# Michael Smith Science Challenge 2017
## Analysis of the Results

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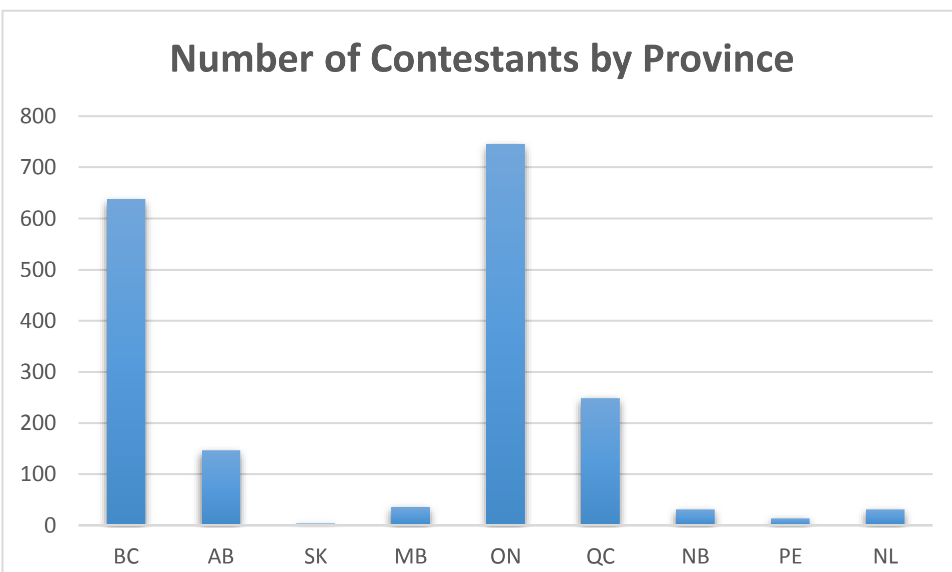
## Introduction

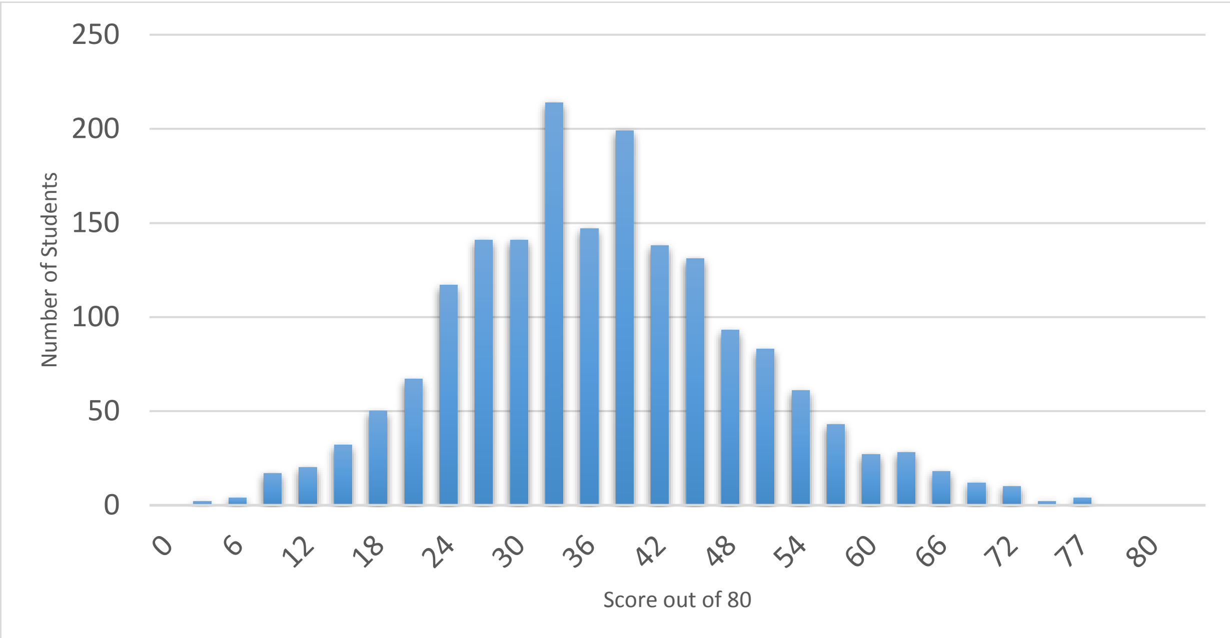
The Michael Smith Science Challenge is a national science contest written by students in grade 10/niveau 4 and below. It was first piloted in the province of British Columbia in April of 2002. Since then it has been run annually across Canada. The purpose of the contest is to challenge students' logical 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. It is offered in English and French.

