



MADE EASY

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Important Questions
for **GATE 2022**

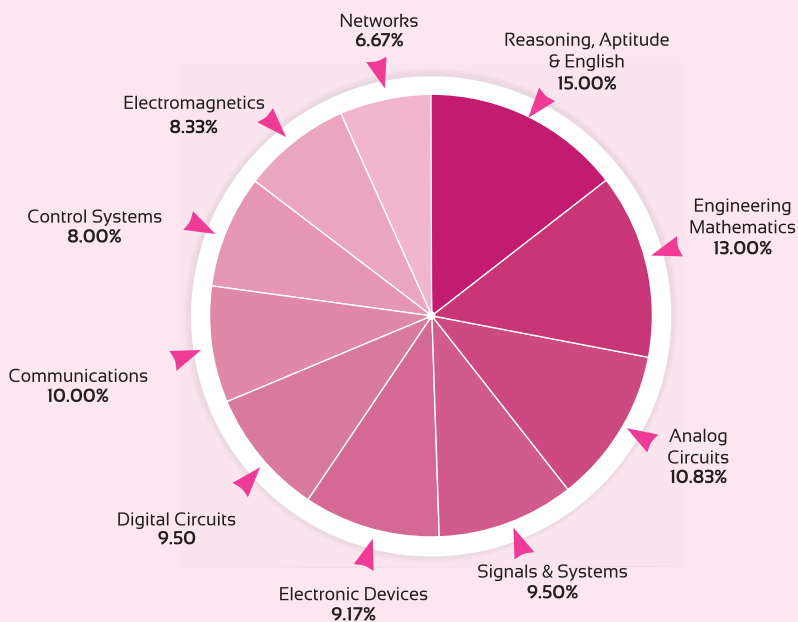
**ELECTRONICS
ENGINEERING**

Day 4 of 8

Q.76 - Q.100 (Out of 200 Questions)

Engineering Mathematics

SUBJECT-WISE WEIGHTAGE ANALYSIS OF GATE SYLLABUS



| Subject | Average % (last 5 yrs)* |
|-------------------------------|-------------------------|
| Reasoning, Aptitude & English | 15.00% |
| Engineering Mathematics | 13.00% |
| Analog Circuits | 10.83% |
| Signals & Systems | 9.50% |
| Electronic Devices | 9.17% |
| Digital Circuits | 9.50% |
| Communications | 10.00% |
| Control Systems | 8.00% |
| Electromagnetics | 8.33% |
| Networks | 6.67% |
| Total | 100% |

- Q.91** A tank initially contain 50 gallons of fresh water. Brine, containing 2 pounds per gallons of salt, flows into the tank at the rate of 2 gallons per minute and the mixture is kept uniform by stirring, flows out at the same rate. The time required for the quantity of salt in the tank to increase from 40 to 80 pound is _____ (in minutes).
- Q.92** The surface integral $\iint_S \frac{2}{\pi}(12xi - 8yj) \cdot n \, dS$ over the sphere given by $x^2 + y^2 + z^2 = 16$ is
- (a) $\frac{1024}{3}$ (b) $\frac{512}{5}$
(c) $\frac{4096}{11}$ (d) $\frac{2048}{3}$
- Q.93** Number of tigers in a reserve is normally distributed with mean and variance respectively as 1200 and 9×10^4 . The probability of finding more than 1800 tigers approximately is
- (a) 0.0125 (b) 0.025
(c) 0.05 (d) None of these
- Q.94** An exam can be given maximum four times. The probability of selection in first attempt is $\frac{1}{24}$ and it increases by 50% for every next attempt. The probability of selection is _____. (Given that individual can give only one successful attempt)
- (a) 0.2 (b) 0.3
(c) 0.4 (d) 0.5
- Q.95** In a certain college, 25% of boys and 10% of girls are studying mathematics. The girls constitute 60% of the student body. If a student is selected at random from student body and is found to be studying mathematics, then the probability that the student is a girl is _____.
- Q.96** If $f(x) = 12x^{4/3} - 6x^{1/3}$, $x \in [-1, 1]$ then the absolute minimum value of the function is _____.
- Q.97** The directional derivative of $\phi = 3x^2y - 4yz^2 + 6z^2x$ at point (1, 1, 1) in the direction of line $\frac{x-1}{2} = \frac{y-4}{2} = \frac{z}{3}$ is
- (a) $2\sqrt{17}$ (b) $\frac{2}{\sqrt{17}}$
(c) $\frac{29}{\sqrt{17}}$ (d) $\frac{40}{\sqrt{17}}$
- Q.98** The non zero value of K such that the system of equations,
 $x + Ky + 3z = 0$, $4x + 3y + Kz = 0$, $2x + y + 2z = 0$
 has non-trivial solution is
- (a) 4 (b) 2.5
(c) 3.5 (d) None

