Physics 2019 v1.2

IA3 high-level annotated sample response

August 2018

Research investigation (20%)

This sample has been compiled by the QCAA to assist and support teachers to match evidence in student responses to the characteristics described in the instrument-specific marking guide (ISMG).

Assessment objectives

This assessment instrument is used to determine student achievement in the following objectives:

2. apply understanding of special relativity, quantum theory or the Standard Model to develop research questions
3. analyse research evidence about special relativity, quantum theory or the Standard Model
4. interpret research evidence about special relativity, quantum theory or the Standard Model
5. investigate phenomena associated with special relativity, quantum theory or the Standard Model through research
6. evaluate research processes, claims and conclusions about special relativity, quantum theory or the Standard Model
7. communicate understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model.

Note: Objective 1 is not assessed in this instrument.

Queensland Government | Queensland Curriculum & Assessment Authority

For all Queensland schools

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Instrument-specific marking guide (ISMG)

Criterion: Research and planning

Assessment objectives

2. apply understanding of special relativity, quantum theory or the Standard Model to develop research questions
5. investigate phenomena associated with special relativity, quantum theory or the Standard Model through research

The student work has the following characteristics:	Marks
• informed application of understanding of special relativity, quantum theory or the Standard Model demonstrated by a considered rationale identifying clear development of the research question from the claim • effective and efficient investigation of phenomena associated with special relativity, quantum theory or the Standard Model demonstrated by – a specific and relevant research question – selection of sufficient and relevant sources.	5–6
• adequate application of understanding of special relativity, quantum theory or the Standard Model demonstrated by a reasonable rationale that links the research question and the claim • effective investigation of phenomena associated with special relativity, quantum theory or the Standard Model demonstrated by – a relevant research question – selection of relevant sources.	3–4
• rudimentary application of understanding of special relativity, quantum theory or the Standard Model demonstrated by a vague or irrelevant rationale for the investigation • ineffective investigation of phenomena associated with special relativity, quantum theory or the Standard Model demonstrated by – an inappropriate research question – selection of insufficient and irrelevant sources.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Analysis and interpretation

Assessment objectives

3. analyse research evidence about special relativity, quantum theory or the Standard Model
4. interpret research evidence about special relativity, quantum theory or the Standard Model

The student work has the following characteristics:	Marks
• systematic and effective analysis of qualitative data and/or quantitative data within the sources about special relativity, quantum theory or the Standard Model demonstrated by – the identification of sufficient and relevant evidence – thorough identification of relevant trends, patterns or relationships – thorough and appropriate identification of limitations of evidence • insightful interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by justified scientific argument/s.	5–6
• effective analysis of qualitative data and/or quantitative data within the sources about special relativity, quantum theory or the Standard Model demonstrated by – the identification of relevant evidence – identification of obvious trends, patterns or relationships – basic identification of limitations of evidence • adequate interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by reasonable scientific argument/s.	3–4
• rudimentary analysis of qualitative data and/or quantitative data within the sources about special relativity, quantum theory or the Standard Model demonstrated by – the identification of insufficient and irrelevant evidence – identification of incorrect or irrelevant trends, patterns or relationships – incorrect or insufficient identification of limitations of evidence • invalid interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by inappropriate or irrelevant argument/s.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Conclusion and evaluation

Assessment objectives

4. interpret research evidence about special relativity, quantum theory or the Standard Model
6. evaluate research processes, claims and conclusions about special relativity, quantum theory or the Standard Model

The student work has the following characteristics:	Marks
• insightful interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by justified conclusion/s linked to the research question • critical evaluation of the research processes, claims and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – insightful discussion of the quality of evidence – extrapolation of credible findings of the research to the claim – suggested improvements and extensions to the investigation that are considered and relevant to the claim.	5–6
• adequate interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by reasonable conclusion/s relevant to the research question • basic evaluation of the research processes, claims and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – reasonable description of the quality of evidence – application of relevant findings of the research to the claim – suggested improvements and extensions to the investigation that are relevant to the claim.	3–4
• invalid interpretation of research evidence about special relativity, quantum theory or the Standard Model demonstrated by inappropriate or irrelevant conclusion/s • superficial evaluation of the research processes, claims and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – cursory or simplistic statements about the quality of evidence – application of insufficient or inappropriate findings of the research to the claim – ineffective or irrelevant suggestions.	1–2
• does not satisfy any of the descriptors above.	0

