

The numodel-plot package*

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Abstract

A PGFPlots engine that auto-sizes plots to a whole number of tick intervals, supports configurable axis-label formats (IEEE-style by default; ISO 80000-1 also supported), and automatically selects label placement for 1-, 2-, and 4-quadrant graphs. Part of the numodel package suite, but can be loaded standalone as an independent PGFPlots styling layer.

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1 Introduction

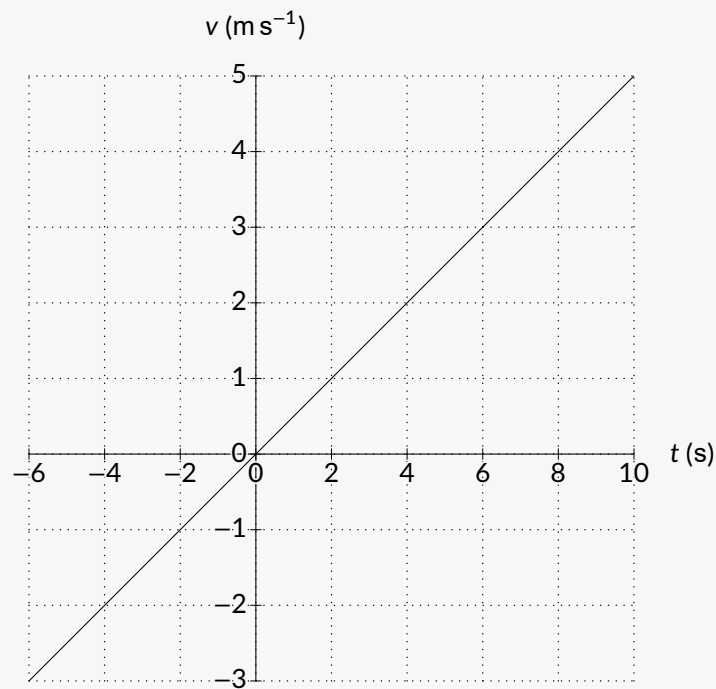
numodel-plot fills a gap between bare PGFPlots and the heavy styling required for physics-teaching material: it sizes every axis to an integer number of centimetre ticks, lays out the axis origin according to which quadrants of the coordinate plane contain data, and renders axis labels as either `quantity (unit)` (IEEE, the default) or one of four alternative conventions selectable at package level. It was extracted from a Dutch high-school physics test set where uniform plot appearance across hundreds of graphs is more valuable than per-graph tweaking, and hence adopts an opinionated default style. Users who need one-off deviations are expected to drop to plain PGFPlots with the variable macros `\xmin`, `\xmax`, ... exposed by this package.

*This document corresponds to numodel-plot v0.9.1, dated September 7, 2026.

2 Usage

Minimum working example (assuming `\usepackage{numodel-plot}` in the preamble):

