Lab4IQM Studio

User guide, version 1.0

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Lab for Integrated Quantitative Modelling · lab4iqm.com

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Abstract

Lab4IQM Studio is a workbench for mathematics, statistics and quantitative modelling inside Blender. You type a model in a short command language, or write it in Python with NumPy, and see it as an interactive 2D or 3D scene with sliders, animation and simulation. Figures go to papers as vector PDF, to 3D printers as STL and to the web as glTF, and LaTeX documents can be written and compiled in the same window, with figures that follow your models. Every figure in this guide was made by Lab4IQM's own code.

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1 Installing

Lab4IQM and its modules are at lab4iqm.com/download. They need Blender 4.2 or newer. There are two ways to install them.

1. **From inside Blender (recommended, with automatic updates).** In *Edit* → *Preferences* → *System* → *Network* tick *Allow Online Access*. Then in *Get Extensions* open the *Repositories* menu (the small arrow at the top right), click +, choose *Add Remote Repository* and paste `https://lab4iqm.com/repo/index.json`. Search for `lab4iqm` and click *Install* for Lab4IQM Studio and the modules you want. Blender offers each new version as an update.
2. **From a downloaded file.** In *Edit* → *Preferences* → *Get Extensions*, open the menu at the top right, choose *Install from Disk* and pick the zip file (`lab4iqm-<version>.zip`, then each module's zip). Accept the permissions notice (network, only to download the Tectonic LaTeX engine when you ask for it; files, to save what you name).

Use one way or the other for each extension: an extension installed from disk and again from the repository appears twice.

Press **N** over the 3D view to show the sidebar; the *Lab4IQM* tab holds the console, the object panel with sliders, the view panel and the examples.

2 First steps

Type a command in the console and press Enter:

```
plot(z=x^2-y^2)
plot(z=sin(a*sqrt(x^2+y^2))/sqrt(x^2+y^2+0.1), a=3, n=200)
```

Every name that is not a variable (here `a`) becomes a **slider** in the object panel. Objects are named `s1`, `c1`, ... and can be changed by name: `set(s2, a=5)`, `animate(s2, a=1..10, seconds=8)`, `color(s2, cmap=plasma)`, `delete(s1)`. Several commands can be pasted at once (the paste button runs the copied lines), separated by new lines or `;`.

- `view2d()` looks straight down with rotation locked (graph paper); `view3d()` frees it again. `axes()` draws axes with ticks around everything.
- `hold(off)` makes each new shape replace the previous ones; `replace=s1` on a shape command swaps out one object.

- `help()` lists the commands by topic, `help(draw)` one topic and `help(plot)` one command with examples. The Examples panel runs ready-made models.

Your own functions. Type a definition and use the name wherever a formula goes:

```
f(x) = x^2 + sin(x)        (or simply  f = x^2 + sin(x))
f(2)                       its value: sin(2) + 4 = 4.909...
plot(f)                    derivative(f=f)       taylor(f=f, n=5)
g(x, y) = x*y + 1          plot(z=g)            h(x) = f(2*x) + 1
f1 = sin(x);  f2 = x^2/4   plot(f1 + f2)        f1*f2       plot(f1(f2))
plot(f1, f2, f1 + f2, x=-4..4)    several curves at once, in different colours
```

With several functions, each is named at the right end of its curve in its own colour (`legend=false` leaves the names out). A graph that shoots off near a vertical asymptote, such as `tan(x)` or `1/x`, is cut to a sensible height and the console says where; `ylim=-5..5` chooses the height yourself. In the 2D view (`view2d()`) a graph runs across the whole screen, with equal units on both axes, as in GeoGebra: zoom with the mouse wheel and pan with Shift and the middle mouse button, and a moment after you stop the graph is drawn again for what you see, so it looks infinite and true to scale. Plotting in the 2D view points it at the graph's x range; `plot(f, x=0..2)` draws only that piece. `axes()` in the 2D view draws thin axes with arrowheads across the screen; their numbers keep their size and the tick spacing adapts to the zoom. `axes(grid=true)` adds grid lines at the ticks. Each new graph gets its own colour, and plotting the same function again redraws it rather than adding a copy. `special(f)` marks the roots, maxima, minima, inflection points and the y-intercept of a graph, and `special(f, g)` also where two graphs meet; the console lists the points, with exact values such as $\sqrt{3}$ or $\pi/2$ where it recognises them. In the 2D view, moving the mouse close to a graph marks that point of the graph and shows the graph's name and the point's coordinates (tracing); graphs carry no written name there unless `legend(on)` is given; `readout(cursor)` also shows the mouse's coordinates anywhere, and `readout(off)` turns the read-out off. `implicit(x^2 + y^2 = 4)` draws a curve given by an equation (circles, ellipses, hyperbolas, $y^2 = x^3 - x$). `handle(c1, x=h, y=k)` adds a point you can drag (click it, then press G or choose the Move tool) that sets the sliders h and k of `c1`; with `on=c1` it slides along a graph, for example to move the point of tangency of a tangent line. Every slider also appears at the top left of the view: drag its knob with the mouse. Graph lines are 2.5 points wide on screen at any zoom; `thickness(4)` makes them bolder. `shade(x^2, x=0..2)` shades the area under a graph, `shade(f, g, x=a..b)` the region between two graphs, and `shade(y > x^2)` or `shade(x^2 + y^2 <= 4)` the region where an inequality holds. `theme(paper)` turns the 2D view into a white page with dark axes, as on a worksheet or a projector; `theme(dark)` goes back. The graph of a function defined in the console is named after it: `plot(f1)` makes the object `f1_graph`; `name=` chooses a name yourself, as in `plot(sin(x), name=wave)`. `sliders(c1, a=0..10)` sets the range of a slider (it is $-5..5$ by default) and `sliders(off)` hides them; the sliders of the selected object are also in the **Object** section of the Lab4IQM sidebar (press N), and `set(c1, a=2)` gives an exact value. `aspect(auto)` squeezes a very tall graph so it fits (the numbers stay true); `aspect(equal)` is the default. Without brackets the variables are taken from the formula (x, y, z; or t; or u, v). `functions()` lists the definitions and `functions(forget=f)` removes one; the `.blend` file keeps them. Typing a definition again replaces it; a function built from another one keeps the version it was built from. Variables (x, y, t, ...), constants and built-in functions cannot be redefined, and `a = 3` gives a named number instead of a slider.

3 Blender basics for Lab4IQM

Lab4IQM draws real Blender objects, so everything Blender can do with an object works on your graphs too. You do not need to learn Blender to use Lab4IQM, but a few minutes with this

section make the 3D view much easier to use. Keys are given for a Mac; on Windows and Linux use Ctrl where it says Cmd.

The screen

- The **3D view** in the middle shows the figure. Press **N** over it for the sidebar; its *Lab4IQM* tab holds the console, the sliders and the examples.
- The **Outliner** (top right) lists the objects by name (`s1`, `c2`, ...). Click a name to select the object; the eye icon hides and shows it.
- The **Properties** editor (bottom right) has a column of tabs. Two matter most: *Object* (orange square) and *Material* (red sphere). For a curve, the *Data* tab (green curve) has its thickness.
- The **Timeline** at the bottom plays animations and simulations.

Moving around the view

To ...	do this
turn the view (orbit)	drag with the middle mouse button; on a trackpad, two-finger drag
move the view (pan)	Shift + middle drag; on a trackpad, Shift + two-finger drag
zoom	scroll wheel; on a trackpad, pinch
look from the front, side, top	numpad 1, 3, 7 (Cmd + numpad: the opposite side)
fit everything in the view	Home
fit the selected object	numpad . (full stop)
flat 2D view / back to 3D	`view2d()` / `view3d()`, or the 3D/2D button

Without a numpad, either click the coloured X, Y, Z balls at the top right of the 3D view, or tick *Edit* → *Preferences* → *Input* → *Emulate Numpad* (then the number keys 1, 3, 7 work). With only a trackpad, *Emulate 3 Button Mouse* in the same place lets Option + drag orbit.

