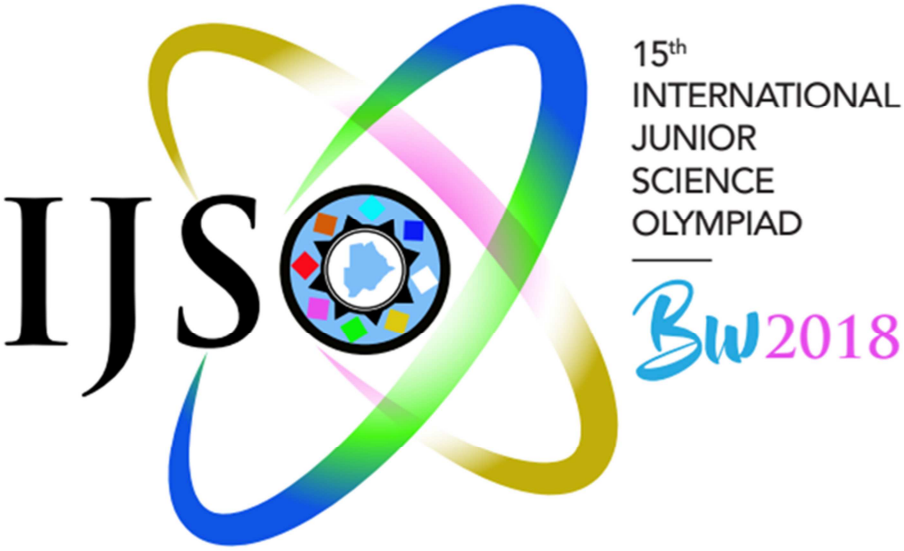
15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



Discovery, Innovation and Environment

Multiple Choice Competition

– Exam Sheet –

December 4, 2018

Do NOT turn to next page

before a whistle is blown.

Otherwise, you will receive a penalty.

1. You have 10 minutes to read “EXAMINATION RULES”, “EXAM INSTRUCTIONS”, and “CALCULATOR INSTRUCTIONS” on pages 1 - 3.

2. Do NOT start answering the questions before the“START”whistle! Otherwise, you will receive a penalty.

QUESTIONS

EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.
4. Do NOT start answering the questions before the “START” whistle.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need any assistance, you may raise your hand and wait for a supervisor to come.
7. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
8. At the end of the examination time you will hear the “STOP” whistle. Do NOT write anything more on the answer sheet after this stop whistle. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and rough book) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

QUESTIONS

EXAM INSTRUCTIONS

1. After the "START" whistle, you will have 3 hours to complete the exam.

2. ONLY use the pen provided by the organizers (not pencil).

3. NOW write your name, code, country and signature in your answer sheet (one page). Raise your hand, if you do not have the answer sheet.

4. Read each problem carefully and indicate your answer on the answer sheet using a cross (as shown below). There is only one right answer for each problem.

   Example : (A) is your answer.

1	~~A~~	B	C	D

5. If you want to change your answer, circle your first answer and then indicate your new answer using a cross (as shown below). You can only make ONE correction per question.

   Example : (A) is your first answer and (D) is your final answer.

1	~~A~~	B	C	~~D~~

6. Only the answer sheet will be evaluated. Before writing your answers on the answer sheet, use the rough book provided.

7. Point rules

Correct answer	: + 1 point
Wrong answer	: − 0.25 point
No answer	: no point

8. The total number of questions is 30. Check that you have a complete set of the test questions (19 pages, page 5 – page 19) after the "START" whistle is blown. Raise your hand, if you find any missing sheets.

QUESTIONS

INSTRUCTIONS FOR CALCULATOR

1. Turning on: Press [ON/C].

2. Turning off: Press [2ndF] [ON/C].

3. Clearing data: Press [ON/C].

4. Addition, subtraction, multiplication, and division

Example 1) $45 + \frac{285}{3}$

[ON/C] *45* [+] *285* [÷] *3* [=] *140.*

Example 2) $\frac{18+6}{15-8}$

[ON/C] [(] *18* [+] *6* [)] [÷] [(] *15* [−] *8* [)] [=] *3.428571429*

Example 3) $42 \times (-5) + 120$

[ON/C] *42* [×] *5* [+/−] [+] *120* [=] *-90.*

[ON/C] *42* [×] [(] [−] *5* [)] [+] *120* [=] *-90.*

5. Exponential

Example 1) 8.6^{-2}

[ON/C] *8.6* [y^x] *2* [+/−] [=] *0.013520822*

Example 2) 6.1×10^{23}

[ON/C] *6.1* [×] *10* [y^x] *23* [=] *6.1 x 10^{23}*

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press [DEL]. If the cursor is located at the right end of a number/function, the [DEL] key will function as a back space key.

QUESTIONS

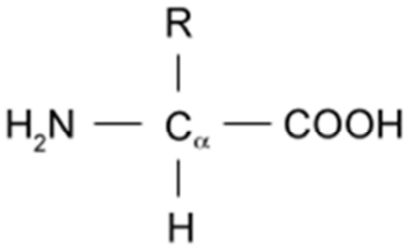
Do NOT turn to next page Before the"START"whistle is blown.

Otherwise, you will receive a penalty.

QUESTIONS

BIOLOGY

1. Amino acids are groups of organic molecules that are building blocks of proteins. The picture below shows a typical amino acid structure. Amino acids serve as buffers to maintain cell pH in the body. Which parts of an amino acid gives it the *pH* buffering properties?



A. Amino group and hydroxyl group
B. Peptide bond and carboxyl group
C. Carboxyl group and hydroxyl group
D. Amino group and carboxyl group

2. In the DNA sequence shown below, the normal Guanine (G) in the top strand was replaced by the mutant enol form G* before replication. This mutant enol form binds to Thymine (T) instead of Cytosine (C).

A A C A T T C G C C C
T T G T A A G C G G G

What would be the proportion of mutant (different from the original strand shown above) progeny in the second filial (F_2) generation?

A. 1/2
B. 1/3
C. 1/4
D. 1/5

QUESTIONS

3. An ecologist driving along the banks of the Chobe River, Botswana, observes little white egrets (*Bubulcus ibis*) sitting on the back of a hippopotamus (*Hippopotamus amphibius*). The hippopotamus did not chase the birds away. The ecologist took out his binoculars and observed what was happening. He recorded that the birds were picking ticks from the hippo's skin.

Source: Flickr.com/photos/38504899@N08/4178471716

The symbiotic interaction between the hippo and the egrets could be described as

A. Commensalism
B. Parasitism
C. Mutualism
D. Amensalism

4. Oxygen consumption can be used as a measure of metabolic rate because oxygen is

A. Required by all living organisms
B. Required to break down lactic acid that is produced in muscles
C, Necessary for Adenosine Tri-Phosphate (ATP) synthesis by oxidation
D. Necessary to replenish glycogen levels

5. Embryonic development is a complex multi-step process that involves transition from single cellularism to multicellularism. In animals, all of the following are associated with embryonic development except

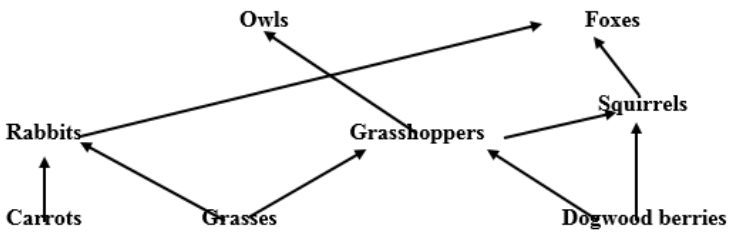
A. Migration of cells to specific areas
B. Formation of germ layers
C. Activation of all the genes in each cell
D. Inductive tissue interactions

QUESTIONS

6. Nitrogen accounts for approximately 79% of air. However, in this form it is inaccessible to most organisms. Atmospheric nitrogen has to be converted into a usable form in the soil by nitrogen fixation for plant growth. The nitrogen fixation mainly occurs by

A. Lightning
B. Biological processes
C. Volcanic eruptions
D. Haber-Bosch process

7. The pesticide Dichlorodiphenyltrichloroethane (DDT) was widely used between 1940 and 1960 to kill mosquitoes that transmit the malaria pathogen. Though useful, the pesticide was found to be persistent, meaning it does not degrade easily in the environment. Supposing DDT was sprayed on grasses to eradicate mosquitoes, which organisms in the food web will have the highest concentration of DDT within its tissues?



A. Rabbits
B. Owls
C. Squirrels
D. Foxes

8. Consider the following statements regarding bacterial, animal and plant cells:

(i) Animal and plant cells have a nucleoid.
(ii) Peptidoglycan is the major cell wall component in bacteria.
(iii) Bacterial cell has no cell wall.
(iv) Animal and plant cells generate ATP within the mitochondria.
(v) The main constituent of plant cell walls is a polysaccharide called lignin.

(vi) Bacterial cell generates ATP within the cytoplasm.

Which of the above statements are correct?
A. (i), (iii) and (vi)
B. (i), (iv) and (v)
C. (ii), (iv) and (vi)
D. (ii), (iv) and (v)

9. Leaves have air spaces in between mesophyll cells, as opposed to being completely occupied by cells or water. How are the air spaces useful for CO_2 diffusion?

A. They increase surface area for CO_2 absorption
B. Allow for faster diffusion of CO_2
C. If there were no air spaces between the cells, the amount of CO_2 would be the rate limiting factor in photosynthesis
D. All of the above

10. Guttation (picture below) in small plants happens at night and is due to osmosis. Which of the following statements describes how the process of guttation occurs?

https://twitter.com/cairotango/status/332246248818106368

A. Positive pressure generated in the roots pushes water out of the xylem in the leaves
B. Water accumulates in the leaves because evaporation happens slower than transpiration
C. Water is pulled up in large quantities to leaves because of an increase in solute concentrations in the leaves
D. Water from dew gathers on the surface of plant leaves

QUESTIONS

CHEMISTRY

11. What is the mass percentage of nitrogen in the following active compounds present in fertilizers; (i) Ammonium Nitrate and (ii) Ammonium Sulfate

	(i) Ammonium Nitrate	(ii) Ammonium Sulfate
A.	35	40
B.	32	21
C.	35	21
D.	21	35

12. The electronic configurations of ions in quick lime (calcium oxide) are;

	Cation	*Anion*
A.	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	$1s^2\ 2s^2\ 2p^6$
B.	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6$	$1s^2\ 2s^2\ 2p^6\ 3s^2$
C.	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 4s^2$	$1s^2\ 2s^2\ 2p^6$
D.	$1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^4\ 4s^2$	$1s^2\ 2s^2\ 2p^4\ 3s^2$

13. Carat is a unit of weight, commonly abbreviated as “ct”. It is used to express the weight of diamonds. Lesedi La Rona [“Our Light” in Tswana language], the second-largest gem-quality diamond ever from Botswana weighed in at 1109 carats, (1 carat = 0.2 g). How many carbon atoms are in the Lesedi La Rona diamond?

A. 1.1×10^{23}
B. 1.1×10^{25}
C. 1.1×10^{26}
D. 1.3×10^{26}

QUESTIONS

14. The following redox equation occurs in an aqueous solution:

$KMnO_4 + KCl + H_2SO_4 \rightarrow MnSO_4 + K_2SO_4 + H_2O + Cl_2$

What is the stoichiometric coefficient for chlorine (Cl_2) when the equation is balanced with the smallest whole number coefficients?

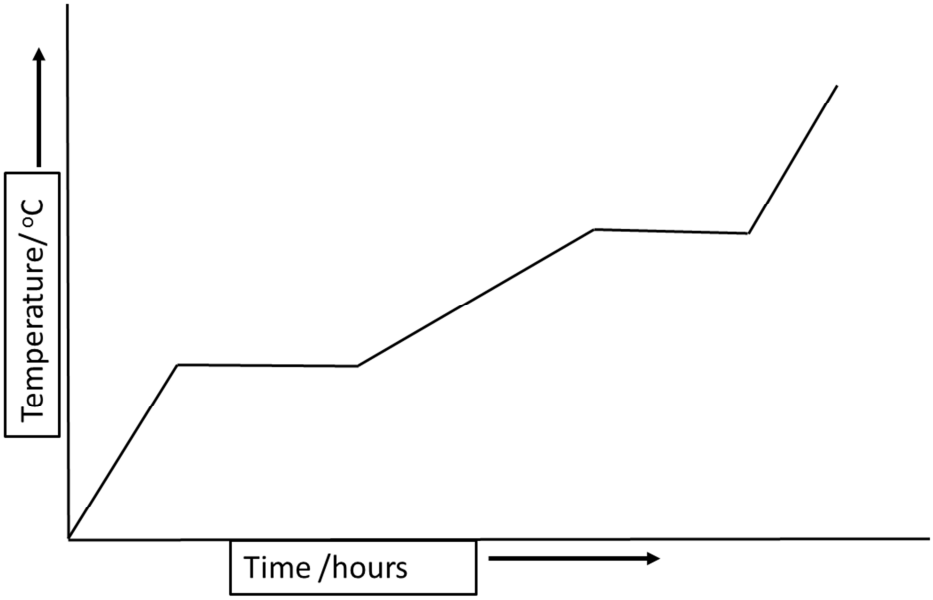
A. 1
B. 3
C. 5
D. 8

15. Equal volumes of 0.1 M $(NH_4)_2SO_4$ and 0.1 M NaI are mixed. Which statement describes what happens?

A. NH_4I precipitates when the solutions are mixed
B. Na_2SO_4 precipitates when the solutions are mixed
C. Both compounds remain in solution when the two solutions are mixed
D. Both NH_4I and Na_2SO_4 precipitate

QUESTIONS

16. The diagram shows how the temperature of a particular substance changes when it is heated at a uniform rate from a temperature below its freezing point to above its boiling point.



Consider the following statements:

I. The heat capacity of the solid form of the substance is larger than its liquid form.

II. The heat capacity of the vapor is larger than that of liquid.

Which of the following statement is correct?

A. Statement I and statement II are correct

B. Statement I is correct, while statement II is incorrect

C. Statement I is false while statement II is correct.

D. Both statement I and statement II are incorrect.

QUESTIONS

17. Use the following data to calculate the enthalpy of combustion for one mole of ethane, C_2H_6.

$$2C_2H_6\,(g) + 7O_2\,(g) \rightarrow 4CO_2\,(g) + 6H_2O\,(l)$$

$2C_2H_2\,(g) + 5O_2\,(g) \rightarrow 4CO_2\,(g) + 2H_2O\,(l)$	$\Delta H = -2600$ kJ
$C_2H_2\,(g) + 2H_2\,(g) \rightarrow C_2H_6\,(g)$	$\Delta H = -311$ kJ
$2H_2\,(g) + O_2\,(g) \rightarrow 2H_2O\,(g)$	$\Delta H = -484$ kJ
$H_2O\,(l) \rightarrow H_2O\,(g)$	$\Delta H = 44$ kJ

A. –1517 kJ/mol

B. –2772 kJ/mol

C. –3122 kJ/mol

D. –1561 kJ/mol

18. X is a symbol for a particular element. Which one of the following formulas is most likely incorrect (is NOT a reasonable formula)

A. X_2S_3
B. $X_2(NO_3)_3$
C. XCl_3
D. X_2O_3

19. Consider the equilibrium reaction: $3ClO^-(aq) \leftrightarrow ClO_3^-(aq) + 2Cl^-(aq)$. The equilibrium constant $K_c = 3.2 \times 10^3$. The following concentrations are present: $[Cl^-] = 0.50$ mol/L, $[ClO_3^-] = 0.32$ mol/L, $[ClO^-] = 0.24$ mol/L.

