### Subject Part – 1: Physics
SECTION 1 (32 Marks)

- This section contains **EIGHT (8)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, darken the bubble on the OMR sheet corresponding to the correct answer.
- Answer to each question will be evaluated <u>according to the following marking scheme</u>:

  Full Marks : $+4$ If **ONLY** the correct option is chosen;
  Zero Marks : 0 If none of the options is chosen (i.e., the question is unanswered).
  Negative Marks : -1 In all other cases

Q.1 *For the simple harmonic motion, the correct statement is*

(A) the kinetic energy varies between zero and a maximum value.
(B) the potential energy remains constant.
(C) the total energy varies between a minimum value and a maximum value.
(D) the kinetic energy remains constant.

Q.2 *An object is placed in front of a thin biconvex lens at a distance $2f$ from the lens, where f is the focal length of the lens. An inverted image of the same size is formed at a distance $2f$ behind the lens. Now the object is shifted by a small distance towards the lens. The image will*

(A) move towards the lens and will reduce in size.
(B) move towards the lens and will increase in size.
(C) move away from the lens and will reduce in size.
(D) move away from the lens and will increase in size.

Q.3 *The angular momentum $\vec{L}$ is conserved for a particle of mass m, moving in a circular path of radius r with a constant angular speed ω. The statement which is **NOT** correct, is*

(A) the associated torque is zero.
(B) direction of $\vec{L}$ does not change with time.
(C) the angular acceleration is zero.
(D) the magnitude of $\vec{L}$ varies with time.

Q.4 *A parallel plate capacitor, having a plate area A and separation between the plates d, stores U_1 amount of energy. If the area of the plates is halved and the distance between the plates is doubled, keeping the surface charge density same, the energy stored in the capacitor is U_2. The correct relation is*

(A) $U_2 = U_1$ (B) $U_2 = 2U_1$ (C) $U_2 = 4U_1$ (D) $2U_2 = U_1$

Q.5 *An inductor of $0.3\ H$ inductance is connected to an AC source of peak e.m.f. $240\ V$ and frequency $50\ Hz$. The value of r.m.s. current through the inductor, in $amperes$, is (rounded off to two decimal places)*

(A) 2.55   (B) 1.80   (C) 3.60   (D) 0.39

Q.6   *A copper sphere of mass* $1\ kg$, *initially at* $50°\ C$, *is suspended from the ceiling of a large room with a thermally non-conducting string. The room temperature is* $25°\ C$. *The curve that best represents the qualitative variation of sphere's temperature* T *with time* t *is*

(A)   (B)   (C)   (D)
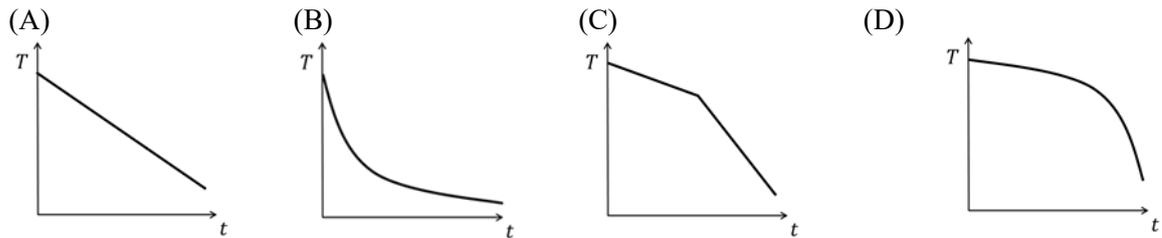
Q.7   *An electron is moving in a force-free region with a speed of* v. *The mass of the electron is measured to be* 4 *times its rest mass. If* c *is the speed of the light in free space, the value of* $\frac{v}{c}$ *is (rounded off to two decimal places)*

