

① Octonions

Reals used in conjunction with seven unconventional units: $e_1, e_2, e_3, e_4, e_5, e_6$ and e_7 (e_1, e_2 and e_4 are comparable to the quaternions' i, j and k).

Multiplication of octonions is **nonassociative** — it matters how they are grouped.

Their multiplication rules are encoded in the "Fano plane." Multiplying two neighboring elements on a line results in the third element on that same line. Imagine additional lines that close the loop for each group of three elements (e.g., the dashed line).

Moving with arrows gives a positive answer:

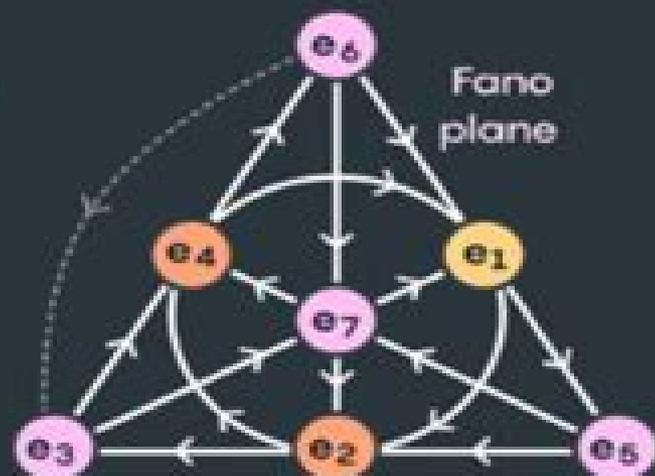
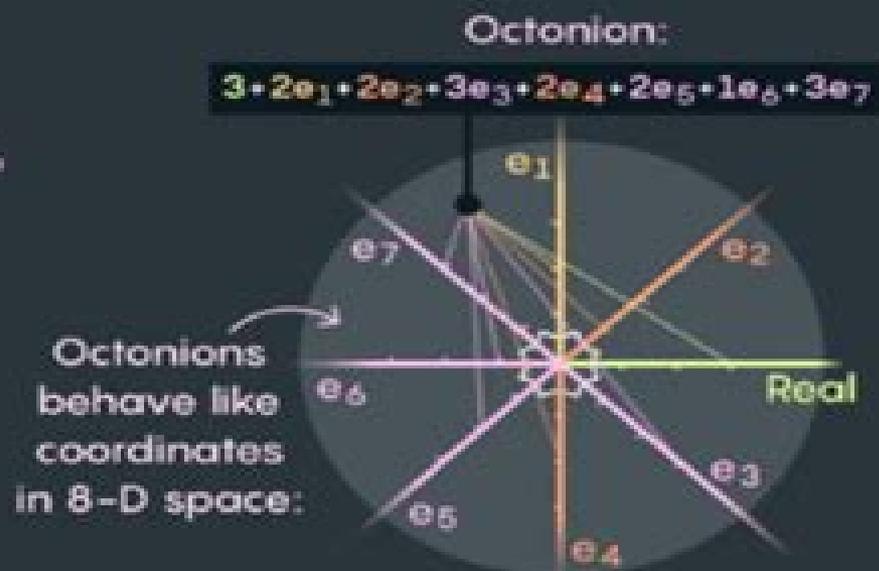
$$\text{e.g. } e_5 \times e_2 = e_3 \quad \text{and} \quad e_6 \times e_3 = e_4$$

Moving against arrows gives a negative answer:

$$\text{e.g. } e_1 \times e_7 = -e_3 \quad \text{and} \quad e_6 \times e_5 = -e_1$$

To see their nonassociative property, multiply three elements e_5, e_2, e_4

$$\left. \begin{aligned} \text{Grouping them like this ... } (e_5 \times e_2) \times e_4 &= (e_3) \times e_4 = e_6 \\ \text{But grouping them like this ... } e_5 \times (e_2 \times e_4) &= e_5 \times (e_1) = -e_6 \end{aligned} \right\} \text{Different answers}$$



On Quaternions And Octonions

Tao Wei



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Table of Contents On Quaternions And Octonions

1. Understanding the eBook On Quaternions And Octonions
 - The Rise of Digital Reading On Quaternions And Octonions
 - Advantages of eBooks Over Traditional Books
2. Identifying On Quaternions And Octonions
 - 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 On Quaternions And Octonions
 - User-Friendly Interface
4. Exploring eBook Recommendations from On Quaternions And Octonions
 - Personalized Recommendations
 - On Quaternions And Octonions User Reviews and Ratings
 - On Quaternions And Octonions and Bestseller Lists
5. Accessing On Quaternions And Octonions Free and Paid eBooks

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