Is the mixture at equilibrium and, if not, in which direction will the reaction proceed?

A. The system is at equilibrium.
B. The system is not at equilibrium; reaction will proceed left to right.
C. The system is not at equilibrium; reaction will proceed right to left.
D. The system cannot reach equilibrium since the ClO_3^- and Cl^- concentrations are not in the stoichiometric ratio.

QUESTIONS

20. Manganese (III) fluoride can be prepared from the following reaction:

$2MnI_2\ (s) + 13F_2\ (g) \rightarrow 2MnF_3\ (s) + 4IF_5\ (l)$

Given that 0.050 mol of MnI_2 (s) is made to react with excess F_2 (g). What mass of MnF_3 will be obtained if the percentage yield is 75%?

A. 4.2 g.
B. 5.6 g
C. 7.5 g
D. 2.8 g

QUESTIONS

PHYSICS

21. A sample of oxygen gas occupies a volume of 0.250 m^3 at a pressure of 125 kPa. Assuming a constant temperature, what volume would the gas occupy at a pressure of 250 kPa?

A. 7.000 m^3

B. 0.125 m^3

C. 2.130 m^3

D. 0.438 m^3

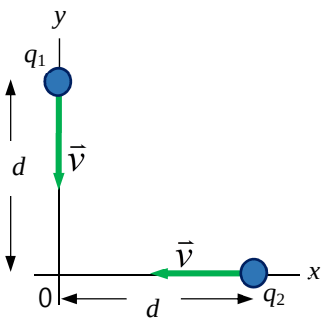
22. Two point charges q_1 and q_2, are each moving in vacuum towards the origin. At the instant shown q_1 is at position (0, d) and q_2 is at (d, 0). What is the magnitude of the electric force between the two charges? (Note $k = \frac{1}{4\pi\varepsilon_o}$).

A. $\frac{q_1 q_2}{4\pi\varepsilon_o d}$

B. $\frac{q_1 q_2}{8\pi\varepsilon_o d}$

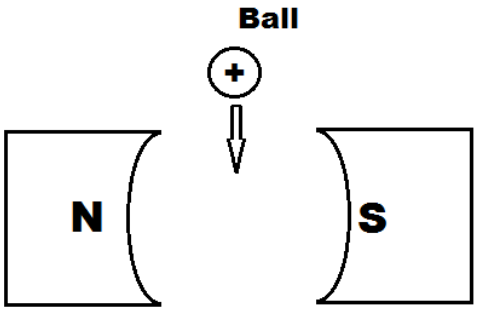
C. $\frac{q_1 q_2}{8\pi\varepsilon_o d^2}$

D. $\frac{q_1 q_2}{4\pi\varepsilon_o d^2}$



QUESTIONS

23. When a charged particle passes through a magnetic field, it is deflected. This deflection is dependent on the charge and the direction of the magnetic field. The diagram shows a positively charged ball falling through the jaws of a C-shaped magnet.



In which direction would the ball be deflected?

A. towards the north pole
B. towards the south pole
C. into the plane of paper
D. out of the plane of paper

24. A 15 kg mass is pulled along a horizontal frictionless surface with a component of force of 40 N along the east and a component of 30 N along north. What is the magnitude and direction (with respect to the east) of the acceleration of the mass?

A. $4.33\ m\ s^{-2}\ at\ an\ angle\ of\ 37^o$

B. $3.33\ m\ s^{-2}\ at\ an\ angle\ of\ 37^o$

C. $3.33\ m\ s^{-2}\ at\ an\ angle\ of\ 67^o$

D. $8.33\ m\ s^{-2}\ at\ an\ angle\ of\ 67^o$

25. When a tree dies it stops taking in carbon dioxide. The amount of carbon-14 decreases with time as it decays with a half-life of about 5700 years. What fraction of it would remain after 17100 years?

A. 7/8

B. 1/3

C. 1/8

D. 1/16

QUESTIONS

26. A dentist uses a spherical mirror to view the tooth of a patient. The required image is to be upright and five times the size of the tooth. Calculate the magnitude of the focal length of the mirror to be used if the tooth is to be viewed with the mirror 1.00 cm from the tooth.

A. 0.83 cm

B. 0.25 cm

C. 1.25 cm

D. 0.17 cm

27. A particle moves along a circular arc of length 5.00 cm. The angle subtended by the arc is 45^o. It takes 2.00 seconds to complete the arc. What is the frequency of the particle?

A. 0.125 Hz

B. 40.0 Hz

C. 2.50 Hz

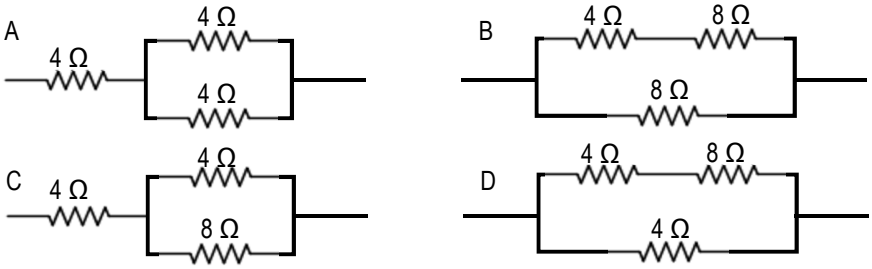
D. 0.0625 Hz

28. During construction of a certain building at Gaborone Central Business District, a crane raises a mass *m* through a vertical height *h* in time *t* at a constant velocity *v*. Which of the following gives the correct expression for the power *P* required to raise the mass?

A. $P = mg$
B. $P = mgh$
C. $P = \frac{mgh}{t}$
D. $P = \frac{mgv}{t}$

29. A student requires a 6 Ω resistor. The only resistors available in the laboratory are packs of 4 Ω and 8 Ω resistors. Which of the resistors combinations in the figure below would yield the required 6 Ω equivalent resistance?

QUESTIONS



30. Road accidents are a major concern to any nation. Momentum is a very crucial parameter when vehicles collide. When comparing the momentum of two moving vehicles, which of the following is correct?

A. The vehicle with the higher velocity will have less momentum, if the masses are equal.

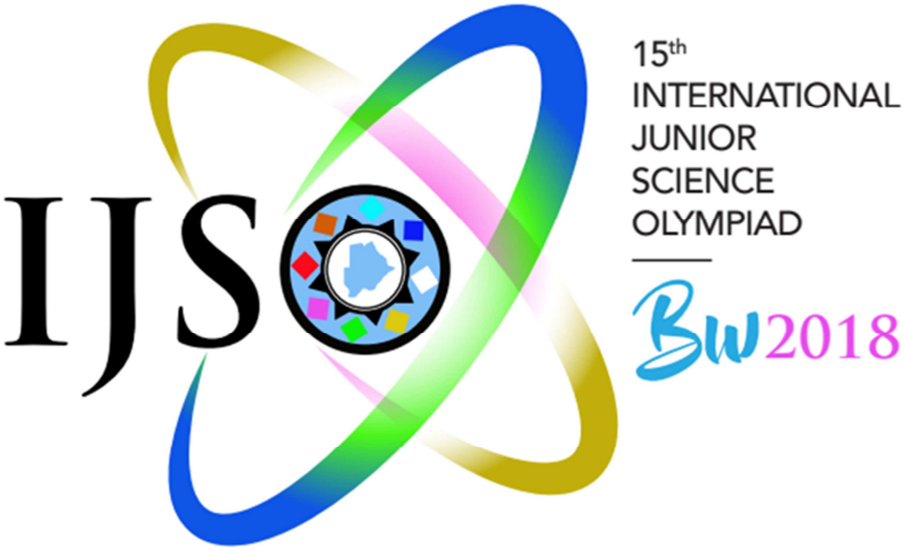
B. The vehicle with a larger mass will have less momentum, if its velocity is greater.

C. The vehicle with a smaller mass will have less momentum, if the velocities are the same.

D. The vehicle with a smaller mass will have more momentum, if the velocities are the same.

15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



Discovery, Innovation and Environment

Theory Competition

– Exam Sheet –

December 6, 2018
Do NOT turn to next page
before a whistle is blown.
Otherwise, you will receive a penalty.

1. You have 10 minutes to read “EXAMINATION RULES”, “EXAM INSTRUCTIONS”, and “CALCULATOR INSTRUCTIONS” on pages 1 - 3.

2. Do NOT start answering the questions before the“START”whistle! Otherwise, you will receive a penalty.

QUESTIONS

EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.
4. Do NOT start answering the questions before the “START” whistle.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need any assistance, you may raise your hand and wait for a supervisor to come.
7. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
8. At the end of the examination time you will hear the “STOP” whistle. Do NOT write anything more on the answer sheet after this stop whistle. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and rough book) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

QUESTIONS

EXAM INSTRUCTIONS

1. After the "START" whistle, you will have 3 hours to complete the exam.
2. ONLY use the pen provided by the organizers (not pencil).
3. NOW write your name, code, country and signature in your answer booklet. Raise your hand, if you do not have the answer booklet.
4. Only the answer booklet will be evaluated. Before writing your answers on the answer sheet, use the rough book if provided.
7. The total number of questions is 12. Check that you have a complete set of the test questions (16 pages + cover page), after the "START" whistle is blown. Raise your hand, if you find any missing sheets.

INSTRUCTIONS FOR CALCULATOR

1. Turning on: Press [ON/C].
2. Turning off: Press [2ndF] [ON/C].
3. Clearing data: Press [ON/C].
4. Addition, subtraction, multiplication, and division

Example 1) $45 + \frac{285}{3}$

[ON/C] *45* [+] *285* [÷] *3* [=] *140.*

Example 2) $\frac{18+6}{15-8}$

[ON/C] [(] *18* [+] *6* [)] [÷] [(] *15* [−] *8* [)] [=] *3.428571429*

Example 3) $42 \times (-5) + 120$

[ON/C] *42* [×] *5* [+/−] [+] *120* [=] *-90.*

[ON/C] *42* [×] [(] [−] *5* [)] [+] *120* [=] *-90.*

QUESTIONS

5. Exponential

Example 1) 8.6^{-2}

ON/C *8.6* y^x *2* +/− = *0.013520822*

Example 2) 6.1×10^{23}

ON/C *6.1* × *10* y^x *23* = *6.1 x* 10^{23}

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press DEL. If the cursor is located at the right end of a number/function, the DEL key will function as a back space key.

Constants and formulas

R= 0.082 L.atm mol^{-1} K^{-1}; R= 8.314 J.mol^{-1} K^{-1}; 1 atm = 101325 Pa.

Henry's law gives Concentration = KP, Law: k has a constant value for the particular liquid, and P is the pressure of the gas.

Do NOT turn to next page
Before the"START"whistle is blown.
Otherwise, you will receive a penalty.

QUESTIONS

BIOLOGY

Q1. [1.5 points]The Okavango Delta in Botswana is the world's largest inland delta, which was named a World heritage site in 2014. The delta's habitats comprise diverse plant and animal species making the area a hotspot for tourism. The swamps of Okavango Delta can be as deep as 7 meters, where dead animal and plant matter that settles at the bottom and decompose to produce biogas, which causes bubbling often observed by tourists during boat tours.

Source: http://www.wafb.com/

a) [0.3 points] Choose two (2) of the gases listed below, which are the major constituents of the gas in the bubbles. Write the appropriate letters into the corresponding box in the answer sheet.

A. C_3H_8
B. CH_4
C. CO
D. CO_2
E. H_2
F. O_2

QUESTIONS

b) [0.3 points] What are the beneficial uses of biogas to man? Select three (3) uses that apply by writing the corresponding letters in the boxes in the answer sheet.

A. heating
B. fermentation
C. cooking
D. fueling cars
E. fertilizer
F. purification

c) Plant and animal matter is decomposed by bacteria at the bottom of the swamps. Decide whether the following statements, regarding that decomposition process, are true or false by crossing the appropriate box in the answer sheet. [*0.4 marks*]

A. The decomposition of plant and animal tissue at the bottom of the swamps is an aerobic process.
B. The gases produced as a result of the degradation are metabolic waste products of bacterial metabolism.
C. The biochemical decomposition processes of plant and animal matter by bacteria does not require water molecules.
D. Bacteria that degrade plant and animal matter at the bottom of the swamp receive more energy from the degradation compared to bacteria decomposing the same plant and animal matter on the surface.

QUESTIONS

d) [0.25 points] The bacteria responsible for the production of biogas have higher activity at certain temperatures, and so is the rate of biogas evolution. A tour guide has over the years observed that bubbling is more intensive during the summer months.

Shown below are some possible explanations for this observation. Indicate on the answer sheet which possible explanations are correct or not by marking the appropriate box with a cross.

A. The bacteria are able to multiply more rapidly due to the higher temperatures.
B. The enzymes in the bacteria are working at close to their optimum rate.
C. More enzyme-substrate complexes are being formed, so more biogas can be made.
D. The kinetic energy of the enzyme and substrate molecules has decreased.
E. The enzymes in the bacteria have begun to denature.

e) Hydrogen peroxide is a reactive oxygen species that can kill bacteria if they do not have the enzymatic machinery to break it down. When an environmental water sample containing bacteria that can decompose plant and animal matter in the absence of oxygen was placed in a drop of hydrogen peroxide, there was no bubble formation.

[0.25 points] What is the most likely explanation for this observation? Write the corresponding letter in the box in the answer sheet.

A. Presence of an active gene encoding catalase
B. Absence of an active gene encoding catalase
C. Bubble formation is not dependent on the presence of catalase

QUESTIONS

Q2. [3.25 points] The genetic structure of a population is determined by the genotype and allele frequencies in the population. In a population, 350 of the individuals have the genotype AA, 100 have the genotype Aa, and 150 individuals have the genotype aa

a) What are the frequencies of the following genotypes?

a-1) [*0.25 points*] AA

a-2) [*0.25 points*] Aa

a-3) [*0.25 points*] aa

b) What are the frequencies of the following alleles in this population?

b-1) [*0.5 points*] A

b-2) [*0.5 points*] a

c) Genetic equilibrium within a population occurs when allele and genotype frequencies do not change over time. The Hardy-Weinberg formula ($p^2+2pq+q^2 = 1$; where, p is the frequency of the first allele and q is frequency of the second allele) shows the proportion of genotypes in a population that is in genetic equilibrium, i.e. allele and genotype frequencies remain constant over time. The expected frequencies of the homozygous genotypes are given by p^2 and q^2.The expected frequency of the heterozygous genotype is 2pq.

