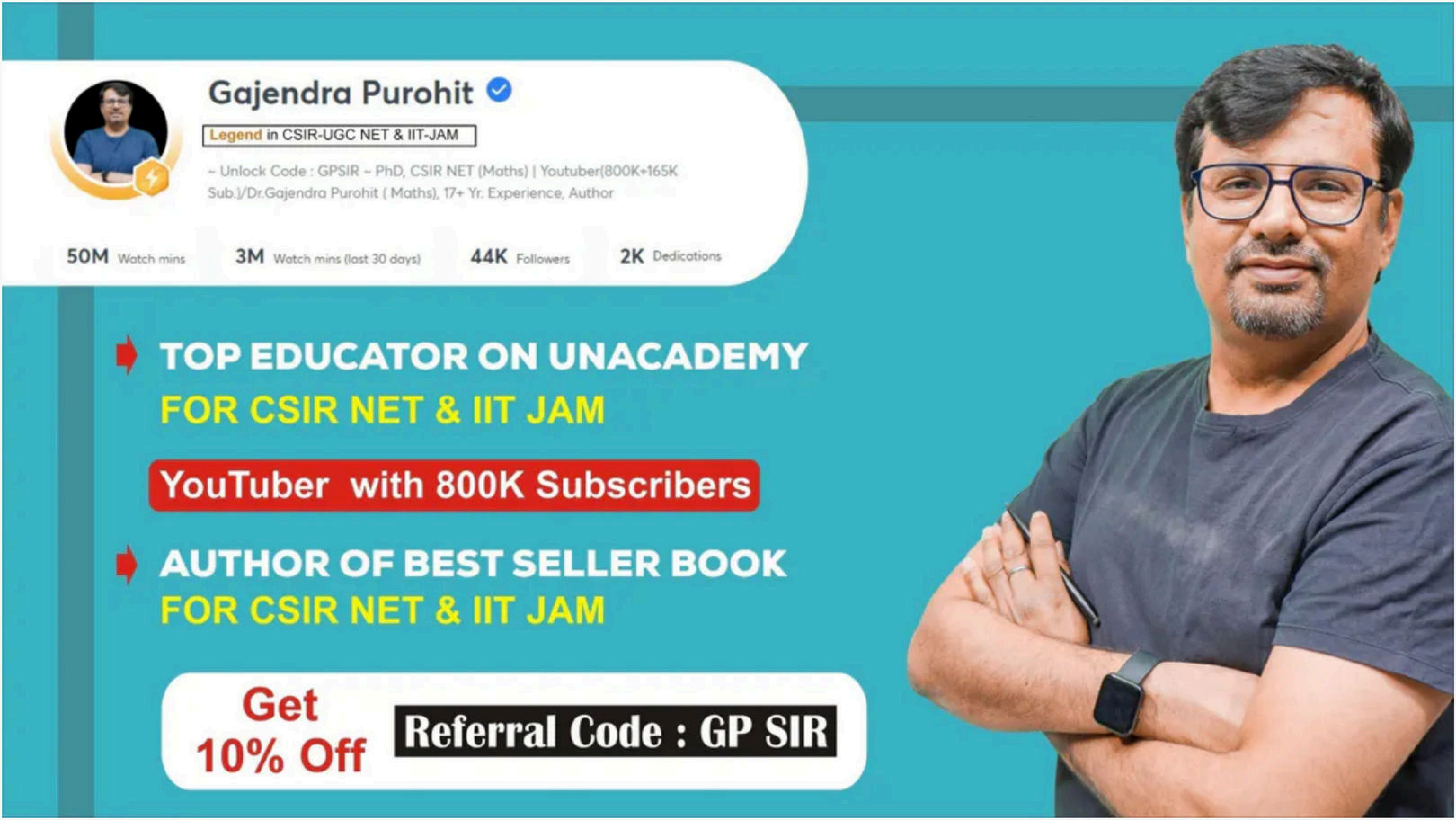

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Limit inferior and limit superior of sequence :

Let $<a_n>$ be a sequence of real number then limit superior and limit inferior are denoted by $\overline{\lim_{n\to\infty}} a_n$ and $\underline{\lim_{n\to\infty}} a_n$.

