

The RUBIKCUBE package

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Abstract

The RUBIKCUBE package provides LaTeX commands and macros for typesetting Rubik cube (3x3x3) notation, configurations, and rotation sequences using the TikZ graphic language. It is part of the Rubik ‘bundle’.



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1 Introduction

The RUBIKCUBE package (part of the RUBIK ‘bundle’) provides a collection of \LaTeX commands and macros for typesetting Rubik cube configurations using the PGF/TikZ graphic languages, and relates only to the familiar 3x3x3 Rubik cube. We have extended the rotation hieroglyph notation, originally developed by Garfath-Cox (1981), and improved by Duvoid (2010, 2011).

The RUBIKCUBE package is designed to be used in conjunction with both the RUBIKROTATION package and the RUBIKPATTERNS package. The RUBIKCUBE package deals primarily with typesetting, while the RUBIKROTATION package processes rotation sequences and keeps track of the cube’s configuration. The RUBIKPATTERNS package is a small database of Rubik cube rotation sequences which generate well-known named cube configurations (patterns). For full functionality it is recommended that all three Rubik packages are used together; for example,

```
\usepackage{tikz,rubikcube,rubikrotation,rubikpatterns}
```

Note that the TikZ package must be loaded *before* the RUBIKCUBE package.

The RUBIKCUBE package has been road-tested on a Microsoft platform (with MiKTeX), a GNU-Linux platform (Debian 8.2.0 and TeXLive 2016), and on a Solaris platform (OpenIndiana).

For the mathematics and group theory associated with the Rubik cube see Chen (2004), Davis (2006), Golomb (1981, 1982), Hofstadter (1981), Hutchings (2011), Heise website, Joyner (2008), Kociemba website, Rokicki *et al.* (2013), Scherphius website, Tran (2005). Other useful websites are the Speedsolving website, and those maintained by Duvoid, by Fridrich, by Jelinek, by Reid, and by Vandenburg. A useful online solver utility (based on an algorithm by Kociemba) is available at the RuWix website. Websites with good pages on patterns and symmetries are those by Fridrich, Kociemba, Longridge, Reid, Randelshofer, Scherphius (see References for details).

1.1 Requirements

The RUBIKCUBE package requires the TikZ package, since it makes use of the TikZ picture environment and the `\pgfmathsetmacro` command. Consequently, the TikZ package must be loaded *before* the RUBIKCUBE package.

Both the RUBIKROTATION and RUBIKPATTERNS packages (see below) require Perl to be installed.

1.2 Supporting tool—the rubikrotation package

The RUBIKROTATION package (also part of the RUBIK ‘bundle’), is a dynamic extension to the RUBIKCUBE package. It consists of the Perl program `rubikrotation.pl` and the associated style option `rubikrotation.sty`. The RUBIKROTATION package implements rotation sequences on-the-fly using a `\RubikRotation{<rotation-sequence>}` command. It returns the new state in a form which can then be used by the RUBIKCUBE package. It also returns some

useful strings associated with the rotation sequence which can be used by the RUBIKCUBE package—see also Section 10.

Since the `\RubikRotation` command works by calling the `rubikrotation.pl` program, it follows that the RUBIKROTATION package requires (a) Perl to be installed, and (b) the L^AT_EX engine needs to be run using the `--shell-escape` command-line option. Those wishing to use LuaL^AT_EX will also need to have access to the recent `shellesc` package (in T_EXLive 2016). The `shellesc` package can always be downloaded from CTAN directly. See the RUBIKROTATION documentation for further details.

1.3 Supporting database—`rubikpatterns.sty`

The RUBIKPATTERNS.STY file (also part of the RUBIK ‘bundle’) is a small database of some well-known Rubik cube rotation sequences, stored as named macros. For example, the ‘fourspot’ and ‘sixspot’ sequences are encoded in this package as follows:

```
\newcommand{\fourspot}{[fourspot],F2,B2,U,Dp,R2,L2,U,Dp,<(12q*, 8f*)>}
\newcommand{\sixspot}{[sixspot],U,Dp,R,Lp,F,Bp,U,Dp,<(8q*, 8f*)>}
```

These sequences can be processed by name (using the `\RubikRotation` command which also requires Perl to be installed—see Section 1.2), and then displayed (using the `\ShowCube` command in conjunction with various `\DrawRubikCube...` commands). So, for example, one could typeset the so-called ‘fourspot’ configuration using the following code:

```
\usepackage{tikz,rubikcube,rubikrotation,rubikpatterns}
...
\RubikCubeSolved
\RubikRotation{\fourspot}
\ShowCube{2.4cm}{0.6}{\DrawRubikCubeRU}
```

See also the RUBIKROTATION documentation—especially Section 5.1.1 *Sequences as macros*.

1.4 Copyright

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2 Installation

The Rubik bundle consists of the three package RUBIKCUBE, RUBIKROTATION and RUBIKPATTERNS, each of which needs to be installed separately. Here we describe the installation of the RUBIKCUBE package.

2.1 Generating the rubikcube files

Place the file `rubikcube.zip` into a temporary directory, and unzip it. This will generate the following files:

```
rubikcube.ins
rubikcube.dtx
rubikcube.pdf          --documentation of the rubikcube package
rubik-doc-figA.pdf
rubik-doc-figB.pdf
rubik-doc-figC.pdf
rubik-doc-figD.pdf
rubik-doc-figE.pdf
rubik-doc-figF.pdf
rubikexamples.tex
rubikexamples.pdf
rubikexamples.sh
rubikexamples.bat
```

The style option `rubikcube.sty` is generated by running (pdf)L^AT_EX on the file `rubikcube.ins` as follows:

```
pdflatex rubikcube.ins
```

This documentation file (`rubikcube.pdf`) can then be generated using the following steps¹:

```
pdflatex rubikcube.dtx
pdflatex rubikcube.dtx
makeindex -s gind.ist rubikcube
makeindex -s gglo.ist -o rubikcube.gls rubikcube.glo
pdflatex rubikcube.dtx
pdflatex rubikcube.dtx
```

Note that the package includes a ‘`rubikexamples`’ file (`rubikexamples.tex`) as well as associated `.sh` (Linux) and `.bat` (Microsoft) batch files which can be used to facilitate processing the file. Note that many of the examples in this file use the `\RubikRotation` command (associated with the `RUBIKROTATION` package), and hence this file needs to be run using the `--shell-escape` command-line option (see Section 1.2 for details).

2.2 Placing the files

Place the files either in the local working directory, or where your system will find them. For a Linux system with a standard T_EX Directory Structure (TDS), then:

```
*.sty → /usr/local/texlive/texmf-local/tex/latex/rubik/
*.pdf → /usr/local/texlive/texmf-local/doc/rubik/
```

¹Several `pdflatex` runs are required, since the documentation includes an index as well as hyperef links (the package `hypdoc` is used). Prior to the first run it is a good idea to delete any relevant `.toc`, `.aux`, `.out` files.

Finally, (depending on your system) update the T_EX file database. For example, on a Linux system one uses the `texhash` command.

2.3 Usage

Load the package by using the command `\usepackage{rubikcube}`. Note that the RUBIKCUBE package requires the TikZ package, and so always load TikZ before RUBIKCUBE as follows:

```
\usepackage{tikz}
\usepackage{rubikcube,rubikrotation,rubikpatterns}
```

However, the RUBIKCUBE package does check for the presence of TikZ, and will load it if TikZ is not already loaded. While RUBIKCUBE is a stand-alone package, it is best to also load the complementary RUBIKROTATION and RUBIKPATTERNS packages.

`\rubikcube` This command generates the logo RUBIKCUBE.

3 Command conventions

All RUBIKCUBE package commands assume a 3x3x3 cube by default. There are three primary command categories: (a) `\Draw..` commands (which must always be used *inside* a TikZ picture environment), (b) ‘parameter-allocation’ commands—e.g., `\RubikCubeSolved`—which can be used either inside or outside a TikZ environment), and (c) commands which can be used in ordinary text (e.g., `\rr{}` rotation commands).

3.1 Environments

Although the RUBIKCUBE package has been designed with TikZ in mind, it is important to appreciate that of all the various RUBIKCUBE package commands only the Rubik `\Draw...` commands and TikZ commands actually have to be used inside a TikZ picture environment.

Indeed, using RUBIKCUBE package commands which influence the Rubik colour state (configuration) outside the `tikzpicture`, `minipage` or `figure` environments can make for useful flexibility when a document is generating more than one figure or image. This is because the scope of any colours specified by commands inside these environments is constrained to be ‘local’ to that particular environment, and hence any change in the Rubik colour state brought about by such commands is not accessible globally (i.e., outside the environment) —see also Section 5 in the documentation of the RUBIKROTATION package.

Consequently users need to be mindful of the environments when drawing sequences of rotations across several figures; for example, keeping commands like `\RubikRotation`, `\RubikFace...`, `\RubikSide...`, `\RubikCubeSolved`, outside the environments keeps their effects global.

3.2 Capital letters

Virtually all Rubik bundle commands start with a capital letter, primarily to avoid any confusion with TikZ commands (these generally start with lower-case letters). However, each ‘word’ in a Rubik bundle command (except the word ‘text’) also starts with a capital letter, primarily to facilitate readability. For example, `\DrawRubikCubeRU`, `\DrawCubieRU`. However, as with L^AT_EX, ‘text..’ commands start with a lower-case ‘t’; for example `\textCubieRU`. Letter arguments for colours (R, O, Y, G, B, W, X) are always written in upper-case letters.

3.3 XYZ argument ordering

Many commands have an appended two, three, or even six ordered arguments or letters which form some feature of the structure of a command; perhaps either face or colour code or a viewpoint direction.

We adopt the convention that where ordering of arguments is critical, then the arguments are ordered in the XYZ, +, – order. An XYZ code implies that the first letter in the code relates to an X-related parameter, for example, L (Left) or R (Right); the second letter relates to a Y-related parameter, for example, U (Up) or D (Down); the third (if required) relates to a Z-related parameter, for example, F (Front) or B (Back) —see Figure 2.

Some commands have six arguments which adopt an (XYZ;+–) format. In this case, for example, the `\SolvedConfig` command, for which the six colour arguments are ordered as X+, X–, Y+, Y–, Z+, Z–. Here the colour argument associated with a face positioned on the +ve axis is ordered before its –ve complement on the same axis.

Another example is the `\DrawCubieRU{G}{Y}{O}` command, which draws a cubie. Here the RU letters are XY ordered; i.e., RightUp viewpoint. The sequence of colour codes for the three visible faces are XYZ ordered, and hence result in the cube having a Green Right face, Yellow Up face and Orange Front face.

3.4 Trailing % on the end of commands

Since the all the output of this package is drawn using graphic elements using TikZ, it is important to include a trailing % on the end of RUBIKCUBE package commands when used *outside* a TikZ picture environment, and also on the end of the `\end{tikzpicture}` environment command itself. In particular it is important to use a trailing % on the end of lines which break before the terminal curly bracket of a `\newcommand`.

This is to prevent accumulating spurious spaces which may otherwise appear in figures and diagrams as a strange or unexpected horizontal shift or white-space. That this can occur is because in T_EX every newline character is automatically converted to a white space—unless you have an empty line (Feuersänger 2016).

The L^AT_EX fbox is a useful aid for visualising unwanted white space which may have accumulated, and for identifying the cause. See Section 6 on the `\ShowCubeF` command for more regarding this approach.

Although this effect is mostly small, and is generally only observed in situations when centering a graphic is critical, it is, however, cumulative and can be surprisingly large. In these situations, the cure is the addition of terminal % characters to preceding code guided by careful detective use of the fbox technique mentioned above.

3.5 Cubies, cubicles, faces and facelets

The sub-cubes which make up the Rubik cube are known as ‘cubies’; the small coloured face of a cubie is known as a ‘facelet’. The cubies are named either according to the colours of their two or three facelets, or according to their physical position.

We distinguish three types of cubie: centre-cubies (single colour), edge-cubies (two colours) and corner-cubies (three colours). For example, the red/white edge-cubie is called the RW cubie, and the red/white/green corner-cubie is called the RWG cubie etc. Note that the colour of a particular face of a 3x3x3 Rubik cube is determined by the colour of its centre-cubie.

