16th International Junior Science Olympiad **Time: 04 hr 00 min**
Doha, Qatar - December 05, 2019 **Points: 30**

Q 1 : During a Safari trip in Qatar, a car starts from rest, moving eastward. If the net force acting on the car is directly proportional to (t^2),where (t) denotes time. What would the car's kinetic energy be proportional to?

A. t^2

B. t^3

C. t^4

D. t^6

Q 2 : A disk-shaped cork of diameter d is placed in water. Paper clips are added on the top of the cork. We repeat this experiment replacing water with cooking oil. Which of the following relationships expresses the maximum number of paper clips that can be added in the two situations before the cork fully submerges under the liquid?
("n" refers to the number of clips, "ρ" refers to density, "w" refers to water, "o" refers to oil and "c" refers to the cork)

A. $\frac{n_w}{n_o} = \frac{(\rho_o + \rho_c)}{(\rho_c - \rho_w)}$

B. $\frac{n_w}{n_o} = \frac{(\rho_o - \rho_c)}{(\rho_c - \rho_w)}$

C. $\frac{n_w}{n_o} = \frac{(\rho_w - \rho_c)}{(\rho_o - \rho_c)}$

D. $\frac{n_w}{n_o} = \frac{(\rho_c - \rho_w)}{(\rho_o - \rho_c)}$

Q 3 : A flask containing photosynthetic green algae and a control flask containing no algae are both placed under a light source, which are set to switch ON for 12 hours and then OFF for 12 hours. The dissolved oxygen concentrations in both flasks are monitored at the end of each 12 hours period. What will be the relative dissolved oxygen concentration in the flask with algae compared to the control flask?

The dissolved oxygen concentration in the flask with algae will…

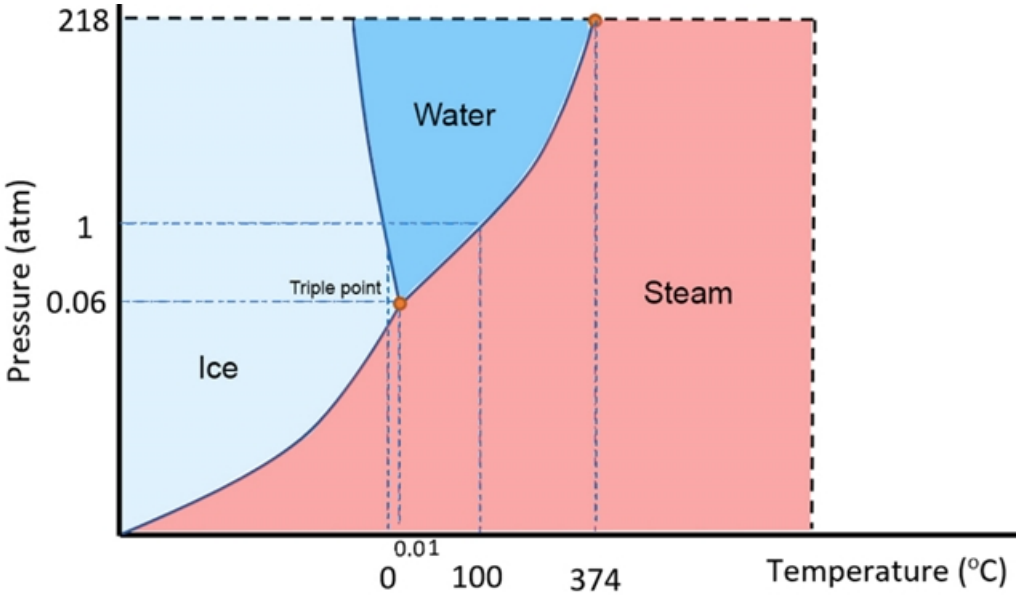
A. Always be higher

B. Always be lower

C. Be higher in the light, but the same in the dark

D. Be higher in the light but lower in the dark

Q 4 : All kinds of life on earth require water, which cycles through our ecosystem in three states: solid, liquid, and gas. The relationship that these three phases have with both temperature and pressure in a sealed container are best represented in the phase diagram below:



Consider the following statements and identify the correct ones?

i. The bold line that separates any two regions shows that two phases of water co-exist in equilibrium.
ii. A decrease in pressure lowers the melting point and raises the boiling point of water.
iii. At a temperature of 0.01 °C and a pressure 0.06 atm ice, liquid water and water vapour can co-exist in equilibrium.
iv. At 100 °C the vapour pressure is higher than the atmospheric pressure at sea level.

