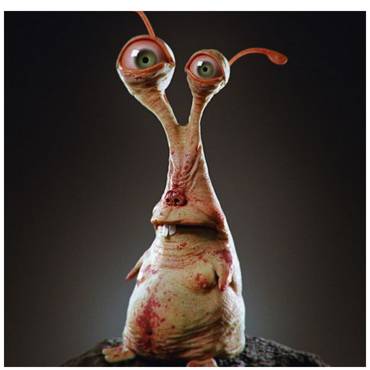

# Introduction

3D Computer Graphics (Lab 1)



# Terminology

## 3D Computer Graphics

*The generation of 2D images from*
*3D representations of geometric objects.*

## CGI

Computer Generated Imagery,
the result of applying 3D Computer Graphics

# Applications of 3D Computer Graphics

- Movie production, animation and special effects
- Computer games
- Art
- CAD (Computer-aided Design)
- Computer-aided Architectural Design
- Scientific Analysis and Visualization
- Displaying simulations

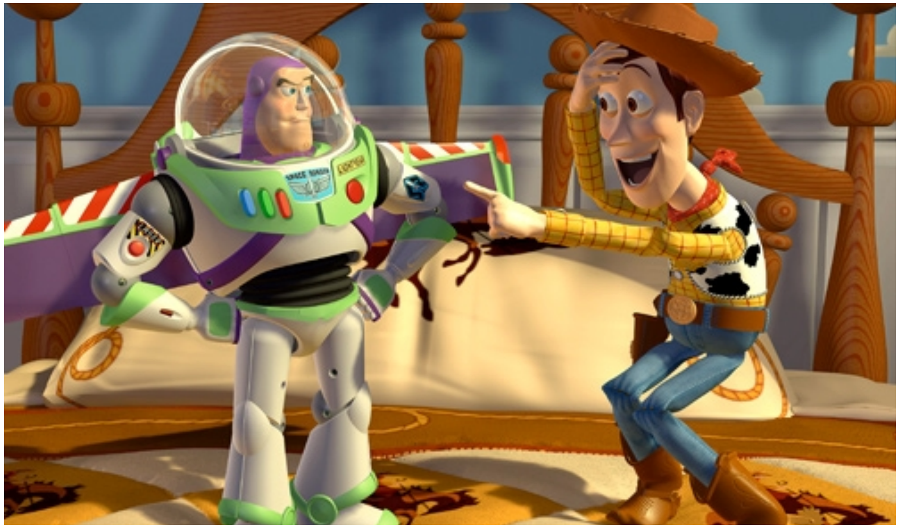
# Movie production, animation and special effects

- The film industry has driven advances in 3D Computer Graphics
- Quest for
  - Photorealism
  - Seamless blending of CGI and live-action

# A few milestones of CGI in the movies

**Jurassic Park (1993)**

First photorealistic CG creatures



**Toy Story (1995)**

First full-length CG film

# A few milestones of CGI in the movies

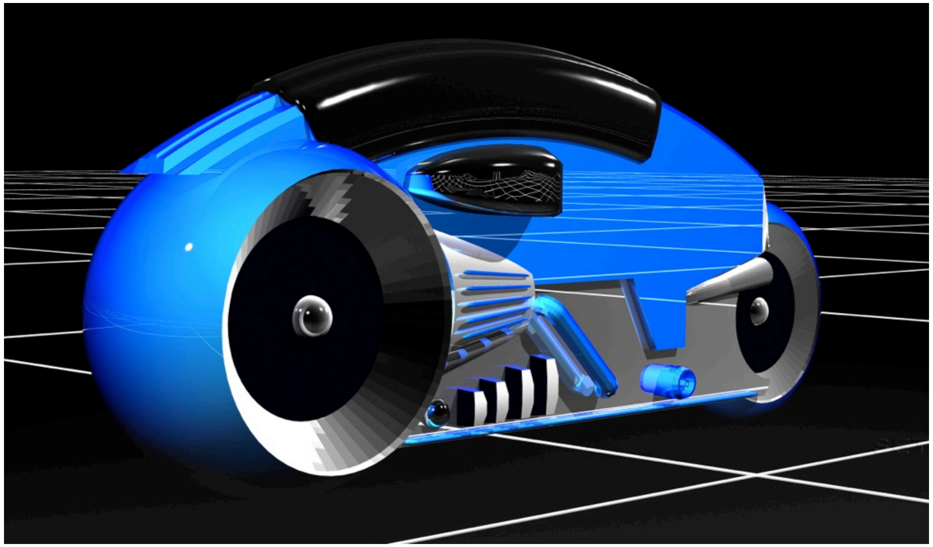
**Titanic (1997)**

Landmark CG effects


**Final Fantasy (2001)**

First near-photorealistic character

# Comparison …



**Tron (1982)**

**Tron Legacy (2010)**

# Computer games

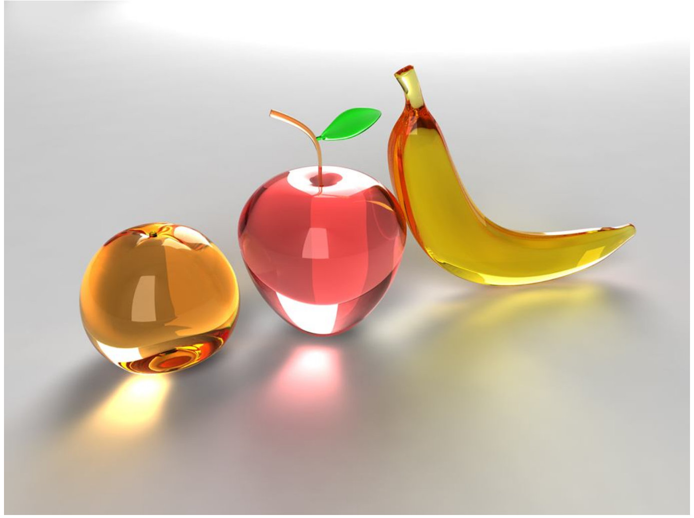
- Heavily influenced by CGI techniques used in movies.
- But different contraints: interactivity and realtime rendering


