IJSO 2021 Physics MCQ Solution

**Constants**

Acceleration due to gravity g = 9.8 ms^{-2}

Specific heat of water is 4.2 kJ kg^{-1} K^{-1} and the density of water is 1000 kg m^{-3}

Mechanical equivalent of heat = 4.18 Jcal^{-1}

1. A siren goes on at a constant frequency in front of (outside) a merry-go-round. If the merry-go-round is rotating in the clockwise direction with the siren as shown in the figure. Following are some conditions at which maximum frequency, minimum frequency, and the original frequency are observed by a person sitting on the merry-go-round.
   1. Original pitch is heard at 12 O'clock and 6 O'clock positions.
   2. Original pitch is heard at 9 O'clock and 3 O'clock positions.
   3. Higher pitch is heard at 3 O'clock and lower pitch at 9 O'clock positions.
   4. Higher pitch is heard at 9 O'clock and lower pitch at 3 O'clock positions.
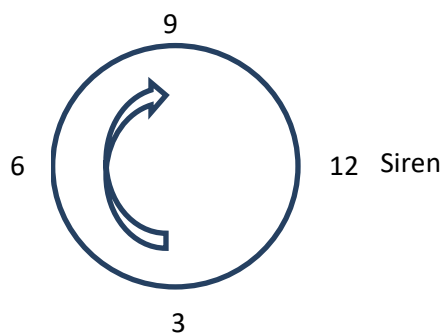
Select the correct statements

a) 1, 4   b) 2, 3   c) 1, 3   d) 2, 4

Answer: (a).

Explanation: At 12 and 6 O' clock positions, the velocity of the observer sitting on the merry-go-round with respect to the siren is zero, so no change in frequency.

At 9 O'clock position the observer is moving towards the source and 3 O'clock the observer is moving away from the source. So the observer gets higher pitch at 9 O'clock position and lower pitch at 3 O'clock position.

2. A light beam is travelling from vertically infinite region 1 to vertically infinite region 4 (refer to figure). The refractive indexes in regions 1, 2, 3, 4 are 1.62, 1.60, 1.55, and 1.50, respectively. The angle of incidence θ for which the beam just misses entering region 4 is

Region 1	Region 2	Region 3	Region 4
1.62	1.60	1.55	1.50

0   0.2 m   0.6 m
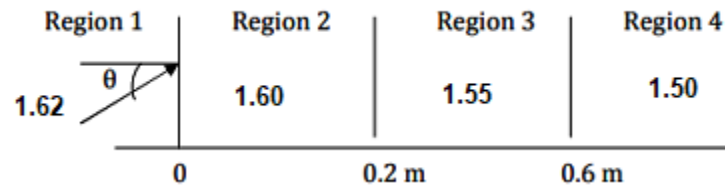
a) $\sin^{-1}\left(\frac{1.50}{1.55}\right)$

b) $\sin^{-1}\left(\frac{1.50}{1.62}\right)$

c) $\sin^{-1}\left(\frac{1.60}{1.62}\right)$

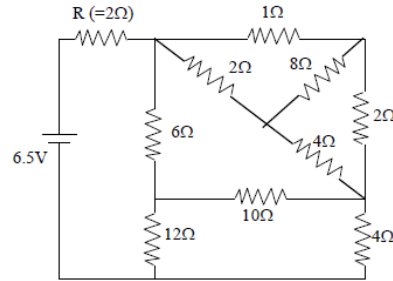d) $\sin^{-1}\left(\frac{1.55}{1.60}\right)$

Ans.: (b)

Critical angle from region 3 to region 4: $\sin\theta_c = \frac{1.50}{1.55}$

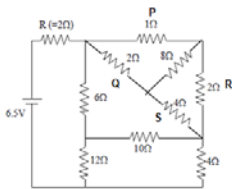Applying Snell's law in consecutive regions: $1.62\sin\theta = 1.60\sin\alpha = 1.55\sin\theta_c$

$1.62\sin\theta = 1.50$ $\theta = \sin^{-1}\frac{1.50}{1.62}$

3. In the following circuit, the current through the resistor R (=2 Ω) is I Amperes. The value of I is
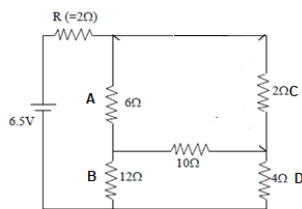

a) 0.5 A
b) 1.0 A
c) 1.8 A
d) 2.0 A

Ans.: b)

P/Q = R/S; So no current will pass through 8 ohms.

Hence P +R will be in parallel with Q+S.

The equivalent resistance of this combination will be 2 ohms.

So now circuit can be rearranged as given below

A/B = C/D; So no current will pass through 10 ohms.

Hence A +B will be in parallel with C+D.

The equivalent resistance of this combination will be 4.5ohms.

So now total resistance of the ciecuit will be 6.5 ohmsn Hence current will be 1 A.

3

4. Heater of an electric kettle is made of a wire of length L and diameter d. It takes 4 minutes to raise the temperature of 0.5 kg of water by 40 K when connected to a line voltage source. This heater is replaced by a new heater having two wires of the same material, each of length L and diameter 2d. Which of the following options is correct regarding the time taken for heating the same amount of water through the same temperature difference?
   a) 4 minutes if wires are in series.
   b) 2 minutes if wires are in parallel.
   c) 1 minute if wires are in series.
   d) 0.5 minute if wires are in parallel.

Ans.: d)

Initial Resistance is $R = \frac{\rho L}{\pi r^2} = \frac{4\rho L}{\pi d^2}$

When wires are changed resistance will be $R' = \frac{\rho L}{\pi (2r)^2} = \frac{\rho L}{\pi d^2} = \frac{R}{4}$

When wires are connected in series the resistance will be 2R' = R/2

When wires are connected in parallel the resistance will be R' /2= R/8

$E = Power \times time = \frac{V^2}{R} t$ $\qquad \frac{E}{V^2} = \frac{4}{R}$

When wires are connected in series the time required will be t = 2 minutes

When wires are connected in parallel the time required will be t = 0.5 minutes

5. Consider a cannon ball of mass 200 kg is projected from cannon placed in front of Burj Khalifa at angle of 60 degree with the horizontal with a velocity 100 km/hr during holy month of Ramadan. The initial kinetic energy at the time of projection of the cannon ball is K. Then, its kinetic energy at maximum height during its projection will be.

   a) K
   b) K/2
   c) K/4
   d) K/3

Ans.: c)

6. A given ray of light suffers minimum deviation in an equilateral prism P. Additional prisms Q and R of identical shape and of the same material as P are now added as shown in the figure. The ray will now suffer
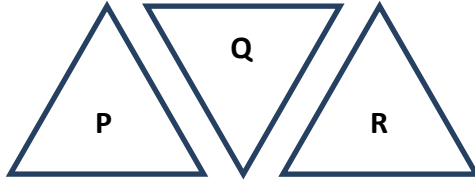
a) Greater deviation.
b) Same deviation as before.
c) Total internal reflection.
d) No deviation.

