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JEE MAIN 2016

ONLINE EXAMINATION

DATE : 09-04-2016

SUBJECT : MATHEMATICS

TEST PAPER
WITH SOLUTIONS & ANSWER KEY

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CORPORATE OFFICE : CG TOWER, A-46 & 52, IPIA, NEAR CITY MALL, JHALAWAR ROAD, KOTA (RAJ.) - 324005

REG. OFFICE : J-2, JAWAHAR NAGAR, MAIN ROAD, KOTA (RAJ.)-324005 | **PH. NO.:** +91-744-3192222 | **FAX NO. :** +91-022-39167222

PH.NO. : +91-744-3012222, 6635555 | **TO KNOW MORE :** SMS **RESO** AT **56677**

WEBSITE : WWW.RESONANCE.AC.IN | **E-MAIL :** CONTACT@RESONANCE.AC.IN | **CIN :** U80302RJ2007PLC024029

Toll Free : 1800 258 5555 08003 444 888 facebook.com/ResonanceEdu twitter.com/ResonanceEdu www.youtube.com/resowatch blog.resonance.ac.in

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JEE (Advanced)

Selections (from 2002-2015)	Selections @ 2015
23182	**4124**
(YCCP: 14864 | DLP+eLP: 8318)	(YCCP: 2570 | DLP+eLP: 1554)

Highest selections in JEE (Adv) 2015 in India from any single institute of Kota

JEE (Main)

Selections (from 2009-2015)	Selections @ 2015
93915	**25542**
(YCCP: 66288 | DLP+eLP: 27627)	(YCCP: 18816 | DLP+eLP: 6726)

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1. If A and B are any two events such that P(A) =2/5 and P(A ∩ B) = 3/20, then the conditional probability, P(A/(A' ∪ B')), where A' denotes the complement of A, is equal to :

(1) $\frac{8}{17}$ (2) $\frac{1}{4}$ (3) $\frac{5}{17}$ (4) $\frac{11}{20}$

Ans. **(3)**

Sol. $P(A) = \frac{2}{5}$

$P(A \cap B) = \frac{3}{20}$

$P(A/(A' \cup B')) = ?$

$$P(A/(A' \cup B')) = \frac{P(A \cap (A' \cup B'))}{P(A' \cap B')} = \frac{P((A \cap A') \cup (A \cap B'))}{P(A \cap B)'} = \frac{P(\phi \cup (A \cap B'))}{1 - P(A \cap B)}$$

$$= \frac{P(A \cap B')}{1 - \frac{3}{20}} = \frac{P(A) - p(A \cap B)}{\frac{17}{20}} = \frac{\frac{2}{5} - \frac{3}{20}}{\frac{17}{20}} = \frac{\frac{5}{20}}{\frac{17}{20}} = \frac{5}{17}$$

2. For $x \in R$, $x \neq 0$, $x \neq 1$, let $f_0(x) = \frac{1}{1-x}$ and $f_{n+1}(x) = f_0\left(f_{(n}(X)\right)$, n = 0, 1, 2,..... Then the value of $f_{100}(3) + f_1\left(\frac{2}{3}\right) + f_2\left(\frac{3}{2}\right)$ is equal to :

(1) $\frac{4}{3}$ (2) $\frac{1}{3}$ (3) $\frac{5}{3}$ (4) $\frac{8}{3}$

Ans. **(3)**

Sol. $f_0(x) = \frac{1}{1-x}$

$f_1(x) = f_0(f_0(x)) = \frac{1}{1 - f_0(x)}$; $f_0(x) \neq 1$

$$= \frac{1}{1 - \frac{1}{1-x}} \qquad x \neq 0$$

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

$f_2(x) = f_0(f_1(x)) = \frac{1}{1 - f_1(x)}$; $f_1(x) \neq 1$

$= \dfrac{1}{1+\dfrac{1-x}{x}} = x$

similarly $f_3(x) = f_0(x)$

$f_4(x) = f_1(x)$ .....

$f_{100}(3) + f_1\left(\frac{2}{3}\right) + f_2\left(\frac{3}{2}\right) = f_1(3) + f_1\left(\frac{2}{3}\right) + \frac{3}{2}$

$= 1 - \frac{1}{3} + 1 - \frac{3}{2} + \frac{3}{2} = \frac{5}{3}$

3. The distance of the point (1, –2, 4) from the plane passing through the point (1, 2, 2) and perpendicular to the planes x – y + 2z = 3 and 2x – 2y + z + 12 = 0, is

(1) $\frac{1}{\sqrt{2}}$ (2) 2 (3) $\sqrt{2}$ (4) $2\sqrt{2}$

Ans. **(4)**

Sol. Equation of plane ⊥ to the planes.

x – y + 2z = 3 & 2x – 2y + z + 12 = 0

and passes through (1, 2, 2) is

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

3(x – 1) + 3(y – 2) = 0

x + y = 3 ..... (1)

distance of plane x + y – 3 = 0 from (1, – 2, 4) is

$= \left|\frac{1-2-3}{\sqrt{1+1}}\right| = 2\sqrt{2}$

4. If the equations $x^2 + bx - 1 = 0$ and $x^2 + x + b = 0$ have a common root different from – 1, then | b | is equal to

(1) $\sqrt{2}$ (2) 2 (3) $\sqrt{3}$ (4) 3

Ans. **(3)**

Sol. $x^2 + bx - 1 = 0$ & $x^2 + x + b = 0$ have common root α.

$\Rightarrow \quad \alpha^2 + b\alpha - 1 = 0$

$\alpha^2 + \alpha + b = 0$

$\Rightarrow \quad \frac{\alpha^2}{b^2+1} = \frac{\alpha}{-(b+1)} = \frac{1}{(1-b)} \quad \Rightarrow \quad (b+1)^2 = (b^2+1)(1-b)$

$\Rightarrow \quad b^2 + 2b + 1 = b^2 - b^3 + 1 - b \quad \Rightarrow \quad b^3 + 3b = 0$

$\Rightarrow \quad b = 0$ or $b^2 = -3$

when b = 0 then common roots is (–1) hence b = 0 rejected.

so $b^2 = -3 \quad \Rightarrow \quad b = \pm\sqrt{3}\,i \quad \Rightarrow \quad |b| = \sqrt{3}$

5. If $2\int_0^1 \tan^{-1}x\,dx = \int_0^1 \cot^{-1}(1-x+x^2)\,dx$ then $\int_0^1 \tan^{-1}(1-x+x^2)\,dx$ is equal to :

(1) log2 (2) $\frac{\pi}{2}+\log 2$ (3) log4 (4) $\frac{\pi}{2}-\log 4$

Ans. **(1)**

Sol. $2\int_0^1 \tan^{-1}x\,dx = \int_0^1 \cot^{-1}(1-x+x^2)dx$ ...(1)

$$\int_0^1 \tan^{-1}(1-x+x^2)dx = \int_0^1 \left\{\frac{\pi}{2}-\cot^{-1}(1-x+x^2)dx\right\}$$

$$= \frac{\pi x}{2}\Big|_0^1 - 2\int_0^1 \tan^{-1}x\,dx = \frac{\pi}{2} - 2\left(\frac{\pi}{4}-\frac{1}{2}\ell n2\right) = \ell n2$$

6. If $P = \begin{bmatrix} \frac{\sqrt{3}}{2} & \frac{1}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}$, $A = \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix}$ and $Q = PAP^T$, then $P^T Q^{2015} P$ is

(1) $\begin{bmatrix} 2015 & 1 \\ 0 & 2015 \end{bmatrix}$ (2) $\begin{bmatrix} 1 & 2015 \\ 0 & 1 \end{bmatrix}$ (3) $\begin{bmatrix} 0 & 2015 \\ 0 & 0 \end{bmatrix}$ (4) $\begin{bmatrix} 2015 & 0 \\ 1 & 2015 \end{bmatrix}$

Ans. **(2)**

Sol. $P\,P^T = \begin{bmatrix} \frac{\sqrt{3}}{2} & \frac{1}{2} \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} \frac{\sqrt{3}}{2} & -\frac{1}{2} \\ \frac{1}{2} & \frac{\sqrt{3}}{2} \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = P^T P$

New $P^T Q^{2015} P = P^T \underbrace{PAP^T \quad PAP^T \quad .....PAP^T}_{2015\text{ times}} \quad P$

because $= A^{2015}$

Now $A^2 - 2A + I = 0$

$\Rightarrow \quad A^n = nA - (n-1)I \quad \Rightarrow \quad A^{2015} = 2015\begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} - (2014)\begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} = \begin{bmatrix} 1 & 2015 \\ 0 & 1 \end{bmatrix}$

7. If $\int \frac{dx}{\cos^3 x\sqrt{2\sin 2x}} = (\tan x)^A + C(\tan x)^B + k$, where k is a constant of integration, then A + B + C equals

(1) $\frac{16}{5}$ (2) $\frac{21}{5}$ (3) $\frac{7}{10}$ (4) $\frac{27}{10}$

Ans. **(1)**

Sol. $I = \int \frac{dx}{\cos^3 x \sin^{\frac{1}{2}} x \cos^{\frac{1}{2}} x} = \frac{1}{2}\int \frac{(\tan^2 x + 1)\sec^2 x}{(\tan x)^{\frac{1}{2}}} dx$

$\tan x = t$

$I = \frac{1}{2}\int t^{\frac{3}{2}} dt + \frac{1}{2}\int t^{-\frac{1}{2}} dt$

$= \frac{t^{\frac{5}{2}}}{5} + t^{1/2} + c = \frac{(\tan x)^{\frac{5}{2}}}{5} + (\tan x)^{1/2}$

$A = \frac{1}{2}, B = \frac{5}{2}, C = \frac{1}{5}$

$A + B + C = \frac{16}{5}$

8. The point (2, 1) is translated parallel to the line L : x – y = 4 by $2\sqrt{3}$ units. If the new point Q lies in the third quadrant, then the equation of the line passing through Q and perpendicular to L is :

(1) $2x + 2y = 1 - \sqrt{6}$ (2) $x = y = 3 - 3\sqrt{6}$

(3) $x + y = 2 - \sqrt{6}$ (4) $x + y = 3 - 2\sqrt{6}$

Ans. **(4)**

Sol. Slopes of x – y = 4

$\Rightarrow \quad \tan\theta = 1 \quad \Rightarrow \quad \left(\sin\theta = \frac{1}{\sqrt{2}}, \cos\theta = \frac{1}{\sqrt{2}}\right)$

or $\left(\sin\theta = -\frac{1}{\sqrt{2}}, \cos\theta = -\frac{1}{\sqrt{2}}\right)$

Q is $\left(2 + 2\sqrt{3}\left(-\frac{1}{\sqrt{2}}\right), 1 + 2\sqrt{3}\left(-\frac{1}{\sqrt{2}}\right)\right)$