(A) 0.90   (B) 0.85   (C) 0.74   (D) 0.97

Q.8   *Three masses,* m, $2m$, *and* $3m$, *are placed in the* xy-*plane on vertices of a triangle whose coordinates are shown below. The coordinates* (x, y) *of the center-of-mass are given by*
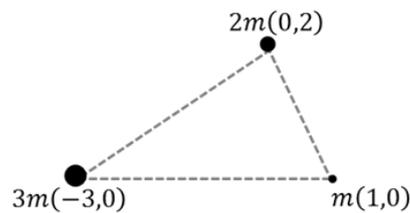
(A) $\left(-\frac{4}{3}, 1\right)$ (B) $(-2, 1)$ (C) $\left(-\frac{4}{3}, \frac{2}{3}\right)$ (D) $\left(-\frac{2}{3}, \frac{4}{3}\right)$

Subject Part – 1: Physics
SECTION 2 (24 Marks)

- This section contains **SIX (6)** questions.
- The answer to each question is a **SINGLE DIGIT NON-NEGATIVE INTEGER** ranging from 0 to 9, both inclusive.
- For each question, darken the correct digit on your **OMR sheet**. **Do not** write the answer on the question paper.
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Q.9 *A ray in a medium of refractive index 1 is incident on an interface with a medium of refractive index $\sqrt{3}$. If the angle of incidence is $60°$, the angle of refraction is $\frac{60}{p}$ degrees. The value of p is _____.*

Q.10 *Two point charges $+q$ and $-q$ are placed at a distance d from each other, as shown below. The electrostatic potential at a point P, at a distance $r \gg d$, is proportional to r^{-n}. The value of n is _____.*
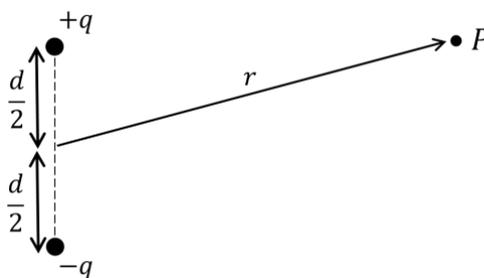
Q.11 *A large rock bed is used as a thermal storage system to run a heat engine. The rock bed has a temperature of $400\ K$ and the ambient surroundings are at $300\ K$. If $4 \times 10^6\ J$ heat is extracted by the heat engine from the rock bed, the maximum possible work output of the heat engine is $n \times 10^6\ J$. The value of n is_____.*

Q.12 *A barometer uses a liquid of density $800\ kg\ m^{-3}$. The least count of the ruler for measuring the liquid level in the barometer is $1\ mm$. The smallest pressure difference that can be measured by the barometer, in pascals, is _____ .*
[Take acceleration due to gravity g as $10\ m\ sec^{-2}$]

Q.13 *A point particle, initially at rest, starts moving in a straight line under the influence of an external force. The power delivered to the particle is proportional to time t. The speed of the particle is proportional to t^α. The value of α is _____.*

Q.14 *The de-Broglie wavelength associated with a ball of mass $3\ kg$, moving with a speed of $1.1\ m\ sec^{-1}$ is $n \times 10^{-34}\ m$. The value of n is _____.*
[Take value of the Planck constant as $6.6 \times 10^{-34}\ J\ sec$]

**Subject Part – 1: Physics**
SECTION 3 (24 Marks)

- This section contains **THREE (3)** paragraphs.
- Based on each paragraph, there are **TWO (2)** questions.
- The questions are of multiple-choice type, based on the given paragraph.
- If the answer is numerical, the final answer is obtainable by truncation/round-off of the value to TWO decimal places.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
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 *Negative Marks* : -1 In all other cases

