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.

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.

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

[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?

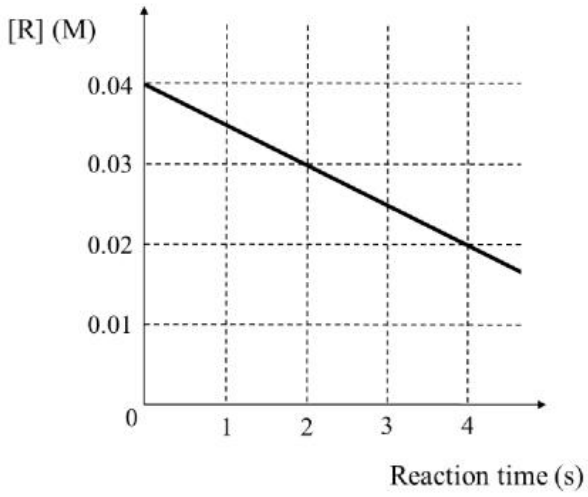
(A) CO_2 (B) CCl_4 (C) C_2H_2 (D) H_2Se

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

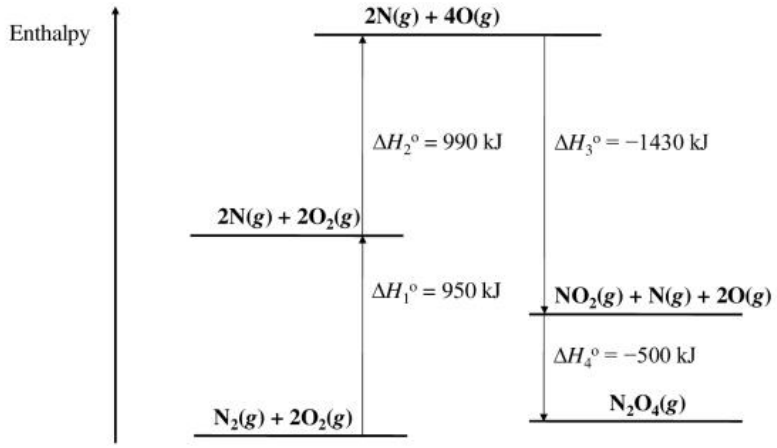
(B) $1s^2 2s^2 2p^6$

(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°) 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° 's $(i = 1, 2, 3, 4)$ are the standard enthalpy changes for the corresponding processes at 25°C.



What is the ΔH_f° 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}

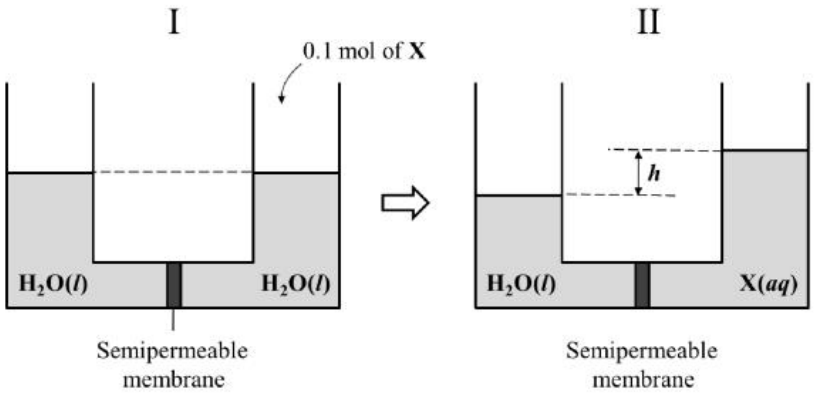
Which of the following options from A to D chooses all the correct statement(s) from the box below? (Assume that the temperatures of the solutions are kept constant at 25 °C.)

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.)

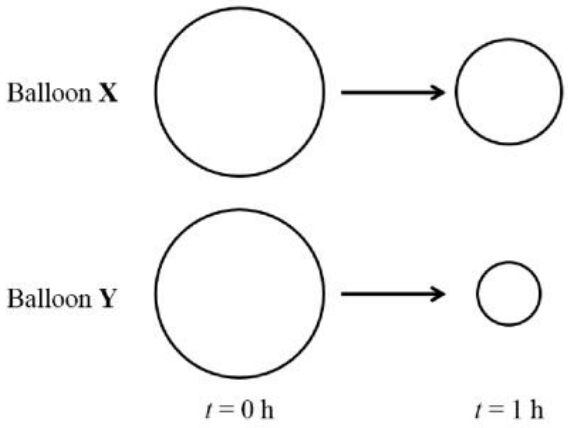


Which of the following **X** would give the SECOND greatest ***h***?

