Michael Smith Science Challenge

2010

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Analysis

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Introduction

Founded in 2003, the Michael Smith Challenge is a national science contest for Grade 10 students that aims to stimulate student interest in science and prepare them for senior high science contests. The Michael Smith Challenge is the only national science competition at the Grade 10 level in Canada, and is also the country's only science contest covering all scientific disciplines. This year, over 1300 students wrote the contest, a 52% increase from 2009. As in previous years, teachers registered students for the contest online during February and March. On the day of the contest, March 24, 2010, teachers downloaded the contest off the Michael Smith Challenge website (www.smithchallenge.ubc.ca, on the UBC Physics Outreach website), printed it, and administered it to students at 9:00 PST.

Design of the Michael Smith Challenge 2010 Exam

The 60-minute exam consisted of 6 short-answer questions, four questions worth 15 points each and two worth 10 points. The questions were similar in length and were arranged in order of increasing complexity. Each question was either divided into subsections or asked for multiple, specific pieces of information: in 2009, an open-ended long-answer question was included, however student marks indicated that question was not effective so no long-answer question was included this year.

Since the inaugural 2003 contest, the format of the exam has shifted from a multiple-choice, knowledge-based exam with many questions to a short-answer exam with only a few questions, emphasizing logical thinking and scientific problem solving. This year's exam continues that trend.

Registration & Participation

The registration system worked the same way as in previous years. Teachers filled out a form on the website and submitted their name and school information, as well as the names, grades, and genders of each of their students. They were able to logon to the system at any time to modify their information. Registration opened on February 1, 2010 and officially closed on March 23, the day before the contest. In the week before the contest, all registered teachers were emailed a password to access the exam on the contest day.

This year, 158 teachers from all 10 provinces registered for the contest, as seen in Figure 1. A total of 1535 students were registered.

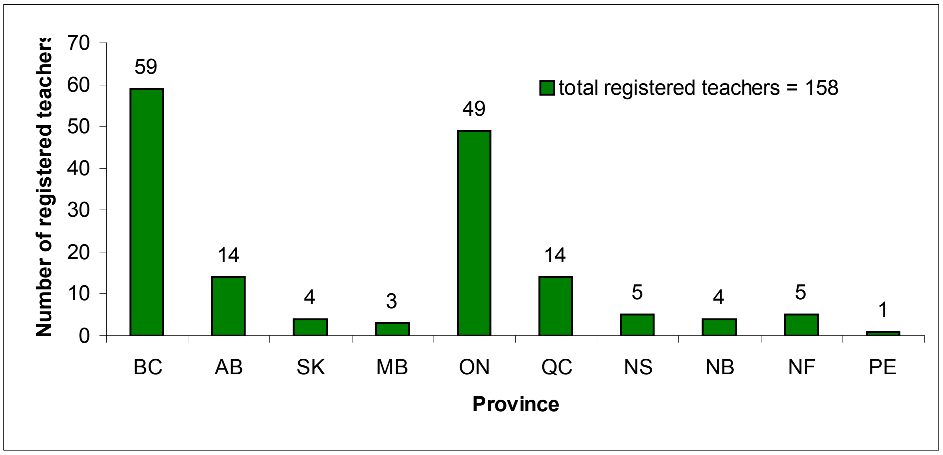


Figure 1: The number of teachers who registered for the challenge in each province. 92% of these teachers submitted exams to be marked.

As in previous years, BC had the most teachers register, followed by Ontario. The most significant change in registration for the 2010 contest was in the number of Quebec teachers who registered: from 1 in 2009 to 14 in 2010. 92% of registered teachers submitted exams, however, due to student absences, not all teachers submitted exams for as many students as they had originally registered. Papers were submitted for 87% of all registered students.

As can be seen in Figure 2, 1328 students participated in this year's contest. This is a 52% increase over last year and a new record for the challenge. Quebec participation was 19 times greater than it was in previous years.

