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>:

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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.1   *A point source produces electromagnetic radiation. The peak electric field is E at a distance d from the source. If the power of the source is reduced to half, the peak value of the electric field at the same location is*

(A) $2E$ (B) $\sqrt{2}E$ (C) $\frac{E}{2}$ (D) $\frac{E}{\sqrt{2}}$

Q.2   *For the simple harmonic motion, the correct statement is*

(A) the speed is minimum and the displacement is maximum at the extrema.
(B) the speed is maximum and the displacement is minimum at the extrema.
(C) the speed is minimum and the displacement is minimum at the extrema.
(D) the speed is maximum and the displacement is maximum at the extrema.

Q.3   *An electromagnetic wave is travelling along the $+z$-direction and its electric field is in the x-direction. The magnetic field vector is*

(A) in the xz plane.
(B) in the yz plane.
(C) along the z-axis.
(D) along the x-axis.

Q.4   *A thin spherical shell of radius R has a uniform surface charge density σ, as shown below. Which of the following curves represents the correct radial variation of total electric field from the center of the shell to a point P outside the shell?*

(A)   (B)   (C)   (D)
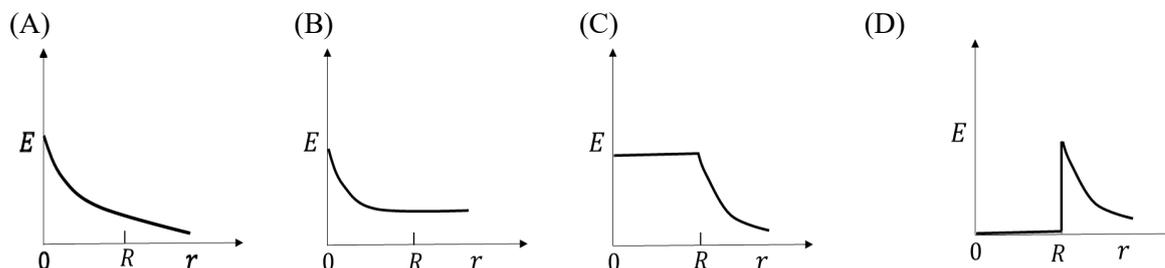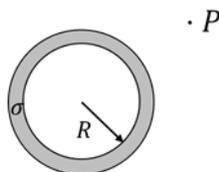
Q.5   *In the emission spectrum of Hydrogen atom, the series limit of the Balmer series is obtained at a wavelength of* 364.6 nm. *The radiation of this wavelength is emitted when an electron jumps from an initial state* n_i *to a final state* n_f. *The correct values of* n_i *and* n_f *are*
[*Take Rydberg constant as* $1.097 \times 10^7 \ m^{-1}$]

(A) $n_i = 2, \ n_f = 1$
(B) $n_i = \infty, \ n_f = 1$
(C) $n_i = 3, \ n_f = 2$
(D) $n_i = \infty, \ n_f = 2$

Q.6   *A rigid cylinder with adiabatic walls is partitioned into two chambers X and Y of equal volumes, as shown below. Chamber X is filled with a gas and chamber Y has vacuum. The partition is now removed and the gas fills the entire cylinder. For this process, the correct option is*
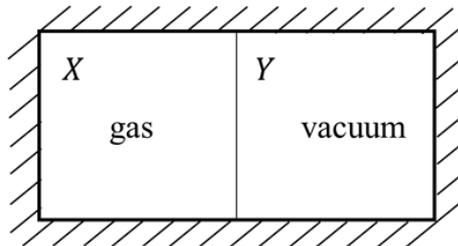
(A) internal energy of the gas increases.
(B) internal energy of the gas decreases.
(C) internal energy of the gas does not change.
(D) internal energy of the gas may increase or decrease depending on the type of gas.

