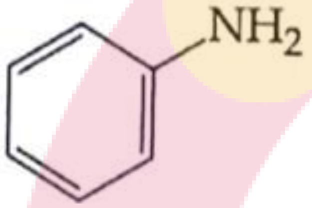
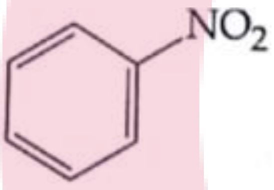
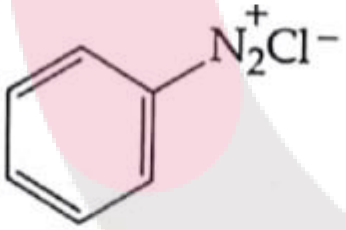
SET C

PART A – Chemistry

1. Which of the following salts is the most basic in aqueous solution?
(A) CH_3COOK (B) $FeCl_3$
(C) $Pb(CH_3COO)_2$ (D) $Al(CN)_3$
Solution: (A)
CH_3COOK

2. Which of the following compounds will be suitable for Kjeldahl's method for nitrogen estimation?
(A)

(B)

(C)

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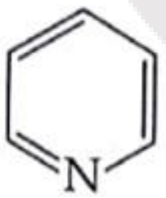
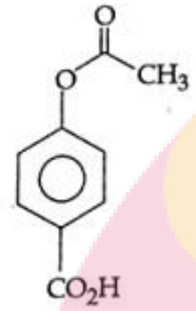
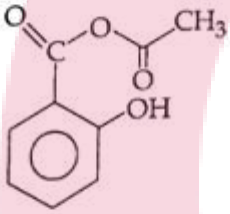
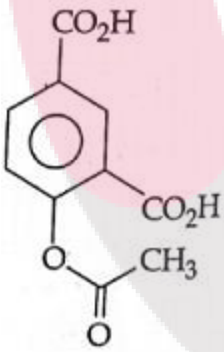
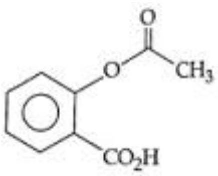
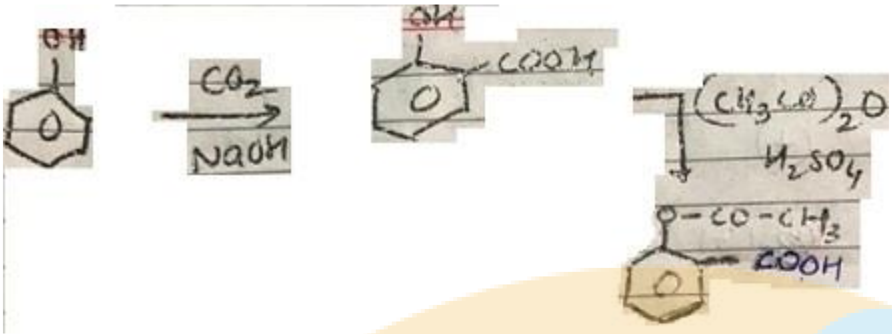

Solution: (A)
Kjedlahl's method can't be used for testing nitrogen in azo nitro and nitrogen in aromatic ring.

3. Which of the following are Lewis acids?
(A) $AlCl_3$ and $SiCl_4$
(B) PH_3 and BCl_3

(C) BCl_3 and $AlCl_3$
(D) PH_3 and $SiCl_4$
Solution: (A)
Has sextet configured

4. Phenol on treatment with CO_2 in the presence of NaOH followed by acidification produces compound X as the major product. X on treatment with $(CH_3CO)_2$ in the presence of catalytic amount of H_2SO_4 produces:
(A)

(B)

(C)

(D)


Solution: (D)



5. An alkali is titrated against an acid with methyl orange as indiactor, which of the following is a correct combination?

(A)

Base	Acid	End point
Strong	strong	Pinkish red to yellow

(B)

Base	Acid	End point
Weak	strong	yellow to Pinkish red

(C)

Base	Acid	End point
Strong	Strong	Pink to colourless

(D)

Base	Acid	End point
Weak	Srtong	Colourless to pink

Solution: (B)

Methyl orange is yellow in basic and reddish id acid

6. An aqueous solution contains 0.10 $M\ H_2S$ and 0.20 M HCl. If the equilibrium constants for the formation of HS^- from H_2S is 1.0×10^{-7} and that of S^{2-} from HS^- ions is 1.2×10^{-13} then the concentration of S^{2-} ions in aqueous solution is:

(A) 3×10^{-20}

(B) 6×10^{-21}

(C) 5×10^{-19}

(D) 5×10^{-8}

Solution: (A)

$$H_2S \rightleftharpoons HS^- + HH^7$$

$$0.1 - x \qquad x \quad (x + 0.2)$$

$$\frac{x(x+0.2)}{0.1-x} = 10^{-7}$$

$$x = \frac{1}{2} \times 10^{-7}$$

$$HS^- \rightleftharpoons S^2 + H^7$$

$$x - y \qquad y \quad x + y + 0.2$$

$$\frac{y(x+y+0.2)}{(x+y)} = 1.2 \times 10^{-13}$$

$$y = 3 \times 10^{-20}$$

7. The combustion of benzene (l) gives $CO_2(g)$ and $H_2O(l)$. Given that heat of combustion of benzene at constant volume is $-3263.9\ kJ\ mol^{-1}$ at 25^oC; heat of combustion $(in\ kJ\ mol^{-1})$ of benzene at constant pressure will be:
$(R = 8.314\ JK^{-1}\ mol^{-1})$

(A) -452.46 (B) 3260 (C) -3267.6 (D) 4152.6

Solution: (C)

$C_6H_6 + O_2 \rightarrow CO_2 + H_2O$

Use, $\Delta H_p = \Delta H_c + \Delta n_g RT$

$-3267.6\ kJ\ mol^{-1}$

8. The compound that does not produce nitrogen gas by thermal decomposition is:

(A) $(NH_4)_2Cr_2O_7$ (B) NH_4NO_2
(C) $(NH_4)_2SO_4$ (D) $Ba(N_3)_2$

Solution: (C)

$(NH_4)_2SO_4$

9. How long (approximate) should water be electrolyzed by passing through 100 amperes current so that the oxygen released can completely burn 27.66 g of diborane? (Atomic weight of B = 10.8 u)

(A) 0.8 hours
(B) 3.2 hours
(C) 1.6 hours
(D) 6.4 hours

Solution: (B)

$B_2H_6 + 3O_2 \rightarrow B_2O_3 + 3H_2O$

$2H_2O \rightarrow 2H_2 + O_2$

$4e^-$ (OS)

$\frac{It}{F}$ =number of moles of electron

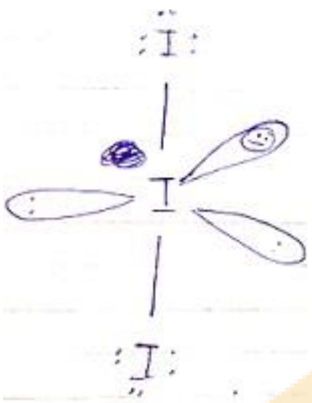
$$\frac{100t}{69500} = 3 \times 4$$

$t = 3.2$ hours

10. Total number of lone pair of electrons in I_3^- ions is:

(A) 6 (B) 9 (C) 12 (D) 3

Solution: (B)

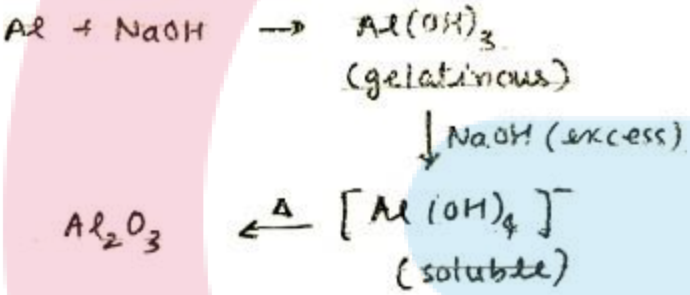


11. When metal 'M' is treated with NaOH, a white gelatinous precipitate 'X' is obtained, which is soluble in excess of NaOH. Compound 'X' when heated strongly gives an oxide which is used in chromatography as an adsorbent. The metal 'M' is:

(A) Ca (B) Al (C) Fe (D) Zn

Solution: (B)

Alumina (Al_2O_3) is used in chromatography



12. According to molecular orbital theory, which of the following will not be a viable molecule?

(A) He_2^+ (B) H_2^- (C) H_2^{2-} (D) He_2^{2+}

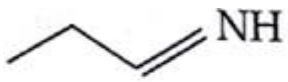
Solution: (C)

In H_2^{2-} bond order is zero

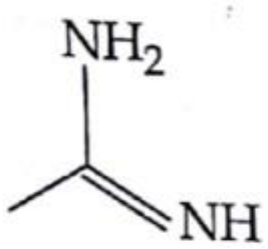
13. The increasing order of basicity of the following compounds is:

(i)

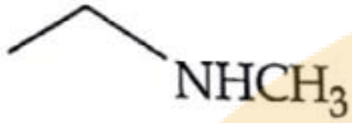
(ii)



(iii)



(iv)



(A) (ii) < (i) < (iii) <(iv)
(B) (ii) < (i) < (iv) < (iii)
(C) (iv) < (ii) < (i) < (iii)
(D) (i) < (ii) < (iii) < (iv)
Solution: (B)
(iii) Is stabilized by resonance when lone pair is donated
(ii) Is most unstable because position charge in double bond is unstable
(i) Is more stable than (d)

14. Which type of 'defect' has the presence of cations in the interstitial sites?
(A) Vacancy defect
(B) Frenkel defect
(C) Metal deficiency defect
(D) Schottky defect
Solution: (B)
Frenkel defect

15. Which of the following compounds contain(s) no covalent bond(s)?
$KCl, PH_3, O_2, B_2H_6, H_2SO_4$
(A) KCl, H_2SO_4
(B) KCl
(C) KCl, B_2H_6
(D) KCl, B_2H_6, PH_3
Solution: (B)
KCl

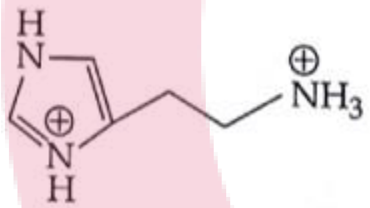
16. The oxidation states of Cr in $[Cr(H_2O)_6]Cl_3$, $[Cr(C_6H_6)_2]$, and $K_2[Cr(CN)_2(O)_2(O)_2(NH_3)]$ respectively are:
(A) $+3, +2$ and $+4$
(B) $+3, 0$ and $+6$
(C) $+3, 0$ and $+4$
(D) $+3, +4$ and $+6$
Solution: (B)

$+3, 0$ and $+6$

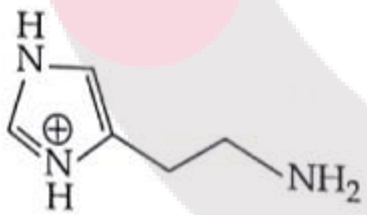
17. Hydrogen peroxide oxidises $[Fe(CN)_6]^{4-}$to $[\mathrm{Fe}(CN)_6]^{3-}$ in acidic medium but reduces $[Fe(CN)_6]^{3-}$to$[Fe(CN)_6]^{4-}$ in alkaline medium. The other products formed are, respectively:
(A) $(H_2O + O_2)$ and $(H_2O + OH^-)$
(B) H_2O and $(H_2O + O_2)$
(C) H_2O and $(H_2O + OH^-)$
(D) $(H_2O + O_2)$ and H_2O
Solution: (B)
H_2O and $(H_2O + O_2)$

