Michael Smith Science Challenge 2012

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Analysis

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Introduction

The Michael Smith Challenge is an annual nationwide challenge exam open to students who have yet to take any Grade 11 sciences. The Challenge is named after Nobel laureate Michael Smith of the University of British Columbia. It is the only challenge exam written across the nation that covers all scientific fields taught at the Grade 10/Niveau 4 level. It is available in both French and English. This year, the contest was written on February 28th and 1735 students participated, a 13% increase from the previous year. The contest consisted of five questions covering logical reasoning, biology, chemistry, physics and earth science.

This year, 198 teachers from all 10 provinces registered for the contest, as seen in Figure 1. 168 teachers, 85% of all registered teachers, were able to submit exams to be marked. A total of 1949 students were registered with 89% of them submitting exams to be marked.

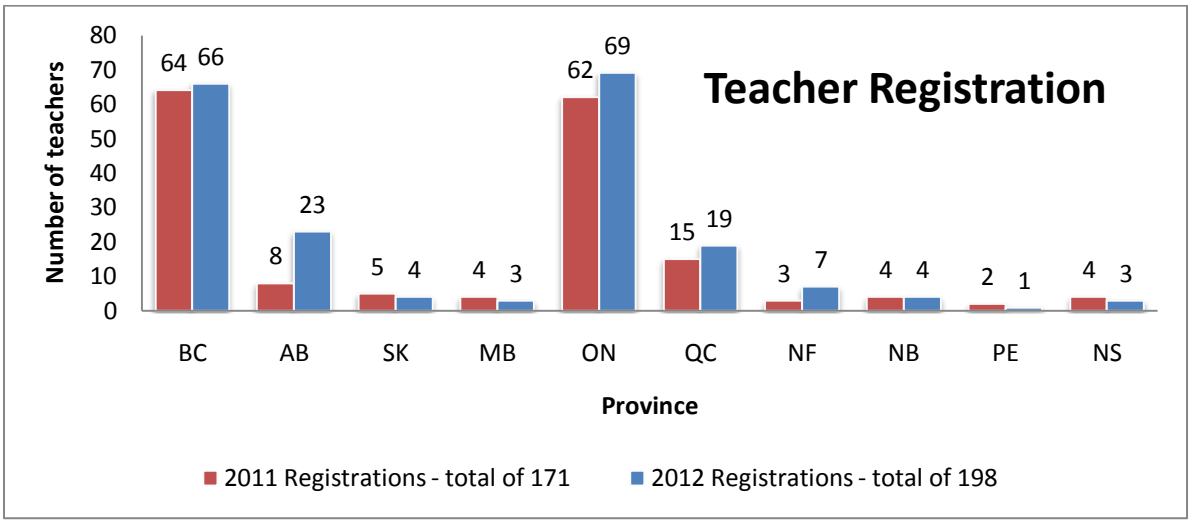


Figure 1: The number of teachers who registered for the challenge in 2011 compared to the number of teachers who registered in 2012

Contrary to previous years, Ontario had more registrations this year than BC. The greatest increase in participants was seen in Alberta where the registration almost tripled. Not all students who registered submitted papers and other students who were not registered submitted exams.

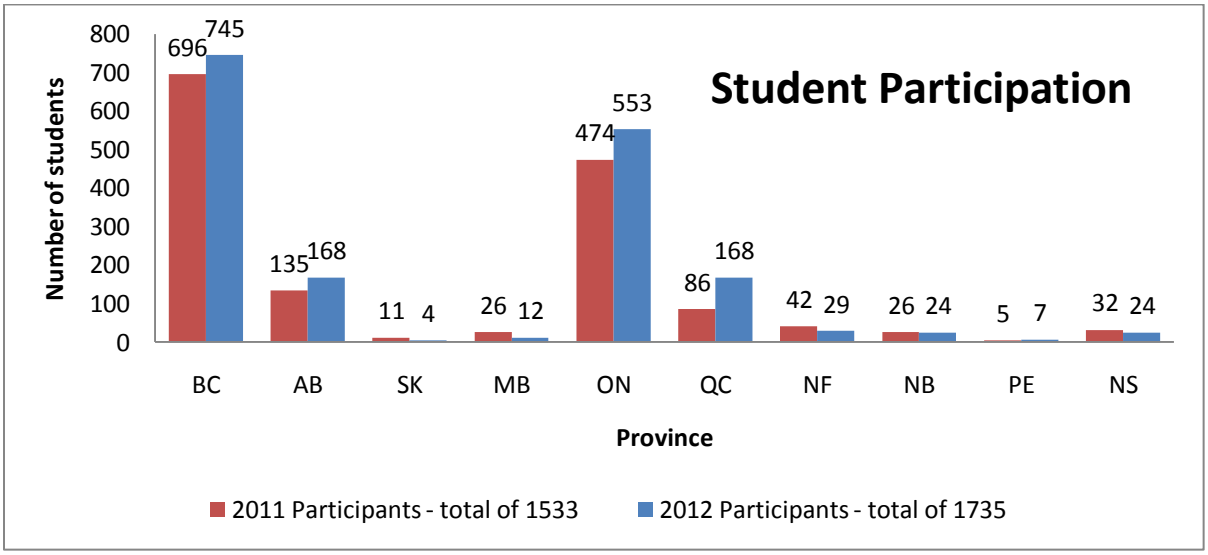


Figure 2: Student participation by province in the 2011 and 2012 Michael Smith Challenges.

Results of the Michael Smith Challenge Exam

Overall

The average score was 44%. This average is 1% higher than last year's and can be seen from the fact that no paper scored 0 marks. On the other hand, there were also no perfect papers due in part to the rarity of perfect scores on question 2. Questions requiring thoughtful analysis, such as questions 2, 3E and 5, seemed to be the dividing factor between those that scored higher marks and those who did not.

