## GENERAL

1. This sealed booklet is your Question Paper. Do not break, the seal till you are told to do so.
2. The paper CODE is printed on the right hand top comer of this sheet and the right hand top comer of the back cover of this booklet.
3. Use the Optical Response Sheet (ORS) provided separately for answering the questions.
4. The paper CODE is printed on the left part as well as the right part of the ORS. Ensure that both these codes are identical and same as that on the question paper booklet. If not, contact the invigilator for change of ORS.
5. Blank spaces are provided within this booklet for rough work.
6. Write your name, roll number and sign in the space provided on the back cover of this booklet.
7. After breaking the seal of the booklet at 2:00 pm, verily that the booklet contains 36 pages and that all the 54 questions along with the options are legible. If not, contact the invigilator for replacement of the booklet.
8. You are allowed to take away the Question Paper at the end of the examination.

## OPTICAL RESPONSE SHEET

9. The ORS (top sheet) will be provided with an attached Candidate's Sheet (bottom sheet). The Candidate's Sheet is a carbon-less copy of the ORS.
10. Darken the appropriate bubbles on the ORS by applying sufficient pressure. This will leave an impression at the corresponding place on the Candidate's Sheet.
11. The ORS will be collected by the invigilator at the end of the examination.
12. You will be allowed to take away the Candidate's Sheet at the end of the examination.
13. Do not tamper with or mutilate the ORS. Do not use the ORS for rough work.
14. Write your name, roll number and code of the examination center, and sign with pen in the space provided for this purpose on the ORS. Do not write any of these details anywhere else on the ORS, Darken the appropriate bubble under each digit of your roll number.

## DARKENING THE BUBBLES ON THE ORS

15. Use a BLACK BALL POINT PEN to darken the bubbles on the ORS.
16. Darken the bubble
 COMPLETELY
17. The correct way of darkening a bubble is as :
18. The ORS is machine-gradable. Ensure that the bubbles are darkened in the correct way.
19. Darken the bubbles ONLY IF you are sure of the answer. There is NO WAY to erase or "un-darken" a darkened bubble.

Please see the last page of this booklet for rest of the instructions.


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## PART I : PHYSICS

## 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
Q. 1 A photoelectric material having work-function $\phi_{0}$ is illuminated with light of wavelength $\lambda$ $\left(\lambda<\frac{h c}{\phi_{0}}\right)$. The fastest photoelectron has a de Broglie wavelength $\lambda_{d}$. A change in wavelength of the incident light by $\Delta \lambda$ results in a change $\Delta \lambda_{d}$ in $\lambda_{d}$. Then the ratio $\Delta \lambda_{d} / \Delta \lambda$ is proportional to
[A] $\lambda_{d}^{3} / \lambda$
(BB) $\lambda_{d} / \lambda$
C] $\lambda_{d}^{2} / \lambda^{2}$
[D] $\lambda_{d}^{3} / \lambda^{2}$

Space for rough work


Q. 2 Consider regular polygons with number of sides $n=3,4,5 \ldots \ldots$ as shown in the figure. The center of mass of all the polygons is at height $h$ from the ground. They roll on a horizontal surface about the leading vertex without slipping and sliding as depicted. The maximum increase in height of the locus of the center of mass for each polygon is $\Delta$. Then $\Delta$ depends on $n$ and $h$ as

$$
\text { [A] } \Delta=h\left(\frac{1}{\cos \left(\frac{\pi}{n}\right)}-1\right)
$$

[C] $\Delta=h \sin \left(\frac{2 \pi}{n}\right)$
[D] $\Delta=h \sin ^{2}\left(\frac{\pi}{n}\right)$
Q. 3 Consider an expanding sphere of instantaneous radius $R$ whose total mass remains constant. The expansion is such that the instantaneous density $\rho$ remains uniform throughout the volume. The rate of fractional change in density $\left(\frac{1}{\rho} \frac{d \rho}{d t}\right)$ is constant. The velocity $v$ of any point on the surface of the expanding sphere is proportional to
[A] $R^{3}$
[D] $R$
[C] $\frac{1}{R}$
[D] $R^{2 / 3}$
Q. 4 A person measures the depth of a well by measuring the time interval between dropping a stone and receiving the sound of impact with the bottom of the well. The error in his measurement of time is $\delta T=0.01$ seconds and he measures the depth of the well to be $L=20$ meters. Take the acceleration due to gravity $g=10 \mathrm{~ms}^{-2}$ and the velocity of sound is $300 \mathrm{~ms}^{-1}$. Then the fractional error in the measurement, $\delta L / L$, is closest to
[A] $5 \%$
[B] $3 \%$
[C. $0.2 \%$
[D] $1 \%$

