

Infinite series

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* Comparison test

If $\sum U_n$ and $\sum V_n$ be two series of (+)ve terms then

If $\lim_{n \rightarrow \infty} \frac{U_n}{V_n}$ be finite and non-zero,

the series will be both convergent or both convergent.

* The infinite series

$$\frac{1}{1^p} + \frac{1}{2^p} + \frac{1}{3^p} + \dots \text{ to } \infty \text{ is}$$

convergent if $p > 1$ and

divergent if $p \leq 1$.

Working rule

1. Find the n^{th} term U_n .

2. consider another auxiliary series

whose n^{th} term (V_n) is equal to

$$V_n = \frac{\text{term of highest power of } n \text{ in numerator of } U_n}{\text{term of highest power of } n \text{ in the denominator of } U_n}.$$

3. Find $\frac{U_n}{V_n}$.

4. Find $\lim_{n \rightarrow \infty} \frac{U_n}{V_n}$.

If $\lim_{n \rightarrow \infty} \frac{U_n}{V_n} =$ finite and non-zero

then proceed as following.

5. compare V_n with the series $\sum \frac{1}{n^p}$.

$\sum \frac{1}{n^p}$ ~~which~~ is cgt if $p > 1$,

is dgt. if $p \leq 1$.

6. By comparison test both the series $\sum U_n$ and $\sum V_n$ will converge or diverge simultaneously.

EXAMPLES

1. Test the convergence of the series

$$1 + \frac{1+2}{1+2^2} + \frac{1+3}{1+3^2} + \dots + \frac{1+n}{1+n^2} + \dots$$

Soln The series can be written as

$$\frac{1+1}{1+1^2} + \frac{1+2}{1+2^2} + \frac{1+3}{1+3^2} + \dots + \frac{1+n}{1+n^2} + \dots$$

Then its n^{th} term ($=U_n$) = $\frac{1+n}{1+n^2}$

Let us consider another series whose n^{th} term is V_n and $V_n = \frac{n}{n^2} = \frac{1}{n}$

$$\begin{aligned} \therefore \frac{U_n}{V_n} &= \frac{\frac{1+n}{1+n^2}}{\frac{1}{n}} = \frac{n(1+n)}{1+n^2} \\ &= \frac{n+n^2}{1+n^2} = \frac{n^2\left(\frac{1}{n}+1\right)}{n^2\left(\frac{1}{n^2}+1\right)} \\ &= \frac{1+\frac{1}{n}}{1+\frac{1}{n^2}} \end{aligned}$$

$$\therefore \lim_{n \rightarrow \infty} \frac{U_n}{V_n} = \lim_{n \rightarrow \infty} \frac{1+\frac{1}{n}}{1+\frac{1}{n^2}} = 1$$

which is finite and non-zero.

So, by comparison test, the two series $\sum U_n$ and $\sum V_n$ behave alike (i.e. converge or diverge simultaneously).

$$\text{Now } V_n = \frac{1}{n} \Rightarrow \sum V_n = \sum \frac{1}{n}$$

$$\Rightarrow \sum V_n = \frac{1}{1} + \frac{1}{2} + \frac{1}{3} + \dots + \frac{1}{n} + \dots \rightarrow \infty$$

Comparing it with $\sum \frac{1}{n^p}$, we have $p=1$.

$\Rightarrow \sum V_n$ is not convergent, i.e. divergent.

Hence, by comparison test, $\sum U_n$ is div.

Q

Test the convergency of the series

$$\sum \frac{5n-3}{2n^3-1}$$

Soln

Here, $U_n = \frac{5n-3}{2n^3-1}$

~~$$\frac{5n-3}{2n^3-1}$$~~

\Rightarrow ~~the~~ consider another series $\sum V_n$ with

$$V_n = \frac{n}{n^3} = \frac{1}{n^2}$$

$$\therefore \frac{U_n}{V_n} = \frac{n^2(5n-3)}{2n^3-1} = \frac{n^2 \left(\frac{5n-3}{n^3} \right)}{\frac{2n^3-1}{n^3}} = \frac{5 - \frac{3}{n}}{2 - \frac{1}{n^3}}$$

$$\therefore \lim_{n \rightarrow \infty} \frac{U_n}{V_n} = \lim_{n \rightarrow \infty} \left(\frac{5 - \frac{3}{n}}{2 - \frac{1}{n^3}} \right) = \frac{5}{2} \text{ which is finite and non-zero}$$

So, by comparison test, they behave alike.

But $\sum V_n = \sum \frac{1}{n^2} = \frac{1}{1^2} + \frac{1}{2^2} + \dots + \frac{1}{n^2} + \dots$ is convergent

$\Rightarrow \sum U_n$ (the given series) is also convergent.