Michael Smith Science Challenge

2011

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Analysis

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Introduction

The Michael Smith Challenge is a national science contest written by students in Grades 8, 9 and 10. It was piloted in the province of British Columbia in April 2002, and run nationally every year since. It is intended to spark enthusiasm in the many different fields of science among young Canadian students. The Michael Smith Science Challenge is the only nationwide competition covering all science subjects taught in grade 10/niveau 4. It is offered in English and French. This year, over 1500 students participated in the contest on March 10, a 15% increase from the previous year.

Design of the Michael Smith Challenge 2011 Exam

The exam consisted of 6 short-answer questions; four questions worth 10 points each and two worth 15 points. Each question was either divided into subsections or required the student to work through the problem step by step in order to get to a final answer.

In 2003, when the contest was originally launched, the exam consisted of many multiple choice questions. After analysis showed a high fraction of random answering, the multiple-choice format was changed in 2005 to one of questions requiring short or graphical answers. After and including the year 2005, the exam was designed to challenge students' logical and creative thinking with a minimum amount of memorization.

Registration & Participation

Teachers filled out a form on the Michael Smith Science Challenge website and submitted their name and school information, as well as their students' information. This year we implemented a new payment system; we allowed teachers to pay via credit card. Registration opened on February 1, 2011 and officially closed on March 9, 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, 171 teachers from all 10 provinces registered for the contest, as seen in Figure 1. A total of 1739 students were registered.

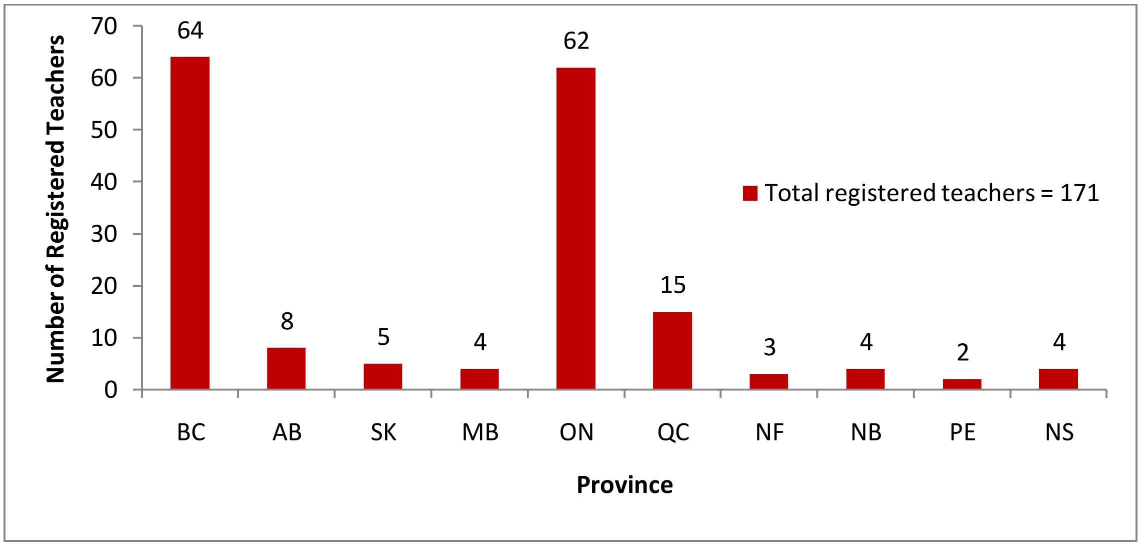


Figure 1: The number of teachers who registered for the challenge in each province. 88% of these teachers submitted exams to be marked.

As in previous years, BC had the most teachers register, followed by Ontario. The most significant change in registration for the 2011 contest was in the number of Ontario teachers who registered: from 49 in 2010 to 62 in 2011. 88% of registered teachers submitted exams. Due to student absences, not all teachers submitted exams for as many students as they had originally registered. Papers were submitted for 88% of all registered students.

As can be seen in Figure 2, 1538 students participated in this year's contest. This is a 15% increase over last year and a new record for the challenge.

