Michael Smith Science Challenge 2021 Analysis

Introduction

The Michael Smith Science Challenge is a national science contest written by students in grade 10/niveau 4 and below. It was first piloted in the province of British Columbia in April of 2002. Since then it has been run annually across Canada. The purpose of the contest is to challenge students' logical and creative thinking with minimal memorization required. The Michael Smith Science Challenge is the only nationwide competition covering all science subjects taught in grade 10/niveau 4.

Due to recent COVID regulations, the 2021 challenge was run entirely online – students completed the challenge at school or at home – depending on local circumstances and at the discretion of the teacher. No teacher invigilation was required.

Participants were allowed access to the internet or books but were not allowed to seek assistance from anyone in person or online. The 2021 challenge did not contain any free response questions and, instead, consisted of 8 multiple choice questions, each with a 7.5-minute time limit. Students were given the questions in a randomized order and could not go back to see a question they had already submitted. For higher security, we randomized number values in 7 of the 8 questions.

The sample contest solution attached in this analysis will be with reference to a randomly selected version of the challenge.

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Participation

A total of 1137 exams were received this year, from 9 provinces, 2 international schools (Hong Kong and Tunisia), and 86 Canadian schools.

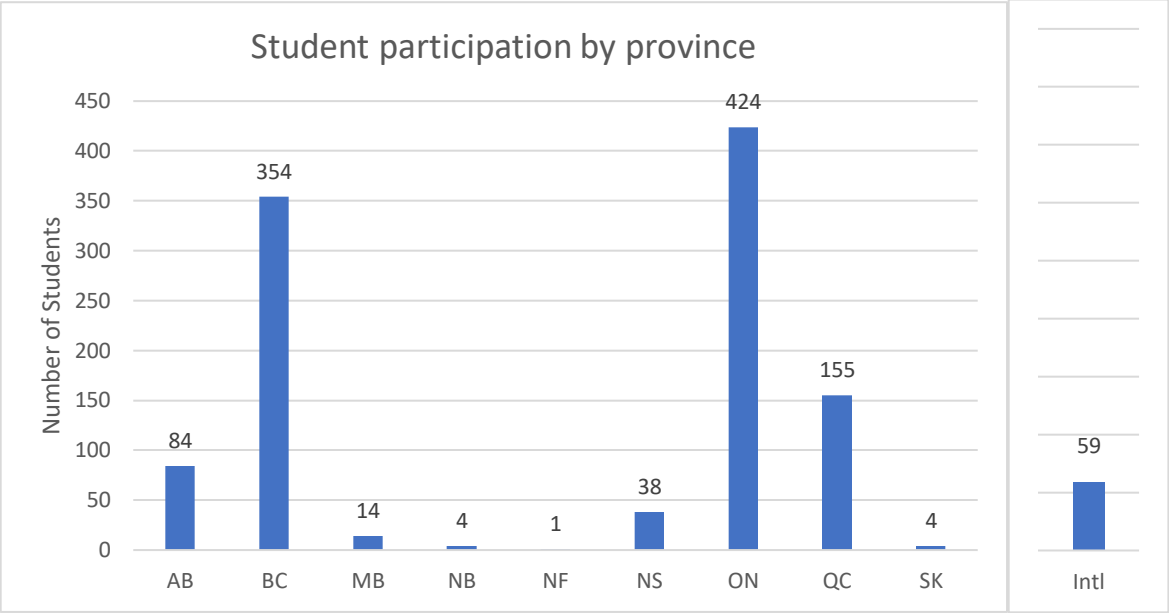

Figure 1 Student demographics across Canada and Hong Kong

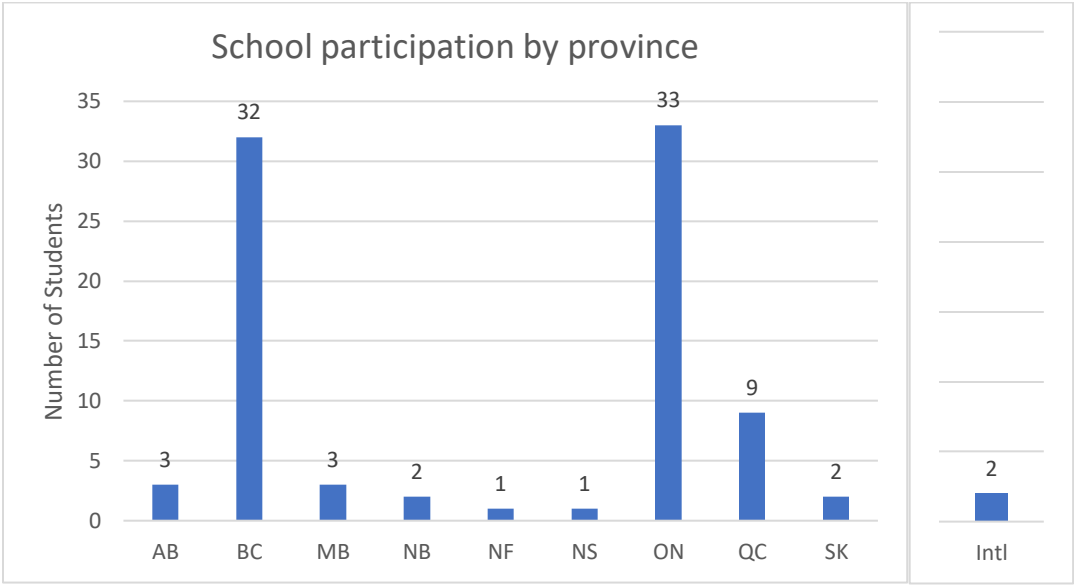

Figure 2 School demographics across Canada and Hong Kong

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Results: Total Mark Distribution

The exam was out of a total of 23 points. The mean score was 9 points, and the median score was 8.5 points.

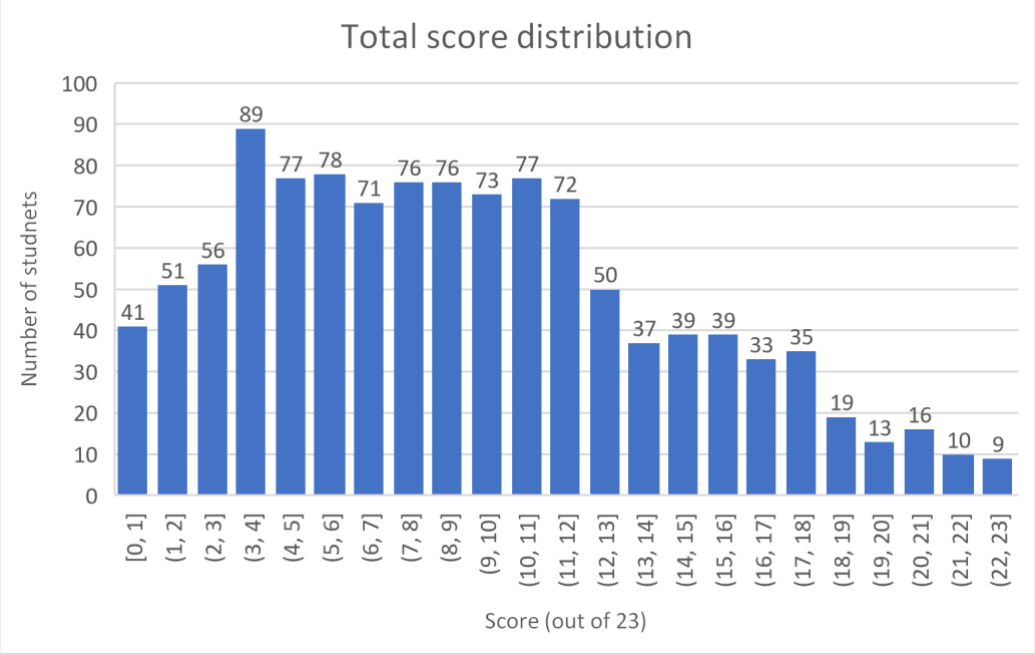

Figure 3 Total score distribution for entire exam (out of 23 points)

Note: (a,b] means a < score <= b

Compared to past years, although the mean percentage has not changed by much, we observe a wider distribution in student scores and saw more students performing better. Three students received full marks of 23 points, and 35 students received higher than 20 points.