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PARAGRAPH I

A uniformly distributed current of $I = 2\,A$ is flowing through an infinitely long wire of radius R, as shown below.
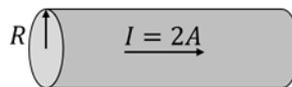
Q.15 *Which of the following correctly represents the radial variation of the magnitude of magnetic field B inside the wire?*
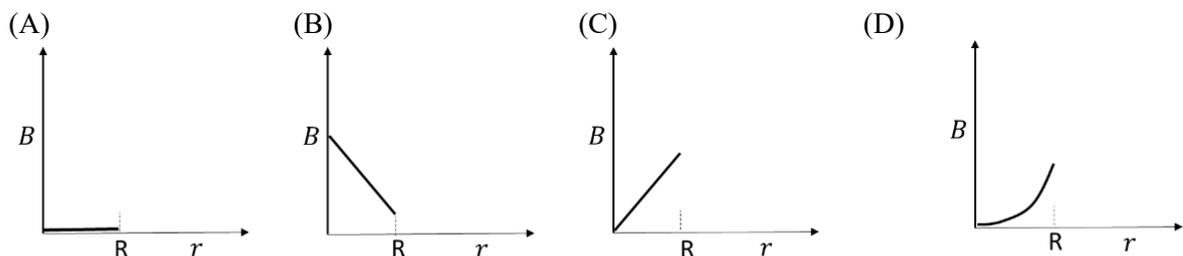

Q.16 *Which of the following correctly represents the radial variation of the magnitude of magnetic field B outside the wire*
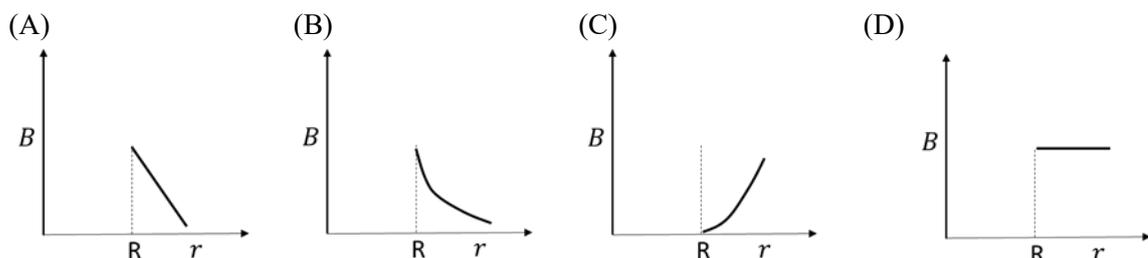
Water of density ρ discharges from a small hole on the side of a large tank with a speed v, as shown below. The top of the tank is open to the atmosphere. The tank is large enough so that the water level remains practically constant at a height H. The hole is located at a height h from the ground. The water stream exiting the hole strikes the ground at a distance L from the tank.
[*Take acceleration due to gravity as g*]
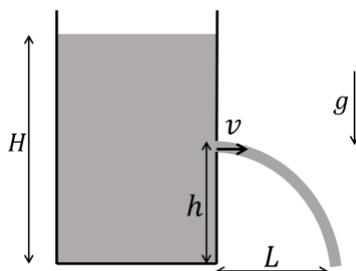
Q.17   *The water exits the hole with a speed v, given by*

(A) $\sqrt{2gH}$ (B) $\sqrt{2g(H-h)}$ (C) $\sqrt{2gh}$ (D) $\sqrt{gh}$

Q.18   *The distance L is*

(A) h (B) $v\sqrt{\dfrac{H}{g}}$ (C) $v\sqrt{\dfrac{2h}{g}}$ (D) $v\sqrt{\dfrac{h}{2g}}$

PARAGRAPH III

An electron in a Hydrogen atom jumps from the sixth energy level to the third energy level.

Q.19   *The wavelength of the light emitted as a result of this transition is $n \times 10^{-6}$ m. The value of n is (rounded off to one decimal places)*
        [*Take Rydberg constant as 1.097×10^7 m^{-1} and the speed of light c as 3×10^8 $m\ sec^{-1}$*]

(A) 1.1   (B) 1.0   (C) 1.2   (D) 0.9

Q.20   *The kinetic energy of the electron in the third energy level, in eV, is (rounded off to two decimal places)*

(A) 0.85   (B) 3.40   (C) 1.90   (D) 1.51

END OF SUBJECT PART - PHYSICS

Subject Part – 2: Chemistry
SECTION 1 (32 Marks)

