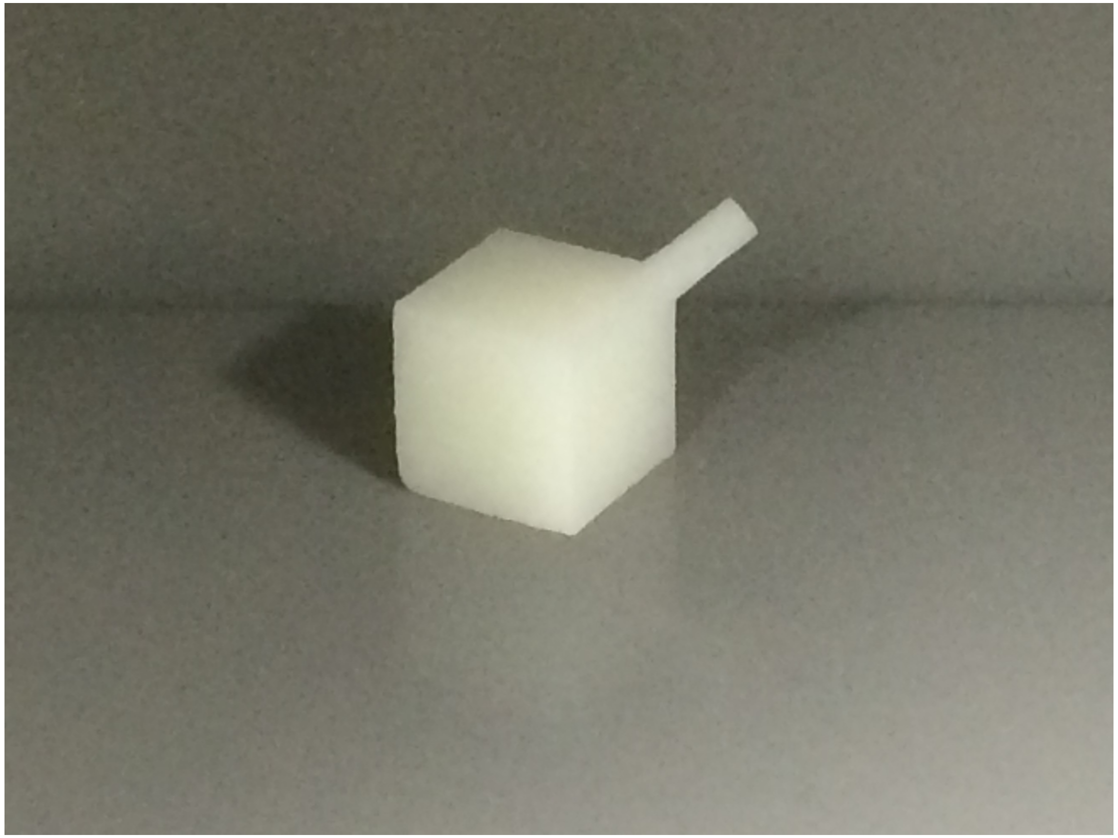
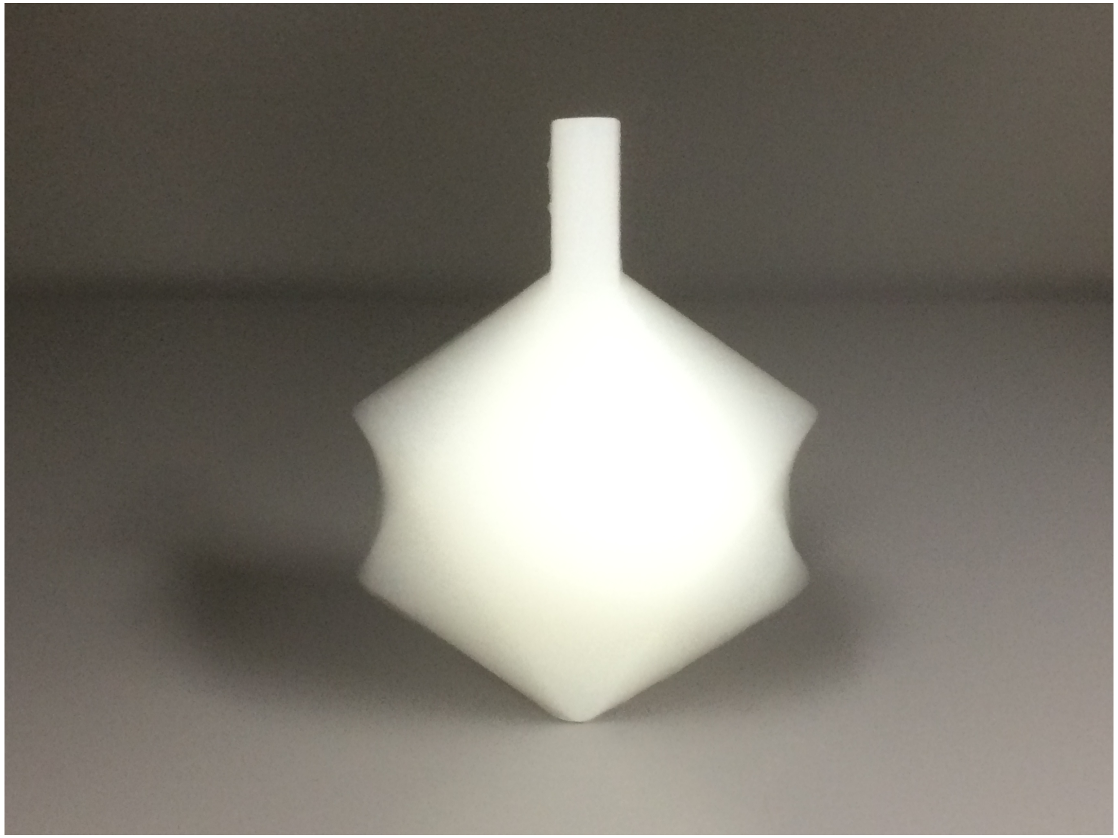
Rotation of Cube

立方体の回転

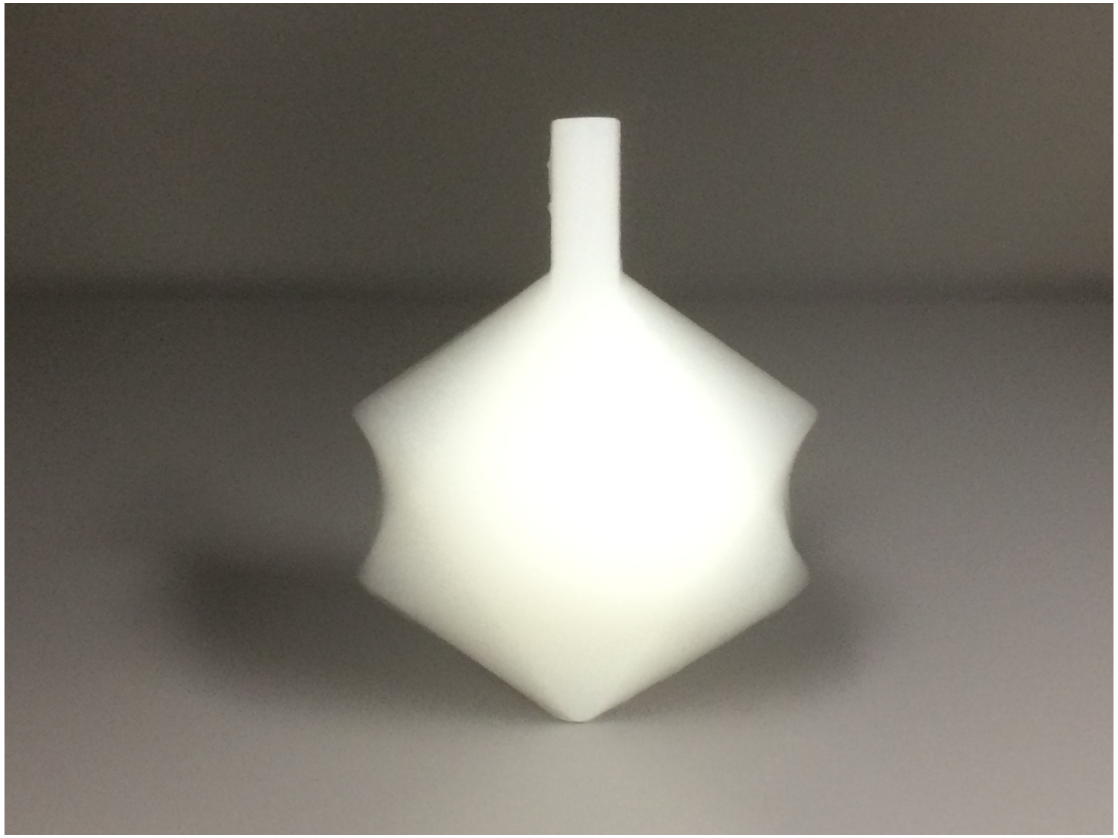
Rotation of Cube



Rotation of Cube



Rotation of Cube

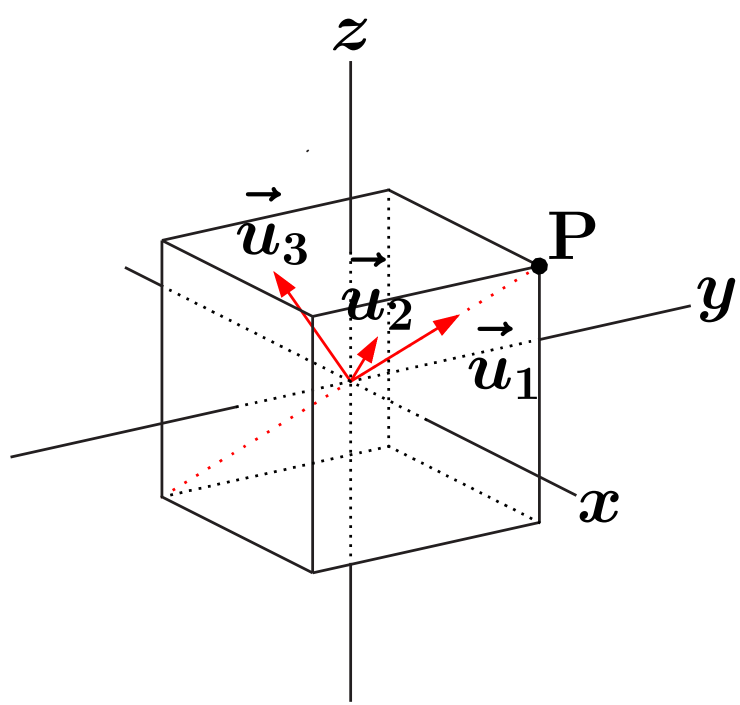


First, we consider the axis of the rotation.

Orthogonal Transformation

Orthogonal Transformation

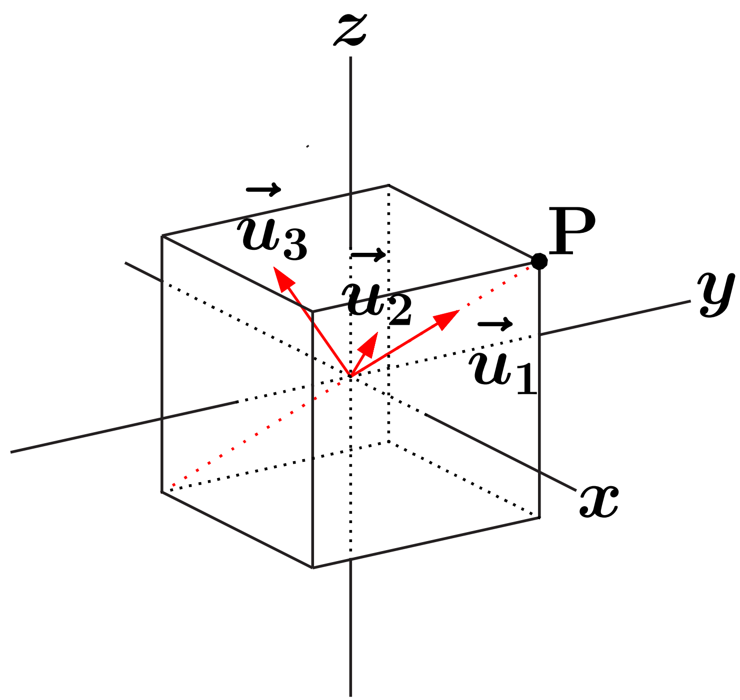
f : orthogonal transformation



Orthogonal Transformation

f : orthogonal transformation

直交変換



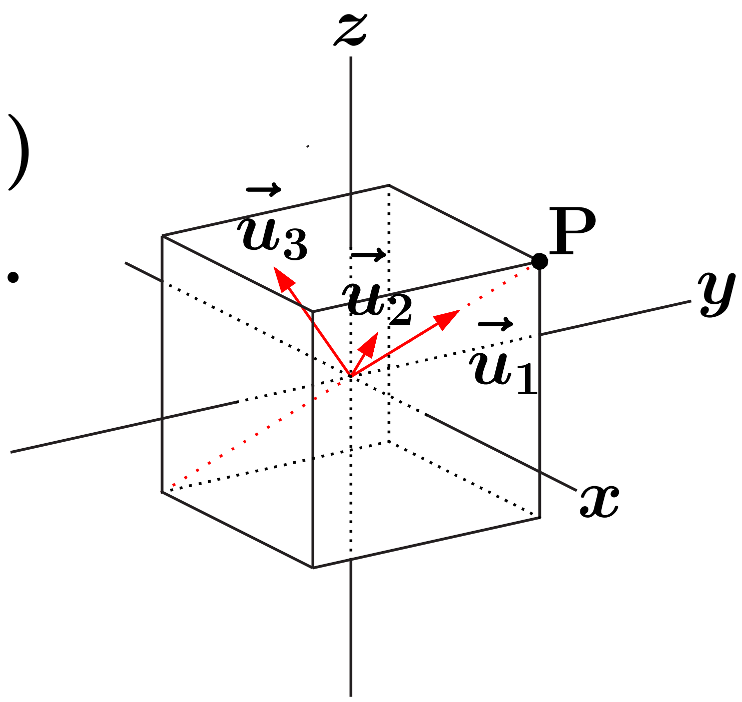
Orthogonal Transformation

f : orthogonal transformation

直交変換

Assume that f maps P(1, 1, 1)

to point P′ on the x-axis.



Orthogonal Transformation

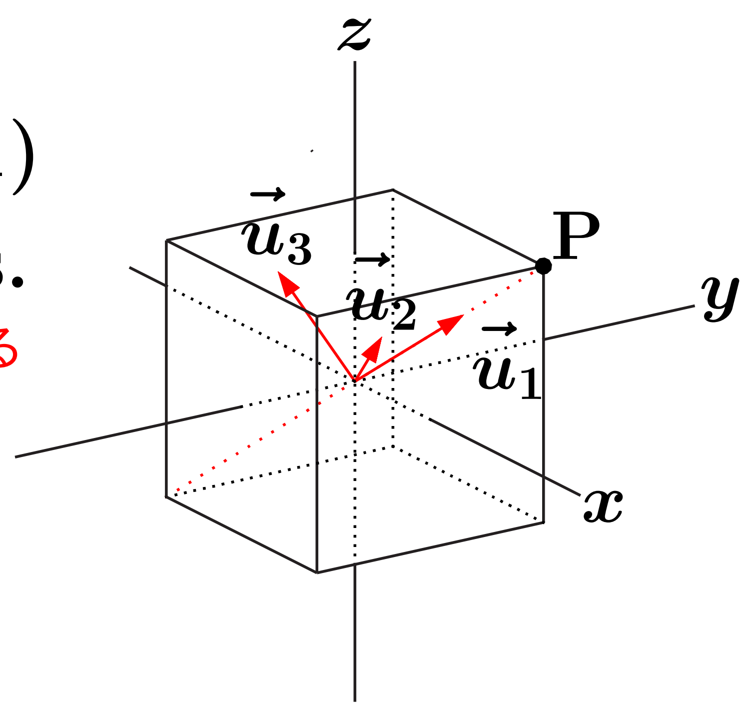
f : orthogonal transformation

直交変換

Assume that f maps P(1, 1, 1)

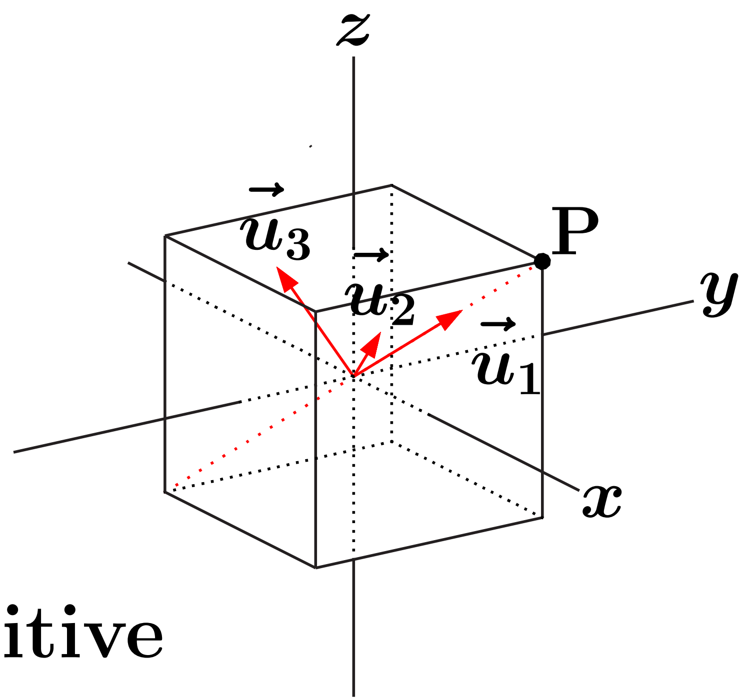
to point P′ on the x-axis.

f は P(1, 1, 1) を x 軸上の点 P′ に移すとする



Orthogonal Transformation

$\{\vec{u}_1,\ \vec{u}_2,\ \vec{u}_3\}$: right-handed orthonormal basis
satisfying



- $\vec{u}_1 = \dfrac{1}{\sqrt{3}} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}$
- $\vec{u}_2$ is on the xy-plane
- z component of $\vec{u}_3$ is positive

Orthogonal Transformation

$\{\vec{u}_1,\ \vec{u}_2,\ \vec{u}_3\}$: right-handed orthonormal basis

右手系の正規直交基底

satisfying

$$\cdot\ \vec{u}_1 = \frac{1}{\sqrt{3}}\begin{pmatrix}1\\1\\1\end{pmatrix}$$

$\cdot\ \vec{u}_2$ is on the xy-plane

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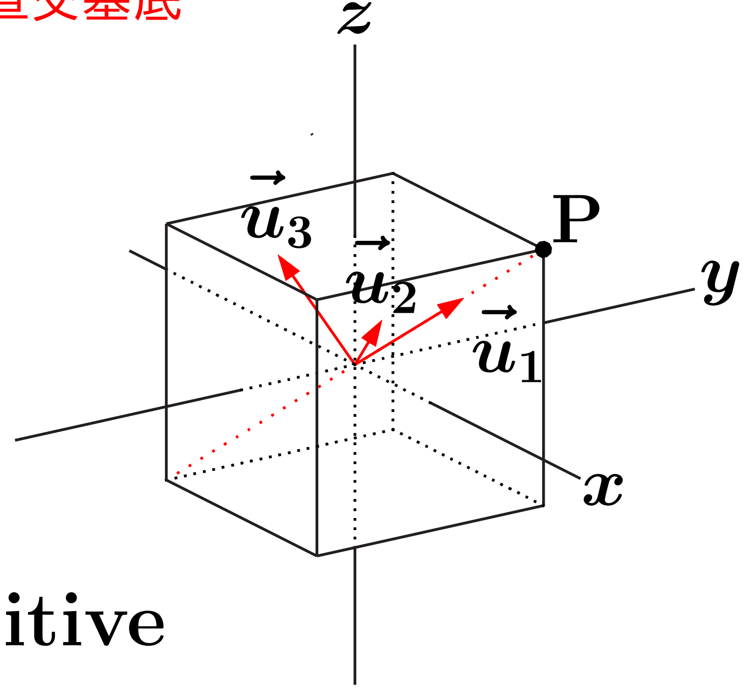

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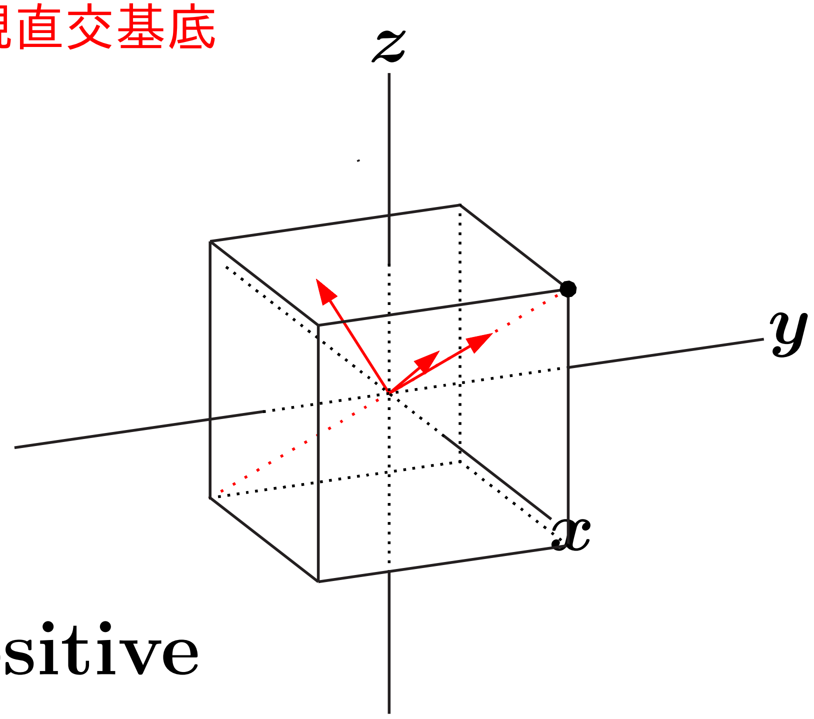

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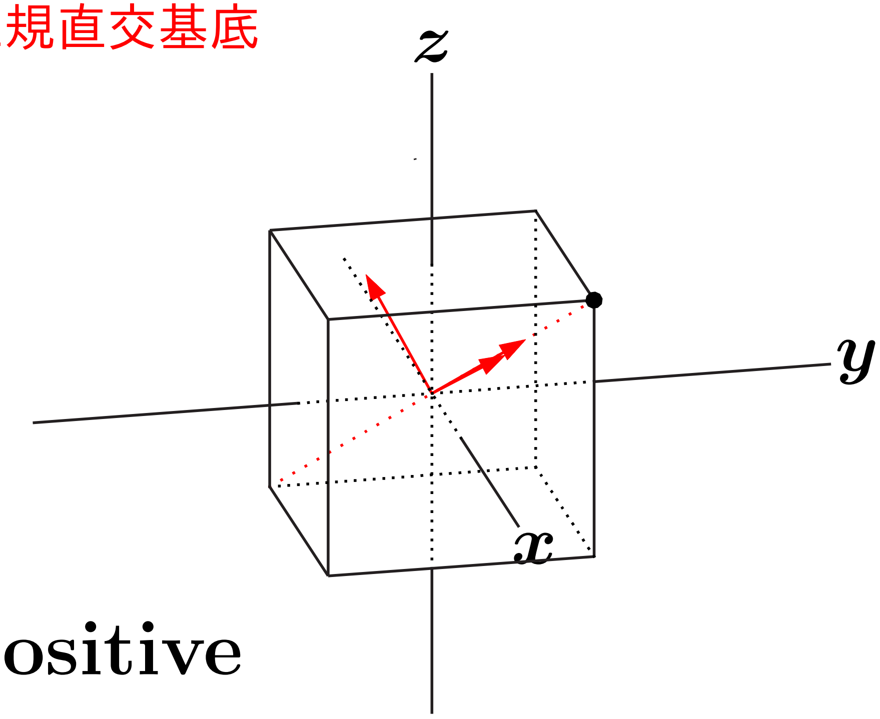

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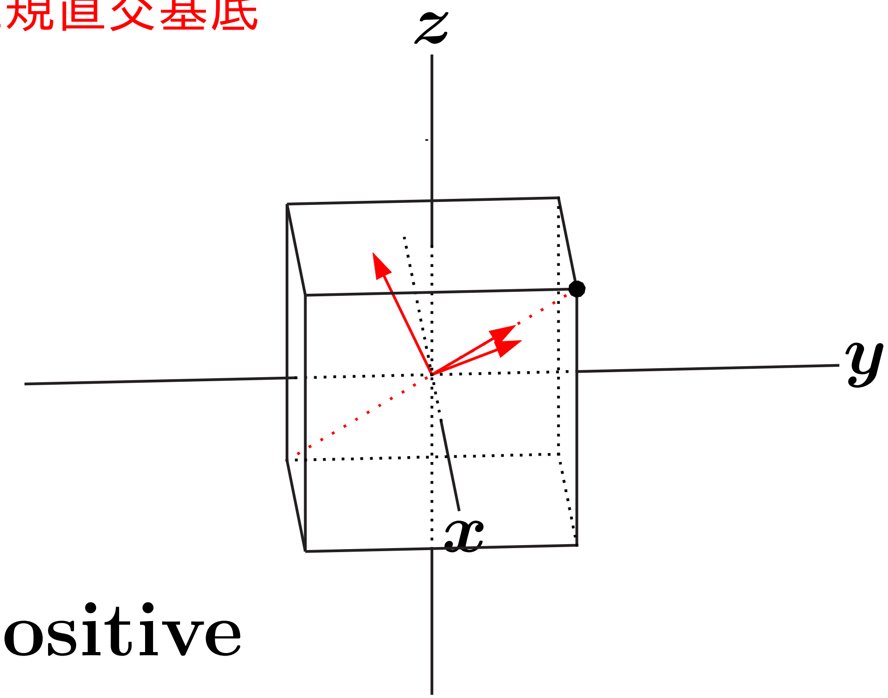

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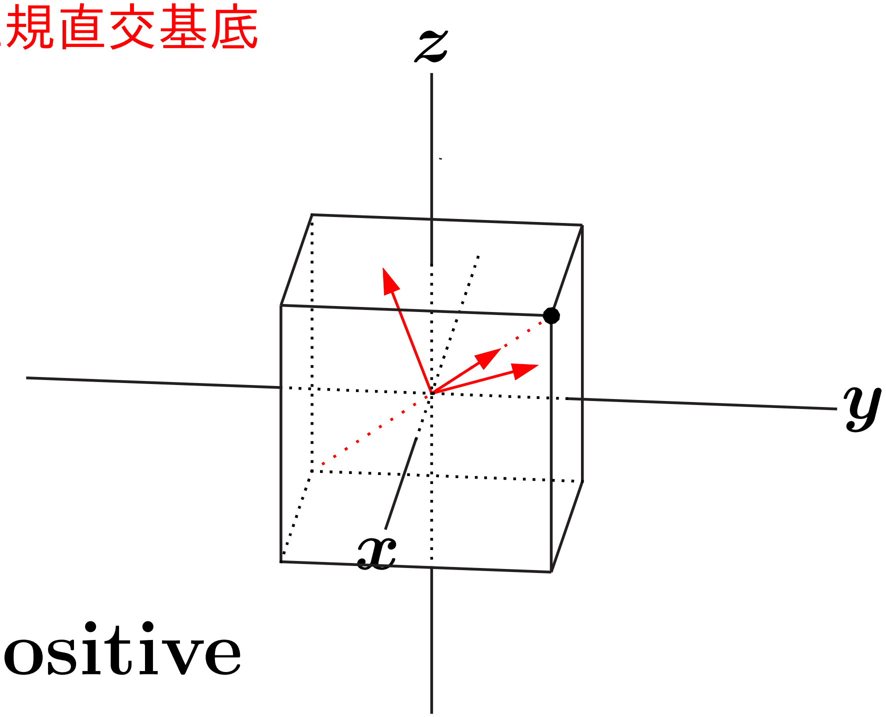

Orthogonal Transformation

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右手系の正規直交基底

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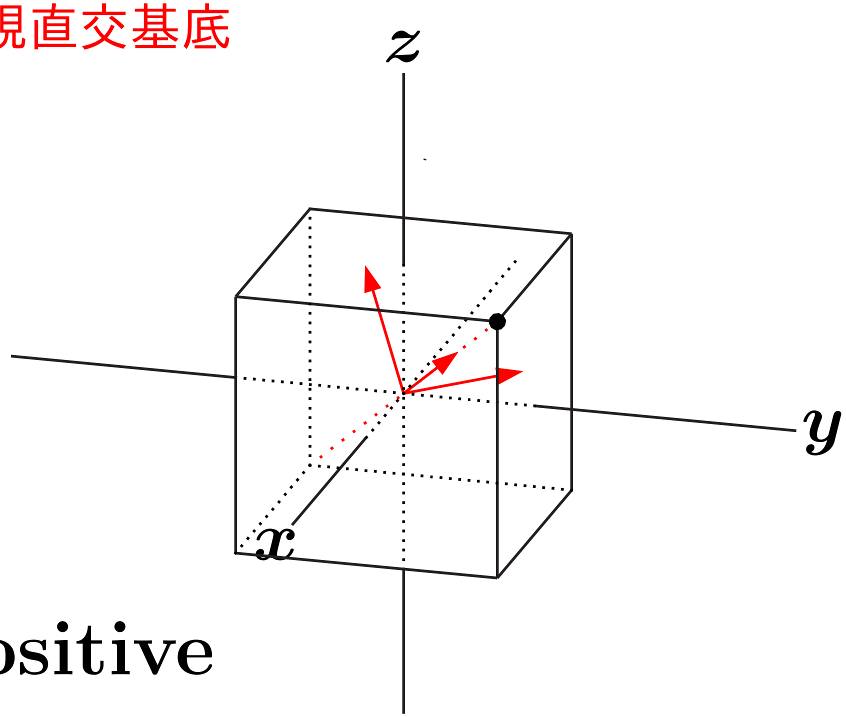

Orthogonal Transformation

$\{\vec{u}_1,\ \vec{u}_2,\ \vec{u}_3\}$: right-handed orthonormal basis satisfying

右手系の正規直交基底

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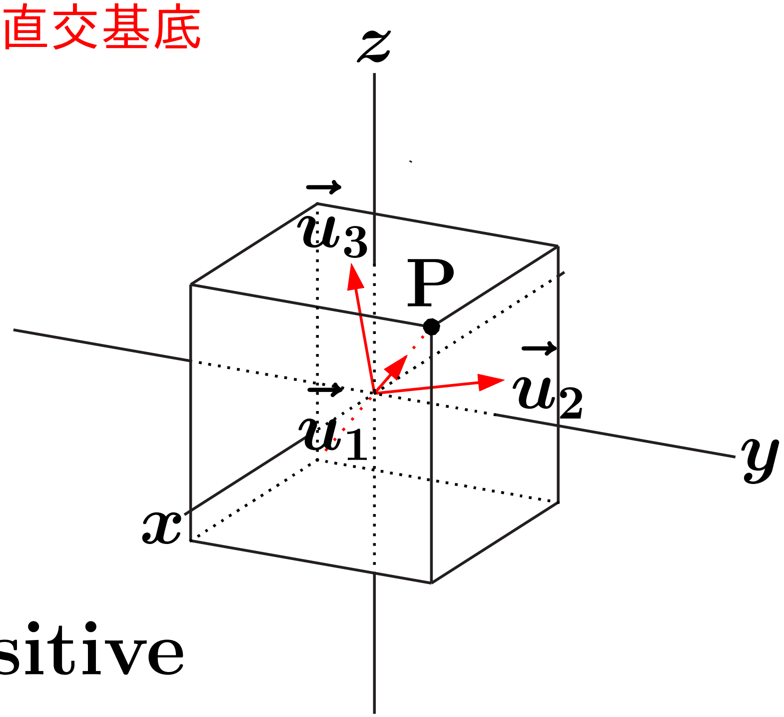

Orthogonal Transformation

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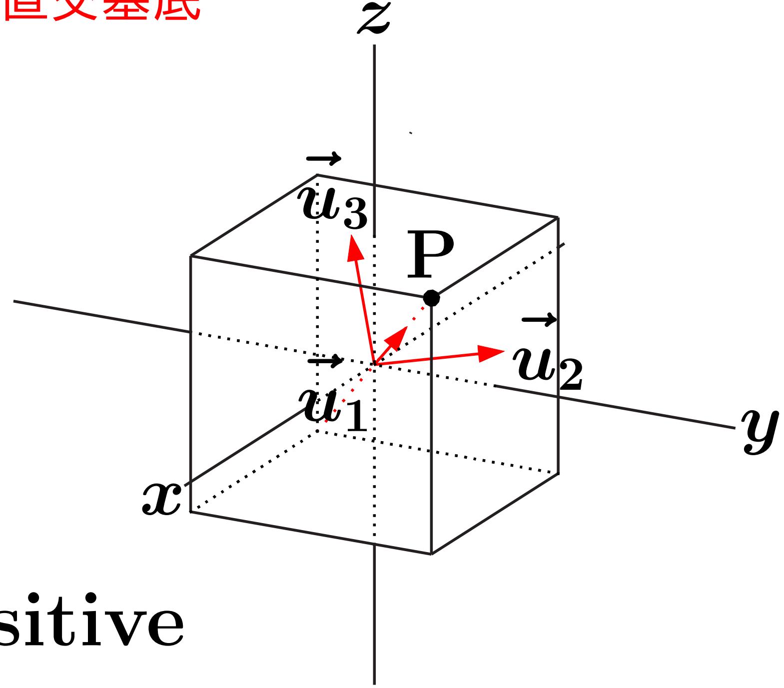
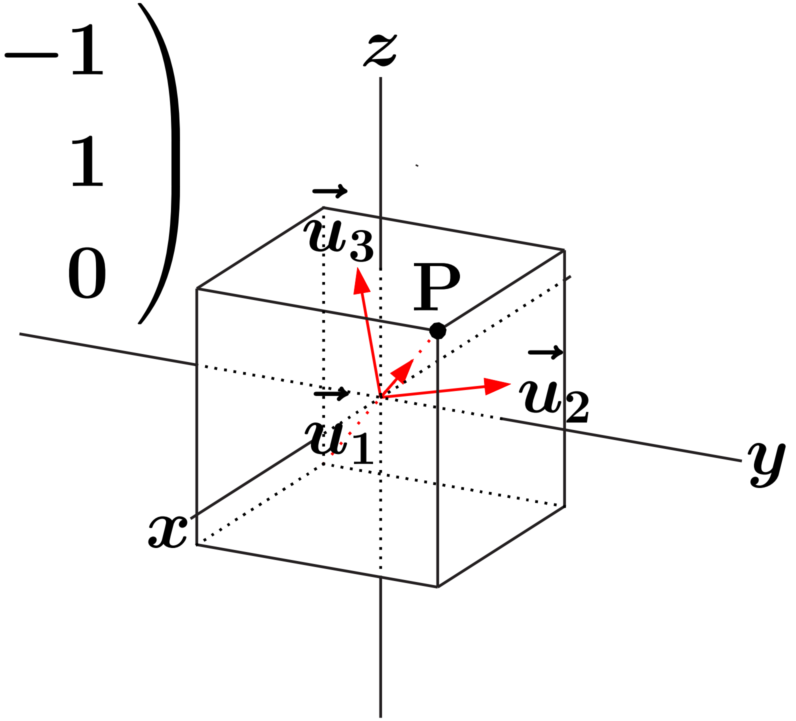


→ 3D viewer

Orthogonal Transformation

From $\vec{u}_1 \cdot \vec{u}_2 = 0$

$$\vec{u}_1 = \frac{1}{\sqrt{3}} \begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \quad \vec{u}_2 = \frac{1}{\sqrt{2}} \begin{pmatrix} -1 \\ 1 \\ 0 \end{pmatrix}$$



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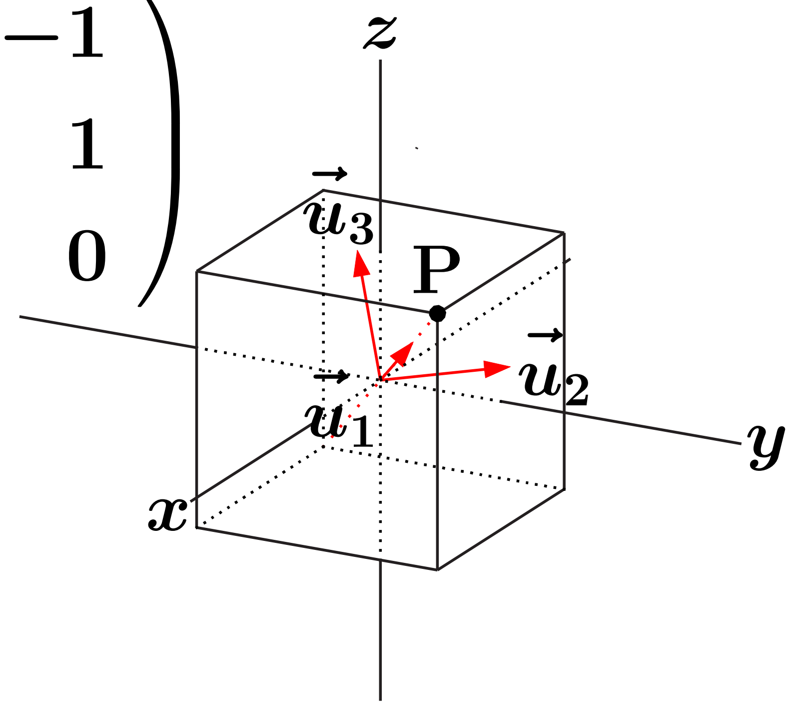