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

10.

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

[PHYSICS]

11.

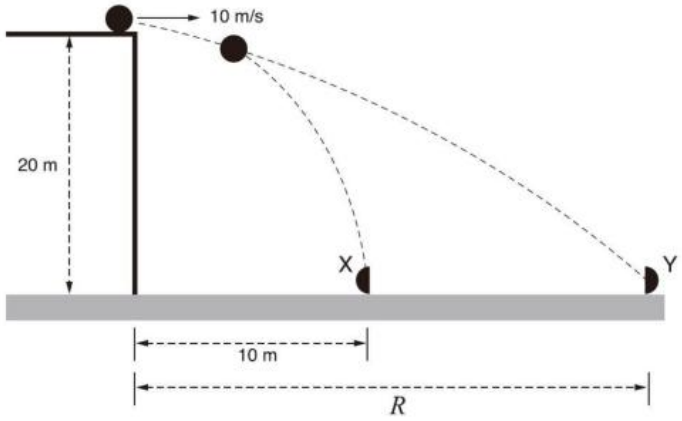
Bats use ultrasonic waves to catch prey. When stationary, a bat emits ultrasonic waves of frequency 82.5 kHz. The bat now starts following a moth along the +x direction. The speeds of the bat and moth are 9.00 m/s and 8.00 m/s, respectively. The bat now emits and detects the wave reflected by the moth.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

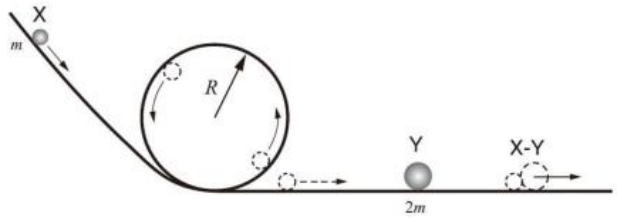


What is the distance R? (Assume there is no air resistance.)

(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.

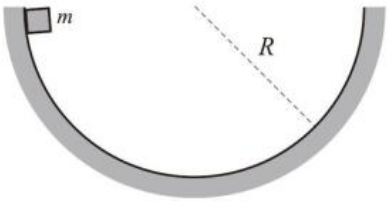


What is $\frac{K_X}{K_{XY}}$? (K_X and K_{XY} are the kinetic energies of X just before the collision and of XY after the collision, respectively.)

(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.

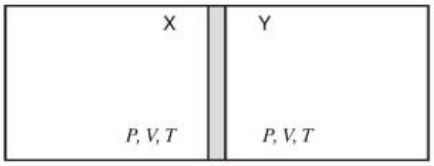


What are the amounts of the work done by gravitational and normal forces?

	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.

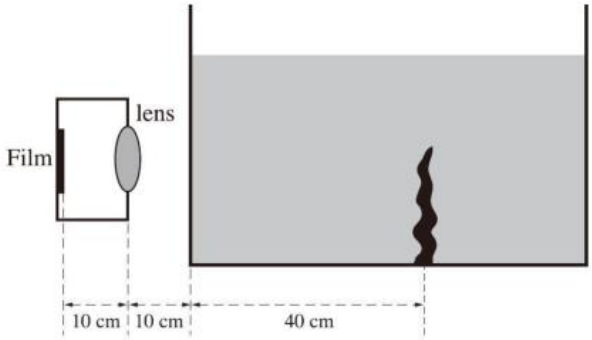


What is the gas pressure of Y at the equilibrium after the heating?

(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.