Similarly, the positions (known as ‘cubicles’) occupied by cubies are defined using either a two or three letter face code. For example, the right edge position in the Up-layer is termed the Up/Right position, or just the UR position, and the corner joining the DOWN FRONT and RIGHT faces is the DFR position.

4 Rubik cube coordinates

The coordinate origin of all 2D Rubik cube images is located at the bottom-left corner of the FRONT face, as shown in Figure 1. Note also that the bottom left extent of this particular 2D rendering of the cube is actually at $(-1, -1)$, and hence the default height and width of all oblique-view cubes is 4 units (i.e., equivalent to 4cm if the TikZ scale-factor = 1).

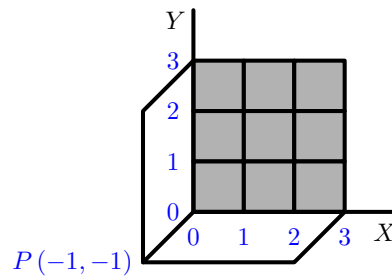


Figure 1: Origin of coordinates is at the bottom left corner of the grey FRONT face. Since P is at $(-1, -1)$ then the default height and width of the 2D cube image is 4 units.

Arranging for P to be at $(-1, -1)$, as well as using the bottom-left corner of

the FRONT face as the origin, are useful design features which make it easy to know the coordinates of any point, and hence facilitate the use any of the TikZ commands (e.g., `\draw` and `\node` commands) to superimpose lines, arrows and text etc., onto the Rubik cube (see Section 12).

4.1 Size of cube `\minipage`

Since the the default height and width of the oblique 2D cube image is 4 units (see Section 4 above), it follows that the width of the `\minipage` required for a cube in a `tikzpicture` environment can be easily calculated. For example, if the `tikzpicture` scale factor used is 0.5, then the minimum width of the required minipage for the `\DrawRubikCubeLD` view (shown above) is therefore $0.5 \times 4\text{cm} = 2\text{cm}$.

Note that the width of the semi-flat (SF) cube representation is therefore 10 units ($= 3+3+1+3$), and that of the flat (F) cube is 12 units ($= 3+3+3+3$) — see Section 9.3 for images of these forms. If in doubt check the horizontal extent of an image using the `\ShowCubeF` command, which places an `fbox` around the image.

5 TikZ picture environment

All the Rubik bundle `\Draw..` commands are designed to be used with the TikZ picture environment, and are compatible with standard TikZ. For a basic introduction to the use of TikZ see the following manuals (from CTAN or from <http://altermundus.com/>).

- <https://en.wikipedia.org/wiki/PGF/TikZ>
- `pgfmanual.pdf`, version 3.0.1a (? 2013) (1161 pages)
- `pgfplot.pdf`, version 1.13 (2016) (544 pages)
- `tkz-base-screen.pdf`, version 1.16c (2011) (91 pages)

An example of the TikZ picture environment for use with the Rubik bundle is as follows:

```
\begin{tikzpicture}[scale=0.5]
...
\end{tikzpicture}%
```

If no scale-factor is used (default scale-factor = 1), then each of the small cubic sides will have a length of 1 cm.

USEFUL COMMANDS: Probably the most useful TikZ commands for use with regard to the Rubik bundle are the `\draw` command (for drawing lines, arrows, circles), and the `\node` command (for writing text at specific coordinate locations). The basic structure of these commands is as follows, where (x,y) represent grid coordinates of start or end points of lines or arrows, or of a circle centre, or of text position (see Sections 9.3 and 12 for examples).

```

\draw[->,thick,color=blue] (4.5, 2.5) -- (3.5,2.5);
\draw[->,ultra thick,color=red] (4.5, 2.5) -- (3.5,2.5);
\draw [color=blue, thick] (0.3, 0.3) circle (1.3);
\node (B) at (7.5, 1.5) [black]{\small\textsf{B}};

```

Remember that all TikZ commands which are valid inside a `tikzpicture` environment require a terminal semicolon (see Section 12 for examples).

COLOURS: The following colors are predefined by TikZ: red, green, blue, cyan, magenta, yellow, black, gray, darkgray, lightgray, brown, lime, olive, orange, pink, purple, teal, violet and white (see <https://en.wikipedia.org/wiki/PGF/TikZ>).

LINE WIDTH: TikZ allows line width to be specified directly (e.g., [`linewidth=<dimension>`]), or by using the following abbreviations: ‘ultra thin’ for 0.1pt, ‘very thin’ for 0.2pt, ‘thin’ for 0.4pt (the default width), ‘semi thick’ for 0.6pt, ‘thick’ for 0.8pt, ‘very thick’ for 1.2pt, ‘ultra thick’ for 1.6pt (see <https://en.wikipedia.org/wiki/PGF/TikZ>).

WHITE SPACE: A particularly useful feature of TikZ is that it automatically minimises any horizontal white-space. However, it is good practice to place a `%` symbol after the `\end{tikzpicture}` command (*see above) to avoid additional white space inadvertently being added by L^AT_EX (see Section 3.4).

When making images it can be helpful to place them inside a minipage (e.g., using the `\ShowCube` command / environment below). A convenient approach is to first adjust the value of the `tikzpicture` scale-factor (to obtain the appropriate size), and then adjust the minipage-width as necessary, using the `fbox` associated with the `\ShowCubeF` command (see Section 4.1 for a useful guide on this).

The main ‘display’ tool for drawing cubes is the `\ShowCube` command (see below), and this incorporates a TikZ picture environment inside a minipage. The equivalent tool for displaying rotation sequences is the `\ShowSequence` command.

6 \ShowCube command

`\ShowCube` This command `\ShowCube{<width>}{<scale-factor>}{<commands>}` is a convenient tool which places one or more commands inside a `tikzpicture` environment and places all of these inside a minipage (see Section 19.4 for the code). This command takes three arguments: the first (**#1**) is the minipage width, the second (**#2**) is the `tikzpicture` scale factor, and the third (**#3**) is a series of any RUBIKCUBE package `\Draw..` and other commands, as well as any TikZ commands which are valid in a `tikzpicture` environment (e.g., `\draw` or `\node` etc.).

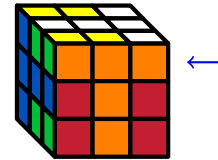
USAGE: The following `\ShowCube` command displays a Rubik cube (the ‘SixT’s configuration²) and a blue arrow in a minipage of width 3cm, using a `tikzpicture` scale factor of 0.5. Note that the TikZ `\draw` command requires a terminal semicolon—see Section 5.

²The `\sixts` macro is from the RUBIKPATTERNS package.

```

\RubikCubeSolved
\RubikRotation{\sixts}
\ShowCube{3cm}{0.5}{%
  \DrawRubikCubeLU
  \draw[->,thick,color=blue] (4.5, 2.5) -- (3.5,2.5);
}

```



The convenience of the `\ShowCube` command is illustrated below; the `\ShowCube` command on the left is equivalent to the bunch of commands on the right (see Section 19.4 for the complete code).

```

\ShowCube{3cm}{0.5}{...} {
  \begin{minipage}{3cm}%
  \centering%
  \begin{tikzpicture}[scale=0.5]
  ...
  \end{tikzpicture}%
  \end{minipage}%
}

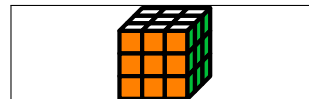
```

`\ShowCubeF`

The `\ShowCubeF` command is similar in all respects except that it places an fbox around the minipage in order to enable users to see the extent of any associated white space. For example, unexpected spacing between two adjacent images, or between an image and adjacent text, is usually related to ‘hidden’ white-space associated with the image itself or excessive width of the associated `\minipage` (see also Section 3.4). Consequently, a temporary fbox around the minipage can be a useful aid when trying to visualise the full extent of the minipage (and its associated white-space). Use the `\ShowCubeF` command for this.

For example, the following use of the `\ShowCubeF` command reveals a significant white-space problem:

```
\ShowCubeF{4cm}{0.3}{\DrawRubikCubeRU}
```



In this example, clearly either the minipage is too wide (4cm) or the `tikzpicture` scale factor is too small (0.3). Once the figure/code has been corrected, then the `F` in the `\ShowCubeF` command can be removed.

Note that while the `\ShowCube` command centres the image inside the minipage, \LaTeX positions the minipage in the `\textwidth`, and hence it is generally best to minimise the white-space as revealed by the `\ShowCubeF` command. The relationship between the required width of the minipage and the TikZ scale factor for the various Rubik cube images is detailed in Section 4.1.

7 Colour commands

The RUBIKCUBE package uses seven colours which are defined as follows: R (red), O (orange), Y (yellow), G (green), B (blue), W (white), and X (grey). Now according to the following webpage³

³We thank Peter Bartal for bringing this webpage to our attention.

<http://The-Rubiks-Cube.deviantart.com/journal/Using-Official-Rubik-s-Cube-Colors-268760351> (Nov 2011)

the official Rubik cube colours are defined as

```
... colours which are red (PMS 200C*), green (PMS 347C*),
blue (PMS 293C*), orange (PMS 021C*), yellow (PMS 012C*)
and white.
```

```
...
```

```
Pantone colors can not be accurately converted to RGB colors,
the colors the web runs on. But they can be approximated.
Through some research, I have found some estimations which
may help you which I have listed below. Remember, these are
just approximate RGB equivalents to the official Rubik's Cube
colors.
```

```
Red: 200C #C41E3A (www.perbang.dk/rgb/c41e3a/)
Green: 347C #009E60 (www.perbang.dk/rgb/009e60/)
Blue: 293C #0051BA (www.perbang.dk/rgb/0051ba/)
Orange: 021C "Pantone Orange" #FF5800 (www.perbang.dk/rgb/ff5800/)
Yellow: 012C "Pantone Yellow" #FFD500 (www.perbang.dk/rgb/ffd500/)
White: N/A #FFFFFF
```

```
Red {HTML}{C41E3A}
green {HTML}{009E60}
Blue {HTML}{0051BA}
Yellow {HTML}{FFD500}
Orange {HTML}{FF5800}
White {HTML}{FFFFFF}
```

However, we have optimised these prescribed colours very slightly for screen & print use (for example, the yellow was made very slightly brighter), and so the actual colours implemented by the RUBIKCUBE package are as follows:⁴. (see Section 19.2):

```
\definecolor{R}{HTML}{C41E33}
\definecolor{G}{HTML}{00BE38}
\definecolor{B}{HTML}{0051BA}
\definecolor{Y}{HTML}{FFFF00}
\colorlet{O}{orange}
\colorlet{W}{white}
\colorlet{X}{black!30}%
```

Different colours can be allocated to the ROYGBWX letters (using the standard \LaTeX `\colorlet` command) as required. For example, the standard ‘red’ colour could be allocated to the letter R using the command

```
\colorlet{R}{red}
```

⁴Although the Pantone colours cannot be converted to RGB, there is a subset of of Pantone colours which can be converted using CMYK (see <https://en.wikipedia.org/wiki/Pantone>)

However, it is important to appreciate that the letter codes ROYGBWX are ‘hard-wired’ into many of the macros in the RUBIKCUBE package, so don’t change these.

7.1 Colour state of the cube

`\RubikFace..` Initially, when L^AT_EX reads the file `rubikcube.sty` all facelets are allocated the colour-code X, which can be regarded as a zero-colour state. Until a facelet is allocated one of the six Rubik colours (using a suitable command) it will be rendered as grey by a Rubik `\Draw...` command, since these commands simply implement the current colour state of the cube (e.g., `\DrawRubikCubeRU`).

`\RubikSlice..`
`\RubikSide..`
`\RubikCubeSolved`
`\RubikCubeGrey`
`\RubikCubeGreyAll`

It is important to appreciate that the various commands which typeset faces or facelets with colours differ in whether they derive the colours from the current internal colour ‘state’ (configuration) of the Rubik cube, or not.

The colour state of cubies in faces and slices can be allocated using `\RubikFace...`, `\RubikSlice...` and `\RubikSide...` commands (see Sections 9.4, 7.6 and 7.7). In addition, the command `\RubikCubeSolved`, allocates a prescribed colour state for the whole ‘solved’ cube, and is a very useful starting point (configuration) for subsequent rotations. The commands `\RubikCubeGrey` and `\RubikCubeGreyAll` allocate different colour states for the whole cube, and are designed to be useful starting points when illustrating aspects of how to solve the cube. These two commands accept both ‘grey’ and ‘gray’ (to be consistent with TikZ). Cubies retain their colour allocation even if the cubies are moved using the `\RubikRotation` command (RUBIKROTATION package), unless they are overwritten by a subsequent colour allocation command.