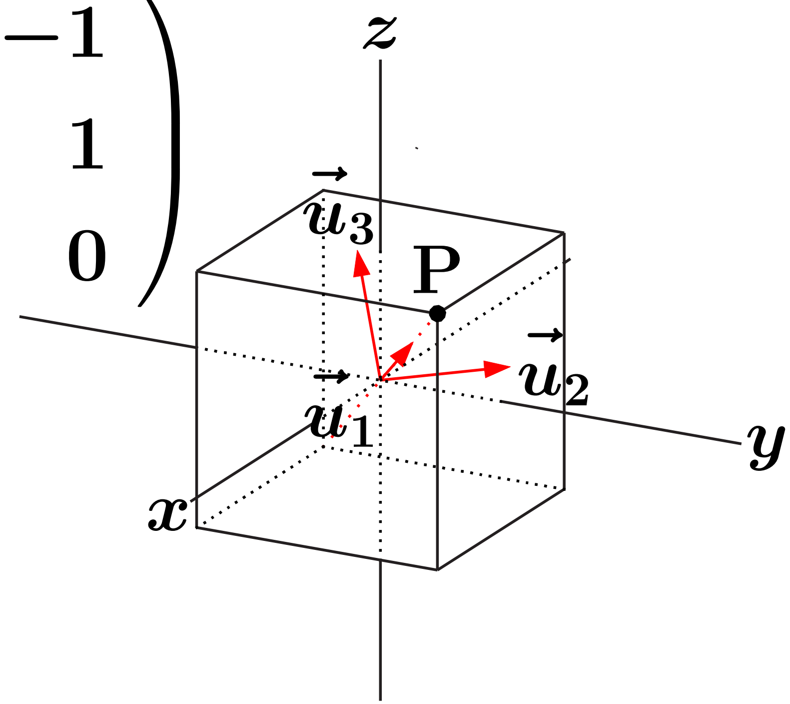
and, then

$$\vec{u}_3 = \vec{u}_1 \times \vec{u}_2$$

Orthogonal Transformation

From $\vec{u}_1 \cdot \vec{u}_2 = 0$

$$\vec{u}_1 = \frac{1}{\sqrt{3}}\begin{pmatrix} 1 \\ 1 \\ 1 \end{pmatrix}, \quad \vec{u}_2 = \frac{1}{\sqrt{2}}\begin{pmatrix} -1 \\ 1 \\ 0 \end{pmatrix}$$



and, then

$$\vec{u}_3 = \vec{u}_1 \times \vec{u}_2$$

→問 1

Orthogonal Transformation

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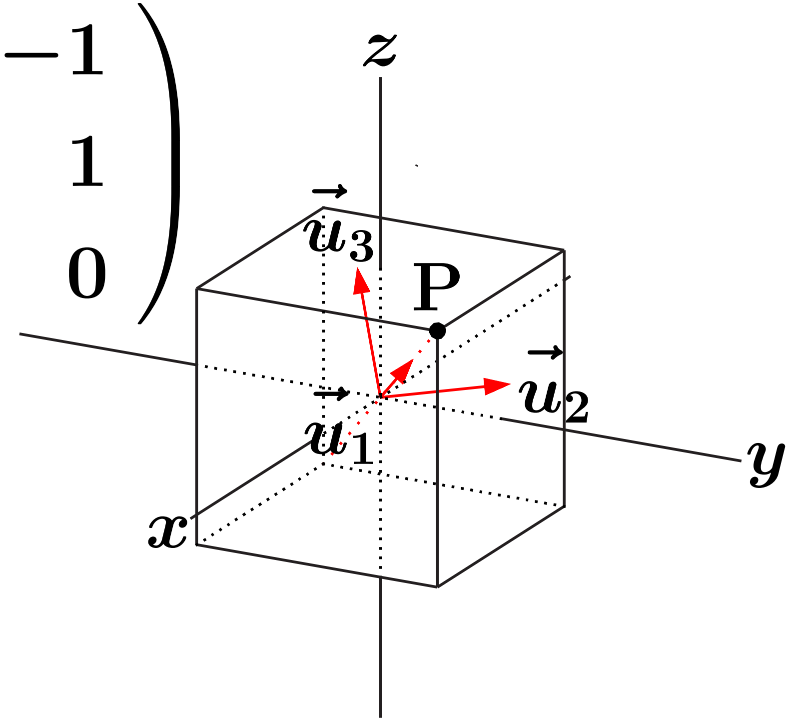


and, then

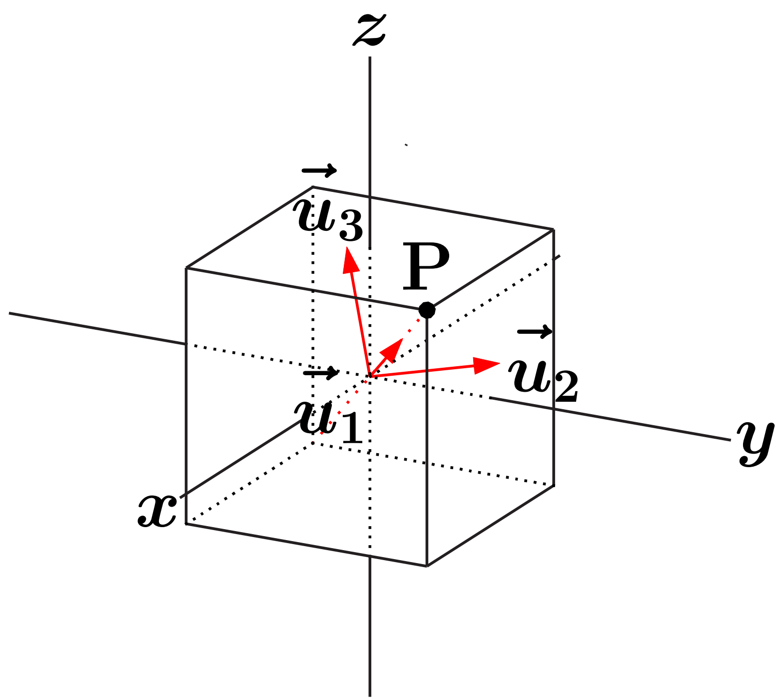
$$\vec{u}_3 = \vec{u}_1 \times \vec{u}_2 = \frac{1}{\sqrt{6}}\begin{pmatrix} -1 \\ -1 \\ 2 \end{pmatrix}$$

→問 1

Orthogonal Transformation

Put $T = \begin{pmatrix} \vec{u}_1 & \vec{u}_2 & \vec{u}_3 \end{pmatrix}$

$$= \begin{pmatrix} \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{6}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{6}} \\ \frac{1}{\sqrt{3}} & 0 & \frac{2}{\sqrt{6}} \end{pmatrix}.$$



Orthogonal Transformation

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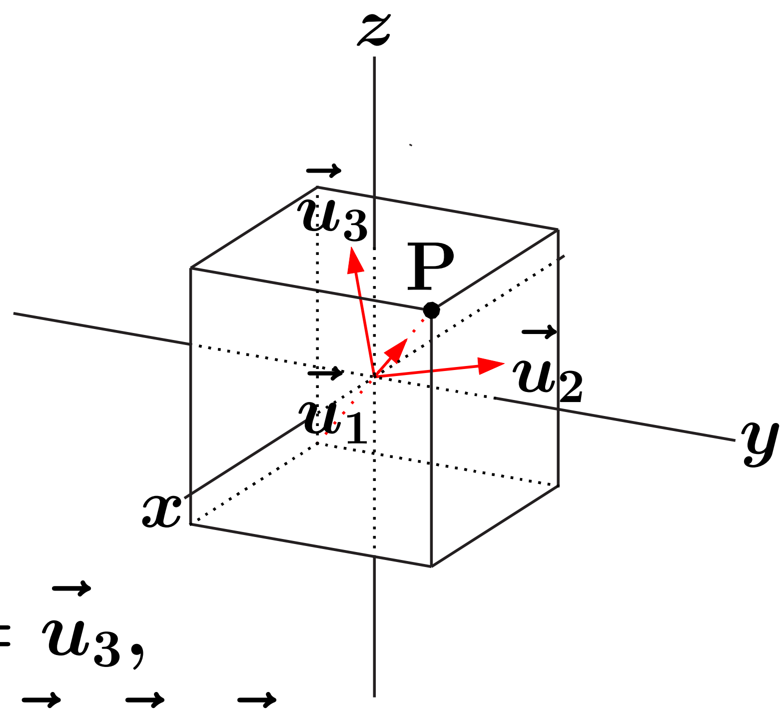

Then $T\vec{i} = \vec{u}_1,\ T\vec{j} = \vec{u}_2,\ T\vec{k} = \vec{u}_3,$

for the fundamental vectors $\vec{i},\ \vec{j},\ \vec{k}.$

Orthogonal Transformation

Put $T = \begin{pmatrix} \vec{u}_1 & \vec{u}_2 & \vec{u}_3 \end{pmatrix}$

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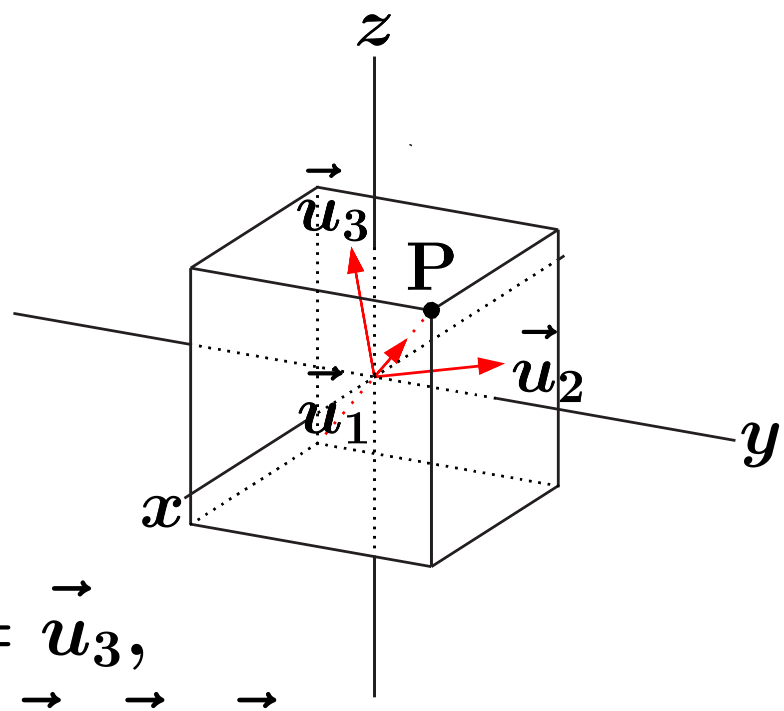

Then $T\vec{i} = \vec{u}_1,\ T\vec{j} = \vec{u}_2,\ T\vec{k} = \vec{u}_3,$

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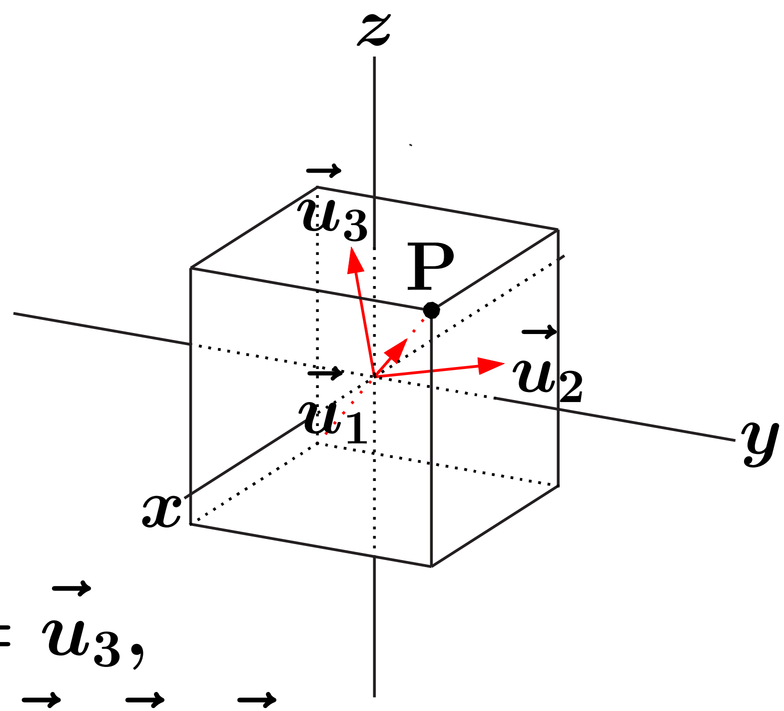
基本ベクトル... 座標軸に平行（正の向き）で大きさ 1 のベクトル

Orthogonal Transformation

Put $T = \begin{pmatrix} \vec{u}_1 & \vec{u}_2 & \vec{u}_3 \end{pmatrix}$

$$= \begin{pmatrix} \frac{1}{\sqrt{3}} & -\frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{6}} \\ \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{2}} & -\frac{1}{\sqrt{6}} \\ \frac{1}{\sqrt{3}} & 0 & \frac{2}{\sqrt{6}} \end{pmatrix}.$$



Then $T\vec{i} = \vec{u}_1$, $T\vec{j} = \vec{u}_2$, $T\vec{k} = \vec{u}_3$,

for the fundamental vectors $\vec{i}$, $\vec{j}$, $\vec{k}$.

基本ベクトル... 座標軸に平行（正の向き）で大きさ 1 のベクトル

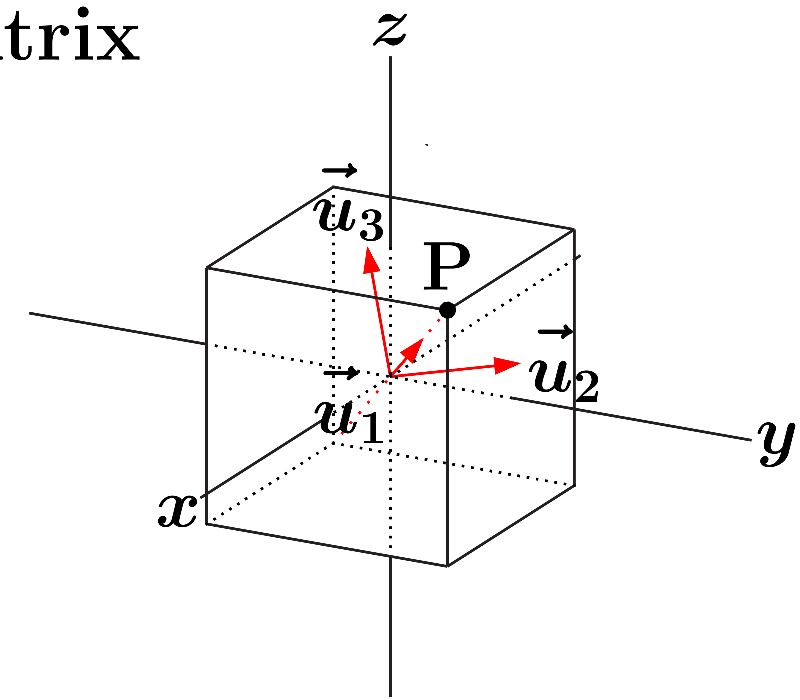
→問 2

Orthogonal Transformation

Since ${}^t T\vec{u}_1 = \vec{i},\ {}^t T\vec{u}_2 = \vec{j},\ {}^t T\vec{u}_3 = \vec{k},$

we can use the orthogonal matrix

$$ {}^t T = \begin{pmatrix} \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} & \frac{1}{\sqrt{3}} \\ -\frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & 0 \\ -\frac{1}{\sqrt{6}} & -\frac{1}{\sqrt{6}} & \frac{2}{\sqrt{6}} \end{pmatrix} $$

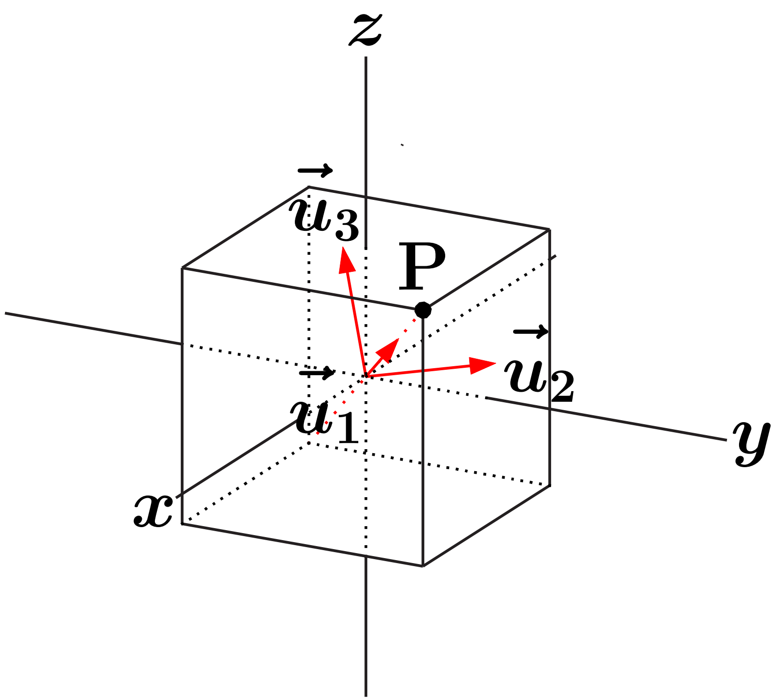


which represents f.

Orthogonal Transformation

$$\boldsymbol{T} = \begin{pmatrix} \vec{\boldsymbol{u}}_1 & \vec{\boldsymbol{u}}_2 & \vec{\boldsymbol{u}}_3 \end{pmatrix}$$

$$= \begin{pmatrix} \dfrac{1}{\sqrt{3}} & -\dfrac{1}{\sqrt{2}} & -\dfrac{1}{\sqrt{6}} \\ \dfrac{1}{\sqrt{3}} & \dfrac{1}{\sqrt{2}} & -\dfrac{1}{\sqrt{6}} \\ \dfrac{1}{\sqrt{3}} & 0 & \dfrac{2}{\sqrt{6}} \end{pmatrix}$$



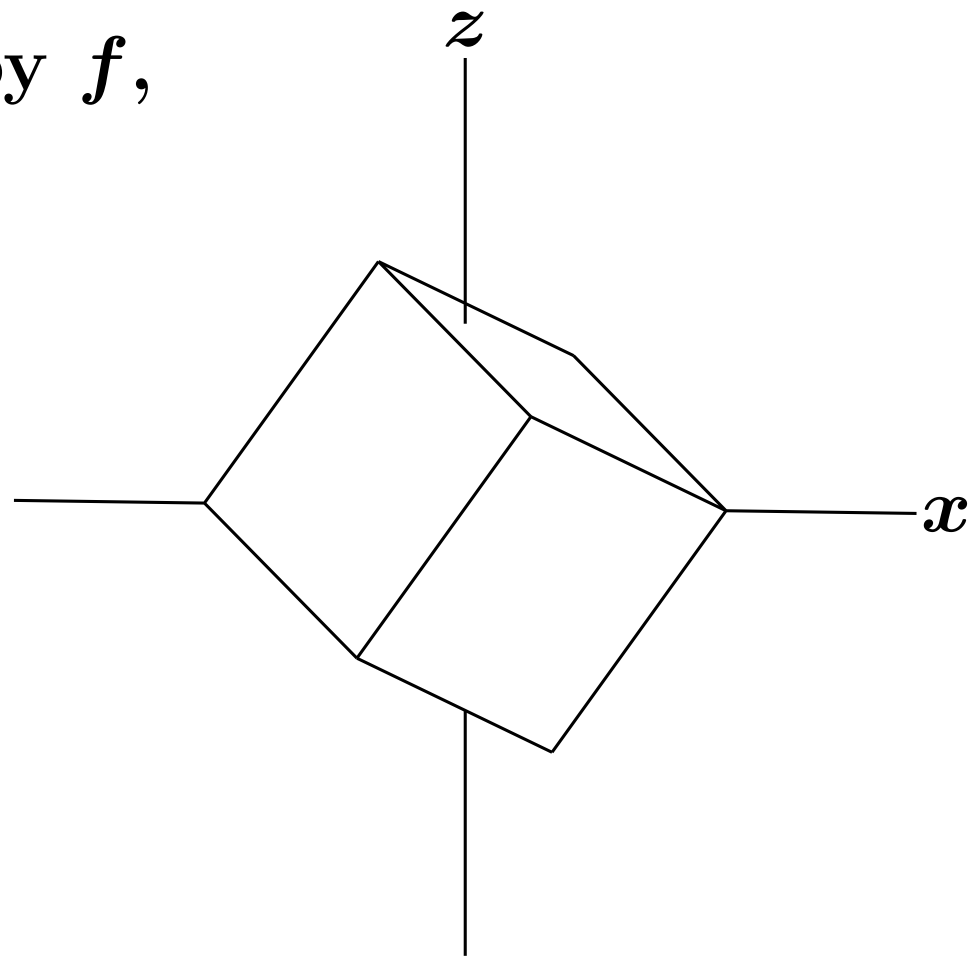
Equation of Hyperbora

Equation of Hyperbora

Each vertex transformed by f,

the cube is rotated

around the x-axis.



Equation of Hyperbora

Each vertex transformed by f,
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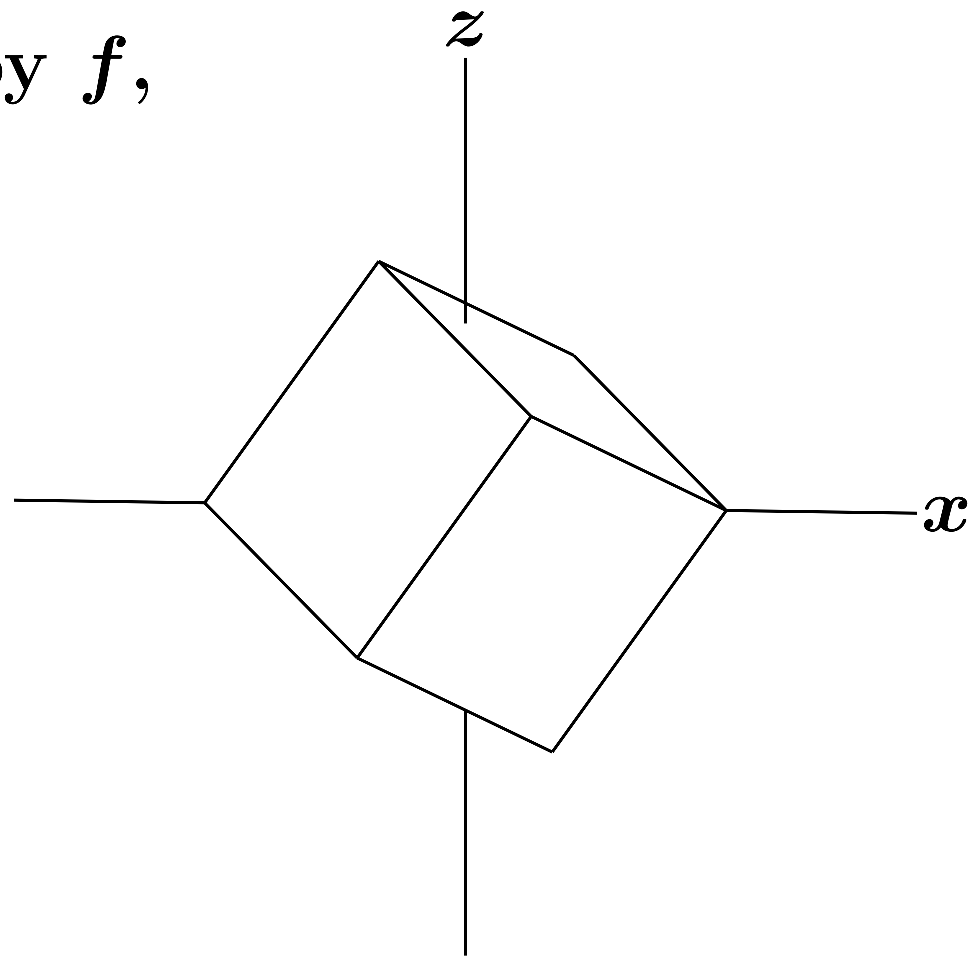
各頂点を f で移した立方体を
x 軸の周りに回転させる



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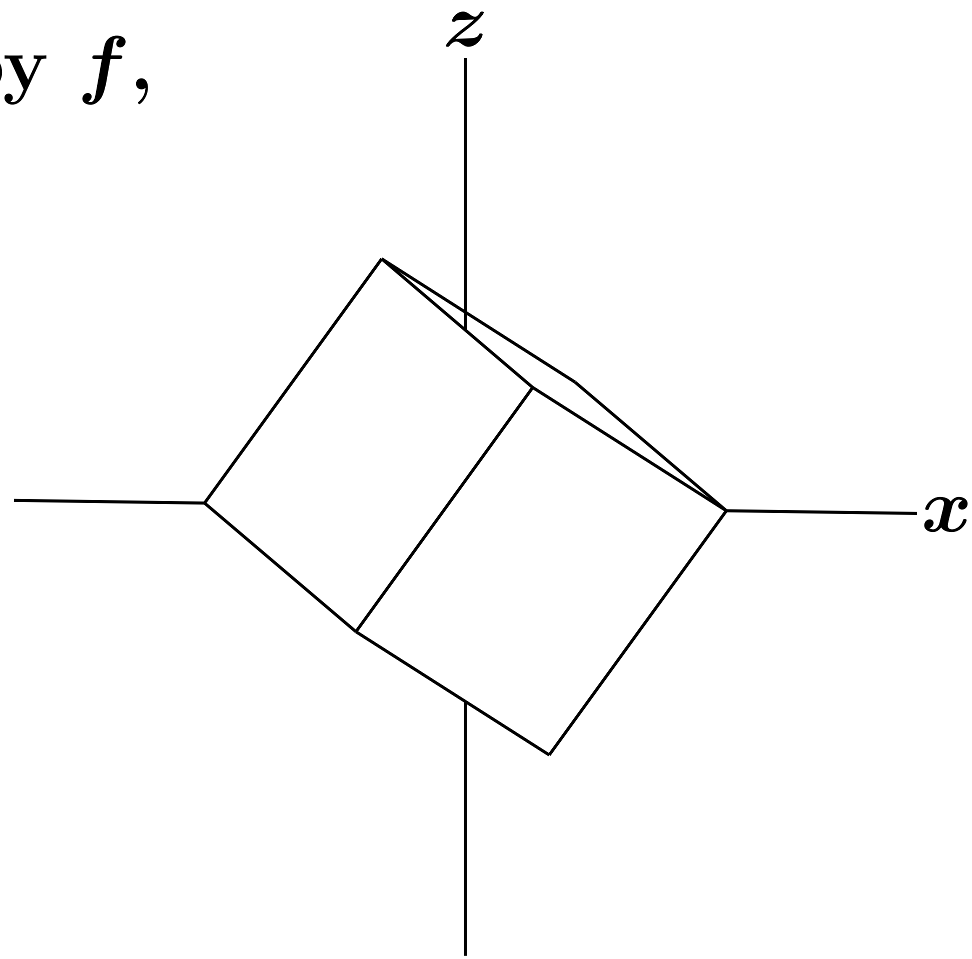

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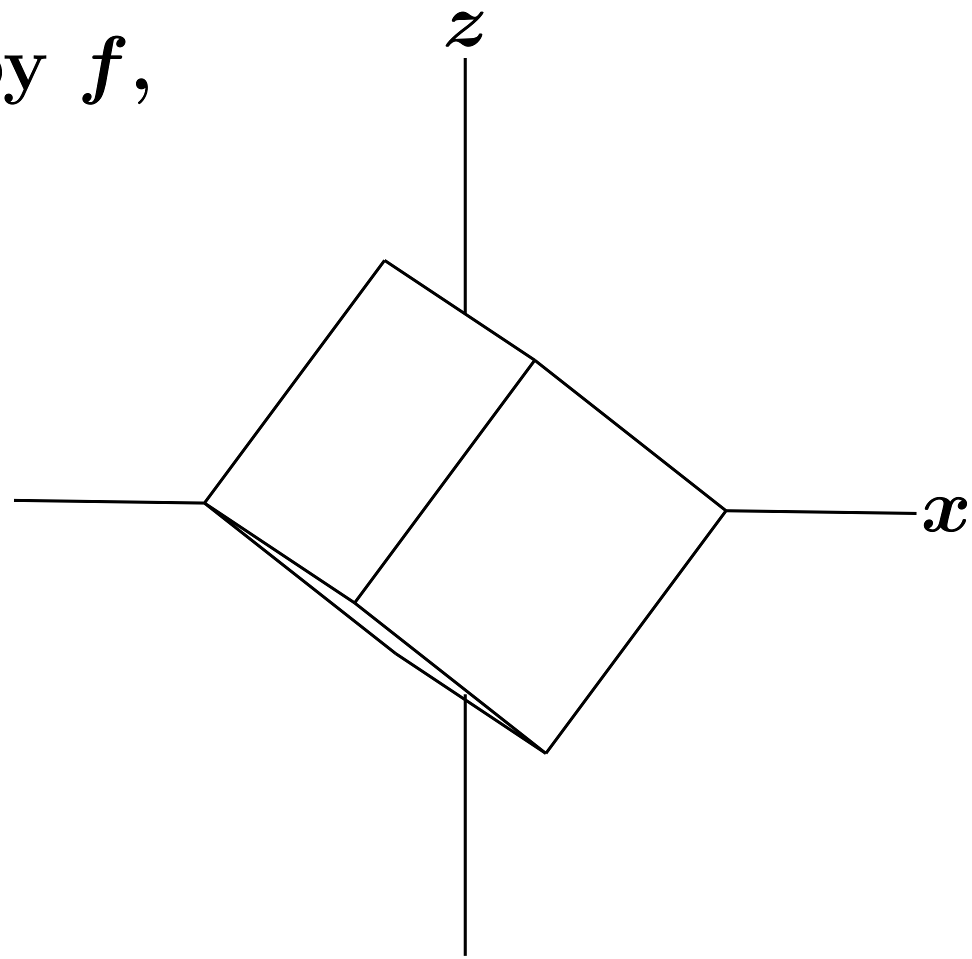

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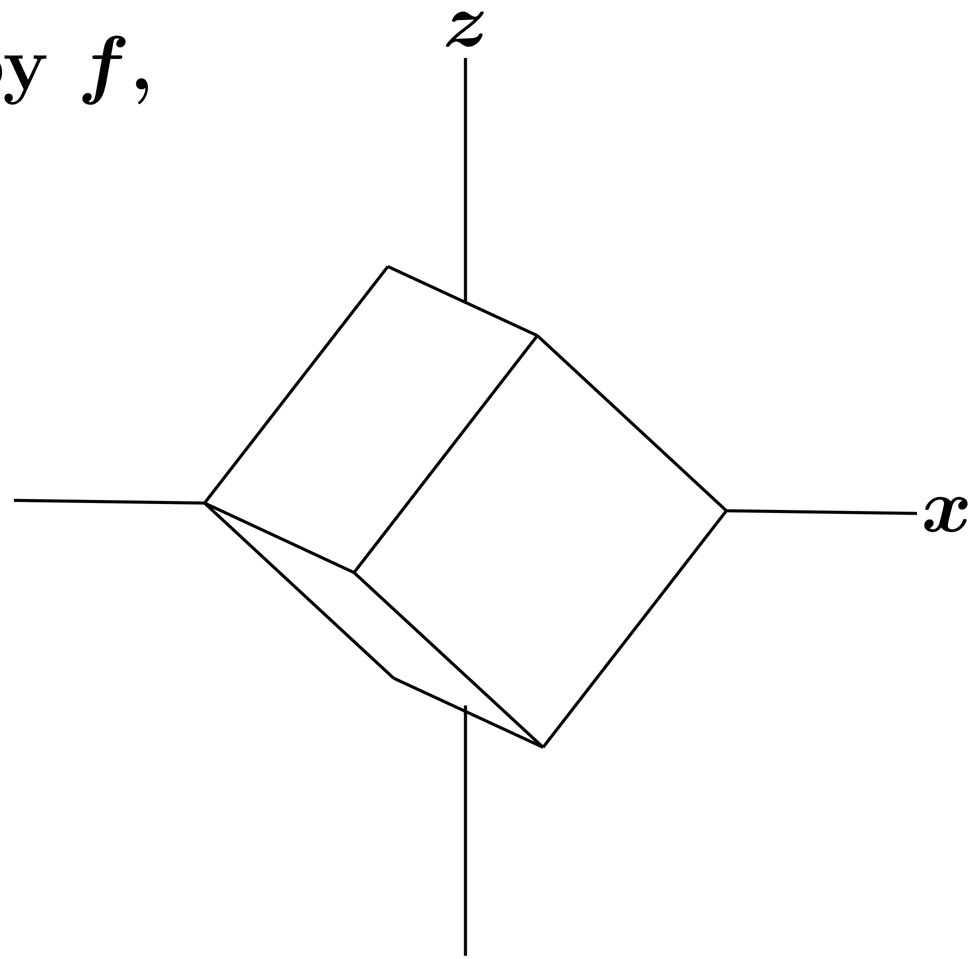

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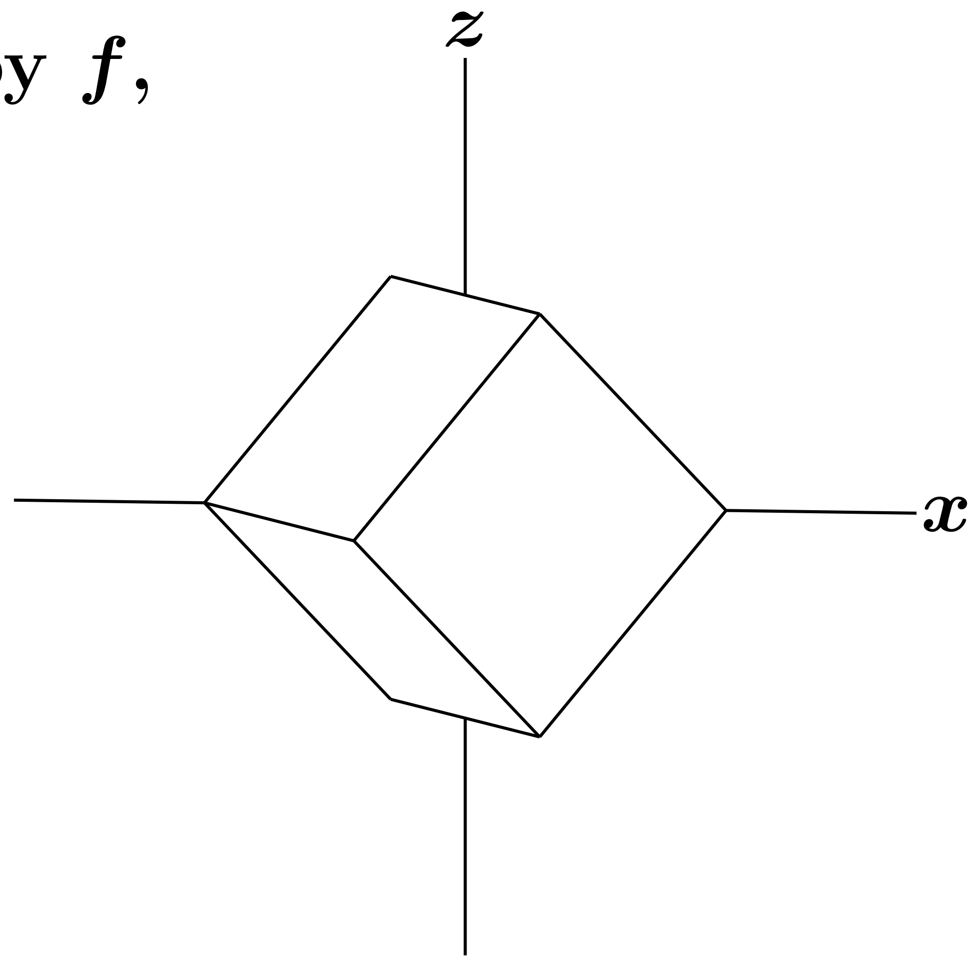

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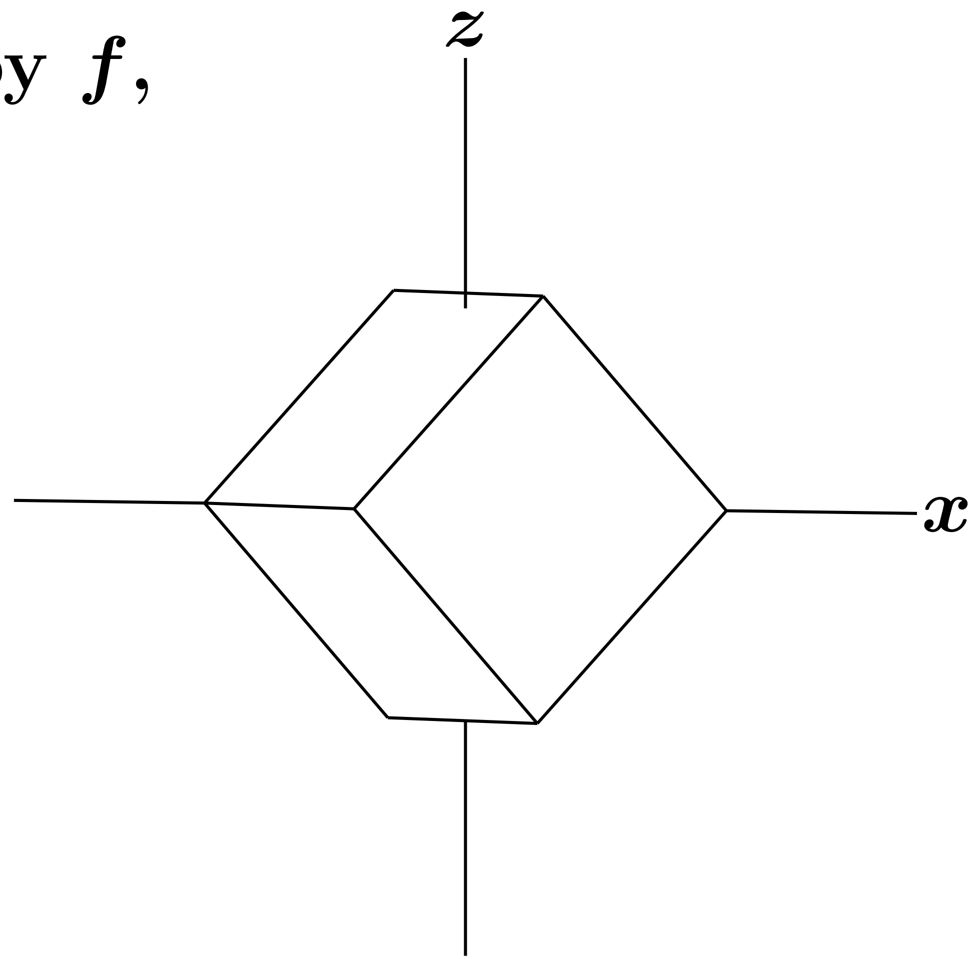

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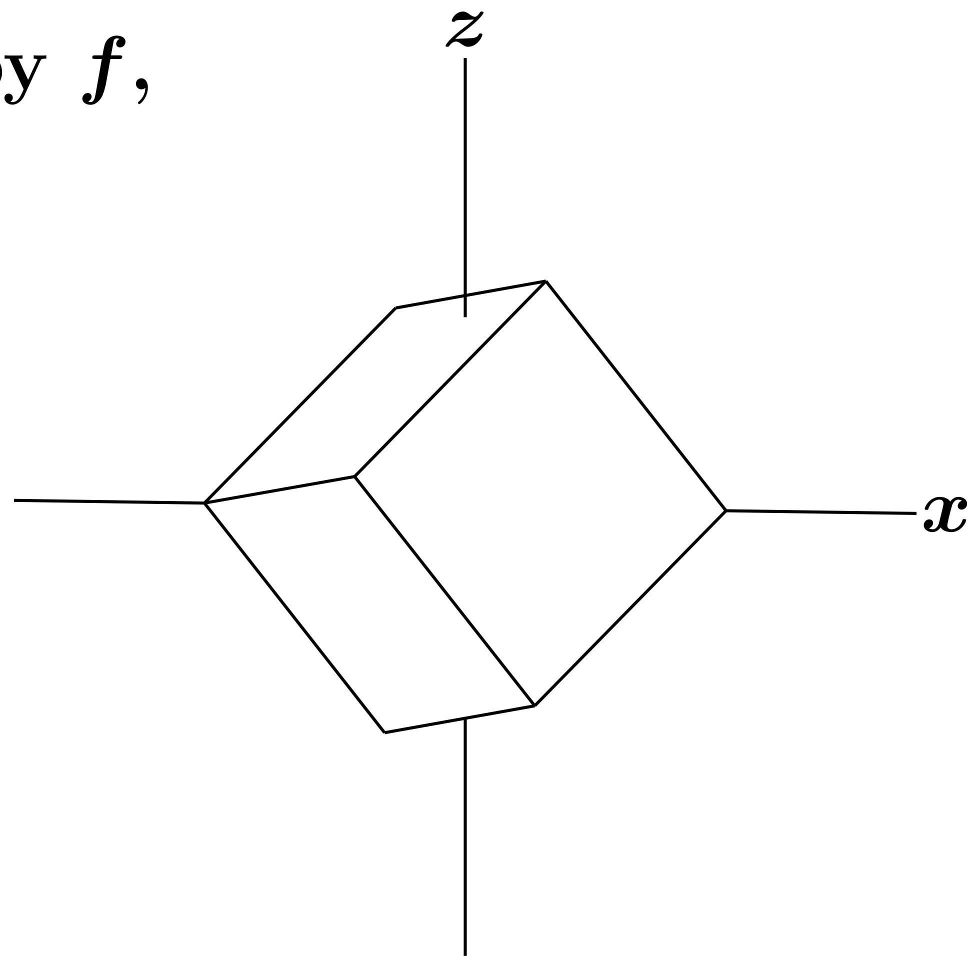