$(2 - \sqrt{6},\ 1 - \sqrt{6})$

equation of required line is $x + y = 3 - 2\sqrt{6}$

9. If the function $f(x) = \begin{cases} -x, & x < 1 \\ a + \cos^{-1}(x + b), & 1 \le x \le 2 \end{cases}$ is differentiable at x = 1, then $\frac{a}{b}$ is equal to :

(1) $\frac{-\pi - 2}{2}$ (2) $-1 - \cos^{-1}(2)$ (3) $\frac{\pi + 2}{2}$ (4) $\frac{\pi - 2}{2}$

Ans. **(3)**

Sol. L.H.L. at x = 1 is – 1

R.H.L at x = 1 is $a + \cos^{-1}(1 + b)$

$\Rightarrow$ $-1 = a + \cos^{-1}(1 + b)$

$\cos^{-1}(1 + b) = -1 - a$ ....(i)

now L.H.D. at x = 1 is – 1

R.H.D at x = 1 is $\dfrac{-1}{\sqrt{1-(1+b)^2}}$

$\Rightarrow$ $(1 + b)^2 = 0$ $\Rightarrow$ $b = -1$

Now $\cos^{-1}(1 - 1) = -1 - a$

$a = -1 - \dfrac{\pi}{2}$

$\dfrac{a}{b} = \dfrac{-(2+\pi)}{2(-1)} = \dfrac{2+\pi}{2}$

10. The value of $\sum_{r=1}^{15} r^2\left(\dfrac{{}^{15}C_r}{{}^{15}C_{r-1}}\right)$ is equal to :

(1) 1085 (2) 560 (3) 680 (4) 1240

Ans. **(3)**

Sol. $\sum_{r=1}^{15} r^2\left(\dfrac{{}^{15}C_r}{{}^{15}C_{r-1}}\right) = \sum_{r=1}^{15} r^2\left(\dfrac{15-r+1}{r}\right) = \sum_{r=1}^{15} r\,(16 - r) = 16\left(\dfrac{15\times16}{2}\right) - \dfrac{15\times16\times31}{6} = \dfrac{15\times16}{6}(17) = 680.$

11. In a triangle ABC, right angled at the vertex A, if the position vectors of A, B and C are respectively $3\hat{i} + \hat{j} - \hat{k}$, $-\hat{i} + 3\hat{j} + p\hat{k}$ and $5\hat{i} + q\hat{j} - 4\hat{k}$, then the point (p, q) lies on a line

(1) parallel to y-axis

(2) making an acute angle with the positive direction of x-axis

(3) parallel to x-axis

(4) making an obtuse angle with the position direction of x-axis.

Ans. **(2)**

Sol. $\overrightarrow{AB} = -4i + 2j + (p + 1)\,\hat{k}$

$\overrightarrow{AC} = 2\hat{i} + (q - 1)\,\hat{j} - 3\hat{k}$

$\overrightarrow{AB}.\overrightarrow{AC} = 0$ $\Rightarrow$ $-8 + 2(9 - 1) - 3(p + 1) = 0$ $\Rightarrow$ $-3p + 2q - 13 = 0$

$\Rightarrow$ (p, q) lies on line

$3x - 2y + 13 = 0$

slope = $\dfrac{3}{2}$

12. If $\lim\limits_{x\to\infty}\left(1+\frac{a}{x}-\frac{4}{x^2}\right)^{2x} = e^3$, then 'a' is equal to :

(1) $\frac{2}{3}$ (2) $\frac{3}{2}$ (3) 2 (4) $\frac{1}{2}$

Ans. **(2)**

Sol. $L = \lim\limits_{x\to\infty}\left(1+\frac{a}{x}-\frac{4}{x^2}\right)^{2x}$ must be of the from 1^∞

$$L = e^{\lim\limits_{x\to\infty}\left(\frac{a}{x}-\frac{4}{x^2}\right)2x}$$

$$\Rightarrow \quad L = e^{\lim\limits_{x\to\infty}\frac{2(ax-4)}{x}}$$

$$= e^{2a} = e^3$$

$$a = \frac{3}{2}$$

13. The number of $x \in [0, 2\pi]$ for which $\left|\sqrt{2\sin^4 x+18\cos^2 x}-\sqrt{2\cos^4 x+18\sin^2 x}\right| = 1$ is

(1) 6 (2) 4 (3) 8 (4) 2

Ans. **(3)**

Sol. $2\sin^4x + 18\cos^2x = 1 + 2\cos^4x + 18\sin^2x + 2\sqrt{2\cos^4 x+18\sin^2 x}$

$2(\sin^2x - \cos^2x) + 18(\cos^2x - \sin^2x) = 1 + 2\sqrt{2\cos^4 x+18\sin^2 x}$

$$\Rightarrow \quad 16(\cos^2x - \sin^2x) = 1 + 2\sqrt{2\cos^4 x+18\sin^2 x}$$

$$\Rightarrow \quad 16\cos2x - 1 = 2\sqrt{2\left(\frac{1+\cos 2x}{2}\right)^2+9(1-\cos 2x)}$$

$$\Rightarrow \quad 256\cos^2 2x + 1 - 32\cos2x = 4\left(\frac{1+2\cos 2x+\cos^2 2x}{2}+9(1-\cos 2x)\right)$$

$$\Rightarrow \quad 256\cos^2 2x + 1 - 32\cos2x = 2(19 - 16\cos2x + \cos^2 2x)$$

$$\Rightarrow \quad 254\cos^2 2x = 37$$

$$\Rightarrow \quad \cos^2 2x = \frac{37}{254} \qquad \Rightarrow \quad \cos2x = \pm\sqrt{\frac{37}{254}} \in [-1, 1]$$

clearly 8 solutions

14. If m and M are the minimum and the maximum values of $4 + \frac{1}{2}\sin^2 2x - 2\cos^4 x$, $x \in R$, then M – m is equal to

(1) $\frac{7}{4}$ (2) $\frac{15}{4}$ (3) $\frac{9}{4}$ (4) $\frac{1}{4}$

Ans. **(3)**

Sol. $4 + \frac{1}{2}\sin^2 2x - \frac{1}{2}(2\cos^2 x)^2$

$= 4 + \frac{1}{2}\sin^2 2x - \frac{1}{2}(1 + \cos 2x)^2 = -\cos^2 2x - \cos 2x + 4 = -[\cos^2 2x + \cos 2x - 4] = \frac{17}{4} - \left(\cos 2x + \frac{1}{2}\right)^2$

M = maximum value = $\frac{17}{4}$

m = minimum value = 2

$M - m = \frac{17}{4} - 2 = \frac{9}{4}$.

15. If a variable line drawn through the intersection of the lines $\frac{x}{3} + \frac{y}{4} = 1$ and $\frac{x}{4} + \frac{y}{3} = 1$, meets the coordinate axes at A and B, $(A \neq B)$, then the locus of the midpoint of AB is

(1) $7xy = 6(x + y)$ (2) $6xy = 7(x + y)$

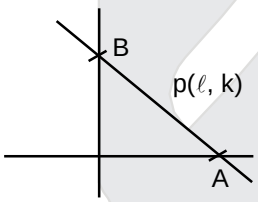
(3) $4(x + y)^2 - 28(x + y) + 49 = 0$ (4) $14(x + y)^2 - 97(x + y) + 168 = 0$

Ans. **(1)**

Sol. $4x + 3y = 12$ ....(1)

$3x + 4y = 12$ ....(2)

equation of lines passing through the intersection of the lines



$4x + 3y - 12 + \lambda(3x + 4y - 12) = 0$

$A = C\left(\frac{12(1+\lambda)}{4+3\lambda}, 0\right)$

$B = \left(0, \frac{12(1+\lambda)}{3+4\lambda}\right)$

$\ell n = \frac{6(1+\lambda)}{4+3\lambda}$ .....(3)

$k = \frac{6(1+\lambda)}{3+4\lambda}$ ... (4)

from (3) & (4)

$\lambda = \frac{3k-4h}{3h-4k}$ put in (1)

$7hk = 6(h + k)$

hence locus is $7xy = 6(x + y)$

16. If f(x) is a differentiable function in the interval $(0, \infty)$ such that f(1) = 1 and $\lim\limits_{t \to x} \frac{t^2 f(x) - x^2 f(t)}{t - x} = 1$, for each $x > 0$, then $f\left(\frac{3}{2}\right)$ is equal to :

(1) $\frac{13}{6}$ (2) $\frac{23}{18}$ (3) $\frac{25}{9}$ (4) $\frac{31}{18}$

Ans. **(4)**

Sol. Differentiate w.r.t. t

$\lim\limits_{t \to x} \frac{2t \quad f(x) - x^2 f'(t)}{1} = 1$

$\Rightarrow \quad 2x\, f(x) - x^2 f'(x) = 1$

$f'(x) = \frac{2x \quad f(x) - 1}{x^2}$

$\frac{dy}{dx} = \frac{2y}{x} - \frac{1}{x^2}$

I.F. $= e^{-\int \frac{2}{x} dx}$

$= e^{-2\ell nx} = \frac{1}{x^2}$

$y\left(\frac{1}{x^2}\right) = \int -\frac{1}{x^4} dx$

$\frac{y}{x^2} = \frac{1}{3x^3} + c$

at x = 1, y = 1

$\Rightarrow \quad c = \frac{2}{3}$

$f(x) = \frac{1}{3x} + \frac{2x^2}{3}$

$f\left(\frac{3}{2}\right) = \frac{31}{18}$

17. If the tangent at a point P, with parameter t, on the curve $x = 4t^2 + 3$, $y = 8t^3 - 1$, $t \in R$, meets the curve again at a point Q, then the coordinates of Q are :

(1) $(t^2 + 3, -t^3 - 1)$ (2) $(t^2 + 3, t^3 - 1)$ (3) $(16t^2 + 3, -64t^3 - 1)$ (4) $(4t^2 + 3, -8t^3 - 1)$

Ans. **(1)**

Sol. $P(x = 4t^2 + 3, y = 8t^2 - 1)$

let $Q(4t_1^2 + 3, 8y_1^3 - 1)$

at P, $\frac{dy}{dx} = \frac{dy/dt}{dx/dt} = \frac{24t^2}{8t} = 3t$

$\therefore$ tangent at P is $y - 8t^3 + 1 = 3t\,(x - 4t^2 - 3)$

Q will satisfy it

$\therefore$ $8t_1^3 - 8t^3 = 3t\,(4t_1^2 - 4t^2)$

$8(t_1 - t)(t_1^2 + t_1t + t^2) = 3t.\ 4(t_1 - t)\,(t_1 + t)$

$2(t_1^2 + t_1t + t^2) = 3t(t_1 + t)$

$2t_1^2 + 2t_1t + 2t^2 = 3t\,t_1 + 3t^2$

$2t_1^2 - t_1t - t^2 = 0$

$(t_1 - t)\,(2t_1 + t) = 0$

$t_1 = -\frac{t}{2}$

$\therefore$ $Q(t^2 + 3, -t^3 - 1)$ **Ans. (1)**

18. If the tangent at a point on the ellipse $\frac{x^2}{27} + \frac{y^2}{3} = 1$ meets the coordinate axes at A and B, and O is the origin, then the minimum area (in sq. units) of the triangle OAB is :