**World of Warcraft**


**Second life**

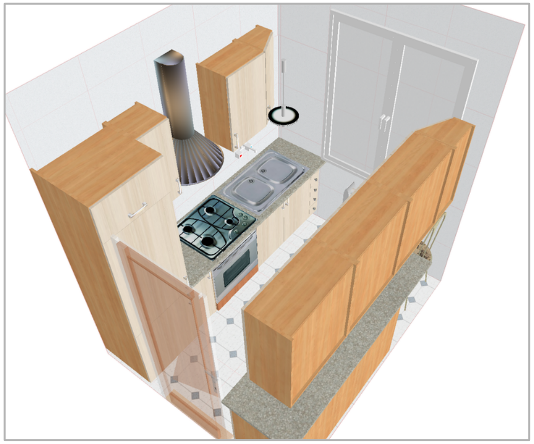
# Art





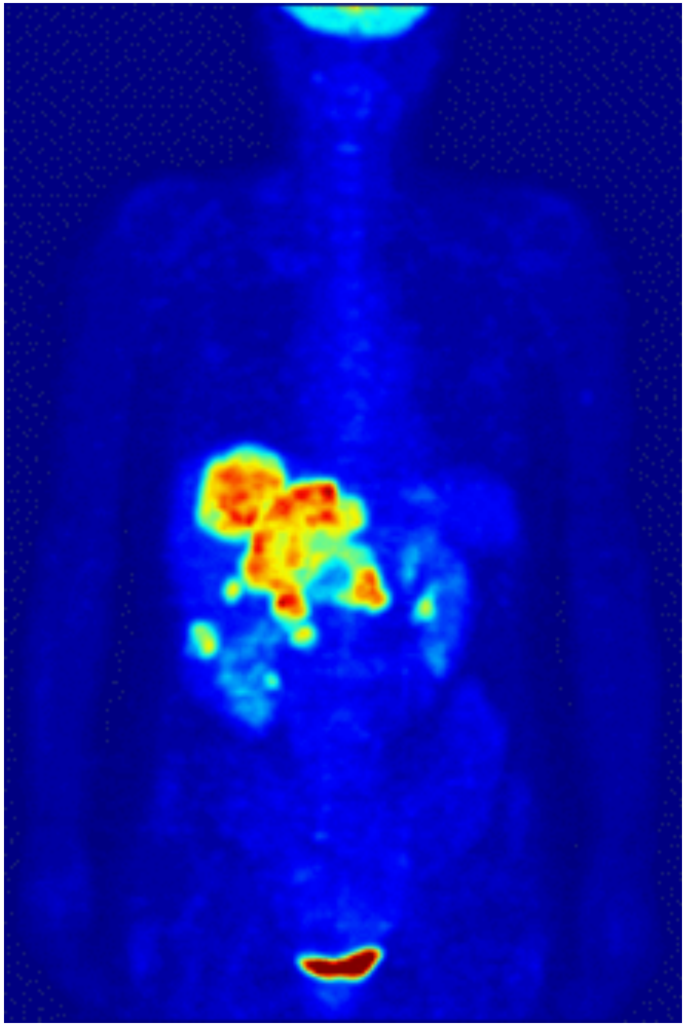
# Computer-aided (architectural) design

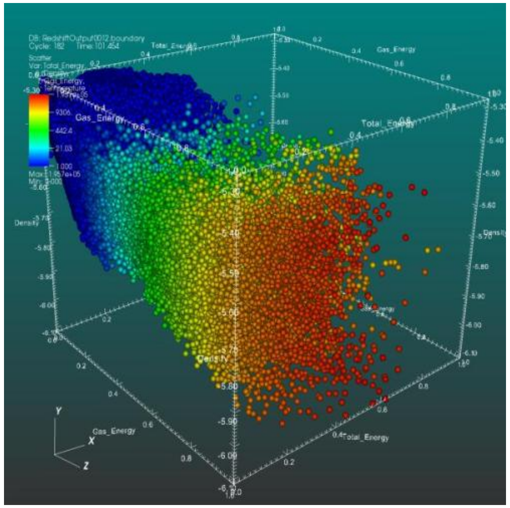
**Virtual prototyping**

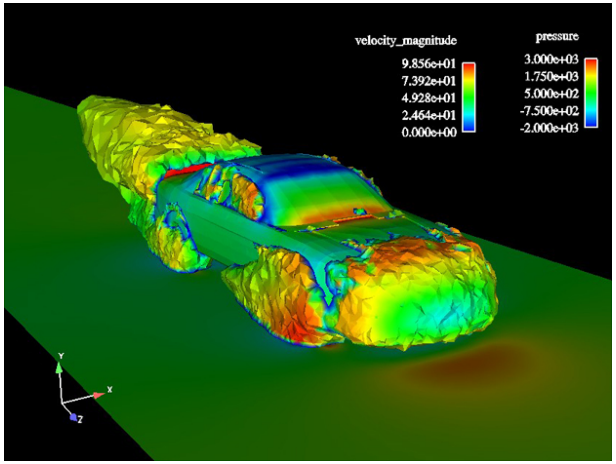


**CAAD**

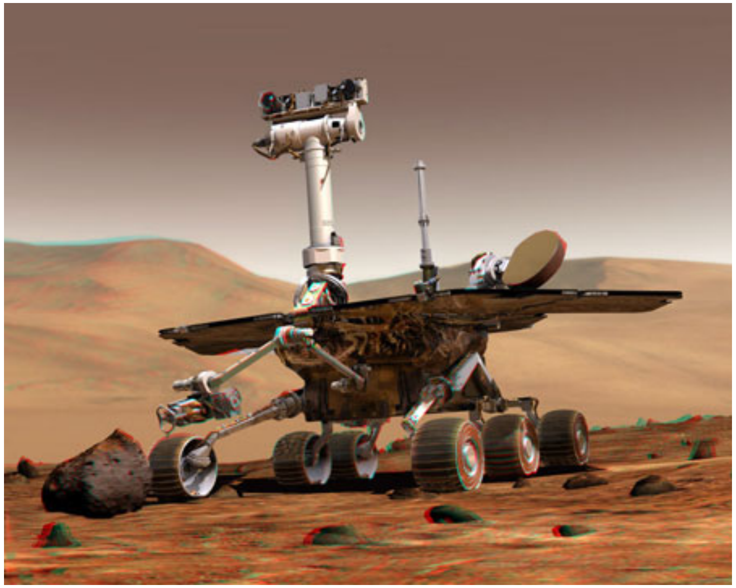
# Scientific analysis and visualization







# Displaying simulations



**Movements of Mars Rover on Martian surface**

**Flight simulator**

# Video

*Replica of King Tut's mummy*

*http://www.youtube.com/watch?feature=player_embedded&v=iQ4TCR9WoLY*

# Course

## Goals

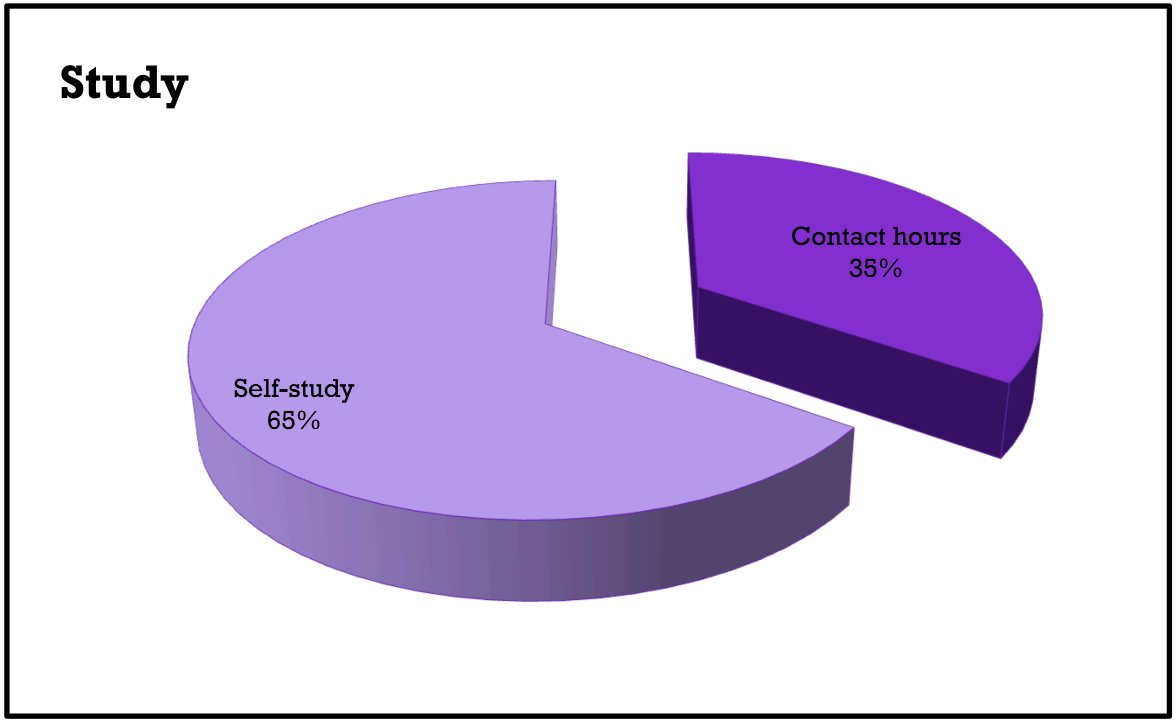
- Knowledge of and insight into the basic concepts and principles of 3D Computer Graphics.
- Knowledge of and insight into mathematical concepts and techniques for multimedia applications.
- Developing software to create and visualize virtual 3D scenes.

## Material

All course material (slides, handouts, …) will be made available online.

I/GT/Export/maaus/3D Computer Graphics/

# Time management




3 SP = 75 hour effort *(all inclusive)*

- Lectures and instruction: 26 hours
- Self-study: 49 hours

# Evaluation

- No permanent evaluation
- No intermediate test/exam
- Exam in January counts for 100% of the final mark.
    - Written exam
    - Closed book
- Second examination is organised in the same way.

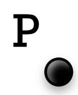
Individual feedback till the end of the week of the last lecture!

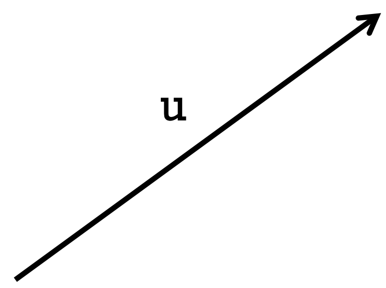
Questions?

# Mathematical preliminaries

# Points vs vectors

- A point defines a location.
  - It has a position.
  - But it has no length or direction.
- A vector has length and direction.
  - But it has no position.
  - It can be moved anywhere.