Selecting, moving, rotating, scaling

Click an object to select it (Shift + click adds to the selection). Then press **G** to move, **R** to rotate or **S** to scale; move the mouse and click to finish (right click or Esc cancels). Type a letter to keep to one axis and a number for an exact amount: **S Z 2 Enter** stretches the object to twice its height, **G X 3 Enter** moves it 3 units along x. Exact values can also be typed in the sidebar, *Item* tab: Location, Rotation, Scale. **Cmd+Z** undoes.

Moving or scaling in Blender changes the picture, not the mathematics: the axes and the numbers in the console still describe the original function. To change the domain or the values, change the command instead, for example `plot(z=f, x=-1..1, y=-1..1)` or `set(s1, a=2)`.

The four ways to look at the scene

The four round buttons at the top right of the 3D view (or **Z**) switch the shading: *Wireframe*, *Solid* (grey, fast), *Material Preview* (the colours and finishes; Lab4IQM switches to it when you draw) and *Rendered* (with the lamps from `lights()`). Colour maps and transparency only show in the last two.

Changing how an object looks

Select the object and open the *Material* tab. Its *Surface* panel lists the settings of the material; the useful ones are:

- **Alpha**: transparency, from 1 (solid) to 0 (invisible). Around 0.4 lets you see one surface through another. If the see-through look is grainy, set *Settings* → *Render Method* to *Blended*.
- **Roughness**: 0 is a mirror, 1 is matte. **Metallic**: 1 for metal.
- **Transmission**: 1 for glass. **Emission**: makes the object glow.
- **Base Color**: the colour of a curve or label. On a surface it is connected to the colour map; change surface colours with `color(s1, cmap=plasma)` instead.

Changes you make here are kept when sliders move. The Lab4IQM commands do the common cases in one line: `material(s1, glass)`, `material(s1, metal)`, `plot(f, color=red)`.

Thicker or thinner curves: select the curve, open the *Data* tab (green curve icon), *Geometry* → *Bevel* → *Depth*.

Always visible: in the *Object* tab, *Viewport Display* → *In Front* draws an object over everything else in the 3D view, and *Display As* → *Wire* shows only its wireframe. Both change the view, not rendered pictures.

Hiding, deleting, saving

H hides the selected object and **Option+H** shows everything again; `delete(s1)` removes an object (use the command rather than Blender's delete, so Lab4IQM knows it is gone). **Cmd+S** saves the `.blend` file with everything in it: objects, sliders, imported modules and your defined functions. `render("fig.png")` or **F12** makes a finished picture; `export("fig.pdf")` a vector figure for a paper.

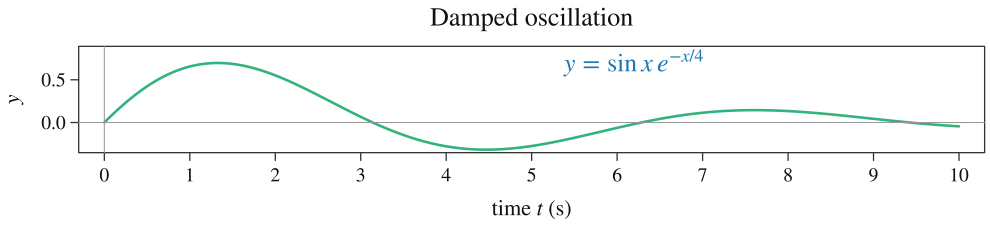
You want to …	Lab4IQM command	or in Blender
change surface colours	`color(s1, cmap=viridis)`	—
make a surface see-through	`material(s1, glass)`	Material → Alpha
change a curve's colour	`plot(f, color=red)`	Material → Base Color
change a curve's thickness	—	Data → Geometry → Bevel → Depth
change a parameter	`set(s1, a=2)` or the slider	—
hide an object	—	H, or the eye in the Outliner
remove an object	`delete(s1)`	—
a picture of the view	`render("fig.png")`	F12

4 Drawing

`plot(z=f(x,y))`, `plot(y=f(x))`	graphs of functions
`param(r=(x(u,v), y(u,v), z(u,v)))`	parametric surfaces and curves
`implicit(x^2+y^2+z^2 = 1)`	closed surfaces $F(x, y, z) = c$ (3D printable)
`field(F=(P, Q, R))`	vector fields as arrows
`label("$E = mc^2$", at=(1, 2))`	text and LaTeX maths in the figure

Labels are typeset by Lab4IQM itself with the STIX fonts, so no TEX installation is needed and they look the same in Blender, SVG and PDF. Sub- and superscripts, fractions, roots, sums and integrals with limits, growing brackets, Greek letters, accents and $\mathbb{R}$ all work; `$$...$$` gives display style. Axes take a title and names:

```
plot(y=sin(x)*exp(-x/4), x=0..10)
label("$y = \sin x\, e^{-x/4}$", at=(6.2, 0.6), color=blue)
axes(title="Damped oscillation", xlabel="time $t$ (s)", ylabel="$y$")
view2d()
export("damped.pdf")
```



In 3D the axis numbers turn to face you when you stop rotating the view, and `axes(box)` draws a box around the figure with the numbers on its nearest edges. Surfaces that shoot off near a pole are cut cleanly along a flat top; `zlim=-h..h` sets the cut, and with a slider `h` the box can be resized by dragging.

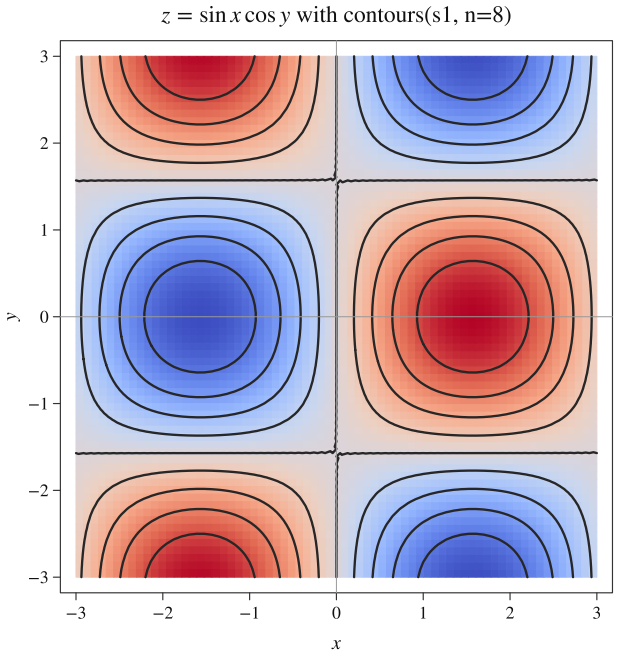
3D printing. `export("shape.stl")` makes a file ready for the printer: 80 mm at its largest side (`size=60` for 60 mm), standing on the bed. Closed shapes such as `implicit()` print as they are; an open surface needs a wall, `thickness=2` (mm), and a graph $z = f(x, y)$ can become a block on a base, `base=3`:

```
plot(z=sin(x)*cos(y), x=-pi..pi, y=-pi..pi)
export(s1, "egg-box.stl", size=100, base=3)
```

Before saving, export checks the model and says what will not print well.

5 Looks: colours, finishes, contours, light

`color(s1, cmap=coolwarm, by=x^2+y^2)` colours by any expression; `material(s1, glossy)` chooses a finish (matte, satin, glossy, ceramic, metal, glass); `lights(studio)`, `lights(soft)` or `lights(dramatic)` place lamps around the figure. `contours(s1, n=8)` draws level curves that follow sliders and animations, and seen from above they give a contour map:



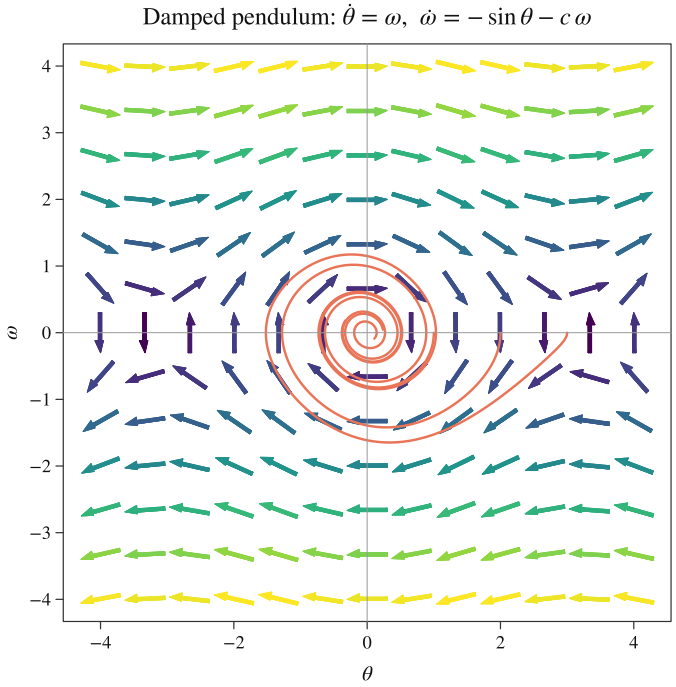
`render("figure.png")` makes a print-quality picture of the view with Cycles (real light, shadows, reflections and glass); `export("view.png")` is the instant alternative. `background("map.png", x=0..10)` puts your own picture under a 2D graph in data coordinates, and `background(color="#202830")` or `background(sky="studio.hdr")` sets the world around a 3D scene.