Q.7   *The Reynolds number for fluid flow in a pipe represents the ratio of*

(A) inertial force to viscous force.
(B) inertial force to buoyancy force.
(C) buoyancy force to viscous force.
(D) surface tension to viscous force.

Q.8   *A person of mass* 60 kg *is sitting at one of the extreme ends of a boat mass* 40 kg *and having a length of* 4 m *(assume that mass is uniformly distributed across the boat). The boat is floating on still water. The person then moves to the middle of the boat. Neglecting friction with the water, the distance moved by the boat on the water, in* meters, *is*

(A) 0.0   (B) 1.2   (C) 1.5   (D) 2.0

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

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- The answer to each question is a **SINGLE DIGIT NON-NEGATIVE INTEGER** ranging from 0 to 9, both inclusive.
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 *Zero Marks*　　 :　 0　In all other cases.

Q.9　*An infinitely long air-core solenoid has 5000 turns per meter. The current required to produce a magnetic field of $4\pi \times 10^{-3}$ Tesla inside the solenoid, in amperes, is _____.*
[Take permeability of the free space μ_0 as $4\pi \times 10^{-7}$ H m^{-1}]

Q.10　*An inductor of 0.02 H inductance and a resistor of $2\ \Omega$ resistance are connected in series to an AC source of r.m.s. value $8\ V$ and frequency $50\ Hz$. The power dissipated in this circuit, in watts, is ____. (rounded off to the nearest integer)*
[Take π^2 as 10]

Q.11　*A ray is incident on a plane mirror such that the angle between the incident ray and the reflected ray is $30°$. The mirror is now tilted by $20°$ in such a way that the angle of incidence increases. The angle between the incident ray and the reflected ray is now θ. The value of $\frac{\theta}{10}$ is _____.*

Q.12　*The sublimation curve of a substance on a pressure versus temperature phase diagram is given by $ln\frac{p}{p_0} = 0.02 - \frac{1}{T}$, where p is the pressure, T is the temperature in kelvin, and $p_0 = 1\ atm$. The vaporization curve for the substance is given by $ln\frac{p}{p_0} = 0.04 - \frac{5}{T}$. The triple point of the substance is T_{tp} kelvin. The value of $\frac{T_{tp}}{100}$ is _____.*

Q.13　*The threshold wavelength for the emission of photo-electrons from a metal surface with a work-function of $4.14\ eV$ is $n \times 10^{-7}\ m$. The value of n is ____.*
[Take value of the Planck constant as $4.14 \times 10^{-15}\ eV\ sec$ and speed of light c as $3 \times 10^8\ m\ sec^{-1}$]

Q.14　*Two balls P and Q are dropped from two buildings of heights h_P and h_Q, respectively. To reach the ground, the ball P takes $1.2\ sec$ while the ball Q takes $0.4\ sec$. The value of $\frac{h_P}{h_Q}$ is _____.*
　[Neglect air resistance. Take acceleration due to gravity g as $10\ m\ sec^{-2}$]

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

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

A composite slab is made by joining two infinite slabs of finite thickness made of copper and brass, as shown below. Both slabs have equal thickness. The free end of the copper slab is maintained at $400\ K$ and the free end of the brass slab is kept at $300\ K$. The thermal conductivity of copper is $400\ W\ m^{-1}\ K^{-1}$ and that of brass is $100\ W\ m^{-1}\ K^{-1}$.
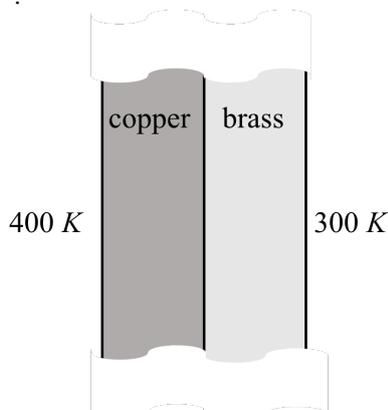
Q.15   *At steady-state, the rate of heat transfer from the free end of the copper slab is $\dot{Q}_C$ and that from the free end of the brass slab is $\dot{Q}_B$. The correct option is*

