

# Biology

## 1. Question 1

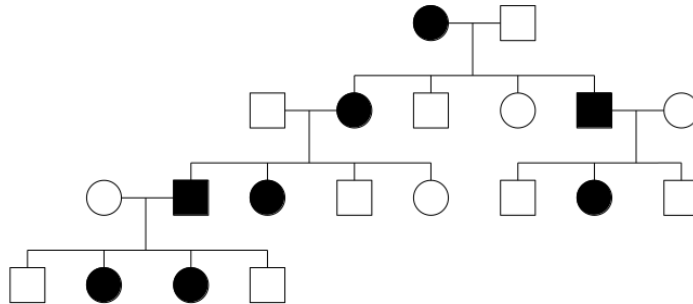
What will be the sequence of RNA synthesized using the following DNA template strand?

5'-GTCTAGGCTTCTC-3'

- (a) 5'-GAGAAGCCUAGAC-3'
- (b) 5'-GUCUAGGCUUCUC-3'
- (c) 5'-CAGAUCCGAAGAG-3'
- (d) 5'-CUCUUCGGAUCUG-3'

2. Question 2

The following pedigree diagram shows the inheritance of a rare genetic disorder (filled shapes depict affected individuals).



Which of the following is the most likely pattern of inheritance of the disorder?

- (a) X-linked dominant
- (b) X-linked recessive
- (c) Autosomal recessive
- (d) Autosomal dominant

3. Question 3

Match the list of conditions (Column I) with the list of affected physiological processes (Column II).

<u>Column I</u>			<u>Column II</u>
P	Allergy	i	Excess secretion of growth hormone
Q	Uremia	ii	Exaggerated immune response to environmental substances
R	Myasthenia gravis	iii	Autoimmune disorder affecting the neuromuscular junction
S	Acromegaly	iv	Malfunctioning of kidneys which can lead to urea accumulation in the blood

Which of the following combinations is correct?

- (a) P - (ii); Q - (iv); R - (iii); S - (i)
- (b) P - (iii); Q - (iv); R - (i); S - (ii)
- (c) P - (iv); Q - (iii); R - (i); S - (ii)
- (d) P - (ii); Q - (i); R - (iv); S - (iii)

4. Question 4

Which of the following proteins plays a direct role in muscle contraction?

- (a) Troponin
- (b) Insulin
- (c) Myoglobin
- (d) Trypsin



5. Question 5

Which of the following is NOT derived from the epidermal cell layer in plants?

- (a) Casparian strip from rice root
- (b) Trichomes from maize leaf
- (c) Subsidiary cells from rice leaf
- (d) Bulliform cells from grass

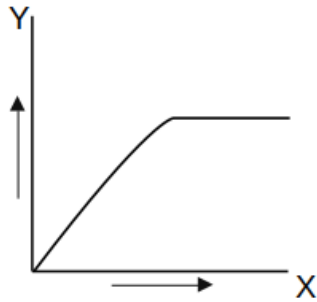
6. Question 6

Which of the following statements about meiosis in sexually reproducing plants is INCORRECT?

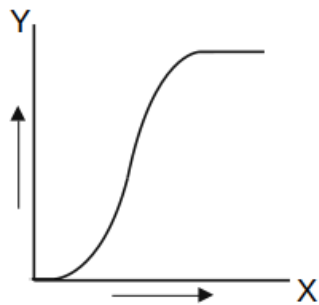
- (a) The end products of meiosis II are haploid gametes.
- (b) The four products of meiosis are genetically different.
- (c) Meiotic recombination takes place in both males and females.
- (d) In most flowering plants, only one of the four products of meiosis survives in females.

7. Question 7

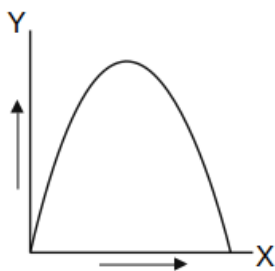
Which of the following graphs represents the correct relationship between light intensity (X-axis) and the rate of photosynthesis (Y-axis)?



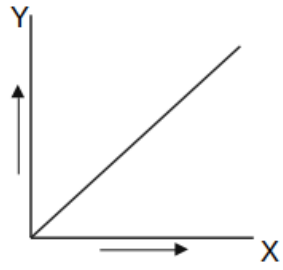
(a)



(b)



(c)



(d)

8. Question 8

Match the enzymes in Column I with the cellular compartments in Column II.

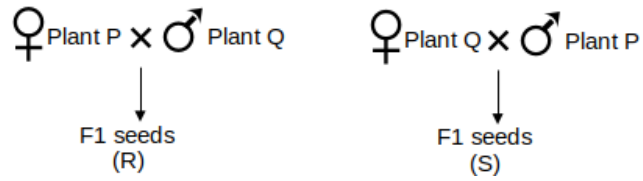
<u>Column I</u>		<u>Column II</u>	
P	Succinate dehydrogenase	i	Cytoplasm
Q	Pyruvate dehydrogenase	ii	Inner mitochondrial membrane
R	Lactate dehydrogenase	iii	Mitochondrial matrix
S	ATP synthase	iv	Thylakoid membrane
		v	Inner chloroplast membrane

Which of the following combinations is correct?

- (a) P - (ii); Q - (iii); R - (i); S - (iv)
- (b) P - (iv); Q - (i); R - (iii); S - (ii)
- (c) P - (iii); Q - (ii); R - (i); S - (v)
- (d) P - (iii); Q - (i); R - (iv); S - (ii)

9. Question 9

Two species of a flowering plant, P ( $2n = 20$  chromosomes) and Q ( $2n = 30$  chromosomes) are reciprocally crossed with each other as male or female as shown below to produce F1 seeds.



Which of the following seed tissues from both the F1 seeds (R and S) will have the same chromosome numbers?