A. i and ii only

B. i and iii only

C. iii and iv only

D. ii and iv only

Q 5 : For the following unbalanced reaction equations below, determine how many H_2 molecules

are required to produce 12 molecules of water, assuming a 100 % yield for the first reaction?

$$H_{2(g)} + N_{2(g)} \longrightarrow NH_{3(g)}$$

$$NH_{3(g)} + CH_3Cl_{(g)} + NaOH_{(aq)} \longrightarrow NaCl_{(s)} + CH_3NH_{2(g)} + H_2O_{(l)}$$

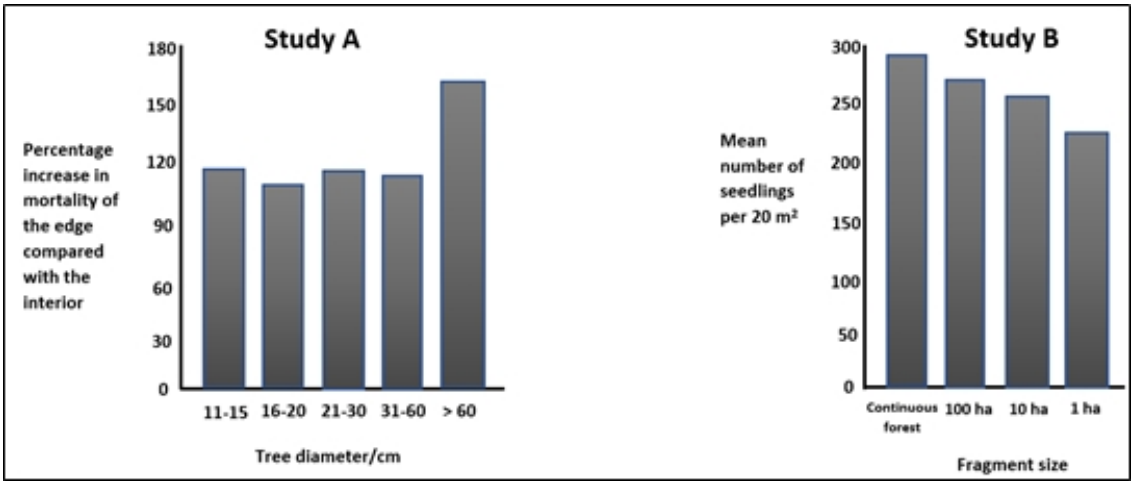
A. 18 molecules

B. 12 molecules

C. 24 molecules

D. 4 molecules

Q 6 : The results below show the effects that fragmentation of forests has on trees. In Study A, the percentage of dead and dying trees of different sizes was estimated in the interior and at the edges of the forest fragments. The percentage increase of dead and dying trees at the edge was compared to that at the interior for trees of varying sizes. In Study B, the number of new tree seedlings was measured in a continuous forest and in forest fragments of areas 100, 10 and 1 hectare (1 hectare = 10,000 square metres). The results are shown below.



Consider the following statements regarding the above study.

i. Conditions at the edge are more suitable for survival of trees.

ii. The widest trees have the highest survival value in the interior.

iii. Trees in the interior may survive better as they are less susceptible to wind damage.

iv. Trees at the edge may survive better as they are less susceptible to wind damage.

v. The density of seedlings of the 100-hectare fragment is up to 25% more than that of the 1-hectare fragment.

vi. Conditions at the edge are more suitable for seedlings.

Which of the above statements are likely to be correct?

A. ii, iii and iv

B. i, iii and iv

C. ii, iii and vi

D. ii, iii and v

Q 7 : Black fur in mice (*B*) is dominant to brown fur (*b*). Long tails (*T*) are dominant to short tails (*t*). What fraction of the progeny of crosses (*BbTt* × *BBtt*) will be expected to have black fur and short tails?

A. 1/16

B. 3/16

C. 3/8

D. 1/2

Q 8 : Your blood alternates between your body's pulmonary circuit and systemic circuit through various vessels and chambers. Below is a list of vessels and structures that are associated with your heart. What is the correct order for the flow of blood entering from the systemic circulation?