Ans.: b)
As the incident ray is suffering minimum deviation, angle of incidence is equal to the angle of emergence which should be the angle of incidence for the second prism as the refracting surfaces are parallel.
Hence the ray will suffer minimum deviation in each prism and the final angle of emergence will be equal to the initial angle of incidence.
Thus the ray will suffer same deviation as the case for a single prism.

7. When two mechanical waves meet in a small region of space, superposition of the two waves takes place. This is known as interference of waves. Which of the following statements is false?

a) The resultant displacement of the two waves can be obtained by adding their individual displacements.
b) The waves leaving the region carry less energy than the waves had before interference.
c) The frequency of each wave does not change after interference.
d) After leaving the region, the characteristics of the waves remain same as before interference.

Ans.: b)

8. While doing an experiment in physics laboratory, Mustafa connected two coils (say coil 1 and coil 2) in series with a galvanometer and dropped a magnet through the coils, as shown in the figure. He noticed that there was no deflection in the galvanometer when the magnet passed through coil 2 and observed a large deflection when it passed through coil 1. He noticed that both coils are identical in shape, size and material. Both had same number of turns and the speed with which the magnet passed through each coil was nearly the same. He concluded that
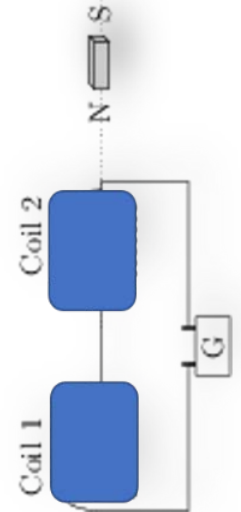
A. The net magnetic flux through coil 2 must be zero.
B. When passing through coil 2, induced emf across coils 1 and 2 must be in the opposite directions.
C. The galvanometer would show deflection for coil 2 if the poles of the bar magnet were reversed.
D. Coil 2 must have different pattern of windings than that of coil 1.

Which of the above statements are correct?

   a) A, B
   b) B, C
   c) B, D
   d) A, D

Ans.: d)

Windings in the coil B has been done in both the directions such that the no of turns in clockwise direction is equal to the no. of turns in the anticlockwise direction.

Thus, the induced emfs produced in coil 2 are in opposite direction because of which galvanometer does not show any deflection.

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9. A typical ping pong ball is dropped from a height of 1 m above a marble floor. The ball bounces several times before it comes to rest. For every successive bounce, it loses 20% of its maximum height. Fatima plotted two quantities that she observed in this phenomenon vs time and the graphs are shown below. Identify the two quantities plotted on vertical axis vs time along the horizontal axis.
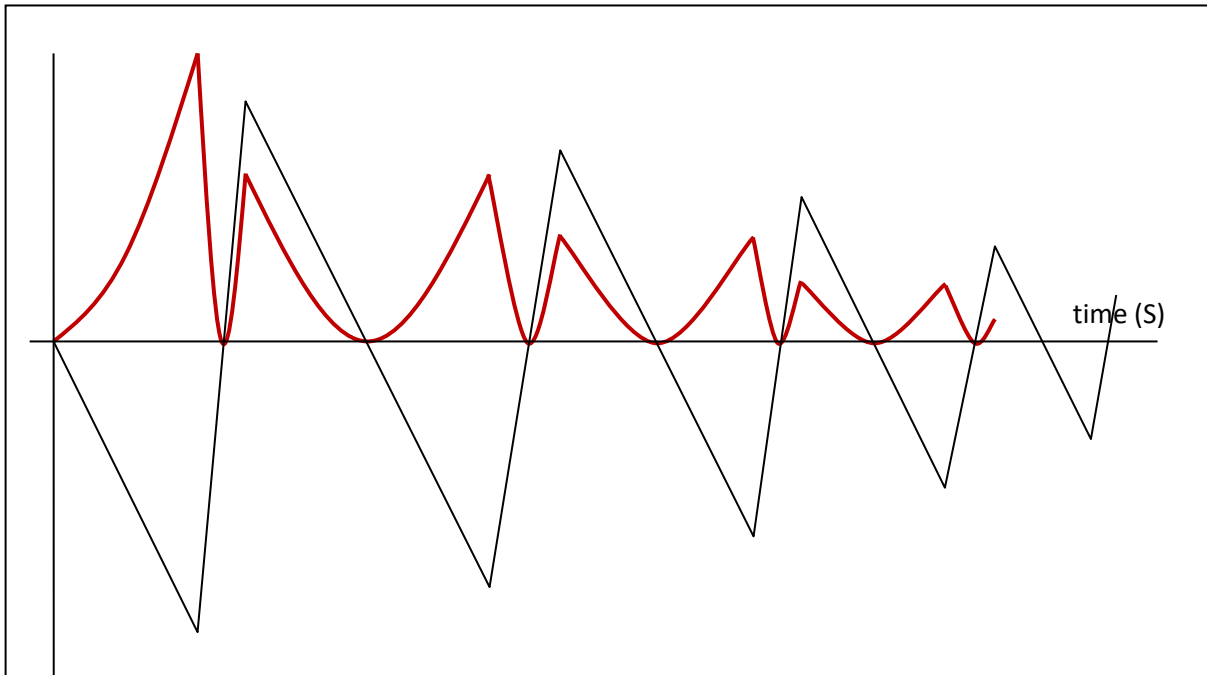
a) Height and velocity,   b) Velocity and kinetic energy   .
c) Potential energy and kinetic energy   d) Velocity and potential energy

Ans.: b)

The velocity keeps on increasing linearly (-gt) with time until the ball hits the ground then it reverses within a short time.

Kinetic energy is always positive and increases quadratic with velocity.

Time taken for each bounce is progressively shorter.

10. Mercury is the fastest planet in the solar system moving with an average orbital speed of 47 km/s. The earth moves slower with an average orbital speed of 30 km/s. What is the radius of mercury's orbit around the Sun in astronomical units (nearly equal to the orbital radius of earth)?