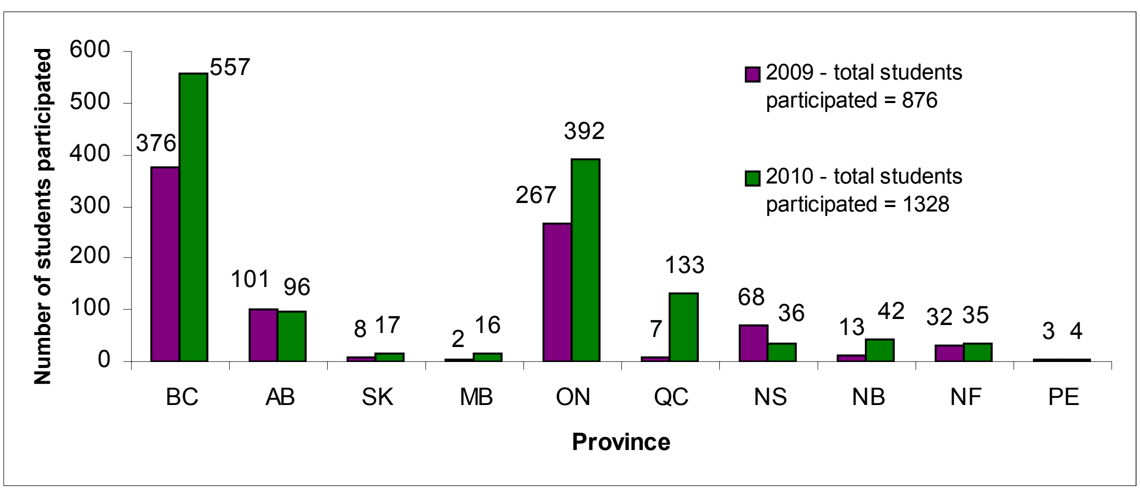


Figure 2: Student participation by province in the 2009 and 2010 Michael Smith Challenges.

Results of the Michael Smith Challenge Exam

Overall

As in previous years' contests, the average score was between 30% and 40%. Last year, only 3 students received a mark above 80%. This year, 28 students received a mark above 80%. It should be noted that the 1st place winner, with a perfect score, was a full 5 marks ahead of the 2nd place winner, and the other students achieving over 80% were closely clustered with marks between 64 and 75.

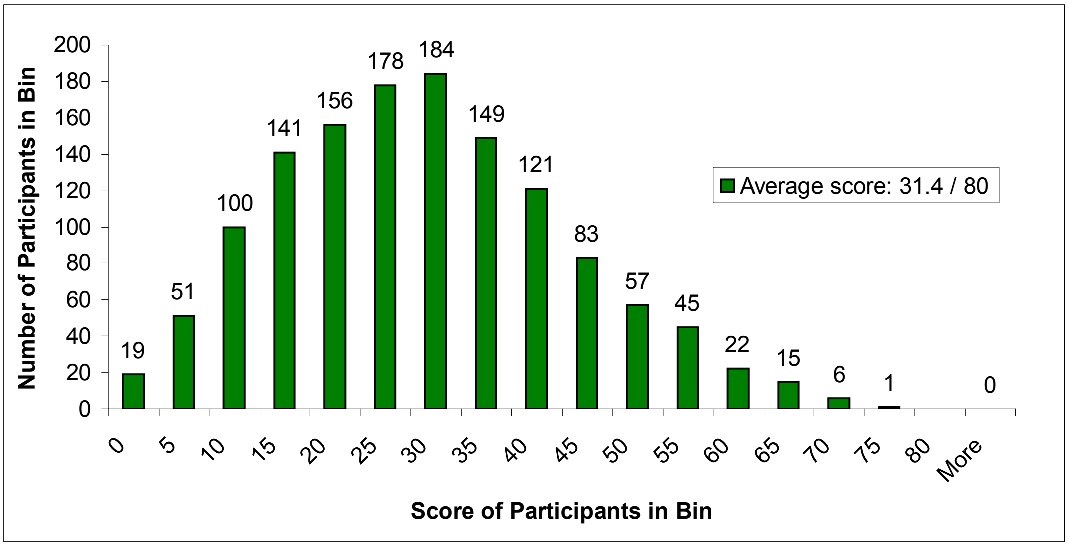


Figure 3: Chart showing the frequency distribution of marks. One student achieved 80 out of 80 and the average was 31.4 out of 80.