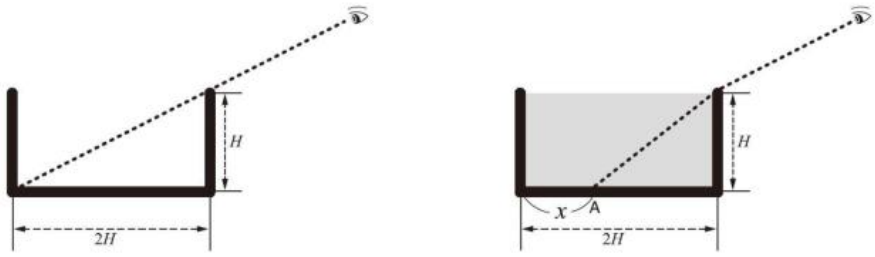


What is the focal length of the convex lens?

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

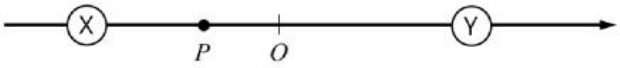
(B) $2H\left(1-\frac{1}{\sqrt{3n^2-1}}\right)$

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

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

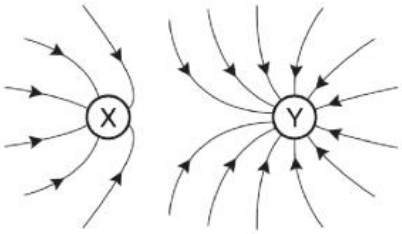
18.

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.

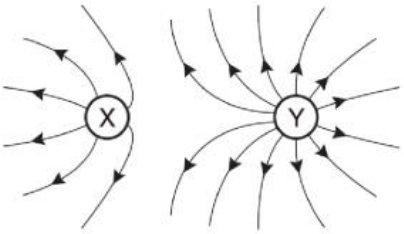


Which of the following sketches shows the correct electric field lines before placing the negative charge at *P*?

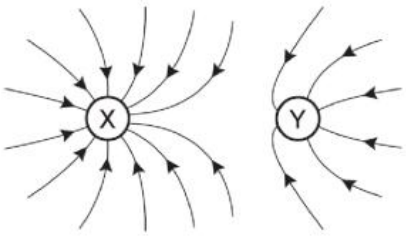
(A)



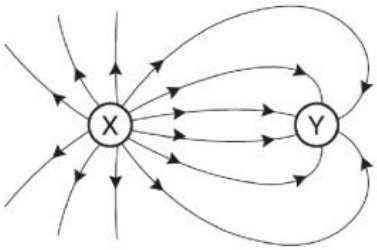
(B)



(C)

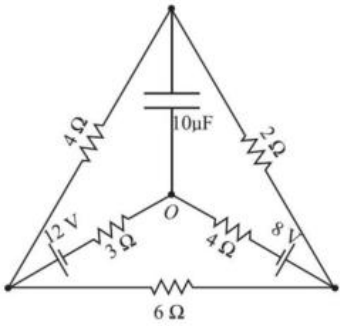


(D)



19.

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

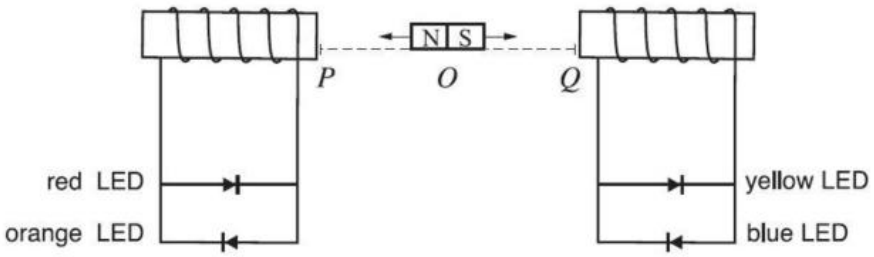


What is the current flowing through the 3Ω resistor after sufficient time has passed?

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

20.

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*→*P*→*O*→*Q*→*O*?