6 Simulations

`ode(F=(...), start=(...), t=0..20)`	ODEs (Runge–Kutta 4), one or many starts
`particles(F=(...), n=400)`	particles moving in a flow
`pde(ut=D*lap(u), u0=..., t=0..2)`	diffusion and reaction–diffusion on a grid
`pde(utt=c^2*lap(u), ...)`	waves

Simulations are computed once and cached; the `time` slider and `play=true` play them back. Parameters are sliders like everywhere else. For example, a damped pendulum in its phase plane:

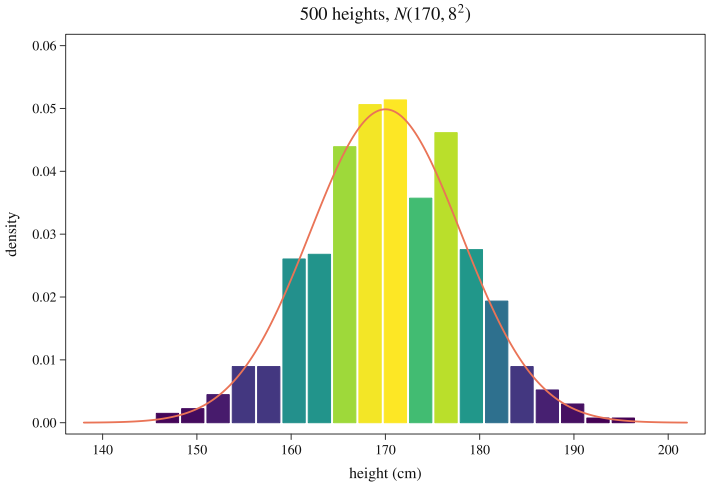
```
field(F=(y, -sin(x)), box=-4..4, normalize=true)
ode(F=(y, -sin(x) - c*y), start=((1,0), (2,0), (3,0)), t=0..20, c=0.2)
view2d()
```



7 Data and statistics

`points("data.csv", x=age, y=dose)` plots data; `hist`, `density`, `fit` and `summary` cover histograms, kernel densities, distributions (normal, uniform, exponential, gamma, beta, lognormal, t, χ^2, Poisson, binomial, bivariate normal) and least-squares or Levenberg–Marquardt fits. Axes and exported figures are in data units:

```
hist(dist=normal, mu=170, sigma=8, n=500, density=true)
density(dist=normal, mu=170, sigma=8)
axes(xlabel="height (cm)", ylabel="density")
```



8 Modules

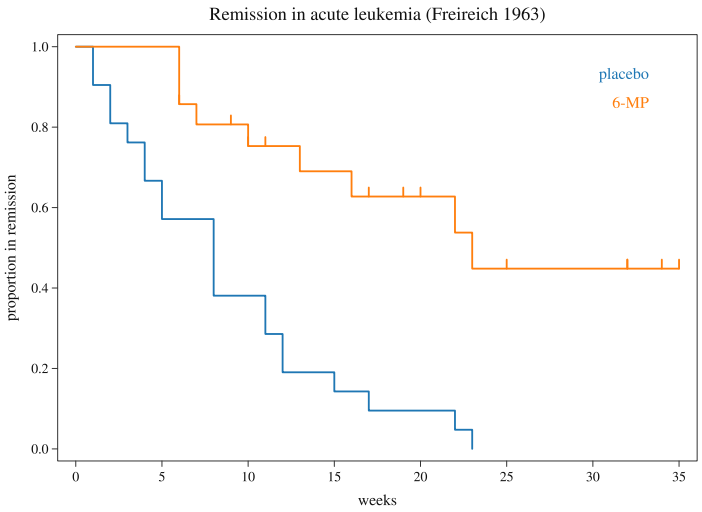
Modules add commands for one subject. Each is a small extension installed like Lab4IQM itself; then, as in Python or R, a file uses it after an import:

```
import biostat
```

The `.blend` file remembers its imports and imports them again when it is opened. `modules()` lists the modules installed and imported, `help(biostat)` the commands of one, and `modules(off=biostat)` stops using one in this file. A module adds a group to the Examples panel and brings example data, read as `"<module>:file.csv"`. The first module is **Biostatistics**:

`km(f, time=t, event=d, group=g)`	Kaplan–Meier, log-rank test, hazard ratio
`roc(f, score=(m1, m2), outcome=y)`	ROC curves, AUC (DeLong), best cut-off
`compare(f, value=v, group=g)`	box plots; t, Mann–Whitney, ANOVA, Kruskal–Wallis
`crosstab(f, row=a, col=b)`	χ^2 and Fisher tests, odds and risk ratios
`dose(f, dose=c, response=r)`	four-parameter logistic fit, EC50 or IC50

Here `f` is a CSV file in quotes, such as `"trial.csv"`. The second module, **Mathematical Oncology**, follows Chaplain & Preziosi, *Mathematical Oncology* (Springer, 2025): `growth`, `rates`, `growthfit`, `tumourvolume`, `contact` and `misperception` cover the growth laws of its Chapter 2; `oxygen`, `nutrient`, `spheroid`, `gif`, `glioma`, `clones` and `spread` the diffusion models of Chapter 3; `radius` and `mixture` the mass balance models of Chapter 4; and `nonnecrotic`, `necrotic`, `greenspan`, `chemomech`, `immunebasic`, `immune`, `turing`, `angiogenesis`, `sprouts`, `invasion`, `cells`, `upa`, `adhesion` and `metastasis` cover Chapters 5–11 (spheroids, mechanics, immunity, pre-patterns, angiogenesis, invasion and metastasis). `guide(oncology)` opens a companion that follows the chapters section by section. The third module, **Graph Theory**, follows West, *Introduction to Graph Theory*: `graph(petersen)` draws a graph (in 3D with `d3=true`) and `isomorphic`, `automorphisms`, `euler`, `bipartite`, `cuts`, `cycles`, `cliques`, `decompose`, `degrees`, `graphic`, `deck`, `orient` and `kings` cover its Chapter 1 and its exercises; `graphsave` writes files for NetworkX. The fourth, **Computational Topology**, follows Edelsbrunner and Harer: `knot`, `link`, `tutte`, `surface`, `intersections`, `simplify`, `complex`, `rips`, `cech`, `delaunay`, `alpha`, `collapse` and `homology` draw knots, surfaces and complexes in 3D and compute their invariants, e.g. `homology(klein, coeff=all)`; `cohomology`, `pairing`, `alexander`, `critical` and `reeb` cover duality and Morse functions; `persistence`, `extended`, `spectral`, `vineyard`, `bottleneck` and `crofton` draw persistence diagrams, barcodes and vineyards and check the stability theorems. The fifth, **Differential Calculus**, follows OpenStax *Calculus Volume 1* on the core's symbolic engine: `function`, `limit`, `continuity`, `derivative`, `sketch`, `optimize`, `lhopital`, `newton`, `antiderivative` and others draw and compute exactly, e.g. `derivative(f=x^3*sin(x))` lists the rules it used; `practice` and `check` generate problems and check students' answers. The sixth, **Integral Calculus**, follows OpenStax *Calculus Volume 2*: `sigma`, `riemann`, `integral`, `average`, `areafunction`, `ftc`, `netchange` and `substitute` shade signed areas, evaluate integrals by the Fundamental Theorem with each rule shown and check them numerically; `between`, `revolve` (disks, washers and shells, drawn in 3D), `arclength`, `work`, `pump` and `centroid` cover the applications, and later chapters add techniques of integration, differential equations, `series`, `taylor`, `parametric`, `polar` and `conic`. The seventh, **Multivariable Calculus**, follows Volume 3 with vectors, lines, planes and quadric surfaces in 3D, space curves, partial derivatives, gradients, extrema, Lagrange multipliers, double and triple integrals, vector fields with the theorems of Green, Stokes and Gauss, and second-order differential equations. Results print in the console as a short report; the plots export like any figure.




```
import biostat
km("biostat:leukemia.csv", time=weeks, event=relapse, group=drug)
  group            n  events  median   95% CI
  placebo [blue]  21      21       8  (4, 12)
  6-MP [orange]   21       9      23  (16, -)
  Log-rank test: chi2 = 16.79, df = 1, p < 0.0001
  Hazard ratio 6-MP vs placebo: 0.19 (95% CI 0.09 to 0.43)
```