What would the expected frequencies of the following genotypes be if this population was in a genetic equilibrium?

c-1) [*0.5 points*] AA

c-2) [*0.5 points*] Aa

c-3) [*0.5 points*] aa

Q3. [3.75 points] The past recorded population of the African elephant (*Loxodonta africana*) in Chobe National Park, Botswana which covers an area of 11700 km^2 is shown

QUESTIONS

in the table below:

Year	*1990*	*1995*	*2000*	*2005*	*2008*	*2010*
Population size	*24500*	*26650*	*28650*	*29000*	*29500*	*31000*

a-1) [1.0 point] Use the data above to plot a graph of elephant population size against year using the graph paper provided.

a-2) [0.5 points] Draw the linear trend line of your data, and determine the equation of the line.

a-3) [0.25 points] What was the average growth rate of the elephant population from 1990 to 2010?

a-4) [0.5 points] What is the projected elephant population size in 2019?

b) [0.5 points] Calculate the difference in the density of the elephant populations in the Chobe National Park in 1995 and 2010.

c) [0.5 points] In vegetation inhabited by elephants, it is common to observe dead large trees. This is because elephants feed on barks of the tree stems during dry months, eventually leading to death of the entire tree. Each elephant consumes on average 200 kg/day of food, of which 35% is stripped from tree barks.

Calculate the total amount of bark that was stripped in 1995.

d) [0.5 points] Of the 200 kg consumed material, about 136 kg is returned to the environment as waste. While this might be good in terms of nutrient dynamics, the waste could pose a risk as a fire hazard due to the accumulation of all the dead material.

Calculate the percentage of the actual material utilized by the elephant per day.

QUESTIONS

Q4. [1.5 points]

Animal cells are surrounded by a cell membrane. Molecules in the membrane are oriented or positioned in a specific way within the membrane depending on their properties and functions.

Below is a list of terms associated with the cell membrane. Decide whether each of those corresponds to the interior of the membrane (within the membrane) or the exterior surfaces of the membrane and fill in the appropriate table in the answer sheet. The following terms given may be associated with one, both or neither of the compartments. Complete the table in your answer sheet, using "+" if the term applies and "0" if the term does not apply.

	Interior	Exterior
Hydrophobic		
Hydrophilic		
Fatty acid tails		
Ribosomes		
Ion Channels		
Oligosaccharides		

QUESTIONS

CHEMISTRY

Acid mine drainage and air pollution at a nickel mine

Q5 [8 points] Acid mine drainage (AMD) formation is widely recognized as one of the major environmental problems caused by mining worldwide. Minerals responsible for the generation of AMD are iron sulphides (pyrites), which are stable and insoluble when not in contact with water and atmospheric oxygen. When pyrite-rich waste ore is exposed to oxygen and water in the presence, of *Thiobacillus ferrooxidans* bacteria, AMD is produced due to the oxidation of pyrites according to the following equation:

$$4FeS_2(s) + 15O_2(g) + 14H_2O(l) \longrightarrow 4Fe(OH)_3(s) + 8H_2SO_4(aq)$$

BCL Limited, a copper-nickel mine in Botswana, mines and produces 450 tons/day of ore and experiences AMD problem. Solid waste material containing 5.00% by mass of pyrite is produced in the copper-nickel concentration processing plant. Due to this, BCL experienced the following problems:

- Neutralized water was discharged into a public stream at a rate of 300 m^3/h. The effluent quality did not meet the permitted level of 500 mg/L sulphate.
- The neutralization cost was too high due to imported lime.
- Excessive acid seepage had resulted in the deterioration of the land around the mine.

To combat these problems, BCL constructed a new chemical neutralization plant to treat 50 m^3/h of AMD in which treatment took place in phases as follows:

- Acid neutralization with limestone
  $CaCO_3(s) + H_2SO_4(aq) \longrightarrow CaSO_4(s) + CO_2(g) + H_2O(l)$
- Iron (iii) is precipitated according to the reaction below:
  $$Fe_2(SO_4)_3(aq) + 3CaCO_3(s) + 3H_2O(l) \longrightarrow 2Fe(OH)_3(s) + 3CaSO_4(s) + 3CO_2(g)$$

During commissioning of the plant (flow rate of 50.0 m^3/h), in which red lake water with a low iron(II) concentration of 100 mg/L was used as feed water, the following were observed:

- Acidity was reduced from 1100 mg/L to 50.0 mg/L (as $CaCO_3$)
- pH was raised from 1.9 to 6.0

It is reported that the BCL smelter emitted 534,000 tons of sulphur dioxide and a further

QUESTIONS

330,000 tons of carbon dioxide into the atmosphere directly and indirectly per annum. Sulphur dioxide may combine with water directly to form sulphurous acid, a weak acid:

$$SO_2(g) + 2H_2O(l) \longrightarrow H_3O^+(aq) + HSO_3^-(aq)$$

Alternatively, in the presence of particulate matter and aerosols, sulphur dioxide may react with atmospheric oxygen to form sulphur trioxide, which forms sulphuric acid in water:

$$2SO_2(g) + O_2(g) \longrightarrow 2SO_3(g)$$
$$SO_3(g) + 2H_2O(l) \longrightarrow H_3O^+(aq) + HSO_4^-(aq)$$

Sulphuric acid is a strong acid that is especially damaging to soil because it causes the leaching of calcium ions. Most soils contain clay particles, which are surrounded by layers of ions, including Ca^{2+}. However, calcium ions on the clay particles can be replaced by hydrogen ions from sulphuric acid.

[Questions]

5a. [0.5 point] If calcium hydroxide, was used instead of limestone, write the balanced equations for the neutralization and precipitation reactions.

5b. [1.75 point] If BCL produces 1.00 ton of solid waste in the copper-nickel processing plant:
What mass in kilograms of $Fe(OH)_3$ will be produced due to oxidation of pyrites?

5c. [0.5 point] Calculate the mass (in grams) of iron(II) in solution pumped into the chemical neutralization plant in 2 hours at the stated flow rate using the red lake water as feed?

5d. [1.0 points] When the red lake water with iron(II) concentration of 100 mg/L was used as feed water in the chemical neutralization plant, the pH of the waste water was observed to rise from 1.9 to 6.0. How many moles of H^+ ions were neutralized in one liter of solution?

5e. Studies have shown that the rate of biological oxidation of iron(II) is given by

$$rate = -\frac{d[Fe^{2+}]}{dt} = kA[Fe^{2+}][O_2]^{0.5}$$

Where k is the rate constant, A is the reactor surface area, $[Fe^{2+}]$ is the concentration of iron(II) and $[O_2]$ is the oxygen concentration.

QUESTIONS

5e-1. [0.15 point] What is the order of the reaction with respect to iron(II) expressed as a number?

5e-2. [0.25 point] A maximum rate of 16.1 $molL^{-1}s^{-1}$ was determined for iron(II) oxidation at BCL. What is the rate of reaction when the surface area of the reactor is doubled at constant volume?

5e-3. [0.5 point] What is the maximum rate of reaction when the pressure of oxygen gas is doubled?

5f. [2.0 points] One process used to clean SO_2 from emissions of coal-fired plants is to pass the emissions through a wet calcium carbonate slurry, where the following reaction occurs:

$$2CaCO_3(s) + 2SO_2(g) + O_2 \longrightarrow 2CaSO_4(s) + 2CO_2(g)$$

BCL used powdered calcium carbonate, a by-product from the paper industry. It contained 35.0% impurities by mass. What mass in tons of calcium carbonate is needed to remove one ton of sulphur dioxide if the removal process is 90.0% efficient?

In a separate study of the decomposition of calcium carbonate, a student added a 50.0 g sample of powdered $CaCO_3$ to a 1.00 L rigid container. The student sealed the container, pumped out all the gases, and then heated the container in an oven at 1100 K. As the container was heated, the total pressure of the CO_2 gas in the container was measured over time. The pressure increased steadily and reached a maximum of 1.04 atm after 12 minutes. The pressure remained constant on further heating.

The student repeated the experiment, but this time the student used a 100.0 g sample of powdered $CaCO_3$. In this experiment, the final pressure in the container was 1.04 atm, which was the same final pressure as in the first experiment.

5g. [0.6 point] Calculate the number of moles of CO_2 gas present in the container after 20 minutes of heating.

5h. After 20 minutes some CO_2 gas was injected into the container, initially raising the pressure to 1.5 atm at constant temperature.

QUESTIONS

5h-1. [0.25 point] What will be the final pressure inside the container?

Tick the correct answer

Less than 1.04 atm	
Greater than 1.04 atm	
Equal to 1.04 atm	

5h-2. [0.25 point] Where will the equilibrium shift to in the reaction equation below?

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Tick the correct answer

Right (product side)	
Left (reactant side)	
No change	

5i. [0.25 point] The equilibrium constant can be expressed in terms of partial pressure (K_p) in the same way as it can be expressed in terms of concentration (K_c). Calculate the value of the equilibrium constant, K_p, for the decomposition of $CaCO_3$ at 1100 K.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

6. [1.5 points] The mineral trona is a source of sodium carbonate according to the equation below:

$$2Na_5(CO_3)_2(HCO_3) \cdot 2H_2O(s) \xrightarrow{heat} 5Na_2CO_3(s) + CO_2(g) + 5H_2O(l)$$

What mass in kilogram of sodium carbonate can be formed from 0.850 ton of trona?

7. [0.5 points] Carbonic acid in rain water, results from the dissolving of atmospheric carbon dioxide in water.

The partial pressure of CO_2 in air saturated with water vapour at 25 °C is 3.04×10^{-4} atm and Henry's constant for CO_2 in water is 2.3×10^{-2} mol L^{-1} atm^{-1}. What is the concentration of carbonic acid in rain water?

QUESTIONS

PHYSICS

Q8. **[1.40 points]** An ambulance's siren emitting sound at 300.0 Hz is moving towards a stationery observer at a velocity of 90.0 km/h. The air temperature is 38.0 ^{o}C and the speed of sound is given by:

$$v_s = 331.3 + 0.606 \times T_c;$$

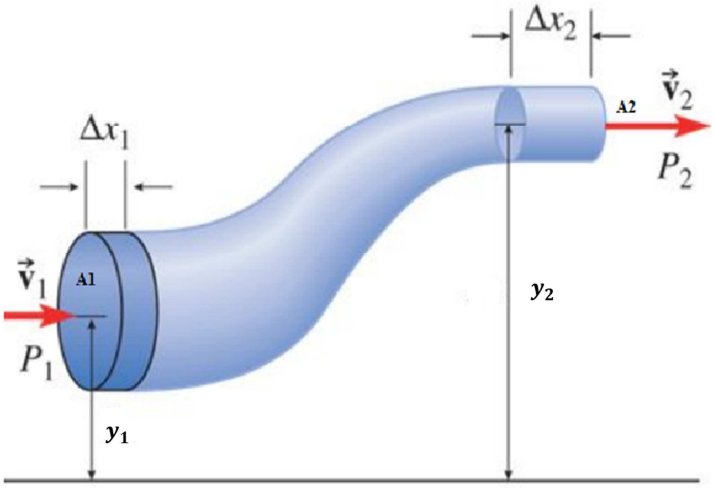
where v_s is the speed expressed in m/s and T_c is the temperature in ℃.

Calculate the frequency of sound that the observer would hear as the ambulance approaches the observer.

Q9 **[1.55 points]** The driver of a car moving on a straight road at a velocity of 33.2 m/s notices a cow crossing the road from 60.0 m away. The reaction time of the driver is 0.20 s. Assuming that the car is moving with uniform acceleration, calculate the acceleration of the car if it stops just before hitting the cow.

QUESTIONS

Q10 [2.55 points] A farmer in Mohembo is pumping water from Okavango river to his farm through a pipe which decreases in diameter from 0.35 m to 0.25 m (see illustration on the right). The farm is at an elevation of 960.0 m and the river is at an elevation of 940.0 m above sea level. The pump is pushing water at a gauge pressure of 670.0 kPa. The pressure P, velocity v, density of water ρ $(1000\, kg/m^3)$ and elevation y are related by Bernoulli's equation:



$$\frac{P}{\rho} + \frac{1}{2}v^2 + gy = constant,$$

The flow rate, Q of water through the pipe is given by continuity equation:

$$Q = A_1 v_1 = A_2 v_2,$$

where A_1 and A_2 are the cross-sectional area of the pipe. (Note that water is incompressible and its flow is laminar. Take the gravitational acceleration, $g = 9.80$ m/s^2).

If water is pumped at a velocity of 1.30 m/s at the river,

a) **[0.85 points]** Calculate the velocity of water through the pipe at the farm.
b) **[0.9 points]** Calculate the gauge pressure of water at the farm.
c) **[0.8 points]** Calculate the amount of time it would take to fill a reservoir of 50000 litres at the farm.

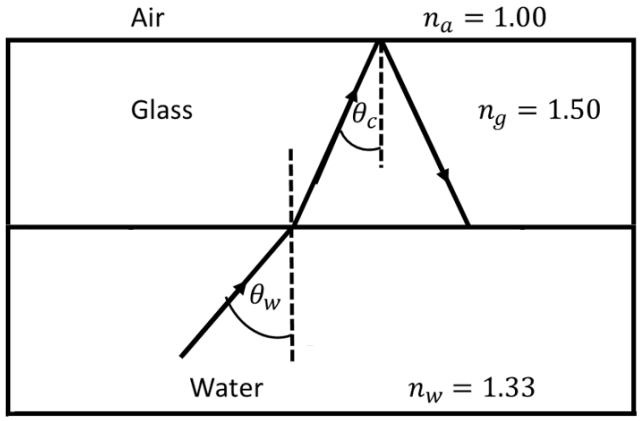
QUESTIONS

Q11. **[1.9 points]** A game is designed such that to win, ball A of mass 60.0 g hits ball B of mass 20.0 g which is at rest on the edge of a 1.225 m high table. After the head-on collision ball A falls and hits the floor at a horizontal distance of 1.0 m from the edge of the table while ball B falls and hits the floor at a horizontal distance of 2.0 m from the edge of the table. Calculate the velocity of ball A just before it hits ball B, for the player to win. (assume that the acceleration due to gravity $g = 9.80$ m/s²)

Q12 [2.6 points]

a) **[1.1 points]** A student placed a torch under water at an angle θ_w. The light ray from the torch passes into a glass plate as shown in the Figure to the right. The student observed that by varying angle θ_w, light passes through the glass or is internally reflected.

What is the minimum angle θ_w that will result in total internal reflection of the ray at the glass-air boundary?



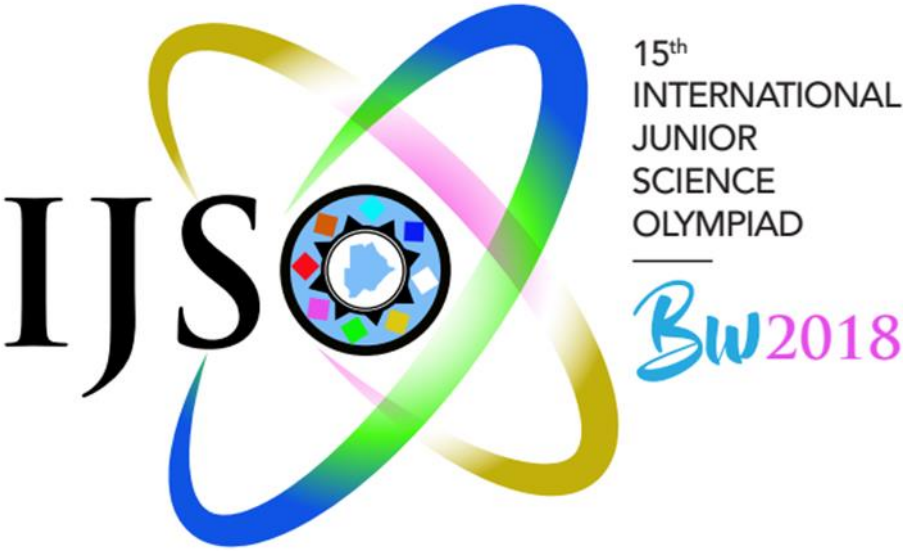
b) **[1.5 points]** When a light ray from air is incident onto a rectangular glass slab of thickness t with an angle of incidence θ_1, the angle of refraction at the air-glass surface is θ_2.

b-1) **[0.6 points]** Illustrate with a diagram the path of the ray through the slab and label the angles θ_1 and θ_2.

b-2) **[0.9 points]** Find the expression for the perpendicular distance s between the extended incident ray and the emergent ray exiting the slab in terms of θ_1 and θ_2 and t.