(a) 0.25   (b) 0.40   (c) 0.50   (d) 0.70

Solution (b)

$T \propto R^{3/2}$ and also $T = 2\pi R/v \Rightarrow v \propto (1/R^{1/2}) \Rightarrow v_1/v_2 = (R_2/R_1)^{1/2}$

Question 1

In a titration of acid mixture with base, the teacher prepared an acid mixture by mixing 4mL of 4M HCl, 4mL of 18M H_2SO_4 and a certain volume of 4M HNO_3, and then made up 3 L of solution using distilled water. She used an aqueous solution of Sodium Carbonate ($Na_2CO_3.10H_2O$) as base for the titration, that was prepared by dissolving 2g of ($Na_2CO_3.10H_2O$) in water and diluting to 100 mL with distilled water. After performing the titration, she observed that 15 mL of the acid mixture required 7.5 mL of Sodium Carbonate solution for complete neutralisation. The amount of nitrate ions in the acid mixture is

   a) 0.124 g
   b) 3.1 g   correct answer
   c) 0.31 g
   d) 1.24 g

Solution:
Let the volume of HNO_3 acid be V mL.
Total equiv.of the acid mixture = [(4 x V)+ (4 x 4) + (36 x 4)]/1000
= (4V+ 16+144)/1000 = (4V+160) /1000
equiv.of acid in 15mL of this acid mixt. = [(160+ 4V)/1000] X 15   Eq.1
                      3000
Now Normality of $Na_2CO_3.10H_2O$ solution = (g/L)/ eq.wt.= 20/143
equiv. of 7.5mL of $Na_2CO_3.10H_2O$ solution = (20/143)X 7.5
                                   1000
Thus equiv. of 15mL of acid mixt. = .equiv. of 7.5mL of $Na_2CO_3.10H_2O$ solution.   Eq. 2

 (160+ 4V/1000) X 15 = (20/143) X 7.5
     3000   1000
 V= 12.44mL
equiv. of 4N HNO_3 in acid mixture = (4 X 12.44)/1000= 0.04976
Equivalent of HNO_3 = 50/1000= 0.05
Equivalence of NO_3^{1-} =0.05
Weight of NO_3^{1-} = eq. X xeq.wt. of NO_3^{1-} = 0.05X62= 3.1g

Alternate Solution:
Let the volume of HNO_3 acid be V mL.
Total mmol of acid in mixture = (4X4) + (4X18)+ 4V
                              HCl H_2SO4 HNO_3

mmol of H^+ in acid in mixture= (4X4) + (4X18x2)+ 4V

Therefore Conc. Of H⁺ in acid mixt. = $(16+144+4V)/3000$ mol/L

Reaction : $2H^+ + Na_2CO_3 \rightarrow H_2O + CO_2 + 2Na^+$

2mol of H^+ = 1 mol Na_2CO_3

15mL acid mixt. = $\underline{[(160+ 4V)/1000\,]}$ X 15   mol H^+ Eq.1
                          3000

For Na_2CO_3 mol in 7.5mL = $(2/286)X\,(7.5)/100$ mol Na_2CO_3

As per stiochiometry

$\{[160+4V/1000]/3000\}$ x15 = $2x(20/286)x(7.5/1000)$

  Mol H^+ mol Na_2CO_3

  V= 12.44 mL

equiv. of 4N HNO_3in acid mixture = (4 X 12.44)/1000= 0.04976

Equivalent of HNO_3 = 50/1000= 0.05

Equivalence of NO_3^{1-} =0.05

Weight of NO_3^{1-} = eq. X xeq.wt. of NO_3^{1-} = 0.05X62= 3.1g

Question 2

UAE has vast reserves of limestone particularly in the eastern and northern parts of the Emirates. Jabel Hafeet Mountain is the part of Hajar mountains and made of predominantly tertiary sedimentary rock –Limestone. It is primarily composed of Calcite which is chemically Calcium carbonate. Calcite is used on a large scale as a building material.

A mason was designing a pattern of transparent calcite tiles that were to be fixed in the laboratory. He spread the tiles on the table to arrange different patterns. Accidently two tiles from the pattern came loose and fell in a container having 100g of hydrochloric acid solution. Each pure calcite tile weighs exactly 20g, and hydrochloric acid solution in the container contains one tenth of its weight of pure acid. Assuming that both tiles dissolve equally, what is the weight of each tile that remain undissolved?

a) 26.31 g

b) 13.15 g   correct answer

c) 6.31g

d) 13.69 g

Solution:

Chemical equation is $CaCO_3$ + 2HCl→ $CaCl_2$ + CO_2 + H_2O

                     100g   73g   111g   44g   18g

Wt. of HCl taken = 100g.   Wt. of pure acid in 100g of HCl solution = 100X0.1=10g

From the equation,

73 g of HCl dissolves100g of calcite tile

10 g of HCl dissolves 100/73) X 10= 13.69.g of tile

Amount of each tile undissolved = (40-13.69)/2= 26.31/2g   = 13.15 g

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Question 3

The solid fuel in the booster stage of the space shuttle is a mixture of ammonium perchlorate (NH_4ClO_4) and aluminium powder. On the ignition of this mixturethe products obtained are solid aluminium oxide, gaseous hydrochloride, water, and nitrogen gas. Using following data find out the standard enthalpy change at 298K for the reaction.
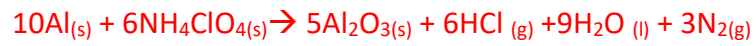
$\Delta_f°H$ of $NH_4ClO_4(s)$ = −295kJ·mol^{-1} $\Delta_f°H$ of $Al_2O_3(s)$ = −1675.7 kJ·mol^{-1}

$\Delta_f°H$ of HCl(g) = −92.3 kJ·mol^{-1} $\Delta_f°H$ of $H_2O(l)$ = −285.8 kJ·mol^{-1}

   a) −9769 kJ

b) –9732.7 kJ   correct answer

c) –8625.1 kJ

d) –8132.1 kJ

Solution:

$10Al_{(s)} + 6NH_4ClO_{4(s)} \rightarrow 5Al_2O_{3(s)} + 6HCl_{(g)} + 9H_2O_{(l)} + 3N_{2(g)}$

$\Delta H = H_P - H_R$

$H_P = 5(-1675.7) + 6(-92.3) + 9(-285.8)$

   $= -8378.5 - 553.8 - 2572.2 = -11504.5$ kJ

$H_R = 6(-295.3) = -1771.8$

$\Delta H = (-11504.8) - (-1771.8) = -9732.7$ kJ

Question 4

When a certain weight of solid potassium permanganate was treated with an excess of hydrogen peroxide at STP, the volume of oxygen formed was 168 L. What is the weight in kg of potassium permanganate used?

