



BRAC University

Department of Mathematics and Natural Sciences

LECTURE ON

Real Analysis (MAT221)

Monotone Sequences

Monotone Convergence Theorem (MCT)

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CONDUCTED BY

Partho Sutra Dhor

Lecturer, BRAC University, Dhaka-1212

partho.dhor@bracu.ac.bd | parthosutradhor@gmail.com
For updates subscribe on [@ParthoSutraDhor](#)

Monotone Sequences

■ Monotonically Increasing Sequence

A sequence $\{a_n\}$ is said to be **monotonically increasing** if for all natural numbers n , the terms of the sequence satisfy the inequality

$$a_n \leq a_{n+1}.$$

■ Monotonically Decreasing Sequence

A sequence $\{a_n\}$ is said to be **monotonically decreasing** if for all natural numbers n , the terms of the sequence satisfy the inequality

$$a_n \geq a_{n+1}.$$

Examples of Monotone Sequences

② Example

The sequence defined by

$$x_n = \frac{1}{n}$$

is a monotone sequence.



② Example

The sequence defined by $x_1 = 3$ and

$$x_{n+1} = \frac{1}{4 - x_n}$$

is a monotone sequence.



② Example

The Sequence

$$\sqrt{2}, \sqrt{2\sqrt{2}}, \sqrt{2\sqrt{2\sqrt{2}}}, \dots$$

is a monotone sequence.



② Example

Let $x_1 = 2$, and define

$$x_{n+1} = \frac{1}{2} \left(x_n + \frac{2}{x_n} \right).$$

is a monotone sequence.



Monotone Convergence Theorem (MCT)

💡 Monotone Convergence Theorem

If a sequence is monotone and bounded, then it converges.

Aoc \implies MCT

Let (a_n) be a monotone and bounded sequence. Using the Axiom of Completeness, show that the sequence (a_n) converges.

② Problem

Prove that the sequence defined by $x_1 = 3$ and

$$x_{n+1} = \frac{1}{4 - x_n}$$

converges and find the limit.

② Problem

Prove that the sequence defined by $x_1 = 1$ and

$$x_{n+1} = 4 - \frac{1}{x_n}$$

converges and find the limit.

② Problem

Show that

$$\sqrt{2}, \sqrt{2\sqrt{2}}, \sqrt{2\sqrt{2\sqrt{2}}}, \dots$$

converges and find the limit.



② Problem

Let $x_1 = 2$, and define

$$x_{n+1} = \frac{1}{2} \left(x_n + \frac{2}{x_n} \right).$$

1. Show that x_n^2 is always greater than 2, and then use this to prove that $x_n - x_{n+1} \geq 0$. Conclude that $\lim x_n = \sqrt{2}$.
2. Modify the sequence (x_n) so that it converges to \sqrt{c} .

Limit Superior

Definition

The **limit superior** of a bounded sequence (a_n) is defined as

$$\limsup_{n \rightarrow \infty} a_n = \lim_{n \rightarrow \infty} \left(\sup_{k \geq n} a_k \right).$$



Explain

Why Limit Superior exists



Limit Inferior

Definition

The **limit inferior** of a bounded sequence (a_n) is defined as

$$\liminf_{n \rightarrow \infty} a_n = \lim_{n \rightarrow \infty} \left(\inf_{k \geq n} a_k \right).$$



Explain

Why Limit Superior exists



② Problem

Find the Limit Superior and Limit Inferior of the sequence

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



Theorem

For every bounded sequence a_n ,

$$\liminf_{n \rightarrow \infty} a_n \leq \limsup_{n \rightarrow \infty} a_n$$



Theorem

Any sequence a_n converges if and only if

$$\liminf_{n \rightarrow \infty} a_n = \limsup_{n \rightarrow \infty} a_n$$



Thank You!

We'd love your questions and feedback.

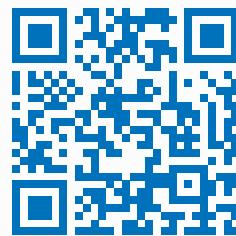
Partho Sutra Dhor

Lecturer, BRAC University, Dhaka-1212

 partho.dhor@bracu.ac.bd |  parthosutradhor@gmail.com



(Lectures, walkthroughs, and course updates)



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References

- [1] Stephen Abbott, *Understanding Analysis*, 2nd Edition, Springer, 2015.
- [2] Terence Tao, *Analysis I*, 3rd Edition, Texts and Readings in Mathematics, Hindustan Book Agency, 2016.