

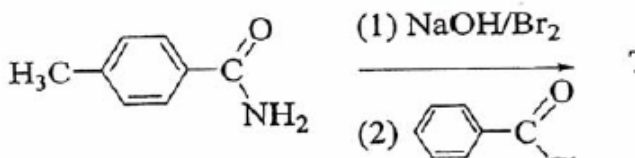
SECTION – I (Single Correct Choice Type)

1. The complex showing a spin-only magnetic moment of 2.82 B.M. is
 A) $\text{Ni}(\text{CO})_4$ B) $[\text{NiCl}_4]^{2-}$ C) $\text{Ni}(\text{PPh}_3)_4$ D) $[\text{Ni}(\text{CN})_4]^{2-}$

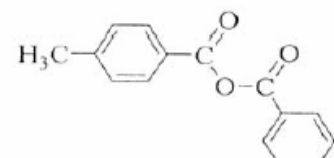
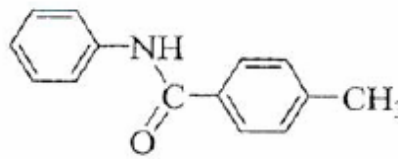
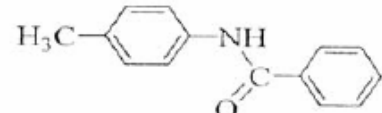
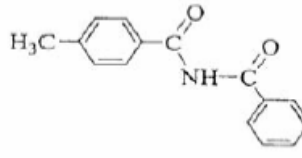
ANSWER: B

2. The species having pyramidal shape is
 A) SO_3 B) BrF_3 C) SiO_3^{2-} D) OSF_2

ANSWER: D

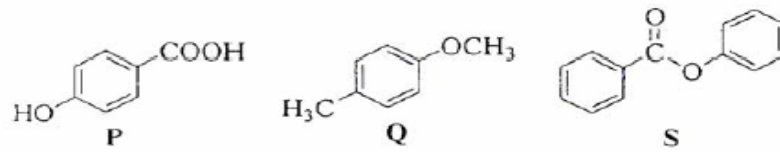
3. In the reaction  the structure of the

Product T is

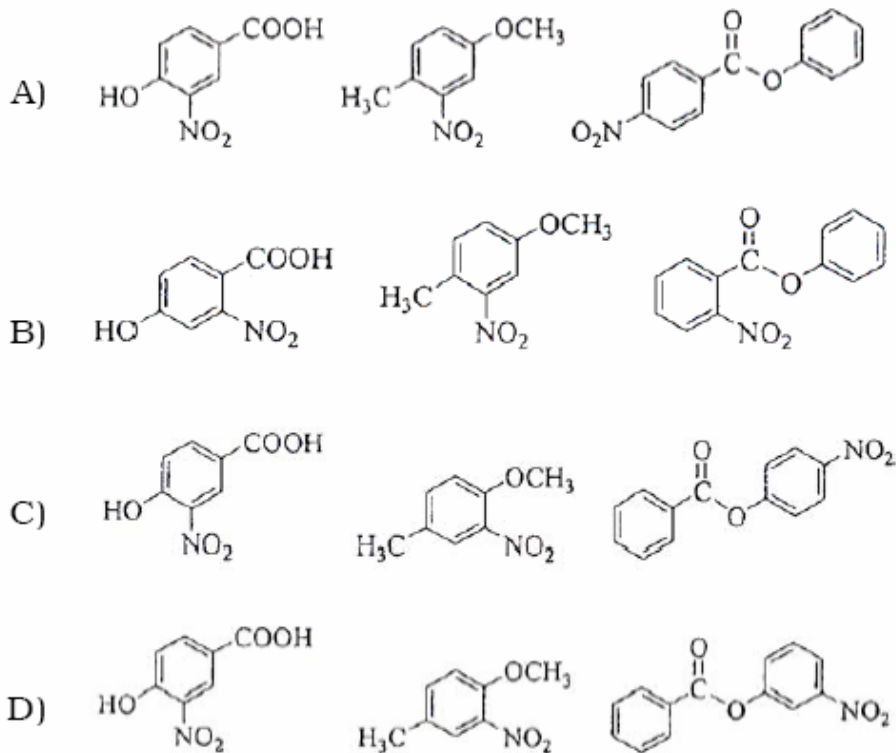
- A)  B) 
- C)  D) 

ANSWER: C

4. The compounds P, Q and S

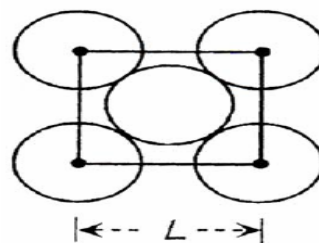


were separately subjected to nitration using $\text{HNO}_3/\text{H}_2\text{SO}_4$ mixture. The major product formed in each case respectively, is