15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



Discovery, Innovation and Environment

Laboratory Experiment

– Exam Sheet –

December 8, 2018
Do NOT turn to next page
before a whistle is blown.
Otherwise, you will receive a penalty.

1. You have 10 minutes to read the "EXAMINATION RULES", "EXPERIMENT INSTRUCTIONS" and "CALCULATOR INSTRUCTIONS" on pages 1 - 4.

2. Do NOT start answering the questions before the "START" whistle! Otherwise, you will receive a penalty.

EXAMINATON RULES

1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated table.
3. Check the stationery items (pen, pencil, calculator, ruler, and scrap paper) provided by the organizers.
4. Do NOT start your experiments before the **"START"** signal.
5. You are NOT allowed to leave the examination room during the experiment, except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need assistance, raise your hand and wait for a supervisor to come.
7. You can ONLY ask questions and discuss the experiments with your own team members. You must STAY at your table until the end of the time allocated for the experiments, even if you have finished the experiments or do not wish to continue.
8. At the end of the experiment time you will hear the **"STOP"** signal. Do NOT write anything more on the answer sheet after this stop signal. Arrange the exam, answer sheets, and the stationary items (pen, calculator, ruler, and scrap paper) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXPERIMENT INSTRUCTIONS

1. After the "START" signal, you will have 15 minutes to read the experiments. In this time, it is NOT allowed to conduct the experiment yet, or answer the questions.

2. After the first 15 minutes, another whistleblow will indicate that you can start the experiment and start answering questions. From this moment you have three hours to complete the test.

3. Use only the pen and pencil provided by the organizers.

4. The total number of experiments is 3. Check if you have a complete set of the exam sheets (19 pages, page 4 – page 19) and answer sheets (23 pages - including the front page). Raise your hand, if you find any sheets missing.

5. Check that your name, code and country are filled in on your answer sheets and sign every page of the answer sheets. Raise your hand, if you find any sheets missing.

6. Read the experimental procedures and questions carefully and write your answers in the corresponding boxes of the answer sheets.

7. When units are provided in the answer sheets, you have to write the answers correctly for the units.

8. Always show your calculations if room for this is provided. If you do not show your calculations, no points are awarded for the question.

9. You should write your final answers down in the appropriate number of digits.

10. You MUST wear a **Lab Coat** and **Safety Glasses** during the experiments.

CALCULATOR INSTRUCTIONS

1. Turning on: Press [ON/C].

2. Turning off: Press [2ndF] [ON/C].

3. Clearing data: Press [ON/C].

4. Addition, subtraction, multiplication, and division

Example 1) $45 + \frac{285}{3}$

[ON/C] *45* [+] *285* [÷] *3* [=] ***140.***

Example 2) $\frac{18+6}{15-8}$

[ON/C] [(] *18* [+] *6* [)] [÷] [(] *15* [−] *8* [)] [=] ***3.428571429***

Example 3) $42 \times (-5) + 120$

[ON/C] *42* [×] *5* [+/−] [+] *120* [=] ***-90.***

[ON/C] *42* [×] [(] [−] *5* [)] [+] *120* [=] ***-90.***

5. Exponential

Example 1) 8.6^{-2}

[ON/C] *8.6* [y^x] *2* [+/−] [=] ***0.013520822***

Example 2) 6.1×10^{23}

[ON/C] *6.1* [×] *10* [y^x] *23* [=] ***6.1 x 10^{23}***

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press [DEL]. If the cursor is located at the right end of a number/function, the [DEL] key will function as a back space key.

Do NOT turn to next page
Before the "START" whistle is blown.
Otherwise, you will receive a penalty.

INTRODUCTION

The population of the earth has grown rapidly over the past decades. To address the demand of a sustainable source of food, plant-based nutrition is gaining importance. To further facilitate this development, modern food engineering focuses on enhancing the properties of plant products, besides nutritional value alone. Extracted plant oils can be used as emulsifiers or a more sustainable energy source; isolated plant pigments offer natural food coloring options or a basis for diverse technological products such as solar panels; plant organic acids can be used as natural preservatives to extend the shelf life of food products or influence the digestion of carbohydrates. Such developments aim to diminish the dependence on fossil resources and rare earths.

This experiment lets you explore the properties of several plant extracts directly.

BIOLOGY LABORATORY PRACTICAL

Total points [13.4 points]

Experiment I: Using thin layer chromatography technique to identify plant compounds

Thin-layer chromatography (TLC) is a technique used to identify compounds contained within biological extracts (e.g. plant extracts from steam distillation). As in other chromatographic methods, TLC is based on the principle of differential separation of compounds within a mixture. However, unlike other chromatographic methods, TLC is a simple, relatively cheap, highly sensitive and has a short development time.

The TLC system consists of different components such as TLC plates, chamber and mobile phase. TLC plates are usually ready-made and are coated with a thin layer of a stationary phase. The stationary phase of the plates is applied uniformly (uniform thickness throughout the plate). The TLC plates are developed in a TLC chamber, which contains the mobile phase. The mobile phase is made of a solvent (or mixture of solvents) which is chemically inert with the sample and is of high purity. It helps to separate compounds as they move up the TLC plate. Upon completion of the vertical separation of different compounds (which will appear as spots), each compound/spot will have a retention factor (also known as retardation factor) R_f value. The R_f value is calculated using the following formula:

R_f = (distance travelled by compound) / (distance travelled by mobile phase)

Since R_f values are unique for each compound, they can be used to identify different compounds. Within plant extracts, TLC can separate and help indicate presence of different compounds such as plant pigments and secondary metabolites. These compounds occur naturally in plants and are often found as a mixture within plant extracts. However, they each have unique R_f values which can help to identify them within the mixture.

Solutions A-D (provided to you) are made of different plant extracts.

Using the TLC technique and protocol below identify compounds found in each of the solutions A-D.

Materials provided

1. One TLC plate
2. Pencil
3. 10 µL capillary tubes (four tubes, in a Petri dish)
4. Four solutions (A-D)
5. TLC chamber (jar) and lid, containing mobile phase (cyclohexane: petroleum ether: ethyl acetate: acetone: methanol in a ratio of 16:60:10:10:4)
6. Ruler
7. Latex gloves
8. Paper towel

Procedure

Notes:

- ***Only a single TLC plate is provided per team. Prepare and use your plate with utmost care, following the procedure outlined below***
- ***The black mark on the capillary tube denotes the 10 µL mark***
- ***Use only pencil when drawing or writing on a TLC plate***
- ***Wear gloves when handling TLC plates***
- ***When opening and closing the TLC chamber, avoid inhaling vapors from the chamber***

1. Place the chromatography plate on a clean surface (paper towel). Draw two straight lines across the TLC plate, 1.5 cm from one end (the bottom) and 1 cm at the other end (the top). Without putting the plate into the TLC chamber, check that it will fit in the chamber.
2. On the line at the bottom, make 4 spots 1 cm apart from each other (the first and last spots should be 0.75 cm away from the edge of the TLC plate). Label each spot A-D.
3. Use a capillary tube to load about 5 µl of sample A on the pencil spot marked A. The sample should be placed drop by drop. A**llow each drop to dry before loading another.** Make sure the sample does not spread to make a circle over a diameter of 0.75 cm. Repeat for samples B-D. See Figure 1 for example of TLC plate. **Note, if the capillary tube breaks, immediately request a replacement one.**

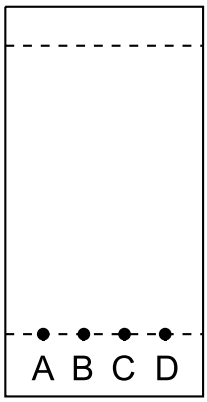


Figure 1: Example of a TLC plate with sample spots

4. Once done, carefully place the TLC plate in the jar containing the mobile phase (spotted side facing you).
5. Close the chamber **tightly** with the lid and watch the mobile phase move up your TLC plate.
6. When the mobile phase reaches the top pencil line that you marked remove the TLC plate, place it on the paper towel and allow it to dry.
7. Use your TLC plate and the information provided in Table 1 to answer the questions that follow.
8. Get the invigilator to take a photograph of your original TLC plate and to sign your answer sheet (this can be done at any time during the experiment)

Table 1: Plant pigments and their R_f values, determined using the above procedure

Plant pigment		**R_f value**
i)	Xanthophyll 2	0.15
ii)	Xanthophyll 1	0.28
iii)	Rutin	0.34
iv)	Chlorophyll b	0.42
v)	Gallic acid	0.54
vi)	Chlorophyll a	0.59
vii)	Pheophytin	0.81
viii)	Carotene	0.98

Questions

DO NOT PROVIDE YOUR FINAL ANSWERS HERE. USE THE ANSWER SHEET

I-1. **[7.15 points]** In your answer sheet, draw a sketch of all the spots observed in lanes A-D on your TLC plate, and complete the table with R_f values and proposed pigments (Roman numeral from Table 1, one per spot) Note that not all pigments in your sample are present in Table 1.
Get your invigilator to take a photograph of your original TLC plate and sign your answer sheet.

I-2. **[1.0 point, 0.25 per statement]** For the following observations about the sample in lane D, mark in your answer sheet whether the following statements are true or false.

Statement	True	False
It separated into distinct pigments, which are not present in other lanes.		
It separated into distinct pigments, which are also present in other lanes.		
It did not move with mobile phase.		
It does not contain any pigments		

I-3. **[1.0 point, 0.25 per statement]** For the following statements, mark in your answer sheet whether the following statements are true or false

The TLC chamber (bottle) is closed to…

Statement	**True**	**False**
prevent evaporation of the mobile phase.		
avoid the smell of the chemicals contained in the mobile phase.		
maintain a dust-free environment.		
decrease the pressure in the chamber.		

I-4. **[1.75 points, 0.25 per statement]** Indicate in your answer sheet, whether each of the factors below affect the R_f value of a compound

Factor	**Affects R_f**	**Does not affect R_f**
Polarity of compound		
Distance travelled by solvent (mobile phase)		
Size of TLC plate		
Type of stationary phase		
Amount of sample loaded		
Size of chamber		
Color of the sample		

I-5. **[0.25 points]** Write the letter that corresponds to the pigment that moves slowest up the TLC plate in the box on your answer sheet.

A. Chlorophyll *a*
B. Xanthophyll 1
C. Pheophytin
D. Chlorophyll *b*

I-6. **[1.0 point, 0.25 per statement]** For the following statements, mark in your answer sheet whether the statements are correct or incorrect.

A compound moves slower than others up a TLC plate in our experimental conditions because…

Statement	Correct	Incorrect
It is less polar than the other compounds		
It is a more hydrophilic compound		
It has a larger molecular weight		
It is more concentrated than the other compounds		

I-7. **[0.25 points]** Will the R_f values change if the ratio of polar and non-polar solvents in the mobile phase is changed? Write the letter that corresponds to your answer in the box on your answer sheet.

A. Yes
B. No

I-8. **[1.0 point, 0.25 per statement]** Indicate in your answer sheet, whether each of the factors could potentially limit the effectiveness of the chromatographic technique you have used.

Factor	Limits effectiveness	Does not limit effectiveness
Leaving the TLC chamber open		
The amount of mobile phase in the TLC chamber		
Geographical location where the experiment is performed		
Running multiple plates in one TLC chamber		

CHEMISTRY LABORATORY PRACTICAL

Total points [13.3 points]

Experiment II: Determination of acid content in a fruit acid solution

The purpose of this experiment is to investigate the acid concentration and properties of the fruit acid. The active ingredient in the fruit solution is a weak acid, which can be titrated with a base in an acid-base neutralization reaction. The abbreviation for the fruit acid is HA. The sodium hydroxide solution will neutralize the fruit acid, HA, which is monoprotic. HA has the molecular mass of 60g/mol. Before you determine the concentration of the fruit acid solution you need to standardize the sodium hydroxide solution using oxalic acid of a known concentration (0.100 mol/L). Note that Oxalic acid is a diprotic acid and may be represented as H_2X.

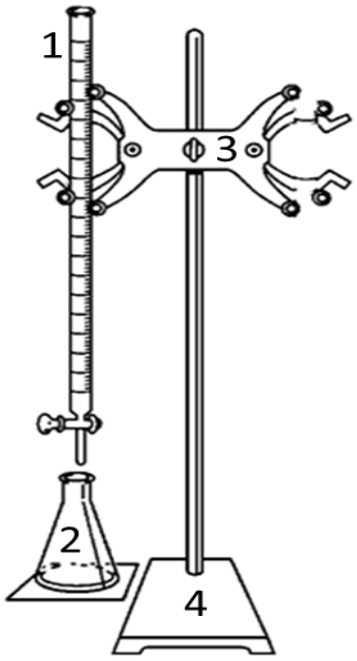


Figure II-1: A diagram showing the set-up for titration.
Key: **1**. Burette, **2**. Conical flask, **3**. Clamp **4**. Stand

Materials provided

1. 10 mL graduated pipette (x 2)
2. Glass funnel
3. Pipette filler
4. 3 x Beakers
5. White ceramic tile
6. 100 mL graduated measuring cylinder
7. Phenolphthalein indicator in a bottle, with dropper
8. Paper towel
9. Distilled water bottle

Procedure

Standardization of the NaOH

III-1. Using a 10 mL pipette place 10.0 mL of 0.100 mol/L oxalic acid solution into the 250-mL conical flask.

III-2. Add 2 to 3 drops of phenolphthalein indicator.

III-3. Titrate to the end point with the NaOH solution.

III-4. Repeat this process (Steps 1-3), until your results are coherent.

Titration of fruit acid solution

III-5. Using a graduated pipette place 4.0 mL of the fruit acid solution into the 250-mL conical flask.

III-6. Add about 50 mL of distilled water into the same 250 mL conical flask.

III-7. Add 2 to 3 drops phenolphthalein indicator.

III-8. Titrate to the end point with the standardized NaOH solution.

III-9. Repeat this process (Steps 5-8), until your results are coherent.