Space for rough work
Q. 7 Three vectors $\vec{P}, \vec{Q}$ and $\vec{R}$ are shown in the figure. Let $S$ be any point on the vector $\vec{R}$. The distance between the points $P$ and $S$ is $b|\vec{R}|$. The general relation among vectors $\vec{P}, \vec{Q}$ and $\vec{S}$ is


Space for rough work

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## 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 options is(are) correct
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS
- For each question, marks will be awarded in one of the following categories:

| Full Marks | $:+4$ | If only the bubble(s) corresponding to all the correct option(s) <br> is(are) darkened |
| :--- | :--- | :--- |
| Partial Marks | $:+1$ | For darkening a bubble corresponding to each correct option, <br> provided NO incorrect option is darkened |
| Zero Marks $: 0$ If none of the bubbles is darkened <br> Negative Marks $:-2$ In all other cases |  |  |

- For example, if [A], [C] and [D] are all the correct options for a question, darkening all these three will get +4 marks; darkening only $[A]$ and $[D]$ will get +2 marks; and darkening $[A]$ and [B] will get -2 marks, as a wrong option is also darkened

Q. 8 The instantaneous voltages at three terminals marked $X, Y$ and $Z$ are given by

$$
\begin{aligned}
& V_{X}=V_{0} \sin \omega t, \\
& V_{Y}=V_{0} \sin \left(\omega t+\frac{2 \pi}{3}\right) \text { and } \\
& V_{Z}=V_{0} \sin \left(\omega t+\frac{4 \pi}{3}\right) .
\end{aligned}
$$

An ideal voltmeter is configured to read $r m s$ value of the potential difference between its terminals. It is connected between points $X$ and $Y$ and then between $Y$ and $Z$. The reading(s) of the voltmeter will be

[B] $\quad V_{Y Z}^{r m s}=V_{0} \sqrt{\frac{1}{2}}$

[D] $V_{X Y}^{r m s}=V_{0}$
Q. 9 A point charge $+Q$ is placed just outside an imaginary hemispherical surface of radius $R$ as shown in the figure. Which of the following statements is/are correct?

[A] Total flux through the curved and the flat surfaces is $\frac{Q}{\varepsilon_{0}} Q$
[B] The circumference of the flat surface is an equipotential

[C] The component of the electric field normal to the flat surface is constant over the surface
[D] The electric flux passing through the curved surface of the hemisphere i $\$$ D $-\frac{Q}{2 \varepsilon_{0}}\left(1-\frac{1}{\sqrt{2}}\right)$

Space for rough work
Q. 10 Two coherent monochromatic point sources $S_{1}$ and $S_{2}$ of wavelength $\lambda=600 \mathrm{~nm}$ are placed symmetrically on either side of the center of the circle as shown. The sources are separated by a distance $d=1.8 \mathrm{~mm}$. This arrangement produces interference fringes visible as alternate bright and dark spots on the circumference of the circle. The angular separation between two consecutive bright spots is $\Delta \theta$. Which of the following options is/are correct?

[A] The angular separation between two consecutive bright spots decreases as we move from $P_{1}$ to $P_{2}$ along the first quadrant
[B] A dark spot will be formed at the point $P_{2}$


IC] At $P_{2}$ the order of the fringe will be maximum
[D] The total number of fringes produced between $P_{1}$ and $P_{2}$ in the first quadrant is close zoo. to 3000

Q. 11 A uniform magnetic field $B$ exists in the region between $x=0$ and $x=\frac{3 R}{2}$ (region 2 in the figure) pointing normally into the plane of the paper. A particle with charge $+Q$ and momentum $p$ directed along $x$-axis enters region 2 from region 1 at point $P_{1}(y=-R)$. Which of the following option(s) is/are correct?