The averages of questions 1, 2, and 5 were consistent with the total average (see Figure 4). Question 3, which required students to draw a series circuit, a parallel circuit, and a circuit involving a combination of the two (see page 9 for a thorough discussion of this question), had the highest average of all 6 questions. Question 4, a graphing question, was almost as well done.

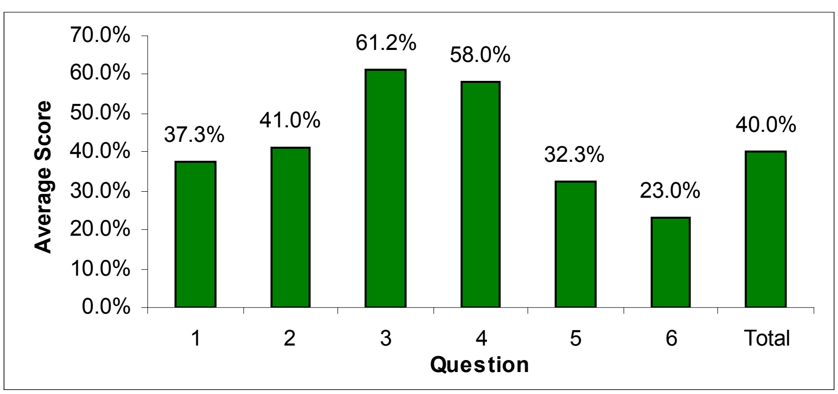


Figure 4: Chart showing the average score on each question.

The weighted marks of each question were provided on the exam (see Table 1 below). The questions were marked out of a different total (whatever corresponded best to the desired responses) and then scaled to be worth the number of marks indicated on the exam paper. Up until this point, all marks mentioned have referred to the weighted marks out of 80. In the marking scheme for each question, the marks will refer to what each question was marked out of. The total unweighted mark will never be considered (marked N/A in the table).

Table 1: Chart listing what each question was marked out of, how it was scaled to the weighted mark out of 80, and what percentage of the test each question was worth. The weighted marks were provided to the students on the exam.

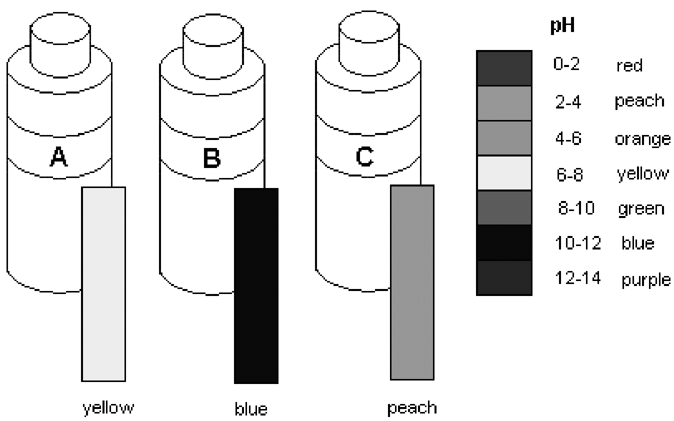
Question	Marked out of	Weighted marks	% of test
1	8	15	18.75%
2	8	15	18.75%
3	8	10	12.5%
4	10	10	12.5%
5	5	15	18.75%
6	8	15	18.75%
Total	N/A	80	100%

Question 1

Peter discovers three unlabelled bottles of cleaning fluid in his house. He guesses that one is full of vinegar and that one contains ammonia (but doesn't know which is which). He has no idea what could be in the third.