18. . Glucose on prolonged heating with HI gives:
(A) 1 – Hexene
(B) Hexanoic acid
(C) 6 – iodohexanal
(D) n – Hexane
Solution: (D)
$C_6H_{12}O_6 + HI + \Delta \rightarrow C_6H_{14}$

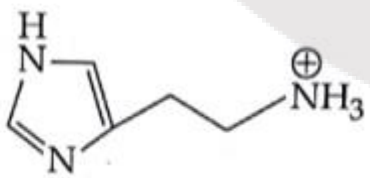
19. The predominant form of histamine present in human blood is $(pK_a, \text{Histidine} = 60.)$
(A)



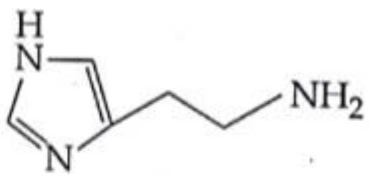
(B)



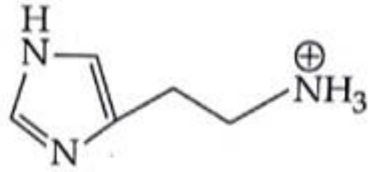
(C)



(D)



Solution: (C)



20. The recommended concentration of fluoride ion in drinking water is up to 1 ppm as fluoride ion is required to make teeth enamel harder by converting $[3Ca_3(PO_4)_2 \, . \, Ca(OH)_2]$ to:

(A) $[3(CaF_2).Ca(OH)_2]$
(B) $[3Ca_3(PO_4)_2.CaF_2]$
(C) $[3\{Ca(OH)_2\}.CaF_2]$
(D) $[CaF_2]$

Solution: (B)

$[3Ca_3(PO_4)_2.CaF_2]$

21. Consider the following reaction and statement:

$[Co(NH_3)_4Br_2]^+ + Br^- \rightarrow [Co(NH_3)_3Br_3] + NH_3$

(i) Two isomers are produced if the reactant complex ion is a cis – isomer.
(ii) Two isomers are produced if the reactant complex ion is a trans – isomer.
(iii) Only one isomer is produced if the reactant complex ion is a trans – isomer.
(iv) Only one is produced if the reactant complex ion is a cis – isomer.

The correct statements are:

(A) (i) and (iii)
(B) (iii) and (iv)
(C) (ii) and (iv)
(D) (i) and (ii)

Solution: (A)

Trans → only meridonial
Cis → fac and mer

22. The trans-alkenes are formed by the reduction of alkynes with:

(A) $NaBH_4$ (B) $Na/liq\,.NH_3$
(C) $Sn - HCl$ (D) $H_2 - Pd/C, BaSO_4$

Solution: (B)

$Na/liq\,.NH_3$

23. The ratio of mass percent of C and H of an organic compound $(C_XH_YO_Z)$ is 6 : 1. If one molecule of the above compound $(C_XH_YO_Z)$ contains half as much oxygen as required to burn one molecule of compound C_XH_Y completely to CO_2 and H_2O. The empirical formula of compound $C_XH_YO_Z$ is:

(A) C_2H_4O (B) $C_3H_4O_2$ (C) $C_2H_4O_3$ (D) $C_3H_6O_3$

Solution: (C)

$$\frac{mass\ of\ C}{mass\ of\ H} = \frac{6}{1}$$

$12x = 6y$

$x : y = 1 : 2$

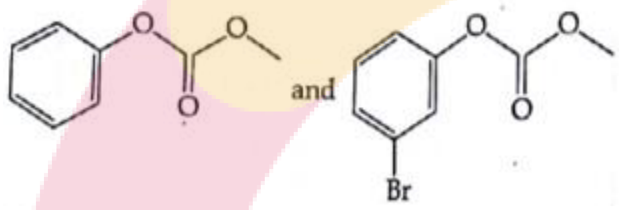
$C_yH_y + \left(\frac{\frac{x+y}{2}}{2}\right) O_2 \rightarrow xCO_2 + \frac{y}{2}\, H_2O$

$$\left(\frac{x + \frac{y}{2}}{2}\right) \times \frac{1}{2} = Z$$

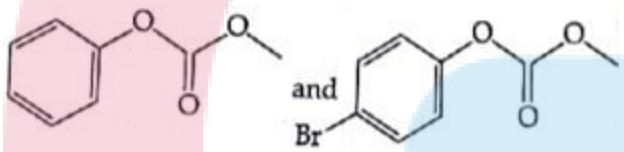
Empirical formula $= C_2H_4O_3$

24. . Phenol reacts with methyl chloroformate in the presence of $NaOH$ to form product A. A reacts with Br_2 to form product B. A and Bare respectively:

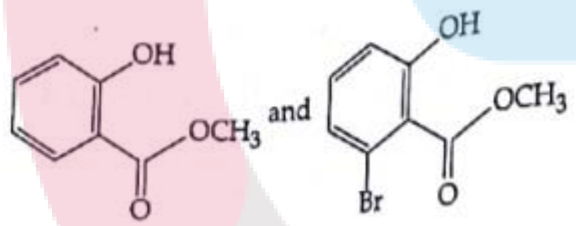
(A)



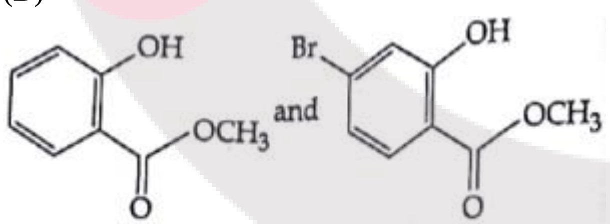
(B)



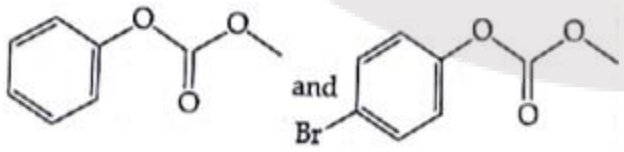
(C)



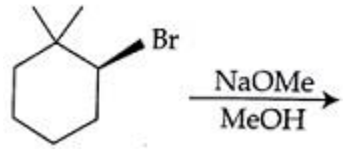
(D)



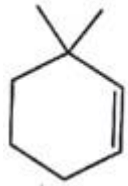
Solution: (B)



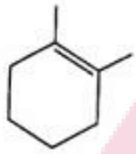
25. The major product of the following reaction is:



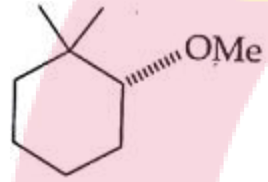
(A)



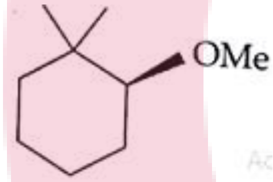
(B)



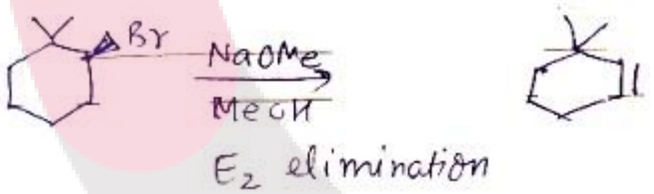
(C)



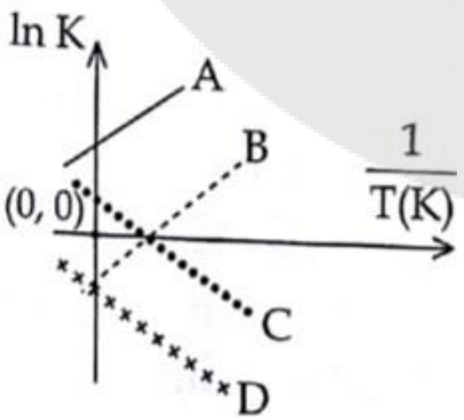
(D)



Solution: (A)



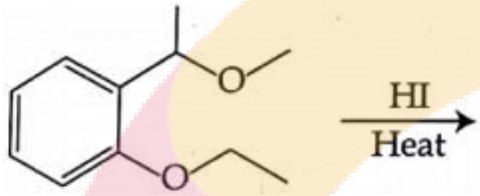
26. Which of the following lines correctly show the temperature dependence of equilibrium constant, K, for an exothermic reaction?



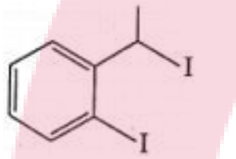
(A) B and C

(B) C and D
(C) A and D
(D) A and B
Solution: (D)
In K $= -\frac{\Delta H}{RT} + C$
$K = Ae^{\frac{-\Delta H}{RT}}$

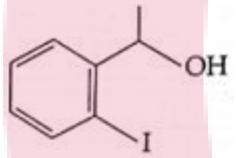
27. The major product formed in the following reaction is:



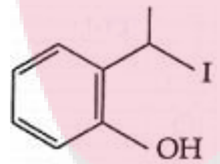
(A)



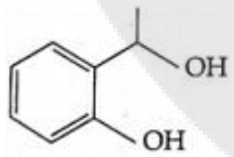
(B)



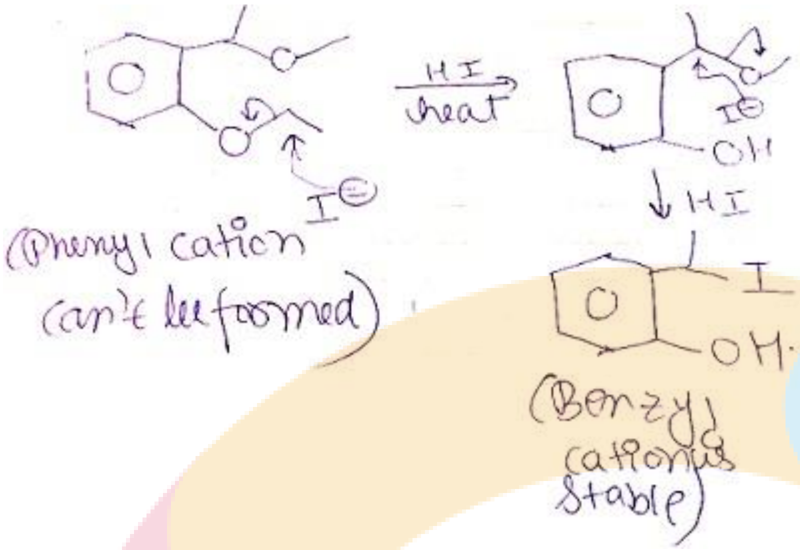
(C)



(D)



Solution: (C)



28. An aqueous solution contains an unknown concentration of Ba^{2+}. When 50 mL of a 1 M solution of Na_2SO_4 is added, $BaSO_4$ just begins to precipitate. The final volume is 500 mL. The solubility product of $BaSO_4$ is 1×10^{-10}. What is the original concentration of Ba^{2+}?