1. Right atrium
2. Left atrium
3. Right ventricle
4. Left ventricle
5. Venae cava
6. Aorta
7. Pulmonary artries
8. Pulmonary veins

A. 1, 7, 3, 8, 2, 4, 6, 5

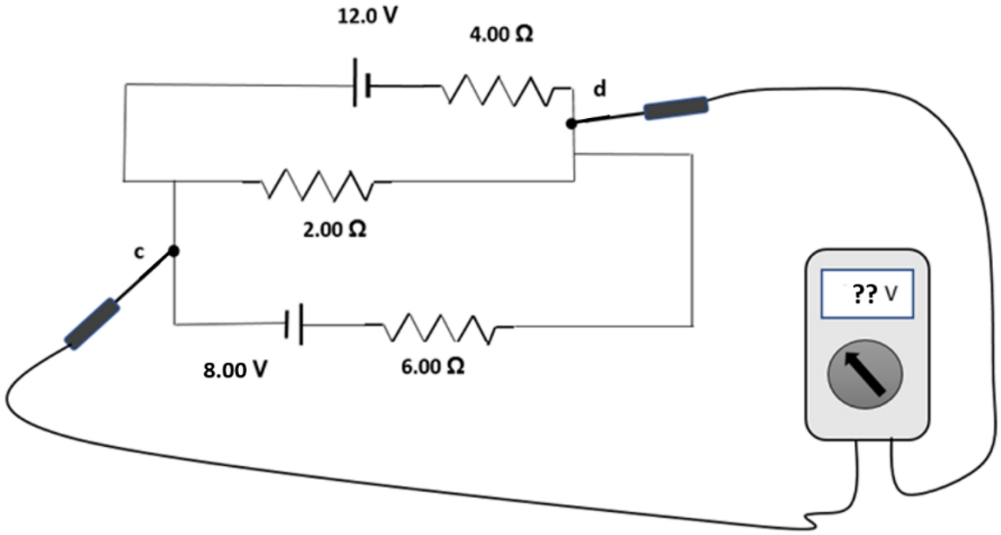
B. 1, 2, 7, 8, 3, 4, 6, 5

C. 5, 1, 3, 8, 7, 4, 2, 6

D. 5, 1, 3, 7, 8, 2, 4, 6

Q 9 : In a physics lab, the teacher decided to test the students' ability to set up electrical circuits and asked them to set up the circuit shown in the figure. Each student was given a combination of 3 resistors of (2.00 Ω, 4.00 Ω and 6.00 Ω) and 2 ideal batteries of (8.00 V and 12.0 V).

The teacher later wanted to assess the students' work, but she did not have enough time to examine each circuit connection. Therefore, she decided to use a voltmeter to measure the voltage between points c and d for each student's circuit. What would be the voltmeter reading in case of correct connection?



A. 1.36 V

B. 1.82 V

C. 3.00 V

D. 4.80 V

Q 10 : In which direction does carbon dioxide move during internal respiration?

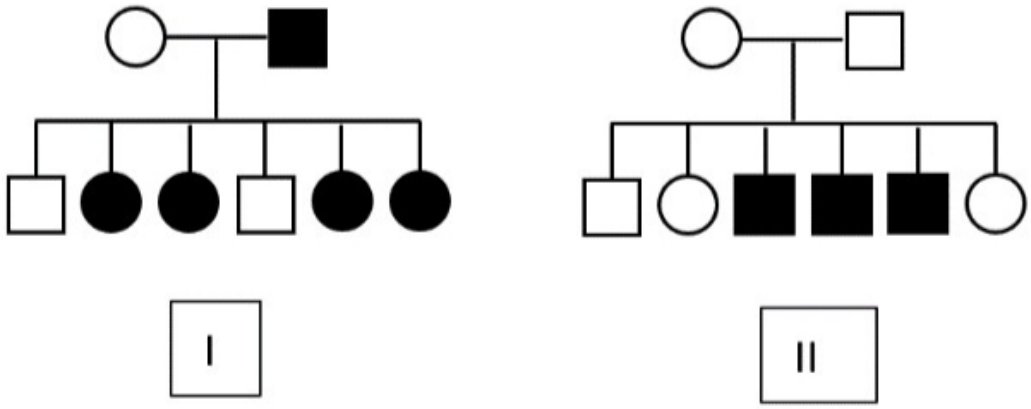
A. From the tissue cells into the blood due to higher partial pressure of carbon dioxide in the tissue cells

B. From the blood into the lungs due to higher partial pressure of carbon dioxide in the lungs

C. From the tissue cells into the blood due to higher partial pressure of carbon dioxide in the blood

D. From the blood into the tissue cells due to higher partial pressure of carbon dioxide in the tissue cells

Q 11 : Consider the following pedigree charts to determine the type of inheritance in (I) and (II)?