ANSWER: C

5. The packing efficiency of the two-dimensional square unit cell shown below is



A) 39.27%

B) 68.02%

C) 74.05%

D) 78.54%

ANSWER: D

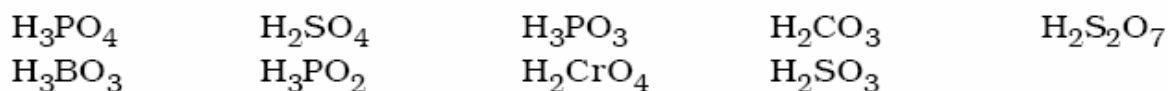
6. Assuming that Hund's rule is violated, the bond order and magnetic nature of the diatomic molecule B_2 is

- A) 1 and diamagnetic C) 1 and paramagnetic
B) 0 and diamagnetic D) 0 and paramagnetic

ANSWER: A

SECTION - II (Integer Type)

7. The total number of diprotic acids among the following is



ANSWER: 6

8. Total number of geometrical isomers for the complex $[RhCl(CO)(PPh_3)(NH_3)]$ is

ANSWER: 3

9. Among the following, the number of elements showing only one non-zero oxidation state is

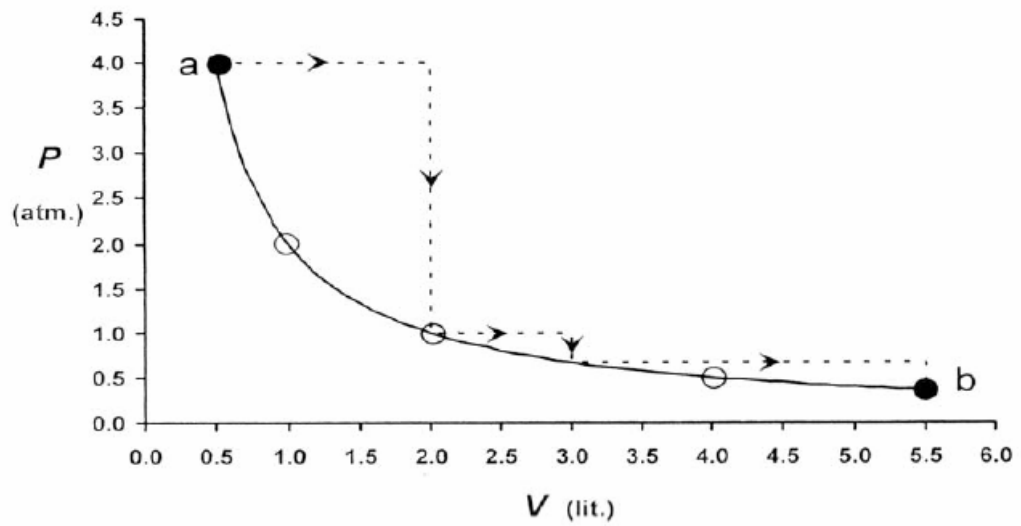


ANSWER: 2

10. Silver (atomic weight = 108 g mol^{-1}) has a density of 10.5 g cm^{-3} . The number of silver atoms on a surface of area 10^{-12} m^2 can be expressed in scientific notation as $y \times 10^x$. The value of x is

ANSWER: 7

11. One mole of an ideal gas is taken from **a** to **b** along two paths denoted by the solid and the dashed lines as shown in the graph below. If the work done along the solid line path is w_s and that along the dotted line path is w_d , then the integer closest to the ratio w_d/w_s is

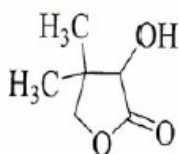


ANSWER: 2

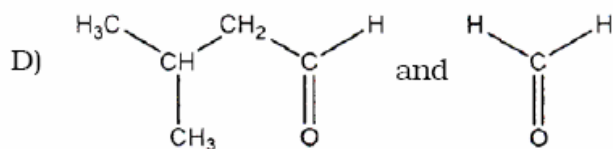
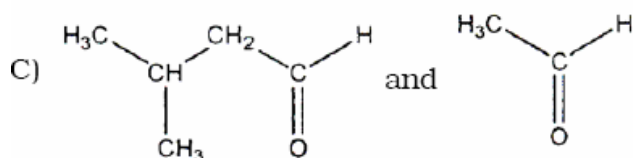
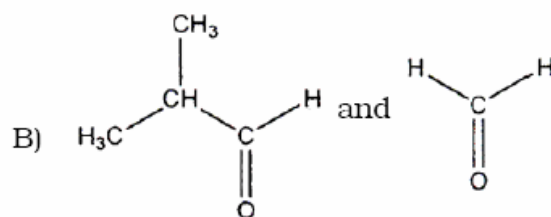
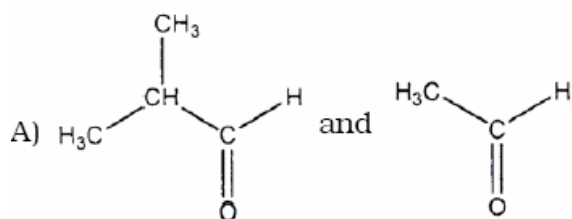
SECTION - III (Paragraph Type)

Paragraph for Questions 12 to 14.