- This section contains **EIGHT (8)** questions.
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- For each question, darken the bubble on the OMR sheet corresponding to the correct answer.
- Answer to each question will be evaluated <u>according to the following marking scheme</u>:
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  Zero Marks   :   0 If none of the options is chosen (i.e., the question is unanswered).
  Negative Marks : -1 In all other cases

Q.21 *The IUPAC name of the following compound is*
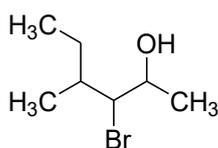
(A) 3-Bromo-4-methylhexan-2-ol   (B) 2-Hydroxy-3-bromo-4-methylhexane
(C) 3-Bromo-4-ethylpentan-2-ol   (D) 2-Ethyl-3-bromo-4-hydroxypentane

Q.22 *The major product **Y**, formed in the following reaction is*

(A)

(B)

(C)

(D)

Q.23 *The correct order of the first ionization enthalpies of the following atoms is*
N, Be, Ne, Li, F

(A) Ne < F < N < Be < Li
(B) Li < Be < N < F < Ne
(C) Be < Li < N < Ne < F
(D) Li < Be < F < N < Ne

Q.24   Among the following compounds, the most acidic oxide is
        B_2O_3, Al_2O_3, N_2O_5, CO

        (A) B_2O_3
        (B) Al_2O_3
        (C) N_2O_5
        (D) CO

Q.25   The element having electronic configuration of $[Kr]4d^{10}4f^{14}5s^25p^66s^2$ belongs to

        (A) s-block   (B) p-block   (C) d-block   (D) f-block

Q.26   6.51 g water occupies a volume of 6.50 ml. The density of water should be reported, with correct
        significant digits, as

        (A) 1 g/ml   (B) 1.0 g/ml   (C) 1.00 g/ml   (D) 1.001 g/ml

Q.27   A molecule is excited by 400 nm light and subsequently emits green light of wavelength 530 nm.
        The loss of energy in the process is $\left[Use\ E \text{ (in eV)} = \frac{1240}{\lambda \text{ (in nm)}}\right]$

        (A) 0.76 eV   (B) 9.54 eV   (C) 2.34 eV   (D) 1.33 eV

Q.28   During vaporization of 1 mole of liquid Q, the molar enthalpy and internal energy change are 11.0
        $kJ\ mol^{-1}$ and 6.5 $kJ\ mol^{-1}$, respectively. If the vaporization occurs at a pressure of 1 bar, the
        temperature during this phase change is [Consider Q vapor to behave as an ideal gas, use $R = 8.314\ J\ mol^{-1}K^{-1}$].

        (A) 2108.4 K   (B) 541.2 K   (C) 468.1 K   (D) 1028.3 K

Subject Part – 2: Chemistry
**SECTION 2 (24 Marks)**

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Q.29   *The total number of pi (π) bonds present in the given organic compound* **R** *is _____.*
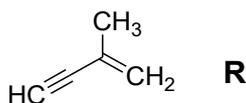
Q.30   *In the following reaction, the number of oxygen atoms present in the aromatic product* **T** *is _____.*
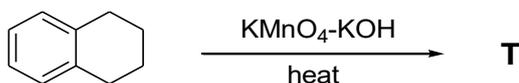
Q.31   *For the preparation of 20 mL of 1.775 mM solution of diphenylamine, the weight (in mg, closest integer value) of the compound required is _____.*
        [*molecular weight of diphenylamine = 169.23*]

Q.32   *The number of bonding electron pairs present in the covalent bonds of H_2SO_4 is _____.*

Q.33   *An ideal gas gets compressed to 1/6 of its volume, when the pressure is increased to twice its initial value. The ratio of temperatures, $T_{initial}/T_{final}$ is _____.*

Q.34   *The order of a reaction, whose half-life remains constant throughout the reaction is _____.*

Subject Part – 2: Chemistry
**SECTION 3 (24 Marks)**

- This section contains **THREE (3)** paragraphs.