- (a) Embryo
- (b) Endosperm
- (c) Embryo and seed coat
- (d) Embryo and endosperm

10. Question 10

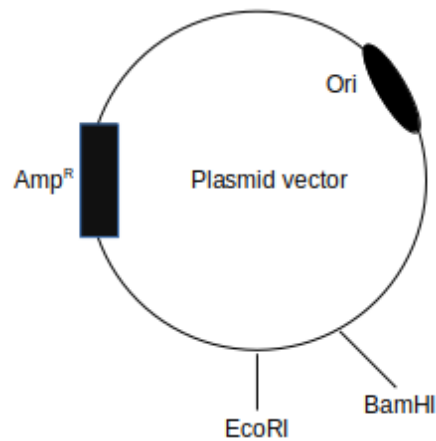
Which of the following is routinely performed to detect typhoid?

- (a) Widal test
- (b) ELISA
- (c) Gel electrophoresis
- (d) RT-PCR

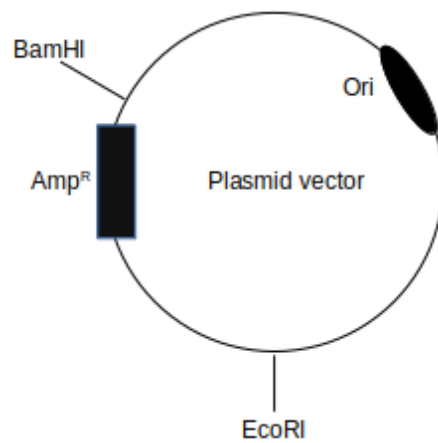
11. Question 11

Which of the following plasmid vectors can be used for cloning of a gene, with restriction enzymes BamHI and EcoRI, and ampicillin-containing nutrient agar for selection?

[Ori and Amp<sup>R</sup> represent origin of replication and gene for ampicillin resistance, respectively.]

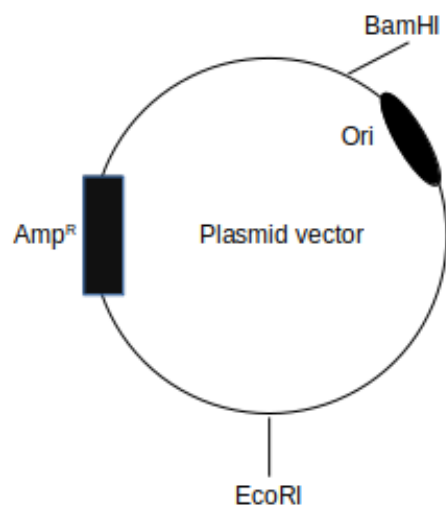


(a)

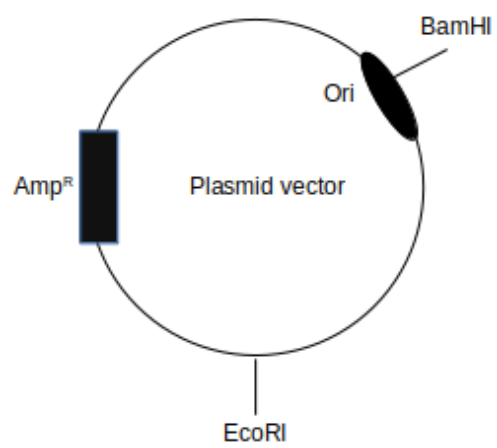


(b)





(c)



(d)

12. Question 12

Polymerase chain reaction (PCR) is used to amplify a gene of interest (GOI). If, after 30 cycles of PCR, 1 billion copies of GOI are produced, approximately how many copies of GOI were present at the end of the 20<sup>th</sup> cycle?

- (a) 1 million
- (b) 0.66 billion
- (c) 10 million
- (d) 0.1 billion

13. Question 13

A population with  $N = 400$  individuals increases in numbers till it reaches an asymptote at  $K = 500$  individuals,  $K$  being the carrying capacity. Assuming the intrinsic rate of natural increase ( $r$ ) to be 0.01, what would be the population growth rate ( $dN/dt$ )?

- (a) 0.8
- (b) 0.05
- (c) 1
- (d) 0.4

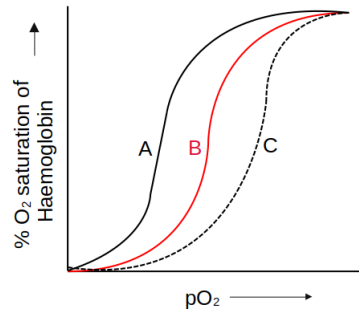
14. Question 14

Which one of the following statements is correct?

- (a) Hemichordata is not considered as a chordate sub-phylum, and possesses a proto-notochord called stomochord.
- (b) Hemichordata is a sub-phylum under Chordata and possesses a proto-notochord called stomochord.
- (c) Hemichordata is a sub-phylum under Chordata and possesses a proper notochord and gill slits like chordates.
- (d) Hemichordata is not considered as a chordate sub-phylum because it possesses a water vascular system.

15. Question 15

Which of the following statements is correct about the oxygen ( $O_2$ ) dissociation curves (**A** and **C**) relative to curve **B**?



- Curve **A** represents favourable  $O_2$  association with haemoglobin at low  $[H^+]$ .
- (a)
- Curve **C** represents favourable  $O_2$  association with haemoglobin at low  $pCO_2$ .
- (b)
- Curve **A** represents favourable  $O_2$  association with haemoglobin at low pH.
- (c)
- Curve **C** represents favourable  $O_2$  association with haemoglobin at high  $pO_2$ .
- (d)

# Chemistry

## 1. Question 1

If an element with  $Z = 120$  is discovered, then which group of elements will it belong to?