[A] For a fixed $B$, particles of same charge $Q$ and same velocity $v$, the distance between the point $P_{1}$ and the point of re-entry into region 1 is inversely proportional to the mass of the particle
[B] For $B=\frac{8}{13} \frac{p}{Q R}$, the particle will enter region 3 through the point $P_{2}$ on $x$-axis \&
[C] When the particle re-enters region 1 through the longest possible path in region 2, the magnitude of the change in its linear momentum between point $P_{1}$ and the farthest point from $y$-axis is $p / \sqrt{2}$

Q. 12 A wheel of radius $R$ and mass $M$ is placed at the bottom of a fixed step of height $R$ as shown in the figure. A constant force is continuously applied on the surface of the wheel so that it just climbs the step without slipping. Consider the torque $\tau$ about an axis normal to that it just climbs the step without slipping. Consider the torque $\tau$ about an axis normal to
the plane of the paper passing through the point $Q$. Which of the following options is/are correct?
int so rs Prut

[A] If the force is applied normal to the circumference at point $X$ then $\tau$ is constant

[B] If the force is applied tangentially at point $S$ then $\tau \neq 0$ but the wheel never climbs the step
[C] If the force is applied at point $P$ tangentially then $\tau$ decreases continuously as the $1=R$ wheel climbs

[D才 If the force is applied normal to the circumference at point $P$ then $\tau$ is zero

Q. 13 A source of constant voltage $V$ is connected to a resistance $R$ and two ideal inductors $L_{1}$ and $L_{2}$ through a switch $S$ as shown. There is no mutual inductance between the two inductors. The switch $S$ is initially open. At $t=0$, the switch is closed and current begins to flow. Which of the following options is/are correct?

Q. 14 A rigid uniform bar AB of length $L$ is slipping from its vertical position on a frictionless floor (as shown in the figure). At some instant of time, the angle made by the bar with the vertical is $\theta$. Which of the following statements about its motion is/are correct?

[A] Instantaneous torque about the point in contact with the floor is proportional to $\sin \theta$
[B] The trajectory of the point $A$ is a parabola
[C] The midpoint of the bar will fall vertically downward
[D] When the bar makes an angle $\theta$ with the vertical, the displacement of its midpoint from the initial position is proportional to $(1-\cos \theta)$

## 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 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 In all other cases


## PARAGRAPH 1

Consider a simple $R C$ 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 $T \gg R C$ ). 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 $T \gg R C$. Then the voltage is raised to $\frac{2 V_{0}}{3}$ without discharging the capacitor and again maintained for a time $T \gg R C$. 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
Q. 15 In Process 1, the energy stored in the capacitor $E_{C}$ and heat dissipated across resistance $E_{D}$ are related by:

Q. 16 In Process 2, total energy dissipated across the resistance $E_{D}$ is:
[A] $E_{D}=\frac{1}{3}\left(\frac{1}{2} C V_{0}^{2}\right)$
[B] $E_{D}=3\left(\frac{1}{2} C V_{0}^{2}\right)$
[C] $E_{D}=\frac{1}{2} C V_{0}^{2}$
[D] $E_{D}=3 \mathrm{CV}_{0}^{2}$

PARAGRAPH 2
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
Q. 17 The total kinetic energy of the ring is
[A] $M \omega_{0}^{2}(R-r)^{2}$
[B] $M \omega_{0}^{2} R^{2}$
[C] $\frac{3}{2} M \omega_{0}^{2}(R-r)^{2}$
[D] $\frac{1}{2} M \omega_{0}^{2}(R-r)^{2}$
Q. 18 The minimum value of $\omega_{0}$ below which the ring will drop down is


## 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
Q. 19 Which of the following combination will produce $\mathrm{H}_{2}$ gas?
[A] Cu metal and conc. $\mathrm{HNO}_{3}$
[B] Au metal and $\mathrm{NaCN}(\mathrm{aq})$ in the presence of air
[e] Zn metal and NaOH (aq)
[D] Fe metal and conc. $\mathrm{HNO}_{3}$
Q. 20 The order of basicity among the following compounds is


Space for rough work

Q. 22 For the following cell,

$$
\mathrm{Zn}(s)\left|\mathrm{ZnSO}_{4}(\mathrm{aq}) \| \mathrm{CuSO}_{4}(\mathrm{aq})\right| \mathrm{Cu}(\mathrm{~s})
$$

when the concentration of $\mathrm{Zn}^{2+}$ is 10 times the concentration of $\mathrm{Cu}^{2+}$, the expression for $\Delta G$ (in J mol${ }^{-1}$ ) is
[ F is Faraday constant; R is gas constant; T is temperature; $E^{o}($ cell $)=1.1 \mathrm{~V}$ ]
[A] $2.303 \mathrm{RT}+1.1 \mathrm{~F}$
[B] $2.303 \mathrm{RT}-2.2 \mathrm{~F}$

