**SECTION 3 (Maximum Marks : 12)**

- This section contains **TWO** paragraphs.
- Based on each paragraph, there are **TWO** questions.
- Each question has **FOUR** options [A], [B], [C] and [D]. **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct integer in the ORS.
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- Full Marks : +3 If only the bubble corresponding to the correct answer is darkened.
- Zero Marks : 0 In all other cases.

**Paragraph for Questions 15 - 16**

Consider a simple RC circuit as shown in Figure 1.

**Process 1 :** In the circuit the switch S is closed at $t = 0$ and the capacitor is fully charged to voltage $V_0$ (i.e., charging continues for time T >> RC). In the process some dissipation $(E_D)$ occurs across the resistance R. The amount of energy finally stored in the fully charged capacitor is $E_C$.

**Process 2:** In a different process the voltage is first set to $\frac{V_0}{3}$ and maintained for a charging time T >>RC. Then the voltage is raised to $\frac{2V_0}{3}$ without discharging the capacitor and again maintained for a time T >> RC. The process is repeated one more time by raising the voltage to $V_0$ and the capacitor is charged to the same final voltage $V_0$ as in Process 1.

These two processes are depicted in Figure 2.

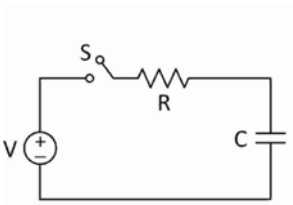


Figure 1

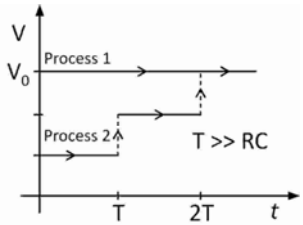


Figure 2

**15.** In Process 2, total energy dissipated across the resistance $E_D$ is:

**(A)** $E_D = 3\left(\frac{1}{2}CV_0^2\right)$ **(B)** $E_D = \frac{1}{2}CV_0^2$

**(C)** $E_D = 3CV_0^2$ **(D)** $E_D = \frac{1}{3}\left(\frac{1}{2}CV_0^2\right)$

**16.** In Process 1, the energy stored in the capacitor $E_C$ and heat dissipated across resistance $E_D$ are related by:

**(A)** $E_C = \frac{1}{2}E_D$ **(B)** $E_C = 2E_D$

**(C)** $E_C = E_D$ **(D)** $E_C = E_D \ln 2$

**Paragraph for Questions 17 - 18**

One twirls a circular ring (of mass M and radius R) near the tip of one's finger as shown in Figure 1. In the process the finger never loses contact with the inner rim of the ring. The finger traces out the surface of a cone, shown by the dotted line. The radius of the path traced out by the point where the ring and the finger is in contact is *r*. The finger rotates with an angular velocity $\omega_0$. The rotating ring *rolls without slipping* on the outside of a smaller circle described by the point where the ring and the finger is in contact (Figure 2). The coefficient of friction between the ring and the finger is $\mu$ and the acceleration due to gravity is *g*.

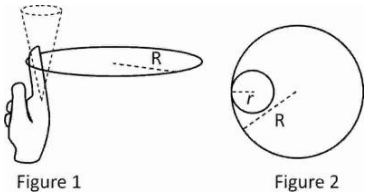



Figure 1 Figure 2

**17.** The minimum vale of $\omega_0$ below which the ring will drop down is :

**(A)** $\sqrt{\frac{2g}{\mu(R-r)}}$ **(B)** $\sqrt{\frac{g}{\mu(R-r)}}$ **(C)** $\sqrt{\frac{3g}{2\mu(R-r)}}$ **(D)** $\sqrt{\frac{g}{2\mu(R-r)}}$