A total of 1812 exams was received this year, from 9 provinces (Nova Scotia was shut down by a snowstorm at the time of the contect) and 159 teachers. Around 50% of the participants identified as male and 50% as female.



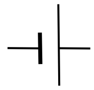
**Results**

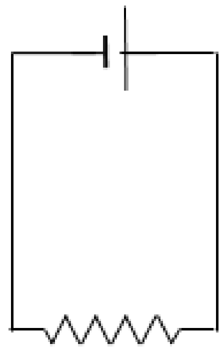
The average score on the contest was 36/80.



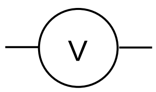
## Solutions and analysis of responses

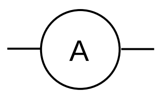
**Question 1:**

Below is a circuit diagram of a power source  connected to a resistor .



Add to the circuit:

- a voltmeter 

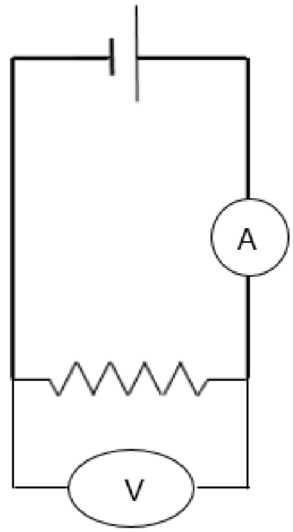
, which measures voltage (*V*, in volts)
- a current meter (ammeter) 

, which measures current (*I,* in amps)

and say how you would measure the power (*P*, in watts) dissipated by the resistor.

- To measure the voltage one must attach the voltmeter in parallel with any of the two elements in the circuit, across the resistor or the battery.
- To measure the current one must attach the ammeter in series with the circuit.
- One possible answer diagram is shown below.

- The power in circuit is calculated by multiplying the readings of the ammeter and voltmeter, using the following formula: $P = I \cdot V$
- Any correct variation of this formula (i.e. $P = I^2 \cdot R$ or $P = \frac{V^2}{R}$) was awarded full marks, if *R* was given as $V/I$.




Common mistakes:

- Students often connected both elements in series with the circuit.
- Students often were aware that the voltmeter has to be connected in parallel, across one of the two elements. Connecting a voltmeter across a length of wire will give a reading of 0 Volts, as there is no potential difference.

- Students often wrote the formula as $P = \frac{IV}{R}$.
- Students often suggested subtracting the power before the resistor from power after the resistor.
- Students often wrote the formula as $P = I - V$

The average score for this question was 9.77 points out of 20. A total of 236 students received a full score for this question (20/20)

**Question 2:**

On November 29, 2016, the Government of Canada granted approval for the Trans Mountain Expansion Project which will have the capacity to move 890,000 barrels of oil (140,000 $m^3$) per day from Edmonton, AB to Burnaby, BC. The hydrocarbons to be transported – diluted bitumen and oils - have a typical density of 0.9 tonnes/$m^3$ and a carbon content of 90% by mass.

When this material is delivered to customers and burnt, estimate how many tonnes of carbon dioxide ($CO_2$) per year will be dumped in the atmosphere as a result. Assume the pipeline operates at full capacity, and no carbon is lost except by burning.

Note: Occasionally end-users employ small-scale carbon capture and storage, but this is mostly to produce $CO_2$ for industrial use or for soft-drinks, and thus the $CO_2$ will end up in the atmosphere anyway.