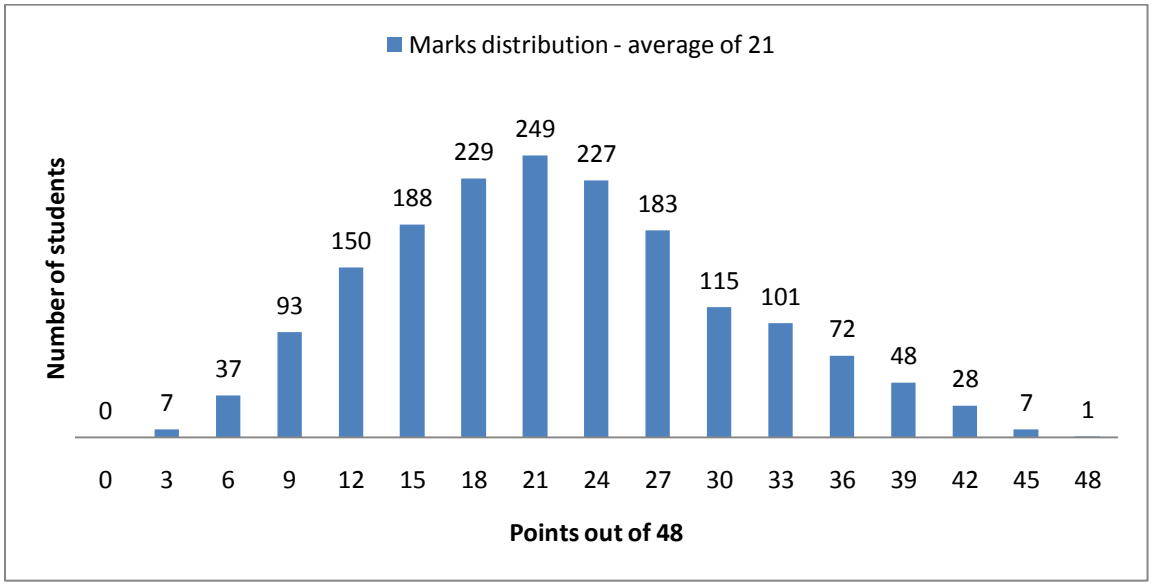


Figure 3: Chart showing the frequency distribution of marks. The highest mark achieved was 46 out of 48 and the average was 21 out of 48. The bins are 3 marks wide such that the 48 bin includes 46, 47, and 48 marks.

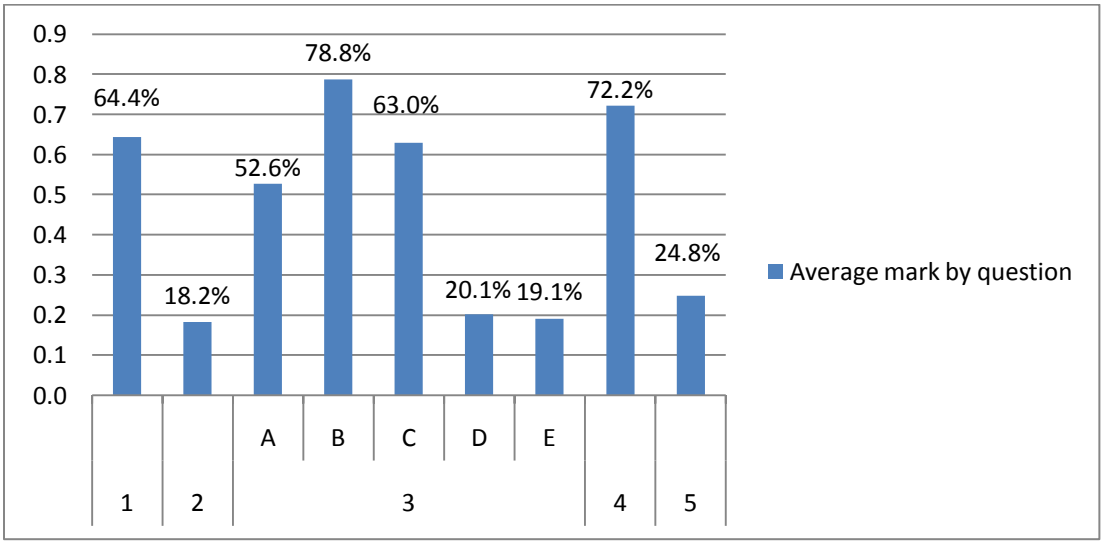
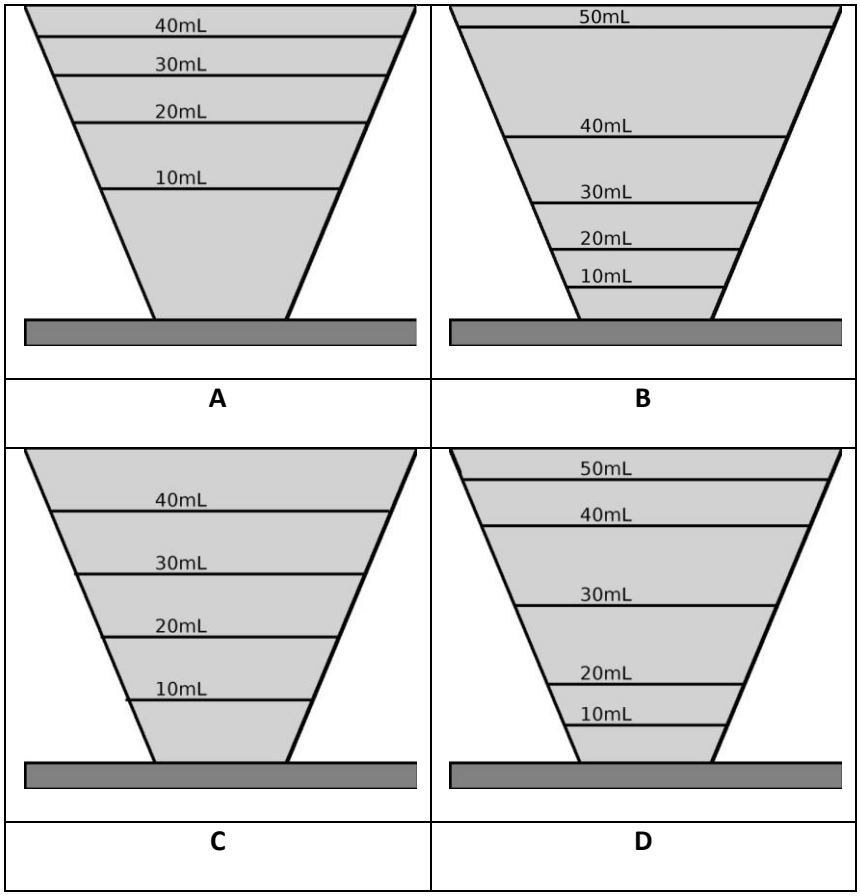


Figure 4: Chart showing the average score on each question. A more detailed breakdown for each question is in the following pages.