In a script (Cmd+Return), `import biostat` gives the commands as functions, which return the report as text; column names and expressions are given in quotes:

```
import biostat
report = biostat.km("trial.csv", time="months", event="died", group="arm")
print(report)
```

Modules are free and listed at lab4iqm.com; anyone can write one (see `modkit/README.md` in the source).

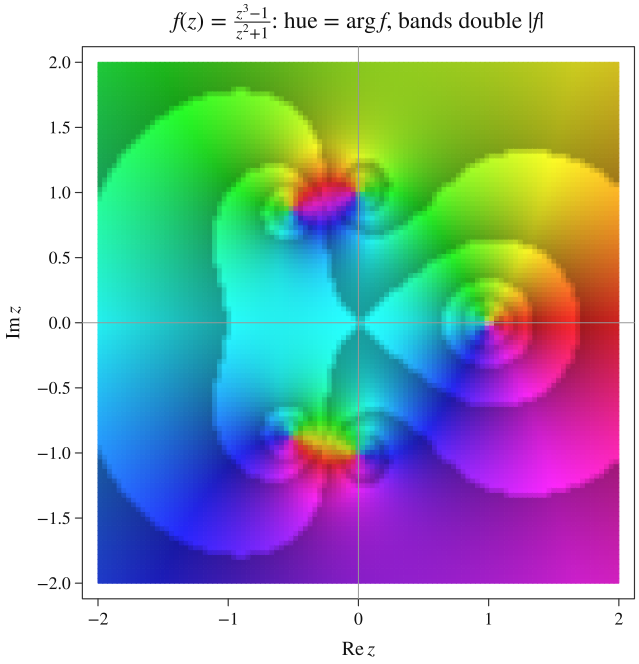
9 Python scripts

`code()` opens a code editor beside the 3D view (`code(window)`: in its own window, for a second screen). Scripts are ordinary Python with NumPy; **Cmd+Return** (Ctrl+Enter) runs them, `print()` output goes to the console and to `output()`, and errors are shown with their line numbers.

```
import numpy as np
import lab4iqm as L

L.clear()
def f(x, y):
    return np.sin(x) * np.cos(y)
L.surface(f, x=(-3, 3), y=(-3, 3), name="wave")
L.contours("wave", n=8)

L.figure("Complex")                    # a second figure tab
L.complex_plot(lambda z: (z**3 - 1) / (z**2 + 1), re=(-2, 2), im=(-2, 2))
```

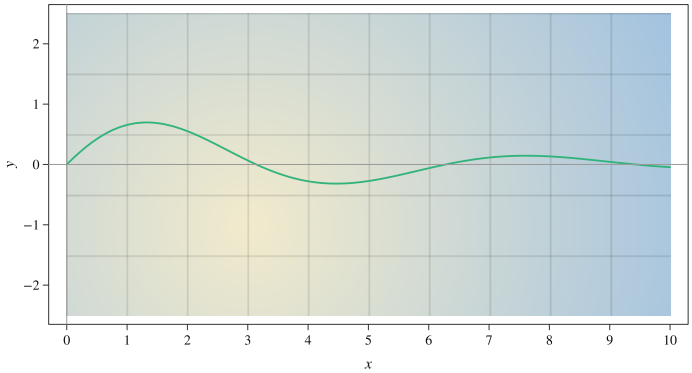


`L.surface`, `L.curve`, `L.parametric`	draw Python functions
`L.points(x, y, z)`	draw arrays of data
`L.complex_plot(f, kind=...)`	complex functions: "domain" or "landscape"
`L.riemann(p, sheets=2)`	Riemann surface of $w^n = p(z)$, with genus
`L.riemann(inverse=np.exp)`	inverse functions, e.g. $\log z$
`L.label`, `L.axes`, `L.export`	as the console commands
`L.run("...")`, `L.show(...)`	any console command; a line in the console

Write LaTeX in raw strings, `r"$\alpha$"`, so that Python keeps the backslashes. `name="..."` makes a script safe to run again: the old object is replaced. `save_script("waves.py")` and `open_script("waves.py")` keep scripts as files.

A background can be computed in the script itself, as a NumPy array or a Pillow image:

```
L.background(img, x=(0, 10))          # img: an (h, w, 3) array, row 0 at the top
```



10 Figures and documents

New Project (on the start screen, or the folder button with a plus in the View panel) or `project("paper1")` makes a folder with the `.blend` file and five folders, which you may use or ignore:

```
paper1/   paper1.blend
          code/main.py      starter script     figures/   figures and pictures
          latex/main.tex    starter document   models/    STL, glTF
          data/             CSV files
```

Inside a project, plain file names go to the folder for their type: `export("fig.pdf")` and `background("map.png")` use `figures/`, `export("shape.stl")` uses `models/`, `points("data.csv")` reads `data/`. Names with a folder part, and full paths, are used as they are. The figures a document includes are written to `figures/` too. `project()` shows the folders. To come back to a project, click its name under **Recent Projects** on the start screen, or use **Open Project...** (start screen or View panel) and choose its folder; this opens its `.blend` file, which brings back the figures, scripts and documents. Opening `paper1.blend` with **Open...** does the same.

Without a project, `folder("~/Documents/maths/paper1")` chooses where a project's files go (scripts, documents, figures, exports); it is saved with the `.blend` file. `export("figure.pdf")` and `export("figure.svg")` write the figure seen from above as vector graphics with LaTeX labels.

`doc("paper")` opens a LaTeX document in the code editor (a new one starts from a template). **Cmd+Return** compiles it in the background, with an installed TeX (MacTeX, TeX Live) or with Tectonic, which `latex(install)` downloads once. Errors appear with their line numbers, and the PDF is shown beside the 3D view (`pdf(window)` for a second screen). Lab4IQM figures enter the document by name:

```
\usepackage{lab4iqm}
...
\labfigure[width=0.8\linewidth]{Complex}
```

At every compile the figure tab is exported again: a vector PDF for a 2D graph, a rendered picture for 3D shapes (re-rendered only when the figure changed). Change the model, compile, and the paper follows.

11 Where next

The commands and the `L.` functions listed in the reference below form the **1.0 interface**: versions 1.x add to it and never remove or rename. Modules that add their own commands — Riemann surfaces and moduli, mathematical oncology, biostatistics — build on it. News, examples and modules: lab4iqm.com.

A Command reference

Every console command, by topic, as `help(topic)` and `help(command)` show it in the app.