Criterion: Communication

Assessment objective

7. communicate understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model

The student work has the following characteristics:	Marks
• effective communication of understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – fluent and concise use of scientific language and representations – appropriate use of genre conventions – acknowledgment of sources of information through appropriate use of referencing conventions.	2
• adequate communication of understandings and research findings, arguments and conclusions about special relativity, quantum theory or the Standard Model demonstrated by – competent use of scientific language and representations – use of basic genre conventions – use of basic referencing conventions.	1
• does not satisfy any of the descriptors above.	0

Task

Context
Investigate one of the following claims: • The Lorentz factor that is included in special relativity formulas is a mathematical convenience, not a physical reality. • The Big Bang theory remains scientifically unchallenged and should now be considered a fact. • Bruce Banner absorbs ambient gamma radiation, converting its energy into mass during the transformation into the Hulk. • The Flash can travel at, and even faster than, the speed of light. • Carbon dioxide is unfairly blamed for anthropogenic climate change, because all greenhouse gases contribute equally. • Mobile phones cause cancer. • The dream of almost limitless clean energy from nuclear fusion is close to being realised. You may identify an alternative claim in consultation with your teacher. This claim must be related to Unit 4 subject matter.
Task
Gather secondary evidence related to a research question in order to evaluate the claim. Develop your research question based on a number of possible claims provided by your teacher. Obtain evidence by researching scientifically credible sources, such as scientific journals, books by well-credentialed scientists, and websites of governments, universities, independent research bodies or science and technology manufacturers. You must adhere to research conventions.

Sample response

Criterion	Marks allocated	Result
Research and planning Assessment objectives 2, 5	6	5
Analysis and interpretation Assessment objectives 3, 4	6	6
Conclusion and evaluation Assessment objectives 4, 6	6	6
Communication Assessment objective 7	2	2
Total	**20**	**19**

The annotations show the match to the instrument-specific marking guide (ISMG) performance-level descriptors.

Key: Research and planning | Analysis and interpretation | Conclusion and evaluation | Communication

Note: Colour shadings show the characteristics evident in the response for each criterion.

Research and planning [5–6]

a considered rationale identifying clear development of the research question from the claim

The rationale shows evidence of careful, deliberate thought. The sequence of ideas involved in the development of the research question from the claim is easily seen.

Communication [2]

acknowledgment of sources of information through appropriate use of referencing conventions

The use of in-text referencing fits the purpose of an essay.

Nuclear fusion

Rationale

The claim, "*The dream of almost limitless clean energy from nuclear fusion is close to being realised*" has several aspects that could be investigated. The first aspect is the assertion that nuclear fusion for power generation is a *clean* process. A power generation process is considered *clean* if it uses renewable resources, and has minimal threat to human safety and environmental health (Haluzan, 2010). The second aspect of the claim is that nuclear fusion can provide *limitless amounts of energy*. The third aspect is the assertion that power generation from nuclear fusion is *close to being realised*. Initial research indicated that nuclear fusion is theoretically 1000% efficient (i.e. the amount of energy released is up to ten times greater than the energy required to produce the fusion reaction (HyperPhysics, 2017). This suggested that the assertion of almost limitless energy is simply a poetic way of saying that nuclear fusion runs at an energy surplus. The remaining two aspects of the claim are in part, interrelated to each other. Some techniques are considered theoretically *clean*, but are not close to realisation. Others are operational (Hurricane et. Al, 2014), but are not considered *clean*. Research revealed a fusion technique developed by the Tokamak Energy company that is both close to realisation, and that involves reactants and products that may, on

Research and planning [3–4]

a relevant research question

The research question is developed from the claim and connected to the topics covered in the unit. However, it is not clearly defined.