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Results: Time Distribution

This year, we also tracked the time spent on the exam by each participant. The exam was capped at an hour, with a mean completion time of 36.6 minutes.

The plot below shows all students' total time spent on the exam and their respective score.

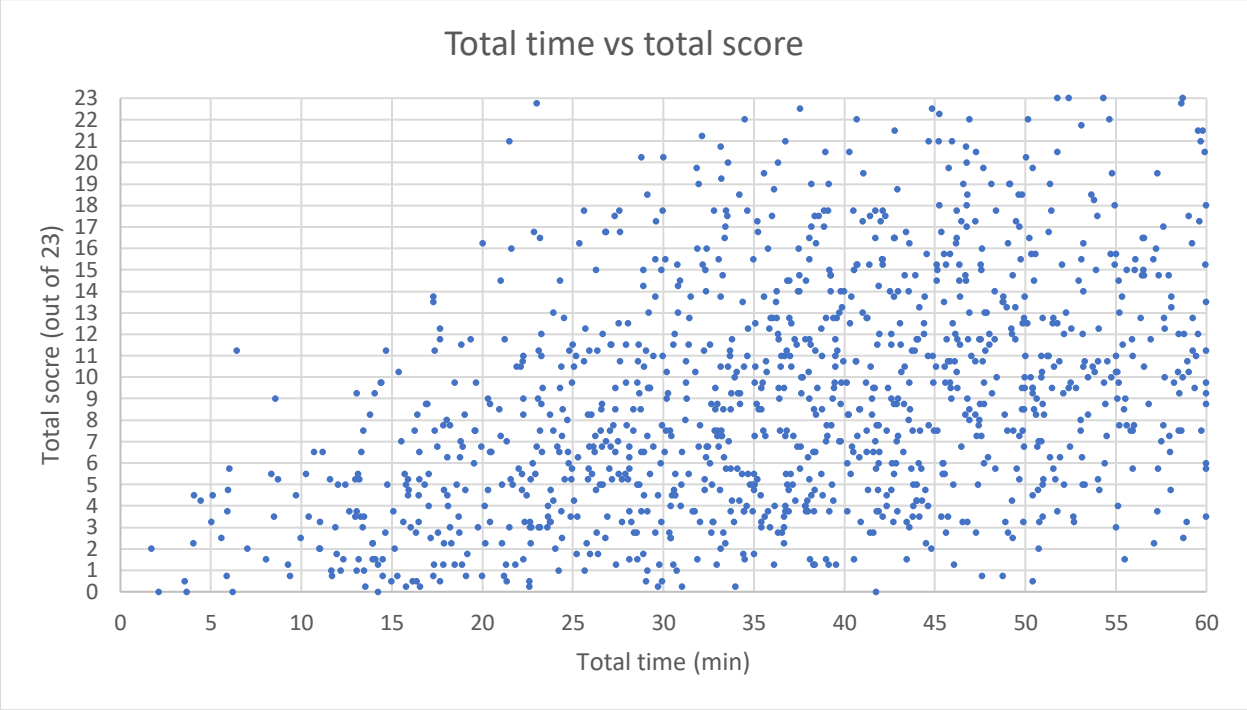

Figure 4 Score distribution based on total time spent

Upon careful analysis, we noticed that students who scored higher tend to stay on each question for the entire 7.5-minute limit before proceeding to the next question. In fact, 87% of the students who scored above 11.5 points (50% score) spent longer than a total of 30 minutes on the exam.

For most questions, 7.5 minutes seemed to be an adequate time limit, since more than 4 or 5 minutes did not improve the answers.

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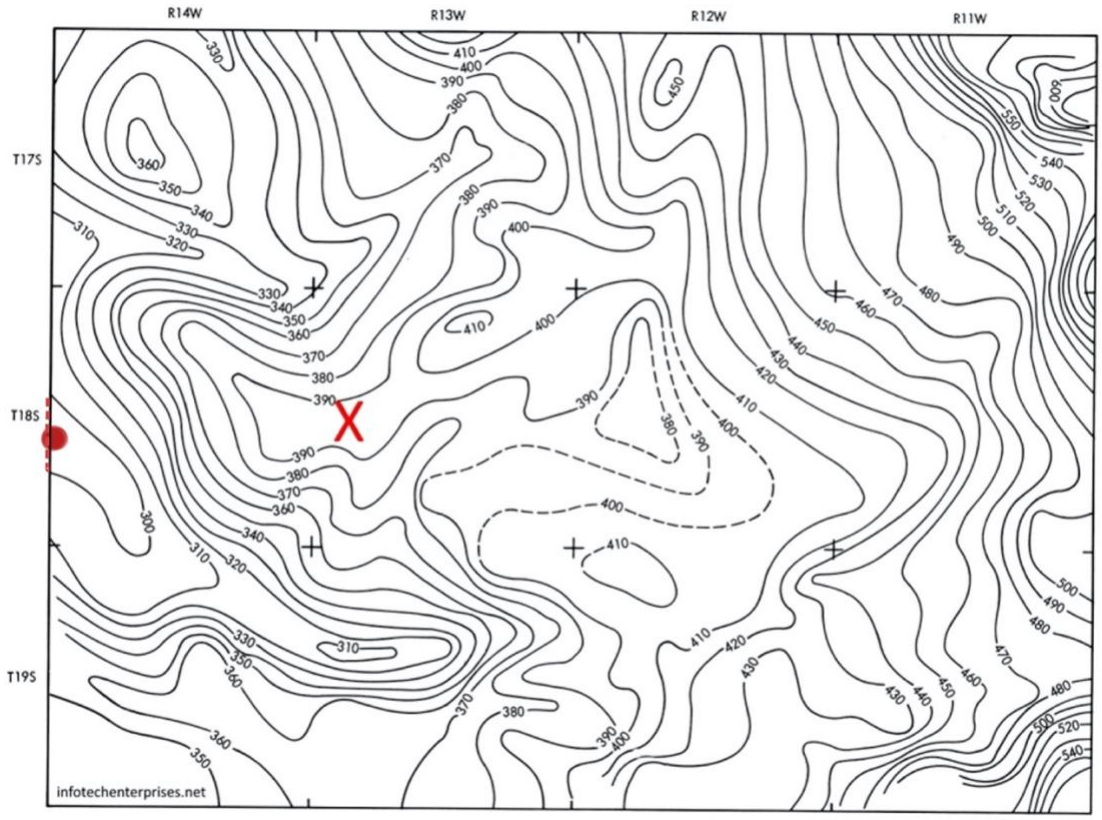
Contest Solutions

Contour Map

The chart shown below is a contour map.

1. A stream that flows from a spring originates at the red X. Place a dot where the stream leaves the map.



Correct answer:

The correct answer is shown with a dot on the above map. All answers on the dotted line were accepted as correct. The goal was to decipher the path of decreasing altitude from the X to the edge of the map.

Note: Each student was shown one of four versions of this map, each with a different spring location.