A.1 Draw shapes and graphs

`help(draw)`

`plot` Graph of a function: a surface z=f(x,y) or a curve y=f(x).

```
plot(z=f(x,y), x=a..b, y=c..d, n=100, cmap=viridis)
plot(y=f(x), x=a..b)
plot(z=x^2+y^2)                     surface over x, y in -3..3
plot(z=sin(a*x)*cos(y), a=2)        'a' becomes a slider in the panel
plot(z=x*y, x=-1..1, y=-2..2, n=200)
plot(y=sin(x), x=0..2*pi)           curve in the xy-plane (try view2d())
plot(y=tan(x), ylim=-5..5)          cut off values outside -5..5
x^2 - y^2                           a bare expression is plotted too
plot(sin(x), name=wave)             the object is called wave (plot(f1) of a function
                                    defined in the console is called f1_graph)
plot(f1, f2, f1 + f2, x=-4..4)      several functions at once, in different colours,
each named at its right end (legend=false: no names)
plot(y=tan(x))                      graphs that shoot off near asymptotes are cut to a
                                    sensible height; ylim=-5..5 chooses it
plot(z=1/(x^2+y^2))                 surfaces are cut the same way near poles, cleanly
                                    along a flat top (a clipping box)
plot(z=x^3-3*x*y^2, zlim=-h..h, h=4)   cut to |z| <= h; h is a slider, so the box
                                    can be resized by dragging
In the 2D view (view2d()) a graph runs across the whole screen and follows
zooming and panning, with equal units on x and y, as on paper; with x=a..b
only that piece is drawn. aspect(auto) squeezes very tall graphs instead.
Options: n= grid points per side, cmap= colour map, color= a colour name
(red, blue, green, orange, purple, ...) or "#rrggbb" for one colour, or an
expression in x, y, z used for colouring; zlim= / ylim= range to keep.
```

`param` Parametric surface (variables u, v) or curve (variable t).

```
param(r=(x(u,v), y(u,v), z(u,v)), u=a..b, v=c..d)
param(r=(x(t), y(t), z(t)), t=a..b)
param(r=(cos(u)*sin(v), sin(u)*sin(v), cos(v)), u=0..2*pi, v=0..pi)    sphere
param(r=((2+cos(v))*cos(u), (2+cos(v))*sin(u), sin(v)))                torus
param(r=(cos(t), sin(t), t/5), t=0..6*pi)                               helix
param(r=(cos(3*t), sin(2*t)))                                           plane curve
Default ranges: u, v, t in 0..2*pi. Other names become sliders.
```

`implicit` Implicit surface F(x,y,z) = c, e.g. spheres, tori, level sets.

```
implicit(x^2+y^2+z^2 = 1, box=-2..2, n=60)
implicit(x^2+y^2+z^2 = 1)                       sphere
implicit((sqrt(x^2+y^2)-R)^2 + z^2 = r^2, R=1.5, r=0.5, box=-2.5..2.5)   torus
implicit(x^4+y^4+z^4 - (x^2+y^2+z^2) = c, c=-0.2)    a level set; c is a slider
implicit(z = x^2 - y^2)                         also works for graphs
implicit(x^2 + y^2 = 4)                         without z, in the 2D view (view2d()):
    a curve
implicit(y^2 = x^3 - x)                         in the plane that follows zooming and
    panning;
in 3D it is a surface (here a cylinder), unless
                                                curve=true is given
A bare expression F means F = 0. The box is -2..2 unless given (box=, or
x=, y=, z= ranges). n= is the grid size per side (default 60, max 120).
If a closed surface does not fit in box=, the box grows automatically
(grow=false turns this off); surfaces that go on for ever keep the box.
x=, y=, z= ranges cut the surface on purpose and are never grown.
Holes or missing parts usually mean the box is too small or n too coarse.
```

`field` Vector field drawn as arrows, coloured by magnitude.

```
field(F=(P, Q, R), box=-2..2, n=7)
field(F=(P, Q))
field(F=(-y, x, 0))                          rotation about the z-axis
field(F=(x, y, z), n=6)                      a source
field(F=(-y, x - k*y), k=0.3)                2D field in the xy-plane (try view2d())
field(F=(y, -sin(x)), box=-4..4, normalize=true)   pendulum phase portrait
Options: n= arrows per side (3D default 7, 2D default 15), scale= arrow
length factor, normalize=true for equal lengths, box= / x= / y= / z= ranges.
```

`label` Write text or LaTeX maths in the figure.

```
label("$E = mc^2$", at=(1, 2))
label("Peak $x_0$", at=(0, 1.5), size=0.4, color=red)
label("$f(z) = \frac{z^3-1}{z^2+1}$", at=(0, 2.5))
label("Energy $E=\frac12 mv^2$", at=(-2, 1), align=left)
label("$$\int_0^\infty e^{-x^2}dx = \frac{\sqrt\pi}{2}$$", at=(0, -2), size=0.35)
Text outside $...$ is plain; inside is LaTeX maths: ^ _ \frac \sqrt \sum
\int \left( \right) Greek letters \mathbb{R} \text{...} and so on. $$...$$
gives display style (large fractions and sums with limits).
at=(x, y) or (x, y, z); size= letter height in scene units (default 0.3);
align=left|center|right; color=black, red, "#3366cc", ... (default: light
in the 3D view, black in exported figures). Labels lie flat in 2D view and
stand upright in 3D, like the axis labels, and export to SVG and PDF.
of="plot(...)" ties a label to that graph: in the 2D view it then stays at the
right end of the visible part of the graph (plot(f1, f2) names its curves so).
```

`functions` List the functions defined in this file, or forget some.

```
functions()
functions(forget=f)
functions(forget=all)
Define a function by typing it:   f(x) = x^2 + sin(x)     or simply   f = x^2 + sin(x)
(without brackets the variables are taken from the formula: x, y, z; or t; or u, v).
Two variables: g(x, y) = x*y + 1. Then use the name wherever a formula goes:
  plot(f)          derivative(f=f)        taylor(f=f, n=5)       f(2)   (its value)
h(x) = f(x)^2 + 1                    plot(z=g)              f      (shows the
      definition)
Typing a definition again replaces it. The .blend file keeps its functions.
Names that are variables (x, y, z, t, u, v, n, ...), constants (pi, e) or built-in
functions (sin, exp, ...) cannot be defined. Letters that are not variables of the
function (a in f(x) = a*x^2) stay free and become sliders where it is drawn.
```

`special` Mark the special points of a graph: roots, maxima, minima, inflection points, intersections.

```
special(f)
special(f, g)
special(x^3 - 3*x, x=-3..3)
special(f, kinds=(root, maximum))
special(x^3 - 3*x)          roots (blue), maximum and minimum (red), inflection
    (purple),
                            y-intercept (black); the console lists their coordinates
special(f, g)               with two functions, also where the graphs meet (black)
special(f, kinds=(root, intersection))     only some kinds: root, maximum, minimum,
```

```
                                          inflection, intercept, intersection
In the 2D view the points follow zooming and panning, like the graphs; otherwise they
are found on x=a..b (default -3..3).
```

`handle` A point you drag with the mouse to change sliders: move it and the graphs follow.

```
handle(c1, x=h, y=k)
handle(c2, x=a, on=c1)
handle(c1, c2, x=h)
plot(y = a*(x - h)^2 + k, h=1, k=2)
handle(c1, x=h, y=k)          a point at (h, k): drag it and the parabola's vertex
    moves
plot(y = x^3 - 3*x)
plot(y = (3*a^2 - 3)*(x - a) + a^3 - 3*a, a=1)
handle(c2, x=a, on=c1)        a point that slides along c1 at x = a; the tangent c2
    follows
handle(c1, c2, x=h)           one point can drive the sliders of several objects

To drag: click the point and press G (or choose the Move tool on the left), move the
mouse, click to drop it. Moving a slider in the panel moves the point too.
```

`sliders` Sliders on the view for every parameter: drag the knob to change it.

```
sliders(on)
sliders(off)
sliders(c1, a=0..10)
plot(y = a*sin(b*x), a=1, b=2)    the sliders a and b appear at the top left of the
    view
sliders(c1, a=0..3, b=1..10)      the range of each slider (default -5..5)
sliders(off)                      hide them (the panel's Object section still has
    them)
sliders(on)                       show them again
Drag a knob with the left mouse button. set(c1, a=2) sets a value exactly.
```

`legend` Graph names in the 2D view: shown when the mouse is on a graph, or written beside it.

```
legend(hover)
legend(on)
legend(hover)   the default: no names on the graphs; point at a graph and the read-out
                shows its name and the coordinates of the point
legend(on)      write each graph's name beside it (plot(f1, f2) names its graphs),
    placed
                where it covers no line and following the graph when sliders move
In the 3D view the names of plot(f1, f2) are always written at the end of each graph.
```