Two aliphatic aldehydes P and Q react in the presence of aqueous K_2CO_3 to give compound R, which upon treatment with HCN provides compound S. On acidification and heating, S gives the product shown below :

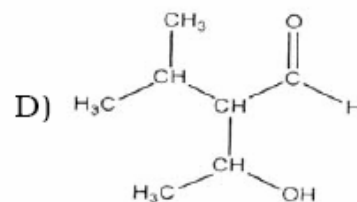
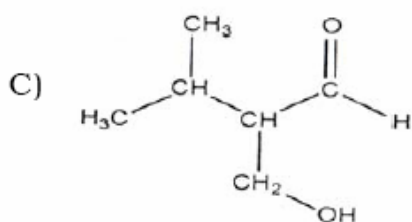
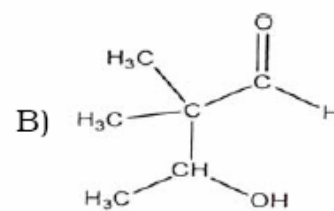
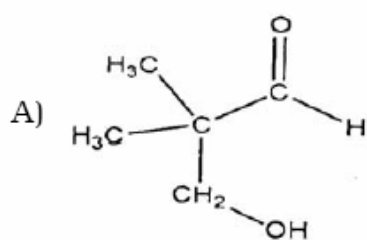


12. The compounds P and Q respectively are



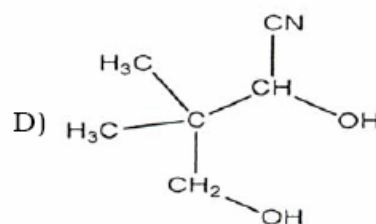
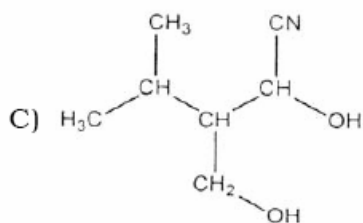
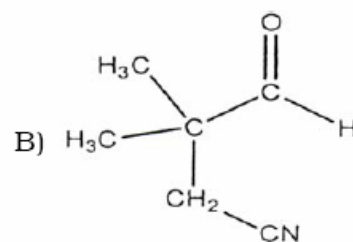
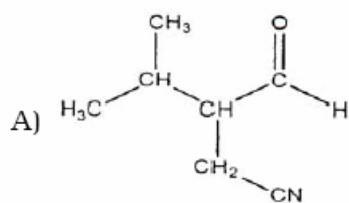
ANSWER: B

13. The compound R is



ANSWER: A

14. The compound S is



ANSWER: D

Paragraph for Questions 15 to 17.

The hydrogen-like species Li^{2+} is in a spherically symmetric state S_1 with one radial node. Upon absorbing light the ion undergoes transition to a state S_2 . The state S_2 has one radial node and its energy is equal to the ground state energy of the hydrogen atom.

15. The state S_1 is

- A) 1s B) 2s C) 2p D) 3s

ANSWER: B

16. Energy of the state S_1 in units of the hydrogen atom ground state energy is

- A) 0.75 B) 1.50 C) 2.25 D) 4.50

ANSWER: C

17. The orbital angular momentum quantum number of the state S_2 is

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

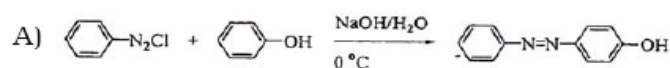
ANSWER: B

SECTION – IV (Matrix Type)

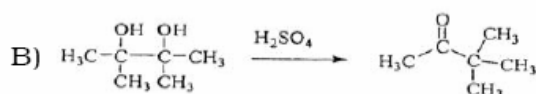
18. Match the reactions in Column I with appropriate options in Column II.

Column I

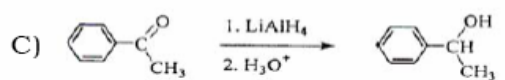
Column II



p) Racemic mixture



q) Addition reaction



r) Substitution reaction



s) Coupling reaction

t) Carbocation intermediate

ANSWER:

A: r and s

B: t

C: p and q

D: r

19. All the compounds listed in **Column I** react with water. Match the result of the respective reactions with the appropriate options listed in **Column II**.