- Q.99 The matrix A is defined as $A = \begin{bmatrix} 1 & 2 & -3 \\ 0 & 3 & 2 \\ 0 & 0 & -2 \end{bmatrix}$, the determinant of matrix $B = 3A^3 + 5A^2 - 6A + 2I$ is
- (a) 110 (b) 1100
(c) 4400 (d) 440

Multiple Select Question (MSQ)

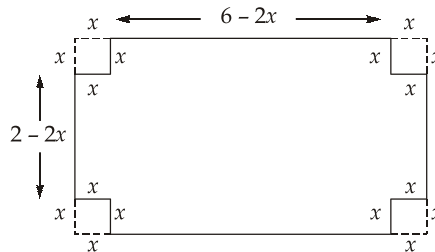
- Q.100 The eigen vectors of matrix $\begin{bmatrix} 4 & 6 \\ 2 & 8 \end{bmatrix}$ is/are

- (a) $\begin{bmatrix} -1 \\ 1 \end{bmatrix}$ (b) $\begin{bmatrix} -3 \\ 1 \end{bmatrix}$
(c) $\begin{bmatrix} 1 \\ 1 \end{bmatrix}$ (d) $\begin{bmatrix} 1 \\ 3 \end{bmatrix}$

■■■■

Detailed Explanations

76. (d)



Let the side of each of the square cut off be x m and the sides of the base are $6 - 2x$, $2 - 2x$ m.

$$\begin{aligned} \therefore \text{Volume } V \text{ of the box} &= x(6 - 2x)(2 - 2x) \\ &= 4(x^3 - 4x^2 + 3x) \end{aligned}$$

Then,

$$\frac{dV}{dx} = 4(3x^2 - 8x + 3)$$

For volume to be maximum

$$\begin{aligned} \frac{dV}{dx} &= 0 \text{ and } \frac{d^2V}{dx^2} < 0 \\ 3x^2 - 8x + 3 &= 0 \end{aligned}$$

$$\therefore x = \frac{8 \pm \sqrt{64 - 36}}{6} = \frac{8 \pm \sqrt{28}}{6} = 0.45 \text{ m or } 2.2 \text{ m}$$

2.2 m is not possible

For $x = 0.45$ m.

$$\begin{aligned} \frac{d^2V}{dx^2} &= 4(6x - 8) \\ &= 4(6 \times 0.45 - 8) = -21.2 < 0 \end{aligned}$$

Hence the volume of the box is maximum when its height is 45 cm.

77. **0.45 (0.43 to 0.47)**

We may represent C by $r(t) = [\cos t, \sin t]$

$$= \cos t \hat{i} + \sin t \hat{j}$$

Where,

$$0 \leq t \leq \frac{\pi}{2}$$

Then $x(t) = \cos t$, $y(t) = \sin t$

and

$$\begin{aligned} F(r(t)) &= -y(t)\hat{i} - x(t)y(t)\hat{j} \\ &= -\sin t \hat{i} - \cos t \sin t \hat{j} \end{aligned}$$

By differentiation,

$$\begin{aligned} r'(t) &= [-\sin t, \cos t] \\ &= -\sin t \hat{i} + \cos t \hat{j} \end{aligned}$$

We know that,

A line integral of a vector function $F(r)$ over a curve,

$$\begin{aligned} \int_c F(r) \cdot dr &= \int_a^b F(r(t)) \cdot r'(t) dt \\ &= \int_0^{\pi/2} [-\sin t \hat{i} - \cos t \sin t \hat{j}] \cdot [-\sin t \hat{i} + \cos t \hat{j}] dt \\ &= \int_0^{\pi/2} [\sin^2 t - \cos^2 t \sin t] dt \\ &= \int_0^{\pi/2} \frac{1}{2} (1 - \cos 2t) dt - \int_0^{\pi/2} \cos^2 t \sin t dt \quad \text{put } \cos t = u \\ &= \frac{1}{2} \left[\frac{\pi}{2} - 0 \right] - 0 - \int_1^0 u^2 (-du) \\ &= \frac{\pi}{4} - 0 - \frac{1}{3} = 0.4521 \end{aligned}$$