(A) $2 \times 10^{-9} M$

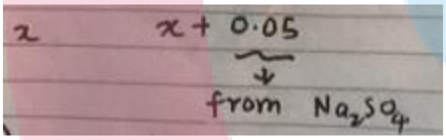
(B) $1.1 \times 10^{-9} M$

(C) $1.0 \times 10^{-10} M$

(D) $5 \times 10^{-9} M$

Solution: (B)

$BaSO_4 \rightleftharpoons Ba^{2+} + SO_4^{2-}$



$\frac{(x)}{0.5} \frac{(x+0.05)}{0.5} = 10^{-10}$

X is small

$x = 5 \times 10^{-10}$

$x + 0.05 \approx 0.05$

Required answer $= 5 \times 10^{-10} \div 0.95 = 1.1 \times 10^{-9} M$

29. At $518^o C$, the rate of decomposition of a sample of gaseous acetaldehyde, initially at a pressure of 363 Torr, was $1.00\ Torr\ s^{-1}$ when 5% had reacted and $0.50\ Torr\ s^{-1}$ when 33% had reacted. The order of the reaction is:

(A) 3

(B) 1

(C) 0

(D) 2

Solution: (D)

Rate $\alpha (cone)^n$

Let initial concentration be x

$0.95x \to 1\ torr\ s^{-1}$

$0.67x \to 0.5\ torr\ s^{-1}$

$\left(\frac{0.95}{0.67}\right)^n = \frac{1}{0.5}$

$\Rightarrow \quad n = 2$

30. For 1 molal aqueous solution of the following compounds, which one will show the highest freezing point?

(A) $[Co(H_2O)_5Cl]Cl_2.H_2O$

(B) $[Co(H_2O)_4Cl_2]Cl.2H_2O$

(C) $[Co(H_2O)_3Cl_3].3H_2O$

(D) $[Co(H_2O)_6]Cl_3$

Solution: (C)

Melting point is lower for more solute concentration $[Co(H_2O)_3Cl_3].3H_2O$ doesn't dissociate into ions and has least solute conc. Is the answer.

PART B – Mathematics

31. The integral $\int \frac{\sin^2 x \cos^2 x}{(\sin^5 x+\cos^3 x \sin^2 x+\sin^3 x \cos^2 x+\cos^5 x)^2} dx$ is equal to:

(A) $\frac{-1}{3(1+\tan^3 x)} + C$ (B) $\frac{1}{1+\cot^3 x} + C$

(C) $\frac{-1}{1+\cot^3 x} + C$ (D) $\frac{1}{3(1+\tan^3 x)} + C$

Solution: (A)

$$\int \frac{\sin^2 x \cos^2 x}{(\sin^5 x + \cos^3 x \sin^2 x + \sin^3 x \cos^2 x + \cos^5 x)^2} dx$$

$$\int \frac{\sin^2 x \cos^2 x}{(\sin^2 x\,(\sin^2 x + \cos^2 x) + \cos^3 x\,(\cos^2 x + \sin^2 x))^2} dx$$

$$\int \frac{\sin^2 x \cos^2 x}{(\sin^3 x + \cos^3 x)^2} dx$$

$$\int \frac{\sin^2 x \cos^2 x}{(\cos^3 x)^2(\tan^3 x + 1)^2} dx$$

$$\int \frac{\tan^2 x \sec^2 x}{(\tan^3 x + 1)^2} dx$$

Put $\tan^3 x + 1 = t$

$dt = 3\tan^2 x \sec^2 x\, dx$

$$\Rightarrow \quad \int \frac{dt}{3(t)^2}$$

$$\Rightarrow \quad \frac{-1}{3t} + C$$

$$\Rightarrow \quad \frac{-1}{3(\tan^3 x + 1)} + C$$

32. Tangents are drawn to the hyperbola $4x^2 - y^2 = 36$ at the points P and Q. If these tangents intersect at the point $T(0, 3)$ then the area (in sq. units) of ΔPTQ is:

(A) $54\sqrt{3}$ (B) $60\sqrt{3}$ (C) $36\sqrt{5}$ (D) $45\sqrt{5}$

Solution: (D)

$4x^2 - y^2 = 36$

$\frac{x^2}{9} - \frac{y^2}{36} = 1$

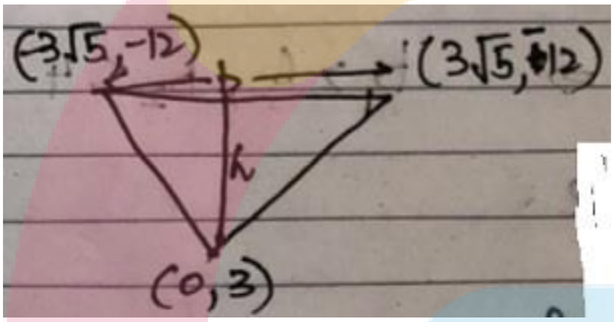
Equation of tangent: $\frac{xx_1}{9} - \frac{yy_1}{36} = 1$

$x = 0, y = 3$

$\Rightarrow \frac{x_1 \times 0}{9} - \frac{y_1 \times 3}{36} = 1$

$\Rightarrow y_1 = -12$

$x_1 = \sqrt{\frac{36 + (144)^2}{4}} = \pm 3\sqrt{5}$



$h = 3 + 12 = 15$

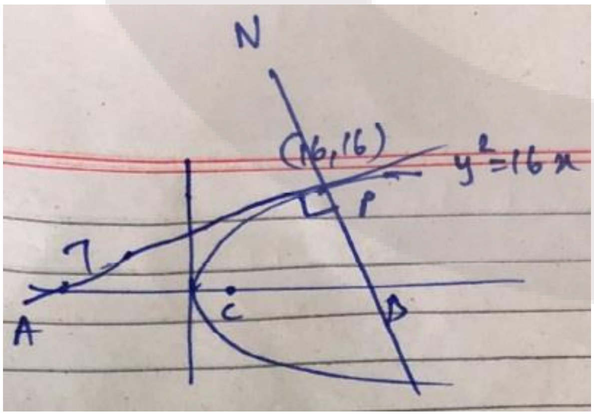
$b = 6\sqrt{5}$

Area $= \frac{1}{2} \times 6\sqrt{5} + 15 = 45\sqrt{5}$

33. Tangent and normal are drawn at $P(16, 16)$ on the parabola $y^2 = 16x$, which intersect the axis of the parabola at A and B, respectively. If C is the centre of the circle through the points P, A and B and $\angle CPB = \theta$, then a value of $\tan\theta$ is:

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

Solution: (A)



Equation of tangent $= ty = x + at^2$

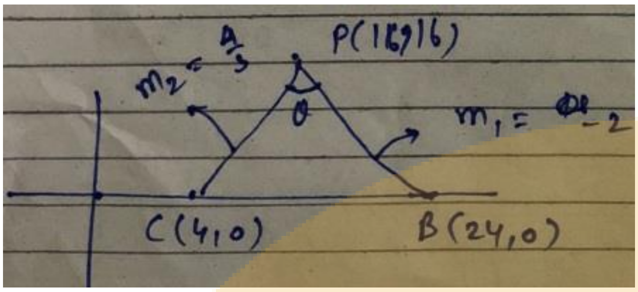
Equation of normal $= y + xt = 2at + at^3$

Tangent $= 2y = x + 16$ $(-16,0)$

Normal $= y + 2x = 48$ (24,0)

Centre – $\left(\frac{24-16}{2}, 0\right)$

Centre $= (4,0)$



$$\tan\theta = \left|\frac{\frac{4}{3} + 2}{1 - 2 \times \frac{4}{3}}\right| = \left|\frac{10}{-5}\right| = 2$$

34. Let $\vec{u}$ be a vector coplanar with the vectors $\vec{a} = 2\hat{\imath} + 3\hat{\jmath} - \hat{k}$ and $\vec{b} = \hat{\jmath} + \hat{k}$. If $\vec{u}$ is perpendicular to $\vec{a}$ and $\vec{u} \cdot \vec{b} = 24$, then $|\vec{u}|^2$ is equal to:

(A) 315 (B) 256 (C) 84 (D) 336

Solution: (D)

$\vec{u} = x\hat{\imath} + y\hat{\jmath} + z\hat{k}$

$$\begin{vmatrix} x & y & z \\ 2 & 3 & -1 \\ 0 & 1 & 1 \end{vmatrix} = 0$$

$4x - 2y + 2z = 0$

$4y - 2z = 0$

$2x - y + z = 0$

$y = 27$

$\vec{u} . \vec{a} = 0 \;\; 2x + 3y - z = 0$

$y + z = 24$

$z = 8$

$y = 16$

$x = 4$

$\therefore \;\; 4^2 + 8^2 + 16^2$

$= 336$

35. If $\alpha, \beta \in C$ are the distinct roots, of the equation $x^2 - x + 1 = 0$, then $\alpha^{101} + \beta^{107}$ is equal to:

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

Solution: (B)

$x^2 - x + 1 = 0$

Roots are $-w, -w^2$

$\alpha^{101} + \beta^{107} = (-w)^{101} + (-w^2)^{107}$

$= -w^{101} - w^{214}$

$= -w^2 - w$

$= 1$

As $(1 + w + w^2 = 0)$

36. Let $g(x) = \cos x^2$, $f(x) = \sqrt{x}$, and $\alpha, \beta (\alpha < \beta)$ be the roots of the quadratic equation $18x^2 - 9\pi x + \pi^2 = 0$. Then the area (in sq. units) bounded by the curve $y = (gof)(x)$ and the lines $x = \alpha, x = \beta$ and $y = 0$, is:

(A) $\frac{1}{2}(\sqrt{3} + 1)$ (B) $\frac{1}{2}(\sqrt{3} - \sqrt{2})$

(C) $\frac{1}{2}(\sqrt{2} - 1)$ (D) $\frac{1}{2}(\sqrt{3} - 1)$

Solution: (D)

Given $g(x) = \cos x^2$, $f(x) = \sqrt{x}$

$18x^2 - 9\pi x + \pi^2 = 0$

The roots : $x = \frac{9\pi \pm \sqrt{81\pi^2 - 72\pi^2}}{2 \times 18}$

$$x = \frac{9\pi \pm \sqrt{9\pi^2}}{36}$$

$$x = \frac{(9 \pm 3)\pi}{36}$$

$$x = \frac{\pi}{3}, \frac{\pi}{6}$$

$y = goflus$

As $\cos\left(\sqrt{x}\right)^2 = \cos x$

Area $= \int_{\frac{\pi}{6}}^{\frac{\pi}{3}} \cos x \; dx$

$= [\sin x]_{\frac{\pi}{6}}^{\frac{\pi}{3}}$

$\Rightarrow \frac{\sqrt{3}}{2} - \frac{1}{2}$

37. The sum of the co-efficient of all odd degree terms in the expansion of $\left(x + \sqrt{x^3 - 1}\right)^5 + \left(x - \sqrt{x^3 - 1}\right)^5, (x > 1)$ is:

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

Solution: (C)

$\left(x + \sqrt{x^3 - 1}\right)^5 + \left(x - \sqrt{x^3 - 1}\right)^5 \; x > 1$

$f(x) = 2[x^5 + {}^5C_3 x^3 (x^3 - 1) + {}^5C_3 x (x^3 - 1)^2]$

For sum of add power coefficient it

Put $\frac{f(1) - f(-1)}{2}$

$f(1) = 2[10]$

$f(-1) = 2[-1 + {}^5C_3 \times 20 - {}^5C_3 \times 4]$

$f(-1) = 2[-1 + 20 - 20] = -2$

$$\frac{f(1) - f(-1)}{2} = \frac{2 - (-2)}{2} = 2$$

38. Let $a_1, a_2, a_3, \dots\dots, a_{49}$ be in A.P. such that $\sum_{k=0}^{12} a_{4k+1} = 416$ and $a_9 + a_{43} = 66$. If $a_1^2 + a_2^2 + \cdots + a_{17}^2 = 140m$, then m is equal to:

(A) 68 (B) 34 (C) 33 (D) 66

Solution: (B)

Let $a_1 = 1$ and d = common difference.