Column I

- A) $(\text{CH}_3)_2\text{SiCl}_2$
- B) XeF_4
- C) Cl_2
- D) VCl_5

Column II

- p) Hydrogen halide formation
- q) Redox reaction
- r) Reacts with glass
- s) Polymerization
- t) O_2 formation

ANSWER:
A: p and s
B: p and q and r and t
C: p and q
D: p

PART – II : MATHEMATICS

SECTION – I (Single Correct Choice Type)

20. For $r = 0, 1, \dots, 10$, let A_r , B_r and C_r denote, respectively, the coefficient of x^r in the expansions of $(1+x)^{10}$, $(1+x)^{20}$ and $(1+x)^{30}$. Then

$$\sum_{r=1}^{10} A_r (B_{10}B_r - C_{10}A_r)$$

is equal to

- A) $B_{10} - C_{10}$
- B) $A_{10} (B_{10}^2 - C_{10}A_{10})$
- C) 0
- D) $C_{10} - B_{10}$

ANSWER: D

21. Let $S = \{1, 2, 3, 4\}$. The total number of unordered pairs of disjoint subsets of S is equal to

- A) 25
- B) 34
- C) 42
- D) 41

ANSWER: D

22. Let f be a real-valued function defined on the interval $(-1, 1)$ such that

$$e^{-x} f(x) = 2 + \int_0^x \sqrt{t^4 + 1} dt, \text{ for all } x \in (-1, 1), \text{ and let } f^{-1} \text{ be the inverse function of } f.$$

Then $(f^{-1})'(2)$ is equal to

- A) 1 B) $\frac{1}{3}$ C) $\frac{1}{2}$ D) $\frac{1}{e}$

ANSWER: B

23. If the distance of the point $P(1, -2, 1)$ from the plane $x + 2y - 2z = \alpha$, where $\alpha > 0$, is 5, then the foot of the perpendicular from P to the plane is

- A) $\left(\frac{8}{3}, \frac{4}{3}, -\frac{7}{3}\right)$ B) $\left(\frac{4}{3}, -\frac{4}{3}, \frac{1}{3}\right)$ C) $\left(\frac{1}{3}, \frac{2}{3}, \frac{10}{3}\right)$ D) $\left(\frac{2}{3}, -\frac{1}{3}, \frac{5}{2}\right)$

ANSWER: A

24. Two adjacent sides of a parallelogram $ABCD$ are given by

$$\overrightarrow{AB} = 2\hat{i} + 10\hat{j} + 11\hat{k} \text{ and } \overrightarrow{AD} = -\hat{i} + 2\hat{j} + 2\hat{k}$$

The side AD is rotated by an acute angle α in the plane of the parallelogram so that AD becomes AD' . If AD' makes a right angle with the side AB , then the cosine of the angle α is given by

- A) $\frac{8}{9}$ B) $\frac{\sqrt{17}}{9}$ C) $\frac{1}{9}$ D) $\frac{4\sqrt{5}}{9}$

ANSWER: B

25. A signal which can be green or red with probability $\frac{4}{5}$ and $\frac{1}{5}$ respectively, is received by station A and then transmitted to station B. The probability of each station receiving the signal correctly is $\frac{3}{4}$. If the signal received at station B is green, then the probability that the original signal was green is

- A) $\frac{3}{5}$ B) $\frac{6}{7}$ C) $\frac{20}{23}$ D) $\frac{9}{20}$

ANSWER: C

SECTION - II (Integer Type)

26. Two parallel chords of a circle of radius 2 are at a distance $\sqrt{3}+1$ apart. If the chords subtend at the center, angles of $\frac{\pi}{k}$ and $\frac{2\pi}{k}$, where $k > 0$, then the value of $[k]$ is
[Note : $[k]$ denotes the largest integer less than or equal to k]

ANSWER: 3

27. Consider a triangle ABC and let a , b and c denote the lengths of the sides opposite to vertices A, B and C respectively. Suppose $a = 6$, $b = 10$ and the area of the triangle is $15\sqrt{3}$. If $\angle ACB$ is obtuse and if r denotes the radius of the incircle of the triangle, then r^2 is equal to

ANSWER: 3

28. Let f be a function defined on \mathbf{R} (the set of all real numbers) such that $f(x) = 2010(x-2009)(x-2010)^2(x-2011)^3(x-2012)^4$, for all $x \in \mathbf{R}$.
If g is a function defined on \mathbf{R} with values in the interval $(0, \infty)$ such that $f(x) = \ln(g(x))$, for all $x \in \mathbf{R}$,

then the number of points in \mathbf{R} at which g has a local maximum is

ANSWER: 1

29. Let $a_1, a_2, a_3, \dots, a_{11}$ be real numbers satisfying

$$a_1 = 15, \quad 27 - 2a_2 > 0 \quad \text{and} \quad a_k = 2a_{k-1} - a_{k-2} \quad \text{for } k = 3, 4, \dots, 11.$$