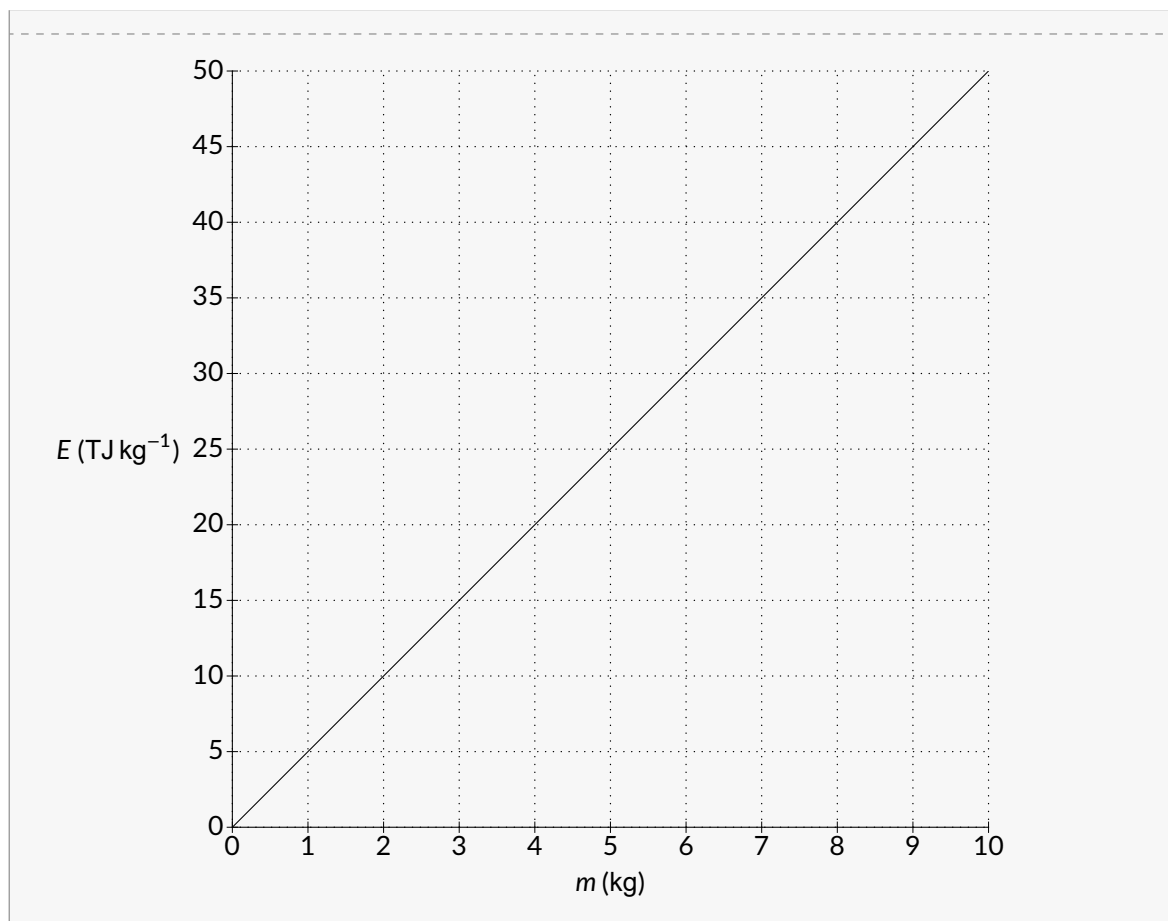
```
\def\xmin{-5} \def\xmax{10}
\def\ymin{-3} \def\ymax{5}
\def\xlabelqty{t} \def\xlabelunit{s}
\def\ylabelqty{v} \def\ylabelunit{m\per{s}}
\drawplot{\addplot[domain=\xmin:\xmax]{0.5*x};}
```



The user sets the data range (`\xmin...``\ymax`) and optionally a quantity symbol plus `siunitx` unit for each axis. `\drawplot` internally calls `\calcplothdms` to round the range to a clean tick lattice and compute the axis size in centimetres, then renders a full `tikzpicture+axis` environment whose body is the argument (one or more `\addplot` lines).

Labels are built automatically from `\xlabelqty+\xlabelunit` (and likewise for the y-axis). If the data magnitude exceeds 10^4 or is below 10^{-2} , an engineering factor 10^n (with n a multiple of 3) is split off and PGFPlots' own scaled ticks are configured so that tick numbers remain small. By default the factor is folded into an SI prefix on the unit — 5000 m becomes s (km) — and only when no engineering prefix fits (say 10^3 m^2 , which would need $10^{1.5}$ per metre) does the label fall back to showing the power of ten itself; the `scale-format` key (section 3.1) forces that form globally. In the next example the data magnitude is 5×10^7 and the unit `\mega\joule\per{kilo\gram}` already carries a prefix on the leading unit; the injected 10^6 combines with mega into tera, giving E (TJ/kg) :

```
\def\xmin{0} \def\xmax{10}
\def\ymin{0} \def\ymax{5e7}
\def\xlabelqty{m} \def\xlabelunit{kilo\gram}
\def\ylabelqty{E} \def\ylabelunit{mega\joule\per{kilo\gram}}
\drawplot{\addplot[domain=\xmin:\xmax]{5e6*x};}
```



Users preferring full control can omit `\xlabelqty/\xlabelunit` and set `\xlabel/\ylabel` directly; the package will use them verbatim.