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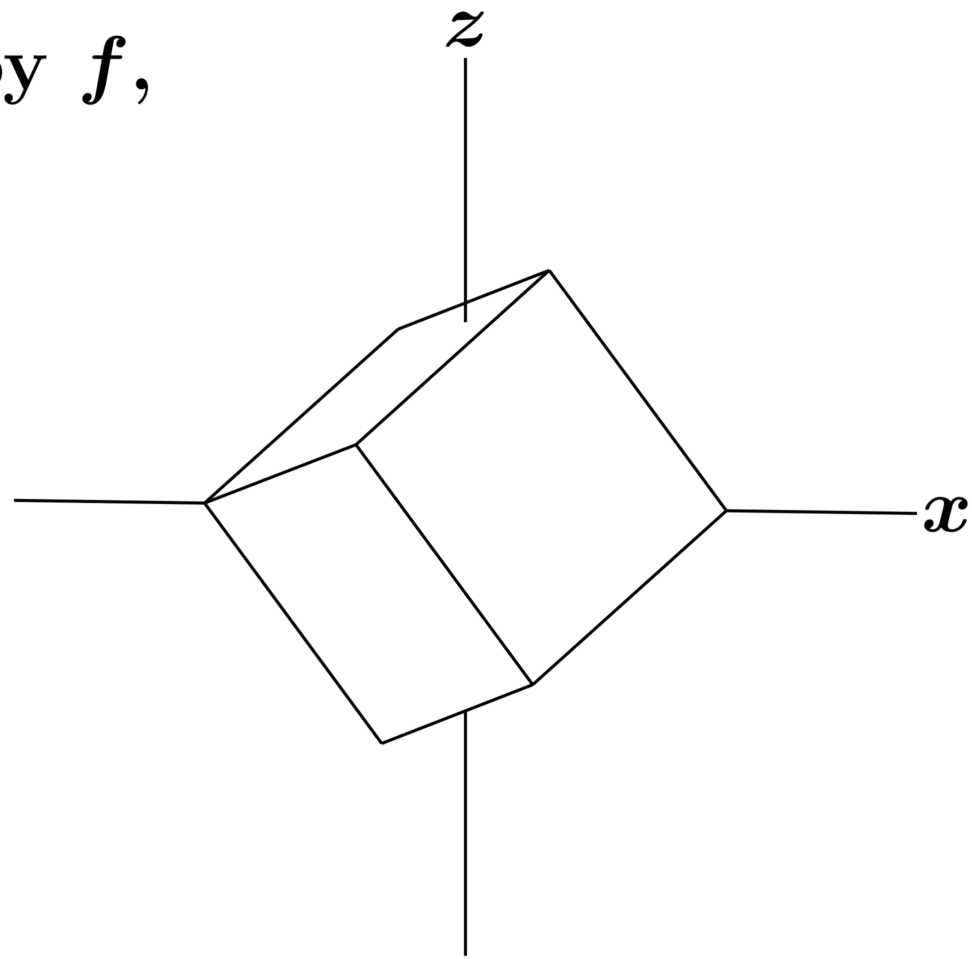

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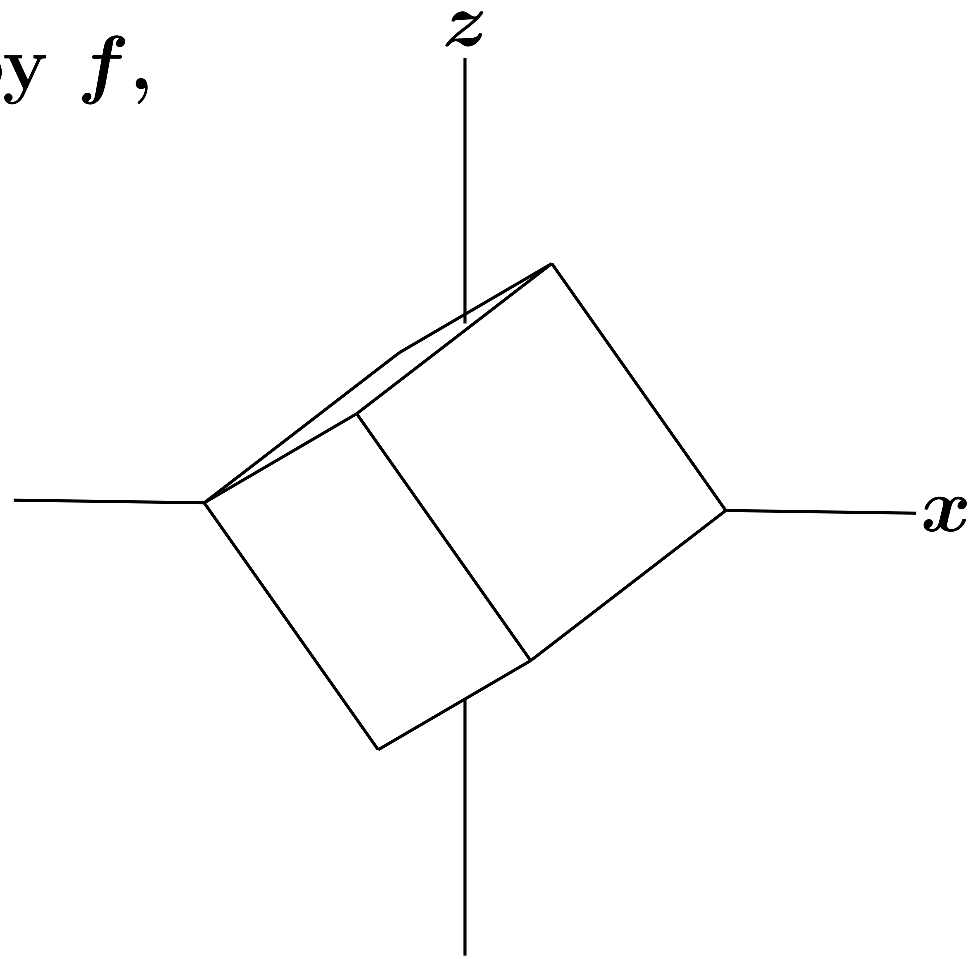

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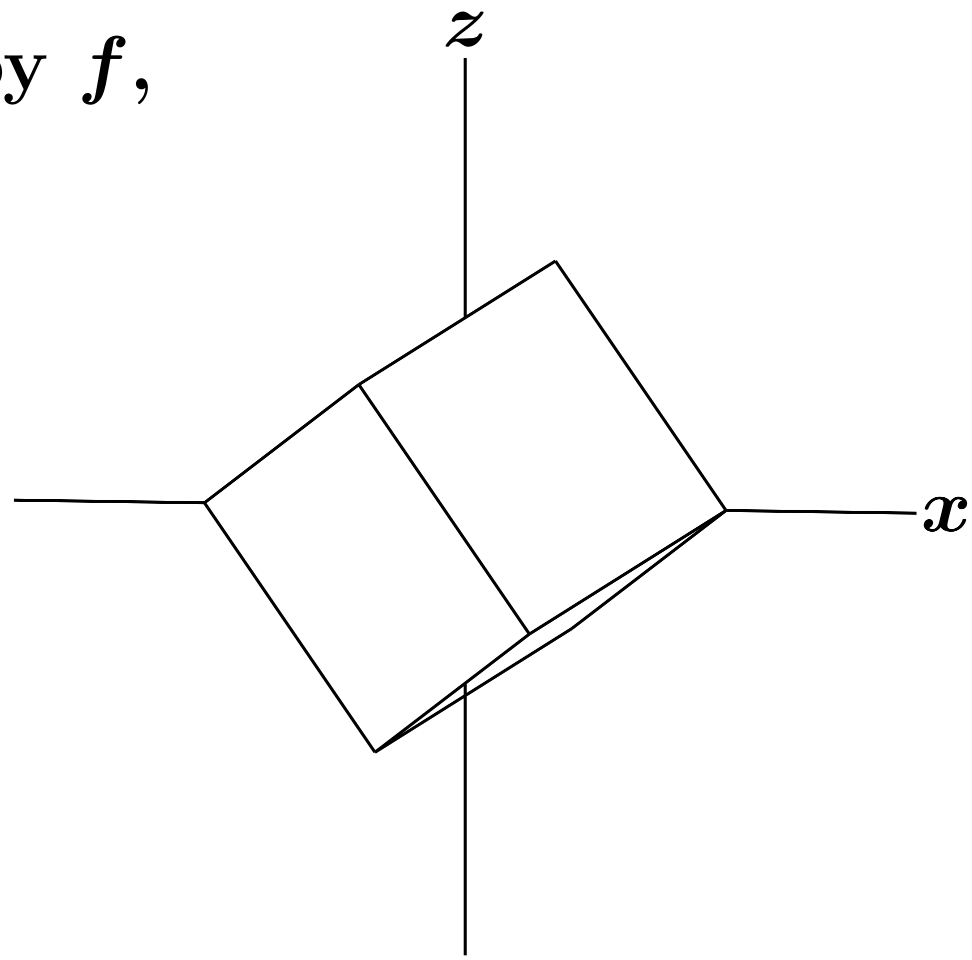

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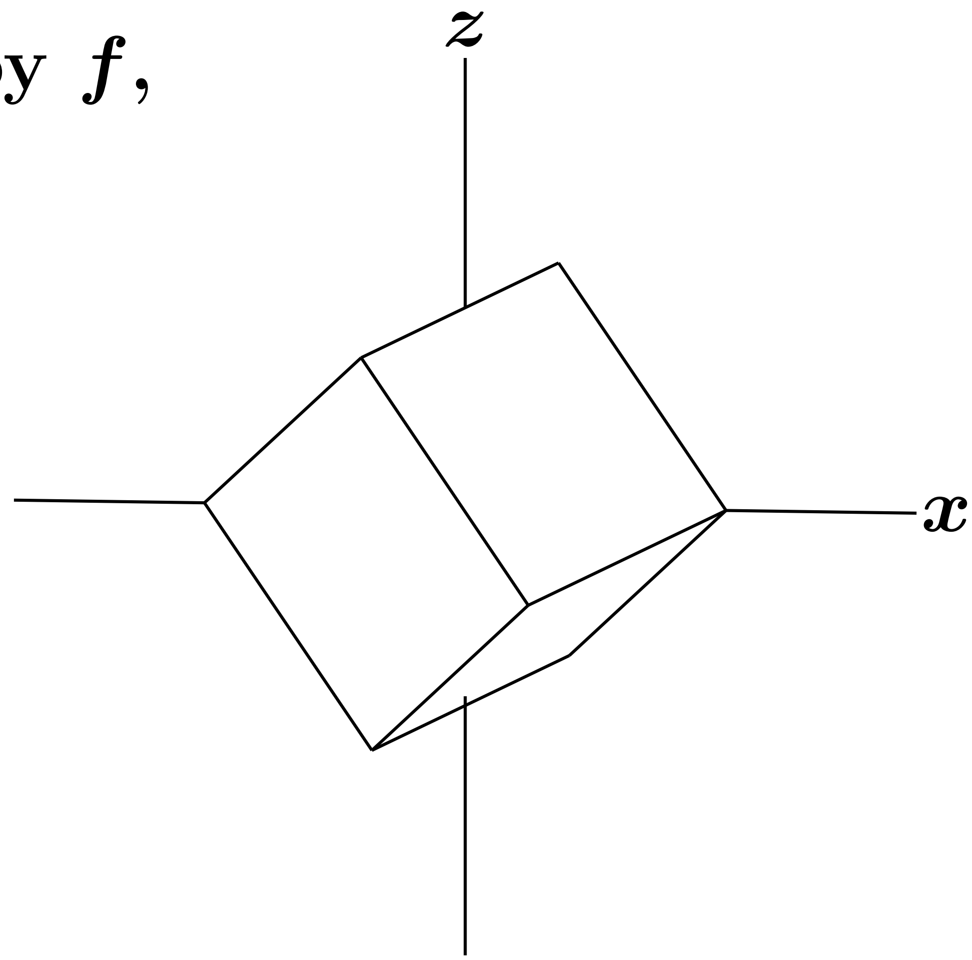

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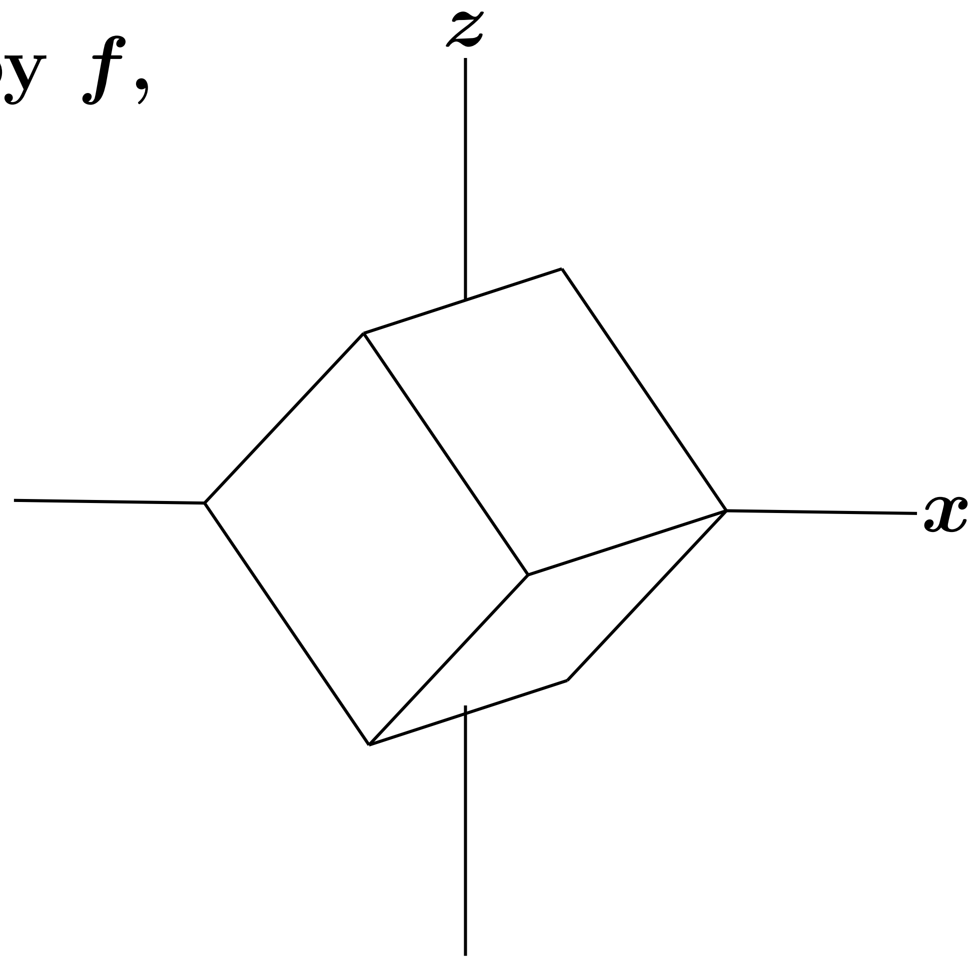

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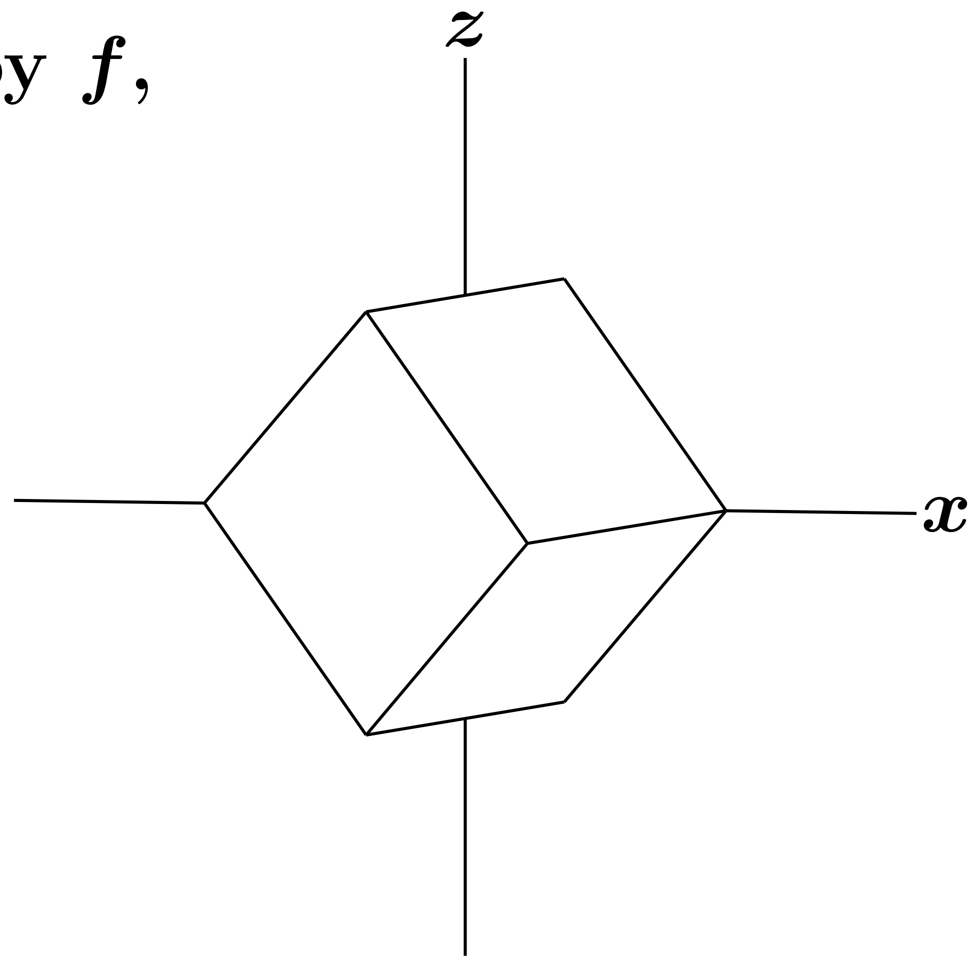

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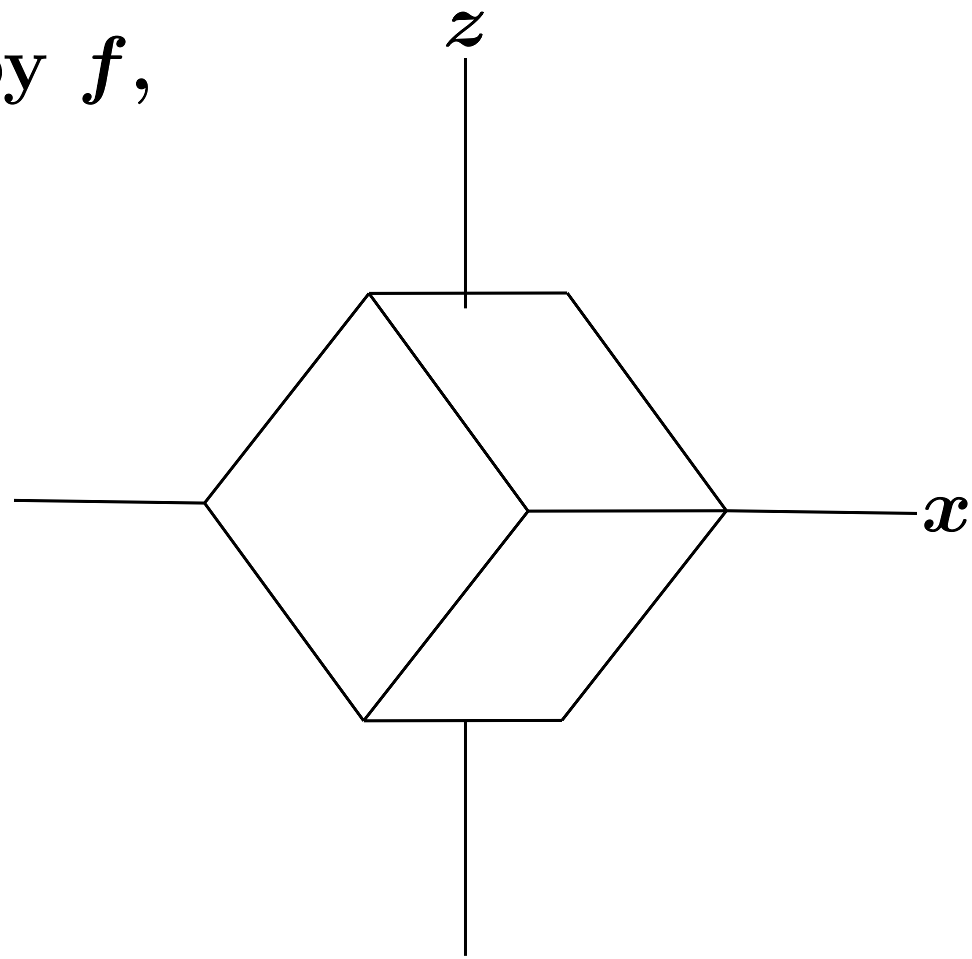

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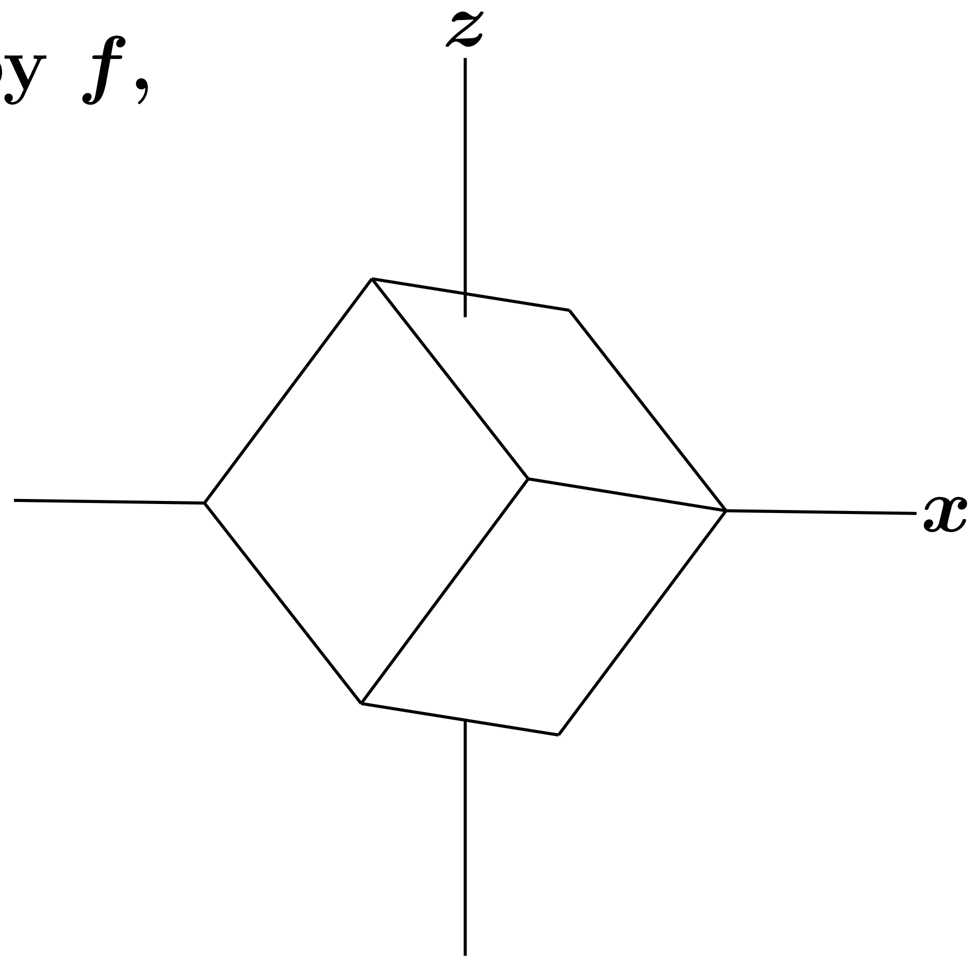
各頂点を f で移した立方体を
x 軸の周りに回転させる



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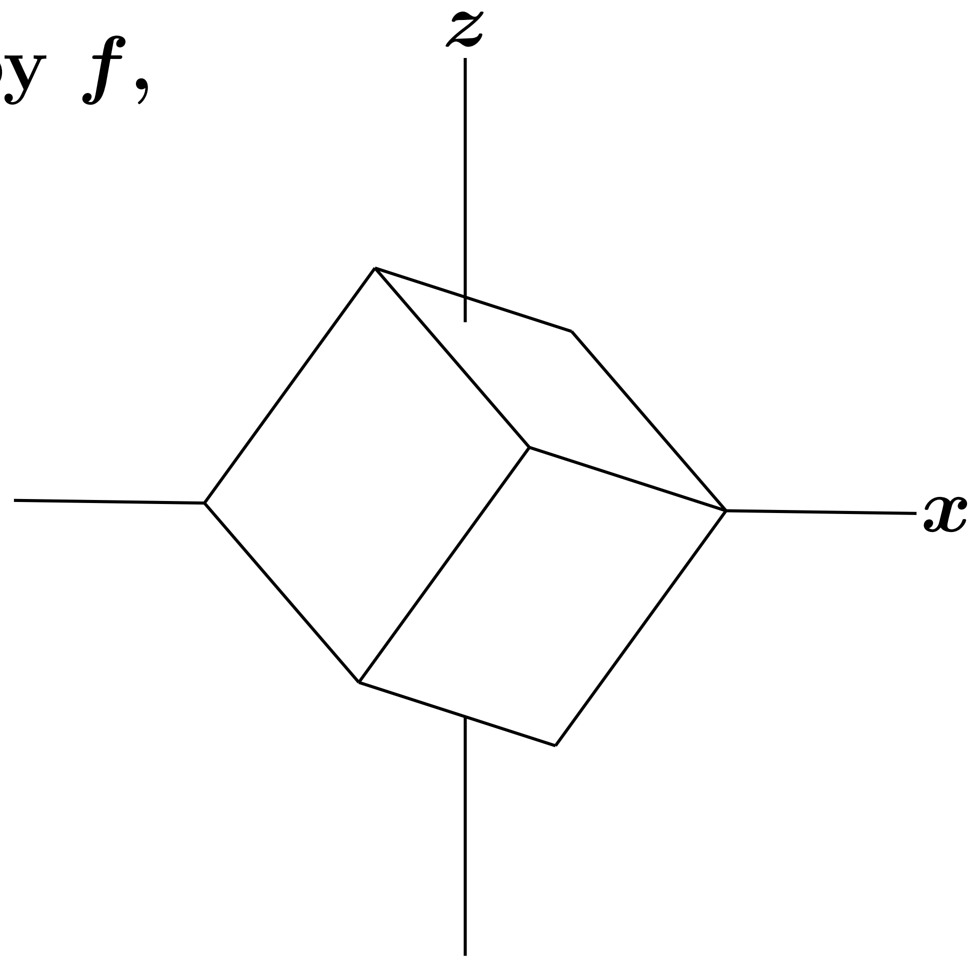

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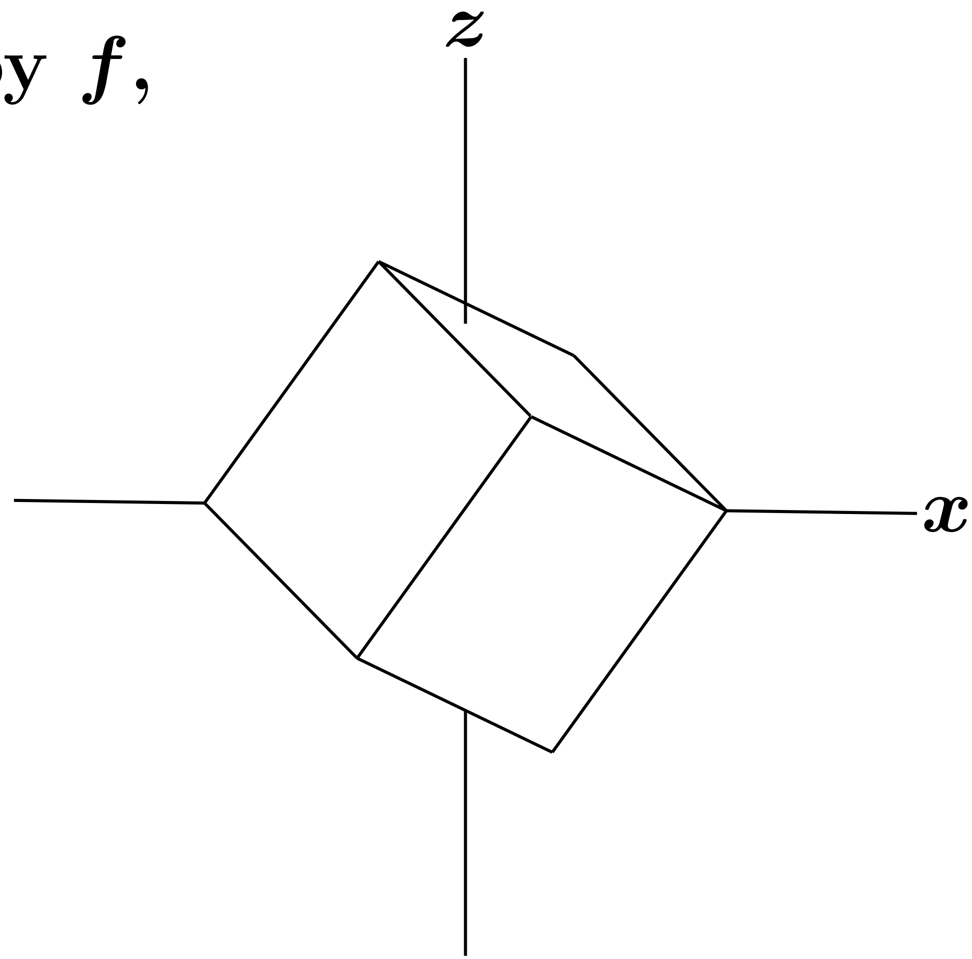

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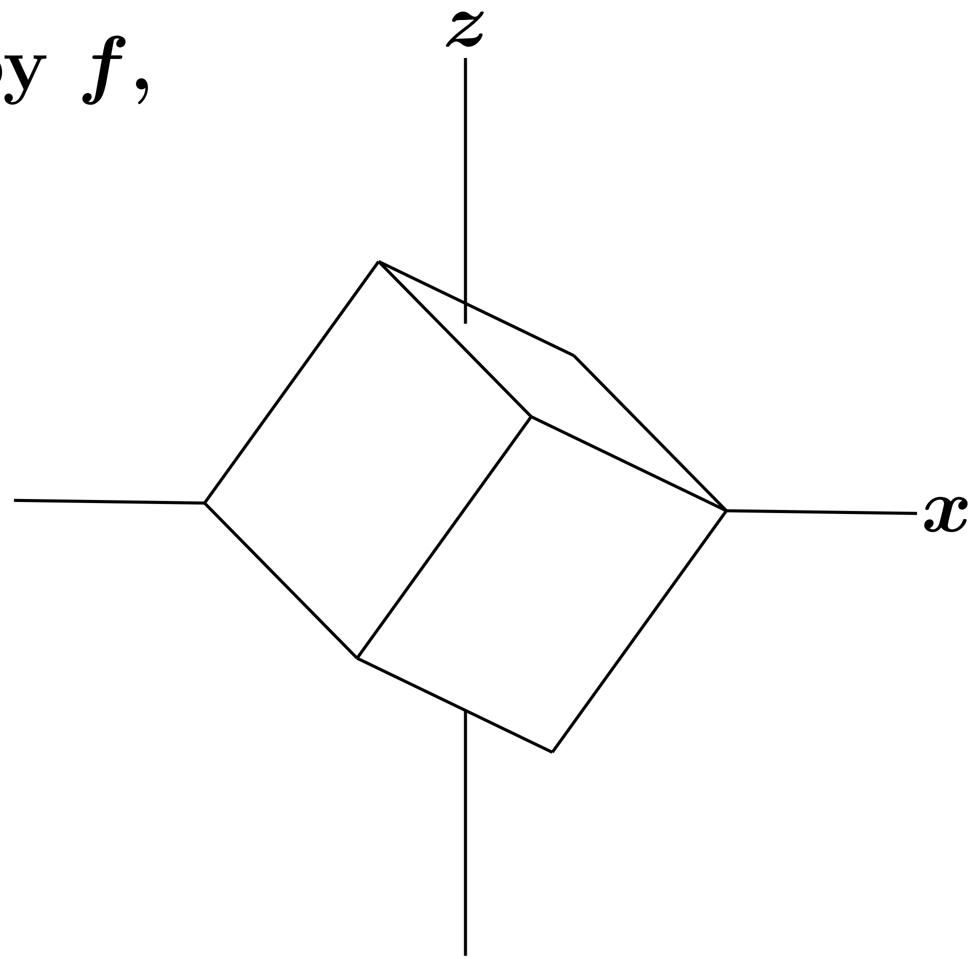

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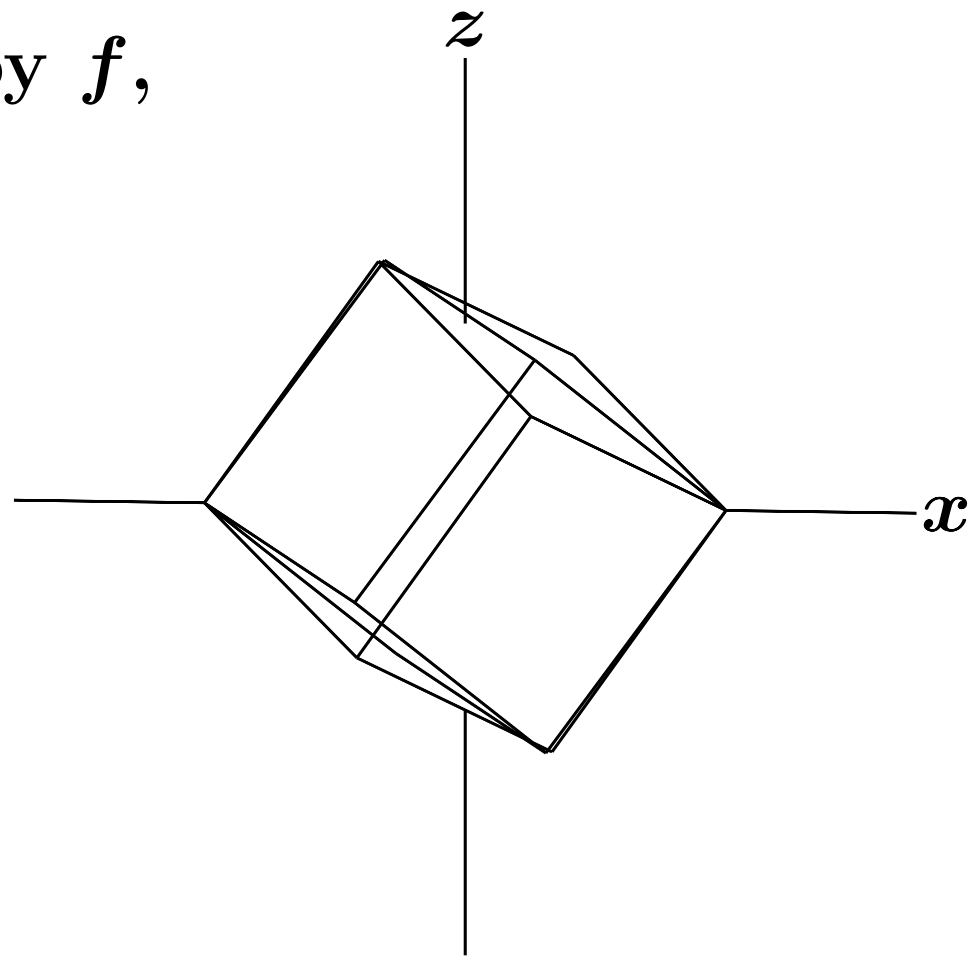

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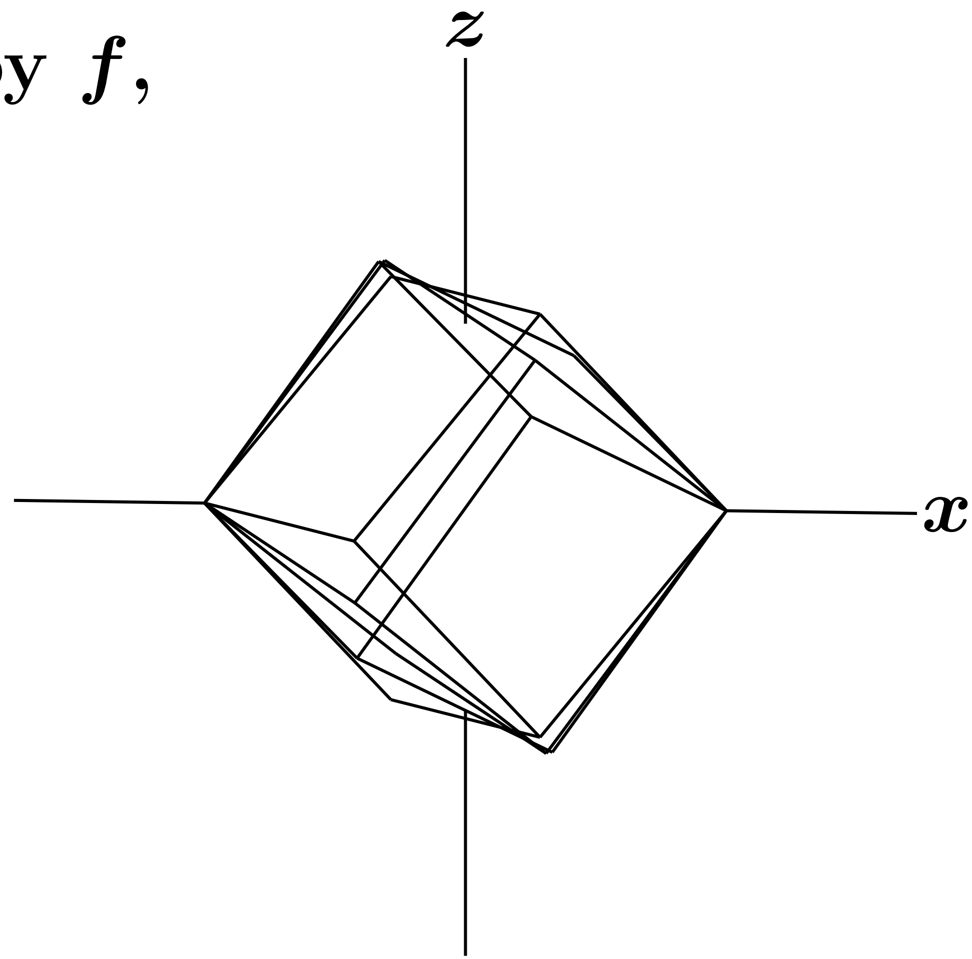

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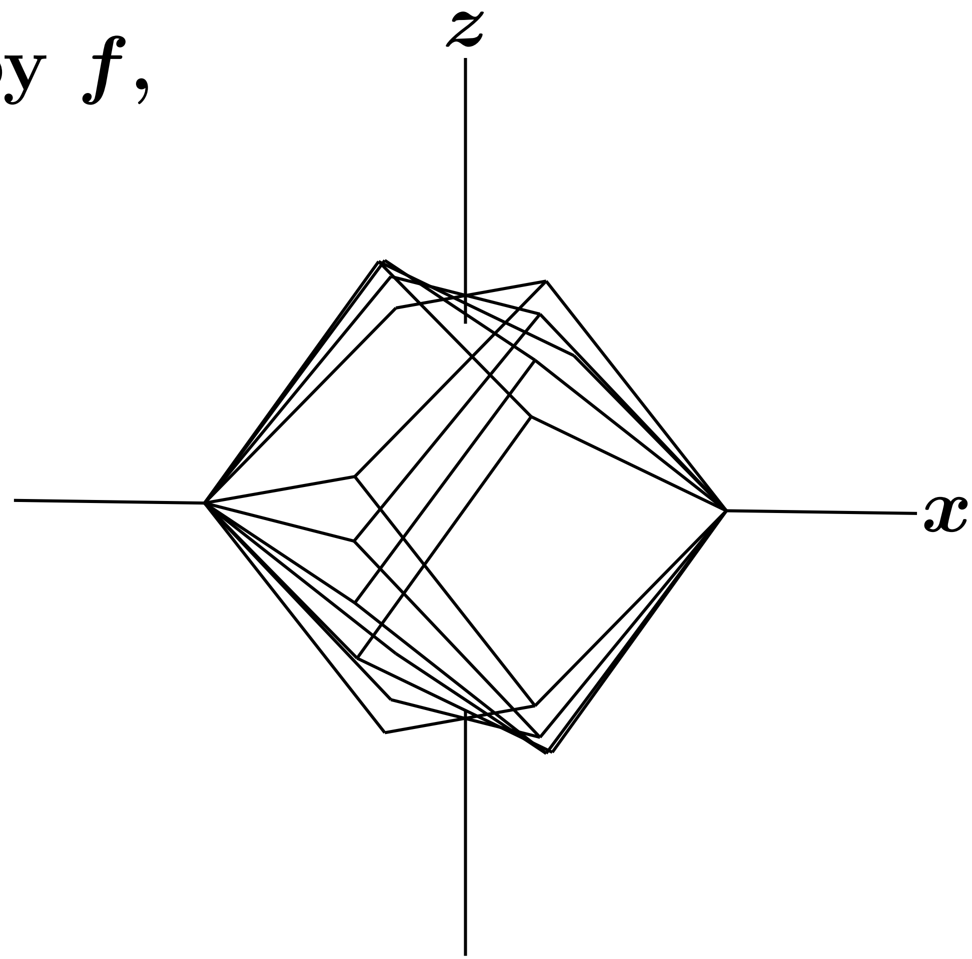