(1) 9 (2) $\frac{9}{2}$ (3) $9\sqrt{3}$ (4) $3\sqrt{3}$

Ans. **(1)**

Sol. Let $P(3\sqrt{3}\cos\theta,\ \sqrt{3}\sin\theta)$

$\therefore$ tangent is $\frac{x}{3\sqrt{3}}\cos\theta + \frac{y}{\sqrt{3}}\sin\theta = 1$

$\Rightarrow$ A $(3\sqrt{3}\sec\theta, 0)$ B $(0, \sqrt{3}\,\mathrm{cosec}\theta)$

$\therefore$ Area of $\Delta OAB = \frac{1}{2}$ OA. OB

$= \frac{1}{2}\,(3\sqrt{3}\sec\theta.\ \sqrt{3}\,\mathrm{cosec}\theta$

$= \frac{9}{2\sin\theta\cos\theta} = \frac{9}{\sin 2\theta}$

$\therefore$ minimum area of $\Delta OAB = \frac{9}{1} = 9$

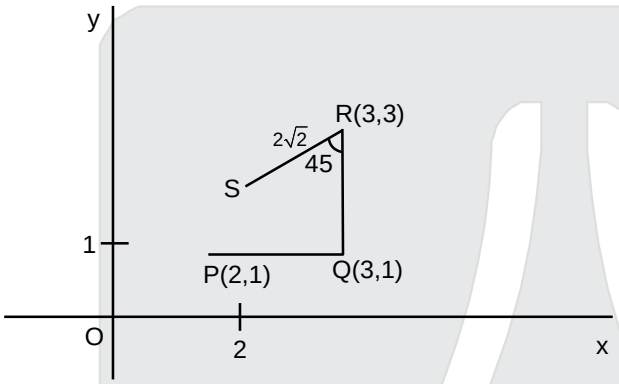
19. The point represented by 2+i in the Argand plane moves 1 unit eastwards, then 2 units northwards and finally from there $2\sqrt{2}$ units in the south-westwards direction. Then its new position in the Argand plane is at the point represented by :

(1) 2 + 2i (2) – 2 – 2i (3) 1 + i (4) – 1 – i

Ans. **(3)**

Sol. Let P(2 + i)

By rotation theorem



$$\frac{z-(3+3i)}{3+i-(3+3i)} = \frac{2\sqrt{2}}{2}\, e^{(-\pi/4)\, i}$$

$$\frac{z-3-3i}{-2i} = 1 - i$$

$z - 3 - 3i = -2i - 2$

$z = 1 + i$

20. A circle passes through (–2, 4). Which one of the following equations can represent a diameter of this circle?

(1) 4x + 5y – 6 = 0 (2) 5x + 2y + 4 = 0 (3) 2x – 3y + 10 = 0 (4) 3x + 4y – 3 = 0

Ans. **(3)**

Sol. Required circle is

$(x - 0)^2 + (y - 2)^2 + \lambda(x) = 0$

it passes (– 2, 4)

$\therefore\ 4 + 4 - 2\lambda = 0$

$\lambda = 4$

$\therefore$ circle is $x^2 + y^2 - 4y + 4x + 4 = 0$

centre (–2, 2) which satisfy

2x – 3y + 10 = 0 Ans. 3

21. The number of distinct real roots of the equation, $\begin{vmatrix} \cos x & \sin x & \sin x \\ \sin x & \cos x & \sin x \\ \sin x & \sin x & \cos x \end{vmatrix} = 0$ in the interval $\left[-\frac{\pi}{4}, \frac{\pi}{4}\right]$ is :

(1) 4 (2) 1 (3) 2 (4) 3

Ans. **(3)**

Sol. $\begin{vmatrix} \cos x & \sin x & \sin x \\ \sin x & \cos x & \sin x \\ \sin x & \sin x & \cos x \end{vmatrix} = 0$

$\Rightarrow \cos^3 x + \sin^3 x + \sin^3 x - 3\sin^2 x\cos x = 0$

$\Rightarrow (\cos x + \sin x + \sin x)(\cos^2 x + \sin^2 x + \sin^2 x - \cos x\sin x - \cos x\sin x - \sin^2 x) = 0$

$\Rightarrow \cos x = -2\sin x$ or $\cos x = \sin x$

$\tan x = -\frac{1}{2}$ $\tan = 1 \Rightarrow x = \pi/4$

$x = -\tan^{-1}\frac{1}{2}$ $\therefore$ two solutions

22. The shortest distance between the lines $\frac{x}{2} = \frac{y}{2} = \frac{z}{1}$ and $\frac{x+2}{-1} = \frac{y-4}{8} = \frac{z-5}{4}$ lies in the interval :

(1) (2, 3] (2) [0, 1) (3) (3, 4] (4) [1, 2)

Ans. **(1)**

Sol. $\frac{x}{z} = \frac{y}{z}\frac{z}{1}$ and $\frac{x+2}{-1} = \frac{y-4}{8} = \frac{z-5}{4}$

shortest distance

$= (\vec{a}_2 - \vec{a}_1).(\vec{b}_1 \times \vec{b}_2)$

here $\vec{b}_1 - \vec{b}_2 = (2i + 2j + k) \times (-i + 8j + 4k)$

$= -9j + 18k$

$(\vec{b}_1 \times \vec{b}_2) = \frac{-j + 2k}{\sqrt{5}}$

$\vec{a}_2 - \vec{a}_1 = -2i + 4j + 5k$

$\therefore$ S.D. $(-2i + 4j + 6k).\frac{(-j + 2k)}{\sqrt{5}} = \frac{6}{\sqrt{5}}$ which lies in (2,3]

23. If the four letter words (need not be meaningful) are to be formed using the letters from the word "MEDITERRANEAN" such that the first letter is R and the fourth letter is E, then the total number of all such words is :

(1) $\frac{11!}{(2!)^3}$ (2) 59 (3) 110 (4) 56

Ans. **(1)**

Sol. There are 1M, 3E, 1D, II, IT, 2R, 2A, 2N

R– –E – – – – – – – – – – –

rest of 11 letters can be arranged in $\frac{11!}{(2\ !)^3}$

24. Let a and b respectively be the semi-transverse and semi-conjugate axes of a hyperbola whose eccentricity satisfies the equation $9e^{-2} - 18e + 5 = 0$. If S(5, 0) is a focus and $5x = 9$ is the corresponding directrix of hyperbola, then $a^2 - b^2$ is equal to

(1) – 7 (2) – 5 (3) 5 (4) 7

Ans. **(1)**

Sol. $9e^2 - 18e + 5 = 0$

$\Rightarrow e = \frac{5}{3}$

$\therefore 1 + \frac{b^2}{a^2} = e^2 = \frac{25}{9}$ ..... (i)

Also distance between foci and directrix is

$= \left(ae - \frac{a}{e}\right) = 5 - \frac{9}{5}$

$\Rightarrow a\left(\frac{5}{3} - \frac{3}{5}\right) = \frac{16}{5} \Rightarrow a = 3$

from (i)

$1 + \frac{b^2}{9} = e^2 = \frac{25}{9} \Rightarrow b^2 = 16$

$\therefore a^2 - b^2 = 9 - 16 = -7$

25. Consider the following two statements :

P : If 7 is an odd number, then 7 is divisible by 2.

Q : If 7 is a prime number, then 7 is an odd number.

If V_1 is the truth value of contrapositive of P and V_2 is the truth value of contrapositive of Q, then the ordered pair (V_1, V_2) equals :

(1) (F, T) (2) (T, F) (3) (F, F) (4) (T, T)

Ans. **(1)**

Sol. Statement P is False
Statement Q is True.
$V_1 \equiv F$
$V_2 \equiv T$
Ans. 1

26. The minimum distance of a point on the curve $y = x^2 - 4$ from the origin is :

(1) $\frac{\sqrt{15}}{2}$ (2) $\frac{\sqrt{19}}{2}$ (3) $\sqrt{\frac{15}{2}}$ (4) $\sqrt{\frac{19}{2}}$

Ans. **(1)**

Sol. Let point at minimum distance from O is
$(h, h^2 - 4)$

$\therefore OP^2 = h^2 + (h^2 - 4)^2$

$\frac{d(OP^2)}{dh} = 2h + 2(h^2 - 4)2h = 0$

$\Rightarrow h = \pm\sqrt{\frac{7}{2}}, 0$

$\left(\frac{d^2(OP^2)}{dh^2}\right)_{h=\pm\sqrt{\frac{7}{2}}} > 0$

$\therefore$ OP is min at $h = \pm\sqrt{\frac{7}{2}}$

$OP_{min} = \sqrt{\frac{7}{2} + \left(\frac{7}{2} - 4\right)^2} = \frac{\sqrt{15}}{2}$

27. Let x, y, z be positive real numbers such that $x + y + z = 12$ and $x^3y^4z^5 = (0.1)(600)^3$. Then $x^3 + y^3 + z^3$ is equal to

(1) 270 (2) 258 (3) 216 (4) 342

Ans. **(3)**

Sol. $x + y + z = 12$
$x^3y^4z^5 = (0.1)(600)^3$

$\frac{3\left(\frac{x}{3}\right) + 4\left(\frac{y}{4}\right) + 5\left(\frac{z}{5}\right)}{12} \geq \left\{\left(\frac{x}{3}\right)^3\left(\frac{y}{4}\right)^4\left(\frac{z}{5}\right)^5\right\}^{1/12}$

$1 \geq \frac{x^3y^4z^5}{(60)^3(4\times 25)}$

$x^3y^4z^5 \leq (0.1)(600)^3$
But $x^3y^4z^5 = (10.1)(600)^3$
Clearly AM = GM

Hence $\frac{x}{3} = \frac{y}{4} = \frac{z}{5}$ $\Rightarrow x = 3, y = 4, z = 5$

$\Rightarrow x^3 + y^3 + z^3 = 27 + 64 + 125 = 216$

28. If the mean deviation of the numbers 1, 1 + d, ..., 1 + 100d from their mean is 255, then a value of d is :

(1) 10 (2) 20.2 (3) 5.05 (4) 10.1

Ans. **(4)**

Sol. Mean is $\frac{101+\frac{100\times101}{2}}{101}$ = 1 + 50 d

sum of deviation about mean is

50 d + 49d + ... d + 0 + d + ... + 50 d

= 50. 51 d

Mean deviation = $\frac{50\times51d}{101}$ = 255

d = $\frac{255\times101}{2550}$ = 10.1

29. For $x \in R$, $x = -1$, if $(1+x)^{2016} + x(1+x)^{2015} + x^2(1+x)^{2014} + \ldots\ldots\ldots + x^{2016} = \sum_{i=0}^{2016} a_i x^i$, then a_{17} is equal to :

