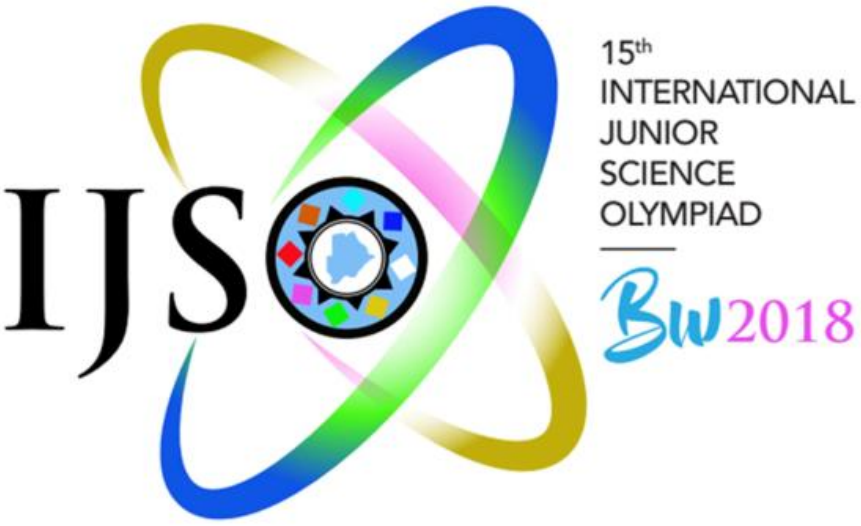
15TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

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.
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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.

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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

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.

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

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.

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

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 °C and the speed of sound is given by:

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

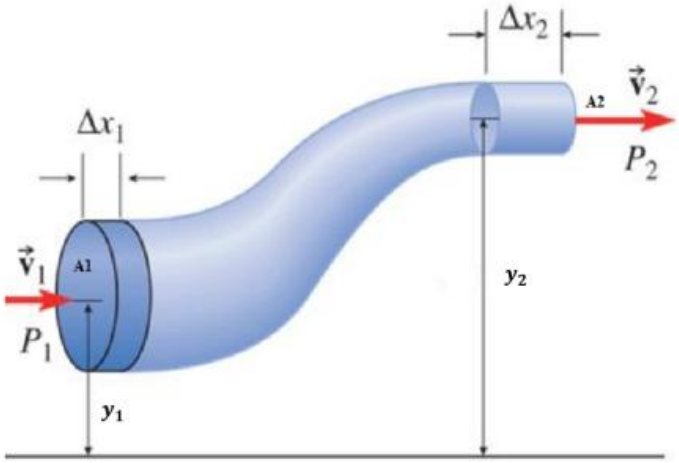
where v_s is the speed expressed in m/s and T_c is the temperature in °C.

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.

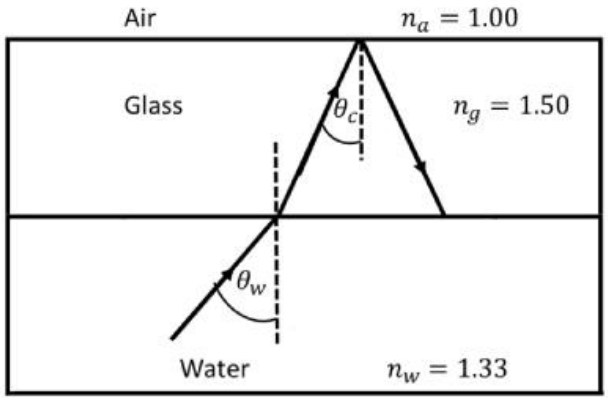
QUESTIONS

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.

