UNIVERSITY OF
BRITISH COLUMBIA
Faculty of Science
Science One

NSERC CRSNG

promo Science

Michael Smith National Science Challenge 2009

Thursday, March 12th, 2009

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

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 you are unsure about something, ask your supervisor.
3. This examination is closed-book. No notes of any kind (printed or electronic) are allowed.
4. You may use a calculator (may be a graphing calculator) and a ruler.
5. Write your answers in this exam booklet and hand it back to your teacher at the end.
6. This exam booklet consists of 6 questions on 8 pages; including this page of instructions and a data sheet. Check to make sure you have all the pages.
7. Print your name and other information clearly. Only those who do so can be counted as official contestants.
8. Do rough work on the back of the paper.
9. 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 best science students in Canada; it is possible that even the best papers may not achieve an overall score of 80%. This is meant to be tough!

Teachers

Please mail* the following **2 items** to Prof. Chris Waltham, Department of Physics & Astronomy, 6224 Agricultural Road, UBC, Vancouver, BC, V6T1Z1 before the end of **Friday, March 13th, 2009**:
1. students' exam booklets
2. a cheque payable to University of British Columbia, for $5.00 per script returned.

* Canada Post regular mail; express/couriers *not* necessary.

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

UBC's 1993 Nobel Prize Winner

Examination Committee

Celeste Leander, UBC Department of Botany
Derek Inman, Andrzej Kotlicki and Chris Waltham, UBC Department of Physics and Astronomy

Translator

Louis Deslauriers, UBC Department of Physics & Astronomy

"It is a small problem merely, but a problem that will agitate the little grey cells most adequately."
- Hercule Poirot

PLEASE TEAR OFF THIS FRONT PAGE

Data Sheet
Fiche de données

Relative Atomic Masses (1985 IUPAC)
*For the radioactive elements the atomic mass of an important isotope is given

Masses Atomiques Relatives (UICPA, 1985)
*Dans le cas des éléments radioactifs, la masse atomique fournie est celle d'un isotope important

1																	18
1 H 1.008	2											13	14	15	16	17	2 He 4.003
3 Li 6.941	4 Be 9.012											5 B 10.811	6 C 12.011	7 N 14.007	8 O 15.999	9 F 18.998	10 Ne 20.180
11 Na 22.990	12 Mg 24.305	3	4	5	6	7	8	9	10	11	12	13 Al 26.982	14 Si 28.086	15 P 30.974	16 S 32.07	17 Cl 35.453	18 Ar 39.948
19 K 39.098	20 Ca 40.08	21 Sc 44.956	22 Ti 47.88	23 V 50.942	24 Cr 51.996	25 Mn 54.938	26 Fe 55.847	27 Co 58.93	28 Ni 58.69	29 Cu 63.55	30 Zn 65.39	31 Ga 69.72	32 Ge 72.61	33 As 74.922	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.468	38 Sr 87.62	39 Y 88.906	40 Zr 91.22	41 Nb 92.906	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.906	46 Pd 106.42	47 Ag 107.87	48 Cd 112.41	49 In 114.82	50 Sn 118.71	51 Sb 121.76	52 Te 127.60	53 I 126.90	54 Xe 131.29
55 Cs 132.905	56 Ba 137.33	57 La 138.91	72 Hf 178.49	73 Ta 180.948	74 W 183.85	75 Re 186.2	76 Os 190.2	77 Ir 192.2	78 Pt 195.08	79 Au 196.967	80 Hg 200.59	81 Tl 204.37	82 Pb 207.2	83 Bi 208.980	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra 226.03	89 Ac 227.03	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs	109 Mt									

			58 Ce 140.12	59 Pr 140.91	60 Nd 144.24	61 Pm (145)	62 Sm 150.4	63 Eu 151.97	64 Gd 157.25	65 Tb 158.93	66 Dy 162.50	67 Ho 164.930	68 Er 167.26	69 Tm 168.934	70 Yb 173.04	71 Lu
			90 Th 232.038	91 Pa 231.04	92 U 238.03	93 Np 237.05	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (260)