(1) $\frac{2016!}{16!}$ (2) $\frac{2017!}{2000!}$ (3) $\frac{2017!}{17!\ 2000!}$ (4) $\frac{2016!}{17!\ 1999!}$

Ans. **(3)**

Sol. $\sum_{i=0}^{2016} c_i.x^i = (1+x)^{2016} + x(1+x)^{2015} + x^2(1+x)^{2014} + \ldots\ldots\ldots + x^{2016}$

$$= \frac{(1+x)^{2016}\left(1-\left(\frac{x}{1+x}\right)^{2017}\right)}{1-\frac{x}{1+x}}$$

$$= \frac{\frac{(1+x)^{2016}}{1} - \frac{x^{2017}}{(1+x)}}{\frac{x+1-x}{1+x}} = \frac{(1+x)^{2017} - x^{2017}}{1}$$

$\therefore\ a_{17} = {}^{2017}C_{17} = \frac{2007!}{17!\quad 2000!}$

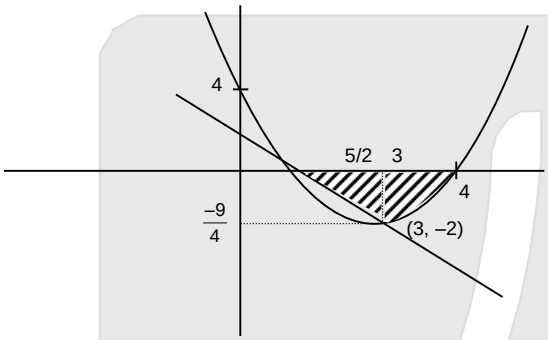
30. The area (in sq. units) of the region described by $A = \{(x, y) \mid y \geq x^2 - 5x + 4, x + y \geq 1, y \leq 0\}$ is :

(1) $\frac{7}{2}$ (2) $\frac{13}{6}$ (3) $\frac{17}{6}$ (4*) $\frac{19}{6}$

Ans. **(4)**

Sol. $A = \{(x,y) | y \geq x^2 - 5x + 4, x + y \geq 1, y \leq 0\}$

Here $y \geq x^2 - 5x + 4$, $x + y \geq 1$, $y \leq 0$



Required area = $\frac{1}{2}.2\ 2+ \int_3^4 (5x - x^2 - 4)dx$

$= 2 + \left[\frac{5x^2}{2} - \frac{x^3}{3} - 4x\right]_3^4$

$= 2 + \frac{5}{2}(16 - 9) - \frac{1}{3}(64 - 27) - 4\ (4 - 3)$

$- 2 + \frac{35}{2} - \frac{37}{3} - 4 = \frac{19}{6}$

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1. The artificial sweetener that has the highest sweetness value in comparison to cane sugar is :

(1) Saccharin (2) Sucralose (3) Alitame (4) Aspartane

Ans. (3)

Sol. Alitame is 2000 times sweeter than sucrose.

2. The non-metal that does not exhibit positive oxidation state is :

(1) Fluorine (2) Oxygen (3) Chlorine (4) Iodine

Ans. (1)

Sol. Fluorine is the most electronegative element in periodic table hence it shows –1 oxidation state in all its compounds.

3. The reaction of ozone with oxygen atoms in the presence of chlorine atoms can occur by a two step process show below:

$O_3(g) + Cl^{\bullet}(g) \rightarrow O_2(g) + ClO^{\bullet}(g)$ ...(i)

$k_i = 5.2 \times 10^9$ L mol^{-1} s^{-1}

$ClO^{\bullet}(g) + O^{\bullet}(g) \rightarrow O_2(g) + Cl^{\bullet}(g)$ ...(ii)

$k_{ii} = 2.6 \times 10^{10}$ L mol^{-1} s^{-1}

The closest rate constant for the overall reaction $O_3(g) + O^{\bullet}(g) \rightarrow 2O_2(g)$ is:

(1) 1.4×10^{20} L mol^{-1} s^{-1} (2) 5.2×10^9 L mol^{-1} s^{-1}

(3) 3.1×10^{10} L mol^{-1} s^{-1} (4) 2.6×10^{10} L mol^{-1} s^{-1}

Ans. (2)

Sol. The rate constant of overall reaction depends slowest step. Hence equation(i) is slowest step.

Option(2) is correct.

4. 5L of an alkane requires 25 L of oxygen for its complete combustion. If all volumes are measured at constant temperature and pressure, the alkane is ;

(1) Butane (2) Isobutane (3) Ethane (4) Propane

Ans. (4)

Sol. $C_nH_{2n+2} + \left(\frac{3n+1}{2}\right)O_2 \longrightarrow nCO_2 + (n+1)\,H_2O$

5 L 25 L

Since volumes are measured at constant T & P

So, Volume $\propto$ mole

$\therefore \quad n_{alkane} = \left(\frac{2}{3n+1}\right) \times n_{O_2}$

$5 = \frac{2}{3n+1} \times 25$

$\therefore$ n = 3

$\therefore$ Alkane is propane (C_3H_8).

5. Match the items in Column I with its main use listed in Column II:

	Column I		Column II
(A)	Silica gel	(i)	Transistor
(B)	Silicon	(ii)	Ion-exchanger
(C)	Silicone	(iii)	Drying agent
(D)	Silicate	(iv)	Sealant

(1) (A)-(iii), (B)-(i), (C)-(iv), (D)-(ii) (2) (A)-(ii), (B)-(i), (C)-(iv), (D)-(iii)
(3) (A)-(iv), (B)-(i), (C)-(ii), (D)-(iii) (4) (A)-(ii), (B)-(iv), (C)-(i), (D)-(iii)

Ans. (1)

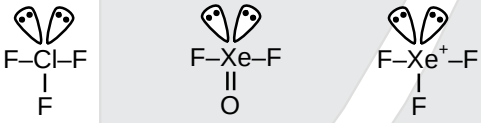
Sol. Based on theoretical fact.

6. The group of molecules having identical shape is :

(1) PCl_5, IF_5, XeO_2F_2 (2) BF_3, PCl_3, XeO_3 (3) ClF_3, $XeOF_2$, XeF_3^+ (4) SF_4, XeF_4, CCl_4

Ans. (3)

Sol. ClF_3, $XeOF_2$ & XeF_3^+ are sp^3d hybridized with 2 lone pair e's, hence all have (T-shape) identical shape.



7. Which one of the following species is stable in aqueous solution?

(1) MnO_4^{2-} (2) MnO_4^{3-} (3) Cu^+ (4) Cr^{2+}

Ans. (1)

Sol. (1) MnO_4^{2-} disproportionates in neutral or acidic solution.

$$3MnO_4^{2-} + 4H^+ \longrightarrow 2MnO_4^{2-} + MnO_2 + 2H_2O$$

(3) Many Cu^+ compounds are unstable in aqueous solution and undergo disproportionation as follows

$$2Cu^+ \longrightarrow Cu^{2+} + Cu$$

8. For the reaction,

A(g) + B(g) $\rightarrow$ C(g) + D(g), ΔH^o and ΔS^o are, respectively, –29.8 kJ mol^{-1} and –0.100 kJ K^{-1} mol^{-1} at 298 K. The equilibrium constant for the reaction at 298 K is:

(1) 1 (2) 10 (3) 1.0×10^{-10} (4) 1.0×10^{10}

Ans. (1)

Sol. $\Delta G^o = \Delta H^o - T.\Delta S^o$

$= -29.8 + 298 \times (0.1)$

$= -29.8 + 29.8$

$\because \Delta G^o = 0$

apply relation between ΔG^o & K_{eq}

$\Delta G^o = -RT\ \ell n\ K_{eq}$

$\therefore \quad K_{eq} = 1$

9. **Assertion :** Rayon is a semisynthetic polymer whose properties are better than natural cotton.

Reason : Mechanical and aesthetic properties of cellulose can be improved by acetylation.

(1) Both assertion and reason are correct, and the reason is the correct explanation for the assertion.

(2) Both assertion and reason are incorrect.

(3) Assertion is incorrect statement, but the reason is correct.

(4) Both assertion and reason are correct, but the reason is not the correct explanation for the assertion.

Ans. (1)

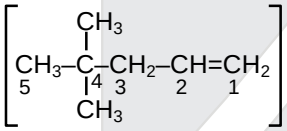
Sol. Rayon is prepared by acetylation of cellulose.

10. The hydrocarbon with seven carbon atoms containing a neopentyl and a vinyl group is :

(1) 4,4-dimethylpentene (2) 2,2-dimethyl-4-pentene

(3) Isopropyl-2-butene (4) 2,2-dimethyl-3-pentene

Ans. (1)

Sol.  has seven carbon atoms containing a neopentyl and a vinyl group.

11. The gas evolved on heating CH_3MgBr in methanol is:

(1) Propane (2) Ethane (3) HBr (4) Methane

Ans. (4)

Sol. $CH_3MgBr + CH_3{-}OH \longrightarrow (CH_3O)MgBr + CH_4\uparrow$ gas.

12. Identify the correct trend given below:

(Atomic No.: Ti = 22, Cr = 24 and Mo = 42)

(1) Δ_o of $[Cr(H_2O)_6]^{2+} < [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} < [Ti(H_2O)_6]^{2+}$

(2) Δ_o of $[Cr(H_2O)_6]^{2+} > [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} > [Ti(H_2O)_6]^{2+}$

(3) Δ_o of $[Cr(H_2O)_6]^{2+} > [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} < [Ti(H_2O)_6]^{2+}$

(4) Δ_o of $[Cr(H_2O)_6]^{2+} < [Mo(H_2O)_6]^{2+}$ and Δ_o of $[Ti(H_2O)_6]^{3+} > [Ti(H_2O)_6]^{2+}$

Ans. (1)

Sol. $\Delta_o \propto$ CFSE (Crystal field stabilization energy)

Δ_o of $[Cr(H_2O)_6]^{2+} < \Delta_o$ of $[Mo(H_2O)_6]^{2+}$

Because here Δ_o depends on Z_{eff} & Z_{eff} of 4d series is more than 3d series.

But Δ_o of $[Ti(H_2O)_6]^{3+} < \Delta_o$ of $[Ti(H_2O)_6]^{2+}$

13. The most appropriate method of making egg-albumin sol is:

(1) Keep the egg in boiling water for 10 minutes. After removing the shell, transfer the yellow part of the content to 100 mL of 5% w/V saline solution and homogenize with a mechanical shaker.

(2) Break an egg carefully and transfer the transparent part of the content to 100 mL of 5% w/V saline solution and stir well.

(3) Keep the egg in boiling water for 10 minutes. After removing the shell, transfer the white part of the content to 100 mL of 5% w/V saline solution and homogenize with a mechanical shaker.