Case – 1 : If sequence is convergent Then $\overline{\lim_{n\to\infty}} a_n = \underline{\lim_{n\to\infty}} a_n = l = \lim_{n\to\infty} a_n$

$\langle a_n \rangle = \langle 1 + \frac{(-1)^n}{n} \rangle$

$\lim_{n \to \infty} a_n = 1 = \lim_{n \to \infty} a_n$

$\langle (-1)^n \rangle$

$\langle -1, 1, -1, 1, \ldots \rangle$

$\lim_{n \to \infty} a_n = -1$

$\lim_{n \to \infty} a_n = 1$

Case – 2 : If sequence is divergent. There arise two cases.

$\langle n \rangle$

(a) If sequence is unbounded above,

$a_n = \langle e^n \rangle$

Then $\overline{\lim\limits_{n\to\infty}}\, a_n = \underline{\lim\limits_{n\to\infty}}\, a_n = \infty$

(b) If sequence is unbounded below, Then,

$\langle -n \rangle$

$$\overline{\lim\limits_{n\to\infty}}\, a_n = \underline{\lim\limits_{n\to\infty}}\, a_n = -\infty.$$

$\langle -2^n \rangle$

Case – 3 : If sequence is oscillatory. There arise again two cases.

(a) If sequence is finitely oscillate :

Let $<a_n>$ be a finitely oscillate sequence and P be the set of all limit points.

Then $\overline{\lim\limits_{n\to\infty}}\, a_n = \sup P$ and $\underline{\lim\limits_{n\to\infty}}\, a_n = Inf\ P$.

$<(-1)^n>$

$<1+(-1)^n>$

$<-1, 1, -1, 1 \ldots>$

$\{-1, 1\}$

$<0, 2, 0, 2 \ldots>$

$\{0, 2\}$

(b) If sequence is infinitely oscillate :

$\langle(-1)^n n\rangle$

(i) Let $\langle a_n \rangle$ be a infinitely oscillate sequence. which is unbounded above and unbounded below then $\overline{\lim\limits_{n\to\infty}}\, a_n = \infty$ and $\underline{\lim\limits_{n\to\infty}}\, a_n = -\infty$.

$-1, 2, -3, 4, -5, 6$

(ii) Let $\langle a_n \rangle$ is infinitely oscillate sequence which is unbounded above but bounded below.

$\overline{\lim\limits_{n\to\infty}}\, a_n = \infty$ & $\underline{\lim\limits_{n\to\infty}}\, a_n =$ smallest limit point

$\begin{cases} -2 & \text{if } n \text{ is prime} \\ n & \text{if } n \text{ is non-prime} \end{cases}$

$\langle 1, 2, 3, 4, 5, 6, \ldots \rangle$

$\lim\limits_{n\to\infty} a_n = -\infty$

$\underline{\lim\limits_{n\to\infty}}\, a_n = -2$

$\langle -1, 2, -4, -3, -4, \ldots \rangle$

(iii) Let <a_n> is infinitely oscillate sequence which is unbounded below but bounded above.

$$\overline{\lim_{n\to\infty}} a_n = \text{biggest limit point} \;\&\; \underline{\lim_{n\to\infty}} a_n = -\infty$$

Q1. Let $x_n = n^{\frac{1}{n}}$ and $y_n = e^{1-x_n}$, $n \in N$. then which of the following is true