`thickness` How thick graph lines are in the 2D view, in points on screen (default 2.5).

```
thickness(2.5)
thickness(2.5)   the default, about as GeoGebra draws graphs
thickness(4)     bolder lines, for a projector
thickness(1.5)   finer lines
The width stays the same on screen when you zoom. In the 3D view lines keep
their own thickness.
```

`shade` Shade a region: under a graph, between two graphs, or where an inequality holds.

```
shade(f)
shade(f, g)
shade(f, x=0..2)
shade(y > x^2)
shade(x^2 + y^2 <= 4)
shade(x^2, x=0..2)          the area under y = x^2 from 0 to 2
shade(sin(x), cos(x), x=pi/4..5*pi/4)     between two graphs
shade(f)                    between the graph of f and the x-axis, across the view
shade(y > x^2)              where an inequality holds (also <, <=, >=)
shade(x^2 + y^2 <= 4, color=green)
The region is pale, under the graphs and the grid. In the 2D view it covers what
you see and follows zooming and panning unless x= (or y=) is given.
```

A.2 Change what is drawn

```
help(change)
```

`set` Change the slider values of an object.

```
set(s1, a=2, b=0.5)
```

`animate` Animate parameters: keyframes from the first value to the second.

```
animate(s1, a=4..20, frames=60, start=1)
animate(s1, a=4..20)                    a goes from 4 to 20 over 60 frames
animate(s1, a=4..20, seconds=30)        ... taking 30 seconds (slow it down at will)
animate(s1, a=4..20, seconds=30, fps=60) smoother: 60 frames per second (default:
    scene's, 24)
animate(s1, a=4..20, bounce=true)       4 -> 20 -> 4: a seamless loop
animate(s1, a=0..2*pi, b=1..3, frames=120, start=1)
The value changes at a constant rate; ease=true gives a gentle start and stop.
The scene's frame range is set to the animation, so playback loops.
Then press Space with the mouse over the viewport to play.
```

`color` Recolour a surface with another colour map and/or colouring expression.

```
color(s1, cmap=plasma, by=x^2+y^2)
Colour maps: viridis, plasma, inferno, magma, coolwarm, terrain, gray, rainbow.
by= may use x, y, z, r (distance from origin) and the object's parameters; by=z is the
    default.
```

`material` Give objects a surface finish: matte, satin, glossy, ceramic, metal or glass.

```
material(s1, glossy)
material(glass)
material()
material(s1, glossy)   s1 shiny, with a clear coat
material(glass)        every Lab4IQM object in this figure as coloured glass
material(s1, satin)    back to the default
material()             list the finishes
Colours still come from the colour map. Glass and metal look their best
with lights(studio) and in render() pictures.
```

`contours` Draw level curves (lines of equal height) on a surface.

```
contours(s1)
contours(s1, n=12)
contours(s1, levels=(0, 0.5, 1))
contours(s1, off)
contours(s1)               about 8 round heights, e.g. 0.2, 0.4, ...
contours(s1, n=15)         more lines
contours(s1, levels=(-1, 0, 1))   exactly these heights
contours(s1, off)          remove them
The lines follow the surface when sliders or animations change it, and
export("fig.svg") draws them: seen from above this is a contour map.
```

`hold` Keep earlier objects when drawing a new one (on, the default) or replace them (off).

```
hold(on)
hold(off)
hold()
hold(off)        each new plot, field, ... replaces everything drawn before
hold(on)         new shapes are added next to the old ones (default)
hold()           show the current setting
To replace a single object instead, add replace=: field(F=(y, -x, 0), replace=f1)
The Hold button in the Console panel does the same as hold(on) / hold(off).
```

`delete` Delete the named objects.

```
delete(s1, c2)
```

`clear` Delete every object made by Lab4IQM.

```
clear()
```

`list` List the objects in the scene and their parameters.

```
list()
```

A.3 Views, figures and the look

```
help(view)
```

`view2d` Lock the view: top-down, orthographic, no rotation (pan and zoom only).

```
view2d()
```

`view3d` Unlock the view and return to a perspective 3D view.

```
view3d()
```

`axes` Draw axes with ticks and labels around everything in the scene.

```
axes()
axes(box)
axes(grid=true)
axes(ticks=8)
axes(x=-5..5, y=0..10)
axes(title="$f(x)=x^2$", xlabel="$t$ (s)")
axes(off)
axes() fits the axes to all Lab4IQM objects; run it again after adding or
changing objects. Give x=, y=, z= ranges to set them yourself, ticks= for
roughly how many ticks per axis, and axes(off) to remove them. Labels lie
flat in 2D view; in 3D view they turn to face you as you rotate the view.
axes(box) draws a box around 3D figures instead, with the numbers on the
edges nearest to you; they move to the visible edges as the view turns.
In the 2D view the axes span the screen and follow zooming and panning: the
numbers, ticks and lines keep their size, and the tick spacing adapts. They
end in arrowheads, and grid=true adds grid lines at the ticks.
title="...", xlabel="...", ylabel="...", zlabel="..." name the figure and
its axes; LaTeX maths works inside $...$, e.g. xlabel="time $t$ (s)".
export("fig.svg") and export("fig.pdf") use them too.
```

`aspect` Equal units on x and y (the default), or squeeze tall graphs to fit.

```
aspect(auto)
aspect(equal)
aspect(equal)    the default: one unit is the same length on x and y, so graphs
                 look as they really are (circles are round)
aspect(auto)     a graph much taller than wide (y = x^3 on -3..3) is squeezed, one
                 much flatter (y = sin(x) on 0..100) is stretched, so the whole graph
                 fits; the axis numbers still show the true values
Figures with surfaces or 3D curves always use equal units.
```

`readout` The coordinates under the mouse in the 2D view: on graphs only, everywhere, or none.

```
readout(on)
readout(cursor)
readout(off)
readout(on)       the default: near a graph the read-out jumps onto it, marks the
    point
                  and shows its coordinates (tracing); elsewhere nothing is shown
readout(cursor)   also show the coordinates of the mouse anywhere in the view
readout(off)      no read-out
```

`theme` The look of the 2D view: a white page (as printed worksheets) or the dark background.

```
theme(paper)
theme(dark)
theme(paper)    white background, dark axes and light grid, flat colours: as on a
                worksheet or a projector; screenshots go straight into handouts
theme(dark)     the default: Blender's dark background
The 3D view keeps its lighting either way.
```

`lights` Light the figure with a set of lamps, sized to what is in it.

```
lights(studio)
lights(soft)
lights(dramatic)
lights(off)
lights(studio)     key, fill and rim lights: clear shapes, soft shadows (the default)
lights(soft)       large, even lights: good for colour maps
lights(dramatic)   one low strong light: deep shadows, shows relief
lights(off)        remove the lamps (back to the plain preview lighting)
The lamps are placed around everything in the figure when you call
lights(); call it again after adding objects far away. render() uses them.
```

`background` Put your own picture behind a 2D graph, or set the colour or sky around the 3D scene.

```
background("paper.png", x=-3..3, y=-2..2)
background(color="#202830")
background(sky="studio.hdr")
background(off)
background("map.png")                    the picture covers the figure, keeping its
    shape
background("map.png", x=-3..3)           from x = -3 to 3; height from the picture's
    shape
background("map.png", x=0..10, y=0..5)   exactly this rectangle (may stretch the
    picture)
background("map.png", opacity=0.5)       half transparent
background(color="#202830")              plain colour around the scene (also white,
    black...)
background(sky="studio.hdr", strength=1) a 360-degree picture as the world (lights 3D
    scenes)
background(off)                          remove the picture and go back to the usual
    look
The picture sits just below z = 0 and takes no light, so its colours stay
exact. It is saved inside the .blend file and appears in export("fig.svg")
and export("fig.pdf"). From Python, L.background(array) takes a NumPy array
or a Pillow image, so you can draw the background yourself.
```

`figure` Open a figure tab (its own scene and objects), or list the figure tabs.

```
figure("Figure 2")
figure()
figure("Complex")      switch to the figure tab "Complex", making it if needed
figure()               list the figure tabs
Each figure tab is a Blender scene, so the scene menu at the top right of the
window switches between them. Objects, sliders, axes and the console history
belong to their figure.
```

