Math 21C (Spring 2005)
Kouba
Exam 3

Please PRINT your name here : KEY

Please SIGN your name here : ____________________

Your Exam ID Number ____________

1. PLEASE DO NOT TURN THIS PAGE UNTIL TOLD TO DO SO.

2. IT IS A VIOLATION OF THE UNIVERSITY HONOR CODE TO, IN ANY WAY, ASSIST ANOTHER PERSON IN THE COMPLETION OF THIS EXAM. PLEASE KEEP YOUR OWN WORK COVERED UP AS MUCH AS POSSIBLE DURING THE EXAM SO THAT OTHERS WILL NOT BE TEMPTED OR DISTRACTED. THANK YOU FOR YOUR COOPERATION.

3. YOU MAY USE A CALCULATOR ON THIS EXAM.

4. No notes, books, or classmates may be used as resources for this exam.

5. Read directions to each problem carefully. Show all work for full credit. In most cases, a correct answer with no supporting work will NOT receive full credit. What you write down and how you write it are the most important means of your getting a good score on this exam. Neatness and organization are also important.

6. You have until 9:50 a.m. sharp to finish the exam. PLEASE STOP WRITING IMMEDIATELY when time is called and close your exam.

7. Make sure that you have 5 pages including the cover page.

8. The following may be used on the exam.

$$(*) \int_1^{n+1} f(x)\,dx < f(1) + f(2) + \cdots + f(n) < f(1) + \int_1^n f(x)\,dx$$

$$(*)(*) \int_{n+1}^{\infty} f(x)\,dx < f(n+1) + f(n+2) + f(n+3) + \cdots < \int_n^{\infty} f(x)\,dx$$

1.) (9 pts. each) Determine whether each of the following series converges or diverges. Write clear and complete solutions including the name of the series test that you use and what your final answer is.

a.) $\sum_{n=1}^{\infty}\left(\frac{n+2}{3n+5}\right)$; $\lim_{n\to\infty} \frac{n+2}{3n+5} = \lim_{n\to\infty} \frac{1+\frac{2}{n}}{3+\frac{5}{n}} = \frac{1+0}{3+0}$

$= \frac{1}{3} \neq 0$ so series diverges by the nth term test.

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b.) $\frac{2}{3}-\frac{4}{9}+\frac{8}{27}-\frac{16}{81}+\frac{32}{243}-\cdots = \frac{2}{3}\left[1-\frac{2}{3}+\frac{4}{9}-\frac{8}{27}+\cdots\right]$

$= \frac{2}{3}\left[1+\left(\frac{-2}{3}\right)+\left(\frac{-2}{3}\right)^2+\left(\frac{-2}{3}\right)^3+\cdots\right]$ so $r = -2/3$ and series converges by geometric series test since $-1<r<1$.

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c.) $\sum_{n=2}^{\infty}\sqrt{\frac{n}{n^4+3}}$; $\lim_{n\to\infty} \frac{\sqrt{\frac{n}{n^4+3}}}{\frac{1}{n^{3/2}}} = \lim_{n\to\infty} \sqrt{\frac{n}{n^4+3}} \cdot \sqrt{n^3}$

$= \lim_{n\to\infty} \sqrt{\frac{n^4}{n^4+3}} = \lim_{n\to\infty} \sqrt{\frac{1}{1+3/n^4}} = \sqrt{\frac{1}{1+0}} = 1$, so series converges by limit comparison test since $\sum_{n=2}^{\infty} \frac{1}{n^{3/2}}$ converges by p-series test ($p = 3/2 > 1$)

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d.) $\sum_{n=2}^{\infty}\left(\frac{1}{n^2}+\frac{1}{n}\right)$; $\sum_{n=2}^{\infty} \frac{1}{n^2}$ converges by p-series test ($p=2>1$) and $\sum_{n=2}^{\infty} \frac{1}{n}$ diverges by p-series test ($p=1\leq 1$); then $\sum_{n=2}^{\infty}\left(\frac{1}{n^2}+\frac{1}{n}\right)$ diverges since the sum of a convergent and a divergent series is divergent.

e.) $\sum_{n=1}^{\infty} \frac{5^{n+1}}{(2n)!}$; $\lim_{n\to\infty} \frac{a_{n+1}}{a_n} = \lim_{n\to\infty} \frac{\frac{5^{n+2}}{(2(n+1))!}}{\frac{5^{n+1}}{(2n)!}}$

$= \lim_{n\to\infty} \frac{5^{n+2}}{(2n+2)!} \cdot \frac{(2n)!}{5^{n+1}}$

$= \lim_{n\to\infty} \frac{5}{(2n+2)(2n+1)} = 0 < 1$ so series converges by ratio test.

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f.) $\sum_{n=3}^{\infty} (-1)^{n+1} \frac{1}{n+\sqrt{n}}$; let $a_n = \frac{1}{n+\sqrt{n}}$, then

a_n is $+$, $\downarrow$, and $\lim_{n\to\infty} a_n = 0$ so series

converges by alternating series test.

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g.) $\frac{1}{1^4} + \frac{1}{2^4} - \frac{1}{3^4} + \frac{1}{4^4} + \frac{1}{5^4} - \frac{1}{6^4} + \frac{1}{7^4} + \frac{1}{8^4} - \frac{1}{9^4} + \cdots$;

$\sum_{n=1}^{\infty} \frac{1}{n^4}$ converges by p-series test ($p = 4 > 1$) so original series converges by absolute convergence test.

