

10.4 Integral Test for Convergence

Name: _____ Class: _____ Date: _____

Total: 14 marks

Objective

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

You must be able to:

- check the conditions (positive, decreasing, continuous)
- compare $\sum a_n$ with $\int_1^\infty f(x) dx$
- conclude convergence or divergence from the integral

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 integral test

If $a_n = f(n)$ where f is **positive, decreasing, and continuous** for $x \geq 1$, then $\sum a_n$ and $\int_1^\infty f(x) dx$ **both converge or both diverge**.

■ A worked test

$\sum \frac{1}{n^2}$: with $f(x) = \frac{1}{x^2}$, $\int_1^\infty x^{-2} dx = 1$ (finite). The integral converges, so the **series converges**.

■ A divergent case

$\sum \frac{1}{n}$: $\int_1^\infty \frac{1}{x} dx = \lim_{b \rightarrow \infty} \ln b = \infty$. The integral diverges, so the series diverges.

■ Check the conditions first

The function must be positive and decreasing (eventually). The integral's **value** is not the series' sum —only its convergence matches.

2 Practice

Now apply the methods above.

2.1 State the three conditions on f for the integral test. [2]

2.2 Evaluate $\int_1^\infty \frac{1}{x^2} dx$. [2]

2.3 From 2.2, does $\sum \frac{1}{n^2}$ converge? [1]

3 Exam-style questions

3.1 The integral test compares a series with [1]

- **A** a geometric series
- **B** an improper integral of the matching function
- **C** the harmonic series
- **D** a partial sum

3.2 Apply the integral test to $\sum_{n=1}^\infty \frac{1}{n^3}$.

(a) Evaluate $\int_1^\infty \frac{1}{x^3} dx$. [3]

(b) State the conclusion. [1]

3.3 Use the integral test to decide whether $\sum_{n=2}^\infty \frac{1}{n \ln n}$ converges. (Use the substitution

$$u = \ln x.)$$

[4]

4 Go further

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

- work through the **10.4 Integral Test for Convergence** lesson on the **Learn** page;
- read the **Integral Test for Convergence** section of the AP Calculus BC handout on the **Know** page.

Solutions

2.1 Positive, decreasing, and continuous for $x \geq 1$.

2.2 $\left[-\frac{1}{x}\right]_1^\infty = 0 - (-1) = 1$.

2.3 Yes —the integral converges, so the series converges.

3.1 B —with an improper integral of the matching function.

3.2 (a) $\int_1^\infty x^{-3} dx = \left[-\frac{1}{2x^2}\right]_1^\infty = 0 + \frac{1}{2} = \frac{1}{2}$. (b) Converges.

3.3 $\int_2^\infty \frac{1}{x \ln x} dx$; $u = \ln x$, $du = \frac{1}{x} dx$; $= \int \frac{1}{u} du = \ln |u| = \ln(\ln x)$; as $x \rightarrow \infty$ this $\rightarrow \infty$, so it **diverges**.