Question 1A

Peter puts universal indicator paper in each solution, with the following results. Is it likely the solutions correspond to Peter's guesses? Which bottle is which?



ammonia: B

vinegar: C

Marking Scheme:

1A
1 Mark: *Ammonia correct*
1 Mark: *Vinegar correct*

1B
1 Mark: *"No," the identity is unknown*
3 Marks: *Valid reason*

1C
4 Marks: *"No," and a valid reason*

Since ammonia is a base and vinegar is in acid, it is likely that the solutions correspond to Peter's guesses.

Question 1B

Is the 3rd solution's identity known? Give reasons.

No, the 3rd solution's identity is not known. It is only known that it is a neutral substance. There are many possible neutral substances it could be.

Question 1C

Can the 3rd solution be disposed of by pouring it down the drain? Give reasons.

No, unknown substances should not be poured down the drain.

The average marks in this question were 1.4/2, 1.7/2, and 0.6/4 for parts a, b, and c respectively. Part A was well done, with 62% of students obtaining full marks. Only about half those students were able to obtain full marks in Part B. While students who correctly answered Part A generally were able to identify that the unknown substance was neutral, many jumped to the erroneous conclusion that the solution was water. Yes, water is a neutral substance, however there are many other neutral substances, such as.gasoline, or kerosene. Any non-polar organic liquid will also be neutral. Only 12% of students obtained full marks in Part C. Unknown substances should never be poured down the drain. Neutral does not mean harmless. Acidity is not the only thing to consider when disposing liquids. Neutral substances can be toxic, reactive, or corrosive (such as concentrated hydrogen peroxide, which is an oxidizer).

Question 2

A star that can be seen from a given location at all hours of any clear night and never dips below the horizon is called "circumpolar."

Question 2A

Where do you have to be on Earth for all the stars you can see in the sky at any given moment to be circumpolar?

At the North or South pole.

Question 2B

Are there any places where none of the stars that can be seen in the sky are circumpolar?

At the Equator.

Question 2C

"Polaris," the "pole-star" indicates the direction of true North. If you didn't know anything about constellations and didn't have a compass (or any other direction-finding means), how would you identify the pole-star?

The "pole-star" is the star that, after observing the sky for several hours, does not appear to move. All the other stars appear to circle around it.

Marking Scheme:

2A

2 Marks: *Correct final answer (with both poles mentioned)*

2B

2 Marks: *Correct final answer*

2C

4 Marks: *The pole-star does not move*

The averages were 1/2 for both 2A and 2B, and 1/4 for 2C. Part A was well done, with 56.9% of students receiving full marks. Part B was almost as well done, with 49% of students obtaining full marks. Part C proved challenging for most students. Only 17% of students received full marks. 26% of students wrote that Polaris could be recognized because it is the brightest star in the sky. This is not true – Polaris is not a particularly bright star (the brightest star title belongs to Sirius). 10% of students referred to a constellation or described a particular combination of stars in their answer, despite the wording of the question clearly stating this would not constitute a good answer! 5% of students suggested finding North by watching where the sun rises and sets, and then finding Polaris based on that. Part marks were awarded for this answer, however the sky is full of stars – knowing which way North is wouldn't be enough to pinpoint exactly which star is Polaris!