(A) $\dot{Q}_C = \dot{Q}_B = 0$ (B) $\dot{Q}_C < \dot{Q}_B$ (C) $\dot{Q}_C = \dot{Q}_B \neq 0$ (D) $\dot{Q}_C > \dot{Q}_B$

Q.16   *At steady-state, the temperature of the junction of the two slabs, in kelvin, is*

(A) 350   (B) 380   (C) 370   (D) 365

PARAGRAPH II

A liquid flows through a venturi tube as shown below. The cross-sectional area at sections 1 and 2 is A_1 and A_2, respectively. The velocity of the liquid at sections 1 and 2 is v_1 and v_2, respectively. The height difference between the liquid levels in the vertical limbs is h. [Take the acceleration due to gravity as g]
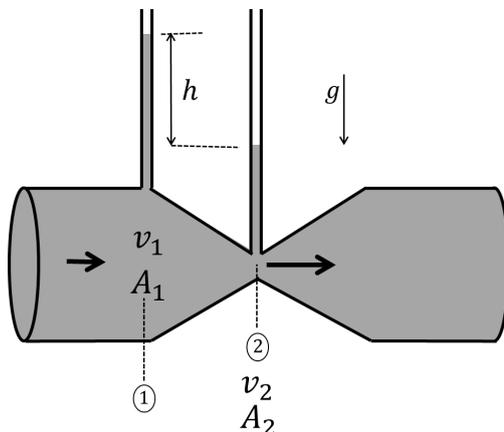
Q.17 The velocity v_2 is given by

(A) $\frac{A_1 v_1}{A_2}$ 　　　(B) $\frac{A_2 v_1}{A_1}$ 　　　(C) $\sqrt{2gh}$ 　　　(D) $v_1\left(1 - \frac{A_2}{A_1}\right)$

Q.18 The height difference h is given by

(A) $\frac{v_1^2}{2g}$ 　　　(B) $\frac{v_2^2 - v_1^2}{2g}$ 　　　(C) $\frac{v_2^2}{2g}$ 　　　(D) $\frac{(v_2 - v_1)^2}{2g}$

PARAGRAPH III

An electron is moving in a force free region with a speed of $3 \times 10^6 \, m \, sec^{-1}$.

Q.19 The kinetic energy of the electron, in eV, is (rounded off to two decimal places)
[Take rest energy of the electron as $511 \, keV$ and the speed of light c as $3 \times 10^8 \, m \, sec^{-1}$]

(A) 28.50 　　　(B) 27.75 　　　(C) 25.55 　　　(D) 26.25

Q.20 The de-Broglie wavelength of the electron, in nm, is (rounded off to two decimal places)
[Take value of Planck constant as $6.6 \times 10^{-34} \, J \, sec$ and rest mass of the electron as $9.1 \times 10^{-31} \, kg$]

(A) 0.18 　　　(B) 0.24 　　　(C) 0.16 　　　(D) 0.29

END OF SUBJECT PART - PHYSICS

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

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  Negative Marks : -1 In all other cases

Q.21 *The compound which is NOT isomeric with ethyl vinyl ether ($CH_3CH_2OCH=CH_2$) is*

(A) Cyclobutanol (B) Butanal
(C) Diethyl ether (D) Cyclopropyl methyl ether

Q.22 *Gabriel phthalimide synthesis is*

(A)
$$RX \ + \ NH_3$$

(B)

(i) ethanolic KOH
(ii) RX, heat
(iii) aqueous NaOH

(C)
$$R\overset{+}{N_2}\overset{-}{Cl} \ + \ H_3PO_4$$

(D)