Questions

DO NOT PROVIDE YOUR FINAL ANSWERS HERE USE THE ANSWER SHEET

Standardization of the NaOH

II-1a. [3.5 points] In your answer sheet, record the volume of NaOH (mL) solution used in the standardization

Record the volume of NaOH (mL) solution used in the standardization				
	Titration #1	Titration #2	Titration ….	Titration …..
Initial Vol.	……..	……..…..	…….	…….
End Vol.	…….	……	….……	……
Vol. Used	……	…….	…….	……
Average NaOH volume used……..……mL				

II-1b. [0.25 points] Write down a balanced chemical equation for the titration reaction of oxalic acid (H_2X) with NaOH

II-1c. [0.5 points] Calculate the concentration of the NaOH solution

Titration of fruit acid solution

II-2. [3.5 points] In your answer sheet, record the volume of NaOH (mL) solution used

Record the volume of NaOH (mL) solution used				
	Titration #1	Titration #2	Titration ….	Titration …..
Initial Vol.	……..	……..…..	…….	……..….
End Vol.	…….	……	….……	……
Vol. Used	……	…….	…….	……
Average NaOH volume used……..……mL				

II-3. [0.25 points] Write down the balanced equation for the titration reaction between fruit acid (HA) and NaOH

II-4. [0.5 points] Determine the number of moles of NaOH used in the titration.

II-5. [1.0 point] Determine the mass (g) of acid in the fruit acid solution titrated with NaOH solution

II-6. [0.5 points] Assuming the density of fruit acid solution is 1.005 g/mL, determine the mass (g) of 4 mL solution.

II-7. [0.5 points] Determine the % mass of the acid in fruit acid solution

II-8. [1.0 point] A student used a different NaOH solution and required 25 mL of 0.54 mol/L NaOH to neutralize a sample of the same fruit acid solution. Calculate the volume of the fruit acid solution that the student used?

II-9. [0.5 points] Another student has measured the pH of the fruit acid solution to be 2.75. Use this value and your data to determine the pK_a of the fruit acid solution.

II-10a. [0.5 points] Calculate the K_b of the conjugate base of the fruit acid solution

II-10b. [0.5 points] Calculate the pH at the end point, assuming that the final volume of the solution is 100 mL. Use the K_b from the previous question

II-11. [0.3 points] If phenolphthalein was unavailable, which of the following indicators would be most suitable for this titration.

In your answer sheet, mark the correct box with an "X"

Indicator	pKa	
Methyl violet	0.8	
Thymol blue	1.6	
Methyl yellow	3.3	
Bromocresol green	4.7	
Thymol Blue	8.9	

PHYSICS LABORATORY PRACTICAL

Total points [13.3 points]

Experiment III: Determination of the coefficient of viscosity of oil

While water can be poured from one container to another easily, honey takes a very long time to flow out of its container. The reason for these different rates of flow is that honey is more viscous and resists flow more than water does. The coefficient of viscosity is a measure of the degree of internal resistance to flow and shear. Coefficient of viscosity is an important parameter in the food industry. Flow of various components of the raw materials to the final product in an automated food industry will depend on this.

The viscosity of a fluid can be determined by measuring the velocity of a falling sphere through a column of fluid of unknown viscosity. This is accomplished by dropping a sphere through a measured distance in a column of fluid and measuring how long it takes to travel the distance.

Materials provided

1. Thermometer
2. Balls of 4 different diameters
3. Cylindrical vertical tube filled with oil
4. Stopwatch
5. Meter ruler
6. Tape to mark
7. Paper towel
8. Magnet

Theoretical aspects

Consider a spherical ball bearing of radius r and density ρ_s falling through a column of fluid of coefficient of viscosity η and density ρ_f as illustrated in Figure 1 below.

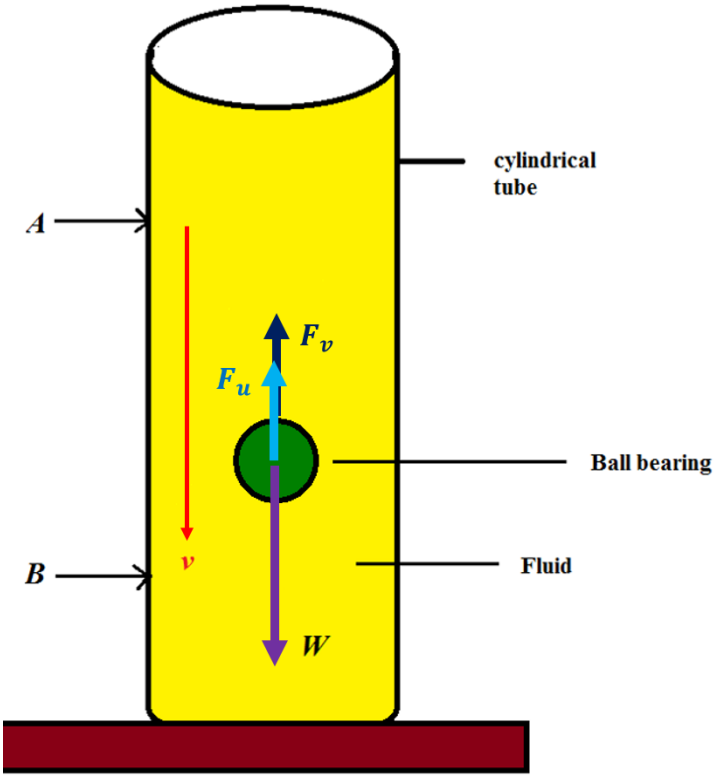


Figure 1: Showing a spherical ball of radius r falling through a column of fluid of density ρ_f. ***A*** *and* ***B*** *marks the distance travelled by the sphere at terminal velocity* v_t.

Initially the ball has some downward acceleration a until the ball acquires a constant velocity, called terminal velocity v_t. According to Newton's second law:

$$\text{Net Force} = ma$$

$$ma = W - (F_u + F_v) \qquad (1)$$

Where:

m is the mass of the ball.
$W = mg$ is the weight of the ball.
$F_u = \frac{4}{3}\pi r^3 \rho_f g$ is the buoyant force = weight of the fluid displaced (Archimedes law)
$F_v = 6\pi\ \eta\ r\ v$ is the viscous force (of a sphere of radius *r*) proportional to the velocity v of the ball (Stokes's Law).

Secondly when the ball attains terminal velocity before point **A**, there is no more acceleration and hence the net force is zero. Note that $\boldsymbol{l}$ is the distance between **A** and **B** and $\boldsymbol{t}$ is the time the ball takes to fall between **A** and **B**.

Procedure **[1.3 points]**

1. Measure the temperature T_b of the oil before starting the experiment and write it in the box on the answer sheet.
2. Use the tape to mark two horizontal lines (**A** and **B**) on the cylindrical tube so that line **A** is 70 cm from the surface of the fluid. Line **B** should be approximately 50 cm below line **A**.
3. Measure the vertical distance $\boldsymbol{l}$ between lines **A** and **B** and write it in the box on the answer sheet provided.
4. Devise a method to measure the average diameter of the balls of the same size using the ruler scale as accurately as possible. Describe your method using only a sketch in the space provided.
5. Use your method to measure the average diameter of each of the four different sizes of balls and write these values in Table III-1 on the answer sheet.
6. Release one of the balls carefully into the fluid at the center of the surface (ensuring that the ball is not near the wall of the cylinder during its motion between **A** and **B**)
7. Measure the time $\boldsymbol{t}$ taken by the ball to travel the distance $\boldsymbol{l}$ between **A** and **B** and record it in the provided table.
8. Repeat steps 6 and 7 above using other balls of the same diameter to have three values of time (the magnet can be used to pull the balls along the cylinder wall out of the oil, ask for help if necessary).
9. Repeat steps 6 to 8 for the other 3 sizes of balls.
10. Measure the temperature T_a of the oil just after finishing the experiment and write it in the box on the answer sheet.

Note the following constants:

Density of the fluid	$\rho_f = 871.4$ kg/m^3
Density of the ball	$\rho_s = 7717$ kg/m^3
Acceleration due to gravity	$g = 9.81$ m/s^2

Questions (results and analysis)

DO NOT PROVIDE YOUR FINAL ANSWERS HERE USE THE ANSWER SHEET

III-1. [5.0 points] Calculate the average time, d^2 and v_t for each set of ball bearings, and complete Table III-1 on the answer sheet.

Table III-1: Experimental results

Ball diameter			**Diameter squared**	**Time taken to fall distance l**				**Terminal velocity**
#	**d** (mm)	**d** (m)	**d^2** (m²)	**t_1** (s)	**t_2** (s)	**t_3** (s)	Average time (s)	**v_t (m/s)**
1								
2								
3								
4								

III-2. [3.0 points] Plot a graph of v_t (y-axis) versus d^2 (x-axis) and draw a straight line of best fit on the grid on the answer sheet.

III-3. [1.5 points] Determine the slope of the graph. Indicate the points that are used on the graph for calculating the slope. Give your answer with appropriate units.

III-4. [1.0 points] The following formula for the terminal velocity v_t can be derived from equation (1):

$$v_t = C \cdot \frac{d^2}{\eta} \qquad (2)$$

Where $C = 3731$ kg m^{-2}s^{-2}.

Write down in the space provided the analytical expression for C in terms of g, ρ_s and ρ_f.

III-5. [1.5 points] Use the value of the slope to determine the coefficient of viscosity η of the oil with the appropriate units.

15th International Junior Science Olympiad
Botswana
December 4, 2018

Multiple Choice Competition
Time : 3 hr
Points : 30

ANSWER SHEET

Name	MARKING GUIDE	Code	MCQ
Country	IJSO 2018	Signature	Binigia

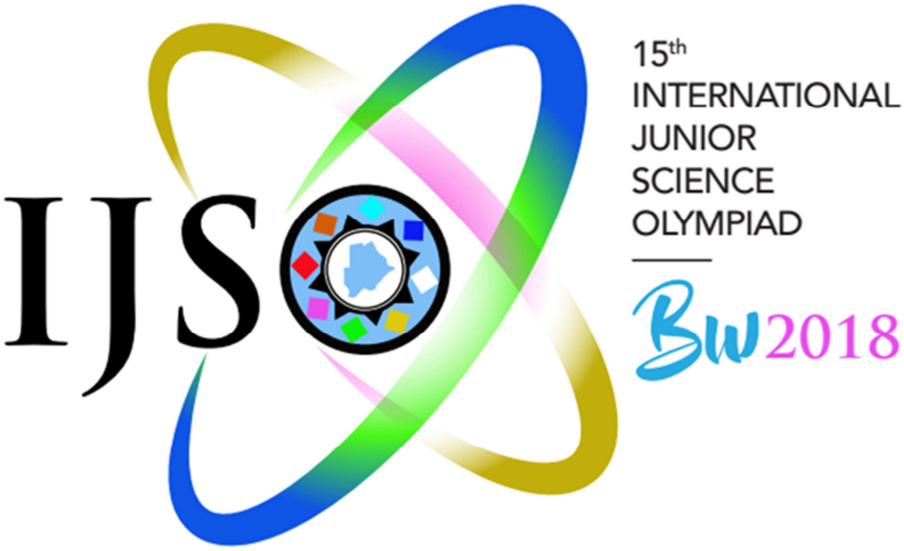
	Answers					Answers			
1	A	B	C	~~D~~	16	A	B	C	~~D~~
2	~~A~~	B	C	D	17	A	B	C	~~D~~
3	A	B	~~C~~	D	18	A	~~B~~	C	D
4	A	B	~~C~~	D	19	A	~~B~~	C	D
5	A	B	~~C~~	D	20	~~A~~	B	C	D
6	A	~~B~~	C	D	21	A	~~B~~	C	D
7	A	B	C	~~D~~	22	A	B	~~C~~	D
8	A	B	~~C~~	D	23	A	B	C	~~D~~
9	A	B	C	~~D~~	24	A	~~B~~	C	D
10	~~A~~	B	C	D	25	A	B	~~C~~	D
11	A	B	~~C~~	D	26	A	B	~~C~~	D
12	~~A~~	B	C	D	27	A	B	C	~~D~~
13	A	~~B~~	C	D	28	A	B	~~C~~	D
14	A	B	~~C~~	D	29	~~A~~	B	C	D
15	A	B	~~C~~	D	30	A	B	~~C~~	D

---------- DO NOT WRITE BELOW ----------

Correct answers		Wrong answers	
No answers		Total point	

15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



Discovery, Innovation and Environment

Theory Competition

MARKING GUIDE

– Exam Sheet –

December 6, 2018

Do NOT turn to next page

before a whistle is blown.

Otherwise, you will receive a penalty.

1. You have 10 minutes to read "EXAMINATION RULES", "EXAM INSTRUCTIONS", and "CALCULATOR INSTRUCTIONS" on pages 1 - 3.

2. Do NOT start answering the questions before the"START"whistle! Otherwise, you will receive a penalty.

QUESTIONS

EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for personal medicine or approved personal medical equipment.
2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.
4. Do NOT start answering the questions before the **"START"** whistle.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need any assistance, you may raise your hand and wait for a supervisor to come.
7. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
8. At the end of the examination time you will hear the **"STOP"** whistle. Do NOT write anything more on the answer sheet after this stop whistle. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and rough book) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

QUESTIONS

INSTRUCTIONS FOR CALCULATOR

1. Turning on: Press [ON/C].

2. Turning off: Press [2ndF] [ON/C].

3. Clearing data: Press [ON/C].

4. Addition, subtraction, multiplication, and division

Example 1) $45 + \frac{285}{3}$

[ON/C] *45* [+] *285* [÷] *3* [=] ***140.***

Example 2) $\frac{18+6}{15-8}$

[ON/C] [(] *18* [+] *6* [)] [÷] [(] *15* [−] *8* [)] [=] ***3.428571429***

Example 3) $42 \times (-5) + 120$

[ON/C] *42* [×] *5* [+/−] [+] *120* [=] ***-90.***

[ON/C] *42* [×] [(] [−] *5* [)] [+] *120* [=] ***-90.***

5. Exponential

Example 1) 8.6^{-2}

[ON/C] *8.6* [y^x] *2* [+/−] [=] ***0.013520822***

Example 2) 6.1×10^{23}

[ON/C] *6.1* [×] *10* [y^x] *23* [=] ***6.1 x 10^{23}***

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press [DEL]. If the cursor is located at the right end of a number/function, the [DEL] key will function as a back space key.

QUESTIONS

Do NOT turn to next page Before the"START"whistle is blown.

Otherwise, you will receive a penalty.

