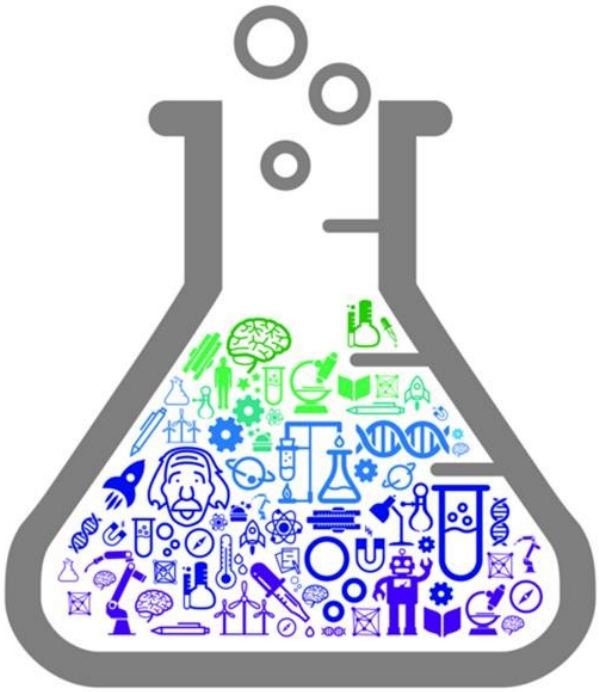
12TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2015



December 2(Wed)-11(Fri), 2015 I Daegu, Republic of Korea

Multiple Choice Competition

– Exam Sheet –

December 4, 2015

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

QUESTIONS

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. 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 (23 pages, page 5 – page 27) 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.***

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 10²³***

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

[CHEMISTRY]

*Part of periodic table of elements, showing the atomic numbers and atomic symbols.

1 H							2 He
3 Li	4 Be	5 B	6 C	7 N	8 O	9 F	10 Ne
11 Na	12 Mg	13 Al	14 Si	15 P	16 S	17 Cl	18 Ar
19 K	20 Ca	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr

1.

Below is incomplete information for neutral atoms I and II.

Atom	I	II
Number of protons		7
Number of neutrons	7	*a*
Number of electrons	7	*b*
Mass number		15

Which of the following is correct?

(A) $a = 7$

(B) $b = 8$

(C) Atomic number of I is 14.

(D) I and II are isotopes of the same element.

2.

Which of the following is the correct order of the decreasing ionic radius for Na^+, Mg^{2+}, O^{2-}, and F^-?

(A) $Na^+ > Mg^{2+} > F^- > O^{2-}$

(B) $Mg^{2+} > Na^+ > O^{2-} > F^-$

(C) $O^{2-} > F^- > Na^+ > Mg^{2+}$

(D) $F^- > O^{2-} > Mg^{2+} > Na^+$

3.

Which of the following molecules has a non-zero dipole moment?

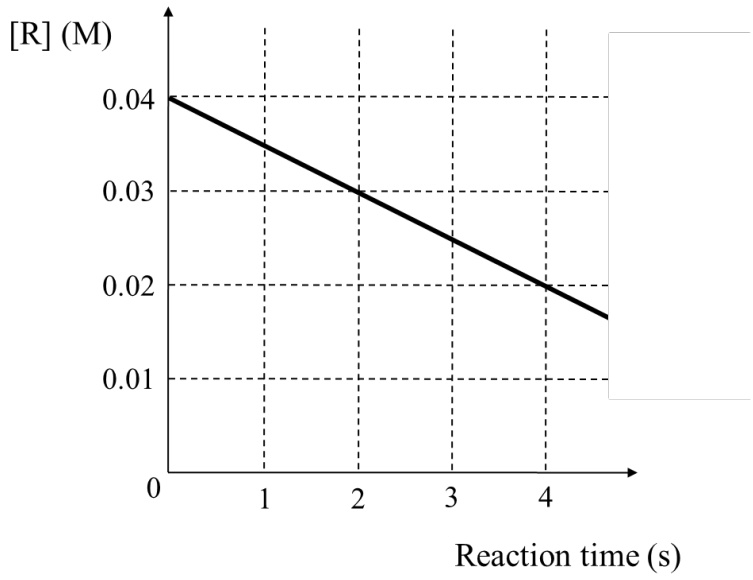
(A) CO_2 (B) CCl_4 (C) C_2H_2 (D) H_2Se

4.

The reaction rate is the change in concentration of a reactant or product with time, the unit of which is M/s. When the reaction rate depends on the *n*-th power to the concentration of a reactant, [R]:

$$\text{Reaction Rate} = k[\text{R}]^n$$

where *k* is the rate constant, it is called an *n*-th order reaction. The following graph shows [R] as a function of time for the chemical reaction R → P. (P denotes the product). M = moles/litre



Which of the following is correct for both *n* and the unit of *k* for the reaction R → P?

(A) 0, 1/s (B) 0, M/s (C) 1, 1/s (D) 1, M/s

5.

A gaseous hydrocarbon **X** has a density of 1.25 g/L at 0 °C and under 1 atm. What is the mass fraction of carbon in **X**? (The atomic masses of carbon and hydrogen are 12.0 and 1.00 g/mol, respectively, and 1.00 mole of gas occupies a volume of 22.4 L at 0 °C and under 1 atm.)

(A) 75.0 % (B) 80.0 % (C) 85.7 % (D) 92.3 %

6.

What is the electron configuration for the most stable ion of aluminum?

(A) $1s^2 2s^2 2p^6 3s^2$

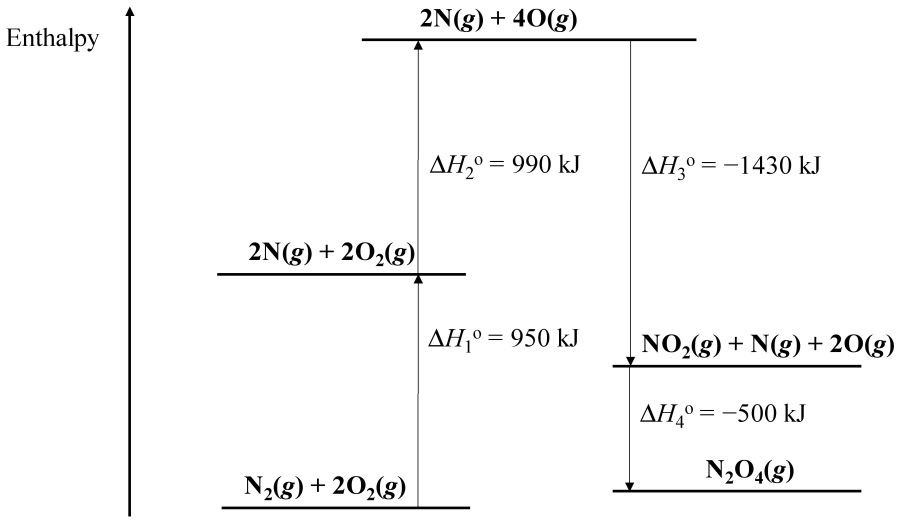
(B) $1s^2 2s^2 2p^6$

(C) $1s^2 2s^2 2p^5 3s^1$

(D) $1s^2 2s^2 2p^6 3p^2$

7.

The standard enthalpy of formation (ΔH_f^o) of a substance is the enthalpy change during a process, where the substance is formed from the most stable forms of the constituent elements at 1 atm. The following figure is the enthalpy diagram of N-, or O-containing compounds. ΔH_i^o's $(i = 1, 2, 3, 4)$ are the standard enthalpy changes for the corresponding processes at 25°C.



What is the ΔH_f^o of $NO_2(g)$ at 25 °C?

(A) 10 kJ/mol

(B) 510 kJ/mol

(C) −460 kJ/mol

(D) −1430 kJ/mol

8.

The table below shows the acid dissociation constant (K_a) of three chemical species at 25 °C.

Species	HF	CH_3COOH	HCN
K_a	6.8×10^{-4}	1.8×10^{-5}	4.9×10^{-10}

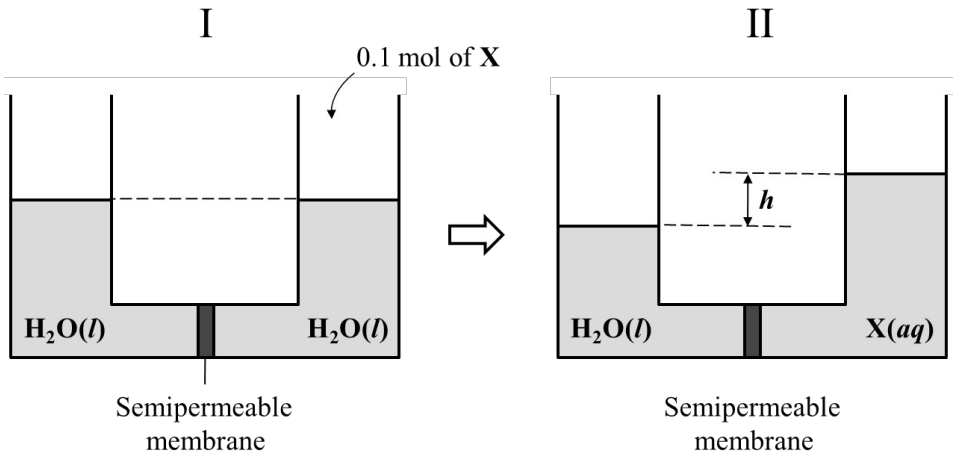
Which of the following options from A to D chooses all the correct statement(s) from the box below? (Assume that the temperatures of the solutions are kept constant at 25 °C.)

① 0.1 M HCN(*aq*) is basic.
② The pH of 0.1 M HF(*aq*) is lower than the pH of 0.1 M CH_3COOH(*aq*).
③ The concentration of H^+ is higher in 1 M HCN(*aq*) than in 0.1 M CH_3COOH(*aq*).

(A) ① (B) ② (C) ①, ③ (D) ②, ③

9.

A U-shaped tube with a semipermeable membrane was filled with 2 L of water as shown in figure I. When 0.1 mol of **X** was completely dissolved in the right arm of the tube, the level of **X**(*aq*) solution has risen as shown in figure II. (Only water can pass through the membrane.)



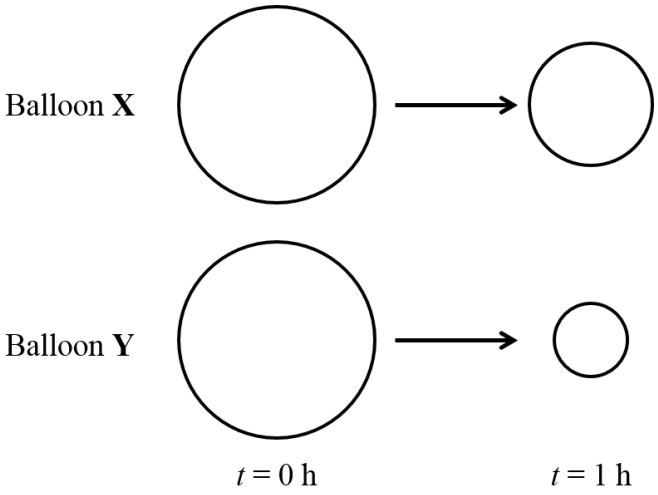
Which of the following **X** would give the SECOND greatest ***h***?

(A) $MgSO_4$ (B) CH_3COOH (C) $CaCl_2$ (D) Sugar

10.

QUESTIONS

Rubber balloons **X** and **Y** were inflated with either pure H_2 or pure Ne gas to the same volume of 10 L. After being left in air for 1 h, the balloons shrank such that balloon **X** had a larger volume than **Y**. (Assume that the ambient temperature and pressure were kept constant between $t = 0$ and $t = 1$ h.)



Which of the following options from A to D chooses all the correct statement(s) from the box below?

① At $t = 0$ h, balloon **X** contained Ne.
② Internal pressure of balloon **X** was constant throughout the above change.
③ At $t = 1$ h, balloon **Y** contained a mixture of gases.

(A) ①　　(B) ②　　(C) ①, ③　　(D) ②, ③

QUESTIONS

[PHYSICS]

11.

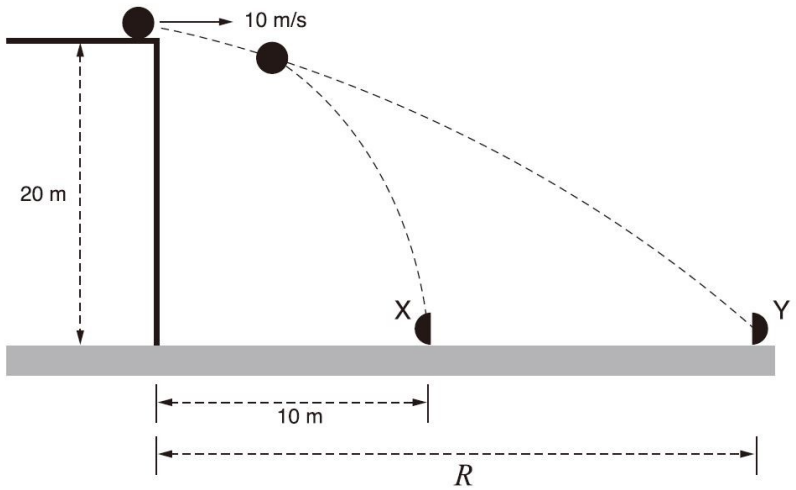
Bats use ultrasonic waves to catch prey. When stationary, a bat emits ultrasonic waves of frequency 82.5 kHz. The bat now starts following a moth along the +x direction. The speeds of the bat and moth are 9.00 m/s and 8.00 m/s, respectively. The bat now emits and detects the wave reflected by the moth. The velocity of sound is 340 m/s.

Which of the following is the closest frequency for the detected wave by the bat?

(A) 82.7 kHz (B) 82.8 kHz (C) 82.9 kHz (D) 83.0 kHz

12.

A ball of mass 1.0 kg is projected with a velocity of 10 m/s horizontally from the edge of a building at a height of 20 m. While falling, the ball splits into two identical pieces, X and Y without external forces. Then, X and Y hit the ground simultaneously at a point 10 m and R horizontally from the building, respectively. Consider the gravitational acceleration to be 10 m/s^2.

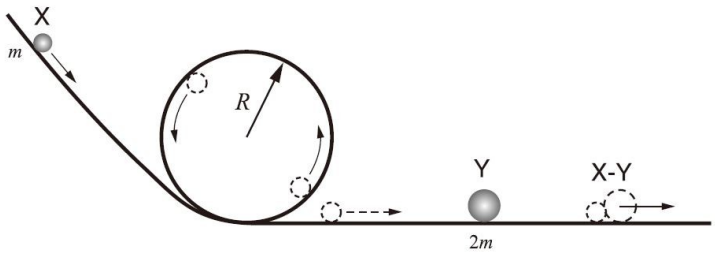


What is the distance R? (Assume there is no air resistance.)

(A) 20 m (B) 30 m (C) 40 m (D) 50 m

13.

A ball X with mass m travels on a frictionless track, as shown in the figure below. After barely rotating on a circular track of radius R, X collides with another ball Y, which has mass $2m$ and is initially at rest. After the collision, X and Y stick together and move.

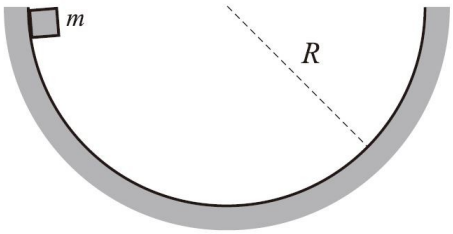


What is $\frac{K_X}{K_{XY}}$? (K_X and K_{XY} are the kinetic energies of X just before the collision and of XY after the collision, respectively.)

(A) 1 (B) 2 (C) 3 (D) 4

14.

A block of mass m is released from one rim of a hemispherical bowl of radius R. In the presence of friction, the block finally stops at the bottom of the hemisphere after oscillating left and right.



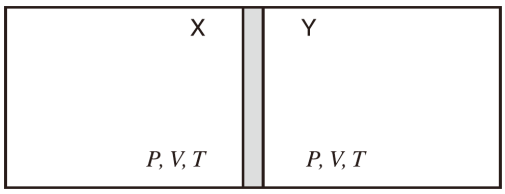
What are the amounts of the work done by gravitational and normal forces?

	Work done by gravitational force	Work done by normal force
(A)	0	0
(B)	mgR	0
(C)	0	mgR
(D)	mgR	mgR

15.

A tank is divided into two compartments X and Y with a thermally-insulating wall that can move

without friction. X and Y contain an ideal gas at the same pressure P, volume V, and temperature T as shown in the figure below. After the temperature of X increases to $3T$, the system reaches an equilibrium state. The temperature of Y remains constant at T throughout the time.

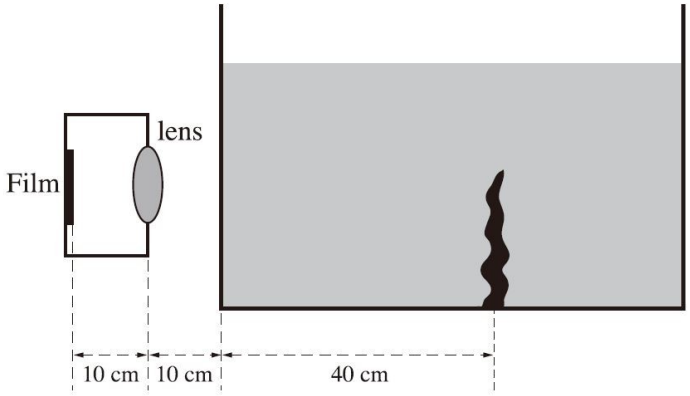


What is the gas pressure of Y at the equilibrium after the heating?

(A) P (B) $1.5P$ (C) $2P$ (D) $3P$

16.

A person takes a picture of a waterweed in a fishbowl using a camera with a convex lens. The fishbowl is filled with water of which the refractive index is $\frac{4}{3}$. When the film, lens, and waterweed are positioned as shown in the figure below, a clear image of the waterweed is recorded on the film.



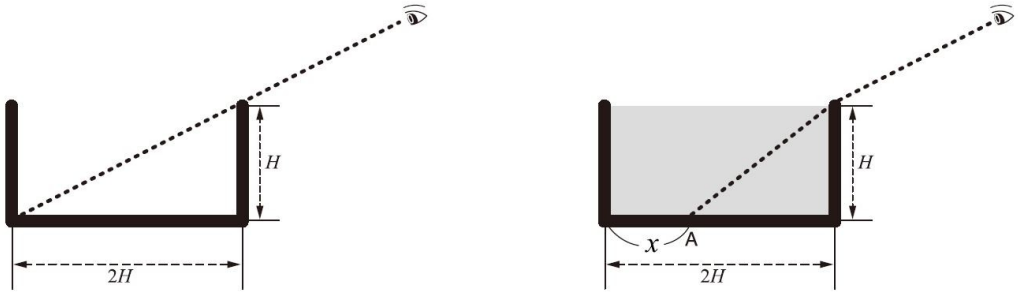
What is the focal length of the convex lens?

(A) 8.0 cm (B) $\frac{50}{6}$ cm (C) $\frac{110}{13}$ cm (D) 9.0 cm

17.

You see along the rim of a container so that the top rim is lined up with the opposite edge of the

bottom (I). The container has a height of H and a width of $2H$. While you keep your eye in the same position, your friend fills the container with a transparent liquid having a refractive index of n. Then you see a coin lying at point A (II).



(I) (II)

What is x, the distance of the coin from the edge of the container?

(A) $H\left(1-\frac{1}{\sqrt{3n^2-1}}\right)$

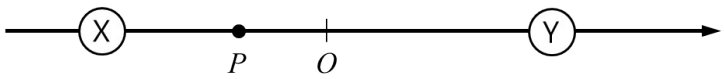
(B) $2H\left(1-\frac{1}{\sqrt{3n^2-1}}\right)$

(C) $H\left(1-\frac{1}{\sqrt{5n^2-4}}\right)$

(D) $2H\left(1-\frac{1}{\sqrt{5n^2-4}}\right)$

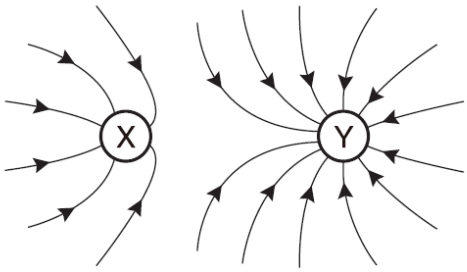
18.

Two point charges X and Y are fixed at the same distance from the origin *O*. The charge of X is positive. When a negative charge is placed at point *P*, this negative charge does not move.

