a place of mind
THE UNIVERSITY OF BRITISH COLUMBIA
Faculty of Science

UBC DEPARTMENT OF PHYSICS ASTRONOMY

Défi Scientifique Michael Smith Science Challenge

Tuesday, February 23rd 2016

9-10 Pacific, 10-11 Mountain, 11-12 Central, 12-1 Eastern, 1-2 Atlantic, 1:30-2:30 Newfoundland

PLEASE PRINT DOUBLE-SIDED (BLACK AND WHITE OK)

Instructions

1. Do not open this examination booklet until you are told to do so.
2. Be certain that you understand all of the instructions. If not, ask your teacher.
3. Do not ask your teacher for any help with the content of the examination.
4. This examination is closed-book. No notes of any kind (printed or electronic) are allowed.
5. You may use a calculator (graphing or scientific) and a ruler.
6. No computers, tablets, cellphones, or other wireless devices are allowed.
7. Write your answers in this exam booklet and hand it back to your teacher at the end.
8. This exam booklet consists of 4 questions on 6 pages, including this page of instruction. Make sure you have all the pages.
9. Print your name and other information clearly. Only those who do so can be counted as official contestants.
10. When your teacher instructs you to begin, you will have **60 minutes** to finish the examination.

Scoring

Full marks will be given to a student who demonstrates clear understanding of the science required by the question. Partial marks will be given for partial understanding. There are no penalties for incorrect answers. The questions are not of equal difficulty. Remember we are challenging the strongest science students in Canada; it is possible that highest overall score will be less than 80%. This is meant to be tough!

Teachers

Please mail* the following **two items** to Michael Smith Challenge, Department of Physics & Astronomy, 6224 Agricultural Road, UBC, Vancouver, BC, V6T 1Z1 by the end of **Tuesday, February 23rd, 2016**:
1. Students' exam booklets
2. A cheque payable to "UBC Physics & Astronomy", for $6.00 per script returned (if paying by cheque) **OR** a printed receipt of your payment (if paid by credit card).

* Canada Post regular mail; express/couriers *not* necessary. Please do not send by email.

Contest Named in Honour of Dr. Michael Smith (1932-2000)

UBC's 1993 Nobel Prize Winner

Examination Committee

Nicholas Larsen, Theresa Liao, and Chris Waltham, UBC Department of Physics & Astronomy
Susan Vickers, UBC Department of Curriculum and Pedagogy

Translator

Nikita Bernier, UBC Department of Physics & Astronomy

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Useful Information

Element	Symbol	Atomic Mass
Hydrogen	H	1
Carbon	C	12
Oxygen	O	16

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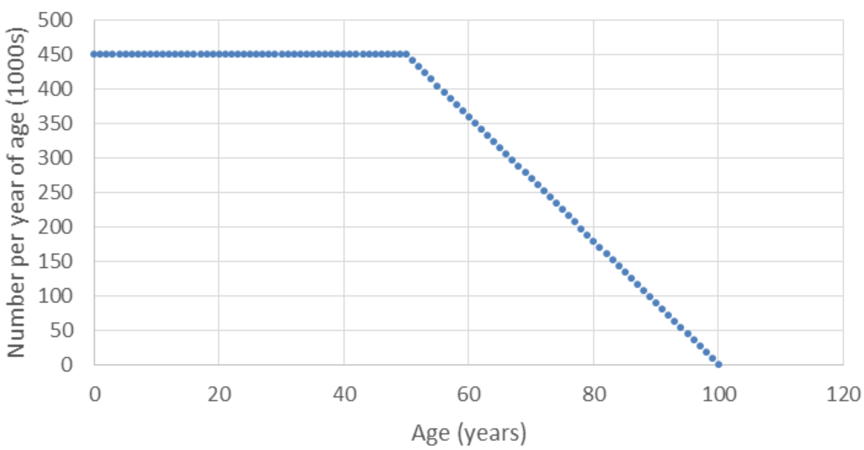
NAME (PRINT)____SCHOOL (PRINT)________________________

Q1	Q2	Q3	Q4	Total
/20	/20	/20	/20	/80

1. The approximate age distribution of the Canadian population is shown in this histogram:



For example, there are about 450,000 of us aged 20 (i.e. born between 20 and 21 years ago), but only about 250,000 aged 72.