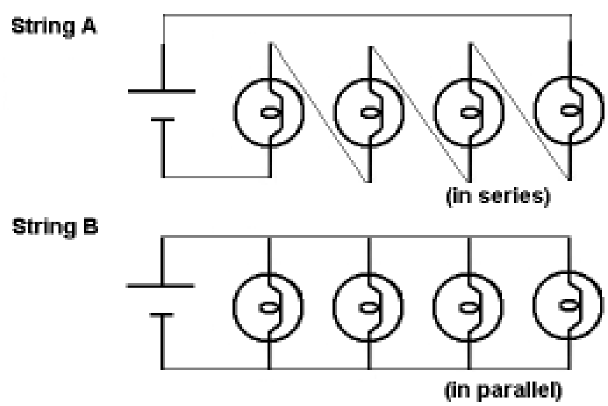
Polaris is a circumpolar star (as 12% of students noted in Part C) that is special because it is located more or less in line with the Earth's axis. Because the axis of the Earth does not move, it only rotates on itself, Polaris appears fixed in position while the other stars in the sky appear to rotate around it (of course it is really the Earth that moves, not the stars). This effect can best be observed by taking a time-exposure photograph of the sky over a period of several hours. The other stars will "move" in concentric circles around Polaris.

Question 3

You have two strings of Christmas lights, string A and string B. While hanging them up, one bulb on string A is smashed, causing all the lights in string A to stop working. A few minutes later, another bulb is smashed, this one from string B. You are surprised to find that the other lights in string B still work.

Question 3A

How are string A and string B wired? Show on the circuit diagram below.



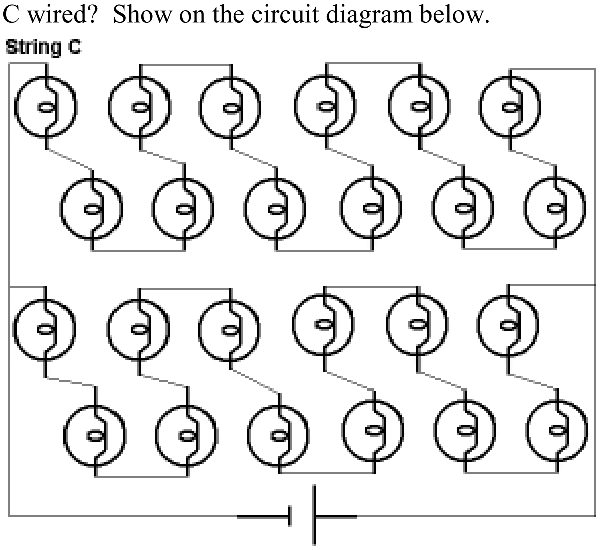
Marking Scheme:

2A
2 Marks: *String A in series*
2 Marks: *String B in parallel*

2B
2 Marks: *The light bulbs in the top half are connected in series, as are the light bulbs in the bottom half*
2 Marks: *The top half and the bottom half are in parallel with each other*

Question 3B

You find another set of lights, string C, which looks like a big net. When you remove a light bulb from the top half, all the lights in the top half go out, but the lights in the bottom half stay on. When you replace that light bulb and instead remove a light bulb from the bottom half, all the lights in the bottom half go out, and the lights in the top half stay on. How is string C wired? Show on the circuit diagram below.

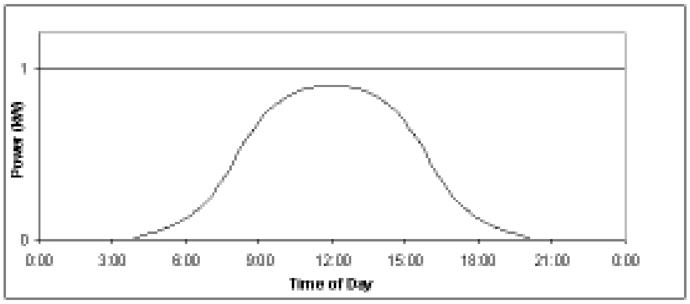


This question had the highest average, 61%. 34% of students earned full marks on this question. 53% of students earned full marks on part a. 18% of students drew parallel circuits for both String A and String B. These students usually drew slightly different connections for each string, but both resulting in a parallel circuit, showing that these students did not understand circuits though they may have been exposed to them before. Interestingly, only 0.6% of students reversed Strings A and B, drawing String A in parallel and string B in series, suggesting that almost all students who are aware there is a difference between series and parallel circuits understand that difference. While in Part A only 5% of students connected their battery incorrectly, or short-circuited their light bulbs for both Strings A and B, this jumped to 41% in String C. While Part A involved simple circuits students most likely had seen in class before, Part B expanded on that and required students to combine series and parallel circuits in one diagram.