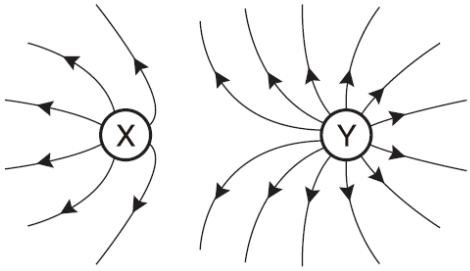


Which of the following sketches shows the correct electric field lines before placing the negative charge at *P*?

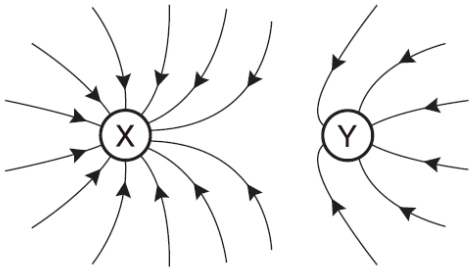
(A)



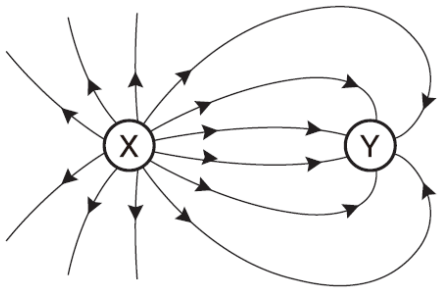
(B)



(C)

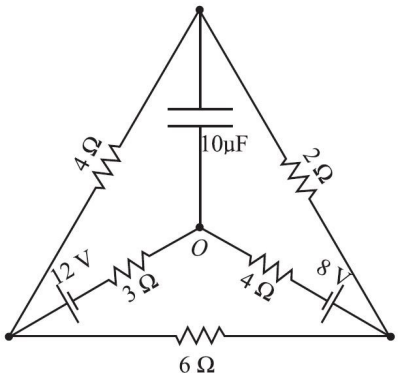


(D)



19.

The figure below is a circuit containing two batteries, five resistors, and one capacitor.



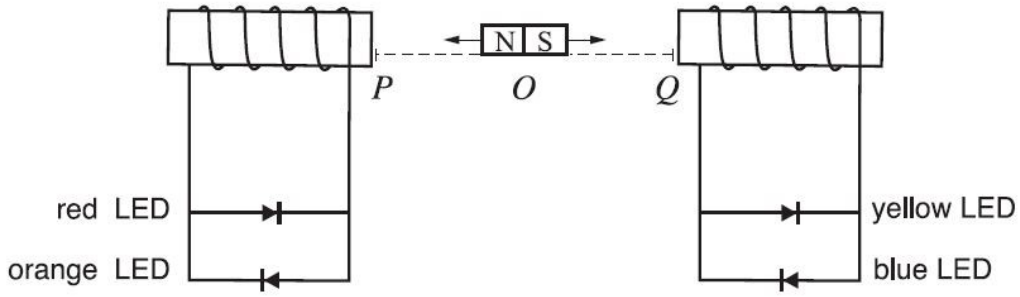
What is the current flowing through the 3Ω resistor after sufficient time has passed?

(A) 0.1 A (B) 0.2 A (C) 0.4 A (D) 0.8 A

20.

QUESTIONS

The figure below shows two circuits containing solenoidal coils and LEDs (Light-Emitting Diodes). The colors of the LEDs in the left circuit are red and orange, and those in the right circuit are yellow and blue. The  LEDs turn on when the current flows to the right, while the  LEDs turn on when the current flows to the left. The magnet moves from side to side between the coils in the following sequence; O→P→O→Q→O. Assume that the current is only induced in the left coil when the magnet moves between O and P, and only in the right coil when the magnet moves between O and Q.



What is the turn-on sequence of the LEDs when the magnet moves in the sequence of $O \rightarrow P \rightarrow O \rightarrow Q \rightarrow O$?

(A) red – orange – yellow – blue

(B) orange – red – blue – yellow

(C) red – orange – blue – yellow

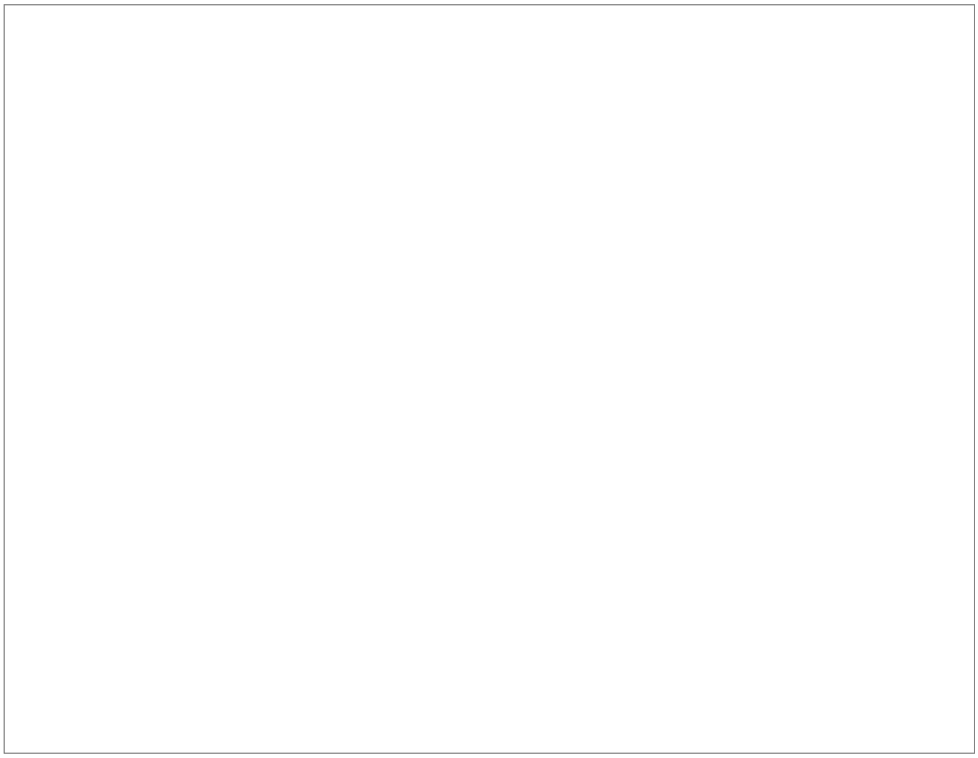
(D) orange – red – yellow – blue

QUESTIONS

[BIOLOGY]

21.

The pathways and reactions involved in the nitrogen cycle are complicated. The following describes some parts of the nitrogen cycle.



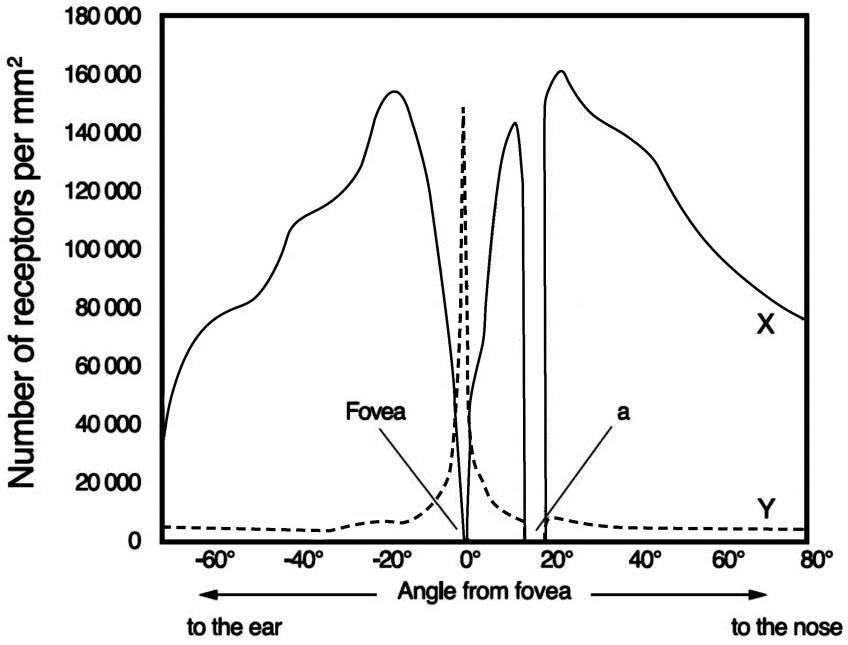
Which of the following options from A to D chooses all the correct statement(s) from the box below?

1	Atmospheric nitrogen (N_2) is fixed into organic molecules containing nitrogen by plants and humans.
2	X and Y are degradation processes by bacteria.
3	Z is a denitrification process by bacteria.
4	Plants are involved in the conversion pathways of NH_4^+ and NO_3^- to organic molecules containing nitrogen following the uptake of these ions

(A) ①, ② (B) ①, ③ (C) ②, ③ (D) ②, ④

22.

The figure below shows the distribution of receptor cells X (solid line) and Y (dashed line) in the retina.



Which of the following options from A to D chooses all the correct statement(s) from the box below?

1	X are usually located in the center of the retina.
2	X are less sensitive to light than Y.
3	"a" is the position of the blind spot.
4	$\frac{Number\ of\ X}{Number\ of\ Y}$ is much higher in nocturnal (active in nighttime) animals than in diurnal (active in daytime) ones.

(A) ①, ② (B) ①, ③ (C) ②, ③ (D) ③, ④

23.

DNA is composed of two strands (I and II), and one of these strands can be used as a template to produce mRNA by the process of transcription. Consider a DNA fragment of 1000 base pairs. The base ratio of (A+T) : (G+C) in the strands is 1 : 4. The table below shows the base compositions of strands I and II, and the mRNA transcribed by one of the strands.

		Base composition (number)					
		G	A	T	C	U	Sum
DNA Strands	I			150			1000
	II				500		1000
mRNA					(X)	150	1000

Which of the following statements is NOT correct?

(A) The number for X is 350.

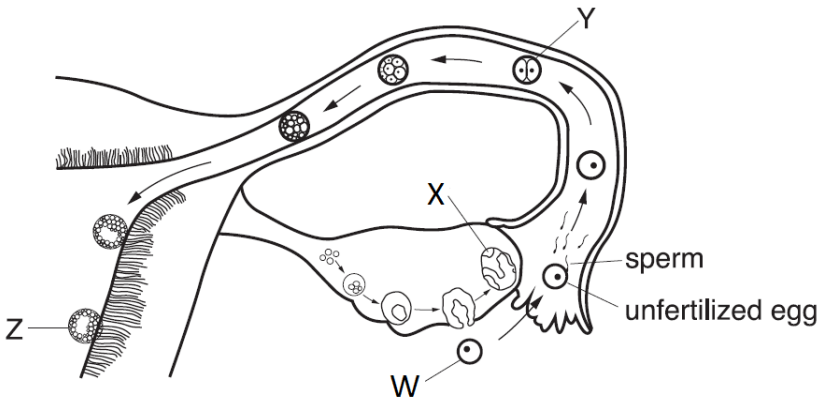
(B) The number for A+G in strand I is 550.

(C) Strand II was used as the template for the mRNA.

(D) The total number of hydrogen bonds between A and T in the strands is 400.

24.

The figure below shows the process of egg production and early development of a healthy fertilized egg in the human reproductive system.



Which of the following statements is NOT correct?

(A) Three polar bodies are attached to W.

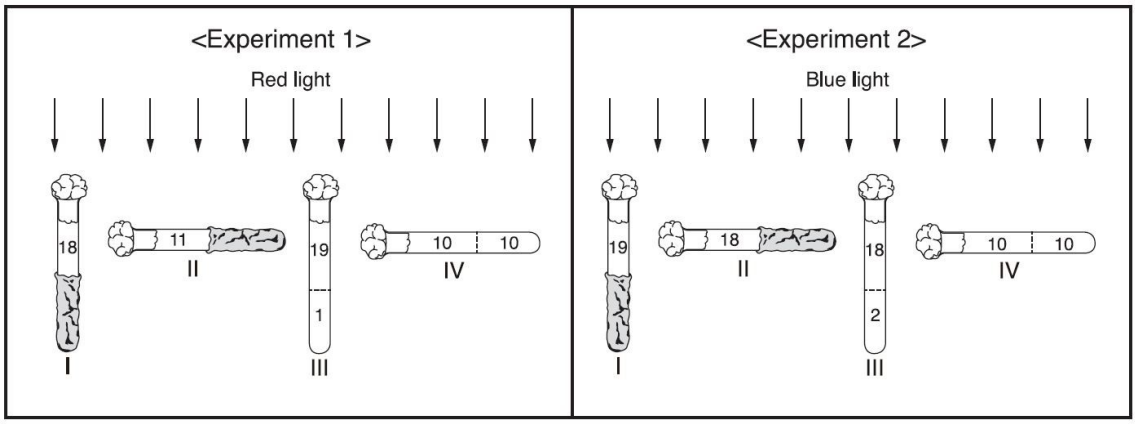
(B) X produces progesterone.

(C) The chromosome number for each cell in Y is 46.

(D) Z is at the stage of blastocyst

25.

Twenty flies are placed in each of the four sealed glass tubes (I –IV). While tubes I and II are partly covered with foil to protect from exposure to light, tubes III and IV are not covered. The numbers inside each tube of experiments 1 and 2 show the distribution of the flies immediately after the exposure to red light and blue light, respectively.



Which of the following statements about the experiments is NOT correct?

(A) The experiments are testing the response of the flies to red light, blue light and gravity.

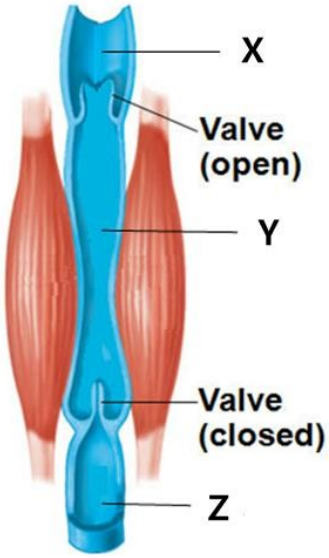
(B) Tubes II and IV are serving as the controls for the light variable.

(C) Experiment 1 shows that flies respond to gravity, but not to red light.

(D) From experiments 1 and 2, it can be concluded that flies respond to blue light, but not to red light.

26.

The figure below shows a vein and contracted muscles surrounding the vein in the leg of a normal person.



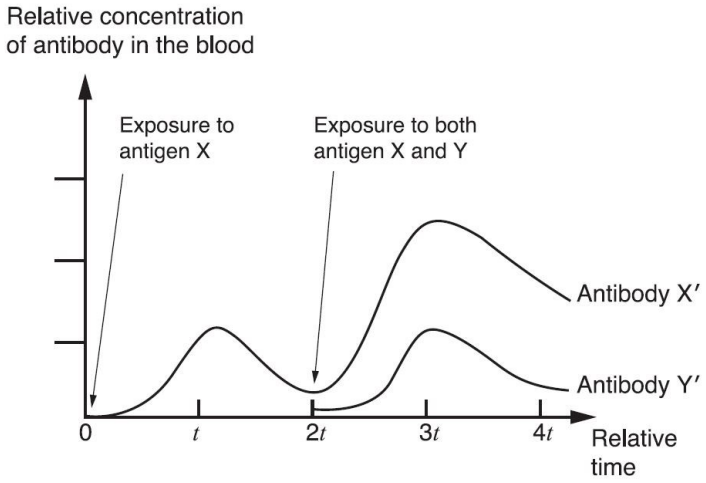
Which of the following options from A to D chooses all the correct statement(s) from the box below?

1	The blood pressure at Y is higher than at X in this situation.
2	The blood flows from X to Y when the muscles relax.
3	The blood flows from Y to Z when the muscles contract.

(A) ① (B) ② (C) ①, ③ (D) ②, ③

27.

The figure below shows the change of relative concentrations of antibody X' and Y' in the blood over time when animals are exposed to antigen X and Y. The animals have not been previously exposed to antigen X or Y.



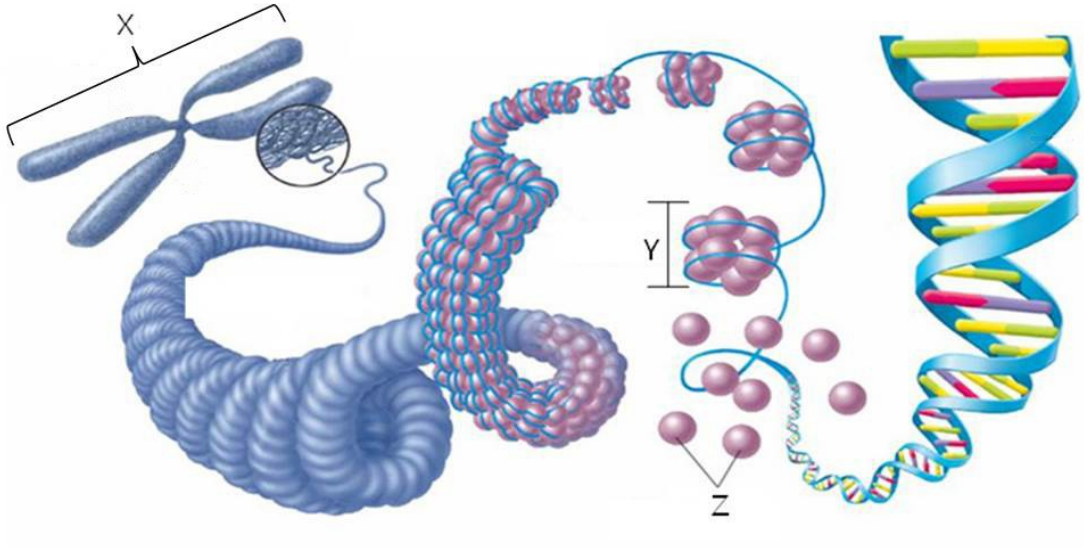
Which of the following options from A to D chooses all the correct statement(s) from the box below?

1	Without antigen X, antibody Y′ would not be produced from 2*t* to 3*t*.
2	The rapid increase of antibody X′ from 2*t* to 3*t* is due to memory cells against antigen X.
3	The increased production of antibody X′ from 2*t* to 3*t* is because antigen X and Y have acted together.

(A) ① (B) ② (C) ①, ② (D) ②, ③

28.

The figure shows the structure and condensation states of a chromosome.



Which of the following options from A to D chooses all the correct statement(s) from the box below?

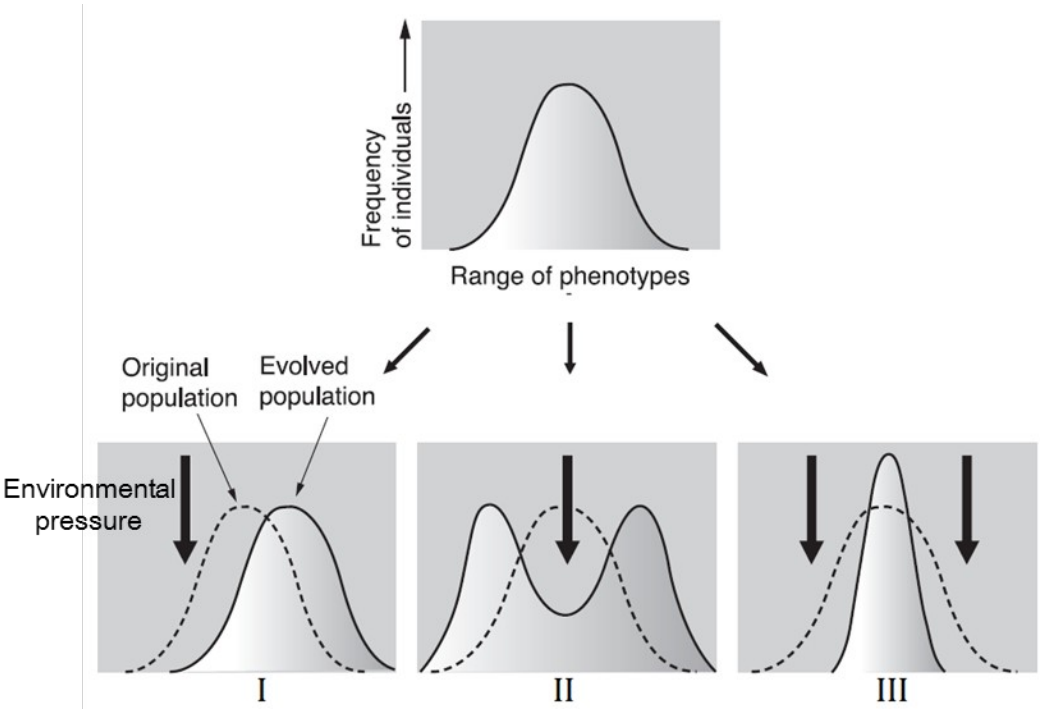
1	X is observed in metaphase of the cell-division cycle.
2	Y is a nucleosome.
3	Bacteria have Z.