QUESTIONS

Biology

Q1

a) Choose two (2) of the gases listed, which are the major constituents of the gas in the bubbles. Write the appropriate letters into the boxes below. **[0.3 marks, 0.15 for each correct answer]**

B	D

b) What are the beneficial uses of biogas to man? Write three (3) letters corresponding to uses in the boxes below. **[0.3 marks, 0.1 for each correct answer]**

A	C	D

c) Decide, whether the following statements regarding that decomposition process are true or false by marking the appropriate box with a cross (X). **[0.4 marks, 0.1 for each correct answer]**

Statement	True	False
The decomposition of plant and animal tissue at the bottom of the swamps is an aerobic process.		X
The gases produced as a result of the degradation are metabolic waste products of bacterial metabolism.	X	
The biochemical decomposition processes of plant and animal matter by bacteria do not require water molecules.		X

QUESTIONS

Bacteria that degrade plant and animal matter at the bottom of the swamp receive more energy from the degradation compared to bacteria decomposing the same plant and animal matter on the surface.		X

d) What could be the explanation of the observation described? Indicate, which of these options could be true and which ones false by marking the appropriate box with a cross (X). **[0.25 marks, 0.05 for each correct answer]**

Possible explanation	True	False
The bacteria are able to multiply more rapidly due to the higher temperatures.	X	
The enzymes in the bacteria are working at close to their optimum rate.	X	
More enzyme-substrate complexes are being formed, so more biogas can be made.	X	
The kinetic energy of the enzyme and substrate molecules has decreased.		X
The enzymes in the bacteria have begun to denature.		X

e) What is the most likely explanation for the observation described? Write the corresponding letter in the box below. **[0.25 marks]**

B

QUESTIONS

Q2

a) Use the space given below to calculate the frequencies of the genotypes AA, Aa and aa. **[0.75 marks, 0.25 for each correct answer]**

Calculations [AA] = (350/600) = **0.583** [Aa] = (100/600) = **0.167** [aa] = (150/600) = **0.250**		
Frequency of genotype AA: **0.583 [*0.25 marks*]**	Frequency of genotype Aa: **0.167 [*0.25 marks*]**	Frequency of genotype aa: **0.250 [*0.25 marks*]**

b) Use the space given below to calculate the frequencies of alleles A and a. **[1.0 mark, 0.5 for each correct answer]**

Calculations [A] = ((700+ 100)/1200) = **0.667** or [350 + 50 /600] [a] = ((100 + 300)/ 1200) = **0.333** [150+50/600]	
Frequency of allele A: **0.6667 [0.5 marks]**	Frequency of allele a: **0.3333 [0.5 marks]**

QUESTIONS

c) Use the space given below to calculate the expected frequencies of the genotypes AA, Aa and aa if the population was in a genetic equilibrium. **[1.5 marks, 0.5 for each correct answer]**

Calculations		
[AA] = p^2 = (0.67*0.67) = **0.450** [Aa] =2pq = 2*0.67 *0.33 = **0.440** [aa] = q^2 = 0.33*0.33 = **0.110**		
Frequency of genotype AA: **0.45 [0.5 marks]**	Frequency of genotype Aa: **0.44 [0.5 marks]**	Frequency of genotype aa: **0.11 [0.5 marks]**

Q3

a-1) Plot a graph of population size against year using the graph paper provided **[1.0 marks]**

QUESTIONS

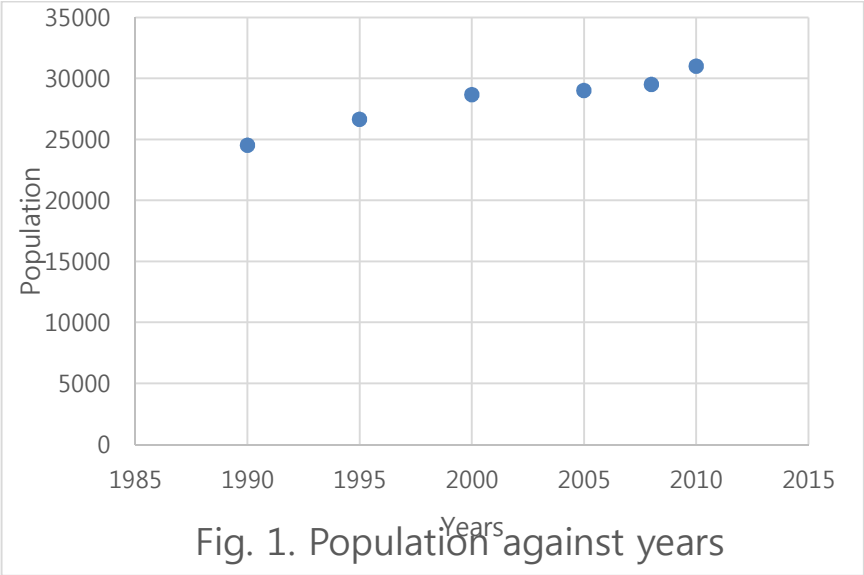


Fig. 1. Population against years

Marks are as follows: **0.6 correct plotting of points (0.1 for each)**

0.2 labelled axes [0.1 for each correctly labelled axis]

0.2 scale

a-2) Draw a linear trendline of your data, determine the equation of the line and write the equation in the box below. **[0.5 marks]**

Calculations

Example of ideal graph line equation calculation:

$$slope = \frac{y_2 - y_1}{x_2 - x_1} = 286.87$$

Where (x_1, y_1) and (x_2, y_2) are coordinates of any two points on the trend line

To find the intercept, substitute (x_1, y_1) or (x_2, y_2) in $y = mx + c$ and solve for c. note that *c* is the intercept and *m* is the slope

[0.25] for correct trend line on student's graph

QUESTIONS

Line equation: **[0.25 marks for correct equation based on the student's graph]**

a-3) Use the space given below to calculate the average growth rate of the elephant population size from 1990 to 2010. **[0.25 marks]**

Calculations **Growth rate is the slope of the trendline or fitted linear line, which is 287 for the ideal graph.** **Students need to take the slope from their equation.**
Average growth rate: **[0.25 marks if they have taken the correct value and added the correct unit]**

a-4) Use the space given below to calculate the projected elephant population size in 2019. **[0.5 marks]**

Calculations **Solved using the ideal trendline equation:** **y = mx + c which is in this case, y = 287x – 545902** **Therefore y = 287 × 2019 – 545902 = 33551** **a) Students may use their line equation to calculate the value in the way above.** **b) Students may take the value for 2010 and add 9 × the annual growth rate.** **c) Student may decide to extend the trendline to 2019 then extrapolate the answer for elephant population from the graph.** **The value should be higher than the value for 2010.**
Projected population size:

QUESTIONS

b) Use the space given below to calculate the difference in the density of the elephant population size in 1995 and 2010 in the Chobe National Park. **[0.5 marks]**

Calculations $\boldsymbol{Density} = \frac{\boldsymbol{number\ of\ animals}}{\boldsymbol{area}}$ $\boldsymbol{Density} = \frac{\mathbf{31000-26650}}{\mathbf{11700}}$ **=0.372 elephants/km^2**
Difference in density: **0.372 elephants/km^2** **[0.25 marks for correct answer + 0.25 marks for correct units**

c) Use the space given below to calculate the total amount of bark that was stripped in 1995. **[0.5 marks]**

QUESTIONS

Calculations
Total food consumed in 1995 **= 26650 × 200 kg/day [0.125]** **= 53300000 kg/day × 365 days [0.125]** **=194545000= 1.95 x 10^{10} kg [0.125]** **The total bark portion of the consumed food is 35%** **Therefore 35% of that number is: $\frac{35}{100}$ x 1.94545 x 10^{10} kg** **= 680907500 kg [0.125]**
Total amount of bark stripped: **680907500 kg = 6.81*10^{8} kg = 680907.5 tons**

d) Use the space given below to calculate the percentage of the actual material utilized by the elephant per day. **[0.5 marks]**

Calculations
Actual material utilized = 200kg – 136kg = 64kg [0.2 marks for correct kg value, 0.05 marks for units] **% of the actual material utilized= $\frac{64}{200}$ x 100 =32% [0.2 marks for correct kg value, 0.05 marks for units]**
Percentage of actual material utilized: **32%**

QUESTIONS

Q4

Decide, whether each of the terms listed below corresponds to the interior of the membrane (within the membrane) or the exterior surfaces of the membrane and fill in the table. Use „+“ if the term applies and „0“ if the term does not apply. **[1.5 marks, 0.125 for each correct answer]**

	Interior	Exterior
Hydrophobic	**+**	**0**
Hydrophilic	**0**	**+**
Fatty acid tails	**+**	**0**
Ribosomes	**0**	**0**
Ion channels	**+**	**+**
Oligosaccharides	**0**	**+**

Chemistry

Q5 Chemistry: Acid mine drainage and air pollution at a nickel mine

Q5a	(0.5)	Write the balanced equations for the neutralization and precipitation reactions Neutralisation $Ca(OH)_{2\,(aq)} + H_2SO_{4\,(aq)} \rightarrow CaSO_{4\,(s)} + 2H_2O_{(l)}$ [0.25; if not balanced substract 0.1, don’t penalize for state symbols] Precipitation $Fe_2(SO_4)_{3\,(s)} + 3Ca(OH)_{2\,(aq)} \rightarrow 2Fe(OH)_{3\,(s)} + 3CaSO_{4\,(s)}$ [0.25; if not balanced substract 0.1, don’t penalize for state symbols]

QUESTIONS

Q5b	(1.75)	What mass in kilogram of $Fe(OH)_3$ will be produced due to oxidation of pyrites? **Molar mass of FeS_2 = 119.97 g/mol** [0.25] **Molar mass of** $Fe(OH)_3$ is 106.85 g/mol [0.25] % of pyrite in solid waste = 5/100 x 10^6 =5 x 10^4g [0.25] **Mole of FeS_2 5x10^4/119.97 = 416.78 mol; mole ratio is 1:1 [0.25]** **Mole of** $Fe(OH)_3$ is 416.78 mol **[0.25]** **Mass of** $Fe(OH)_3$ is then 5x**10^4/119.97 x 106.85 =44533.08 g = 44.5 kg [0.5]** [Final answer should be given to the correct significant figure, if not substract 0.1] $Fe(OH)_3$ mass ……44.5……kg
5c	(0.5)	How much iron (II) (in grams) is pumped into the chemical neutralization plant in 2 hours at the stated flow rate using red lake water as feed? Volume of iron(II) pumped in two hours = 50.0 m^3/h x 2 hours = 100 m^3 [0.25] Iron(II) mass 100mg/L x 100 m^3 x 1000L/1m^3 = 10 000 000 mg = 10 000 g Or =1.00 x 10^4 g [0.25]
		Iron (II) …… g
	(1.0)	How many moles of H^+ ions were neutralized in one liter of solution?

QUESTIONS

5d		pH= -Log $[H^+]$ [0.25] At pH 6.0 concentration = -Log $[H^+]$; $[H^+] = 1.00 \times 10^{-6}$ [0.25] At pH 1.9 concentration = -Log $[H^+]$; $[H^+] = 1.26 \times 10^{-2}$ [0.25] Concentration = 1.26×10^{-2} mol/L Moles of $H^+ = 1.26 \times 10^{-2}$ mol [0.25]
		Moles of acid =
Q5e	5e-1 (0.15)	What is the order of the reaction with respect to iron(II) expressed as a number? 1 [0.15]
	e-2 (0.25)	What is the rate of reaction when the surface area of the reactor is doubled at constant volume? Rate = 16.1x2 = 32.2 $molL^{-1}s^{-1}$ [0.25]
	e-3 (0.5)	What is the rate of reaction when the pressure of oxygen gas is doubled? Pressure is $2^{0.5} = 1.41$ [0.25] Rate = 16.1x1.41 = 22.7 $molL^{-1}s^{-1}$ [0.25]
Q5f	(2.0)	What mass in tons of calcium carbonate is needed to remove one ton of sulphur dioxide if the removal process is 90.0% efficient? Moles of 10^6 / 64.06 = 15610.37 mol [0.25] Mol ratio $CaCO_3:SO_2$ = 1:1 [0.25] Mol of $CaCO_3$ = 15610.37 mol [0.25]

QUESTIONS

		Mass of $CaCO_3$ = 15610.37 x 100.09 = 1562441.93 g [0.25] Mass in ton = 1562441.93 / 10^6 = 1.56 t (for 100 % efficiency) [0.5] a) 90% = 1.56 t / 0.9 = 1.73 t [0.25] b) Total amount of $CaCO_3$ needed = 1.73 / 0.65 = 2.66 t [0.25]
Q5g	(0.6)	Calculate the number of moles of CO_2 gas present in the container after 20 minutes of heating (R= 0.082 L.atm mol^{-1} K^{-1}; R= 8.314 J.mol^{-1} K^{-1}), 1 atm = 101325 Pa. $PV = nRT$ $n = \frac{PV}{RT}$ [0.1] $n = \frac{1.04atm \times 1.00L}{0.082\frac{L\,atm}{mol\,K} \times 1100K}$ [0.25] $= 0.0115\ mol$ [0.25]
Q5h	h-1(0.25)	What will be the final pressure inside the container? Tick the correct answer Less than 1.04 atm: ☐ greater than 1.04 atm: ☐ Equal to 1.04 atm: √
	h-2 (0.25)	Where will the equilibrium shift to in the reaction equation below? Tick the correct answer Right (product side): ☐ Left (reactant side): √ No change: ☐
Q5i		

QUESTIONS

	(0.25)	Calculate the value of the equilibrium constant, K_p, for the decomposition of $CaCO_3$ at 1100 K. $K_p = P_{CO_2} = 1.04$ atm (or 105378 Pa) [award 0.1 for the Kp expression and 0.15 for the answer]
6	(1.5)	What mass in kilogram of sodium carbonate can be formed from 0.850 ton of trona? Molar mass of trona = 332 g/mol [0.25] Moles of trona = 0.85×10^6 g / 332 g/mol = 2.56×10^3 moles [0.25] 5 moles of Na_2CO_3 : 2 moles of Trona [0.25] Moles of $Na_2CO_3 = 2.56 \times 10^3 \times 5/2 = 6.4 \times 10^3$ moles [0.25] Molar mass of Na_2CO_3 = 106 g/mol [0.25] Mass of Na_2CO_3 = 6.4×10^3 moles x 106 g/mol = 6.78×10^5 g = 678 kg [0.25]

QUESTIONS

7	(0.5)	What is the concentration of carbonic acid in air saturated with water vapour at 25 °C? Henry's law is Conc = KP = $2.3x10^{-2}$ mol/L.atm x 3.04 x 10^{-4} atm [0.25] =7.0×10^{-6} mol/L [0.25]

Total points for question Q5a	
Total points for question Q5b	
Total points for question Q5c	
Total points for question Q5d	
Total points for question Q5e	
Total points for question Q5f	
Total points for question Q5g	
Total points for question Q5h	
Total points for question Q5i	
Total points for question Q6	
Total points for question Q7	
Total marks	

QUESTIONS

Physics Theory answer sheet

No unit in final answer: -0.1		
Questions	**Points**	**Waves: Doppler effect: Answers (show your working)**
Q8	(1.40)	**Calculation of frequency as the ambulance approaches the observer** Step 1: calculate v_s (note speed of sound increases as temperature increases) $v_s = 331.3 + 0.606 * T_C = 331.3 + 0.606 * 38 = 354.328\ m/s$ [0.20] **ambulance approaching the observer** **convert 90 km/h = 25 m/s** [0.25] $f_o = f_s\left(\frac{v_s}{v_s - v_o}\right)$ **correct equation!!** [0.45] $f_o = 300.0 * \left(\frac{354.328}{354.328-25}\right)$ [0.25] *Approaching ambulance* f_o *=323 Hz* [0.25]
Q9	(1.55)	(Show your working) **Kinematics** During reaction time: Calculation of the acceleration of the car if it stops just before hitting the cow. **Initial velocity *u*** $u = 33.2\ ^m/_s,\ \ a = 0, t = 0.20s$ [0.20] $s = ut + \frac{1}{2}at^2$ [0.25] $s = 33.2\ ^m/_s * 0.2s + 0 = 6.64m$ = distance covered during the reaction time For acceleration; $s = 60m - 6.64m = 53.36m$ [0.25]