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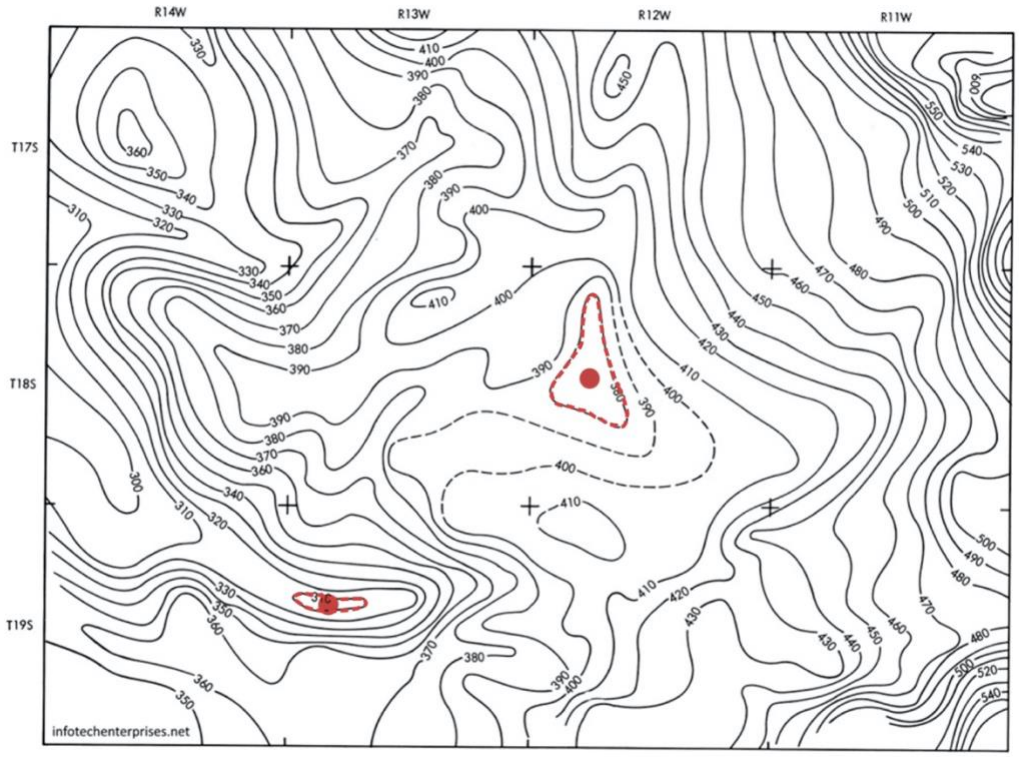
2. Place two dots on the map where a lake might form. Order does not matter.



Correct answer:

The correct answers are shown with dots on the above chart. All answers within the dotted lines were accepted as correct. The goal was to find the pools with the lowest altitude amongst its surroundings.

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Score distribution:

Each correct placement of a dot is worth 1 point, for a total of 3 points. The mean score was 1 point. Around 9% of all students received full marks on this question.

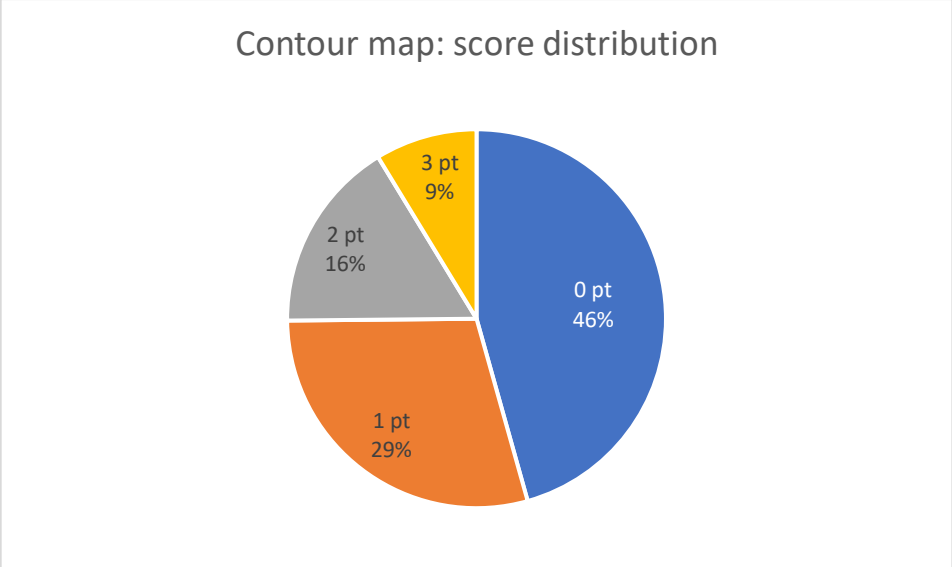

Figure 5 Score distribution for contour map question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 4 minutes. The following figure plots the mean score against every 30 second interval.

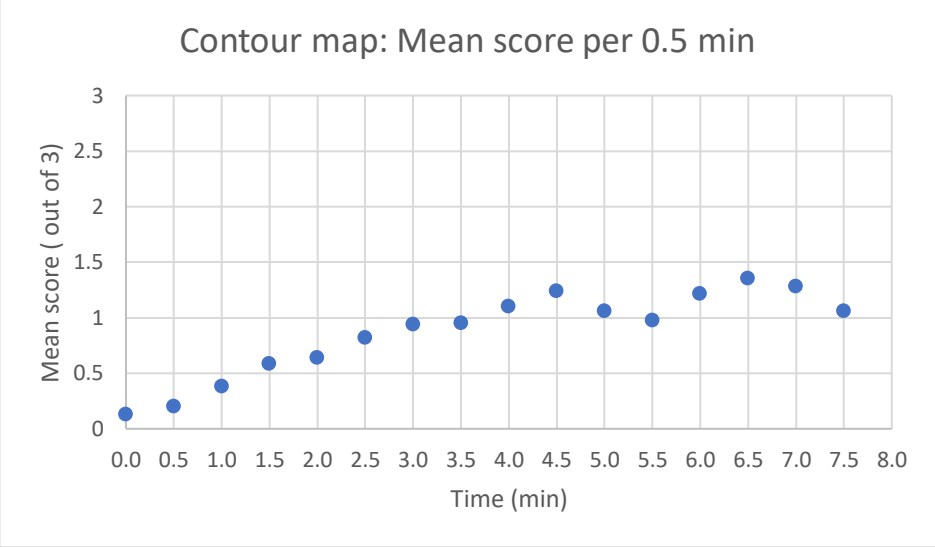

Figure 6 Mean score every 30 seconds for contour map question

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Plant Classification

For the following question, you may access the following given links to aid in your research to find the correct answer.

Land plants are divided into four groups: (please right click and open these links in a new tab)

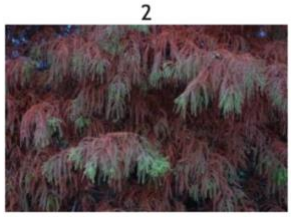
A) Bryophyte
B) Pteridophyte
C) Gymnospermae
D) Angiospermae

Drag and drop the following into their correct groups.

Items

1


5


2


6


3


7


4


8


Bryophyte	Pteridophyte
5	1

Gymnospermae	Angiospermae
3 7	4 6 8

Not plants
3

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Correct answer:

Correct classification of the given plants is shown by their corresponding numbers in red above.

Score distribution:

Each correct classification of an image was given 0.25 points, for a total of 2 points. The mean score was 1.3 points. On average, students correctly classified 5 of the 8 given plants. About 9% of all students received full marks on this question.