Q. 23 The order of the oxidation state of the phosphorus atom in $\mathrm{H}_{3} \mathrm{PO}_{2}, \mathrm{H}_{3} \mathrm{PO}_{4}, \mathrm{H}_{3} \mathrm{PO}_{3}$, and $\mathrm{H}_{4} \mathrm{P}_{2} \mathrm{O}_{6}$ is
[A] $\mathrm{H}_{3} \mathrm{PO}_{3}>\mathrm{H}_{3} \mathrm{PO}_{2}>\mathrm{H}_{3} \mathrm{PO}_{4}>\mathrm{H}_{4} \mathrm{P}_{2} \mathrm{O}_{6}$
[B] $\mathrm{H}_{3} \mathrm{PO}_{4}>\mathrm{H}_{3} \mathrm{PO}_{2}>\mathrm{H}_{3} \mathrm{PO}_{3}>\mathrm{H}_{4} \mathrm{P}_{2} \mathrm{O}_{6}$
[C] $\mathrm{H}_{3} \mathrm{PO}_{2}>\mathrm{H}_{3} \mathrm{PO}_{3}>\mathrm{H}_{4} \mathrm{P}_{2} \mathrm{O}_{6}>\mathrm{H}_{3} \mathrm{PO}_{4}{ }^{\circ}$
[D] $\mathrm{H}_{3} \mathrm{PO}_{4}>\mathrm{H}_{4} \mathrm{P}_{2} \mathrm{O}_{6}>\mathrm{H}_{3} \mathrm{PO}_{3}>\mathrm{H}_{3} \mathrm{PO}_{2}$

## Space for rough work

Q. 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 $2 \mathrm{~K} \mathrm{~kg} \mathrm{~mol}^{-1}$. The figures shown below represent plots of vapour pressure (V.P.) versus temperature (T). [molecular weight of ethanol is $46 \mathrm{~g} \mathrm{~mol}^{-1}$ ]
Among the following, the option representing change in the freezing point is

Q. 25 The standard state Gibbs free energies of formation of C (graphite) and C (diamond) at $\mathrm{T}=298 \mathrm{~K}$ are

$$
\begin{gathered}
\Delta_{f} G^{o}[\mathrm{C}(\text { graphite })]=0 \mathrm{~kJ} \mathrm{~mol}^{-1} \\
\Delta_{f} G^{o}[\mathrm{C}(\text { diamond })]=2.9 \mathrm{~kJ} \mathrm{~mol}^{-1}
\end{gathered}
$$

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 $2 \times 10^{-6} \mathrm{~m}^{3} \mathrm{~mol}^{-1}$. If C (graphite) is converted to C (diamond) isothermally at $\mathrm{T}=298 \mathrm{~K}$, the pressure at which C (graphite) is in equilibrium with C (diamond), is
[Useful information: $1 \mathrm{~J}=1 \mathrm{~kg} \mathrm{~m}^{2} \mathrm{~s}^{-2} ; 1 \mathrm{~Pa}=1 \mathrm{~kg} \mathrm{~m}^{-1} \mathrm{~s}^{-2} ; 1$ bar $=10^{5} \mathrm{~Pa}$ ]
[A] 29001 bar
[B] 1450 bar
[C] 14501 bar
[D] 58001 bar

## Space for rough work

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## SECTION 2 (Maximum Marks: 28)

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Full Marks $\quad:+4$ If only the bubble(s) corresponding to all the correct option(s) is(are) darkened
Partial Marks $:=+1$ For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened
Zero Marks : 0 If none of the bubbles is darkened
Negative Marks
$-2 \quad$ In all other cases