(A) ① (B) ② (C) ①, ② (D) ②, ③

29.

The box below explains three cases of natural selection, and the figures show three different types of natural selection.

1	The peppered moth gets its name from the peppery-looking coloration on its wings and body, which may be a light color or a dark color, with very few individuals being a color in between the two extremes.
2	Robins typically lay four eggs. A larger number of eggs may result in malnourished chicks, while a smaller number of eggs may result in no viable offspring.
3	Individuals of giraffe population with short necks could not reach as many leaves on which to feed. As a result, the distribution of neck length shifted to favor individuals with long necks.

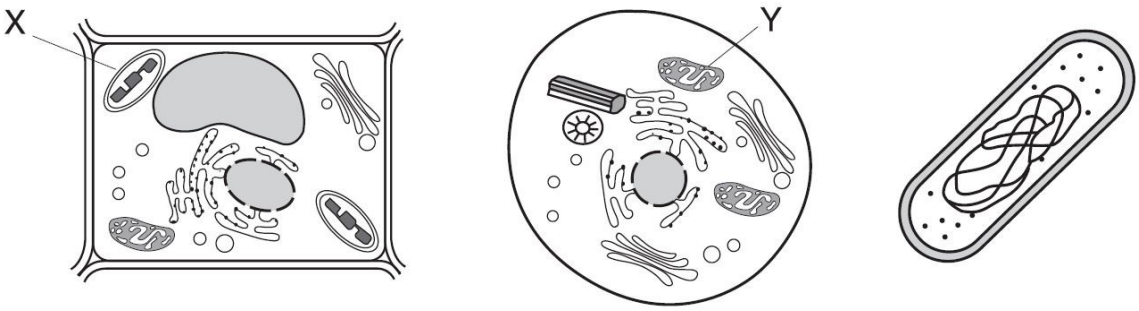


Which of the following figure-explanation matches is correct?

(A) I - ③ (B) II - ② (C) II - ① and ② (D) III - ① and ③

30.

The figures below show typical cells of three different living organisms (I, II, and III).



I II III

Which of following statements is correct?

(A) X in I is often found inside cyanobacteria.

(B) The cell wall can be observed in I and II.

(C) A nuclear envelope (membrane) encloses the nucleus in III.

(D) Genetic materials can be found in X and Y.

IJSO-2015

12th International Junior Science Olympiad
Daegu, Republic of Korea
December 4, 2015

Multiple Choice Competition
Time : 3 hr
Points : 30

ANSWER SHEET

Name		Code	
Country		Signature	

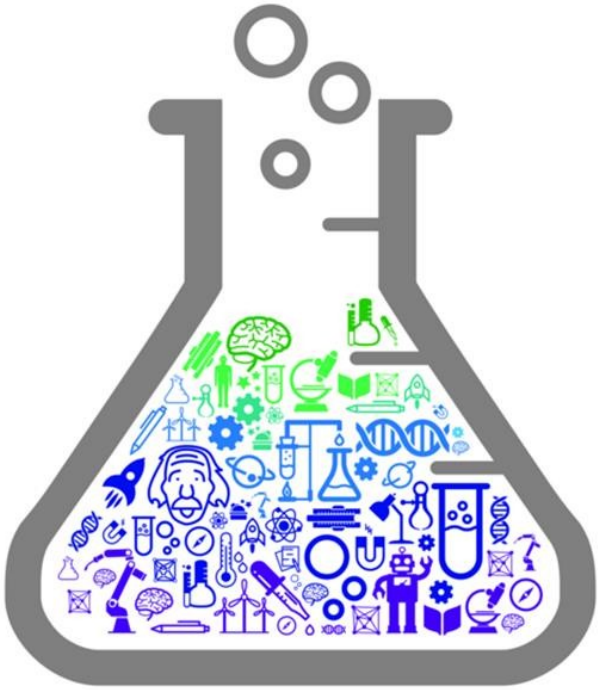
	Answers					Answers			
1	A	B	C	D	16	A	B	C	D
2	A	B	C	D	17	A	B	C	D
3	A	B	C	D	18	A	B	C	D
4	A	B	C	D	19	A	B	C	D
5	A	B	C	D	20	A	B	C	D
6	A	B	C	D	21	A	B	C	D
7	A	B	C	D	22	A	B	C	D
8	A	B	C	D	23	A	B	C	D
9	A	B	C	D	24	A	B	C	D
10	A	B	C	D	25	A	B	C	D
11	A	B	C	D	26	A	B	C	D
12	A	B	C	D	27	A	B	C	D
13	A	B	C	D	28	A	B	C	D
14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

12TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2015



December 2(Wed)-11(Fri), 2015 I Daegu, Republic of Korea

Multiple Choice Competition

– Solution –

December 4, 2015

SOLUTION

[CHEMSTRY]

1.

(Answer) D

(Explanation) Atom is formed of proton(s), electron(s) and neutron(s), where the atomic number is defined by the number of protons, and the mass number is defined by the number sum of protons and neutrons. Any neutral atom has equal numbers of protons and electrons. When two atoms have the same number of protons but different numbers of neutrons, they are classified as same elements in the isotopic relation.

II has 8 neutrons, and $a = 8$. (A is incorrect)
II has 7 electrons, and $b = 7$. (B is incorrect)
Atomic number of I is 7. (C is incorrect)
I and II have same number of protons but different numbers of neutrons; they are isotopes of the same element (D is correct).

2.

(Answer) C

(Explanation) All the four ions, in the question, are isoelectronic but have different nuclear charges. Since the numbers of electrons are the same, the higher the nuclear charge is, the smaller the ionic radius is.

Ionic radii sizes: $O^{2-} > F^{-} > Na^{+} > Mg^{2+}$

3.

(Answer) D

(Explanation) Because the molecular geometry of H_2Se is bent linear, with two lone-pair electrons on the central atom, Se, there is a non-zero dipole moment in H_2Se. The other three have symmetric molecular geometry and have zero dipole moment.

4.

(Answer) B

(Explanation) When the concentration of the reactant is linearly decreasing with time, the reaction is zeroth order reaction, that is, $n = 0$.
Reaction rate = k
By writing the equation in the unit,
M/s = (the unit for the k)
The unit for the k is M/s.

5.

(Answer) C

(Explanation) According to the density information (1.25 g/L), 1 mole of **X**, corresponding to a volume of 22.4 L, has a mass of 28 g. That is, the molecular mass of **X** is 28 g/mol.
Hydrocarbon **X** consists of only hydrogen (H, atomic mass: 1 g/mol) and carbon (C, atomic mass: 12 g/mol), and will have a chemical formula of C_mH_n. Considering the molecular mass of **X**, it is deduced that m = 2, and n = 4.
As an **X** molecule (28 g/mol) consists of two carbon atoms (24 g/mol) and four hydrogen atoms (4 g/mol), the mass fraction of carbon in **X** is 24/28 = 85.7 %.

6.

(Answer) B

(Explanation) The electron configuration of the ground state of $_{13}Al$ is $1s^22s^22p^63p^3$ and the most stable ion of Al is Al^{3+}. Therefore, the electron configuration of Al^{3+} is $1s^22s^22p^6$.

7.

(Answer) C

(Explanation) ΔH_f^o of $NO_2(g)$ is the enthalpy change for a process where $NO_2(g)$ is formed from the most stable elemental components:

$$\frac{1}{2}N_2(g)+O_2(g) \rightarrow NO_2(g)\ \Delta H_{(i)}^o=\Delta H_f^o[NO_2(g)]$$

The above process can be broken down to two steps

$$\frac{1}{2}N_2(g)+O_2(g) \rightarrow N(g)+2O(g)\ \Delta H_{(ii)}^o=\frac{(950+990)}{2}kJ/mol$$

$$N(g)+2O(g) \rightarrow NO_2(g)\ \Delta H_{(iii)}^o=-1430\,kJ/mol$$

($\Delta H_{(ii)}^o \wedge \Delta H_{(iii)}^o$ can be evaluated from the diagram given in question)

As the enthalpy is an extensive property, $\Delta H_{(i)}^o=\Delta H_{(ii)}^o+\Delta H_{(iii)}^o$, and consequently, ΔH_f^o of $NO_2(g)$ is –460 kJ/mol.

8.

(Answer) B

(Explanation)

In aqua, HCN is dissociated to H^+ and CN^-, where the final concentrations of [HCN], [H^+] and [CN^-] are governed by K_a ($= 4.9 \times 10^{-10}$).

	HCN	↔	H^+	+	CN^-
initial conc. (M)	0.1		0		0
final conc. (M)	$0.1 - x$		x		x

$$K_a = \frac{[H^+][CN^-]}{[HCN]}$$

As x should be far smaller than 0.1, an approximation can be made such that

$$\frac{x^2}{0.1} = 4.9 \times 10^{-10}$$

$$x^2 = 49 \times 10^{-12}$$

[H^+], which is x, is calculated to be 7×10^{-6} M, larger than 10^{-7} M.
Therefore 0.1 M HCN(aq) is acidic: ① is incorrect.

The larger K_a corresponds to the greater acid strength, and the lower pH for the given concentration. If the concentration is same, HF(aq) is more acidic and has lower pH than CH_3COOH(aq): ② is correct.

In a similar manner to above, [H^+] is calculated to be $\sqrt{4.9} \times 10^{-5}$ M for 1 M HCN(aq), and $\sqrt{1.8} \times 10^{-3}$ M for CH_3COOH: ③ is incorrect.

9.

(Answer) A

(Explanation) In figure II, the difference in water levels arises from the osmotic pressure exerted by the solute particles. Depending on the solute type, different numbers of solute particles are released into water, and different extents of osmotic pressure are built. When 0.1 mol of each solute is added to water, following amounts of solute particles will be released:

$MgSO_4$: 0.2 mol
CH_3COOH : $(1 + \alpha)/10$ mol $(0 < \alpha < 1)$
$CaCl_2$: 0.3 mol
Sugar : 0.1 mol

Therefore, the osmotic pressure will decrease in the order

$CaCl_2$ solution > $\underline{MgSO_4 \text{ solution}}$ > CH_3COOH solution > Sugar solution

10.

(Answer) C

(Explanation) According to *Graham's law**, effusion of H_2 (2 g/mol) will be faster than that of Ne (20 g/mol). The larger size of balloon X than balloon Y, at t = 1 h, indicates that effusion occurred more slowly in balloon X. Therefore we can deduce that balloons X and Y initially contained Ne and H_2, respectively: ① is correct.

The volume contraction from t = 0 h to t = 1 h is a spontaneous process reflecting that the internal pressure of each balloon was higher than the ambient pressure. From t = 0 h to t = 1 h, the internal pressure of each balloon continuously decreased toward the ambient pressure. (② is incorrect)

Over the process, gas molecules pass through the balloon, toward an "equilibrium", where all the gaseous species have the equilibrated partial pressures. From t = 0 h to t = 1 h, not only H_2 and Ne but also the components in air diffuse through the balloon. (③ is correct)

**Graham's law*: The effusion rate of a gas is inversely proportional to the square root of the molar mass.

SOLUTION

[PHYSICS]

11.

(Answer) D

(Explanation) According to the equation of Doppler effect, the frequency that the moth detects is

$$f_{md} = f_{be}\frac{v - v_m}{v - v_b} = 82.5\frac{340-8}{340-9} = 82.749\ \text{kHz}$$

The bat detects a reflected ultrasonic wave from the moth. Therefore, the frequency that the bat detects is

$$f_{bd} = f_{me}\frac{v + v_b}{v + v_m} = 82.749\frac{340+9}{340+8} = 82.98\ \text{kHz} \sim 83.0\ \text{kHz}$$

12.

(Answer) B

(Explanation) If object is projected horizontally, the object moves at the constant velocity horizontally and does at the constant acceleration vertically.

$$H = 20\text{m} = \frac{1}{2}(10\text{m/s}^2)\text{t}^2$$

From the distance for vertical movement ( ), one can find the time of

$$D = 10\text{m/s} \times 2\,\text{sec} = 20\text{m}$$

falling is 2 sec. So, the distance for horizontal movement is .

From the equation of center of mass, one can find the position of the other piece (X),

$$20\text{m} = \frac{0.5\text{kg}\times 10\text{m} + 0.5\text{kg}\times x}{1\text{kg}}$$

R=30m

13.

(Answer) C

(Explanation) Due to the barely circular movement of substance X, the centripetal force at the maximum height should be same as the gravitational force. That is

$$\frac{mv^2}{R} = mg$$

By the conservation of energy, the momentum of X before collision is

$$\frac{1}{2}mv^2 + mg(2R) = \frac{1}{2}mv'^2 \quad \square \quad mv' = m\sqrt{5gR} \quad , \quad \frac{1}{2}mv'^2 = \frac{5}{2}mgR$$

Since the momentum should be conserved during the collision, the velocity and kinetic energy of X-Y after the collision is

$3mV = m\sqrt{5gR}$ □ $V = \frac{1}{3}\sqrt{5gR}$, $\frac{1}{2}(3m)V^2 = \frac{1}{2}(3m)\frac{1}{9}(5gR) = \frac{1}{3}(\frac{1}{2}mv'^2)$

Therefore, the kinetic energy ratio between the kinetic energy of X before collision and that of X-Y after collision, i.e. $K_X/K_{X-Y}=3$.

14.

(Answer) B

(Explanation) Because gravity is conservative force, the amount of work is irrelevant to the path.
The amount of work by gravity: mgR ($\because$ moves as much as R by mg)
The amount of work by normal force: 0 ($\because$Normal force is perpendicular to the moving direction of the object.)

15.

(Answer) C

(Explanation) $\frac{P'V'_A}{3T}=\frac{P'V'_B}{T}$ $\Rightarrow$ $V'_A=3V'_B$

Since the total volume is constant at $2V$,

$V'_A+V'_B=2V$ $\Rightarrow$ $V'_B=\frac{1}{2}V$.

From the Boyle - Charles law

$\frac{PV}{T}=\frac{P'V'_B}{T}$ $\Rightarrow$ $P'=2P$

16.

(Answer) A

(Explanation) A fish in water appears to be closer than it actually is. As the refractive index of water is 3/4, the image of fish is located in 30cm to the wall.

By thin lens formula ($\frac{1}{a}+\frac{1}{b}=\frac{1}{f}$), $\frac{1}{10+30}+\frac{1}{10}=\frac{1}{f}$. Therefore, f = 8cm

17.

(Answer) D

(Explanation) A ray of light is refracted on the surface of water like below Figure. By the Snell's law, $n\sin i=\sin r$.

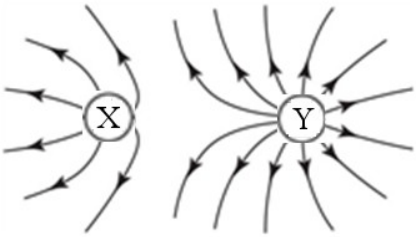
Using $\sin i=\frac{(2H-x)}{\sqrt{(2H-x)^2+H^2}}$, $\sin r=\frac{2H}{\sqrt{(2H)^2+H^2}}$, we can find

$x=2H\left(1-\frac{1}{\sqrt{5n^2-4}}\right)$.

SOLUTION

18.

(Answer) B



(Explanation) The charges X and Y are the same kind. But the quantity of charge X is less than that of charge Y.

19.

(Answer) C

(Explanation) In a steady state condition, current does not flow along the capacitor. By the Kirchhoff's law (i_1 : the current along 3Ω-4Ω resistors, i_2 : the current along 4Ω-2Ω resisters, and i_3 : the current along a 6Ω resister), $i_2 = i_1 + i_3$, $-8-4i_1-3i_1+12+6i_3=0$, $-12+3i_1+4i_1+8+6i_2=0$

$i_1 = 0.4A,\ \ i_2 = 0.2A,\ \ i_3 = -0.2A$

So,

20.

(Answer) B

(Explanation) By the Lenz's law, P would be N-pole for an approaching magnet and be S-pole for a receding magnet. So we are able to know that the sequence of turn-on of LEDs would be orange-red-blue-yellow from Fleming's right hand rule

SOLUTION

[BIOLOGY]

21.

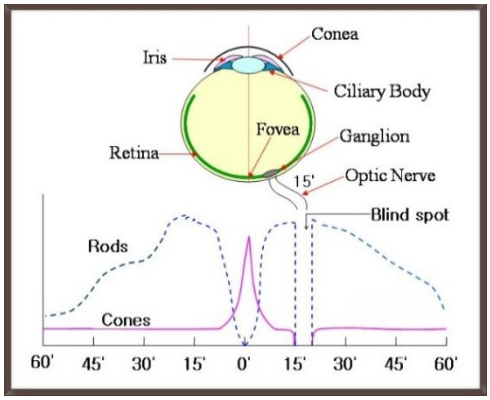
(Answer) D

(Explanation) The nitrogen is fixed to organic nitrogen by bacteria. The organic material is decomposed to ammonia by the bacteria. The process of ammonia to nitrite and nitrate by bacteria is nitrification. Plants are the producer, which uptake NH_4^+ and NO_3 to synthesize organic materials.

22.

(Answer) D

(Explanation) X is rod cell, and Y is cone cell. Con cells distinguish various wavelength of visible light. Rod cells is sensitive to light. Nocturnal animals have more rod cell.



23.

(Answer) A

(Explanation) A binds to base T by two hydrogen bonds and base G to base C with three hydrogen bonds in DNA double strands. Since base ratio of A+T/G+C = 1/4 in given double strands, A+T would be 400 bases in DNA double strands (2000 x 1/5 = 400) and G+C would be 1600 bases. It indicates that A+T and G+C are 200 and 800 bases in one strand, respectively. Since mRNA contains 150 U, DNA strand with 150 A should be a template strand, which is strand II. Based on those information, table can be filled out with proper bases as shown below

		Base composition (number)					
		G	A	T	C	U	Sum
DNA	I	500	50	150	300	-	1000
	II	300	150	50	500	-	1000
mRNA		500	50	150	(300)	150	1000

24.

(Answer) A

(Explanation) The first polar body is attached to ovulated egg and the two second polar bodies will be formed after fertilization occurred. Thus three polar bodies will be found attached to egg after and fertilization occurred and then meiosis completed. Corpus luteum produces estrogen and progesterone. Each blastomere as a human cell has 46 chromosomes. At the time of implantation, zygote is at the stage of blastocyst.

25.

(Answer) B

(Explanation) In a first experiment, flies respond to gravity but not to red light, and in a second experiment, flies respond to both blue light and gravity. Tube Ⅱ and Ⅳ were served as controls for the gravity variable.

26. .

(Answer) A

(Explanation) The valves in the vein prevent reverse flow and make blood flows to heart smooth. The surrounding muscles near the veins help this mechanism. In this figure contracted muscles squeeze the vein to help the blood flow from Y to X. So the blood pressure at Y is higher than at X to make the blood flow well when the muscles contract. When the muscles relaxed, the valve opening between Y and Z makes blood flow from Z to Y as normal.

27.

(Answer) B

(Explanation) For secondary immune response, when the same antigen again invade in the body, the memory cells are differentiated into plasma cells, and produce large amounts of antibodies within a short time.

28.

(Answer) C

(Explanation) Highly condensed chromosome are formed in metaphase in cell cycle. Allele is gene that is found at same site on homologous chromosome. Nucleosome is basic unit of chromosome and consists of histone octamer and ~200 bp DNA. Bacteria have circular DNA that does not contain histone protein.

29.

(Answer) A

(Explanation) As natural selection works on a population, the gene pool changes. The favorable adaptations become more plentiful and the less desirable traits become fewer or even disappear from the gene pool completely.

Directional selection (I): a mode of natural selection in which a single phenotype is favored, causing the allele frequency to continuously shift in one direction. The genetic variance of the population shifts toward a new phenotype when exposed to environmental changes. In the case of

such selection, the mean of the population graph shifts. Using the familiar example of giraffe necks, there was a selection pressure against short necks, since individuals with short necks could not reach as many leaves on which to feed. As a result, the distribution of neck length shifted to favor individuals with long necks. Another example, light-colored peppered moths are better camouflaged against a pristine environment, and dark-colored are better camouflaged against a sooty environment. Thus, as Industrial Revolution progressed in nineteenth-century England, the color of the moth population shifted from light to dark. (resistance).

