

P1-16-3-0

PAPER-1

CODE

0

Time : 3 Hours

Maximum Marks : 186

**READ THE INSTRUCTIONS CAREFULLY**



**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 corner of this sheet and the right hand top corner 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 9:00 am, verify 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.

DO NOT BREAK THE SEALS WITHOUT BEING INSTRUCTED TO DO SO BY THE INVIGILATOR

SEAL

SEAL



*Abhinav*

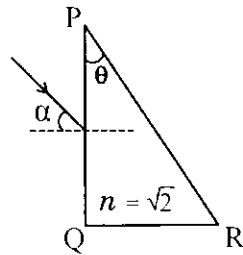
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# PART I : PHYSICS

## SECTION 1 (Maximum Marks: 15)

- This section contains **FIVE** 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 parallel beam of light is incident from air at an angle  $\alpha$  on the side PQ of a right angled triangular prism of refractive index  $n = \sqrt{2}$ . Light undergoes total internal reflection in the prism at the face PR when  $\alpha$  has a minimum value of  $45^\circ$ . The angle  $\theta$  of the prism is



(A)  $15^\circ$

(B)  $22.5^\circ$

(C)  $30^\circ$

(D)  $45^\circ$

Space for rough work

*Handwritten rough work:*

Diagram showing a ray incident on side PQ at angle  $\alpha$ . The ray refracts into the prism and undergoes total internal reflection at side PR. The angle of incidence at PR is  $\theta$ . The refractive index is  $n = \sqrt{2}$ .

$36\alpha^2 + 152\alpha + 121 = 0$   
 ~~$72\alpha^2 + 152\alpha + 121 = 0$~~   
 $36\alpha^2 + 152\alpha + 92 = 0$   
 $98\alpha^2 + 96\alpha + 63 = 0$



Q.4 A uniform wooden stick of mass 1.6 kg and length  $l$  rests in an inclined manner on a smooth, vertical wall of height  $h (< l)$  such that a small portion of the stick extends beyond the wall. The reaction force of the wall on the stick is perpendicular to the stick. The stick makes an angle of  $30^\circ$  with the wall and the bottom of the stick is on a rough floor. The reaction of the wall on the stick is equal in magnitude to the reaction of the floor on the stick. The ratio  $h/l$  and the frictional force  $f$  at the bottom of the stick are

( $g = 10 \text{ m s}^{-2}$ )

(A)  $\frac{h}{l} = \frac{\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3} \text{ N}$

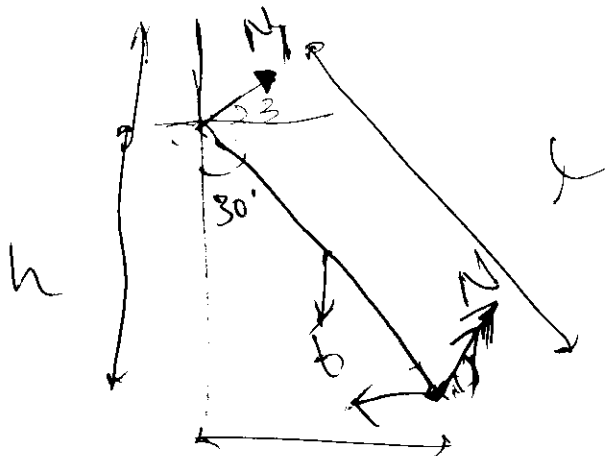
(B)  $\frac{h}{l} = \frac{3}{16}, f = \frac{16\sqrt{3}}{3} \text{ N}$

(C)  $\frac{h}{l} = \frac{3\sqrt{3}}{16}, f = \frac{8\sqrt{3}}{3} \text{ N}$

(D)  $\frac{h}{l} = \frac{3\sqrt{3}}{16}, f = \frac{16\sqrt{3}}{3} \text{ N}$

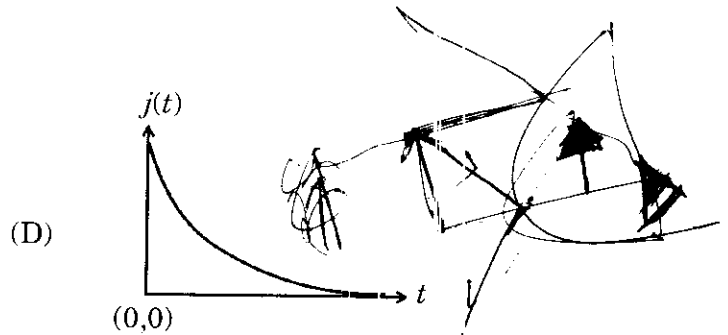
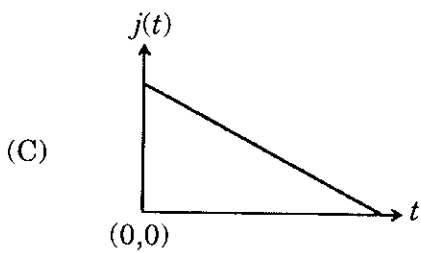
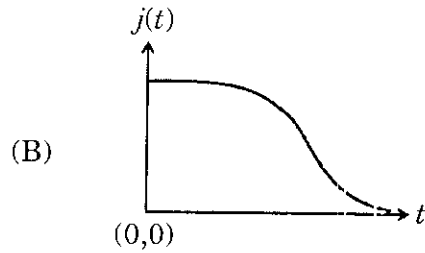
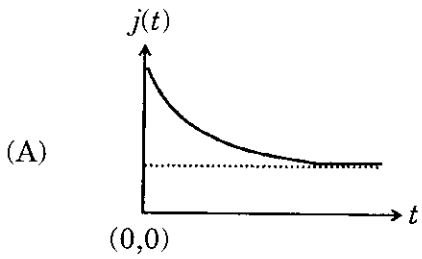
Space for rough work

*Handwritten notes:*  
 $20 \times 4 \times 2 \text{ N} \times 1.6 \text{ kg} \times 10$   
 $20 \times 0.2 \times 1.6 \text{ kg} \times 10 + 1.6 \times 3 \times 10 \times \sqrt{3} = 1.6 \times 10 \times (0.2 + 3\sqrt{3})$