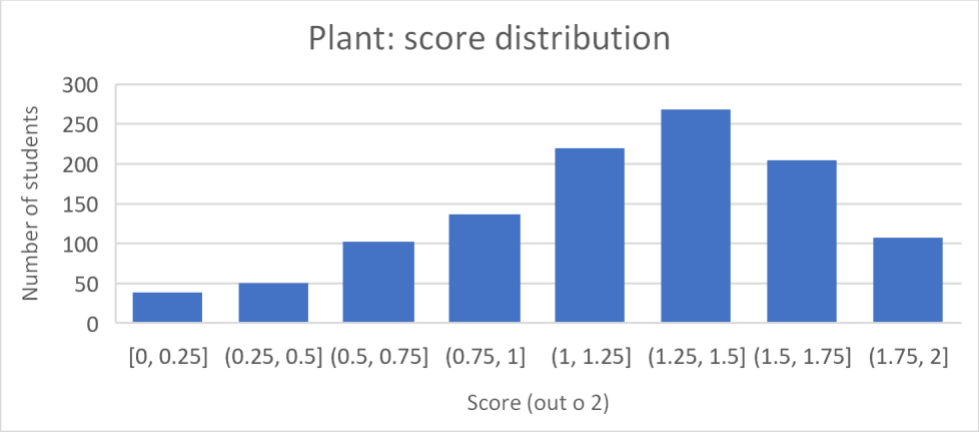

Figure 7 Score distribution for plant question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 4 minutes. The following figure plots the mean score against every 30 second interval.

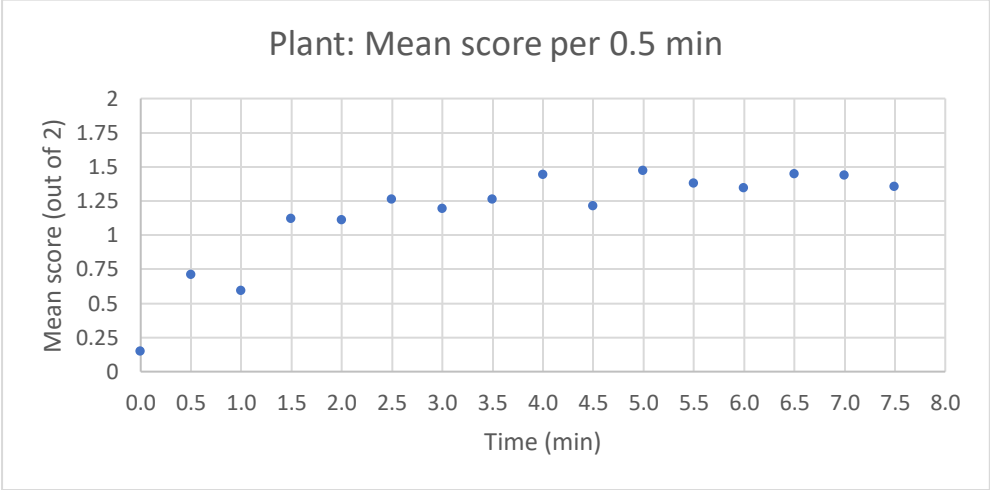

Figure 8 Mean score every 30 seconds for plant question

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Gold-Slice

Assume that you have an infinitely sharp knife and the ability to manipulate and observe matter all the way down to the atomic scale. Start cutting a solid in half. After the first cut, you take one of the two resulting pieces and cut it in half, and continue repeating this process until you can no longer do it because you are down to a single atom. Approximately how many times could you cut a mass of *700 g* of pure gold in half? **Round down to the closest integer if your result is not a whole number.**

- ○ 75
- ○ 76
- ○ 77
- ○ 78
- ○ 79
- ● 80
- ○ 81
- ○ 82
- ○ 83
- ○ 84
- ○ 85

Correct answer:

In this sample answer, we have a mass of 700g of pure gold. A simple internet search will yield the atomic mass of pure gold (Au) as 197 g/mol, and Avogadro's number as 6.022 x 10^{23} atoms/mol.

Using these values, we can find the total number of atoms in our mass of gold:

$$\#\ of\ atoms = 700g * 6.022 * 10^{23} \frac{atoms}{mol\ Au} * \frac{mol\ Au}{197g} = 2.14 * 10^{24}\ atoms$$

With every slice, we remove half the number of atoms we have. Therefore, to find the number of slices we can make, take the $\log_2$ of the total number of atoms we have:

$$\#\ of\ slices = log_2(\#\ of\ atoms) \approx 80.8$$

Rounding down to the closest integer, we obtain an answer of 80 for the number times you can cut the mass of pure gold in half before you are only left with one atom.

Note: Each student was given a randomized mass for the pure gold. The calculations methods remain the same.

Score distribution:

The correct answer was worth 4 points, no partial marks were given. The mean score was 0.8 points. About 20% of all students answered this question correctly.

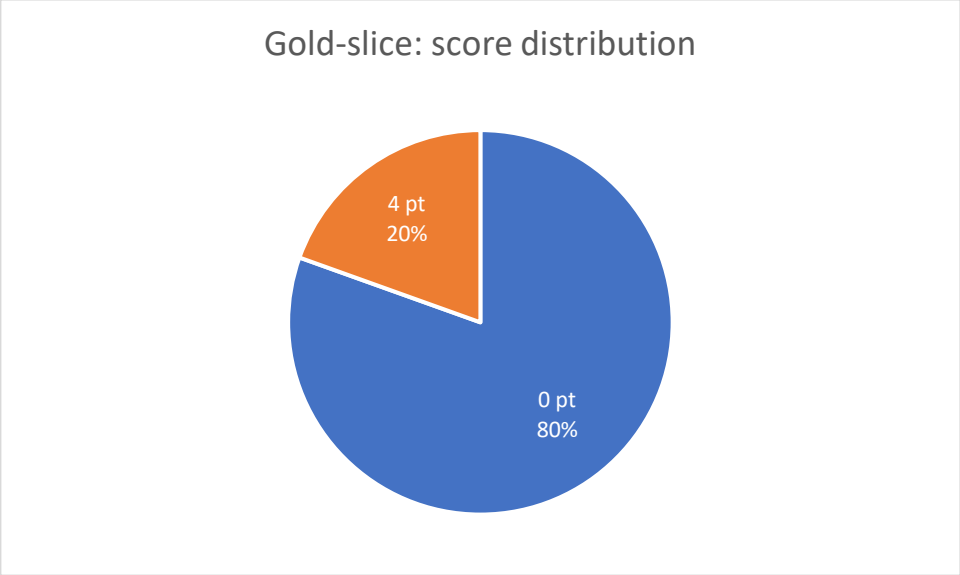

Figure 9 Score distribution for gold-slice question

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Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 5.3 minutes. The following figure plots the mean score against every 30 second interval. Notice that there is no apparent trend and the score received was quite random compared to the time taken to answer the question. This was the hardest question of the exam.