3 Configuration

`\numodelplotsetup` Configuration is set through a single key–value interface:

```
\numodelplotsetup{axis-label-format=ieee, grid=mm-dots}
```

3.1 Keys

axis-label-format Default `ieee`. Determines the notation emitted for axis labels built from `\x_` `labelqty` and `\xlabelunit`:

<code>ieee</code>	<code>v (m/s)</code>	IEEE (default)
<code>iso</code>	<code>v / (m/s)</code>	ISO 80000-1
<code>brackets</code>	<code>v [m/s]</code>	older physics convention
<code>qty-only</code>	<code>v</code>	quantity symbol only
<code>unit-only</code>	<code>m/s</code>	unit only

When scaling is applied (data exceeds 10^4 or below 10^{-2}), the factor is integrated into the label according to `scale-format`, e.g. `v (km/s)` for IEEE. Under `qty-only` the exponent remains in PGFPlots' scaled-tick label instead (otherwise the scale information would be lost).

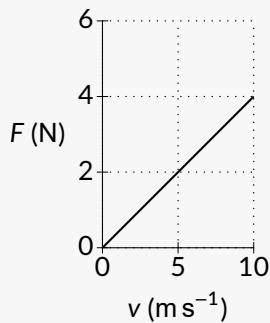
scale-format Default `prefix`. How a scaled axis presents its power of ten in the label. `prefix` folds it into an SI prefix on (the first unit atom of) the unit: `s (km)`, `E (TJ/kg)`, `m (Mg)`. The fold respects unit powers (10^6 m^2 becomes km^2) and existing prefixes, and silently falls back to the power-of-ten form whenever no engineering prefix fits (10^3 m^2 , or 10^3 m^3 which would need the non-engineering deca). `exponent` always shows the power of ten: `s (10^3 m)`.

grid Default `mm-dots` (black millimetre dots, matching engineering millimetre paper). Accepts `no`, `ne`, or any PGFPlots style list which will be passed verbatim to the `numodel/grid` style.

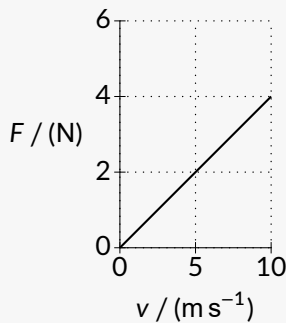
xcmmmax, ycmmmax Maximum axis width and height in centimetres (defaults 12 and 10).

The first three axis-label formats render as follows. Each plot uses `\numodelplotsetup{xcmmmax=3, ycmmmax=3}` so the axis itself is trimmed to a 2 cm by 3 cm tick lattice (the package's invariant 1 cm major-grid spacing is preserved):

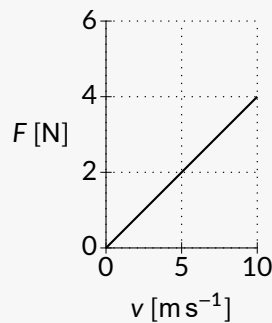
```
\captionsetup{type=figure}%
\begin{subfigure}{0.33\textwidth}\centering
\numodelplotsetup{xcmmmax=3, ycmmmax=3, axis-label-format=ieee}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{v}\def\xlabelunit{\m\per\s}%
\def\ylabelqty{F}\def\ylabelunit{\N}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.4*x};}
\caption*{\texttt{ieee}}
\end{subfigure}\hspace{-1cm}%
\begin{subfigure}{0.33\textwidth}\centering
\numodelplotsetup{xcmmmax=3, ycmmmax=3, axis-label-format=iso}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{v}\def\xlabelunit{\m\per\s}%
\def\ylabelqty{F}\def\ylabelunit{\N}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.4*x};}
\caption*{\texttt{iso}}
\end{subfigure}\hspace{-1cm}%
\begin{subfigure}{0.33\textwidth}\centering
\numodelplotsetup{xcmmmax=3, ycmmmax=3, axis-label-format=brackets}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{v}\def\xlabelunit{\m\per\s}%
\def\ylabelqty{F}\def\ylabelunit{\N}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.4*x};}
\caption*{\texttt{brackets}}
\end{subfigure}
```