(a) $\lim\sup y_n = \lim\inf y_n = 0$

(b) $\lim\sup y_n \neq \lim\inf y_n$

(c) $\lim\sup y_n = \lim\inf y_n = 1$

(d) $\lim\sup x_n = \lim\inf y_n$

$\lim_{n\to\infty} x_n = \lim_{n\to\infty} n^{1/n} = \boxed{1}$

$\lim_{n\to\infty} y_n = e^{\lim_{n\to\infty}(1-x_n)}$

$= e^{1-\lim_{n\to\infty} x_n}$

$= e^{1-1}$

$= e^{0}$

$= 1$

Q.2. Consider the sequence $< a_n >$,

where $a_n = 3 + 5\left(-\dfrac{1}{2}\right)^n + (-1)^n\left(\dfrac{1}{4} + (-1)^n \dfrac{2}{n}\right)$

then the interval $\left(\lim\limits_{n\to\infty}\inf a_n, \lim\limits_{n\to\infty}\sup a_n\right)$

(a) (-2 , 8)

(b) $\left(\dfrac{11}{4}, \dfrac{13}{4}\right)$

(c) (3 , 5)

(d) $\left(\dfrac{1}{4}, \dfrac{7}{4}\right)$

$$\langle a_n \rangle = \begin{cases} 3 \pm 5\left(\frac{1}{2}\right)^n + \left(\frac{1}{4} + \frac{2}{n}\right) & \text{n-even} \\ 3 - 5\left(\frac{1}{2}\right)^n - \left(\frac{1}{4} - \frac{2}{n}\right) & \text{n odd} \end{cases}$$

$3 + 1/4$ $\quad 13/4$

$3 - 1/4$ $\quad 11/4$

Q

$$x_n = 1 + (-1)^n + \frac{1}{3^n}$$

$$\overline{\lim_{n\to\infty}}\, a_n + \underline{\lim_{n\to\infty}\, a_n} =$$

(a) 0 (b) 1

(c) 2 (d) -1

$$2 \begin{cases} 1+1+\left(\frac{1}{3}\right)^n & \underline{n \text{ even}} \\ 0+\left(\frac{1}{3}\right)^n & \underline{n \text{ odd}} \end{cases}$$

$\cancel{+}$ 0

Q $\langle a_n \rangle = \langle 1, 1, 1/2, 1, 1/2, 1/3, 1, 1/2, 1/3, 1/4, 1 \ldots \rangle$

(a) $\langle a_n \rangle$ has infinite number of limit point.

(b) $\lim\sup a_n = 1$

(c) $\lim\inf a_n = 0$

(d) $\langle a_n \rangle$ has infinite convergent subseq.

$\langle 1, \frac{1}{2}, \frac{1}{3}, \frac{1}{4} \ldots \frac{1}{n} \rangle$ (a)

(a) a, b

(b) b, c

(c) a, b, c

(d) a, b, c, d

$\langle 1, 1, 1, \ldots \rangle$

$\langle \frac{1}{2}, \frac{1}{2}, \ldots \rangle$

$\langle \frac{1}{3}, \ldots \rangle$

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Q3. Consider the sequence $a_n = \left[1 + (-1)^n \frac{1}{n}\right]^n$, then

(a) lim sup a_n = lim inf a_n = 1

(b) lim sup a_n = lim inf a_n = e

(c) lim sup a_n = e, lim inf a_n = 1/e

(d) lim sup a_n = lim inf a_n = 1/e

$e \quad \left(1+\frac{1}{n}\right)^n$ n - even

$e^{-1} \quad \left(1-\frac{1}{n}\right)^n$ n - odd

$n=1$ (3), $2-\frac{1}{3}$, $2-\frac{1}{5}$, ...

Q4. Let $a_n = \begin{cases} 2+\frac{(-1)^{\frac{n-1}{2}}}{n} & \text{if } n \text{ is odd} \\ 1+\frac{1}{2^n}; & \text{if } n \text{ is even} \end{cases}$. then which of the following are true?

$1+\frac{1}{4}$, $1+\frac{1}{8}$ ...