A. The traits are X-linked dominant in (I) and X-linked recessive in (II)

B. The traits are X-linked recessive in (I) and X-linked dominant in (II)

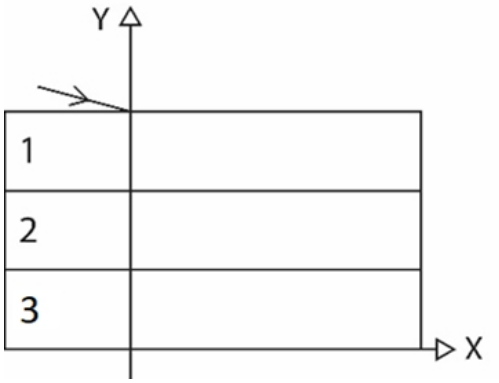
C. Both traits are Y-linked

D. Both traits are X-linked dominant

Q 12 : Which of the following combinations of quantum numbers is not possible for an electron in a ground-state of Ag^{+} ion according to the table below?

	n	l	m_l	m_s
A.	1	0	0	1/2
B.	3	2	-1	-1/2
C.	5	0	0	1/2
D.	4	2	2	-1/2

Q 13 : A narrow beam of light in air hits a block of three layers (layer 1, layer 2 , layer 3) of different transparent materials stacked on top of each other as shown in the figure. The thickness of each layer is $10.0\ cm$. The index of refraction of the respective layers are:
$n_1 = 2.40$, $n_2 = 2.00$, and $n_3 = 1.50$. If the incident angle of the light is 75.0^{o} , find how far laterally from the vertical line marked Y will the beam of light exit on the X-axis.



A. 30.3 cm

B. 23.4 cm

C. 18.3 cm

D. 9.02 cm

Q 14 : Photography has been one of the amazing gifts of science and technology that has added considerable enjoyment to our life. In traditional film photography, chlorine chemistry plays an important role in providing the light-sensitive compound, silver(I) chloride (AgCl). The enthalpy of formation of $AgCl_{(s)}$ is given by the equation below:

$$Ag_{(s)} + \frac{1}{2}Cl_{2(g)} \longrightarrow AgCl_{(s)} \quad \Delta H_F^\circ = -127\ kJ/mol$$

Refer to the following tabulated information to answer the question below:

Process	ΔH°_{rxn} (kJ/mol)
$Ag_{(s)} \rightarrow Ag_{(g)}$	P
$Ag_{(g)} \rightarrow Ag^+_{(g)} + e^-$	Q
$Cl_{2(g)} \rightarrow 2Cl_{(g)}$	R
$Cl_{(g)} + e^- \rightarrow Cl^-_{(g)}$	S
$Ag^+_{(g)} + Cl^-_{(g)} \rightarrow AgCl_{(s)}$	T

Which of the following expressions is equivalent to ΔH^o_{rxn} for the following reaction?

$Cl_{2\,(g)} + 2e^- \rightarrow 2Cl^-_{(g)}$

A. R + S

B. R -S

C. R + 2S

D. $\frac{R}{2}$ - S

Q 15 : One of the petrochemicals produced by the Qatar Fuel Additives Company (QAFAC) is methanol (CH_3OH). Within the petrochemical industry, methanol is used as a raw material for the manufacture of various solvents. It is a clean energy source, as well as a raw material for everyday items we use like adhesives, plastics, LCD screens, furniture, carpeting, methanol fuel cells, and in the pharmaceuticals industry.

The enthalpy of combustion of liquid methanol is ΔH^o = -726.4 kJ/mol. Use the combustion reaction of liquid methanol along with the following information. Calculate the standard enthalpy of formation of methanol (CH_3OH).