**18.** The total kinetic energy of the ring is :

**(A)** $\frac{3}{2}M\omega_0^2(R-r)^2$ **(B)** $\frac{1}{2}M\omega_0^2(R-r)^2$

**(C)** $M\omega_0^2(R-r)^2$ **(D)** $M\omega_0^2R^2$

| PART-II | CHEMISTRY |
|---|---|

**SECTION 1 (Maximum Marks : 21)**

- This section contains **SEVEN** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
- For each question, marks will be awarded in one of the following categories :

| | | |
|---|---|---|
| *Full Marks* | : +3 | If, only the bubble corresponding to the correct option is darkened. |
| *Zero Marks* | : 0 | If none of the bubbles is darkened. |
| *Negative Marks* | : –1 | In all other cases. |

**19.** For the following cell.

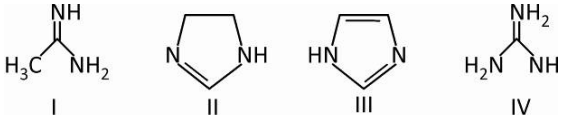
$$Zn(s)\,|\,ZnSO_4(aq)\,||\,CuSO_4(aq)\,|\,Cu(s)$$

When the concentration of $Zn^{2+}$ is 10 times the concentration of $Cu^{2+}$, the expression for $\Delta G$ (in J $mol^{-1}$) is [F is Faraday constant; R is gas constant; T is temperature; E° (cell) = 1.1 V]

**(A)** 2.303 RT – 2.2 F **(B)** 2.303 RT + 1.1 F

**(C)** 1.1 F **(D)** – 2.2 F

**20.** The order of basicity among the following compounds is :



I II III IV

**(A)** I > IV > III > II **(B)** II > I > IV > III

**(C)** IV > I > II > III **(D)** IV > II > III > I

**21.** The standard state Gibbs free energies of formation of C(graphite) and C(diagram) as T = 298 K are :

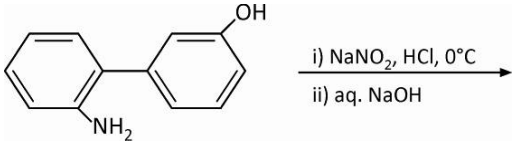
$\Delta_f G°\,[C(graphite)] = 0$ kJ $mol^{-1}$

$\Delta_f G°\,[C(diamond)] = 2.9$ kJ $mol^{-1}$.

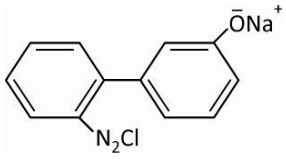
The standard state means that the pressure should be 1 bar, and substance should be pure at a given temperature. The conversion of graphite [C(graphite)] to diamond [C(diamond)] reduces its volume by $2\times10^{-6}\,m^3mol^{-1}$. If C(graphite) is converted to C(diamond) isothermally at T = 298 K, the pressure at which C(graphite) is in equilibrium with C(diamond), is : [Useful information: $1J = 1kg\,m^2s^{-2}$; $1\,Pa = 1kg\,m^{-1}s^{-2}$; $1\,bar = 10^5\,Pa$]

**(A)** 14501 bar **(B)** 29001 bar **(C)** 1450 bar **(D)** 58001 bar

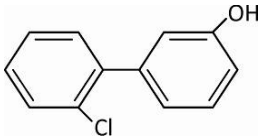
**22.** The major product of the following reaction is :



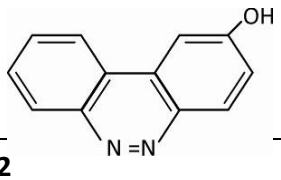

**(A)**



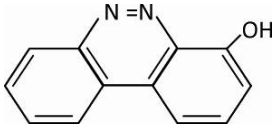

**(B)**




**(C)**




**(D)**



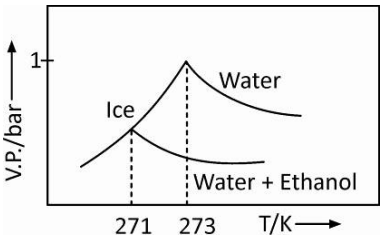
**23.** The order of the oxidation state of the phosphorus atom in $H_3PO_2$, $H_3PO_4$, $H_3PO_3$, and $H_4P_2O_6$ is :