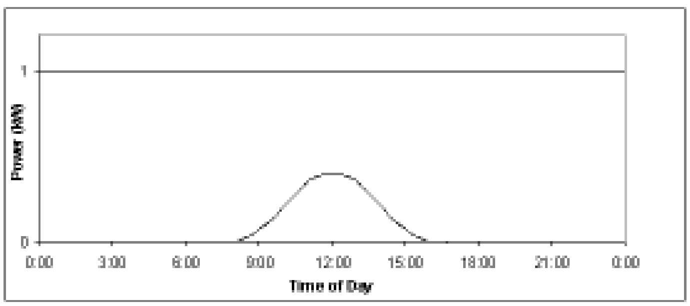
Question 4

When an array of solar panels is positioned in such a way that sunlight hits it normally (with the sun's rays 90º to the surface of the panels), 1kW of power is produced. The panels are now placed horizontally on top of a flat roof of a home in a Canadian town. Sketch graphs of the power produced by the solar panel as a function of the time of day. Assume it is a clear day.

In June:



In December:



Marking Scheme:

June

1 Mark: *Max occurs around 12pm*
1 Mark: *Graph is symmetrical*
1 Mark: *Sun rises and sets at approximately the right time*
1 Mark: *Graph is a curve or semi-circle*
1 Mark: *Maximum power is below 1kW*

December

1 Mark: *Max occurs around 12pm*
1 Mark: *Graph is symmetrical*
1 Mark: *Sun rises and sets at approximately the right time, less hours of sunlight than in June (full marks if the average of the hours of sunlight is 12hrs)*
1 Mark: *Graph is a curve or semi-circle*
1 Mark: *Maximum power is below the maximum in June.*

The average national scores were 2.5/5 for June and 3/5 for December. Only 3% of students received full marks for both June and December. 11% of students obtained all marks except the mark for the maximum power being under 1kW in June, and under the maximum for June in December. Since Canada is considerably North of the equator, the sun never will hit a horizontal solar panel at exactly 90º, even at the summer solstice. Not counting those students who achieved a perfect score, 21% of students recognized that the maximum power in December would be less than the maximum in June, however only 5% recognized that the maximum power in June would be less than 1kW.

Many students did not consider the sunrise and sunset times, and drew a triangle from 0 at midnight to some maximum, and back down to 0 at midnight again, for both June and December. 18% of students made an attempt at sunrise times, but made some mistake. For example, many students thought there are 12 hrs of sunlight in one of June or December. While part marks were given for this, full marks were only awarded if the average of the hours of daylight in June and December was close to 12 hours and there were more hours of sunlight in June than December. At the equator, there are 12 hours of sunlight every day all year, however in Canada there are only 12 hours of sunlight at the equinoxes (in March and September). At the solstices, in June and December, the sun shines for the maximum and minimum hours in the year.

4% of students drew a bar graph for this question. Bar graphs are not useful for graphing power as they do not convey that the power produced by the panel is continuous and they give no information about the shape of the graph. 8% of students plotted hypothetical points on the graph before drawing the graph. This can be a good way of relating everyday experience to the question (for example, I know that at 12:00 the sunlight is more direct than at 9am), however most students who used this technique made the mistake of connecting all their points with straight lines instead of drawing a best-fit line or curve. Connect-the-dots is not a valid scientific graphing method!

Question 5

A hypothetical ecosystem contains only 1 bird, and some number of insects and trees, which form a food chain. Using what you know about ecology, estimate the biomass of each species. Roughly how many insects and trees are in this system? Remember that living things are composed primarily of water. Show your work.