$+ \ R\overset{+}{N_2}\overset{-}{Cl}$

Q.23 *The structure of major product **P** in following reaction sequence is*

$$C_8H_6 \ + \ H_2O \xrightarrow[\text{333 K}]{\text{HgSO}_4,\ \text{dil. H}_2\text{SO}_4} C_8H_8O \xrightarrow[\text{(ii) H}_3\text{O}^+]{\text{(i) CH}_3\text{CH}_2\text{MgBr}} \mathbf{P}$$

(A)

(B)

(C)

(D)

Q.24 *Among the molecules BF₃, SF₄, XeF₄, PCl₅, the one having maximum number of atoms lying in the same plane is*

(A) BF_3 (B) SF_4 (C) XeF_4 (D) PCl_5

Q.25 *Among the following ions, the CORRECT order of increasing oxidation number of the central metal ion is*

(A) $MnO_4^- < CrO_4^{2-} < VO_4^{3-} < CrO_2^-$
(B) $CrO_2^- < VO_4^{3-} < MnO_4^- < CrO_4^{2-}$
(C) $CrO_2^- < CrO_4^{2-} < VO_4^{3-} < MnO_4^-$
(D) $CrO_2^- < VO_4^{3-} < CrO_4^{2-} < MnO_4^-$

Q.26 *Which of the following is NOT an example of an endothermic process?*

(A) Melting of ice cubes
(B) Dilution of sulfuric acid
(C) Boiling of water at 1 atmospheric pressure
(D) Sublimation of dry ice

Q.27 *The correct graph with temperature $T_1 > T_2 > T_3$ for 1 mole of an ideal gas is*
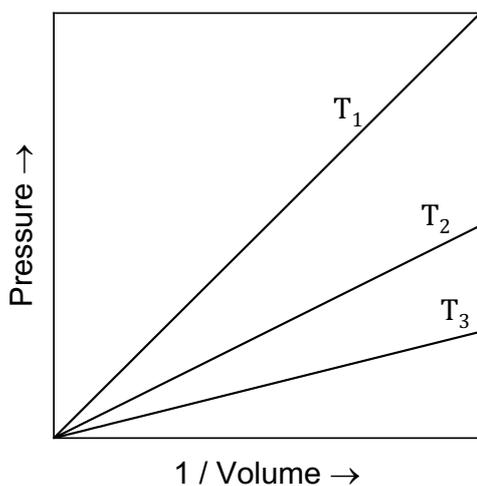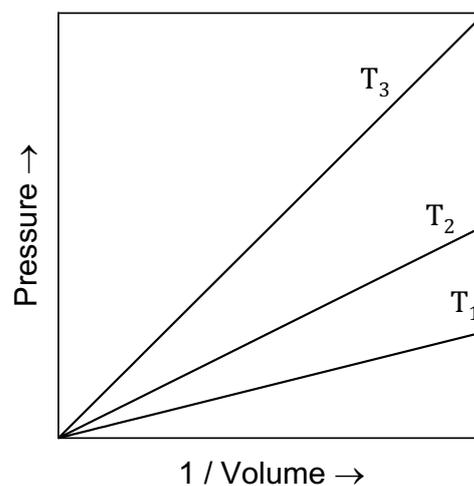
(A)
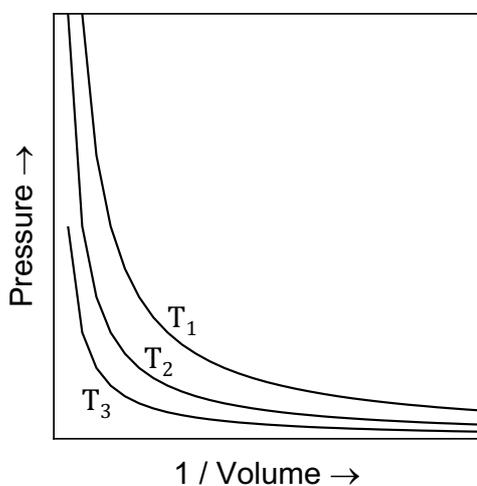
(B)
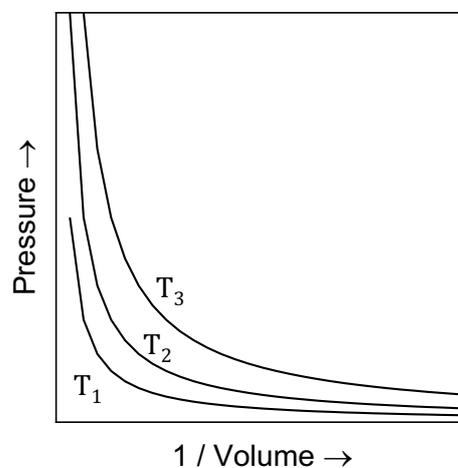
(C)