a) 3.16 kg
b) 0.158 kg
c) 0.790 kg   correct answer
d) 7.90 kg

Solution:

$2\ KMnO_4 + 3\ H_2O_2 \rightarrow 2MnO_2 + 2\ KOH + 2\ H_2O + 3\ O_2$

Volume at STP = 168 L hence mol of O_2 = 168/22.4   = 7.5mol

2 mol $KMnO_4 \equiv$ 3 mol O_2. Hence mol $KMnO_4$reqd = (2 x 7.5)/3 = 5mol

= 5 x 158 = 790g = 0.790 kg

Question 5

X ray diffraction studies show that an alkaline earth metal has a face centred cubic structure with a unit cell width 0.197 nm. If the density of the metal is 1.55 g·cm^{-3}, the number of atoms present in 40 g of the metal are:

a) 3.37 x 10^{24}
b) 6.74 x 10^{24}
c) 1.35 x 10^{25} correct answer
d) 2.70 x 10^{25}

Solution:
Volume of unit cell =(0.197 x 10^{-9} m)^3= (0.197 x 10^{-7}cm)^3= 7.65 x 10^{-24}cm^3
Volume of 40 g of metal= mass/density=40/1.55=25.81 cm^3
Number of unit cells in this volume=25.81 / 7.65 x 10^{-24} = 3.37 x 10^{24}
Number of atoms in this volume = 4[3.37 x 10^{24}] =1.35 x 10^{25}

Question 6

The graphs in the table below represent conductometric titrations. Choose the appropriate entry/entries from graphs to match each of the entries in titrations. All entries in titrations refer to aqueous solutions. (Hint: Conductance depends on number of ions as well as nature of the ions).

	P	Q	R	S
Graph				
Titrations				
	(i)	(ii)	(iii)	(iv)

Graph and diagram Specifications:

X = Conductance; Y = Volume in the burette solution

(i). Acetic acid vs. Ammonia (in burette),

(ii) Silver nitrate vs. Potassium chloride (in burette)

(iii) Nitric acid vs. Ammonia (in burette)

(iv) Magnesium Sulphate vs. Barium Hydroxide (in burette)

a) (i) → (R), (ii) → (S), (iii) → (Q), (iv) → (P)

b) (i) → (R), (ii) → (S), (iii) → (P), (iv) → (Q)   correct answer

c) (i) → (P), (ii) → (S), (iii) → (R), (iv) → (Q)

d) (i) → (S), (ii) → (Q), (iii) → (R), (iv) → (P)

Solution:

1- Ammonium acetate is a strong electrolyte.

2- Number of ions increases as potassium chloride is added.

3- Ammonium ion conducts less than proton.

4- $Mg(OH)_2$ and $BaSO_4$ precipitate out.

Question 7

When a l g piece of metal (Atomic Weight 89) was dropped into dilute sulphuric acid, a large amount of gas was evolved. All the gas was collected and dried to remove moisture and was found to occupy a volume of $378cm^3$ at STP. The resulting solution was electrolysed between platinum electrodes using a current of 1A for a period of 15 minutes. The following statements can be made about the above entire process:

(A) The metal sulphate is MSO_4

(B) Oxygen is liberated at anode.

(C) The gas collected is hydrogen.

(D) Persulfate is produced at the anode.

(E) The metal sulphate is $M_2(SO_4)_3$

(F) The percentage of metal recovered by electrolysis is about 26-27%.

Choose the right options:

a) only options A, C, D are correct.

b) only options B, C, E, F are correct.   Correct answer

c) only options C, D, E are correct.

d) only options A, B, C, F are correct.

Solution

22400 cm^3 of hydrogen = 2 equivalents of hydrogen.

378 cm^3 of hydrogen = 0.03375 equivalents of hydrogen.

Metal produced=0.03375 equivalents = 1 g.

Equivalent mass of the metal -=1/0.03375=29.63

Valency of metal= atomic mass/equivalent mass=89/29.63 = 3. The metal sulphate is $M_2(SO_4)_3$

Charge passing through = 1 x 15 x 60 = 900 C

     96500 Coulombs →1 equiv of M gets liberated.

       Hence 900C   →   only 0.0093 equivalents of metal gets liberated.

        Therefore   % recovery (0.0093/0.03375)x100= 26.6%

Question 8

Ion exchange Resins are used to soften water. They contain sodium ions which get exchanged with 'hard' ions like Ca^{2+} and Mg^{2+}. Resins are not 100% efficient *i.e.* all sodium ions present in the resin do not get exchanged at once and may need repeated passage of a solution through the column to attain full efficiency.

Molecular formula of a commercial ion –exchange resin is $C_7H_6SO_3Na$. A 100 cm^3 solution containing 0.3 mol L^{-1} of Mg^{2+} is passed through a column of ion exchange resin weighing 20g only once. What are the molarities of Mg^{2+} andNa^+, respectively, in the solution obtained after passing through the column, if the exchange efficiency is only 25 %.

a)   0.13 M and 0.26 M

b) 0.26 M and 0.17 M

c) 0.17M and 0.26 M   correct answer

d) 0.21 M and 0.14 M

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Solution:

Molar mass of the resin =193

2 molecules of the resin take up one Mg^{2+} ion.

386g of resin takes up 1mol of Mg^{2+} ions.

1g of the resin can take 2.59×10^{-3} mol of Mg^{2+}

20g of the resin can take 51.8×10^{-3} mol of Mg^{2+} or 51.8 mmol

Exchange efficiency is only 25% →0.25 x 51.8 mmol of Mg^{2+} is exchanged = 12.95 m mol of Mg^{2+} is exchanged.

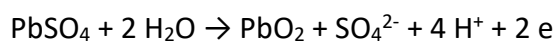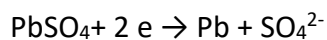Initial amount of Mg^{2+} is 100 X 0.3 = 30 mmol

Amount exchanged = 12.95 mmol.