To visualise the current state of the cube one has to use a Rubik `\Draw...` command. Although some `\Draw...` commands (e.g., `\DrawRubikLayerFace...`) allow you to specify colours as arguments, `\Draw...` commands really only ‘paint’ colours onto cubie positions (on the page, so to speak). `\Draw..` commands never influence the internal Rubik colour state.

The current colour state / configuration of the Rubik cube can be saved and written to a named file (using the `\SaveRubikState` command) in a form which can then be easily `\input` and processed when required.

7.2 RubikFace commands

`\RubikFaceUp`
`\RubikFaceDown`
`\RubikFaceLeft`
`\RubikFaceRight`
`\RubikFaceFront`
`\RubikFaceBack`

These commands take nine colour arguments and allocate colours to the individual cubies of a Rubik cube face. The ordering is isomorphic to the sequence 1–9, i.e., numbering the small squares 1-3 (top row, left to right), 4-6 (middle row, left to right), 7-9 (bottom row, left to right), as follows:

#1	#2	#3
#4	#5	#6
#7	#8	#9

Conveniently, L^AT_EX allows the colour arguments to be separated by spaces (e.g., separated in groups of three), or even spread across several lines (e.g., in

a square block to resemble a 9-face). This is fortunate, as it allows the command to be formulated in a visually intuitive way, as in the following examples.

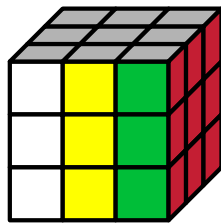
```
\RubikFaceUp{G}{B}{G}   {G}{W}{O}   {G}{O}{G}

\RubikFaceFront{O}{W}{R}
   {W}{W}{W}
   {G}{W}{G}
```

```
\RubikFaceUpAll
\RubikFaceDownAll
\RubikFaceLeftAll
\RubikFaceRightAll
\RubikFaceFrontAll
\RubikFaceBackAll
```

Each of the above commands has an associated ‘All’ version which allocates the same colour to all the cubies on a 9-face (i.e., only a single colour argument is required).

If you want a particular face to be all grey, then use the colour-code X; for example, `\RubikFaceUpAll{X}`. Failure to include a valid colour argument will generate a ‘missing parameter’ error, and no colour will be allocated (i.e., you will see a black-hole). Use of these commands is shown in the following figure.



```
\RubikFaceUpAll{X}
\RubikFaceRightAll{R}
\RubikFaceFront{W}{Y}{G}
   {W}{Y}{G}
   {W}{Y}{G}
\ShowCube{3cm}{0.7}{\DrawRubikCubeRU}
```

7.3 Solved Configuration

```
\SolvedConfig
```

This command allocates the six face colours according to the following ordered XYZ+- argument rule, namely X+, X-, Y+, Y-, Z+, Z-; i.e., the order of the six colour arguments follows the face order RIGHT, LEFT, UP, DOWN, FRONT, BACK (for notation see Section 3.3 and Figure 2).

USAGE: `\SolvedConfig{G}{B}{W}{Y}{O}{R}`

Examples of its use are shown in the next section.

7.4 RubikCubeSolved command

```
\RubikCubeSolved
\RubikCubeSolvedWY
```

The action of both of these commands is identical: they both set all the face colours to the following standard ‘solved’ cube configuration, namely Up=white, Down=yellow, Right=green, Left=blue, Front=orange, Back=red, by invoking the above `\SolvedConfig` command, as follows:

```
\newcommand{\RubikCubeSolved}{\SolvedConfig{G}{B}{W}{Y}{O}{R}}
```

Note that this is in fact just a convenient short-hand for the following:

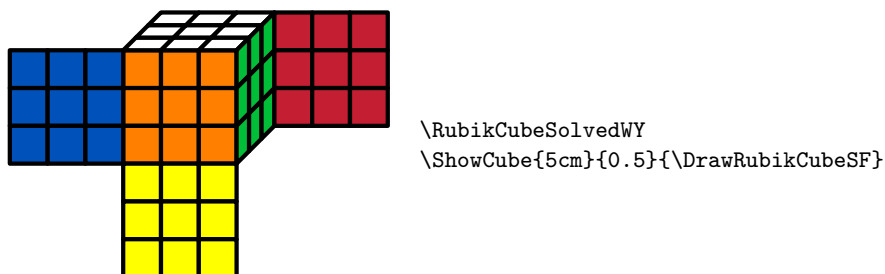
```
\newcommand{\RubikCubeSolved}{%
  \RubikFaceRightAll{G}%
  \RubikFaceLeftAll{B}%
```

```

\RubikFaceUpAll{W}%
\RubikFaceDownAll{Y}%
\RubikFaceFrontAll{O}%
\RubikFaceBackAll{R}%
}

```

Note that for convenience, this configuration is also available using the command `\RubikCubeSolvedWY` (WY denoting White opposite Yellow). This solved configuration is shown in the following semi-flat (SF) image.



Note that the width of the minipage used in `\ShowCube` command above is set to 5cm. This value is derived from the fact that the *unscaled* width of the semi-flat image is 10cm (9 + 1 squares), and hence if the TikZ scale factor is set to 0.5 then the minimum minipage width = $10 \times 0.5 = 5\text{cm}$ (see Section 4 for details).

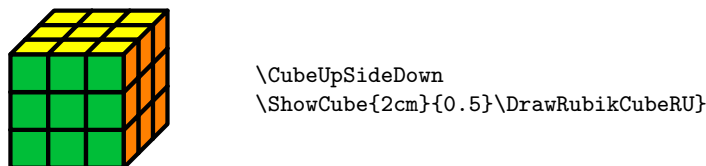
Other orientations: If other orientations of the solved cube are required, this can be easily achieved using the `\RubikRotation` command (from the `RubikRotation` package) to rotate the cube as required. For example, we could make a command to show the above solved cube upsidedown and rotated slightly, as follows:

```

\newcommand{\CubeUpSideDown}{\RubikCubeSolved\RubikRotation{x2,y}}

```

—this uses the rotations `x`, `x`, to invert, and then `y` to turn the cube 90 deg:

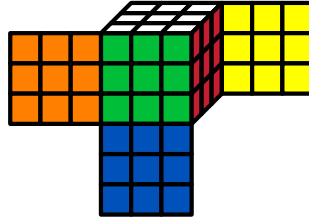


```

\RubikCubeSolvedWB

```

Other configurations: While the ‘solved’ WY colour configuration described above (White face opposite Yellow) is that of the most commonly occurring Rubik cube, another ‘solved’ colour configuration which is also commercially available has the White opposite Blue configuration, which is available using the command `\RubikCubeSolvedWB`. Its colour configuration is as follows:



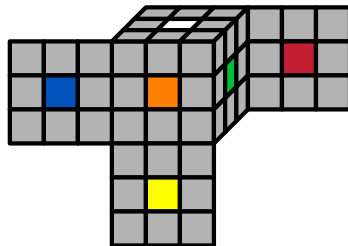
Note that users can easily create their own alternative ‘solved’ face/colour versions. For example, the above mentioned white opposite blue (WB) solved configuration command `\RubikCubeSolvedWB` (white opposite blue, red opposite orange, and green opposite yellow), was created using `\SolvedConfig{R}{O}{W}{B}{G}{Y}` (for the code see 19.11).

7.5 RubikCubeGrey command

`\RubikCubeGrey`
`\RubikCubeGreyAll`

The command `\RubikCubeGrey` generates a 3x3x3 cube with no colours allocated *except* for the central cubie of each face, which takes the same colour configuration as defined for the `\RubikCubeSolved` command. The command `\RubikCubeGreyAll` generates a cube with *all* the faces completely grey. Both these commands will accept either ‘grey’ or ‘gray’ (to be consistent with TikZ).

These two commands, are designed to be useful starting points when wanting to describe the movement of particular cubies. We can see the effect of the `\RubikCubeGrey` command by viewing the cube in a semi-flat (SF) format, as follows:



```
\RubikCubeGrey
\ShowCube{4.5cm}{0.45}{\DrawRubikCubeSF}
```

Users can easily set their own alternative face/colour configuration either by ‘renewing’ the `\RubikCubeGrey` command along the lines shown above (the code is in Section 19.8), or simply creating a new ‘variant’ command altogether.

7.6 RubikSlice commands

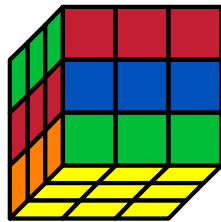
`\RubikSliceTopX`
`\RubikSliceMiddleX`
`\RubikSliceBottomX`

These three commands allocate the six visible cubie colours associated with a *horizontal* slice of a Rubik cube. There are three pairs of Slice commands; one pair (Left view & Right view) for each of the horizontal slices Top, Middle, Bottom. The six colour arguments associated with a given slice run in sequence from left to right irrespective of the viewpoint, e.g., #1 #2 #3 #4 #5 #6.

Since the viewpoint of the Rubik cube (from the Right or from the Left) influences which face the colours are associated with, it is necessary to have the view (R or L) specified in the command name.

The format of the ‘slice’ command is shown in the following example. The Rubik cube is shown from the LeftDown (LD) view and consequently each of the ‘slice’ commands in this particular example ends in L, consistent with the final `\DrawRubikCubeLD` command.

Note that the two legacy ‘Equator’ versions (now replaced by ‘Middle’) are retained to allow backward compatibility.



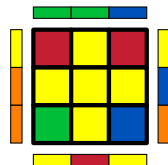
```
\RubikFaceDownAll{Y}
\rubikSliceTopL    {G}{G}{G} {R}{R}{R}
\rubikSliceMiddleL {R}{R}{R} {B}{B}{B}
\rubikSliceBottomL {O}{O}{O} {G}{G}{G}
\ShowCube{3cm}{0.7}{\DrawRubikCubeLD}
```

7.7 RubikSide commands

`\RubikSideLeft` `\RubikSideRight` `\RubikSideFront` `\RubikSideBack` These RubikSide commands allocate colours to the side facelets of the UP face, and each takes three ordered colour arguments, running from top-left to top-right when looking directly at the side faces—see Section 19.18. These facelets are the top three facelets of each side Front, Back, Left, Right.
USAGE: `\RubikSideBack{B}{G}{G}`

`\RubikSideLeftAll` `\RubikSideRightAll` `\RubikSideFrontAll` `\RubikSideBackAll` These commands allocate the same colour to all three side cubies, and hence take only a single colour argument.
USAGE: `\RubikSideBackAll{R}`

The `\RubikSide..` and `\RubikFace..` commands are useful for setting up the colours for just part of the cube. For example, the following commands set-up the UP-face and sides, and then draws the face and sidebars using `\DrawFlatUpSide`.



```
%set up the UP face
\rubikFaceUp    {R}{Y}{R}%
                {Y}{Y}{Y}%
                {G}{Y}{B}%
\rubikSideBack{B}{G}{G}%
\rubikSideFront{Y}{R}{Y}%
\rubikSideRight{O}{B}{Y}%
\rubikSideLeft{Y}{O}{O}%
%draw the UP face and sides
\ShowCube{2cm}{0.5}{\DrawFlatUpSide}
```

Note that we could instead have drawn the above image using `\DrawRubikLayer..` commands. However, using the `\RubikSide..` and `\RubikFace..` commands makes for a much more flexible and dynamic system, since the colours allocated using these commands (provided they are external to an environment) will be global, and hence will follow subsequent `\RubikRotation` commands.

8 Rotation commands

The Rubik bundle implements not only the standard Rubik cube notation of the World Cube Association (see WCA website), but also the main variant notations used by the Rubik interest groups and websites.

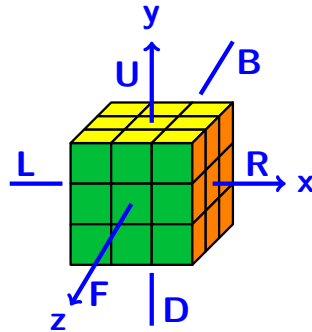


Figure 2: Face rotations

To avoid confusion the Rubik bundle uses a trailing ‘p’ (lower-case) in rotation-codes to denote a ‘prime’ (reversed direction); we also recommend that commas are used to separate sequential Rubik rotations (moves). While these are mainly to avoid ambiguity, they also greatly facilitate computer searching and copy-and-pasting of rotation sequences.