(4) Break an egg carefully and transfer only the yellow part of the content to 100 mL of 5% w/V saline solution and stir well.

Ans. (2)

Sol. Only the transparent part of egg has albumin.

14. Which one of the following complexes will consume more equivalents of aqueous solution of $Ag(NO_3)$?

(1) $Na_3[CrCl_6]$ (2) $[Cr(H_2O)_5Cl]Cl_2$ (3) $[Cr(H_2O)_6]Cl_3$ (4) $Na_2[CrCl_5(H_2O)]$

Ans. (3)

Sol. Complex $[Cr(H_2O)_6]Cl_3$ will consume more equivalents of aqueous solution of $Ag(NO_3)$.

15. At very high pressures, the compressibility factor of one mole of a gas is given by :

(1) $1 + \frac{pb}{RT}$ (2) $\frac{pb}{RT}$ (3) $1 - \frac{b}{(VRT)}$ (4) $1 - \frac{pb}{RT}$

Ans. (1)

Sol. According to Vander waal's equation for one mole of gas

$$\left(P + \frac{a}{V^2}\right)(V - b) = RT$$

at high pressure $\frac{a}{V^2}$ can be neglected with respect to P,

$$\therefore \quad P + \frac{a}{V^2} \simeq P$$

$P(V - b) = RT$

$PV - Pb = RT$

$PV = RT + Pb$

divided on RT on both side,

$$Z = 1 + \frac{Pb}{RT}$$

16. A reaction at 1 bar is non-spontaneous at low temperature but becomes spontaneous at high temperature. Identify the correct statement about the reaction among the following:

(1) Both ΔH and ΔS are positive. (2) ΔH is negative while ΔS is positive.

(3) ΔH is positive while ΔS is negative. (4) Both ΔH and ΔS are negative.

Ans. (1)

Sol. $\Delta G = \Delta H - T.\Delta S$

If ΔH & ΔS are both positive, then ΔG may be negative at high temperature hence reaction becomes spontaneous at high temperature.

17. Which intermolecular force is most responsible in allowing xenon gas to liquefy?

(1) Instantaneous dipole-induced dipole (2) Ionic

(3) Ion-dipole (4) Dipole-dipole

Ans. (1)

Sol. Instantaneous dipole-induced dipole forces are most responsible in allowing xenon gas to liquify.

18. Identify the incorrect statement regarding heavy water:

(1) It reacts with CaC_2 to produce C_2D_2 and $Ca(OD)_2$.

(2) It is used as a coolant in nuclear reactors.

(3) It reacts with Al_4C_3 to produce CD_4 and $Al(OD)_3$.

(4) It reacts with SO_3 to form deuterated sulphuric acid (D_2SO_4).

Ans. (2)

Sol. Heavy water (D_2O) acts as moderator used to slow down the speed of neutrons in nuclear reactor, hence option (2) is incorrect.

19. A particular adsorption process has the following characteristics: (i) It arises due to vander Waals forces and (ii) it is reversible. Identify the correct statement that describes the above adsorption process:

(1) Enthalpy of adsorption is greater than 100 kJ mol^{-1}.

(2) Adsorption is monolayer.

(3) Adsorption increases with increase in temperature.

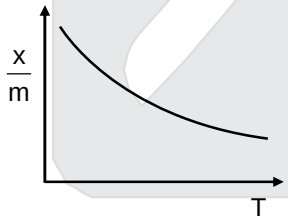
(4) Energy of activation is low.

Ans. (4)

Sol. Adsorption aries due to Vander waal forces & reversible, hence it should be physisorption (physical adsorption).

(i) Enthalpy of physisorption is low (20 – 40 kJ/mol)

(ii) In physisorption multimolecular layer form.

(iii) 

Physisorption decreases with increase in temperature.

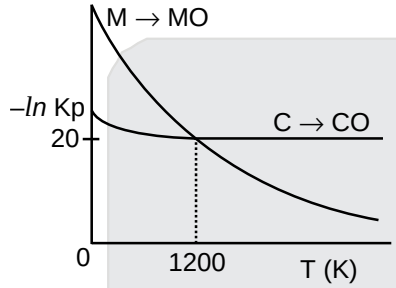
(iv) Physisorption required number activation energy.

Hence answer is (4)

20. The plot shows the variation of –ln Kp versus temperature for the two reactions.

$M(s) + \frac{1}{2}O_2(g) \longrightarrow MO(s)$ and

$C(s) + \frac{1}{2}O_2(g) \longrightarrow CO(s)$



Identify the correct statement:

(1) At T > 1200 K, carbon will reduce MO(s) to M(s).

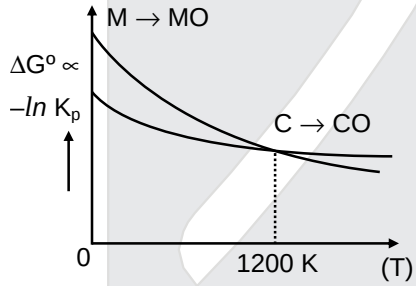
(2) At T < 1200 K, oxidation of carbon is unfavourable.

(3) Oxidation of carbon is favourable at all temperatures.

(4) At T < 1200 K, the reaction MO(s) + C(s) → M(s) + CO(g) is spontaneous.

Ans. (4)

Sol. According to Ellingham diagram, as given



At T < 1200, carbon will reduce $MO_{(s)}$ to $M_{(s)}$ hence, chemical reaction

$C_{(s)} + MO_{(s)} \longrightarrow M_{(s)} + CO_{(g)}$ is spontaneous.

21. BOD stands for:

(1) Biochemical Oxygen Demand (2) Biochemical Oxidation Demand

(3) Biological Oxygen Demand (4) Bacterial Oxidation Demand

Ans. (1)

Sol. BOD stands for Biochemical oxygen demand.

22. What will occur if a block of copper metal is dropped into a beaker containing a solution of 1M $ZnSO_4$?

(1) The copper metal will dissolve and zinc metal will be deposited.

(2) The copper metal will dissolve with evolution of oxygen gas.

(3) The copper metal will dissolve with evolution of hydrogen gas.

(4) No reaction will occur.

Ans. (4)

Sol. If a block of copper metal is dropped into a beaker containing solution of 1 M $ZnSO_4$, no reaction will occur because $E^{o}_{Zn^{2+}/Zn} = -0.76$ V

$E^{o}_{Cu^{2+}/Cu} = +0.34$ V

Hence Cu can't displace Zn from $ZnSO_4$ solution.

23. The test to distinguish primary, secondary and tertiary amine is:

(1) Mustard oil test (2) $C_6H_5SO_2Cl$

(3) Sandmeyer's reaction (4) Carbylamine reaction

Ans. (2)

Sol. Benzene sulphonyl chloride ($C_6H_5SO_2Cl$) is used to distinguish primary, secondary and tertiary amine.

24. The total number of orbitals associated with the principal quantum number 5 is:

(1) 5 (2) 20 (3) 25 (4) 10

Ans. (3)

Sol. n = 5

Possible subshell are

$\Rightarrow$ 5s, 5p, 5d, 5f, 5g

$\therefore$ Total number of orbital = 1 + 3 + 5 + 7 + 9 = 25

25. The correct order of the solubility of alkaline-earth metal sulphates in water is:

(1) Mg < Sr < Ca < Ba (2) Mg > Ca> Sr > Ba (3) Mg > Sr > Ca > Ba (4) Mg < Ca < Sr < Ba

Ans. (2)

Sol. Solubility of sulphates of alkaline earth metal decreases down the group. Hence correct order of solubility is Mg > Ca > Sr > Ba

26. An organic compound contains C, H and S. The minimum molecular weight of the compound containing 8% sulphur is:

(atomic weight of S = 32 amu)

(1) 300 g mol^{-1} (2) 400 g mol^{-1} (3) 200 g mol^{-1} (4) 600 g mol^{-1}

Ans. (2)

Sol. 8 g sulphur present in = 100 g of organic compound.

$\therefore$ 32 g sulphur present in = $\frac{100}{8} \times 32 = 400$ g of organic compound.

Hence, minimum molecular weight of compound = 400 g/mol

27. Bouveault-Blanc reduction reaction involves:

(1) Reduction of an anhydride with $LiAlH_4$.

(2) Reduction of an ester with Na/C_2H_5OH.

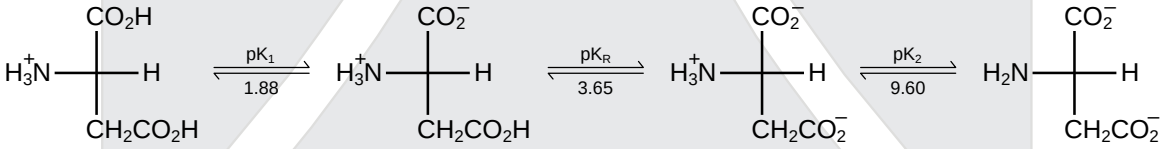
(3) Reduction of a carbonyl compound with Na/Hg and HCl.

(4) Reduction of an acyl halide with H_2/Pd.

Ans. (2)

Sol. Reduction using Na in ethylalcohol is called Bouveault-Blanc reduction.

28. Consider the following sequence for aspartic acid:



The pI (isoelectric point) of aspartic acid is:

(1) 5.74 (2) 3.65 (3) 2.77 (4) 1.88

Ans. (3)

Sol. In given reaction sequence

$$PI = \frac{pK_1 + pK_R}{2}$$

$$= \frac{1.88 + 3.65}{2} = 2.77$$

29. The amount of arsenic pentasulphide that can be obtained when 35.5 g arsenic acid is treated with excess H_2S in the presence of conc. HCl (assuming 100% conversion)

(1) 0.25 mol (2) 0.125 mol (3) 0.333 mol (4) 0.50 mol

Ans. (2)

Sol. $H_3AsO_4 \xrightarrow{H_2S/HCl} As_2S_5$

Assuming 100% conversion of As, apply POAC rule for 'As' atom

$1 \times n_{H_3AsO_4} = 2 \times n_{As_2O_5}$

$\frac{35.5}{142} = 2 \times n_{As_2O_5}$

$\therefore \quad n_{As_2O_5} = 0.125$ mol

30. The solubility of N_2 in water at 300 K and 500 torr partial pressure is 0.01 g L^{-1}. The solubility (in g L^{-1}) at 750 torr partial pressure is :

(1) 0.02 (2) 0.015 (3) 0.0075 (4) 0.005

Ans. (2)

Sol. According to Henery law

$\frac{P_1}{P_2} = \frac{S_1}{S_2}$ $\quad \therefore S_1$ & S_2 are solubility of gas (g/L)

$\frac{500}{750} = \frac{0.01}{S_2}$

$\therefore \quad S_2 = \frac{750 \times 0.01}{500} = 0.015$ g/L

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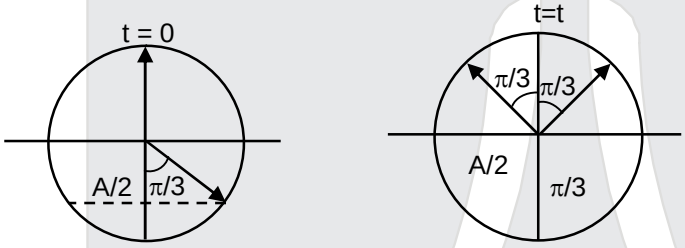
1. Two particles are performing simple harmonic motion in a straight line about the same equilibrium point. The amplitude and time period for both particles are same and equal to A and T, respectively. At time t = 0 one particle has displacement A while the other one has displacement $\frac{-A}{2}$ and they are moving towards each other .If they cross each at time t, then t is :

(1) $\frac{T}{4}$ (2) $\frac{5T}{6}$ (3) $\frac{T}{3}$ (4) $\frac{T}{6}$

Ans. **(4)**

Sol.