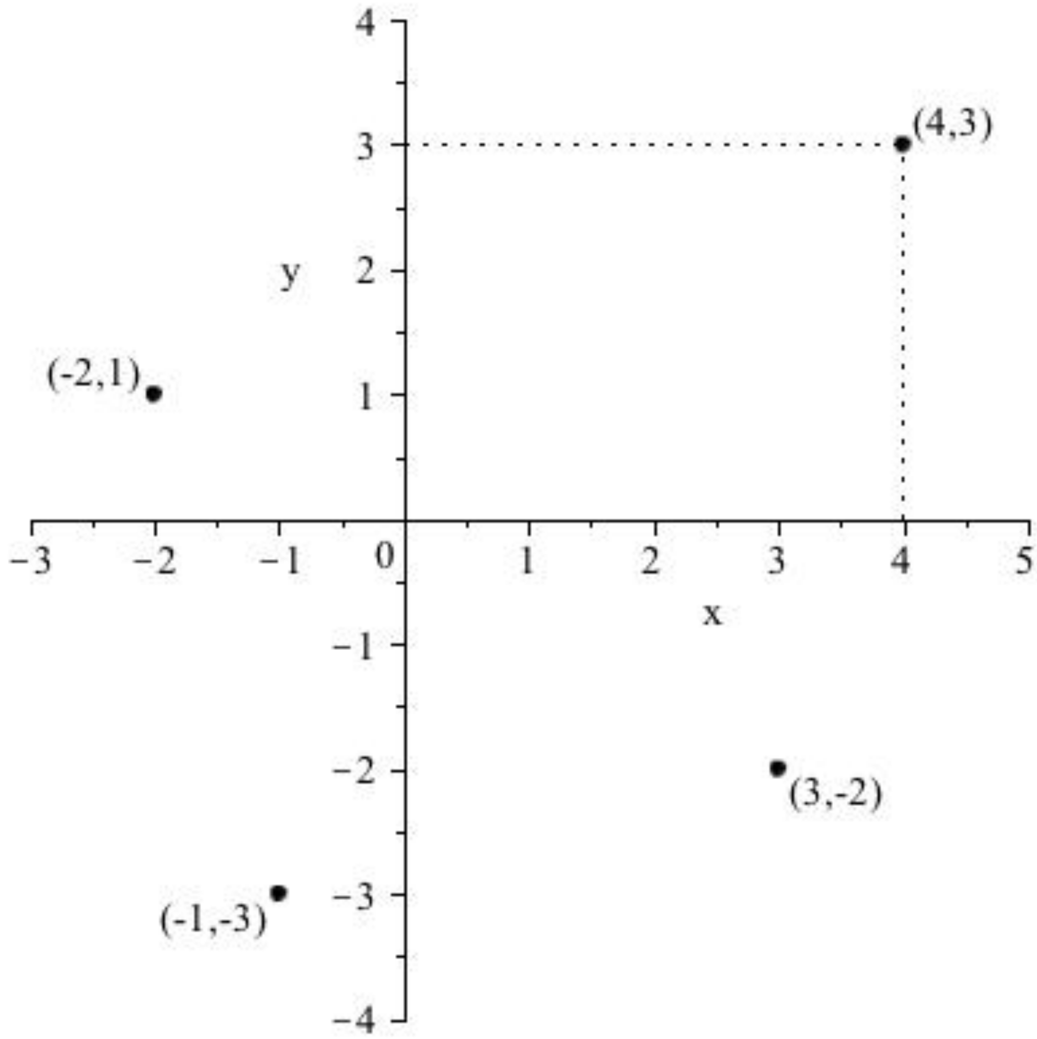




Notation: P, Q, …

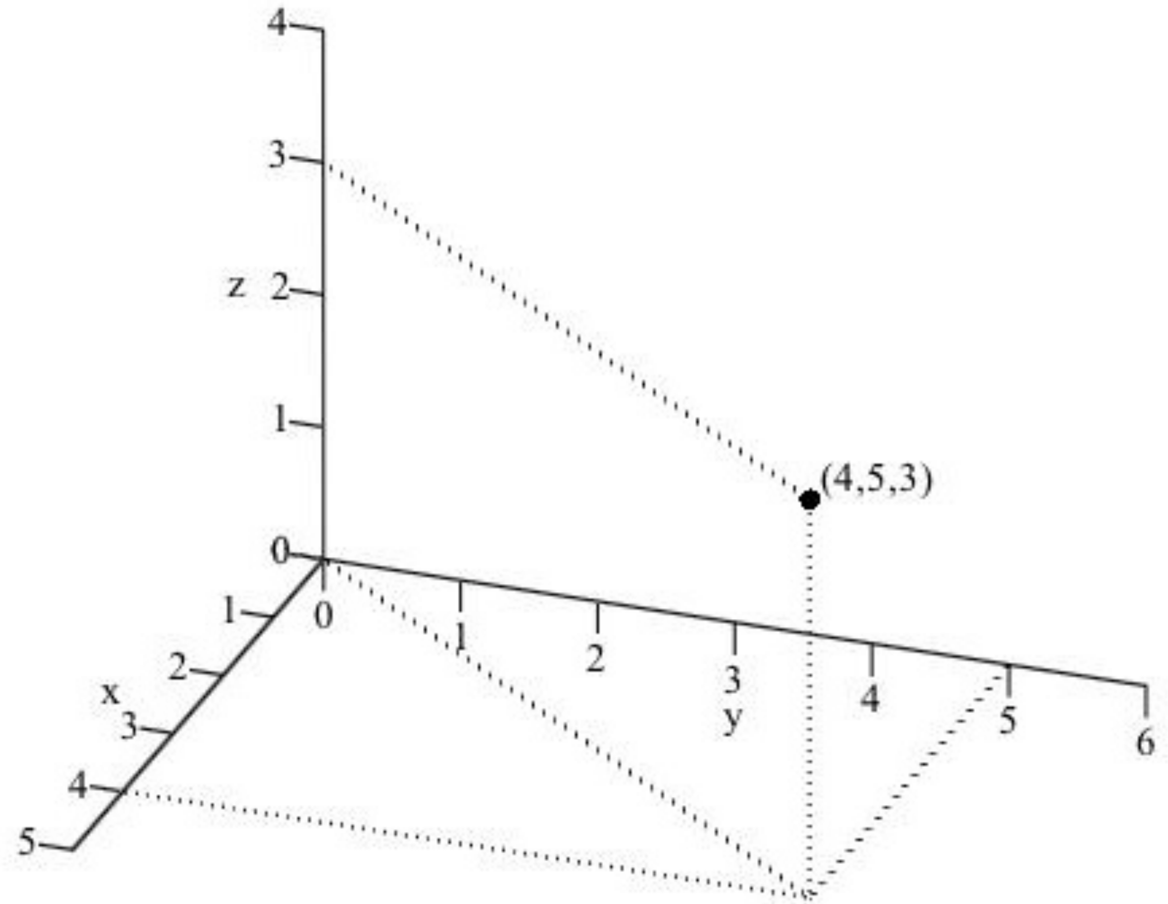
Notation: u, v, …

We need a way to quantify them …

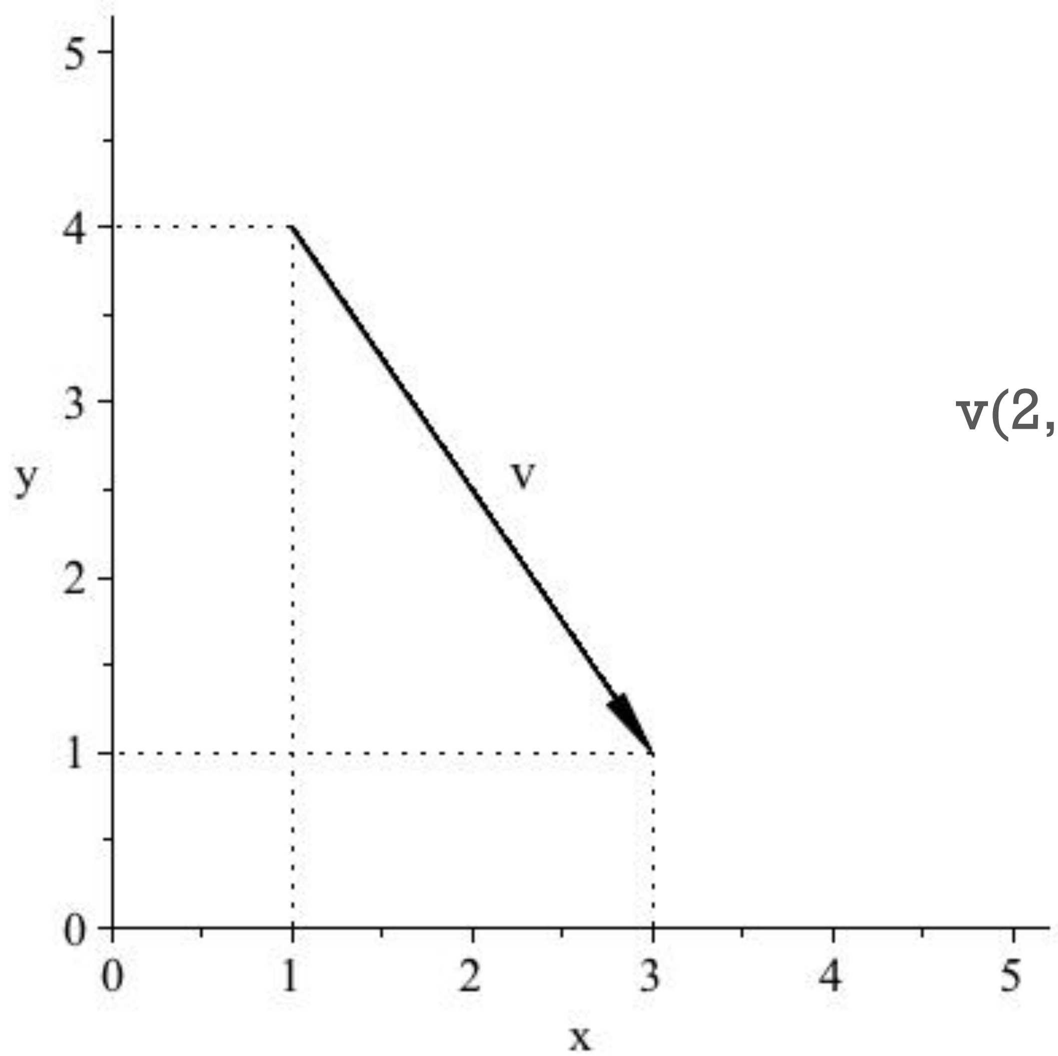
# Points in 2D



# Points in 3D

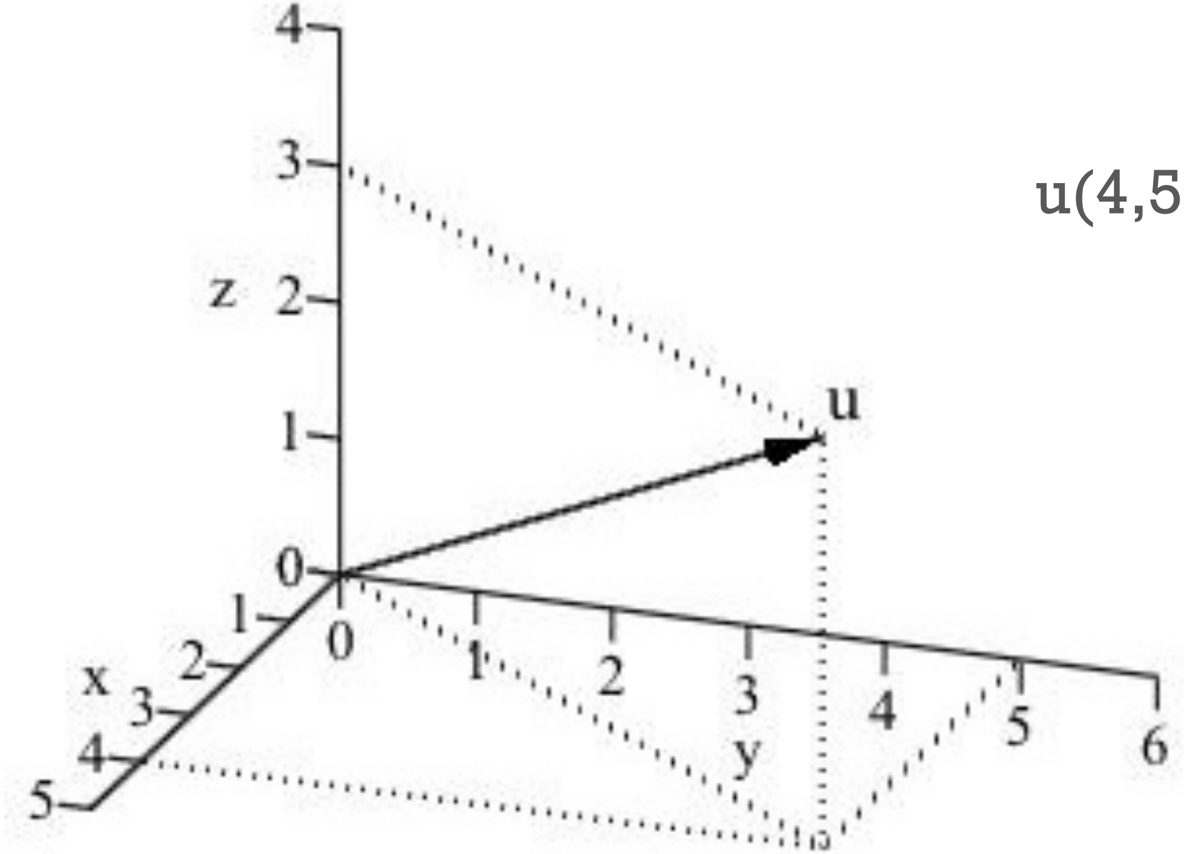


# Vectors in 2D




v(2,-3)

# Vectors in 3D




u(4,5,3)

# Conclusion

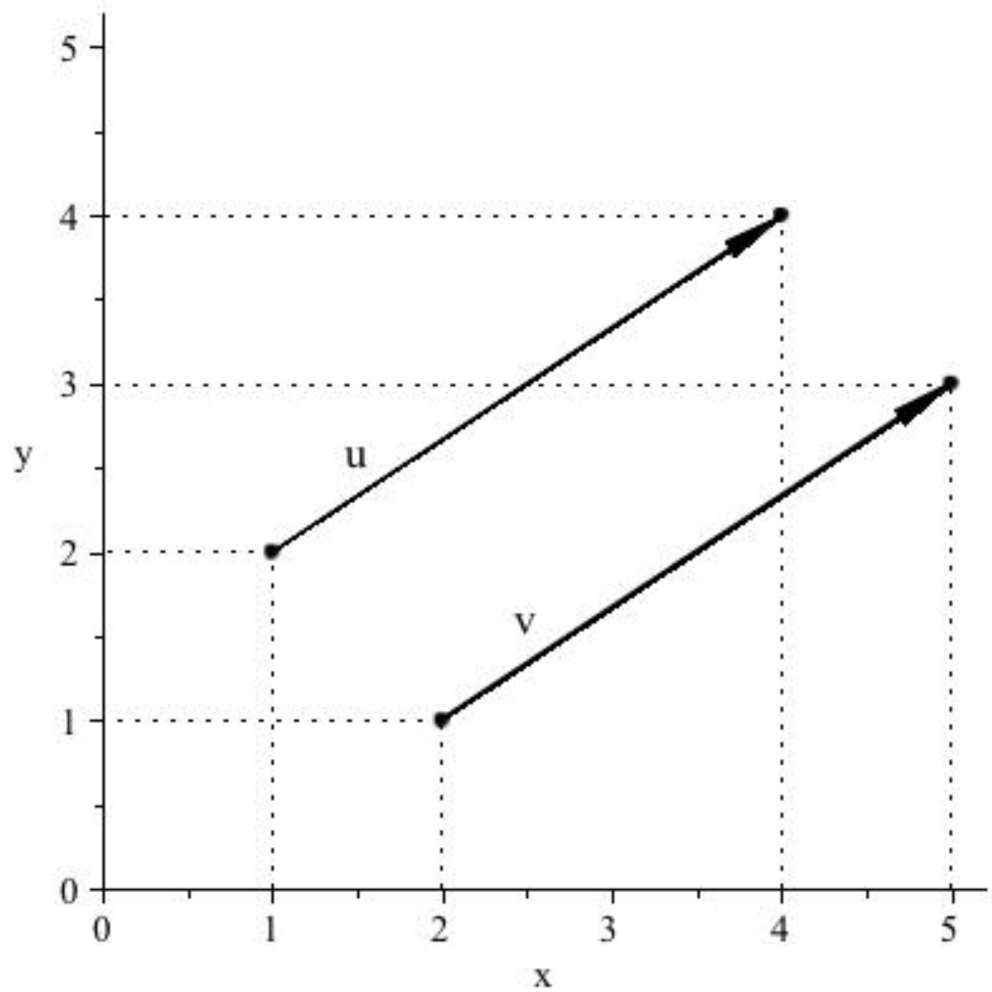