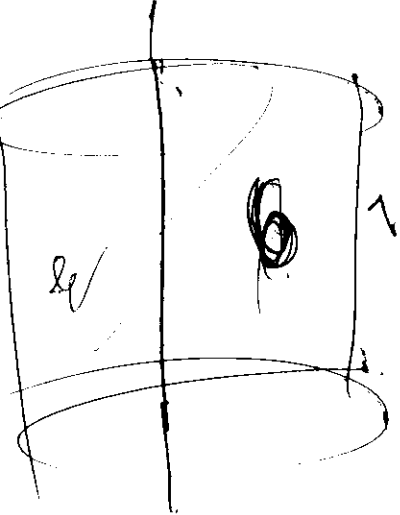


$N_1 \text{ (A)}$

Q.5 An infinite line charge of uniform electric charge density  $\lambda$  lies along the axis of an electrically conducting infinite cylindrical shell of radius  $R$ . At time  $t=0$ , the space inside the cylinder is filled with a material of permittivity  $\epsilon$  and electrical conductivity  $\sigma$ . The electrical conduction in the material follows Ohm's law. Which one of the following graphs best describes the subsequent variation of the magnitude of current density  $j(t)$  at any point in the material?



Space for rough work



$$\frac{1}{u} - \frac{1}{u} = \frac{1}{R}$$

$$\frac{1}{60} + \frac{1}{30}$$

$$= \frac{1}{20}$$

$$\frac{1}{f} = (n-1) \left( \frac{1}{R_1} - \frac{1}{R_2} \right)$$

$$\frac{1}{20} = (n-1) \frac{1}{R_1}$$

$$\frac{1}{u} + \frac{1}{u} = \frac{1}{f}$$

**SECTION 2 (Maximum Marks: 32)**

- This section contains **EIGHT** 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.
- 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) 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 In all other cases.
- 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.

Q.6 A plano-convex lens is made of a material of refractive index  $n$ . When a small object is placed 30 cm away in front of the curved surface of the lens, an image of double the size of the object is produced. Due to reflection from the convex surface of the lens, another faint image is observed at a distance of 10 cm away from the lens. Which of the following statement(s) is(are) true?

- (A) The refractive index of the lens is 2.5
- (B) The radius of curvature of the convex surface is 45 cm
- (C) The faint image is erect and real
- (D) The focal length of the lens is 20 cm



Space for rough work

Handwritten rough work for Q.6:

Diagram showing a plano-convex lens with an object at 30 cm from the curved surface. The image is formed at 10 cm from the lens. The refractive index is  $n$ .

Equations and calculations:

$$\frac{1}{v} + \frac{1}{u} = \frac{n-1}{R}$$

$$\frac{1}{10} + \frac{1}{30} = \frac{n-1}{R}$$

$$\frac{4}{30} = \frac{n-1}{R}$$

$$R = \frac{30(n-1)}{4}$$

Another equation for the faint image:

$$\frac{1}{v} + \frac{1}{u} = \frac{n-1}{R}$$

$$\frac{1}{10} + \frac{1}{\infty} = \frac{n-1}{R}$$

$$\frac{1}{10} = \frac{n-1}{R}$$

$$R = 10(n-1)$$

Equating the two expressions for  $R$ :

$$\frac{30(n-1)}{4} = 10(n-1)$$

$$\frac{30}{4} = 10$$

$$7.5 = 10$$

Another calculation:

$$\frac{1}{10} = \frac{n-1}{R}$$

$$\frac{1}{10} = \frac{n-1}{\frac{30(n-1)}{4}}$$

$$\frac{1}{10} = \frac{4}{30}$$

$$30 = 40$$

Final calculation for  $n$ :

$$\frac{1}{10} = \frac{n-1}{R}$$

$$\frac{1}{10} = \frac{n-1}{\frac{30(n-1)}{4}}$$

$$\frac{1}{10} = \frac{4}{30}$$

$$30 = 40$$

Final result:

$$n = 2.5$$

Boxed calculation:

$$f = \frac{45 \times 30}{1.5}$$

Other calculations:

$$\frac{1}{v} + \frac{1}{u} = \frac{n-1}{R}$$

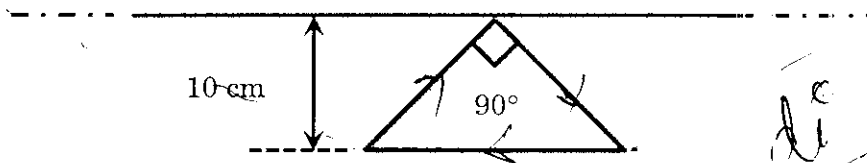
$$\frac{1}{10} + \frac{1}{\infty} = \frac{n-1}{R}$$

$$\frac{1}{10} = \frac{n-1}{R}$$

$$R = 10(n-1)$$

Final answer:  $n = 2.5$

Q.7 A conducting loop in the shape of a right angled isosceles triangle of height 10 cm is kept such that the  $90^\circ$  vertex is very close to an infinitely long conducting wire (see the figure). The wire is electrically insulated from the loop. The hypotenuse of the triangle is parallel to the wire. The current in the triangular loop is in counterclockwise direction and increased at a constant rate of  $10 \text{ A s}^{-1}$ . Which of the following statement(s) is(are) true?