78. (2)

$$\begin{aligned} f(y) &= y^2 e^{-y} \\ f'(y) &= y^2 (-e^{-y}) + e^{-y} \times 2y \\ &= e^{-y} (2y - y^2) \end{aligned}$$

Putting $f'(y) = 0$

$$e^{-y} (2y - y^2) = 0$$

$$e^{-y} y (2 - y) = 0$$

$y = 0$ or $y = 2$ are the stationary points

Now,

$$\begin{aligned} f''(y) &= e^{-y} (2 - 2y) + (2y - y^2) (-e^{-y}) \\ &= e^{-y} (2 - 2y - 2y + y^2) \\ &= e^{-y} (y^2 - 4y + 2) \end{aligned}$$

At $y = 0$, $f''(0) = e^{-0} (0 - 0 + 2) = 2$

Since $f''(0) = 2$ is > 0 at $y = 0$ we have a minima

$$\begin{aligned} \text{Now, at } y = 2 \quad f''(2) &= e^{-2} (2^2 - 4 \times 2 + 2) \\ &= e^{-2} (4 - 8 + 2) \\ &= -2e^{-2} < 0 \end{aligned}$$

\therefore At $y = 2$ we have a maxima.

79. -193.74 (-203 to -185)

The equation is $4y''(x) + 64y(x) = 0$

The auxiliary equation is

$$4m^2 + 64 = 0$$

$$m^2 + 16 = 0$$

$$m = \pm 4i$$

Solution is $y = C_1 \cos 4x + C_2 \sin 4x$

Given that $y(0) = 0$

$$\therefore 0 = C_1$$

$$y' = -4C_1 \sin 4x + 4C_2 \cos 4x$$

$$y'(0) = 1024$$

$$1024 = 4C_2$$

$$\Rightarrow C_2 = 256$$

\therefore Solution is $y = 256 \sin 4x$

At $x = 1$, $y = 256 \sin 4 = -193.74$

80. (b)

$$\lim_{x \rightarrow 2^-} f(x) = \lim_{x \rightarrow 2^-} (x - 2) = 0$$

$$\lim_{x \rightarrow 2^+} f(x) = \lim_{x \rightarrow 2^+} (x^3 - 8) = 0$$

Also $f(2) = 0$

Thus $\lim_{x \rightarrow 2^-} f(x) = \lim_{x \rightarrow 2^+} f(x) = f(2)$

$\therefore f$ is continuous at $x = 2$

and $Lf'(2) = 1$ and $Rf'(2) = 12$

$\therefore f$ is not differentiable at $x = 2$.

81. (a)

The volume of a solid generated by revolution about the x-axis, of the area bounded by curve $y = f(x)$, the x-axis and the ordinates $x = a$, $y = b$ is

$$\text{Volume} = \int_a^b \pi y^2 dx$$

Here, $a = 2$, $b = 3$ and $y = 2\sqrt{x} \Rightarrow y^2 = 4x$

$$\begin{aligned} \therefore \text{Volume} &= \int_2^3 \pi 4x dx = 4\pi \left[\frac{x^2}{2} \right]_2^3 = 2\pi [x^2]_2^3 \\ &= 2\pi [9 - 4] = 10\pi \end{aligned}$$

82. (c)

Comparing the given equation with general form of second order partial differential equation,

$$A = 1,$$

$$B = \frac{1}{2},$$

$$C = 0$$

$$\Rightarrow B^2 - 4AC = \frac{1}{4} > 0$$

\(\therefore\) PDE is hyperbolic.

83. (a)

$$\begin{aligned} \int_0^\pi \frac{dx}{c \left(\cos^2 \frac{x}{2} + \sin^2 \frac{x}{2} \right) + d \left(\cos^2 \frac{x}{2} - \sin^2 \frac{x}{2} \right)} &= \int_0^\pi \frac{dx}{(c+d) \cos^2 \frac{x}{2} + (c-d) \sin^2 \frac{x}{2}} \\ &= \int_0^\pi \frac{\sec^2 \frac{x}{2} dx}{(c+d) + (c-d) \tan^2 \frac{x}{2}} = \frac{1}{(c-d)} \int_0^\pi \frac{\sec^2 \frac{x}{2} dx}{\frac{(c+d)}{(c-d)} + \tan^2 \frac{x}{2}} \\ &= \frac{2}{c-d} \sqrt{\frac{c-d}{c+d}} \left[\tan^{-1} \left\{ \tan \frac{x}{2} \sqrt{\frac{c-d}{c+d}} \right\} \right]_0^\pi \\ &= \frac{2}{c-d} \sqrt{\frac{c-d}{c+d}} \left[\tan^{-1} \infty - \tan^{-1} 0 \right] \\ &= \frac{2}{\sqrt{(c-d)(c+d)}} \times \frac{\pi}{2} = \frac{\pi}{\sqrt{c^2 - d^2}} \end{aligned}$$