Once a coordinate system is fixed, points and vectors can be identified by means of

- an ordered set of two real numers in 2D
- an ordered set of three real numers in 3D

The ordered set of real numbers identifying a point/ vector are called the coordinates of this point/vector.

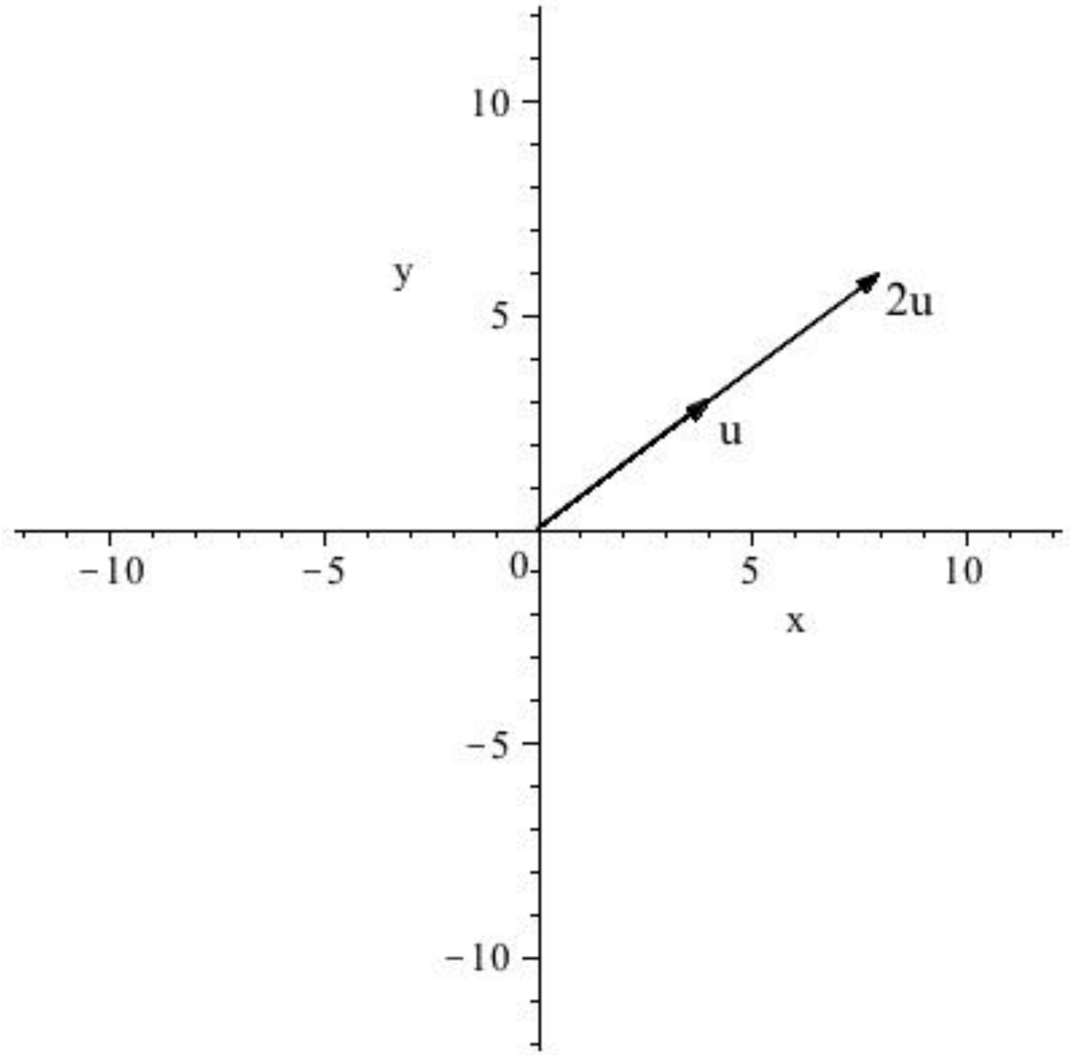
# Example






u en v are the same vector and have the same coordinates (3,2).