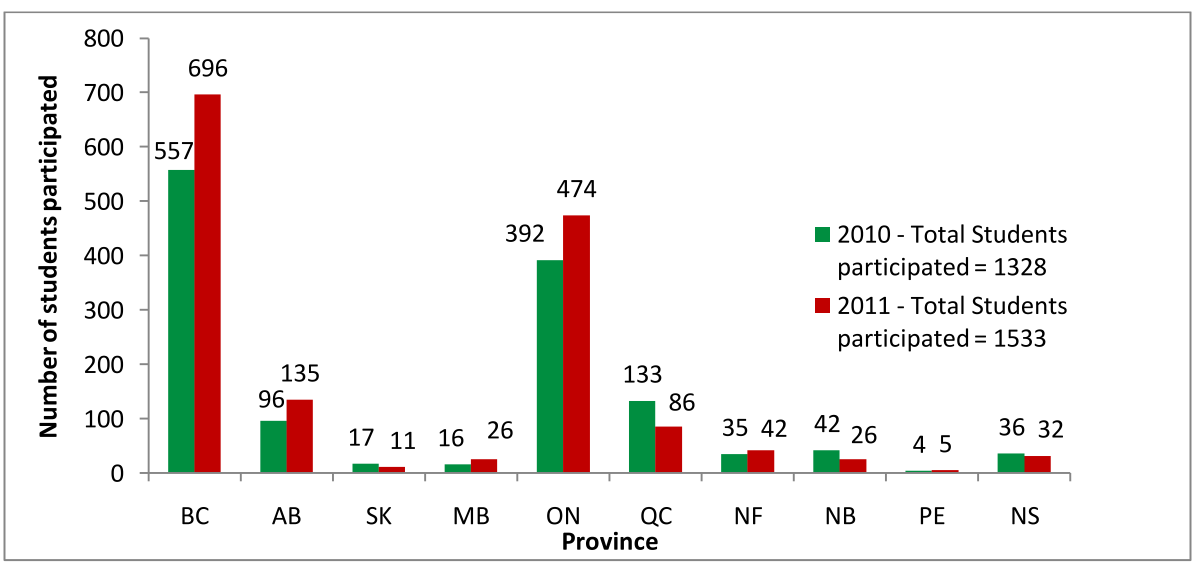


Figure 2: Student participation by province in the 2010 and 2011 Michael Smith Challenges.

Results of the Michael Smith Challenge Exam

Overall

The average score was 43%. Last year, 28 students received a mark above 80%. This year, only 12 students received a mark above 80%. It should be noted that the 1st place winner was a full 4 marks ahead of the 2nd place winner, and the other students achieving over 80% were closely clustered with marks between 57 and 61.

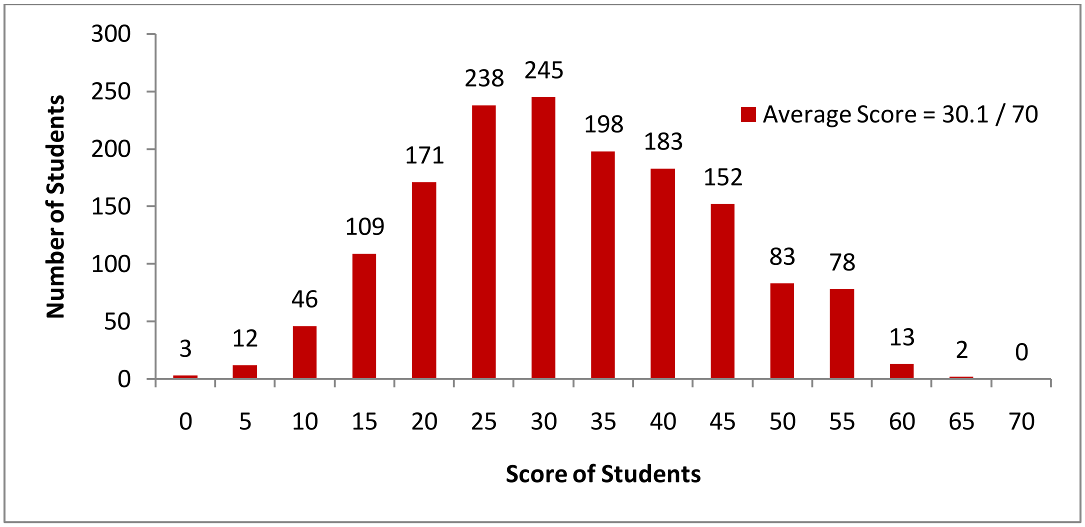


Figure 3: Chart showing the frequency distribution of marks. The highest mark achieved was 65 out of 70 and the average was 30.1 out of 70.