Amount left = 30-12.95= 17.05 mmol

Molarity= 17.05 / 100= 0.17 M

Na^+ molarity is twice the molarity of Mg^{2+} exchanged = 25.9/100= 0.259 M

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Question 9

The electrode reactions involved in the charging process of a lead storage battery are:

$PbSO_4$ + 2 e → Pb + SO_4^{2-}

$PbSO_4$ + 2 H_2O → PbO_2 + SO_4^{2-} + 4 H^+ + 2 e

In a certain lead storage battery containing 2 L of aqueous sulphuric acid, the specific gravity of the electrolyte was found to be 1.14 (20% H_2SO_4 by weight). This was charged using average current of 1.67 A till the specific gravity rose to 1.28 (36.9% H_2SO_4 by weight). What was the duration of the charging process?

a) 80 hours   correct answer

b) 100 hours

c) 160 hours

d) 188 hours

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Solution:

Overall rxn is   2 $PbSO_4$ + 2 H_2O →Pb + PbO_2 + 2 H_2SO_4
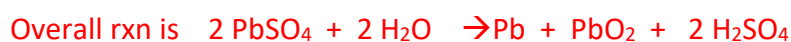
Hence in this rxn., .eq. wt of H_2SO_4 = mol wt = 98 (2 moles electrons for 2 mol H_2SO_4)

Before charging: (100/1.14) mL H_2SO_4 soln contains (20/98) eq of H_2SO_4

2000 mL soln = (20/98) x 2000 /(100/1.14) = 4.65 eq

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After charging: 2000 mL =   (36.9/98) x 2000 x (1.28/100) =   9.64 eq

No of eq H_2SO_4 added = no of Faradays of charge used = 4.99 F
                              = 4.99 x 96500 coulombs
Av current =   Charge in coulombs / time in sec

Time required for charging = 4.99 x 96500 / 1.67   =   288344 sec = 80 hours

Question 10

Arrange the molecules H_2O, H_2S, BF_3 and NH_3 in order of their increasing dipole moment.

a) $BF_3 > NH_3 > H_2S > H_2O$
b) $BF_3 < H_2S < H_2O < NH_3$
c) H2S > NH3 > BF3 > H2O
d) $BF_3 < H_2S < NH_3 < H_2O$ correct answer

Molecule	Dipole Moment (D)
BF_3	0
H_2S	0.95
NH_3	1.47
H_2O	1.85

Solution:

BF_3 is symmetric,zero dipole

NH_3 is pyramidal, N-H bond moment is larger than S-H bond moment

O-H bond moment larger than S-H bond moment

O is more electronegative than S

IJSO 2021 Biology MCQ Solution

1. _____

An ecologist found a small water body on an isolated island and observed the various organisms present in it. He classified the organisms based on different trophic levels as shown in the table:

Trophic level	Name of Trophic level	Organisms found	Description
Trophic level 1	Producers	Phytoplankton	Phytoplankton are autotrophs which produce their own organic nutrients
Trophic level 2	Primary consumers	Zooplankton	Zooplankton are herbivores. They feed on the phytoplankton for their energy source.
Trophic level 3	Secondary consumers	Small Planktivorous fish	These small fish are the primary carnivores. They feed on the zooplankton and derive their energy from it.

For studying the interactions between the organisms, the ecologist introduced a population of a carnivorous fish (which feed only on other small fish) in the waterbody.

Which one of the following statements is the correct statement regarding the long term consequence of this introduction?

a. There will be an increase in the biomass of autotrophs.
b. There will be a decrease in the biomass of both autotrophs and herbivores.
c. There will be an increase in the biomass of herbivores.
d. There will be a decrease in the biomass of herbivores and increase in the biomass of autotrophs.

Ans. c. [Explanation: Food webs are defined by their biomass. Biomass is the energy in living organisms. Autotrophs, the producers in a food web, convert the sun's energy into biomass. Biomass decreases with each higher trophic level. Because biomass decreases with each trophic level, there are always more autotrophs than herbivores in a healthy food web. There are more herbivores than carnivores. As a population of carnivorous fish is introduced in the waterbody, the carnivorous fish will start feeding on the small fish (secondary consumers). This will lead to a decline in the population of the secondary consumers. As the population of secondary consumers declines, it will result in the population growth of the herbivores because now there will be fewer small fish to feed on them. With the increase of the herbivore population, the population of the autotrophs will decline because a greater number of herbivores will be available to feed on them. Thus, the longtime consequence of the introduction of tertiary consumer will lead to an increase in the Herbivore biomass and a decrease in the Autotroph biomass.]

2.

Paramecium lives in pond water that is hypotonic to its cellular contents. However, the Paramecium does not burst due to excess water uptake because of its contractile vacuole. The vacuole collects fluids from a system of canals present in the cytoplasm. When full, the vacuole and canals contract, expelling the fluid from the Paramecium.

In an experiment, the activity of contractile vacuole was monitored over time after placing the Paramecium in a growth medium having an osmotic concentration (osmolarity) of 4 mosmol L^{-1} for 30 minutes and then shifted to a growth medium having an osmolarity of 24 mosmol L^{-1}. Which one of the following graphs is a correct representation of the activity of contractile vacuole in these two media?
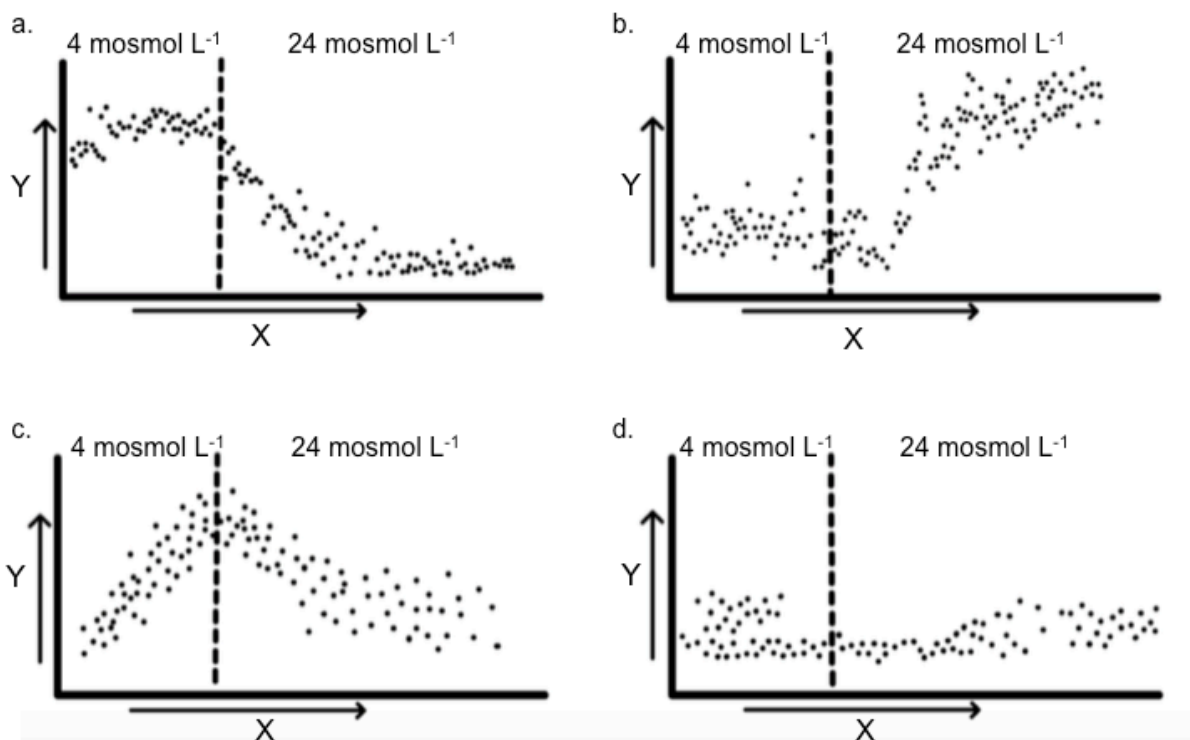
X = Time (min); Y = Activity