	Symbol **Symbole**	**Value** **Quantité numérique**	
Atomic mass unit	amu	1.66054×10^{-27} kg	Unité de masse atomique
Avogadro's number	N	6.02214×10^{23} mol^{-1}	Nombre d'Avogadro
Bohr radius	a_0	5.292×10^{-11} m	Rayon de Bohr
Boltzmann constant	k	1.38066×10^{-23} J K^{-1}	Constante de Boltzmann
Charge of an electron	e	1.60218×10^{-19} C	Charge d'un électron
Dissociation constant (H_2O)	K_w	10^{-14} (25 °C)	Constante de dissociation de l'eau (H_2O)
Faraday's constant	F	96 485 C mol^{-1}	Constante de Faraday
Gas constant	R	8.31451 J K^{-1} mol^{-1} 0.08206 L atm K^{-1} mol^{-1}	Constante des gaz
Mass of an electron	m_e	9.10939×10^{-31} kg 5.48580×10^{-4} amu	Masse d'un électron
Mass of a neutron	m_n	1.67493×10^{-27} kg 1.00866 amu	Masse d'un neutron
Mass of a proton	m_p	1.67262×10^{-27} kg 1.00728 amu	Masse d'un proton
Planck's constant	h	6.62608×10^{-34} J s	Constante de Planck
Speed of light	c	2.997925×10^{8} m s^{-1}	Vitesse de la lumière

1 Å	=	1×10^{-8} cm
1 eV	=	1.60219×10^{-19} J
1 cal	=	4.184 J
1 atm	=	101.325 kPa
1 bar	=	1×10^{5} Pa

PLEASE TEAR OFF THIS DATA SHEET

NAME (PRINT): _____

SCHOOL: _____

GRADE: _____ PROVINCE: _____

Questions

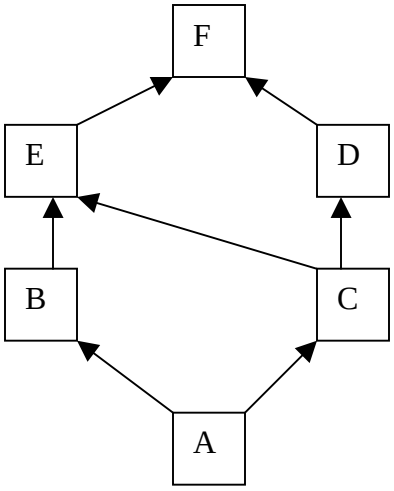
1. (5 marks each)

a) How many cubic millimetres are there in a cubic metre? Show how you arrived at your answer.

b) What is the surface area, in m^2, of a one-mm cube?

c) Suppose you have 512 of these one-mm cubes and are free to combine them into any shape you see fit. What is the minimum surface area your shape could have? What is the maximum surface area your shape could have? Leave your answers in mm^2.

2. (5 marks each)



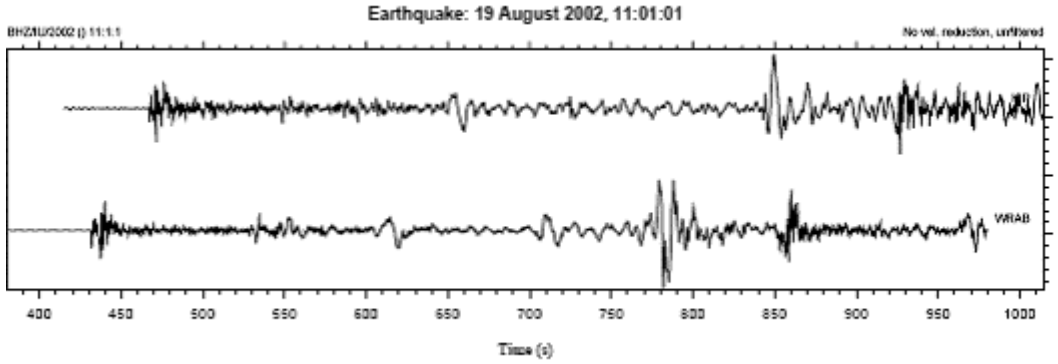
(a) In the above closed food web, which species has the most biomass? Why?

b) In one sentence, describe the interaction between species E and species D.

c) Species B makes a toxin that prevents species D from preying on it. (Species E is unaffected by the toxin). Species B is brightly coloured. Assuming colouration is an indicator of toxicity, which species would benefit most by mimicking the colouration of species B? Why?

d) Many years ago, PCBs (a class of chemicals susceptible to bioaccumulation) were introduced into the ecosystem where this community lives. For dinner, you have a choice of eating the same mass of species A, species C, or species F. These three species have equal concentrations of fat per kg body-mass. Which species would have the highest concentration of PCB?