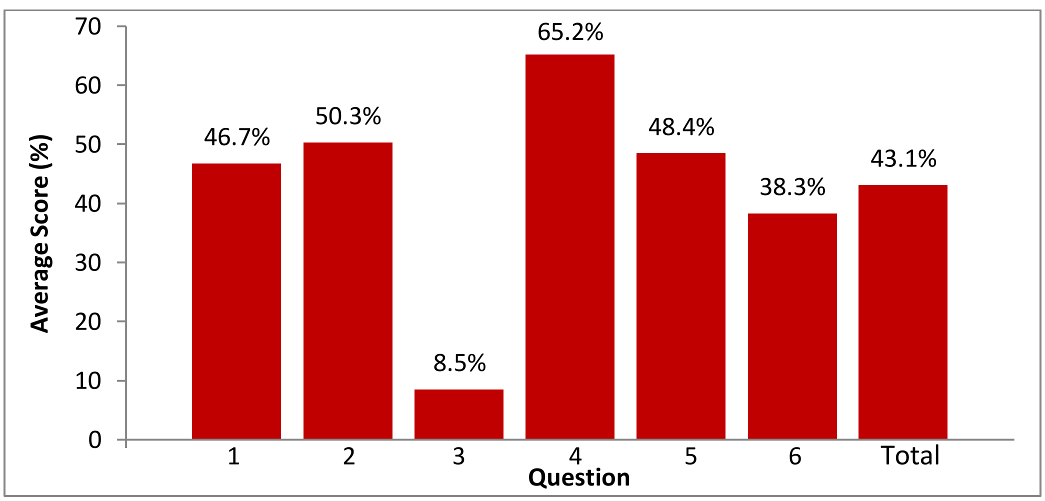
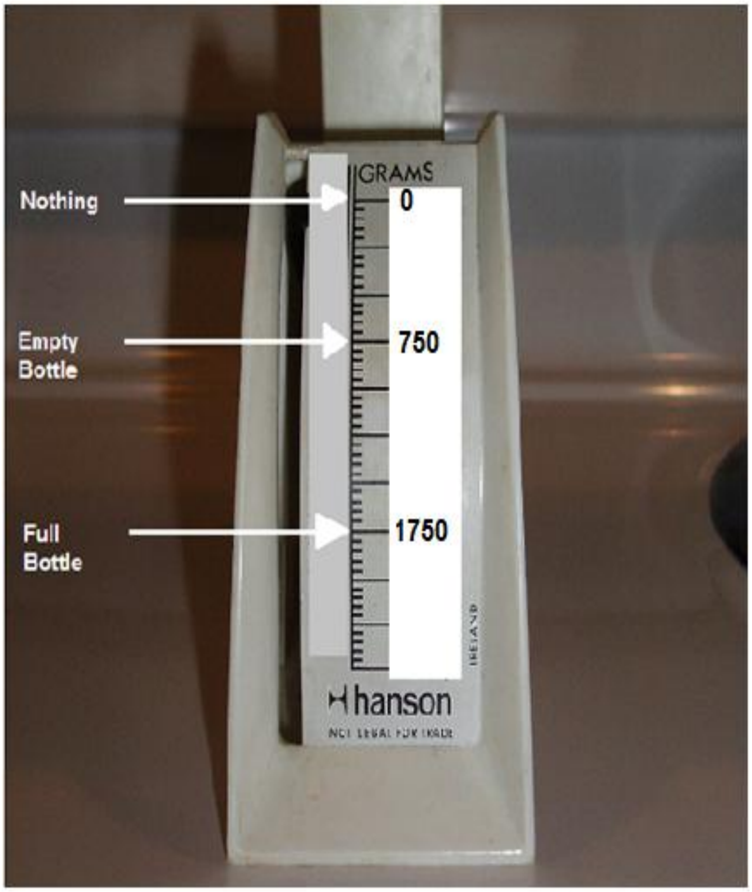


Figure 4: Chart showing the average score on each question.