# Scalar multiplication



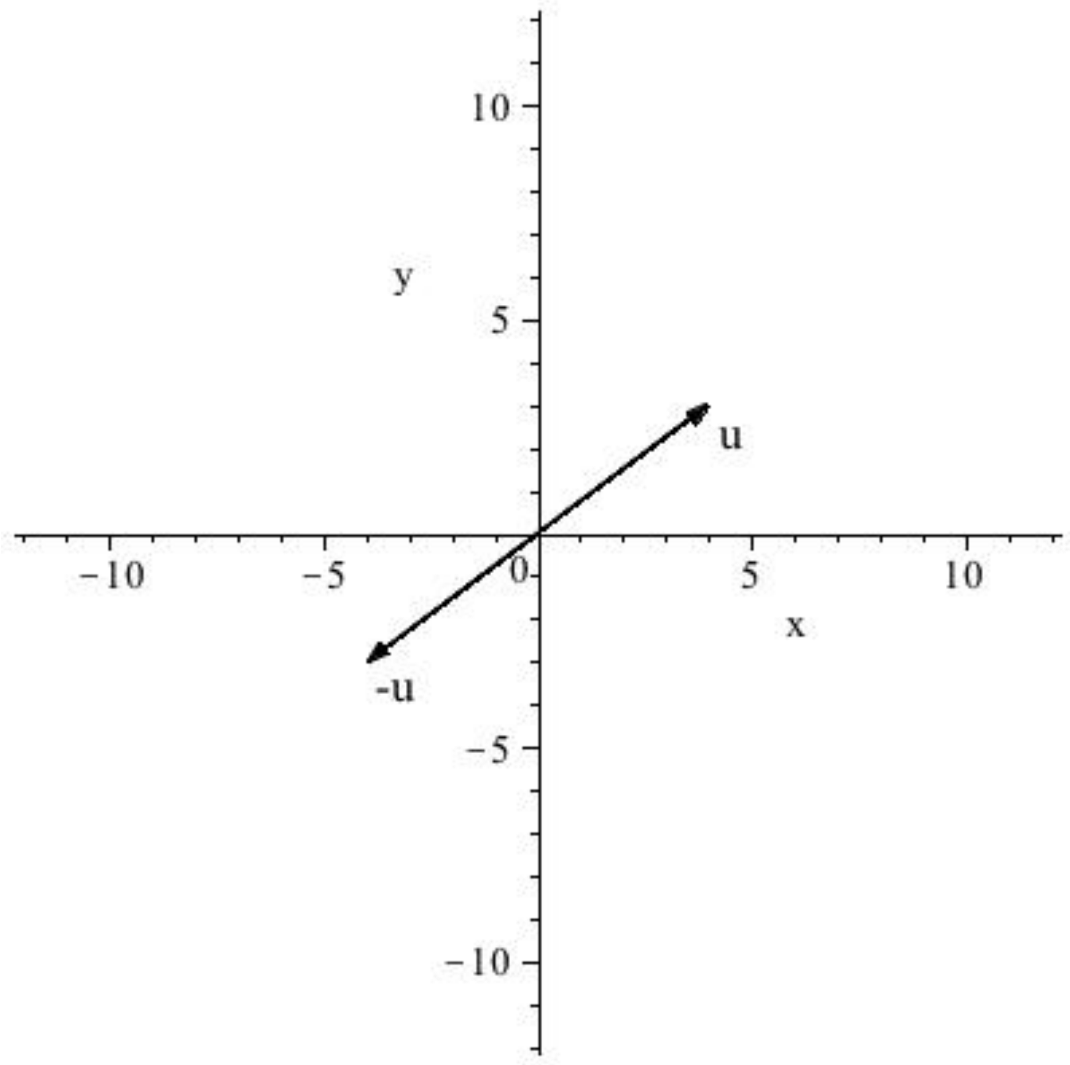

Assume $u = (4,3)$

$2u = 2(4,3) = (8,6)$

- same direction
- length x 2

# Scalar multiplication



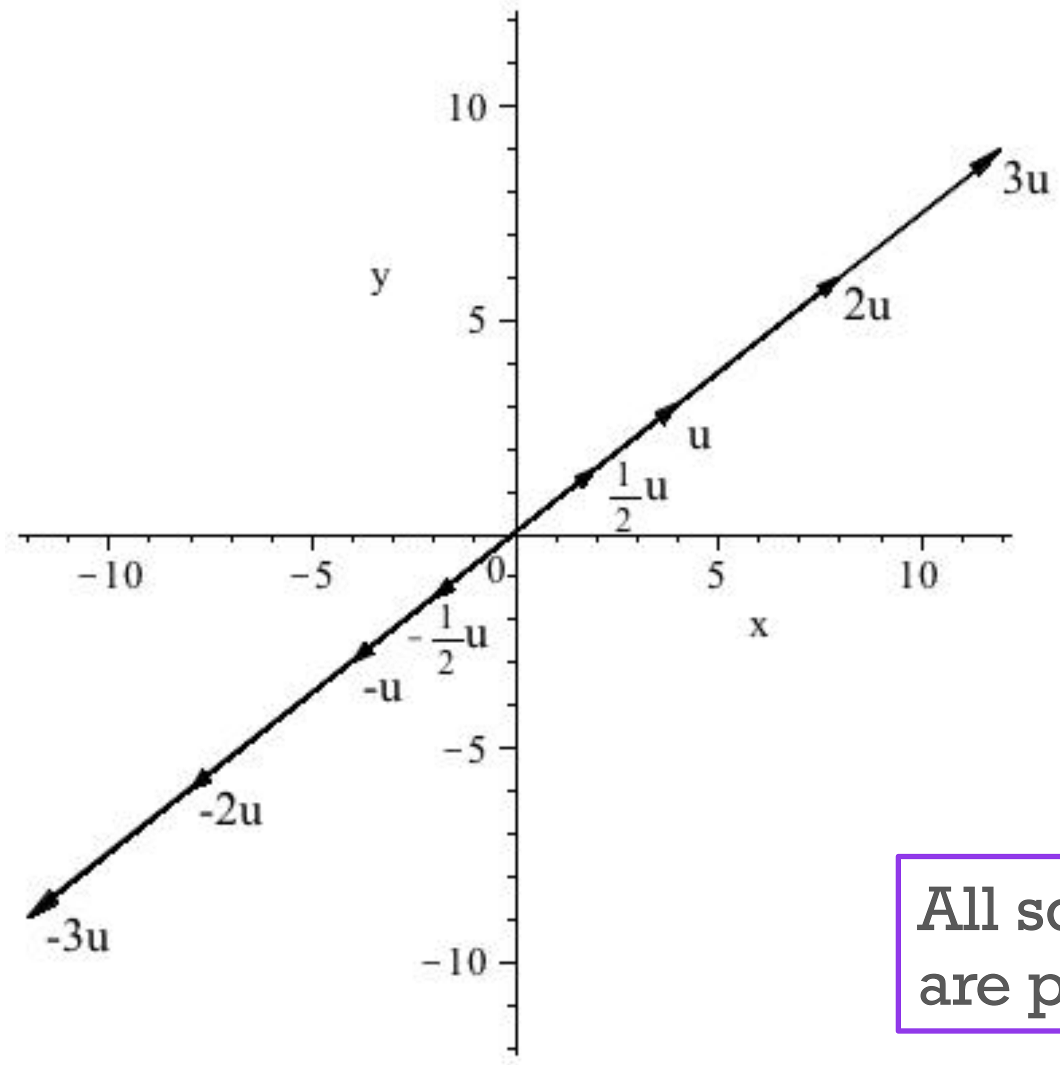



Assume u = (4,3)

-u = -(4,3) = (-4,-3)