Communication [2]

appropriate use of genre conventions

The use of headings and paragraphs fits the purpose of an essay.

Research and planning [5–6]

selection of sufficient and relevant sources

Sources throughout the response are scientific and provide enough evidence for the development of a scientific argument that responds to the research question.

Communication [2]

acknowledgment of sources of information through appropriate use of referencing conventions

The use of in-text referencing fits the purpose of an essay.

further investigation, be considered as *clean*. Subsequently, the research question to be investigated is as follows:

Is the Tokamak Energy nuclear fusion power generation technique able to be considered as clean?

If it can be established using evidence, that the Tokamak Energy nuclear fusion power generation technique is clean, then the first aspect of the claim can be supported.

Overview of the Tokamak Energy nuclear fusion power generation technique.

The UK based Tokamak Energy organisation has built a reactor that fuses hydrogen atoms. Theoretically, effective fusion of hydrogen atoms requires them to be heated to 100 million degrees Celsius. At this temperature, hydrogen is a plasma. This means a reduction in the electrostatic repulsion between hydrogen atoms. This allows nuclear forces to bind two hydrogen nuclei. At this stage one of the protons decays into a neutron, forming deuterium and releasing energy. Deuterium can then be fused to form helium, releasing energy. The energy used during the heating of hydrogen enables enormous amounts of energy to be released during each stage of the fusion process. (Tokamak Energy, 2014 and HyperPhysics, 2017). The goal of the use of a fusion reaction is to produce enough energy to maintain conditions for continued fusion as well as sufficient surplus energy (i.e. heat) to generate electricity via traditional methods. The Tokamak Energy organisation reactor only achieves a plasma at 15 million degrees, but is working towards the required 100 million degrees. They predict that they will be producing commercially available power by 2030 (Tokamak Energy, 2014).

The difficulty encountered with the Tokamak Energy reactor is the management of the plasma. The extreme heat of the plasma will either damage or destroy the containment facility. This will result in heat loss and a state change back to gas. Two models of containment are currently being explored: magnetic field confinement and inertial field confinement. Of these, magnetic field confinement has been explored and tested for over 50 years with some advances in recent years, however significant and rapid advances in inertial field confinement have also been seen recently (Lindl & Hammel, 2004).

The renewability of resources required in the Tokamak Energy nuclear fusion power generation technique

The renewability of energy resources is dependent on whether the energy source is available in “undiminished quantity at present costs for as long as the current relationship between the sun and Earth persists” (Cohen, 1983). Subsequently, both the efficiency and availability of an energy source must be considered when determining whether an energy source is renewable. Power that is generated via thermal power requires the burning of fossil fuel, hydro power generation requires large amounts of water in a position of relatively high gravitational potential energy, and nuclear power generated is currently restricted to nuclear fission reactions. At this point in time, worldwide coal-fired power plant efficiency average 35.1% in 2007 (IEA 2010), and may achieve up to 44% efficiency. This efficiency is higher than many other forms of power generation. The efficiency of an energy source is important because the higher the

Analysis and interpretation [5–6]

identification of sufficient and relevant evidence

The evidence is appropriate for the purpose of responding to the research question. It is applicable and directly connected to the formation of the scientific argument.

Communication [2]

fluent and concise use of scientific language and representations

The response is easily understood, avoids unnecessary repetition and meets the required length.

Analysis and interpretation [5–6]

thorough and appropriate identification of limitations of evidence

The response identifies limitations of evidence that affect how well it can be used to develop a response to the research question.

justified scientific argument/s

The scientific argument uses a process of sound reasoning and draws upon valid and reliable evidence.

identification of sufficient and relevant evidence

The evidence is appropriate for the purpose of responding to the research question. It is applicable and directly connected to the formation of the scientific argument.

efficiency, the lower the amount of the energy source is used. Theoretically, a fusion reactor similar to Tokamak Energy's reactor can produce energy at an efficiency of 1000% (Hyperphysics, 2017). An efficiency of this magnitude indicates that the amount of the energy source used during energy production is minimal.