Question 1

A kitchen scale has lost its numbers. You want to put them back, but all you have is a 1 litre milk bottle of unknown mass. You place the empty bottle on the scale, and then place it on again full of water. **Mark the numbers on the scale.**



Marking Scheme:

3 Marks*: 1 mark for each correct number placed on the scale (0,750 and 1750.)*

2 Marks: *Converting a litre of water into grams or kilograms*

5 Marks: *Showing reasoning (calculating that every interval represents 250 grams or 0.25 litres by noticing that the difference between the empty bottle mark and the full bottle mark is 4 intervals).*

The density of water is 1 g/cm^3 (given in the data sheet).

1 g/cm^3 x 1000 cm^3/L = 1000 g/L

1000 g/L x 1L = 1000 g

Since you fill the milk bottle with water, the difference between the empty bottle mark and the full bottle mark is 1000 g. There are 4 equal intervals between both marks, so every interval represents 250 g.

The average mark for this question was 4.7/10. 29% of all students obtained full marks for this question. An important step in solving this question is to convert one litre of water into grams or kilograms. 10% of all students were only able to do this step. 44% of students observed that the amount of water between the “empty bottle” mark and the “full bottle” mark could be divided into 4. If they hadn’t been able to convert they would simply leave their answer in litres. A very small number of students thought that the substance inside the milk bottle was milk. They would proceed by assuming that the density of milk is similar to the density of water or they would estimate the density of milk. There were also very few students who marked the numbers on the scale upside down.

Question 2

In North America, wind farms kill approximately 200 000 birds per year. By way of comparison, estimate as best you can how many birds are killed by cats each year in North America. Hint: If you do not have an outside cat of your own, you may wish to consider that one of the authors of this contest has a family of five people and two cats, one of which kills about 10 birds per year.

There are about 500 000 000 people in North America. The ratio between people and bird killing cats is about 5:1, so there are about 100 000 000 bird killing cats in North America. If one cat kills approximately 10 birds per year then:

100 000 000 cats x 10 birds/cat = 100 000 000 (10^9) birds.

Approximately one billion birds are killed by cats each year in North America.

***Marking Scheme*:**

6 Marks: *Showing a reasonable thought process and calculations*

2 Marks: *If answer is within 100 million and 10 billion*

3 Marks: *If answer is within 400 million and 1.6 billion*

4 Marks: *Correct final answer*

The average for this question was 5/10. The answer is a function of the first assumption the student has to make when estimating the population of North America. For this reason, more marks were given for using a reasonable thought process while solving this question, instead of giving more importance to a precise numerical answer. When estimating the population of North America, we considered the three most populated countries in North America which are Canada, the United States and Mexico. Some students only considered the first two. Only 2% of participants got a perfect score on this question. 33% of students started this question by estimating the population of North America. 25% of students estimated the population of North America then estimated the number of families in North America and from there came up with their own estimate of what percentage of families in North America own a cat. All of the students, excluding the ones who got a perfect score on this question used an incorrect ratio of humans to bird killing cats when calculating how many bird killing cats there are in our continent. The hint that was given indicated that out of 5 people there is one bird killing cat. However, students assumed each cat killed 10 and so there would be 20 dead birds per family of 5. There was a significant mistake that was common among 5% of the students that wrote the exam; they assumed two cats per family, but when calculating how many cats there are in North America, they would divide the population by 5 and then by 2 instead of dividing by 5 and then multiplying by 2.

Question 3

The composition of wood is 49% carbon, 6% hydrogen

and 44% oxygen, by weight.

Question 3A

We can write the approximate chemical (empirical) formula

for wood as CxH_YO_Z. Give values for x, y, z.

If we had 100 g of the compound $C_XH_YO_Z$, we would have 49 g of C, 6 g of H, and 44g of O (according to the percentages).

49 g of C x 1 mol/12g = 4.1 mol of C

6 g of H x 1 mol/1g = 6.0 mol of H

44 g of O x 1 mol/16 g = 2.8 mol of O

Divide each number by the smallest value to find the correct ratio:

C - 4.1/2.8 ≈ 1.5

H – 6.0/2.8 ≈ 2

O – 2.8/2.8 = 1

The atoms are present in the ratio 1.5:2:1 or 3:4:2

Therefore the approximate chemical (empirical) formula for wood is $C_3H_4O_2$

Question 3B

What mass of atmospheric CO_2 goes into making a tonne of wood?