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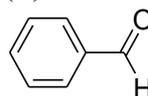

PARAGRAPH IV

Aldehydes can undergo Cannizzaro reaction. They undergo self-oxidation and reduction reaction on heating with concentrated alkali.

Q.35   *Among the given aldehydes, which will NOT undergo Cannizzaro reaction?*
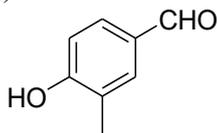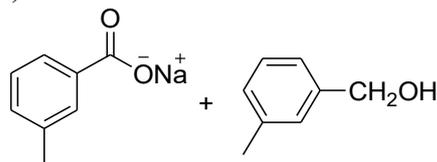
(A)
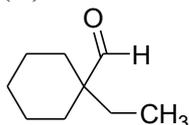
(B)

(C) HCHO

(D) CH_3CHO

Q.36   *m-Tolualdehyde on heating with concentrated NaOH, gives a product/ product mixture, represented by* **P**. *Here,* **P** *is*
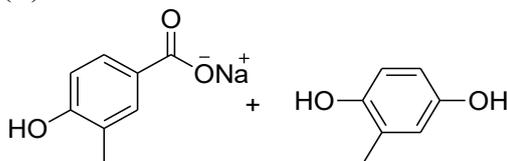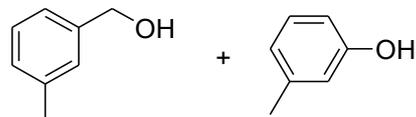
(A)

(B)

(C)

(D)

PARAGRAPH V

Pauli exclusion principle states that no two electrons in an atom can have the same set of four quantum numbers.

Q.37   *The INCORRECT statement below is:*

(A) A maximum of two electrons may exist in the same orbital.
(B) In an atom, the total number of up-spins need not necessarily be equal to the total number of down-spins.
(C) The maximum number of electrons that can be accommodated in the shell with principal quantum number n is equal to $2n^2$.
(D) In d subshell, the maximum number of electrons that can be accommodated is 5.

Q.38   *The CORRECT electronic configuration of carbon is*

(A)

$1s$ $2s$ $2p$

(B)

$1s$ $2s$ $2p$

(C)

$1s$ $2s$ $2p$

(D)

$1s$ $2s$ $2p$
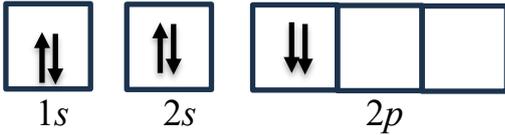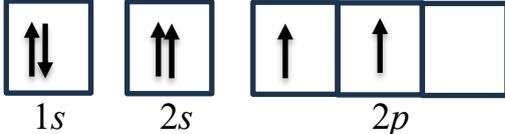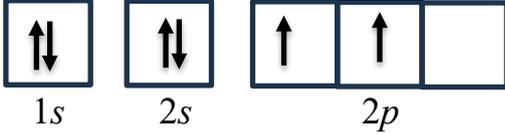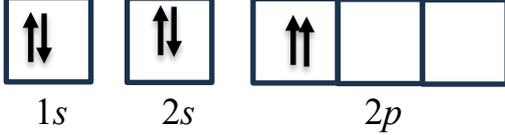
PARAGRAPH VI

Electromagnetic waves cover a wide range of radiations such as microwaves, X-rays, radio waves, visible light and others.

Q.39   *The correct order of energy of these radiations is*

(A) X-rays > visible light > microwaves > radio waves
(B) microwaves > radio waves > X-rays > visible light
(C) visible light > X-rays > radio waves > microwaves
(D) X-rays > visible light > radio waves > microwaves

Q.40   *The electromagnetic radiation of 1000 m wavelength belongs to*

(A) microwave   (B) X-rays
(C) visible light   (D) radio wave

END OF SUBJECT PART – CHEMISTRY

Subject Part – 3: Mathematics
SECTION 1 (32 Marks)

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Q.41 *The function $f(x) = \frac{x[x]}{x^2+1}$, where $[x]$ is the greatest integer which is less than or equal to x, is continuous on*

(A) $(-1, 1)$ (B) $(1, 3)$ (C) $(0, 2)$ (D) $(-2, 0)$

Q.42 *The age of X is the double the age of his daughter, and fifteen years back his age was three times the age of his daughter. Consider the following statements.*
  I)   Twenty years back, the age of X was five times the age of his daughter.
  II)   Their age difference is 30.
  Then which one of the following is TRUE?