(A) red – orange – yellow – blue

(B) orange – red – blue – yellow

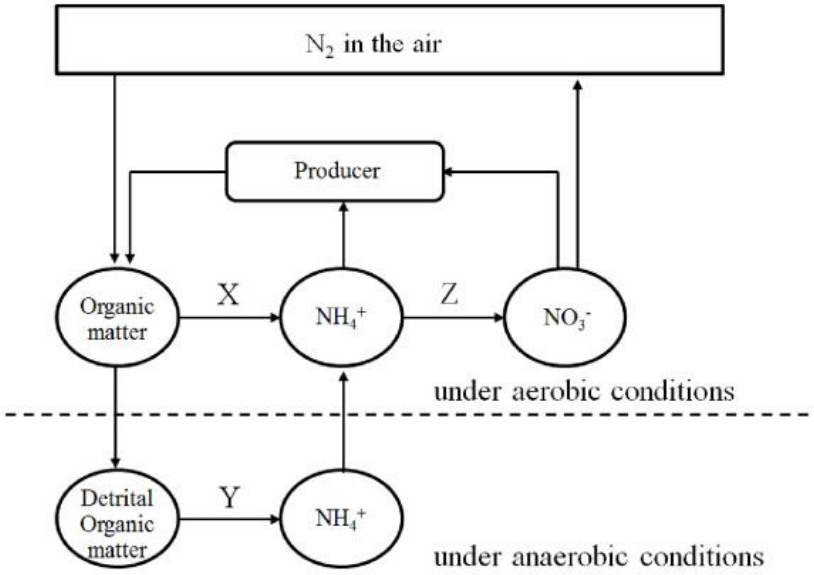
(C) red – orange – blue – yellow

(D) orange – red – yellow – blue

[BIOLOGY]

21.

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



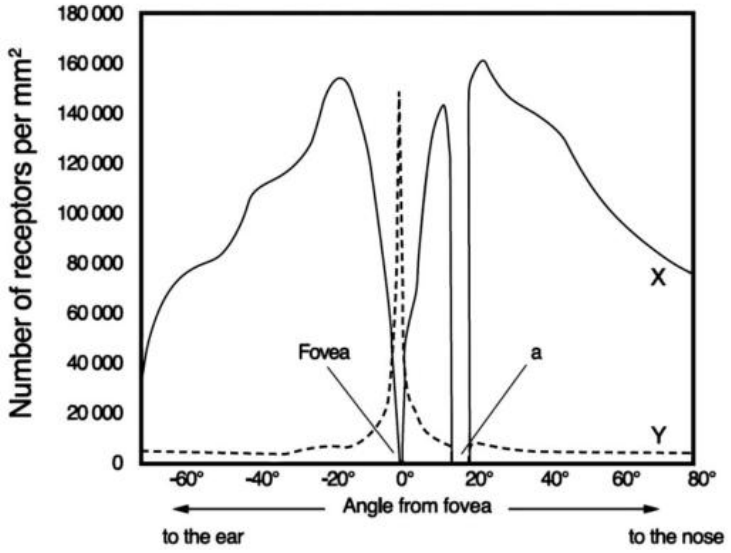
Which of the following options from A to D chooses all the correct statement(s) from the box below?

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 $\frac{\text{Number of X}}{\text{Number of Y}}$ 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.

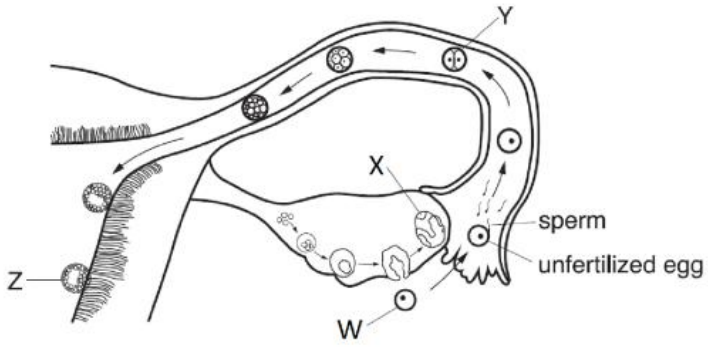
(B) The number for A+G in strand I is 550.

(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.