(D)

Q.28   *For a zeroth order reaction, the half-life is*

(A) a constant.
(B) inversely proportional to the initial concentration of the reactant.
(C) directly proportional to the initial concentration of the reactant.
(D) directly proportional to the concentration of the product.

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

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Q.29   *The value of **n** in the following reaction is _____.*

   $3\ C_6H_5CHO + K_2Cr_2O_7 + 8\ HCl \rightarrow 3\ C_6H_5COOH + 2\ CrCl_3 + 2\ KCl + \textbf{n}\ H_2O$

Q.30   *The total number of different carbonyl compounds formed after complete ozonolysis ($O_3/Zn\text{-}H_2O$) of the given compound **U** is _____.*
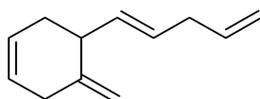
U

Q.31   *n-Heptane on heating to 773 K at 10-20 atmospheric pressure in the presence of V_2O_5, produces a product **X**. The number of sp^2 hybridized carbon atoms in **X** is _____.*

Q.32   *The orbital angular momentum quantum number (l) for " f " orbital is_____.*

Q.33   *A container of volume 8.314 m^3 under a total pressure of 6 mbar at 300 K has a mixture of gases with 0.5 mole fraction Argon. Assuming ideal gas behavior, the number of moles of Argon in the mixture is _____. [Use $R = 8.314$ $JK^{-1}mol^{-1}$, 1 bar $= 10^5$ Pa]*

Q.34   *A monochromatic beam of light delivers 1156.224 kJ energy. Each photon has 2 eV energy. The number of moles of photons in this beam is _____. [Use 1 eV $= 1.6 \times 10^{-19}$ J, Avogadro constant $= 6.022 \times 10^{23}$]*

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

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PARAGRAPH IV

In phenols, the aromatic ring undergoes electrophilic substitution reaction. The –OH group of phenol directs the incoming group at the ortho- and para- positions in the ring. The physical and chemical properties of phenols get influenced by inter- and intra- molecular interactions with the –OH group.

Q.35   *Among the following compounds, which one is the most acidic*

(A) Phenol   (B) 4-Methylphenol
(C) Ethanol   (D) 3-Nitrophenol
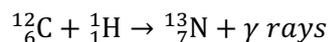
Q.36   *For the below given transformation of phenol, the correct reaction condition is*
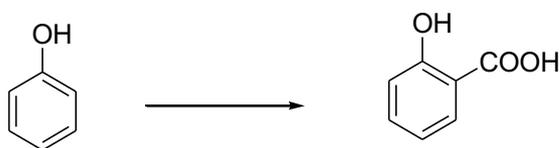
(A) (i) NaOH (ii) CO_2 (iii) H^+
(B) (i) $CHCl_3$ + aq. NaOH (ii) NaOH (iii) H^+
(C) (i) CO_2 (ii) H^+
(D) (i) $Na_2Cr_2O_7$ (ii) CO (iii) H^+

PARAGRAPH V

At higher stellar temperature, the following reaction occurs:

$$^{12}_{6}C + {}^{1}_{1}H \rightarrow {}^{13}_{7}N + \gamma \ rays$$

Q.37   The type of the reaction is

(A) fission   (B) fusion   (C) addition   (D) elastic scattering

Q.38   The charge of γ rays is

(A) +2e   (B) +e   (C) 0   (D) –e

PARAGRAPH VI

The reaction $C_2H_4(g) + H_2(g) \rightarrow C_2H_6(g)$ occurs at 298 K.