$t = \frac{\pi}{3\omega} = \frac{T}{6}$

2. To find the focal length of a convex mirror, a student records the following data :

Object pin	Convex Lens	Convex Mirror	Image Pin
22.2 cm	32.2cm	45.8 cm	71.2 cm

The focal length of the convex lens is f_1 and that of mirror is f_2. Then taking index correction to be negligibly small, f_1 and f_2. are close to :

(1) f_1 = 15.6 cm f_2 = 25.4 cm

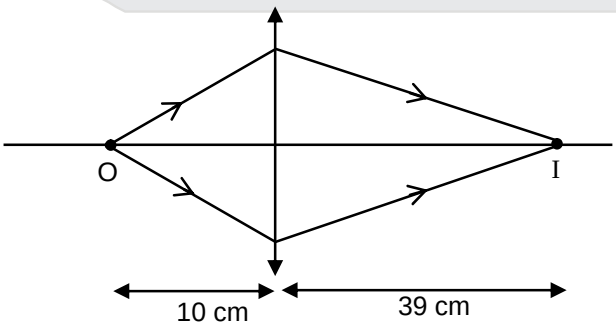
(2) f_1 = 7.8 cm f_2 = 12.7 cm

(3) f_1 = 7.8 cm f_2 = 25.4 cm

(4) f_1 = 12.7 cm f_2 = 7.8 cm

Ans. **(2)**

Sol. For convex lens



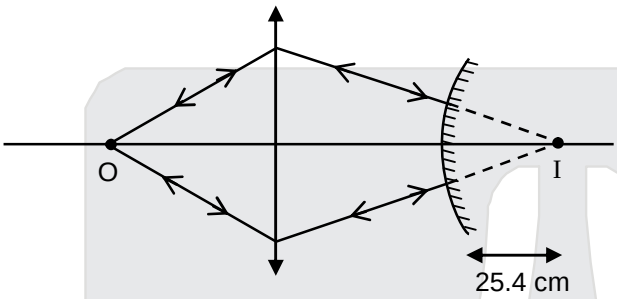
u =–10 cm

v = 39 cm

$f_1 = \frac{uv}{u - v}$

$= \frac{390}{49} = 7.8$ cm

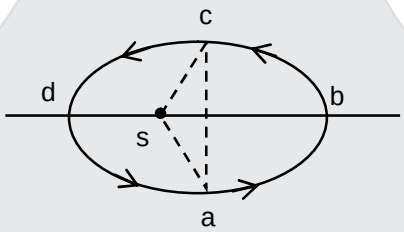
For convex mirror



R = 25.4 cm

$f_2 = 12.7$ cm

3. Figure shows elliptical path abcd of a planet around the sun S such that the area of triangle csa is $\frac{1}{4}$ the area of the ellipse . (See figure) With db as the semi major axis, and ca as the semi minor axis. If t_1 is the time taken for planet to go over path abc and t_2 for path taken over cda then :



(1) $t_1 = 3t_2$ (2) $t_1 = t_2$ (3) $t_1 = 2t_2$ (4) $t_1 = 4t_2$

Ans. **(1)**

Sol. Total area = A

Area of sabc = $\frac{3A}{4}$

Area of sadc = $\frac{A}{4}$

$\frac{3A}{4t_1} = \frac{A}{4t_2} \Rightarrow t_1 = 3t_2$

4. A simple pendulum made of a bob of mass m and a metallic wire of negligible mass has time period 2s at T = 0°C. If the temperature of the wire is increased and the corresponding charge in its time period is plotted against its temperature, the resulting graph is a line of slop S. If the coefficient of linear expansion of metal is a then the value of S is :

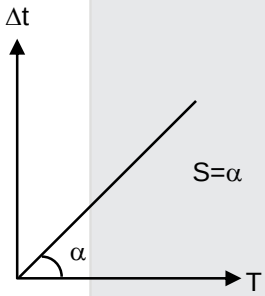
(1) $\frac{1}{\alpha}$ (2) 2α (3) $\frac{\alpha}{2}$ (4) α

Ans. **(4)**

Sol. $t_0 = 2 = 2\pi\sqrt{\frac{\ell_0}{g}}$

$t = 2\pi\sqrt{\frac{\ell_0(1+\alpha T)}{g}} = 2(1+\alpha T)^{1/2} = 2 + \alpha T$

$t - t_0 = \alpha T \Rightarrow \Delta t = \alpha T$



5. The ratio of work done by an ideal monatomic gas to the heat supplied to it in an isobaric process is :

(1) $\frac{3}{2}$ (2) $\frac{2}{3}$ (3) $\frac{3}{5}$ (4) $\frac{2}{5}$

Ans. **(4)**

Sol. $\Delta w = P\Delta V = nR\Delta T$

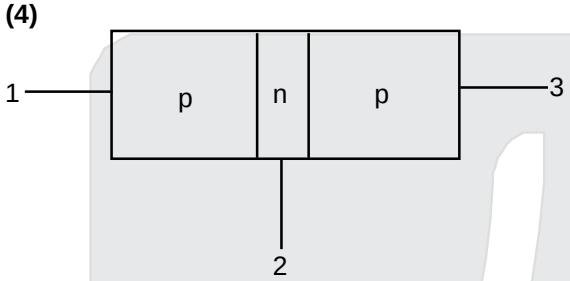
$\Delta Q = nc_p \Delta T = \frac{5}{2} nR\Delta T$

$\frac{\Delta w}{\Delta Q} = \frac{2}{5}$

6. An unknown transistor needs to be identified as npn or pnp type .A multimeter, with +ve and –ve terminals, is used to measure resistance between different terminals transistor. If terminal 2 is the base of the transistor then which of the following is correct for a pnp transistor ?
(1) +ve terminal 3, –ve terminal 2, resistance high
(2) +ve terminal 2, –ve terminal 3, resistance low
(3) +ve terminal 1, –ve terminal 2, resistance high
(4) +ve terminal 2, –ve terminal 1, resistance high

Ans. **(4)**

Sol.



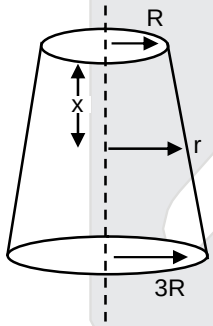
when pn junction is forward biased resistance is law. When pn junction reverse biased resistance is high

7. A uniformly tapering conical wire is made from a material of Young's modulus Y and has a normal, unextended length L. The radii, at the upper and lower ends of this conical wire , have values R and 3R, respectively, The upper end of the wire is fixed to a rigid support and a mass M is suspended from its lower and . The equilibrium extended length, of this wire, would equal

(1) $L\left(1+\frac{1}{3}\frac{Mg}{\pi YR^2}\right)$ (2) $L\left(1+\frac{2}{3}\frac{Mg}{\pi YR^2}\right)$ (3) $L\left(1+\frac{1}{9}\frac{Mg}{\pi YR^2}\right)$ (4) $L\left(1+\frac{2}{9}\frac{Mg}{\pi YR^2}\right)$

Ans. **(1)**

Sol.

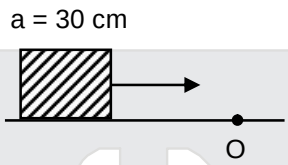


$$\frac{r-R}{x}=\frac{3R-R}{L}\Rightarrow r=R\left(1+\frac{2x}{L}\right)\ ;\ Y=\frac{Mg}{\pi R^2\frac{dL}{dx}}$$

$$dL=\frac{Mg}{\pi R^2}\frac{dx}{\left(1+\frac{2x}{L}\right)^2}$$

$$\Delta L=\frac{Mg}{Y\pi R^2}\int_0^L\frac{dx}{\left(1+\frac{2x}{L}\right)^2}=\frac{MgL}{3\pi R^2Y}\ ;\quad L'=L+\Delta L=L\left(1+\frac{1}{3}\frac{Mg}{\pi R^2Y}\right)$$

8. A cubical block of side 30cm is moving with velocity 2ms^{-1} on a smooth horizontal surface. The surface has a bump ata point O as shown in figure. The angular velocity (in rad/s) of the block immediately after it hits the bump, is :



(1) 9.4 (2) 6.7 (3) 5.0 (4) 13.3

Ans. **(3)**

Sol. Using conservation of angular momentum

$$mv\frac{a}{2}=\frac{2}{3}ma^2\omega \Rightarrow \omega=\frac{3v}{4a}=5rad/s$$

9. In Young's double slit experiment, the distance between slits and the screen is 1.0 m and monochromatic light of 600 nm is being used. A person standing near the slits is looking at the fringe pattern . When the separation between the slits is varied, the interference pattern disappears for a particular distance d_0 between the slits. If the angular resolution of the eye is $\frac{1^\circ}{60}$ the value of d_0 is close to

(1) 2 mm (2) 1 mm (3) 3mm (4) 4 mm

Ans. **(1)**

Sol. Angular fringe width $\theta = \frac{\beta}{D}=\frac{\lambda}{d}$

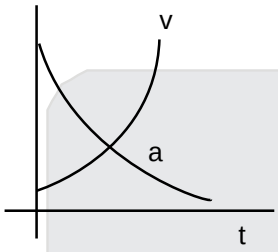
$$\frac{\lambda}{d_0}=\frac{1^\circ}{60}=\frac{\pi}{180\times 60}$$

$$d_0 = \lambda\left(\frac{180\times 60}{\pi}\right)$$

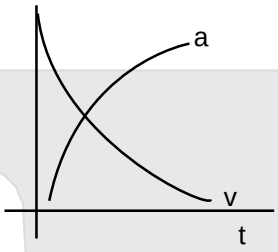
$= 2 \times 10^{-3}$ m = 2mm.