1 tonne = 1000 kg

If the composition of wood is 49% carbon, 6% hydrogen and 44% oxygen by weight, then we have:

0.49 x 1000 kg = 490 kg of C

0.44 x 1000kg = 440 kg of O

490 kg of C x 1000 g/kg x 1 mol of C/12 g = 40796 mol of C

440 kg of O x 1000 g/kg x 1 mol of O/15 g = 27502 mol of O

To make a tonne of wood we need at least 40796 moles of C so we need at least 40796 moles of CO_2. The molar mass of CO_2 is 12 + 2 x 16 = 44g/mol

44g of CO_2 /mol x 40796 moles = 1795 kg of CO_2 (about 2 tonnes of CO_2)

Marking Scheme:

3A

2 Marks: *Finding the number of moles of each element in 100 grams of wood*

2 Marks: *Finding a close ratio between the elements*

3B

1 Mark: *Calculating the mass of one mole of CO_2*

2 Marks: *Calculating the amount of C and O (in kg or g) in a tonne of wood*

2 Marks: *Calculating the moles of CO_2 needed*

This question was the most challenging of the Michael Smith contest. The average score was 0.4/10 for Part A and 0.45/10 for Part B. Most students had no idea how to correctly solve this question and attempted to get the solution intuitively. 2% of all students got a perfect score on the first part of the question. 21% of students multiplied the number that was given as a percentage by the atomic number of the respective element. 4% of students tried to find a lowest common factor between the molar masses of the elements and 2% of students added the three molar masses and multiplied the total by the percentages that were given in the question. Even though solving part A is not necessary for solving part B, 7.4% of all participants tried to use their answer from part A. 17.6% of all students were able to find the molar mass of one mole of $C0_2$. This step would usually be the first thing students would do and 1 mark was given for this calculation. 11.6% of students were able to find that in a tonne of wood there are 490 kg of carbon and 440kg of oxygen.

Question 4

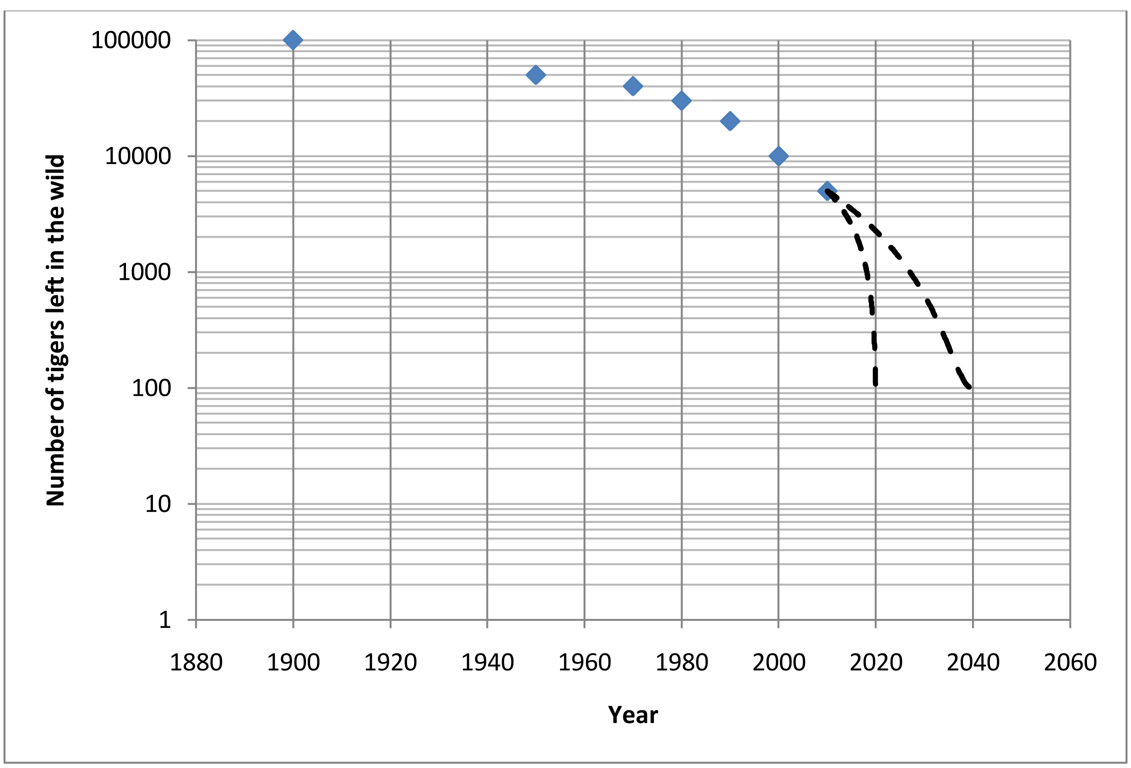
Unfortunately, a significant number of animals are currently at risk of extinction. For example, the number of tigers living in the wild has decreased dramatically during the last century. Tigers have become an endangered species primarily because of habitat destruction and hunting. The following data table shows how many tigers remained in the wild during a given year. If there is no human intervention to increase the number of tigers living in the wild, estimate when wild tigers will become extinct.