Q.39   Given $K_p = 8.1 \times 10^{-25}$, the standard Gibbs free energy change is [Use $R = 8.314 \ JK^{-1}mol^{-1}$]

(A) 137.4 kJ mol^{-1} (B) 59.7 kJ mol^{-1} (C) 16.5 kJ mol^{-1} (D) 461.2 kJ mol^{-1}

Q.40   Given that the heat exchanged reversibly, $q_{rev} = 80$ kJ mol^{-1}, the change in entropy (ΔS) is

(A) 2.3×10^4 kJ mol^{-1}K^{-1} (B) 0.53 kJ mol^{-1}K^{-1}
(C) 0.27 kJ mol^{-1}K^{-1} (D) 0 kJ mol^{-1}K^{-1}

END OF SUBJECT PART - CHEMISTRY

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

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  Negative Marks : -1　In all other cases

Q.41　*The range of the function*
$$f(x) = \frac{x|x|}{x^2 + 1}, \qquad x \in (-\infty, \infty)$$
　is

　(A) $[-1, 1]$　　　　(B) $(-1, 1)$　　　　(C) $(-\infty, \infty)$　　　　(D) $(0, \infty)$

Q.42　*There are 100 balls, each of which are painted with any two of the following three colors such that the two colors cover equal surface area: red, blue and green. If blue and red color used to paint are respectively* 40% *and* 30% *, then what is the probability that a ball picked at random is painted with red and green color?*

　(A) $\frac{1}{5}$　　　　(B) $\frac{1}{6}$　　　　(C) $\frac{1}{3}$　　　　(D) $\frac{2}{5}$

Q.43　*If S consists of the pair (p, q) of real numbers that satisfy $x^2 + 2px + q > 0$ for every real number x, and T consists of the pair (p, q) of real numbers that satisfy $y^2 + 2qy + p^4 > 0$ for every real number y. Then which one of the following statements is TRUE?*

　(A) $S = T$　　　　(B) $S \subset T$　　　　(C) $S \supset T$　　　　(D) $S \cap T$ is the empty set

Q.44　*Let P, Q and R be the mid points of the sides of the triangle EFG, and X, Y and Z be the mid points of the sides of triangle PQR. If the area of the triangle EFG is 1024 sq. cm., then the area of the triangle XYZ, in sq. cm., is*

　(A) 128　　　　(B) 64　　　　(C) 32　　　　(D) 16

Q.45　*If x, y, z are the side lengths of the triangle formed by the points with position vectors given by $\hat{\imath} + \hat{\jmath} - \hat{k}, -\hat{\imath} + 2\hat{\jmath}$ and $\hat{\jmath} + \hat{k}$, respectively, then the value of $x^2 + y^2 + z^2$ is*

　(A) 11　　　　(B) 12　　　　(C) 13　　　　(D) 14

Q.46   *If P and Q are two square matrices such that $PQ = Q$ and $QP = P$, then $P^2 + Q^2$ is equal to*

(A) $P + Q$ (B) $(P + Q)^2$ (C) PQ (D) $2P + Q$

Q.47   *The area bounded by the curves $y = e^x$, $y = xe^x$, and $x = 0$ is equal to*

(A) $e - 1$ (B) $2e - 1$ (C) $e - 2$ (D) $2e - 3$

Q.48   *The value of the integral*

$$\int_0^1 \frac{\sqrt{x}}{1 + \sqrt{x}} \, dx$$

is equal to

(A) $3 \log_e 2 - 1$ (B) $\log_e 2 - 1$ (C) $2 \log_e 2 - 1$ (D) $4 \log_e 2 - 1$