Question 1

Consider the measuring cups below:



Which measuring cup appears to be the most trustworthy? Explain your choice in no more than 60 words. (7 marks)

"A" appears to be the most trustworthy measuring cup. As you fill the cup, the amount of volume gained per increase in height becomes larger due to the increasing radius. This means that there is less volume gained per height at the bottom. As a result the increments at the bottom must be further apart than the increments at the top.

This question was designed to test the students' appreciation of 2D representations of volume. The most common error was to assume the cup with equal gradations was the most trustworthy cup. This does not take into account the presumed shape of the cup.

Marking Scheme:

1 Mark: *Choosing cup "A"*

6 Marks: *Explanation of why it should be cup "A". This may include any of the points listed:*

- *The bottom has a smaller area per unit height than the top.*
- *The bottom will fill higher with the same amount of fluid than the top.*
- *Due to increasing radius/width/length, the gradations must get thinner as they near the top.*

Students receive a maximum of 3 marks for choosing the incorrect cup but showing correct reasoning.

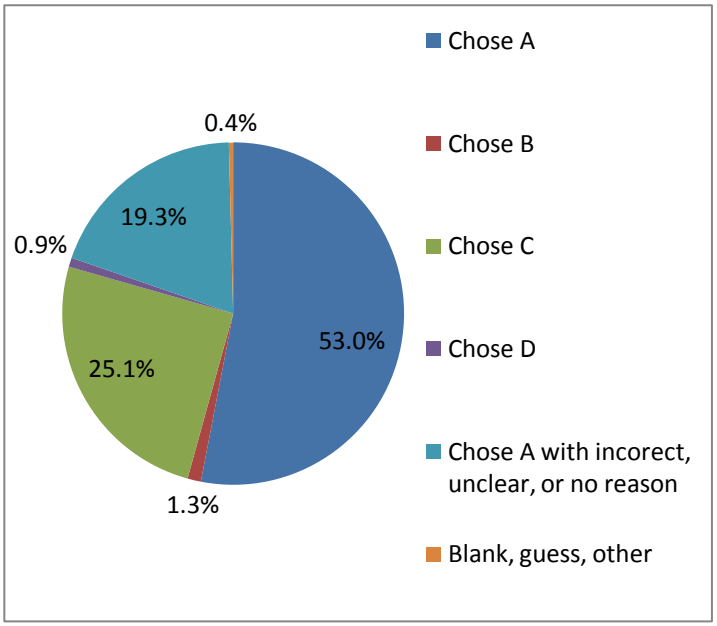


Figure 5: Analysis of the responses for question 1. The average mark was 5/7. Read the pie chart from the top clockwise.

Question 2

Some scientists have pointed out that it may be better for the environment for a person to commute in a car than to cycle to and from work, particularly if that person is an exclusive carnivore. How can this possibly be, given that a car is about 100 times heavier than a bicycle? (10 marks)

The environmental damage done in commuting to work by car largely arises from (a) burning the fuel and (b) the manufacture of the car. With the exception of fuel derived from the tar sands or corn, relatively little damage is caused in the extraction of the original oil. For a cyclist, while some GHGs are produced "burning" food, by far most of the damage is done in the production of that food in GHG production and fertilizer run-off. It is worse for meat production, especially for grain-fed cattle, where that grain has to be grown first. Considering that food energy is much less energy-efficient than the chemical energy of gasoline because food must go through trophic levels, even when a car is 100 times heavier than a bicycle, more food energy may be consumed than chemical energy from gasoline to go the same distance. Therefore, it is possible for an exclusively carnivorous and athletic cyclist to do more environmental harm than the car commuter, particularly if the cyclist also owns a car.

Marking Scheme: 7

2 Marks: *Mentioning that a person who exercises must eat more than one who does not*

2 Marks: *Realizing that people run on food energy just as cars run on chemical energy from gasoline*

2 Marks: *Understanding the large environmental impact of agriculture*

2 Marks: *Going through multiple trophic levels causes food energy to have a lower efficiency than gasoline*

2Marks: *Total mechanical efficiency of a person is worse than that of a car and as a result may cause more GHG to be emitted*

No quantitative (numerical) solution was needed for full marks. However, all points listed above needed to be recognized for full marks including realization that the human body is a heat engine just like an internal combustion engine.