***Marking Scheme**:*

***7 Marks:** Observing a pattern and continuing the pattern for the following years, or graphing data points correctly*
***1 Mark:** If answer is within the years 2020 and 2040*
***2 Marks:** Giving an explanation of when a species is considered to become extinct*

Year	Number of tigers left in the wild
1900	100 000
1950	50000
1970	40000
1980	30000
1990	20000
2000	10000
2010	5000

The best way to solve this problem is by plotting the data given on the semi-log graphing paper:



If we consider tigers to become extinct once there is only one left, then this would be probably be between the years 2035 and 2060. It is also reasonable to say that wild tigers will be extinct by the time there are only 100 left (2020-2040), since this is not a sustainable amount. In other words, the tigers that are left will probably not be enough to reproduce because they are situated far away from each other, they are not healthy or because of a lack of individuals of the opposite sex.

This question, with an average of 6.5/10, was the question which was best answered. 0.5% of students got 10/10 on this question. Full marks were reserved for students who gave an explanation of when they considered a species to become extinct. This showed if the student was going a step further than just predicting when the number of wild tigers would equal zero. Students either drew a graph or identified a pattern with the information that was provided. 39.5% of students identified a pattern and 46.5% of students graphed the data. Most of the students who graphed the data points drew a best-fit line, but some were still just connecting every point. Not a single student used the semi-log graphing paper that was provided. The most popular patterns observed were the following.

Year	Number of tigers left in the wild
1900	100 000
1950	50000
1970	40000
1980	30000
1990	20000
2000	10000
2010	5000

Patterns continued

Year	Number of tigers left in the wild
2020	4000
2030	3000
2040	2000
2050	1000
2060	500
2070	400
...	...
Year	Number of tigers left in the wild
2020	250
2030	125
2040	62.5
2050	31.3
2060	15.6
2070	8
...	...

Since the answer to this question is not really known we only assigned one mark for getting close to an answer within 2020 and 2040, and we assigned more marks to the calculations and reasoning shown by the student.

Marking Scheme

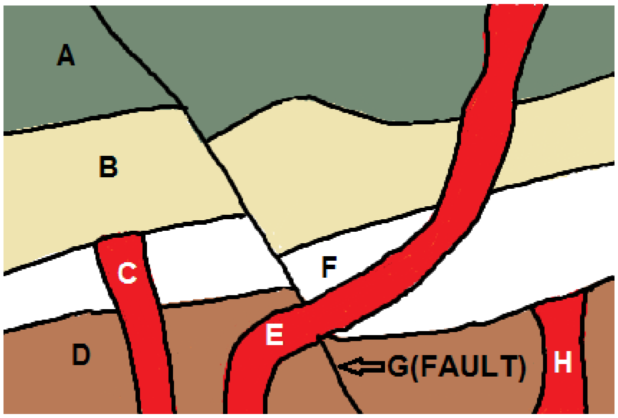
5A
***1 Mark:** For each layer*

5B
***3 Marks:** Correct Answer*

5C
***1 Mark:** For every letter in a*

Question 5

The face of a cliff shows the following geological structure. It contains a fault, layers of sedimentary rock and igneous dikes.



Question 5A

Identify all the layers of sedimentary rock.

A, B, F, D are all layers of sedimentary rock resulting from the settling of different sizes and kinds of sediments.

Question 5B

Which of the igneous dikes is the oldest?

As stated by the crosscutting law; any event that disturbs a rock is always more recent (younger) than the rock itself. Layer F is younger than dike H (because it sits on top) and it is older than the other two dikes (since both dikes cut through it). Therefore dike H is the oldest.