- same length
- opposite/reverse direction

# Scalar multiplication



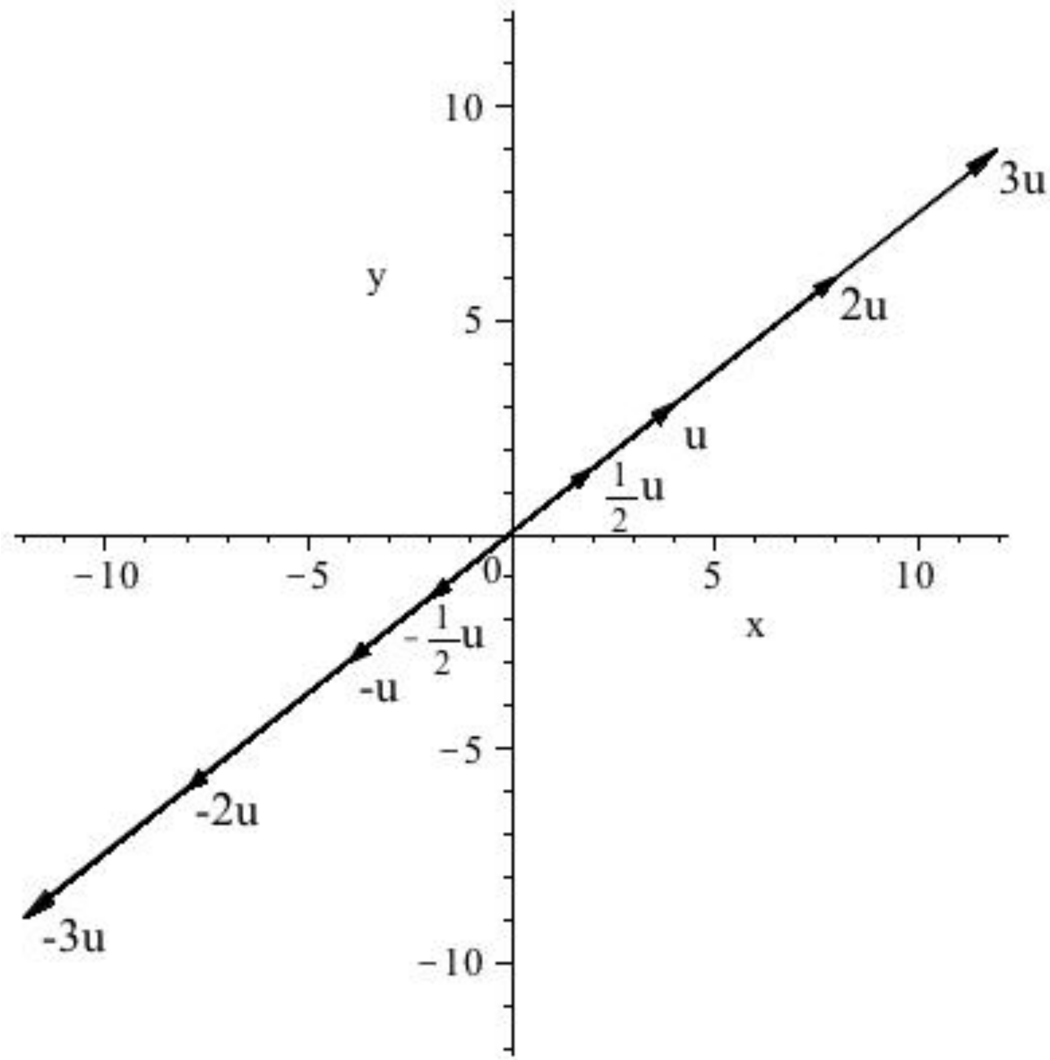

Assume u = (4,3)

-3u = (-12,-9)
-2u = (-8,-6)
-u = (-4,-3)
$-\frac{1}{2}$u = (-2,-1.5)
$\frac{1}{2}$u = (2,1.5)
u = (4,3)
2u = (8,6)
3u = (12,9)

All scalar multiples of u are parallel to each other.

# Scalar multiplication






if $c > 0$
cu and u have the same direction.

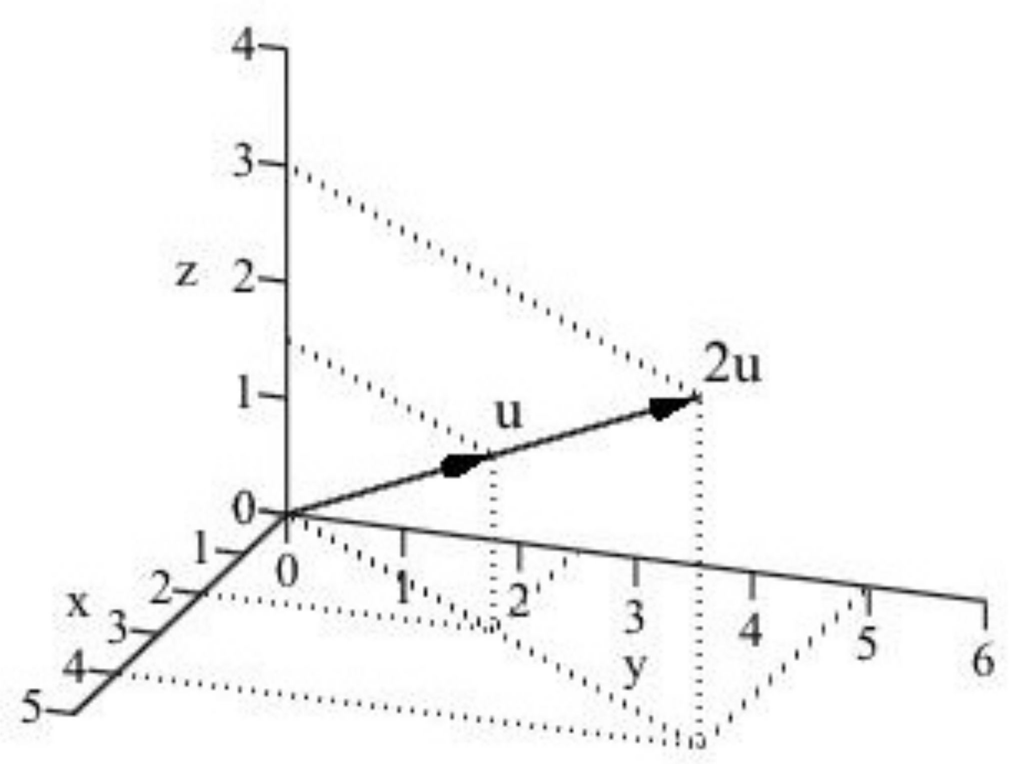
if $c < 0$
cu and u have the opposite/ reverse direction.

if $-1 < c < 1$
cu has a smaller length than u.

If $c < -1$ or $c > 1$
cu has a larger length than u.

# Scalar multiplication






The same ideas apply in 3D

Assume u = (2, 2.5, 1.5)

2u = 2(2, 2.5, 1.5) = (4, 5, 3)

u and 2u are parallel vectors.

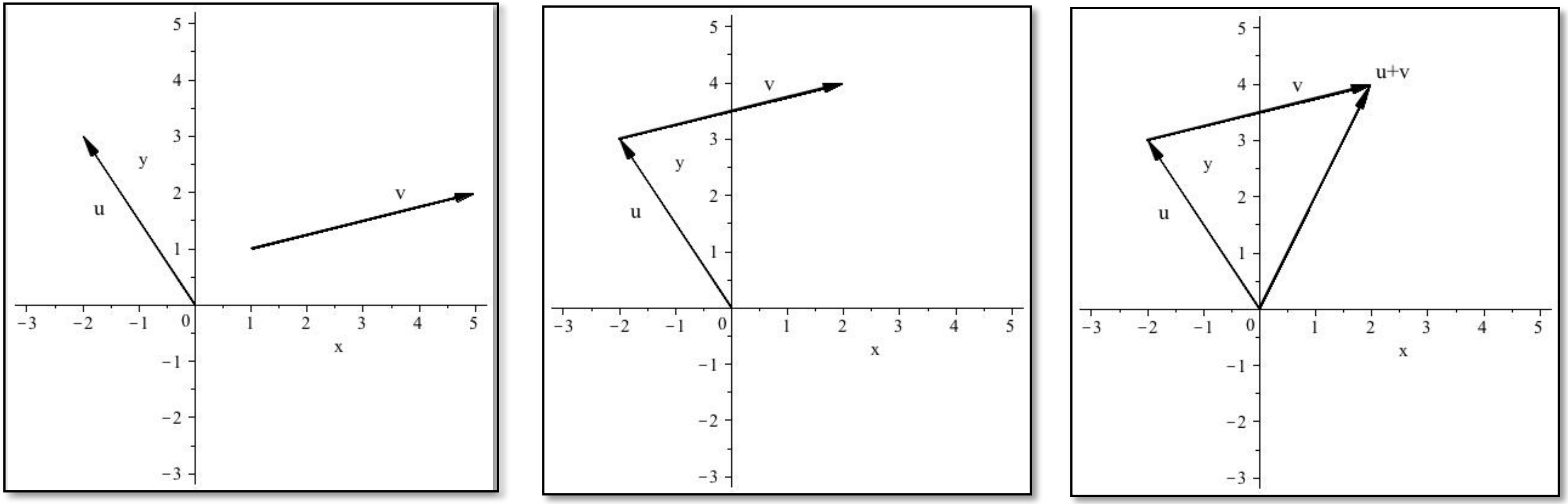
2u has the same direction as u because c = 2 > 0.

2u has a larger length than u because c = 2 > 1.

# Sum of two vectors (in 2D)

Assume $u = (-2,3)$ and $v = (4,1)$

$$u + v = (-2,3) + (4,1) = (-2+4,3+1) = (2,4)$$



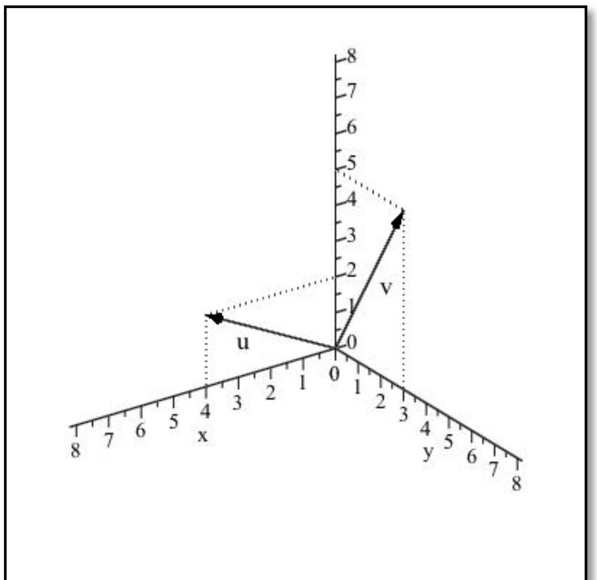

Move v so that its startpoint coincides with the endpoint of u.