- (a) Alkaline earth metals
- (b) Alkali metals
- (c) Halogens
- (d) Noble gases

2. Question 2

Which one of the following statements is correct about  $\text{N}_2$ ,  $\text{CO}$ , and  $\text{NO}^+$ ?

- (a) These are isoelectronic and have identical bond order.
- (b) These are isoelectronic and have different bond orders.
- (c) These are not isoelectronic but have identical bond order.
- (d) These are neither isoelectronic nor have identical bond order.

3. Question 3

Which of the following complexes exhibit(s) magnetic moment close to 2 Bohr Magneton?

$[\text{Fe}(\text{H}_2\text{O})_6](\text{NO}_3)_2$ ,  $\text{K}_2[\text{MnCl}_4]$ ,  $\text{K}_4[\text{Mn}(\text{CN})_6]$ , and  $[\text{Ni}(\text{CO})_4]$

- (a) Only  $\text{K}_4[\text{Mn}(\text{CN})_6]$
- (b)  $\text{K}_2[\text{MnCl}_4]$  and  $\text{K}_4[\text{Mn}(\text{CN})_6]$
- (c)  $[\text{Fe}(\text{H}_2\text{O})_6](\text{NO}_3)_2$  and  $\text{K}_2[\text{MnCl}_4]$
- (d)  $\text{K}_4[\text{Mn}(\text{CN})_6]$  and  $[\text{Ni}(\text{CO})_4]$



4. Question 4

According to the VSEPR theory, what are the most stable shapes of  $\text{XeF}_4$  and  $\text{SF}_4$ , respectively?

- (a) Square planar and see-saw
- (b) Both see-saw
- (c) See-saw and square planar
- (d) Both square planar

5. Question 5

The following complex ions absorb in the ultraviolet-visible region of light.

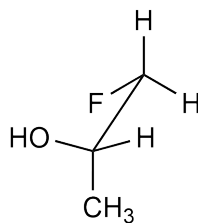
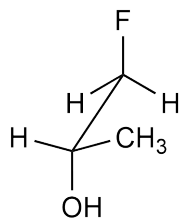
Which one of these shows violet colour?

$[\text{CoCl}(\text{NH}_3)_5]^{2+}$ ,  $[\text{Co}(\text{H}_2\text{O})(\text{NH}_3)_5]^{3+}$ ,  $[\text{Co}(\text{NH}_3)_6]^{3+}$ , and  $[\text{Co}(\text{CN})_6]^{3-}$

- (a)  $[\text{CoCl}(\text{NH}_3)_5]^{2+}$
- (b)  $[\text{Co}(\text{H}_2\text{O})(\text{NH}_3)_5]^{3+}$
- (c)  $[\text{Co}(\text{NH}_3)_6]^{3+}$
- (d)  $[\text{Co}(\text{CN})_6]^{3-}$

6. Question 6

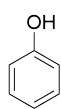
What is the relationship between the structures depicted below?



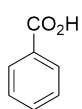
- (a) Conformational isomers
- (b) Structural isomers
- (c) Enantiomers
- (d) Positional isomers

7. Question 7

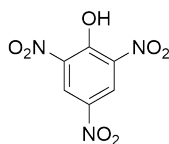
What is the correct order of acidity for the following compounds?



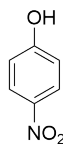
**M**



**N**



**P**

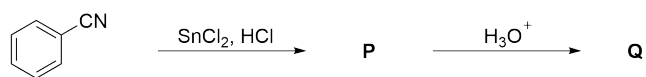
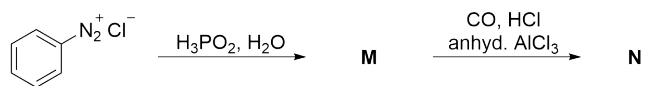


**Q**

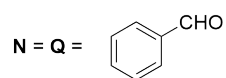
- (a) **P > N > Q > M**
- (b) **P > Q > N > M**
- (c) **N > P > M > Q**
- (d) **N > P > Q > M**

8. Question 8

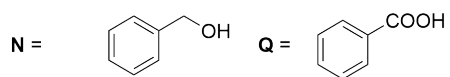
What are the products **N** and **Q** in the following reaction sequences?



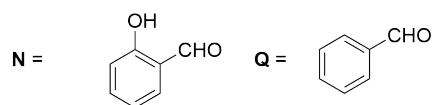
(a)



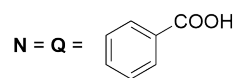
(b)



(c)

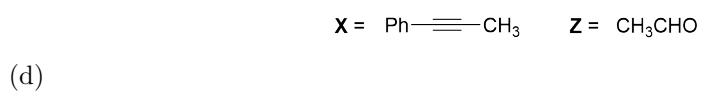
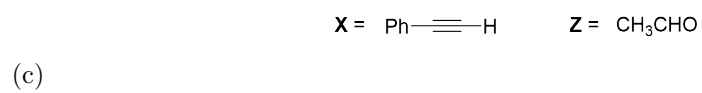
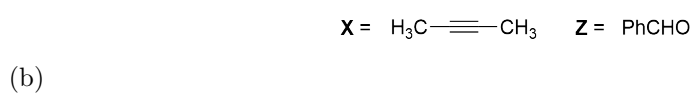
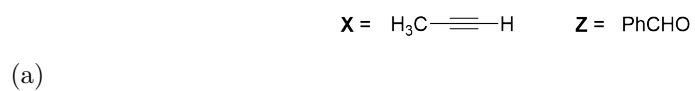
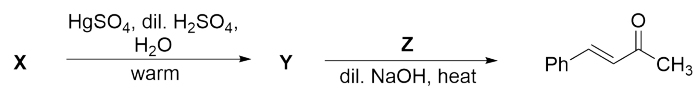


(d)



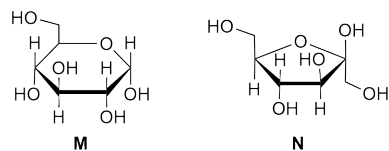
9. Question 9

What are **X** and **Z** in the following sequence of reactions?