ieee



iso



brackets

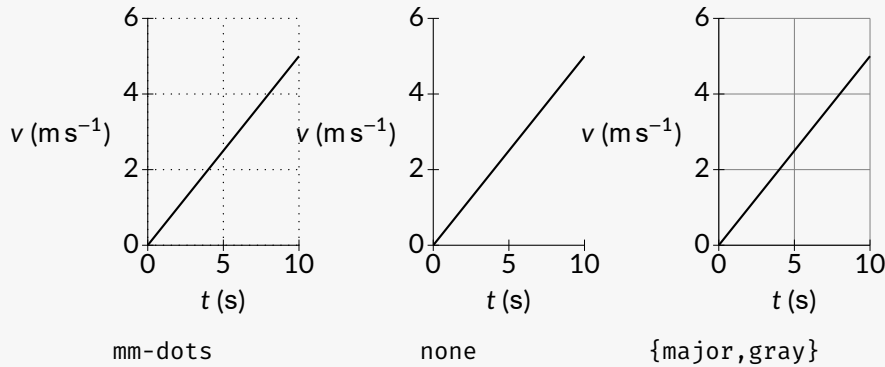
Three grid variants, sized the same way:

```
\captionsetup{type=figure}%
\begin{subfigure}{0.33\textwidth}\centering
\numodelplotsetup{xcmmmax=3, ycmmmax=3, grid=mm-dots}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{t}\def\xlabelunit{\s}%
\def\ylabelqty{v}\def\ylabelunit{\m\per\s}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*{\texttt{mm-dots}}
\end{subfigure}\hspace{-1cm}%
\begin{subfigure}{0.33\textwidth}\centering
\numodelplotsetup{xcmmmax=3, ycmmmax=3, grid=none}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{t}\def\xlabelunit{\s}%
\def\ylabelqty{v}\def\ylabelunit{\m\per\s}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*{\texttt{none}}
```

```

\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*{\texttt{none}}
\end{subfigure}\hspace{-1cm}%
\begin{subfigure}{0.33\textwidth}\centering
\umodelplotsetup{xcmm=3, ycmm=3,
  grid={grid=major, grid style={gray, very thin}}}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{t}\def\xlabelunit{\s}%
\def\ylabelqty{v}\def\ylabelunit{\m\per\s}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*{\texttt{\{major,gray\}}}
\end{subfigure}