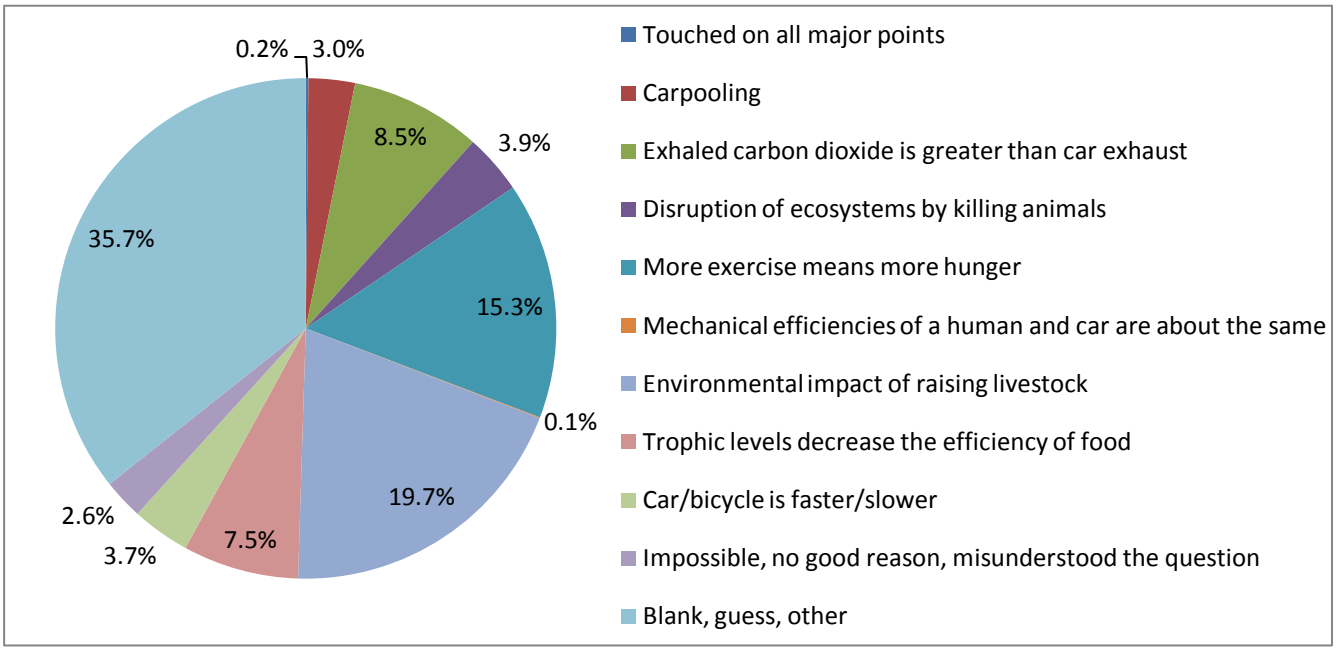


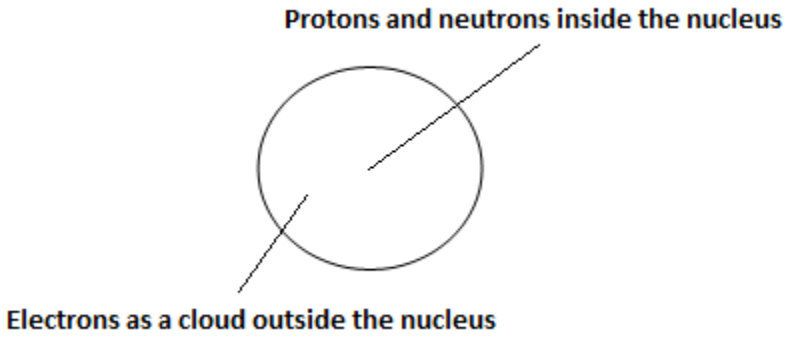
Figure 6: Analysis of the responses for question 2. The average mark was 1.82/10. The labels in the above chart are the main arguments the students presented. Many of them noted more than one point. Read the pie chart from the top clockwise.

This question looks for students' ability to see both driving and cycling as energy processes, to identify where that energy is coming from, and how the environment may be affected in each case.
Only 0.2% of all students were able to attain full marks for his question. Obtaining full marks required the students to touch on all points listed in the criteria with enough detail to show that they understood the concepts.55% of the students understood that the cyclist must eat more to maintain their energy requirements. More than half of these students expanded further to write about trophic levels, the environmental impact of raising livestock or the disruption of the ecosystem through excessive killing of animals. The "Other" category included answers discussing the need to build bicycle paths, cyclists damaging the environment by riding through pristine natural environments, and positive and negative effects of cycling such as better health, exposure to exhaust fumes, and the possibility of injury while cycling.

Note: *Our statement that the car is 100 times heavier than the bicycle is somewhat misleading as the bicycle is much lighter than the rider. A typical car with a driver would be approximately 20 times heavier than the typical bicycle with a rider.*

Question 3A

In the diagram of a spherical atom below, label where you would find the protons, neutrons and electrons (3 marks)



Marking Scheme: 9

1 Mark: *Having protons and neutrons grouped together as a nucleus and electrons outside*

1 Mark: *All particles inside the circle, since the sphere is the atom*

1 Mark: *Notes the electron cloud model of the atom and/or extremely small size of the nucleus*

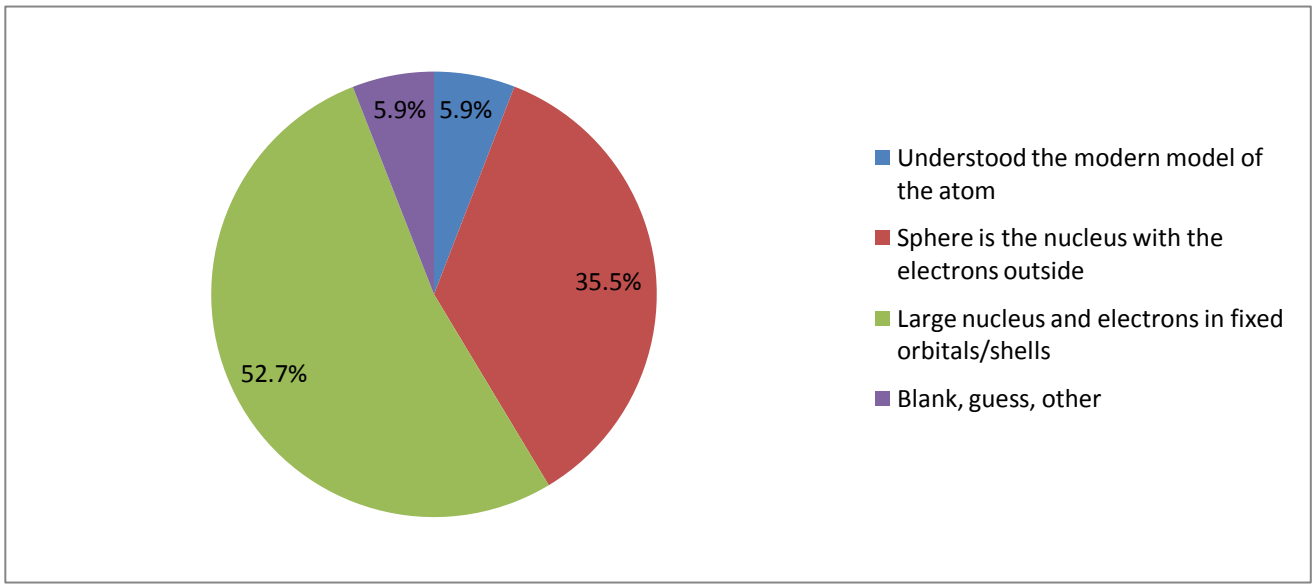


Figure 7: Analysis of the responses for question 3. The average mark was 1.58/3. Read the pie chart from the top clockwise.

