Basic Maths for Non-mathematicians

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$$\int_a^b f(x)\,\mathrm{d}x = \lim_{\Delta x \to 0} \sum_{k=1}^{N} f(x_k)\Delta x$$

$$(AB)^\top = B^\top A^\top \qquad \mathbb{R}^n \xrightarrow{T} \mathbb{R}^m$$

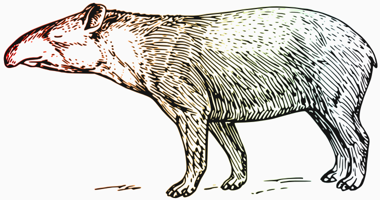
$$\vec{v} = \sum_{i=1}^{n} \alpha_i \hat{e}_i$$

$$\frac{\mathrm{d}f}{\mathrm{d}x} = \lim_{\Delta x \to 0} \frac{f(x+\Delta x) - f(x)}{\Delta x} \qquad A = Q\Lambda Q^{-1}$$

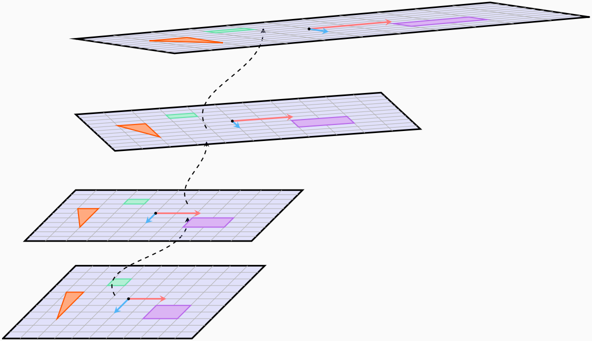
$$A\vec{v} = \lambda\vec{v}$$

$$\mathrm{Rot}(\theta) = \begin{bmatrix} \cos(\theta) & -\sin(\theta) \\ \sin(\theta) & \cos(\theta) \end{bmatrix} \qquad \int_a^b f(x)\,\mathrm{d}x = F(b) - F(a)$$

$$T(\alpha\vec{u} + \beta\vec{v}) = \alpha T(\vec{u}) + \beta T(\vec{v}) \qquad \langle \hat{e}_i, \hat{e}_j \rangle = \delta_{ij}$$



Chapter 3: Linear Transformations



Linear Transformations: Definition

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2. **Additivity**: For any $x, y \in A$:

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Therefore, f is linear.

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Therefore, g is **NOT** linear.

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Challenge

Check whether the function g from before complies with the 2nd criterion (additivity).

Linear Transformations: Definition

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Is the function $h(x) = x^2$ linear? Let's check additivity first:

$$h(x+y) = (x+y)^2 = x^2+2xy+y^2, \quad h(x)+h(y) = x^2+y^2.$$

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Thus, h is also **NOT** linear.

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Check whether h fulfills the 1st criterion (scalability).

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We can combine both criteria to a single test for linearity of a transformation T:

Definition

A transformation $T : A \to B$ is linear, if for all $x, y \in A$ and $\alpha, \beta \in \mathbb{R}$

$$T\left(\alpha x + \beta y\right) = \alpha T(x) + \beta T(y).$$

Transforming Vectors

Vectors can also be transformed, specifically by functions of the type $T : \mathbb{R}^n \to \mathbb{R}^m$, with $n, m \in \mathbb{N}$.

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In this course we will mostly concentrate on transformations of the types

- $T : \mathbb{R}^2 \to \mathbb{R}^2$ and
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However, everything we learn about these transformations is applicable for any linear transformation, **regardless of its dimensionality**.