Unfortunately, obtaining a good balance between an intuitive notation for defining rotations and the need for flexibility is difficult, and consequently some notation is more intuitive than others. A good compromise seems to be the World Cube Association’s FADN structure; i.e., Face (L,R,U,D,F,B), Action (m,w,s,a,c), Direction (p), N (n); for example, codes like **R**, **R2**, **Rc**, **Rm**, **Rwp**, **Rwp2** etc.

The RUBIKCUBE package includes commands for typesetting a wide range of rotation-codes (e.g., **R**, **y**, **Bw**) and equivalent hieroglyphs (e.g., $\boxed{\uparrow\uparrow}$, $\boxed{[y]}$, \boxed{Bw}), as well as commands for typesetting 3x3x3 cubes and single cubies. All the rotation-codes and hieroglyphs are typeset using one particular font & size which we call the ‘rubikfont’ for convenience (see Section 8.10 for details). All of the rotation-codes described here are recognised by the RUBIKROTATION package (see Section 1.2).

Note that there are some rotation codes which are not represented by arrow hieroglyphs, since their rotation is not visible from the FRONT face, and hence cannot easily be rendered as an arrow hieroglyph. Consequently these rotations have a simple ‘letter’ hieroglyph in the form of the rotation-code in a square; for example, \boxed{Bw} , \boxed{Fm} .

8.1 Overview

We now describe the four commands used for typesetting the various rotation-codes.

<code>\rr</code>	The text version of a rotation-code is typeset using the rubik-rotation command <code>\rr{<rotation-code>}</code> , i.e., R is typeset using the command <code>\rr{R}</code> . The
<code>\rrh</code>	hieroglyph of a rotation is generated (in text) by using instead the command <code>\rrh{<rotation-code>}</code> . For example, the command <code>\rrh{R}</code> generates $\boxed{\uparrow\uparrow}$ which is the hieroglyph associated with the rotation R .
<code>\Rubik</code>	A vertically combined rotation-code and its hieroglyph is generated using the command <code>\Rubik{<rotation-code>}</code> . For example, $\boxed{\uparrow\uparrow}$ is generated by the command <code>\Rubik{R}</code> , with the square hieroglyph sitting on the baseline. For some hieroglyphs (e.g., \boxed{x} , \boxed{y} , \boxed{z} denoting 90 degree cube-axis rotations) the only difference between the <code>\rrh{}</code> and <code>\Rubik{}</code> form is that the <code>\Rubik{}</code> form is elevated to sit on the baseline just like the other <code>\Rubik{}</code> hieroglyphs. For example, <code>\rrh{yp}</code> generates $\boxed{y'}$, while <code>\Rubik{yp}</code> generates $\boxed{y'}$.
<code>\textRubik</code>	A horizontally combined rotation-code and its hieroglyph (in sequence as in text) is generated using the command <code>\textRubik{<rotation-code>}</code> . For example, $\mathbf{R} \boxed{\uparrow\uparrow}$ is typeset using the command <code>\textRubik{R}</code> . A list of all rotation-code commands and their associated hieroglyphs is given in Section 8.9.

8.2 Face rotations

U	The six main faces of the cube are denoted as FRONT (towards the observer),
D	BACK, LEFT, RIGHT, UP, DOWN. The upper-case initial letter of each face-name
L	(F , B , L , R , U , D) denotes a clockwise 90-degree rotation of the face as shown in
R	Figure 2. For example, D is generated by the ‘rubik rotation’ command <code>\rr{D}</code> .
F	An appended prime ‘ <i>prime</i> ’ indicates an anticlockwise rotation; e.g., F’ . This is some-
B	times written as \mathbf{F}^{-1} . The ‘prime’ notation is achieved by appending a lower-case
Up	‘p’ to the face rotation command. For example, R’ is generated by <code>\rr{Rp}</code> . More
Dp	formally, R’ is the ‘inverse’ of R .
Lp	The superscript ² , or sometimes just an ordinary 2, indicates that the rotation
Rp	is applied twice. For example, R² or R2 denote <i>two</i> successive 90 degree clockwise
Fp	rotations of the RIGHT face; R³ is equivalent to R’ etc.
Bp	

8.3 Inner-slice rotations

The Rubik cube (3x3x3) has three orthogonal so-called ‘inner’ slices (middle layers, middle slices), whose +ve rotation direction follows that of a named face. For example, the inner-slice rotation between the RIGHT and LEFT faces whose rotation direction follows the rotation **R** (i.e., its rotation is isomorphic to **R**). The inner-slice rotations form a group (the Slice group), originally described by John Conway (Frey and Singmaster, 1982, p 105).

The ‘m’ notation

Um Here ‘m’ stands for the ‘middle’ slice, namely that parallel to the designated FACE;
Dm its rotation mirrors that of the FACE. The **m** must be in lower-case. Each of these
Lm rotation-codes has a complementary ‘prime’ version, formed by appending a ‘p’;
Rm for example, **Rm** (`\rr{Rm}`) is a middle layer rotation $\boxed{\uparrow\uparrow}$ between the RIGHT and
Fm LEFT faces, and is in the same direction as **R**. The code **Rm**’ (`\rr{Rmp}`) refers to
Bm the same middle slice, but rotated in the opposite direction $\boxed{\downarrow\downarrow}$.

This notation, which was probably invented by Singmaster, was originally used on the Cube Lovers usenet group (1981–1997). It is now much used on the Jaap Puzzles website (see Scherphius J) —see also Section 19.23.

The ‘M’ notation

MU This variant of the above ‘middle’ slice notation (e.g., **MR** \equiv **Rm**) is part of the
MD ‘superset’ notation of Randelshofer. As before, the rotation direction follows that
ML of the designated FACE. Each has a complementary ‘prime’ version formed by
MR appending a ‘p’. The **M** must be in upper-case.

MF

MB

The MES notation

M An alternative but very confusing inner-slice notation (e.g., **Ep** \equiv **Um**) which is oc-
E casionally used is the so-called MES notation, as used in the Waterman algorithm
S (Treep and Waterman 1987).

Mp

Ep **M** (MIDDLE $\boxed{\downarrow\downarrow}$, between the LEFT and RIGHT faces; direction follows **L**),

Sp

E (EQUATOR $\boxed{\rightleftharpoons}$, between the UP and DOWN faces; direction follows **D**),

S (STANDING $\boxed{\mathbf{S}}$, between the FRONT and BACK faces; direction follows **F**).

Each of these also has an inverse (prime) version.

The ‘S’ notation

Su In this equally confusing inner-slice notation, ‘S’ stands for ‘inner-slice’; the face
Sd letter must be in lower-case (e.g., **Sr** \equiv **Rm**). For example, the inner-slice rotation
S1 between the RIGHT and LEFT faces whose rotation direction follows the rotation
Sr **R** is denoted as **Sr**, which is typeset using the command `\rr{Sr}`. Each has an
Sf inverse (prime) p-form.

Sb

8.4 Outer-slice rotations

Slice notation

Us This is a ‘paired’ form of notation (two rotations at once), which can be thought
Ds of as complementing the inner-slice (middle layer) rotations. Each of these
Ls ‘slice’ commands denotes a rotation of two opposite faces in the *same* direction.
Rs For example, $\mathbf{U}_s \left[\begin{array}{c} \leftarrow \\ \rightleftarrows \\ \leftarrow \end{array} \right] \equiv \mathbf{U} \left[\begin{array}{c} \leftarrow \\ \rightleftarrows \\ \leftarrow \end{array} \right] + \mathbf{D}' \left[\begin{array}{c} \leftarrow \\ \rightleftarrows \\ \leftarrow \end{array} \right]$; i.e., both face-rotations are in the *same*
Fs direction as \mathbf{U} . Each of these rotation-codes has a complementary ‘anti-slice’ ver-
Bs sion (see below).

This notation was originally described by Singmaster (Frey and Singmaster, 1982), and is much used on the ‘Pretty patterns’ page of the Fridrich website (this page also has a useful link to ‘notation’).

SU This variant of the above ‘slice’ notation (e.g., $\mathbf{SU} \equiv \mathbf{Us}$) is part of the ‘superset’
SD notation of Randelshofer. As before, the rotation direction follows that of the
SL designated FACE. Each has a complementary ‘prime’ version formed by appending
SR a ‘p’.
SF
SB

Anti-slice notation

Ua Each of these commands denotes a rotation of two opposite faces in *opposite*
Da directions. For example, $\mathbf{U}_a \left[\begin{array}{c} \leftarrow \\ \rightleftarrows \\ \leftarrow \end{array} \right] \equiv \mathbf{U} \left[\begin{array}{c} \leftarrow \\ \rightleftarrows \\ \leftarrow \end{array} \right] + \mathbf{D} \left[\begin{array}{c} \leftarrow \\ \rightleftarrows \\ \leftarrow \end{array} \right]$. This notation is much used
La on the ‘Pretty patterns’ page of the Fridrich website (see the note above re: ‘slice
Ra notation’).
Fa
Ba

8.5 Wide rotations

Uw The clockwise *combined* rotation of an outer face AND its inner-slice (officially
Dw known as a ‘double outer slice’ rotation, or a ‘double block’ move) is denoted
Lw by appending a lower-case **w** (denoting ‘wide’) to a rotation-code (endorsed by
Rw the WCA). For example, a RIGHT double outer slice rotation $\boxed{\uparrow\uparrow}$ ($\backslash\text{rrh}\{\mathbf{Rw}\}$) is
Fw denoted as \mathbf{Rw} ($\backslash\text{rr}\{\mathbf{Rw}\}$). The ‘prime’ version is formed by appending a ‘p’ to
Bw the rotation-code. For example, \mathbf{Rw}' is generated by $\backslash\text{rr}\{\mathbf{Rwp}\}$.

The ‘T’ notation

TU This confusing variant of the above ‘w’ notation (e.g., $\mathbf{TR} \equiv \mathbf{Rw}$) is part of the
TD ‘superset’ notation of Randelshofer. As before, the rotation direction follows that
TL of the designated FACE. Each has a complementary ‘prime’ version formed by
TR appending a ‘p’.
TF
TB

8.6 Axis rotations

x Whole-cube clockwise rotations of 90-degrees about about the orthogonal axes
y centred on the RIGHT, UP, FRONT faces are denoted as **x**, **y**, **z** (the `\rr{}` forms) re-
z spectively (see Figure 2), with their hieroglyphs (the `\rrh{}` forms) being denoted
as **[x]**, **[y]**, **[z]** in order to distinguish them from square layer-rotation hieroglyphs.
Note that since **x**, **y**, **z** rotations are always expressed in lower-case; this practice
is also extended to the commands.

For example, an **x2** rotation (two **x** rotations one after the other, i.e., **[x] [x]**)
denotes rotating the cube 180 degrees about its x axis so as to bring the DOWN
face into the UP position.

An appended prime ' indicates an anticlockwise rotation; for example, **x'** (which
is generated by appending a 'p' to the rotation-code, i.e., `\rr{xp}`).

The `\Rubik{}` forms (and their prime 'p' versions) generate the same hiero-
glyphs as their `\rrh{}` versions, except that their spacing is similar to that associ-
ated with the 'square box' `\Rubik{}` hieroglyphs. Consequently when typesetting
an axis command in a sequence of 'square-box' `\Rubik{}` commands, it is better to
use the `\Rubik{}` form rather than the equivalent `\rrh{}` form (see the examples
in Section 8.7). There are no `\textRubik{}` forms for the axis commands (since
they are not necessary).

The u, d, l, r, f, b notation

u A commonly used alternative for the **x**, **y**, **z** notation (and endorsed by the WCA)
d uses these lower-case face letter to denote a 90 degree whole-cube rotation in the
l same directional sense as that of the standard face rotations.

r Thus **u** \equiv **y**, **d** \equiv **y'**, **l** \equiv **x'**, **r** \equiv **x**, **f** \equiv **z**, **b** \equiv **z'**,

f For example, **d** is generated by the command `\rr{d}`.

b Note that these rotations do not have prime ' versions since **u** is the opposite of
d, **l** is the opposite of **r**, and **f** is the opposite of **b**.