$C\,(graphite) + O_2(g) \longrightarrow CO_2(g)$ $\quad \Delta H^o = -393.5$ kJ/mol

$H_2(g) + ½\ O_2(g) \longrightarrow H_2O(l)$ $\quad \Delta H^o = -285.8$ kJ/mol

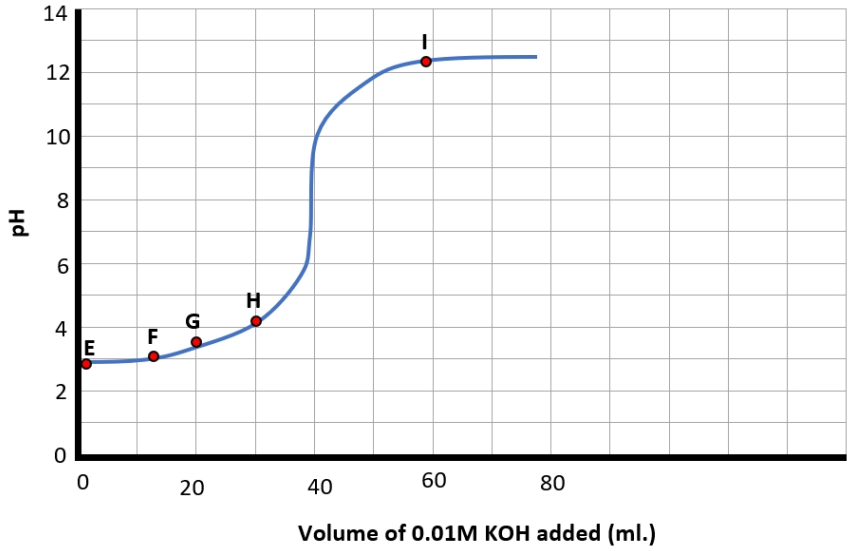
A. -1691.5 kJ/mol

B. -238.7 kJ/mol

C. 296.4 kJ/mol

D. 47.1 kJ/mol

Q 16 : A 60.0 mL sample of a monoprotic acid, HA, of unknown molarity was titrated using 0.01 M KOH solution. The pH of the titration was monitored as a function of the volume of the base as shown below:



Which of the following species will have the highest concentration at point "F" and at which point in the titration curve will the $[A^-]$ be roughly close to twice that of [HA] to correctly fill the following table respectively ?

	At point F	$[A^-]= 2$ [HA]

A. HA , H
B. A^- , G
C. HA , F
D. A^- , E

Q 17 : Arabic coffee, or "Qahwah" is a very important drink in the Gulf region and in the Middle East generally. It refers to a version of brewed coffee beans that contains spices like cardamom and saffron. Qahwah is usually consumed without sugar. Finjan is a small delicate cup (typically of 25 mL volume) that is traditionally used to serve this Arabic coffee.
During celebrations and gatherings, half-filled Finjans of Arabic coffee are served several times to guests. An average Finjan contains about 4.10 mg of caffeine, $C_8H_{10}N_4O_2$.

Arabic Coffee pot and Finjan cup)

How many molecules of caffeine are there in a half-filled Finjan?

A. 3.07×10^{24} molecules

B. 2.52×10^{19} molecules

C. 1.27×10^{19} molecules

D. 6.36×10^{18} molecules

Q 18 : The Museum of Islamic Art is one of the most important cultural achievements of the State of Qatar. One of its many collections is a golden enameled falcon statue related to the Mughal period, India, 17th century. It has a mass of 152 g and is made of gold and copper alloy. Assuming it were to be heated to 96.72 °C and then placed in contact with 13.40 g of water at 20.00 °C in an isolated system, the temperature of the water after thermal equilibrium reached 46.97 °C. What is the percent by mass of copper in the golden enameled falcon assuming no heat was lost?

(specific heat of gold = 0.129 J/g °C, specific heat of copper = 0.389 J/g °C, specific heat of water = 4.184 J/g °C)

http://www.mia.org.qa/en/visitin

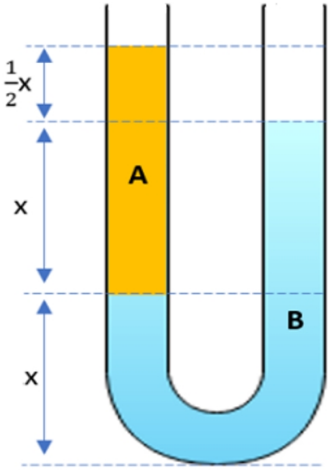
A. 27.3%

B. 35.3%

C. 53.8%

D. 72.7%

Q 19 : In an open U-shaped tube containing two liquids, A and B, in equilibrium (the two liquids do not mix), what is the ratio between the densities of the two liquids ($\frac{\rho_A}{\rho_B}$)?