Disruptive Selection (II): a mode of natural selection in which extreme values for a trait are favored over intermediate values. The genetic variance of the population increases when natural selection selects for two or more extreme phenotypes that each have specific advantages. For example, imagine a plant of extremely variable height that is pollinated by three different pollinators, one that was attracted to short plants, another that preferred plants of medium height and a third that visited only the tallest plants. If the pollinator that preferred plants of medium height disappeared from an area, medium height plants would be selected against and the population would tend toward both short and tall, but not medium height plants. (Multi-niche)

Stabilizing selection (III): a type of natural selection in which genetic diversity decreases as the population stabilizes on a particular trait value. The genetic variance of the population decreases when natural selection favors an average phenotype and selects against extreme variations. Robins typically lay four eggs. Larger clutches may result in malnourished chicks, while smaller clutches may result in no viable offspring. (tolerance)

Directional or disruptive selection: One of the best-studied examples of directional selection is the peppered moth in England. The moth gets its name from the peppery-looking coloration on its wings and body. The peppered moth may be a light color or a dark color, with very few individuals being a color in between the two extremes.

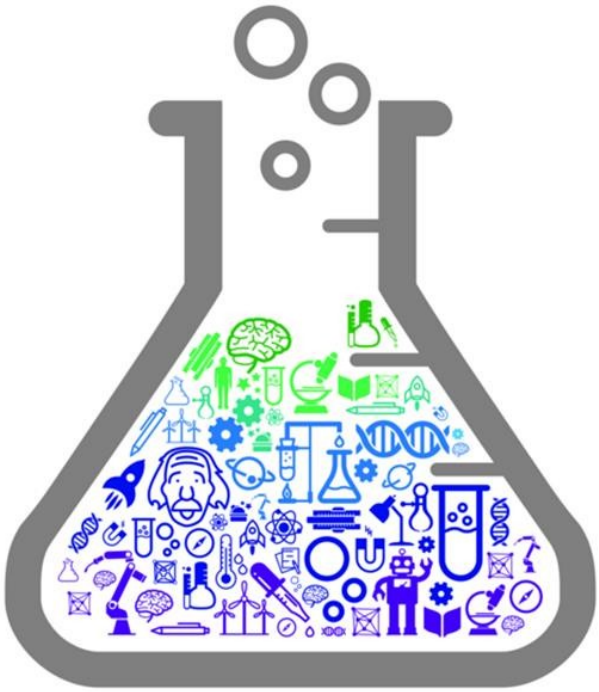
30.

(Answer) D

(Explanation) I is a plant cell. II is an animal cell. III is a bacterial cell. There are cell walls in plant and bacterial cell. There is no nuclear envelope (membrane) in bacteria cell. Organelle X is chloroplast and organelle Y is mitochondria. Both have DNA, which is genetic material.

12TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2015



December 2(Wed)-11(Fri), 2015 I Daegu, Republic of Korea

Theoretical Competition

– Exam Sheet –

December 6, 2015

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

QUESTIONS

1. You have 5 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 is blown! 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. After the "START" whistle, you will have 3 hours 30 minutes to complete the exam.
2. ONLY use the pen provided by the organizers (not pencil).
3. You have **13** pages of answer sheets. Raise your hand, if you find any missing sheets.
4. NOW write your name, code, country and signature in your first answer sheet, and your name and code in the next pages of your answer sheets.
5. Read carefully the problems and write the correct answers in the corresponding boxes of the answer sheet.
6. When units are provided in the answer sheets, you have to write the answers correctly for the units.
7. Only the answer sheets will be evaluated. Before writing your answers on the answer sheets, use the rough book provided.
8. Point rules : Each question marking
9. The total number of questions is 6. Check that you have a complete set of the test questions sheet (12 pages, page 5 – page 16) after the **"START"** whistle is blown. Raise your hand, if you find any missing sheets.

QUESTIONS

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, 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 10²³***

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.

I. Chemical Oxygen Demand (COD) Test

The chemical oxygen demand (COD) test is commonly used for indirectly measuring the amount of organic compounds in water. Most applications of COD are related to determining the amount of organic pollutants found in surface water (e.g. lakes and rivers) or wastewater, making COD a useful measure of water quality. It is expressed in ppm (parts per million), which indicates *the mass of oxygen molecules (in mg) consumed for oxidizing the pollutants per liter of solution*. The basis for the COD test is that nearly all organic compounds can be fully oxidized to CO_2 with a strong oxidizing agent under acidic conditions.

The amount of oxygen molecules required to oxidize an organic compound to CO_2 and water is given by:

$$C_aH_bO_c + x\,O_2 \rightarrow a\,CO_2 + \frac{b}{2}\,H_2O \quad (1)$$

Potassium dichromate ($K_2Cr_2O_7$) is a strong oxidizing agent and is used to oxidize organic compounds in the COD determination under acidic conditions. The net reaction of $K_2Cr_2O_7$ with an organic compound is given by:

$$C_aH_bO_c + y\,Cr_2O_7^{2-} + z\,H^+ \rightarrow a\,CO_2 + \frac{b+z}{2}H_2O + 2y\,Cr^{3+} \quad (2)$$

The general procedure for the COD test can be described as follows.

(A) A solution of $K_2Cr_2O_7$ (with a known concentration) is added to a solution containing organic pollutants. $K_2Cr_2O_7$ oxidizes the organic pollutants by the reaction (2).

(B) After completely oxidizing the organic pollutants, the remaining [$K_2Cr_2O_7$] is determined by titration with Fe^{2+}. In the titration, Fe^{2+} is oxidized to Fe^{3+} and $Cr_2O_7^{2-}$ is reduced to Cr^{3+}. This titration will let you know the amount of $Cr_2O_7^{2-}$ used to oxidize the pollutants in the solution.

(C) Using the amount of $K_2Cr_2O_7$ obtained in step (B), the theoretical amount of oxygen molecules required to oxidize the same amount of the pollutants can be calculated by comparing x and y in equations (1) and (2). This is called COD.

[Questions]

I-1. To determine the COD from the consumed $K_2Cr_2O_7$ for oxidizing organic pollutants, the mole ratio between O_2 and $K_2Cr_2O_7$ for oxidizing 1 mole of organic pollutant is required. The mole ratio can be determined by comparing x and y in equations (1) and (2) after balancing them. The following procedure is useful.

I-1-1. [0.5 points] Express x in terms of a, b, and c by balancing the equation (1).

I-1-2. [0.5 points] Express z in terms of y by balancing the charge in the equation (2).

I-1-3. [0.5 points] Express y in terms of a, b, and c by balancing the equation (2).

I-1-4. [0.5 points] Express x in terms of y by comparing your answers.

I-2. To determine the COD of an aqueous solution containing an unknown pollutant, 2.60×10^{-4} mol of $K_2Cr_2O_7$ was added to 10.0 mL of the pollutant solution. After the oxidation was completed, 1.20×10^{-3} mol of Fe^{2+} was required to titrate the remaining $K_2Cr_2O_7$.

I-2-1. [1.0 point] In the following balanced equation for the reaction between $Cr_2O_7^{2-}$ and Fe^{2+} in acidic media, what is the coefficient f?

$$Cr_2O_7^{2-} + f\ Fe^{2+} + 14\ H^+ \rightarrow 2\ Cr^{3+} + f\ Fe^{3+} + 7\ H_2O$$

I-2-2. [1.0 point] How many moles of $K_2Cr_2O_7$ were consumed for oxidizing the pollutants in 10.0 mL of the polluted solution?

I-2-3. [1.0 point] What is the COD of the unknown sample in ppm? The molecular mass of O_2 is 32.0 g/mol.

I-2-4. [2.0 points] If the unknown pollutant was C_6H_6, what was the amount of pollutant in milligrams per liter of solution and the volume of CO_2 produced during the complete oxidation of the 1.00 liter solution at 298 K and 1.00 atm. Molecular mass of C_6H_6 is 78.0 g/mol and the gas constant R = 0.0821 L·atm/mol·K. (Assume that CO_2 is an ideal gas.)

I-2-5. [1.0 point] How many moles of Cr^{3+} existed right before and after the titration with Fe^{2+}?

I-3. [2.0 points] When 10 mg of each of the following compounds is completely dissolved in 1.0 L of water, which compound produces the highest COD and what is its COD value? (The atomic masses of C, H, and O are 12, 1.0, and 16 g/mol, respectively.)

HCOOH (formic acid)	CH_3OH (methanol)	CH_3CHO (acetaldehyde)

QUESTIONS

II. Ski Jumping

The 2018 Winter Olympics will take place on February 2018, in PyeongChang, Republic of Korea. One of the Winter Olympic competitions is ski jumping, where the skier descends a specially constructed take-off ramp (known as the in-run), then jumps from the launcher (jumping point) with as much speed as he/she can generate, and flies as far as possible down a steeply sloped hill. Figure II-1 shows an outline of a ski jumping hill, divided into four parts: in-run, jump, flight, and landing.

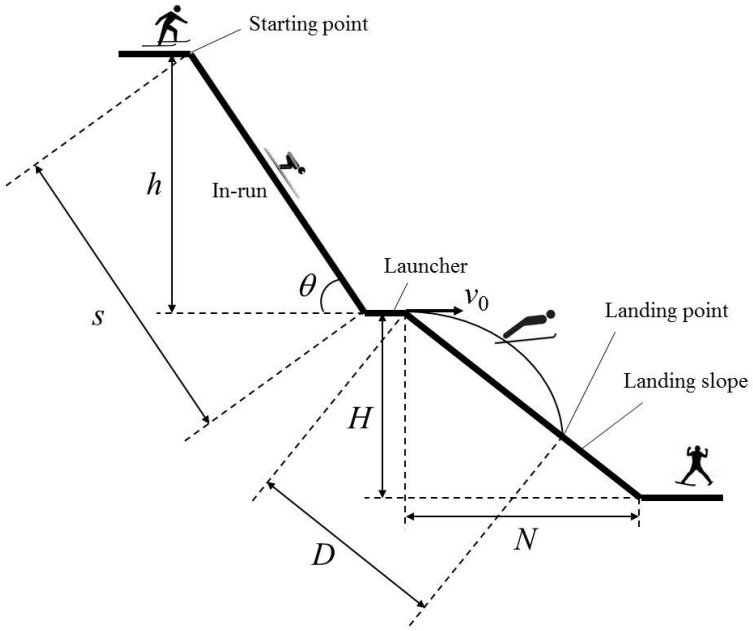


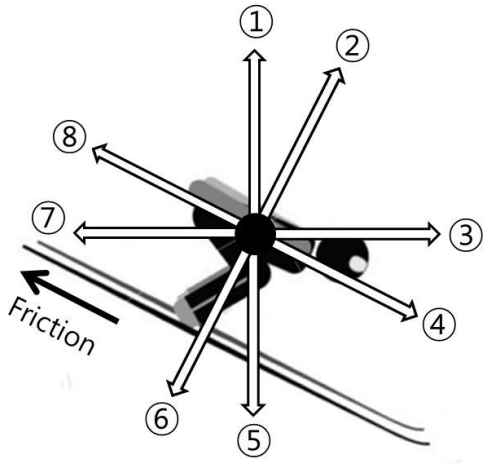
Figure II-1. Ski jumping

During the in-run the skier tries to maximize their acceleration by minimizing the friction in order to obtain the maximum in-run speed. This, in turn, has a significant influence on the jump length. θ, s, and h are the inclination angle, length, and height of the in-run, respectively. H and N are the height and horizontal length of the landing slope, respectively. Therefore, the gradient (k) of the landing slope is $k=\frac{H}{N}$. We use g for the gravitational acceleration. Assume that the velocity (v_o) of the skier off the launcher is horizontal.

QUESTIONS

[Questions]

II-1. [0.75 points] Which of the following numbers represented the directions of the gravitational force, normal force, and air resistance, respectively, exerted on the skier during the in-run?



II-2. [1.5 points] If the speed of the skier is v at the bottom of the in-run, what is the coefficient (μ) of the kinetic friction between the ski and the snow? Express μ in terms of h, g, s, v, and θ. (Ignore the air resistance and lift.)

II-3. [1.5 points] If the launching speed of the skier is v_0, what is the flight time (t) from the launcher to the landing point? Express t in terms of k, g, and v_0. (Ignore the air resistance and lift.)

II-4. [1.25 points] What is the distance (D) between the launcher and the landing point? Express D in terms of k, g, and v_0. (Ignore the air resistance and lift.)

III. Thomson's Cathode-Ray Experiment

[Thomson's Experiment]

In 1897, Thomson showed that a cathode ray is composed of negatively charged particles, electrons, which he calculated must have bodies much smaller than atoms and a very large value for their charge-to-mass (e/m) ratio, where e and m are the charge and mass of the electron, respectively.

Figure III-1 represents a schematic of Thomson's cathode-ray experiment to measure e/m for an electron. In a highly evacuated vacuum tube, two sets of metal electrodes (L_1-M_1 and L_2-M_2) are placed normal to each other. The potential differences are V_1 between L_1 and M_1, and V_2 between L_2 and M_2, respectively. In the space between L_2 and M_2, a uniform magnetic field with strength B is directed perpendicular to the plane of the figure, pointing into the page (depicted by 'X' in the figure).

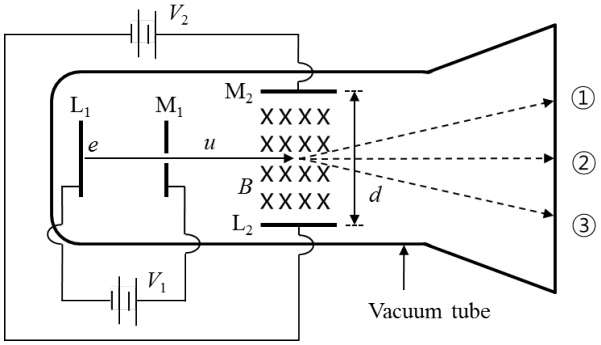


Figure III-1. Thomson's experiment

When L_1 is heated, the electrons from the hot cathode (L_1) are accelerated by V_1 and pass with a speed of u through the slit in M_1. The electrons continue to fly in the region between L_2 and M_2 and finally strike the screen at the end of the tube. During the flight of the electrons between L_2 and M_2, separated by the distance d, only electric (field strength V_2/d) and magnetic (field strength B) forces exert on the electrons.

QUESTIONS

[Charge in Electric and Magnetic Fields]

Figure III-2 shows a particle with charge q in a uniform electric field between two parallel electrodes. The electric field strength (E) is determined by the distance (d) and electric potential difference (V) between the two electrodes as in equation (1). When the particle is placed in the electric field, the magnitude of the force exerted on the particle is given by equation (2). For a **positively**-charged particle, the potential energies of the particle are qV and 0 at the (+) and (−) electrodes, respectively.

$$E = \frac{V}{d} \tag{1}$$

$$F_{electric} = qE \tag{2}$$

Figure III-3 shows a **positively**-charged particle with charge q and speed u in a uniform magnetic field of field strength B. In the figure, the magnetic field is directed perpendicular to the plane of the figure, pointing out of the page (depicted by '∘' in the figure). In this arrangement, the direction of the force exerted on the particle is upward and its magnitude is given by

$$F_{magnetic} = quB \tag{3}$$

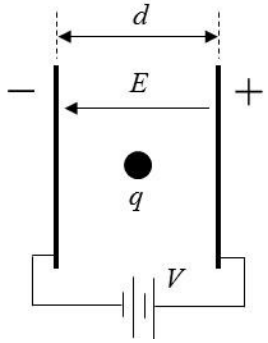


Figure III-2. Charge in electric field

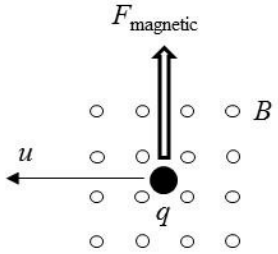


Figure III-3. Positive charge in magnetic field

QUESTIONS

[Questions] Answer the following questions about Thomson's experiment **(Figure III-1)**.

III-1. [1.0 point] Express the speed of the electron u in terms of e, m, and V_1, at the moment the electron passes through the slit in M_1.

III-2. After the electron passes through the region between L_2 and M_2,

III-2-1. [1.0 point] If only an electric field is present, i.e. $V_2 \neq 0$ and $B = 0$, which of ①, ②, and ③ in Figure III-1 would be the trace of the electron?

III-2-2. [1.0 point] If only a magnetic field is present, i.e. $V_2 = 0$ and $B \neq 0$, which of ①, ②, and ③ in Figure III-1 would be the trace of the electron?

III-3. [1.5 points] Thomson adjusted the electric ($V_2 \neq 0$) and magnetic ($B \neq 0$) fields to let the electrons fly straight (trace ②) with a constant speed of u. Under this condition, what would be the speed of the electron u? Express u in terms of V_2, B, and d.

III-4. [0.5 points] Compare the results of **III-1** and **III-3**, then express the charge-to-mass ratio (e/m) for the electron in terms of V_1, V_2, B, and d.

QUESTIONS

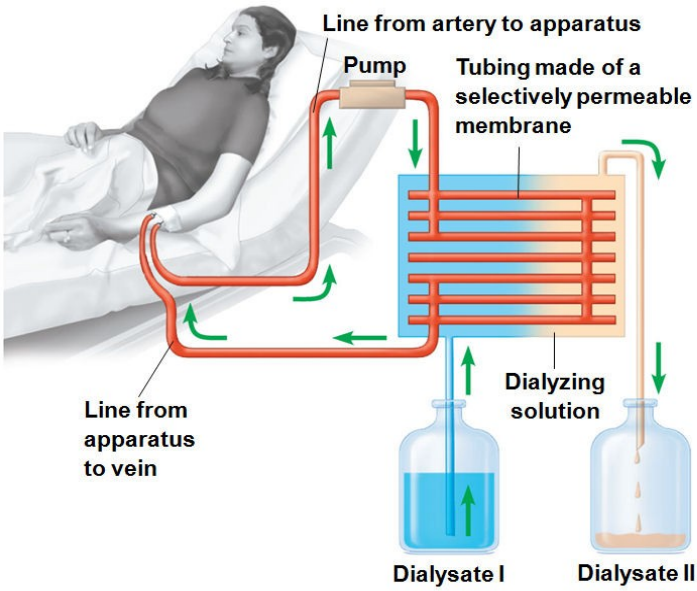
IV. Excretory System

The table shows the constituents of samples collected from the nephron of a healthy human.

(unit: g/100mL)

Constituents	Blood plasma	Primitive urine (glomerular filtrate)	Urine
Water	90 ~ 93	90 ~ 93	95
X	8	0	0
Y	0.1	0.1	0
Minerals	0.9	0.9	0.9 ~ 3.6
Z	0.03	0.03	2.0

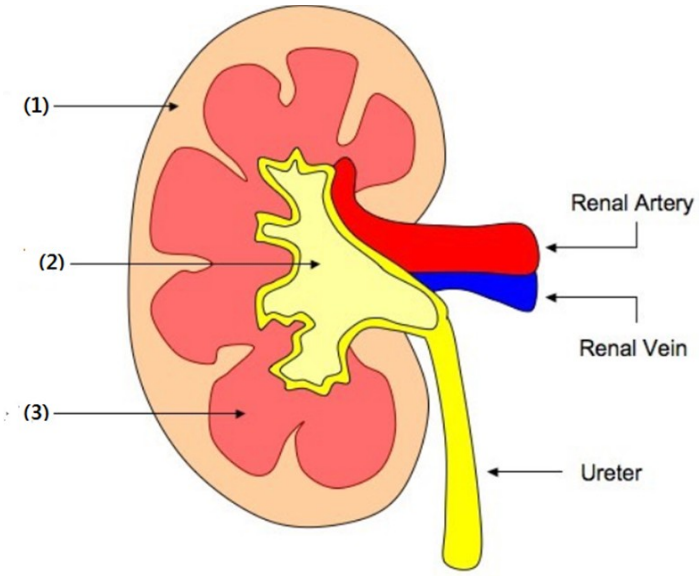
The figure shows an artificial hemodialyzer. (The permeability of the glomerular membrane and the hemodialyzer membrane is same.)



[Questions]

IV-1. [1.0 points] Which of the three parts of kidney indicated below plays a similar role as an artificial hemodialyzer?

QUESTIONS



IV-2. [1.5 points] What are the concentrations of X, Y, and Z in dialysate I? (each answer 0.5 points)

IV-3. [1.5 points] Through which of the following processes (I, II and III) in a healthy human kidney do substances X, Y and Z go? (More than one option may be possible). (Each answer 0.5 points)

I. Reabsorption	II. Filtration	III. Neither reabsorption or filtration

QUESTIONS

V. Genetics

While studying a common genetic condition in one family, it was found that the mutant allele differed from the wild-type allele by a single base-pair (bp) substitution. It was also noticed that this substitution removed the restriction enzyme I recognition site that is present in the wild-type allele. (This restriction enzyme recognizes a specific DNA sequence and cuts it. This sequence is called the 'restriction enzyme recognition site'.) Figure V-1 is the pedigree of the family showing this genetic condition.