$\frac{di}{dt} = 10 \text{ A s}^{-1}$   
 $\text{10}$  (circled) with an arrow pointing right

- (A) There is a repulsive force between the wire and the loop
- (B) If the loop is rotated at a constant angular speed about the wire, an additional  $emf$  of  $\left(\frac{\mu_0}{\pi}\right)$  volt is induced in the wire
- (C) The magnitude of induced  $emf$  in the wire is  $\left(\frac{\mu_0}{\pi}\right)$  volt
- (D) The induced current in the wire is in opposite direction to the current along the hypotenuse

Space for rough work

$\frac{\mu_0 I}{2\pi r}$   $q \rightarrow$   $\epsilon - \text{permittivity}$   $T - \text{temp}$   
 $k \equiv \int \mu_0 I^2$   $n = \frac{i}{m^3}$   
 $q - \text{charge}$   
 $e = \frac{F r^2}{a^2}$   
 $\sqrt{\text{XXXX } q^2 \times n \times F r^2}$   
 $\sqrt{\text{XX } q^2 \text{ (K) T PV}}$   
 $\sqrt{\text{XX } q^2 \times \text{XX} \times \text{XX}}$   
 $\sqrt{\text{XX } q^2 \times \text{XX} \times \text{XX}}$

Q.8 The position vector  $\vec{r}$  of a particle of mass  $m$  is given by the following equation

$$\vec{r}(t) = \alpha t^3 \hat{i} + \beta t^2 \hat{j},$$

where  $\alpha = 10/3 \text{ m s}^{-3}$ ,  $\beta = 5 \text{ m s}^{-2}$  and  $m = 0.1 \text{ kg}$ . At  $t = 1 \text{ s}$ , which of the following statement(s) is(are) true about the particle?

- (A) The velocity  $\vec{v}$  is given by  $\vec{v} = (10\hat{i} + 10\hat{j}) \text{ m s}^{-1}$
- (B) The angular momentum  $\vec{L}$  with respect to the origin is given by  $\vec{L} = -(5/3)\hat{k} \text{ N m s}$
- (C) The force  $\vec{F}$  is given by  $\vec{F} = (\hat{i} + 2\hat{j}) \text{ N}$
- (D) The torque  $\vec{\tau}$  with respect to the origin is given by  $\vec{\tau} = -(20/3)\hat{k} \text{ N m}$

Q.9 A length-scale ( $l$ ) depends on the permittivity ( $\epsilon$ ) of a dielectric material, Boltzmann constant ( $k_B$ ), the absolute temperature ( $T$ ), the number per unit volume ( $n$ ) of certain charged particles, and the charge ( $q$ ) carried by each of the particles. Which of the following expression(s) for  $l$  is(are) dimensionally correct?

- (A)  $l = \sqrt{\left(\frac{nq^2}{\epsilon k_B T}\right)}$
- (B)  $l = \sqrt{\left(\frac{\epsilon k_B T}{nq^2}\right)}$
- (C)  $l = \sqrt{\left(\frac{q^2}{\epsilon n^{2/3} k_B T}\right)}$
- (D)  $l = \sqrt{\left(\frac{q^2}{\epsilon n^{1/3} k_B T}\right)}$

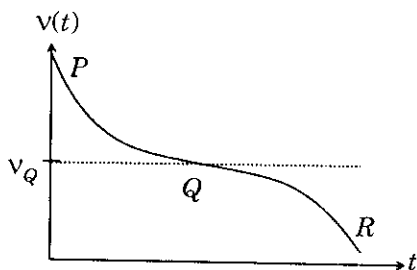
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*[Handwritten rough work showing calculations for Q.8 and Q.9, including vector components and dimensional analysis.]*



Q.10 Two loudspeakers  $M$  and  $N$  are located 20 m apart and emit sound at frequencies 118 Hz and 121 Hz, respectively. A car is initially at a point  $P$ , 1800 m away from the midpoint  $Q$  of the line  $MN$  and moves towards  $Q$  constantly at 60 km/hr along the perpendicular bisector of  $MN$ . It crosses  $Q$  and eventually reaches a point  $R$ , 1800 m away from  $Q$ . Let  $v(t)$  represent the beat frequency measured by a person sitting in the car at time  $t$ . Let  $v_P$ ,  $v_Q$  and  $v_R$  be the beat frequencies measured at locations  $P$ ,  $Q$  and  $R$ , respectively. The speed of sound in air is  $330 \text{ m s}^{-1}$ . Which of the following statement(s) is(are) true regarding the sound heard by the person?

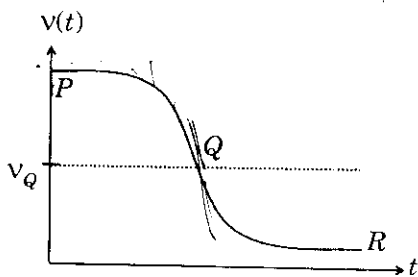
(A) The plot below represents schematically the variation of beat frequency with time



(B) The rate of change in beat frequency is maximum when the car passes through  $Q$

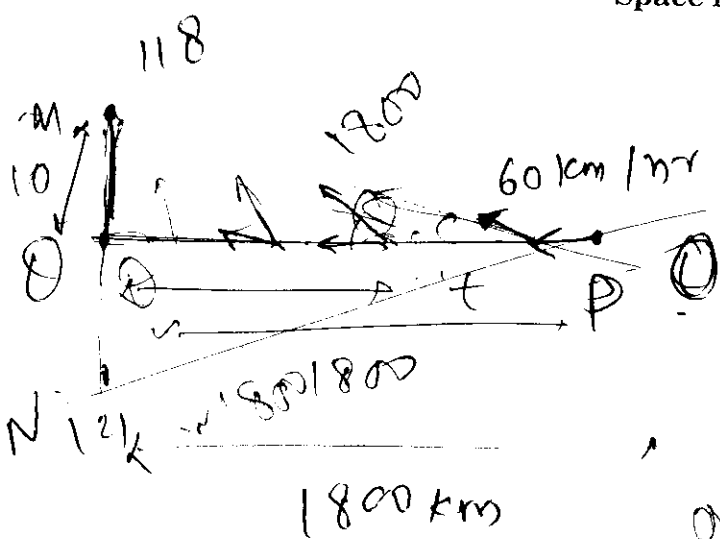
(C)  $v_P + v_R = 2v_Q$

(D) The plot below represents schematically the variation of beat frequency with time



$\frac{118 \times 330}{330} = 118$   
 $\frac{121 \times 330}{330} = 121$

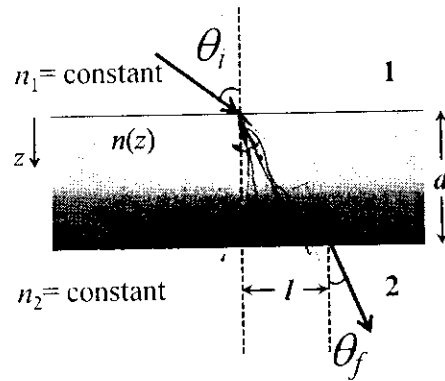
Space for rough work



$$118 \times \left( \frac{330 + 50}{3} \right)$$

$$\frac{118 \times 1040}{3 \times 330}$$

Q.11 A transparent slab of thickness  $d$  has a refractive index  $n(z)$  that increases with  $z$ . Here  $z$  is the vertical distance inside the slab, measured from the top. The slab is placed between two media with uniform refractive indices  $n_1$  and  $n_2 (> n_1)$ , as shown in the figure. A ray of light is incident with angle  $\theta_i$  from medium 1 and emerges in medium 2 with refraction angle  $\theta_f$  with a lateral displacement  $l$ .



