

Solution: We prove that $\sum_{i=1}^n \frac{1}{\sqrt{i}} > 2(\sqrt{n+1} - 1)$ for all integers $n \geq 1$ by induction on n .

Base Case: ($n = 1$)

Since $1^2 = 1 < 2 < 2.25 = \left(\frac{3}{2}\right)^2$, we see that $1 < \sqrt{2} < \frac{3}{2}$, and hence $\sqrt{2} - 1 < \frac{1}{2}$. Thus,

$$\sum_{i=1}^1 \frac{1}{\sqrt{i}} = \frac{1}{\sqrt{1}} = 1 = 2 \times \frac{1}{2} > 2(\sqrt{2} - 1) = 2\sqrt{1+1} - 1.$$

Inductive step: Let $k \geq 1$ be an integer and suppose that

$$\sum_{i=1}^k \frac{1}{\sqrt{i}} > 2(\sqrt{k+1} - 1). \quad (\text{IH})$$

We want to prove that $\sum_{i=1}^{k+1} \frac{1}{\sqrt{i}} > 2(\sqrt{k+2} - 1)$.

Now,

$$\begin{aligned} \sum_{i=1}^{k+1} \frac{1}{\sqrt{i}} &= \left(\sum_{i=1}^k \frac{1}{\sqrt{i}} \right) + \frac{1}{\sqrt{k+1}} \\ &> 2(\sqrt{k+1} - 1) + \frac{1}{\sqrt{k+1}} && \text{by (IH).} \\ &= 2\sqrt{k+1} + \frac{1}{\sqrt{k+1}} - 2 \\ &= 2\left(\sqrt{k+1} + \frac{1}{2\sqrt{k+1}}\right) - 2 \\ &= 2\left(\frac{2(k+1)+1}{2\sqrt{k+1}}\right) - 2 \\ &= 2\left(\frac{2k+3}{\sqrt{4(k+1)}}\right) - 2 \\ &= 2\left(\frac{(2k+3)}{\sqrt{4(k+1)(k+2)}}\sqrt{k+2}\right) - 2 \\ &= 2\left(\sqrt{\frac{(2k+3)^2}{4(k+1)(k+2)}}\sqrt{k+2}\right) - 2 \\ &= 2\left(\sqrt{\frac{4k^2+12k+9}{4k^2+12k+8}}\sqrt{k+2}\right) - 2 \\ &> 2\sqrt{k+2} - 2 && \text{because } \frac{4k^2+12k+9}{4k^2+12k+8} > 1 \\ &= 2(\sqrt{k+2} - 1). \end{aligned}$$

Thus, by the Principle of Mathematical Induction, we conclude that $\sum_{i=1}^n \frac{1}{\sqrt{i}} > 2(\sqrt{n+1} - 1)$ for all integers $n \geq 1$.

Discrete Math With Proof

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Table of Contents Discrete Math With Proof

1. Understanding the eBook Discrete Math With Proof
 - The Rise of Digital Reading Discrete Math With Proof
 - Advantages of eBooks Over Traditional Books
2. Identifying Discrete Math With Proof
 - Exploring Different Genres
 - Considering Fiction vs. Non-Fiction
 - Determining Your Reading Goals
3. Choosing the Right eBook Platform
 - Popular eBook Platforms
 - Features to Look for in an Discrete Math With Proof
 - User-Friendly Interface
4. Exploring eBook Recommendations from Discrete Math With Proof
 - Personalized Recommendations
 - Discrete Math With Proof User Reviews and Ratings
 - Discrete Math With Proof and Bestseller Lists

5. Accessing Discrete Math With Proof Free and Paid eBooks
 - Discrete Math With Proof Public Domain eBooks
 - Discrete Math With Proof eBook Subscription Services
 - Discrete Math With Proof Budget-Friendly Options
6. Navigating Discrete Math With Proof eBook Formats
 - ePub, PDF, MOBI, and More
 - Discrete Math With Proof Compatibility with Devices
 - Discrete Math With Proof Enhanced eBook Features
7. Enhancing Your Reading Experience
 - Adjustable Fonts and Text Sizes of Discrete Math With Proof
 - Highlighting and Note-Taking Discrete Math With Proof
 - Interactive Elements Discrete Math With Proof
8. Staying Engaged with Discrete Math With Proof
 - Joining Online Reading Communities
 - Participating in Virtual Book Clubs
 - Following Authors and Publishers Discrete Math With Proof
9. Balancing eBooks and Physical Books Discrete Math With Proof
 - Benefits of a Digital Library
 - Creating a Diverse Reading Collection Discrete Math With Proof
10. Overcoming Reading Challenges
 - Dealing with Digital Eye Strain
 - Minimizing Distractions
 - Managing Screen Time
11. Cultivating a Reading Routine Discrete Math With Proof
 - Setting Reading Goals Discrete Math With Proof
 - Carving Out Dedicated Reading Time
12. Sourcing Reliable Information of Discrete Math With Proof
 - Fact-Checking eBook Content of Discrete Math With Proof
 - Distinguishing Credible Sources
13. Promoting Lifelong Learning

- Utilizing eBooks for Skill Development
- Exploring Educational eBooks

14. Embracing eBook Trends

- Integration of Multimedia Elements
- Interactive and Gamified eBooks

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