Using only data shown in this histogram, answer the following questions, briefly describing your reasoning:

(a) What is the total Canadian population?

(b) What percentage of the Canadian population is 50 or younger?

(c) If there was no immigration into or emigration from Canada, how many Canadians would have to be born each year to keep this histogram looking the same for the foreseeable future?

(d) If there was no immigration into or emigration from Canada, how many Canadians would have to die each year to keep this histogram looking the same for the foreseeable future?

(e) Some medical researchers think they can cure aging. If no-one died from now on, what would the histogram look like in 10 years time (assuming all else stays the same, and no immigration/emigration)? Draw the new line on the histogram above.

2. We Canadians each waste about 100 kg of food carbohydrates per year. If these carbohydrates are composted anaerobically, half the carbon atoms end up as carbon dioxide (CO_2) and half end up as methane (CH_4).

The energy needs of a small single-family dwelling is typically 0.3 GJ per day averaged over a year. How long could such a house be supplied with energy from composting 100 kg of carbohydrates?

The approximate ratio of carbon, hydrogen and oxygen atoms in carbohydrates, C:H:O, is 1:2:1.

The enthalpy of combustion of CH_4 (i.e. the “energy content”) is 55 MJ/kg

3. In recent weeks the astronomers have been excited about a possible large planet with an orbital radius twenty times that of Neptune. The planet may be a gas giant like Neptune, or a rocky planet like other smaller objects beyond Neptune. The gravitational disturbance of known minor planets indicates that its mass may be ten times that of the Earth.

(a) Why haven't we found it already? Circle any reasonable explanation:

I. Our telescopes cannot see that far.

II. It is too far away for light to reach us; the light dies out on the way.

III. Light from the planet hasn't had time to get to us yet.

IV. It receives too little light from the Sun to reflect enough back for us to see easily.

V. There are too many objects as dim out there and we would have to know precisely where to look to say which one it is; our understanding of that part of the Solar System is not yet that good.

VI. It takes so long to orbit the Sun, moving too slowly across the sky for easy identification as a planet.

(b) Once identified, how do you think we will first find out whether it is a gas giant or a rocky planet. Circle any reasonable possibility:

I. We'll send a satellite there to look.

II. If we see rocks on the surface, it is a rocky planet.

III. If it has craters, it has to be a rocky planet.

IV. If it has lots of moons it has to be a gas giant.

V. Gas giants are only made of gas so they are almost invisible compared to rock.

VI. Gas giants are much bigger than rocky planets for the same mass and so will be much brighter.

(c) If this planet was rocky with the same internal structure as the Earth, what would its diameter be? The Earth's diameter is 13,000 km.

4. The atomic nucleus consists of positively charged protons and electrically neutral neutrons bound together by a mysterious force ("MF") in a tiny space, the nucleus, much smaller than the atom itself. We can learn something about this force by making some observations:

1. Neutrons and protons do not individually fly out of the nucleus spontaneously.
2. Negatively charged electrons are in stable orbitals around the nucleus, held by electrostatic attraction, and do not stick to the nucleus.
3. Atomic nuclei only exist stably up to the certain size (e.g. ^{209}Bi), then they fall apart spontaneously (e.g. ^{238}U).
4. The most common atoms have more or less equal numbers of the protons and neutrons (e.g. ^{12}C, ^{16}O).

What can you deduce from the above observations? Here are some possibilities:

(a) The MF is just like the electrostatic force, except that positive charges attract each other
(b) The MF may have nothing to do with electrical charge
(c) The MF must be much weaker than the electrostatic force
(d) The MF must be much stronger than the electrostatic force
(e) The MF is attractive, affecting only the neutrons
(f) The MF is attractive, affecting both protons and neutrons
(g) The MF seems strongest in the presence of both protons and neutrons
(h) The MF must have a short range, much less than the radius of an atom
(i) The MF must have a very long range, much more than the radius of an atom

Pair off as many deductions and observations that you think are correct

Observation used as evidence	Deduction
e.g. (2)	e.g. (a)