$n(z)$   $n_1 > n_2$   
 $n_1 \sin \theta_i = n(z) \sin \theta$   
 $d \cos \theta = l$

Which of the following statement(s) is(are) true?

- (A)  $l$  is dependent on  $n(z)$  ✓ (B)  $n_1 \sin \theta_i = (n_2 - n_1) \sin \theta_f$   
 (C)  $n_1 \sin \theta_i = n_2 \sin \theta_f$  ✓ (D)  $l$  is independent of  $n_2$  ✓

Space for rough work

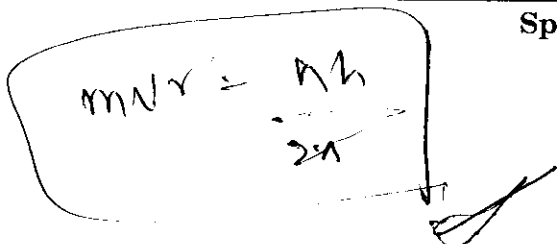
Handwritten calculations for rough work:

$1800 - t$   
 $\frac{10}{1800 - \frac{50t}{3}}$   
 $60 \cos \theta =$   
 $330 + 60 \sqrt{1 - \frac{10}{1800 - \frac{50t}{3}}}$   
 $\frac{3 \times 940}{990} + \frac{2 \times 940}{990}$   
 $330 - \frac{50}{2} \frac{940}{990}$   
 $\frac{940}{330}$   
 $\frac{1980}{330}$   
 $l = \frac{d}{\cos \theta}$   
 $2 \frac{d}{\cos \theta}$

- Q.12 Highly excited states for hydrogen-like atoms (also called Rydberg states) with nuclear charge  $Ze$  are defined by their principal quantum number  $n$ , where  $n \gg 1$ . Which of the following statement(s) is(are) true?
- (A) Relative change in the radii of two consecutive orbitals does not depend on  $Z$
  - (B) Relative change in the radii of two consecutive orbitals varies as  $1/n$
  - (C) Relative change in the energy of two consecutive orbitals varies as  $1/n^3$
  - (D) Relative change in the angular momenta of two consecutive orbitals varies as  $1/n$

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Space for rough work



A hand-drawn box containing the handwritten equation  $mvr = \frac{nh}{2\pi}$ . The box is roughly rectangular with rounded corners and a scribbled bottom-right corner. The equation is written in black ink.

$$mvr = \frac{nh}{2\pi}$$

- Q.13 An incandescent bulb has a thin filament of tungsten that is heated to high temperature by passing an electric current. The hot filament emits black-body radiation. The filament is observed to break up at random locations after a sufficiently long time of operation due to non-uniform evaporation of tungsten from the filament. If the bulb is powered at constant voltage, which of the following statement(s) is(are) true?
- (A) The temperature distribution over the filament is uniform
  - (B) The resistance over small sections of the filament decreases with time
  - (C) The filament emits more light at higher band of frequencies before it breaks up
  - (D) The filament consumes less electrical power towards the end of the life of the bulb

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**Space for rough work**

SECTION 3 (Maximum Marks: 15)

- This section contains **FIVE** questions.
- The answer to each question is a **SINGLE DIGIT INTEGER** ranging from 0 to 9, both inclusive.
- 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.

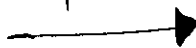
Q.14 A hydrogen atom in its ground state is irradiated by light of wavelength  $970 \text{ \AA}$ . Taking  $hc/e = 1.237 \times 10^{-6} \text{ eV m}$  and the ground state energy of hydrogen atom as  $-13.6 \text{ eV}$ , the number of lines present in the emission spectrum is

Q.15 The isotope  ${}^{12}_5\text{B}$  having a mass  $12.014 \text{ u}$  undergoes  $\beta$ -decay to  ${}^{12}_6\text{C}$ .  ${}^{12}_6\text{C}$  has an excited state of the nucleus ( ${}^{12}_6\text{C}^*$ ) at  $4.041 \text{ MeV}$  above its ground state. If  ${}^{12}_5\text{B}$  decays to  ${}^{12}_6\text{C}^*$ , the maximum kinetic energy of the  $\beta$ -particle in units of MeV is ( $1 \text{ u} = 931.5 \text{ MeV}/c^2$ , where  $c$  is the speed of light in vacuum).

Space for rough work

$12.014 \text{ u}$

$4.041$



- Q.16 Consider two solid spheres P and Q each of density  $8 \text{ gm cm}^{-3}$  and diameters 1 cm and 0.5 cm, respectively. Sphere P is dropped into a liquid of density  $0.8 \text{ gm cm}^{-3}$  and viscosity  $\eta = 3$  poiseulles. Sphere Q is dropped into a liquid of density  $1.6 \text{ gm cm}^{-3}$  and viscosity  $\eta = 2$  poiseulles. The ratio of the terminal velocities of P and Q is
- Q.17 Two inductors  $L_1$  (inductance 1 mH, internal resistance  $3 \Omega$ ) and  $L_2$  (inductance 2 mH, internal resistance  $4 \Omega$ ), and a resistor  $R$  (resistance  $12 \Omega$ ) are all connected in parallel across a 5 V battery. The circuit is switched on at time  $t = 0$ . The ratio of the maximum to the minimum current ( $I_{\max} / I_{\min}$ ) drawn from the battery is
- Q.18 A metal is heated in a furnace where a sensor is kept above the metal surface to read the power radiated ( $P$ ) by the metal. The sensor has a scale that displays  $\log_2(P/P_0)$ , where  $P_0$  is a constant. When the metal surface is at a temperature of  $487^\circ\text{C}$ , the sensor shows a value 1. Assume that the emissivity of the metallic surface remains constant. What is the value displayed by the sensor when the temperature of the metal surface is raised to  $2767^\circ\text{C}$ ?