Tric ; put $d = 0$ and check

84. (-3)

$$D^2 + 5D + 6 = 0$$

$$D = -2, -3$$

$$y(t) = c_1 e^{-2t} + c_2 e^{-3t}$$

Given,

$$y(0) = 2$$

\(\Rightarrow\)

$$c_1 + c_2 = 2 \quad \dots(i)$$

$$y(1) = -\left(\frac{1-3e}{e^3}\right)$$

\(\Rightarrow\)

$$\frac{c_1}{e^2} + \frac{c_2}{e^3} = -\left(\frac{1-3e}{e^3}\right)$$

\(\Rightarrow\)

$$ec_1 + c_2 = 3e - 1 \quad \dots(ii)$$

Now solving equation (i) and (ii), we get

$$c_1 = 3$$

$$c_2 = -1$$

Substituting in $y(t)$, we get

$$y(t) = 3e^{-2t} - e^{-3t}$$

Now,

$$\frac{dy}{dt} = -6e^{-2t} + 3e^{-3t}$$

$$\left(\frac{dy}{dt}\right)_{t=0} = -6 + 3 = -3$$

85. (a)

Since
$$\sum_{x=0}^4 P(x) = 1$$

$$c + 2c + 2c + c^2 + 5c^2 = 1$$

$$6c^2 + 5c - 1 = 0$$

$$c = \frac{1}{6}, -1$$

Since $P(x) \geq 0$, the possible value of

$$c = \frac{1}{6}$$

| | | | | | |
|---------|---------------|---------------|---------------|----------------|-----------------|
| x | 0 | 1 | 2 | 3 | 4 |
| $P(x)$ | $\frac{1}{6}$ | $\frac{2}{6}$ | $\frac{2}{6}$ | $\frac{1}{36}$ | $\frac{5}{36}$ |
| $xP(x)$ | 0 | $\frac{2}{6}$ | $\frac{4}{6}$ | $\frac{3}{36}$ | $\frac{20}{36}$ |

$$\begin{aligned} \text{Mean} &= \sum_{x=0}^4 xP(x) = 0 + \frac{2}{6} + \frac{4}{6} + \frac{3}{36} + \frac{20}{36} \\ &= \frac{59}{36} = 1.638 \end{aligned}$$

$$\begin{aligned} \text{Variance} &= \sigma^2 = E(x^2) - [E(x)]^2 \\ &= \left[0\left(\frac{1}{6}\right) + 1\left(\frac{2}{6}\right) + 4\left(\frac{2}{6}\right) + 9\left(\frac{1}{36}\right) + 16\left(\frac{5}{36}\right) - \left(\frac{59}{36}\right)^2 \right] \\ &= 1.45 \end{aligned}$$

86. (d)

Given differential equation is

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

$$\Rightarrow \frac{dy}{dx} + \left(\frac{y}{x}\right) = x^3 \quad \dots (i)$$

Standard form of liebnitz linear equation is

$$\frac{dy}{dx} + Py = Q \quad \dots (ii)$$

where P and Q function of x only and solution is given by

$$y(IF) = \int Q(IF)dx + c$$

where, integrating factor (IF) = $e^{\int P dx}$

here in equation (ii),

$$P = \frac{1}{x}, \text{ and } Q = x^3$$

$$IF = e^{\int \frac{1}{x} dx} = e^{\ln x} = x$$

Solution
$$y(x) = \int x^3 \cdot x dx + c = \frac{x^5}{5} + c$$

Given condition,
$$y(2) = \frac{21}{5}$$

$$\begin{aligned} \therefore \quad \frac{21}{5} \times 2 &= \frac{2^5}{5} + c \\ \Rightarrow \quad c &= \frac{42 - 32}{5} = 2 \\ \therefore \quad yx &= \frac{x^5}{5} + 2 \\ \Rightarrow \quad y &= \frac{x^4}{5} + \frac{2}{x} \end{aligned}$$