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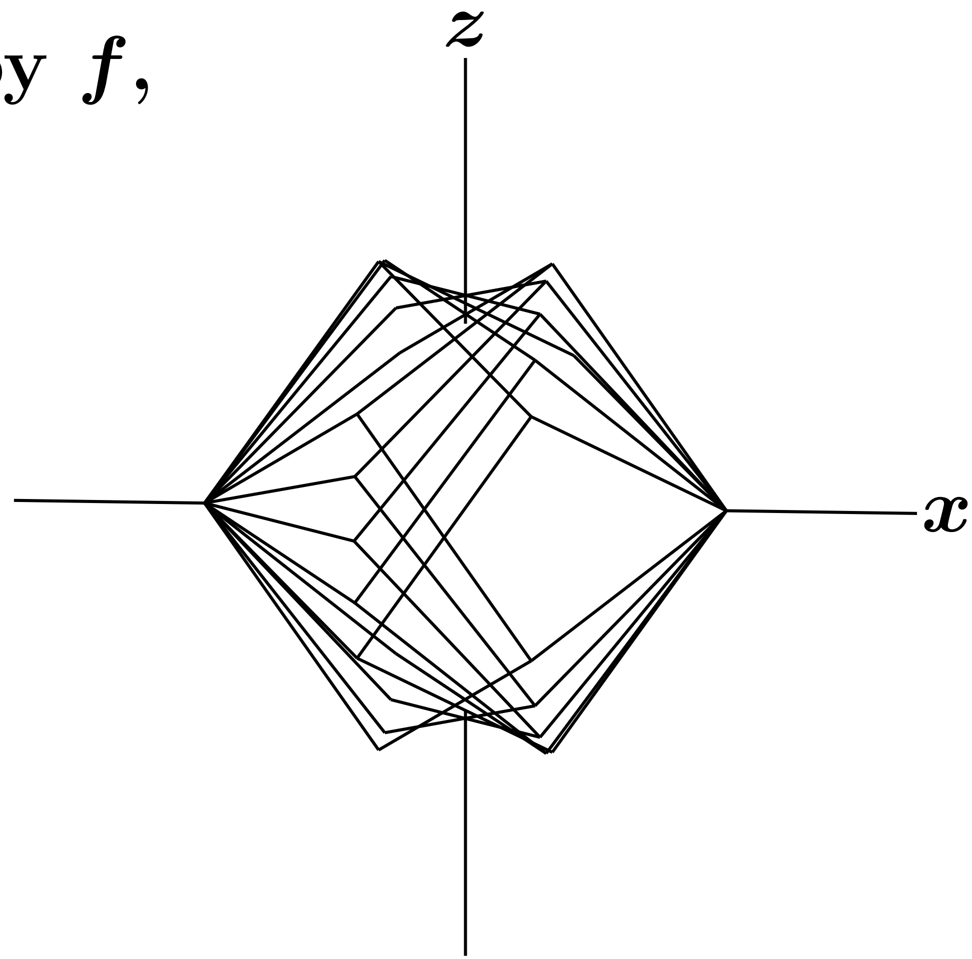

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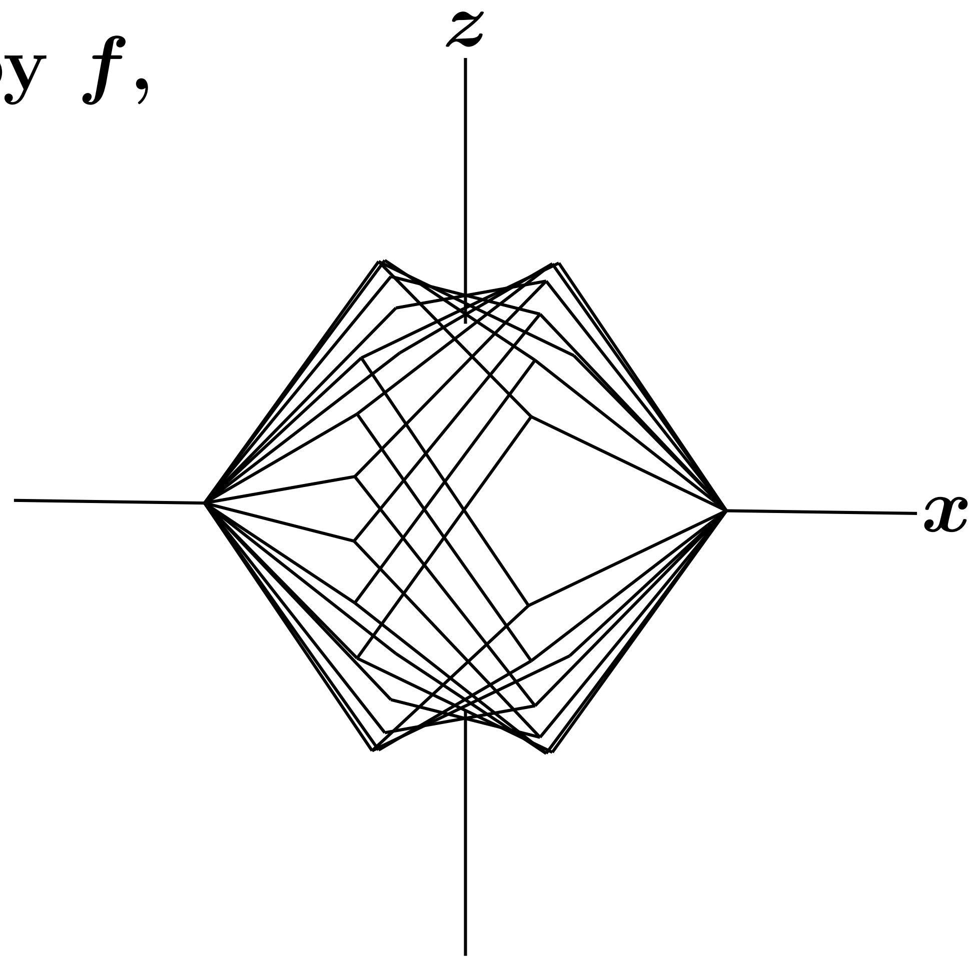

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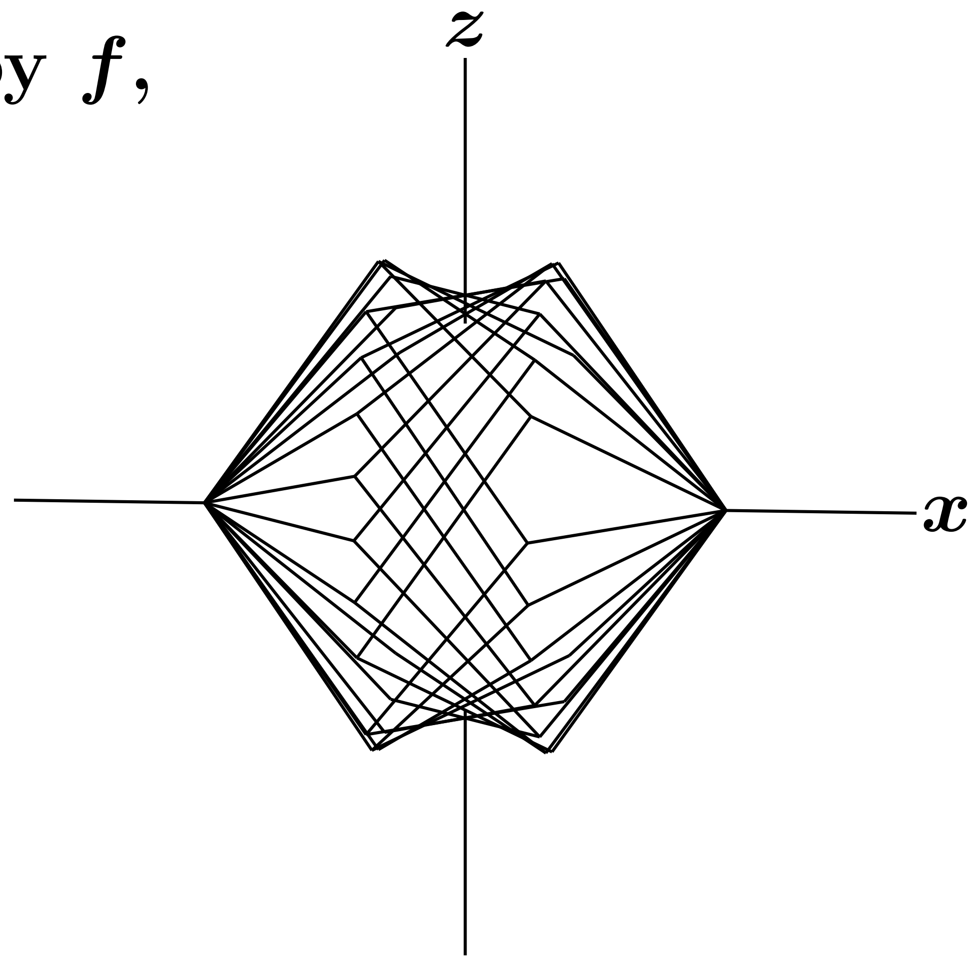

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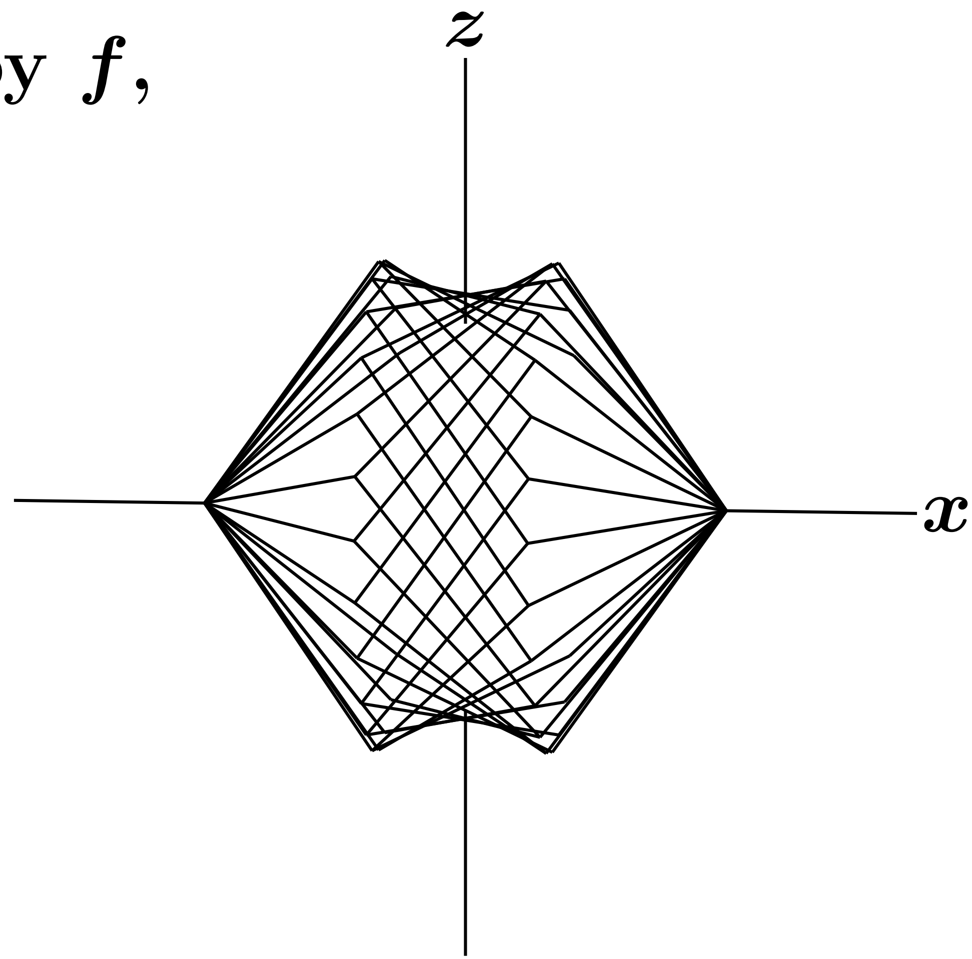

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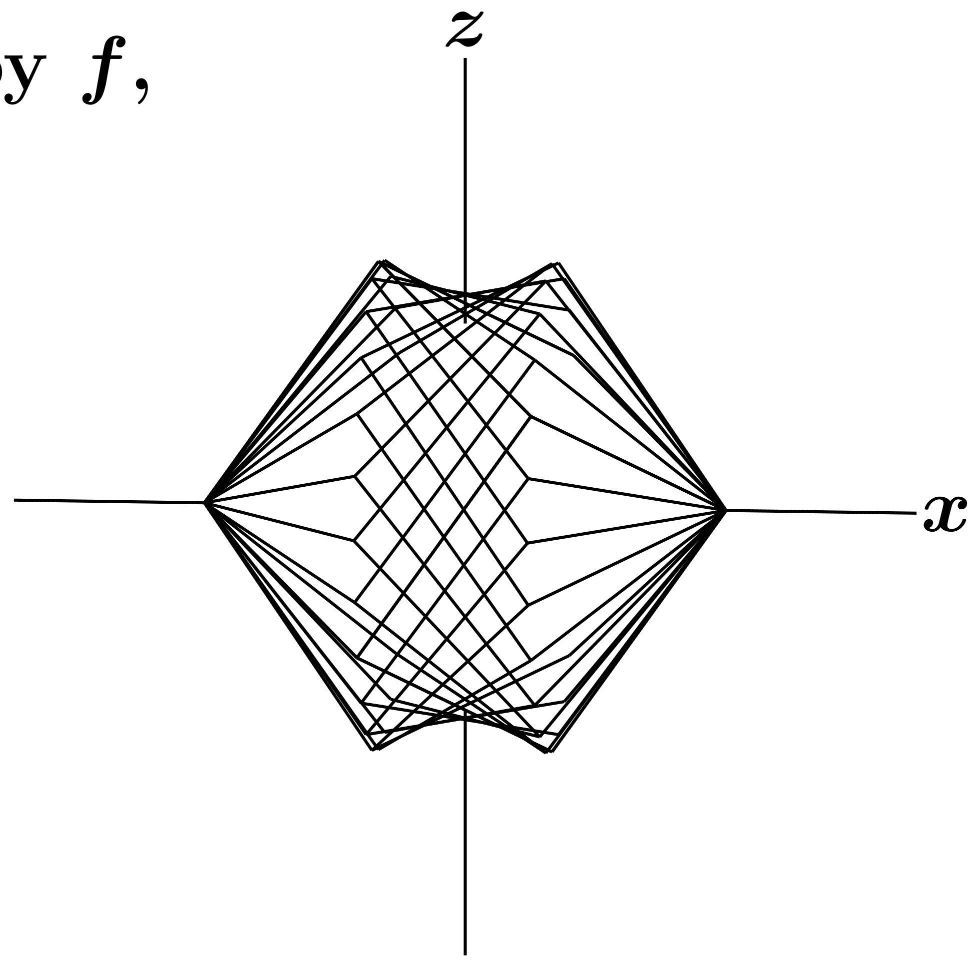

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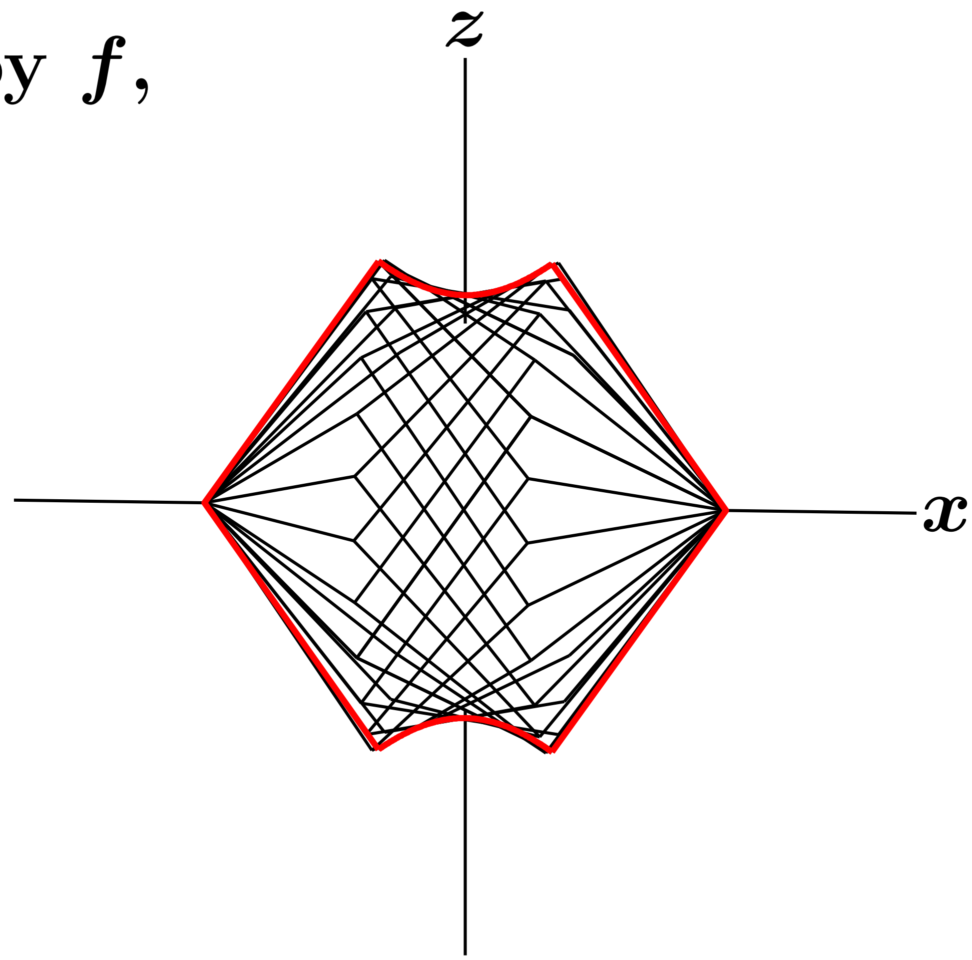

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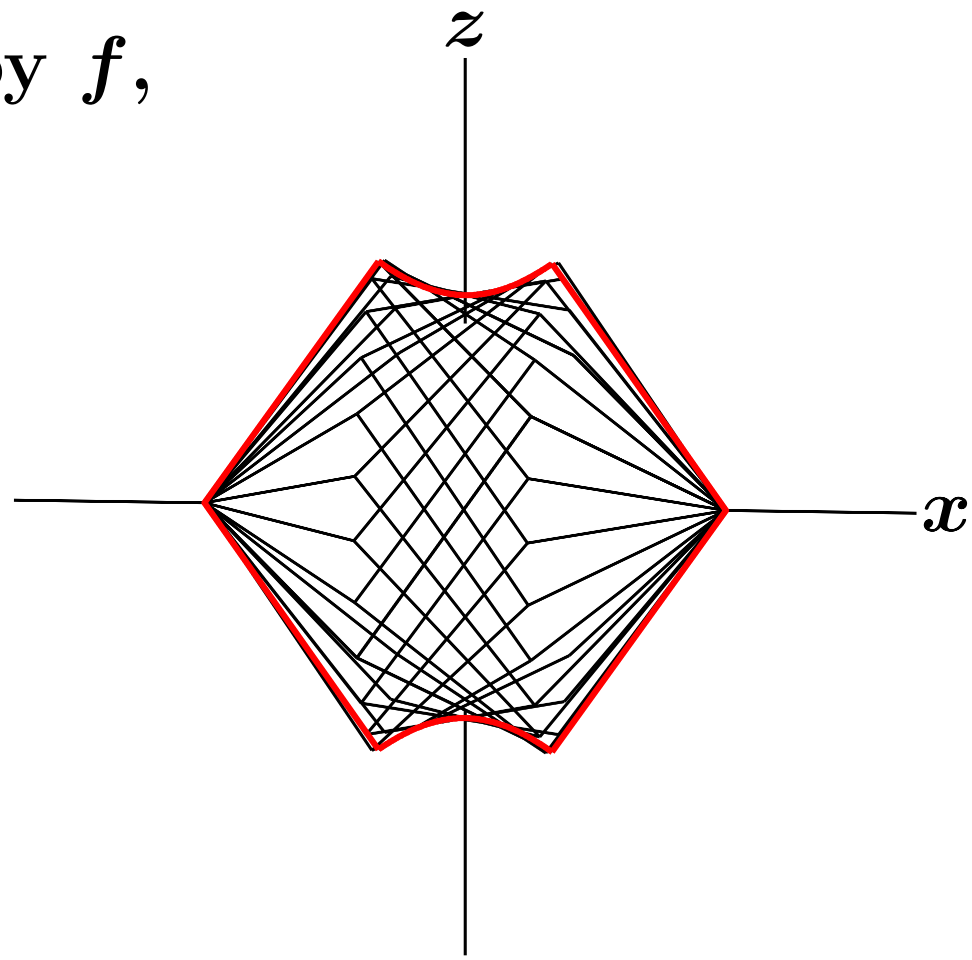
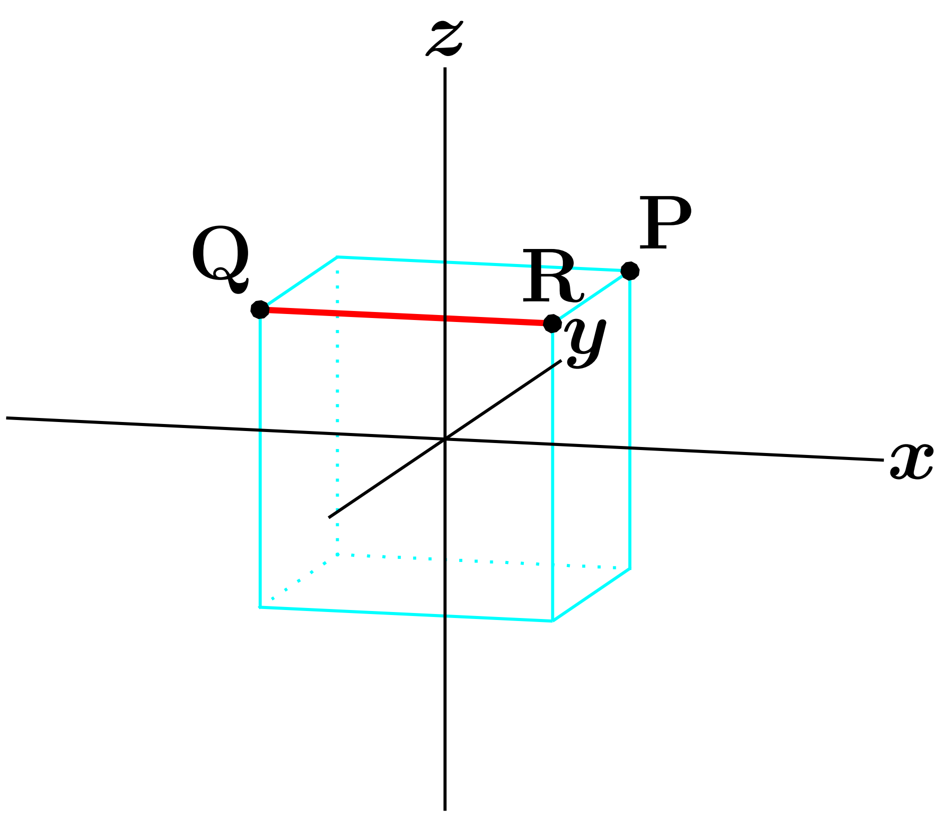


Equation of Hyperbora

f maps segment QR to Q′R′.



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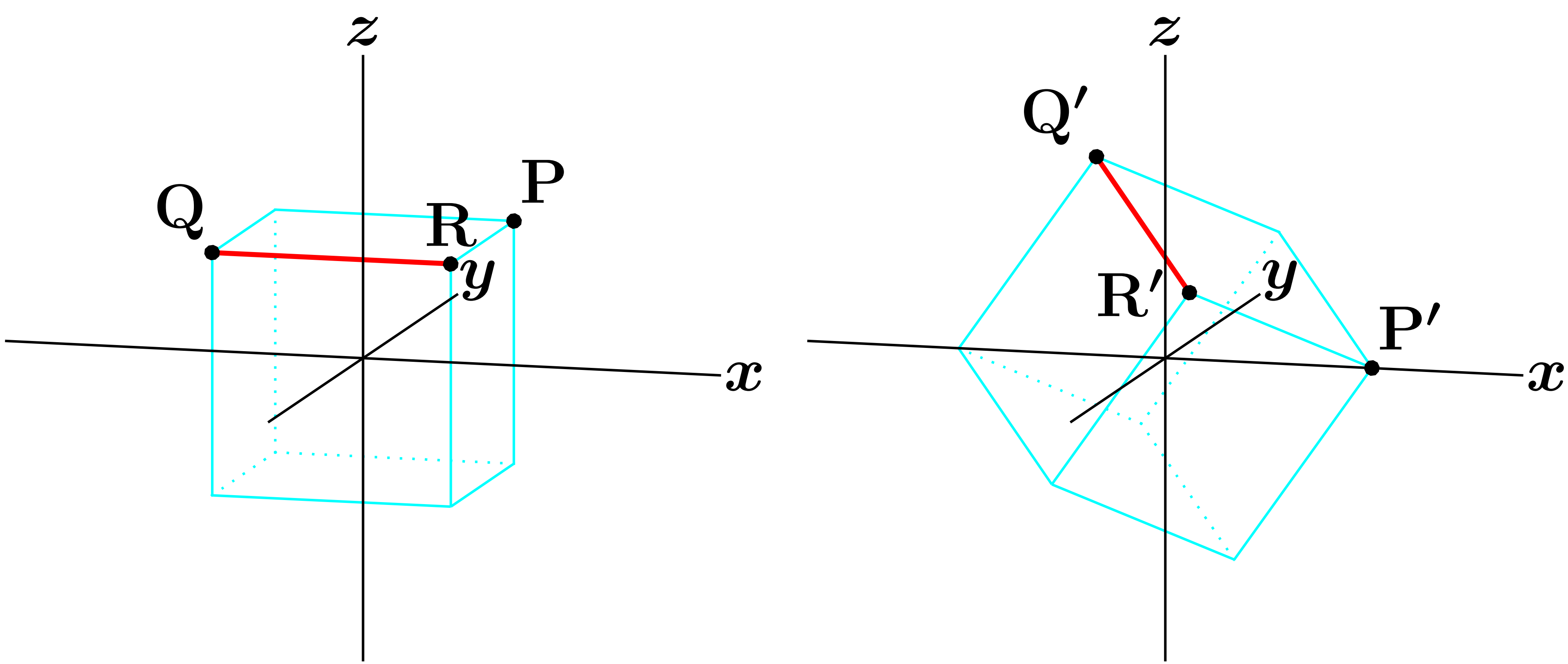
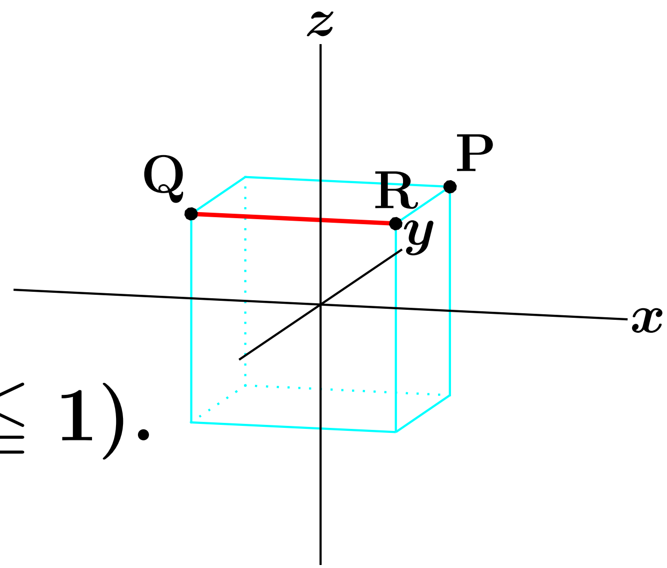
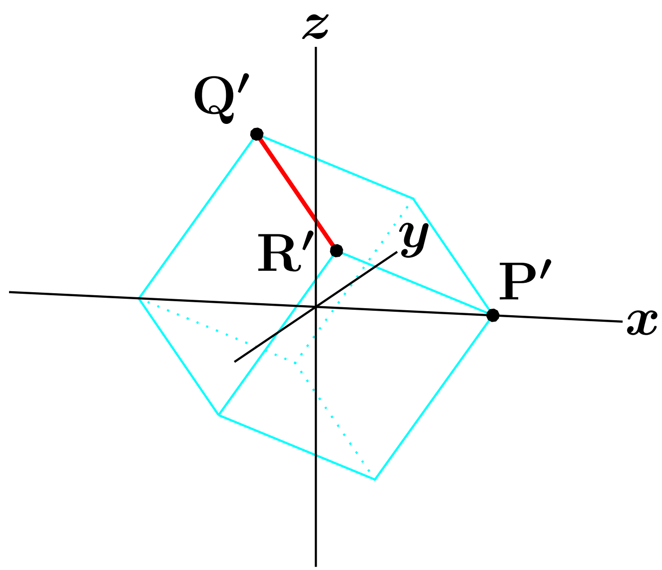


Equation of Hyperbora

QR is represented as follows:

$$x = t,\ y = -1,\ z = 1 \quad (-1 \leqq t \leqq 1).$$





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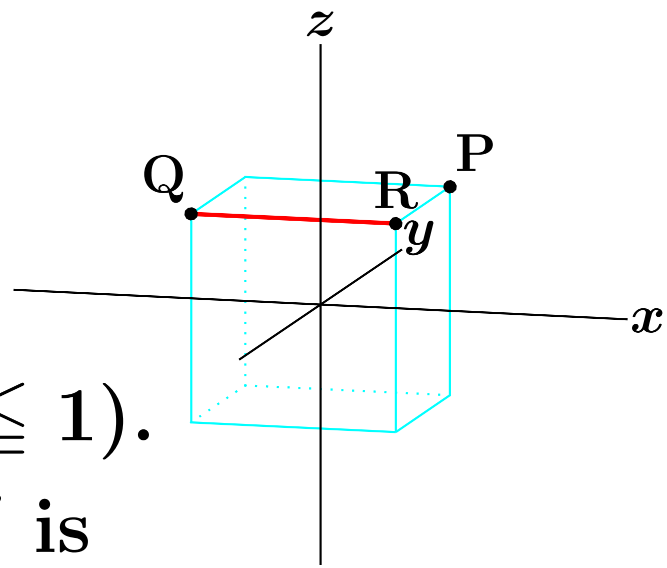

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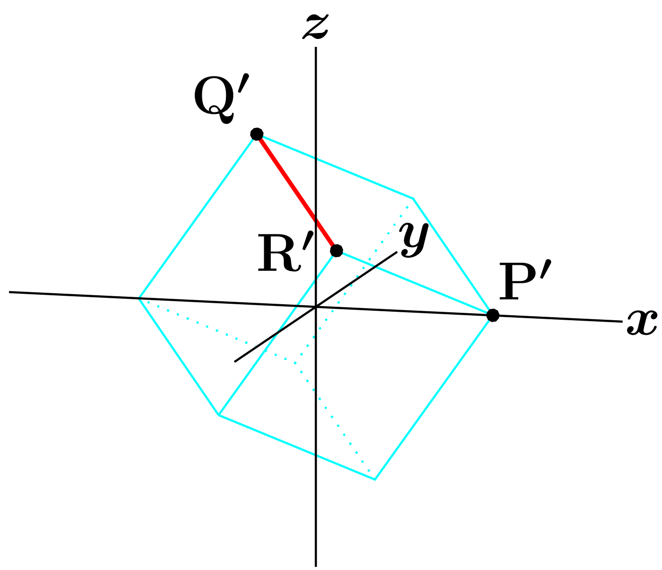
Multiplied by ${}^tT$, equation of Q′R′ is



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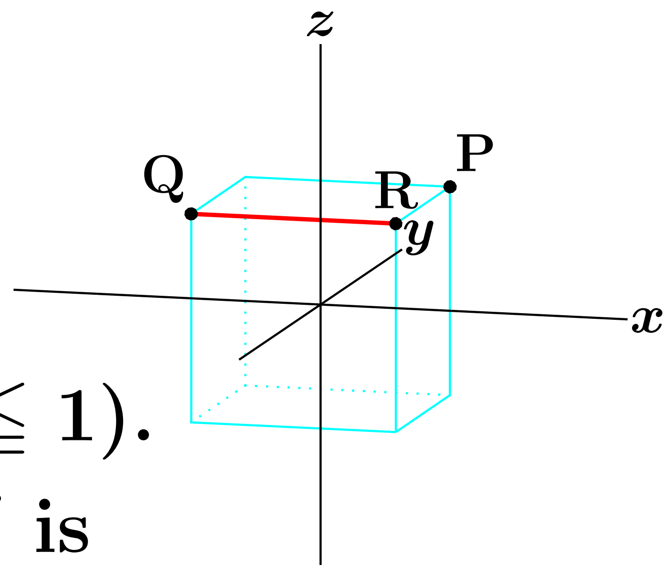

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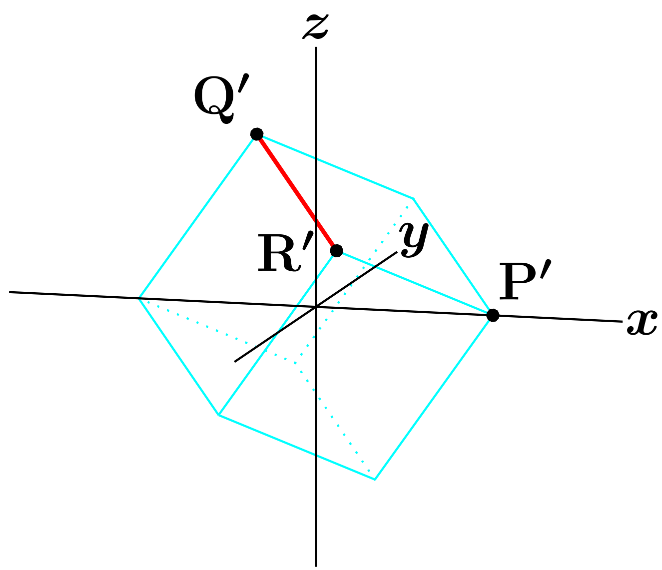
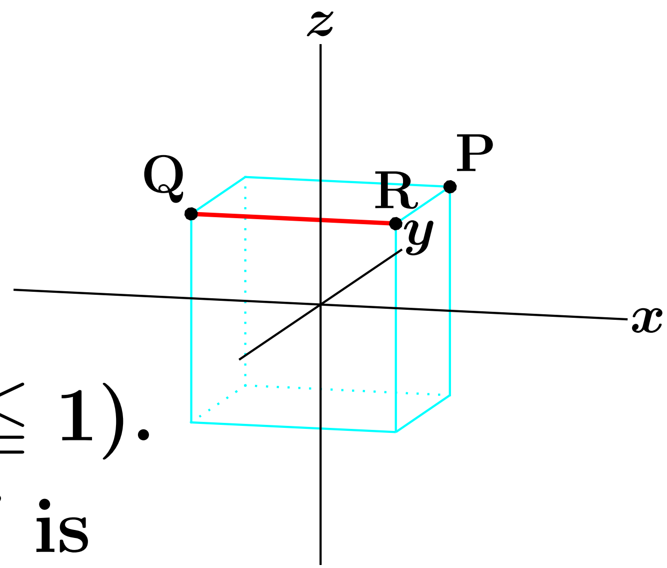


→問 3

Equation of Hyperbora



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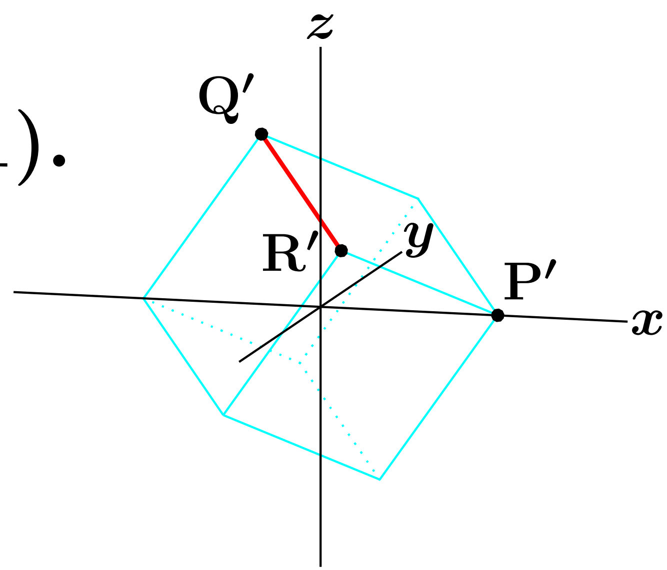
$$\begin{cases} x = \dfrac{1}{\sqrt{3}}t \\ y = -\dfrac{1}{\sqrt{2}}(t+1) \qquad (-1 \leqq t \leqq 1). \\ z = -\dfrac{1}{\sqrt{6}}(t-3) \end{cases}$$



→問 3

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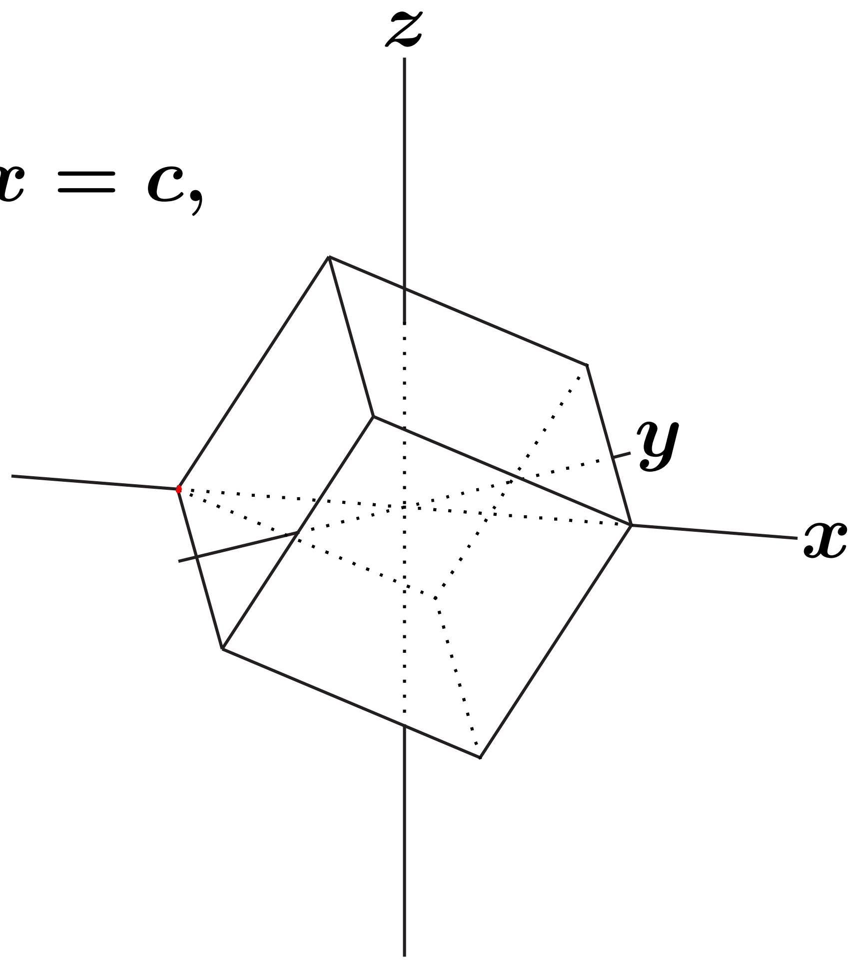