END OF PART I: PHYSICS

Space for rough work

## PART II : CHEMISTRY

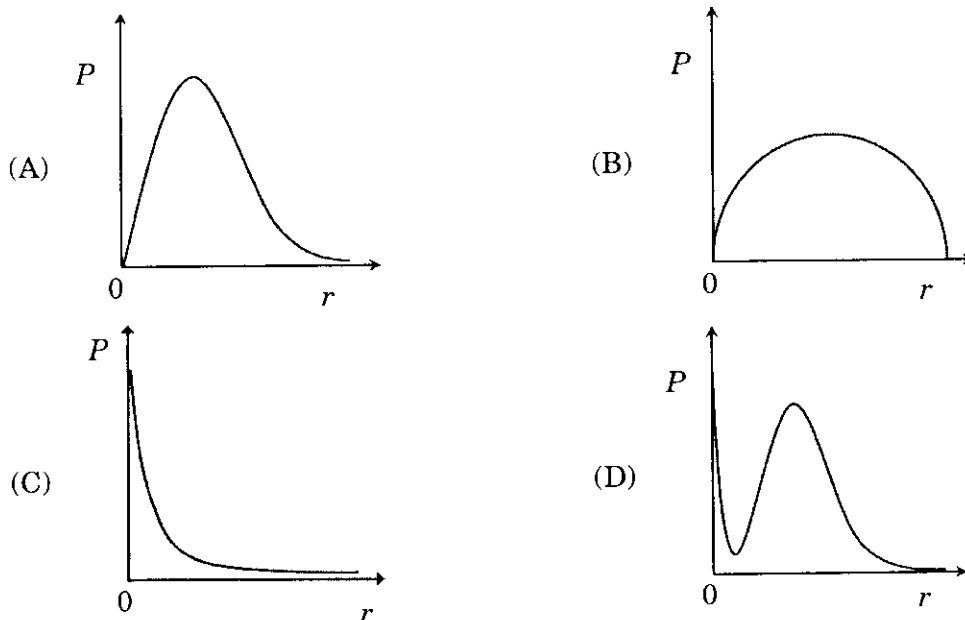
### SECTION 1 (Maximum Marks: 15)

- This section contains **FIVE** 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 The increasing order of atomic radii of the following Group 13 elements is  
(A)  $\text{Al} < \text{Ga} < \text{In} < \text{Tl}$  (B)  $\text{Ga} < \text{Al} < \text{In} < \text{Tl}$   
(C)  $\text{Al} < \text{In} < \text{Ga} < \text{Tl}$  (D)  $\text{Al} < \text{Ga} < \text{Tl} < \text{In}$
- Q.20 Among  $[\text{Ni}(\text{CO})_4]$ ,  $[\text{NiCl}_4]^{2-}$ ,  $[\text{Co}(\text{NH}_3)_4\text{Cl}_2]\text{Cl}$ ,  $\text{Na}_3[\text{CoF}_6]$ ,  $\text{Na}_2\text{O}_2$  and  $\text{CsO}_2$ , the total number of paramagnetic compounds is  
(A) 2 (B) 3 (C) 4 (D) 5
- Q.21 On complete hydrogenation, natural rubber produces  
(A) ethylene-propylene copolymer (B) vulcanised rubber  
(C) polypropylene (D) polybutylene

Space for rough work

Q.22  $P$  is the probability of finding the 1s electron of hydrogen atom in a spherical shell of infinitesimal thickness,  $dr$ , at a distance  $r$  from the nucleus. The volume of this shell is  $4\pi r^2 dr$ . The qualitative sketch of the dependence of  $P$  on  $r$  is



Q.23 One mole of an ideal gas at 300 K in thermal contact with surroundings expands isothermally from 1.0 L to 2.0 L against a constant pressure of 3.0 atm. In this process, the change in entropy of surroundings ( $\Delta S_{surr}$ ) in  $\text{J K}^{-1}$  is

(1 L atm = 101.3 J)

- (A) 5.763      (B) 1.013      (C) -1.013      (D) -5.763

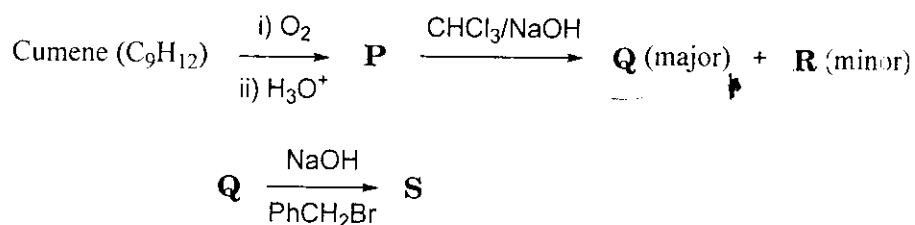
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**SECTION 2 (Maximum Marks: 32)**

- This section contains **EIGHT** questions.
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Q.24 The correct statement(s) about the following reaction sequence is(are)