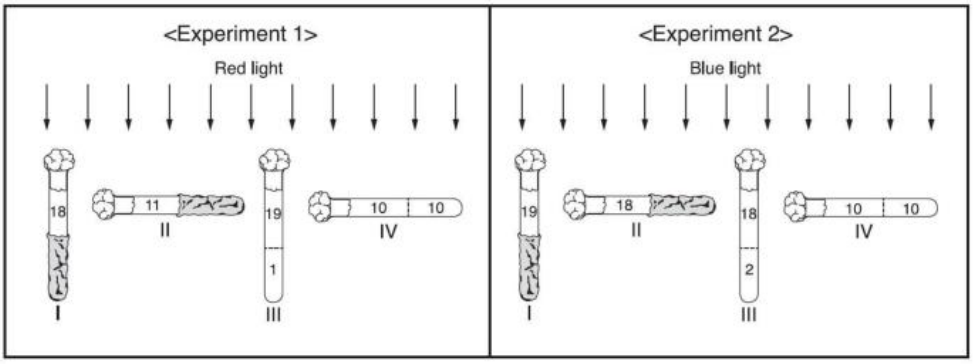
(B) X produces progesterone.

(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.

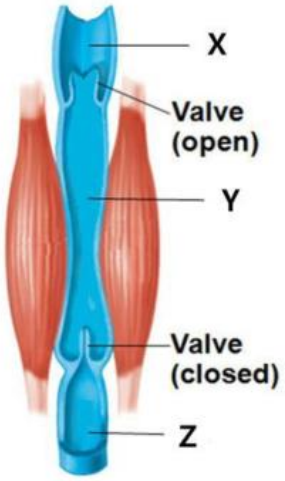
(B) Tubes II and IV are serving as the controls for the light variable.

(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.



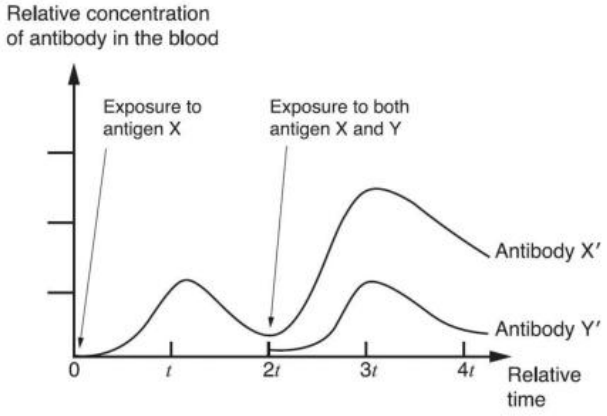
Which of the following options from A to D chooses all the correct statement(s) from the box below?

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.



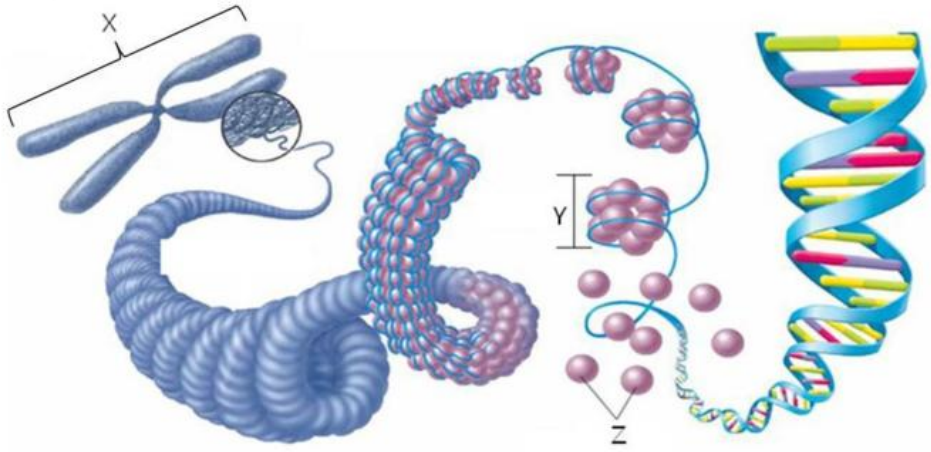
Which of the following options from A to D chooses all the correct statement(s) from the box below?