**(A)** $H_3PO_4 > H_3PO_2 > H_3PO_3 > H_4P_2O_6$ **(B)** $H_3PO_3 > H_3PO_2 > H_3PO_4 > H_4P_2O_6$

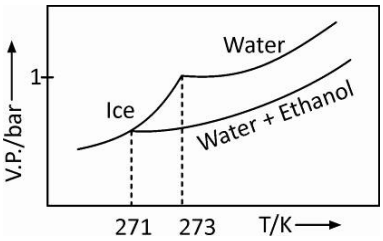
**(C)** $H_3PO_2 > H_3PO_3 > H_4P_2O_6 > H_3PO_4$ **(D)** $H_3PO_4 > H_4P_2O_6 > H_3PO_3 > H_3PO_2$

**24.** Pure water freezes at 273 K and 1 bar. The addition of 34.5 g of ethanol to 500 g of water changes the freezing point of the solution. Use the freezing point depression constant of water as 2 K kg $mol^{-1}$. The figures shown below represent plots of vapour pressure (V.P.) versus temperature (T). [molecular weight of ethanol is 46 g $mol^{-1}$] Among the following, the option representing change in the freezing point is :

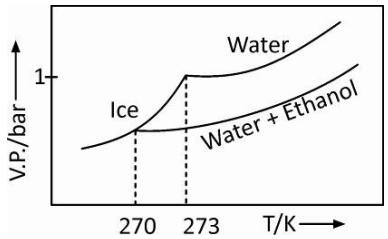
**(A)**



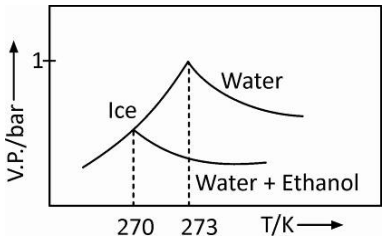

**(B)**




**(C)**




**(D)**




**25.** Which of the following combination will produce $H_2$ gas?

**(A)** Au metal and NaCN(aq) in the presence of air **(B)** Cu metal and conc. $HNO_3$

**(C)** Fe metal and conc. $HNO_3$ **(D)** Zn metal and NaOH(aq)

**SECTION 2 (Maximum Marks : 28)**

- This section contains **SEVEN** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
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**26.** The option(s) with only amphoteric oxides is(are) :

**(A)** $Cr_2O_3$, BeO, SnO, $SnO_2$ **(B)** $Cr_2O_3$, CrO, SnO, PbO

**(B)** ZnO, $Al_2O_3$, PbO, $PbO_2$ **(D)** NO, $B_2O_3$, PbO, $SnO_2$

**27.** The correct statement(s) about surface properties is(are) :

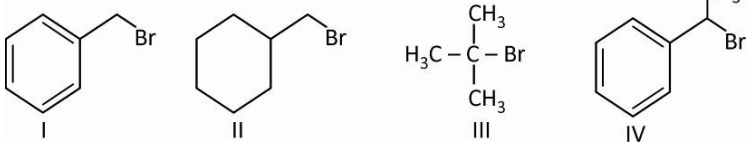
**(A)** Cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium

**(B)** Adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system

**(C)** The critical temperatures of ethane and nitrogen are 563 K and 126 K, respectively. The adsorption of ethane will be more than that of nitrogen on same amount of activated charcoal at a given temperature

**(D)** Brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution

**28.** For the following compounds, the correct statement(s) with respect to nucleophilic substitution reactions is(are) :