$a_n = 1 + (n-1)d$

Given, $\sum_{k=0}^{12} a_{4k+1} = 416$

$a_1 + a_5 + a_9 + \cdots a_{49} = 416$

$a + a + 4d + d + 8d + \cdots + d + 48d = 416$

$13a + \dfrac{4 \times 23 \times 13d}{2} = 416$

$a + 24d = 32 \dots$ (i)

$a_9 + a_{43} = 66$

$a + 8d + a + 42d = 66$

$2a + 50d = 66$

$a + 25d = 33 \ \dots$ (ii)

On solving we get,

$d = 1, a = 8$

Now, $a_1^2 + a_2^2 + \cdots a_{17}^2 = 140m$

$a^2(a+d)^2 + \cdots (a+16d)^2$

$\Rightarrow a^2 + a^2 + d^2 + 2d + a^2 + 4d^2 + 4d + \cdots a^2 + 256d^2 + 32d$

$\Rightarrow 17a^2 + d^2(1 + 4 + 9 + \cdots 256) + 2d(1 + 2 + \cdots 16)$

$\Rightarrow 17a^2 + d^2 \times \dfrac{16 \times 17 \times 33}{6} + 2d\left(\dfrac{16 \times 17}{2}\right)$

$\Rightarrow 17 \times 64 + 1496 + 272 \times 8$

$\Rightarrow 1088 + 1496 + 272 \times 8$

$= 4760$

39. If $\sum_{i=1}^{9}(x_i - 5) = 9$ and $\sum_{i=1}^{9}(x_i - 5)^2 = 45$, then the standard deviation of the 9 items $x_1, x_2, \dots, x_9$ is:

(A) 4 (B) 2 (C) 3 (D) 9

Solution: (B)

$$\sum_{i=1}^{9}(x_i - 5) = 9$$

Mean $= \frac{9}{9} + 5 = 6$

$\overline{x} = 6$

$\sum_{i=1}^{9}(x_i - 5)^2 = 459$

$$\sum_{i=1}^{9} x^2 - 10\sum_{i=1}^{9} x\,; +25 \times 9 = 45$$

$$\sum_{i=1}^{9} x_1^2 = 45 - 25 \times 9 + 10 \times (9 + 5 \times 9)$$

$= \ 360$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{9}(x; -6)^2}{9}}$$

$$\sigma = \sqrt{\frac{\sum_{i=1}^{9} x^2 - 12\sum_{i=1}^{9} x; + 36 + 9}{9}}$$

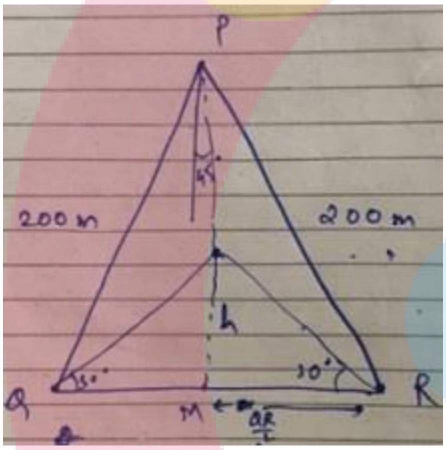
$$\sigma = \sqrt{\frac{360 - 12 \times 54 + 36 + 9}{9}}$$

$$= \ 2$$

40. PQR is a triangular park with PQ = PR = 200m. A T.V. tower stands at the mid-point of QR. If the angles of elevation of the top of the tower at P, Q and R are respectively $45^o, 30^o$ and 30^o, then the height of the tower (in m) is:

(A) 50 (B) $100\sqrt{3}$ (C) $50\sqrt{2}$ (D) 100

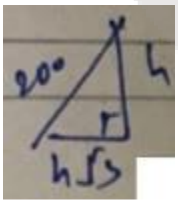
Solution: (D)



$$\tan 30 = \frac{2R}{QR}$$

$$QR = \frac{2h}{\left(\frac{1}{\sqrt{3}}\right)} = 2h\sqrt{3}$$

$$\tan 45^o = \frac{h}{PM} \ PM = h$$



So, $4h^2 = 200^2$

$h^2 + 3h^2 = 200^2$

$2h = 200$

$h = 100$

41. Two sets A and B are as under:

$A = \{(a, b) \in R \times R : |a - 5| < 1 \text{ and } |b - 5| < 1\};$

$B = \{(a,b) \in R \times R: 4(a-6)^2 + 9(b-5)^2 \leq 36\}$. Then:

(A) $A \subset B$

(B) $A \cap B = \phi$ (an empty set)

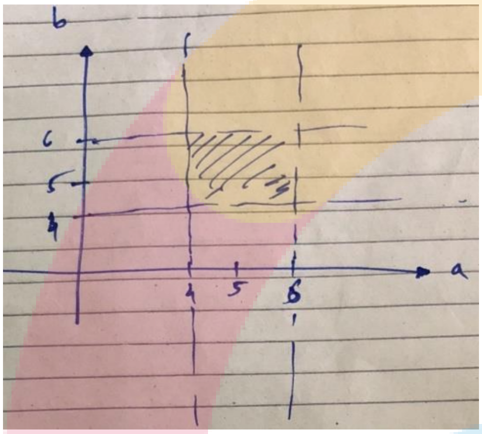
(C) Neither $A \subset B$ nor $B \subset A$

(D) $B \subset A$

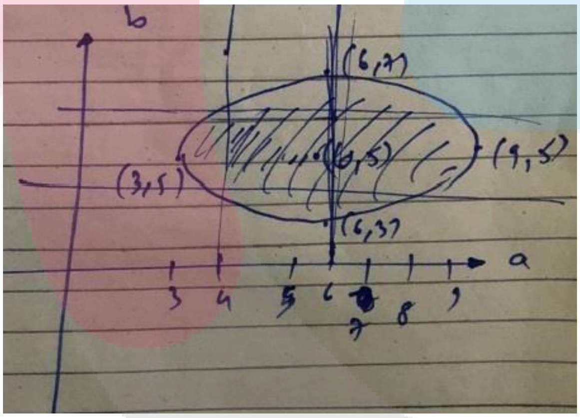
Solution: (A)

$A = \{(a,b) \in R \times R : |a-5| < 1 \text{ and } |b-5| < 1\}$;

$\frac{(a-6)^2}{9} + \frac{(b-5)^2}{4} \leq 1$



$\frac{4}{9} + \frac{1}{4} \leq 1$ (4, 4) lies in B



(4,6) lies in B

(6, 4) lies in B (6,3) lies in A

42. From 6 different novels and 3 different dictionaries, 4 novels and 1 dictionary are to be selected and arranged in a row on a shelf so that the dictionary is always in the middle. The number of such arrangements is:

(A) Less than 500

(B) At least 500 but less than 750

(C) At least 750 but less than 1000

(D) At least 1000

Solution: (D)

N_1, N_2, D, N_3, N_4

N → Novels

D→ Dictionary
D can be chosen in 3 ways
$N_1 \to 6$
$N_2 \to 5$
$N_3 \to 4$
$N_4 \to 3$
Total ways $= 3 \times 6 \times 5 \times 4 \times 3 = 1080$

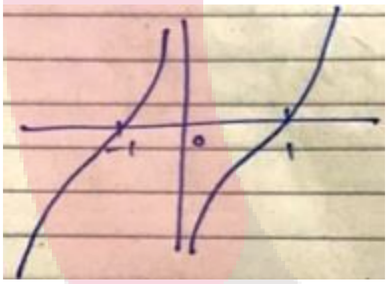
43. Let $f(x) = x^2 + \frac{1}{x^2}$ and $g(x) = x - \frac{1}{x}, x \in R - \{-1, 0, 1\}$. If $h(x) = \frac{f(x)}{g(x)}$, then the local minimum value of $h(x)$is:
(where C is a constant of integration)
(A) -3 (B) $-2\sqrt{2}$ (C) $2\sqrt{2}$ (D) 3
Solution: (C)

$$f(x) = x^2 + \frac{1}{x^2} = \left(x - \frac{1}{x}\right)^2 + 2$$

$$g(x) = x - \frac{1}{x}$$

$x \in R - \{-1. 0, 1\}$
Let $x - \frac{1}{x} = t$

$$h(x) = \frac{f(x)}{g(x)} = \frac{t^2 + 2}{t} = t + \frac{2}{t}$$



$$p(x) = x - \frac{1}{x}$$

$$p'(x) = 1 + \frac{1}{x^2}$$

$$t = x - \frac{1}{x}$$

Since $x \neq (-1, 0, 1)$
$t \in R - \{0\}$

$$h(x) = t + \frac{2}{t}$$

$AM \div\geq GM$

Min of $h(x) \Rightarrow \frac{t + \frac{2}{t}}{2} \geq \sqrt{t \times \frac{2}{t}}$

$$t + \frac{2}{t} \geq 2\sqrt{2}$$

Local minimum $= 2\sqrt{2}$

44. For each $t \in R$, let $[t]$ be the greatest integer less than or equal to t. Then $\lim_{x \to 0+} x\left(\left[\frac{1}{x}\right] + \left[\frac{2}{x}\right] + \cdots + \left[\frac{15}{x}\right]\right)$

(A) Is equal to 15

(B) IS equal to 120

(C) Does not exist (in R)

(D) Is equal to 0

Solution: (B)

$$\lim_{x \to 0^+} x\left(\left[\frac{1}{x}\right] + \left[\frac{2}{x}\right] + \cdots \left[\frac{15}{x}\right]\right)$$

$$\lim_{x \to 0^+} x\left(\frac{1}{x} + \frac{2}{x} + \cdots \frac{15}{x}\right)$$

$\left[\frac{1}{x}\right] - \left[\frac{2}{x}\right] \ldots . \left[\frac{15}{x}\right] \rightarrow$ these terms will be neglected as $\lim_{x \to 0^+} x\left\{\left[\frac{1}{x}\right] - \left[\frac{2}{x}\right] \ldots . \left[\frac{15}{x}\right]\right\}$ lying between 0 and 1

$$\lim_{x \to 0^+} x\left(\frac{1 + 2 + \cdots 15}{x}\right)$$

$$1 + 2 + \cdots 15 = \frac{15 \times 16}{2}$$

$$= 120$$

45. The values of $\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\sin^2 x}{1+2^x} dx$ is:

(A) $\frac{\pi}{2}$ (B) 4π (C) $\frac{\pi}{4}$ (D) $\frac{\pi}{8}$

Solution: (C)

$$I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\sin^2 x}{1+2^x}\, dx \qquad \ldots\ldots(i)$$

$$\int_a^b f(x)\, dx$$

$$\int f(x) = \int (a + b - x)$$

$$I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\sin^2(-x)}{1 + 2^{-x}} dx$$

$$I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{2^x \sin^2 x}{1+2^x} dx \qquad \ldots\ldots(ii)$$

Equations (i) and (ii)

$$2I = \int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \frac{\sin^2 x\,(1 + 2^x)}{(1 + 2^x)}\, dx$$

$$2I = 2\int_{-\frac{\pi}{2}}^{\frac{\pi}{2}} \sin^2 x\, dx$$

$$I = \int_0^{\frac{\pi}{2}} \cos^2 x \, dx$$

$$2I = \int_0^{\frac{\pi}{2}} (\sin^2 x + \cos^2 x) \, dx$$

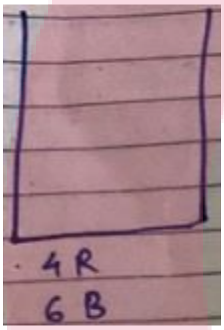
$$2I = \int_0^{\frac{\pi}{2}} 1 \, dx$$

$$I = \frac{\pi}{2} \times \frac{1}{2} = \frac{\pi}{4}$$

46. A bag contains 4 red and 6 black balls. A ball is drawn at random from the bag, its colour is observed and this ball along with two additional balls of the same colour are returned to the bag. If now a ball is drawn at random from the bag, then the probability that this drawn ball is red, is:

(A) $\frac{2}{5}$ (B) $\frac{1}{5}$ (C) $\frac{3}{4}$ (D) $\frac{3}{10}$

Solution: (A)



P(red, red) + p(black, red)