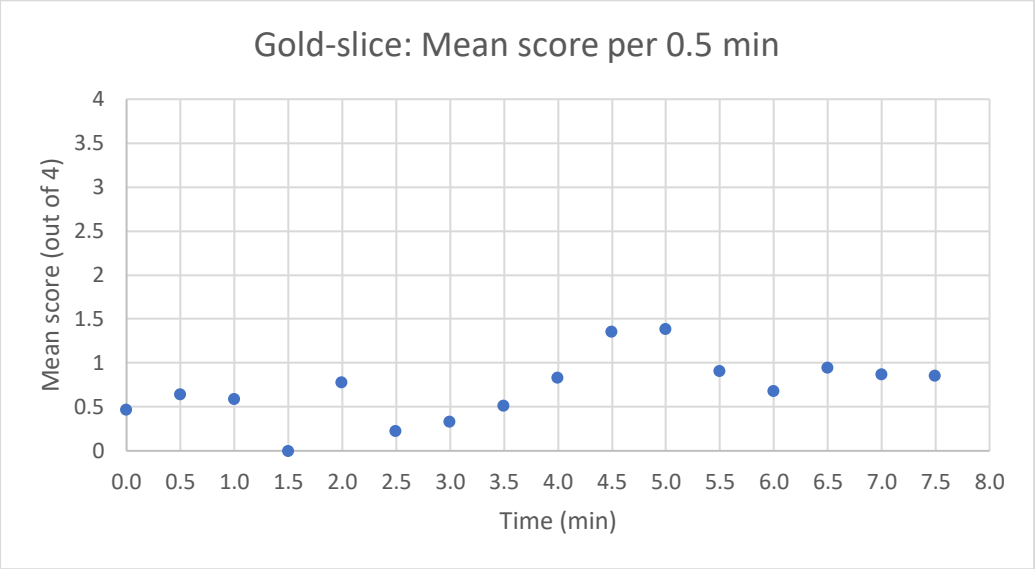

Figure 10 Mean score every 30 seconds for gold-slice question

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COVID-19

Consider the COVID infection rates for health regions A, B, C.

Health region A has a population of *848450*, and *880* infections per day, averaged over the last week.
Health region B has a population of *2049310*, and *4345* infections in the last week.
Health region C has *700* infections per 100,000 people in the last week.

Drag and drop the following health regions by the size of their COVID problem:

Items

Health region A

Health region B

Health region C

Worst COVID Problem (one answer only)

Health region A

Least Bad COVID Problem (one answer only)

Health region B

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Correct answer:

In order to compare the COVID problem size for all three regions, let us convert the given COVID-19 infection rates in all three regions into the following format:

$$infections/day/100{,}000\ people$$

To find the new COVID -19 infection rate in health region A:

$$rate_A = \frac{880\ infections/day}{848450\ people} * 100{,}000$$

$$= \mathbf{103.7\ infections/day/100{,}000\ people}$$

To find the new COVID -19 infection rate in health region B:

$$rate_B = \frac{4345\ infections/week}{2{,}049{,}310\ people} * \frac{week}{7\ days} * 100{,}000$$

$$= \mathbf{30.3\ infections/day/100{,}000\ people}$$

To find the new COVID -19 infection rate in health region C:

$$rate_C = \frac{700\ infections/week}{100{,}000\ people} * \frac{week}{7\ days}$$

$$= \mathbf{100\ infections/day/100{,}000\ people}$$

Comparing these rates, we find that health region A has the fastest COVID-19 infection rate, while health region B has the slowest.

Note: Each student received randomized population numbers and infection rates for each health region. The calculation methods, however, remain the same.

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Score distribution:

The correct answer in both boxes was worth 2 points, no partial marks were given. The mean score was 1 point. There was a 50/50 distribution of students who answered correctly and incorrectly.

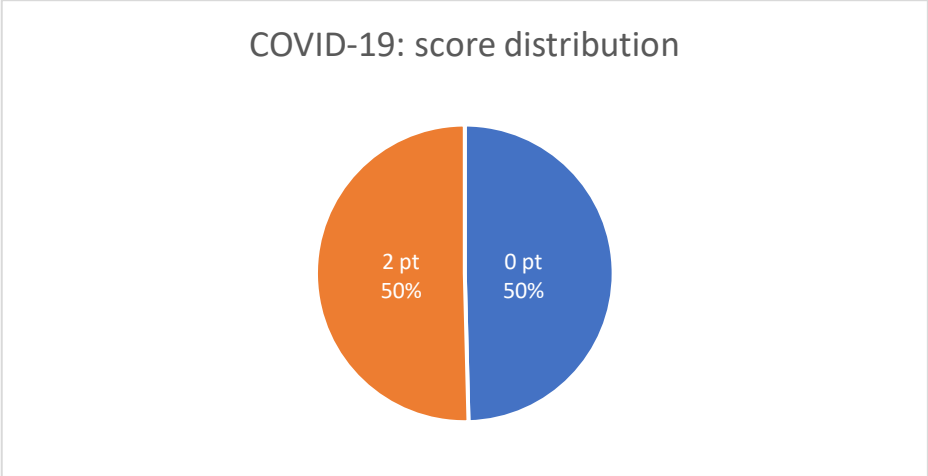

Figure 11 Score distribution for COVID-19 question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 4.3 minutes. The following figure plots the mean score against every 30 second interval.

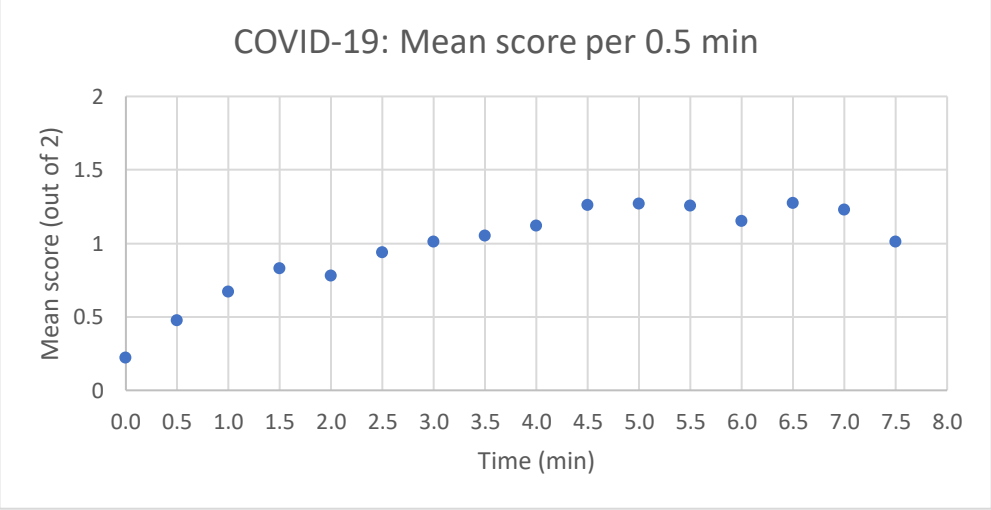

Figure 12 Mean score every 30 seconds for COVID-19 question

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Antilock Braking System (ABS)

Antilock Braking Systems (ABS) cause a sharply braking vehicle to leave rubber skid marks on the road at a rate of **18 times per second**. In the case of an accident, police can use the spacing of these marks to determine the vehicle's speed prior to the crash.

The same information can be obtained from an iPhone video, by measuring the distance the car travels between frames, taken at **24 frames per second.**

Consider three cases involving cars A, B, C below.

Car A: Speed is *82* km/h, speed limit is 60 km/h
Car B: ABS spacing is *118* cm, speed limit is 60 km/h
Car C: iPhone frame spacing is *84* cm, speed limit is 60 km/h

Rank how much each car was violating the speed limit by dragging and dropping the cars into their corresponding group.

Items

Car A

Car B

Car C

Violating the speed limit the most (one answer only)

Car A

Violating the speed limit the least (one answer only)

Car C

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Correct answer:

Let's find each car's speed at a common rate, say, km/h. The positive difference between their speed and the speed limit (also in km/h) will be a measure of how much they are violating the speed limit.