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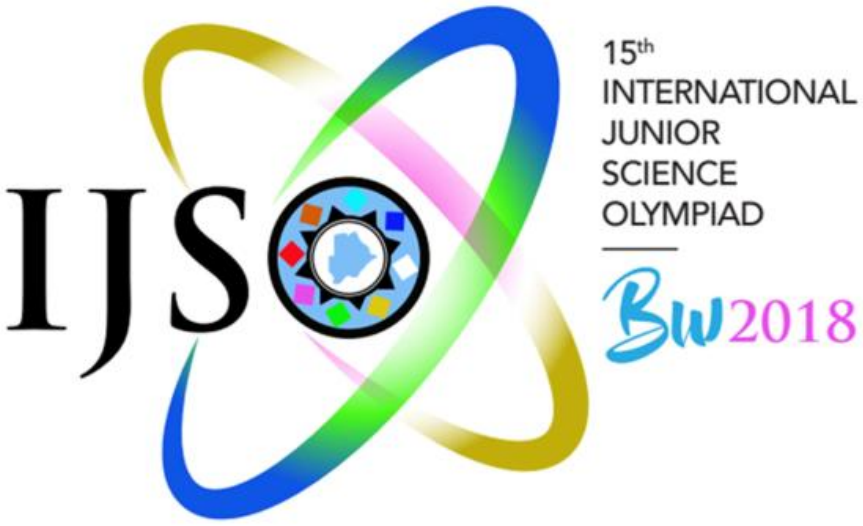

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QUESTIONS

INSTRUCTIONS FOR CALCULATOR

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

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

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

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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

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]**

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

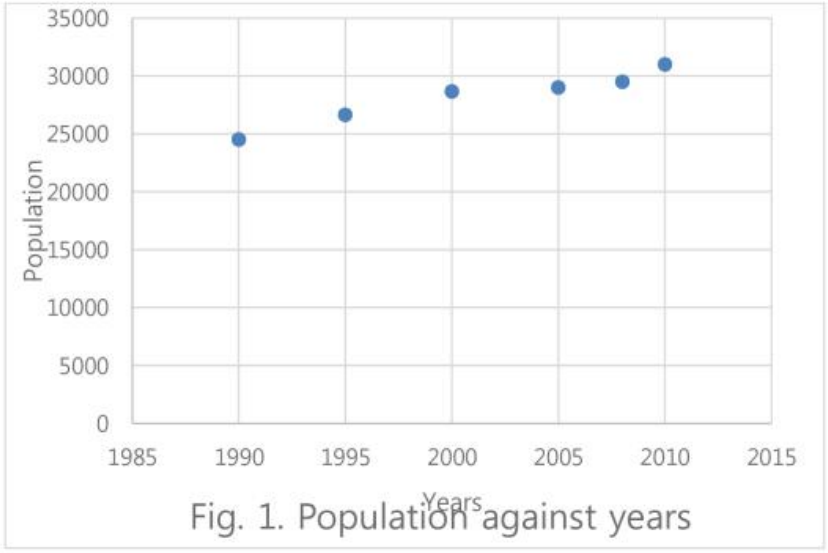


Fig. 1. Population against years

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

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:

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
$\boldsymbol{Density} = \frac{number\ of\ animals}{area}$ $\boldsymbol{Density} = \frac{31000-26650}{11700}$ **=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

		$P_2 = 670000 - 2401.152 - 196000$ [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]

$$\boldsymbol{u_y} = 0 \text{ hence}$$

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

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

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

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

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

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

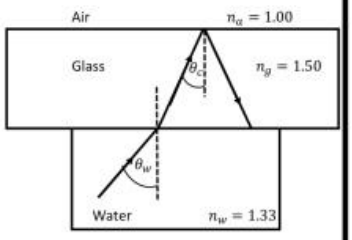
$$m_A u_A = m_A v_A + m_B v_B$$

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

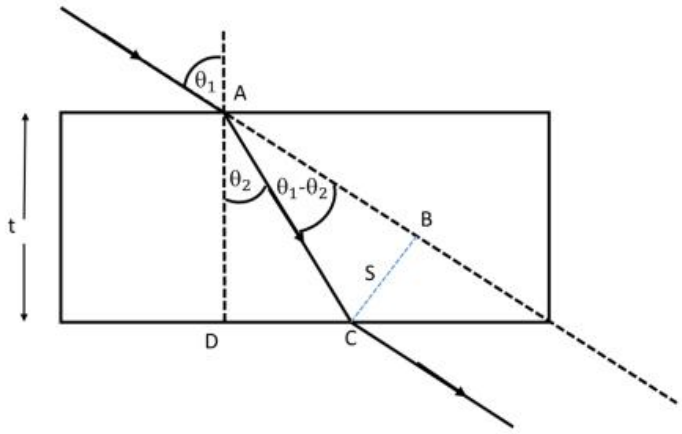
QUESTIONS

		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	