A. 1/2

B. 2/3

C. 3/4

D. 2/1

Q 20 : What is the maximum concentration of Mg^{2+} ions that remains dissolved in a solution that

contains 0.7147 M NH_3 and 0.2073 M NH_4Cl?
(K_{sp} for $Mg(OH)_2$ is 1.2 10^{-11}; K_b for NH_3 is 1.77 10^{-5}).

A. 1.9 X 10^{-7} M

B. 3.2 X10^{-3} M

C. 1.3 X 10^{-3} M

D. 6.4 X10^{-6} M

Q 21 : Nitrogen cycle is an important process for nutrient recycling and ecosystem functionality. Nitrogen fixing bacteria form an important part of the process as they:

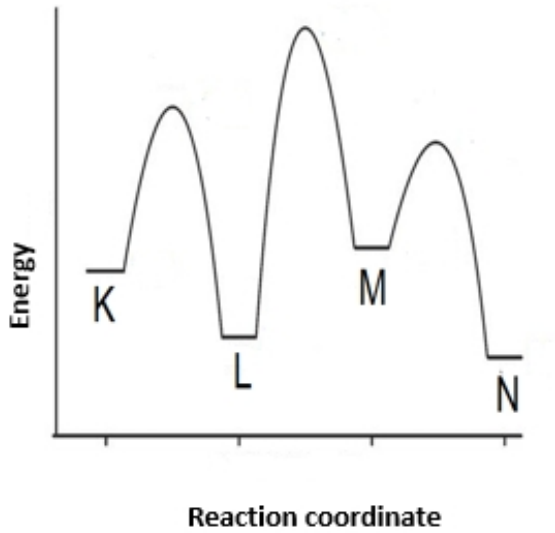
A. Decompose protein to ammonia.

B. Use atmospheric nitrogen to form nitrates.

C. Use atmospheric nitrogen to form ammonia.

D. Change nitrates to N_2 that is then released into the atmosphere.

Q 22 : Based on the energy diagram, which chemical processes shown below are exothermic bearing in mind that the reaction starts from the left to the right?



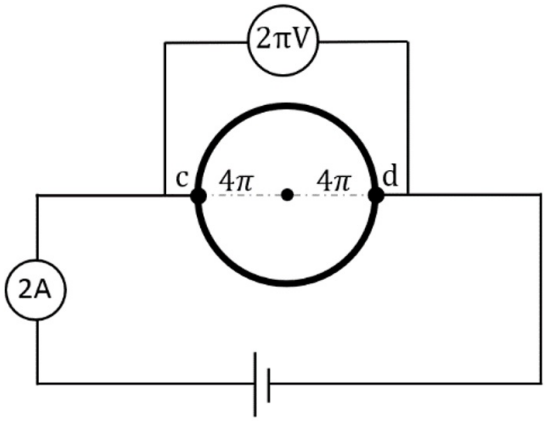
A. K → L; M → N; K → M; L → M

B. L → M; L → N; K → L; K → M

C. K → L; M → N; K → N; L → N

D. K → M; L → M; K → N; M → N

Q 23 : A metallic wire of diameter $\pi\ mm$ was made into a circular loop of radius $4\pi\ cm$ and was connected to an electric circuit. The potential difference between terminals (c, d) and the current passing in the circuit are shown in the figure. What do you expect the conductivity of the wire to be? Consider π to be 3.14 .



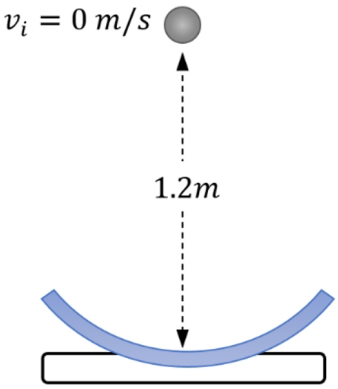
A. $1.01\times10^{3}\ \Omega^{-1}\ m^{-1}$

B. $2.03\times10^{3}\ \Omega^{-1}\ m^{-1}$

C. $4.06\times10^{3}\ \Omega^{-1}\ m^{-1}$

D. $8.11\times10^{3}\ \Omega^{-1}\ m^{-1}$

Q 24 : A concave mirror of focal length $f = 0.50\ m$ is placed on a base as shown in the figure. A ball of mass (M) falls from a height of $1.2\ m$ vertically along the principal axis towards the mirror. If the ball loses 16% of its energy after each collision with the mirror, what is the distance between the ball and its image when the ball reaches its maximum height after the second collision? Assume that the falling ball does not break the mirror.