- For example, if $[\mathrm{A}]_{,}[\mathrm{C}]$ and $[\mathrm{D}]$ are all the correct options for a question, darkening all these three will get +4 marks; darkening only [A] and [D] will get +2 marks; and darkening [A] and $[\mathrm{B}]$ will get -2 marks, as a wrong option is also darkened
Q. 26 Among the following, the correct statement(s) is(are)
[A] $\mathrm{AlCl}_{3}$ has the three-centre two-electron bonds in its dimeric structure
[17) $\mathrm{BH}_{3}$ has the three-centre two-electron bonds in its dimeric structure
[C] $\mathrm{Al}\left(\mathrm{CH}_{3}\right)_{3}$ has the three-centre two-electron bonds in its dimeric structure
[D] The Lewis acidity of $\mathrm{BCl}_{3}$ is greater than that of $\mathrm{AlCl}_{3}$
Space for rough work UPIQPBANK.COM
Q. 27 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 the entropy change of the system is negative
[C] With increase in temperature, the value of $K$ for endothermic reaction increases because unfavourable change in entropy of the surroundings decreases


D] With increase in temperature, the value of $K$ for exothermic reaction decreases because favourable change in entropy of the surroundings decreases
Q. 28 Compounds $\mathbf{P}$ and $\mathbf{R}$ upon ozonolysis produce $\mathbf{Q}$ and $\mathbf{S}$, respectively. The molecular formula of $\mathbf{Q}$ and $\mathbf{S}$ is $\mathrm{C}_{8} \mathrm{H}_{8} \mathrm{O}$. $\mathbf{Q}$ undergoes Cannizzaro reaction but not haloform reaction, whereas $S$ undergoes haloform reaction but not Cannizzaro reaction.


The options) with suitable combination of $\mathbf{P}$ and $\mathbf{R}$, respectively, is(are)


Space for rough work
Q. 29 For the following compounds, the correct statement(s) with respect to nucleophilic substitution reactions is(are)

Q. 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] The value of frequency factor predicted by Arrhenius equation is higher than that determined experimentally
[B] Experimentally determined value of frequency factor is higher than that predicted by Arrhenius equation
[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
Space for rough work
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Q. 31 The correct statements) about surface properties is(are)


Cloud is an emulsion type of colloid in which liquid is dispersed phase and gas is dispersion medium
[D] Adsorption is accompanied by decrease in enthalpy and decrease in entropy of the system
[C] Brownian motion of colloidal particles does not depend on the size of the particles but depends on viscosity of the solution
[D] 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
Q. 32 The options) with only amphoteric oxides is(are)
[A] $\mathrm{ZnO}, \mathrm{Al}_{2} \mathrm{O}_{3}, \mathrm{PbO}, \mathrm{PbO}_{2}$
[C] $\mathrm{NO}, \mathrm{B}_{2} \mathrm{O}_{3}, \mathrm{PbO}, \mathrm{SnO}_{2}$

[B] $\left.\mathrm{Cr}_{2} \mathrm{O}_{3}, \mathrm{BeO}, \mathrm{SnO}, \mathrm{SnO}_{2}\right]$
[D] $\mathrm{Cr}_{2} \mathrm{O}_{3}, \mathrm{CrO}, \mathrm{SnO}, \mathrm{PbO}$

## SECTION 3 (Maximum Marks: 12)

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- Based on each paragraph, there are TWO questions
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Full Marks : +3 If only the bubble corresponding to the correct option is darkened Zero Marks : 0 In all other cases


## PARAGRAPH 1

Upon heating $\mathrm{KClO}_{3}$ in the presence of catalytic amount of $\mathrm{MnO}_{2}$, a gas $\mathbf{W}$ is formed. Excess amount of $W$ reacts with white phosphorus to give $\mathbf{X}$. The reaction of $\mathbf{X}$ with pure $\mathrm{HNO}_{3}$ gives $\mathbf{Y}$ and $\mathbf{Z}$.
Q. $33 \mathbf{Y}$ and $\mathbf{Z}$ are, respectively
[A] $\mathrm{N}_{2} \mathrm{O}_{5}$ and $\mathrm{HPO}_{3}$.
[B] $\mathrm{N}_{2} \mathrm{O}_{4}$ and $\mathrm{HPO}_{3}$
[C] $\mathrm{N}_{2} \mathrm{O}_{4}$ and $\mathrm{H}_{3} \mathrm{PO}_{3}$
(D) $\mathrm{N}_{2} \mathrm{O}_{3}$ and $\mathrm{H}_{3} \mathrm{PO}_{4}$
Q. $34 \mathbf{W}$ and $\mathbf{X}$ are, respectively
[A] $\mathrm{O}_{3}$ and $\mathrm{P}_{4} \mathrm{O}_{10}$
[B] $\mathrm{O}_{2}$ and $\mathrm{P}_{4} \mathrm{O}_{6}$