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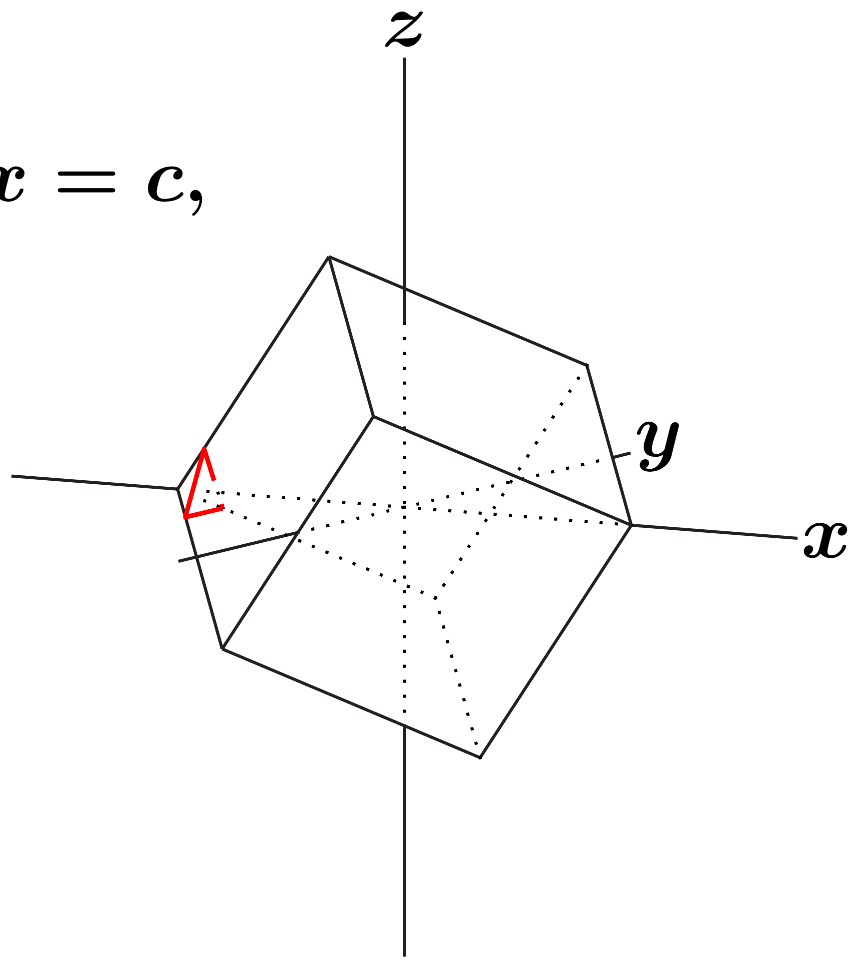

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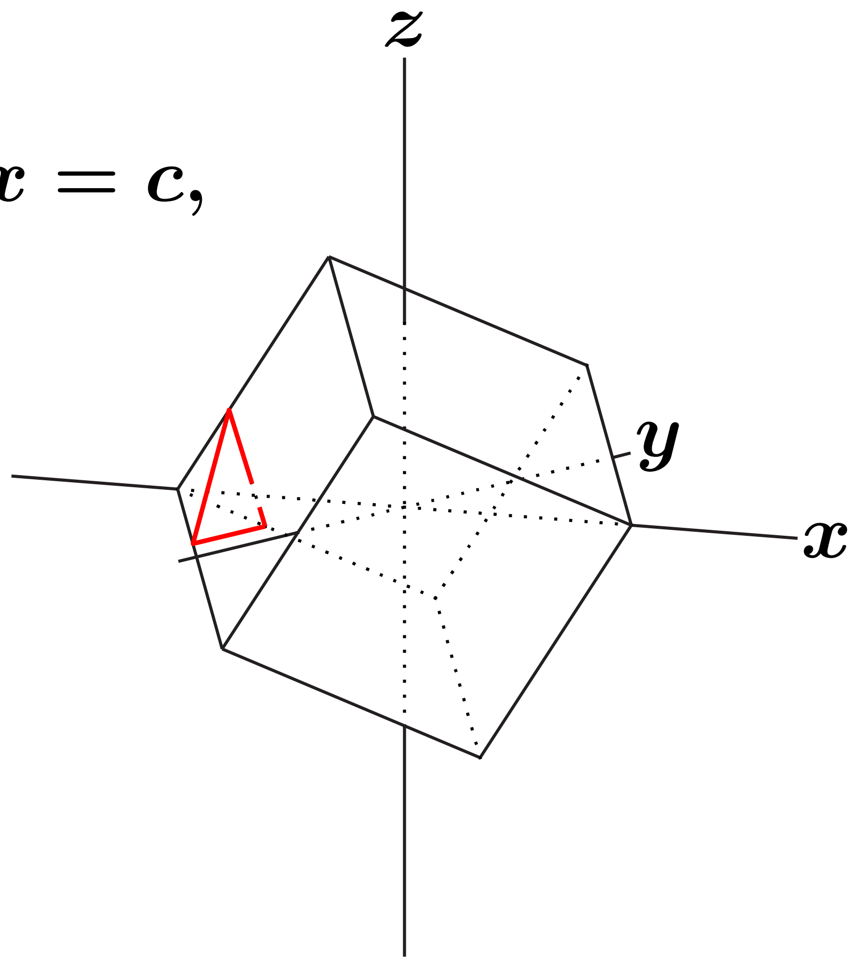

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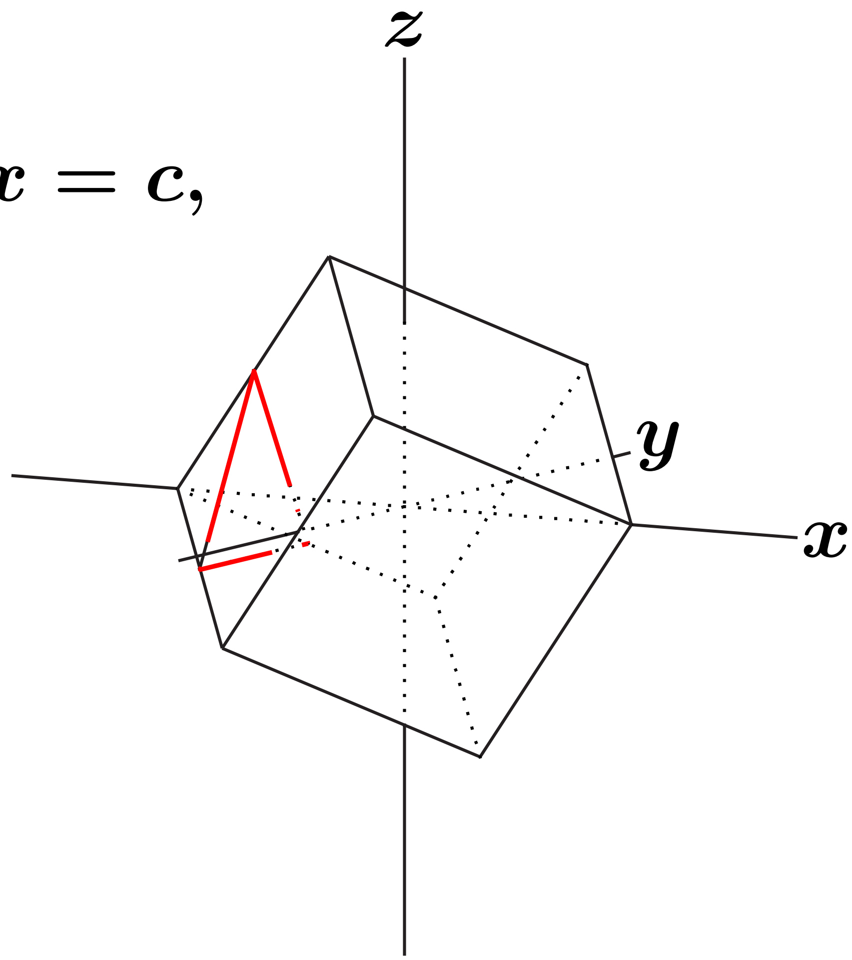

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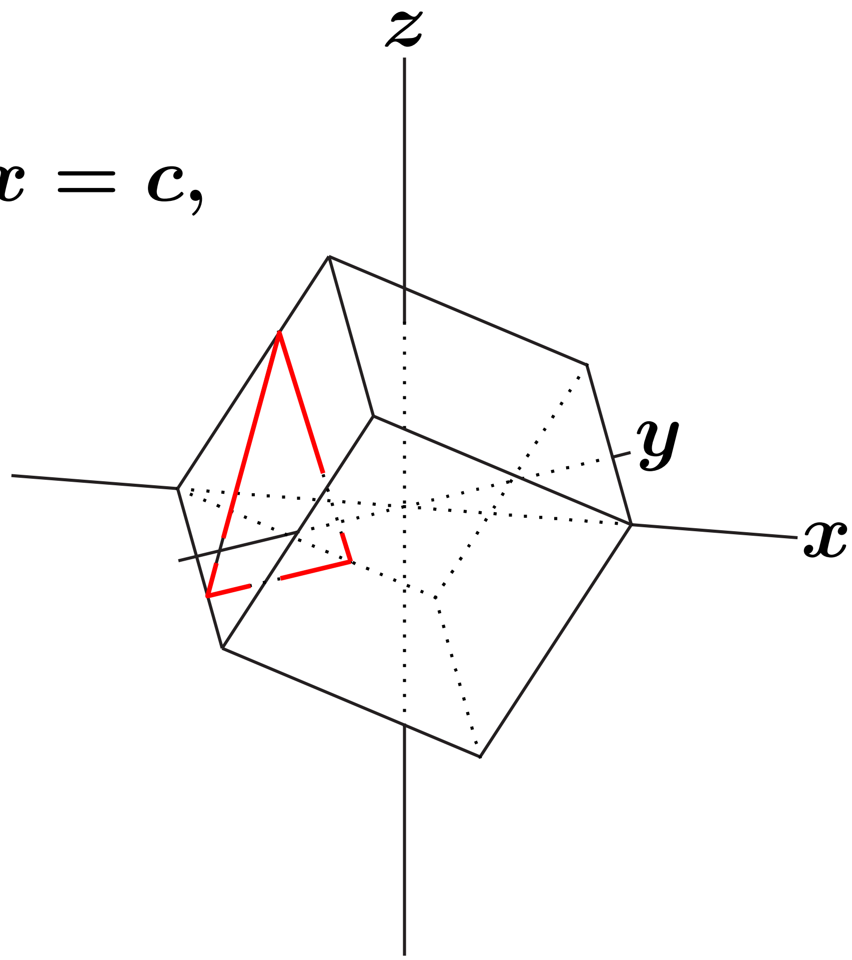

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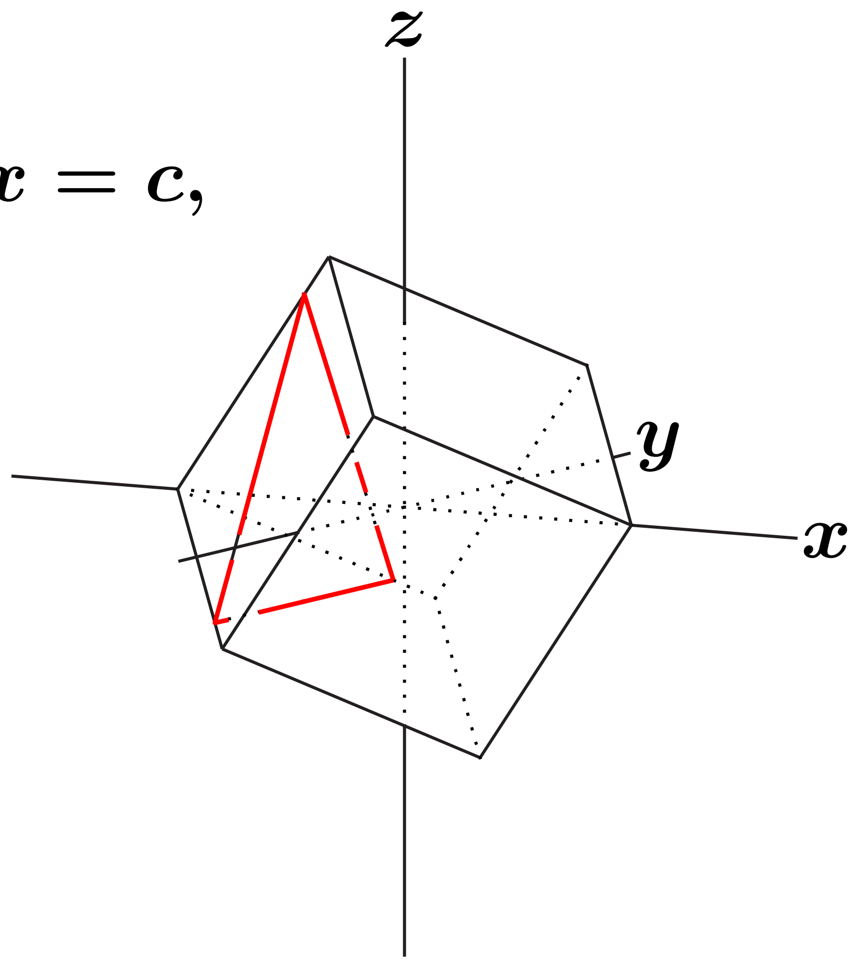

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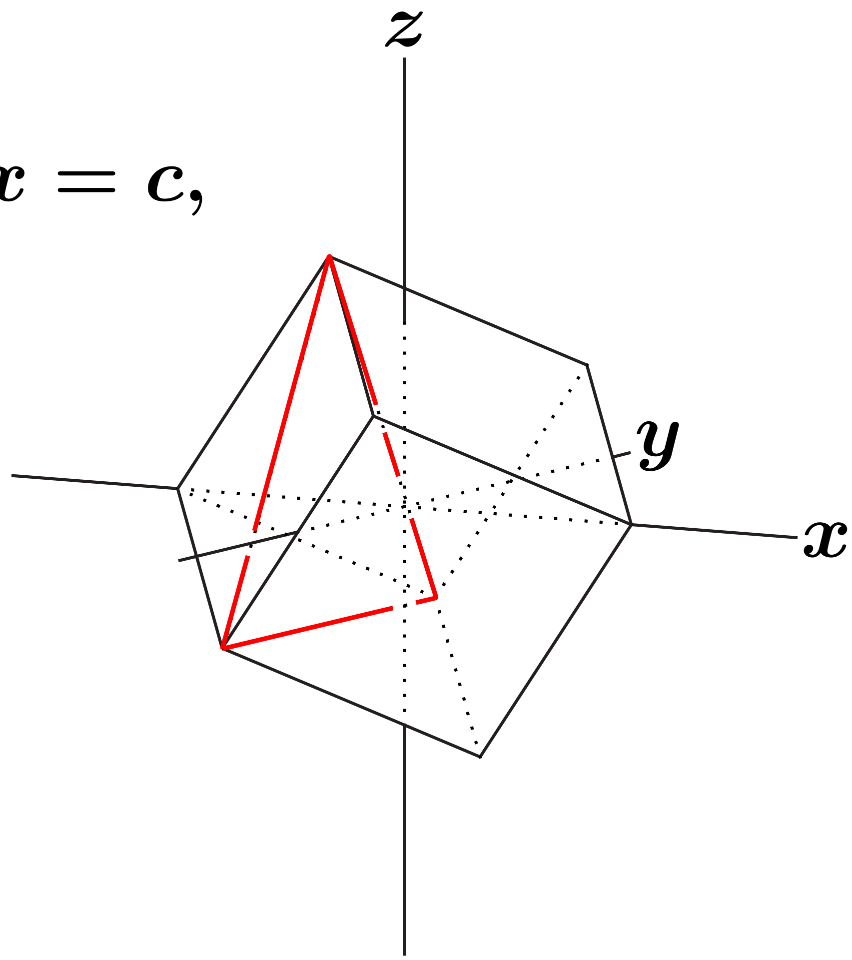

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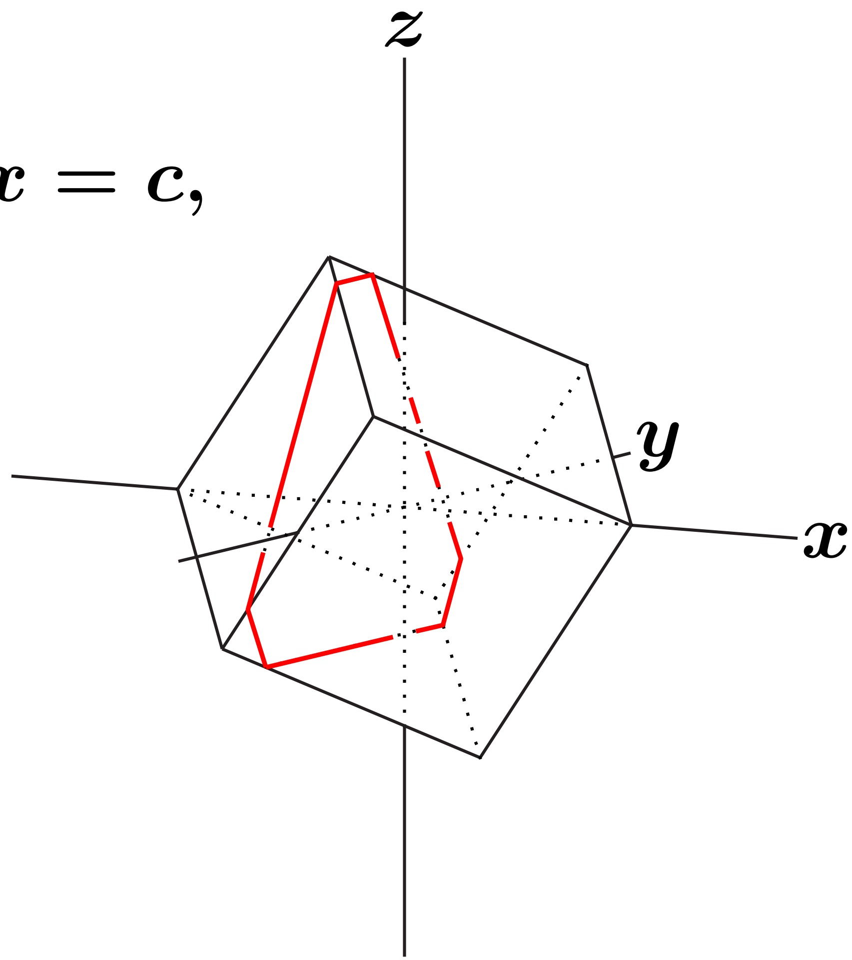

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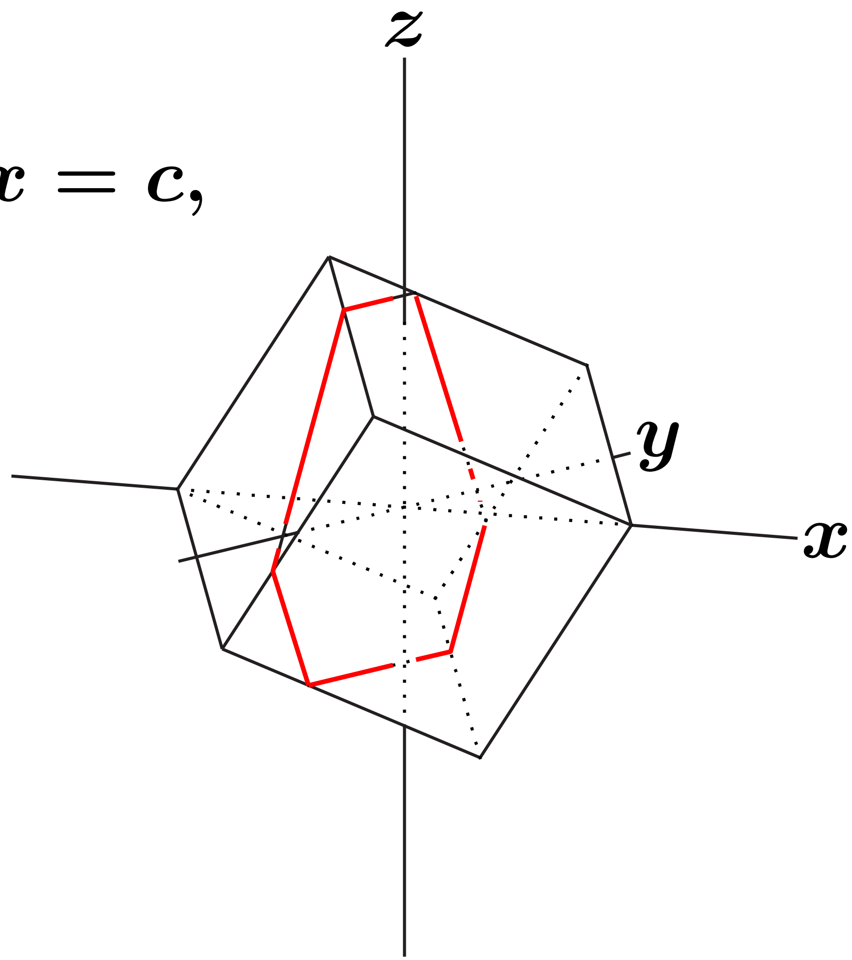

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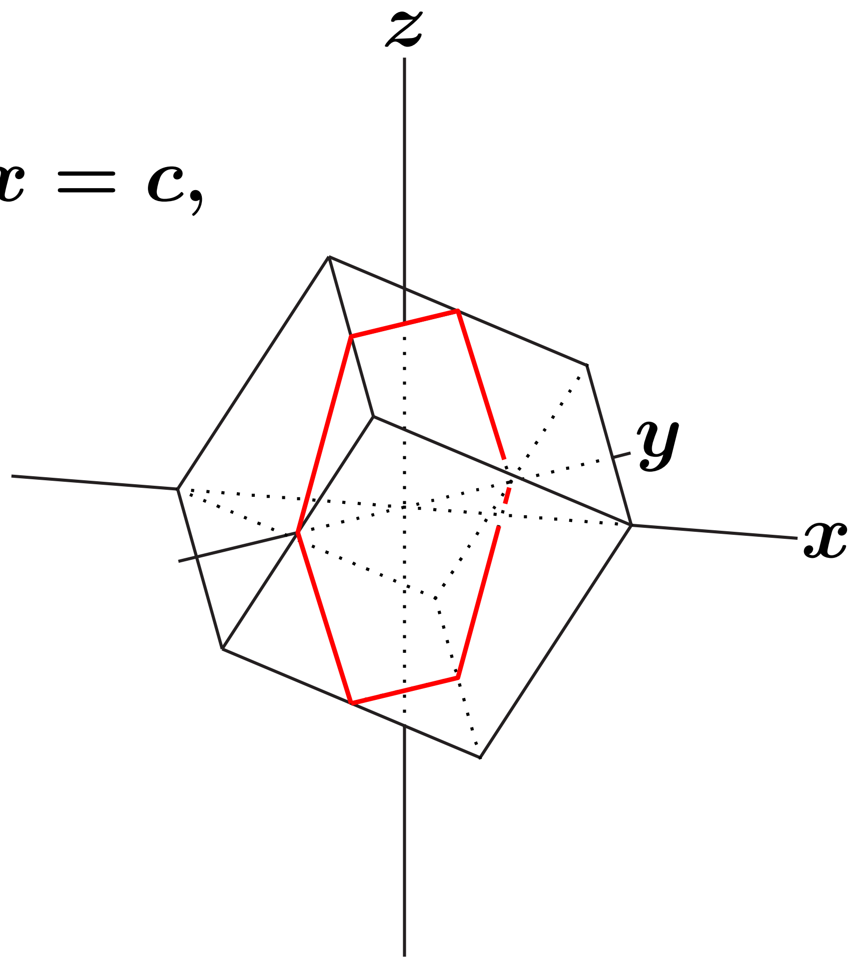

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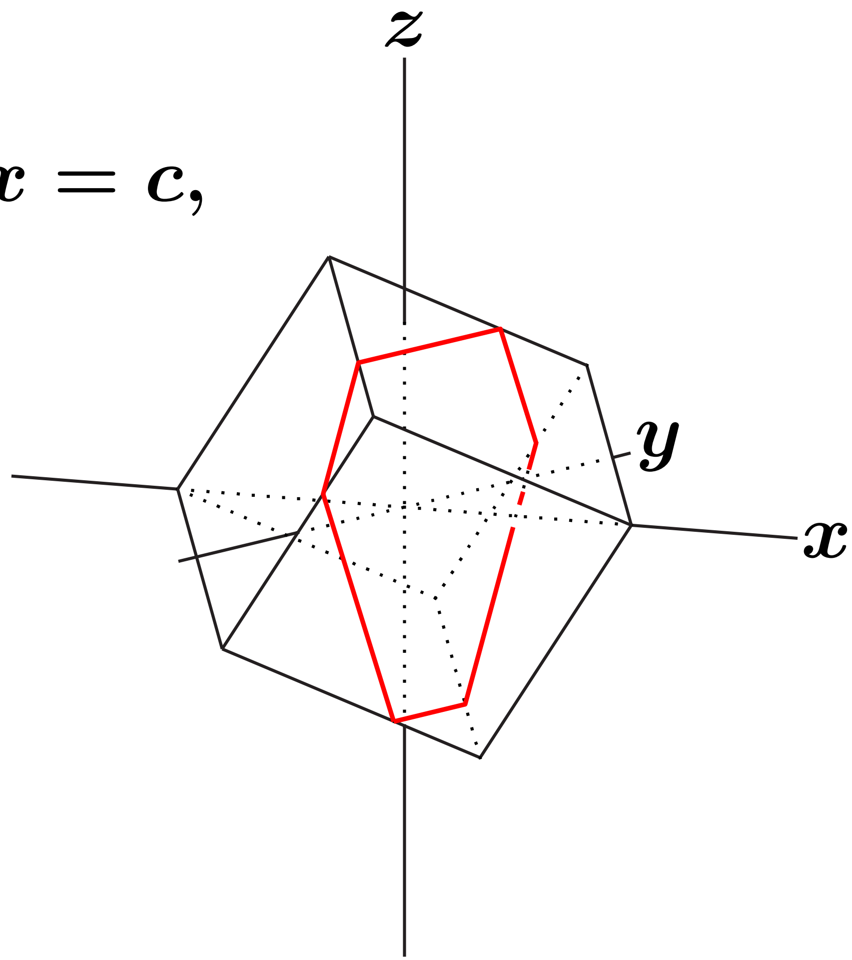

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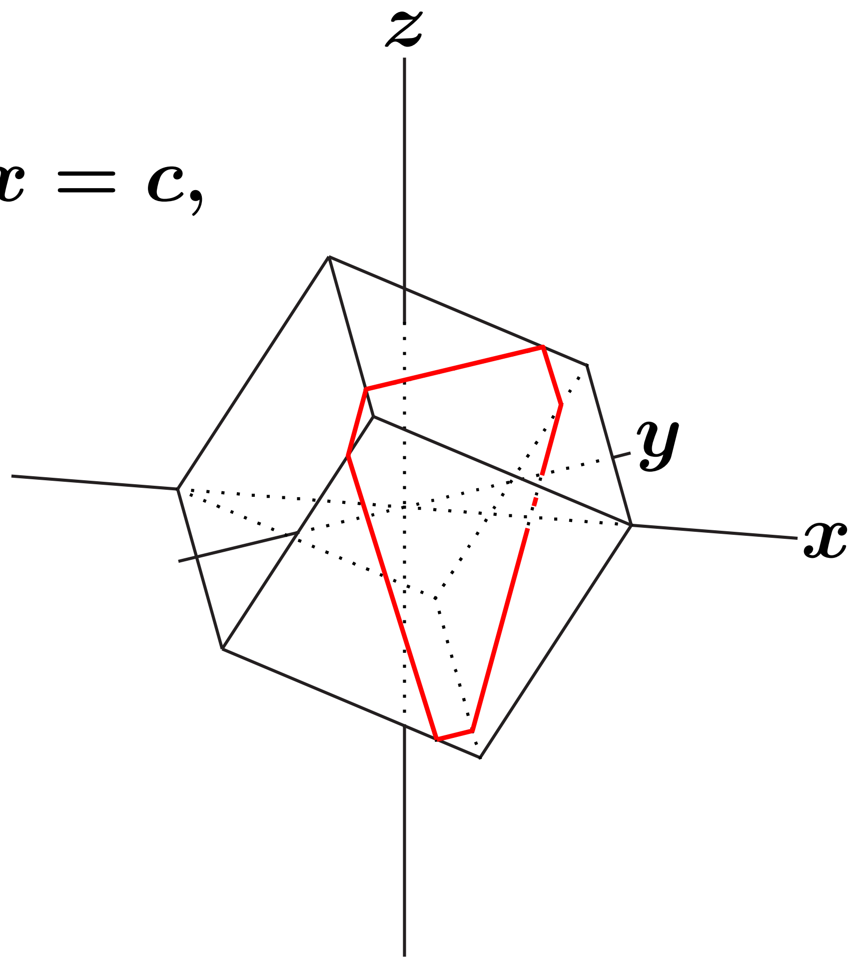

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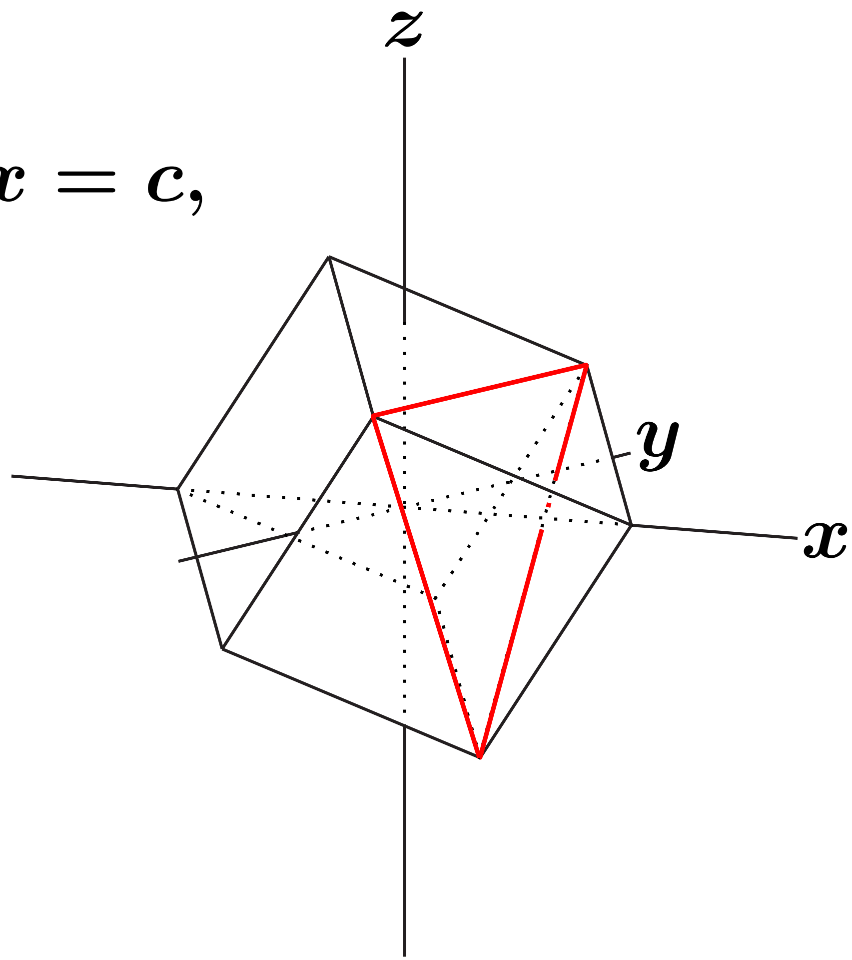

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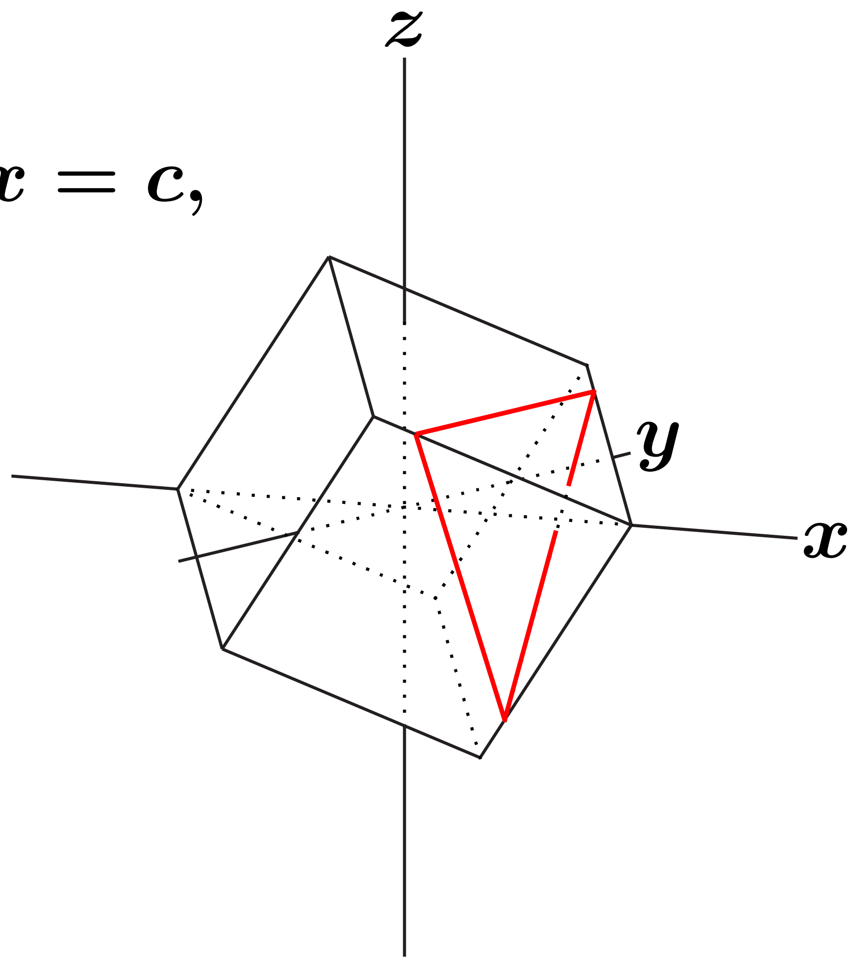

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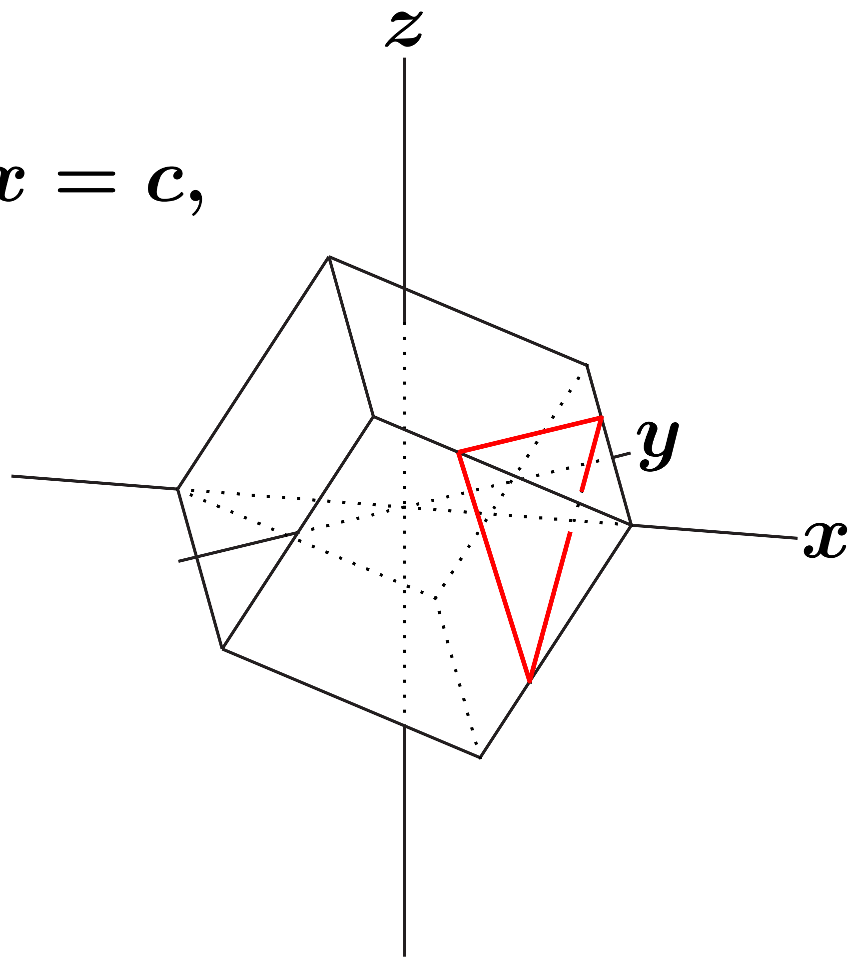

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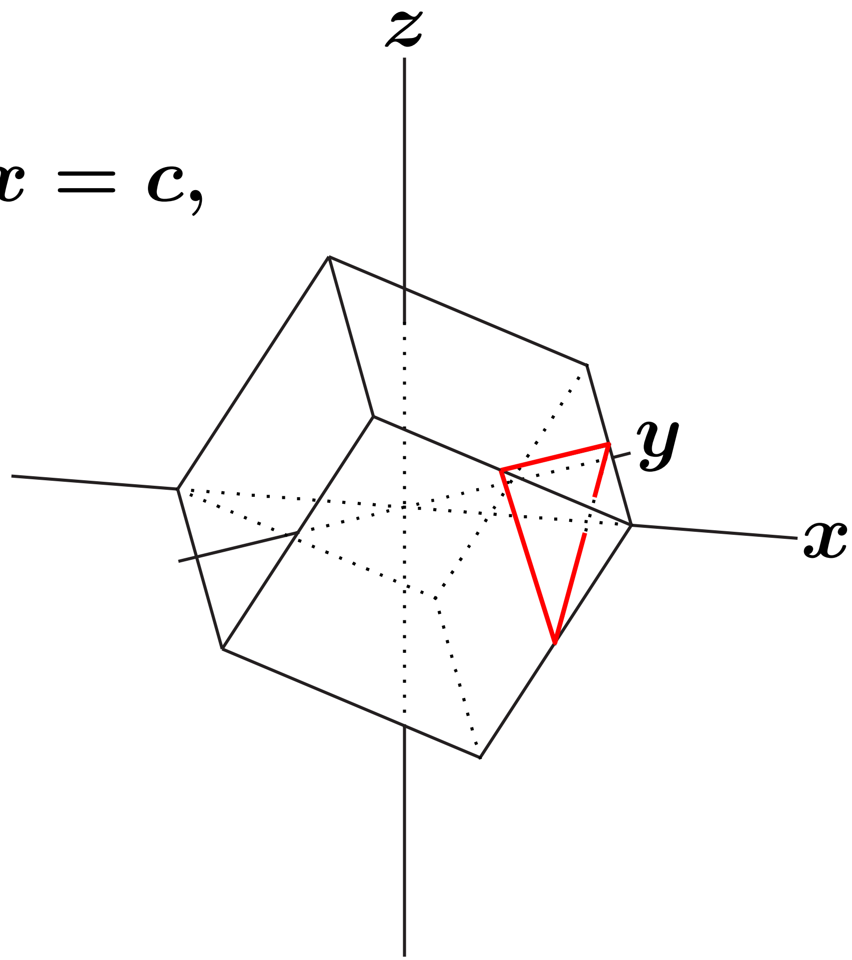