87. (0.08) (0.075 to 0.085)

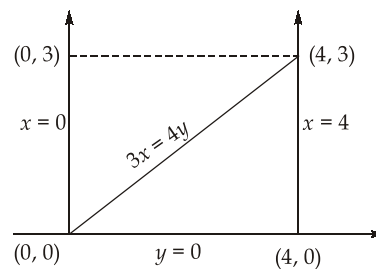
$$\begin{aligned} P &= 1\% = 0.01 \\ n &= 100 \\ m &= nP = 100 \times 0.01 = 1 \end{aligned}$$

$$P(r) = \frac{e^{-m} m^r}{r!}$$

$P(3 \text{ or more faulty condensers})$

$$\begin{aligned} &= P(3) + P(4) + \dots + P(100) \\ &= 1 - [P(0) + P(1) + P(2)] \\ &= 1 - \left[\frac{e^{-1} 1^0}{0!} + \frac{e^{-1} 1^1}{1!} + \frac{e^{-1} 1^2}{2!} \right] = 1 - \left[e^{-1} + e^{-1} + \frac{e^{-1}}{2} \right] \\ &= 1 - e^{-1} \left[\frac{5}{2} \right] = 0.0803 \end{aligned}$$

88. (26)



$$\begin{aligned} \text{Volume} &= \iiint dz dx dy = \iint z dy dx \\ &= \int_0^4 \int_0^{\frac{3x}{4}} (8 - x - y) dy dx = \int_0^4 \left(8y - xy - \frac{y^2}{2} \right) \Big|_0^{\frac{3x}{4}} dx \\ &= \int_0^4 \left(6x - \frac{33x^2}{32} \right) dx = \left(\frac{6x^2}{2} - \frac{33}{32} \times \frac{x^3}{3} \right) \Big|_0^4 \\ &= \left(3x^2 - \frac{11x^3}{32} \right) \Big|_0^4 = 48 - 22 = 26 \end{aligned}$$

89. (b)

For limit to exist, LHL = RHL

Now,

$$\text{RHL} \quad \lim_{x \rightarrow 0^+} f(x) = 4 - 6x = 4$$

$$\text{LHL} \quad \lim_{x \rightarrow 0^-} f(x) = 3x + 4 = 4$$

⇒ Limit exists

Now for continuity,

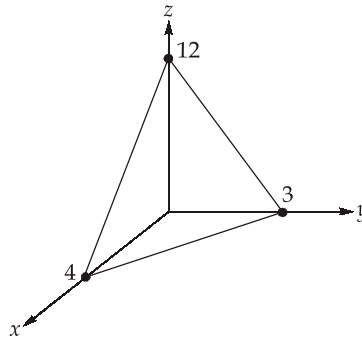
$$\text{LHL} = \text{RHL} = \text{Functional value}$$

At $x = 0$

$$f(x) = -4 \neq \text{RHL}$$

⇒ Discontinuous.

90. 24 (23 to 25)



As shown in figure above, the solid lies above the triangle in the xy -plane bounded by $3x + 4y = 12$ and the x and y axes.

$$\begin{aligned} V &= \int_0^4 \int_0^{3-3x/4} (12 - 3x - 4y) dy dx \\ &= \int_0^4 \left[12y - 3xy - 2y^2 \right]_0^{3-3x/4} dx = \int_0^4 \left(3 - \frac{3x}{4} \right) \left(12 - 3x - 6 + \frac{3x}{2} \right) dx \\ &= \int_0^4 3 \left(\frac{4-x}{4} \right) 3 \left(\frac{4-x}{2} \right) dx = \int_0^4 \frac{9}{8} (4-x)^2 dx \\ &= \left[\frac{9}{8} \left(-\frac{1}{3} \right) (4-x)^3 \right]_0^4 = \frac{-3(-4^3)}{8} = \frac{192}{8} = 24 \end{aligned}$$

91. 27.46 (27.00 to 28.00)

Let the salt content at time t be u lb, so that its rate of change is $\frac{du}{dt}$.