Ans.: a [Tests the understanding of osmolarity and interpretation of graphs. **Osmotic concentration** or **osmolarity** is the measure of solute concentration, defined as the number of osmoles (Osm) of solute per litre (L) of solution (osmol/L or Osm/L).

Water will move from the side with lower osmolarity to side with high osmolarity. The higher activity of the contractile vacuole indicates that the medium has lesser osmolarity than that of the cell. Thus a shift of paramecium from low to high osmolar solution would lead to decrease in the activity of the contractile vacuole.]

3.
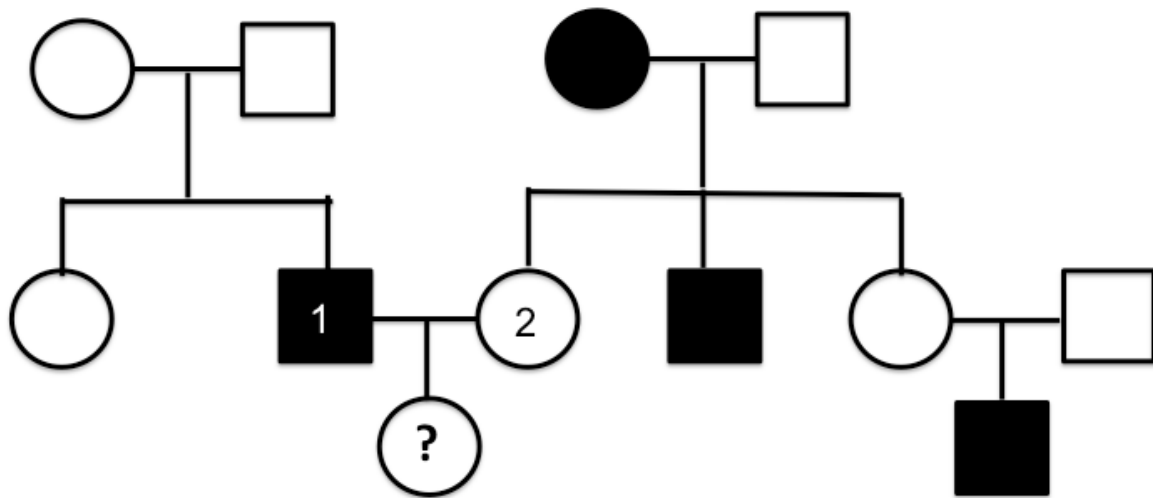
Female   Affected female   Male   Affected male

The pedigree above represents the inheritance of a genetic disorder. If the individuals marked 1 and 2 had a daughter, what is the probability that the daughter would show the disorder?

a. 1
b. 1/2
c. 2/3
d. 1/4

Ans.: b [The student has to first identify the mode of inheritance, which is X-linked recessive. Individual 1 has the genotype X^aY. Individual 2 is also a carrier X^aX. The daughter will get one X from the father that has the recessive allele and there is 50% chance of receiving the recessive allele from the mother.]

4.
_____

Given below are schematic representations of chromosomes at Metaphase I of meiosis. Which one of the following arrangement of chromosomes at the equatorial plane will definitely ensure independent assortment of the genes 'A' and 'B' under normal meiotic division?

The figures below depict the arrangement of alleles on the chromosomes and the alignment of chromosomes at the equatorial plane.
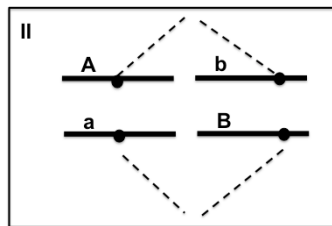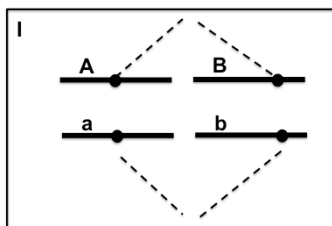
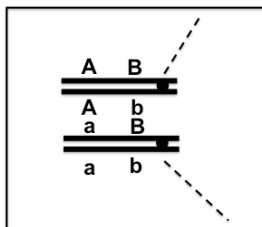a. hen chromosomes are arranged as shown and there is crossing over between genes *A* and *B*.
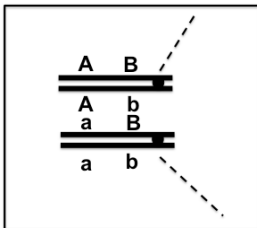
b. hen 50% of the cells in meiosis have orientation I and 50% have orientation II.
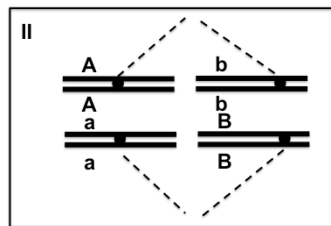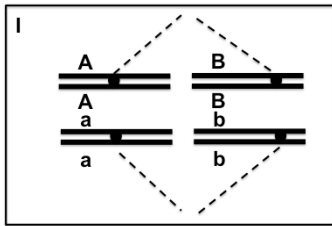
c. hen 50% of the cells in meiosis have orientation I and 50% have orientation II.

d. hen there is no crossing over between genes *A* and *B*.

Answer: b [If two genes are on different chromosomes they will always independently assort and that is because of the two possible orientations. Option 1 is incorrect, as although this will produce 4 kinds of gametes, all cells in meiosis will not undergo crossing over. Answer 3 is incorrect, as in metaphase I as there will be 2 chromatids per chromosomes. Answer 4 is incorrect, as sister chromatids should have the same alleles.]

