

10.8 Ratio Test for Convergence

Name: _____ Class: _____ Date: _____

Total: 14 marks

Objective

Build the skills to answer exam questions on the **ratio test** for convergence.

You must be able to:

- compute $L = \lim_{n \rightarrow \infty} \left| \frac{a_{n+1}}{a_n} \right|$
- conclude: $L < 1$ converges, $L > 1$ diverges, $L = 1$ inconclusive
- apply it to series with **factorials** or **n th powers**

1 Worked examples

Study these first. Each one shows the method for a question type used later — follow the steps and you can do the Practice and Exam-style questions yourself.

■ The ratio test

Compute

$$L = \lim_{n \rightarrow \infty} \left| \frac{a_{n+1}}{a_n} \right|.$$

- $L < 1$: **converges absolutely**;
- $L > 1$: **diverges**;
- $L = 1$: **inconclusive**.

■ A factorial example

$$\sum \frac{2^n}{n!}: \frac{a_{n+1}}{a_n} = \frac{2^{n+1}/(n+1)!}{2^n/n!} = \frac{2}{n+1} \rightarrow 0 < 1. \text{ Converges.}$$

■ An n -th power example

$$\sum \frac{n}{2^n}: \frac{a_{n+1}}{a_n} = \frac{(n+1)/2^{n+1}}{n/2^n} = \frac{n+1}{2n} \rightarrow \frac{1}{2} < 1. \text{ Converges.}$$

■ When it is inconclusive

For a p -series, $L = 1$, so the ratio test says nothing — use the p -series rule instead. The ratio test shines with factorials and exponentials.

2 Practice

Now apply the methods above.

2.1 For $\sum \frac{3^n}{n!}$, write $\frac{a_{n+1}}{a_n}$. [2]

2.2 Find $\lim_{n \rightarrow \infty} \frac{3}{n+1}$ and state the conclusion. [2]

2.3 For a p-series, the ratio test gives $L = 1$. What does this mean? [1]

3 Exam-style questions

3.1 If the ratio test gives $L = 1$, the series [1]

- **A** converges
 - **B** diverges
 - **C** the test is inconclusive
 - **D** equals 1
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3.2 Apply the ratio test to $\sum_{n=1}^{\infty} \frac{n!}{10^n}$.

(a) Find $\frac{a_{n+1}}{a_n}$ and its limit. [3]

(b) State the conclusion. [1]

3.3 Use the ratio test on $\sum \frac{5^n}{n^2}$.

[4]

4 Go further

You are now ready for the real exam questions on this subtopic:

- work through the **10.8 Ratio Test for Convergence** lesson on the **Learn** page;
- read the **Ratio Test for Convergence** section of the AP Calculus BC handout on the **Know** page.

Solutions

$$\mathbf{2.1} \quad \frac{a_{n+1}}{a_n} = \frac{3^{n+1}/(n+1)!}{3^n/n!} = \frac{3}{n+1}.$$

$$\mathbf{2.2} \quad \frac{3}{n+1} \rightarrow 0 < 1, \text{ so the series } \mathbf{converges}.$$

2.3 The ratio test is inconclusive; use another test (the p-series rule).

3.1 C —inconclusive when $L = 1$.

$$\mathbf{3.2} \quad (\text{a}) \quad \frac{a_{n+1}}{a_n} = \frac{(n+1)!/10^{n+1}}{n!/10^n} = \frac{n+1}{10} \rightarrow \infty. \quad (\text{b}) \quad L > 1, \text{ so it } \mathbf{diverges}.$$

$$\mathbf{3.3} \quad \frac{a_{n+1}}{a_n} = \frac{5^{n+1}/(n+1)^2}{5^n/n^2} = 5 \cdot \frac{n^2}{(n+1)^2} \rightarrow 5; \quad L = 5 > 1, \text{ so it } \mathbf{diverges}.$$