3. (20 marks)

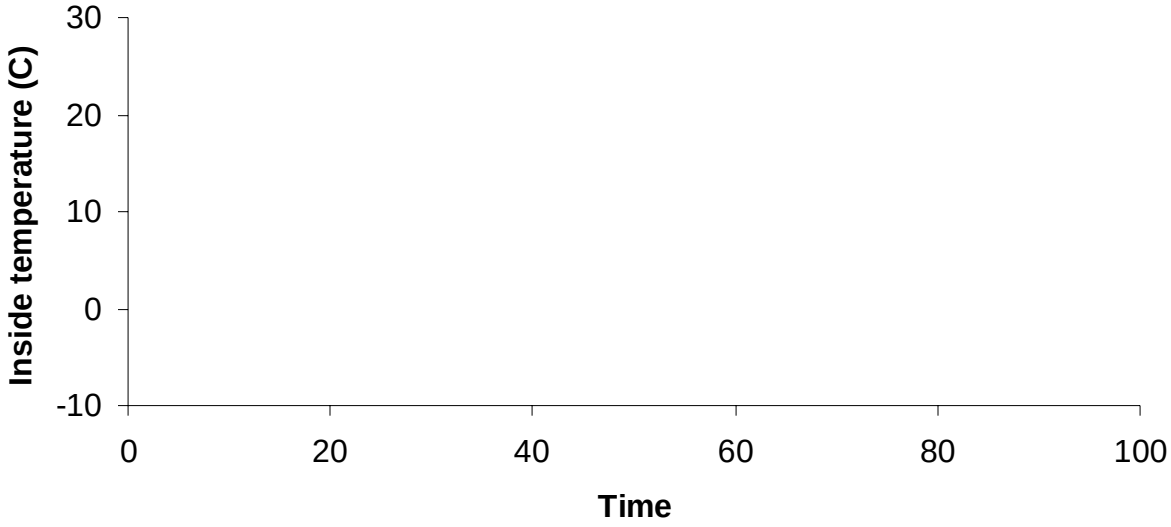


Data from Robert Myhill, Department of Earth Sciences, University of Cambridge

The above figure shows traces from two seismographs positioned 500 km apart. The time is measured from that of the earthquake (calculated using data from many such stations). Using these traces, tell us what you can deduce, especially about the speed of the seismic waves. Feel free to draw on the figure.

4. (10 marks each)

(a) The supply of natural gas to a gas-heated home is suddenly cut off. The temperature outside is -5^{o}C. Sketch on the plot below how the inside temperature of the house changes with time. What are reasonable units for the timescale?



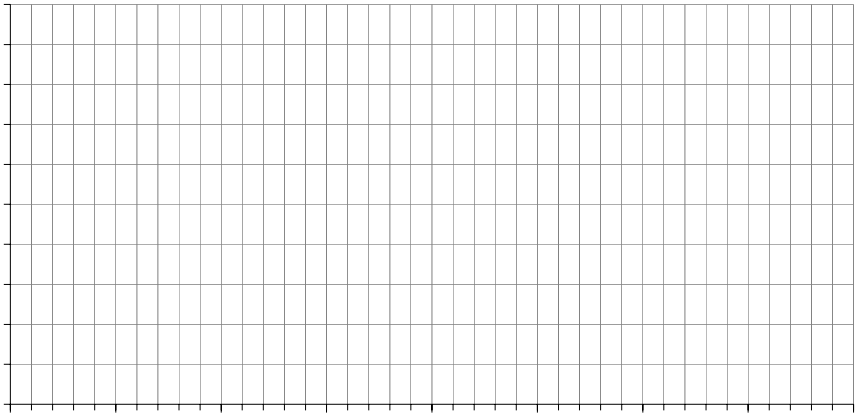
b) Natural gas is composed mostly of methane (CH_4) and is burnt in order to generate heat. Write a chemical equation describing this combustion. Is this reaction exothermic or endothermic?

c) The heat of combustion of methane is 55.2 GJ/tonne. Suppose the furnace of a house burns methane at a rate of 10 kW during the winter. How much CO_2 does the furnace produce per day?

5. (15 marks)

The following table shows the average surface temperatures (T, given in Celsius) of a small rocky planet orbiting around an average-sized star. The measurements were made over the last 20 years. Using these data (and no other consideration), estimate what the mean surface temperature of this planet will be in the year 2025. (Hint: some graph paper is printed below).

Year	T(^{o}C)
1989	14.13
1990	14.32
1991	14.29
1992	14.06
1993	14.08
1994	14.18
1995	14.32
1996	14.24
1997	14.34
1998	14.51
1999	14.27
2000	14.27
2001	14.42
2002	14.50
2003	14.49
2004	14.43
2005	14.56
2006	14.48
2007	14.51
2008	14.38



6. (5 marks each)

We can express the basic mechanism for life in the form of word equations, like:

wordA + wordB +… $\rightarrow$ word1 +word2 + …

Using some of the following words (and no others):

- argon
- carbon dioxide
- oxygen
- glucose
- hydrocarbon
- water
- ice
- ultra-violet
- sunlight
- kinetic energy
- heat

write a word equation for

a) plant life

b) animal life

Now construct a word equation for a non-living thing, a gasoline-powered (non-hybrid) car.

c) accelerating

d) braking