Marking Scheme

1 Mark: *Mass of bird*
1 Mark: *Recognizing bird eats insects eats trees*
1 Mark: *Many more insects than trees & birds*
1 Mark: *Biomass of trees > insects (by at least a factor of 3)*
1 Mark: *Biomass of insects > bird (by at least a factor of 3)*

Sample solution:

In this food chain, the bird eats insects, and the insects eat trees.

1 bird (let's say a crow) ≈ 600g (consider the body of the crow to have the same density of water, then consider the body to be a cylinder 20cm long with 3cm radius - approximately 600mL)

Insects (ladybugs):
90% of available energy is lost (as heat/waste) at each trophic level. So 600g of crow would require roughly 6 kg of insects to sustain itself.

Consider the density of an insect to be the same as water. An insect is approximately 5mmx5mm so its volume is 1/8cm3. Therefore its mass is approximately 1/8g = 0.125 grams. 6000g/0.125g = 50000. So roughly 50 000 insects need to exist.

Trees:
90% of energy is lost at each trophic level. So 6 kg of insects would need 60 kg of trees to sustain the population.

(1kg/L)(1L/0.1m)(5m) = 50 kg

(I am just under 2m tall. The lower branches on my cherry tree are just under my head. The upper branches of the cherry tree are probably twice that height again above the lower branches so the tree is probably about 5m tall.)

60kg/50kg = 1 small tree

The national average was 1.6 out of 5 on this question, with 6% of students obtaining full marks. The key concept is that the energy transfer between trophic levels in a food chain is inefficient. This means the biomass of the trees is greater than the biomass of the insects, which in turn is greater than the biomass of the bird. The biomass should differ by a factor of 10, however any difference of at least a factor of 3 was accepted. Many students remembered the factor of 10, however used it on the numbers of species instead of the biomass: ie 1 bird, 10 insects, and 100 trees. Several students applied the factor of 10 to both the numbers of species *and* the biomass, not recognizing that trees have much more mass than birds, so less of them are needed. Only 10% of students correctly estimated the biomass of the insects – many students assumed that since insects are small, they would have a smaller total biomass than anything else.

The density of water was provided to make estimating the mass of a bird, a tree, and an insect easier, as most people have more experience estimating lengths than masses. This proved to be more confusing than it was helpful. Many students provided their final answer in kg/m^3. This does not make sense: it was given in the question that the density of each species is about the same. Other unit errors included omitting units entirely, or using units such as litres or other non-mass units for biomass.

Many students seemed uncomfortable making numerical order-of-magnitude estimations. The words "lots of," "a few," or "more" do not constitute estimations – they are too vague! Students were not expected to provide the exact number of insects or trees in this ecosystem (that number does not exist!), but rather they were expected to know that the mass of a bird is around 1kg (as 24% did), not 1000kg, and that a bird needs 1 tree, not 10 000, to survive! Another common mistake was not answering all parts of the question.

Question 6

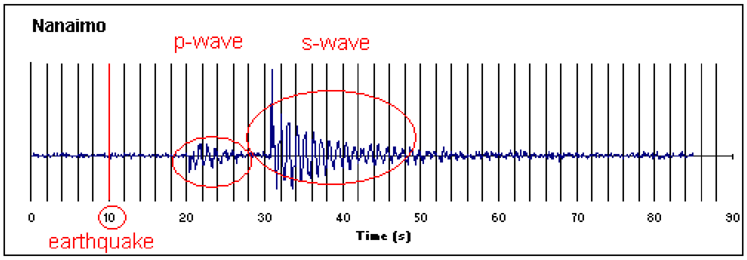
Seismographs located in Nanaimo, Kelowna, and Victoria record an earthquake. In this region, assume s waves travel at 4000 m/s and that p waves travel at 8000 m/s.