As with the **[x]**, **[y]**, **[z]** forms (described above) there are also equivalent `\rrh{}`
and `\Rubik{}` forms. For example, **[d]** is generated by the command `\rrh{d}`.

The 'c' notation

Uc This slightly more intuitive notation (the 'c' stands for 'cube') also associates
Dc the rotation direction with that of the designated FACE (e.g., **Rc** \equiv **x**). Each has
Lc a complementary 'prime' version formed by appending a 'p'. For example, **Rc**
Rc (`\rr{Rc}`) is equivalent to **x**; **Rc'** (`\rr{Rcp}`) is equivalent to **x'**.

Fc This notation, which was probably invented by Singmaster, was originally used
Bc on the Cube Lovers usenet group (1981–1997). It is now much used on the Jaap
Puzzles website (see Scherphius J) — see also Section 19.23.

The ‘C’ notation

CU This variant of the whole cube rotation notation (e.g., $\mathbf{CR} \equiv \mathbf{Rc} \equiv \mathbf{x}$) is part of
 CD the ‘superset’ notation of Randelshofer. As before, the rotation direction follows
 CL that of the designated FACE. Each has a complementary ‘prime’ version formed
 CR by appending a ‘p’.

CF

CB

8.7 Examples

\mathbf{R} is generated by the command `\rr{R}`

\mathbf{Fw} is generated by the command `\rr{Fw}`

\mathbf{L}^2 is generated by `\rr{L}2`

$\mathbf{L2}$ is generated by `\rr{L}2`

\mathbf{R}' is generated by `\rr{Rp}`

\mathbf{Fw}' is generated by `\rr{Fwp}`

\mathbf{x} and $\mathbf{[y]}$ and $\mathbf{[z']}$ are generated by `\rr{x}` and `\rrh{y}` and `\Rubik{zp}`

\mathbf{Fc} and $\mathbf{[Bc]}$ are generated by `\rr{Fc}` and `\rrh{Bc}`

\mathbf{UURR} is generated by `\rr{U}\rr{U}\rr{R}\rr{R}`

$\mathbf{Q} \mathbf{[y]} \mathbf{[Lw]}$ `\Rubik{F}\Rubik{U}\Rubik{y}\Rubik{Rp}\Rubik{Lwp}`
F U R' Lw'

$\mathbf{F} \mathbf{Q} \mathbf{U}$ `\textRubik{F}\ \textRubik{U}`

Commas can be important in avoiding ambiguity; for example,

$\mathbf{D,U2,F2,Ds2,B}$, `\rr{U}2,\rr{F}2,\rr{Ds}2,\rr{B}`,

$\mathbf{[U]}2, \mathbf{[F]}2, \mathbf{[Ds]}2$, `\rrh{U}2,\,\,\rrh{F}2,\,\,\rrh{Ds}2`,

$\mathbf{Q} \mathbf{[y]} \mathbf{[Lw]}$ `\rrh{F}\rrh{U}\rrh{y}\rrh{Rp}\rrh{Lwp}`

Note that if each rotation element uses the *same* font or encoding, then typesetting a rotation sequence can be achieved more easily using the `\ShowSequence` command (see Section 10). For example, we can typeset the last sequence much more conveniently, as follows:

`\ShowSequence{\rrh}{F,U,y,Rp,Lwp}` \rightarrow $\mathbf{Q} \mathbf{[y]} \mathbf{[Lw]}$

8.8 Backwards compatibility

Note that in keeping with ‘backwards compatibility’ all rotation commands (see below) can still be written without the usual curly braces `{}`. For example, the hieroglyph $\mathbf{[D]}$ (`\rrh{D}`) can also be generated using the command `\rrhD`.

8.9 Listing of all rotation commands

Note that all the commands presented here also have a `\Rubik{}` equivalent form which typesets both the hieroglyph and its lettercode in a vertical format, as shown in the ‘Examples’ section above. These have been omitted here owing to the difficulty of including this form easily in the following table.

Note also that some `\rrh{}` commands (e.g., the `\rrh{B}` command) show only the lettercode in a square box, e.g., $\boxed{\text{B}}$. This is because these rotations do not have a ‘true’ visual representation as seen from the FRONT face, and hence can be somewhat ambiguous unless typeset with their associated lettercode.

<code>U \rr{U}</code>	$\boxed{\leftarrow}$ <code>\rrh{U}</code>	<code>U</code> $\boxed{\leftarrow}$ <code>\textRubik{U}</code>
<code>U' \rr{Up}</code>	$\boxed{\rightarrow}$ <code>\rrh{Up}</code>	<code>U'</code> $\boxed{\rightarrow}$ <code>\textRubik{Up}</code>
<code>Uw \rr{Uw}</code>	$\boxed{\leftarrow}$ <code>\rrh{Uw}</code>	<code>Uw</code> $\boxed{\leftarrow}$ <code>\textRubik{Uw}</code>
<code>Uw' \rr{Uwp}</code>	$\boxed{\rightarrow}$ <code>\rrh{Uwp}</code>	<code>Uw'</code> $\boxed{\rightarrow}$ <code>\textRubik{Uwp}</code>
<code>Us \rr{Us}</code>	$\boxed{\leftarrow}$ <code>\rrh{Us}</code>	<code>Us</code> $\boxed{\leftarrow}$ <code>\textRubik{Us}</code>
<code>Us' \rr{Usp}</code>	$\boxed{\rightarrow}$ <code>\rrh{Usp}</code>	<code>Us'</code> $\boxed{\rightarrow}$ <code>\textRubik{Usp}</code>
<code>Ua \rr{Ua}</code>	$\boxed{\leftarrow}$ <code>\rrh{Ua}</code>	<code>Ua</code> $\boxed{\leftarrow}$ <code>\textRubik{Ua}</code>
<code>Ua' \rr{Uap}</code>	$\boxed{\rightarrow}$ <code>\rrh{Uap}</code>	<code>Ua'</code> $\boxed{\rightarrow}$ <code>\textRubik{Uap}</code>
<code>Um \rr{Um}</code>	$\boxed{\leftarrow}$ <code>\rrh{Um}</code>	<code>Um</code> $\boxed{\leftarrow}$ <code>\textRubik{Um}</code>
<code>Um' \rr{Ump}</code>	$\boxed{\rightarrow}$ <code>\rrh{Ump}</code>	<code>Um'</code> $\boxed{\rightarrow}$ <code>\textRubik{Ump}</code>
<code>Uc \rr{Uc}</code>	$\boxed{\text{Uc}}$ <code>\rrh{Uc}</code>	$\boxed{\text{Uc}}$ <code>\Rubik{Uc}</code>
<code>Uc' \rr{Ucp}</code>	$\boxed{\text{Uc'}}$ <code>\rrh{Ucp}</code>	$\boxed{\text{Uc'}}$ <code>\Rubik{Ucp}</code>
<code>D \rr{D}</code>	$\boxed{\rightarrow}$ <code>\rrh{D}</code>	<code>D</code> $\boxed{\rightarrow}$ <code>\textRubik{D}</code>
<code>D' \rr{Dp}</code>	$\boxed{\leftarrow}$ <code>\rrh{Dp}</code>	<code>D'</code> $\boxed{\leftarrow}$ <code>\textRubik{Dp}</code>
<code>Dw \rr{Dw}</code>	$\boxed{\rightarrow}$ <code>\rrh{Dw}</code>	<code>Dw</code> $\boxed{\rightarrow}$ <code>\textRubik{Dw}</code>
<code>Dw' \rr{Dwp}</code>	$\boxed{\leftarrow}$ <code>\rrh{Dwp}</code>	<code>Dw'</code> $\boxed{\leftarrow}$ <code>\textRubik{Dwp}</code>
<code>Ds \rr{Ds}</code>	$\boxed{\rightarrow}$ <code>\rrh{Ds}</code>	<code>Ds</code> $\boxed{\rightarrow}$ <code>\textRubik{Ds}</code>
<code>Ds' \rr{Dsp}</code>	$\boxed{\leftarrow}$ <code>\rrh{Dsp}</code>	<code>Ds'</code> $\boxed{\leftarrow}$ <code>\textRubik{Dsp}</code>

$\mathbf{Da} \ \rr{Da}$	$\boxed{\Leftrightarrow} \ \rrh{Da}$	$\mathbf{Da} \ \boxed{\Leftrightarrow} \ \text{\textRubik{Da}}$
$\mathbf{Da}' \ \rr{Dap}$	$\boxed{\Rrightarrow} \ \rrh{Dap}$	$\mathbf{Da}' \ \boxed{\Rrightarrow} \ \text{\textRubik{Dap}}$
$\mathbf{Dm} \ \rr{Dm}$	$\boxed{\Rrightarrow} \ \rrh{Dm}$	$\mathbf{Dm} \ \boxed{\Rrightarrow} \ \text{\textRubik{Dm}}$
$\mathbf{Dm}' \ \rr{Dmp}$	$\boxed{\Leftrightarrow} \ \rrh{Dmp}$	$\mathbf{Dm}' \ \boxed{\Leftrightarrow} \ \text{\textRubik{Dmp}}$
$\mathbf{Dc} \ \rr{Dc}$	$[\mathbf{Dc}] \ \rrh{Dc}$	$[\mathbf{Dc}] \ \text{\textRubik{Dc}}$
$\mathbf{Dc}' \ \rr{Dcp}$	$[\mathbf{Dc}'] \ \rrh{Dcp}$	$[\mathbf{Dc}'] \ \text{\textRubik{Dcp}}$
$\mathbf{L} \ \rr{L}$	$\boxed{\Downarrow} \ \rrh{L}$	$\mathbf{L} \ \boxed{\Downarrow} \ \text{\textRubik{L}}$
$\mathbf{L}' \ \rr{Lp}$	$\boxed{\Uparrow} \ \rrh{Lp}$	$\mathbf{L}' \ \boxed{\Uparrow} \ \text{\textRubik{Lp}}$
$\mathbf{Lw} \ \rr{Lw}$	$\boxed{\Downarrow} \ \rrh{Lw}$	$\mathbf{Lw} \ \boxed{\Downarrow} \ \text{\textRubik{Lw}}$
$\mathbf{Lw}' \ \rr{Lwp}$	$\boxed{\Uparrow} \ \rrh{Lwp}$	$\mathbf{Lw}' \ \boxed{\Uparrow} \ \text{\textRubik{Lwp}}$
$\mathbf{Ls} \ \rr{Ls}$	$\boxed{\Downarrow} \ \rrh{Ls}$	$\mathbf{Ls} \ \boxed{\Downarrow} \ \text{\textRubik{Ls}}$
$\mathbf{Ls}' \ \rr{Lsp}$	$\boxed{\Uparrow} \ \rrh{Lsp}$	$\mathbf{Ls}' \ \boxed{\Uparrow} \ \text{\textRubik{Lsp}}$
$\mathbf{La} \ \rr{La}$	$\boxed{\Downarrow\Uparrow} \ \rrh{La}$	$\mathbf{La} \ \boxed{\Downarrow\Uparrow} \ \text{\textRubik{La}}$
$\mathbf{La}' \ \rr{Lap}$	$\boxed{\Uparrow\Downarrow} \ \rrh{Lap}$	$\mathbf{La}' \ \boxed{\Uparrow\Downarrow} \ \text{\textRubik{Lap}}$
$\mathbf{Lm} \ \rr{Lm}$	$\boxed{\Downarrow} \ \rrh{Lm}$	$\mathbf{Lm} \ \boxed{\Downarrow} \ \text{\textRubik{Lm}}$
$\mathbf{Lm}' \ \rr{Lmp}$	$\boxed{\Uparrow} \ \rrh{Lmp}$	$\mathbf{Lm}' \ \boxed{\Uparrow} \ \text{\textRubik{Lmp}}$
$\mathbf{Lc} \ \rr{Lc}$	$[\mathbf{Lc}] \ \rrh{Lc}$	$[\mathbf{Lc}] \ \text{\textRubik{Lc}}$
$\mathbf{Lc}' \ \rr{Lcp}$	$[\mathbf{Lc}'] \ \rrh{Lcp}$	$[\mathbf{Lc}'] \ \text{\textRubik{Lcp}}$
$\mathbf{R} \ \rr{R}$	$\boxed{\Uparrow} \ \rrh{R}$	$\mathbf{R} \ \boxed{\Uparrow} \ \text{\textRubik{R}}$
$\mathbf{R}' \ \rr{Rp}$	$\boxed{\Downarrow} \ \rrh{Rp}$	$\mathbf{R}' \ \boxed{\Downarrow} \ \text{\textRubik{Rp}}$
$\mathbf{Rw} \ \rr{Rw}$	$\boxed{\Uparrow} \ \rrh{Rw}$	$\mathbf{Rw} \ \boxed{\Uparrow} \ \text{\textRubik{Rw}}$
$\mathbf{Rw}' \ \rr{Rwp}$	$\boxed{\Downarrow} \ \rrh{Rwp}$	$\mathbf{Rw}' \ \boxed{\Downarrow} \ \text{\textRubik{Rwp}}$
$\mathbf{Rs} \ \rr{Rs}$	$\boxed{\Uparrow} \ \rrh{Rs}$	$\mathbf{Rs} \ \boxed{\Uparrow} \ \text{\textRubik{Rs}}$
$\mathbf{Rs}' \ \rr{Rsp}$	$\boxed{\Downarrow} \ \rrh{Rsp}$	$\mathbf{Rs}' \ \boxed{\Downarrow} \ \text{\textRubik{Rsp}}$