```



3.2 PGFPlots styles

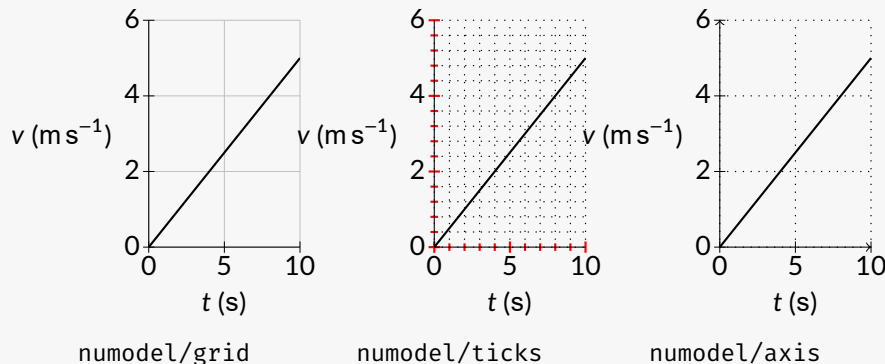
The package defines three PGFPlots styles applied by `\drawplot`: `numodel/grid`, `numodel/ticks`, `numodel/axis`. These can be overridden wholesale through `\pgfplotsset{numodel/axis/.style={...}}` from the calling preamble, giving projects a single choke point for house-style customisation. One override per style, on the same plot:

```

\captionsetup{type=figure}%
\begin{subfigure}{0.33\textwidth}\centering
\pgfplotsset{numodel/grid/.style={grid=major,
  grid style={gray!50, very thin}}}%
\umodelplotsetup{xcmm=3, ycmm=3}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{t}\def\xlabelunit{\s}%
\def\ylabelqty{v}\def\ylabelunit{\m\per\s}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*{\texttt{numodel/grid}}
\end{subfigure}\hspace{-1cm}%
\begin{subfigure}{0.33\textwidth}\centering
\pgfplotsset{numodel/ticks/.style={tick style={red, thick},
  minor tick num=4}}%
\umodelplotsetup{xcmm=3, ycmm=3}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{t}\def\xlabelunit{\s}%
\def\ylabelqty{v}\def\ylabelunit{\m\per\s}%
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*{\texttt{numodel/ticks}}
\end{subfigure}\hspace{-1cm}%
\begin{subfigure}{0.33\textwidth}\centering
\pgfplotsset{numodel/axis/.append style={axis line style={->}}}%
\umodelplotsetup{xcmm=3, ycmm=3}%
\def\xmin{0}\def\xmax{10}\def\ymin{0}\def\ymax{5}%
\def\xlabelqty{t}\def\xlabelunit{\s}%
\def\ylabelqty{v}\def\ylabelunit{\m\per\s}%

```

```
\drawplot{\addplot[domain=\xmin:\xmax,thick]{0.5*x};}
\caption*\texttt{numodel/axis}}
\end{subfigure}
```



3.3 Tick label halos

When `\calcplothdms` places an axis *through the middle* of the plot (the data straddles zero), grid lines and plotted curves pass behind the scale numbers. To keep those numbers readable, every tick label on such an axis is backed by a semi-transparent halo that follows the character outlines: the label is printed twice, first stroke-only — a fat pen (1.6pt, round joins, 80% opacity, via the `pdfrender` package) traces the glyph outlines — and then the normal label on top. Between and around the digits the grid and the curves run through untouched; there is no rectangular patch. So that the halo covers the curves and not only the grid, the haloed labels are lifted onto the `pgfplots` layer `axis descriptions`, above the main layer carrying the curves (set `layers` is activated automatically in these cases).

An axis placed on the plot edge (the default bottom/left, or the top/right placements used for single-sign data) leaves its labels on the white margin and gets no halo. Tick labels also stay visible where a crossing axis would otherwise hide them (hide obscured `x ticks=false` and the `y`-counterpart); the halo provides the visual separation from the crossing axis line.

The halo colour is controlled by the setup key `halo-color`. Its default, `halo-color=auto`, matches the halo to the surrounding background at every `\drawplot`: inside a `tcolorbox` it takes the box's `colback` (this manual's `plotexample` boxes rely on exactly that), on a beamer slide it takes the colour theme's `bg`, on a page coloured through the `pagecolor` package it takes `\thepagecolor`, and otherwise it falls back to white. (Plain `\pagecolor` without the `pagecolor` package leaves no readable record, so it cannot be detected.) A colour value pins the halo instead:

```
\numodelplotsetup{halo-color=<your-color>} % pin
\numodelplotsetup{halo-color=auto}         % re-enable matching
```

The resolved colour is exposed as the named colour `numodelhalo`. The mechanism itself lives in the styles `numodel/xticklabel halo` and `numodel/yticklabel halo`; redefining them to be empty (`\pgfplotsset{numodel/xticklabel halo/.style={}}` and the `y`-counterpart) removes the halos entirely.

