

## 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:

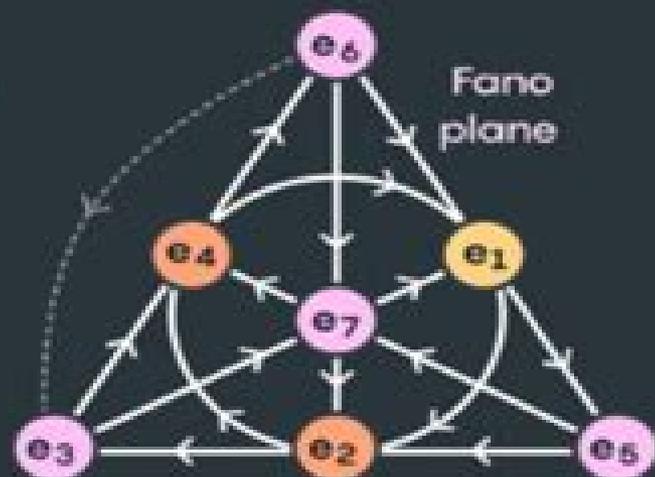
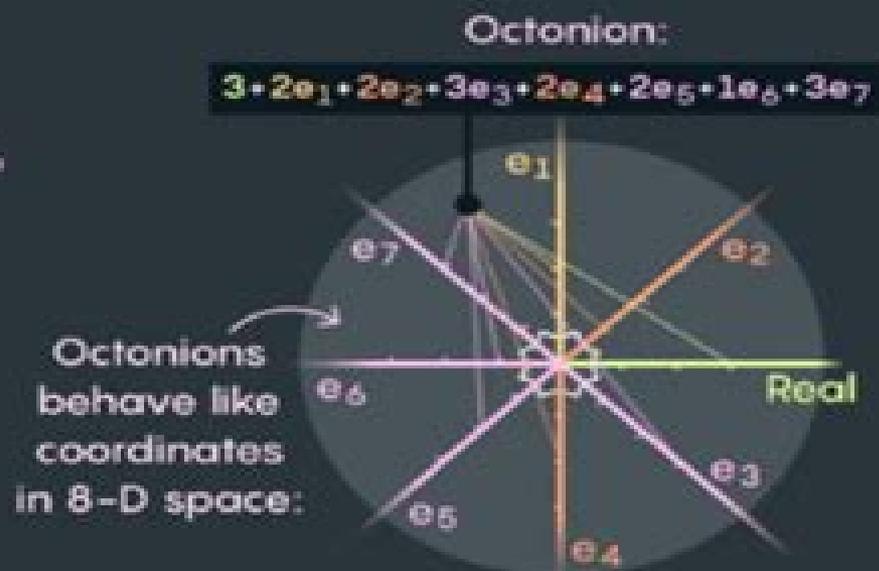
$$\text{e.g. } e_5 \times e_2 = e_3 \quad \text{and} \quad e_6 \times e_3 = e_4$$

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  $e_5, e_2, e_4$

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



# On Quaternions And Octonions

**M Woodhall**



## **On Quaternions And Octonions:**

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