$\mathbf{Ra} \ \rr{Ra}$	$\boxed{\downarrow\uparrow} \ \rrh{Ra}$	$\mathbf{Ra} \ \boxed{\downarrow\uparrow} \ \text{\textRubik{Ra}}$
$\mathbf{Ra}' \ \rr{Rap}$	$\boxed{\uparrow\downarrow} \ \rrh{Rap}$	$\mathbf{Ra}' \ \boxed{\uparrow\downarrow} \ \text{\textRubik{Rap}}$
$\mathbf{Rm} \ \rr{Rm}$	$\boxed{\uparrow\uparrow} \ \rrh{Rm}$	$\mathbf{Rm} \ \boxed{\uparrow\uparrow} \ \text{\textRubik{Rm}}$
$\mathbf{Rm}' \ \rr{Rmp}$	$\boxed{\downarrow\downarrow} \ \rrh{Rmp}$	$\mathbf{Rm}' \ \boxed{\downarrow\downarrow} \ \text{\textRubik{Rmp}}$
$\mathbf{Rc} \ \rr{Rc}$	$\boxed{\mathbf{Rc}} \ \rrh{Rc}$	$\boxed{\mathbf{Rc}} \ \text{\textRubik{Rc}}$
$\mathbf{Rc}' \ \rr{Rcp}$	$\boxed{\mathbf{Rc}'} \ \rrh{Rcp}$	$\boxed{\mathbf{Rc}'} \ \text{\textRubik{Rcp}}$
$\mathbf{F} \ \rr{F}$	$\boxed{\curvearrowright} \ \rrh{F}$	$\mathbf{F} \ \boxed{\curvearrowright} \ \text{\textRubik{F}}$
$\mathbf{F}' \ \rr{Fp}$	$\boxed{\curvearrowleft} \ \rrh{Fp}$	$\mathbf{F}' \ \boxed{\curvearrowleft} \ \text{\textRubik{Fp}}$
$\mathbf{Fw} \ \rr{Fw}$	$\boxed{\curvearrowright\circ} \ \rrh{Fw}$	$\mathbf{Fw} \ \boxed{\curvearrowright\circ} \ \text{\textRubik{Fw}}$
$\mathbf{Fw}' \ \rr{Fwp}$	$\boxed{\curvearrowleft\circ} \ \rrh{Fwp}$	$\mathbf{Fw}' \ \boxed{\curvearrowleft\circ} \ \text{\textRubik{Fwp}}$
$\mathbf{Fs} \ \rr{Fs}$	$\boxed{\mathbf{Fs}} \ \rrh{Fs}$	$\boxed{\mathbf{Fs}} \ \text{\textRubik{Fs}}$
$\mathbf{Fs}' \ \rr{Fsp}$	$\boxed{\mathbf{Fs}'} \ \rrh{Fsp}$	$\boxed{\mathbf{Fs}'} \ \text{\textRubik{Fsp}}$
$\mathbf{Fa} \ \rr{Fa}$	$\boxed{\mathbf{Fa}} \ \rrh{Fa}$	$\boxed{\mathbf{Fa}} \ \text{\textRubik{Fa}}$
$\mathbf{Fa}' \ \rr{Fap}$	$\boxed{\mathbf{Fa}'} \ \rrh{Fap}$	$\boxed{\mathbf{Fa}'} \ \text{\textRubik{Fap}}$
$\mathbf{Fm} \ \rr{Fm}$	$\boxed{\mathbf{Fm}} \ \rrh{Fm}$	$\boxed{\mathbf{Fm}} \ \text{\textRubik{Fm}}$
$\mathbf{Fm}' \ \rr{Fmp}$	$\boxed{\mathbf{Fm}'} \ \rrh{Fmp}$	$\boxed{\mathbf{Fm}'} \ \text{\textRubik{Fmp}}$
$\mathbf{Fc} \ \rr{Fc}$	$\boxed{\mathbf{Fc}} \ \rrh{Fc}$	$\boxed{\mathbf{Fc}} \ \text{\textRubik{Fc}}$
$\mathbf{Fc}' \ \rr{Fcp}$	$\boxed{\mathbf{Fc}'} \ \rrh{Fcp}$	$\boxed{\mathbf{Fc}'} \ \text{\textRubik{Fcp}}$
$\mathbf{B} \ \rr{B}$	$\boxed{\mathbf{B}} \ \rrh{B}$	$\boxed{\mathbf{B}} \ \text{\textRubik{B}}$
$\mathbf{B}' \ \rr{Bp}$	$\boxed{\mathbf{B}'} \ \rrh{Bp}$	$\boxed{\mathbf{B}'} \ \text{\textRubik{Bp}}$
$\mathbf{Bw} \ \rr{Bw}$	$\boxed{\mathbf{Bw}} \ \rrh{Bw}$	$\boxed{\mathbf{Bw}} \ \text{\textRubik{Bw}}$
$\mathbf{Bw}' \ \rr{Bwp}$	$\boxed{\mathbf{Bw}'} \ \rrh{Bwp}$	$\boxed{\mathbf{Bw}'} \ \text{\textRubik{Bwp}}$
$\mathbf{Bs} \ \rr{Bs}$	$\boxed{\mathbf{Bs}} \ \rrh{Bs}$	$\boxed{\mathbf{Bs}} \ \text{\textRubik{Bs}}$
$\mathbf{Bs}' \ \rr{Bsp}$	$\boxed{\mathbf{Bs}'} \ \rrh{Bsp}$	$\boxed{\mathbf{Bs}'} \ \text{\textRubik{Bsp}}$































$\mathbf{Ba} \rrr{\mathbf{Ba}}$	$\boxed{\mathbf{Ba}} \rrrh{\mathbf{Ba}}$	$\boxed{\mathbf{Ba}} \text{\textRubik}\{\mathbf{Ba}\}$
$\mathbf{Ba}' \rrr{\mathbf{Bap}}$	$\boxed{\mathbf{Ba}'} \rrrh{\mathbf{Bap}}$	$\boxed{\mathbf{Ba}'} \text{\textRubik}\{\mathbf{Bap}\}$
$\mathbf{Bm} \rrr{\mathbf{Bm}}$	$\boxed{\mathbf{Bm}} \rrrh{\mathbf{Bm}}$	$\boxed{\mathbf{Bm}} \text{\textRubik}\{\mathbf{Bm}\}$
$\mathbf{Bm}' \rrr{\mathbf{Bmp}}$	$\boxed{\mathbf{Bm}'} \rrrh{\mathbf{Bmp}}$	$\boxed{\mathbf{Bm}'} \text{\textRubik}\{\mathbf{Bmp}\}$
$\mathbf{Bc} \rrr{\mathbf{Bc}}$	$[\mathbf{Bc}] \rrrh{\mathbf{Bc}}$	$[\mathbf{Bc}] \text{\textRubik}\{\mathbf{Bc}\}$
$\mathbf{Bc}' \rrr{\mathbf{Bcp}}$	$[\mathbf{Bc}'] \rrrh{\mathbf{Bcp}}$	$[\mathbf{Bc}'] \text{\textRubik}\{\mathbf{Bcp}\}$
$\mathbf{Su} \rrr{\mathbf{Su}}$	$\boxed{\Leftarrow} \rrrh{\mathbf{Su}}$	$\mathbf{Su} \boxed{\Leftarrow} \text{\textRubik}\{\mathbf{Su}\}$
$\mathbf{Su}' \rrr{\mathbf{Sup}}$	$\boxed{\Rightarrow} \rrrh{\mathbf{Sup}}$	$\mathbf{Su}' \boxed{\Rightarrow} \text{\textRubik}\{\mathbf{Sup}\}$
$\mathbf{Sd} \rrr{\mathbf{Sd}}$	$\boxed{\Rightarrow} \rrrh{\mathbf{Sd}}$	$\mathbf{Sd} \boxed{\Rightarrow} \text{\textRubik}\{\mathbf{Sd}\}$
$\mathbf{Sd}' \rrr{\mathbf{Sdp}}$	$\boxed{\Leftarrow} \rrrh{\mathbf{Sdp}}$	$\mathbf{Sd}' \boxed{\Leftarrow} \text{\textRubik}\{\mathbf{Sdp}\}$
$\mathbf{Sl} \rrr{\mathbf{Sl}}$	$\boxed{\Downarrow} \rrrh{\mathbf{Sl}}$	$\mathbf{Sl} \boxed{\Downarrow} \text{\textRubik}\{\mathbf{Sl}\}$
$\mathbf{Sl}' \rrr{\mathbf{Slp}}$	$\boxed{\Uparrow} \rrrh{\mathbf{Slp}}$	$\mathbf{Sl}' \boxed{\Uparrow} \text{\textRubik}\{\mathbf{Slp}\}$
$\mathbf{Sr} \rrr{\mathbf{Sr}}$	$\boxed{\Uparrow} \rrrh{\mathbf{Sr}}$	$\mathbf{Sr} \boxed{\Uparrow} \text{\textRubik}\{\mathbf{Sr}\}$
$\mathbf{Sr}' \rrr{\mathbf{Srp}}$	$\boxed{\Downarrow} \rrrh{\mathbf{Srp}}$	$\mathbf{Sr}' \boxed{\Downarrow} \text{\textRubik}\{\mathbf{Srp}\}$
$\mathbf{Sf} \rrr{\mathbf{Sf}}$	$\boxed{\mathbf{Sf}} \rrrh{\mathbf{Sf}}$	$\boxed{\mathbf{Sf}} \text{\textRubik}\{\mathbf{Sf}\}$
$\mathbf{Sf}' \rrr{\mathbf{Sfp}}$	$\boxed{\mathbf{Sf}'} \rrrh{\mathbf{Sfp}}$	$\boxed{\mathbf{Sf}'} \text{\textRubik}\{\mathbf{Sfp}\}$
$\mathbf{Sb} \rrr{\mathbf{Sb}}$	$\boxed{\mathbf{Sb}} \rrrh{\mathbf{Sb}}$	$\boxed{\mathbf{Sb}} \text{\textRubik}\{\mathbf{Sb}\}$
$\mathbf{Sb}' \rrr{\mathbf{Sbp}}$	$\boxed{\mathbf{Sb}'} \rrrh{\mathbf{Sbp}}$	$\boxed{\mathbf{Sb}'} \text{\textRubik}\{\mathbf{Sbp}\}$
$\mathbf{E} \rrr{\mathbf{E}}$	$\boxed{\Rightarrow} \rrrh{\mathbf{E}}$	$\mathbf{E} \boxed{\Rightarrow} \text{\textRubik}\{\mathbf{E}\}$
$\mathbf{E}' \rrr{\mathbf{Ep}}$	$\boxed{\Leftarrow} \rrrh{\mathbf{Ep}}$	$\mathbf{E}' \boxed{\Leftarrow} \text{\textRubik}\{\mathbf{Ep}\}$
$\mathbf{M} \rrr{\mathbf{M}}$	$\boxed{\Downarrow} \rrrh{\mathbf{M}}$	$\mathbf{M} \boxed{\Downarrow} \text{\textRubik}\{\mathbf{M}\}$
$\mathbf{M}' \rrr{\mathbf{Mp}}$	$\boxed{\Uparrow} \rrrh{\mathbf{Mp}}$	$\mathbf{M}' \boxed{\Uparrow} \text{\textRubik}\{\mathbf{Mp}\}$
$\mathbf{S} \rrr{\mathbf{S}}$	$\boxed{\mathbf{S}} \rrrh{\mathbf{S}}$	$\boxed{\mathbf{S}} \text{\textRubik}\{\mathbf{S}\}$
$\mathbf{S}' \rrr{\mathbf{Sp}}$	$\boxed{\mathbf{S}'} \rrrh{\mathbf{Sp}}$	$\boxed{\mathbf{S}'} \text{\textRubik}\{\mathbf{Sp}\}$