$$\frac{du}{dt} = 2 \text{ gal} \times 2 \text{ lb} = 4 \text{ lb/min}$$

If C is concentration of brine at time t , the rate at which salt content decrease due to out flow
 $= 2 \text{ gal} \times C \text{ lb} = 2 C \text{ lb/min}$

$$\therefore \frac{du}{dt} = 4 - 2C \quad \dots(i)$$

Also, since there is no increase in volume of liquid the concentration,

$$C = \frac{u}{50}$$

$$\therefore \text{Eq. (i) becomes } \frac{du}{dt} = 4 - \frac{2u}{50}$$

Separating the variables and integrating,

$$\int dt = 25 \int \frac{du}{100 - u} + K$$

$$t = -25 \log_e (100 - u) + K \quad \dots(ii)$$

Putting $t = 0$ for $u = 0$,

$$\Rightarrow 0 = -25 \log_e 100 + K \quad \dots(iii)$$

$$\therefore t = 25 \log_e \frac{100}{100 - u}$$

If $u = 40$ at $t = t_1$
 and $u = 80$ at $t = t_2$,

$$t_1 = 25 \log \frac{100}{60}$$

and $t_2 = 25 \log \frac{100}{20}$

$$\therefore t_2 - t_1 = 25 \log_e \frac{100}{20} \times \frac{60}{100}$$

$$= 25 \times \log_e 3 = 27.46 \text{ minutes}$$

92. (d)

According to Gauss divergence theorem

$$\iint_S \frac{2}{\pi} (12xi - 8yj) n dS = \frac{2}{\pi} \int \text{divergence } (12xi - 8yj) dv$$

$$= \frac{2}{\pi} [12 - 8] \times \frac{4}{3} \times \pi [r^3] \quad [r = 4 \text{ (given)}]$$

$$= \frac{2}{\pi} \times 4 \times \frac{4}{3} \pi \times 64 = \frac{2048}{3}$$

93. (b)

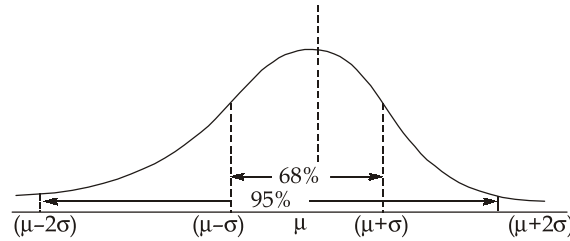
Given,

Mean, $\mu = 1200$

Variance, $\sigma^2 = 9 \times 10^4$

$$\Rightarrow \text{Standard deviation, } \sigma = \sqrt{9 \times 10^4} = 300$$

Using Standard normal curve,



Probability of finding tigers between

$$(\mu - 2\sigma) \text{ \& } (\mu + 2\sigma) = 0.95$$

$$\mu - 2\sigma = 1200 - 2 \times 300 = 600$$

$$\mu + 2\sigma = 1200 + 2 \times 300 = 1800$$

i.e. $P(600 \leq X \leq 1800) = 0.95$

$$\Rightarrow P(X \leq 600) + P(X \geq 1800) = 0.05$$

Since normal curve is symmetric wrt mean value,

So, $P(X \leq 600) = P(X \geq 1800)$

$$\Rightarrow 2P(X \geq 1800) = 0.05$$

$$\Rightarrow P(X \geq 1800) = 0.025$$

94. (b)

Let, P_1, P_2, P_3, P_4 be probability of selection in 1st, 2nd, 3rd & 4th attempt respectively,

Now,

$$P_1 = \frac{1}{24}; P_2 = \frac{1}{24}[1+0.5]$$

$$P_2 = \frac{1}{24} \times \frac{3}{2}$$

$$P_3 = \frac{1}{24} \times \frac{3}{2}[1+0.5] = \frac{1}{24} \times \left(\frac{3}{2}\right)^2$$

$$P_4 = \frac{1}{24} \times \left(\frac{3}{2}\right)^3$$

Now let A_i be selection in i^{th} attempt & \bar{A}_i be unsuccessful attempt,

So,

$$P_{\text{selection}} = A_1 + \bar{A}_1 A_2 + \bar{A}_1 \bar{A}_2 A_3 + \bar{A}_1 \bar{A}_2 \bar{A}_3 A_4$$

$$= \frac{1}{24} + \frac{23}{24} \times \frac{1}{24} \times \frac{3}{2} + \frac{23}{24} \left(1 - \frac{3}{48}\right) \times \frac{1}{24} \times \left(\frac{3}{2}\right)^2 + \frac{23}{24} \left(1 - \frac{3}{48}\right)$$

$$\left(1 - \frac{9}{96}\right) \cdot \frac{1}{24} \times \left(\frac{3}{2}\right)^3 = 0.3$$