Transforming Vectors

Example

Applying the transformation $T : \mathbb{R}^2 \to \mathbb{R}^2$,

$$T\begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} -x \\ 3y \end{pmatrix}$$

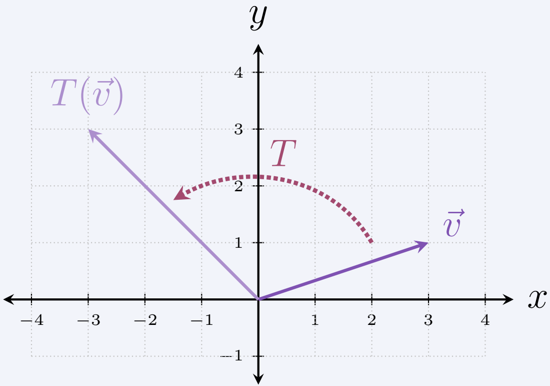
to the vector $\vec{u} = \begin{pmatrix} 3 \\ 1 \end{pmatrix}$:

$$T\begin{pmatrix} 3 \\ 1 \end{pmatrix} = \begin{pmatrix} -3 \\ 3 \cdot 1 \end{pmatrix} = \begin{pmatrix} -3 \\ 3 \end{pmatrix}.$$

Transforming Vectors

Example

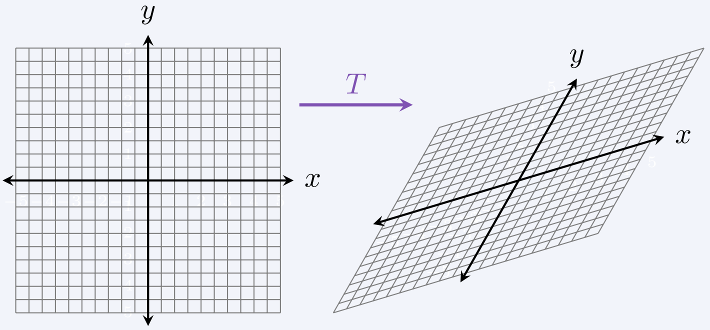
Graphically, the transformation looks as follows:



Transforming Spaces

We can visualize the way an entire space is transformed by a transformation T by looking at how the axes and main gridlines of the space are transformed.

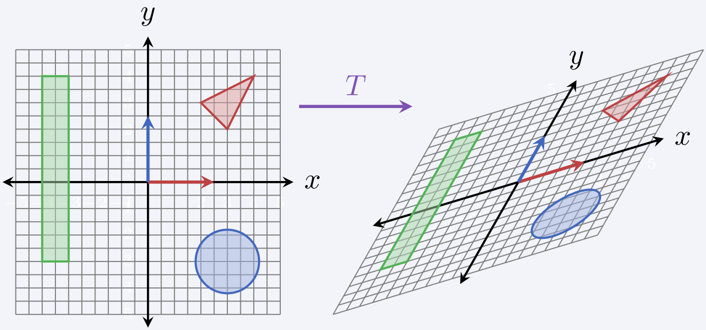
Example



Transforming Spaces

This method also allows us to see how the basis vectors $\hat{x}$ and $\hat{y}$ are transformed by linear transformations, and also the transformations of shapes (all this will come in handy later).

Example



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Challenge

Show that these properties can be derived from the definition of linear transformations.

Types of Linear Transformations

Many linear transformations $T : \mathbb{R}^2 \to \mathbb{R}^2$ can be created by composition of two or more of the following basic transformations:

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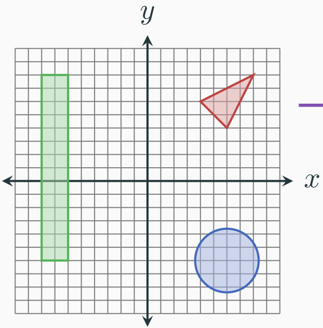
Scaling in the x-axis



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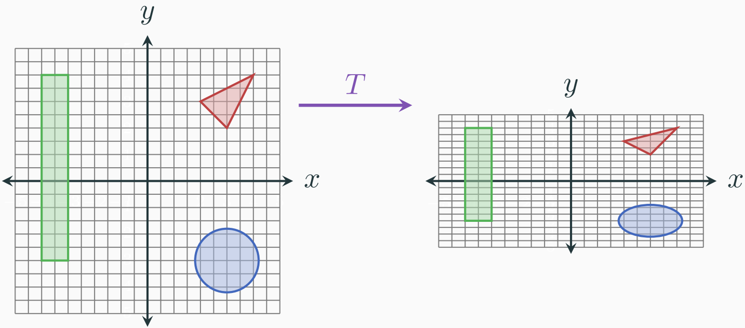