\mathbf{x} \rr{x}	$[\mathbf{x}]$ \rrh{x}	$[\mathbf{x}]$ \Rubik{x}
\mathbf{x}' \rr{xp}	$[\mathbf{x}']$ \rrh{xp}	$[\mathbf{x}']$ \Rubik{xp}
\mathbf{y} \rr{y}	$[\mathbf{y}]$ \rrh{y}	$[\mathbf{y}]$ \Rubik{y}
\mathbf{y}' \rr{yp}	$[\mathbf{y}']$ \rrh{yp}	$[\mathbf{y}']$ \Rubik{yp}
\mathbf{z} \rr{z}	$[\mathbf{z}]$ \rrh{z}	$[\mathbf{z}]$ \Rubik{z}
\mathbf{z}' \rr{zp}	$[\mathbf{z}']$ \rrh{zp}	$[\mathbf{z}']$ \Rubik{zp}
\mathbf{u} \rr{u}	$[\mathbf{u}]$ \rrh{u}	$[\mathbf{u}]$ \Rubik{u}
\mathbf{d} \rr{d}	$[\mathbf{d}]$ \rrh{d}	$[\mathbf{d}]$ \Rubik{d}
\mathbf{l} \rr{l}	$[\mathbf{l}]$ \rrh{l}	$[\mathbf{l}]$ \Rubik{l}
\mathbf{r} \rr{r}	$[\mathbf{r}]$ \rrh{r}	$[\mathbf{r}]$ \Rubik{r}
\mathbf{f} \rr{f}	$[\mathbf{f}]$ \rrh{f}	$[\mathbf{f}]$ \Rubik{f}
\mathbf{b} \rr{b}	$[\mathbf{b}]$ \rrh{b}	$[\mathbf{b}]$ \Rubik{b}

8.9.1 Randelshofer notation

\mathbf{CR} \rr{CR}	$[\mathbf{CR}]$ \rrh{CR}	$[\mathbf{CR}]$ \Rubik{CR}
\mathbf{CR}' \rr{CRp}	$[\mathbf{CR}']$ \rrh{CRp}	$[\mathbf{CR}']$ \Rubik{CRp}
\mathbf{CL} \rr{CL}	$[\mathbf{CL}]$ \rrh{CL}	$[\mathbf{CL}]$ \Rubik{CL}
\mathbf{CL}' \rr{CLp}	$[\mathbf{CL}']$ \rrh{CLp}	$[\mathbf{CL}']$ \Rubik{CLp}
\mathbf{CU} \rr{CU}	$[\mathbf{CU}]$ \rrh{CU}	$[\mathbf{CU}]$ \Rubik{CU}
\mathbf{CU}' \rr{CUp}	$[\mathbf{CU}']$ \rrh{CUp}	$[\mathbf{CU}']$ \Rubik{CUp}
\mathbf{CD} \rr{CD}	$[\mathbf{CD}]$ \rrh{CD}	$[\mathbf{CD}]$ \Rubik{CD}
\mathbf{CD}' \rr{CDp}	$[\mathbf{CD}']$ \rrh{CDp}	$[\mathbf{CD}']$ \Rubik{CDp}
\mathbf{CF} \rr{CF}	$[\mathbf{CF}]$ \rrh{CF}	$[\mathbf{CF}]$ \Rubik{CF}
\mathbf{CF}' \rr{CFp}	$[\mathbf{CF}']$ \rrh{CFp}	$[\mathbf{CF}']$ \Rubik{CFp}

CB $\backslash rr\{CB\}$	[CB] $\backslash rrrh\{CB\}$	[CB] $\backslash Rubik\{CB\}$
CB' $\backslash rr\{CBp\}$	[CB'] $\backslash rrrh\{CBp\}$	[CB'] $\backslash Rubik\{CBp\}$
MR $\backslash rr\{MR\}$	[↑↑] $\backslash rrrh\{MR\}$	MR [↑↑] $\backslash textRubik\{MR\}$
MR' $\backslash rr\{MRp\}$	[↓↓] $\backslash rrrh\{MRp\}$	MR' [↓↓] $\backslash textRubik\{MRp\}$
ML $\backslash rr\{ML\}$	[↓↓] $\backslash rrrh\{ML\}$	ML [↓↓] $\backslash textRubik\{ML\}$
ML' $\backslash rr\{MLp\}$	[↑↑] $\backslash rrrh\{MLp\}$	ML' [↑↑] $\backslash textRubik\{MLp\}$
MU $\backslash rr\{MU\}$	[⇐] $\backslash rrrh\{MU\}$	MU [⇐] $\backslash textRubik\{MU\}$
MU' $\backslash rr\{MUp\}$	[⇒] $\backslash rrrh\{MUp\}$	MU' [⇒] $\backslash textRubik\{MUp\}$
MD $\backslash rr\{MD\}$	[⇒] $\backslash rrrh\{MD\}$	MD [⇒] $\backslash textRubik\{MD\}$
MD' $\backslash rr\{MDp\}$	[⇐] $\backslash rrrh\{MDp\}$	MD' [⇐] $\backslash textRubik\{MDp\}$
MF $\backslash rr\{MF\}$	[MF] $\backslash rrrh\{MF\}$	[MF] $\backslash textRubik\{MF\}$
MF' $\backslash rr\{MFp\}$	[MF'] $\backslash rrrh\{MFp\}$	[MF'] $\backslash textRubik\{MFp\}$
MB $\backslash rr\{MB\}$	[MB] $\backslash rrrh\{MB\}$	[MB] $\backslash textRubik\{MB\}$
MB' $\backslash rr\{MBp\}$	[MB'] $\backslash rrrh\{MBp\}$	[MB'] $\backslash textRubik\{MBp\}$
SR $\backslash rr\{SR\}$	[↑↑] $\backslash rrrh\{SR\}$	SR [↑↑] $\backslash textRubik\{SR\}$
SR' $\backslash rr\{SRp\}$	[↓↓] $\backslash rrrh\{SRp\}$	SR' [↓↓] $\backslash textRubik\{SRp\}$
SL $\backslash rr\{SL\}$	[↓↓] $\backslash rrrh\{SL\}$	SL [↓↓] $\backslash textRubik\{SL\}$
SL' $\backslash rr\{SLp\}$	[↑↑] $\backslash rrrh\{SLp\}$	SL' [↑↑] $\backslash textRubik\{SLp\}$
SU $\backslash rr\{SU\}$	[⇐] $\backslash rrrh\{SU\}$	SU [⇐] $\backslash textRubik\{SU\}$
SU' $\backslash rr\{SUp\}$	[⇒] $\backslash rrrh\{SUp\}$	SU' [⇒] $\backslash textRubik\{SUp\}$
SD $\backslash rr\{SD\}$	[⇒] $\backslash rrrh\{SD\}$	SD [⇒] $\backslash textRubik\{SD\}$
SD' $\backslash rr\{SDp\}$	[⇐] $\backslash rrrh\{SDp\}$	SD' [⇐] $\backslash textRubik\{SDp\}$
SF $\backslash rr\{SF\}$	[SF] $\backslash rrrh\{SF\}$	[SF] $\backslash textRubik\{SF\}$

SF' \rr{SFp}	 \rrh{SFp}	 \textRubik{SFp}
SB \rr{SB}	 \rrh{SB}	 \textRubik{SB}
SB' \rr{SBp}	 \rrh{SBp}	 \textRubik{SBp}
TR \rr{TR}	 \rrh{TR}	TR  \textRubik{TR}
TR' \rr{TRp}	 \rrh{TRp}	TR'  \textRubik{TRp}
TL \rr{TL}	 \rrh{TL}	TL  \textRubik{TL}
TL' \rr{TLp}	 \rrh{TLp}	TL'  \textRubik{TLp}
TU \rr{TU}	 \rrh{TU}	TU  \textRubik{TU}
TU' \rr{TUp}	 \rrh{TUp}	TU'  \textRubik{TUp}
TD \rr{TD}	 \rrh{TD}	TD  \textRubik{TD}
TD' \rr{TDp}	 \rrh{TDp}	TD'  \textRubik{TDp}
TF \rr{TF}	 \rrh{TF}	TF  \textRubik{TF}
TF' \rr{TFp}	 \rrh{TFp}	TF'  \textRubik{TFp}
TB \rr{TB}	 \rrh{TB}	 \textRubik{TB}
TB' \rr{TBp}	 \rrh{TBp}	 \textRubik{TBp}

8.10 The rubikfont

For hieroglyph-related text we use the standard Computer Modern Sans (cmss) bold extended (bx) 10pt font for upper-case letters, and the 8pt footnote size for lower-case (see Section 19.3 for details). This font (rubikfont) and the ‘prime’ symbol (rubikprime) can be easily changed by ‘renewing’ the three commands there.

For example, to change to the somewhat ‘lighter’ semi-bold extended (sbx) CM Sans (cmss) form one can simply include the following in the preamble (the FNS suffix stands for ‘footnotesize’):

```

\makeatletter
\renewcommand{\@rubikfont}{\fontsize{10}{12pt}\usefont{T1}{cmss}{sbx}{n}}
\renewcommand{\@rubikfontFNS}{\fontsize{8}{12pt}\usefont{T1}{cmss}{sbx}{n}}
\makeatother

```

The ‘rubikprime’ symbol

We currently use the apostrophe for the prime symbol (see Section 19.3), since the maths `\prime` seems to be a bit too faint (especially since we need to use the ‘scriptstyle’ size in this setting). However, users can easily make the Rubik bundle use the maths prime instead, by loading the following in the preamble.

```
\makeatletter
\renewcommand{\@rubikprime}{\raisebox{1.2pt}{\ensuremath{\scriptstyle{\prime}}}}
\makeatother
```

9 Draw commands

A `\Draw..` command typesets either a Rubik cube, cubie or a face or layer using parameters set or defined via previous parameter-allocation commands (e.g., face colours, dimensions etc). Note that those `\Draw..` commands which do take colours as arguments do not update the cube’s internal ‘colour state’, but simply ‘paint’ these colours.

It is important to distinguish between the RUBIKCUBE package `\Draw..` commands and TikZ `\draw..` commands. `\Draw..` commands are implemented by the TikZ `\draw..` commands, and consequently `\Draw..` commands can only be used *inside* a TikZ picture environment—and hence they can also be used safely in conjunction with the `\ShowCube` command, which itself uses a TikZ picture environment. See also Section 9.1 below.

9.1 \Draw error message

If a `\Draw..` command is used *outside* a TikZ picture environment, then L^AT_EX issues an “Undefined control sequence” error message, indicating that it is trying to draw something using an undefined TikZ `\draw` command⁵.

This is because all Rubik `\Draw..` commands achieve their effects by implementing a series of TikZ `\draw..` and other commands, all of which need to be inside a `tikzpicture` environment.