5.
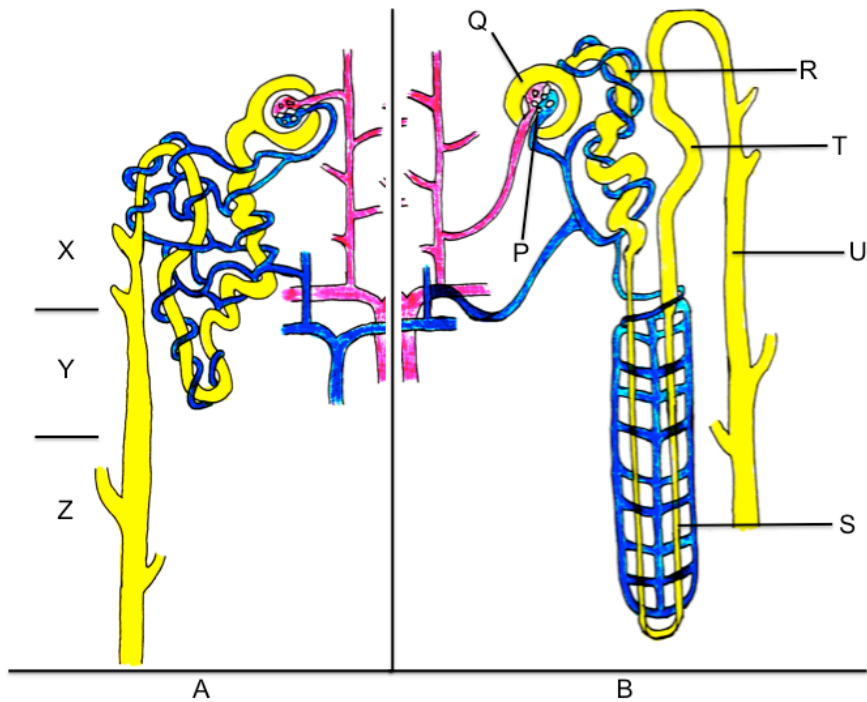
A- Type A nephron; B- Type B nephron; P- Glomerulus; Q- Bowman's capsule; R-Proximal convoluted tubule; S- Loop of Henle; T- Distal convoluted tubule; U- Collecting duct; X- Cortex; Y- Outer medulla; Z- Inner medulla

The figure above represents two types of nephrons (labeled as A and B) observed in mammals. Which one of the following statements regarding the nephrons is correct?

a. In comparison to type A nephron, the urine produced by type B nephron is likely to be more concentrated.
b. Type B nephron is likely to absorb more potassium ions as compared to type A nephrons.
c. In comparison to type B nephron, in type A nephron, reabsorption of NaCl leads to subsequent osmosis of water from loop of Henle into the blood.
d. In comparison to type B nephron, type A nephron is likely to remove poisonous substances from the blood more efficiently.

Ans. a Explanation: The main difference in the two types of nephron is the long Loop of Henle in type B and its deeper extension into the renal medulla. The longer the loop an the deeper its extends into the renal medulla, the greater the concentrating power of the nephron. The loops of Henle are the longest and the urine is most hypertonic in desert dwellers such as the kangaroo rat.
Statement b is incorrect as K^+ ions are absorbed in the distal convulated tubule
Statement c is incorrect as type B nephron will absorb more sodium chloride
Statement d is incorrect as secretion of poisionous substances from bloof occurs in proximal convulated tubule.

A small population of monkeys from Africa (Old World) are thought to have drifted to South America (New World) on natural rafts about 40 million years ago. There were no monkeys in the New World. On reaching South America, these monkeys bred and over time looked very different from the monkeys in Africa. They formed new species.
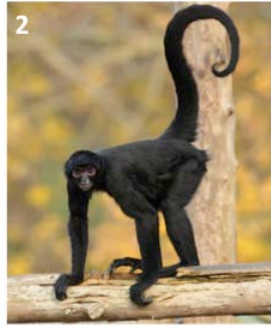

1 – Old world monkeys
2- New world monkeys

Arrange the evolutionary processes that would lead to the formation of the new species.

a. Migration→ Adaptation → Natural selection

b. Genetic drift → Natural selection → Adaptation

c. Natural selection → Adaptation → Genetic drift

d. Adaptation → Genetic drift → Natural selection

Ans. b [Migration refers to gene flow from one population to another. The founding population of monkeys showed genetic drift and not migration, since no gene flow could occur because of the absence of monkey populations in S. America. Hence 1 is wrong. 2 is correct because the founding population formed by genetic drift, was acted upon by natural selection over generations, which led to their adaptation to the new habitat. Natural selection or adaptation will occur only after migration or genetic drift brings about an alteration in allelic / gene frequencies, hence 3 and 4 are wrong. Ref: https://www.britannica.com/science/evolution-scientific-theory/Genetic-drift]

7.

In 1881, a scientist named Engelmann mounted a filamentous green alga, Spirogyra, on a slide and placed some motile bacteria in a nutrient medium around the algal filament. He illuminated the algal filament with a light spectrum (400-700nm) obtained using a prism and viewed the slide under a microscope.
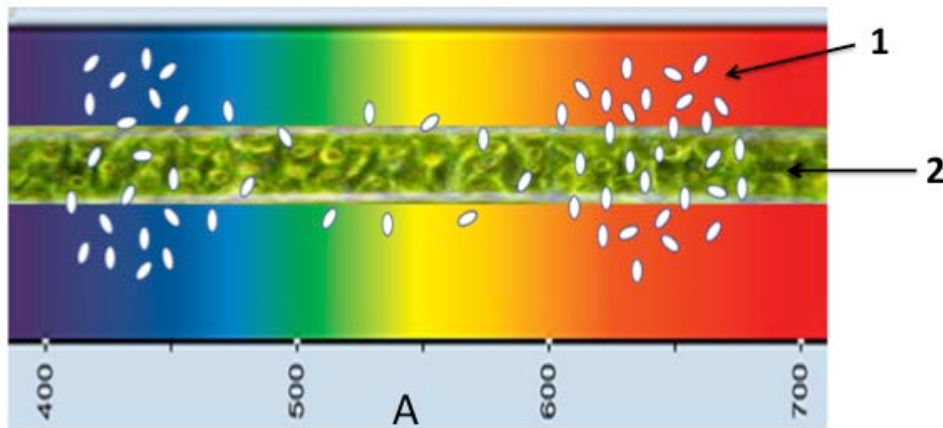
1 – Bacteria   2- Algal filament   A- Wavelength (nm)

Based on the above, which one of the following statements is correct?

a. The experiment was carried out to study respiration in algae.
b. The bacteria used in this experiment are aerobic in nature.
c. The bacteria are naturally attracted to red and blue light and not dependent on the algal filament.
d. The distrubtion of bacteria is dependent on the specific structures present in the algal filament.