- 140,000 $m^3$ of dilbit weighs 126,000 tonnes:

$$140{,}000\ \mathrm{m}^3 * \frac{0.9\mathrm{tonnes}}{\mathrm{m}^3} = 126{,}000\ \mathrm{tonnes}_{dilbit}$$

- 126,000 tonnes of dilbit contains 113,000 tonnes of carbon:

$$126{,}000\ \mathrm{tonnes}_{dilbit} * 90\% = 113{,}000\ \mathrm{tonnes}_{carbon}$$

- Now that we know the mass of carbon that is being transported per day, we must calculate the mass of carbon dioxide ($CO_2$) that corresponds to 113,000 tonnes of carbon. Knowing the atomic mass of oxygen (16) and of carbon (12), we can calculate the atomic mass of carbon dioxide:
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$$(1\ \mathrm{carbon})\ \cdot 12 + (2\ \mathrm{oxygen}) \cdot 16 = 44$$

From this calculation we can see the ratio of proportionality between the carbon and the entire mass in $CO_2$. Since there is only one carbon in the molecule, the ratio of proportionality is:

$$\frac{(\mathrm{Atomic\ Mass\ of\ CO_2})}{(\mathrm{Atomic\ Mass\ of\ C})} = \frac{44}{12}$$

Then we know that 113,000 tonnes of carbon are equivalent to 415,800 tonnes of carbon dioxide:

$$113{,}000 \text{ tonnes}_{carbon} * \frac{44}{12} = 415{,}800 \text{ tonnes}_{CO_2}$$

Now that we know the mass of carbon dioxide that is going to be dumped in the atmosphere per day, we just have to multiply the answer by 365 day in a year to get the yearly mass:

$$415{,}800 \frac{\text{tonnes}_{CO_2}}{\text{day}} \cdot \frac{365 \text{ days}}{\text{year}} = \mathbf{151,767,000} \frac{\textbf{tonnes}_{\boldsymbol{CO_2}}}{\textbf{year}} = \textbf{152 Mtonnes/year}$$

This amount represents an additional 27% to Canada's annual national $CO_2$ production (2015 numbers) – and all from one pipeline.

Common Mistakes:

- Students often forgot to convert their answer from mass per day to mass per year.
- Students often forgot to convert mass of carbon into mass of carbon dioxide.
- Many students used the volume in barrels instead of $m^3$.

The average score for this this question was a 10.13/20. A total of 190 students received a full score for this question.

**Question 3:**

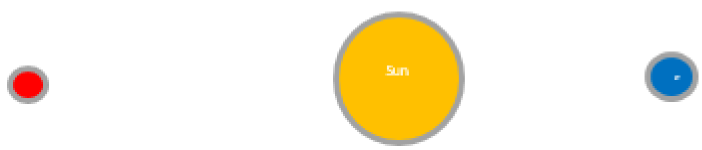
NASA has recently revealed plans to establish a colony on Mars. If this happens, communication with Earth will be an essential aspect of this mission, and timing will be crucial when sending signals to Mars Base.

Earth and Mars travel around the Sun in approximately circular orbits, with radii 1 AU* and 1.5 AU respectively. Light takes about 8 minutes to travel from the Sun to the Earth. How long will it take to transmit a short greeting "Hello" to Mars and receive a "Hello" back, assuming the colonists reply immediately?

* AU = astronomical unit (of distance).

There are multiple situations to be considered here. The two planets will be in different positions and distances relative to each other depending on the moment in time. For example, the shortest time possible to get a reply would occur when the planets are lined up in the following way:

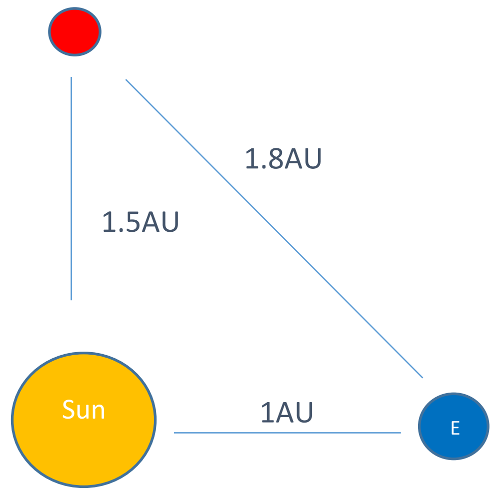

In this case, the transmission would take 8 minutes, since the distance from Earth to Mars would be 0.5 AU, both ways 1AU, and we already know that a radio signal which travels in the speed of light takes around 8 minutes to travel 1AU. Another case to be considered is the longest possible time:




In this case, the distance between Earth and Mars is of 2.5 AU, a sum of both planetary distances from the Sun (1AU + 1.5AU). Therefore a round trip would sum 5AU. Since we know that light takes 8 minutes to travel 1AU, we can calculate that it will take 40 minutes for a radio signal to travel to Mars and back:

$$5\text{AU} \cdot \frac{8 \text{ minutes}}{\text{AU}} = 40 \text{ minutes}$$

There are more cases that are mathematically simple to calculate, such as the following:




Then, we can calculate that a round trip of 3.6 AU would take 28.8 minutes:

$$3.6\ \text{AU} \cdot \frac{8\ \text{minutes}}{\text{AU}} = 28.8\ \text{minutes}$$

There is an infinity of such scenarios, but from these simple cases we can determine that the time range from 8-40 minutes.

*Full marks for this question were only awarded if there was a calculation of the shortest time, the longest time, an intermediate scenario and the recognition that there will be a continuum of times between the two.

Common mistakes:

- Students misread the question and switched the distances from the Sun.
- Many students forgot to consider the round trip, and gave "one-way" answers.
- Students often said that sound travels slower than light, which is true, however sound cannot travel through space! No marks were deducted for this, as it was not the focus of the question.
- One student said that it would be instantaneous, due to the invention of internet!

The average score for this question was of 5.29/20 points. Only 4 students received full marks for this question.

**Question 4:**

4. (a) Use the following words/phrases to fill in the gaps in the paragraph below:

- cooler, energy, evaporation, food, less than, mechanical work, more than, sunshine, the same as, warmer, water

You may use a word/phrase more than once.

*Answers in blue

*Human beings are homeotherms; i.e. our biology requires that we maintain a constant core temperature. Like all living things we are constantly exchanging _energy_ with our environment. As our cores are neither heating up nor cooling down, we know that for a given period of time, the amount of _energy_ we gain from the environment must be _the same as_ the amount of _energy_ we lose to the environment. We gain _energy_ from _food_, _sunshine_, and, if our surroundings are _warmer_ than our skin, heat from the environment. We lose _energy_ to _evaporation_, _mechanical work_, and, if our surroundings are _cooler_ than our skin, heat to the environment.*

Common Mistakes;

- Students often thought that we gain energy from "water".
- Students would often say we lose energy to "sunshine"

(b) The metabolic rate (rate of energy use) in mammals does not scale with mass. That is, mammal A, 100 times more massive than mammal B, uses much less than 100 times the energy per day as mammal B (actually about 30 times). Suggest a reason for this.

This nonlinear proportionality occurs because of the relationship between mass and surface area. Mass (proportional to volume) scales with the cube of length, while surface area scales with the square of length. You can see this mathematically with the equations for a sphere:

$$Area = 4\pi r^2$$

$$Volume = \frac{4}{3}\pi r^3$$

Therefore, a mammal that is 100 greater in volume will not have a surface area that is 100 larger than a smaller mammal. Surface area is directly proportional to energy use for mammals, since that is how we lose heat and we have to keep a constant core temperature. With more surface area, more energy will be lost by convection and radiation to surrounding colder air, and to evaporation of sweat.

Common Mistakes:

- Many students misunderstood the question and focused on specific cases, for example, a cheetah and a sloth.
- Students would argue that big animals are at the top of the food chain.
- Students often used the argument that bigger animals have bigger legs, and have to "move less" to travel the same distance.

The average score for this question was 10.93/20. Only 26 students received a full score for this question (less than 2% of participants).