Full marks required that the student could depict the electron cloud model of the atom and/or the tiny nucleus. That is, understanding that the nucleus is an extremely small part of the atom. The most common drawing was that of a Bohr Model atom with its electron shells in fixed orbits and a visible center with protons and neutrons. The next most common was where the given circle was the nucleus and electrons orbited outside. As the question says "In the diagram of a spherical atom below", the electrons must be included within the circle. Other diagrams included those with neutrons in the center and protons and electrons orbiting and those with the protons and electrons are the nucleus and the neutrons orbit.

Question 3B

The mass of an element is determined from the sum of certain particles within an atom. If given the symbol $^{12}_{6}C$ for the neutral element carbon, how many neutrons are there? How do you know? (2 marks)

There are 6 neutrons. Neutral carbon has 6 electrons and 6 protons to balance the charge. If the mass is 12 amu and there are 6 protons, there must therefore be (12-6 =) 6 neutrons.

Marking Scheme: 10

1 Mark: *The correct number of neutrons*

1 Marks: *Correct reasoning*

Having incorrect reasoning and the correct number was awarded no marks

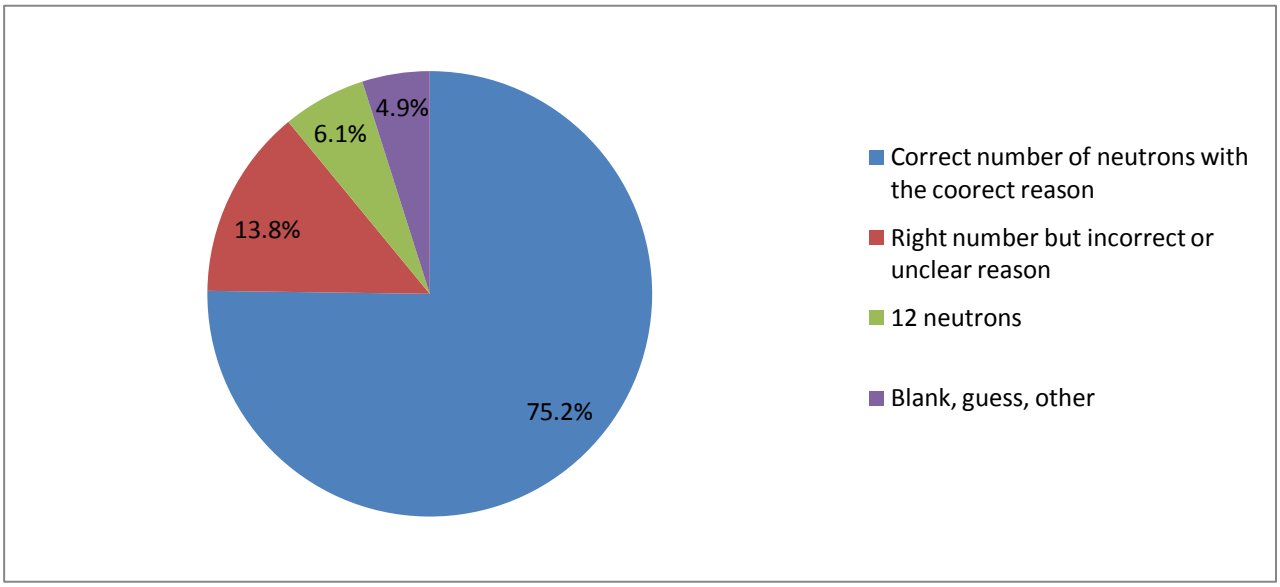


Figure 8: Analysis of the responses for question 3B. The average mark was 1.58/2. Read the pie chart from the top clockwise.

This question tested students' understanding that it is the number of protons that determines which element the atom belongs to. A student understanding this should have been able to do this question without prior knowledge of the conventional notation.
As it was, there were no students who had the right reasoning but the incorrect final answer. Most students understood the meaning of the symbol for neutral carbon and were able to obtain full marks for this question. Incorrect reasoning accompanied by the correct number included the 6 being the number of neutrons, the number of neutrons being equal to the difference between the number of protons and electrons, and the number of neutrons having to equal the number of protons in a neutral atom. The most common incorrect answer was that of 12 neutrons, taken from the 12 on the symbol.

Question 3C

Carbon dating is a technique used to determine the age of very old artefacts. It is performed with a very rare isotope of carbon known as carbon-14 ($^{14}_{6}C$). How is this atom of carbon different from the more common atom of carbon known as carbon-12 ($^{12}_{6}C$)? (2 marks)

Isotopes are the same element but with different numbers of neutrons. In the case of carbon- 14, there are 2 more neutrons present. ($^{14}_{6}C$)

Marking Scheme:

1 Mark: *Stating the change in the number of neutrons with the proper reason*

1 Marks: *Explanation of what an isotope is*

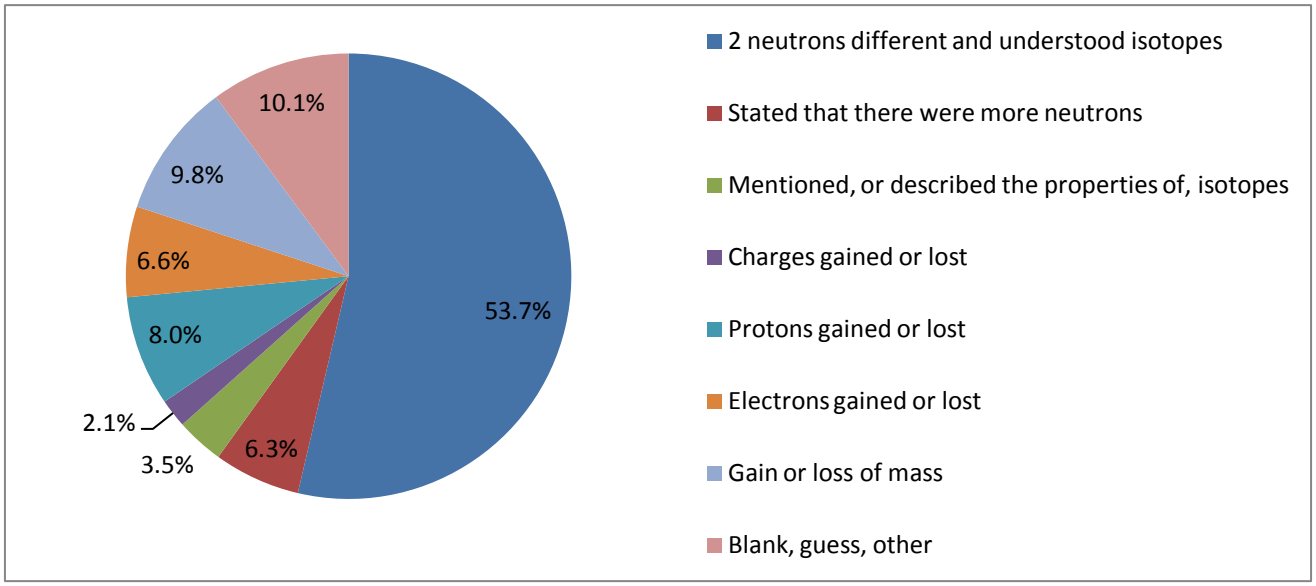


Figure 9: Analysis of the responses for question 3C. The average mark was 1.26/2. Read the pie chart from the top clockwise.