10. Question 10

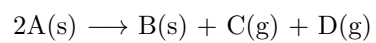
What are the correct structural descriptions for **M** and **N**?



- (a) **M** is  $\alpha$ -D-(+)-glucopyranose and **N** is  $\beta$ -D-(-)-fructofuranose
- (b) **M** is  $\beta$ -D-(+)-glucopyranose and **N** is  $\beta$ -D-(-)-fructofuranose
- (c) **M** is  $\alpha$ -D-(+)-glucopyranose and **N** is  $\alpha$ -D-(-)-fructofuranose
- (d) **M** is  $\alpha$ -D-(+)-glucofuranose and **N** is  $\beta$ -D-(-)-fructopyranose

11. Question 11

Consider an exothermic reaction:



The correct statement about the reaction is

- (a) spontaneous at all temperatures.
- (b) spontaneous only at very high temperatures.
- (c) spontaneous only at very low temperatures.
- (d) non-spontaneous at all temperatures.



12. Question 12

The minimum energy needed to remove an electron from a metal corresponds to a wavelength of 500 nm. What is the total kinetic energy of all the photoelectrons ejected per second when the entire radiation from a 100 Watt bulb with a wavelength of 300 nm falls on the surface of the metal?

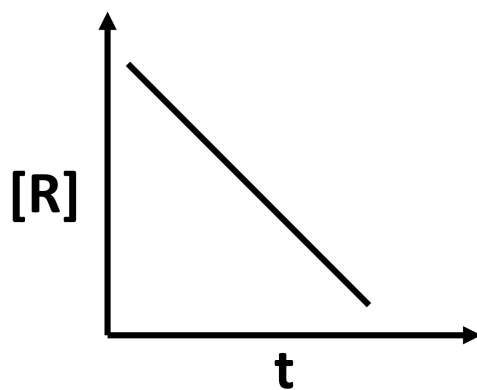
Planck's constant =  $6.6 \times 10^{-34}$  J s; speed of light =  $3 \times 10^8$  m s<sup>-1</sup>

- (a) 40 J
- (b)  $2.6 \times 10^{-19}$  J
- (c)  $1.6 \times 10^{-19}$  J
- (d) 80 J

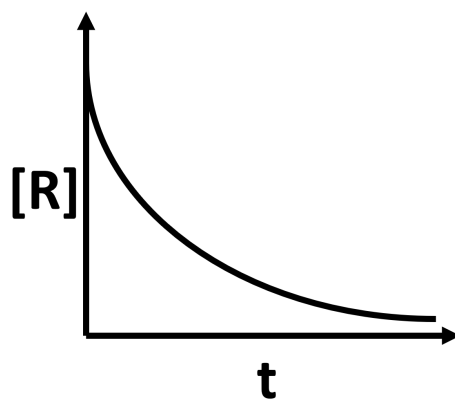
13. Question 13

For a reaction  $R \longrightarrow P$  with a rate constant of  $3 \times 10^{-3} \text{ mol L}^{-1} \text{ s}^{-1}$ , which one of the following plots is correct?

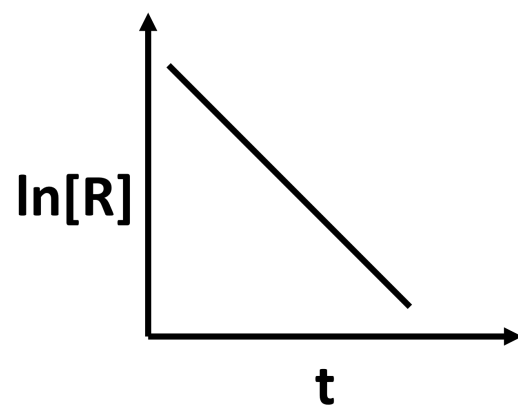
(Given  $[R]_0$  is the initial concentration of R and  $[R]$  is the concentration of R at time  $t$ )



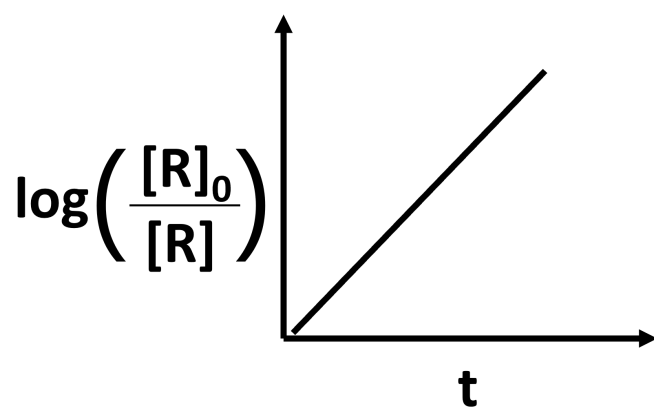
(a)



(b)



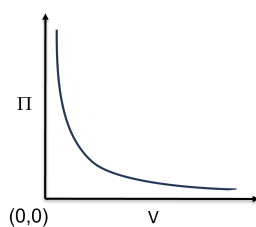
(c)



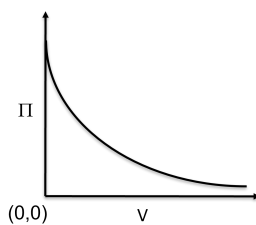
(d)

14. Question 14

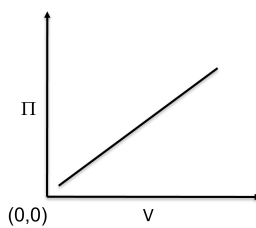
Which one of the following plots correctly describes the variation of osmotic pressure ( $\Pi$ ) of a fixed amount of a solute against the volume ( $V$ ) of the solution at a fixed temperature?