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

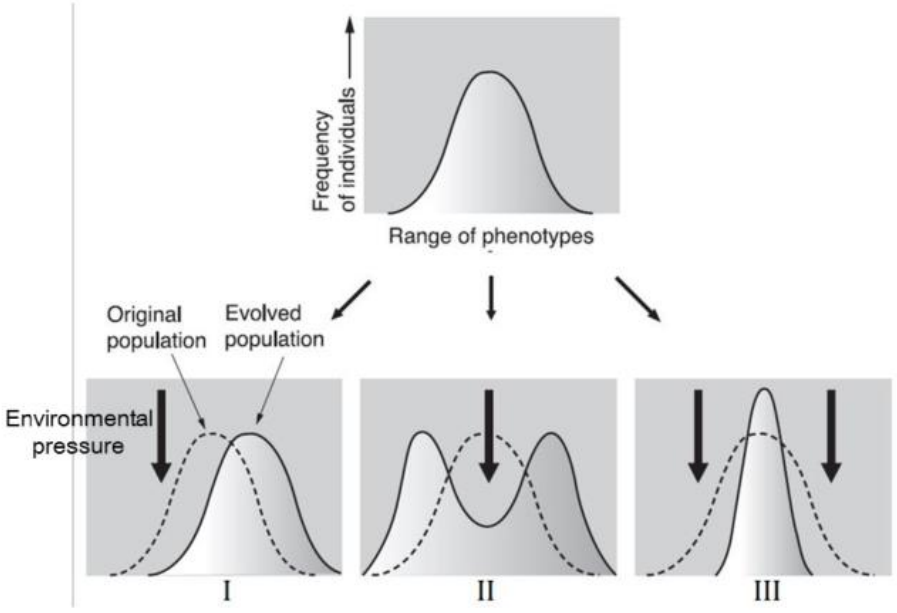
29.

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.

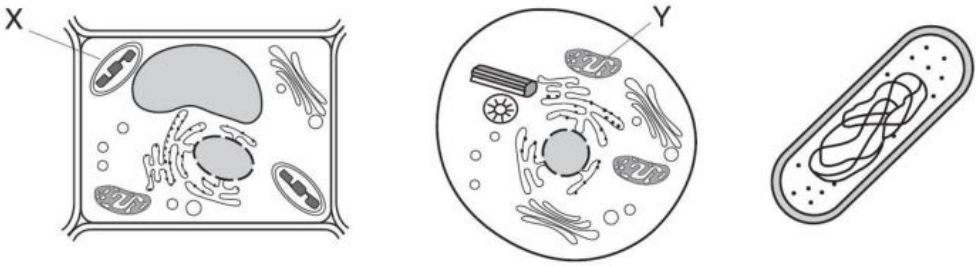


Which of the following figure-explanation matches is correct?

(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

[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 $1s^2 2s^2 2p^6 3p^3$ and the most stable ion of Al is Al^{3+}. Therefore, the electron configuration of Al^{3+} is $1s^2 2s^2 2p^6$.

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:

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

The above process can be broken down to two steps

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

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

($\Delta H_{(ii)}^o$ and $\Delta H_{(iii)}^o$ 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 (= 4.9×10^{-10}).

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

$$K_a = \frac{[H^+][CN^-]}{[HCN]} = \frac{x^2}{0.1 - x} = 4.9 \times 10^{-10}$$

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 > $MgSO_4$ 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.

[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.

From the distance for vertical movement ($H = 20\text{m} = \frac{1}{2}(10\text{m/s}^2)\text{t}^2$), one can find the time of falling is 2 sec. So, the distance for horizontal movement is $D = 10\text{m/s} \times 2\text{sec} = 20\text{m}$.

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

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

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

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

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

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

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

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.

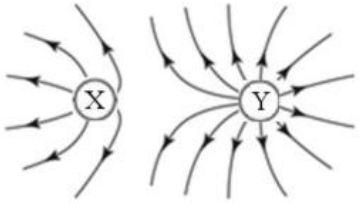
(Answer) D

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

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), $i_2 = i_1 + i_3$, $-8 - 4i_1 - 3i_1 + 12 + 6i_3 = 0$, $-12 + 3i_1 + 4i_1 + 8 + 6i_2 = 0$

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

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

[BIOLOGY]

21.

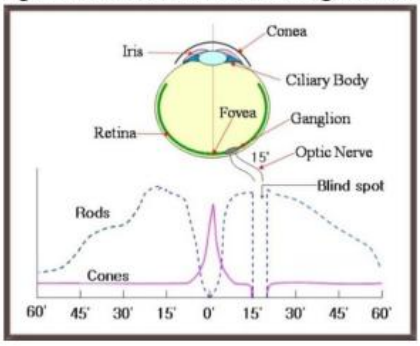
(Answer) D

(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.