4 Public API

<code>\drawplot</code>	Renders a <code>tikzpicture</code> containing an axis whose body is the single mandatory argument. Typically a block of <code>\addplot</code> and <code>\addlegendentry</code> lines. Calls <code>\calcplothdms</code> internally, so the user does not need to invoke it separately.
<code>\calcplothdms</code>	Reads <code>\xmin</code> , <code>\xmax</code> , <code>\ymin</code> , <code>\ymax</code> , and (if set) <code>\xlabelqty/\xlabelunit/\ylabelqty/\ylabelunit</code> . Writes <code>\xcm</code> , <code>\ycm</code> , <code>\xtickdistance</code> , <code>\ytickdistance</code> , <code>\xlabel</code> , <code>\ylabel</code> , and may rewrite <code>\xmin... \ymax</code> to align with the tick lattice (floor/ceil to the nearest tick). It also appends axis-positioning styles to <code>numodel/axis</code> based on which quadrants the data occupies. <code>\drawplot</code> invokes it automatically; expose for advanced cases where dimensions are needed before rendering (overlay TikZ, custom axis environment).
<code>\xlabelqty</code> <code>\xlabelunit</code> <code>\ylabelqty</code> <code>\ylabelunit</code>	Input hooks for automatic label construction. <code>\xlabelqty</code> is the mathematical quantity symbol

(e.g. v, F, E); the corresponding `\xlabelunit` is a bare `siunitx` unit macro sequence (e.g. `\m\per\s, \J, \N\m`) *without* a surrounding `\si{}` or `\qty{}` wrapper.

`\xcmmax` Maximum axis dimensions in centimetres. Can be set directly through `\def` for backwards compatibility, or via `\numodelplotsetup`.

`\ycmmax` Like `siunitx`'s `\qty` but prints no numeric mantissa when the number has come out as exactly 1 with no exponent left over: the unit then stands alone, without the quantity-product symbol that would otherwise separate the two. Used internally to inject scale factors into axis labels; exposed because the same need recurs in other scaled-axis contexts.

All three `siunitx` prefix-mode values are supported, and everything `\qtyPlain` does not special-case — a number carrying an uncertainty, a blank number, `parse-numbers=false` — is passed to `\qty` unchanged. A mantissa of 1 that is preceded by a sign or a comparator (`-1`, `<1`) keeps its digit.

`pzuIfUnitNonEngTF` Boolean conditional testing whether a unit macro sequence carries a power of ten that is not a multiple of three — `\centi`, `\deci`, `\deca`, `\hecto` and their `siunitx` abbreviations `\cm`, `\dm`, `\h`, `L`, ... Used internally to suppress scaling on units where the user has already encoded the order of magnitude; exposed for completeness.

The verdict is the net power of ten `siunitx` itself extracts from the whole unit expression, so it accounts for unit powers and for prefixes that cancel: `\centi\metre\squared` is 10^{-4} and counts as non-engineering, while `\centi\metre\cubed` (10^{-6}) and `\centi\metre\per\centi\sec` and (10^0) do not.

5 Requirements

`numodel-plot` requires `expl3`, `xparse`, `l3keys2e`, `siunitx` (mandatory, for quantities in labels), and `pgfplots` (with the `fillbetween` library). `LuaLaTeX` is not required at the plot layer (it is required by the sibling `numodel` package).

`siunitx` is requested with a date of 2023-11-06 (v3.3.8). Everything the axis labels call has been public since `siunitx` v3.0.0, but two fixes in v3.3.7 and v3.3.8 — the empty-exponent case of `prefix-mode=combine-exponent` and the printing of a bare 1 under `print-unity-mantissa=false` — are what keeps a scaled label correct. An older `siunitx` produces a $\LaTeX$ warning rather than an error, and the labels may come out subtly wrong.