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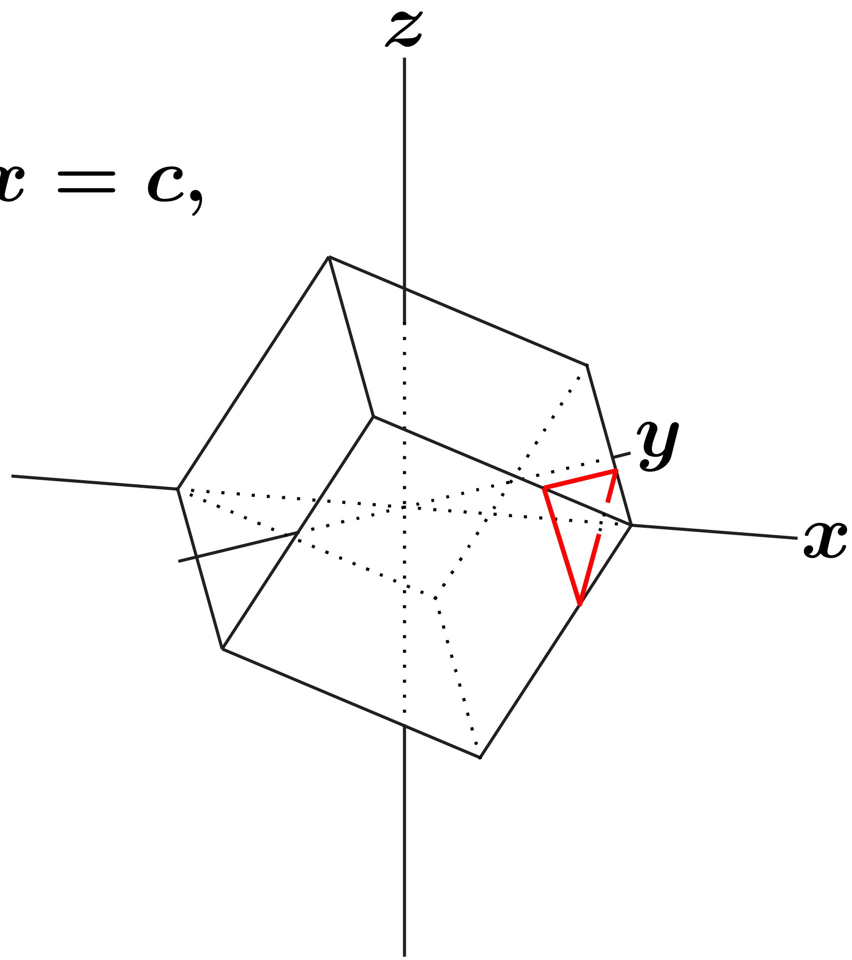

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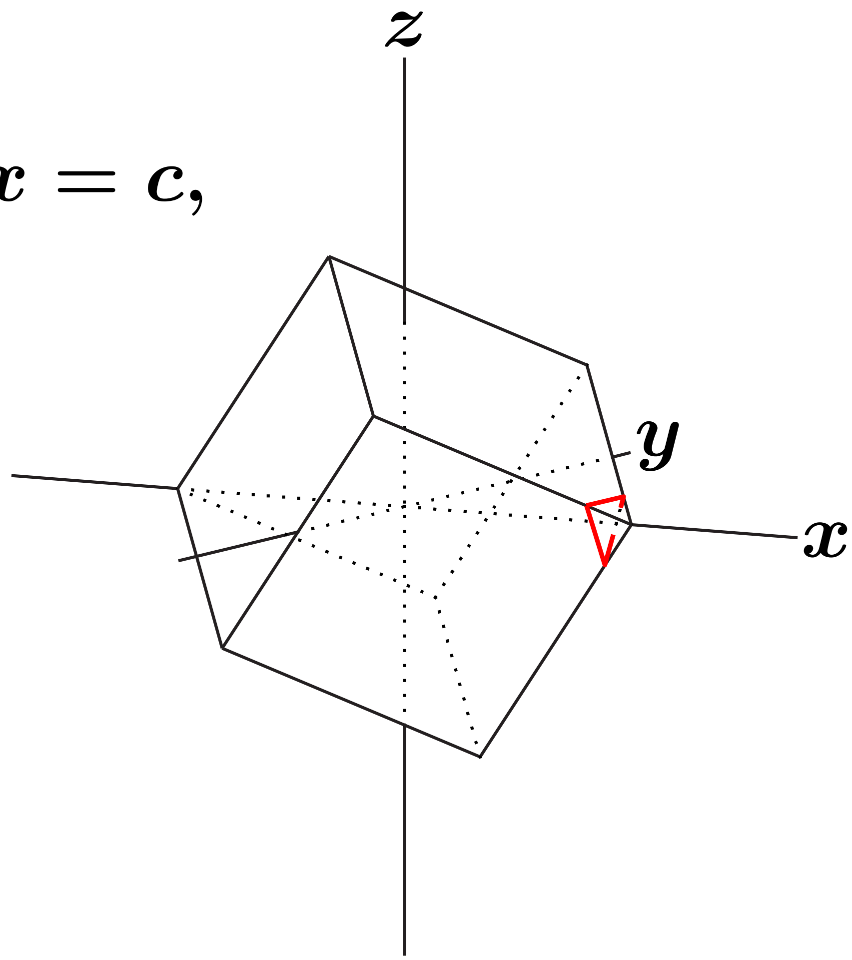

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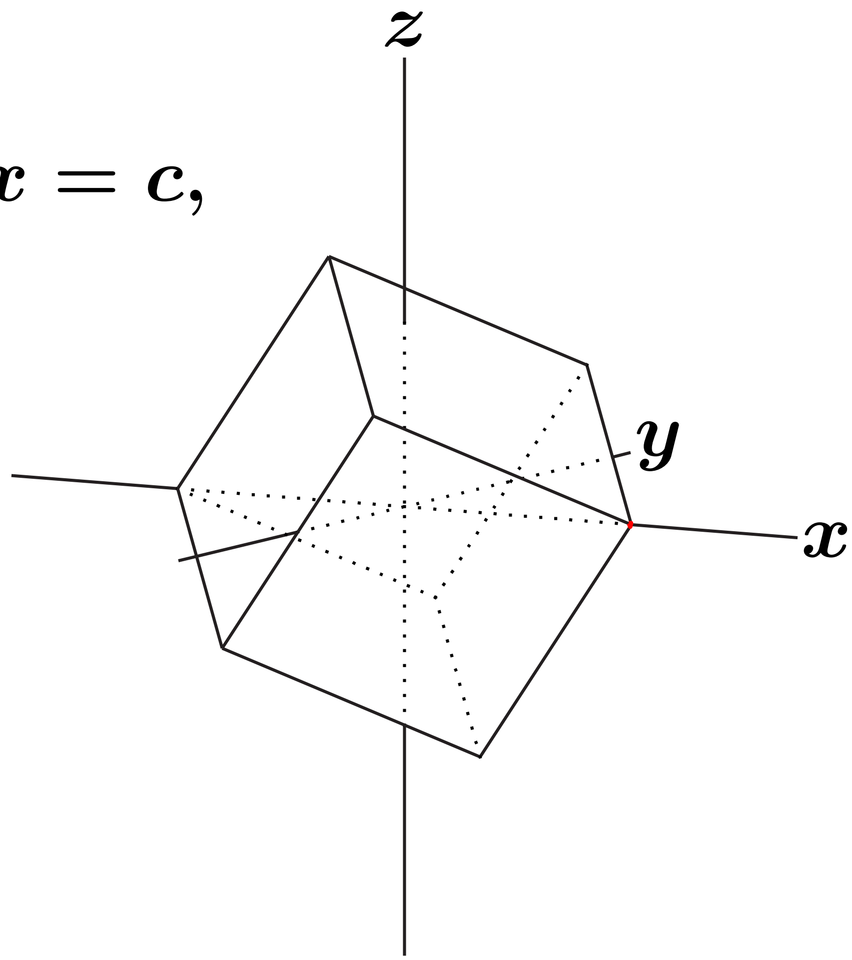

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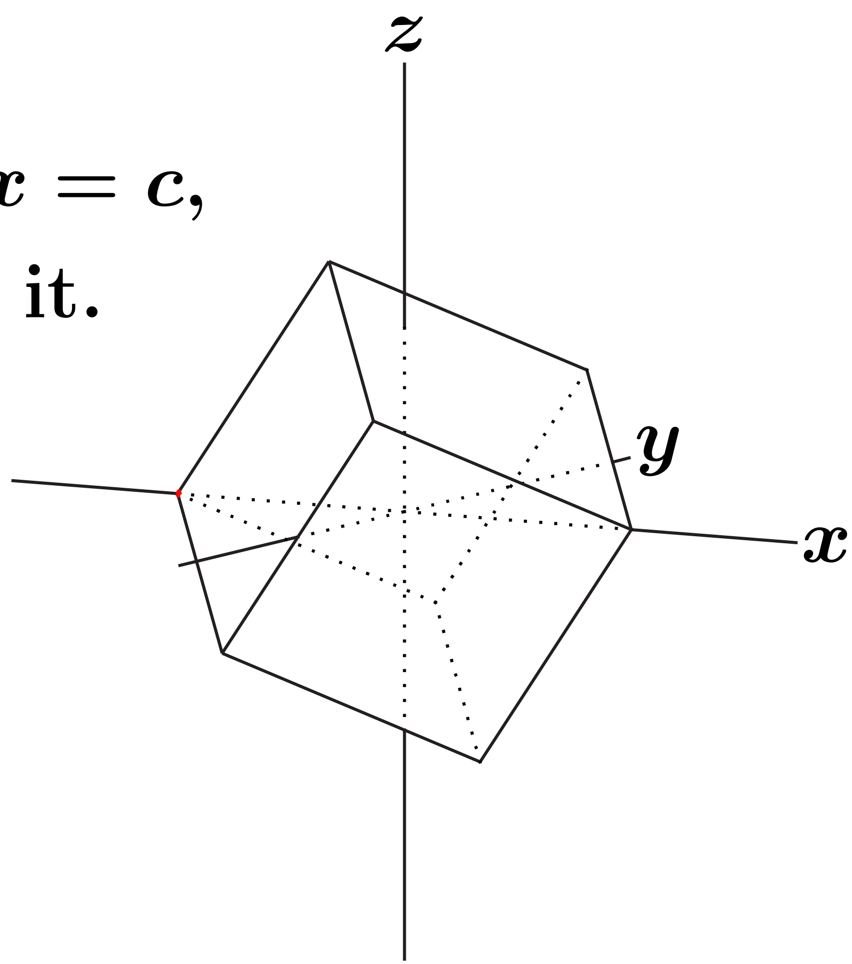

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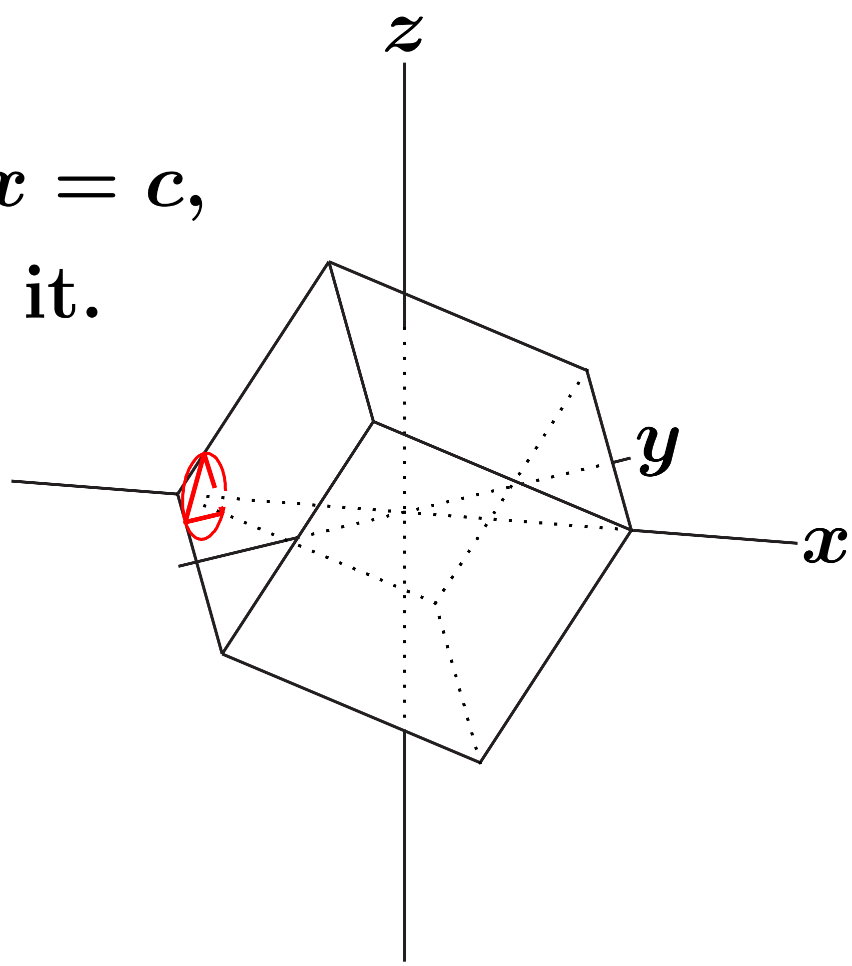

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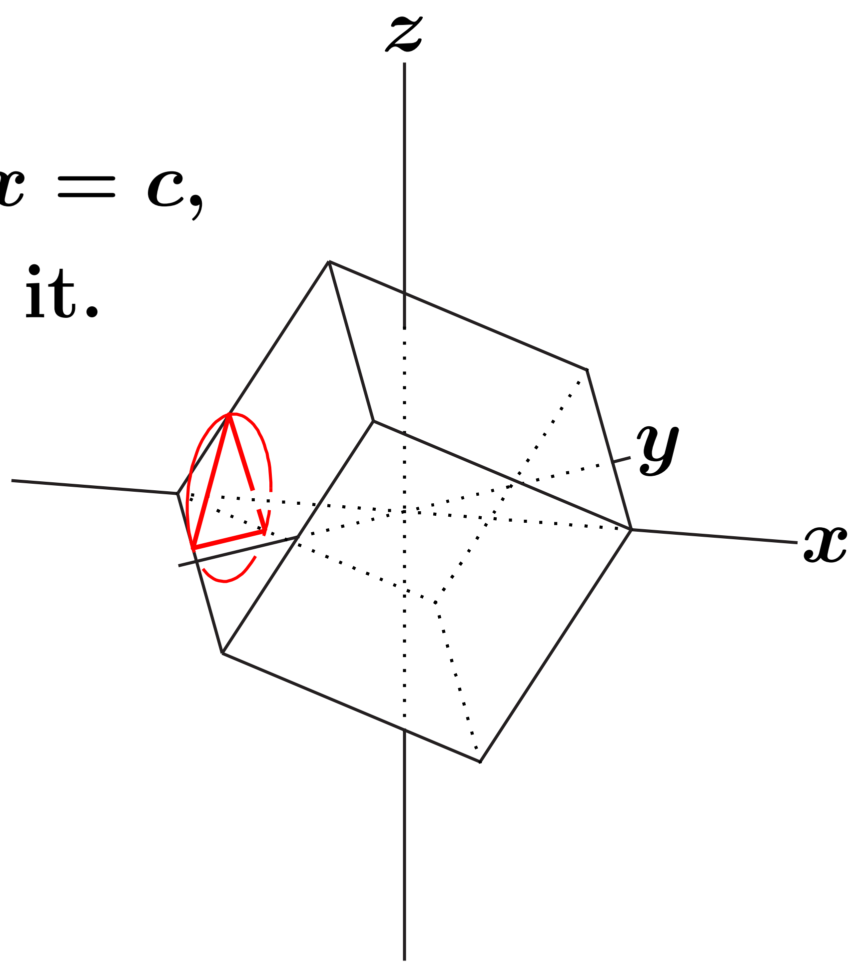

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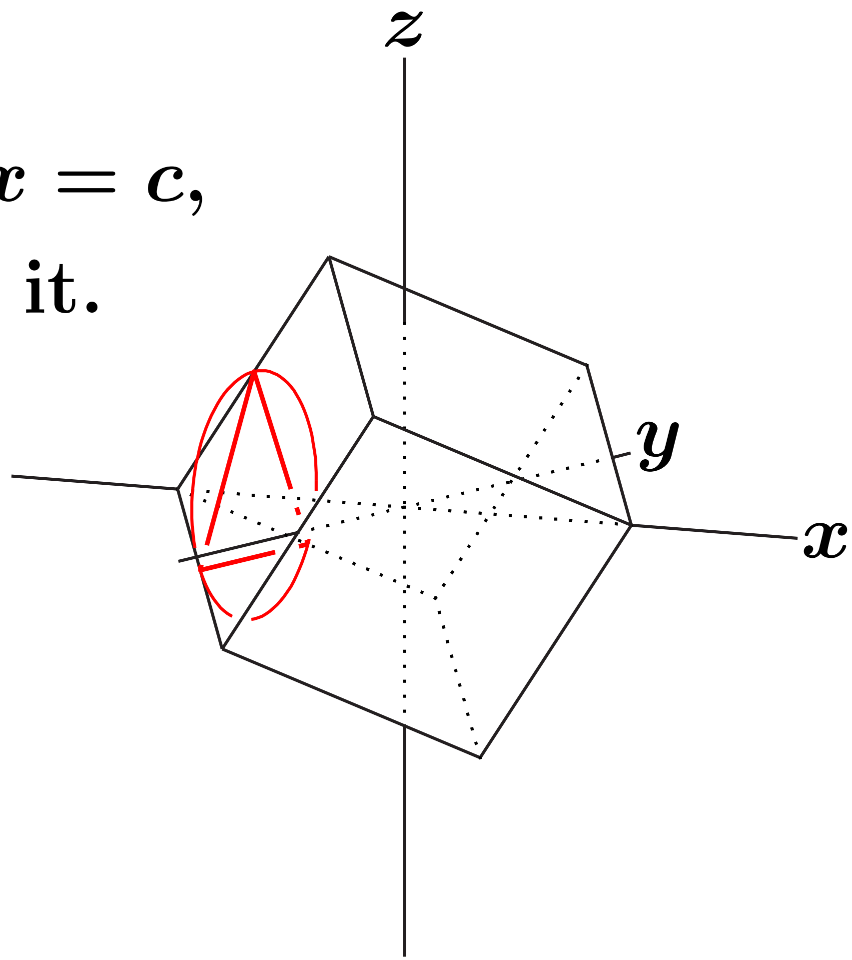

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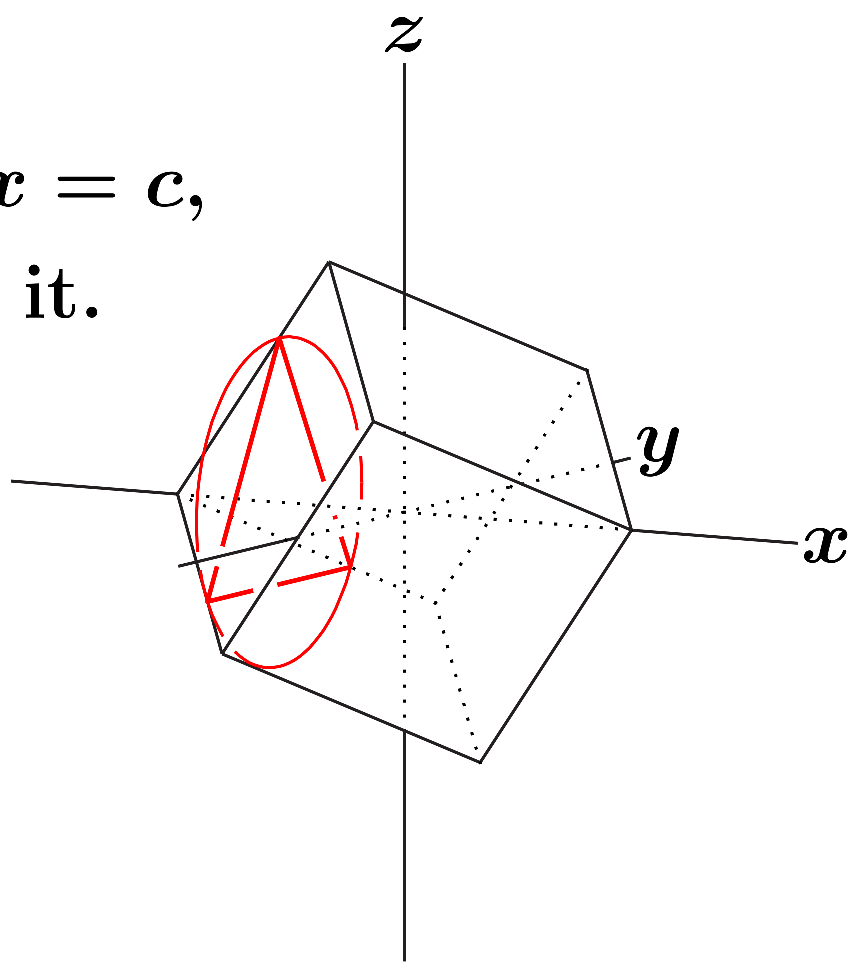

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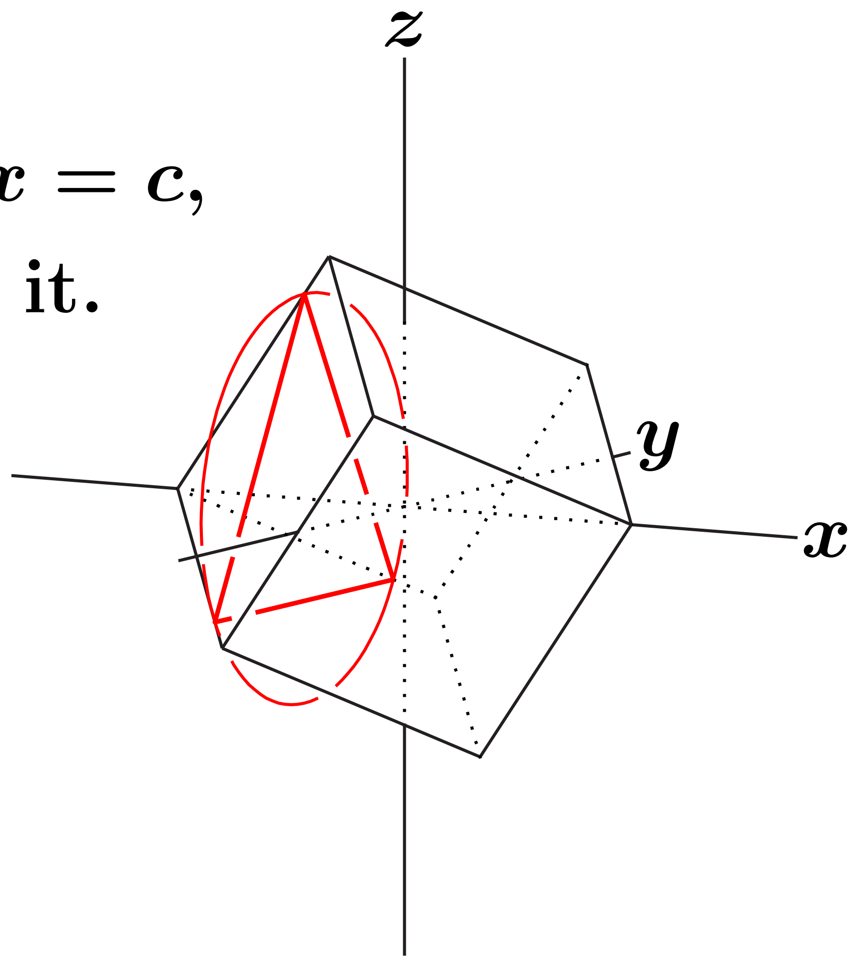

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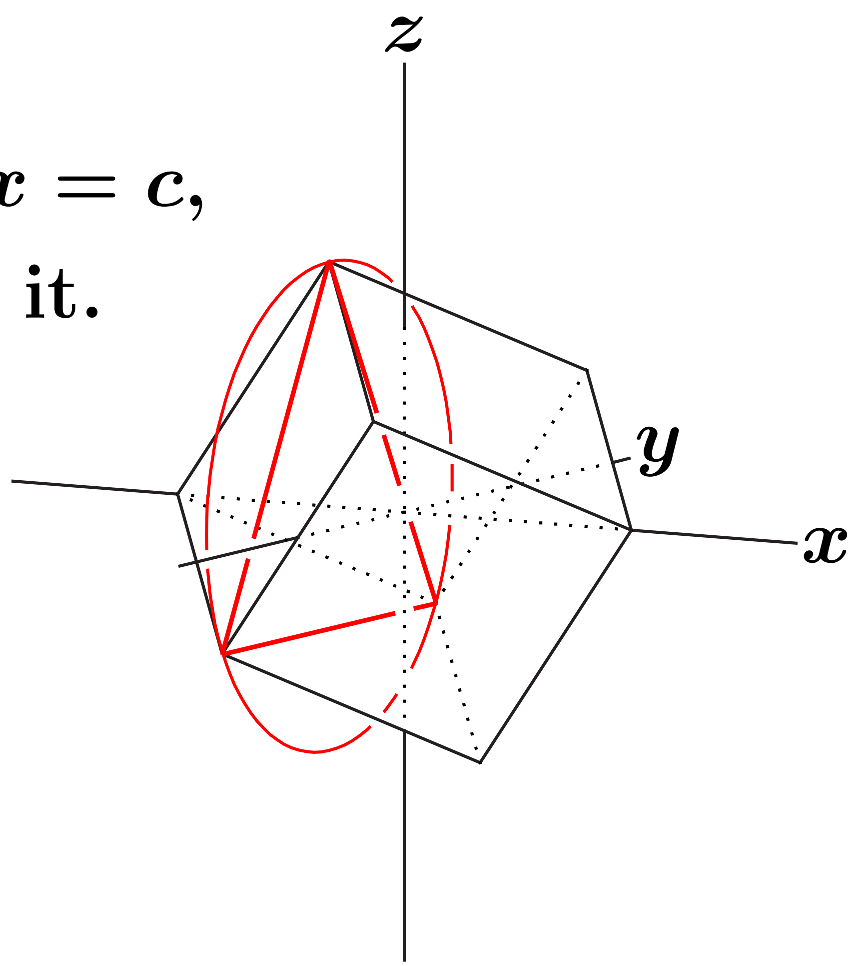

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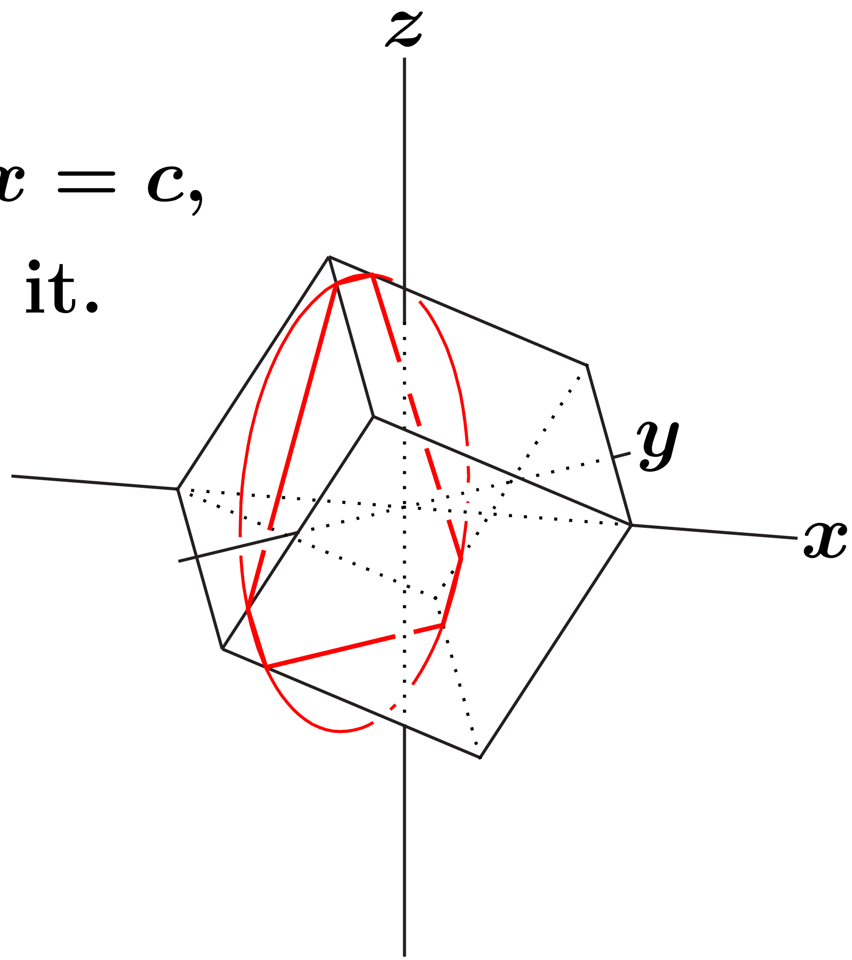

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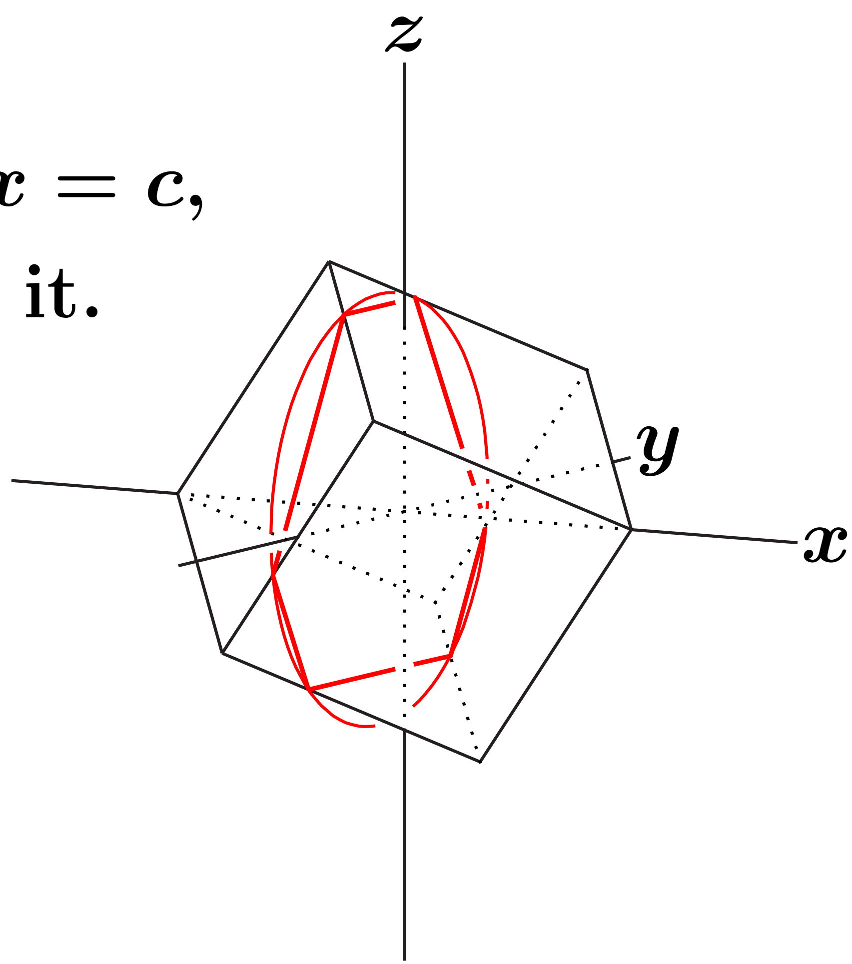

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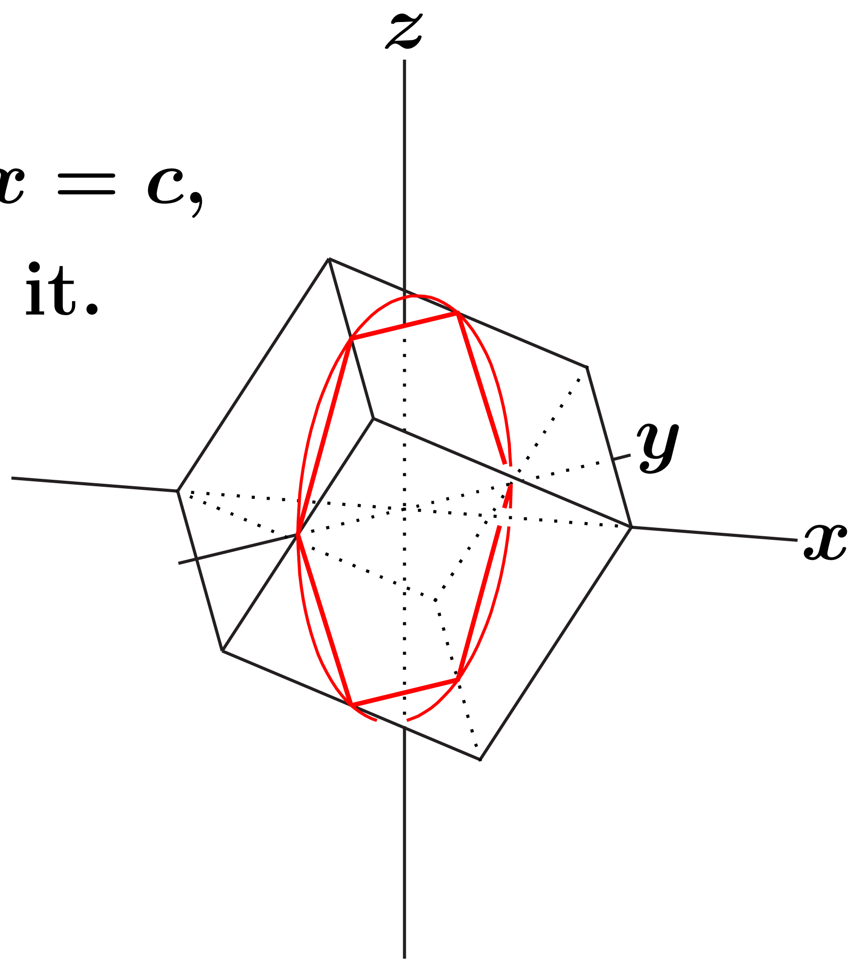

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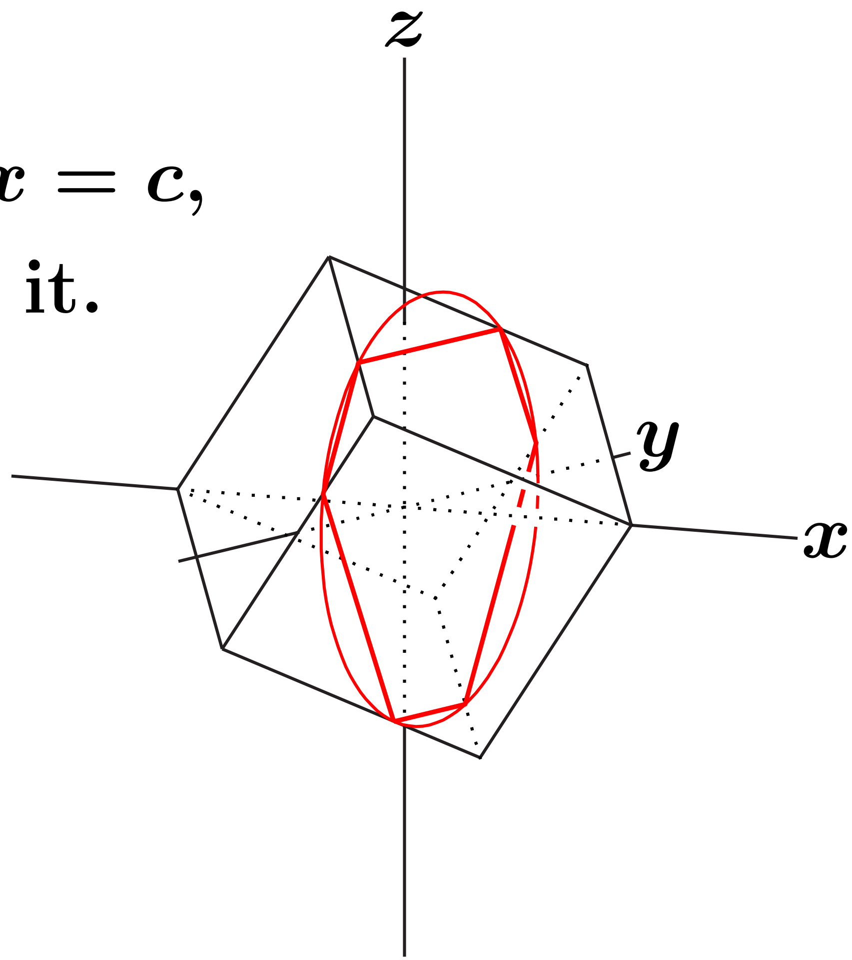

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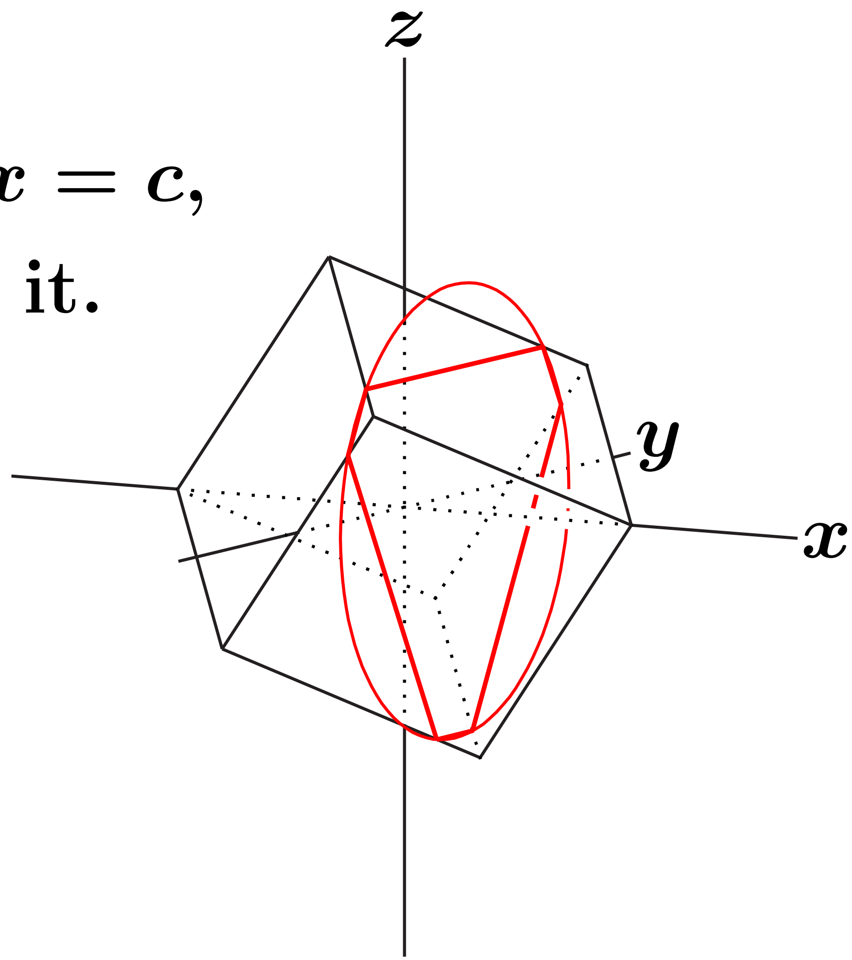