Car A's speed:

$$\mathbf{82 km/h}, \text{ as given}$$

Car B:

$$\frac{118cm}{mark} * \frac{1m}{100cm} * \frac{18\ marks}{seconds} * \frac{1km}{1000m} * \frac{3600seconds}{1hr}$$

$$= \mathbf{76.464\ km/h}$$

Car C:

$$\frac{84cm}{frame} * \frac{1m}{100cm} * \frac{24\ frames}{seconds} * \frac{1km}{1000m} * \frac{3600seconds}{1hr}$$

$$= \mathbf{72.576\ km/h}$$

Since all three cars are over the 60km/h speed limit, the car with the fastest speed is violating the speed limit the most, and the car with the slowest speed is violating the speed limit the least.

Note: Each student received randomized values (speed, ABS spacing, frame spacing) for each car. The calculation methods, however, remain the same.

Défi Scientifique Michael Smith Science Challenge

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Score distribution:

The correct answer in both boxes was worth 4 points, no partial marks were given. The mean score was 1.4 points. About 36% of all students answered this question correctly.

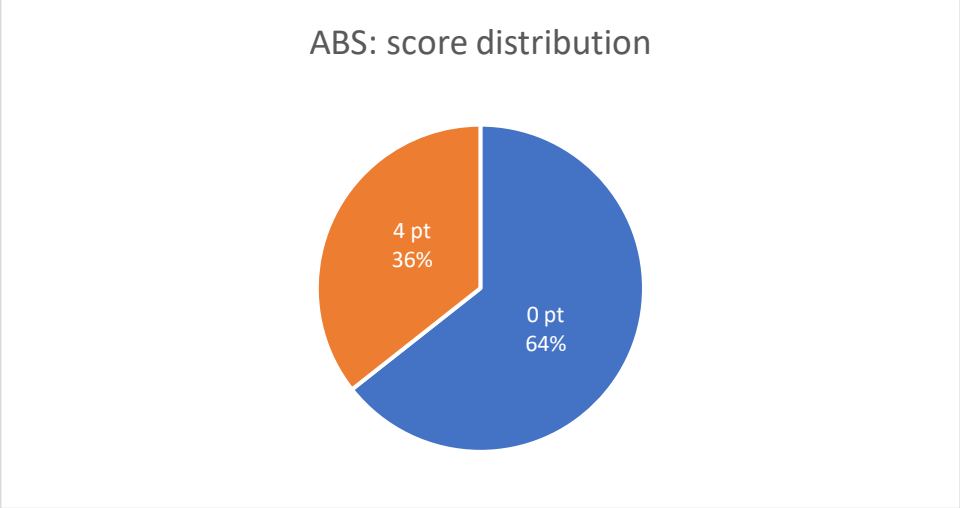

Figure 13 Score distribution for ABS question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 5 minutes. The following figure plots the mean score against every 30 second interval.

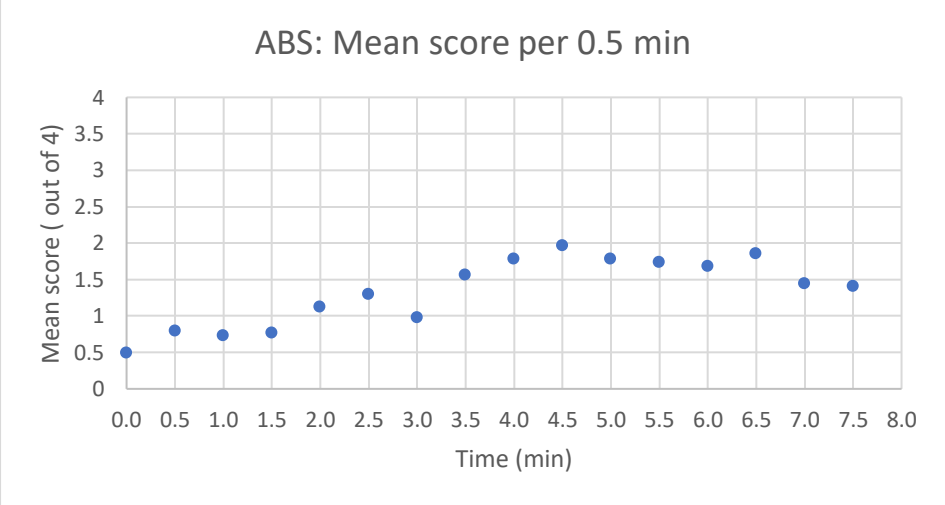

Figure 14 Mean score every 30 seconds for ABS question

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Moon

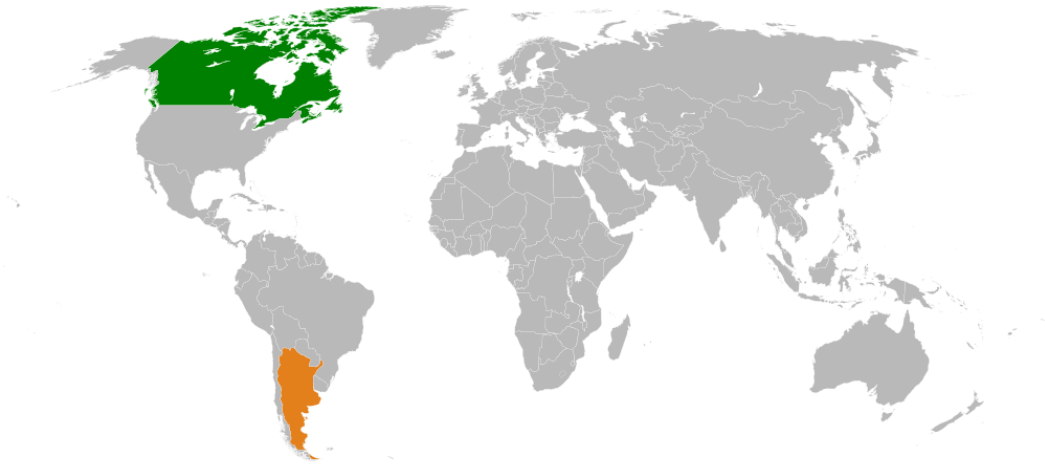
You are standing somewhere in Canada and the Moon appears like one of the images (1-8) below:

How would the Moon appear to someone standing in Argentina at the same time?

Given moon in Canada is 3, moon in Argentina: 7

Given moon in Canada is 1, moon in Argentina: 1

Correct answer:



Argentina is “upside down” on the globe compared to Canada. So, its view of the moon would be flipped.

Note: Each student was given randomized numbers for how the Moon appears in Canada. Answer options were a dropdown list of integers 1-8.

Michael Smith Science Challenge 2021 Analysis

Score distribution:

The correct answer was worth 4 points, no partial marks were given. The mean score was 1.5 points. About 37% of all students answered this question correctly.

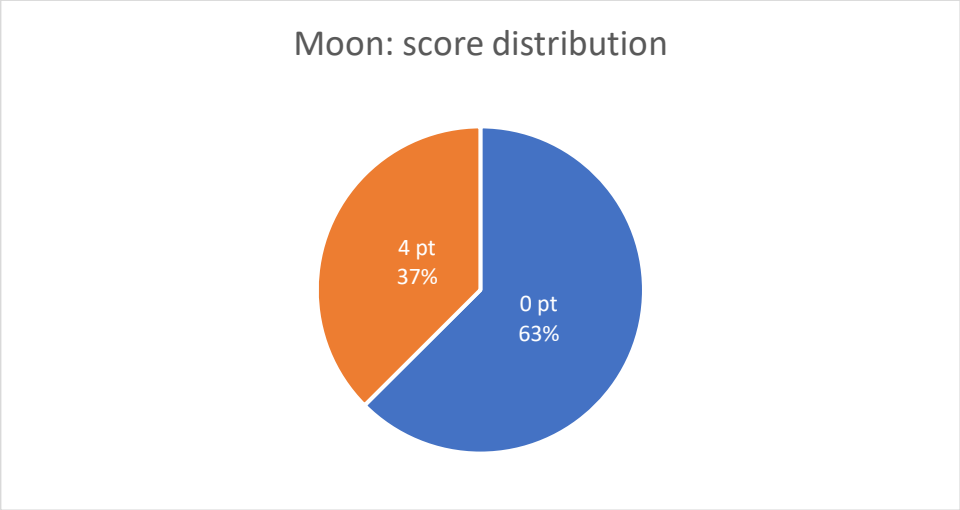


Figure 15 Score distribution for moon question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 3.6 minutes. The following figure plots the mean score against every 30 second interval.