I II III IV

**(A)** I and III follow $S_N1$ mechanism **(B)** Compound IV undergoes inversion of configuration

**(C)** I and II follow $S_N2$ mechanism **(D)** The order of reactivity for I, III & IV is IV > I > III

**29.** Among the following, the correct statement(s) is(are)

**(A)** $BH_3$ has the three-centre two-electron bonds in its dimeric structure

**(B)** $Al(CH_3)_3$ has the three-centre two-electron bonds in its dimeric structure

**(C)** $AlCl_3$ has the three-centre two-electron bonds in its dimeric structure

**(D)** The Lewis acidity of $BCl_3$ is greater than that of $AlCl_3$

**30.** In a bimolecular reaction, the steric factor P was experimentally determined to be 4.5. The correct option(s) among the following is(are)

**(A)** Experimentally determined value of frequency factor is higher than that predicted by Arrhenius equation

**(B)** The value of frequency factor predicted by Arrhenius equation is higher than that determined experimentally

**(C)** The activation energy of the reaction is unaffected by the value of the steric factor

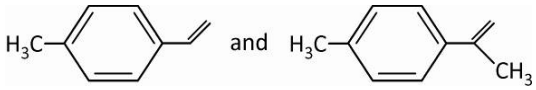
**(D)** Since $P = 4.5$, the reaction will not proceed unless an effective catalyst is used

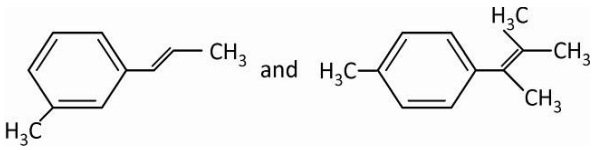
**31.** Compounds P and R upon ozonolysis produce Q and S, respectively. The molecular formula of Q and S is $C_8H_8O$. Q undergoes Cannizzaro reaction but not haloform reaction, whereas S undergoes haloform reaction but not Cannizzaro reaction.

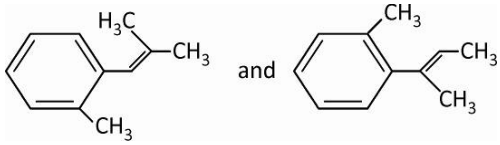
(i) $P \xrightarrow[ii)\ Zn/H_2O]{i)\ O_3/CH_2Cl_2} Q\ (C_8H_8O)$

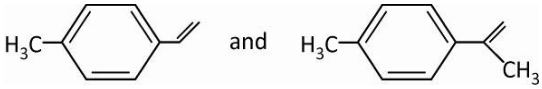
(ii) $R \xrightarrow[ii)\ Zn/H_2O]{i)\ O_3/CH_2Cl_2} Q\ (C_8H_8O)$

The option(s) with suitable combination of P and R, respectively, is(are)

**(A)** 

**(B)** 

**(C)** 

**(D)** 

**32.** For a reaction taking place in a container in equilibrium with its surroundings, the effect of temperature on its equilibrium constant K in terms of change in entropy is described by

**(A)** With increase in temperature, the value of K for exothermic reaction decreases because the entropy change of the system is positive

**(B)** With increase in temperature, the value of K for endothermic reaction increases because unfavourable change in entropy of the surroundings decreases

**(C)** With increase in temperature, the value of K for endothermic reaction increases because the entropy change of the system is negative

**(D)** With increase in temperature, the value of K for exothermic reaction decreases because favourable change in entropy of the surroundings decreases

**SECTION 3 (Maximum Marks : 12)**

- This section contains **TWO** paragraphs.
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**Paragraph for Questions 33 - 34**

Upon heating $KClO_3$ in the presence of catalytic amount of $MnO_2$, a gas **W** is formed. Excess amount of **W** reacts with white phosphorus to give **X.** The reaction of **X** with pure $HNO_3$ gives **Y** and **Z.**