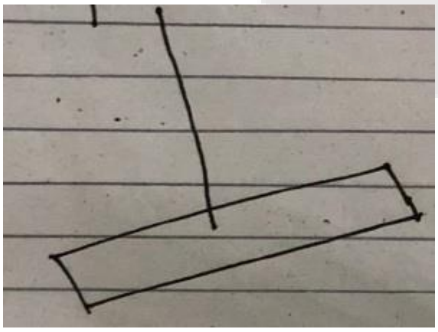
$$\frac{4}{(4+6)} \times \frac{6}{(4+6+2)} + \frac{6}{6+4} \times \frac{4}{6+4+2}$$

$$= \frac{24+24}{10 \times 12} = \frac{48}{10 \times 12} = \frac{2}{5}$$

47. The length of the projection of the line segment joining the points (5, -1, 4) and (4, -1, 3) on the plane, $x + y + z = 7$ is:

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

Solution: (C)



$A(5, -1, 4)\,;\, b(4, -1, 3)$

Vector joining A, B

$AB = 1\hat{\imath} + 0\hat{\jmath} + 1\hat{k}$

Normal vector $\hat{\imath} + \hat{\jmath} + \hat{k}$

$|AB| = \sqrt{2}$

$|AB_1| = \frac{1+1}{\sqrt{3}} = \frac{2}{\sqrt{3}}$

$AB_{11} = \sqrt{2 - \frac{4}{3}} = \sqrt{\frac{2}{3}}$

48. If sum of all the solutions of the equation $8\cos x . \left(\cos\left(\frac{\pi}{6}+x\right).\cos\left(\frac{\pi}{6}-x\right) - \frac{1}{2}\right) = 1$ in $[0, \pi]$ is $k\pi$, then k is equal to:

(A) $\frac{13}{9}$ (B) $\frac{8}{9}$ (C) $\frac{20}{9}$ (D) $\frac{2}{3}$

Solution: (B)

$8\cos x . \left(\cos\left(\frac{\pi}{6}+x\right).\cos\left(\frac{\pi}{6}-x\right) - \frac{1}{2}\right) = 1$

We would use the formula

$\cos(A+B).\cos(A-B) = \cos^2 A - \sin^2 B$

Now, $\cos\left(\frac{\pi}{6}+x\right).\cos\left(\frac{\pi}{6}-x\right) = \cos^2\frac{\pi}{6} - \sin^2 x$

$= \frac{3}{4} - \sin^2 x$

$8\cos x\left(\frac{3}{4} - \sin^2 x - \frac{1}{2}\right) = 1$

$8\cos x\left(\frac{1}{4} - \sin^2 x\right) = 1$

$8\cos x\left(\frac{1}{4} - (1 - \cos^2 x)\right) = 1$

$8\cos x\left(\cos^2 x - \frac{3}{4}\right) = 1$

$8\cos^3 x - 6\cos x = 1$

$2(4\cos^3 x - 3\cos x) = 1$

$2\cos 3x = 1$

$\cos 3x = \frac{1}{2}$

$3x = 2n\pi \pm \frac{\pi}{3}$

$x = \frac{2n\pi}{3} \pm \frac{\pi}{9}$

$x \in [0, \pi]$

$\therefore \quad x = \frac{\pi}{9}, \frac{7\pi}{9}$

Sum $= \frac{8\pi}{9}$ $k = \frac{8}{9}$

49. A straight line through a fixed point (2, 3) intersects the coordinate axes at distinct points P and Q. If O is the origin and the rectangle OPRQ is completed, then the locus of R is:

(A) $2x + 3y = xy$ (B) $3x + 2y = xy$

(C) $3x + 2y = 6xy$ (D) $3x + 2y = 6$

Solution: (B)

Let the equation of line be

$$\frac{x}{p} + \frac{y}{q} = 1$$

(p, 0), (O,q) are the points & Q representing passes through (2, 3)

$\Rightarrow \frac{2}{p} + \frac{3}{q} = 1$

Q locus of R is (p, q)

$p = x, q = y$

$$\frac{4}{2x} + \frac{6}{2y} = 1$$

$y + 6x = 2xy$

$= 2y + x = xy$

50. Let A be the sum of the first 20 terms and B be the sum of the first 40 terms of the series $1^2 + 2 \cdot 2^2 + 3^2 + 2 \cdot 4^2 + 5^2 + 2 \cdot 6^2 + \cdots$.

If $B - 2A = 100\lambda$, then λ is equal to:

(A) 248 (B) 464 (C) 496 (D) 232

Solution: (A)

$S = 1 + 2.2^2 + 3^2 + 3 + 2.4^2 + 5^2 + 2.6^2 + \cdots$

$S = 1 + 2^2 + 3^2 + 4^2 + \cdots$

$$S_1 = \frac{20 \times 21 \times 41}{6} + \frac{4 \times 10 \times 11 \times 21}{6}$$

$S - 1\,A = 4410$

$$B = \frac{40 \times 41 \times 81}{6} + \frac{4 \times 20 \times 21 \times 41}{6}$$

$= 33620$

$B - 2A = 24800$

$= 100\lambda = 7\lambda = 248$

51. If the curves $y^2 - 6x, 9x^2 + by^2 = 16$ intersect each other at right angles, then the value of b is:

(A) $\frac{7}{2}$ (B) 4 (C) $\frac{9}{2}$ (D) 6

Solution: (C)

$y^2 = 6x$

$9x^2 + by^2 = 16$

$$2y_1 \frac{dy}{dx} = 6$$

$$\Rightarrow \frac{dy}{dx} = \frac{3}{y_1}$$

$$18x_1 + 2by_1 \frac{dy}{dx} = 0$$

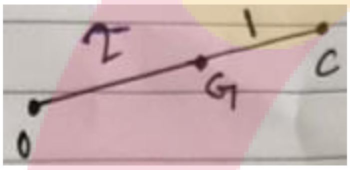
$$\Rightarrow \frac{dy}{dx} = \frac{-9x_1}{by_1}$$

$\left(\frac{3}{y_1}\right) \times \left(\frac{-9x_1}{by_1}\right) = -1$
$27x_1 = by_1^2$
$y_1^2 = 6x_1$
$27x_1 = b(6x_1)$
$x_1 \neq 0$
$b = \frac{27}{6} = \frac{9}{2}$

52. Let the orthocentre and centroid of a triangle be $A(-3,5)$ and $B(3,3)$ respectively. If C is the circumcentre of this triangle, then the radius of the circle having line segment AC as diameter, is:

(A) $2\sqrt{10}$ (B) $3\sqrt{\frac{5}{2}}$ (C) $\frac{3\sqrt{5}}{2}$ (D) $\sqrt{10}$

Solution: (B)



Centroid divides the line joining O and C in the ratio 2 : 1
A = O, B = G
$OG = \sqrt{(3+3)^2 + (5-3)^2} = \sqrt{6^2 + 2^2} = \sqrt{40} = 2\sqrt{10}$
$OC = \frac{3}{2} \times 2\sqrt{10} = 3\sqrt{10}$
Radius $= \frac{OC}{2} = 3\sqrt{\frac{10}{4}} = 3\sqrt{\frac{5}{2}}$

53. Let $S = \{t \in R: f(x) = |x-\pi| \cdot (e^{|x|} - 1)\sin|x|$ is not differentiable at $t\}$. Then the set S is equal to:
(A) $\{0\}$ (B) $\{\pi\}$
(C) $\{0, \pi\}$ (D) ϕ (an empty set)
Solution: (D)
$f(x) = (x-\pi).(e^{|x|} - 1).sin|x|$
$f'(\pi + h) = \lim_{x \to h+\pi} \frac{f(\pi+h) - f(\pi)}{h} = \frac{|h|\sin(\pi+h)(e^{\pi}-1)}{h} = 0$
$f'(\pi + h) = \lim_{x \to h+\pi} \frac{f(\pi) - f(\pi-h)}{h} = \frac{|h|\sin(\pi+h)(e^{\pi}-1)}{h} = 0$
Differentiable at π
$f'(0+h) = \lim_{L \to 0} \frac{f(h) - f(0)}{h} = |\pi| \times \frac{|h|sin|h|}{h} = 0$
$f'(0-h) = \lim_{L \to 0} \frac{f(0) - f(h)}{h} = |\pi| \times \frac{|h|sin|h|}{h} = 0$
Differentiable at 0
F(x) is d9fferentiable everywhere
$S = \phi$

54. If $\begin{vmatrix} x-4 & 2x & 2x \\ 2x & x-4 & 2x \\ 2x & 2x & x-4 \end{vmatrix} = (A+Bx)\,(x-A)^2$, then the ordered pair (A, B) is equal to:

(A) $(-4,3)$ (B) $(-4,5)$ (C) $(4,5)$ (D) $(-4,-5)$

Solution: (B)

$$\begin{vmatrix} x-4 & 2x & 2x \\ 2x & x-4 & 2x \\ 2x & 2x & x-4 \end{vmatrix} = (A+Bx)\,(x-A)^2$$

Put $x = 0 \Rightarrow \begin{vmatrix} -4 & 0 & 0 \\ 0 & -4 & 0 \\ 0 & 0 & -4 \end{vmatrix} = A^3 \Rightarrow 4$

$$\begin{vmatrix} x-4 & 2x & 2x \\ 2x & x-4 & 2x \\ 2x & 2x & x-4 \end{vmatrix} = (Bx-4)(x+4)^2$$

$$\begin{vmatrix} 1-\frac{4}{x} & 2 & 2 \\ 2 & 1-\frac{4}{x} & 2 \\ 2 & 2 & 1-\frac{4}{x} \end{vmatrix} = \left(B-\frac{4}{x}\right)\left(1+\frac{4}{x}\right)^2$$

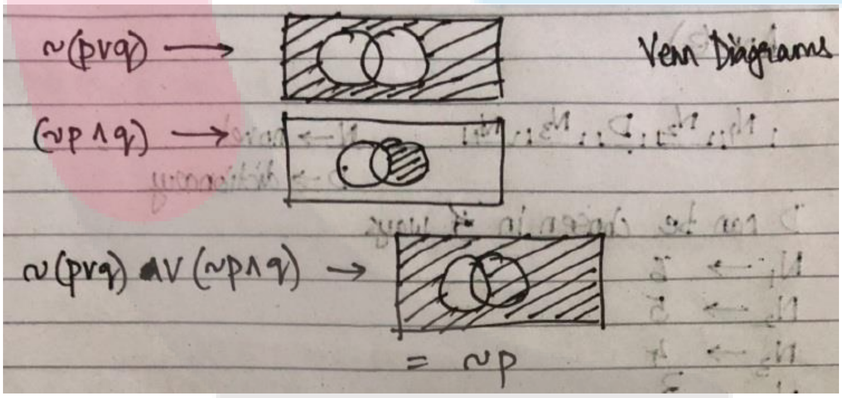
Put $x \to \infty \Rightarrow \begin{vmatrix} 1 & 2 & 2 \\ 2 & 1 & 2 \\ 2 & 2 & 1 \end{vmatrix} = B \Rightarrow B = 5$

Ordered pair (A, B) is (-4, 5)

55. The Boolean expression $\sim(p \vee q) \vee (\sim p \wedge q)$ is equivalent to:

(A) p (B) q (C) $\sim q$ (D) $\sim p$

Solution: (D)



$\sim(p \vee q) = (\sim P \wedge \sim q) \vee (\sim p \wedge q)$

$= \sim p \wedge (\sim q \vee q)$

$= \sim p \wedge q = \sim p$

56. If the system of linear equations

$x + ky + 3z = 0$

$3x + ky - 2z = 0$

$2x + 4y - 3z = 0$

has a non-zero solution (x, y, z), then xz/y^2 is equal to:

(A) 10 (B) -30 (C) 30 (D) -10

Solution: (A)

$$\begin{vmatrix} 1 & k & 3 \\ 3 & k & -2 \\ 2 & 4 & -3 \end{vmatrix} = 0$$

$(-3k+8) - 3(-3k-12) + 2(-5k) = 0$

$-4k + 44 = 0 \qquad k = 11$

$x + 11y + 3z = 0 \qquad$ …. (i)

$3x + 11y - 2z = 0 \qquad$ ….. (ii)

$2x + 4y - 3z = 0 \qquad$ … (iii)

Equation (ii) and (i)

$2x - 5z = 0$

$x = \frac{5z}{2} = -5y$

Put it in

$2z + 4y = 0$

$z = -2y$

$\frac{xz}{y^2} = \frac{(-2y) \times (-5y)}{y^2} = 10$

57. Let $S = \{x \in R : x \geq 0 \text{ and } 2|\sqrt{x} - 3| + \sqrt{x}\,(\sqrt{x} - 6) + 6 = 0\}$. Then S:

(A) Contains exactly one element

(B) Contains exactly two elements

(C) Contains exactly four elements

(D) Is an empty set

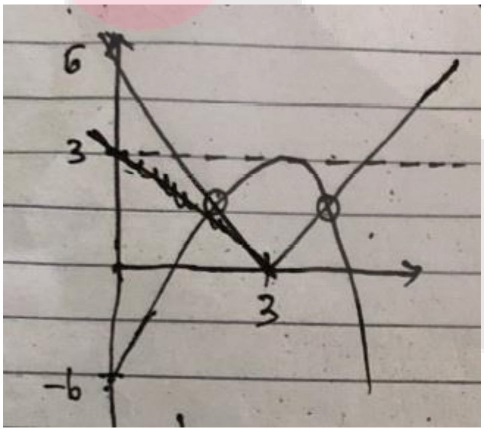
Solution: (B)

$2|\sqrt{x} - 3| + \sqrt{x}(\sqrt{x} - 6) + 6 = 0$

Let $\sqrt{x} = t > 0$

$2|t - 3| + t(t - 6) + 6 = 0$

$= 2|t - 3| = -(t^2 - 6t + 6) = -(t^2 - 6t + 9) + 3$

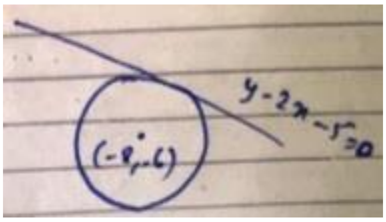


Has 2 solutions for t = 2 solutions for x

58. If the tangent at $(1, 7)$ to the curve $x^2 = y - 6$ touches the circle $x^2 + y^2 + 16x + 12y + c = 0$ then the value of c is:

(A) 185 (B) 85 (C) 95 (D) 195

Solution: (C)



$2x = \frac{dy}{dx}$

$\left.\frac{dy}{dx}\right|_{(1,7)} = 2 \times 1 = 2$

$\frac{y-7}{x-1} = 2$

$y = 2x + 5$

Distance from centre =

$\left[\frac{-6-2(-8)-5}{\sqrt{1^2+2^2}}\right]$

$\left|\frac{5}{\sqrt{5}}\right| = \sqrt{5}$

Radius of circle = $\sqrt{8^2+6^2-c}$

$\sqrt{100-c} = \sqrt{5}$

$c = 95$

59. Let $y = y(x)$ be the solution of the differential equation $\sin x \frac{dy}{dx} + y \cos = 4x, x \in (0, \pi)$. If $y\left(\frac{\pi}{2}\right) = 0$, then $y\left(\frac{\pi}{6}\right)$ is equal to:

(A) $\frac{-8}{9\sqrt{3}}\pi^2$ (B) $-\frac{8}{9}\pi^2$ (C) $-\frac{4}{9}\pi^2$ (D) $\frac{4}{9\sqrt{3}}\pi^2$

Solution: (B)

$$\frac{dy}{dx}+y\cot x=\frac{x}{\sin x}\quad x\in(0,\pi)$$

$$I.F=e^{\int \cot x}=e^{\ln \sin x}=\sin x$$

$$\therefore y\sin x=\int\frac{x}{\sin x}.\sin x\,dx$$

$$y\sin x=2x^2+x$$

$$y\left(\frac{\pi}{2}\right)=0$$

$$0\times 1=3\times\left(\frac{\pi}{2}\right)^2+c$$

$$=c=-\frac{\pi^2}{2}$$

$$\left(\frac{\pi}{6}\right)=\frac{2\times\left(\frac{\pi}{6}\right)^2-\left(\frac{\pi}{2}\right)^2}{\frac{1}{2}}=\left(\frac{\pi^2}{18}\right)-\left(\frac{\pi^2}{2}\right)\times 2$$

$$=\frac{\pi^2}{9}-\pi^2$$

$$=-\frac{8\pi^2}{9}$$

60. If L_1 is the line of intersection of the planes $2x-2y+3z-2=0, x-y+z+1=0$ and L_2 is the line of intersection of the planes $x+2y-z-3=0, 3x-y+2z-1=0$, then the distance of the origin from the plane, containing the lines L_1 and L_2 is:

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

Solution: (A)

Dr'S of L_1

$$\begin{vmatrix} i & j & k\\ 2 & -2 & 3\\ 1 & -1 & 1\end{vmatrix}$$

$i(1)-j(-1)+k(0)$

$(1,1,0)$

But $y=0$

$$\left.\begin{matrix}2x+3z=2\\ x+z=-1\end{matrix}\right]\rightarrow \text{(-5, 0, 4) point}$$

Equation of L_1

$$\frac{x+5}{1}=\frac{y}{1}=\frac{z-4}{0}=\alpha$$

Similarly for L_2

$$\frac{x-\frac{7}{5}}{3}=\frac{y}{-5}=\frac{z+\frac{8}{5}}{-7}=\beta$$

Point of intersection

(-1, 4, 4)

$$\hat{n}\ (\text{Plane})\begin{vmatrix} i & j & k\\ 1 & 1 & 0\\ 3 & -5 & -7\end{vmatrix}=(-7,7,-2)$$

Equation of plane

$-7x + 7y - 8z = C.$

(-1, 4, 4)

$c = 3$

Equation of plane

$7x - 7y + 2\,z + 3 = 0$

Distance from origin

$= \frac{3}{\sqrt{162}} = \frac{3}{9\sqrt{2}}$

$= \frac{1}{3\sqrt{2}}$

PART C – Physics

61. The angular width of the central maximum in a single slit diffraction pattern is 60^o. The width of the slit is $1\mu m$. The slit is illuminated by monochromatic plane waves. If another slit of same width is made near it, Young's fringes can be observed on a screen placed at a distance 50 cm from the slits. If the observed fringe width is 1 cm, what id slit separation distance?

(i.e. distance between the centres of each slit.)

(A) 50 μm

(B) 75 μm

(C) 100 μm

(D) 25 μm

Solution: (D)

25 μm

62. An electron from various excited states of hydrogen atom emit radiation to come to the ground state. Let λ_n, λ_g be the de Broglie wavelength of the electron in the n^{th} state and the ground state respectively. Let Λ_n be

the wavelength of the emitted photon in the transition from the n^{th} state to the ground state. For large n, (A, B are constants)

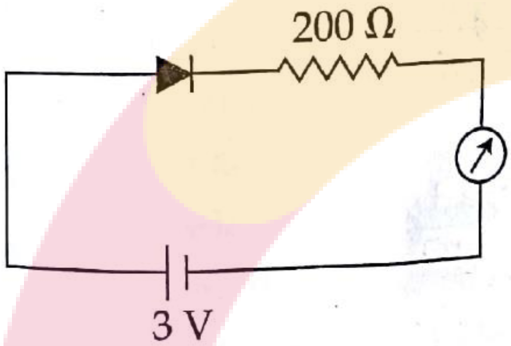
(A) $\wedge_n \approx A + B\lambda_n$ (B) $\wedge_n^2 \approx A + B\lambda_n^2$

(C) $\wedge_n^2 \approx \lambda$ (D) $\wedge_n \approx A + \frac{B}{\lambda_n^2}$

Solution: (D)

$\wedge_n \approx A + \frac{B}{\lambda_n^2}$

63. The reading of the ammeter for a silicon diode in the given circuit is:



(A) 15 mA (B) 11.5 mA (C) 13.5 mA (D) 0

Solution: (B)

The diode is in forward bias.

So its resistance = 0

Therefore, $i = \frac{V}{R}$

$i = \frac{3}{200} = 15\ mA$

64. The density of a material in the shape of a cube is determined by measuring three sides of the cube and its mass. If the relative errors in measuring the mass and length are respectively 1.5% and 1%, the maximum error in determining the density is:

(A) 3.5%

(B) 4.5%

(C) 6%

(D) 2.5%

Solution: (B)

$e \Rightarrow \frac{M}{L^3}$

$\frac{\Delta e}{e} \Rightarrow \frac{\Delta M}{M} + \frac{3\Delta L}{L}$

$\frac{\Delta e}{e} \times 100 \Rightarrow 1.5 + 3 \times 1$

% relative error $= 4.5\%$

65. An electron, a proton and an alpha particle having the same kinetic energy are moving in circular orbits of radii r_e, r_p, r_α respectively in a uniform magnetic field B. The relation between r_e, r_p, r_α is:

(A) $r_e < r_p = r_\alpha$ (B) $r_e < r_P < r_\alpha$

(C) $r_e < r_\alpha < r_p$ (D) $r_e > r_p = r_\alpha$

Solution: (A)

$r = \frac{mV}{qB} = \frac{\sqrt{2mK}}{qB}$

$r \propto \frac{\sqrt{m}}{q}$

$r_e = \frac{\sqrt{m_e}}{q}$

$r_a = \frac{\sqrt{u_m}}{2q}$

$r_p = \frac{\sqrt{m}}{q}$

$= \frac{2\sqrt{m}}{2q}$

$r_e = r_a < r_p$

66. Three concentric metal shells A, B and C of respective radii a, b and c (a < b <c) have surface charge densities $+\sigma, -\sigma$ and $+\sigma$ respectively. The potential of shell B is:

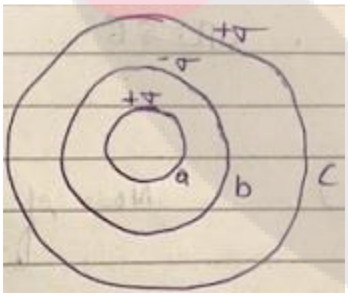
(A) $\frac{\sigma}{\varepsilon_0}\left[\frac{a^2-b^2}{b} + c\right]$

(B) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2-c^2}{b} + a\right]$

(C) $\frac{\sigma}{\varepsilon_0}\left[\frac{b^2-c^2}{c} + a\right]$

(D) $\frac{\sigma}{\varepsilon_0}\left[\frac{a^2-b^2}{a} + c\right]$

Solution: (A)



Potential $\frac{1}{4\pi\varepsilon_0} \frac{\sigma 4\pi R^2}{d}$

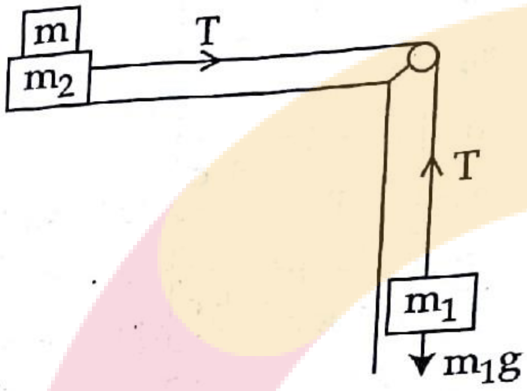
$= \frac{\sigma R^2}{\varepsilon_0 d}$

Required potential of b

$= \frac{\sigma a^2}{\varepsilon_0 b} - \frac{\sigma b^2}{\varepsilon_0 b} + \frac{\sigma c^2}{\varepsilon_0 c}$

$$= \frac{\sigma}{\varepsilon_0}\left(\frac{a^2 - -b^2}{b} + c\right)$$

67. Two masses $m_1 = 5\ kg$ and $m_2 = 10\ kg$, connected by an inextensible string over a frictionless pulley, are moving as shown in the figure. The coefficient of friction of horizontal surface is 0.15. The minimum weight m that should be put on top of m_2 to stop the motion is:



(A) 27.3 kg
(B) 43.3 kg
(C) 10.3 kg
(D) 18.3 kg
Solution: (Bonus)
Does not match.
In this question coefficient of friction b/w masses m_1 and m_2 is unknown. Without knowing that the problem cannot be solved.
Even is as assume that friction b/w m_1 and m_2 is sufficient to prevent slipping.
Answer does not match.