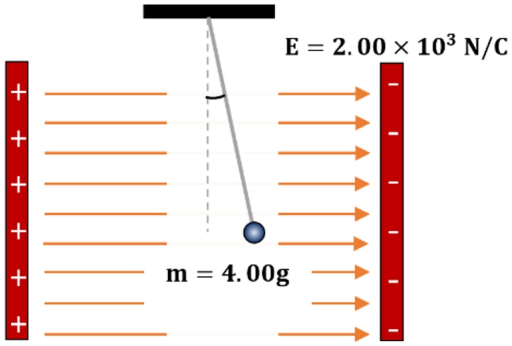
A. $0.37\ m$

B. $0.55\ m$

C. $0.66\ m$

D. $0.75\ m$

Q 25 : A small, $4.00\ g$ plastic ball of electric charge $+3.00\ \mu C$ is suspended by a $20.0\ cm$ long string in a uniform electric field as shown in the figure. If the ball is in equilibrium when the string makes an angle θ with the vertical, what is the linear displacement of the ball between the position at which θ equals zero and the equilibrium position?



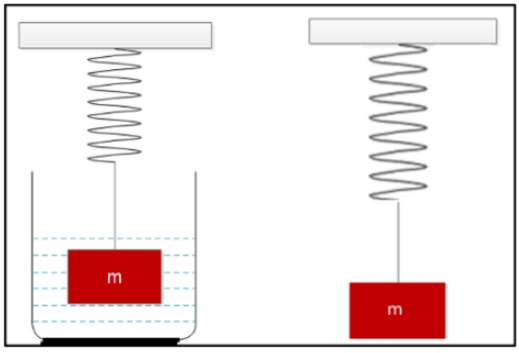
A. 1.80 *cm*

B. 2.02 *cm*

C. 3.03 *cm*

D. 4.20 *cm*

Q 26 : A block of material with a density of 2700 kg/m^3 is attached to a spring with spring constant (k). The block is immersed in water of density 1000 kg/m^3 as shown in the figure. Calculate the ratio of the extension of the spring when the block is in water to that when it is in air.



A. $\frac{5}{9}$

B. $\frac{17}{27}$

C. $\frac{19}{33}$

D. $\frac{233}{457}$

Q 27 : A scientist is growing corn in a greenhouse, aiming to achieve mass production. She is concerned that her greenhouse is getting too hot from too much light. She seeks to shade the greenhouse with coloured translucent plastic sheets. What colour of sheets should she choose in order to reduce overall light energy while still maintaining maximum plant growth?

A. Green

B. Blue

C. Orange

D. Any colour can be chosen

Q 28 : In an experiment to study optimum catalase enzyme activity, a team of students conducted the following experiments:

They added 1 cm^3 of hydrogen peroxide to a test tube, followed by 1 cm^3 of catalase solution. Bubbles of oxygen were produced and caused the content in the test tube to rise up, forming a foam. The students measured the maximum height of the foam. They recorded their data in Table 1, as shown below.

The equation for the reaction is:

$$2H_2O_2 \xrightarrow{\text{Catalase}} 2H_2O + O_2$$

Table-1. Height of foam versus temperature

Temperature °C	Height of foam (cm)			
	Test 1	Test 2	Test 3	Mean
20	3.3	0.2	3.1	2.2
30	5.0	5.2	5.3	5.1
40	3.9	4.3	4.2	4.1
50	2.2	2.1	1.9	2.0
60	0.0	0.0	0.0	0.0

On the basis of data shown in Table 1, the students deduced different conclusions, as below

i. The rate of reaction decreases up to 40 °C

ii. The rate of reaction increases up to 30 °C

iii. The rate of reaction increases up to 40 °C

iv. Catalase is a protein and is observed to be fully denatured at 60 °C

v. If the experiment is repeated, data at 35 °C should be obtained to better investigate the temperature for optimum catalase activity.

Which of the choices given below is (are) considered correct by you?