**33.** **W** and **X** are, respectively :

**(A)** $O_2$ and $P_4O_{10}$ **(B)** $O_2$ and $P_4O_6$

**(C)** $O_3$ and $P_4O_6$ **(D)** $O_3$ and $P_4O_{10}$

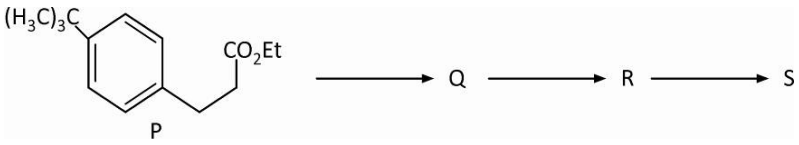
**34.** **Y** and **Z** are respectively :

**(A)** $N_2O_5$ and $HPO_3$ **(B)** $N_2O_4$ and $HPO_3$

**(C)** $N_2O_4$ and $H_3PO_3$ **(D)** $N_2O_3$ and $H_3PO_4$

**Paragraph for Questions 35 - 36**

The reaction of compound P with $CH_3MgBr$ (excess) in $C_2H_5)_2O$ following by addition of $H_2O$ gives Q. The compound Q on treatment with $H_2SO_4$ at 0°C gives R. The reaction of R with $CH_3COCol$ in the presence of anhydrous $AlCl_3$ in $CH_2Cl_2$ followed by treatment with $H_2O$ produces compounds S. [Et in compound P is ethyl group.




**35.** The reactions, Q to R and R to S, are :

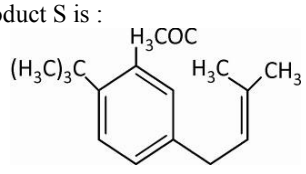
**(A)** Dehydration and Friedel-Crafts acylation

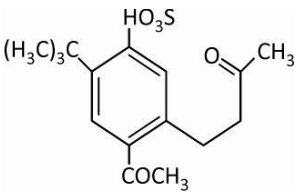
**(B)** Friedel-Crafts alkylation and Friedel-Crafts acylation

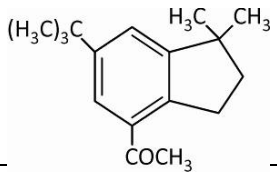
**(C)** Friedel-Crafts alkylation, dehydration and Friedel-Crafts acylation

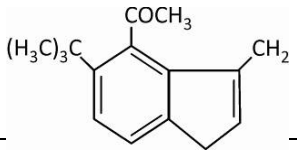
**(D)** Aromatic sulfonation and Friedel-Crafts acylation

**36.** The product S is :

**(A)** 


**(B)** 


**(C)** 


**(D)** 

| PART-III | MATHEMATICS |
|---|---|

**SECTION 1 (Maximum Marks : 21)**

- This section contains **SEVEN** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct option in the ORS.
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| | | |
|---|---|---|
| *Full Marks* | : +3 | If, only the bubble corresponding to the correct option is darkened. |
| *Zero Marks* | : 0 | If none of the bubbles is darkened. |
| *Negative Marks* | : –1 | In all other cases. |

**37.** Three randomly chosen nonnegative integers *x*, *y* and *z* are found to satisfy the equation $x+y+z=10$. Then the probability that *z* is even, is :

**(A)** $\frac{5}{11}$ **(B)** $\frac{1}{2}$ **(C)** $\frac{6}{11}$ **(D)** $\frac{36}{55}$

**38.** If $f:R\to R$ is a twice differentiable function such that $f''(x)>0$ for all $x\in R$, and $f\left(\frac{1}{2}\right)=\frac{1}{2}, f(1)=1$ then :

**(A)** $f'(1)>1$ **(B)** $f'(1)\le 0$ **(C)** $\frac{1}{2}<f'(1)\le 1$ **(D)** $0<f'(1)\le\frac{1}{2}$

**39.** The equation of the plane passing through the point (1, 1, 1) and perpendicular to the planes $2x+y-2z=5$ and $3x-6y-2z=7$, is