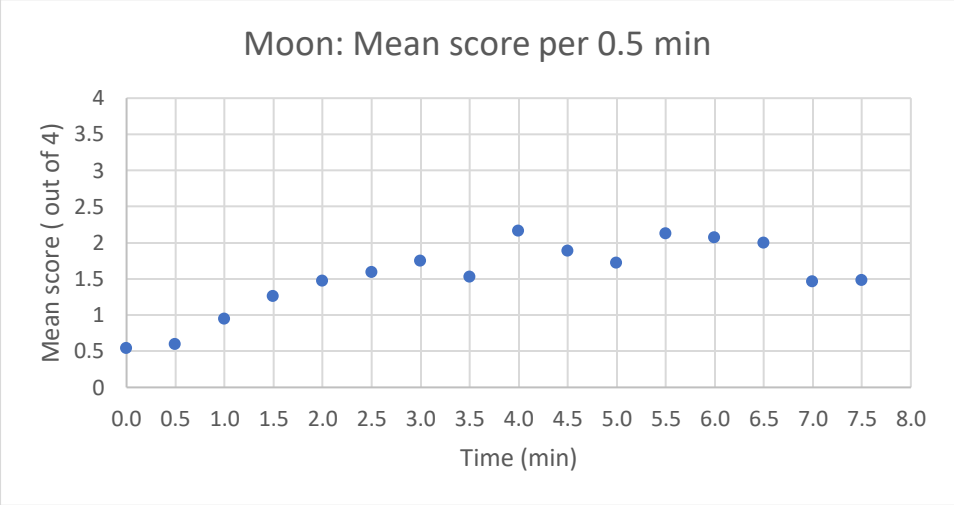


Figure 16 Mean score every 30 seconds for moon question

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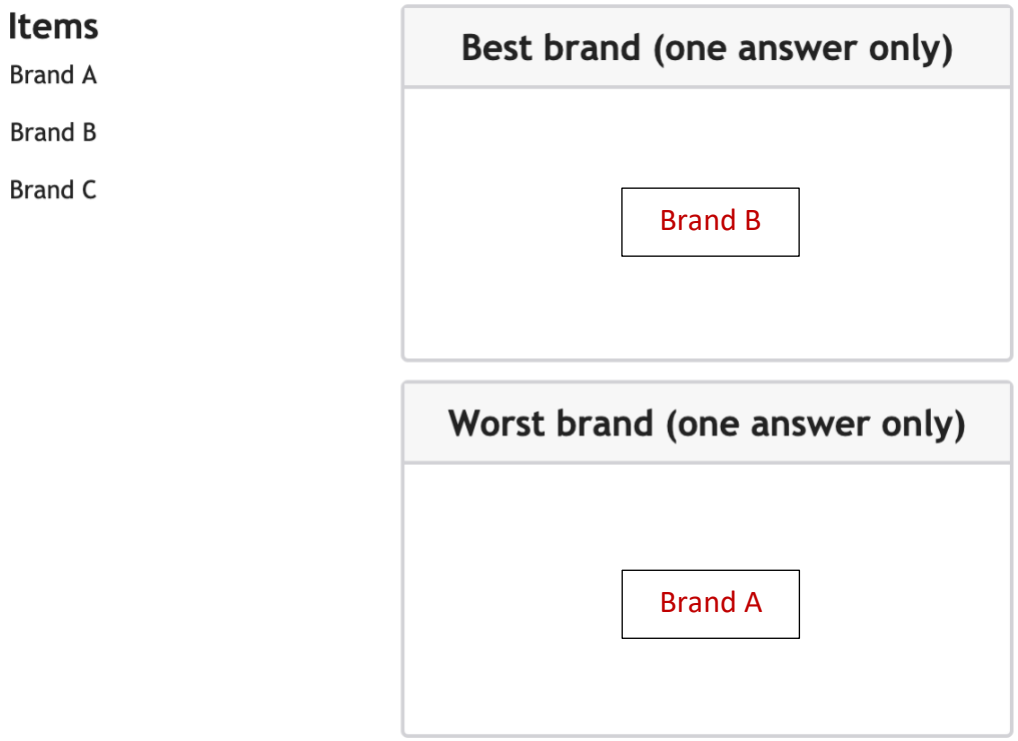
Marathon

You are training for a marathon and need a lot of energy. On the other hand, you are trying to reduce the salt in your diet. You have three brands of bread A, B, C to choose from.

Brand A: *12* g carbohydrate and *100* mg salt per slice (25 g)
Brand B: *249* g carbohydrate and *1206* mg salt per loaf (20 slices)
Brand C: *46* g carbohydrate and *341* mg salt per 100 g

Rank the brands from better to worse for your requirements by dragging and dropping the brands into their corresponding group.



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Correct answer:

From the question description, we can assume the definition of a better brand to be the brand of bread with a higher concentration of carbohydrates (energy source) and lower concentration of salt.

The easiest way to do this would be to check the ratio of carbohydrates to salt in each brand.

Brand A:

$$\frac{12g\ carb}{100\ mg\ salt} = 0.12\frac{g\ carb}{mg\ salt}$$

Brand B:

$$\frac{249g\ carb}{1206\ mg\ salt} \approx 0.206\frac{g\ carb}{mg\ salt}$$

Brand C:

$$\frac{46g\ carb}{341\ mg\ salt} \approx 0.135\frac{g\ carb}{mg\ salt}$$

Since brand B has the highest carbohydrates to salt ratio, it is the best brand of bread to choose. Brand A has the lowest carbohydrates to salt ratio and is therefore the worst brand to choose.

Note: Each student received randomized grams of carbohydrates and milligrams of salt for each brand.

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Score distribution:

The correct answer was worth 2 points, no partial marks were given. The mean score was 1 point. There was a roughly 50/50 distribution of students who answered correctly and incorrectly.

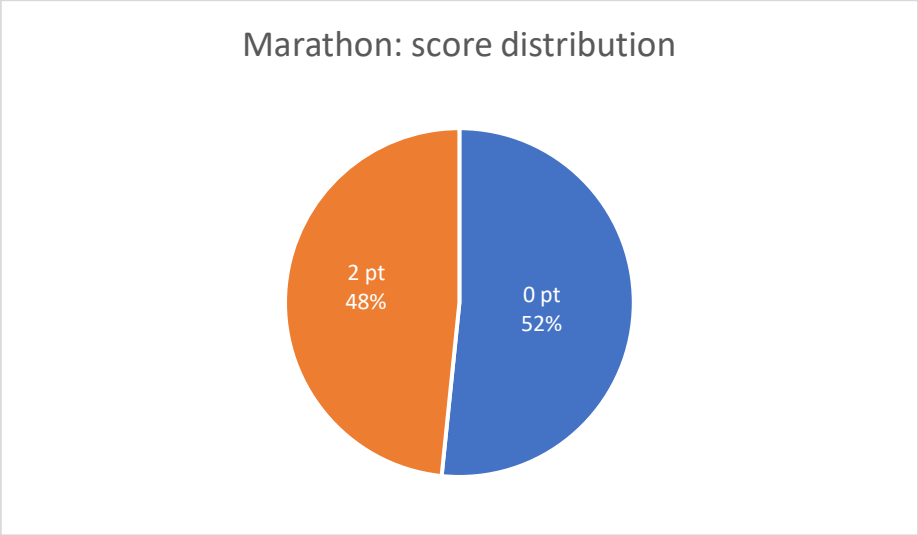

Figure 17 Score distribution for marathon question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 4.4 minutes. The following figure plots the mean score against every 30 second interval.