Q. 36 The reactions, $\mathbf{Q}$ to $\mathbf{R}$ and $\mathbf{R}$ to $\mathbf{S}$, are
[A] Friedel-Crafts alkylation and Friedel-Crafts acylation-

[B] Friedel-Crafts alkylation, dehydration and Friedel-Crafts acylation.
[C] Dehydration and Friedel-Crafts acylation
[D] Aromatic sulfonation and Friedel-Crafts acylation
END OF PART II : CHEMISTRY
Space for rough work

## PART III : MATHEMATICS

## SECTION 1 (Maximum Marks: 21)

- This section contains SEVEN questions
- Each question has FOUR options $[\mathrm{A}],[\mathrm{B}],[\mathrm{C}]$ and $[\mathrm{D}]$. 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
Q. 37 The equation of the plane passing through the point $(1,1,1)$ and perpendicular to the planes $2 x+y-2 z=5$ and $3 x-6 y-2 z=7$, is
[A] $14 x+2 y+15 z=31 \quad \cap$
[B] $14 x-2 y+15 z=27$
$[\mathrm{C}]_{\sigma}-14 x+2 y+15 z=3$
[D] $14 x+2 y-15 z=10$
Q. 38 How many $3 \times 3$ matrices $M$ with entries from $\{0,1,2\}$ are there, for which the sum of the diagonal entries of $M^{T} M$ is 5 ?
[A] 162
[B] 198
[C] 126
[D] 135

Space for rough work
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Q. 39 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
[时] $\frac{1}{2}$

$$
\left.-\left(B^{-1}\right]\right) \frac{36}{55}
$$

[泣] $\frac{5}{11}$
[16) $\frac{6}{14}$
Q. 40 Let $O$ be the origin and let $P Q R$ be an arbitrary triangle. The point $S$ is such that

$$
\overrightarrow{O P} \cdot \overrightarrow{O Q}+\overrightarrow{O R} \cdot \overrightarrow{O S}=\overrightarrow{O R} \cdot \overrightarrow{O P}+\overrightarrow{O Q} \cdot \overrightarrow{O S}=\overrightarrow{O Q} \cdot \overrightarrow{O R}+\overrightarrow{O P} \cdot \overrightarrow{O S}
$$

Then the triangle $P Q R$ has $S$ as its
[A] orthocenter

Q. 41 If $y=y(x)$ satisfies the differential equation

$$
8 \sqrt{x}(\sqrt{9+\sqrt{x}}) d y=(\sqrt{4+\sqrt{9+\sqrt{x}}})^{-1} d x
$$

[d] 3
[最 9

[D] $\frac{a}{80}$


$$
\text { and } y(0)=\sqrt{7}, \text { then } y(256)=
$$

Q. 42 If $f: \mathbb{R} \rightarrow \mathbb{R}$ is a twice differentiable function such that $f^{\prime \prime}(x)>0$ for all $x \in \mathbb{R}$, and $f\left(\frac{1}{2}\right)=\frac{1}{2}, f(1)=1$, then

[G] $0<f^{\prime}(1) \leq \frac{1}{2}$
[(0) $f^{\prime}(1) \leq 0$
Q. 43 Let $S=\{1,2,3, \ldots, 9\}$. For $k=1,2, \ldots, 5$, let $N_{k}$ be the number of subsets of $S$, each containing five elements out of which exactly $k$ are odd. Then $N_{1}+N_{2}+N_{3}+N_{4}+N_{5}=$


125
数 210
([1) $252 a$
Space for rough work

os


- This section contains SEVEN questions

- For each question, marks will be awarded in one of the following categories:

Full Marks
$:+4$
If only the bubbles) corresponding to all the correct options) is(are) darkened
Partial Marks
: +1
Zero Marks
For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened Negative Marks

If none of the bubbles is darkened
In all other cases


- For example, if $[\mathrm{A}],[\mathrm{C}]$ and [D] are all the correct options for a question, darkening all these 5 in then
three will get +4 marks; darkening only $[\mathrm{A}]$ and $[\mathrm{D}]$ will get +2 marks; and darkening $[\mathrm{A}]-5$ ? and $[B]$ will get -2 marks, as a wrong option is also darkened