**(A)** $-14x+2y+15z=3$ **(B)** $14x+2y-15z=1$

**(C)** $14x+2y+15z=31$ **(D)** $14x-2y+15z=27$

**40.** Let O be the origin and let PQR be an arbitrary triangle. The point S is such that

$$\overrightarrow{OP}\cdot\overrightarrow{OQ}+\overrightarrow{OR}\cdot\overrightarrow{OS}=\overrightarrow{OR}\cdot\overrightarrow{OP}+\overrightarrow{OQ}\cdot\overrightarrow{OS}=\overrightarrow{OQ}\cdot\overrightarrow{OR}+\overrightarrow{OP}\cdot\overrightarrow{OS}$$

Then the triangle PQ has S as its:

**(A)** circumcentre **(B)** orthocenter **(C)** incentre **(D)** centroid

**41.** How many $3\times 3$ matrices M with entries from $\{0, 1, 2\}$ are there, for which the sum of the diagonal entries of $M^TM$ is 5 ?

**(A)** 126 **(B)** 198 **(C)** 162 **(D)** 135

**42.** Let $S=\{1, 2, 3,....., 9\}$. For $k=1, 2,....., 5,$ let $N_k$ be the number of subsets of *S*, each containing five elements out of which exactly *k* are odd. Then $N_1+N_2+N_3+N_4+N_5=$ ?

**(A)** 210 **(B)** 252 **(C)** 125 **(D)** 126

**43.** If $y=y(x)$ satisfies the differential equation $8\sqrt{x}\left(\sqrt{9+\sqrt{x}}\right)dy=\left(\sqrt{4+\sqrt{9+\sqrt{x}}}\right)^{-1}dx,\ x>0$ and $y(0)=\sqrt{7}$, then $y(256)=$

**(A)** 16 **(B)** 80 **(C)** 3 **(D)** 9

**SECTION 2 (Maximum Marks : 28)**

- This section contains **SEVEN** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is(are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS.
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- For example, if (A), (C) and (D) are all the correct options for a question, darkening all these three will result in +4 marks; darkening only (A) and (D) will result in +2 marks; and darkening (A) and (B) will result in –2 marks, as a wrong option is also darkened.

**44.** Let $f(x)=\dfrac{1-x(1+|1-x|)}{|1-x|}\cos\left(\dfrac{1}{1-x}\right)$ for $x\neq 1$. Then :

**(A)** $\lim\limits_{x\to 1^-} f(x)$ does not exist **(B)** $\lim\limits_{x\to 1^+} f(x)$ does not exist

**(C)** $\lim\limits_{x\to 1^-} f(x)=0$ **(D)** $\lim\limits_{x\to 1^+} f(x)=0$

**45.** Let $\alpha$ and $\beta$ be nonzero real numbers such that $2(\cos\beta-\cos\alpha)+\cos\alpha\cos\beta=1$. Then which of the following is/are true ?

**(A)** $\sqrt{3}\tan\left(\dfrac{\alpha}{2}\right)+\tan\left(\dfrac{\beta}{2}\right)=0$ **(B)** $\sqrt{3}\tan\left(\dfrac{\alpha}{2}\right)-\tan\left(\dfrac{\beta}{2}\right)=0$

**(C)** $\tan\left(\dfrac{\alpha}{2}\right)+\sqrt{3}\tan\left(\dfrac{\beta}{2}\right)=0$ **(D)** $\tan\left(\dfrac{\alpha}{2}\right)-\sqrt{3}\tan\left(\dfrac{\beta}{2}\right)=0$

**46.** If $f(x)=\begin{vmatrix}\cos(2x) & \cos(2x) & \sin(2x)\\ -\cos x & \cos x & -\sin x\\ \sin x & \sin x & \cos x\end{vmatrix}$, then :

**(A)** $f'(x)=0$ at exactly three points in $(-\pi,\pi)$

**(B)** $f'(x)=0$ at more than three points in $(-\pi,\pi)$

**(C)** $f(x)$ attains its maximum at $x=0$

**(D)** $f(x)$ attains its minimum at $x=0$

**47.** If the line $x=\alpha$ divides the area of region $R=\left\{(x,y)\in R^2 : x^3\le y\le x,\ 0\le x\le 1\right\}$ into two equal parts, then :