68. A particle is moving in a circular path of radius a under the action of an attractive potential $U = -\frac{k}{2r^2}$. Its total energy is:
(A) $\frac{k}{2a^2}$
(B) Zero
(C) $-\frac{3}{2}\frac{k}{a^2}$
(D) $-\frac{k}{4a^2}$
Solution: (B)

$$V = -\frac{K}{2r^2}$$

$$F = -\frac{ru}{rr} = \frac{2K}{2r^3} = \frac{K}{r^3}$$

$$\frac{mv^2}{r} = \frac{K}{r^3}$$

$$V^2 = \frac{K}{mr^2}$$

$$\frac{1}{2}mv^2 = \frac{K}{2r^2}$$
$$E = \frac{K}{2r^2} - \frac{K}{2r^2} = 0$$

69. A parallel plate capacitor of capacitance 90 pF is connected to a battery of emf 20V. If a dielectric material of dielectric constant $K = \frac{5}{3}$ is inserted between the plates, the magnitude of the induced charge will be:

(A) 0.3 nC

(B) 2.4 nC

(C) 0.9 nC

(D) 1.2 nC

Solution: (D)

$Q_1 = CV_1$Q

$Q = KCV$

$$Q = \frac{5}{3} \times 90 \times 10^{-12} \times 20$$

$5 \times 30 \times 20 = 0.3\ nC$

70. A silver atom in a solid oscillates in simple harmonic motion in some direction with a frequency of $10^{12}/sec$. What is the force constant of the bonds connecting one atom with the other? (Mole wt. of silver = 108 and Avagadro number = 6.02 × $10^{23} gm\ mole^{-1}$)

(A) 7.1 N/m

(B) 2.2 N/m

(C) 5.5 N/m

(D) 6.4 N/m

Solution: (A)

$v = 10^{12} s^{-1}$

$$w = \sqrt{\frac{k}{m}}$$
$$T = 2\pi\sqrt{\frac{k}{m}}$$
$$v = \frac{1}{2\pi}\sqrt{\frac{k}{m}}$$
$$v = \frac{1}{\pi}\sqrt{\frac{k}{m}}$$
$$v = \frac{1}{2\pi}\sqrt{\frac{K \times 6.02 \times 10^{23}}{108 \times 10^{-3}}}$$
$$K = \frac{4\pi^2 \times 10^{24} \times 108 \times 10^{-3}}{6.02 \times 10^{23}}$$
$\approx 7.1\ N/m$

71. It is found that if a neutron suffers an elastic collinear with deuterium at rest, fractional loss of its energy is P_d ; while for its similar collision with carbon nucleus at rest, fractional loss of energy is P_c. The values of P_d and P_c are respectively.

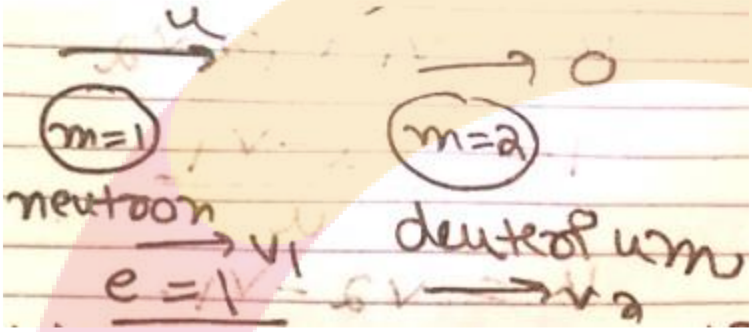
(A) (.28, .89)

(B) (0 0)

(C) (0, 1)

(D) (.89, .28)

Solution: (D)



By momentum conservation

$u = V_1 + 2V_2$

$e = 1 = \frac{V_2 - V_1}{u}$

$u = V_2 - V_1$

$V_2 = \frac{2u}{3}$; $V_1 = -\frac{u}{3}$

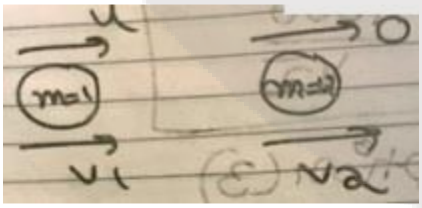
Initial energy $= \frac{1}{2}u^2$

Final energy $= \frac{1}{2} \times 1 \times \frac{u^2}{9}$

$= \frac{u^2}{18}$

Fractional change $= \frac{\frac{u^2}{2} - \frac{u^2}{18}}{\frac{u^2}{2}}$

$= 0.88$



$u = V_1 + 12V_2$

$1 = \frac{V_2 - V_1}{u}$

$u = V_2 - V_1$

$V_2 = \frac{2u}{13}$

$V_1 = -\frac{11u}{13}$

Change in energy $= u^2 - \left(\frac{11u}{13}\right)^2 \times 100$

$= 0.294$

72. The dipole moment of a circular loop carrying a current I, is m and the magnetic field at the centre of the loop is B_1. When the dipole moment is doubled by keeping the current constant, the magnetic field at the centre of the loop is B_2 . The ration $\frac{B_1}{B_2}$ is:

(A) $\sqrt{3}$

(B) $\sqrt{2}$

(C) $\frac{1}{\sqrt{2}}$

(D) 2

Solution: (B)

Dipole moment = IA

For $Loop_1$

$m = I\pi R^2$

$B_1 = \frac{\mu_0 i}{2r}$

For $Loop_2$

If current is constant m is doubled.

$r = \frac{r}{\sqrt{2}}$

$B_2 = \frac{\mu_0 i}{\frac{r}{\sqrt{2}}}$

$\frac{B_1}{B_2} = \sqrt{2}$

73. In a potentiometer experiment, it is found that no current passes through the galvanometer when the terminals of the cell are connected across 52 cm of the potentiometer wire. If the cell is shunted by a resistance

of 5 Ω, balance is found when the cell is connected across 40 cm of the wire. Find the internal resistance of the cell.

(A) 1.5Ω

(B) 2Ω

(C) 2.5Ω

(D) 1Ω

Solution: (A)

1.5Ω

74. A telephonic communication service is working at carrier frequency of 10 GHz. Only 10% of it is utilized for transmission. How many telephonic channels can be transmitted simultaneously if each channel requires a bandwidth of 5 kHz?

(A) 2×10^4

(B) 2×10^5

(C) 2×10^6

(D) 2×10^3

Solution: (B)

No. of channel $\Rightarrow \frac{10^6}{5\times10^3} = 2 \times 10^5$

75. Unpolarized light of intensity I passes through an ideal polarizer A. Another identical polarizer B is placed behind A. The intensity of light beyond B is found to be $\frac{1}{2}$. Now another identical polarizer C is placed between A and B. The intensity beyond B is now found to be $\frac{1}{8}$. The angle between polarizer A and C is

(A) 30^o

(B) 45^o

(C) 60^o

(D) 0^o

Solution: (B)

When unpolarized light passes through a polarizer.

Intensity becomes $\frac{I}{2}$

$$\frac{I}{2}\cos^2 a = \frac{I}{8}$$

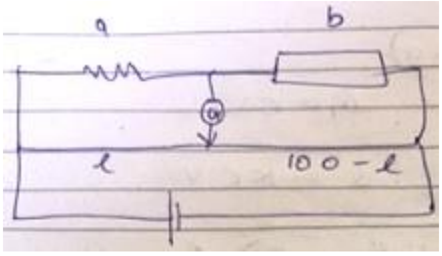
$$\cos^2 a = \frac{1}{4}$$

$$a = \frac{\pi}{3}$$

76. On interchanging the resistances, the balance point of a meter bridge shifts to the left by 10cm. The resistance of their series combination is $1k\Omega$. How much was the resistance on the left slot before interchanging the resistances?

(A) 505 Ω (B) 550 Ω (C) 910 Ω (D) 990 Ω

Solution: (B)



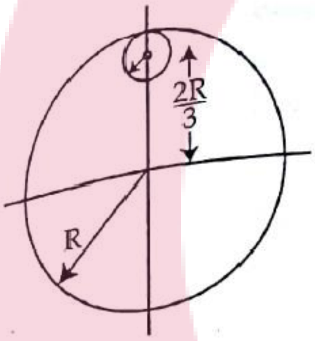
$a + b = 1000$

$\frac{a}{b} = \frac{l}{100 - l}$

$\frac{b}{a} = \frac{l - 10}{110 - l}$

$1 = \frac{;(l - 10)}{(100 - l)(110 - l)}$

77. From a uniform circular disc of radius R and mass 9 M, a small disc of radius $\frac{R}{3}$ is removed as shown in the figure. The moment of inertia of the remaining disc about an axis perpendicular to the plane of the disc and passing through centre of disc is:



(A) $\frac{40}{9} MR^2$

(B) $10MR^2$

(C) $\frac{37}{9} MR^2$

(D) $4MR^2$

Solution: (D)

By parallel axis theorem,

MI of smaller disc $= \frac{M\left(\frac{R}{3}\right)^2}{2} + M\left(\frac{3R}{3}\right)^2$

$MI = \frac{MR^2}{18} + \frac{4MR^2}{9}$

$MI = \frac{MR^2}{2}$

$MI = MI(Bigger) - MI(Smaller)$

$= \frac{9MR^2}{2} - \frac{MR^2}{2}$

$= 4MR^2$

78. In a collinear collision, a particle with an initial speed v_0 strikes a stationary particle of the same mass. If the final total kinetic energy is 50% greater than the original kinetic energy, the magnitude of the relative velocity between the two particles, after collision, is:

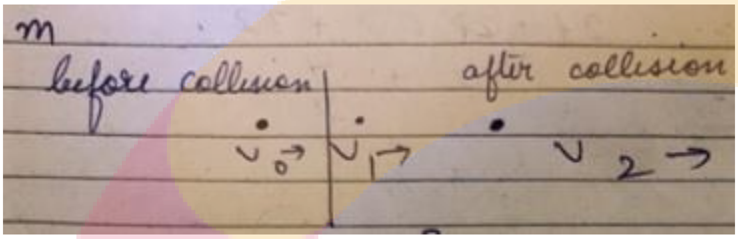
(A) $\sqrt{2}\, v_0$

(B) $\frac{v_0}{2}$

(C) $\frac{v_0}{\sqrt{2}}$

(D) $\frac{v_0}{4}$

Solution: (A)



$KE_2 = \frac{3}{2} m v_0^2$

Conservation of momentum,

$v_1 + v_2 = 2v_0$

Conservation of energy

$\frac{1}{2} m V_1^2 + \frac{1}{2} m V_2^2 = \frac{3}{2} m V_0^2$

$V_1^2 + V_2^2 = 3V_0^2$

$V_1^2 + V_2^2 + 2V_1 V_2 = 4V_0$

$2V_1 V_2 = V_0^2$

$(V_1 - V_2)^2 \Rightarrow V_1^2 + V_2^2 - 2V_1 V_2$

$\Rightarrow 3V_0^2 - 2V_0^2$

$\Rightarrow \ \sqrt{2} V_0$

79. An EM wave from air enters a medium. The electric fields are $\vec{E}_1 = E_{01}\hat{x}\cos\left[2\pi v\left(\frac{z}{c} - t\right)\right]$ in air and $\vec{E}_2 = E_{02}\hat{x}\cos[k(2z - ct)]$ in medium, where the wave number k and frequency v refer to their values in air. The

medium is non-magnetic. If ϵ_{r_1} and ϵ_{r_2} refer to relative permittivities of air and medium respectively, which of the following, option is correct?

