**3 (Sem–2/CBCS) MAT HC 1**

**2022**

# MATHEMATICS

( Honours )

Paper : MAT–HC–2016

***( Real Analysis )***

*Full Marks : 80*

Time : Three hours

***The figures in the margin indicate full marks for the questions.***

1. Answer ***any ten*** questions : 1×10=10

(a) Find the infimum of the set

$$\left\{1-\frac{(-1)^n}{n} : n \in N\right\}$$

(b) If $A$ and $B$ are two bounded subsets of $\mathbb{R}$, then which one of the following is true?

(i) $sup(A \cup B) = sup\{sup A, sup B\}$

(ii) $sup(A \cup B) = sup\ A + sup\ B$

(iii) $sup(A \cup B) = sup\, A \,.\, sup\, B$

(iv) $sup(A \cup B) = sup\, A \cup sup\, B$

(c) There does not exist a rational number $x$ such that $x^2 = 2$. *(Write True or False)*

(d) The set $Q$ of rational numbers is uncountable. *(Write True or False)*

(e) If $I_n = \left(0, \frac{1}{n}\right)$ for $n \in \mathbb{N}$, then $\bigcap_{n=1}^{\infty} I_n = ?$

(f) The convergence of $\{|x_n|\}$ imply the convergence of $\{x_n\}$.

*(Write True or False)*

(g) What are the limit points of the sequence $\{x_n\}$, where $x_n = 2 + (-1)^n$, $n \in \mathbb{N}$ ?

(h) If $\{x_n\}$ is an unbounded sequence, then there exists a properly divergent subsequence. *(Write True or False)*

(i) A convergent sequence of real numbers is a Cauchy sequence.

*(Write True or False)*



(j) If $0 < a < 1$ then $\lim_{n \to \infty} a^n = ?$

(k) The positive term series $\sum \frac{1}{n^p}$ is convergent if and only if

(i) $p > 0$

(ii) $p > 1$

(iii) $0 < p < 1$

(iv) $p \le 1$

*(Write correct one)*

(l) Define conditionally convergent of a series.

(m) If $\{x_n\}$ is a convergent monotone sequence and the series $\sum_{n=1}^{\infty} y_n$ is convergent, then the series $\sum_{n=1}^{\infty} x_n y_n$ is also convergent.

*(Write True or False)*

(n) Consider the series $\sum_{n=1}^{\infty} \frac{1}{n^m\left(1+\frac{1}{n^p}\right)}$

where $m$ and $p$ are real numbers under which of the following conditions does the above series convergent ?

(i) $m>1$

(ii) $0<m<1$ and $p>1$

(iii) $0 \le m \le 1$ and $0 \le p \le 1$

(iv) $m=1$ and $p>1$

(o) Let $\{x_n\}$ and $\{y_n\}$ be sequences of real numbers defined by $x_1=1$, $y_1=\frac{1}{2}$,

$x_{n+1}=\frac{x_n+y_n}{2}$ and $y_{n+1}=\sqrt{x_n y_n}$ $\forall n \in \mathbb{N}$

then which one of the following is true ?

(i) $\{x_n\}$ is convergent, but $\{y_n\}$ is not convergent

(ii) $\{x_n\}$ is not convergent, but $\{y_n\}$ is convergent



(iii) Both $\{x_n\}$ and $\{y_n\}$ are convergent and $\lim\limits_{n\to\infty} x_n > \lim\limits_{n\to\infty} y_n$

(iv) Both $\{x_n\}$ and $\{y_n\}$ are convergent and $\lim\limits_{n\to\infty} x_n = \lim\limits_{n\to\infty} y_n$

2. Answer ***any five*** parts : 2×5=10

(a) If $a$ and $b$ are real numbers and if $a<b$, then show that $a<\frac{1}{2}(a+b)<b$.

(b) Show that the sequence $\left\{\frac{2n-7}{3n+2}\right\}$ is bounded.

(c) If $\{x_n\}$ converges in $\mathbb{R}$, then show that $\lim\limits_{n\to\infty} x_n = 0$

(d) Show that the series 1+2+3+...., is not convergent.

(e) Test the convergence of the series :

$$\frac{1}{1^2}-\frac{1}{2^2}+\frac{1}{3^2}-\frac{1}{4^2}+\dots$$



*Contd.*

(f) State Cauchy's integral test of convergence.

(g) State the completeness property of $\mathbb{R}$ and find the $sup\left\{\frac{1}{n} : n \in \mathbb{N}\right\}$.