**(A)** $2\alpha^4-4\alpha^2+1=0$ **(B)** $\alpha^4+4\alpha^2-1=0$

**(C)** $0<\alpha\le\dfrac{1}{2}$ **(D)** $\dfrac{1}{2}<\alpha<1$

**48.** If $I\sum\limits_{k=1}^{98}\int_k^{k+1}\dfrac{k+1}{x(x+1)}dx$, then :

**(A)** $I < \frac{49}{50}$ **(B)** $I > \log_e 99$ **(C)** $I > \frac{49}{50}$ **(D)** $I < \log_e 99$

**49.** If $f : R \to R$ is a differentiable function such that $f'(x) > 2f(x)$ for all $x \in R$ and $f(0) = 1$, then :

**(A)** $f(x)$ is decreasing in $(0, \infty)$ **(B)** $f'(x) < e^{2x}$ in $(0, \infty)$

**(C)** $f(x)$ is increasing in $(0, \infty)$ **(D)** $f(x) > e^{2x}$ in $(0, \infty)$

**50.** If $g(x) = \int_{\sin x}^{\sin(2x)} \sin^{-1}(t)\,dt$, then :

**(A)** $g'\left(\frac{\pi}{2}\right) = -2\pi$ **(B)** $g'\left(-\frac{\pi}{2}\right) = -2\pi$ **(C)** $g'\left(-\frac{\pi}{2}\right) = 2\pi$ **(D)** $g'\left(\frac{\pi}{2}\right) = 2\pi$

**SECTION 3 (Maximum Marks : 12)**

- This section contains **TWO** paragraphs.
- Based on each paragraph, there are **TWO** questions.
- Each question has **FOUR** options [A], [B], [C] and [D]. **ONLY ONE** of these four options is correct.
- For each question, darken the bubble corresponding to the correct integer in the ORS.
- For each question, marks will be awarded in one of the following categories:
- Full Marks : +3 If only the bubble corresponding to the correct answer is darkened.
- Zero Marks : 0 In all other cases.

**Paragraph for Questions 51 - 52**

Let $O$ be the origin, and $\overrightarrow{OX}$, $\overrightarrow{OY}$, $\overrightarrow{OZ}$ be three unit vectors in the directions of the sides $\overrightarrow{QR}$, $\overrightarrow{RP}$, $\overrightarrow{PQ}$, respectively of a triangle $PQR$.

**51.** $|\overrightarrow{OX} \times \overrightarrow{OY}| =$

**(A)** $\sin(P + R)$ **(B)** $\sin 2R$ **(C)** $\sin(Q + R)$ **(D)** $\sin(P + Q)$

**52.** If the triangle $PQR$ varies, then the minimum value of $\cos(P + Q) + \cos(Q + R) + \cos(R + P)$ is :

**(A)** $-\frac{3}{2}$ **(B)** $\frac{5}{3}$ **(C)** $\frac{3}{2}$ **(D)** $-\frac{5}{3}$

**Paragraph for Questions 53 - 54**

Let $p$, $q$ be integers and let $\alpha, \beta$ be the roots of the equation, $x^2 - x - 1 = 0$, where $\alpha \neq \beta$. For $n = 0, 1, 2, \ldots$, let $a_n = p\alpha^n + q\beta^n$. **FACT:** If $a$ and $b$ are rational numbers and $a + b\sqrt{5} = 0$, then $a = 0 = b$.

**53.** If $a_4 = 28$, then $p + 2q =$

**(A)** 7 **(B)** 21 **(C)** 14 **(D)** 12

**54.** $a_{12} =$

**(A)** $a_{11} + a_{10}$ **(B)** $a_{11} - a_{10}$ **(C)** $a_{11} + 2a_{10}$ **(D)** $2a_{11} + a_{10}$