This question re-affirms the importance of the number of protons in determining the element. About half of the students were able to obtain full marks for this question. Almost all of them were those who answered the previous question correctly. Those that had the previous question incorrect mostly reached an incorrect conclusion on this question as well. Answers included those that described changes in the number of all three particles that make up the atom, statements about changes in mass, and description of the properties of isotopes.

Question 3D

Natural carbon (12.011 amu) has 2 common isotopes known as carbon-12 (12.0 amu), and carbon-13 (13.003 amu). The given mass of an element is the weighted average of its isotopes, what are the relative percentages (%) of each isotope in carbon? (3 marks)

Weighted Mass = ∑([% isotope]*[weight of isotope])

12.011 = $\%^{12}C(12.0) + \%^{13}C(13.003)$

Let a be $\%^{12}C$, therefore $1-a = \%^{13}C$

$12.011 = a\,(12.0) + (1-a)\,13.003$

$1.003a = 0.992$ $\quad a = 0.989$

Therefore $\%^{12}C = 98.9\%$, and $^{13}C = 100-98.9 = 1.1\%$

Marking Scheme: 12

1 Marks: *The final answer of 98.9% carbon-12 and 1.1% carbon-13*

2 Marks: *Showing the work for solving for the percentages*

Only 1 mark was awarded for work if the solution was obtained through guess-and-check

Final answers obtained coincidentally through guessing or formula that would not work with other numbers were awarded 0 marks

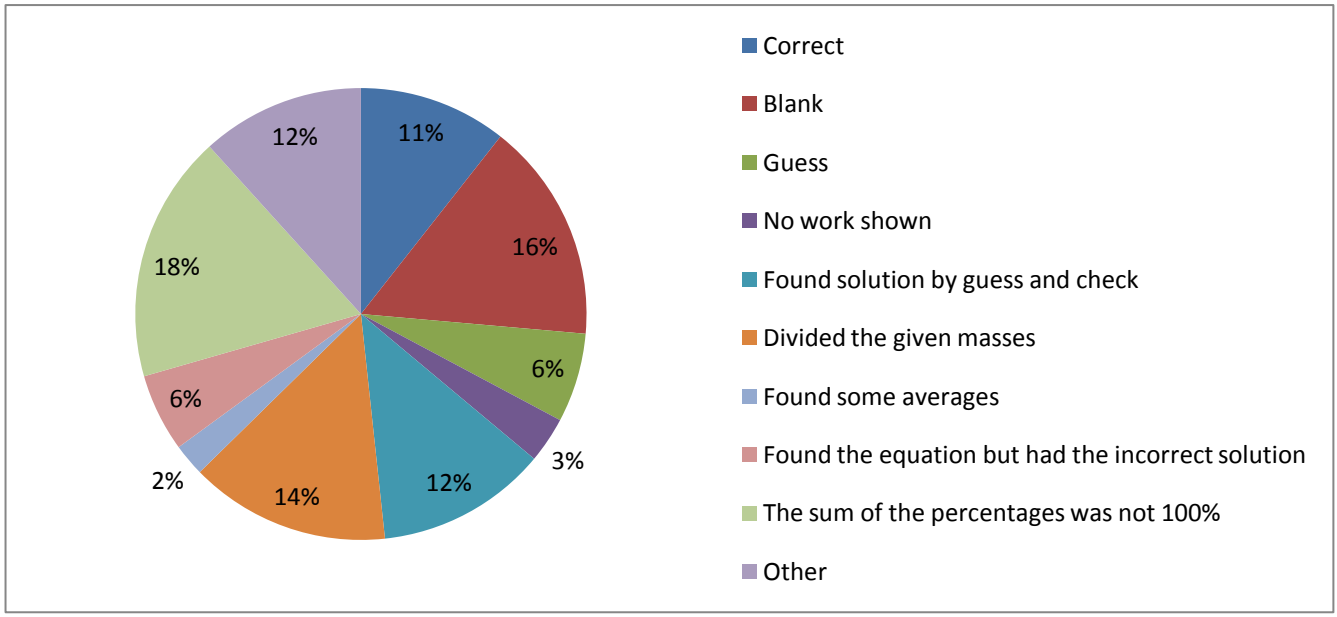


Figure 10: Analysis of the responses for question 3D. The average mark was 0.60/3. Read the pie chart from the top clockwise.

The purpose of this question was to test whether the students were able to do a weighted average and whether they understood that the sum of all parts should be 100%.

The two most common mistakes were attempts to find the simple average of carbon-12 and carbon-13 and dividing the masses of the two carbons with the mass of natural carbon or vice versa. In many cases this led to a sum of percentages that was not 100%.

Question 3E

One of the radioactive isotopes released when the Fukushima reactor failed was Plutonium-240. This radioactive isotope undergoes a series of alpha and beta decays to become Lead-208. The series includes stages with thorium-228 and polonium-212.