QUESTIONS

		$note\ that\ v = 0\ ^{m}/_{s}, u = 33.2\ ^{m}/_{s}$ $v^2 = u^2 + 2as$ [0.25] $a = \frac{v^2 - u^2}{2s}$ [0.20] $a = \frac{0 - 33.2^2}{2 * 53.36}$ [0.20] $a = -10.3\ m/s^2$ In case of missing "-" sign: -0.10
		acceleration of the car = $a = -10.3\ m/s^2$ [0.20]

QUESTIONS

Fluid flow: conservation of energy and continuity principles

Questions	Points	Answers (show your working)
Q10 (a)	(0.85)	Calculate the velocity of water through the pipe at the farm *from the continuity equation* $Q = A_1 v_1 = A_2 v_2$ Note $A = \pi R^2 = \pi \frac{D^2}{4}$ [0.20] $v_2 = \frac{A_1 v_1}{A_2} = \frac{\pi D_1^2/4}{\pi D_2^2/4} * v_1$ [0.25] $v_2 = \frac{\pi * 0.35^2}{\pi * 0.25^2} * 1.30$ [0.20] $v_2 = 2.55\ m/s$ [0.20]
Q10 (b)	(0.9)	*Calculation of the pressure of water at the farm* *Consider Bernoulli's equation* $$\frac{P}{\rho} + \frac{1}{2}v^2 + gy = constant$$ $Or\ \ P_1 + \frac{1}{2}\rho v_1^2 + \rho g y_1 = P_2 + \frac{1}{2}\rho v_2^2 + \rho g y_2$ [0.20] $P_2 = P_1 + \frac{1}{2}\rho(v_1^2 - v_2^2) + \rho g(y_1 - y_2)$ [0.25] $P_2 = 670000 + \frac{1}{2}(1000) * (1.30^2 - 2.55^2) + 1000 * 9.8 * (940 - 960)$

QUESTIONS

		$P_2 = 670000 - 2401.152 - 196000$ [0.25]
		Pressure P_2 at the farm =4.72*10^5 Pa = 4.72*10^5 N/m^2 [0.20]
Q10 (c)	(0.8)	Flow rate at the farm $Q = A_2 v_2 = \frac{\pi D_2^2}{4} v_2$ [0.20] $Q = \frac{\pi 0.25^2}{4} 2.55 = 0.125\ m^3/s$ [0.10] Calculation of time it takes to fill a 50000L reservoir *Convert* $L \rightarrow m^3$ *50000L = 50m^3* [0.10] *Time taken* $= \frac{50m^3}{0.125 m^3/_s}$ [0.20]
		$t = 400\ sec$ [0.20]

QUESTIONS

Q11 (1.9)

ELASTIC COLLISIONS

Momentum before collision = momentum after collision

$m_A u_A = m_A v_A + m_B v_B$ [0.25]

After collision: $x = v_x t$; horizontal distance

$x_A = 1m = v_{xA} t$ distance travelled by ball A [0.20]

$x_B = 2m = v_{xB} t$ distance travelled by ball B [0.20]

Vertical Motion:

$y = u_y t - \frac{1}{2} g t^2$ [0.20]

$\boldsymbol{u_y} = 0$ hence

$$-1.225 = -\frac{1}{2} * 9.8 * t^2$$

$$\boldsymbol{t = \sqrt{\frac{1.225}{4.9}} = 0.50s} \quad \textbf{[0.25]}$$

$$x_A = 1 = v_{xA} t = 0.5 v_{xA}$$

$$\boldsymbol{v_{xA} = 2.0\ ms^{-1}} \quad \textbf{[0.20]}$$

$$x_B = 2 = v_{xB} t = 0.5 v_{xB}$$

$$\boldsymbol{v_{xB} = 4.0\ ms^{-1}} \quad \textbf{[0.20]}$$

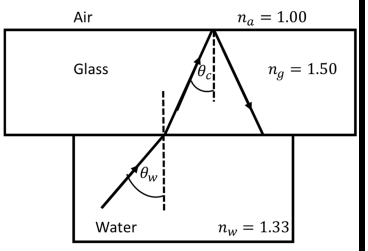
$$m_A u_A = m_A v_A + m_B v_B$$

$u_A = \frac{m_A v_A + m_B v_B}{m_A}$ [0.20]

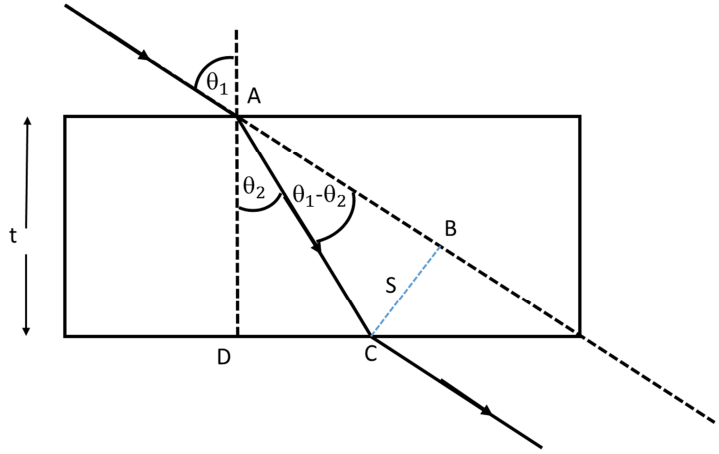
QUESTIONS

		Mass can be used in ***g*** *or* ***kg****:* $$u_A = \frac{0.060 * 2 + 0.020 * 4}{0.060} = 3.33\ m/s$$ *Velocity before impact=* ***3.33 m/s*** **[0.20]**

QUESTIONS

Q12a	1.1	For minimum angle θ_w, angle of incidence at the glass- air boundary is the critical angle θ_c.  From Snell's law (steps 1-3): $n_g \sin\theta_c = n_a \sin 90$ [0.20] $sin\theta_c = \frac{n_a}{n_g} = \frac{1}{1.5}$ [0.10] $\theta_c = sin^{-1}\left(\frac{1}{1.5}\right) = 41.8°$ [0.20] **At water- glass surface interface** $n_w \sin\theta_w = n_g \sin\theta_c$ [0.20] $sin\theta_w = \frac{n_g \sin\theta_c}{n_w} = \frac{n_g}{n_w} * \frac{n_a}{n_g}$ $\theta_w = sin^{-1}\left(\frac{n_g}{n_w} * \frac{n_a}{n_g}\right) = sin^{-1}\left(\frac{n_a}{n_w}\right) = sin^{-1}\left(\frac{1}{1.33}\right)$ [0.20] Students will not be penalized for not using step 1-3 when final answer is correct **Final answer:** $\theta_w = 48.8°$ [0.20] Illustration showing incident, transmitted and emergent ray and labelling

QUESTIONS

Q12b	1.5	of slab thickness [0.4] Correct labelling of angles θ_1 and θ_2 [0.2]  From triangle ABC, $\frac{BC}{AC} = sin(\theta_1 - \theta_2)$ [0.20] From triangle ADC, $\frac{AD}{AC} = cos(\theta_2)$ [0.20] Therefore $AC = \frac{AD}{cos(\theta_2)} = \frac{t}{cos(\theta_2)}$ [0.20] $sin(\theta_1 - \theta_2) = \frac{BC}{AC} = \frac{BC*cos(\theta_2)}{t}$ **That is:** $BC * cos(\theta_2) = t * sin(\theta_1 - \theta_2)$ [0.20] $BC = \boldsymbol{s} = \frac{\boldsymbol{t*sin(\theta_1-\theta_2)}}{\boldsymbol{cos(\theta_2)}}$ [0.10]

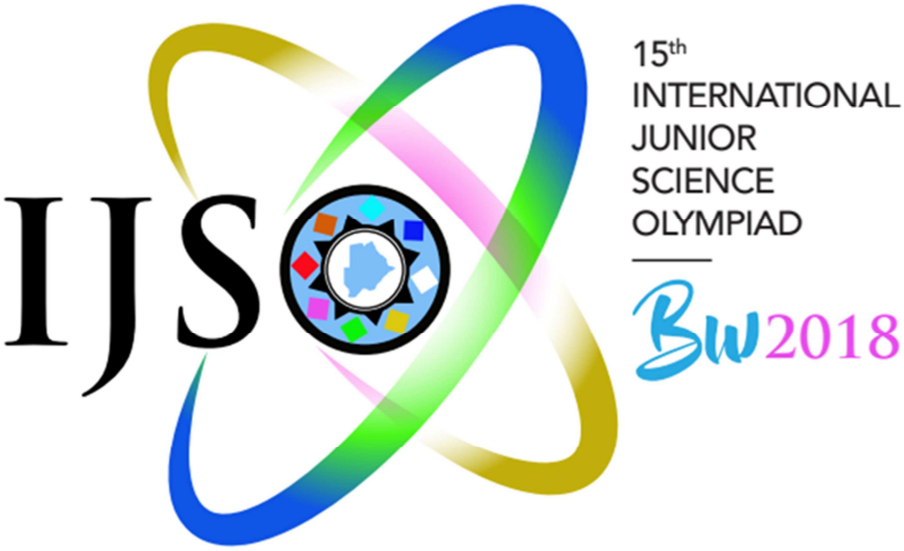
---------- DO NOT WRITE BELOW ----------

QUESTIONS

Total points for question Q6	
Total points for question Q7	
Total points for question Q8	
Total points for question Q9	
Total points for question Q10	
Total marks	

15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2018



Discovery, Innovation and Environment

Laboratory Experiment

– Exam Sheet –

December 8, 2018
Do NOT turn to next page
before a whistle is blown.
Otherwise, you will receive a penalty.

1. You have 10 minutes to read "EXAMINATION RULES", "EXAM INSTRUCTIONS", and "CALCULATOR INSTRUCTIONS" on pages 1 - 3.

2. Do NOT start answering the questions before the"START"whistle! Otherwise, you will receive a penalty.

EXAMINATION RULES

1. You are NOT allowed to bring any personal items into the examination room, except for

personal medicine or approved personal medical equipment.

2. You must sit at your designated desk.
3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.
4. Do NOT start answering the questions before the **"START"** whistle.
5. You are NOT allowed to leave the examination room during the examination except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need any assistance, you may raise your hand and wait for a supervisor to come.
7. Do NOT discuss the examination questions. You must stay at your desk until the end of the examination time, even if you have finished the exam.
8. At the end of the examination time you will hear the **"STOP"** whistle. Do NOT write anything more on the answer sheet after this stop whistle. Arrange the exam, answer sheets, and the stationary items (pen, calculator, and rough book) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXAM INSTRUCTIONS

1. You are NOT allowed to bring any personal items into the examination room, except for
   personal medicine or approved personal medical equipment.
2. You must sit at your designated table.
3. Check the stationery items (pen, calculator, ruler, and scrap paper) provided by the organizers.
4. Do NOT start your experiments before the **"START"** signal.
5. You are NOT allowed to leave the examination room during the experiment, except in an emergency in which case you will be accompanied by a supervisor/volunteer/invigilator.
6. Do NOT disturb other competitors. If you need assistance, raise your hand and wait for a supervisor to come.
7. You can ONLY ask questions and discuss the experiments with your own team members.
   You must STAY at your table until the end of the time allocated for the experiments, even if you have finished the experiments or do not wish to continue.
8. At the end of the experiment time you will hear the **"STOP"** signal. Do NOT write anything more on the answer sheet after this stop signal. Arrange the exam, answer sheets, and the stationary items (pen, calculator, ruler, and scrap paper) neatly on your desk. Do NOT leave the room before all the answer sheets have been collected.

EXPERIMENT INSTRUCTIONS

1. After the "START" signal, you will have 15 minutes to read the experiments. In this time, it is NOT allowed to conduct the experiment yet, or answer the questions.

2. After the first 15 minutes, another whistleblow will indicate that you can start the experiment and start answering question. From this moment you have three hours to complete the test.
3. Use only the pen and pencil provided by the organizers.
4. The total number of experiments is 3. Check if you have a complete set of the exam sheets (20 pages, page 4 – page 20) and answer sheets (28 pages - including the front page). Raise your hand, if you find any sheets missing.
5. Check that your name, code and country are filled in on your answer sheets and sign every page of the answer sheets. Raise your hand, if you find any sheets missing.
6. Read the experimental procedures and questions carefully and write your answers in the corresponding boxes of the answer sheets.
7. When units are provided in the answer sheets, you have to write the answers correctly for the units.
8. Always show your calculations if room for this is provided. If you do not show your calculations, no points are awarded for the question.
9. You should write your final answers down in the appropriate number of digits.
10. You MUST wear a **Lab Coat** and **Safety Glasses** during the experiments.

INSTRUCTIONS FOR CALCULATOR

1. Turning on: Press [ON/C].

2. Turning off: Press [2ndF] [ON/C].

3. Clearing data: Press [ON/C].

4. Addition, subtraction, multiplication, and division

Example 1) $45 + \frac{285}{3}$

[ON/C] *45* [+] *285* [÷] *3* [=] ***140.***

Example 2) $\frac{18+6}{15-8}$

ON/C (*18* + *6*) ÷ (*15* − *8*) =

3.428571429

Example 3) $42 \times (-5) + 120$

ON/C *42* × *5* +/− + *120* = ***-90.***

ON/C *42* × (− *5*) + *120* = ***-90.***

5. Exponential

Example 1) 8.6^{-2}

ON/C *8.6* y^x *2* +/− = ***0.013520822***

Example 2) 6.1×10^{23}

ON/C *6.1* × *10* y^x *23* = ***6.1 x 10^{23}***

6. To delete a number/function, move the cursor to the number/function you wish to delete, then press DEL. If the cursor is located at the right end of a number/function, the DEL key will function as a back space key.

Do NOT turn to next page
Before the"START"whistle is blown.
Otherwise, you will receive a penalty.

BIOLOGY

Biology Practical [13.4 points]

Q1. [7.15 points] Draw a sketch of the spots observed on your TLC plate, and complete the table in your answer sheet with *Rf* values and proposed pigments (Roman numeral from Table 1, one per spot):

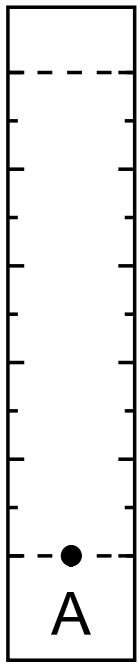
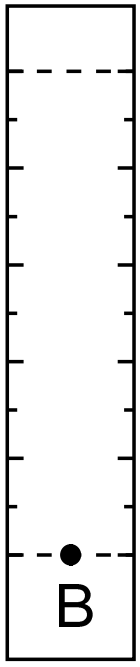
[1.75 points – awarded in a deductive manner – loss of points for omissions] Each lane corresponds to the original – check photograph for comparison and check if any obvious spots are omitted.