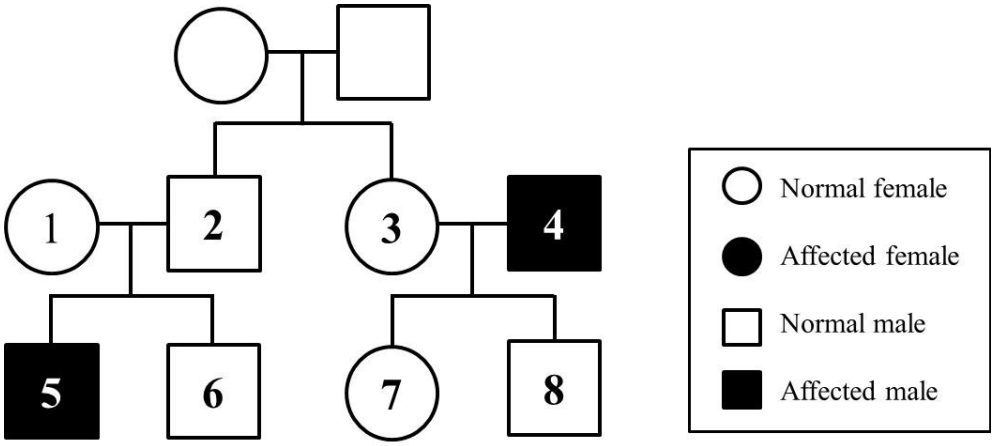


Figure V-1. Pedigree

After isolating DNA from four individuals (5, 6, 7, and 8) in the pedigree, 1500 bp of the DNA from each individual was amplified, including the site affected by the mutation, with a modern DNA technique. The amplified DNA was digested using the restriction enzyme I, and the resulting sizes of the DNA fragments were analyzed. The results of the DNA digestion experiments are summarized in Table V-1.

Table V-1. Results of DNA digestion experiments

Individuals		5	6	7	8
Fragment sizes	1500bp	+	–	+	+
	900bp	–	+	+	+
	600bp	–	+	+	+

(+ : present, – : absent)

QUESTIONS

[Questions]

V-1. [1.0 point] Based on the data, which of the following is the mode of inheritance of the genetic condition?

1 X-linked dominant	② X-linked recessive	3 Y-linked dominant
④ Y-linked recessive	⑤ Autosomal dominant	6 Autosomal recessive
⑦ Mitochondrial inheritance		

V-2. [1.0 point] If individuals 1 and 2 have another child, what is the probability that this child will be an affected female?

V-3. [1.0 point] The region around the restriction enzyme I recognition site in the amplified DNA from the wild type and the corresponding region in the amplified DNA of the mutant type were sequenced and compared. The experiment revealed that the mutation not only removed the restriction enzyme I recognition site in the mutant allele but also created a new restriction enzyme II recognition site. The recognition sites for the two restriction enzymes are indicated below.

Restriction enzyme I recognizes: 5'-TACGGT-3'
Restriction enzyme II recognizes: 5'-AGGTCA-3'

Based on the results, if a portion of one strand of the wild-type DNA sequence determined here is [5'-----TACGGTCA-----3'], what is the sequence of the corresponding portion of DNA in the mutant allele ?

QUESTIONS

VI. Blood Circulation

Figure VI-1 shows the changes of pressure and blood volume in the left ventricle over time.

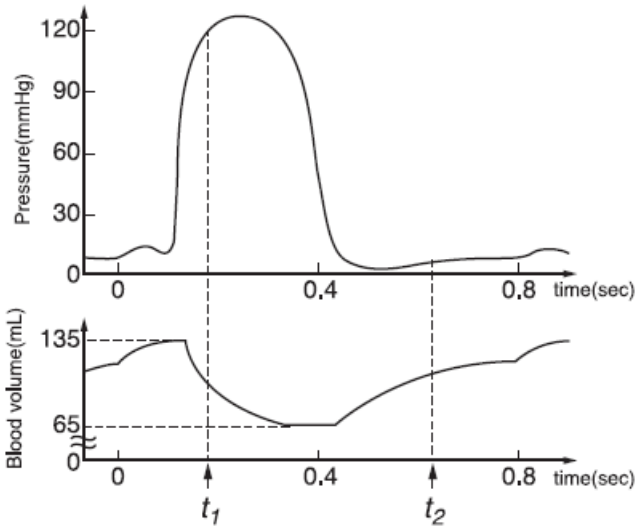


Figure VI-1. Changes of blood pressure and volume over time

[Questions]

VI-1. [1.0 point] At t_1 and t_2, indicate whether the left semilunar valve and left atrioventricular valve are open or closed. (Mark '○' for open and '×' for closed on the answer sheet.)

VI-2. [1.0 point] What is the heart rate (beats per min) depicted in Figure VI-1? (Answer it to a precision of two significant figures.)

VI-3. [1.0 point] The cardiac output is defined as the volume of blood pumped per ventricle per unit time. Calculate the cardiac output (L/min) in this condition? (Answer it to a precision of two decimal points.)

ANSWER SHEET

Name		Code	
Country		Signature	

I. Chemical Oxygen Demand (COD) Test

Questions		Points	Answers
I-1	I-1-1	0.5	(Show your working) x =
	I-1-2	0.5	(Show your working) z =

ANSWER SHEET

I. Chemical Oxygen Demand (COD) Test (Continued)

Questions		Points	Answers
I-1	I-1-3	0.5	(Show your working) y =
	I-1-4	0.5	(Show your working) x =

Name		Code	

I. Chemical Oxygen Demand (COD) Test (Continued)

Questions	Points	Answers

ANSWER SHEET

I-2	I-2-1	1.0	(Show your working) f =
	I-2-2	1.0	(Show your working) Number of moles = mol

Name		Code	

I. Chemical Oxygen Demand (COD) Test (Continued)

Questions	Points	Answers

ANSWER SHEET

I-2	**I-2-3**	1.0	(Show your working) COD = ppm
	I-2-4	2.0	(Show your working) Amount of C_6H_6 = mg/L Volume of CO_2 = L

Name		Code	

I. Chemical Oxygen Demand (COD) Test (Continued)

Questions	Points	Answers

ANSWER SHEET

I-2-5	1.0	(Show your working) Moles of Cr^{3+} right before titration : mol Moles of Cr^{3+} after titration : mol

ANSWER SHEET

Name		Code	

I. Chemical Oxygen Demand (COD) Test (Continued)

Questions	Points	Answers
I-3	2.0	(Show your working) Compound Name : COD = ppm

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

Total points for question I	

Name		Code	

ANSWER SHEET

II. Ski Jumping

Questions	Points	Answers	
II-1		Forces	Choose one for each force from ① to ⑧
	0.25	Gravitational force	
	0.25	Normal force	
	0.25	Air resistance	
II-2	1.5	(Show your working)	
		$\mu =$	

Name		Code	

ANSWER SHEET

II. Ski Jumping (Continued)

Questions	Points	Answers
II-3	1.5	(Show your working)
		t = □.□
II-4	1.25	(Show your working)
		D = □

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

Total points for question II			
Name		Code	

III. Thomson's Cathode-Ray Experiment

Questions	Points	Answers

ANSWER SHEET

III-1		1.0	(Show your working) u =	
III-2	**III-2-1**	1.0	Choose one from ① to ③	
	III-2-2	1.0	Choose one from ① to ③	
III-3		1.5	(Show your working) u =	

Name		Code	

III. Thomson's Cathode-Ray Experiment (Continued)

Questions	Points	Answers

ANSWER SHEET

III-4	0.5	(Show your working)
		e/m =

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

Total points for question III	

ANSWER SHEET

Name		Code	

IV. Excretory System

Questions	Points	Answers		
IV-1	1.0			
IV-2	1.5	X	Y	Z
		g/100mL	g/100mL	g/100mL
IV-3	1.5	X	Y	Z

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

Total points for question IV	

ANSWER SHEET

Name		Code	

V. Genetics

Questions	Points	Answers	
V-1	1.0	Multiple Choice (Choose one from ① to ⑦)	
V-2	1.0	(Show your working)	
		Probability :	
V-3	1.0	Sequence	**[5'---- ----3']**

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

Total points for questions V	

ANSWER SHEET

Name		Code	

VI. Blood Circulation

Questions	Points	Answers		
VI-1	1.0		Left semilunar valve (Mark either '○' or '×')	Left atrioventricular valve (Mark either '○' or '×')
		t_1		
		t_2		
VI-2	1.0	(Show your working)		
		Heart rate: beats/min		
VI-3	1.0	(Show your working)		
		Cardiac output : L/min		

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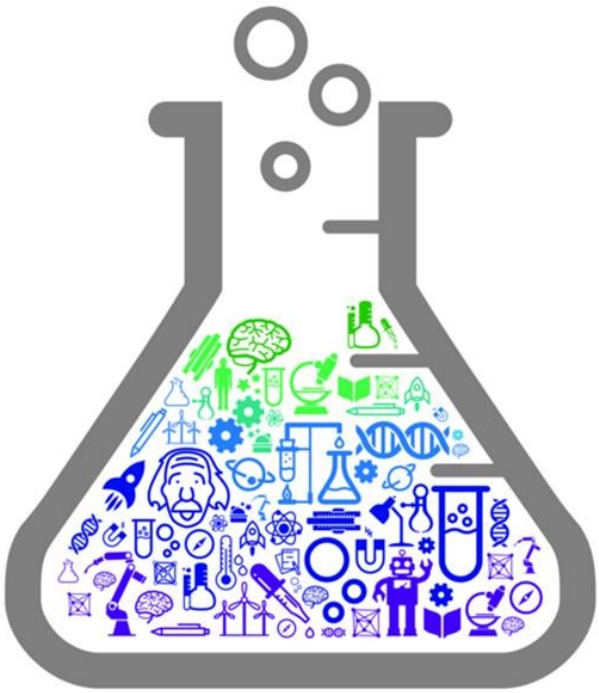
Total points for question VI	

12TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2015



December 2(Wed)-11(Fri), 2015 I Daegu, Republic of Korea

Theoretical Competition

– Solution –

December 6, 2015

I. Chemical Oxygen Demand (COD) Test

I-1

I-1-1 [0.5 points]

(Answer) $a + b/4 - c/2$

(Explanation) Balance the masses of O for both sides.

$c + 2x = 2a + 0.5b$ **[0.3 points]**

$x = a + 0.25b - 0.5c$ **[0.2 points]**

I-1-2. [0.5 points]

(Answer) $8y$

(Explanation) Balance the charges for both sides.

$(-2)y + (+1)z = 2y(+3)$ **[0.3 points]**

$z = 8y$ **[0.2 points]**

I-1-3. [0.5 points]

(Answer) $2a/3 + b/6 - c/3$

(Explanation)

$$C_aH_bO_c + yCr_2O_7^{2-} + zH^+ \rightarrow aCO_2 + \left(\frac{b+z}{2}\right)H_2O + 2yCr^{3+}$$

Balance the masses of O.

$c + 7y = 2a + 0.5b + 0.5z$ **[0.2 points]**

Substitute $8y$ for z

$3y = 2a + 0.5b - c$ **[0.2 points]**

$y = 2a/3 + b/6 - c/3$ **[0.1 points]**

I-1-4. [0.5 points]

(Answer) $3y/2$

(Explanation)

From the former questions,

$x = a + b/4 - c/2$ **[0.1 points]**

$y = 2a/3 + b/6 - c/3 = (2/3) \times (a + b/4 - c/2)$ **[0.2 points]**

Therefore, $x = 3y/2$ **[0.2 points]**

I-2

I-2-1. [1.0 point]

(Answer) 6

(Explanation)

(Method 1) Balance the charge sums on both sides.

$-2 + 2f + 14 = +6 + 3f$ **[0.5 points]**

$f = 6$ **[0.5 points]**

(Method 2) The electron flows for the redox pairs can be compared

Oxidation) $f\,Fe^{2+} \rightarrow f\,Fe^{3+} + f\,e^-$ number of electrons released: f **[0.2 points]**

Reduction) $Cr_2O_7^{2-} + 6e^- \rightarrow 2Cr^{3+}$ number of electrons consumed: 6 **[0.3 points]**

$f = 6$ **[0.5 points]**

I-2-2. [1.0 point]

6.0×10^{-5}

(Answer)

(Explanation)

The titration in the step (B) involves the redox reaction of Fe and Cr.

$$\begin{gathered} 3+¿ \\ 3+¿+Cr^{¿} \\ 2-¿ \rightarrow 6\,Fe^{¿} \\ 2+¿+Cr_2O_7^{¿} \\ 6\,Fe^{¿} \end{gathered} \quad \text{(unbalanced)}$$

As the reduction of $Cr_2O_7^{2-}$ (Cr^{6+}) to $2Cr^{3+}$ has to be coupled by oxidation of $6Fe^{2+} \rightarrow 6Fe^{3+}$, titration of $Cr_2O_7^{2-}$ requires 6 equivalents of Fe^{2+}. **[0.2 points]**

That is, at the beginning of step (B), the amount of $K_2Cr_2O_7$ was $(1.20 \times 10^{-3})/6 = 2.00 \times 10^{-4}$ mol. **[0.5 points]**

So, 6.0×10^{-5} $(= 2.60 \times 10^{-4} - 2.00 \times 10^{-4})$mol of $K_2Cr_2O_7$ had been consumed for oxidizing pollutants. **[0.3 points]**

I-2-3. [1.0 point]

(Answer) 288

(Explanation)

6.0×10^{-5} mol of $K_2Cr_2O_7$ were required to treat 10.0 mL of waste water.

Thus, 1.00 L of waste water should require 6.0×10^{-3} mol of $K_2Cr_2O_7$. **[0.2 points]**

Equivalently this corresponds to 9.0×10^{-3} mol $(=6.0 \times 10^{-3}$ mol $\times 3/2)$ **[0.3 points]** and 0.288 g $(9.0 \times 10^{-3}$ mol $\times 32) = 288$ mg of O_2 **[0.3 points]**.

Then, the COD can be expressed as 288 ppm. **[0.2 points]**

I-2-4. [2.0 points]

(Answer) 93.6, 0.176

(Explanation)

1 mole of C_6H_6 can be fully decomposed by 7.5 moles of O_2.

Or express chemical equation. $C_6H_6 + \frac{15}{2}O_2 \rightarrow 6CO_2 + 3H_2O$ **[0.3 points]**

So, 9.0×10^{-3} mol of O_2 corresponds to 9.0×10^{-3} mol/7.5 = 1.2×10^{-3} mol **[0.3 points]**

$$C_6H_6 : 0.0012\,mol \times \left(\frac{78\,g}{1\,mol}\right) = 0.0936\,g = 93.6\,mg$$ **[0.4 points]**

1 mole of C_6H_6 is decomposed to 6 moles of CO_2. **[0.2 points]**

Therefore in the present case, 7.2×10^{-3} moles (= 1.2×10^{-3} mol × 6) of CO_2 are evolved. **[0.3 points]**

CO_2 volume is calculated as followed:

$PV = nRT$ **[0.2 points]**

$$V = \frac{(7.2 \times 10^{-3}\,mol)(0.0821\,L \cdot atm/mol \cdot K)(298\,K)}{1.00\,atm} = 0.176\,L$$ **[0.3 points]**

I-2-5. [1.0 point]

(Answer) 1.2×10^{-4}, 5.2×10^{-4}

(Explanation)

Initially, there were 2.60×10^{-4} moles of $Cr_2O_7^{2-}$ but no Cr^{3+} in the test system. **[0.1 points]**

From the results of titration with Fe^{2+}, we figure that 2.00×10^{-4} moles of $Cr_2O_7^{2-}$ were present at the beginning of step (B), which means that 0.60×10^{-4} moles of $Cr_2O_7^{2-}$ were used to decompose the pollutant and to produce the 1.20×10^{-4} (=$0.60 \times 10^{-4} \times 2$) moles of Cr^{3+} before the Fe^{2+} titration. **[0.4 points]**

In the step (B), 2.00×10^{-4} moles of $Cr_2O_7^{2-}$ were used and 4.00×10^{-4} (=$2.00 \times 10^{-4} \times 2$) moles of Cr^{3+} ions produced. **[0.3 points]**

Therefore the concentration of Cr^{3+} ions after Fe^{2+} titration is 5.20×10^{-4} (=$4.00 \times 10^{-4} + 1.20 \times 10^{-4}$) moles. **[0.2 points]**

	Amounts present	
	$Cr_2O_7^{2-}$	Cr^{3+}
Initial	2.60×10^{-4} mol	0
Change during step (A)	-0.60×10^{-4} mol	$+1.2 \times 10^{-4}$ mol
After step (A)/ Before step (B)	2.00×10^{-4} mol	1.2×10^{-4} mol
Change during step (B)	-2.00×10^{-4} mol	$+4.00 \times 10^{-4}$ mol

After step (B)	0	5.2×10^{-4} mol

I-3. [2.0 points]

(Answer) CH_3CHO, 18

(Explanation) Based on equation (1), oxidation of each pollutant requires following amount of O_2.

$$HCOOH + \frac{1}{2}O_2 \rightarrow CO_2 + H_2O$$

$$CH_3OH + \frac{3}{2}O_2 \rightarrow CO_2 + 2H_2O$$

$$CH_3CHO + \frac{5}{2}O_2 \rightarrow 2CO_2 + 2H_2O$$

[0.3 points, each 0.1 points]

The COD of the pollutant solutions can be calculated stepwise,

	Moles of O_2 per 1 mole pollutant	Moles of O_2 per 10.0 mg pollutant **[0.6 points] = [each 0.2 point]**	COD for 10.0 mg/L pollutant solution **[0.9 points] = [each 0.3 point]**
HCOOH (46 g/mol)	0.5	$0.5 \times (10.0 \times 10^{-3})/46$	$32 \times 10^3 \times 0.5 \times (10.0 \times 10^{-3})/46$ = 3.5 ppm
CH_3OH (32 g/mol)	1.5	$1.5 \times (10.0 \times 10^{-3})/32$	$32 \times 10^3 \times 1.5 \times (10.0 \times 10^{-3})/32$ = 15 ppm
CH_3CHO (44 g/mol)	2.5	$2.5 \times (10.0 \times 10^{-3})/44$	$32 \times 10^3 \times 2.5 \times (10.0 \times 10^{-3})/44$ = 18 ppm

Of the three samples, CH_3CHO solution has the highest COD **[0.1 points]**, which is 18 ppm. **[0.1 points]**

In any case, student who make correct answer (CH3CHO and 18 ppm), will have full credits.

II. Ski Jumping

II-1 [0.75 points] [Correct answer: 0.25, wrong answer: 0 for each force]
(Answer) Gravitational force ⑤, Normal force ②, Air resistance ⑧

II-2 [1.5 point]

(Answer) $\mu=\frac{2gh-v^2}{2g\cos\theta\cdot s}$ (Explanation) By conservation of energy [1.0] or dynamitic & kinematic [0.5 + 0.5 or proportional rating for any other method]

$$mgh-\frac{1}{2}mv^2=\mu mg\cdot\cos\theta\cdot s$$

$$\mu=\frac{gh-\frac{1}{2}v^2}{g\cos\theta\cdot s}$$ [0.5]

II-3 [1.5 point]

(Answer) $t=\frac{2v_0}{g}\kappa$

(Explanation) The horizontal distance to the landing point is $N_{landing}=v_0t$. [0.5]

The vertical distance to the landing point is $H_{landing}=\frac{1}{2}gt^2$. [0.5]

Or proportional rating for any other method

From $¿\kappa\vee¿\frac{H}{N}=\frac{H_{landing}}{N_{landing}}=\frac{\frac{1}{2}gt^2}{v_0t}$, we can find $t=\frac{2v_0}{g}\kappa$. [possible 0.25 for using ratio in slope + 0,25 rearranging the equation]

II-4 [1.25 point]

(Answer) $D=\frac{2v_0^2}{g}\kappa\sqrt{1+\kappa^2}$ [0.25 final answer]

(Explanation) $D=\sqrt{N_{landing}^2+H_{landing}^2}=N_{landing}\sqrt{1+\kappa^2}=\frac{2v_0^2}{g}\kappa\sqrt{1+\kappa^2}$

[0.5 + 0.5 for any method steps]

III. Thomson's Cathode-Ray Experiment

III-1 [1.0 point]

(Answer) $u=\sqrt{\frac{2eV_1}{m}}$

(Explanation) Potential energy of the electron at L_1 is eV_1 [0.25]. At the moment of electron passing through a slit of M1, kinetic energy of the electron at M_1 is $\frac{1}{2}mu^2$ [0.25], all of the potential energy converts to the kinetic energy [0.25].

$$eV_1=\frac{1}{2}mu^2 \rightarrow u=\sqrt{\frac{2eV_1}{m}} \quad [0.25]$$

III-2.