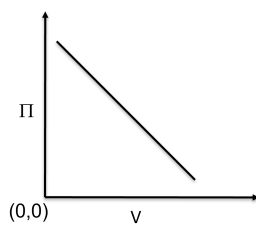
(a)



(b)



(c)



(d)

15. Question 15

Consider the following data for KCl solution at a particular temperature:

Concentration (mol L <sup>-1</sup> )	Molar Conductivity (S cm <sup>2</sup> mol <sup>-1</sup> )
$1 \times 10^{-4}$	149.1
$9 \times 10^{-4}$	147.1

What is the value of the limiting molar conductivity?

- (a) 150.1 S cm<sup>2</sup> mol<sup>-1</sup>
- (b) 149.2 S cm<sup>2</sup> mol<sup>-1</sup>
- (c) 151.1 S cm<sup>2</sup> mol<sup>-1</sup>
- (d) 152.1 S cm<sup>2</sup> mol<sup>-1</sup>

# Mathematics

## 1. Question 1

Consider the following lines in the  $XY$ -plane:

$$L_1 : 5x - 2y = 1,$$

$L_2$  : the line passing through  $(0, 1)$  and  $(100, 101)$ ,

$L_3$  : the line passing through  $(1, 11)$  and parallel to the vector  $-\hat{i} + 2\hat{j}$ .

Let  $A = (L_1 \cap L_2) \cup (L_2 \cap L_3) \cup (L_3 \cap L_1)$ . What is the total number of elements of  $A$  ?

- (a) 3
- (b) 0
- (c) 1
- (d) 2

2. Question 2

Let  $A$  be the set of points in the  $XY$ -plane which are equidistant from  $P(-1, 0)$  and  $Q(1, 0)$ . Let  $B$  be the set of points in the  $XY$ -plane which are equidistant from  $A$  and  $Q$ . If  $(5, y)$  is a point in  $B$ , then what is the value of  $y^2$  ?

- (a) 9
- (b) 1
- (c) 4
- (d) 16

3. Question 3

Consider the lines  $L_1$  and  $L_2$  given below:

$$L_1 : x = 2 + \lambda, \quad y = 3 + 2\lambda, \quad z = 4 + 3\lambda;$$

$$L_2 : x = 4 + \lambda, \quad y = 4, \quad z = 4 + \lambda.$$

If  $(2, 3, 4)$  is the point of  $L_1$  that is closest to  $L_2$ , then which point of  $L_2$  is closest to  $L_1$ ?

- (a)  $(3, 4, 3)$
- (b)  $(3, 4, 4)$
- (c)  $(5, 4, 5)$
- (d)  $(4, 4, 4)$



4. Question 4

Let  $a_1, a_2, a_3, \dots$  be a sequence of real numbers. Let  $s_n = a_1 + a_2 + \dots + a_n$ . If  $2s_n = n(c + a_n)$  for some real number  $c$  and for all  $n = 1, 2, 3, \dots$ , then which one of the following statements is Correct?

- (a)  $a_1, a_2, a_3, \dots$  is an Arithmetic Progression.
- (b)  $a_1, 2a_2, 3a_3, \dots$  is an Arithmetic Progression.
- (c)  $a_1, a_2, a_3, \dots$  is a Geometric Progression.
- (d)  $a_1, 2a_2, 3a_3, \dots$  is a Geometric Progression.

5. Question 5

Let  $f: \mathbf{R} \rightarrow \mathbf{R}$  be a strictly decreasing function with  $|f(t)| < \pi/2$  for all  $t \in \mathbf{R}$ . Let  $g: [0, \pi] \rightarrow \mathbf{R}$  be a function defined by  $g(t) = \sin(f(t))$ . Which one of the following statements is Correct ?

- (a)  $g$  is decreasing on  $[0, \pi]$ .
- (b)  $g$  is increasing on  $[0, \pi]$ .
- (c)  $g$  is increasing on  $(0, \pi/2)$  and decreasing on  $(\pi/2, \pi)$ .
- (d)  $g$  is decreasing on  $(0, \pi/2)$  and increasing on  $(\pi/2, \pi)$ .

6. Question 6

Let  $f, g: \mathbf{R} \rightarrow \mathbf{R}$  be functions. If  $g$  is continuous, then which one of the following cases implies that  $f$  is continuous ?

(a)  $g(x) = (f(x))^3$

(b)  $g(x) = |f(x)|$

(c)  $g(x) = (f(x))^2$

(d)  $g(x) = \sin(f(x))$

7. Question 7

What is the largest area of a rectangle, whose sides are parallel to the coordinate axes, that can be inscribed under the graph of the curve

$$y = 1 - x^2$$

and above the  $X$ -axis ?

(a)  $\frac{4}{3\sqrt{3}}$

(b)  $\frac{2}{3\sqrt{3}}$

(c)  $\frac{4}{3}$

(d)  $\frac{1}{3}$

8. Question 8

Let  $M$  be the set of all  $3 \times 3$  matrices with real entries. Consider the relation  $R$  on  $M$  given by  $R = \{(A, B) \in M \times M : \det(A - B) \text{ is an integer}\}$ . Which one of the following statements is Correct ?

- (a)  $R$  is reflexive and symmetric, but not transitive.
- (b)  $R$  is reflexive, but neither symmetric nor transitive.
- (c)  $R$  is an equivalence relation.
- (d)  $R$  is symmetric and transitive, but not reflexive.

9. Question 9

What is the value of  ${}^{23}C_0 + {}^{23}C_2 + {}^{23}C_4 + \cdots + {}^{23}C_{22}$  ?