10. Which of the following option correctly describes the variation of the speed v and acceleration 'a' of a point mass falling vertically in a viscous medium that applies a force F = –kv, where 'k' is constant , on the body ?(Graphs are schematic and not drawn to scale)

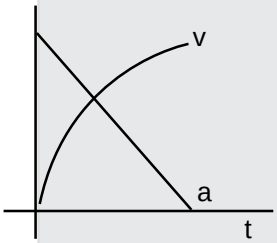
(1)



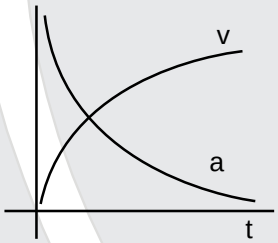
(2)



(3)



(4)



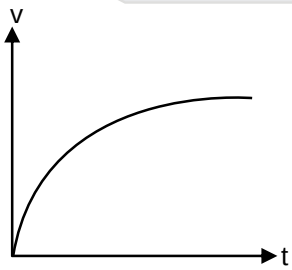
Ans. **(4)**

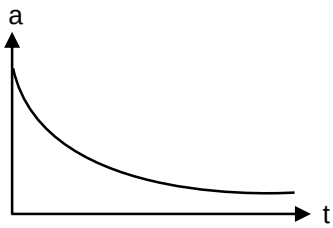
Sol. $a = g - \alpha v$

$$\frac{dv}{dt} = g - \alpha v$$

$$\int_0^v \frac{dv}{g-\alpha v} = \int_0^t dt \Rightarrow \ell n\left(\frac{g-\alpha v}{v}\right) = -\alpha t$$

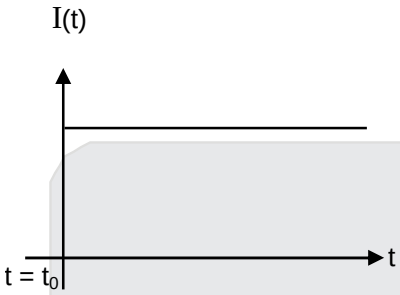
$$V = v_0\,(1 - e^{-\alpha t}),\ a = \frac{dv}{dt} = v_0 \alpha e^{-\alpha t} = a_0 e^{-\alpha t}$$



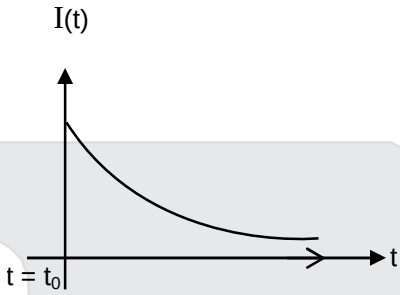


11. A series LR circuit is connected to a voltage source with $V(t) = V_0 \sin\Omega t$. After very large time current $I(t)$ behaves as $\left(t_0 >> \frac{L}{R}\right)$:

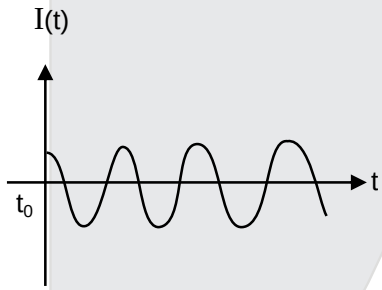
(1)



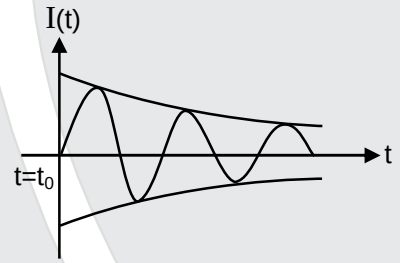
(2)



(3)



(4)



Ans. **(3)**

Sol. Current will be in the form of
$I = I_0 \sin(\Omega t - \phi)$
Graph will be sinusoidal

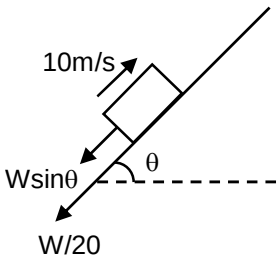
12. A car of weight W is on an inclined road that rises by 100 m over a distance of 1km and applies a constant frictional force $\frac{W}{20}$ on the car. While moving uphill on the road at a speed of $10 ms^{-1}$, the car needs power P. If it needs power $\frac{P}{2}$ while moving downhill at speed v then value of v is :

(1) $5 ms^{-1}$ (2) $20 ms^{-1}$ (3) $10 ms^{-1}$ (4) $15 ms^{-1}$

Ans. **(4)**

Sol. While going up

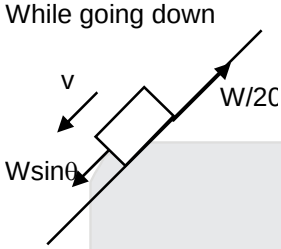
$(\sin\theta = \tan\theta = \frac{1}{10})$



$W\sin\theta\ 10 + \frac{W}{20}\ 10 = P$

$\frac{3W}{2} = P$

While going down



$\frac{W}{20}v = \frac{P}{2} = \frac{3W}{4}$

v = 15 m/s

13. A rocket is fired vertically from the earth with an acceleration of 2g, where g is the gravitational acceleration. On an inclined plane inside the rocket, making an angle θ. With the horizontal , a point object of mass m is kept. The minimum coefficient of friction μ_{min} between the mass and the inclined surface such that he mass does not move is :

(1) $\tan\theta$ (2) $\tan2\theta$ (3) $3\tan\theta$ (4) $2\tan\theta$.

Ans. **(1)**

Sol. $g_{eft} = 3g$ but $\mu_{min} = \tan\theta$

14. Two engines pass each other moving in opposite directions with uniform speed of 30m/s. One of them is blowing a whistle of frequency 540 Hz. Calculate the frequency heard by driver of second engine before pass each other. Speed sound is 330 m/sec.

(1) 540 Hz (2) 648 Hz (3) 270 Hz (4) 450 Hz

Ans. **(2)**

Sol.

$f_0 = \left(\frac{330+30}{330-30}\right)540 = 648\,Hz$

15. The potential (in volts) of a charge distribution is given by

$V(z) = 30 - 5z^2$ for $|z| \le 1m$

$V(z) = 35 - 10\,|z|$ for $|z| \ge 1m$.

V(z) does not depend on x and y . If this potential is generated by a constant charge per unit volume ρ_0, (in units of ε_0) which is spread over certain region ,then choose the correct statement.

(1) $\rho_0 = 40\ \varepsilon_0$ in the entire region

(2) $\rho_0 = 20\ \varepsilon_0$ in the entire region

(3) $\rho_0 = 20\ \varepsilon_0$ for $|z|$ in ≤ 1 m and $\rho_0 = 0$ else where

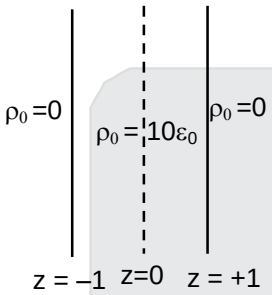
(4) $\rho_0 = 10\ \varepsilon_0$ for $|z|$ in ≤ 1 m and $\rho_0 = 0$ else where

Ans. **(4)**

Sol. $E = \begin{cases} 10z \quad v/m & |z| \le 1m \\ 10 \quad v/m & |z| \ge 1m \end{cases}$

If should be for a sheet lying in x–y plane of thickness z = 2m.

For $|z| \ge 1m$ $E = \frac{\sigma}{2\epsilon_0} = \frac{\rho(2)}{2\epsilon_0} = \frac{\rho}{\epsilon_0} = 10 \Rightarrow P = 10\epsilon_0$



16. An audio signal consists of two distinct sound : one a human speech signal in the frequency band of 200 Hz to 2700 Hz, while the other is a high frequency music signal in the frequency band of 10200 Hz to 15200 Hz. The ratio of the AM signal band width required to send both the signals together to the AM signal band width required to send just the human speech is :

(1) 6 (2) 5 (3) 3 (4) 2

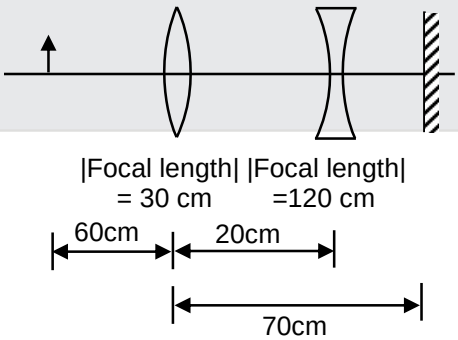
Ans. **(1)**

Sol. Band width for both signals 15200 Hz –200 Hz = 15000 Hz

Band width for human speech 2700 Hz – 200 Hz = 2500 Hz

The ratio = $\frac{15000}{2500} = 6$

17. A convex lens, of focal length 30cm, a concave lens of focal length 120 cm, and a plane mirror are arranged as shown. For an object kept at a distance of 60 cm from the convex lens, the final image, formed by the combination, is a real image, at a distance of :

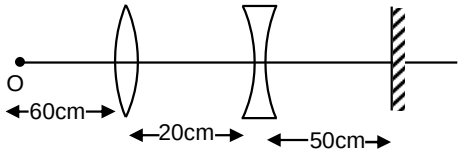


(1) 70 cm from the concave lens (2) 60 cm from the convex lens

(3) 60 cm from the concave lens (4) 70 cm from the convex lens

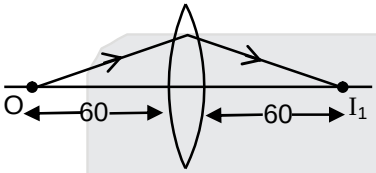
Ans. **[BONUS]**

Sol. $f_1 = +30cm$ $f = -120cm$



Event –1 Refraction from convex lens.

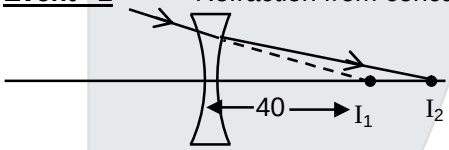
$f = +30$



$$\frac{1}{v} - \frac{1}{-60} = \frac{1}{30}$$

$v = +60$ cm

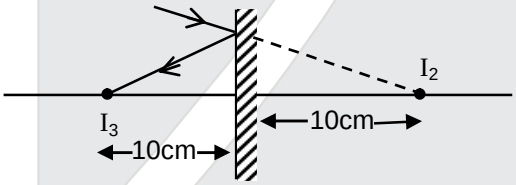
Event –2 Refraction from concave lens



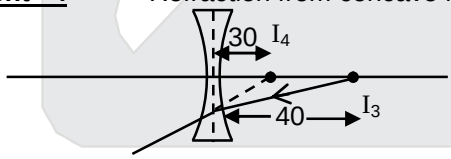
$$\frac{1}{v} - \frac{1}{+40} = \frac{1}{-120}$$

$v = +60cm$

Event –3 Refraction from plane mirror



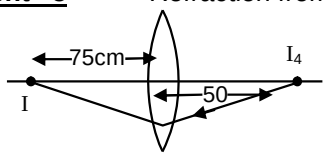
Event –4 Refraction from concave lens



$$\frac{1}{v} - \frac{1}{-40} = \frac{1}{-120}$$

$v = -30$

Event –5 Refraction from convex lens



$$\frac{1}{v} - \frac{1}{-50} = \frac{1}{30} \quad ; \quad v = +75 \text{ cm}$$

18. Three capacitors each of 4μF are to be connected in such a way that the effective capacitance is 6μF. This can be done by connecting them :

(1) all in series

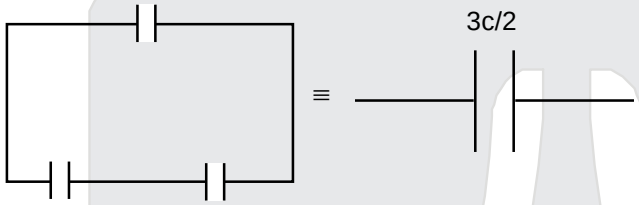
(2) two in parallel and one in series

(3) two in series and one in parallel

(4) all in parallel

Ans. **(3)**

Sol.