A. I and IV only.

B. II and V only.

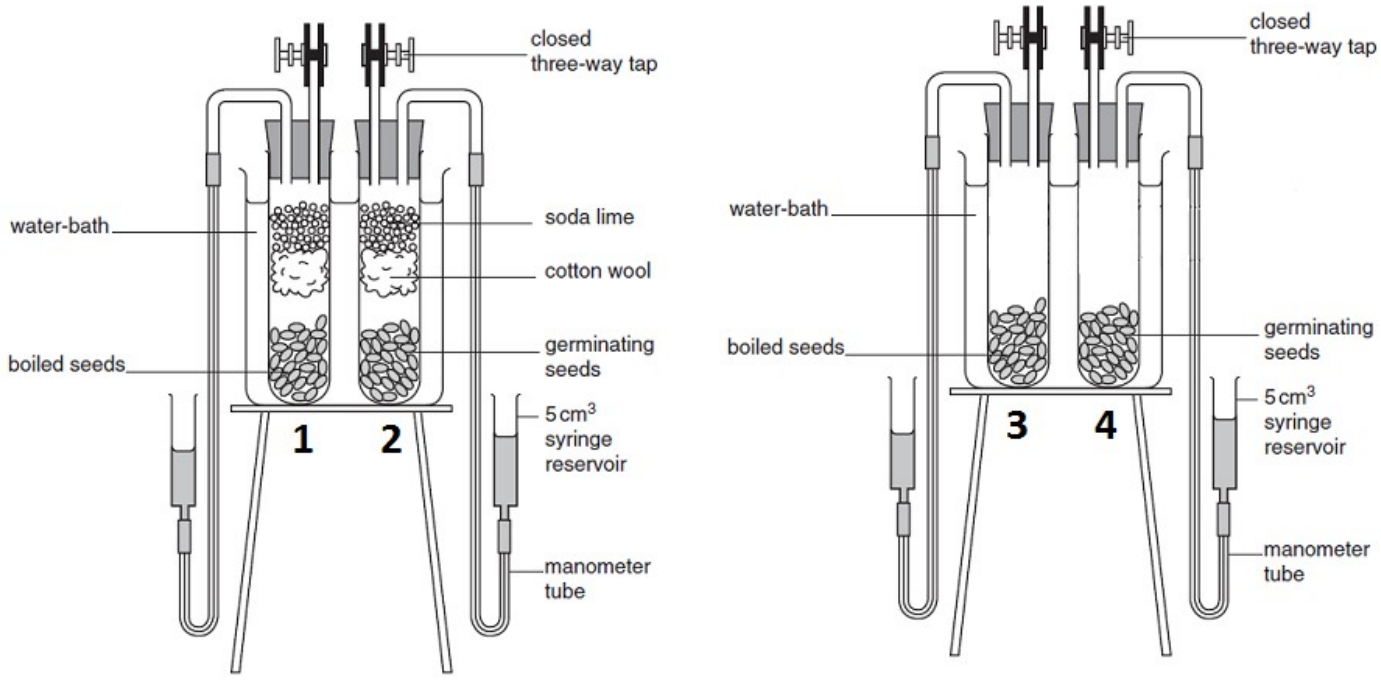
C. II, IV, and V only.

D. III , IV and V only.

Q 29 : The illustration below shows a respirometer, a device used to measure the rate of respiration in a living organism. It detects oxygen uptake by manometry.

Respirometers 1, 2, 3 and 4 are set up at 25 ^{0}C as shown below. The levels of the liquid in the 5cm^3 reservoir are noted after 30 minutes.

Soda-lime is a chemical mixture of calcium oxide and sodium hydroxide.



Using the information provided in the figure, predict what will happen to the level of liquid in the 5 cm^3 syringe reservoir.

A.	1: falls	2: rises	3: falls	4: rises
B.	1: stays the same	2: falls	3: stays the same	4: falls
C.	1: stays the same	2: falls	3: stays the same	4: rises
D.	1: falls	2: rises	3: stays the same	4: falls

Q 30 : During Qatar marathon 2019, an ambulance with a speed of 30.0 m/s and siren frequency of 5.00 x 10^2 Hz passes by an athlete running with a speed of 4.00 m/s as shown in the figure.

What would be the change in the frequency perceived by the runner as the ambulance passes by him. The speed of sound in air is 343 m/s.

A. $-0.76\times10^{2}\ Hz$

B. $0.99\times10^{2}\ Hz$

C. $-0.89\times10^{2}\ Hz$

D. $0.85\times10^{2}\ Hz$