If $\frac{a_1^2 + a_2^2 + \dots + a_{11}^2}{11} = 90$, then the value of $\frac{a_1 + a_2 + \dots + a_{11}}{11}$ is equal to

ANSWER: 0

30. Let k be a positive real number and let

$$A = \begin{bmatrix} 2k-1 & 2\sqrt{k} & 2\sqrt{k} \\ 2\sqrt{k} & 1 & -2k \\ -2\sqrt{k} & 2k & -1 \end{bmatrix} \text{ and } B = \begin{bmatrix} 0 & 2k-1 & \sqrt{k} \\ 1-2k & 0 & 2\sqrt{k} \\ -\sqrt{k} & -2\sqrt{k} & 0 \end{bmatrix}.$$

If $\det(\text{adj } A) + \det(\text{adj } B) = 10^6$, then $[k]$ is equal to

[Note : $\text{adj } M$ denotes the adjoint of a square matrix M and $[k]$ denotes the largest integer less than or equal to k].

ANSWER: 4

SECTION - III (Paragraph Type)

Paragraph for questions 31 to 33.

Consider the polynomial

$$f(x) = 1 + 2x + 3x^2 + 4x^3.$$

Let s be the sum of all distinct real roots of $f(x)$ and let $t = |s|$.

31. The real number s lies in the interval

- A) $\left(-\frac{1}{4}, 0\right)$ B) $\left(-11, -\frac{3}{4}\right)$ C) $\left(-\frac{3}{4}, -\frac{1}{2}\right)$ D) $\left(0, \frac{1}{4}\right)$

ANSWER: C

32. The area bounded by the curve $y = f(x)$ and the lines $x = 0$, $y = 0$ and $x = t$, lies in the interval

- A) $\left(\frac{3}{4}, 3\right)$ B) $\left(\frac{21}{64}, \frac{11}{16}\right)$ C) $(9, 10)$ D) $\left(0, \frac{21}{64}\right)$

ANSWER: A

33. The function $f'(x)$ is

- A) increasing in $\left(-t, -\frac{1}{4}\right)$ and decreasing in $\left(-\frac{1}{4}, t\right)$
- B) decreasing in $\left(-t, -\frac{1}{4}\right)$ and increasing in $\left(-\frac{1}{4}, t\right)$
- C) increasing in $(-t, t)$
- D) decreasing in $(-t, t)$

ANSWER: B

Paragraph for Questions 34 to 36.

Tangents are drawn from the point $P(3, 4)$ to the ellipse $\frac{x^2}{9} + \frac{y^2}{4} = 1$ touching the ellipse at points A and B.

34. The coordinates of A and B are

- A) $(3, 0)$ and $(0, 2)$
- B) $\left(-\frac{8}{5}, \frac{2\sqrt{161}}{15}\right)$ and $\left(-\frac{9}{5}, \frac{8}{5}\right)$
- C) $\left(-\frac{8}{5}, \frac{2\sqrt{161}}{15}\right)$ and $(0, 2)$
- D) $(3, 0)$ and $\left(-\frac{9}{5}, \frac{8}{5}\right)$

ANSWER: D

35. The orthocenter of the triangle PAB is

- A) $\left(5, \frac{8}{7}\right)$
- B) $\left(\frac{7}{5}, \frac{25}{8}\right)$
- C) $\left(\frac{11}{5}, \frac{8}{5}\right)$
- D) $\left(\frac{8}{25}, \frac{7}{5}\right)$

ANSWER: C

36. The equation of the locus of the point whose distances from the point P and the line AB are equal, is

- A) $9x^2 + y^2 - 6xy - 54x - 62y + 241 = 0$
- B) $x^2 + 9y^2 + 6xy - 54x + 62y - 241 = 0$
- C) $9x^2 + 9y^2 - 6xy - 54x - 62y - 241 = 0$
- D) $x^2 + y^2 - 2xy + 27x + 31y - 120 = 0$

ANSWER: A

SECTION - IV (Matrix Type)

37. Match the statements in **Column-I** with those in **Column-II**.

[**Note:** Here z takes values in the complex plane and $\text{Im } z$ and $\text{Re } z$ denote, respectively, the imaginary part and the real part of z .]

