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3. $\alpha \in \Phi$ implies $-\alpha \in \Phi$. Let $h_{\alpha}=\left[e^{\alpha}, e^{-\alpha}\right]$. Then $\operatorname{span}\left\{h_{\alpha}, e^{\alpha}, e^{-\alpha}\right\} \cong s l_{2}(\mathbb{C})$.

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(They are Combinatorial objects!!!)

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\begin{array}{ll}
\alpha+n d, & \alpha \text { is a root of } \mathfrak{g}, n \in \mathbb{Z}, \\
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## Moonshine VOA

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Frenkel-Lepowsky-Meurman's Moonshine VOA

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Note

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G=\left(\sqrt{2} A_{\ell}\right)^{*} / \sqrt{2} A_{\ell} \cong\left\{\begin{array}{l}
\mathbb{Z}_{2}^{\ell} \times \mathbb{Z}_{\ell+1} \quad \text { if } \ell \text { is even },
\end{array}\right.
$$

## Leech lattice

Let $\wedge$ be the Leech lattice (i.e., the unique even unimodular lattice of rank 24 such that $\Lambda_{2}=\{\alpha \in \Lambda \mid<\alpha, \alpha>=2\}=\emptyset$.

Let $L=A_{\ell}$ (the root lattice for the Lie algebra $s l_{n+1}(\mathbb{C})$ ).

Theorem: For any $\ell$ divides 24 , let $\Gamma=A_{\ell}{ }^{24 / \ell}$. Then, there is at least one (and in general several) isometric embedding

$$
\sqrt{2} \Gamma \longrightarrow \wedge,
$$

into the Leech lattice $\wedge$.

Note

$$
G=\left(\sqrt{2} A_{\ell}\right)^{*} / \sqrt{2} A_{\ell} \cong \begin{cases}\mathbb{Z}_{2}^{\ell} \times \mathbb{Z}_{\ell+1} & \text { if } \ell \text { is even } \\ \mathbb{Z}_{2}^{\ell-1} \times \mathbb{Z}_{2(\ell+1)} & \text { if } \ell \text { is odd }\end{cases}
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Question 2: For a given $D$, compute $A u t D$. Again it is related to the determination of $A u t V_{L_{D}}$ and the properties of the Monster group.

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Is $\sqrt{k} A_{\ell}^{24 / \ell} \subset \Lambda$ for any positive integer $k ? ?$