Ans. b [This experiment demonstrated the photosynthetic evolution of oxygen. The student should first identify the non-random ditribution of the bacteria. This can then be correlated to the physiological activity. Looking at the spectrum they have to arrive at the conclusion that it is photosynthesis and this could involve oxygen liberation and thus the bacteria are aerobic]

8. _____

Filamentous cyanobacteria have special thick-walled structures called heterocysts that help in nitrogen fixation. Nitrogen from the atmosphere is fixed by the enzyme nitrogenase present in the heterocysts and converted to ammonia, using ATP as a source of energy. Nitrogenase is very sensitive to inactivation by oxygen. Which of the following modifications will allow heterocysts to effectively carry out nitrogen fixation?

a. High chlorophyll content
b. Lack of photosystem II activity
c. Enhanced CO_2 fixation
d. Low respiratory rate

Ans: b [Photosystem ll is the site of oxygen evolution. Switching it off will reduce oxygen levels and enable nitrogen fixation by nitrogenase. Chlorophyll content and CO_2 fixation is reduced and respiratory rate is high in heterocysts, so a, c and d are wrong]. Ref: Cyanobacterial Heterocysts. Krithika Kumar et al. Cold Spring Harb Perspect Biol 2009;2:a000315)

A phylogenetic tree is a diagram that depicts the lines of evolutionary descent of different species, from a common ancestor. In the phylogenetic trees shown below, the evolutionary descent of three organisms –Humans (1), Whale (2) and Sharks (3) has been depicted. Which of the following phylogenetic trees correctly represents the relatedness between these three organisms?
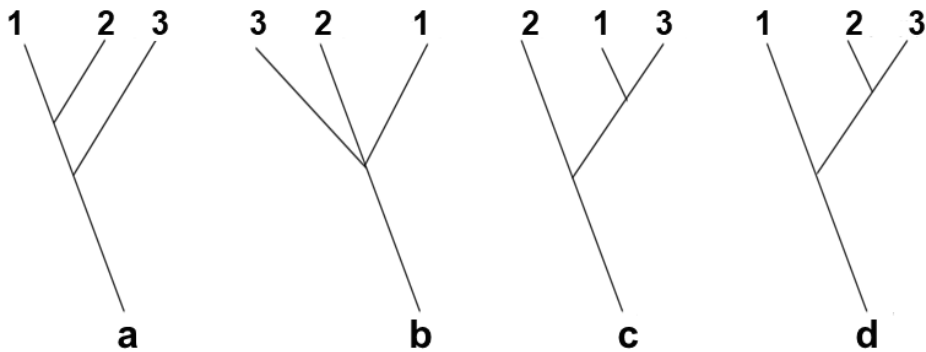
Ans. a [c and d are wrong because the shark is very different from whales or humans, since it is a fish while the latter two are mammals. b is wrong because it shows that all three - sharks, humans and whales have diversified from a common ancestor. a is correct because it shows that whales and humans share a more recent common ancestry than they do with sharks.]
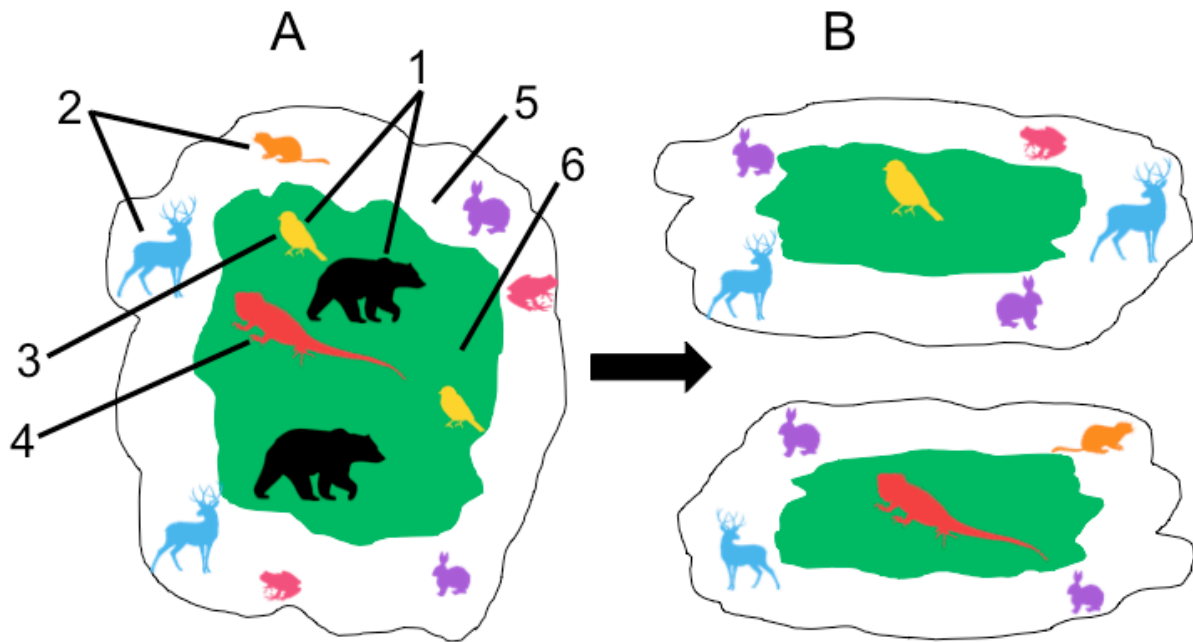
1- Interior species; 2- Edge species; 3- Sp-Y (bird); 4- Sp-X (reptile) 5- boundary zone; 6- deep forest.

The figure depicts a forest area depicitng fauna living in deep forest or the boundary zone. The different species may reside in specific niches. An ecological niche is defined as the sum of its use of the biotic and abiotic resources in its environment.

Compare A and B and analyse the inferences given below:

i. A and B are examples of ecological succession.
ii. A and B are examples of habitat fragmentation.
iii. In B, interior habitat has shrunk while number of edge species increased.
iv. In B, there is an increase in both inner habitat and interior species.
v. In A and B, sp-X and sp-Y occupy different niches.

Choose the option with correct combination of inferences cited above:

a. i and iii only
b. ii and iv only
c. ii, iii and v
d. i, iv and v

Ans: c