Question 6A

Circle and label the p waves and s waves on the Nanaimo seismograph.

Question 6B[1]

What time did the earthquake occur? Mark the time on the Nanaimo graph.



Question 6C

Where was the epicentre of the earthquake? Use all three seismographs. Feel free to draw on the map provided.

Marking Scheme:

6A

2 Marks: *Correctly identifying p and s waves.*

6B

0 Marks

6C

2 Marks: *Using the correct earthquake start time (10s) for calculations.*

2 Marks: *Calculating the correct distances between the earthquake and each city based on the chosen start time.*

1 Mark*: Drawing intersecting circles to locate the epicentre*

1 Mark: *Identifying Squamish as the epicentre*

Nanaimo: t_s = 20.75s *d = (4km/s)(20.75s)* *= 83km*	*Kelowna* t_s = 69.25s *d = (4km/s)(69.25s)* *= 277km*	*Victoria* t_s = 35.75s *d = (4km/s)(35.75s)* *= 143km*
Nanaimo: t_p = 10.38s *d = (8km/s)(10.38s)* *= 83km*	*Kelowna* t_p = 34.63s *d = (8km/s)(34.63s)* *= 277km*	*Victoria* t_p = 17.88s *d = (8km/s)(17.88s)* *= 143km*

[1] The question was not counted for marks as it was deemed to be too ambiguous. It should have been worded “What time did the earthquake start?” since earthquakes are not instantaneous. The start time was needed for part C, however, so the marks for start time were included there instead.

The epicentre of the earthquake was in Squamish.

The average score for this question was 1.8/8. 38% of the scripts scored 0. Many of these had the s- and p-waves reversed: there was no possibility of producing a reasonable answer if the slower waves arrived before the faster ones. Simply getting the s- and p-waves in the right order was awarded 2 marks. Of the rest, many students did not recognize that the earthquake had to occur at the 10s mark to produce a 10s gap between waves whose velocity differed by a factor 2. Assuming 0s as the start time and getting all the arithmetic right produced an epicentre off the top of the map. This scored a maximum of 3 more marks, making a total of 5/8. For those who did recognize the 10s start time, most were able to pinpoint Squamish, and this received full marks 8/8. Minor errors in positioning scored 7/8, with 6/8 reserved for more significant problems. 6% of students scored 7/8 or 8/8. The only real difficulty in marking was caused by a handful of students who circled Squamish with no apparent working. It is possible (although foolish) for a smart student to do this without writing anything down, but marks were only awarded if the 10s start time was indicated.

The major conceptual issue behind this question is the recognition that the start of an earthquake is a point in time and occurs at a particular place, and that all seismograph traces are delayed in time depending on their distance from the epicentre. There were two common symptoms that this recognition was missing: (a) marking the start of the earthquake at different times on different graphs, and (b) marking the epicentre on the time graphs rather than the map (despite the fact that we asked WHERE the epicentre was, rather than WHEN). An additional common problem was the failure to recognize two pulses in the seismograph traces as distinct from the time-independent noise background. This said, we felt that we had given enough information and clues in the wording of the question that it could be solved by a thoughtful student with no formal instruction in earthquake science.

Awards

The highest scoring student, with a perfect paper, received a prize of \$500. The 2nd place student was awarded \$250, and the 3rd place student \$100. 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.

Three other types of certificates were awarded, to the top 1%, 10%, and 25% of students. The top 1% certificate was new this year. It was introduced because increased participation made the distinction more meaningful, and because it was thought that those with closely clustered marks in the top 1% deserved special recognition. All students in the top 1% received at least 67.5/80 marks. The students in the top 10% received at least 51.4/80 marks. The top 25% of students received at least 41/80 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.

References

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Waltham, C., Kotlicki, A., Bates, G., & Leander, C. (2008). Canada's National Grade 10 Science Contest: The Michael Smith Science Challenge. *Physics Competitions , 10* (2), 16-23.