The Tokamak Energy fusion reactor uses hydrogen as its energy source. Hydrogen is the most abundant element in the universe (Live Science, 2017) and accounts for approximately three quarters of all known matter. It can be reasonably predicted that there will be sufficient hydrogen able to be sourced for use in fusion reactions for as long as the Earth-Sun relationship continues. Having established that hydrogen is likely to be available in undiminished quantity, attention should be turned to determining the costs associated with accessing hydrogen fuel. The evidence gathered during research was limited by the absence of any data on how much it costs for the Tokamak Energy company to harvest the hydrogen fuel. As such, to truly evaluate whether the Tokamak energy nuclear fission power generation technique uses renewable energy sources, more information is required to establish the cost effectiveness of using hydrogen as a source.

Tokamak Energy nuclear fusion power generation technique threat to human safety and the environment

The threat that nuclear power generation has to human safety can be approached statistically. Nuclear power generation has been used since the 1950s (Bright Hub Engineering, 2017). Incidents such as the Chernobyl disaster (1986) have brought fuel availability and radiation losses to local surroundings into public debate. Overall, there have been eleven significant incidents with nuclear power in the last 60 years, resulting in significant effects on the local environment, and in some instances fatalities (DiaNuke.org, 2017 - see Appendix A for full ranking of these incidents). A concern with the use of (fission) nuclear power is the management of waste associated with power generation, and the risk of catastrophic failure of the plant. Nuclear waste must be isolated for up to 50 years (World Nuclear Association, 2017) to allow radioactivity decay to occur to a safe level, then disposed away from possible interactions with the biosphere where it can harm humans. Importantly, "In more than 50 decades of civil nuclear power experience nuclear wastes have not caused any serious health or environmental problems nor posed any real risks to people. There has been no pollution or plausible hazard from such material routinely removed from power stations…" (World Nuclear Association, 2017). Compared with the several thousand-year timeframe associated with biohazards released from coal-burning, this is a more manageable risk. In terms of failure risk (and by inference, health risk), Forbes, in an article titled "How deadly is your kilowatt?", (Forbes, 2012) has considered overall deaths able to be attributed directly to forms of power generation on a per kilowatt basis, and have identified that worldwide coal-powered fuel generation is over one thousand times more dangerous than nuclear power.

The Tokamak Energy reactor uses hydrogen and produces helium gas. Helium gas does not need to be stored in the same way as products from nuclear fission reactors (Tokamak Energy, 2017). It is an inert gas and is not dangerous once dispersed in an atmosphere (Tokamak Energy, 2017). Whilst it has been established that the Tokamak Energy nuclear

Analysis and interpretation [5–6]

thorough and appropriate identification of limitations of evidence

The response identifies limitations of evidence that affect how well it can be used to develop a response to the research question.

thorough identification of relevant trends, patterns or relationships

The identified relationships are adequate for the purpose of responding to the research question and can support a valid conclusion. They have direct bearing upon and are applicable to the formation of the scientific argument.

Conclusion and evaluation [5–6]

insightful discussion of the quality of evidence

The discussion shows how the limitations identified in the analysis have affected the use of the evidence to evaluate the claim.

extrapolation of credible findings of the research to the claim

The response uses the conclusion to the research question to support or refute the claim within the limitations of the evidence identified in the analysis.

Communication [2]

fluent and concise use of scientific language and representations

The response is easily understood, avoids unnecessary repetition and meets the required length.

fusion power generation technique produces helium that does not pose a threat to humans or the environment once dispersed in the atmosphere, data was not found regarding the quantity of helium that is produced. Without further research determining the amount of helium released, establishing the safety of humanity and the environment of nuclear fusion power generation cannot be done. As this data was not found in the Tokamak Energy company literature, the evidence gathered is limiting, preventing any firm conclusion to be made that the Tokamak Energy nuclear fusion power generation technique does not pose a threat to human safety or the environment.