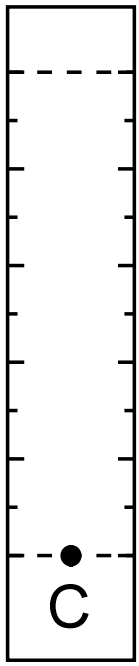
[1.9 points (0.1 x 19)] for the drawing. Minimum 7 for lane A (& 1 weak), min. 5 for B, min. 6 for lane C (& some weak), max. 1 for lane D (lose points for additional spots – carry over)

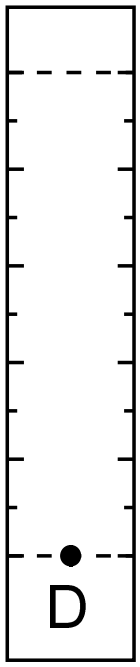
[2.0 points, 0.25per Rf (0.25x8)] Points for the calculation of *Rf*.(margin of error? Invigilators will prepare and run plate in their rooms and take photo for comparison and to decide Rf for grading)

[1.5 points, 0.25 per pigment (0.25x6)] Suggested pigments – minimum of six correct. If the same pigment is present in A,B&C but not identified in one, deduct one third of marks (0.08), if present in two lanes and only identified once, deduct 50% of marks (i.e. 0.125)

	Spot no. (e.g. A1)	*Calculations*	*Rf*	Suggested pigment, if any

 A				
 B				

	Spot no. (e.g. A1)	*Calculations*	*Rf*	Suggested pigment, if any
				

 D				

Q2 [1.0 points, 0.25 per statement]

For the following observations about the sample in lane D, mark in your answer sheet whether the following statements are true or false [X points].

Statement	True	False
It separated into distinct pigments, which are not present in other lanes.		X
It separated into distinct pigments, which are also present in other lanes.		X
It did not move with mobile phase.	X	
It does not contain any pigments		X

Q3 For the following statements, mark in your answer sheet whether the following statements are true or false [1.0 points, 0.25 per statement]

The TLC chamber (bottle) is closed to…

Statement	True	False
To prevent evaporation of the mobile phase.	X	
To avoid the smell of the chemicals contained in the mobile phase.	X	
To maintain a dust-free environment.	X	
To decrease the pressure in the chamber		X

Q4. Indicate in your answer sheet, whether each of the factors below affect the *Rf* value of a compound [1.75 points, 0.25 per statement]

	Affects *Rf*	Does not affect *Rf*
A. Polarity of compound	X	
B. Distance travelled by solvent (mobile phase)		X
C. Size of TLC plate		X
D. Type of stationary phase	X	
E. Amount of sample loaded		X
F. Size of chamber		X
G. Color of the sample		X

Q5. Write the letter that corresponds to the pigment that moves slowest up the TLC plate in the box on your answer sheet. [0.25 points]

A. Chlorophyl *a*
B. Xanthophyll 1
C. Pheophytin
D. Chlorophyl *b*

Q6 [1.0 points, 0.25 per statement] For the following statements, mark in your answer sheet whether the statements are correct or incorrect.
A compound moves slower than others up a TLC plate in our experimental conditions because…

Statement	Correct	Incorrect
It is less polar than the other compounds		X
It is a more hydrophilic compound	X	
It has a larger molecular weight		X
It is more concentrated than the other compounds		X

Q7. Will the *Rf* values change if the ratio of polar and non-polar solvents in the mobile phase is changed? Write the letter that corresponds to your answer in the box on your answer sheet. [0.25 points]

A. Yes
B. No

Q8. What could potentially limit the effectiveness of the chromatographic technique you have used? [1.0 points, 0.25 per statement]

Statement	Correct	Incorrect
Leaving the TLC chamber open	X	
The amount of mobile phase in the TLC chamber	X	
Geographical location where the experiment is performed		X
Running multiple plates in one TLC chamber		X

CHEMISTRY

Experiment II: Determination of acid content in a fruit acid solution **[13.3 points]**

ANSWER KEYS

Standardization of the NaOH

Question (Points)	Record the volume of NaOH (mL) solution used in the standardization
II-1a [3.5 points]	Titration #1 Titration #2 Titration …. Titration ….. Initial Vol. …….. …….. ……. ……. End Vol. ……. …… ……. ….. Vol. Used …… …… ……. …… [1.0 for proper and consistent recording and 0.5 point for at least two titrations] Average NaOH volume used ……xxxx……mL [0.5] Precision = [max 0.5] ±0.1, [award 0.5], ±0.2, [award 0.25], any value beyond 0.2 award 0.0 mark, for the two best titrations Accuracy = [max 1.0] ± 0.3 [award 1.0], ±0.5 [award 0.5], ±1.0 [award 0.25]

Question (Points)	Write down a balanced chemical equation for the titration reaction of oxalic acid (H_2X) with NaOH
II-1b [0.25 points]	$2NaOH + H_2X$ ….. $Na_2X + 2H_2O$ If not balanced substract 0.1 points
Question (Points)	Calculate the concentration of the NaOH solution
II-1c [0.5 points]	Mol of H_2X = 0.100 mol/L x 10 mL/1000 mL = xxxx mol Mol ratio of NaOH to H_2X = 2:1 [0.25] Mol of NaOH = xxxx mol x 2 Concentration of NaOH = xxx/ Titre value = yyy mol/L [0.25] Accept alternative suitable calculations

Titration of fruit acid solution

Question (Points)	Record the volume of NaOH (mL) solution used
II-2 [3.5 points]	Titration #1 Titration #2 Titration ….. Titration …... Initial Vol. ……. ……. ……..…… ……. End Vol. ……. ……. ……..…… ……. Vol. Use ……. ……. ……..…… ……. [1.0 for proper and consistent recording and 0.5 point for at least two titrations] Average NaOH volume used …….25.65 ml…… mL [0.5] Precision = [max 0.5] ±0.1, [award 0.5], ±0.2, [award 0.25], any value beyond 0.2 award 0.0 mark, for the two best titrations Accuracy = [max 1.0] ± 0.3 [award 1.0], ±0.5 [award 0.5], ±1.0 [award 0.25]

Question (Points)	Write down the balanced equation for the titration reaction
II-3 [0.25 points]	$HA_{(aq)} + NaOH_{(aq)} \rightarrow NaA_{(aq)} + H_2O_{(l)}$ Do not penalize for the state symbols

Question (Points)	Determine the number of moles of NaOH used in the titration
II-4 [0.5 points]	Moles = Con x vol = 0.1 mol/L x 25.65 x 10^{-3} L [0.25] = 2.565 x 10^{-3} mol [0.25]

Question (Points)	Determine the mass (g) of acid in the fruit acid solution titrated with NaOH solution
II-5 [1.0 points]	Mole ratio of NaOH : HA is 1:1 [0.25] HA moles = 2.565 x 10^{-3} mol [0.25] MW of HA = 60.0 g/mol Mass of HA = 2.565x10^{-3} x 60.0 g/mol [0.25] = 1.539 x 10^{-1} g or 0.1539 g [0.25]

Question (Points)	Assuming the density of fruit acid solution is 1.005g/mL, determine the mass (g) of 4 mL solution.
II-6 [0.5 points]	Mass = density x volume 1.005g/mLx 4.0 mL [0.25] 4.02 g [0.25]

Question (Points)	Determine the % mass of the acid in fruit acid solution.
II-7 [0.5 points]	= 0.1539 g/4.02 g x 100% [0.25] = 3.83 % [0.25]

Question (Points)	Calculate the volume of the fruit acid solution that the student used?
II-8 [1.0 points]	Mole of NaOH = 0.54 mol/L x25 x 10^{-3}L = 0.0135 mol [0.25] Moles ratio is 1:1, therefore HA mol is 0.0135 mol. [0.25] Concentration of fruit acid solution = moles/volume = 2.565 x

	$1.35x10^{-3}$mol/25.65 x 4 $x10^{-3}$L =0.641 mol/L Volume of fruit acid solution required = moles/conc = 0.0135 mol /0.641 mol/L =0.021 L =21 mL [0.5] *OR Volume of fruit acid solution = 25 mL x 0.54 mol/L / 0.641 = 21.09 mL [0.5]*

Question (Points)	Another student has measured the pH of the fruit acid solution to be 2.75. Use this value and your data to determine the pK_a of the fruit acid solution.
II-9 [0.5 points]	pKa = Sq of pH = ????????

Question (Points)	Calculate the Kb of the conjugate base of the fruit acid solution
II-10a [0.5 points]	pKa + pKb = 14 14-pKa = y Kb = 10^{-y}

Question (Points)	Calculate the pH at end point. Use the Kb from the previous question
II-10b [0.5 points]	Kb = [HA] [OH]/ [A] Kb = X^2/x-z z= mol HA/ $4*10^{-1}$

Question (Points)	If phenolphthalein was unavailable, which of the following indicators would be most suitable for this titration.
II-11 [0.3 points]	Tick the correct box

Indicator	pKa	
Methyl violet	0.8	
Thymol blue	1.6	
Methyl yellow	3.3	
Bromocresol green	4.7	
Thymol Blue	8.9	√

PHYSICS

Physics Laboratory practical

Total marks [13.3]

Title: Determination of the coefficient of viscosity of oil

Introduction

While water can be poured from one container to another easily, honey takes a very long time to flow out of its container. The reason for these different rates of flow is that honey is more viscous and resists flow more than water does. The coefficient of viscosity is a measure of the degree of internal resistance to flow and shear. Coefficient of viscosity is an important parameter in food industry. Flow of various components of the raw materials to the final product in an automated food industry will depend on this.
The viscosity can be determined by measuring the velocity of a falling sphere through a column of fluid of unknown viscosity. This is accomplished by dropping a sphere through a measured distance in a column of fluid and measuring how long it takes to travel the distance.

Materials

- Thermometer
- Balls of 4 different diameters
- Cylindrical vertical tube filled with oil
- Stopwatch
- Meter ruler
- Tape to mark
- Paper towel
- Magnet

Theoretical aspects

Consider a spherical ball bearing of radius r and density ρ_s falling through a column of fluid of coefficient of viscosity η and density ρ_f as illustrated figure 1 below.

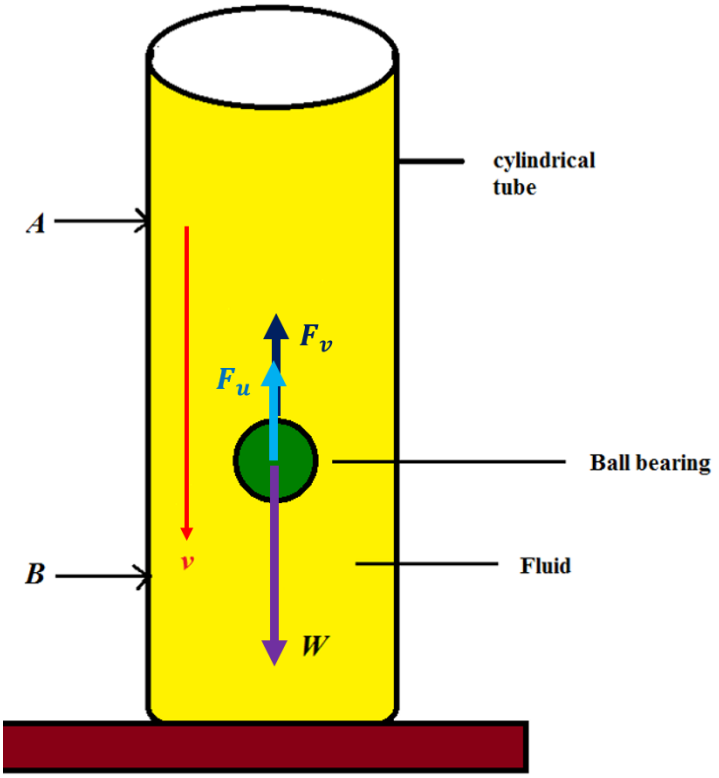


*Figure 1: Showing a spherical ball of radius r falling through a column of fluid of density ρ_f. **A** and **B** marks the distance travelled by the sphere at terminal velocity v_t.*

Initially the ball has some downward acceleration a until the ball acquires a constant velocity, called terminal velocity v_t. According to Newton's second law:

$$\text{Net Force} = ma$$

$$ma = W - (F_u + F_v) \qquad (1)$$

Where:

m is the mass of the ball.

$W = mg$ is the weight of the ball.

$F_u = \frac{4}{3}\pi r^3 \rho_f g$ is the buoyant force = weight of the fluid displaced (Archimedes law)

$F_v = 6\pi\,\eta\,r\,v$ is the viscous force (of a sphere of radius *r*) proportional to the velocity v of the ball (Stokes's Law).

Secondly when the ball attains terminal velocity before point **A**, there is no more acceleration and hence the net force is zero. Note that $\boldsymbol{l}$ is the distance between **A** and **B** and ***t*** is the time the ball takes to fall between **A** and **B**.

Procedure

[1.3]

1. Measure the temperature T_b of the oil before starting the experiment and write it in the box on the answer sheet.
2. Use the tape to mark two horizontal lines (**A** and **B**) on the cylindrical tube so that line **A** is 70 cm from the surface of the fluid. Line **B** should be approximately 50 cm below point **A**.
3. Measure the vertical distance ***l*** between points **A** and **B**. and write it in the box on the answer sheet provided.
4. Devise a method to measure the average diameter of the balls using the ruler scale as accurately as possible. Describe your method using only a sketch in the space provided.
5. Use your method to measure the average diameter of each of the four different sizes of balls and write these values in Table III-1 on the answer sheet.
6. Release one of the balls carefully into the fluid at the center of the surface (ensuring that the ball is not near the wall of the cylinder during its motion between **A** and **B**)
7. Measure the time ***t*** taken by the ball to travel the distance ***l*** between **A** and **B** and record it in the provided table.
8. Repeat steps 6 and 7 above using other balls of the same diameter to have three values of time (the magnet can be used to pull the balls along the cylinder wall out of the oil, ask for help if necessary).
9. Repeat steps 6 to 8 for the other 3 sizes of balls.
10. Measure the temperature T_a of the oil just after finishing the experiment and write it in the box on the answer sheet.

<u>Note the following constants</u>:

Density of the fluid $\rho_f = 871.4$ kg/m^3
Density of the ball $\rho_s = 7717$ kg/m^3
Acceleration due to gravity $g = 9.81$ m/s^2

(DO NOT PROVIDE YOUR FINAL ANSWERS HERE USE THE ANSWER BOOKLET

Results and analysis

III-1 Calculate the average time, d^2 and v_t for each set of ball bearings, and complete Table III-1 on the answer sheet.
[5.0]

Table III-1: Experimental results

Ball diameter			**Diameter squared**	**Time taken to fall distance l**				**Terminal velocity**
#	d (mm)	d (m)	d^2 (m²)	t_1 (s)	t_2 (s)	t_3 (s)	Average time (s)	v_t (m/s)
1								
2								
3								
4								

III-2 Plot a graph of v_t (y-axis) versus d^2 (x-axis) and draw a straight line of best fit on the grid on the answer sheet. **[3.0]**

III-3 Determine the slope of the graph. Indicate the points that are used on the graph for calculating the slope. Give your answer with appropriate units. **[1.5]**

III-4 The following formula for the terminal velocity v_t can be derived from equation (1):

$$v_t = C \cdot \frac{d^2}{\eta} \qquad (2)$$

Where $C = 3731$ kg m^{-2}s^{-2}. Write down in the space provided the analytical expression for C in terms of g, ρ_s and ρ_f. **[1.0]**

III-5 Use the value of the slope to determine the coefficient of viscosity η of the oil with the appropriate units. **[1.5]**