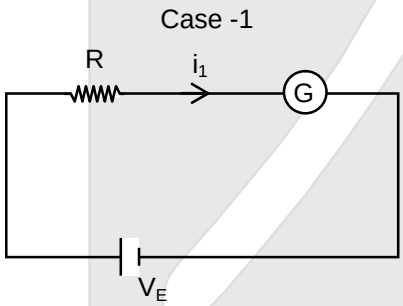
where c = 4μF

19. To know the resistance G of a galvanometer by half deflection method, a battery of emf V_E and resistance R is used to deflect the galvanometer by angle θ. If a shunt of resistance S is needed to gat half deflection then G, R and S are related by the equation :

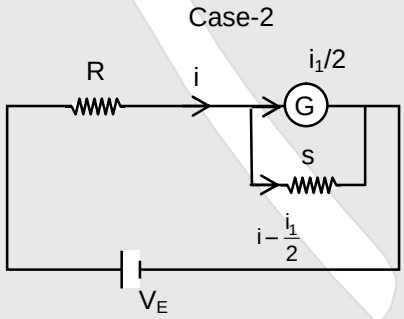
(1) 2S = G (2) 2G = S (3) S(R+G) = RG (4) 2S(R+G) = RG

Ans. **(3)**

Sol.



$$i_1 = \frac{V_E}{R+G}$$



$$i = \frac{V_E}{R+\frac{GS}{G+S}}$$

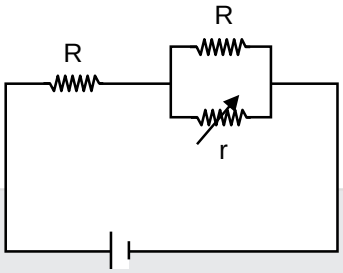
$$\frac{i_1}{2}G = \left(i - \frac{i_1}{2}\right)S$$

$i_1 (G+S) = 2 i S$

substituting i_1 and i we get

S(R+G) = RG

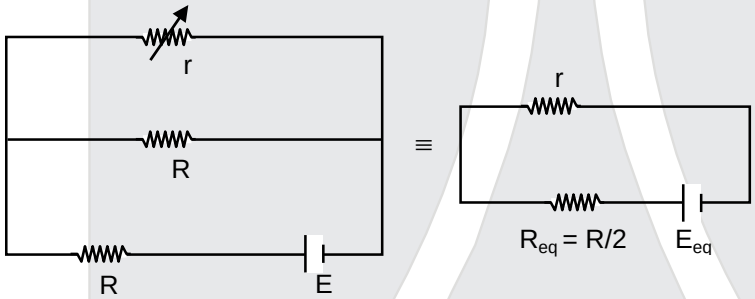
20. In the circuit shown, the resistance r is a variable resistance. If for r =fR, the heat generation in r is maximum then the value of f is :



(1) 1 (2) $\frac{3}{4}$ (3) $\frac{1}{4}$ (4) $\frac{1}{2}$

Ans. **(4)**

Sol.



to get maximum heat generation from r.

$r = R_{eq} = R/2$

21. A hydrogen atom makes a transition from n = 2 to n=1 and emits a photon. This photon strikes a doubly ionized lithium atom (z = 3) in excited state and completely removes the orbiting electron. The least quantum number for the excited stated of the ion for the process is :

(1) 4 (2) 5 (3) 2 (4) 3

Ans. **(1)**

Sol. Energy of proton = 13.6 – 3.4 = 10.2eV

For removal of electron

$$10.2eV > 13.6\ \frac{z^2}{n^2}$$

$$n^2 > 13.6\ \frac{9}{10.2}$$

so minimum value of n = 4

22. 200 g water is heated from 40°C to 60°C. Ignoring the slight expansion of water, the change in its internal energy is closed to (Given specific heat of water = 4184 J/kg/K) :

(1) 16.7 kJ (2) 167.4kJ (3) 4.2 kJ (4) 8.4 kJ

Ans. **(1)**

Sol. $\Delta U = mS\Delta T$

$$= \left(\frac{2}{10}\right)(4184)(20) = 16736J$$

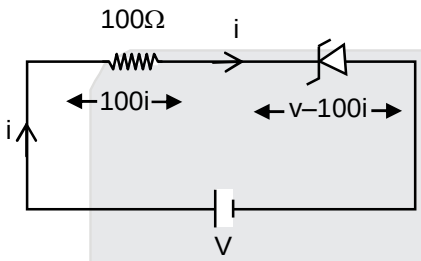
= 16.7 kJ

23. An experiment is performed to determine the I - V characteristics of a Zener diode, which has a protective resistance of R =100 Ω, and maximum power of dissipation rating of 1W. The minimum voltage range of the DC source in the circuit is :

(1) 0 – 12V (2) 0 – 5V (3) 0 – 24 (4) 0 – 8V

Ans. **(3)**

Sol.



$P_{zener} = (v-100i)i = 1$

$vi - 100i^2 = 1$

$100i^2 - vi + 1 = 0$

i must be real

$v^2 - 4(100) \geq 0$

$v \geq 20$

24. Microwave oven acts on the principle of :

(1) giving rotational energy to water molecules

(2) giving vibrational energy to water molecules

(3) giving translational energy to water molecules

(4) transferring electrons from lower to higher energy levels in water molecule

Ans. **(2)**

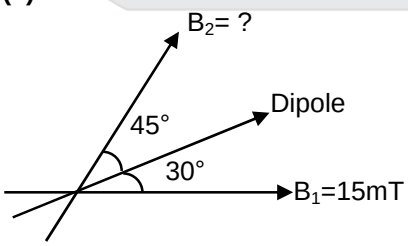
Sol. Energy of microwaves lie in range of vibration energy of water molecules.

25. A magnetic dipole is acted upon by two magnetic fields which are inclined to each other a tan angle of 75°. One of the fields has magnitude of 15mT. The dipole attains stable equilibrium at an angle 30° with this field. The magnitude of the other field (in mT) is close to :

(1) 11 (2) 1060 (3) 36 (4) 1

Ans. **(1)**

Sol.



$B_1 \sin 30° = B2 \sin 45°$

$B_2 = \frac{B_1}{\sqrt{2}} = 10.60 \text{ mT} \approx 11\text{mT}$

26. A 50Ω resistance is connected to a battery of 5V. A galvanometer of resistance 100Ω is to be used as ammeter to measure current through the resistance, for this a resistance r_s is connected to the galvanometer. Which of the following connections should be employed if the measured current is within 1% of the current without the ammeter in the circuit ?

(1)r_s = 0.5Ω n parallel with the galvanometer

(2) r_s = 0.5 Ω in series with the galvanometer

(3) r_s = 1Ω in series with galvanometer

(4) r_s = 1Ω in parallel with galvanometer

Ans. **(1)**

Sol. Its clear, shunt should be applied in parallel and least the shunt resistance, better the ammeter is.

27. When photons of wavelength λ_1, are incident on an isolated sphere, the corresponding stopping potential is found to be V. When photons of wavelength λ_2, are used , the corresponding stopping potential was thrice that of the above value. If light of wavelength λ_3. is used then find the stopping potential for this case

(1) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{3}{2\lambda_1}\right]$ (2) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

(3) $\frac{hc}{e}\left[\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{1}{\lambda_1}\right]$ (4) $\frac{hc}{e}\left[\frac{1}{\lambda_3}-\frac{1}{\lambda_2}-\frac{1}{\lambda_1}\right]$

Ans. **(1)**

Sol. $eV = \frac{hc}{\lambda_1}-\phi_0$

$3eV = \frac{hc}{\lambda_2}-\phi_0$

$eV' = \frac{hc}{\lambda_3}-\phi_0$

using these equations $V' = \frac{hc}{e}\left(\frac{1}{\lambda_3}+\frac{1}{2\lambda_2}-\frac{3}{2\lambda_1}\right)$

28. In the following 'I' refers to current and other symbols have their usual meaning choose the option that corresponds to the dimensions of electrical conductivity :

(1) $M^{-1}L^{-3}T^3I^2$ (2) $M^{-1}L^3T^3I$ (3) $ML^{-3}T^{-3}I^2$ (4) $M^{-1}L^{-3}T^3I$

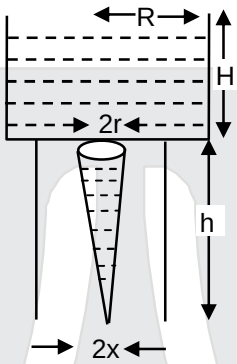
Ans. **(1)**

Sol. $J = \sigma E$

$\sigma = \frac{J}{E} = \frac{I^1L^{-2}}{\frac{M^1L^1T^{-2}}{I^1T^1}}$

$\sigma = M^{-1}L^{-3}T^3I^2$

29. Consider a water jar of radius R that has water filled up to height H and is kept on a stand of height h (see figure). Through a hole of radius r (r<<R) at its bottom, the water leaks out and the stream of water coming down towards the ground has a shape like a funnel as shown in the figure. If the radius of the cross-section of water stream when it hits the ground is x. Then :



(1) $x = r\left(\frac{H}{H+h}\right)^2$ (2) $x = r\left(\frac{H}{H+h}\right)$ (3) $x = r\left(\frac{H}{H+h}\right)^{\frac{1}{4}}$ (4) $x = r\left(\frac{H}{H+h}\right)^{\frac{1}{2}}$

Ans. **(4)**

Sol. Using equation of continuity

$$\pi r^2\sqrt{2gH} = \pi x^2\sqrt{2g(H+h)}$$

$$x = r\left(\frac{H}{H+h}\right)^{½}$$

30. The truth table given in fig. represents :

A	B	Y
0	0	0
0	1	1
1	0	1
1	1	1

(1) AND - Gate

(2) OR - Gate

(3) NOR - Gate

(4) NAND – Gate

Ans. **(2)**

Sol. from truth table its clear.

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