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

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Q.49   *The area bounded by the curves $y = 3x|x|$ and $y|y| = 9x$ is equal to _____*

Q.50   *The value of the limit*

$$\lim_{x \to 0}(\sin x)\log_{\mathrm{e}}|x|$$

is equal to _____

Q.51   *For $k \in \{1,2,\dots,n\}$, let $A_k = \begin{pmatrix} 1 & k \\ 0 & 1 \end{pmatrix}$. If the product $A_1\, A_2 \cdots A_n = \begin{pmatrix} 1 & 45 \\ 0 & 1 \end{pmatrix}$, then the value of n is equal to _____*

Q.52   *If $\bar{z}$ denotes the complex conjugate of z, then the number of complex numbers z satisfying the relation $z^2 = (\bar{z})^5$ is equal to _____*

Q.53   *Let E_1 and E_2 be two events such that $P(E_1) = 0.5$ and $P(E_1 \cup E_2) = P(E_1 \cap E_2)$. Then the value of $4P(E_2)$ is equal to _____*

Q.54   *The tangent to the ellipse $\dfrac{x^2}{2} + \dfrac{y^2}{3} = 1$ at the point $\left(1, \sqrt{\dfrac{3}{2}}\right)$ intersects the x-axis at P and the y-axis at Q. If d is the distance between P and Q, then $\dfrac{d^2}{2}$ is equal to _____*

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

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PARAGRAPH VII

A box contains 8 black, 6 white and 9 red coins. If the coin is black, white and red, then the probability of getting a head on tossing it is $\frac{1}{2}$, $\frac{1}{3}$ and $\frac{1}{4}$ respectively.

Q.55　*If a coin is picked randomly and tossed, then the probability that it is a tail is equal to*

(A) $\frac{59}{92}$　　　　　(B) $\frac{33}{92}$　　　　　(C) $\frac{35}{92}$　　　　　(D) $\frac{43}{92}$

Q.56　*A coin is picked randomly and tossed. If the outcome is a head, then the probability that the coin is red, is equal to*

(A) $\frac{8}{11}$　　　　　(B) $\frac{3}{11}$　　　　　(C) $\frac{5}{11}$　　　　　(D) $\frac{6}{11}$

PARAGRAPH VIII

For $x \in (-\infty, \infty)$, let $f(x) = 4 - x^2$ and $g(x) = -3|x|$.

Q.57　*The value of the integral*

$$4 \int_{-1}^{4} f(x)g(x)\, dx$$

　　　is equal to
　(A) 361　　　　　(B) 362　　　　　(C) 363　　　　　(D) 364

Q.58　*The area bounded by the curves $y = f(x)$ and $y = g(x)$ is equal to*

(A) $\frac{109}{3}$　　　　　(B) $\frac{110}{3}$　　　　　(C) $\frac{112}{3}$　　　　　(D) $\frac{114}{3}$

PARAGRAPH IX

Suppose $\vec{u}, \vec{v}$ are vectors such that the square of the moduli of $\vec{u}, \vec{v}$ and $\vec{u} + \vec{v}$ are in arithmetic progression with common difference 1.

Q.59   *If $\vec{u} - \vec{v} = \hat{\imath}$, then the value of $|\vec{u}|^2 + |\vec{v}|^2 + |\vec{u} + \vec{v}|^2$ is equal to*

   (A) 3   (B) 4   (C) 5   (D) 6

Q.60   *If $\vec{u} \cdot \vec{v} = 0$, then the value of $|\vec{u}|^2 + |\vec{v}|^2 + |\vec{u} + \vec{v}|^2$ is equal to*

   (A) 3   (B) 4   (C) 5   (D) 6

END OF THE QUESTION PAPER

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