III-2-1. [1.0 point] (Correct answer: 1 point, wrong answer: 0 point)

(Answer) ①

(Explanation) The electric force exerts on the electron. Because the charge of the electron is negative, the electric force exerts to the M_2 direction. So the trace of the electron is ①.

III-2-2. [1.0 point] (Correct answer: 1 point, wrong answer: 0 point)

(Answer) ③

(Explanation) The magnetic force exerts on the electron. Because the negative electron moves to the right and the magnetic field points into the page, the magnetic force exerts to the L_2 direction. So the trace of the electron is ③.

III-3 [1.5 point]

(Answer) $u=\frac{V_2}{Bd}$

(Explanation) When the electron flies straight (trace ②), the electric force directed to M_2 and the magnetic force directed to L_2 are compensated with the same magnitude ($\sum F=0$ or $F_E=F_B$ 0.5 point). Then, $\frac{eV_2}{d}=euB$. [0.5] The speed of the electron is ¿$\frac{V_2}{Bd}$. [0.5]

III-4 [0.5 point]

(Answer) $\frac{e}{m}=\frac{V_2^2}{2B^2d^2V_1}$

(Explanation) $u=\sqrt{\frac{2eV_1}{m}}=\frac{V_2}{Bd} \rightarrow \frac{e}{m}=\frac{V_2^2}{2B^2d^2V_1}$ (0.25 point for $u_{III-2}=u_{III-3}$)

(0.25 point for rearranging the formula)

IV. Excretory System

(Explanation) The blood arrives through the renal artery and leaves in the renal vein. The kidneys produce urine which is carried to the bladder along the ureter. There are three major anatomical demarcations in the kidney: the cortex, the medulla, and the renal pelvis. The cortex receives most of the blood flow, and is mostly concerned with reabsorbing filtered material.

X is protein. Y is glucose. Z is urea. Water is filtered from the glomerulus to the Bowman's capsule and re-absorbed, and discharged to form urine. Urea is the substance to be filtered, so is in both the plasma and the filtrate. Glucoses and amino acids are filtered, and 100%re-absorbed. Proteins are not filtered.

IV-1.[1.0 points]

(Answer)

I-1	**(1)**

IV-2.[1.5 points]= 3 x 0.5 points

(Answer)

(X)	(Y)	(Z)
(0.0)g/100mL	(0.1)g/100mL	(0.0)g/100mL

unit (g/100mL)

constituent	Blood plasma	Primitive urine	urine
Water	92-93	92	95
Urea (Z)	0.03	0.03	2.00
Uric acid	0.004	0.004	0.05
Glucose (Y)	0.1	0.1	0
Amino acids	0.005	0.005	0
Minerals	0.9	0.9	0.9-3.6
Proteins (X)	8.0	0	0

IV-3.[1.5 points]= 3x 0.5 points

(Answer)

(X)	(Y)	(Z)
III	I, II Alternatives Only I or II: (0.25 points) Other: (0 point)	II

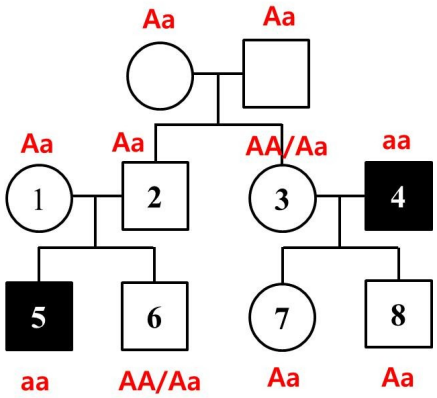
V. Genetics

(Answer)

V-1	V-2	V-3
6	1/8	5’ -----TAAGGTCA-----3’

(Explanation)

V-1.[1.0 point]The answer is autosomal recessive. Because the individual 4 is an affected male, his genotype should be homo-recessive (aa). Thus, his offspring has to have at least one recessive allele. That is, although individuals 7 and 8 are both phenotypically normal, they have a mutant allele, respectively.



V-2. [1.0 point]Since individuals 1 and 2 already have an affected child, they must be heterozygotes. Aa x Aa AA, Aa, Aa, aa. Therefore, the probability that anew born female will be affected is 1/8 (1/4 x 1/2).

(1 point) for the correct answer

(1 point) for zero probability, if the answer to V-1 was 2

(0 point) for other options

V-3. [1.0 point]The nucleotide ‘C’ in[5’----**TACGGTCA**----3’] from the wild type has been replaced to ‘A’in the mutant allele, making [5’----TA**AGGTCA**----3’].

VI. Blood Circulation

VI-1.[1.0 point]= 4 x 0.25 points

(Answer)

	Semilunar valves	Atrioventricular valves
t_1	Opened (○)	Closed(×)
t_2,	Closed (×)	Opened(○)

(Explanation)Atrioventricular valves (AV valves) are thin flaps of tissue between the atria and ventricles. Semilunar valves lie at the openings from the ventricles into the arteries and prevent blood pumped out of the heart from returning to it. At t_1 of ventricle contraction, AV valves are closed while semilunar valves are opened. At t_2 of ventricle relaxation, semilunar valves are closed while AV valves are opened to fill ventricle out with blood.

VI-2.[1.0 point]

(Answer)

Heart rate	(75) beats/min

(Explanation)Heart rate is beating number of heart per unit time (min). Referring to the graph, the second heartbeat comes in 0.8 sec after the first heartbeat.

$\therefore$ Heart rate = $\frac{1\,beat}{0.8\,sec}$ X $\frac{60\,sec}{1\,min}$ = 75 beats/min

(1 points) for the correct answer
(0.5 points) for the correct calculation, if the answer is not correct

VI-3.[1.0 point]

(Answer)

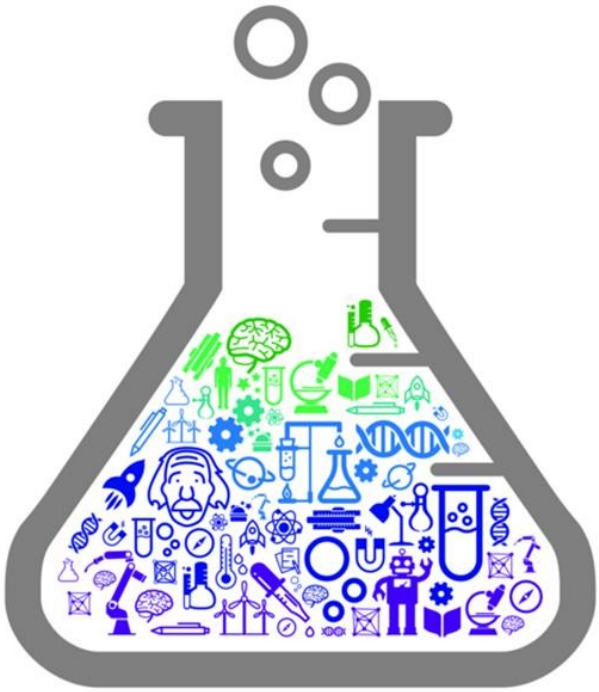
Cardiac output	(5.25) L/min

(Explanation)Cardiac output is defined as the volume of blood pumped per ventricle per unit time. It can be calculated by multiplying heart rate (beats per min) by stroke volume (mL/beat)
Cardiac output = heart rate X stroke volume
Stroke volume = Volume of blood before contraction - Volume of blood after contraction
By graph, stroke volume = 135 mL – 65 mL = 70 mL
$\therefore$ Cardiac output = 75 beats/min x 70 mL/beat = 5250 mL/min (5.25 L/min)

(1 points) for the correct answer, according to the answer of the question VI.2
(0.5 points) for the correct calculation, if the answer is not correct

12TH INTERNATIONAL JUNIOR SCIENCE OLYMPIAD

IJSO-2015



December 2(Wed)-11(Fri), 2015 I Daegu, Republic of Korea

Experiment Competition

– Exam Sheet –

December 8, 2015

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

1. You have 30 minutes to read “EXAMINATION RULES”, “EXPERIMENT INSTRUCTIONS”, “CALCULATOR INSTRUCTIONS”, and whole exam sheets and to plan your experiments.

2. Do NOT start your experiments before the"START"whistle is blown. 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 table.
3. Check the stationery items (pen, calculator, and rough book) provided by the organizers.
4. Do NOT start your experiments before the **"START"** whistle.
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"** 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.

EXPERIMENT INSTRUCTIONS

1. After the "START" whistle, you will have 3 hours and 30 minutes to complete the experiments.

2. Use only the pen provided by the organizers (not pencil).

3. The total number of experiments is 3. Check you have a complete set of the exam sheets (15 pages, page 4 – page 18) and answer sheets (10 pages). Raise your hand, if you find any missing sheets.

4. NOW write your name, code, country and signature in your first answer sheet, and your name and code in the next pages of your answer sheets.

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

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

7. You MUST wear a **Lab Coat** and **Gloves** during the experiments.

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

10. Point rules: Each question marking

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, 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 10²³***

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.

Introduction of Experiments

"Gam-Gyul" (Figure 1), a seedless and easy-peeling citrus species, is one of the most popular fruits in Korea with a unique 'sweet' and 'sour' taste. All of you have already tasted "Gam-Gyul" during your stay in Korea.

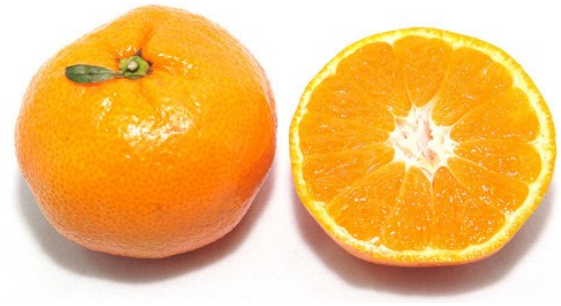


Figure 1. Gam-Gyul

In this competition, you will perform the following three experiments related to "Gam-Gyul".

Experiment I. Determination of the Densities of Fruit Juices

Experiment II. Determination of the Citric Acid Contents of Fruit Juices

Experiment III. Anatomy of Fruits and Seeds

In experiments I and II, mandarin (Gam-Gyul) and apple juices will be analyzed. In experiment III, you will observe the inside of some fruits.

Have Fun!

Experiment I: Determination of the Densities of Fruit Juices

1.Background

[Hooke's Law]

Hooke's law is a principle of physics that states that the force F needed to extend or compress a spring by some distance x is proportional to that distance. That is: $F = -kx$, where k is the spring constant, characteristic of the spring, its stiffness.

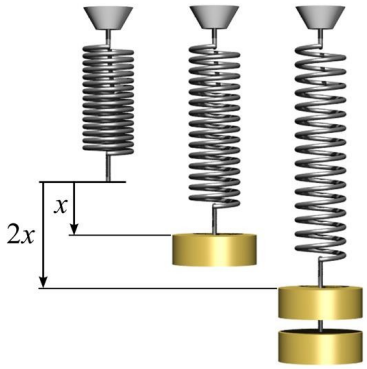


Figure I-1. Hooke's law

[Archimedes' Principle]

Any object, wholly or partially immersed in a fluid, is buoyed up by a force equal to the weight of the fluid displaced by the object.

2. Materials

Equipment	Materials
Support stand and clamp	20 g weight
Spring	50 g weight (x3)
50 cm ruler	Fresh juices (mandarin and apple)
100 mL graduated cylinder	Distilled water
Kimwipes (cleaning tissue)	

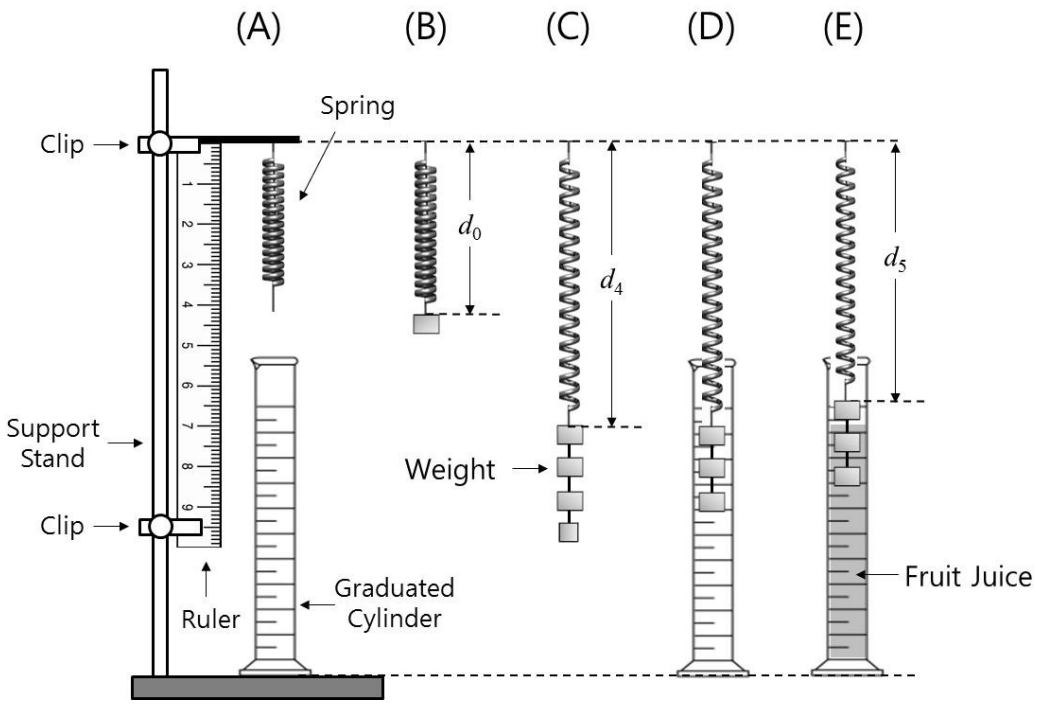


Figure I-3. Experimental set-up for Hooke's law

3. Experimental Procedure

[In this experiment, the exact masses of all weights are already provided on the envelope of each weight. You should use the given masses for your calculation.]

1. Suspend a spring from a clamp as shown in Figure I-3(A).
2. Hook a 50g weight to the spring. Record the exact value of the mass in column d_0 on **Answer Sheet** (**I-1-1**).
3. Record the length of the spring (d_0) as shown in figure I-3(B) with accuracy of one decimal place on **Answer Sheet (I-1-1)**.
4. Perform 4 more measurements with the other weights, increasing the total weight on the spring by adding more weights. For each combination (columns d_1 to d_4), record the exact mass and measure the length of the spring and write them on **Answer Sheet (I-1-1)**. The accuracy for length measurement should be to one decimal place.
5. Remove all weights from the spring.
6. Pour about 70 mL of water into the graduated cylinder and record the volume on **Answer Sheet** (**I-2-1**)
7. Lower the spring and the 50g + 50g + 50g weights such that only the two bottom weights are fully immersed into the water and record the volume on **Answer Sheet** (**I-2-1**).
8. Lower the spring and the chain further so that all three weights are fully immersed into the water and record the volume on **Answer Sheet** (**I-2-1**). You may have to pull the spring down or raise the cylinder to ensure all three weights are immersed.
9. Remove the water and clean the cylinder and weights.
10. Wipe off the water on the weights using Kimwipes.
11. Hang the spring and the chain of 50g + 50g + 50g weights into the graduated cylinder. Record the length of the spring on **Answer Sheet** (**I-2-2**). Gently pour in the apple juice until only the two bottom weights are fully immersed into the juice (you might have to raise the cylinder).
12. Record the length of the spring with accuracy of one decimal place on **Answer Sheet** (**I-2-2**).
13. Gently pour more apple juice into the graduated cylinder until all three weights are fully immersed into the juice (you might have to raise the cylinder).
14. Record the length of the spring with accuracy of one decimal place on **Answer Sheet** (**I-2-2**).
15. Rinse off the juice with water and repeat steps 10 through 14 for the mandarin juice.
16. Answer the following questions using your results.

4. Questions [14 Points]

I-1. [6.0 points]

I-1-1. [1.25 points] Procedure1 through 5

I-1-2. [2.5 points] Plot the lengths of the spring (y) with the corresponding values of masses (x). Draw the best fitted line on your plot on **Answer Sheet** (**I-1-2**).

I-1-3. [1.25 points] Determine the slope and intercept from the graph and write them down on on **Answer Sheet** (**I-1-3**).

I-1-4. [1.0 point] Calculate the spring constant in N/m on **Answer Sheet** (**I-1-4**) (Assume that the gravitational acceleration is 9.81 m/s^2)

I-2. [6.0 points]

I-2-1. [2.0 points] Fill in the table on **Answer sheet** (**I-2-1**) for the measurements of the procedures 7 and 8. Calculate the volumes of two 50g weights and three 50g weights.

I-2-2. [2.0 points] Calculate the difference in the lengths of the spring with weights in the apple juice and mandarin juice, respectively, from procedures 11, 12, 13, 14 and 15 on **Answer sheet** (**I-2-2**).

I-2-3. [2.0 points] Calculate the buoyant forces exerted by both juices (respectively) on the different weights on **Answer sheet** (**I-2-3**).

I-3. [2.0 points] Calculate the average densities of the apple juice and mandarin juice, respectively on **Answer sheet** (**I-3**).

Experiment II. Determination of the Citric Acid Contents in Fruit Juices

1. Background

[Citric Acid]

Citric acid, present in citrus fruits, is a weak organic acid with the formula $C_6H_8O_7$. (Figure II-1) It is also used to add a sour taste to foods and drinks. Citric acid, together with small amounts of malic and tartaric acid, gives citrus fruits their tartness and unique taste. The levels of the acid in citric fruits are at the highest early in the season and then decrease as the fruits mature.

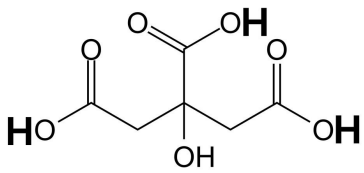


Figure II-1. Molecular structure of citric acid

[Acid and Base]

Arrhenius proposed that an acid and a base are substances that release protons (H^+) and hydroxide ions (OH^-), respectively, when they are dissolved in water. Though there are more general definitions of acid and base, Arrhenius' acid-base concept is still useful for analyzing many acid-base reactions in aqueous solutions.

When dissolved in water, citric acid becomes a triprotic acid capable of releasing maximum 3 H^+ ions (marked by the bolded **H** in figure II-1). If a strong base, such as sodium hydroxide (NaOH), is added to an aqueous solution containing the acid, each of the protons from the acid react with one OH^- from NaOH to form water (H_2O), and the sodium ion (Na^+) remaining from NaOH takes the place of each proton of the acid to form a dissolved salt. This type of acid-base reaction is called a neutralization reaction.

$$C_6H_8O_7\,(aq) + 3\ NaOH(aq) \rightarrow Na_3C_6H_5O_7(aq) + 3\ H_2O(l) \qquad (1)$$

[Acid-Base Titration]

By using the neutralization reaction, we can determine the concentration of an acid or a base. The

method is called *titration*. A titration involves delivery (from a burette) of a measured volume of a solution of known concentration (the *titrant*) into a solution containing the substance being analyzed (the *analyte*). The point in the titration where enough titrant has been added to react exactly with the analyte is called **equivalence point**. This point is often marked by an **indicator**, a substance added at the beginning of the titration that changes color at (or very near) the equivalence point. The point where the indicator actually changes color is called **endpoint**.

In this experiment, you will use a NaOH solution as a titrant to determine the concentrations of citric acid (analyte) in fruit juice. Phenolphthalein will be used as an indicator. Figure II-2 shows the experimental set-up for the titration. You will add the NaOH solution into the fruit juices. During early stages of the titration, the color of the juice will remain yellowish. When a pink/purple color starts to develop, add the solution more slowly. At this point you should add one drop at a time until a light pink/purple color persists for at least 30 seconds. This is the endpoint which will be considered as an equivalence point for this experiment.