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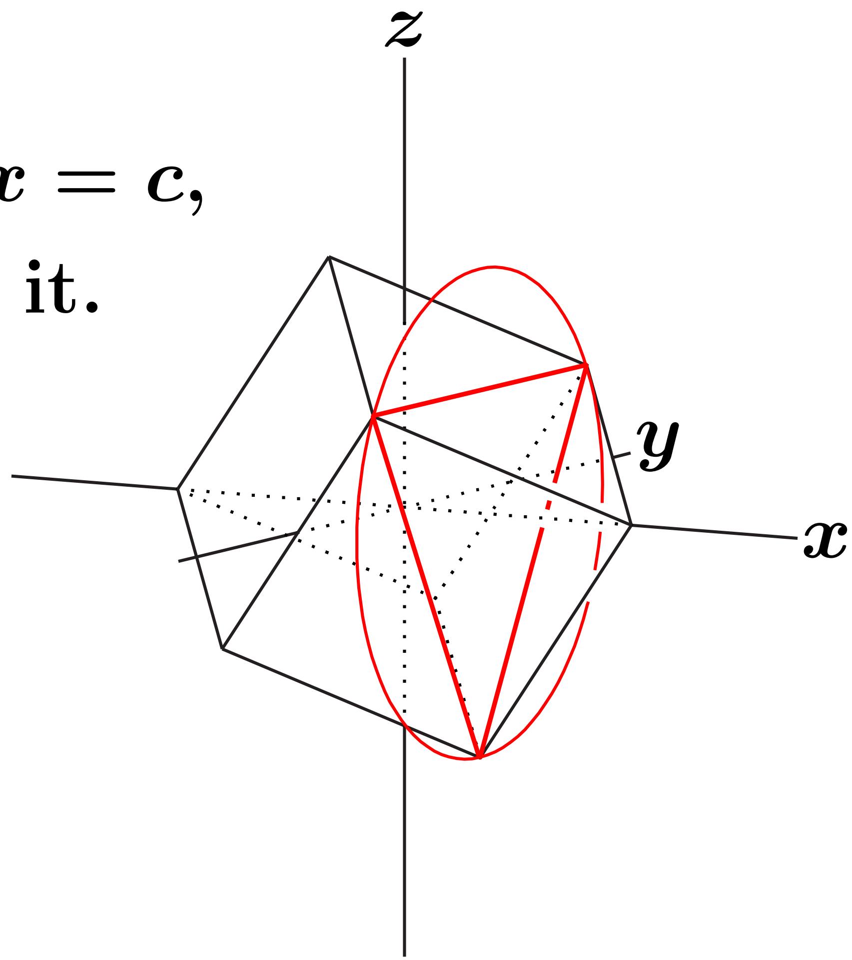

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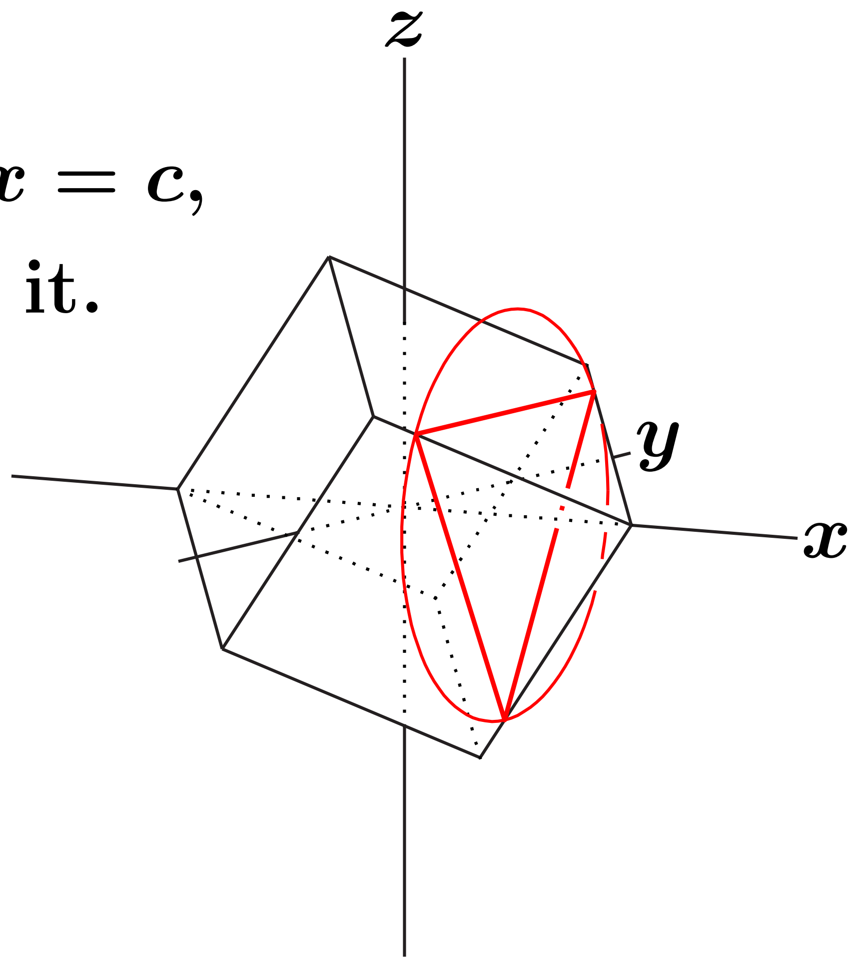

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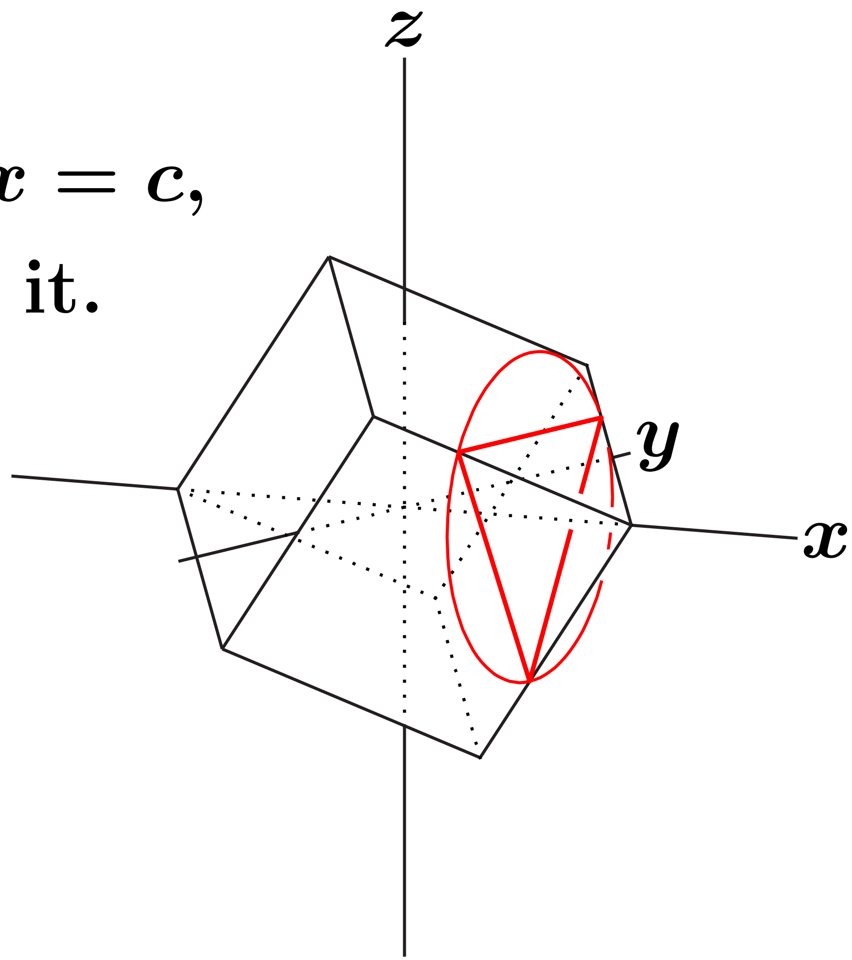

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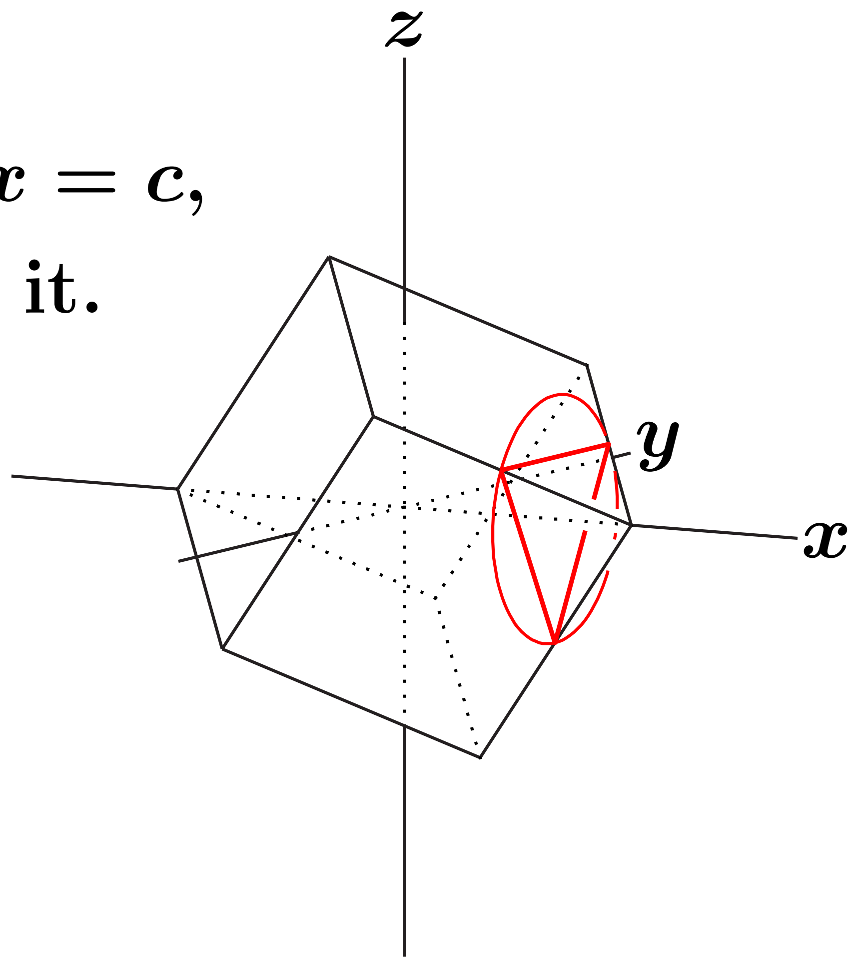

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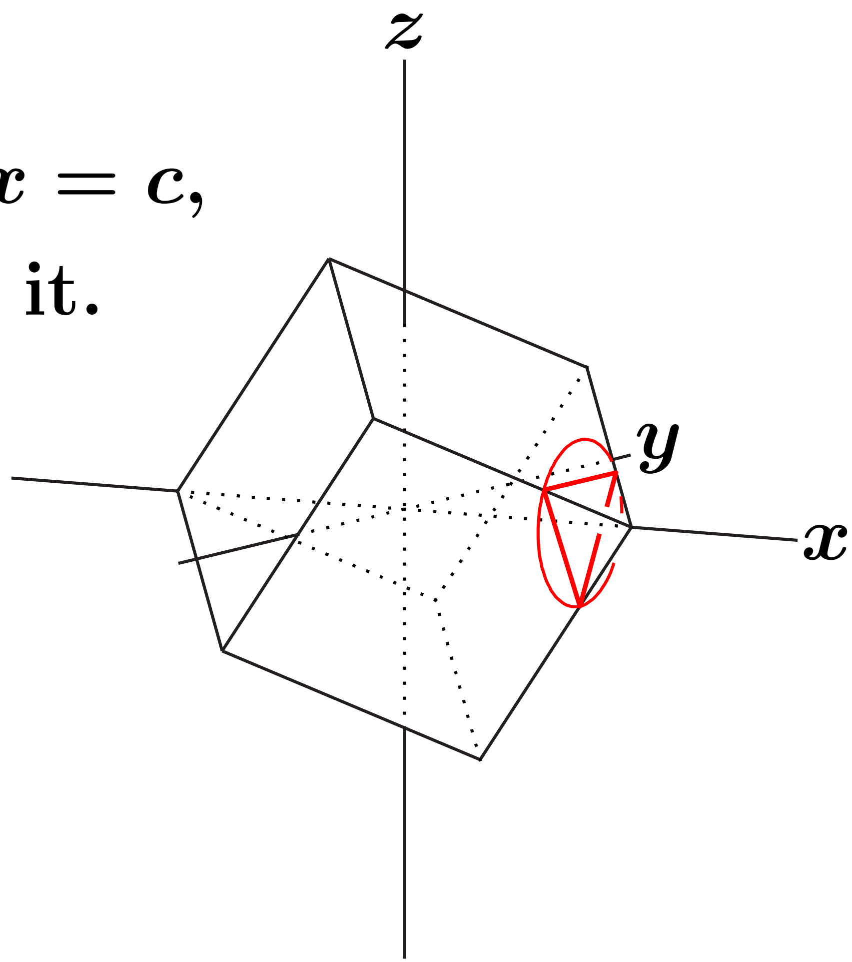

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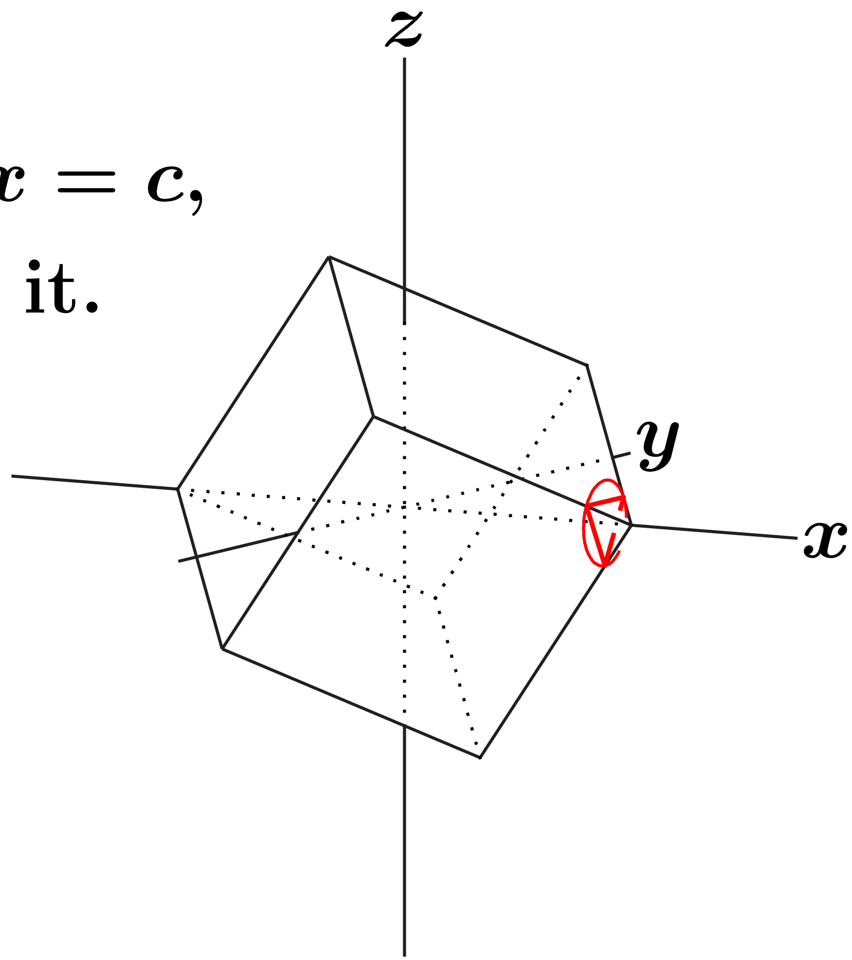
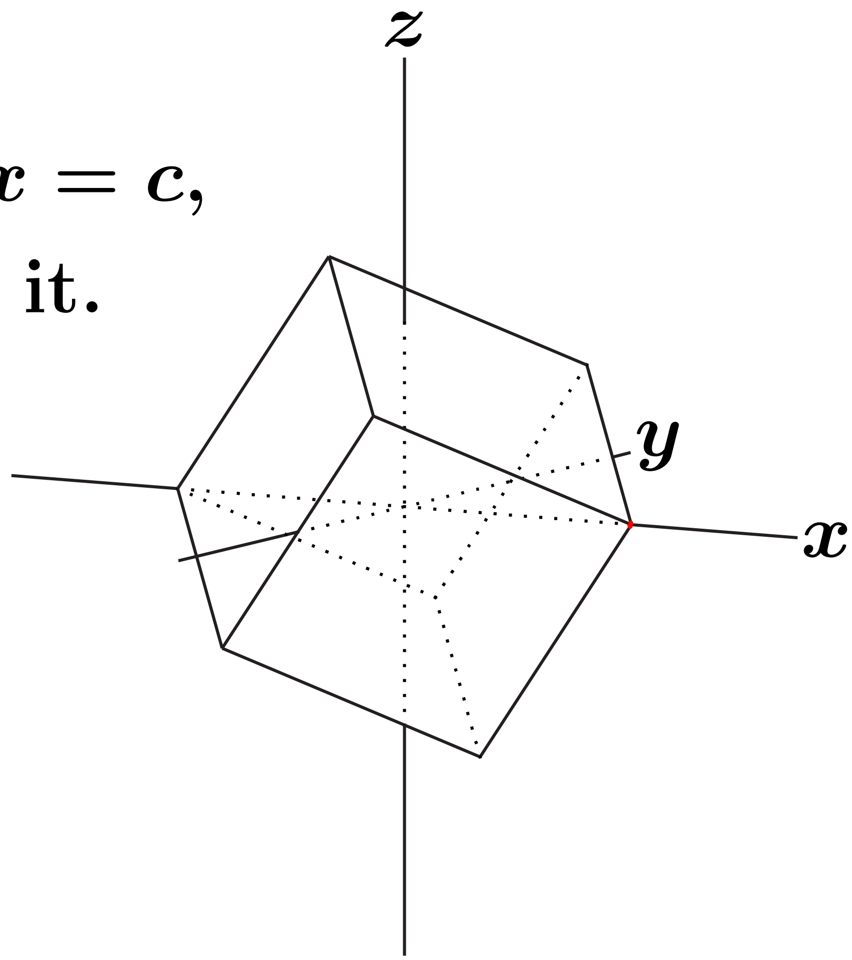


Equation of Hyperbora

Consider intersection of

face of this cube and plane $x = c$,

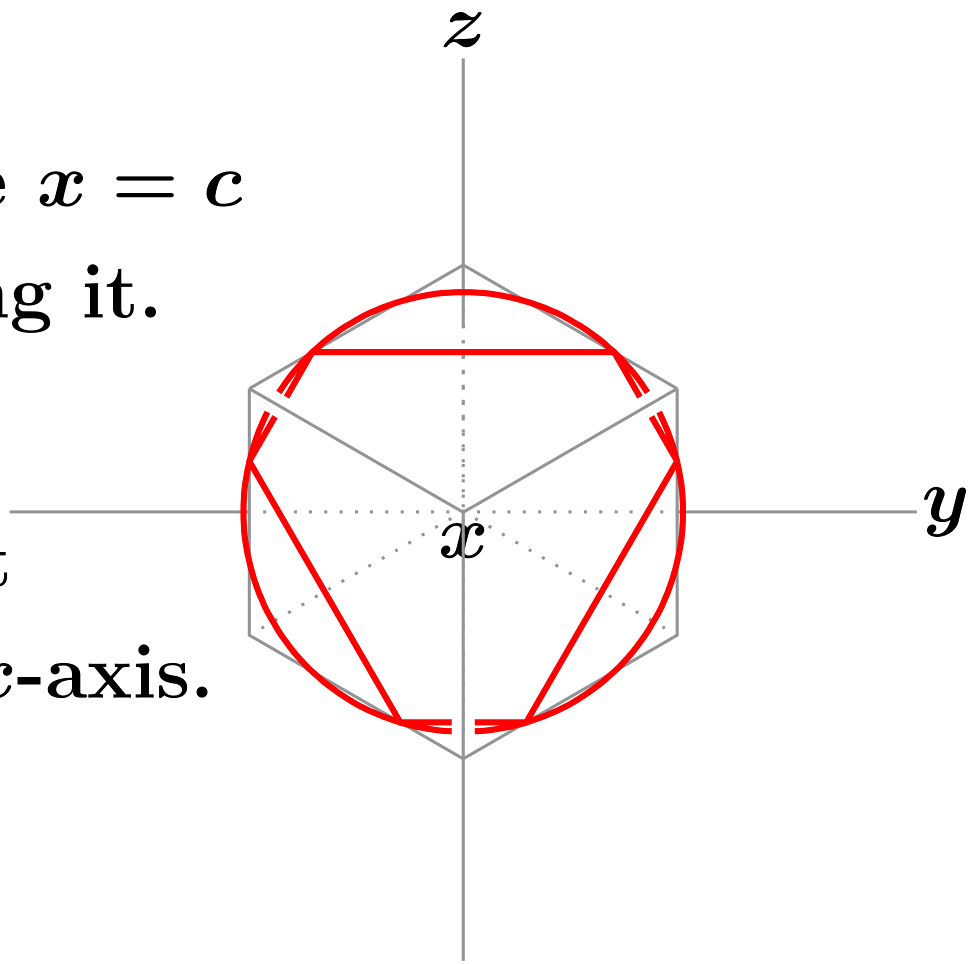
...with circles while rotating it.



Equation of Hyperbora

Consider intersection of
face of this cube and plane $x = c$
...with circles while rotating it.

The radius of circle is
distance between the point
on the segment Q′R′ and x-axis.



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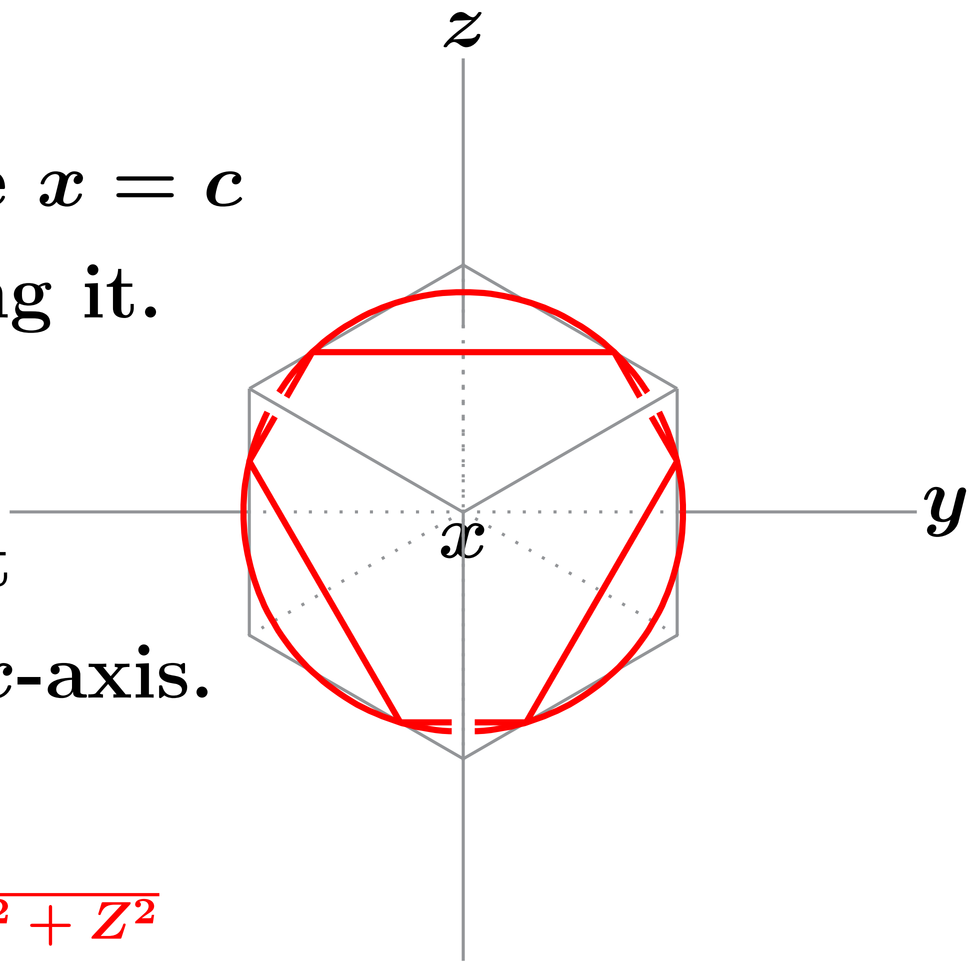

半径は線分 Q′R′ 上の点 $(X,\ Y,\ Z)$ と x 軸上の点 $(X,\ 0,\ 0)$ との距離 $\sqrt{Y^2 + Z^2}$

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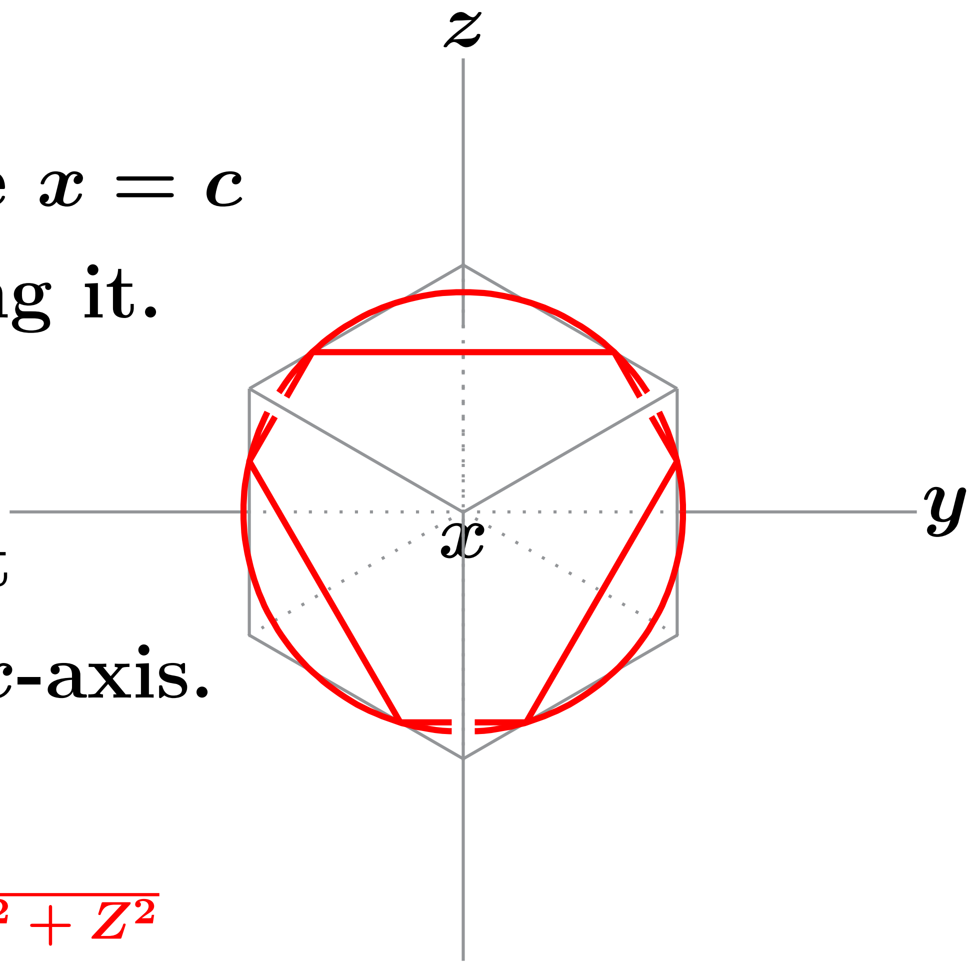

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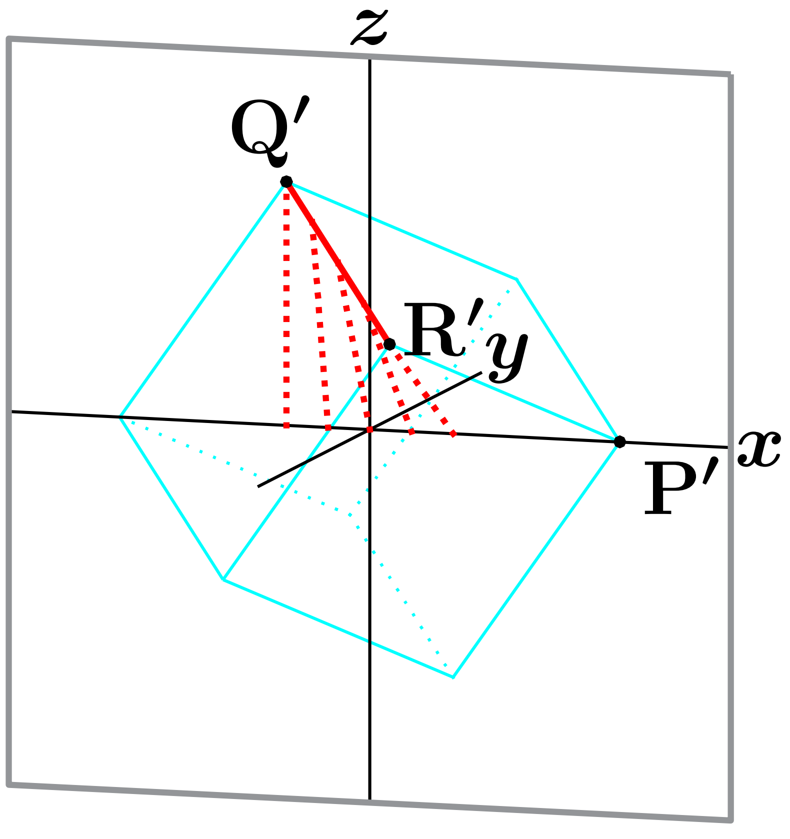
→問 4

Equation of Hyperbora

$$z^2 = \left\{-\frac{1}{\sqrt{2}}(t+1)\right\}^2 + \left\{-\frac{1}{\sqrt{6}}(t-3)\right\}^2$$



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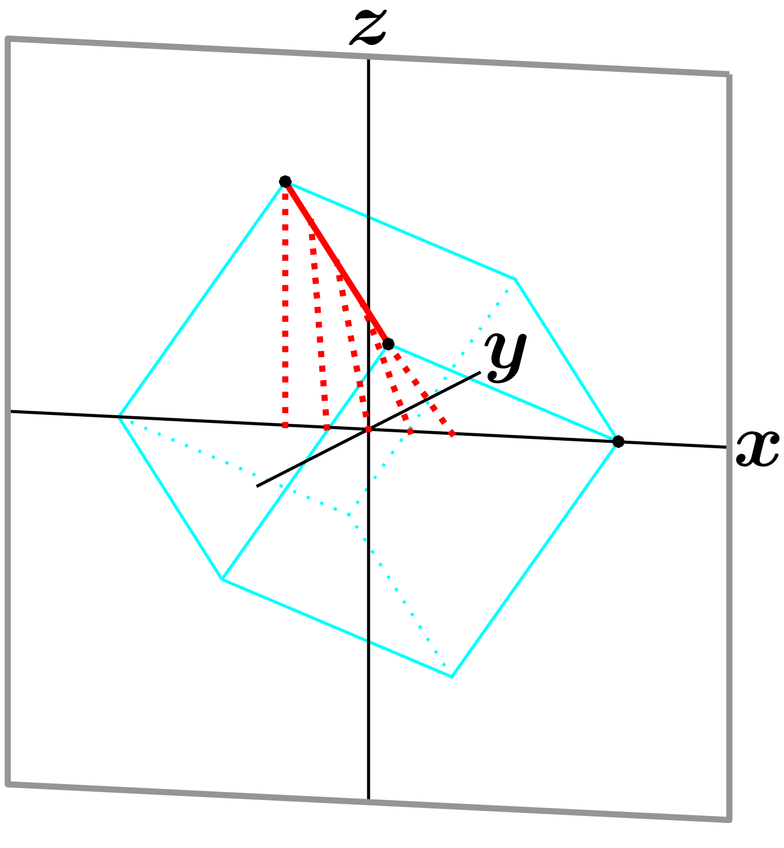

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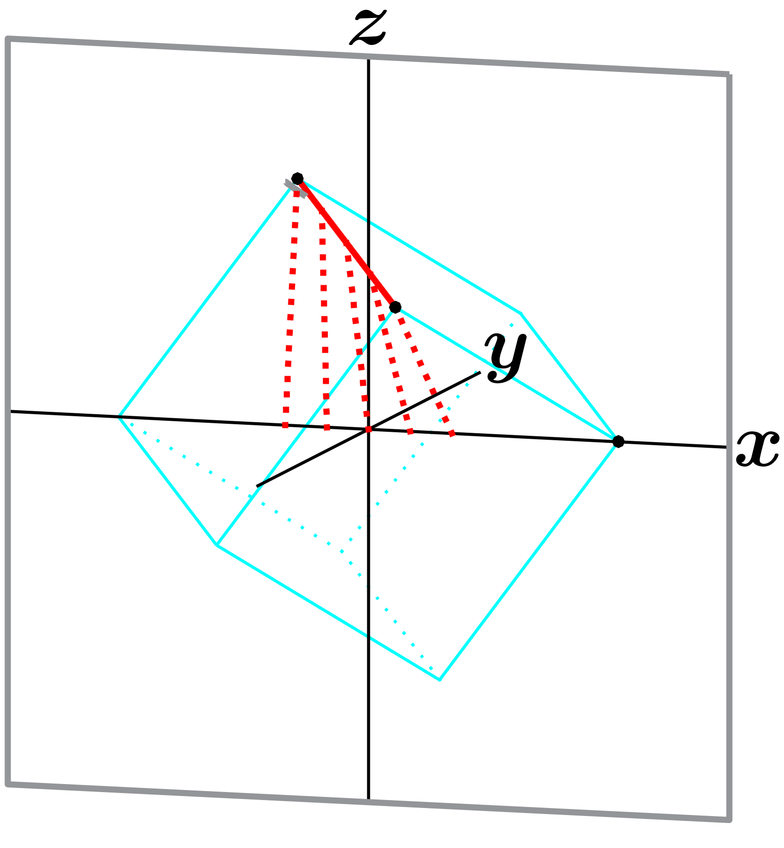

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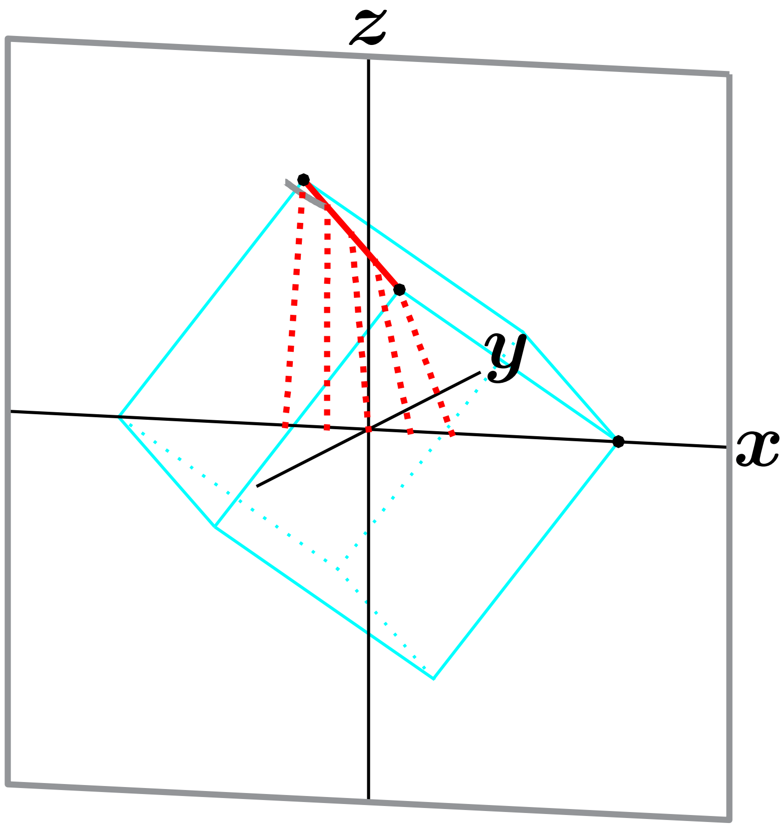

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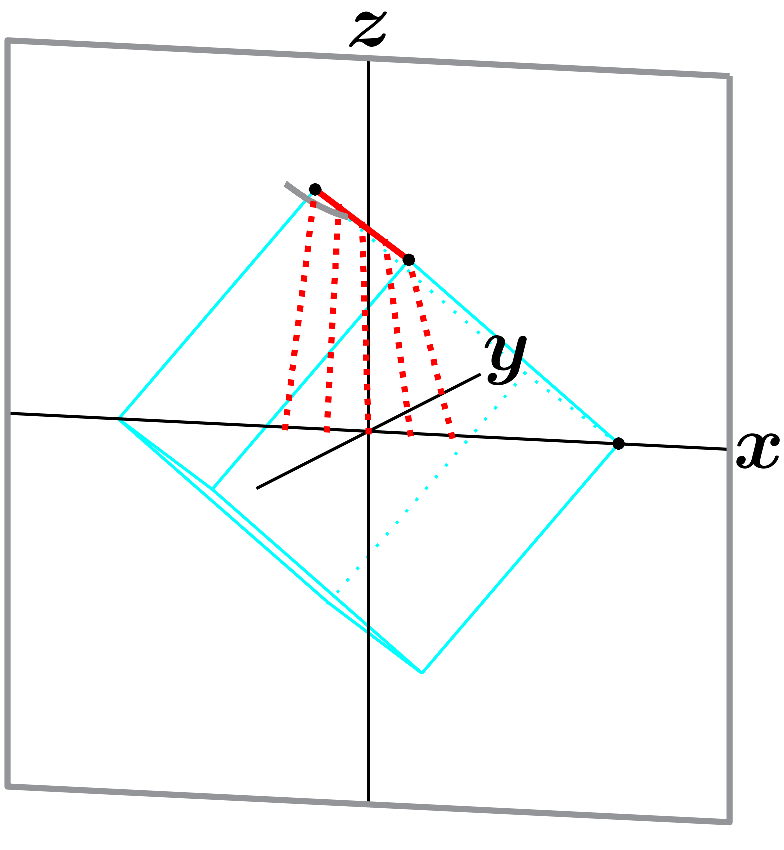

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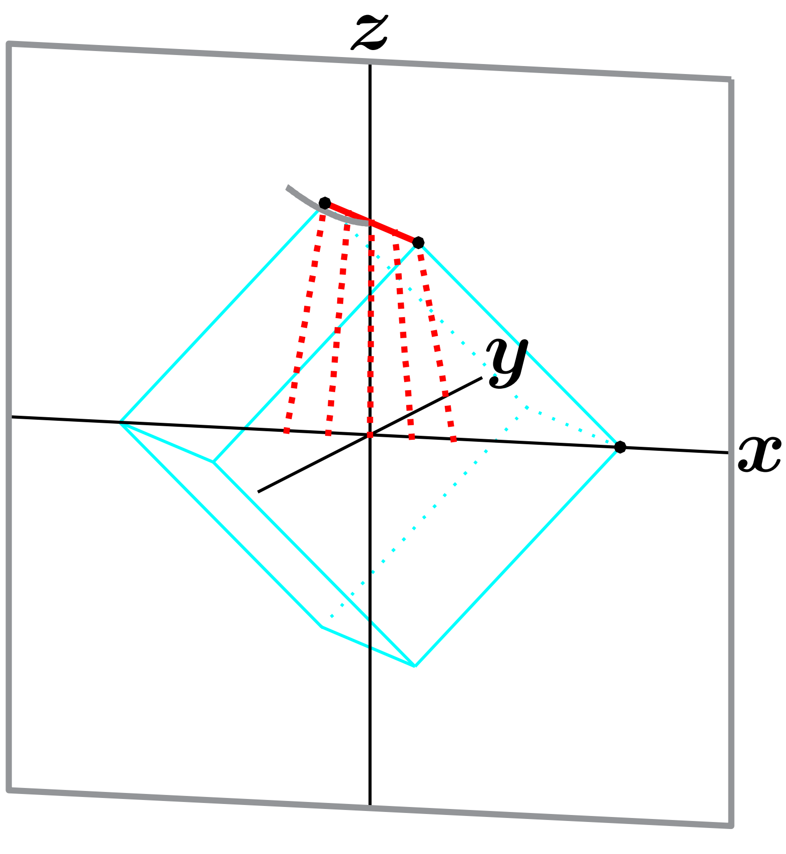