(h) Does the Nested Interval theorem hold for open intervals ? Justify with a counter example.

3. Answer ***any four*** parts : 5×4=20

(a) If $x$ and $y$ are real numbers with $x < y$, then prove that there exists a rational number $r$ such that $x < r < y$.

(b) Show that a convergent sequence of real numbers is bounded.

(c) Prove that $\lim_{n\to\infty}\left(n^{\frac{1}{n}}\right) = 1$.

(d) $\{x_n\}$ be a sequence of real numbers that converges to $x$ and suppose that $x_n \geq 0$. Show that the sequence $\{\sqrt{x_n}\}$ of positive square roots converges and $\lim_{n\to\infty}\sqrt{x_n} = \sqrt{x}$.



(e) Show that every absolutely convergent series is convergent. Is the converse true ? Justify. 4+1=5

(f) Using comparison test, show that the series $\sum\left(\sqrt{n^4+1}-\sqrt{n^4-1}\right)$ is convergent.

(g) State Cauchy's root test. Using it, test the convergence of the series

$$\left(\frac{2^2}{1^2}-\frac{2}{1}\right)^{-1}+\left(\frac{3^3}{2^3}-\frac{3}{2}\right)^{-2}+\left(\frac{4^4}{3^4}-\frac{4}{3}\right)^{-3}+\ldots..$$

1+4=5

(h) Show that the sequence defined by the recursion formula

$$u_{n+1} = \sqrt{3u_n}, \; u_1 = 1$$

is monotonically increasing and bounded. Is the sequence convergent ? 2+2+1=5

4. Answer ***any four*** parts : 10×4=40

*(a)* Show that the sequence $\left\{\left(1+\frac{1}{n}\right)^n\right\}$ is convergent and $\lim_{n\to\infty}\left(1+\frac{1}{n}\right)^n = e$ which lies between 2 and 3.

*(b)* *(i)* Let $\{x_n\}$, $\{y_n\}$ and $\{z_n\}$ are sequences of real numbers such that $x_n \le y_n \le z_n$ for all $n \in \mathbb{N}$ and $\lim_{n\to\infty} x_n = \lim_{n\to\infty} z_n$.

Show that $\{y_n\}$ is convergent and $\lim_{n\to\infty} x_n = \lim_{n\to\infty} y_n = \lim_{n\to\infty} z_n$ 5

*(ii)* What is an alternating series ? State Leibnitz's test for alternating series. Prove that the series $1-\frac{1}{2}+\frac{1}{3}-\frac{1}{4}+\ldots\ldots\infty$ is a conditionally convergent series. 1+1+3=5

*(c)* Test the convergence of the series

$1+a+a^2+\ldots\ldots+a^n+\ldots\ldots$



*(d)* *(i)* Using Cauchy's condensation test, discuss the convergence of the series $\sum_{n=2}^{\infty}\frac{1}{n(\log n)^p}$ 5

*(ii)* Define Cauchy sequence of real numbers. Show that the sequence $\left\{\frac{1}{1!}+\frac{1}{2!}+\frac{1}{3!}+\ldots\ldots+\frac{1}{n!}\right\}$ is a Cauchy sequence. 1+4=5

*(e)* *(i)* Show that a convergent sequence of real numbers is a Cauchy sequence. 5

*(ii)* Using Cauchy's general principle of convergence, show that the sequence $\left\{1+\frac{1}{2}+\ldots\ldots+\frac{1}{n}\right\}$ is not convergent. 5

*(f)* *(i)* Prove that every monotonically increasing sequence which is bounded above converges to its least upper bound. 5

(ii) Show that the limit if exists of a convergent sequence is unique. 5

(g) State and prove $p$-series.

(h) (i) Test the convergence of the series

$$x+\frac{3}{5}x^2+\frac{8}{10}x^3+\ldots\ldots+\frac{n^2-1}{n^2+1}x^n+\ldots\ldots(x>0)$$

5

(ii) If $\{x_n\}$ is a bounded increasing sequence then show that $\lim_{n\to\infty} x_n = sup\{x_n\}$ 5

(i) (i) Show that a bounded sequence of real numbers has a convergent subsequence. 5

(ii) State and prove Nested Interval theorem. 5

(j) (i) Show that Cauchy sequence of real numbers is bounded. 5



(ii) Test the convergence of the series

$$x^2+\frac{2^2}{3.4}x^4+\frac{2^2.4^2}{3.4.5.6}x^6+\frac{2^2.4^2.6^2}{3.4.5.6.7.8}x^8+\ldots\ldots(x>0)$$

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