. An evaluation of a claim after investigating raw other sources that the claim. | |
| Poster                     | An oral presentation accompanies the poster. Poster presents ideas concisely and clearly. These ideas are expanded on in the oral presentation. | - Includes all the above.  
- Visual, oral and text presentation  
- Use of font size, colour, dot points, subheadings, logical flow of information to effectively deliver information. |
LITERATURE REVIEW

A literature review usually includes an introduction, body, and conclusion. It critically analyses information and convinces the reader of the significance or importance of the topic being investigated. This is achieved by presenting the information in a logical sequence that guides the reader through the material to understand its significance. The research question provides the foundational direction and guidance of the literature review.

Qualities found in a literature review

Not all qualities and elements of a full literature review will be appropriate for the research investigation. The literature review will be limited to the word count and ISMCI characteristics in the syllabus. Depending on the research question and the topic being investigated, your literature review may:

- determine the current understanding on the topic
- provide an overview of key concepts (relevant to the research question)
- identify important relationships between variables (specific to variables that influence the independent or dependent variables stated in the research question)
- identify strengths and weaknesses of evidence in the information used for the above points
- identify any gaps in the research
- identify any conflicting evidence.

One of the key qualities of a literature review is that it is a critical analysis of the evidence to communicate a true understanding of the 'big picture' about a topic. It does not just summarise information. Science is about models, theories, laws and principles, and their continual development. The literature review should critically analyse evidence, the strengths and weaknesses as well as the gaps and conflicts, to convince the reader about the current state of a large jigsaw puzzle of conceptual relationships.

A literature review should:

- critically analyse the evidence—establish what it means and account for the statistical processing of data used (be sure to analyse the methodologies, samples, results and data processing and analysis)
- discriminate between relevant and irrelevant sources and content—only use the relevant in the literature review
- logically inform and convince the reader—plan the introduction, body and conclusion.

There is no hard-and-fast rule about the number of articles you should consult for the research investigation. The term 'sufficient' is defined by the QCAA syllabus as 'enough or adequate for the purpose'. The purpose of the research investigation is to evaluate the claim. Therefore, if the number of articles enables you to draw a justified conclusion about the research question and explore both sides of the argument, then the number of sources is sufficient. Relevant research is that which is connected to the rationale and unit under study.

A thorough analysis requires complete attention to every detail. Therefore the research should include analysis and synthesis from different sources. It should identify patterns, trends and relationships that are related to the investigation. Also it should be explicitly connected to the research question as well as clarify where the sources agree and disagree.
The analysis should identify all the limitations of the research, because this may have a bearing on how valid the information (primary or secondary) is to the research question. It is important that when you analyse data and its limitations you do not do it in a way that only demonstrates what you want to show. Such bias will result in an inappropriate and erroneous conclusion that is invalid. Quality scientific analysis is open to any result.

Justified scientific arguments are those that are supported by sound reasons or evidence. Therefore, you must apply your scientific understanding and conceptual knowledge to the evidence that you have examined. You should consider the following factors:

• State whether a pattern, trend or relationship was observed between the independent and dependent variables.
• Describe the pattern mathematically and specify under what conditions it was observed.
• Note and explain any deviations in the data or information.
• Identify any limitations and uncertainties in the data or information researched. Why and how do these limitations affect the validity to the research question or conclusion?

Your analysis of information may also include an evaluation of the methodology used by the authors to obtain their data or information.

**Conclusion and evaluation**

In the conclusion, the discussion should include an understanding of the features of the evidence that limit its usefulness. For example, did the sampled population reflect the population referred to in the research question? Is the data from measured samples or from estimated models? Did the studies occur under different conditions or categories the independent variables differently so that comparison was impossible?

The above questions require a justified discussion that evaluates the reliability and validity of the evidence. Therefore, it is important to discuss the limitations of each source. You can do this by:

• evaluating the method of evidence collection
• identifying issues that could affect validity, accuracy, precision and reliability of evidence
• stating sources of systematic and random errors
• recommending improvements to the evidence to improve validity.

In the discussion, you should recommend improvements to the investigation that are linked to the evidence and would address the limitations and gaps in knowledge that you have identified during the research investigation. Your suggestions must be connected to the claim and allow further investigation.

**Communication**

This section will provide a guide to writing an appropriate scientific report and some of the general conventions that need to be followed for a literature review.

Once a plan for the literature review has been developed, word limit guides can be assigned to each section. The notes in your research journal will give you a good idea of which sections will require more words for explanations than others. The journal will also help you make decisions on which figures, data and evidence to include, and how many words may be required to elaborate on the evidence. Distribute the total word count across all sections you plan to include in the literature review.
The word guide is not binding. As you complete your review you can alter the word guide and distribution of the word count if you feel it is necessary. However, make sure the limit outlined in the syllabus is never exceeded.

Planning the research investigation report will help address the syllabus ISMG. Figure 1.14.1 illustrates how planning can be done to ensure the syllabus ISMG is addressed.

**Figure 1.14.1** Planning the literature review (a) A planned outline of the research investigation report to ensure the ISMG is addressed (b) Allocating the ISMG discussion to the sections in the planned outline (c) Shows the word count guide planned.
Structure of a written report

Although the use of headings in scientific reports is essential to guide and direct scientists to particular information, there is no single correct convention for a scientific report. A typical structure includes an introduction, body, conclusion and reference list.

Edit the report after you have completed it. Editing is an important part of the process. After editing your report, save new drafts with different file names and always back up your files in another location. Pretend you are reading your report for the first time when editing. When reading your own work, do not read it as what you intended to write, but what you have actually written. Reading the report out loud will help you to read it more critically. When editing, look for content that is:
- Ambiguous or unclear
- Repetitive
- Awkwardly phrased
- Too lengthy
- Not relevant to your research question
- Poorly structured
- Lacking evidence
- Lacking a reference (if it is another researcher's work).

1.14 Review

SUMMARY
- There are several genres that can be used to report a research investigation, such as a literature review, empirical essay, poster presentation and annotated bibliography.
- A literature review critically analyses information and convinces the reader of the significance or importance of the topic being investigated.

KEY QUESTIONS

Retrieval
1. Recall the convention for the flow of information through a literature review.
2. State the convention for the literature review genre.

Comprehension
3. Explain the purpose of a literature review.

Analysis
4. Outline how you would achieve an analysis of the methodologies, sample size and results in a literature review.