Suggest a series of alpha and beta decays that could make up this process by plotting the isotopes and the path between them on the graph below. The names of the intermediate species are not needed here.
Note: remember that alpha decay is the release of an alpha particle (helium-4) and beta decay is the transmutation of a neutron into a proton. (5 marks)

The marks below were awarded to those who were able to achieve a certain level of success

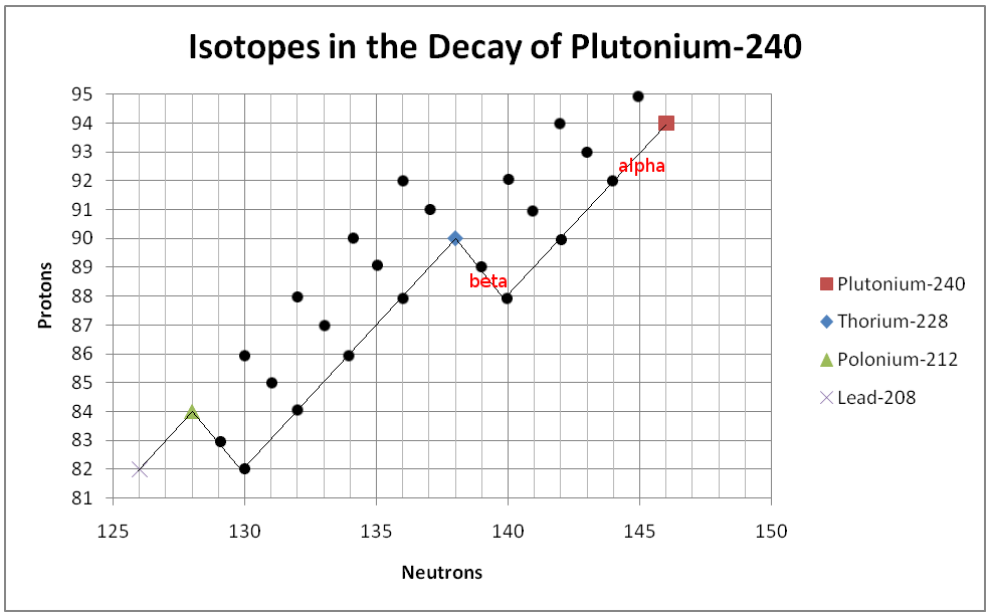
1 Mark: *Successfully plotted one of a beta or alpha decay on the graph*

2 Marks: *Stated the total number of alpha and beta decays in the process*

3 Marks: *Stated the number of alpha and beta decays between each of the given elements*

5 Marks: *Plotted the appropriate graph*

While the line depicted is the actual decay process, we will accept any combination connecting the dots from right to left through a series of alpha and beta decays.



The line plotted above is the solution that actually occurs in nature, but any combination of alpha and beta decays that passed through the black points to the end was accepted for full marks.

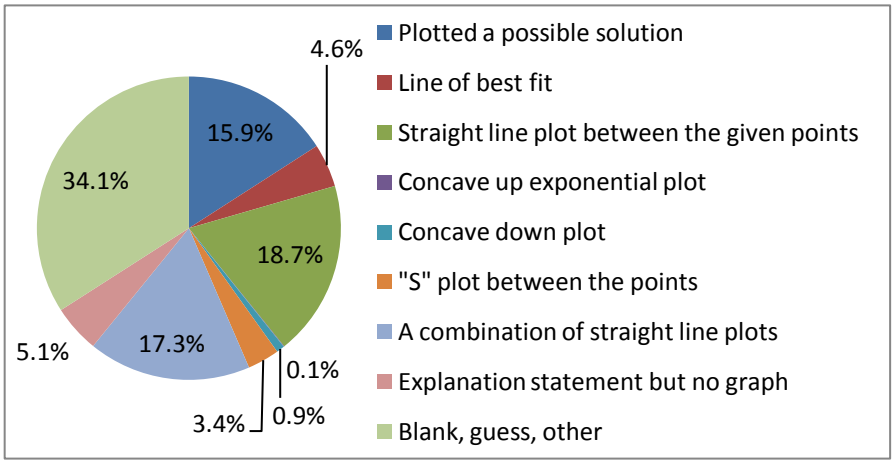


Figure 11: Analysis of the responses for question 3E. The average mark was 0.95/5. Read the pie chart from the top clockwise.

This question tested whether the students were capable of comprehending a question and representing the answer in graphical form. This question required no prior knowledge on what radioactive decay is.
Some of the solutions seen suggested that the horizontal axis was misunderstood to be that of its mass as opposed to the number of neutrons.

Question 4

Marking Scheme:
1 Mark: *Every correctly filled blank*

The following paragraph explains some of the science behind the Touhoku Earthquake that shook Japan on March 11, 2011. Complete the paragraph by filling in the blanks with the words provided. (10 marks)

Earthquakes happen when the earth's 'crust' suddenly moves due to stored up 'potential' energy being released as 'kinetic' energy; the greater the movement of the crust, the greater the 'magnitude' of the earthquake. The earthquake in Japan had its 'epicentre' off the east coast of Japan. The earthquake displaced a large amount of 'water' and resulted in a 'tsunami', a wave that started off with low 'amplitude' and long 'wavelength' but became tall by the time it reached the shore. The power of it was so great that it set off warnings all around the Pacific Rim. Even after the earthquake, smaller tremors called 'aftershocks' continued to occur, causing worry about the damaged nuclear power plants.

magnitude	damage	movement	Moving	wavelength
micro vibrations	Crust	frequency	Amplitude	S-wave
mantle	Potential	core	Zero	Dirt
P-wave	Water	epicentre	Air	elastic
aftershocks	Tsunami	kinetic		