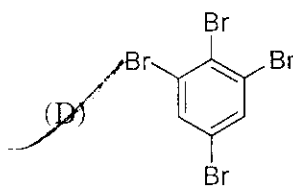
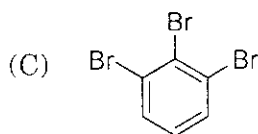
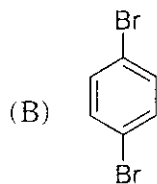
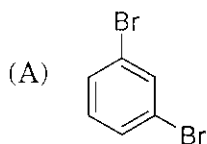
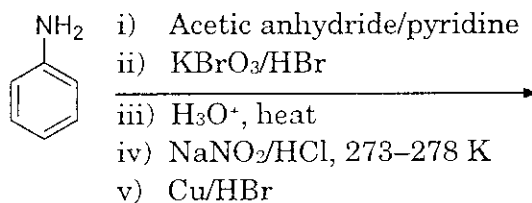
- (A) R is steam volatile
- (B) Q gives dark violet coloration with 1% aqueous FeCl<sub>3</sub> solution
- (C) S gives yellow precipitate with 2, 4-dinitrophenylhydrazine
- (D) S gives dark violet coloration with 1% aqueous FeCl<sub>3</sub> solution

Space for rough work

Q.25 The compound(s) with TWO lone pairs of electrons on the central atom is(are)

- (A)  $\text{BrF}_5$       (B)  $\text{ClF}_3$       (C)  $\text{XeF}_4$       (D)  $\text{SF}_4$

Q.26 The product(s) of the following reaction sequence is(are)



Space for rough work

Q.27 According to the Arrhenius equation,

- (A) a high activation energy usually implies a fast reaction.
- (B) rate constant increases with increase in temperature. This is due to a greater number of collisions whose energy exceeds the activation energy.
- (C) higher the magnitude of activation energy, stronger is the temperature dependence of the rate constant.
- (D) the pre-exponential factor is a measure of the rate at which collisions occur, irrespective of their energy.

Q.28 The crystalline form of borax has

- (A) tetranuclear  $[B_4O_5(OH)_4]^{2-}$  unit
- (B) all boron atoms in the same plane
- (C) equal number of  $sp^2$  and  $sp^3$  hybridized boron atoms
- (D) one terminal hydroxide per boron atom

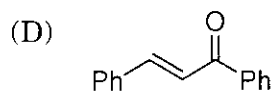
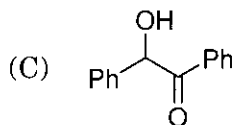
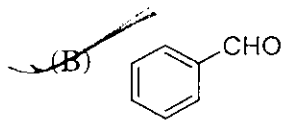
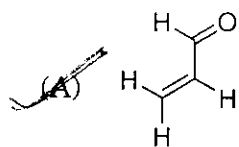
Q.29 The reagent(s) that can selectively precipitate  $S^{2-}$  from a mixture of  $S^{2-}$  and  $SO_4^{2-}$  in aqueous solution is(are)

- (A)  $CuCl_2$       (B)  $BaCl_2$       (C)  $Pb(OOCCH_3)_2$       (D)  $Na_2[Fe(CN)_5NO]$

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Space for rough work

Q.30 Positive Tollen's test is observed for



Q.31 A plot of the number of neutrons ( $N$ ) against the number of protons ( $P$ ) of stable nuclei exhibits upward deviation from linearity for atomic number,  $Z > 20$ . For an unstable nucleus having  $N/P$  ratio less than 1, the possible mode(s) of decay is(are)

(A)  $\beta^-$ -decay ( $\beta$  emission)

(B) orbital or  $K$ -electron capture

(C) neutron emission

(D)  $\beta^+$ -decay (positron emission)

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Space for rough work

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Q.32 The diffusion coefficient of an ideal gas is proportional to its mean free path and mean speed. The absolute temperature of an ideal gas is increased 4 times and its pressure is increased 2 times. As a result, the diffusion coefficient of this gas increases  $x$  times. The value of  $x$  is

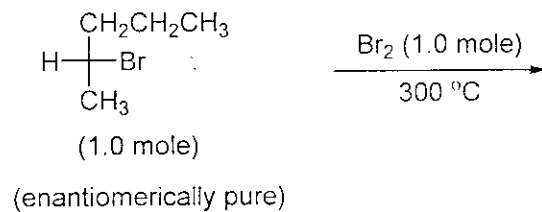
Q.33 The number of geometric isomers possible for the complex  $[\text{CoL}_2\text{Cl}_2]^-$  ( $\text{L} = \text{H}_2\text{NCH}_2\text{CH}_2\text{O}^-$ ) is

Q.34 The mole fraction of a solute in a solution is 0.1. At 298 K, molarity of this solution is the same as its molality. Density of this solution at 298 K is  $2.0 \text{ g cm}^{-3}$ . The ratio of the molecular weights of the solute and solvent,  $\left(\frac{MW_{\text{solute}}}{MW_{\text{solvent}}}\right)$ , is

**Space for rough work**

Handwritten notes and diagrams for rough work. Includes chemical structures for isomers (AA, BB, AB, BA, A, B) and mathematical expressions like  $d\alpha$  and  $\frac{d\alpha}{V}$ .

Q.35 In the following monobromination reaction, the number of possible chiral products is



Q.36 In neutral or faintly alkaline solution, 8 moles of permanganate anion quantitatively oxidize thiosulphate anions to produce X moles of a sulphur containing product. The magnitude of X is

END OF PART II : CHEMISTRY

Space for rough work







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Q.42 A solution curve of the differential equation  $(x^2 + xy + 4x + 2y + 4)\frac{dy}{dx} - y^2 = 0$ ,  $x > 0$ , passes through the point (1, 3). Then the solution curve

- (A) intersects  $y = x + 2$  exactly at one point
- (B) intersects  $y = x + 2$  exactly at two points
- (C) intersects  $y = (x + 2)^2$
- (D) does **NOT** intersect  $y = (x + 3)^2$

Handwritten notes:  $1, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}, \frac{1}{2}$  (circled),  $(1, \sqrt{2})$ ,  $(0, 9)$ ,  $(0, -3)$ ,  $(1, \sqrt{2})$

Space for rough work

$$(x^2 + xy + 4x + 2y + 4)\frac{dy}{dx} - y^2 = 0$$

$$\frac{dx}{dy} = \frac{x^2}{y^2} + \frac{x}{y} + \frac{4x}{y} + \frac{2}{y} + \frac{4}{y^2}$$