Another difficulty in establishing any firm conclusion, is that the mechanisms required to heat hydrogen fuel to 100 million degrees Celsius may require processes that threaten human safety and the environment. The safety of the processes undertaken during power generation and the threat that the quantity of waste is yet to be established because no data was found about how the Tokamak Energy technique achieves the high temperatures required. However, unlike nuclear fission reactors, there is no danger from loss of confinement of the fuel (i.e. only hydrogen gas would be released), and no unsafe waste from the process, then risks associated with the production of nuclear fusion power appear to be minimal (Tokamak Energy, 2017).

Quality of the evidence

The statement, “in more than 50 decades of civil nuclear power experience nuclear wastes have not caused any serious health or environmental problems nor posed any real risks to people. There has been no pollution or plausible hazard from such material routinely removed from power stations…” was made by the World Nuclear Association in 2017. It is suggested that a second source confirming this would be required to remove claims of bias, and to have greater confidence in the accuracy of the statement.

A lot of the information about the Tokamak Energy nuclear fusion power generation technique was sourced from the Tokamak Energy company. Whilst there is no indication that Tokamak Energy company is negligent, dishonest or biased, it is essential that an outside authority confirm the information as true at some point in the future. Understandably, evidence such as this is likely to be commercially sensitive, making it publicly available may threaten their business opportunities. As such, it is not suggested that an outside authority act on behalf of the public, but as a confidential agent of a nuclear fusion certification authority such as the Nuclear Regulatory Authority.

Evaluation of the claim

The research question, “Is the Tokamak Energy nuclear fusion power generation technique able to be considered clean?” was addressed by gathering evidence. The evidence suggests that the Tokamak Energy nuclear fusion technique uses fuel, and produces waste that bears no threat to humans or the environment. However, as no evidence was found regarding the cost or processes required to source the hydrogen fuel, heat the fuel or the human or environmental impact of the quantity of helium waste produced, it cannot be fully established that the technique can be considered as ‘clean’. The findings of this investigation, if applied to the claim, suggest that the claim is not yet able to be supported with the evidence gathered in this investigation.

Conclusion and evaluation [5–6]

suggested improvements and extensions to the investigation that are considered and relevant to the claim

The improvements address the limitations associated with the evidence. The extensions identify modifications that would complement the findings of the investigation and have the potential to provide new evidence that could be used to evaluate the claim further.

Improvements to the investigation

In order to address the limitations of the evidence identified previously, some improvements could be made. The first improvement would be to research how the hydrogen fuel is produced. It would be important to establish the cost of this process, and the risk to the environment and human safety associated with this process. Further data is required to establish how they hydrogen fuel is heated to such a high temperature. This process itself may not be 'clean', suggesting that the nuclear fusion process in its entirety is not clean.

Extensions to the investigation

It is recognised that the research question used to direct this investigation focussed on one aspect of the claim. An aspect of the claim that clean energy is "close to being realized" was not been directly considered in this research. Further research that could be considered is whether timelines being publicised by private corporations conducting research and building power plants are realistic. Further, research could be conducted to estimate the amount of fuel (hydrogen) required to provide power for a city, or country, and whether this amount of fuel is readily available on Earth. Finally, research into the processes involved in containing the hydrogen fuel during the reaction should be conducted. This will help establish the likelihood of achieving containment using inertial or magnetic methods.

Conclusion and evaluation [5–6]

justified conclusion/s linked to the research question

The response uses sound reasoning and valid and reliable evidence to support conclusions that directly respond to the research question.

Communication [2]

acknowledgment of sources of information through appropriate use of referencing conventions

The use of a referencing system fits the purpose of an essay.

Conclusion

It can be seen that not enough evidence has been gathered to establish whether nuclear fusion processes for generation of power, using Tokamak Energy's technique, are clean. However, no evidence was found to the contrary. As such, the claim "The dream of almost limitless clean energy from nuclear fusion is close to being realized" cannot be supported by this research, but at the same time, it was not refuted by the findings of this research.

Word count: 1973

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