Column I

Column II

A) The set of points z satisfying
 $|z-i|z| = |z+i|z|$
 is contained in or equal to

p) an ellipse with eccentricity $\frac{4}{5}$

q) the set of points z satisfying $\text{Im } z = 0$

B) The set of points z satisfying
 $|z + 4| + |z - 4| = 10$
 is contained in or equal to

r) the set of points z satisfying $|\text{Im } z| \leq 1$

C) If $|w| = 2$, then the set of points
 $z = w - \frac{1}{w}$ is contained in or equal to

s) the set of points z satisfying $|\text{Re } z| \leq 2$

D) If $|w| = 1$, then the set of points
 $z = w + \frac{1}{w}$ is contained in or equal to

t) the set of points z satisfying $|z| \leq 3$

ANSWER:

A: q and r

B: p

C: p and s and t

D: q and r and s and t

38. Match the statements in **Column-I** with the values in **Column-II**.

Column I

Column II

A) A line from the origin meets the lines

p) - 4

$$\frac{x-2}{1} = \frac{y-1}{-2} = \frac{z+1}{1} \text{ and } \frac{x-\frac{8}{3}}{2} = \frac{y+3}{-1} = \frac{z-1}{1} \text{ at P and Q}$$

respectively. If length PQ = d, then d² is

B) The values of x satisfying

$$\tan^{-1}(x+3) - \tan^{-1}(x-3) = \sin^{-1}\left(\frac{3}{5}\right) \text{ are}$$

q) 0

C) Non-zero vectors \vec{a}, \vec{b} and \vec{c} satisfy $\vec{a} \cdot \vec{b} = 0$,
 $(\vec{b} - \vec{a}) \cdot (\vec{b} + \vec{c}) = 0$ and $2|\vec{b} + \vec{c}| = |\vec{b} - \vec{a}|$.

If $\vec{a} = \mu\vec{b} + 4\vec{c}$, then the possible values of μ are

r) 4

D) Let f be the function on $[-\pi, \pi]$ given by

$$f(0) = 9 \text{ and } f(x) = \sin\left(\frac{9x}{2}\right) / \sin\left(\frac{x}{2}\right) \text{ for } x \neq 0.$$

s) 5

The value of $\frac{2}{\pi} \int_{-\pi}^{\pi} f(x) dx$ is

t) 6

ANSWER:

A: t

B: p and r

C: either q or (q and s)

D: r

PART – III : PHYSICS

SECTION – I (Single Correct Choice Type)

39. A Vernier calipers has 1 mm marks on the main scale. It has 20 equal divisions on the Vernier scale which match with 16 main scale divisions. For this Vernier calipers, the least count is
- A) 0.02 mm B) 0.05 mm C) 0.1 mm D) 0.2 mm

ANSWER: D

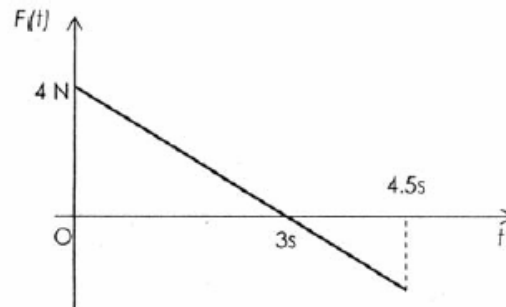
40. A hollow pipe of length 0.8 m is closed at one end. At its open end a 0.5 m long uniform string is vibrating in its second harmonic and it resonates with the fundamental frequency of the pipe. If the tension in the wire is 50 N and the speed of sound is 320 ms^{-1} , the mass of the string is
- A) 5 grams B) 10 grams C) 20 grams D) 40 grams

ANSWER: B

41. A biconvex lens of focal length 15 cm is in front of a plane mirror. The distance between the lens and the mirror is 10 cm. A small object is kept at a distance of 30 cm from the lens. The final image is
- A) virtual and at a distance of 16 cm from the mirror
B) real and at a distance of 16 cm from the mirror
C) virtual and at a distance of 20 cm from the mirror
D) real and at a distance of 20 cm from the mirror

ANSWER: B

42. A block of mass 2 kg is free to move along the x-axis. It is at rest and from $t = 0$ onwards it is subjected to a time-dependent force $F(t)$ in the x direction. The force $F(t)$ varies with t as shown in the figure. The kinetic energy of the block after 4.5 seconds is



- A) 4.50 J B) 7.50 J C) 5.06 J D) 14.06 J

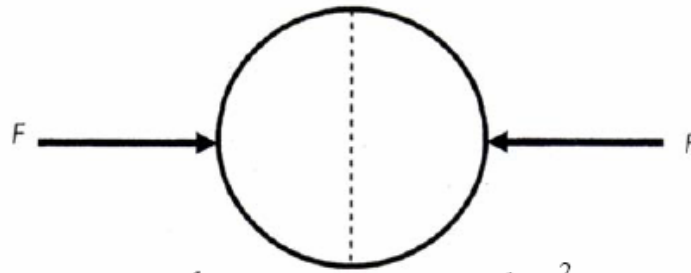
ANSWER: C

43. A tiny spherical oil drop carrying a net charge q is balanced in still air with a vertical uniform electric field of strength $\frac{81\pi}{7} \times 10^5 \text{ Vm}^{-1}$. When the field is switched off, the drop is observed to fall with terminal velocity $2 \times 10^{-3} \text{ m s}^{-1}$. Given $g = 9.8 \text{ m s}^{-2}$, viscosity of the air = $1.8 \times 10^{-5} \text{ N s m}^{-2}$ and the density of oil = 900 kg m^{-3} , the magnitude of q is