$1+\frac{1}{2^n} \to 1$

(a) sup $\{a_n \mid n \in N\} = 3$ & inf $\{a_n \mid n \in N\} = 1$

(b) lim inf a_n = lim sup $a_n = 3/2$

(c) sup $\{a_n \mid n \in N\} = 2$ and inf $\{a_n \mid n \in N\} = 1$

(d) lim inf $a_n = 1$ & lim sup $a_n = 3$

$2+\frac{(-1)^0}{1}$

Q5. Let $<a_n> = 1 + \frac{(-1)^n}{n}, n \in N$, then which of the following is/are true.

(a) $<a_n>$ is finitely oscillatory sequence.

(b) $<a_n>$ is convergent sequence

(c) $\overline{\lim_{n\to\infty}} a_n \neq \underline{\lim_{n\to\infty}} a_n$

(d) $<a_n>$ is divergent sequence.

(e) lvl

Q7. The limit inferior of the sequence $<a_n>$, where $< a_n >= 1 + (-1)^n + \frac{1}{3^n}$.

(a) 1 (b) 2

(c) 3 (d) 0

Q8. If $< a_n >= 1 + (-1)^n + \sin\frac{1}{n}$ then

(a) $<a_n>$ is convergent sequence

(b) $\lim\sup a_n \neq \lim\inf a_n$

(c) $\lim\sup a_n = \lim\inf a_n$

(d) $\lim\sup a_n = 2$

2 $\left\{ \begin{array}{ll} 2+\sin\frac{1}{n} & n-\text{even} \\ \sin\frac{1}{n} & n-\text{odd} \end{array} \right.$ 0

Some important theorem on Limit :

(1) If $\lim\limits_{n\to\infty} a_n = l$ then $\lim\limits_{n\to\infty} |a_n| = |l|$ But converse may not true

Example : Let $< a_n > = < (-1)^n >$ then $<|a_n|> = < 1 >$

Here $\lim |a_n| = 1$ but limit a_n does not exist

(2) **Cauchy's First Theorem :** Let $< a_n >$ be a sequence of real numbers

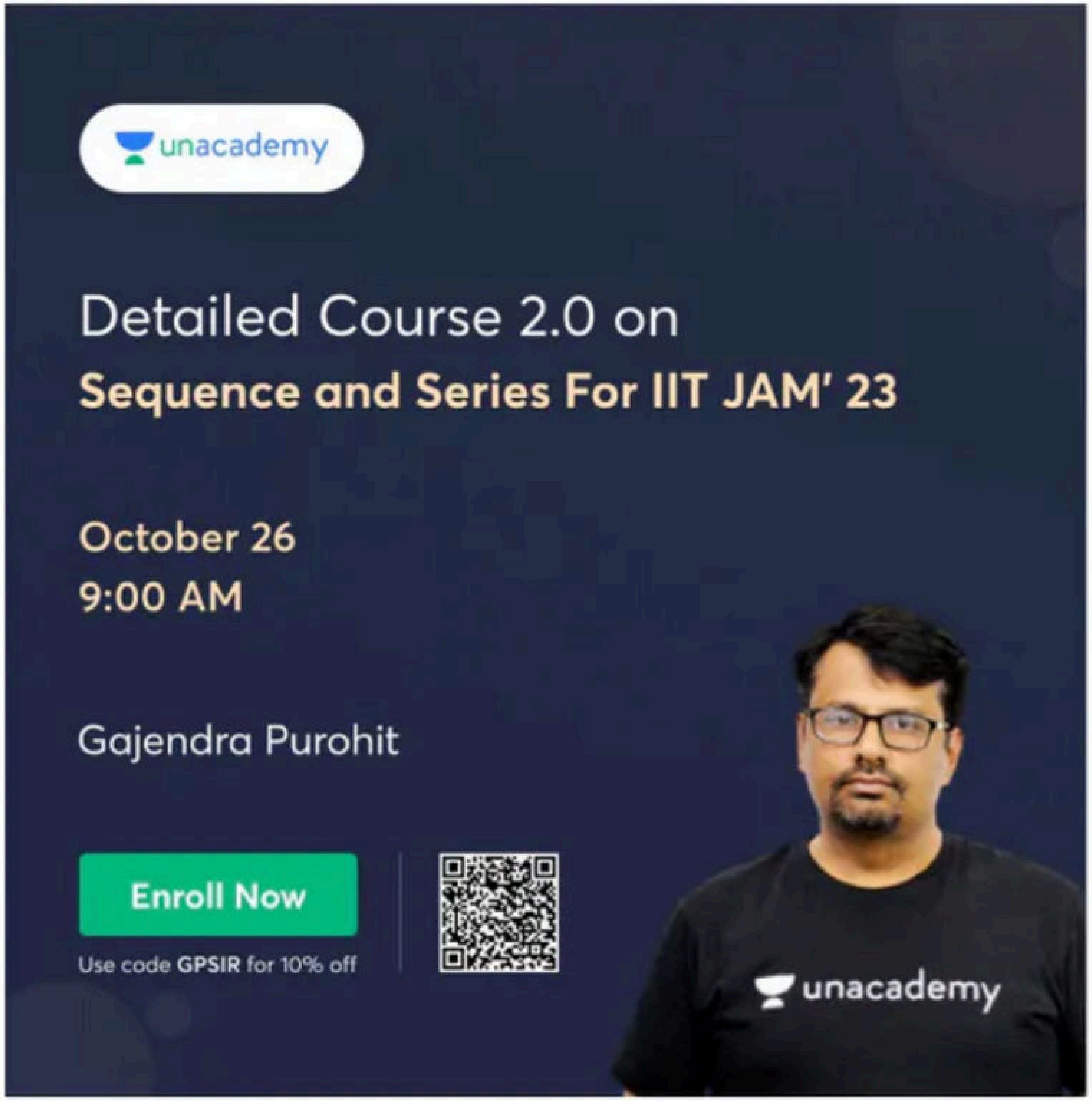
and $\lim\limits_{n\to\infty} a_n = l$ then $\lim\limits_{n\to\infty} \dfrac{a_1 + a_2 + \ldots\ldots + a_n}{n} = l$