(A) *I) only*   (B) *II) only*   (C) *Both I) and II)*   (D) *Neither I) nor II)*

Q.43 *Suppose that P is a point such that the difference of the square of the distances of P from the lines $x + y = 1$ and $x - y = -1$ is 50. Then the locus of P is*

(A) $xy = 25$ (B) $xy - x = 25$ (C) $xy - y = 25$ (D) $xy - x - y = 25$

Q.44 *Consider the vectors*

$$\vec{a} = 4\hat{\imath} + 3\hat{\jmath}, \ \vec{b} = 3\hat{\jmath} + 4\hat{k} \text{ and } \vec{c} = 8\hat{\imath} + 6\hat{k}.$$

Which one of the following vectors makes equal angle with $\vec{a}, \vec{b}$ and $\vec{c}$?

(A) $\hat{\imath} - \hat{\jmath} + \hat{k}$ (B) $\hat{\imath} + \hat{\jmath} - \hat{k}$ (C) $-\hat{\imath} + \hat{\jmath} + \hat{k}$ (D) $\hat{\imath} + \hat{\jmath} + \hat{k}$

Q.45 *The faces of an unfair die are marked 1 to 6. The probability of a face while rolling the die is given by the following table where two entries are missing:*

Outcome	1	2	3	4	5	6
probability	0.1	0.1	0.2	0.1	–	–

If the expected value of an outcome when the die is rolled is 4.1, then what is the absolute difference between the missing entries?

(A) 0   (B) 0.1   (C) 0.15   (D) 0.2

Q.46 *Let a, b, c, d be real numbers such that $a^2 + b^2 + c^2 + d^2 = 1$ and $i = \sqrt{-1}$.*

If $P = \begin{pmatrix} a - ib & -c + id \\ c + id & a + ib \end{pmatrix}$, then P^{-1} is

(A) $\begin{pmatrix} a + ib & c - id \\ -c - id & a - ib \end{pmatrix}$

(B) $\begin{pmatrix} -a + ib & c + id \\ -c + id & -a - ib \end{pmatrix}$

(C) $\begin{pmatrix} -a - ib & c - id \\ -c - id & -a - ib \end{pmatrix}$

(D) $\begin{pmatrix} a - ib & -c + id \\ c + id & a + ib \end{pmatrix}$

Q.47 *The area bounded by the curves $y = x^2 - 2$ and $x + y = 0$ is equal to*

(A) $\dfrac{10}{3}$ (B) $\dfrac{9}{2}$ (C) $\dfrac{7}{2}$ (D) $\dfrac{11}{3}$

Q.48 *The value of the integral*

$$\int_{\frac{\pi}{4}}^{\frac{\pi}{2}} \frac{\cos 5x}{\sin x}\, dx$$

is equal to

(A) $\log_e 2$ (B) $\dfrac{\log_e 3}{2}$ (C) $\dfrac{\log_e 2}{2}$ (D) $\dfrac{\log_e 3}{4}$

Subject Part – 3: Mathematics
SECTION 2 (24 Marks)

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  Zero Marks　　:　 0   In all other cases.