(A) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = 2$

(B) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = \frac{1}{4}$

(C) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = \frac{1}{2}$

(D) $\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = 4$

Solution: (B)

$$\frac{\epsilon_{r_1}}{\epsilon_{r_2}} = \frac{1}{4}$$

80. For an RLC circuit driven with voltage of amplitude v_m and frequency $\omega_0 = \frac{1}{\sqrt{LC}}$ the current exhibits resonance. The quality factor, Q is given by

(A) $\frac{\omega_0 R}{L}$

(B) $\frac{R}{(\omega_0 C)}$

(C) $\frac{CR}{\omega_0}$

(D) $\frac{\omega_0 L}{R}$

Solution: (D)

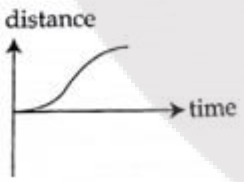
Quality factor $= \frac{1}{R}\sqrt{\frac{L}{C}}$

But, $\omega_0 = \frac{1}{\sqrt{LC}}$

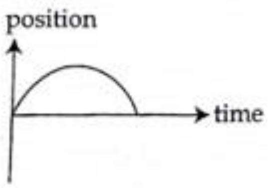
So, $\frac{\omega_0 L}{R} = \frac{1}{R}\sqrt{\frac{L}{C}}$

81. All the graphs below are intended to represent the same motion. One of them does it incorrectly. Pick it up.

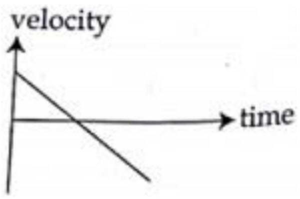
(A)



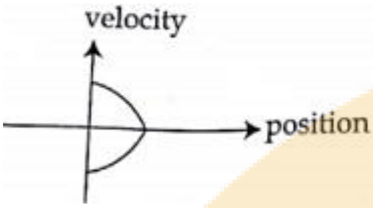
(B)



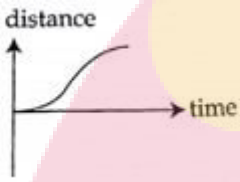
(C)



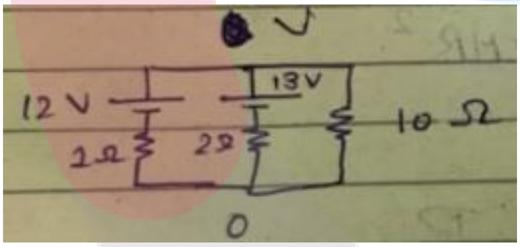
(D)



Solution: (A)



82. Two batteries with e.m.f. 12 V and 13 V are connected in parallel across a load resistor of 10Ω. The internal resistances of two batteries are 1Ω and 2Ω respectively. The voltage across the load lies between:
(A) 11.5 V and 11.6 V
(B) 11.4 and 11.5 V
(C) 11.7 V and 11.8 V
(D) 11.6 V and 11.7 V
Solution: (A)



$$\frac{V-12}{1}+\frac{V-13}{2}+\frac{V}{10}=0$$

$$V+\frac{V}{2}+\frac{V}{10}\Rightarrow 12+\frac{13}{2}$$

$$V\Rightarrow\frac{12+\frac{13}{2}}{1+\frac{1}{2}+\frac{1}{10}}=11.562$$

83. A particle is moving with a uniform speed in a circular orbit of radius R in a central force inversely proportional to the n^{th} power of R. If the period of rotation of the particle is T, then:
(A) $T\propto R^{\frac{n}{2}+1}$
(B) $T\propto R^{\frac{n+1}{2}}$
(C) $T\propto R^{n/2}$

(D) $T \propto R^{3/2}$ for any n

Solution: (A)

$F = \frac{K}{r^n}$

$\frac{mV^2}{r} = \frac{K}{r^n}$

$V^2 \propto \frac{K}{r^{n-1}}$

$V \propto \frac{1}{r^{\frac{n-1}{2}}}$

$T = \frac{2\pi r}{V} \propto \frac{r}{V}$

$T \propto \frac{r}{\frac{1}{r^{\frac{n-1}{2}}}}$

$T \propto R^{\frac{n+1}{2}}$

84. If the series limits frequency of the Lyman series is $v_L{}'$ then the series limits frequency of the P fund series is:

(A) $16v_L$

(B) $\frac{v_L}{16}$

(C) $\frac{v_L}{25}$

(D) $25v_L$

Solution: (C)

$\frac{1}{\lambda} = RHZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$v = f\lambda$

$v = CRHZ^2\left(\frac{1}{n_1^2} - \frac{1}{n_2^2}\right)$

$v_1 = \frac{Lyman}{CRHZ^2}\left(\frac{1}{1^2} - \frac{1}{\infty^2}\right)$

P-fund

$v_2 = CRHZ^2\left(\frac{1}{S^2} - \frac{1}{\infty^2}\right)$

$V_2 = \frac{V_1}{25}$

85. In an a.c circuit, the instantaneous e.m.f. and current are given by

$e = 100 \sin 30t$

$r = 20 \sin\left(30t - \frac{\pi}{4}\right)$

In one cycle of a.c., the average power consumed by the circuit and the wattles current are, respectively:

(A) $\frac{1000}{\sqrt{2}}, 10$

(B) $\frac{50}{\sqrt{2}}, 10$

(C) 50,0
(D) 50,10
Solution: (A)
$e = 100 \sin 30t$
$r = 20 \sin\left(30t - \frac{\pi}{4}\right)$
$Average\ power = V_{rms}\, I_{rms} cos\phi$
$= \frac{100}{\sqrt{2}} \times \frac{20}{\sqrt{2}} \times \frac{1}{\sqrt{2}}$
$= \frac{1000}{\sqrt{2}}$

86. Two moles of an ideal monoatomic gas occupies a volume V at $27^o C$. The gas expands adiabatically to a volume 2V. Calculate (a) the final temperature of the gas and (b) change in its internal energy.
(A) (a) 195 K (b) -2.7 kJ
(B) (a) 189 K (b) -2.7 kJ
(C) (a) 195 K (b) 2.7 kJ
(D) (a) 189 K (b) 2.7 kJ
Solution: (B)
$TV^{\gamma-1} = Constant$
$\gamma = \frac{5}{3}$
$300(V)^{\frac{2}{3}} = T(2V)^{\frac{2}{3}}$
$T = 189K$
$\Delta u = ncVaT$
$= 2 \times \frac{3}{2} \times 8.314 \times 11$
$= 2.7\ kJ(-ve)$

87. A solid sphere of radius r made of a soft material of bulk modulus K is surrounded by a liquid in a cylindrical container. A massless piston of area a floats on the surface of the liquid, covering entire cross

section of cylindrical container. When a mass m is placed on the surface of the piston to compress the liquid, the fractional decrement in the radius of the sphere, $\left(\frac{dr}{r}\right)$, is:

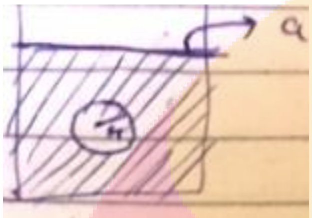
(A) $\frac{Ka}{3mg}$

(B) $\frac{mg}{3kA}$

(C) $\frac{mg}{Ka}$

(D) $\frac{Ka}{mg}$

Solution: (B)



$$P = K\frac{\Delta V}{V}$$

$$P = K.3\left(\frac{\Delta R}{R}\right)$$

$$\frac{mg}{3Ka} = \left(\frac{\Delta R}{R}\right)$$

88. A granite rod of 60 cm length is clamped at its middle point and is set into longitudinal vibrations. The density of granite is $2.7 \times 10^3\ kg/m^3$ and its Young's modulus is $9.27 \times 10^{10}\ Pa$. What will be the fundamental frequency of the longitudinal vibrations?

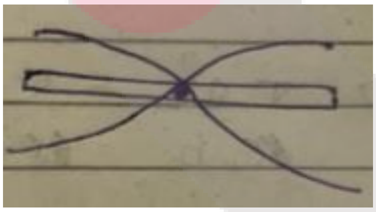
(A) 2.5 kHz

(B) 10 kHz

(C) 7.5 kHz

(D) 5 kHz

Solution: (D)



$$L = \frac{\lambda}{2}$$

$$v = \sqrt{\frac{T}{e}}$$

$$v = 2L\sqrt{\frac{T}{e}}$$

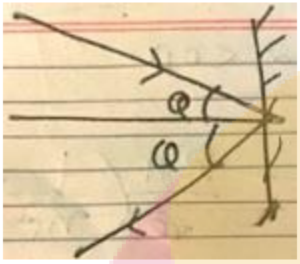
$$v = \frac{1}{2 \times 0.6}\sqrt{\frac{9.27 \times 10^{10}}{2.7 \times 10^3}} \approx 4.88 \times 10^3 HZ$$

89. The mass of a hydrogen molecule is $3.32 \times 10^{-27} kg$. If 10^{23} hydrogen molecules strike, per second, a fixed wall of area $2\ cm^2$ at an angle of 45^o to the normal, and rebound elastically with a speed of $10^3\ m/s$, then the pressure on the wall is nearly:

(A) $4.70 \times 10^3\ N/m^2$ (B) $2.35 \times 10^2\ N/m^2$

(C) $4.70 \times 10^2\ N/m^2$ (D) $2.35 \times 10^3\ N/m^2$

Solution: (D)



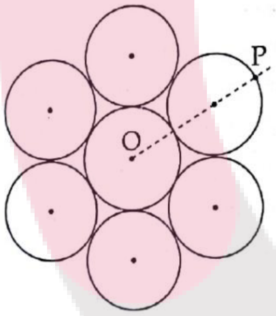
$F = 2mnVcos\theta$

$$P = \frac{2mnVcos\theta}{A}$$

$$P = \frac{2 \times 3.32 \times 10^{-27} \times 10^{23} \times 10^3}{\sqrt{2} \times 2 \times 10^{-4}}$$

$P = 2.35 \times 10^3\ N/m^2$

90. Seven identical circular planar disks, each of mass M and radius R are welded symmetrically as shown. The moment of inertia of the arrangement about the axis normal to the plane and passing through the point P is:



(A) $\frac{55}{2} MR^2$

(B) $\frac{73}{2} MR^2$

(C) $\frac{181}{2} MR^2$

(D) $\frac{19}{2}\ MR^2$

Solution: (C)

MI of system about O

$$\frac{1}{2}MR^2 + 6 \times \frac{1}{2}MR^2 + 6 \times M \times (2R)^2$$

$$\Rightarrow \quad I_1 = \frac{7}{2}MR^2 + 24MR^2$$

MI of system about P

$\Rightarrow \quad I_1 + 7MD^2$

$\Rightarrow \quad \frac{7}{2}MR^2 + 24MR^2 + 7M \times (3R)^2$

$\Rightarrow \quad \frac{181}{2}MR^2$