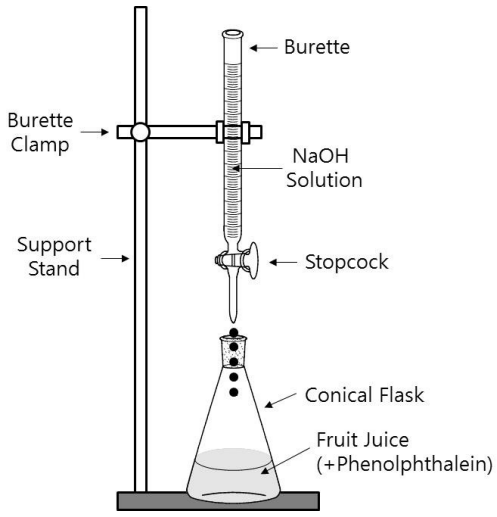


Figure II-2. Experimental set-up for acid-base titration

Since the amount of H^+ released from the citric acid of the fruit juice is exactly the same as that of OH^- in the total volume of the added NaOH solution up to the endpoint, it is possible to determine the concentration of the acid. Recall that molar concentration (mol/L) can be measured in molarity:

$$\text{Molarity (M)} \quad ¿ \frac{Moles\ of\ solute\,(mol)}{Volume\ of\ solution\,(L)} \qquad (2)$$

You may assume that the only acid present in the fruit juice is citric acid.

The molarity of OH^- is equal to the molarity of NaOH, due to the fact that when NaOH is added to water it ionizes 100% in a one to one ratio. Therefore, from the molarity of the NaOH solution, you can calculate the number of moles of OH^- by using equation (2). Once the moles of OH^- are known, the moles of citric acid can be determined by using the molar ratio from equation (1) between citric acid and NaOH.

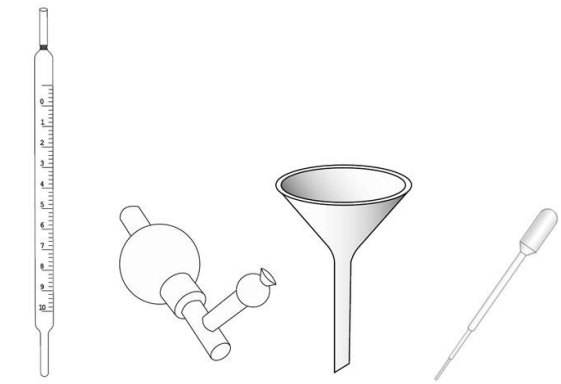
EXPERIMENTS

Two fruit juices, mandarin and apple, are prepared for your experiment. You will report the percent concentration of citric acid in each juice. The percent concentration (mass fraction) is expressed as:

$$\text{Percent (\%)} \quad ¿\frac{Mass\ of\ citric\ acid}{Mass\ of\ solution} \times 100 \qquad (3)$$

2. Materials

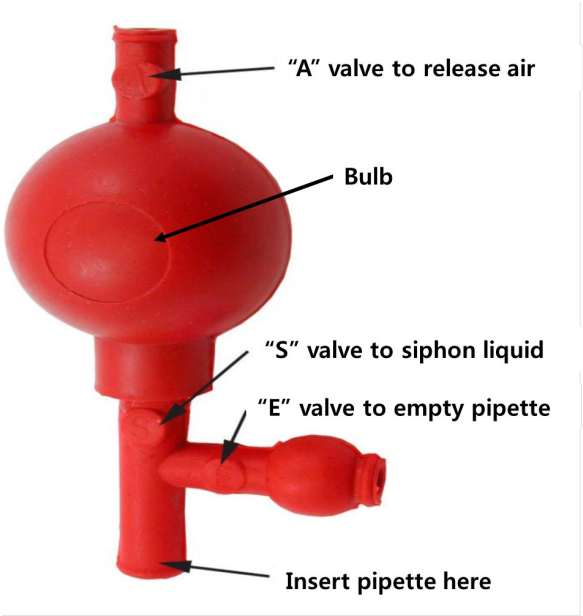
Equipment	Chemicals
50 mL burette	0.100 M NaOH solution
Support stand and burette clamp	1% Phenolphthalein indicator
10 mL pipette and pipette filler	Distilled water
100 mL conical flask	Fresh juice (mandarin and apple)
1L bucket (for waste)	
Funnel	
Dropper	



Pipette Pipette Filler Funnel Dropper

Pipette filler instruction

1. Carefully secure the bottom of the pipette filler to the top of the pipette (without forcing) while holding the pipette near its top.
2. Release air from the pipette filler by squeezing valve “A” on the top of the pipette filler while simultaneously squeezing the bulb. Release more air for larger volume pipettes.
3. Put the tip of the pipette into the liquid to be measured.
4. Draw liquid up into the pipette to the desired level by squeezing valve “S” on the bottom of the pipette filler. This uses the vacuum created in the bulb to draw liquid up into the pipette. Be careful not to draw liquid up into the pipette filler.
5. Empty the pipette by squeezing valve “E” on the side-tube. This allows you to release liquid at the desired rate and to the desired level.
6. It works best to fill the pipette past the zero mark in step 4 (valve “S”) and then release some fluid until it reaches the level down to the zero mark in step 5 (valve “E”). Once the pipette is filled to the desired level, the contents can be dispensed using valve “E”.



3. Experimental Procedure

→ **Before starting with experiment, read the instructions for the pipette filler carefully and if necessary, make yourself familiar with it's use by practicing with water.**

1. Shake the bottle of juice. Pipette 10 mL of mandarin juice into a clean conical flask.
2. Clean the pipette immediately with distilled water.
3. Add approximately 10 mL of distilled water into the conical flask containing the juice.
4. Add six drops of phenolphthalein indicator to the flask.
5. Mix the solution carefully by swirling it around.
6. Fill the burette with the 0.100 M NaOH solution using a funnel.
7. Open the burette stopcock and allow a trickle of the NaOH solution to run into a waste bucket. This is to ensure no air is in the burette prior to titration.
8. Record the initial volume of NaOH solution with accuracy of two decimal places in the burette on **Answer Sheet (II-1)**.
9. Place the conical flask under the burette and slowly add the NaOH solution to the flask.
10. When color change starts to develop, add the NaOH solution more slowly. Titrate with the sodium hydroxide solution until the end point is achieved. (Color change persists for at least 30 seconds.)
11. Record the final volume of NaOH solution of the burette with accuracy of two decimal places on **Answer Sheet (II-1)**.
12. Clean the flask with distilled water.
13. Repeat steps 1 – 12 with mandarin juice three more times.
14. Repeat steps 1 – 12 with the apple juice four times.
15. Answer the questions using your results.

4. Questions [13 Points]

II-1. [7.0 points] Calculate the volume (in mL) of the NaOH solution consumed for each titration and the average volume for titrating the mandarin and apple juices.

II-2. [2.0 points] Calculate the average number of moles of NaOH to complete the titration of citric acids in mandarin and apple juices.

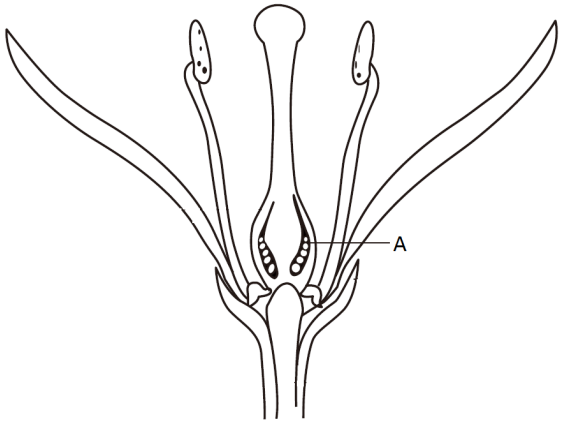
II-3. [2.0 points] Calculate the number of moles and masses (in grams) of citric acid in 10 mL of the mandarin and apple juices. (The atomic masses of C, H, and O are 12.0, 1.00, and 16.0 g/mol, respectively.)

II-4. [2.0 points] Calculate the percent concentrations of citric acid in the mandarin and apple juices. In the calculations, assume the density of each juice is 1.00 g/cm^3.

Experiment III. Anatomy and classification of fruits and seeds

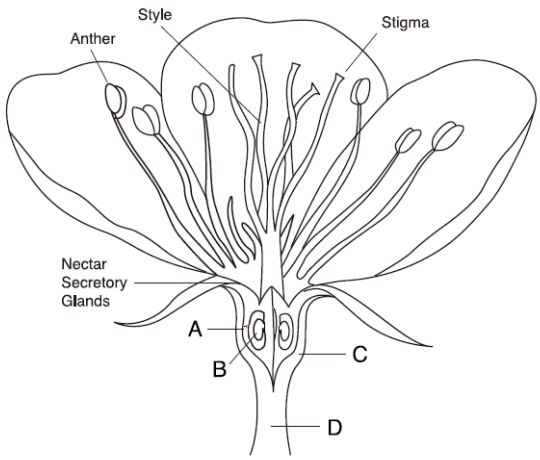
EXPERIMENTS

III-1. [1.0 point] The figure below shows a diagrammatic portrayal of open lemon flower.



Make a cross section by cutting through the middle of the lemon horizontally. **Draw** the section. **Label** the location of the structure(s) originated from A in the diagram.

III-2. [2.5 points] The figure shows a diagrammatic portrayal of an open apple flower.



Make a longitudinal section of the apple by cutting the apple lengthwise through its centre. D**raw** the section. **Label** the locations of the tissues originating from A, B, C and D in the diagram.

III-3. Angiosperms are known as the flowering plants. They are characterized by flowers, endosperm within the seeds, and the production of fruits that contain the seeds. A typical fruit has an outer wall called the pericarp that is composed of the exocarp, mesocarp, and endocarp. For example, if you cut an apple in half longitudinally, the skin is the exocarp, the fleshy portion is the mesocarp and the papery part is the endocarp. Inside the endocarp is the seed. Fruits can be classified by using the following incomplete classification key:

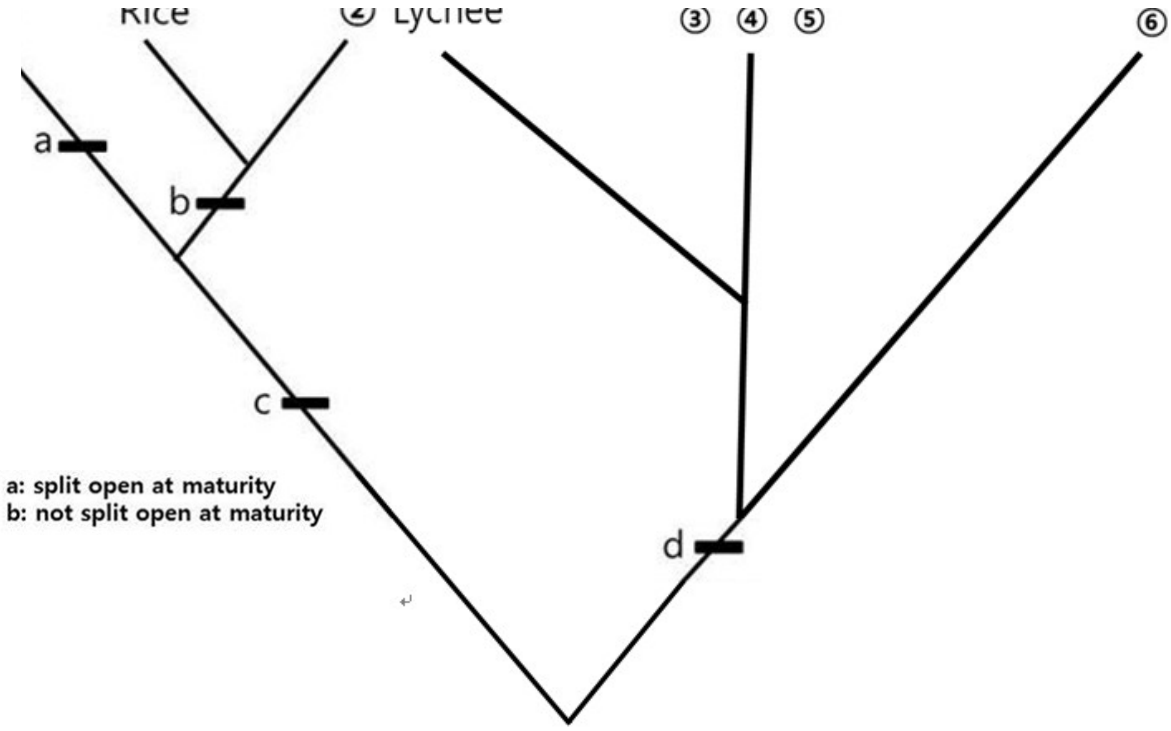


Figure III-1. Classification key for eight fruits

III-3-1. [2.0 points] Select a letter of the alphabet (A) to (H) from Box 1 that best represents fruit ① in Figure III-1. Do the same for fruit ②.

[Box 1]

(A) Acorn (B) Apple (C) Bean pod (D) Lychee (E) Lemon (F) Persimmon (G) Rice (H) Strawberry

III-3-2. [2.0 points] Select from Box 2 which fruit classification feature best represents ‘c’ and ‘d’ in Figure III-1 (There is only one correct feature for ‘c’ and one correct answer for ‘d’).

[Box 2]

<Fruit classification scheme>

I. Origins

I-a. Simple fruit : formed from a single pistil (carpel)
I-a-1 Single seed fruit
I-a-2 Many seeded fruit
I-b. Compound fruit : formed from more than one pistil (aggregate fruit and multiple fruit)
I-b-1. Aggregate fruit : formed from a cluster of separate pistils born in a single flower
I-b-2. Multiple fruit : formed from the pistils of several to many flowers

II. Composition

II-a. True fruit : composed of only the ripened ovary with its seeds contained
II-b. Accessory fruit: composed of the ripened ovary with other additional parts such as receptacle, bracts, portions of perianth, etc.

III. Descriptions

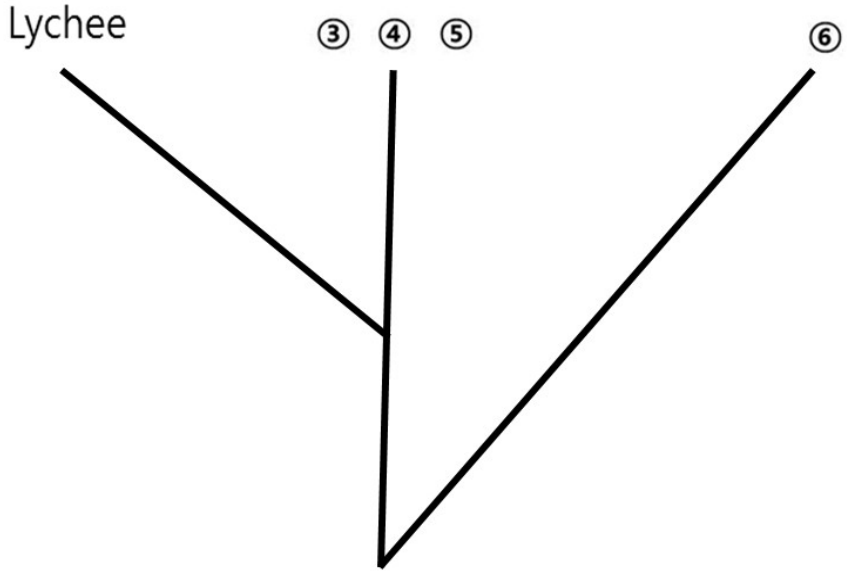
III-a. Fleshy fruit: outer wall becomes soft and fleshy as it matures.

III-b. Dry fruit: outer wall becomes dry at maturity.

III-3-3. [4 points] Examine the fruits carefully. You may need to section the fruit in order to do so. Refer to the fruits as indicated in Box 1 and tick (√) **all** appropriate classification categories in the table below for each of the fruits (A to H).

Fruit / Classification	A Acorn	B Apple	C Bean pod	D Lychee	E Lemon	F Persimmon	G Rice	H Strawberry
Single seed fruit								
Many seeded fruit								
Aggregate fr								
Multiple fr								
True frui								
Accessory fr								
Fleshy fru								
Dry fruit								

III-3-4. [1.5] by ③, ④, ⑤ and ⑥.



Number	Alphabet in Box 1
③	
④	
⑤	
⑥	

Part of Figure III-1

ANSWER SHEET

Country			
	Student 1	Student 2	Student 3
Name			
Code			
Signature			

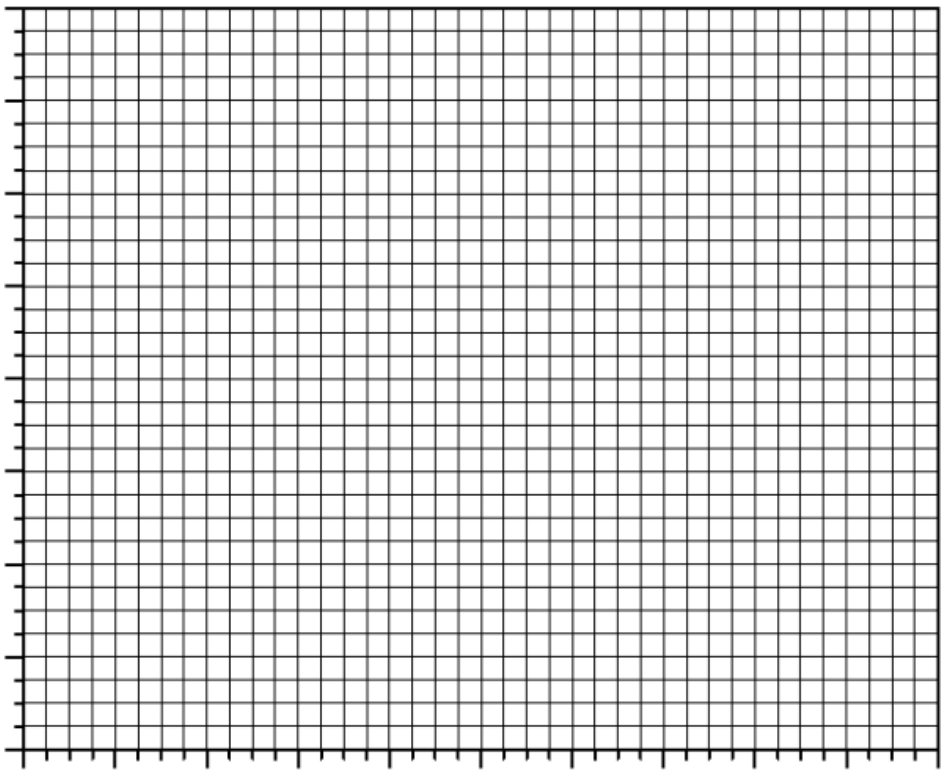
Experiment I. Determination of the Densities of Fruit Juices

I-1 (6.0)

I-1-1 (1.25)

	d_0	d_1	d_2	d_3	d_4
Masses (g)					
Lengths of spring (cm)					

I-1-2 (2.5)



I-1-3 (1.25)

Slope	cm/g	Intercept	cm

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment I. Determination of the Densities of Fruit Juices (Cont'd)

<table>
<tr><td rowspan="2">I-1
(6.0)</td><td rowspan="2">I-1-4
(1.0)</td><td colspan="3">(Show your working)</td></tr>
<tr><td>Spring Constant</td><td colspan="2">N/m</td></tr>
<tr><td rowspan="4">I-2
(6.0)</td><td rowspan="4">I-2-1
(2.0)</td><td>Immersed weights</td><td>50g + 50g</td><td>50g + 50g + 50g</td></tr>
<tr><td>Volume of water without weights in it (cm^3)</td><td></td><td></td></tr>
<tr><td>Volume read from scale after immersing weights (cm^3)</td><td></td><td></td></tr>
<tr><td>Volume difference (cm^3) (= Volume of liquid displaced)</td><td></td><td></td></tr>
</table>

	Student 1	Student 2	Student 3
Name			

ANSWER SHEET

Code			

Experiment I. Determination of the Densities of Fruit Juices (Cont'd)

Questions (Points)		Data and Answers				
I-2 (6.0)	I-2-2 (2.0)	Juice	Apple		Mandarin	
		Lengths of spring with the weights outside juice (cm)				
		Immersed weights	50g + 50g	50g + 50g + 50g	50g + 50g	50g + 50g + 50g
		Length of spring with the weights after immersing (cm)				
		Length difference (cm)				
	I-2-3 (2.0)	Buoyant force (N)				
I-3 (2.0)		Density (g/cm^3)				
		Average density (g/cm^3)				

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

Total points for experiment I	

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices

Questions (Points)	Data and Answers
II-1 (7.0)	Show your calculation of the average titer (for both juices)

	Juices							
	Mandarin				Apple			
Trials	1	2	3	4	5	6	7	8
Initial Readings (in)								
Final Readings (in)								
Volumes of NaOH solution consumed for titration								
	Average volume				Average volume			