- A) $1.6 \times 10^{-19} \text{ C}$ B) $3.2 \times 10^{-19} \text{ C}$ C) $4.8 \times 10^{-19} \text{ C}$ D) $8.0 \times 10^{-19} \text{ C}$

ANSWER: D

44. A uniformly charged thin spherical shell of radius R carries uniform surface charge density of σ per unit area. It is made of two hemispherical shells, held together by pressing them with force F (see figure). F is proportional to



- A) $\frac{1}{\epsilon_0} \sigma^2 R^2$ B) $\frac{1}{\epsilon_0} \sigma^2 R$ C) $\frac{1}{\epsilon_0} \frac{\sigma^2}{R}$ D) $\frac{1}{\epsilon_0} \frac{\sigma^2}{R^2}$

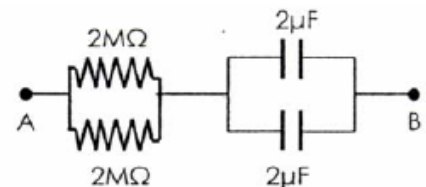
ANSWER: A

SECTION – II (Integer Type)

45. A diatomic ideal gas is compressed adiabatically to $\frac{1}{32}$ of its initial volume. In the initial temperature of the gas is T_i (in Kelvin) and the final temperature is aT_i , the value of a is

ANSWER: 4

46. At time $t = 0$, a battery of 10 V is connected across points A and B in the given circuit. If the capacitors have no charge initially, at what time (in seconds) does the voltage across them become 4 V ?



[Take : $\ln 5 = 1.6$, $\ln 3 = 1.1$]

ANSWER: 2

47. Image of an object approaching a convex mirror of radius of curvature 20 m along its optical axis is observed to move from $\frac{25}{3}$ m to $\frac{50}{7}$ m in 30 seconds. What is the speed of the object in km per hour ?

ANSWER: 3

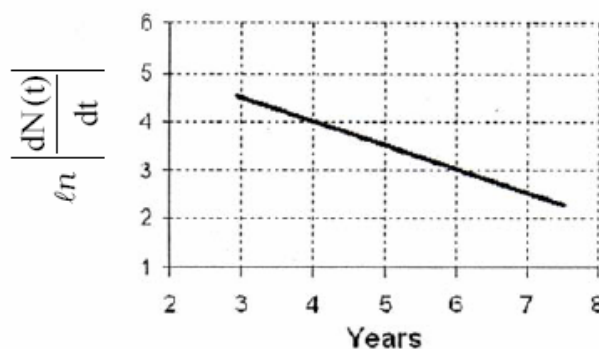
48. A large glass slab ($\mu = 5/3$) of thickness 8 cm is placed over a point source of light on a plane surface. It is seen that light emerges out of the top surface of the slab from a circular area of radius R cm. What is the value of R ?

ANSWER: 6

49. To determine the half life of a radioactive element, a student plots a graph of

$$\ln \left| \frac{dN(t)}{dt} \right| \text{ versus } t. \text{ Here } \frac{dN(t)}{dt} \text{ is the rate}$$

of radioactive decay at time t . If the number of radioactive nuclei of this element decreases by a factor of p after 4.16 years, the value of p is



ANSWER: 8

SECTION - III (Paragraph Type)

Paragraph for questions 50 to 52.

When liquid medicine of density ρ is to be put in the eye, it is done with the help of a dropper. As the bulb on the top of the dropper is pressed, a drop forms at the opening of the dropper. We wish to estimate the size of the drop. We first assume that the drop formed at the opening is spherical because that requires a minimum increase in its surface energy. To determine the size, we calculate the net vertical force due to the surface tension T when the radius of the drop is R . When this force becomes smaller than the weight of the drop, the drop gets detached from the dropper.

50. If the radius of the opening of the dropper is r , the vertical force due to the surface tension on the drop of radius R (assuming $r \ll R$) is

- A) $2\pi rT$ B) $2\pi RT$ C) $\frac{2\pi r^2 T}{R}$ D) $\frac{2\pi R^2 T}{r}$

ANSWER: C

51. If $r = 5 \times 10^{-4} \text{ m}$, $\rho = 10^3 \text{ kg m}^{-3}$, $g = 10 \text{ ms}^{-2}$, $T = 0.11 \text{ Nm}^{-1}$, the radius of the drop when it detaches from the dropper is approximately
- A) $1.4 \times 10^{-3} \text{ m}$ B) $3.3 \times 10^{-3} \text{ m}$ C) $2.0 \times 10^{-3} \text{ m}$ D) $4.1 \times 10^{-3} \text{ m}$

ANSWER: A

52. After the drop detaches, its surface energy is
- A) $1.4 \times 10^{-6} \text{ J}$ B) $2.7 \times 10^{-6} \text{ J}$ C) $5.4 \times 10^{-6} \text{ J}$ D) $8.1 \times 10^{-6} \text{ J}$

ANSWER: B

Paragraph for Questions 53 to 55.