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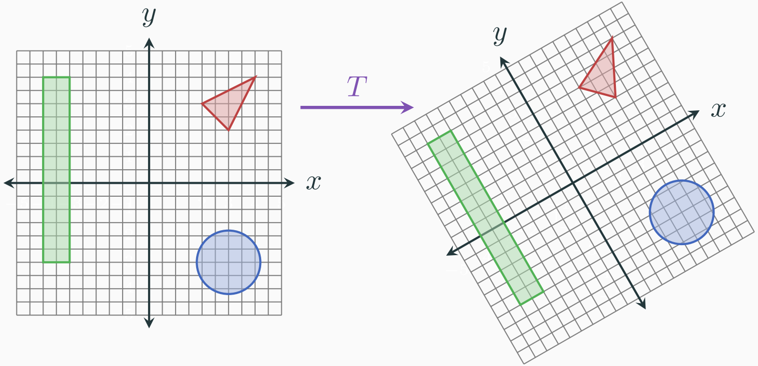
Rotation around the origin



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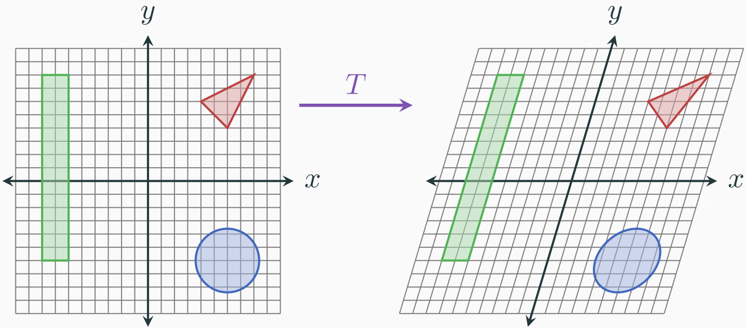

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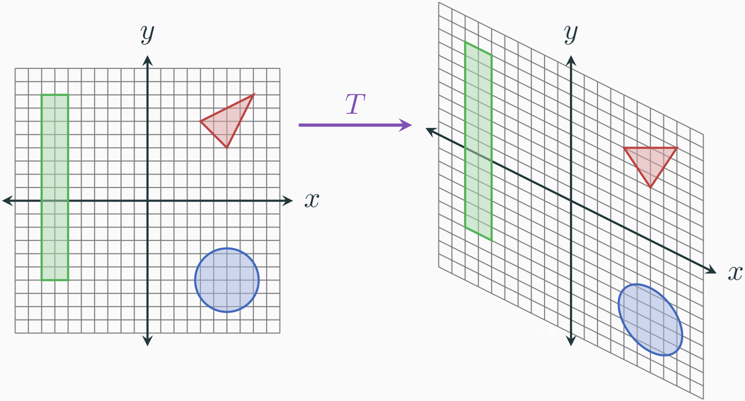

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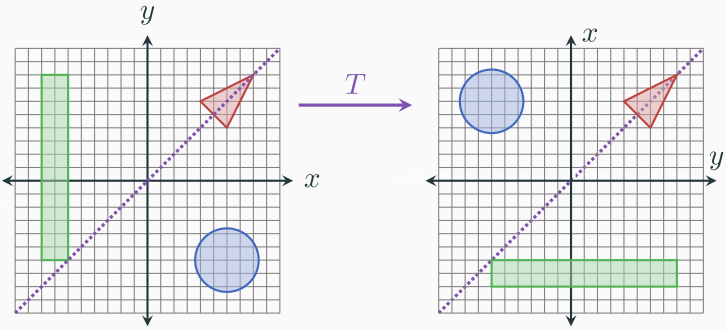
Reflection by a line going through the origin



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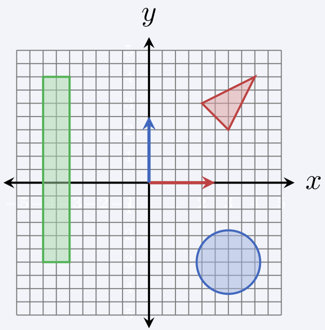
The following transformation is a composition of a scaling transformation in the y-axis, followed by a rotation around the origin:



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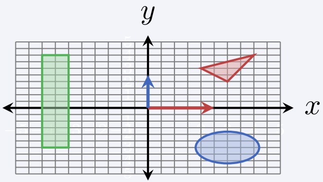

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