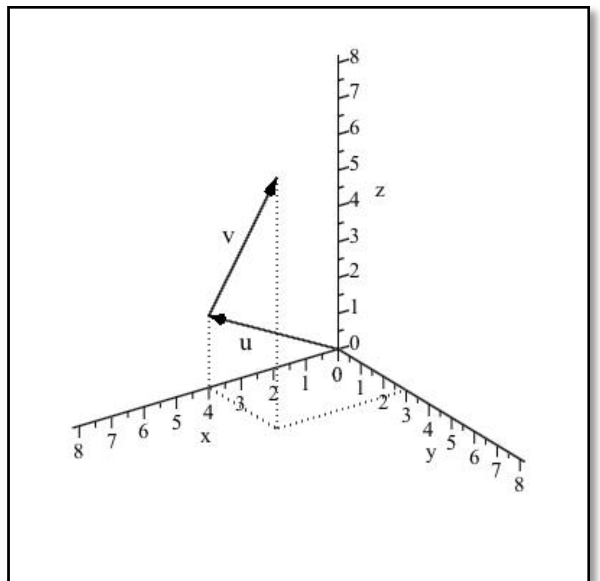
u+v is the vector from the startpoint of u to the endpoint of v.

# Sum of two vectors (in 3D)

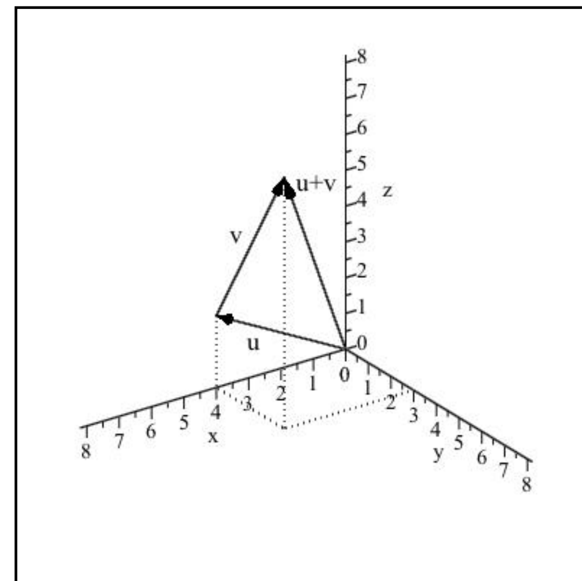
Assume u = (4,0,2) and v = (0,3,5)

u + v = (4,0,2) + (0,3,5) = (4,3,7)




Move v so that its startpoint coincides with the endpoint of u.



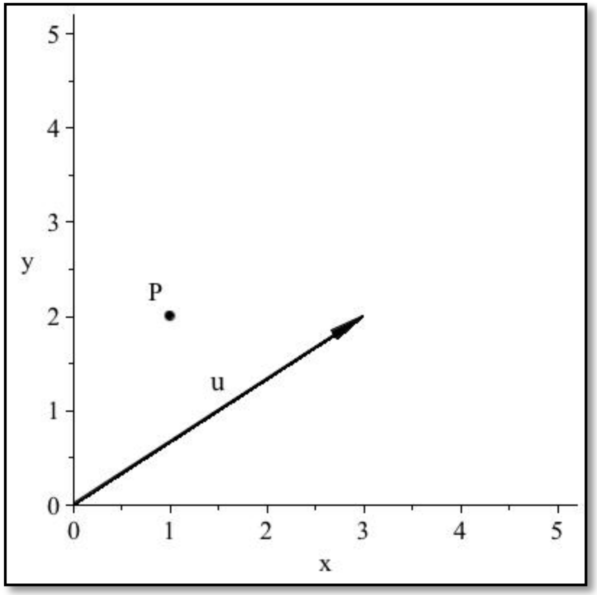

u+v is the vector from the startpoint of u to the endpoint of v.

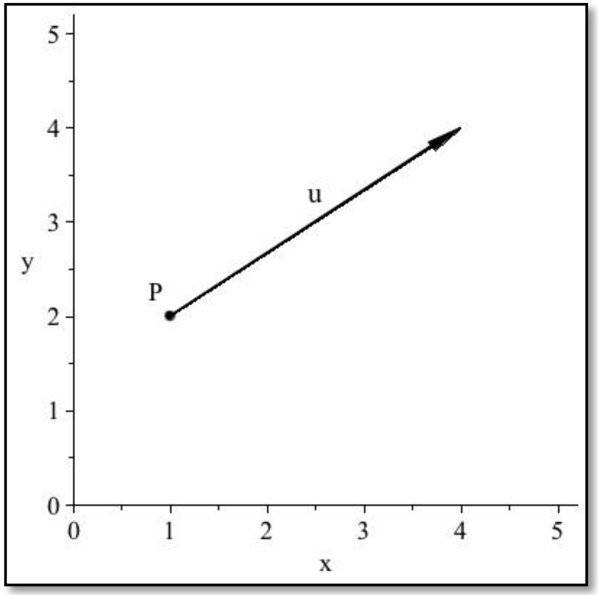
# Sum of a point and a vector

Assume a point P = (1,2) and a vector u = (3,2)

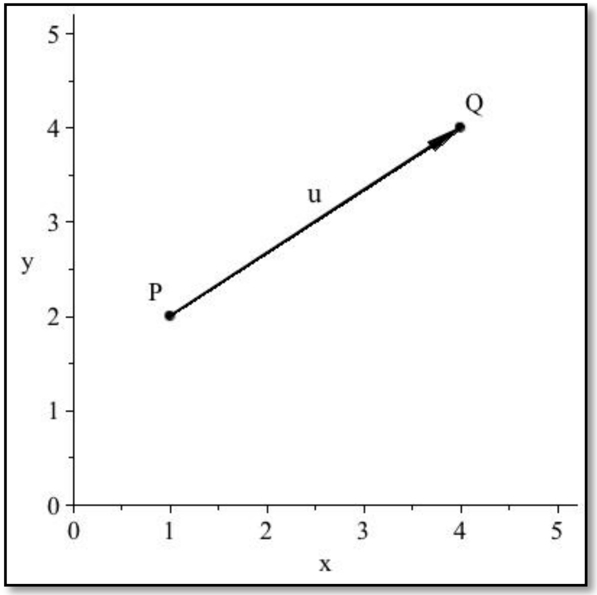
P + u = (1,2) + (3,2) = (4,4)

The same applies in 3D.




Move u so that its startpoint coincides with the point P.

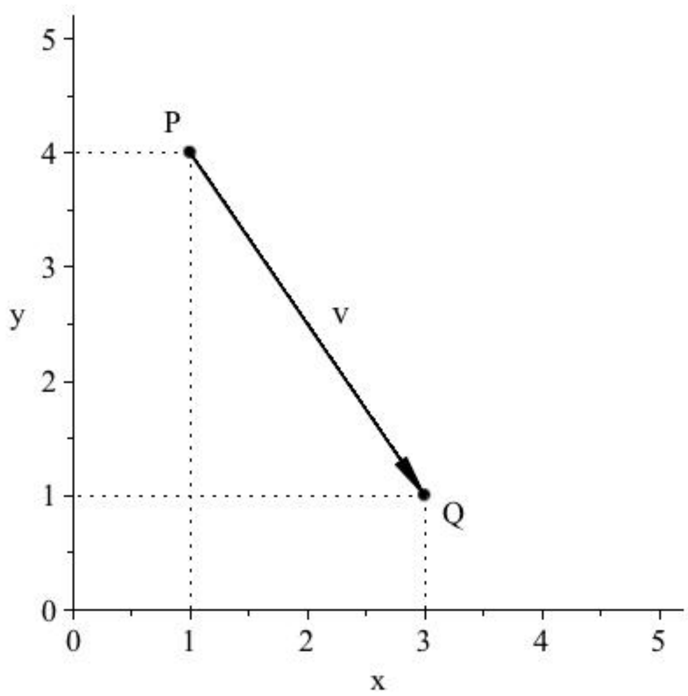



P+u is the point Q, the endpoint of u.

# Exercise

Assume two points P = (1,4) and Q = (3,1).

What is the vector which starts at point P and ends at point Q?




We are looking for the vector v such that

$$P + v = Q$$

or

$$v = Q - P$$

This yields

$$v = (3,1) - (1,4)$$
$$= (2,-3)$$

The difference of 2 points is a vector!

A vector from point P to Q can be obtained by computing Q - P. (Reverse order!)

# Length of a vector

- The length of a 2D vector v = $(v_x, v_y)$ is given by

$$|\mathbf{v}| = \sqrt{v_x^2 + v_y^2}$$

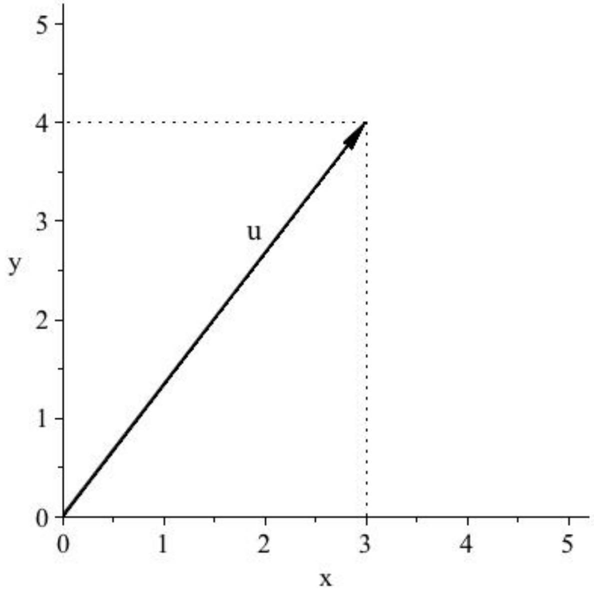
- The length of a 3D vector v = $(v_x, v_y, v_z)$ is given by

$$|\mathbf{v}| = \sqrt{v_x^2 + v_y^2 + v_z^2}$$

Example

What is the length of the vector u = (3,4)?

$$|\mathbf{u}| = \sqrt{3^2 + 4^2} = 5$$



# Normalizing a vector

## Definition

Normalizing a vector u is

converting u to a vector with the same direction but length 1.