$\frac{x}{y} = u$

$$\frac{dx}{dy} = 4 + y \frac{du}{dy}$$

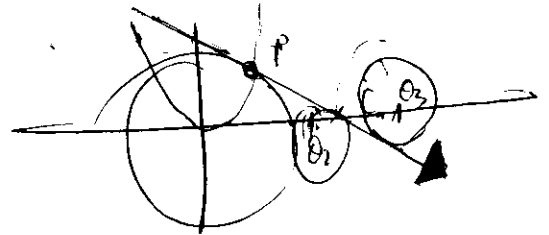
$$y + y \frac{dy}{dy} = u^2 + y + \frac{4y}{y} + \frac{2}{y} + \frac{4}{y^2}$$

Q.43 Consider a pyramid  $OPQRS$  located in the first octant ( $x \geq 0, y \geq 0, z \geq 0$ ) with  $O$  as origin, and  $OP$  and  $OR$  along the  $x$ -axis and the  $y$ -axis, respectively. The base  $OPQR$  of the pyramid is a square with  $OP = 3$ . The point  $S$  is directly above the mid-point  $T$  of diagonal  $OQ$  such that  $TS = 3$ . Then

- (A) the acute angle between  $OQ$  and  $OS$  is  $\frac{\pi}{3}$
- (B) the equation of the plane containing the triangle  $OQS$  is  $x - y = 0$
- (C) the length of the perpendicular from  $P$  to the plane containing the triangle  $OQS$  is  $\frac{3}{\sqrt{2}}$
- (D) the perpendicular distance from  $O$  to the straight line containing  $RS$  is  $\sqrt{\frac{15}{2}}$

Q.44 The circle  $C_1 : x^2 + y^2 = 3$ , with centre at  $O$ , intersects the parabola  $x^2 = 2y$  at the point  $P$  in the first quadrant. Let the tangent to the circle  $C_1$  at  $P$  touches other two circles  $C_2$  and  $C_3$  at  $R_2$  and  $R_3$ , respectively. Suppose  $C_2$  and  $C_3$  have equal radii  $2\sqrt{3}$  and centres  $Q_2$  and  $Q_3$ , respectively. If  $Q_2$  and  $Q_3$  lie on the  $y$ -axis, then

- (A)  $Q_2Q_3 = 12$
- (B)  $R_2R_3 = 4\sqrt{6}$
- (C) area of the triangle  $OR_2R_3$  is  $6\sqrt{2}$
- (D) area of the triangle  $PQ_2Q_3$  is  $4\sqrt{2}$



Space for rough work

Handwritten work for Q.44:

$\frac{dy}{dx} = 2x$   
 $x^2 + y^2 = 3$   
 $2x + 2y \frac{dy}{dx} = 0$   
 $2x + 2y(2x) = 0$   
 $2x + 4xy = 0$   
 $x(1 + 2y) = 0$   
 $x = 0$  or  $y = -\frac{1}{2}$  (not in 1st quadrant)  
 $x^2 = 2y$   
 $x^2 + x^2 = 3$   
 $2x^2 = 3$   
 $x^2 = \frac{3}{2}$   
 $x = \sqrt{\frac{3}{2}}$   
 $y = \frac{x^2}{2} = \frac{3/2}{2} = \frac{3}{4}$   
 $P = (\sqrt{\frac{3}{2}}, \frac{3}{4})$   
 $(1, \sqrt{2})$  is a point on the circle.  
 $\sqrt{2}x + y = 3$  is the tangent line.  
 $12 + 24 = 36$   
 $\frac{12 + 24}{\sqrt{3}} = 2\sqrt{3}$   
 $Q_2 = (0, 9)$   
 $Q_3 = (0, 9)$   
 $R_2 = (0, 9)$   
 $R_3 = (0, 9)$   
 $Q_2Q_3 = 12$   
 $R_2R_3 = 4\sqrt{6}$   
 $Area \triangle OR_2R_3 = 6\sqrt{2}$   
 $Area \triangle PQ_2Q_3 = 4\sqrt{2}$

3<sup>u</sup>

$g'(f(x)) \cdot f'(x) = I$  1/3

Q.45 Let  $f: \mathbb{R} \rightarrow \mathbb{R}$ ,  $g: \mathbb{R} \rightarrow \mathbb{R}$  and  $h: \mathbb{R} \rightarrow \mathbb{R}$  be differentiable functions such that  $f(x) = x^3 + 3x + 2$ ,  $g(f(x)) = x$  and  $h(g(g(x))) = x$  for all  $x \in \mathbb{R}$ . Then

(A)  $g'(2) = \frac{1}{15}$

(B)  $h'(1) = 666$

(C)  $h(0) = 16$

(D)  $h(g(3)) = 36$

$g(g(x))$   
 $g(g(x)) = 0$   
 $|A| = 1$   
 $|A|^{-1}$

Q.46 Let  $P = \begin{bmatrix} 3 & -1 & -2 \\ 2 & 0 & \alpha \\ 3 & -5 & 0 \end{bmatrix}$ , where  $\alpha \in \mathbb{R}$ . Suppose  $Q = [q_{ij}]$  is a matrix such that  $PQ = kI$ , where

$k \in \mathbb{R}$ ,  $k \neq 0$  and  $I$  is the identity matrix of order 3. If  $q_{23} = -\frac{k}{8}$  and  $\det(Q) = \frac{k^2}{2}$ , then

(A)  $\alpha = 0, k = 8$

(B)  $4\alpha - k + 8 = 0$

(C)  $\det(P \text{ adj}(Q)) = 2^9$

(D)  $\det(Q \text{ adj}(P)) = 2^{18}$

$-12$   
 $12$   
 $\frac{-12}{8} = 12$

$|A|^{(n-1)}$   
 $|A|$

Q.47 Let  $RS$  be the diameter of the circle  $x^2 + y^2 = 1$ , where  $S$  is the point  $(1, 0)$ . Let  $P$  be a variable point (other than  $R$  and  $S$ ) on the circle and tangents to the circle at  $S$  and  $P$  meet at the point  $Q$ . The normal to the circle at  $P$  intersects a line drawn through  $Q$  parallel to  $RS$  at point  $E$ . Then the locus of  $E$  passes through the point(s)