95. 0.375 (0.37 to 0.38)

$$P(\text{Girl}) = P(G) = \frac{60}{100} = \frac{3}{5}$$

$$P(\text{Boy}) = P(B) = \frac{40}{100} = \frac{2}{5}$$

Probability that mathematics is studied given that the student is a girl

$$= P\left(\frac{M}{G}\right) = \frac{10}{100} = \frac{1}{10}$$

By Baye's theorem, probability of maths student is a girl

$$= P\left(\frac{G}{M}\right) = \frac{P(G)P\left(\frac{M}{G}\right)}{P(M)} = \frac{P(G)P\left(\frac{M}{G}\right)}{P(G)P\left(\frac{M}{G}\right) + P(B)P\left(\frac{M}{B}\right)}$$

$$= \frac{\frac{3}{5} \times \frac{1}{10}}{\frac{3}{5} \times \frac{1}{10} + \frac{2}{5} \times \frac{1}{10}} = \frac{\frac{3}{50}}{\frac{3}{50} + \frac{2}{50}} = \frac{3}{5} = 0.375$$

96. (-2.25) (-2.30 to -2.20)

Given, $f(x) = 12x^{4/3} - 6x^{1/3}, x \in [-1, 1]$

Differentiating w.r.t. x , we get,

$$\begin{aligned} f'(x) &= 12 \cdot \frac{4}{3} x^{1/3} - 6 \cdot \frac{1}{3} x^{-2/3} \\ &= 16x^{1/3} - \frac{2}{x^{2/3}} = \frac{2(8x - 1)}{x^{2/3}} \end{aligned}$$

Now, $f'(x) = 0$
 $2(8x - 1) = 0$

$$x = \frac{1}{8}$$

$$\begin{aligned} f\left(\frac{1}{8}\right) &= 12\left(\frac{1}{8}\right)^{4/3} - 6\left(\frac{1}{8}\right)^{1/3} \\ &= 12\left(\frac{1}{2}\right)^4 - 6\left(\frac{1}{2}\right) \\ &= \frac{12}{16} - 3 = -\frac{9}{4} \end{aligned}$$

$$f(-1) = 12(-1)^{4/3} - 6(-1)^{1/3} = 12(1) - 6(-1) = 18$$

$$f(1) = 12(1)^{4/3} - 6(1)^{1/3} = 12 - 6 = 6$$

$$\therefore \text{Absolute minimum value} = \frac{-9}{4} = -2.25$$

97. (a)

$$\vec{\nabla}\phi = \left(\frac{\partial\phi}{\partial x}\hat{i} + \frac{\partial\phi}{\partial y}\hat{j} + \frac{\partial\phi}{\partial z}\hat{k} \right) [3x^2y - 4yz^2 + 6z^2x]$$

$$\Rightarrow \vec{\nabla}\phi = (6xy + 6z^2)\hat{i} + (3x^2 - 4z^2)\hat{j} + (-8yz + 12zx)\hat{k}$$

Now at (1, 1, 1)

$$\vec{\nabla}\phi = 12\hat{i} - \hat{j} + 4\hat{k} \quad \dots(1)$$

Also direction of line is, $\hat{A} = \frac{2\hat{i} + 2\hat{j} + 3\hat{k}}{\sqrt{17}} \quad \dots(2)$

\Rightarrow Directional derivative using (1) & (2)

$$\begin{aligned} \vec{\nabla}\phi \cdot \hat{A} &= (12\hat{i} - \hat{j} + 4\hat{k}) \left(\frac{2\hat{i} + 2\hat{j} + 3\hat{k}}{\sqrt{17}} \right) \\ &= \frac{24 - 2 + 12}{\sqrt{17}} = \frac{34}{\sqrt{17}} = 2\sqrt{17} \end{aligned}$$

98. (d)

The set of equations is written in the form of matrix

$$\begin{bmatrix} 1 & K & 3 \\ 4 & 3 & K \\ 2 & 1 & 2 \end{bmatrix} \begin{bmatrix} x \\ y \\ z \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

$$AX = B,$$

$$C = [A : B] = \left[\begin{array}{ccc|c} 1 & K & 3 & 0 \\ 4 & 3 & K & 0 \\ 2 & 1 & 2 & 0 \end{array} \right]$$