- (a)  $2^{22}$
- (b)  $2^{22} - 1$
- (c)  $2^{23} + 1$
- (d)  $2^{23}$

10. Question 10

Let  $f : \mathbf{Q} \rightarrow \mathbf{Q}$  be a function such that  $f(x + y) = f(x) + f(y)$  for all  $x, y \in \mathbf{Q}$ , and  $f(1) = 10$ . Which one of the following statements is Correct ?

- (a)  $f$  is bijective.
- (b)  $f$  is injective but not surjective.
- (c)  $f$  is surjective but not injective.
- (d)  $f$  is neither injective nor surjective.

11. Question 11

Let

$$I = \int_{e^{-\pi/2}}^{e^{\pi/2}} (\sin^2(\log(x)) + \sin(\log(x^2))) \, dx.$$

What is the value of  $I$  ?

(a)  $e^{\pi/2} - e^{-\pi/2}$

(b)  $0$

(c)  $\frac{\pi e^{\pi/2}}{2}$

(d)  $e^{\pi} - 1$



12. Question 12

Consider the following subset of the  $XY$ -plane:

$$S = \{(|z - iz|, |z|^2) : z \text{ is a complex number}\}.$$

Which one of the following statements is Correct ?

- (a)  $S$  is a parabola.
- (b)  $S$  is a circle.
- (c)  $S$  is an ellipse but not a circle.
- (d)  $S$  is a hyperbola.

13. Question 13

A ship sets off on a voyage with three engines, labelled A, B, and C, which work independently. The ship can complete the voyage only if at least two of these engines keep working. The probability that engine A breaks down is  $1/4$ , that engine B breaks down is  $1/4$ , and that engine C breaks down is  $1/2$ . What is the probability that the ship can complete the voyage ?

(a)  $\frac{3}{4}$

(b)  $\frac{1}{2}$

(c)  $\frac{1}{32}$

(d)  $\frac{1}{4}$

14. Question 14

Consider the differential equation

$$\cos(y) \frac{dy}{dx} + \frac{1}{x} \sin(y) = x, \quad (x > 0);$$

given that  $y = \frac{\pi}{2}$  at  $x = \sqrt{3}$ . Which one of the following is the value of  $y$  at  $x = \sqrt{\frac{3}{2}}$  ?

(a)  $\frac{\pi}{6}$

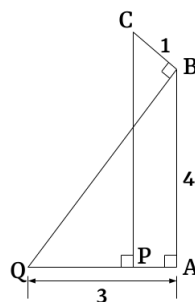
(b)  $\frac{\pi}{3}$

(c)  $\frac{\pi}{2}$

(d)  $\frac{\pi}{4}$

15. Question 15

In the given figure, the angles  $\angle BAQ = \angle CPQ = \angle CBQ = \frac{\pi}{2}$ ; and the lengths  $QA = 3$  unit,  $AB = 4$  unit, and  $BC = 1$  unit. What is the length of  $PQ$ ?



- (a) 2.2 unit
- (b) 2 unit
- (c)  $\sqrt{2}$  unit
- (d)  $3 - \sqrt{2}$  unit

# Physics

## 1. Question 1

On a circular track, two cyclists, Abhijit and Vani, start moving in opposite directions from a point. Abhijit moves with a constant speed. Vani starts with a constant acceleration from rest. They meet again on the track with the same speed. Which of the following is correct?

- (a) Abhijit travelled double the distance travelled by Vani.
- (b) Abhijit travelled half the distance travelled by Vani.
- (c) Abhijit travelled the same distance travelled by Vani.
- (d) Abhijit travelled  $\frac{4}{3}$  of the distance travelled by Vani.

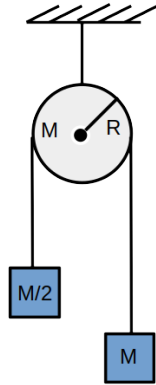
2. Question 2

Consider a simple pendulum undergoing simple harmonic motion with a time period  $T$ , and a fixed amplitude  $\theta_0$  of angular oscillation. Its angular momentum about the point of suspension exhibits an oscillatory behavior with an amplitude  $A$ . Which of the following relations between  $A$  and  $T$  is correct?

- (a)  $A \propto T^3$
- (b)  $A \propto T^2$
- (c)  $A \propto T$
- (d)  $A \propto T^4$

3. Question 3

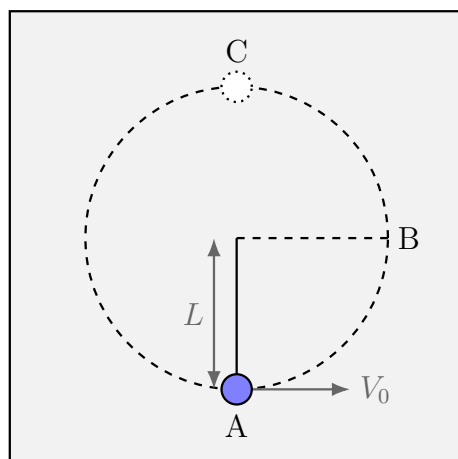
An inextensible cord of negligible mass passes over the rim of a solid disc of mass  $M$  and radius  $R$ . The disc is free to rotate about an axis passing through the centre perpendicular to the plane of the screen, as shown in the figure. Two blocks of masses  $M$  and  $M/2$  are attached to the two free ends of the cord. Assume that there is no slipping of the cord on the disc. The acceleration due to gravity is  $g$ . What is the value of the angular acceleration of the disc?