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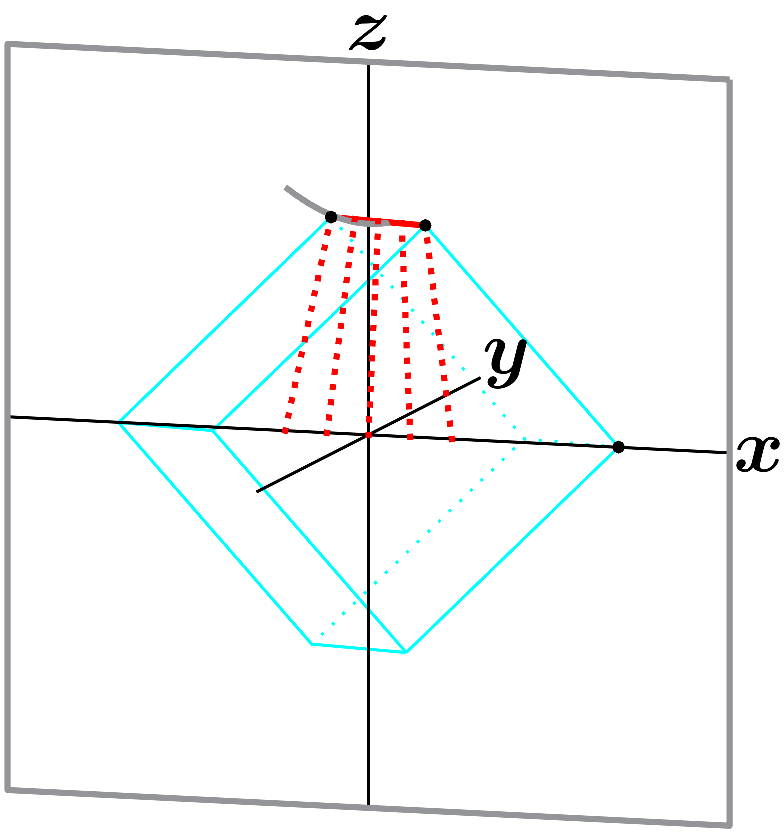

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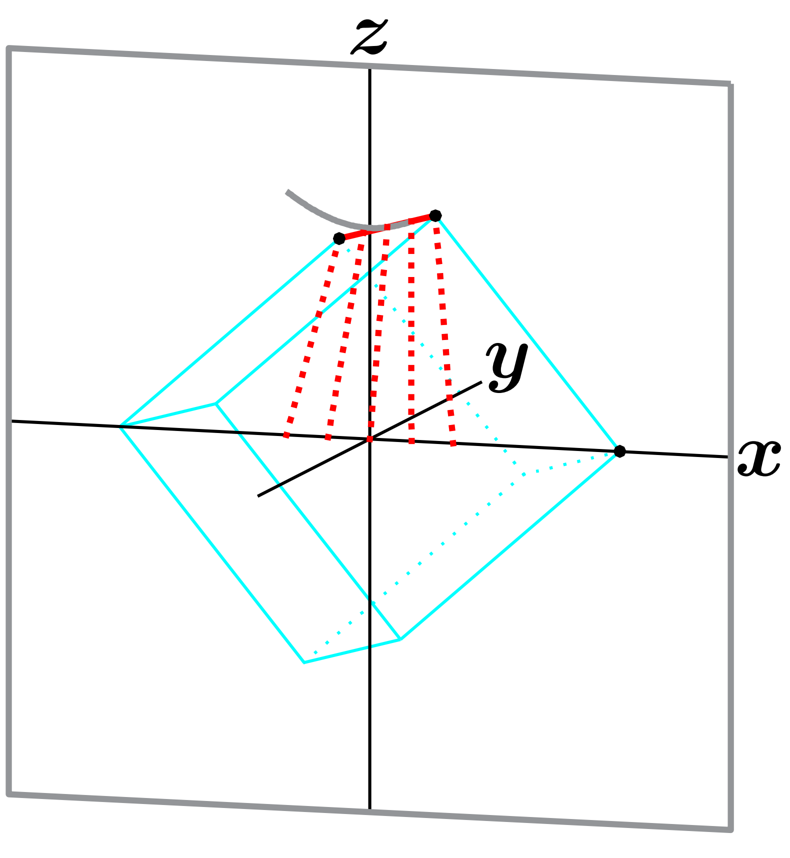

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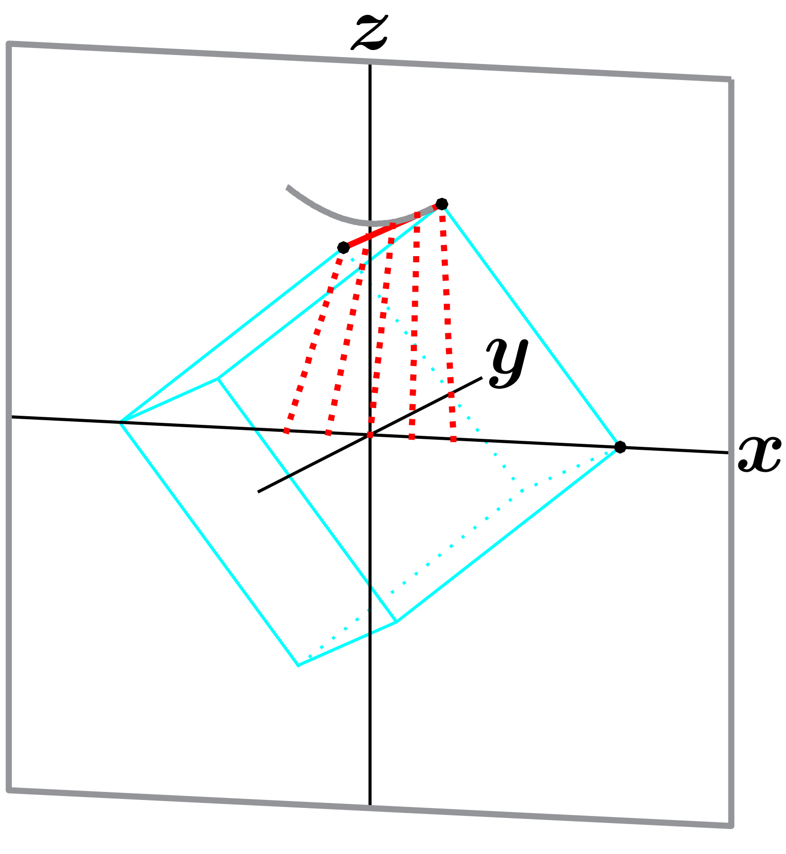

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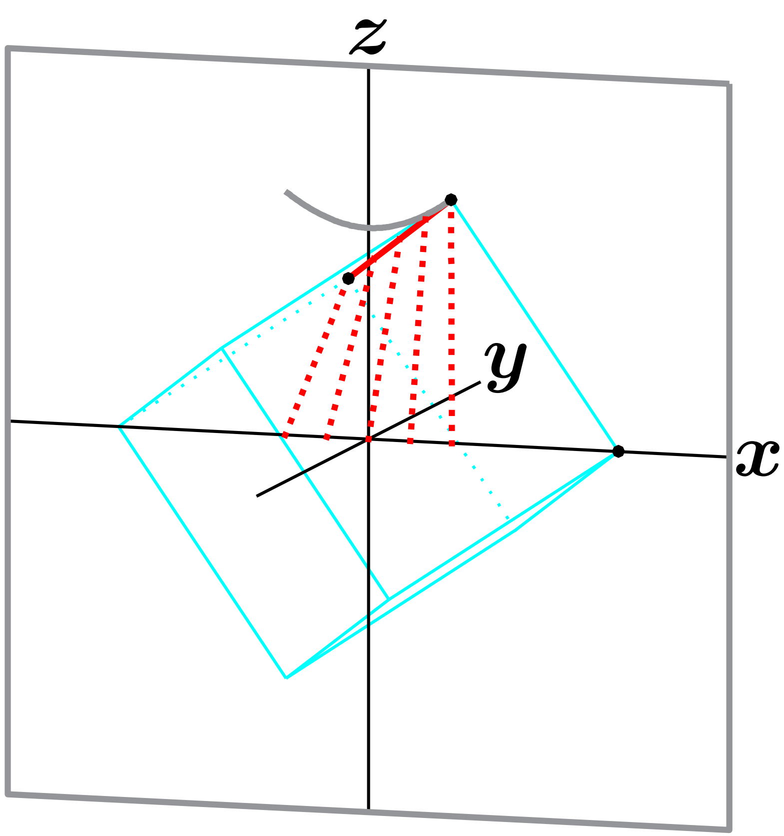

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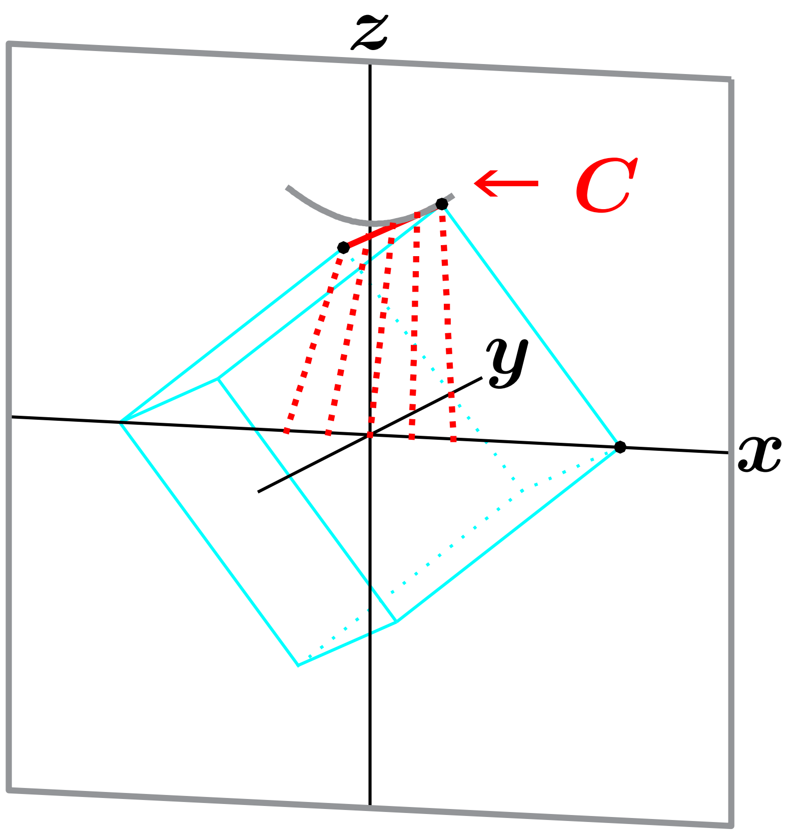

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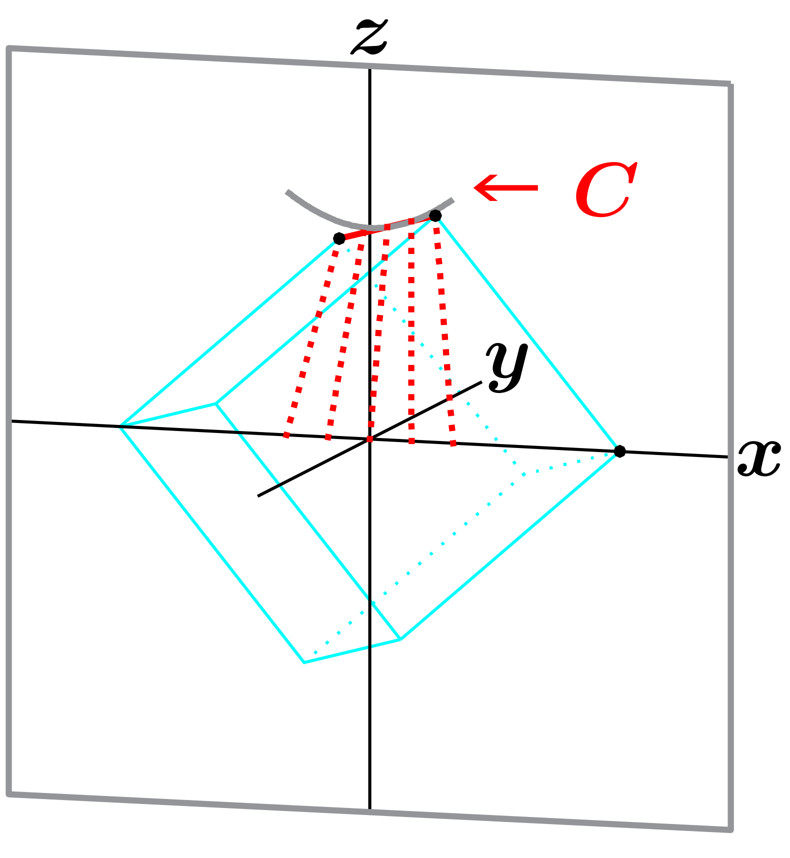

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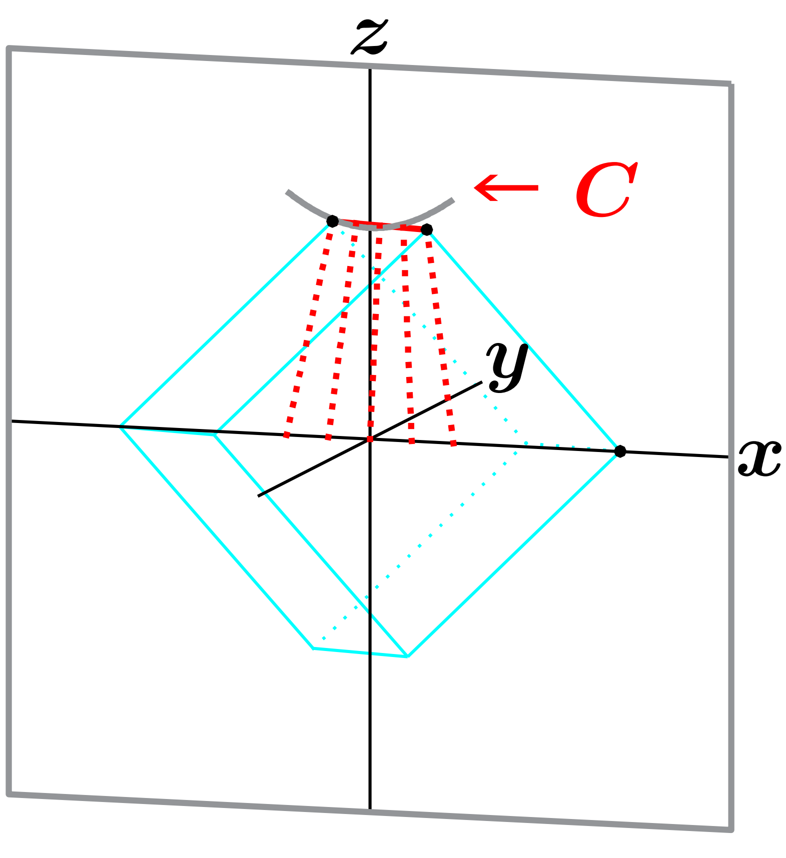

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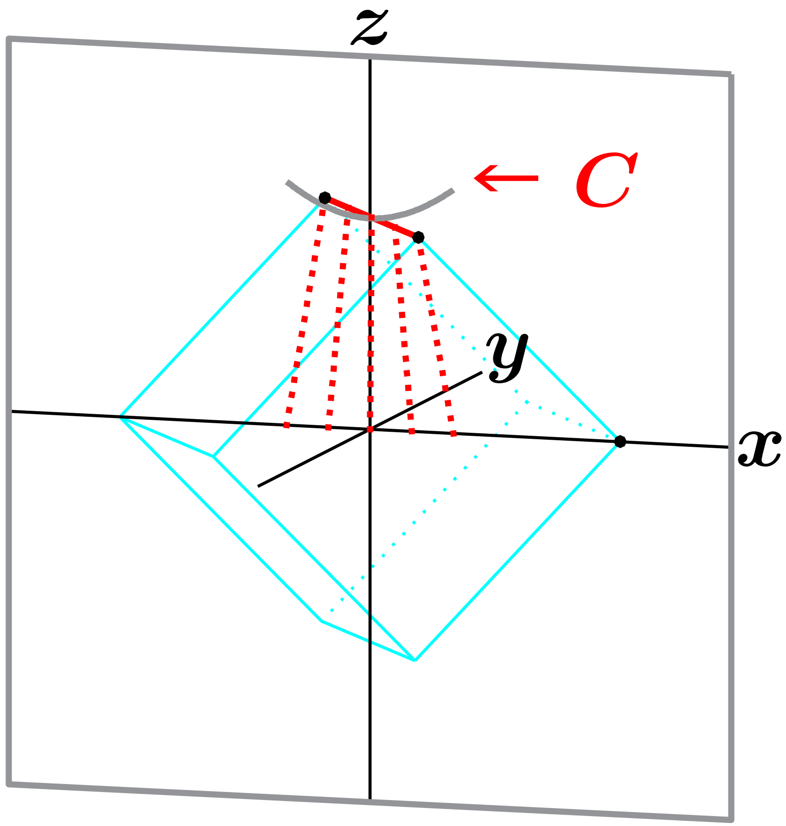

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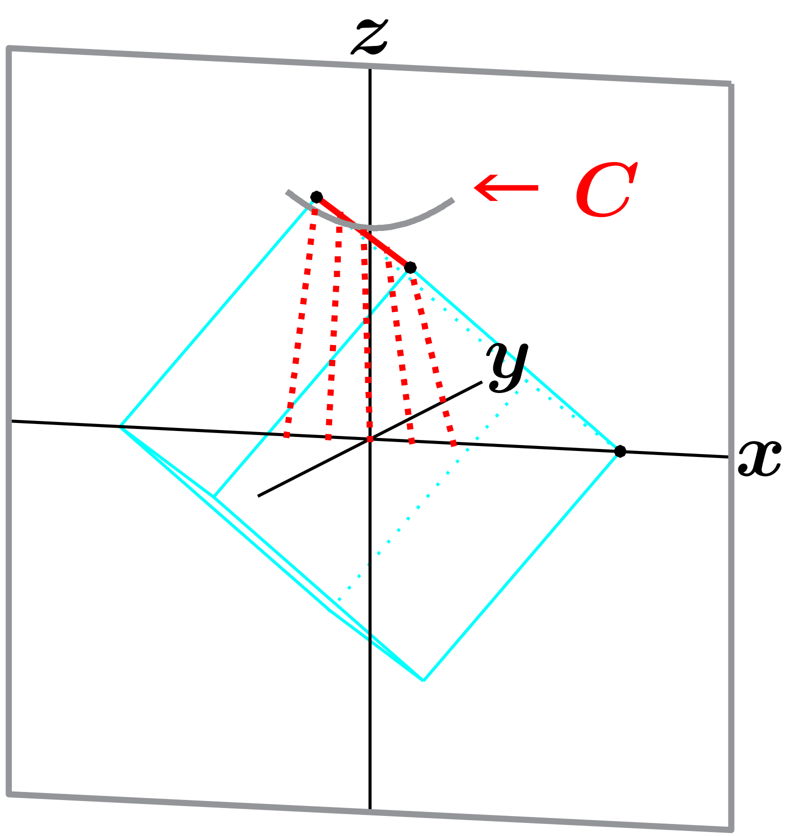

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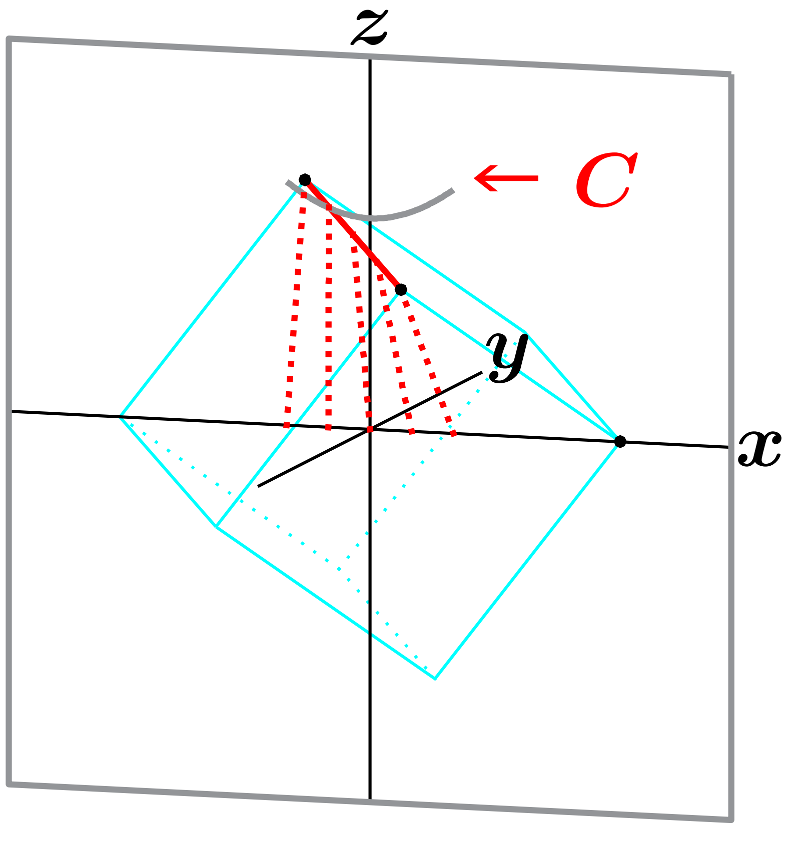

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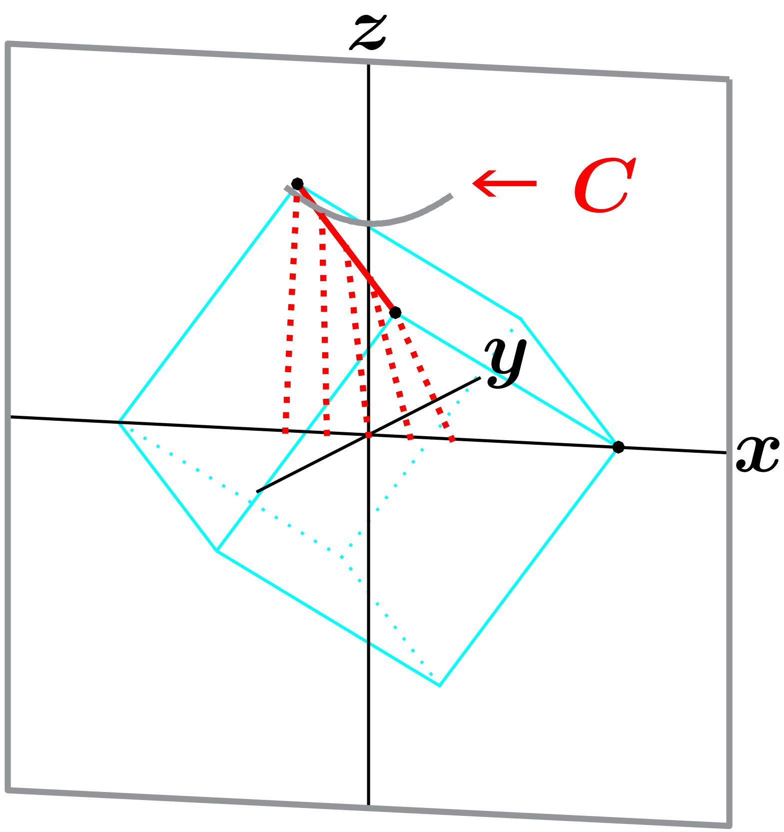

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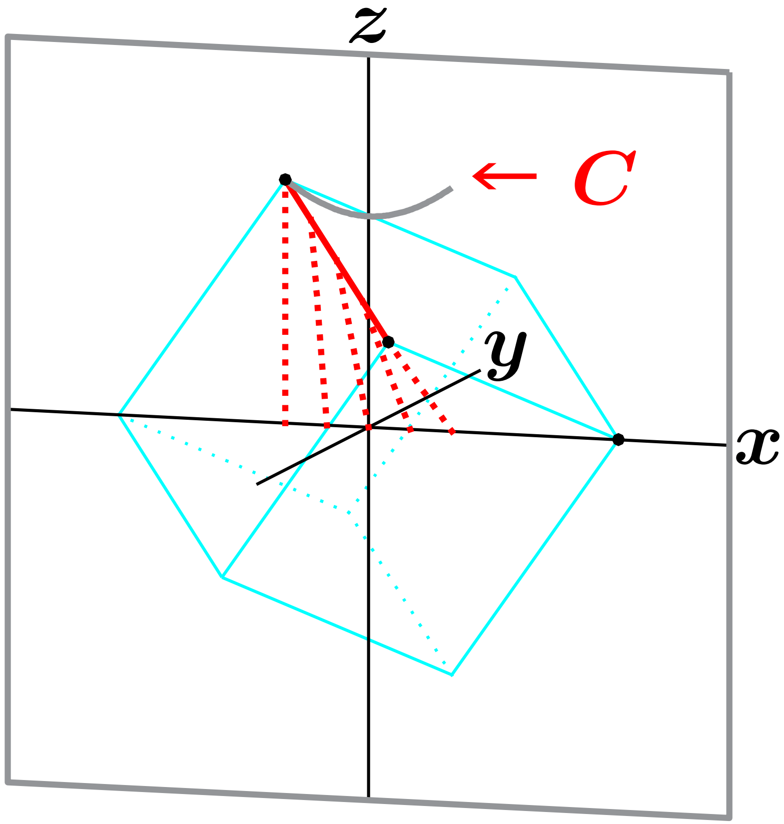

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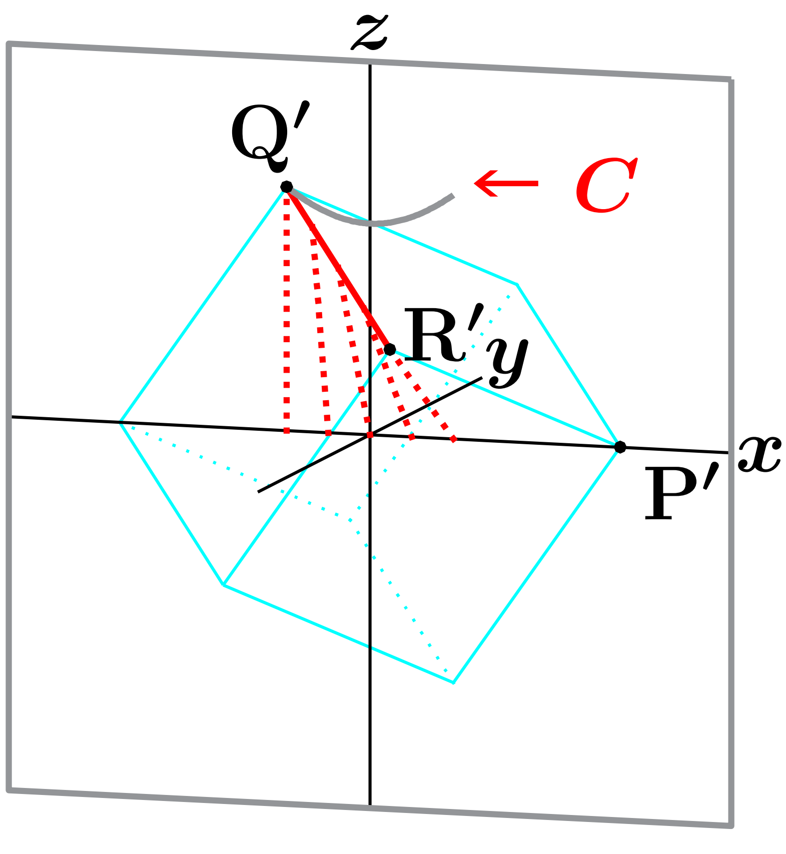

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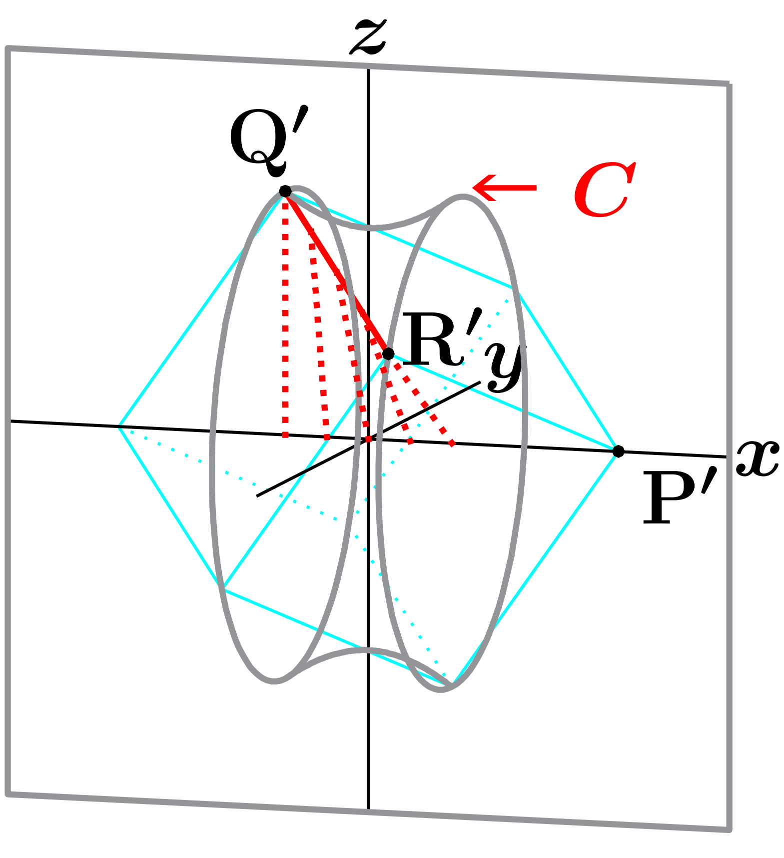

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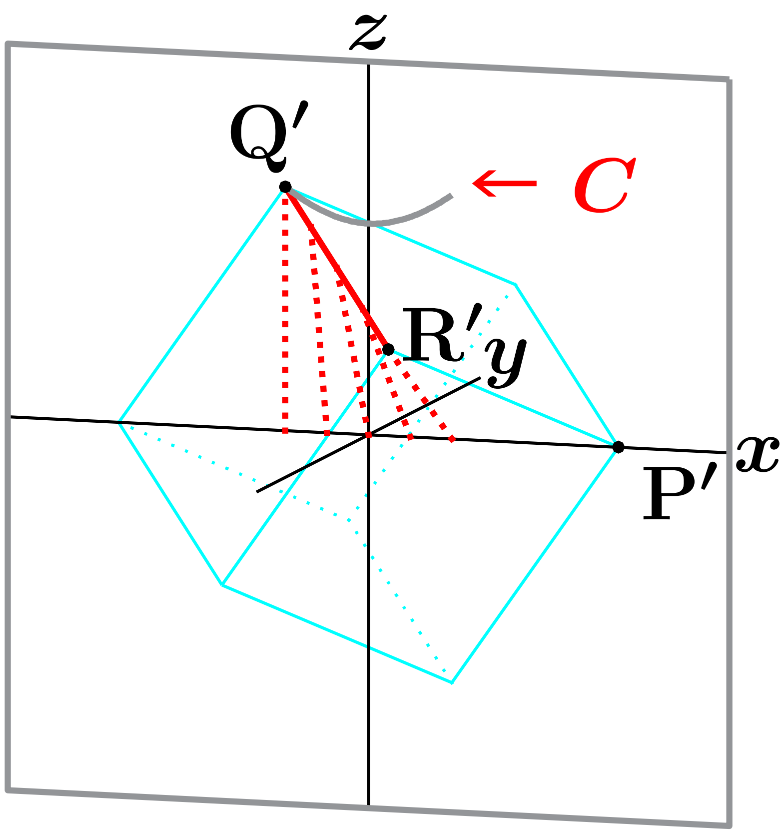
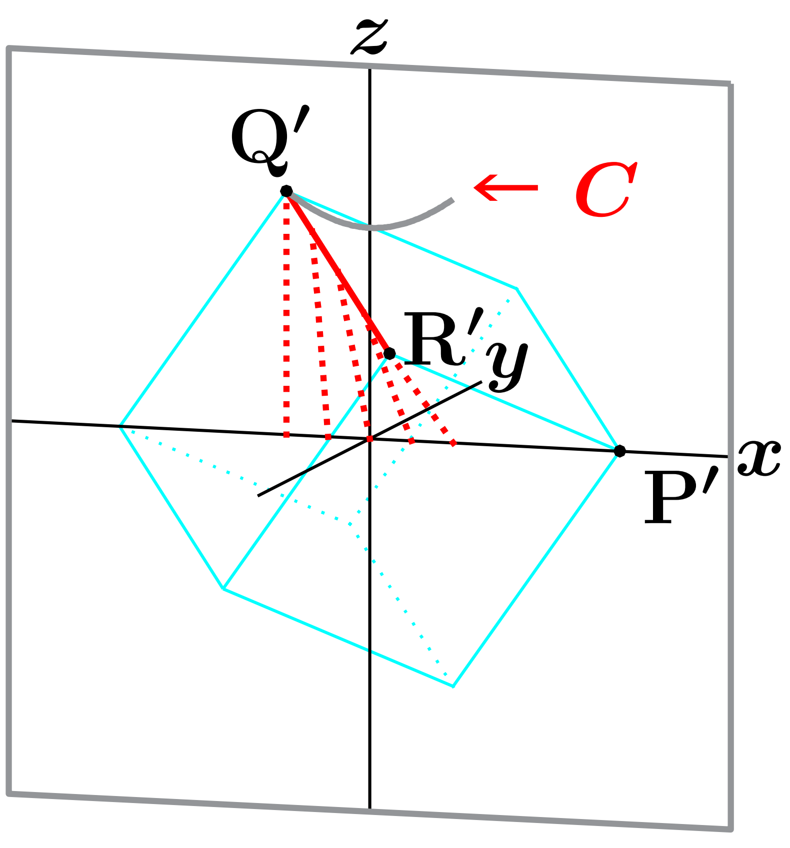


Equation of Hyperbora

$$z^2 = \left\{-\frac{1}{\sqrt{2}}(t+1)\right\}^2 + \left\{-\frac{1}{\sqrt{6}}(t-3)\right\}^2$$
$$= 2 \cdot \frac{1}{3}t^2 + 2$$



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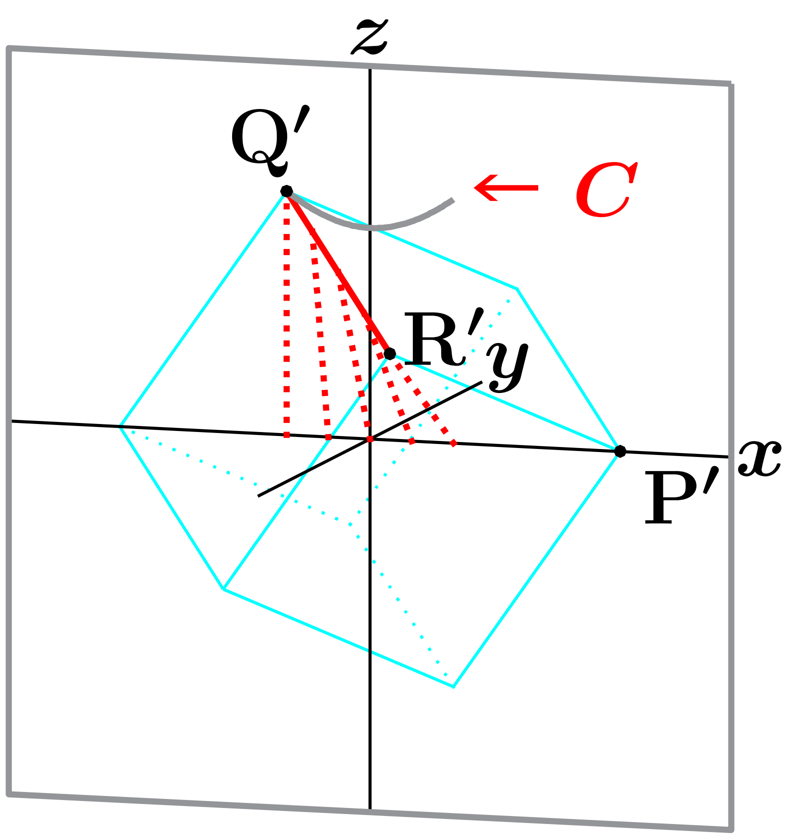
Using $x = \frac{1}{\sqrt{3}}t$, we have



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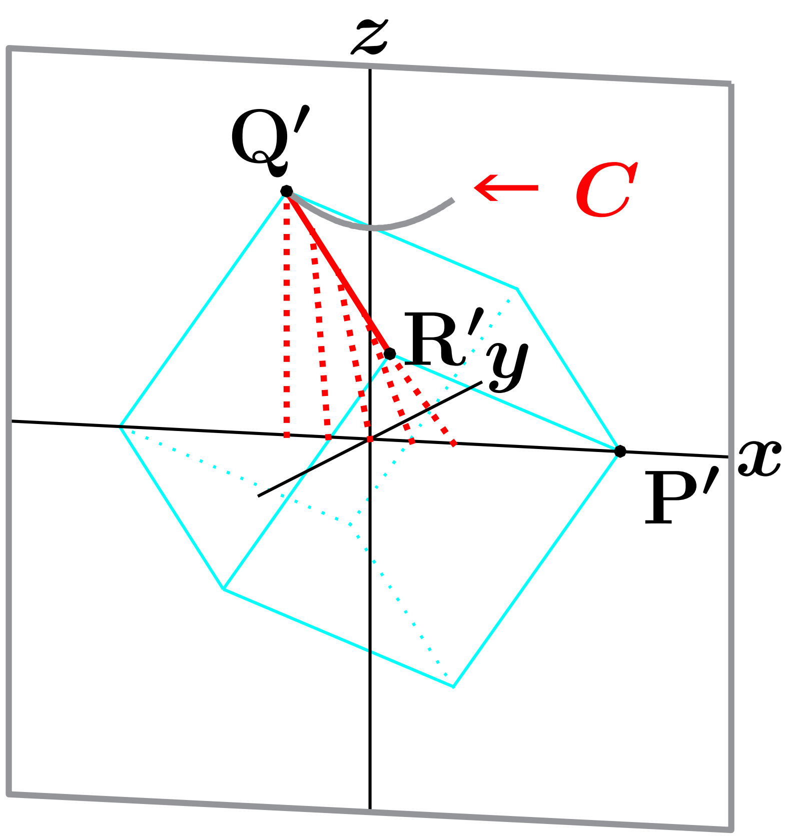
Using $x = \frac{1}{\sqrt{3}}t$, we have

$z^2 = 2x^2 + 2$, and hence,

$$C : x^2 - \frac{z^2}{2} = -1$$



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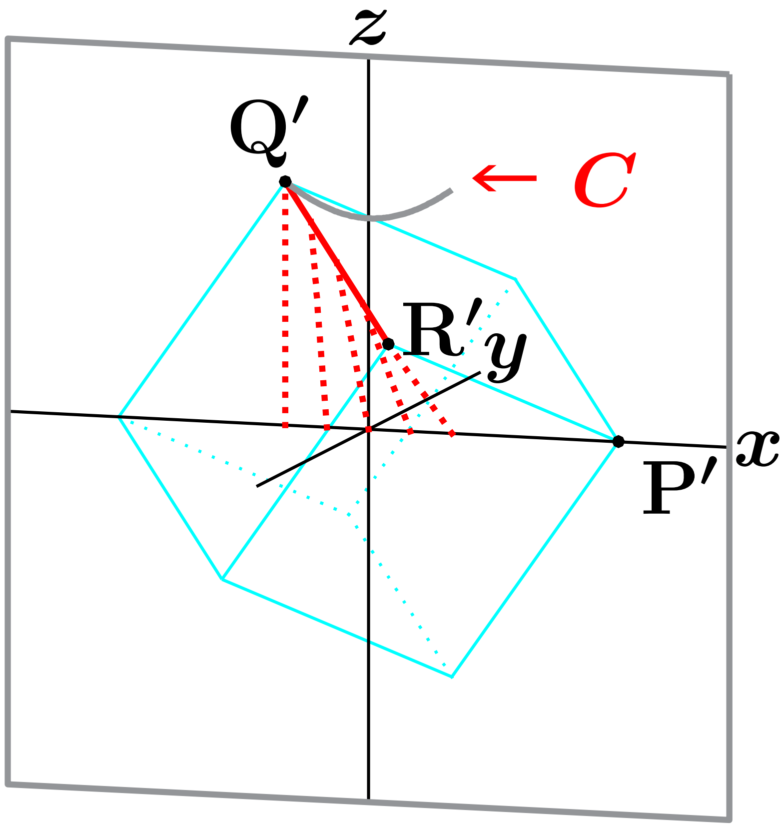

→ 3D viewer