On interchanging first and third rows, we have,

$$\left[\begin{array}{ccc|c} 2 & 1 & 2 & 0 \\ 4 & 3 & K & 0 \\ 1 & K & 3 & 0 \end{array} \right]$$

Applying, $R_2 \rightarrow R_2 - 2R_1$ and $R_3 \rightarrow R_3 - \frac{1}{2}R_1$

$$\left[\begin{array}{ccc|c} 2 & 1 & 2 & 0 \\ 0 & 1 & K-4 & 0 \\ 0 & K-\frac{1}{2} & 2 & 0 \end{array} \right]$$

Applying $R_3 \rightarrow R_3 - \left(K - \frac{1}{2}\right)R_2$

$$\left[\begin{array}{ccc|c} 2 & 1 & 2 & 0 \\ 0 & 1 & K-4 & 0 \\ 0 & 0 & 2 - \left(K - \frac{1}{2}\right)(K-4) & 0 \end{array} \right]$$

For a nontrivial solution

$$\rho(A) = \rho(C) = 2$$

So, $2 - \left(K - \frac{1}{2}\right)(K-4) = 0$

$$2 - K^2 + \frac{1}{2}K + 4K - 2 = 0$$

$$-K^2 + \frac{9}{2}K = 0$$

$$K \left(-K + \frac{9}{2} \right) = 0$$

$$K = \frac{9}{2} \text{ and } 0$$

Hence non-zero value of $K = 4.5$

Alternative Solution :

$Ax = 0$ has non-trivial solution

$$|A| = 0$$

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

$$= 1(6 - K) - K(8 - 2K) + 3(4 - 6) = 0$$

$$6 - K - 8K + 2K^2 - 6 = 0$$

$$2K^2 - 9K = 0$$

$$K(2K - 9) = 0$$

$$K = 0, K = 4.5$$

99. (c)

$$|A - \lambda I| = 0$$

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

$$(1 - \lambda)(3 - \lambda)(-2 - \lambda) = 0$$

$$\lambda = 1, 3, -2$$

Eigen values of $A^3 = 1, 27, -8$

Eigen values of $A^2 = 1, 9, 4$

Eigen values of $A = 1, 3, -2$

Eigen values of $I = 1, 1, 1$

Eigen values of matrix B ,

$$\text{First eigen value} = 3(1)^3 + 5(1)^2 - 6(1) + 2(1) = 4$$

$$\text{Second eigen value} = 3(27) + 5(9) - 6(3) + 2(1) = 110$$

$$\text{Third eigen value} = 3(-8) + 5(4) - 6(-2) + 2(1) = 10$$

Hence, required eigen values are, 4, 110 and 10

$$\text{Determinant of matrix } B = \lambda_1\lambda_2\lambda_3 = 4400$$

100. (b, c)

The characteristic equation $[A - \lambda I] = 0$

$$\text{i.e. } \begin{bmatrix} 4-\lambda & 6 \\ 2 & 8-\lambda \end{bmatrix} = 0$$

$$\text{or } (4 - \lambda)(8 - \lambda) - 12 = 0$$

$$\text{or } 32 - 8\lambda - 4\lambda + \lambda^2 - 12 = 0$$

$$\Rightarrow \lambda^2 - 12\lambda + 20 = 0$$

$$\Rightarrow \lambda^2 - 10\lambda - 2\lambda + 20 = 0$$

$$\Rightarrow (\lambda - 10)(\lambda - 2) = 0$$

$$\Rightarrow \lambda = 10, 2$$

Corresponding to $\lambda = 10$, we have

$$[A - \lambda I]x = \begin{bmatrix} -6 & 6 \\ 2 & -2 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$\text{Which gives, } -6x + 6y = 0$$

$$\Rightarrow x = y$$

$$2x - 2y = 0$$

$$\Rightarrow x = y$$

$$\text{i.e. eigen vector } \begin{bmatrix} 1 \\ 1 \end{bmatrix}$$

Corresponding to $\lambda = 2$, we have

$$[A - \lambda I]x = \begin{bmatrix} 2 & 6 \\ 2 & 6 \end{bmatrix} \begin{bmatrix} x \\ y \end{bmatrix}$$

$$\text{Which gives, } 2x + 6y = 0 \text{ i.e. eigen vector } \begin{bmatrix} -3 \\ 1 \end{bmatrix}$$

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