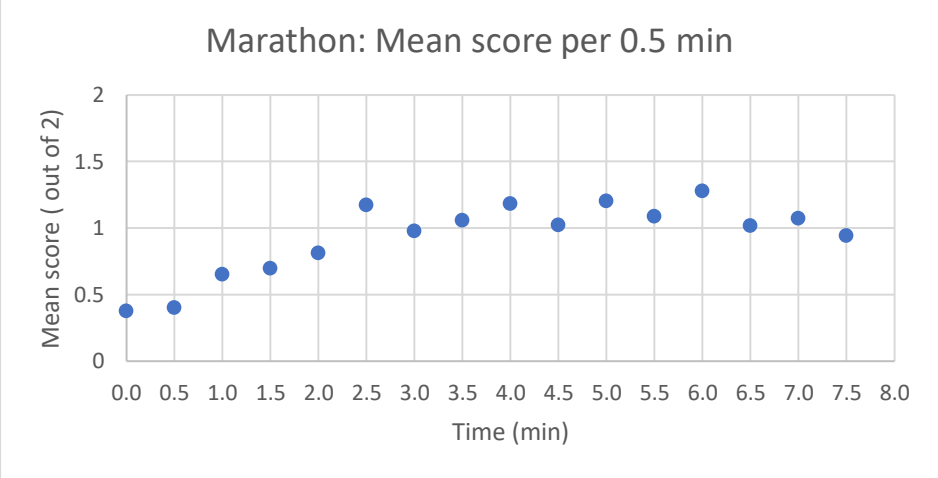

Figure 18 Mean score every 30 seconds for marathon question

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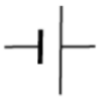
<u>Circuit</u>

In the incomplete circuit below you will see

A battery:

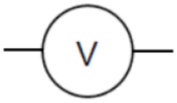


,

and a resistor:

.

Where would you place a voltmeter:

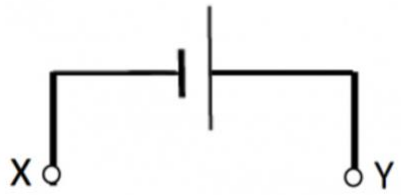


,

An ammeter:

And length of wire:

in order to measure the power coming from the battery and absorbed in the resistor?



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Correct answer:

The voltmeter should be placed parallel to the battery to measure its supplied potential. It could have been placed at either XY or WZ.

Voltmeter:

- ○ WX
- ● XY
- ○ YZ
- ● WZ

The ammeter should be placed in series with the resistor to find the current in the circuit. It could have been placed at either WX or YZ.

Ammeter:

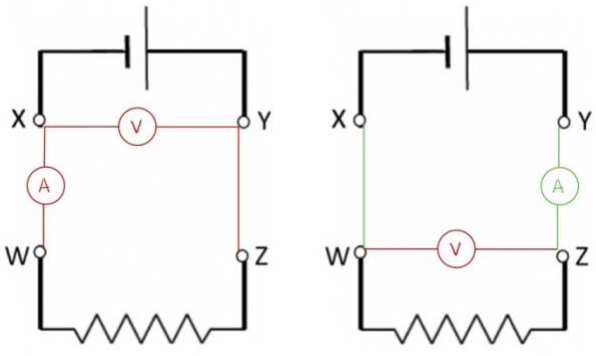
- ● WX
- ○ XY
- ● YZ
- ○ WZ

This leaves the wire to be placed opposite of the ammeter in order to complete the circuit and connect all elements.

Wire:

- ● WX
- ○ XY
- ● YZ
- ○ WZ

Here are two sample solution circuit diagrams:



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Score distribution:

The correct answer was worth 2 points, no partial marks were given. The mean score was 1.2 point. There was a roughly 50/50 distribution of the scores, with a more students scoring correctly than incorrectly.

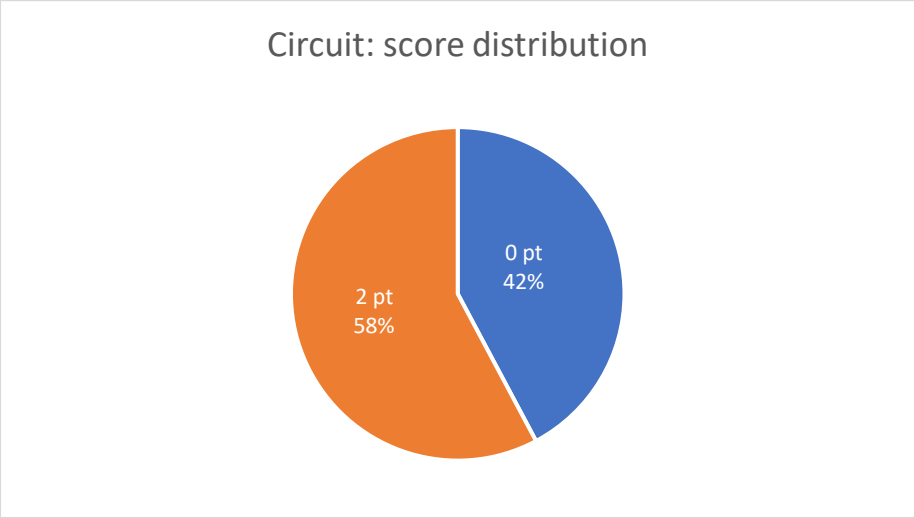

Figure 199 Score distribution for circuit question

Time:

A maximum of 7.5 minutes was allotted for this question. The overall mean time was 4 minutes. The following figure plots the mean score against every 30 second interval.

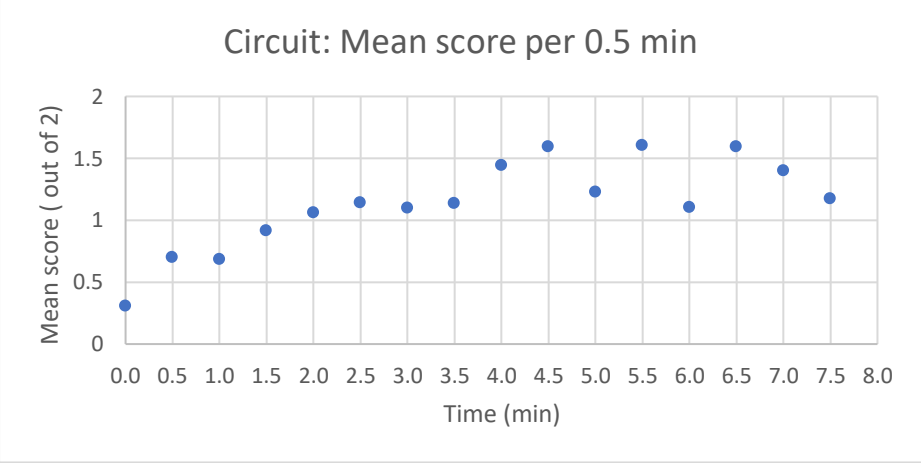

Figure 20 Mean score every 30 seconds for circuit question