[C] $\lim _{x \rightarrow 1^{-}} f(x)$ does not exist
[D] $\lim _{x \rightarrow 1^{+}} f(x)=0$
Q. 46 If $I=\sum_{k=1}^{98} \int_{k}^{k+1} \frac{k+1}{x(x+1)} d x$, then
[A] $I>\frac{49}{50}$
[白] $I>\log _{e} 99$

(6) $<\frac{49}{50}$
Q. 47 If $g(x)=\int_{\sin x}^{\sin (2 x)} \sin ^{-1}(t) d t$, then
[A] $g^{\prime}\left(\frac{\pi}{2}\right)=-2 \pi$
[B] $g^{\prime}\left(-\frac{\pi}{2}\right)=-2 \pi$
[G] $g^{\prime}\left(\frac{\pi}{2}\right)=2 \pi$

Q. 48 If the line $x=\alpha$ divides the area of region $R=\left\{(x, y) \in \mathbb{R}^{2}: x^{3} \leq y \leq x, 0 \leq x \leq 1\right\}$ into two equal parts, then
[4] $2 \alpha^{4}-4 \alpha^{2}+1=0$
[B] $\alpha^{4}+4 \alpha^{2}-1=0$
[8] $\frac{1}{2}<\alpha<1$
[B] $0<\alpha \leq \frac{1}{2}$

Space for rough work

Q. 49 If $f: \mathbb{R} \rightarrow \mathbb{R}$ is a differentiable function such that $f^{\prime}(x)>2 f(x)$ for all $x \in \mathbb{R}$, and $f(0)=1$, then
[A] $f(x)$ is decreasing in $(0, \infty)$
[8] $f(x)>e^{2 x}$ in $(0, \infty)$
[G] $f^{\prime}(x)<e^{2 x}$ in $(0, \infty)$
$f(x)$ is increasing in $(0, \infty)$
Q. 50 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] $\tan \left(\frac{\alpha}{2}\right)+\sqrt{3} \tan \left(\frac{\beta}{2}\right)=0$
[B] $\tan \left(\frac{\alpha}{2}\right)-\sqrt{3} \tan \left(\frac{\beta}{2}\right)=0$
[C] $\sqrt{3} \tan \left(\frac{\alpha}{2}\right)-\tan \left(\frac{\beta}{2}\right)=0$
[D] $\sqrt{3} \tan \left(\frac{\alpha}{2}\right)+\tan \left(\frac{\beta}{2}\right)=0$


## 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 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 In all other cases

## PARAGRAPH 1

Let $O$ be the origin, and $\overrightarrow{O X}, \overrightarrow{O Y}, \overrightarrow{O Z}$ be three unit vectors in the directions of the sides $\overrightarrow{Q R}, \overrightarrow{R P}$, $\overrightarrow{P Q}$, respectively, of a triangle $P Q R$.
Q. $51|\overrightarrow{O X} \times \overrightarrow{O Y}|=$
[d] $\sin 2 R$
[虭] $\sin (P+R)$

$\sin (P+Q)$
Q. 52 If the triangle $P Q R$ varies, then the minimum value of



## QUESTION PAPER FORMAT AND MARKING SCHEME

20. The question paper has three parts: Physics, Chemistry and Mathematics.
21. Each part has three sections as detailed in the following table:

|  |  |  | Category-wise Marks for Each Question |  |  |  | Maximum <br> Marks <br> of the <br> Section |
| :---: | :---: | :---: | :---: | :---: | :---: | :---: | :---: |
| Section | Question Type | Number of | Full Marks | Partial Marks | Zero Marks | Negative Marks |  |
| 1 | Single Correct Option | 7 | If only the bubble corresponding to the correct option is darkened | $-$ | 0 If none of the bubbles is darkened | -1 <br> In all other <br> cases | $21$ |
| 2 | One or <br> more <br> correct <br> option(s) |  |  | For darkening a bubble corresponding to each correct option, provided NO incorrect option is darkened | If none of the bubbles is darkened |  | 28 |
| 3 | Comprehension | 4 | If only the bubble corresponding to the correct option is darkened | - | 0 <br> In all other cases | - | 12 |