The key feature of Bohr's theory of spectrum of hydrogen atom is the quantization of angular momentum when an electron is revolving around a proton. We will extend this to a general rotational motion to find quantized rotational energy of a diatomic molecule assuming it to be rigid. The rule to be applied is Bohr's quantization condition.

53. A diatomic molecule has moment of inertia I . By Bohr's quantization condition its rotational energy in the n^{th} level ($n = 0$ is not allowed) is
- A) $\frac{1}{n^2} \left(\frac{h^2}{8\pi^2 I} \right)$ B) $\frac{1}{n} \left(\frac{h^2}{8\pi^2 I} \right)$ C) $n \left(\frac{h^2}{8\pi^2 I} \right)$ D) $n^2 \left(\frac{h^2}{8\pi^2 I} \right)$

ANSWER: D

54. It is found that the excitation frequency from ground to the first excited state of rotation for the CO molecule is close to $\frac{4}{\pi} \times 10^{11}$ Hz. Then the moment of inertia of CO molecule about its center of mass is close to (Take $h = 2\pi \times 10^{-34}$ J s)
- A) 2.76×10^{-46} kg m² B) 1.87×10^{-46} kg m²
C) 4.67×10^{-47} kg m² D) 1.17×10^{-47} kg m²

ANSWER: B

55. In a CO molecule, the distance between C (mass = 12 a.m.u.) and O (mass = 16 a.m.u.), where 1 a.m.u. = $\frac{5}{3} \times 10^{-27}$ kg, is close to
- A) 2.4×10^{-10} m B) 1.9×10^{-10} m C) 1.3×10^{-10} m D) 4.4×10^{-11} m

ANSWER: C

SECTION - IV (Matrix Type)

56. Two transparent media of refractive indices μ_1 and μ_3 have a solid lens shaped transparent material of refractive index μ_2 between them as shown in figures in **Column II**. A ray traversing these media is also shown in the figures. In **Column I** different relationships between μ_1, μ_2 and μ_3 are given. Match them to the ray diagrams shown in **Column II**

Column I

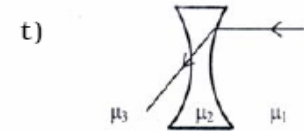
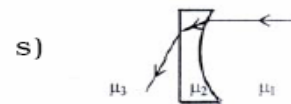
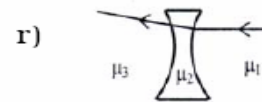
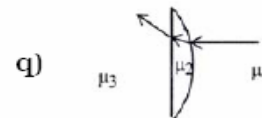
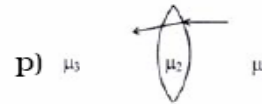
A) $\mu_1 < \mu_2$

B) $\mu_1 > \mu_2$

C) $\mu_2 = \mu_3$

D) $\mu_2 > \mu_3$

Column II



ANSWER:

A: p and r

B: q and s and t

C: p and r and t

D: q and s

57. You are given many resistances, capacitors and inductors. These are connected to variable DC voltage source (the first two circuits) or an AC voltage source of 50 Hz frequency (the next three circuits) in different ways as shown in **Column II**. When a current (steady state for DC or *rms* for AC) flows through the circuit, the corresponding voltage V_1 and V_2 . (indicated in circuits) are related as shown in **column I**. Match the two

Column I

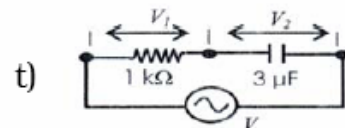
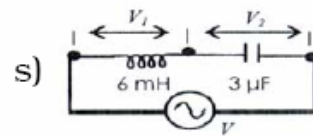
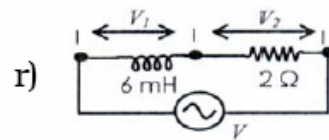
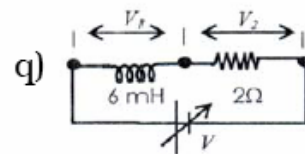
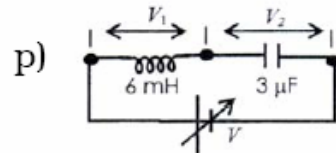
A) $I \neq 0, V_1$ is proportional to I

B) $I \neq 0, V_2 > V_1$

C) $V_1 = 0, V_2 = V$

D) $I \neq 0, V_2$ is proportional to I

Column II



ANSWER:
A: r and s and t
B: q and r and s and t
C: p and q
D: q and r and s and t