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h.) $\sum_{n=4}^{\infty} \left(\frac{1}{\sqrt{n}} - \frac{1}{\sqrt{n+1}} \right)$;

$S_1 = \frac{1}{2} - \frac{1}{\sqrt{5}}$,

$S_2 = \left(\frac{1}{2} - \cancel{\frac{1}{\sqrt{5}}}\right) + \left(\cancel{\frac{1}{\sqrt{5}}} - \frac{1}{\sqrt{6}}\right) = \frac{1}{2} - \frac{1}{\sqrt{6}}$,

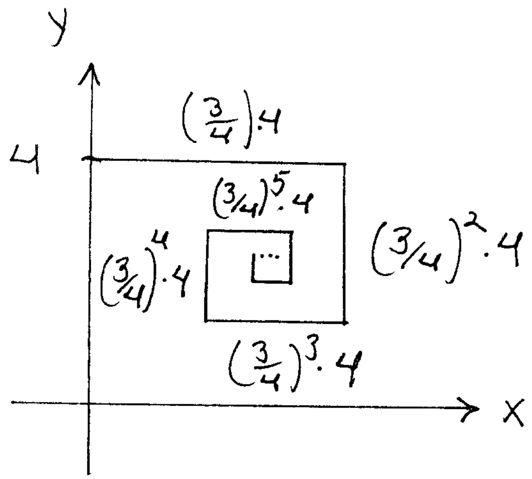
$S_3 = \left(\frac{1}{2} - \cancel{\frac{1}{\sqrt{5}}}\right) + \left(\cancel{\frac{1}{\sqrt{5}}} - \cancel{\frac{1}{\sqrt{6}}}\right) + \left(\cancel{\frac{1}{\sqrt{6}}} - \frac{1}{\sqrt{7}}\right) = \frac{1}{2} - \frac{1}{\sqrt{7}}$,

$\vdots$

$S_n = \frac{1}{2} - \frac{1}{\sqrt{n+4}}$ and $\lim_{n\to\infty} S_n = \frac{1}{2}$

so series converges by sequence of partial sums test.

2.) (10 pts.) Start at the origin and move 4 units along the positive y-axis. Turn 90 degrees to the right and move 75% of that distance. Turn 90 degrees to the right and move 75% of that distance. Turn 90 degrees to the right and move 75% of that distance. Continue this process forming a "spiral with square corners." Determine the *y-coordinate* for the point (x, y) where this spiral "ends."



$$y = 4 - \left(\tfrac{3}{4}\right)^2 \cdot 4 + \left(\tfrac{3}{4}\right)^4 \cdot 4 - \left(\tfrac{3}{4}\right)^6 \cdot 4 + \cdots$$

$$= 4\left(1 + \left(\tfrac{-9}{16}\right) + \left(\tfrac{-9}{16}\right)^2 + \left(\tfrac{-9}{16}\right)^3 + \cdots\right)$$

$$= 4 \cdot \frac{1}{1-(-9/16)} = 4 \cdot \frac{16}{25} = \frac{64}{25} = 2.56$$

3.) (8 pts.) The alternating series $\sum_{n=1}^{\infty} (-1)^{n+1} \frac{1}{\sqrt{n+7}}$ converges. What should n be so that the partial sum $S_n = \sum_{i=1}^{n} (-1)^{i+1} \frac{1}{\sqrt{i+7}}$ estimates the exact value of the series with absolute error at most 0.001 ?

We want $|R_n| \leq 0.001$ and we know that $|R_n| < a_{n+1}$, so require that

$$a_{n+1} = \frac{1}{\sqrt{n+8}} \leq 0.001 \longrightarrow \sqrt{n+8} \geq 1000 \longrightarrow$$

$n+8 \geq 1{,}000{,}000 \longrightarrow$ choose $n \geq 999{,}992$.

4.) (10 pts.) The series $\sum_{n=2}^{\infty} \frac{1}{n(\ln n)^2}$ converges. What should n be so that the partial sum $S_n = \sum_{i=2}^{n} \frac{1}{i(\ln i)^2}$ estimates the exact value of the series with error at most 0.1 ?

$$(*)(*)\ R_n < \int_n^{\infty} f(x)\,dx \le 0.1 \rightarrow$$

$$\lim_{A\to\infty} \int_n^A \frac{1}{x(\ln x)^2}\,dx \le 0.1 \rightarrow$$

$$\lim_{A\to\infty} \left.\frac{-1}{\ln x}\right|_n^A \le 0.1 \rightarrow$$

$$\lim_{A\to\infty} \left(\overset{0}{\cancel{\frac{-1}{\ln A}}} - \frac{-1}{\ln n}\right) \le 0.1 \rightarrow$$

$$\frac{1}{\ln n} \le 0.1 \rightarrow \ln n \ge 10$$

$$\rightarrow e^{\ln n} \ge e^{10}$$

$$\rightarrow n \ge e^{10}$$

($n \ge 22{,}026.47$ so choose $n \ge 22{,}027$)

The following EXTRA CREDIT PROBLEM is worth 12 points. This problem is OPTIONAL.

1.) The following series converges. Determine the *exact* value of this infinite series :

$$\frac{1}{1} - \frac{2}{3} + \frac{3}{3^2} - \frac{4}{3^3} + \frac{5}{3^4} - \frac{6}{3^5} + \cdots$$

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

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

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

$$\vdots$$

$$= \frac{1}{1-(-1/3)} \cdot \left[1 - \frac{1}{3} + \frac{1}{3^2} - \frac{1}{3^3} + \cdots\right]$$

$$= \frac{3}{4} \cdot \frac{1}{1-(-1/3)} = \frac{3}{4} \cdot \frac{3}{4} = \frac{9}{16}.$$