- (a)  $\frac{g}{4R}$
- (b)  $\frac{g}{2R}$
- (c)  $\frac{g}{R}$
- (d)  $\frac{g}{3R}$

4. Question 4

A solid bob of a material having density twice that of water is suspended with a massless and inextensible string of length  $L$ . The whole set-up is placed inside a water-filled tank. The bob is imparted a horizontal velocity  $V_0$  at the lowest point A, while the other end of the string is fixed, such that the bob completes a semi-circular trajectory in the vertical plane. The string becomes slack only when the bob reaches the topmost point C. Assume that the effects of viscosity and water currents are negligible. The acceleration due to gravity is  $g$ . What is the expression for  $V_0$ ?



- (a)  $\sqrt{\frac{5}{2}gL}$
- (b)  $\sqrt{5gL}$
- (c)  $\sqrt{2gL}$
- (d)  $\sqrt{\frac{3}{2}gL}$



5. Question 5

Consider a solid sphere of radius  $R$  floating in a pond with half of the sphere submerged. The sphere is pushed vertically downwards at the topmost point and released, such that it executes a simple harmonic motion. Acceleration due to gravity is  $g$ . What is the time period of oscillation?

(a)  $2\pi\sqrt{\frac{2R}{3g}}$

(b)  $2\pi\sqrt{\frac{R}{g}}$

(c)  $2\pi\sqrt{\frac{3R}{2g}}$

(d)  $2\pi\sqrt{\frac{2R}{g}}$

6. Question 6

One mole of an ideal gas of volume  $V$  and temperature  $T$  is allowed to expand adiabatically to volume  $2V$  while doing no external work. The universal gas constant is  $R$ . What is the pressure of the gas after expansion?

(a)  $\frac{RT}{2V}$

(b)  $\frac{RT}{4V}$

(c)  $\frac{RT}{V}$

(d)  $\frac{2RT}{V}$

7. Question 7

Consider the motion of a particle along the  $x$ -axis. The position of the particle varies with time  $t$  as  $x(t) = \sin^2(\omega t) \cos^3(\omega t)$ , where  $\omega$  is a constant. What is the time period of the motion?

(a)  $\frac{2\pi}{\omega}$

(b)  $\frac{2\pi}{3\omega}$

(c)  $\frac{2\pi}{5\omega}$

(d)  $\frac{2\pi}{15\omega}$

8. Question 8

Two identical boxes contain the same ideal gas. Let  $(n_1, \lambda_1, T_1)$  and  $(n_2, \lambda_2, T_2)$  be the number density, mean free path and temperature of the gas in the first and the second box, respectively. One of the boxes is emptied into the other one. What will be the mean free path  $\lambda$  and temperature  $T$  of the gas now?

(a)  $\lambda = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}, T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$

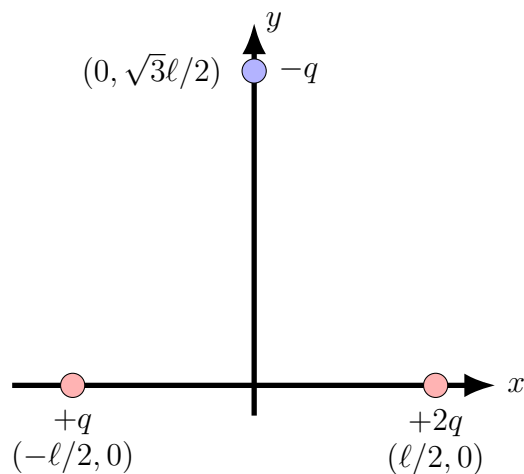
(b)  $\lambda = \frac{n_1 \lambda_1 + n_2 \lambda_2}{n_1 + n_2}, T = \frac{n_1 T_1 + n_2 T_2}{n_1 + n_2}$

(c)  $\lambda = \frac{n_1 \lambda_1 + n_2 \lambda_2}{n_1 + n_2}, T = \sqrt{T_1 T_2}$

(d)  $\lambda = \frac{\lambda_1 \lambda_2}{\lambda_1 + \lambda_2}, T = \sqrt{T_1 T_2}$

9. Question 9

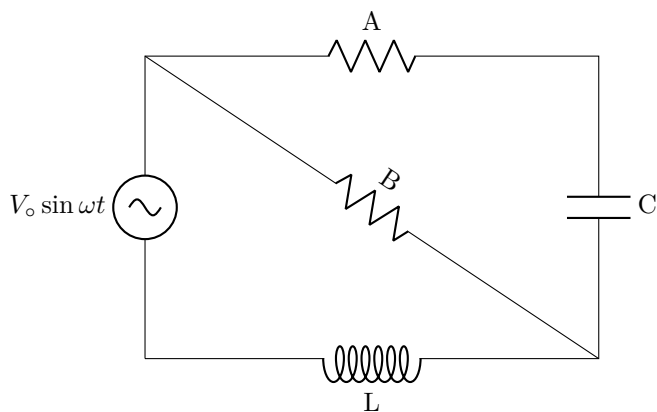
Consider two point charges  $+q$  and  $+2q$  fixed on the  $x-y$  plane at  $(-\ell/2, 0)$  and  $(\ell/2, 0)$  respectively. Another point charge  $-q$  having mass  $m$  is released from rest at  $(0, \frac{\sqrt{3}}{2}\ell)$  on the  $x-y$  plane, as shown in the figure. The permittivity of free space is  $\epsilon_0$ . What is the acceleration of the charge  $-q$  at the time of release?