`render` A print-quality picture of the 3D view, with real light, shadows and reflections (Cycles).

```
render("picture.png")
render("big.png", width=3000, height=2000, samples=256)
render("picture.png")                 the view as you see it, path-traced
render("hi.png", width=3000, height=2000)
render("fig.png", samples=256)        less noise, slower (default 96)
render("clear.png", transparent=true) no background
render("quick.png", engine=eevee)     much faster, a little less exact
Uses the lamps from lights(); without them a studio set is used for the
```

```
picture only. It can take from seconds to a few minutes; Blender waits
until it is done. export("view.png") is the instant, as-seen alternative.
```

A.4 Simulations

```
help(simulate)
```

`ode` Solve x' = F(x, t) and draw the trajectory (1, 2 or 3 unknowns x, y, z).

```
ode(F=(f, g, h), start=(x0, y0, z0), t=0..T)
ode(F=f(t, x), start=x0)
ode(F=(s*(y-x), x*(r-z)-y, x*y-b*z), start=(1,1,1), t=0..40, s=10, r=28, b=8/3)
    Lorenz
ode(F=(y, -sin(x) - c*y), start=((1,0), (2,0), (3,0)), t=0..20, c=0.2)   damped
    pendulum
ode(F=x*(1-x), start=(0.1, 0.5, 1.5), t=0..8)      logistic growth, x against t
Several starting points: start=((1,1,1), (1,1,1.001)). The 'time' slider
shows the trajectory up to that time; animate(c1, time=0..40, seconds=10)
draws it, or add play=true. Options: n= RK4 steps (default 4000).
With one unknown the curve is drawn as (t, x(t)) in the xy-plane.
```

`particles` Many particles carried by a flow x' = F(x, t), as an animation.

```
particles(F=(f, g, h), n=300, box=-2..2, t=0..10)
particles(F=(-y, x, 0.2*sin(3*t)), n=400)                swirling cloud
particles(F=(s*(y-x), x*(r-z)-y, x*y-b*z), s=10, r=28, b=8/3, box=-15..15, t=0..5)
particles(F=(y, -sin(x)), box=-3..3, n=500)              pendulum phase plane (2D)
Particles start at random places in the box (seed= picks another random
set). They are coloured by speed. The animation starts at once (play=false
to switch off; seconds= sets its length). Options: steps= RK4 steps (600).
```

`pde` Solve a PDE on a grid (1D or 2D) and animate the solution u.

```
pde(ut=D*lap(u) + f(u), u0=g(x,y), t=0..T)
pde(utt=c^2*lap(u), u0=..., ut0=...)
pde(ut=D*lap(u), u0=exp(-4*(x^2+y^2)), D=0.5)                      heat equation
pde(ut=D*lap(u) + r*u*(1-u), u0=exp(-10*(x^2+y^2)), D=0.05, r=1, box=-5..5, t=0..20)
    Fisher-KPP
pde(utt=c^2*lap(u), u0=exp(-10*(x^2+y^2)), c=1, boundary=zero)   wave equation
pde(ut=D*lap(u), u0=heaviside(1-abs(x)), D=0.2)                   1D: no y in u0
Gray-Scott spots (two unknowns u, v; one line):
pde(ut=0.16*lap(u) - u*v^2 + F*(1-u), vt=0.08*lap(v) + u*v^2 - (F+k)*v,
    u0=1-0.5*heaviside(8-hypot(x,y)), v0=0.25*heaviside(8-hypot(x,y)), F=0.04, k=0.06,
    box=-40..40, t=0..4000, show=v, height=10)
Operators: lap(u) Laplacian, ddx(u), ddy(u) first derivatives; formulas may
also use x, y, t. A second unknown v needs vt= and v0=. The problem is 2D
when the formulas use y. boundary= free (no flux, default), zero or periodic.
The grid has n= points per side (2D: 80, 1D: 200). The time step is chosen
automatically (dt= to set it). height= scales u in the view.
```

A.5 Data and statistics

```
help(data)
```

`points` Scatter plot of data from a CSV file (2D with x, y; 3D with x, y, z).

```
points(file="data.csv", x=age, y=dose, z=response)
points(file="data.csv")                        first three numeric columns (3D)
points(file="data.csv", x=age, y=dose_mg)      2D scatter plot
points(file="data.csv", x=age, y=dose_mg, z=log(response))
points(data=((1, 2), (2, 3.5), (3, 3.9)))      numbers typed in
Column names are cleaned to identifiers: "dose (mg)" becomes dose_mg.
Each axis is scaled to fit the view and axes() labels data units; the next
statistics plot uses the same scale (rescale=true starts a new one, raw=true
draws in plain coordinates). Relative file names are looked up next to the
saved .blend file, or on the Desktop.
```

`hist` Histogram of data (bars), or of a random sample; 3D bars with x= and y=.

```
hist(file="data.csv", x=age, bins=20)
hist(dist=normal, n=1000)
hist(file="data.csv", x=age)                   bars of counts
hist(file="data.csv", x=age, density=true)     heights as density (area 1)
hist(file="data.csv", x=age, y=dose_mg)        3D histogram of two columns
hist(data=(2.1, 3.5, 3.7, 4.0, 5.2), bins=4)
hist(dist=normal, n=1000, mu=0, sigma=1)       random sample; mu, sigma are sliders
hist(dist=exp, n=5000, average=10)             means of 10 draws: central limit theorem
Distributions: normal, uniform, exp, gamma, beta, lognormal, t, chisq,
poisson, binomial. seed= picks another random sample.
```

`density` Smooth density of data (kernel estimate), or of a probability distribution.

```
density(file="data.csv", x=age)
density(dist=normal, mu=0, sigma=1)
density(file="data.csv", x=age)                kernel density estimate (curve)
density(file="data.csv", x=age, y=dose_mg)     2D density as a surface
density(dist=normal, mu=0, sigma=1)            normal curve; mu, sigma are sliders
density(dist=gamma, k=2, theta=1)              also uniform, exp, beta, lognormal, t,
    chisq
density(dist=poisson, lam=4)                   discrete: probability bars
density(dist=binormal, rho=0.7)                bivariate normal surface (sx, sy, mx, my)
bw= sets the kernel bandwidth (default: Silverman's rule). To compare with a
histogram, draw hist(..., density=true) first so both share one scale.
```

`fit` Least-squares fit of a line, polynomial or any formula; prints the estimates.

```
fit(file="data.csv", x=age, y=response)
fit(..., deg=2)
fit(..., model=K/(1+exp(-r*(x-m))))
fit(file="data.csv", x=dose_mg, y=response)            straight line
fit(file="data.csv", x=dose_mg, y=response, deg=3)     cubic polynomial
fit(file="data.csv", x=age, y=dose_mg, z=response)     plane z = a + b x + c y
fit(file="data.csv", x=t, y=volume, model=V0*exp(r*x), V0=1, r=0.1)   any formula
In model=, x (and y for surfaces) are the data; every other name is an
unknown to estimate, starting from the value you give (default 1). The
console shows each estimate with its standard error, R^2 and the RMSE.
Draw the data first with points(...) so the fit shares its scale.
```

`summary` Descriptive statistics of every numeric column, and their correlations.

```
summary(file="data.csv")
summary(data=(1, 2, 3))
```

A.6 Files, scripts and export

```
help(files)
```

`project` Start a project: a folder with code, latex, figures, models and data, and the .blend file.

```
project("paper1")
project("paper1", at="~/Documents")
project()
project("paper1")                   a new project folder paper1 in Documents (or the
                                    default folder): paper1.blend, code/main.py,
                                    latex/main.tex, figures/, models/, data/
project("paper1", at="~/research")  somewhere else
project()                           show this project's folders
Inside a project, plain file names go to the folder for their type:
.py -> code, .tex -> latex, .pdf .svg .png .jpg -> figures, .stl .glb -> models,
.csv -> data (reading looks there too). Full paths work as they are.
The figures documents include (\labfigure) are written to figures/.
```

`folder` Choose the project folder: where scripts, documents, figures and exports go.

```
folder("~/Documents/maths/paper1")
folder()
folder("...", default=true)
folder(reset)
folder("~/Documents/maths/paper1")   files with plain names (save_script("a.py"),
                                     doc("paper"), export("fig.pdf"), data files)
                                     go to this folder; it is created if needed and
                                     saved with the .blend file
folder("...", default=true)          also the folder for new, unsaved projects
folder()                             show the folder in use
folder(reset)                        back to: next to the .blend file, else the
    Desktop
Full paths always work as they are. The View panel has a folder button.
```