## Example

Given is a vector u = (3,4). How can we find v

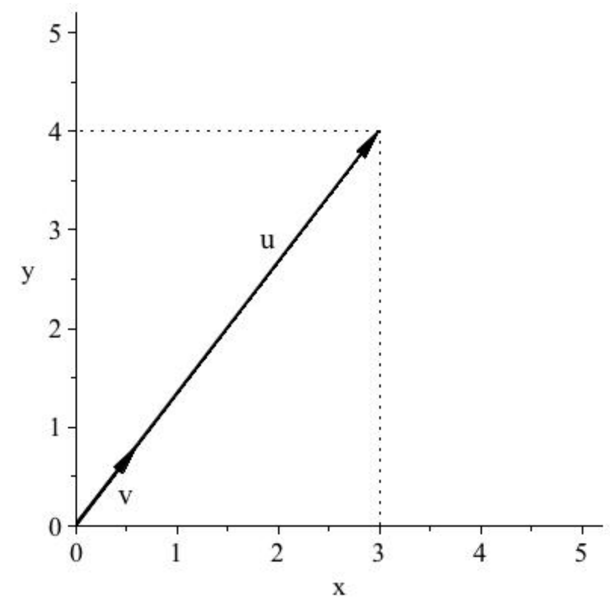
which has the same direction as u but length 1?

Scalar multiplication of u with $\frac{1}{|u|}$.

Because $|u| = \sqrt{3^2 + 4^2} = 5$

is $v = \frac{1}{|u|}u = \frac{1}{5}u = \frac{1}{5}(3,4) = (0.6,0.8)$

(Check: $|v| = \sqrt{0.6^2 + 0.8^2} = 1$.)



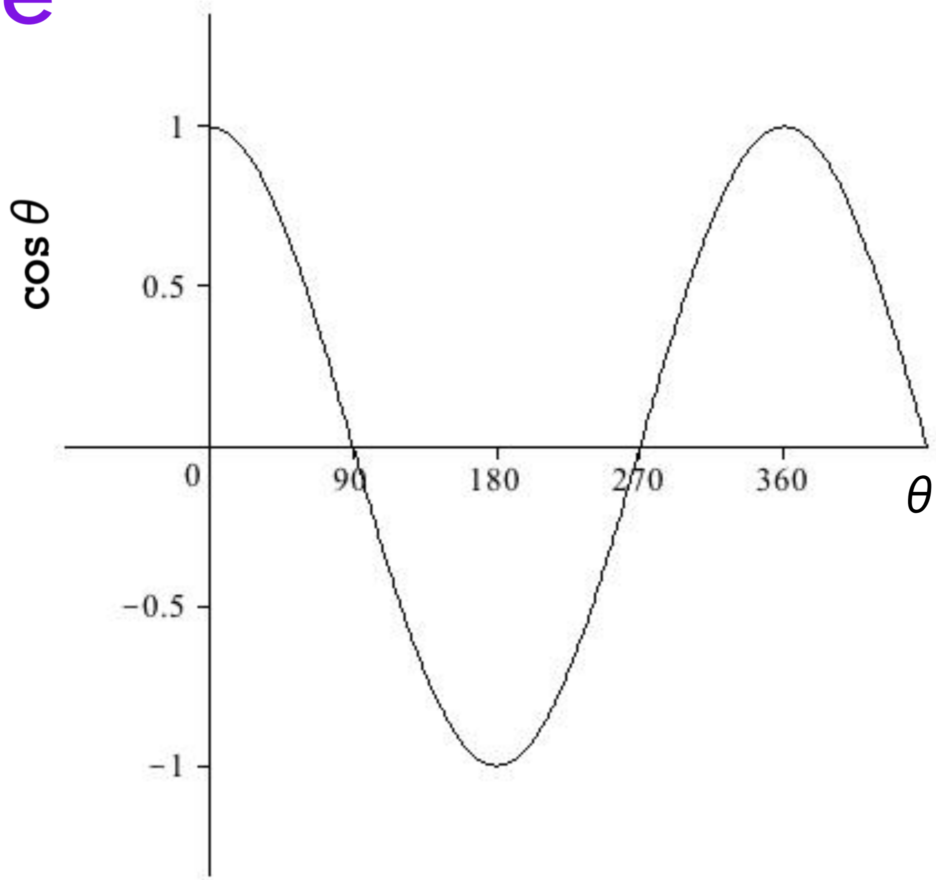
# Intermezzo: cosine

- Examples

  $\cos(0) = 1$

  $\cos(90) = 0$

  $\cos(180) = -1$




| | | | |
|---|---|---|---|
| If | $0° < \theta < 90°$ | then | $\cos\theta > 0$ |
| If | $90° < \theta < 180°$ | then | $\cos\theta < 0$ |

# Dot product

## Definition

The dot product of two vectors $v = \left(v_x, v_y, v_z\right)$ and $w = \left(w_x, w_y, w_z\right)$ is a real number given by

$$v.w = v_x w_x + v_y w_y + v_z w_z$$

## Example

The dot product of two vectors $v = \left(1,2,3\right)$ and $w = \left(3,-2,1\right)$ is given by

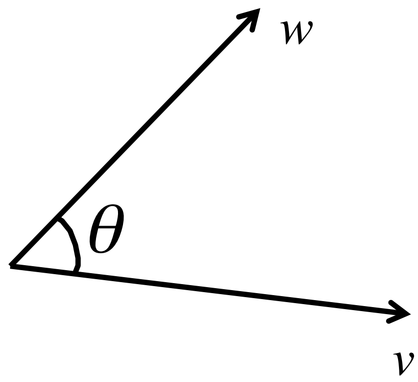
$$v.w = 1.3 + 2(-2) + 3.1 = 2$$

# Dot product

## Property

The dot product of two vectors $v$ and $w$ equals

$$v.w = |v||w|\cos(\theta)$$




with $\theta$ the (smaller) angle between these two vectors.

This formule is often used in the form $\cos(\theta) = \dfrac{v.w}{|v||w|}$

## Example

What is the angle between $v = (3,0)$ and $w = (\sqrt{3},1)$?

$$\left.\begin{aligned} v.w &= 3\sqrt{3} + 0.1 = 3\sqrt{3} \\ |v| &= \sqrt{3^2 + 0^2} = 3 \\ |w| &= \sqrt{(\sqrt{3})^2 + 1^2} = 2 \end{aligned}\right\} \quad \cos(\theta) = \frac{v.w}{|v||w|} = \frac{3\sqrt{3}}{3.2} = \frac{\sqrt{3}}{2}$$

$$\Rightarrow \quad \theta = 60^\circ$$

# Cross product

## Definition

The cross product of two vectors $a = (a_x, a_y, a_z)$ and $b = (b_x, b_y, b_z)$ is a vector given by

$$a \times b = (a_y b_z - a_z b_y, a_z b_x - a_x b_z, a_x b_y - a_y b_x)$$

## Example

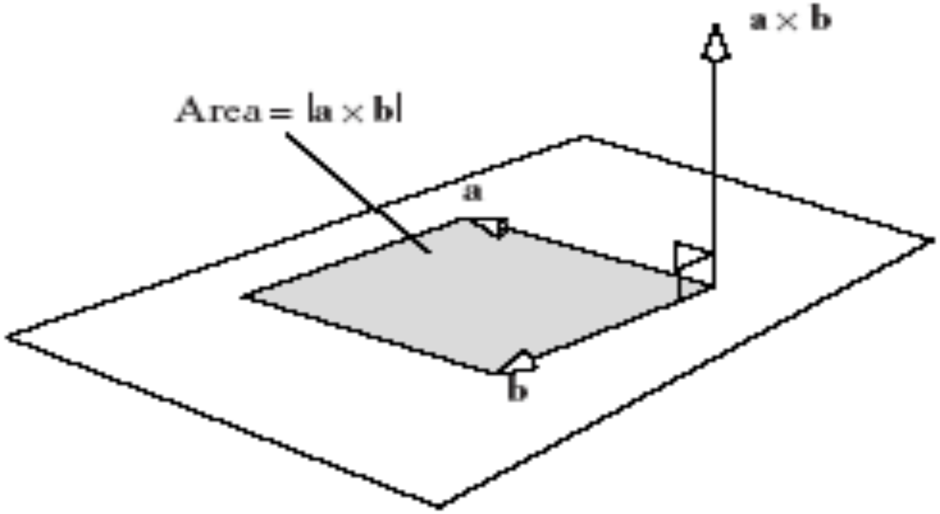
The cross product of two vectors $a = (1,2,3)$ and $b = (3,-2,1)$ is given by

$$a \times b = ( 2.1\text{-}3(\text{-}2),\ 3.3\text{-}1.1,\ 1(\text{-}2)\text{-}2.3 ) = (8,8,\text{-}8)$$

# Cross product

Property

- $a \times b$ is a vector perpendicular to $a$ and $b$
- The direction of $a \times b$ can be found by the right hand rule.
- The length of $a \times b$ is the area of the parallelogram formed by $a$ and $b$



Questions?