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices (Cont'd)

Questions (Points)	Data and Answers
II-2 (2.0)	(Show your working)

Moles of NaOH	Mandarin		Apple	

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices (Cont'd)

Questions (Points)	Data and Answers
II-3 (2.0)	(Show your working)

ANSWER SHEET

	Moles of citric acid	Mandarin		Apple	
	Masses of citric acid	Mandarin		Apple	

	Student 1	Student 2	Student 3
Name			
Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices (Cont'd)

Questions (Points)	Data and Answers
II-4 (2.0)	(Show your working)

ANSWER SHEET

	Percent concentration of citric acid	Mandarin	%	Apple	%

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

Total points for experiment II	

	Student 1	Student 2	Student 3
Name			
Code			

Experiment III. Anatomy and classification of fruits and seeds

Question (Points)	Data and Answers	
III-1 (1.0)	Location of the structure(s) originated from A	

ANSWER SHEET

III-2 (2.5)	Location of the tissues originated from A, B, C and D	

	Student 1	Student 2	Student 3
Name			
Code			

Experiment III. Anatomy and classification of fruits and seeds (Cont'd)

Question

(Points)

Data and Answers

III-3-1

(2.0)

fruits

Fruit Classification	A Acorn	B Apple	C Bean pod	D Lychee	E Lemon	F Persi-mmon	G Rice	H Straw-berry
Single seed fruit								
Many seeded fruit								
Aggregate fruit								
Multiple fruit								
True fruit								
Accessory fruit								
Fleshy fruit								
Dry fruit								

Fruits for ① and ②

III-3-2

(2.0)

Classification schemes for ‘c’ and ‘d’

characters

c

d

III-3-3

(4.0)

Student 1

Student 2

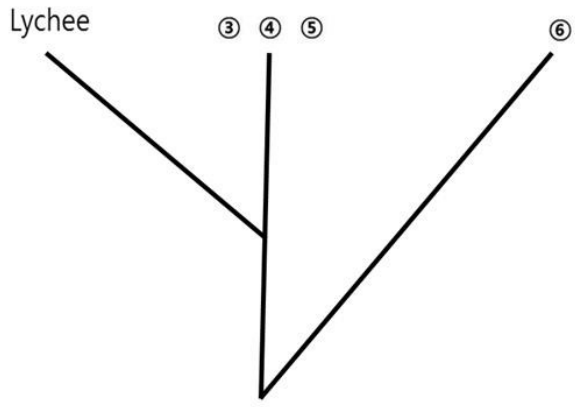
Student 3

Name

ANSWER SHEET

Code

III-3-4
(1.5)



Number	Alphabet in Box 1
③	
④	
⑤	
⑥	

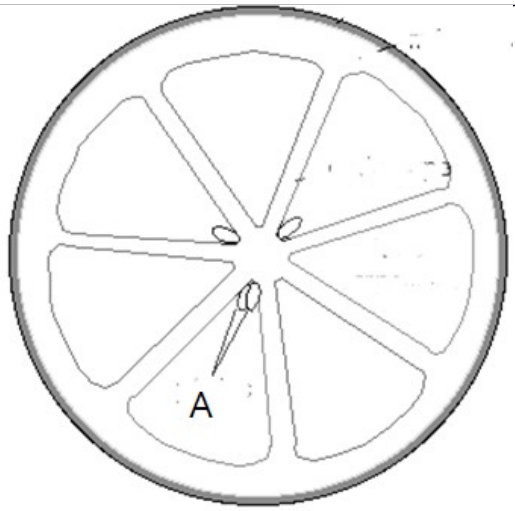
---------- DO NOT WRITE BELOW ----------

Total points for experiment III	

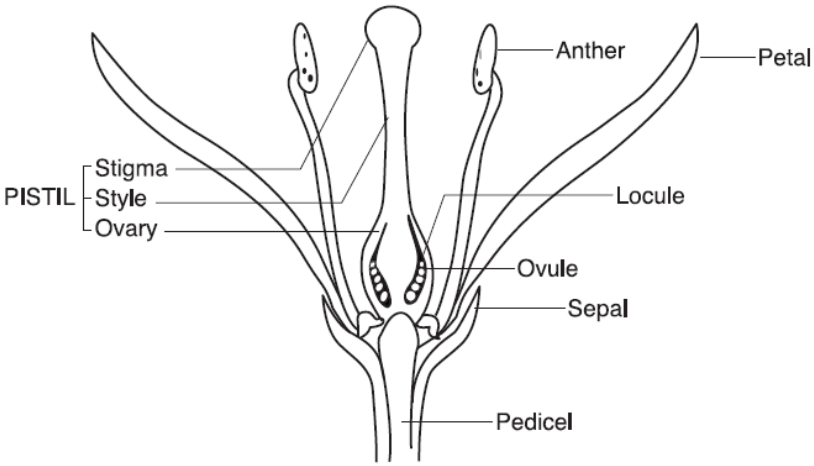
Experiment III. Anatomy and classification of fruits and seeds

III-1. [1.0 point](Answer): 0.5 points for correct drawing (separate sections and seeds) and 0.5 points for correct labeling.

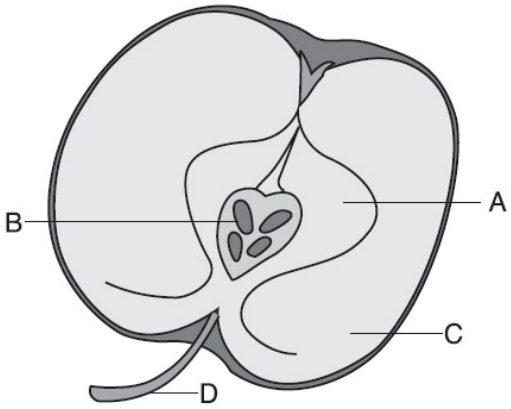
III-1



(Explanation) A is ovules which become seeds.

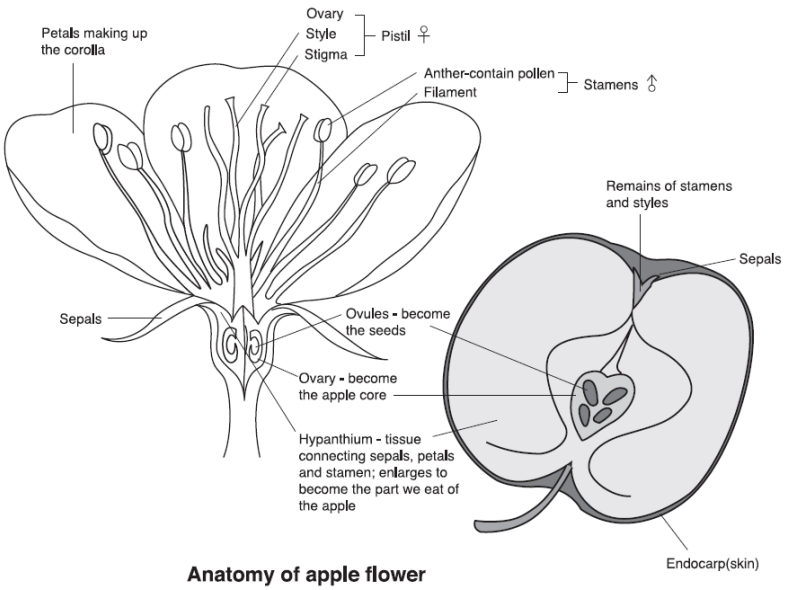


III-2. [2.5 point](Answer) = **4 x 0.5 points for correct labeling and 0.5 points for correct drawing (Seeds, stem and inner and outer fleshy tissue).**

III-2	

(Explanation)

A is originated from ovary, B from ovules, C from hypanthium, and D from pedicel.



Anatomy of apple flower

III-3-1. [2.0 points] (Answer) = **2 x 1 point**

1	**2**
C	A

III-3-2. [2.0 point] (Answer) = **2 x 1 point**

c	d
III-b	III-a

III-3-3. [4.0 points] (Answer)
0.5 points per correct fruit (column)
0.25 points for only one mistake per column.

Fruit **Classification**	**A** **Acorn**	**B** **Apple**	**C** **Bean pod**	**D** **Lychee**	**E** **Lemon**	**F** **Persimmon**	**G** **Rice**	**H** **Strawberry**
Single seed fruit	√			√			√	
Many seeded fruit		√	√		√	√		√
Aggregate fruit								√
Multiple fruit								
True fruit	√		√	√	√	√	√	
Accessory fruit		√						√
Fleshy fruit		√		√	√	√		√
Dry fruit	√		√				√	

III-3-4. [1.5 points] Identify which fruits from box 1 most appropriately are represented by 3, 4, 5 and 6.

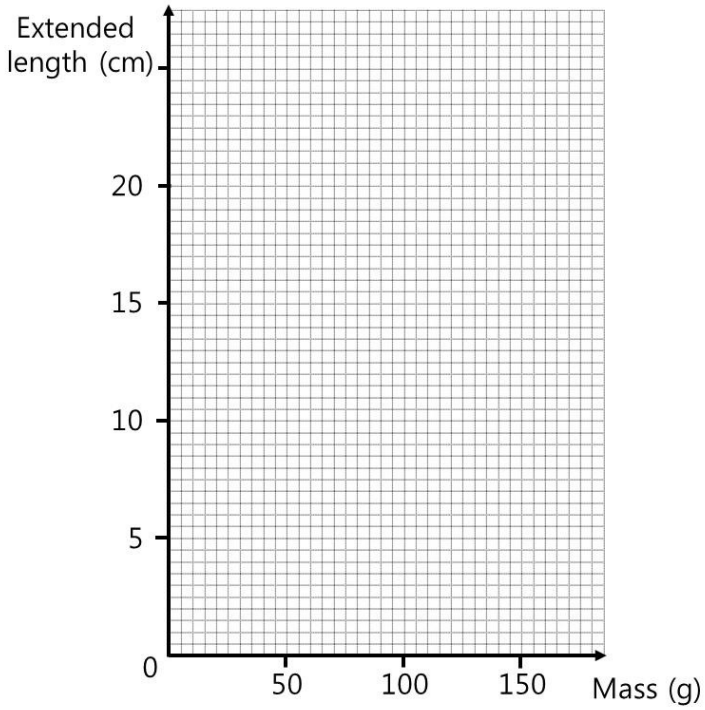
		Points
3	B, E, F in any order	0.25 per correct fruit
4		
5		
6	H	0.75

ANSWER SHEET

Country			
	Student 1	Student 2	Student 3
Name			
Code			
Signature			

Experiment I. Determination of the Densities of Fruit Juices

Questions (Points)		Data and Answers					
I-1 (1.0)		Length of spring (cm)					
I-2 (6.0)	I-2-1 (1.0)	Masses (g)	0				
		Lengths of spring (cm)					
	I-2-2 (1.0)	Extended lengths of spring (cm)	0				
	I-2-3 (2.0)						



	Student 1	Student 2	Student 3
Name			

ANSWER SHEET

Code			

Experiment I. Determination of the Densities of Fruit Juices (Cont'd)

I-2 (6.0)

I-2-3 (2.0)

(Show your working)

<x>		<y>	
$< x^2 >$		<xy >	
Slope, *A*	cm/g	Intercept, *B*	cm

I-2-4 (2.0)

Spring Constant	N/m

	Student 1	Student 2	Student 3
Name			
Code			

ANSWER SHEET

Experiment I. Determination of the Densities of Fruit Juices (Cont'd)

Questions (Points)		Data and Answers		
I-3 (4.0)	I-3-1 (1.0)	Juice	Mandarin	Apple
		Lengths of spring (cm)		
	I-3-2 (1.0)	Extended lengths of spring (cm)		
	I-3-3 (2.0)	(Show your working)		
		Juice	Mandarin	Apple
		Buoyant forces (N)		

	Student 1	Student 2	Student 3
Name			
Code			

Experiment I. Determination of the Densities of Fruit Juices (Cont'd)

ANSWER SHEET

<table>
<tr><td>Questions
(Points)</td><td colspan="3">Data and Answers</td></tr>
<tr><td>I-4
(1.0)</td><td>Volume (cm^3)</td><td colspan="2"></td></tr>
<tr><td rowspan="3">I-5
(2.0)</td><td colspan="3">(Show your working)</td></tr>
<tr><td>Juice</td><td>Mandarin</td><td>Apple</td></tr>
<tr><td>Densities (g/cm^3)</td><td></td><td></td></tr>
</table>

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

Total points for experiment I	

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices

Questions (Points)	Data and Answers

II-1 **(7.0)**

(Show your working)

0.5 per juice for completing all readings to two decimal places and all appropriate units

0.5 per juice for correct calculation of average values (if necessary disregarding anomalous values); 0.25 if anomalous values are included

0.5 per juice if at least two titers are no more than 0.1 mL apart

---

Marks for accuracy compared to **ideal titer**

≤ ±0.25 mL [2.0] per juice
± 0.26 – 0.45 mL [1.5]
± 0.46 – 0.65mL [1.0]
± 0.66 – 0.85 mL [0.5]
±0.85 – 0.99 mL [0.2]
≥ 1 mL [0.0]

	Juices							
	Mandarin				Apple			
Trials	1	2	3	4	5	6	7	8
Initial Readings (in)								
Final Readings (in)								
Volumes of NaOH solution consumed for titration								
	Average volume				Average volume			

	Student 1	Student 2	Student 3
Name			

ANSWER SHEET

Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices (Cont'd)

Questions (Points)	Data and Answers				
II-2 (2.0)	(Show your working) n(NaOH) = V(NaOH) * c(NaOH) [1] Correct values for each juice [0.5]				
	Moles of NaOH	Mandarin	mol	Apple	mol
II-3 (2.0)	(Show your working) Mole ratio: 3:1 Calculation n(acid) = n(NaOH) / 3 [0.5 per juice] Calculation m(acid) = n(acid) * M_r(acid) [0.5 per juice] 0.25 if error in M_r or missing units				
	Moles of citric acid	Mandarin		Apple	
	Masses of citric acid	Mandarin		Apple	

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment II. Determination of the Citric Acid Contents in Fruit Juices (Cont'd)

Questions (Points)	Data and Answers
II-4 (2.0)	(Show your working) Calculation m(juice) = density * volume = 1.00 g/cm^3 * 10.0 cm^3 = 10.0 g [0.5] Calculation Percent Concentration m(acid) / m(juice) * 100 [0.75 per juice] Or value based on students' answer of II-3

Percent concentration of citric acid	Mandarin	%	Apple	%

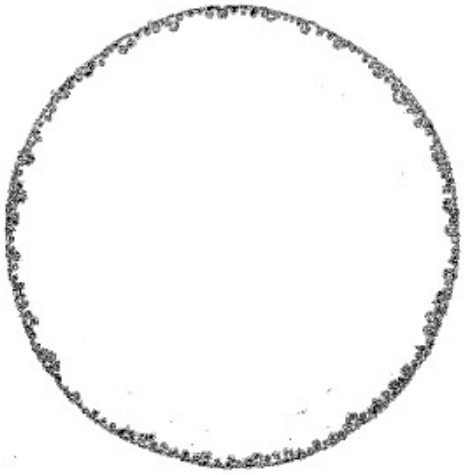
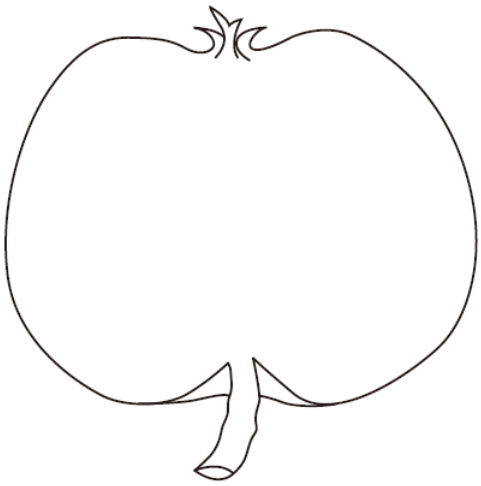
---------- DO NOT WRITE BELOW ----------

Total points for experiment II	

ANSWER SHEET

	Student 1	Student 2	Student 3
Name			
Code			

Experiment III. Anatomy and classification of fruits and seeds

Question (Points)	Data and Answers	
III-1 (1.0)	Location of tissues originated from A	
III-2 (2.0)	Location of tissues originated from A, B, C and D	

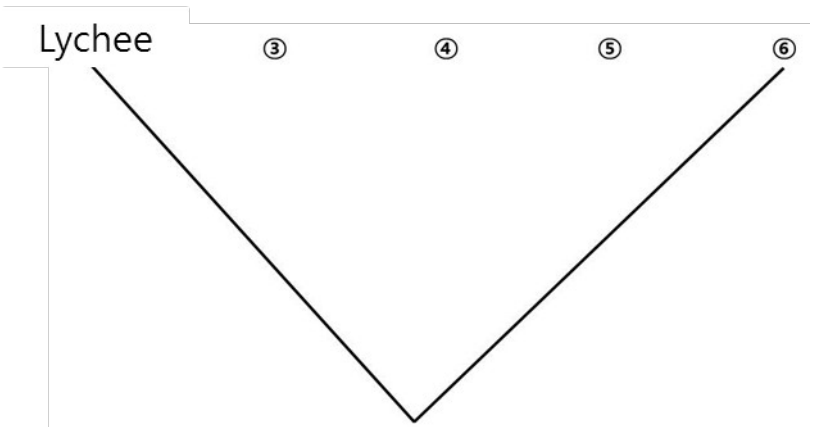
	Student 1	Student 2	Student 3
Name			

ANSWER SHEET

Code			

Experiment III. Anatomy and classification of fruits and seeds (Cont'd)

<table>
<tr><td>Question (Points)</td><td colspan="3">Data and Answers</td></tr>
<tr><td rowspan="3">III-3-1 (2.0)</td><td rowspan="2"></td><td colspan="2">fruits</td></tr>
<tr><td>1</td><td>2</td></tr>
<tr><td>Fruits for ① and ②</td><td></td><td></td></tr>
<tr><td rowspan="3">III-3-2 (2.0)</td><td rowspan="3">Classification schemes for 'c' and 'd'</td><td colspan="2">characters</td></tr>
<tr><td>c</td><td>d</td></tr>
<tr><td></td><td></td></tr>
<tr><td rowspan="5">III-3-3 (6.0)</td><td>III-3-3-1

Draw branch lines to complete the diagram.
(4.0 points)</td><td colspan="2"> 
</td></tr>
<tr><td>III-3-3-2
(0.5 points)</td><td colspan="2">A fruit for ③</td></tr>
<tr><td>III-3-3-3
(0.5 points)</td><td colspan="2">A fruit for ④</td></tr>
<tr><td>III-3-3-4
(0.5 points)</td><td colspan="2">A fruit for ⑤</td></tr>
<tr><td>III-3-3-5
(0.5 points)</td><td colspan="2">A fruit for ⑥</td></tr>
</table>

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

Total points for experiment III	

Partially marking scheme

I-1. [6.0 points]

I-1-1 [1.25 points] 0.25 points for each of the lengths measure.

I-1-2.[2.5 points]

- 0.25 each for drawing axes, writing down quantity and unit 0.5
- 1.5 if all 5 measurement points are presented in the graph
- 0.5 for drawing the best fitted line

I-1-3. [1.25 points]

- 1.0 for calculating the slope A (within $\pm$ 10% error)
- 0.5 for calculating the slope A (within ± 2 0% error)
- 0.25 for reading the intercept B

I-1-4. [1.0 point] Calculate the spring constant in N/m. (Assume that the gravitational acceleration is 9.81 m/s^2)

- 0.5 for the formula to get the spring constant
- 0.5 for calculating the value in N/m

I-2. [6.0 points]

I-2-1. [2.0 points]

- 0.25 each for measuring the volume without weights immersed 0.5
- 0.5 each for measuring the volume with weights immersed 1.0
- 0.25 each for calculating the differences 0.5

I-2-2. [2.0 points].

- 0.25 each for measuring the length before emersion 0.5
- 0.25 each for measuring the length for 2 and 3 weights immersed for apple juice 0.5
- 0.25 each for measuring the length for 2 and 3 weights immersed for mandarin juice 0.5
- 0.125 each for calculating the length differences 0.5

I-2-3. [2.0 point]

- 0.5 each for calculating the buoyant force value in N 2.0

I-3. [2.0 points] Calculate the average densities of the apple juice and mandarin juice respectively.

- 0.25 each for calculating the density using volumes and buoyant forces 1.0
- 0.5 each for calculating the average density (if between 0.70 g/cm^3 and 1.30 g/cm^3)