`export` Save objects as STL (3D printing), glTF/GLB (web, 3D software), or SVG/PDF (2D figure).

```
export("shape.stl")
export(s1, "sphere.stl", scale=20)
export(s1, f1, "scene.glb")
export("figure.svg")
export("all.stl")                    every Lab4IQM object in one file
export(s1, "sphere.stl", size=60)    one object, 60 mm across at its largest
export(s1, "bowl.stl", thickness=2)  an open surface printed as a 2 mm wall
export(s1, "hill.stl", base=3)       a graph z = f(x,y) as a block on a 3 mm base
export(s1, "x.stl", scale=10)        10 mm for each unit, instead of size=
export(s1, f1, "scene.glb")          glTF binary with colours, for the web
export("figure.svg")                 2D vector figure seen from above, with axes
export("figure.pdf")                 the same as a vector PDF (for LaTeX
    \includegraphics)
export(c1, "curve.svg", axes=false)  without the axes frame
```

```
export("view.png")                    picture of the 3D view as you see it
export("view.png", width=3000, height=2000, transparent=true)   large, no background
export(s1, "shape.jpg")               only s1 in the picture
Relative names are saved next to the .blend file, or on the Desktop if it
is not saved yet. The console shows the full path.
STL files are made ready for a 3D printer: the figure is size= mm at its
largest side (80 mm if neither size= nor scale= is given), stands on the bed
(lowest point at height 0), and every solid faces outwards. Printers need
closed solids: implicit() shapes are closed; open surfaces (z = f(x,y)
graphs, param() sheets, curves' open tubes) need thickness= (a wall, in mm)
or, for a graph, base= (a block down to a flat base, in mm; base=true is
3 mm). Before saving, export checks the file and says what will not print
well: open surfaces, walls under 0.8 mm, a model larger than a printer bed.
```

`code` Open the Python code editor beside the view, or in its own window (for a second screen).

```
code()
code(window)
code(off)
code()           the code editor opens on the left of the 3D view (again: closes it)
code(window)     the code editor opens in a new window, e.g. for a second monitor
code(off)        close the code editor beside the view
Scripts use the lab4iqm module: import lab4iqm as L, then L.surface(f, ...),
L.curve(f, ...), L.parametric(f, ...), L.complex_plot(f, ...), L.points(...).
Run a script with Cmd+Return (Ctrl+Enter) or "Run in Lab4IQM" in the editor's
header; print() output goes to the console and to output().
```

`output` Show everything your scripts printed, in a large scrollable panel or its own window.

```
output()
output(window)
output(off)
output(clear)
output()         the output panel opens below the code editor (again: closes it)
output(window)   the output opens in a new window, e.g. for a second monitor
output(off)      close the output panel
output(clear)    empty the output
The sidebar console shows only the last lines; the output keeps whole matrices
and long results, and you can select and copy text from it.
```

`save_script` Save the script in the code editor as a .py file.

```
save_script("waves.py")
save_script()
save_script("waves.py", overwrite=true)
save_script("waves.py")        save it next to the .blend file (or on the Desktop)
save_script("~/Documents/maths/waves.py")   anywhere
save_script()                  save again to the file it came from
An existing file is not replaced unless it is the script's own file or you
add overwrite=true. The script also stays inside the .blend file.
```

`open_script` Open a .py file in the code editor (it is not run until you run it).

```
open_script("waves.py")
open_script("waves.py")        from next to the .blend file (or the Desktop)
```

```
open_script("~/Documents/maths/waves.py")
Opening a file that is already open reloads it from disk. Run it with
Cmd+Return (Ctrl+Enter); save_script() writes your changes back.
```

`new_script` Start a new, empty script in the code editor.

```
new_script("riemann")
```

`scripts` List the scripts in this file and the .py files in the scripts folder.

```
scripts()
```

A.7 LaTeX documents

```
help(documents)
```

`doc` Open (or start) a LaTeX document in the code editor.

```
doc("paper.tex")
doc()
doc("paper.tex")     open paper.tex next to the .blend file (or on the Desktop),
                     or start it from a template if it does not exist yet
doc()                show the last document again
Compile it with Cmd+Return (Ctrl+Enter) or compile(): the PDF opens in your
PDF viewer and updates at every compile. In the document,
\usepackage{lab4iqm} and \labfigure[width=0.8\linewidth]{Complex} put the
figure tab "Complex" in the document at each compile: a vector PDF for a 2D
graph, a rendered picture for 3D shapes (\labrender{Name} always renders).
```

`compile` Compile the LaTeX document to PDF (and re-export its Lab4IQM figures).

```
compile()
compile("paper.tex")
compile()             the document in the code editor (or the last one)
compile("paper.tex")  a document file
Uses Tectonic (latex(install) downloads it once), or MacTeX / TeX Live if
installed. Errors are listed with line numbers; the PDF opens in your
viewer. The first Tectonic compile downloads the LaTeX packages it needs
(an internet connection is needed once).
```

`pdf` Show the compiled PDF inside Lab4IQM (beside the view, or in its own window).

```
pdf()
pdf(3)
pdf(window)
pdf(open)
pdf(off)
pdf()          show the document's PDF beside the 3D view (again: hide it)
pdf(3)         go to page 3 (the arrows in the panel's header turn pages)
pdf(window)    show it in its own window, e.g. on a second screen
pdf(open)      open it in your usual PDF viewer instead
pdf(off)       hide the PDF panel
After each compile the panel shows the new PDF on the same page.
```

`latex` Show or choose the LaTeX engine; latex(install) downloads Tectonic.

```
latex()
latex(install)
latex(tectonic)
latex(system)
latex()            which engine compile() will use
latex(install)     download Tectonic (about 21 MB), a complete LaTeX in one
                   program; it fetches packages as documents need them
latex(tectonic)    prefer Tectonic
latex(system)      prefer an installed TeX (MacTeX, TeX Live, MiKTeX)
```

A.8 Help

```
help(help)
```

`help` Show the commands by topic, the commands of one topic, or details of one command.

```
help()
help(draw)
help(plot)
```

`guide` Open the Lab4IQM Studio user guide, or a module's guide (shown beside the 3D view).

```
guide()
guide(oncology)
```

`import` Use a module's commands (in this file; the .blend remembers its imports).

```
import biostat
import biostat, oncology
import biostat            the Biostatistics commands: km, roc, compare, ...
Modules are installed like Lab4IQM (Get Extensions, or Install from Disk) and
wait until a file imports them, as in Python or R's library(). A .blend file
remembers its imports and loads them again when it is opened. modules() lists
the modules installed; modules(off=biostat) stops using one in this file.
From a script: L.run("import biostat").
```

`modules` List the Lab4IQM modules installed and imported; stop using one (off) or import it (on).

```
modules()
modules(off=biostat)
modules(on=biostat)
Modules add commands, help topics, examples and example data for a subject,
for example Biostatistics. Install a module like the Lab4IQM extension
(Get Extensions, or Install from Disk), then type import biostat.
modules(off=biostat)   stop using it in this file; modules(on=biostat) = import
    biostat
help(<module id>) lists a module's commands; "<module id>:<file>" reads one of
its example data files, e.g. km("biostat:leukemia.csv", ...).
To remove a module for good: Preferences > Add-ons, its menu, Uninstall.
```

A.9 Maths in expressions

Functions: `abs`, `acos`, `acosh`, `acot`, `acsc`, `arccos`, `arccot`, `arccsc`, `arcsec`, `arcsin`, `arctan`, `asec`, `asin`, `asinh`, `atan`, `atan2`, `atanh`, `cbrt`, `ceil`, `cos`, `cosh`, `cot`, `csc`, `ddx`, `ddy`, `exp`, `factorial`, `floor`, `heaviside`, `hypot`, `lap`, `ln`, `log`, `log10`, `log2`, `max`, `min`, `mod`, `round`, `sec`, `sign`, `sin`, `sinh`, `sqrt`, `tan`, `tanh`. Constants `pi`, `e`, `tau`; powers `x^2` or `x**2`; ranges `a..b`.