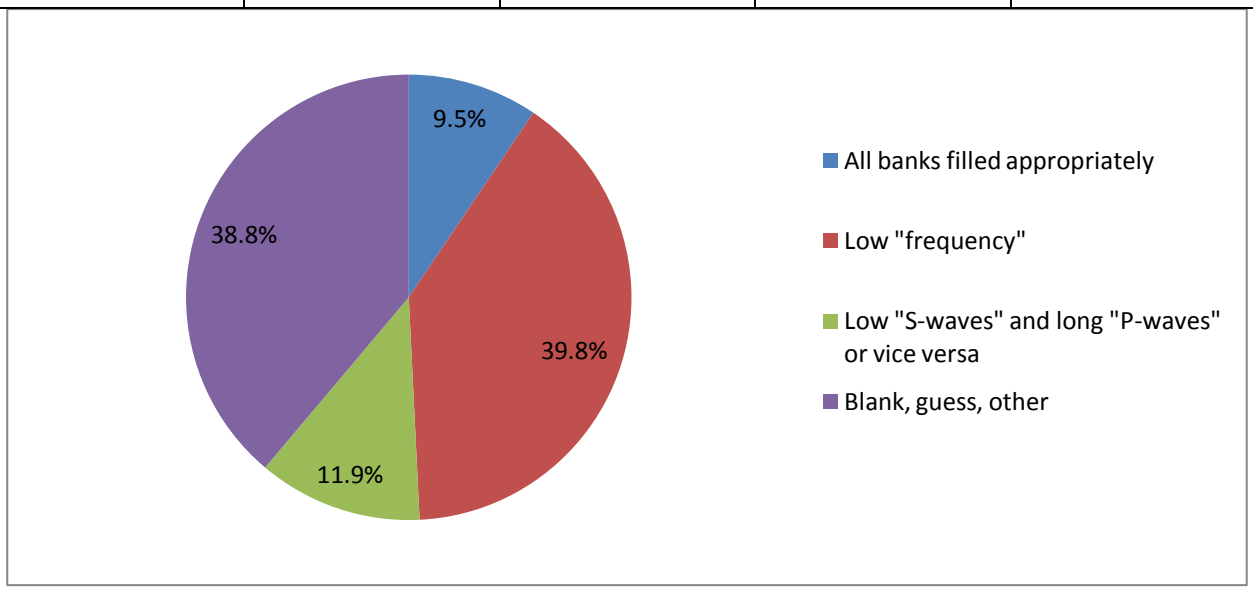


Figure 12: Analysis of the responses for question 4. The average mark was 7.22/10. Read the pie chart from the top clockwise.

This question was designed to see how well the student absorbed and organized information that appeared in the news last year.
There were many different answers to this question but the most common mistakes were the ones listed above in the chart. The answer of "low frequency" is incorrect since a tsunami is a pulse wave and not a regular train of waves

Question 5

A list of household appliances is given below with their power ratings. Given a house circuit with a circuit breaker rated for 16A, what is the maximum number of appliances you can run on this circuit? Which appliances are they? Assume a house circuit has a voltage of 120V. Show your calculations. (6 marks)

Appliance	Power rating(Watts)
Bank of incandescent lights(10 bulbs)	1000
Refrigerator	70 (average)*, 480 (peak)
Vacuum	600
Microwave	720
Toaster	1200

*This average assumes 2 hours of usage per week

Appliance	Maximum current drawn in house circuit (Amperes)
Bank of incandescent lights(10 bulbs)	8.3
Refrigerator	4
Vacuum	5
Microwave	6
Toaster	10

Max power that the circuit can take: 16A*120V = 1920W

3 appliances can be plugged in: refrigerator, vacuum, and microwave.

Marking Scheme:

1 Mark: *Stating P=IV or other equivalent formula*

3 Marks: *Finding the current drawn by each appliance or finding the maximum power that the circuit can take*

2 Marks: *Finding the maximum number of appliances that can be run on the circuit*

No marks were given for just the final answer

The maximum number of marks given when the average value for the refrigerator was used was 4 marks

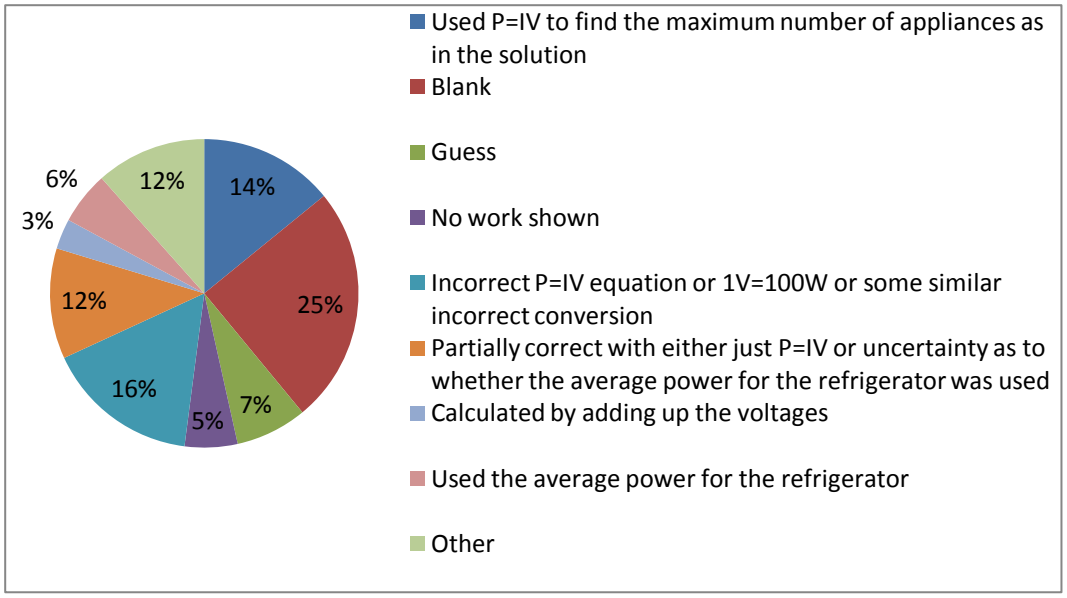


Figure 13: Analysis of the responses for question 5. The average mark was 1.49/6. Read the pie chart from the top clockwise.

This question was designed to test students' appreciation of the basics of electrical power distribution in their own homes. It required the students to know the relationship between power and current, and that fuses trip not on average current but on maximum current.
A quarter of all students left this question blank. Other than the common errors listed above, the most common errors occurred after the students were successful in finding the maximum power output of the house circuit. These errors were attempting to find a combination of powers that was exactly 1920W and using the average power of the refrigerator and saying that the maximum was 1920W / 70W = 27 refrigerators.

Awards

The highest scoring student received a prize of $500. 2nd place was tied between two students and each was awarded $175. The top student from each province who did not receive a national prize was awarded $100. Teachers of all these prize-winning students received a $50 prize. All prizewinners, both students and teachers, received certificates commending their achievements.

Four other types of certificates were awarded, to the top 1%, 3%, 10%, and 25% of students. All students in the top 1% received at least 42/48 marks. The students in the top 3% received at least 38/48 marks. The students in the top 10% received at least 33/48 marks. The top 25% of students received at least 28/48 marks.

Results Package to Teachers

Teachers were mailed a package containing a list of their students' results, certificates for high-scoring students, and a receipt for payment. For those teachers with a prize-winning student, a cheque for the prize money was also included.

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