Question 5C

Arrange the letters corresponding to each part of the geological structure in order, from oldest to youngest:

If we look at the four layers first and apply the law of superposition we notice that the order is the following (oldest to youngest): D, F, B, A. We note that dike H only cut through the bottom layer and is therefore younger but older than all of the layers above it. Then we note that dike C cut through layers D and F and lies below layers A and B, therefore it's younger than D and F but older than A and B. Our new order is: D, F, C, B, A. By applying the crosscutting law, we note that G (fault) is younger than all of the layers. Finally, dike E is younger than G since it cuts over the fault line.

D H F C B A G E
Oldest Youngest

The average on this question was 2.2/4, 1.6/3, and 3.4/8, for part A, B and C, respectively. 37% of students got a perfect score on Part A. 3.3% thought that G (fault) was one of the layers of sedimentary rock. 5.2% thought that one of the igneous dikes was a layer of sedimentary rock.

54% of students got Part B correct. 16.4% of students thought that E was the oldest igneous dike; some of those students also explained that they thought it was E because it was the longest one so it took more time to be created. 9.8% of the students thought that one of the layers of sedimentary rock was the oldest igneous dike, and 2% thought that the fault was the oldest igneous dike.

14% of all writers got a perfect score on Part C. For the marking of Part C, 1 mark was given for every letter in a correctly ordered series. For example: H, C, D, F, B, A, G, E; contains a correctly ordered series of 4 letters (B A G E) so this answer would score 4 marks.

Question 6

Question 6A

You see a flash of lightning and 8 seconds later you hear the start of a thunderclap. How far away was the strike?

It took 8 seconds for the sound to get to you. If the speed of sound is 333.3 m/s, then using the formula d = v x t:

d = 333.3 m/s x 8s = 2666.4 m. The strike occurred 2666.4 m away.

Question 6B

You are standing close to a small storm travelling from the west. The weather forecast had accurately predicted that it would be travelling at 20 km/h. You see that three lightning strikes are produced, each one at a different location. You hear the thunder and see the light created by the strikes at the following times:

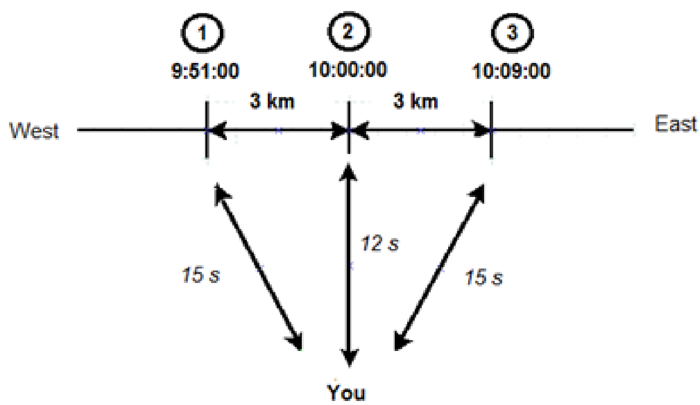
LIGHTNING STRIKE	LIGHT	THUNDER
1	09:51:00	09:51:15
2	10:00:00	10:00:12
3	10:09:00	10:09:15

Marking Scheme:

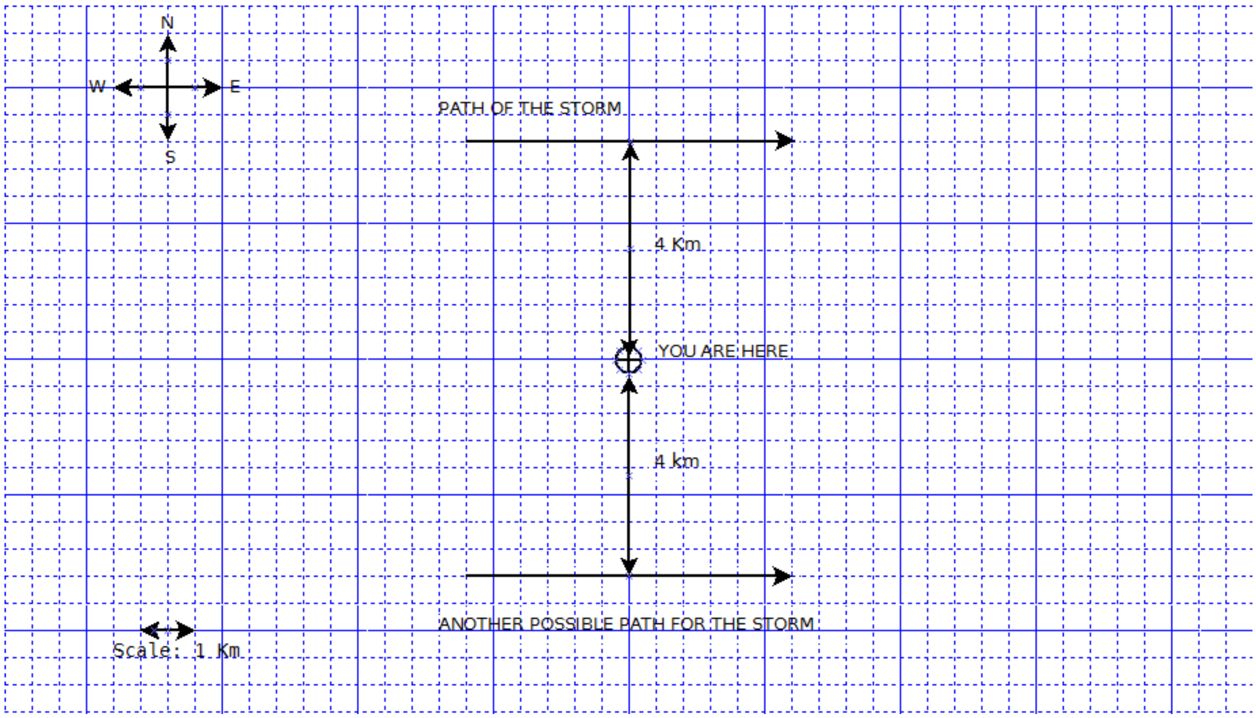
6A
5 Marks: *Correct answer*

6B
5 Marks: *Calculating the distance from "You" to the strikes*
1 Mark: *Calculating the distance between each strike*
3 Marks: *Marking a correct path for the storm*
1 Mark: *Noticing that there are two possible paths*

The storm is travelling from the West (going towards the East) at 20 km/h. 20 km/h x 1hour/60 min = 1km/3 min. The first flash of lightning occurred at 9:51:00, the second one occurred 9 minutes later, and the third one occurred 9 minutes after the second one. 1km/3min x 9 min = 3km; there are 3 km between each strike. The sound created by the first strike took 15 seconds to get to your location, the sound of the second one took 12 seconds and the last one took 15 seconds. 333.3 m/s x 15 s ≈ 5km. 333.3 m/s x 12 s ≈ 4km.



There is another possible answer; the storm could have taken the same path, but 4 km below "You".



The average score for this question was 2.9/5 and 2.8/10 for Part A and for Part B, respectively. 53.4% of all students got 5/5 on Part A, which just consisted of multiplying the amount of time it took for the sound of the thunderclap to get you (8 seconds) by the speed of sound. A common mistake was to use the speed of light instead. In fact 10.3% of the participants did it this way. A few students tried to incorporate the time it takes for the light to reach them in order to find the difference between that time and the time it took the sound to get to them, but find that the travel time for the light is negligible so they got the right answer in the end. 12.4% of students used 1km/s or 1mile/s as the speed of sound; it seems to be a common misconception that for every second that passes between the flash of lightning and the start of the thunder it is 1 kilometre or 1 mile away.

1% of all students received 10/10 on Part B of this question. About the same number of students that used the speed of light for part A also used it for Part B. 10.3% of students drew circles, zigzags or curves as a possible path for the storm. Since the first and the third strike both occurred 5 km away from “you”, some students thought that the storm was actually going back to where it started. 1.1% of writers noticed that there are two possible answers for this question. If all the previous work was well done, and the student noticed the two possible answers, they would receive a perfect score.

Awards

The highest scoring student 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. If there was a tie for the top student in a province, each student in the tie received $50. 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. The top 3% certificate was new this year. All students in the top 1% received at least 56/70 marks. The students in the top 3% received at least 53/70 marks. The students in the top 10% received at least 47/70 marks. The top 25% of students received at least 39/70 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

Ruthven, A., et al. (2010). Analysis – Michael Smith Challenge 20010. http://outreach.phas.ubc.ca/smith/Documents/MSC2010 - English Solutions.pdf

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.