- (a)  $\frac{q^2}{8\pi\epsilon_0 m \ell^2} (\hat{\mathbf{i}} - 3\sqrt{3} \hat{\mathbf{j}})$
- (b)  $\frac{q^2}{8\pi\epsilon_0 m \ell^2} (\hat{\mathbf{i}} - \sqrt{3} \hat{\mathbf{j}})$
- (c)  $\frac{q^2}{8\pi\epsilon_0 m \ell^2} (3 \hat{\mathbf{i}} - \sqrt{3} \hat{\mathbf{j}})$
- (d)  $\frac{q^2}{8\pi\epsilon_0 m \ell^2} (3\sqrt{3} \hat{\mathbf{i}} - \hat{\mathbf{j}})$

10. Question 10

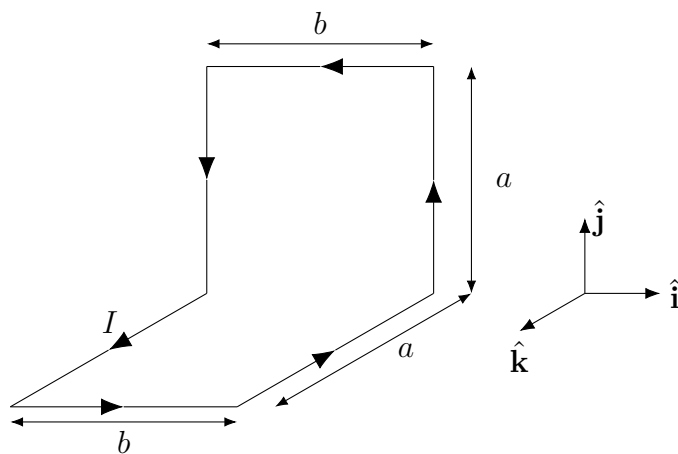
Consider the circuit diagram as shown in the figure. The source has a voltage  $V = V_0 \sin \omega t$ . Both the resistors A and B have the same resistance. The capacitor and the inductor have capacitance  $C$  and inductance  $L$ , respectively. For some frequency  $\omega$ , and certain initial charge in the capacitor, the current through the resistor A is in phase with the source. What is the value of  $\omega$ ?



- (a)  $\frac{1}{\sqrt{2LC}}$
- (b)  $\frac{1}{\sqrt{LC}}$
- (c)  $\frac{1}{2\sqrt{LC}}$
- (d)  $\frac{1}{\sqrt{3LC}}$

11. Question 11

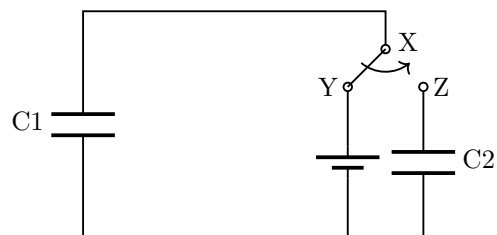
A conducting wire carrying a steady current  $I$  is shaped as shown in the figure below. All connected straight segments meet at right angles. What is the magnetic moment of the current loop?



- (a)  $Iab (\hat{j} + \hat{k})$
- (b)  $Iab (\hat{j} - \hat{k})$
- (c)  $\sqrt{2}Iab (\hat{j} + \hat{k})$
- (d)  $Iab (\hat{k} - \hat{j})$

12. Question 12

Consider the circuit shown in the figure. The capacitors  $C_1$  and  $C_2$  have capacitances  $2\ \mu\text{F}$  and  $8\ \mu\text{F}$ , respectively. The switch can connect point X to either Y or Z. Initially XY is connected until the capacitor is fully charged by the battery. Then the switch connects X and Z, and the final charges on  $C_1$  and  $C_2$  are  $Q_1$  and  $Q_2$ , respectively. What is the value of the ratio  $\frac{Q_2}{Q_1 + Q_2}$ ?



- (a)  $\frac{4}{5}$
- (b)  $\frac{1}{5}$
- (c)  $\frac{1}{4}$
- (d)  $\frac{1}{2}$



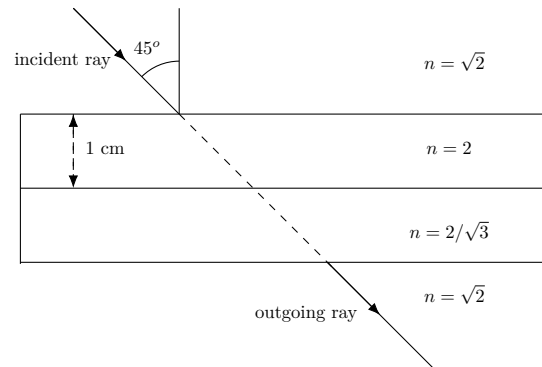
13. Question 13

Atomic masses of two oxygen isotopes  $^{16}_8\text{O}$  and  $^{18}_8\text{O}$  are 15.99491 u and 17.99916 u, respectively, where u is the atomic mass unit. Masses of proton and neutron are given by 1.00727 u and 1.00866 u, respectively. The speed of light is  $c$ . What is the difference between the binding energies of  $^{18}_8\text{O}$  and  $^{16}_8\text{O}$  nuclei in units of  $\text{u } c^2$ ?

- (a) 0.01307
- (b) 2.00425
- (c) 0.99559
- (d) 3.01291

14. Question 14

The refractive indices ( $n$ ) of two transparent slabs are 2 and  $2/\sqrt{3}$ . They are attached together and placed in a third transparent medium of refractive index  $\sqrt{2}$ , as shown in the figure. The thickness of the upper slab is 1 cm. A monochromatic light ray is incident on the upper slab at  $45^\circ$ . What would be the thickness in cm of the lower slab such that the lateral shift of the ray after passing through both the slabs is zero?



- (a)  $1/\sqrt{3}$
- (b)  $1/\sqrt{2}$
- (c)  $1/2$
- (d)  $\sqrt{3}/2$

15. Question 15

Two monochromatic sources emit light at wavelengths  $\lambda$  and  $\lambda/2$ . The stopping potentials for a photosensitive material using these two sources are found to be  $1\text{ V}$  and  $3\text{ V}$ , respectively. What is the work function of the material ?

- (a)  $1\text{ eV}$
- (b)  $2\text{ eV}$
- (c)  $1.5\text{ eV}$
- (d)  $1.25\text{ eV}$