(A)  $(\frac{1}{3}, \frac{1}{\sqrt{3}})$

(B)  $(\frac{1}{4}, \frac{1}{2})$

(C)  $(\frac{1}{3}, -\frac{1}{\sqrt{3}})$

(D)  $(\frac{1}{4}, -\frac{1}{2})$

Space for rough work

$\theta = (1, \tan \frac{\theta}{2})$   $P \text{ adj } P = |A|$   
 $y = x \tan \theta$   
 $E = (\frac{1 - \tan^2 \theta}{2}, \tan \frac{\theta}{2})$   
 $x \cos \theta + y \sin \theta = 1$   
 $y \sin \theta = 1 - \cos \theta$   
 $y = \frac{\tan \theta}{2}$   
 $x = \frac{1 - \tan^2 \theta}{2}$   
 $\frac{1 - \tan^2 \theta}{2} = \frac{\tan^2 \theta}{2} - h$   
 $\frac{1}{4} = \tan^2 \theta$

adj  $|P| |P|^{n-1}$   $|P|^5$   $g(f)$

Q.48 Let  $f: (0, \infty) \rightarrow \mathbb{R}$  be a differentiable function such that  $f'(x) = 2 - \frac{f(x)}{x}$  for all  $x \in (0, \infty)$  and  $f(1) \neq 1$ . Then

(A)  $\lim_{x \rightarrow 0^+} f\left(\frac{1}{x}\right) = 1$

(B)  $\lim_{x \rightarrow 0^+} x f\left(\frac{1}{x}\right) = 2$

(C)  $\lim_{x \rightarrow 0^+} x^2 f'(x) = 0$

(D)  $|f(x)| \leq 2$  for all  $x \in (0, 2)$

$12x + 20$

Q.49 In a triangle XYZ, let  $x, y, z$  be the lengths of sides opposite to the angles X, Y, Z, respectively, and  $2s = x + y + z$ . If  $\frac{s-x}{4} = \frac{s-y}{3} = \frac{s-z}{2}$  and area of incircle of the triangle XYZ is  $\frac{8\pi}{3}$ , then

(A) area of the triangle XYZ is  $6\sqrt{6}$

(B) the radius of circumcircle of the triangle XYZ is  $\frac{35}{6}\sqrt{6}$

(C)  $\sin \frac{X}{2} \sin \frac{Y}{2} \sin \frac{Z}{2} = \frac{4}{35}$

(D)  $\sin^2 \left( \frac{X+Y}{2} \right) = \frac{3}{5}$

Handwritten notes for Q.49:  $p \text{ adj } p^2$ ,  $|P| I$ ,  $K = |P|$ ,  $3x + 4 = \frac{K^2}{8}$ ,  $K = -32$ ,  $-12$

Space for rough work

Rough work for Q.48:  $C = x^2 \left( 2 - \frac{f(x)}{x} \right) = \frac{y}{-1} = |A|$ ,  $2x^2 - 2x f(x)$ ,  $1 - 2x = y^2$ ,  $(p \text{ adj } \text{adj } p)$ ,  $|P| (\text{adj } \text{adj } P)$ ,  $|P| \cdot (P)$ ,  $(n-1)^2$ ,  $12x + 20$

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Q.50 Let  $m$  be the smallest positive integer such that the coefficient of  $x^2$  in the expansion of  $(1+x)^2 + (1+x)^3 + \dots + (1+x)^{49} + (1+mx)^{50}$  is  $(3n+1) {}^{51}C_3$  for some positive integer  $n$ . Then the value of  $n$  is

Q.51 Let  $\alpha, \beta \in \mathbb{R}$  be such that  $\lim_{x \rightarrow 0} \frac{x^2 \sin(\beta x)}{\alpha x - \sin x} = 1$ . Then  $6(\alpha + \beta)$  equals

**Space for rough work**

*Handwritten work for Q.50:*  
 Let  $m$  be the smallest positive integer such that the coefficient of  $x^2$  in the expansion of  $(1+x)^2 + (1+x)^3 + \dots + (1+x)^{49} + (1+mx)^{50}$  is  $(3n+1) {}^{51}C_3$  for some positive integer  $n$ . Then the value of  $n$  is

*Handwritten work for Q.51:*  
 Let  $\alpha, \beta \in \mathbb{R}$  be such that  $\lim_{x \rightarrow 0} \frac{x^2 \sin(\beta x)}{\alpha x - \sin x} = 1$ . Then  $6(\alpha + \beta)$  equals

Q.52 Let  $z = \frac{-1 + \sqrt{3}i}{2}$ , where  $i = \sqrt{-1}$ , and  $r, s \in \{1, 2, 3\}$ . Let  $P = \begin{bmatrix} (-z)^r & z^{2s} \\ z^{2s} & z^r \end{bmatrix}$  and  $I$  be the identity matrix of order 2. Then the total number of ordered pairs  $(r, s)$  for which  $P^2 = -I$  is

Q.53 The total number of distinct  $x \in \mathbb{R}$  for which  $\begin{vmatrix} x & x^2 & 1+x^3 \\ 2x & 4x^2 & 1+8x^3 \\ 3x & 9x^2 & 1+27x^3 \end{vmatrix} = 10$  is

Q.54 The total number of distinct  $x \in [0, 1]$  for which  $\int_0^x \frac{t^2}{1+t^4} dt = 2x - 1$  is

END OF THE QUESTION PAPER

Space for rough work

$\frac{x^1}{x^2} = x^{-1}$   
 $x^2 \cdot 2x^{-2} = 2$   
 $2x^{-1} = x^{-1} + ?$   
 $2x^{-1} - x^{-1} = x^{-1}$   
 $1 = x^{-1} \Rightarrow x = 1$

$f(x) = x^3 + 3x + 2$   
 $g(f(x)) = x$   
 $h(g(g(x))) = x$

$g'(f(x)) \cdot f'(x) = 1$   
 $h'(g(g(x))) \cdot g'(g(x)) \cdot g'(x) = 1$

$g(g(x)) = 1$   
 $g(g(x)) = 1$

$18x^2 + 26x + 63 = 0$