Q.49　*Suppose* $f(x) = ax^2 + bx + \frac{c}{x} + \frac{d}{x^2}, \ x \neq 0,$ *where* a, b, c, d *are real numbers,* $f(2) = 6, f'(2) = 3,$ *and* $\lim_{x \to 0} f(x) = 0.$ *Then* $a + b$ *is equal to_____*

Q.50　*In an experiment, two observations are missing where each observation is a positive integer. The data set is* $5, 1, 2, 2, 2, 3, 3, 4, 4, -, -, 5, 1.$ *If the difference between the missing observations is 1 and the median of the data is 2, then the sum of the missing observations is equal to _____*

Q.51　*The number of values of* $k \in (-\infty, \infty)$ *for which the system of equations*

$$(k + 1)x + 8y = 4k$$

$$kx + (k + 3)y = 3k - 1$$

　　　has infinitely many solutions is equal to _____

Q.52　*In a fraction if both the numerator and the denominator are decreased by 1, it is equal to* $\frac{1}{2}.$ *If the numerator is increased by 2, it is equal to* $\frac{2}{3}.$ *The absolute value of the difference between the numerator and the denominator is equal to _____*

Q.53　*The value of the integral*

$$\frac{1}{\pi} \int_0^2 \frac{\sqrt{3}}{x^2 - x + 1} \, dx$$

　　　is equal to _____

Q.54　*Suppose the latus rectum of the ellipse* $\frac{x^2}{9} + \frac{y^2}{b^2} = 1$ *is* $\frac{50}{3}.$ *If* e *is the eccentricity of the ellipse, then* $b + 5e$ *is_____*

Subject Part – 3: Mathematics
SECTION 3 (24 Marks)

- This section contains **THREE (3)** paragraphs.
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- The questions are of multiple-choice type, based on the given paragraph.
- If the answer is numerical, the final answer is obtainable by truncation/round-off of the value to TWO decimal places.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, darken the bubble on the OMR sheet corresponding to the correct answer.
- Answer to each question will be evaluated <u>according to the following marking scheme</u>:
  Full Marks   : $+4$ If **ONLY** the correct option is chosen;
  Zero Marks   :   0 If none of the options is chosen (i.e., the question is unanswered).
  Negative Marks : -1 In all other cases

PARAGRAPH VII

Consider the system of two linear equations:
$$px + qy = \alpha$$
$$rx + sy = \beta$$
where α, β are real numbers and $p, q, r, s \in \{0, 1\}$.

Q.55 *If $\alpha = \beta = 0$, then the number of 2×2 matrices $\begin{pmatrix} p & q \\ r & s \end{pmatrix}$ for which the above system has a unique solution is*

  (A) 6   (B) 7   (C) 8   (D) 9

Q.56 *If $\alpha = 1, \beta = 0$, then the number of 2×2 matrices $\begin{pmatrix} p & q \\ r & s \end{pmatrix}$ for which the above system has infinitely many solutions is*

  (A) 0   (B) 7   (C) 3   (D) 6

PARAGRAPH VIII

Consider the function
$$f(x) = \begin{cases} (\log_e |x|) \, e^{-\frac{1}{x^2}}, & x \neq 0 \\ 0, & x = 0 \end{cases}$$

Q.57 *Then the value of the limit*
$$\lim_{x \to 0} f(x)$$
  is equal to

  (A) 0   (B) 1   (C) e^{-1} (D) e

Q.58 *The number of points of local maxima or local minima of $f(x)$ is equal to*

  (A) 2   (B) 3   (C) 1   (D) 0

PARAGRAPH IX

Consider the experiment of rolling an unbiased die. Let P and Q be the events of getting a prime number and an odd number respectively.

Q.59   *Which one of the following statements is TRUE?*

(A) The probability of happening of both P and Q is $\frac{1}{2}$

(B) The probability of happening of Q but not P is $\frac{1}{3}$

(C) The probability of not happening of P is $\frac{1}{2}$

(D) The probability of happening of P but not Q is $\frac{1}{3}$

Q.60   *The probability of happening of P or Q is*

(A) $\frac{1}{3}$ (B) $\frac{1}{2}$ (C) $\frac{1}{4}$ (D) $\frac{2}{3}$

END OF THE QUESTION PAPER

Rough work:

Rough Work

Rough Work

Rough Work

Rough Work