Q.9. Find the Limit of $\dfrac{1+\sqrt{2}+\sqrt[3]{3}\ldots\ldots+\sqrt[n]{n}}{n}$ **CSIR NET 2022**

(a) 1 (b) 2

(c) 3 (d) 4

(2) Cauchy's Second theorem : Let <a_n> be a sequence of real number and $\lim_{n \to \infty} a_n = l$ Then $\lim_{n \to \infty} (a_1 . a_2 ..... a_n)^{\frac{1}{n}} = l$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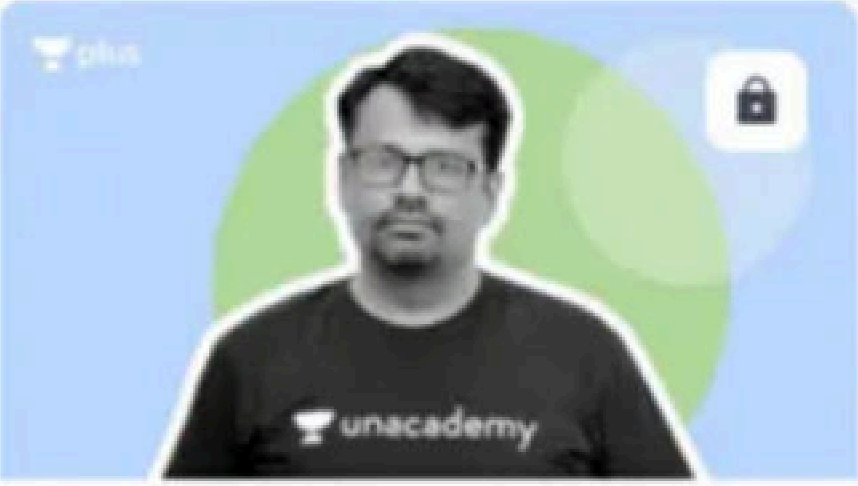

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