For example, if the command `\DrawRubikCubeF` is used without a surrounding TikZ picture environment, then something similar to the following error message will be generated.

```
! Undefined control sequence.
\DrawFlatUp ... }{#1}\pgfmathsetmacro {\uy }{#2}\draw
                                                    [line join=round,...
1.56 \DrawRubikCubeF
```

9.2 DrawRubikCube commands

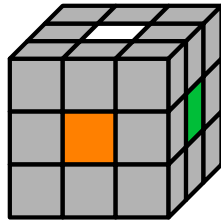
`\DrawRubikCubeXY` This command draws Rubik cubes in one of four oblique orientations or con-
`\DrawRubikCubeF`
`\DrawRubikCubeSF`

⁵Note that the TikZ `\draw` command uses a lower-case ‘d’, while all RUBIKCUBE commands start with an upper-case letter.

figurations as denoted by the following terminal XY viewing-direction codes: RU (RightUp), RD (RightDown), LU (LeftUp), LD (LeftDown); two additional terminal codes are F (Flat) and SF (Semi-Flat). For example, the command

```
\DrawRubikCubeRU
```

will draw a Rubik cube as viewed from the RightUp direction (RU), as shown in the following figure.



```
\RubikCubeSolved
\begin{tikzpicture}[scale=0.7]
\DrawRubikCubeRU
\end{tikzpicture}%
```

Note that the above commands are equivalent to:

```
\RubikCubeSolved
\ShowCube{3cm}{0.7}{\DrawRubikCubeRU}
```

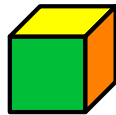
`\DrawCubieXYxyz`

This command draws a single cubie in one of four orientations as denoted by the terminal XY viewing-direction codes. Since a single cubie has only three visible faces we can include colour parameters in `\DrawCubie` commands. Consequently `\DrawCubie` commands have the format

```
\DrawCubieXY{x}{y}{z}
```

where the XY pair denotes the viewing direction as before, and the xyz parameters denote the face colours associated with each of the three axes.

For example, the command `\DrawCubieRU{O}{Y}{G}` draws a single cubie as viewed from the RightUp direction, with face colours Orange (x-axis), Yellow (y-axis), Green (z-axis), as follows.



```
\ShowCube{1.33cm}{1}{\DrawCubieRU{O}{Y}{G}}
```

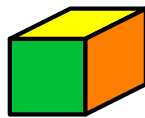
Since the front face is 1 unit wide and the 2D width of the side approx 1/3 unit, and the scale-factor = 1, then the minipage width required for the cubie image = $(1.33 \times 1) = 1.33\text{cm}$.

`\Cubiedy`
`\Cubiedx`

Minor cubie configuration changes can be effected by adjusting the dy and dx values (> 0 ; no units) shown in Figure 3 via the two commands

```
\Cubiedy{}
\Cubiedx{}
```

as shown in the following example.



```
\ShowCube{1.7cm}{1}{%
\Cubiedy{0.4}
\Cubiedx{0.8}
\DrawCubieRU{O}{Y}{G}
}
```

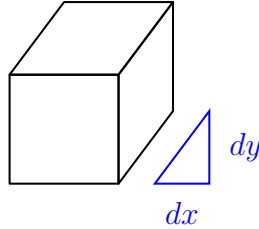


Figure 3: Cubie dy dx parameters

Note that the FRONT face of the cubie is a unit square, and the graphic origin of the cubie image is at the bottom left corner of the FRONT face (see also the section on Arrows: Section 12). The default values of dy and dx are 0.4.

`\textCubieRU`
`\textCubieRD`
`\textCubieLU`
`\textCubieLD`

For convenience, there are also four (smaller) ‘text’ versions of the four `\DrawCubie` commands for use in ordinary text, as follows:



`\textCubieRU{0}{Y}{G}`



`\textCubieRD{0}{Y}{G}`



`\textCubieLU{0}{Y}{G}`



`\textCubieLD{0}{Y}{G}`

Note that these `\textCubieXY` commands are not influenced by the `\Cubiedy`, `\Cubiedx` commands as their size is pre-set for text use.

9.3 Flat commands

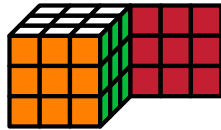
`\DrawFlatUp`
`\DrawFlatDown`
`\DrawFlatLeft`
`\DrawFlatRight`
`\DrawFlatFront`
`\DrawFlatBack`

These commands `\DrawFlat..{x}{y}` draw a ‘flat’ (square) representation of the current state of a specified face such that its bottom left corner is positioned at (x, y) . They are designed to supplement the `\DrawRubikCube...` commands and allow hidden faces to be represented. Each command (except `\DrawFlatFront`) takes two arguments, namely the X-coordinate and Y-coordinate of the bottom left corner of the face. This (x,y) pair allows the user to position the face.

Note that the Y-argument set for the `\DrawFlatLeft` and `\DrawFlatRight` commands is not currently actioned (see Section 19.15). This is because both the LEFT and RIGHT faces, as used by the `\DrawRubikCubeSF` (Semi-Flat) command which incorporates the RU view, require only $Y=0$. It is anticipated that this (x,y) facility will be fully extended to the left and right forms in a later version.

Note also that the `\DrawFlatFront` command currently takes *no* arguments, since by definition the bottom left corner of this face is always at (0,0), and there seems to be no reason (just now) for this face to have the (x,y) facility.

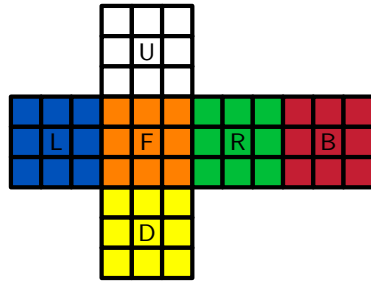
USAGE: In the following example we use the command `\DrawFlatBack{4}{1}` to append the BACK face to the side of a 3D cube. Note that since the coordinates of the bottom/back/right corner of the cube rendered by the command `\DrawRubikCubeRU` is (4,1) (see Section 4), we can position the lower/left corner of the BACK face at this point using the command `\DrawFlatBack{4}{1}` as follows:



```
\RubikCubeSolved
\ShowCube{3cm}{0.4}{%
  \DrawRubikCubeRU
  \DrawFlatBack{4}{1}
}
```

`\DrawRubikCubeF`

This command draws the completely flat (F) format of the cube, as shown in the following example.



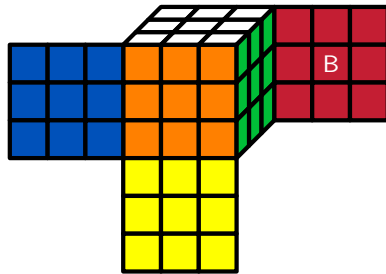
```
\RubikCubeSolved
\ShowCube{5cm}{0.4}{\DrawRubikCubeF}
```

The addition of text (numbers or letters) in the faces is straightforward—the origin of the 1-unit grid is located at the bottom left corner of the FRONT face (orange here). The letters were placed using the following TikZ code inside the TikZ picture environment.

```
\RubikCubeSolved
\ShowCube{5cm}{0.4}{%
  \DrawRubikCubeF
  \node (U) at (1.5, 4.5) [black]{\small\textsf{U}};
  \node (D) at (1.5, -1.5) [black]{\small\textsf{D}};
  \node (L) at (-1.5, 1.5) [black]{\small\textsf{L}};
  \node (R) at (4.5, 1.5) [black]{\small\textsf{R}};
  \node (F) at (1.5, 1.5) [black]{\small\textsf{F}};
  \node (B) at (7.5, 1.5) [black]{\small\textsf{B}};
}
```

`\DrawRubikCubeSF`

A useful ‘semi-flat’ (SF) alternative format, which uses the standard RU view of the cube and appends the three hidden sides (cf., Rokicki *et al.*, 2013), is generated by the command `\DrawRubikCubeSF` as follows.



```

\RubikCubeSolved
\ShowCube{5cm}{0.5}{%
  \DrawRubikCubeSF
  \node (B) at (5.5, 2.5)
    [white]{\small\texsf{B}};
}

```

Note that even in this configuration it is straight-forward to write text on the graphic, since the 2D width (on the page) of the green RIGHT face is exactly 1-unit, and the bottom right-hand corner of the green face is raised exactly 1-unit (see Figure 1). Consequently, since the origin of the coordinate-grid is at the bottom left corner of the FRONT face (the orange face here), the coordinates of the centre of the red BACK face are easily determined to be (5.5, 2.5).

9.4 Face commands

```

\DrawFaceUp
\DrawFaceDown
\DrawFaceLeft
\DrawFaceRight
\DrawFaceFront
\DrawFaceBack

```

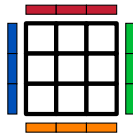
These commands draw the current state of a specified face (e.g., `\DrawFaceUp`), or the face and all the associated side-bars (e.g., `\DrawFaceUpSide`). NOTE: these commands do NOT take any arguments—for code see Section 19.16.

In the following example we use the `\DrawFlatUpSide` command to draw the UP face and all its side-bars of a cube having a ‘solved’ configuration.

```

\DrawFaceUpSide
\DrawFaceDownSide
\DrawFaceLeftSide
\DrawFaceRightSide
\DrawFaceFrontSide
\DrawFaceBackSide

```



```

\RubikCubeSolved
\ShowCube{1.6cm}{0.4}{%
  \DrawFaceUpSide
}

```

9.5 NCube (NxNxN)

```

\DrawNCubeAll

```

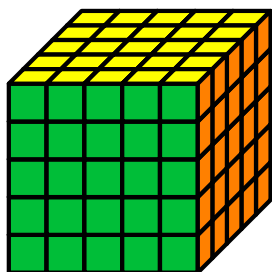
An ‘NCube’ is a solved $N \times N \times N$ cube drawn from the RU direction; (i.e., only shows faces UP, FRONT, RIGHT). The cubie colours of each face are All the same.

```

\DrawNCubeAll{N}{Xcolour}{Ycolour}{Zcolour}.

```

This command takes four ordered parameters (N , X , Y , Z)—the number (integer; $N > 0$) of cubies along an edge, followed by three face colours in XYZ order. Since the viewpoint is only from the RU direction, the three colour parameters are: X(Right), Y(Up), Z(Front).



```
\ShowCube{3.5cm}{0.5}{\DrawNCubeAll{5}{0}{Y}{G}}
```

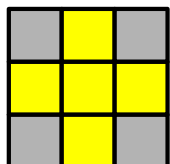
9.6 LayerFace

While a cube has faces and layers, a layer has a face (the face you are looking at or drawing) and four sides (consisting of the nine side facelets of the associated cubies). The two ‘Layer’ commands described here are intended for drawing final layer configurations from ‘scratch’ without any prior configuration information.

Typically, we might wish to show the yellow face in the UP position, with or without the associated side faces of the cubies of this layer. Of course, if we already know the rotation history from some initial configuration, it would be much simpler just to invoke the `\RubikRotation` command and then use the `\DrawFlatUpSide` command (see Section 9.3).

These two LayerFace commands draw a simple 3x3 face and allocate colours to the 9 facelets. The `\DrawRubikLayerFace` command takes nine ordered colour arguments. The command is illustrated in the following example, which shows a yellow cross configuration.

```
\DrawRubikLayerFace
\DrawRubikLayerFaceAll
```



```
\ShowCube{2.1cm}{0.7}{%
\DrawRubikLayerFace{X}{Y}{X}
{Y}{Y}{Y}
{X}{Y}{X}
}
```

The `\DrawRubikLayerFaceAll` command takes a single colour argument, and paints the whole face the same colour.

9.7 LayerSide (sidebars)

```
\DrawRubikLayerSideXYp
```

LayerSide commands draw the associated side colours of the layer as small rectangular sidebars. The LayerSide command adopts a three-letter XYp **position** notation where the XY pair define the location (X:[Left | Middle | Right]; Y:[Top | Middle | Bottom]) of a particular cubie in the layer face, as depicted in Figure 4.

Since corner cubies have two side faces, the ‘p’ parameter (p:[x|y]) is required to denote the directional ‘position’ of the cubie side-face relative to the cubie XY position (x indicates adjacent along the x-axis, and y indicates adjacent along the y-axis). Since edge cubies have only one side face, the ‘p’ parameter is optional (for consistency), since it is not strictly necessary.

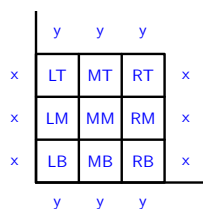



Figure 4: LayerSide rotation-codes

Commands: Various different LayerSide commands are available: those for drawing a single colour side bar, and others for facilitating drawing all 12 side bars. For example, *either* of the following commands

```
\DrawRubikLayerSideLM{G}
\DrawRubikLayerSideLMx{G}
```

draws a single small vertical green rectangle  just to the left of the Left Middle (LM) square of the 9-face. The following commands draw all three side bars of a given side (Top, Bottom, Left, Right)

```
\DrawRubikLayerSideT{}{}{}
\DrawRubikLayerSideB{}{}{}
\DrawRubikLayerSideL{}{}{}
\DrawRubikLayerSideR{}{}{}

```

where the T and B forms require the colour parameters to be in left-right horizontal order (e.g., left, middle, right), while the L and R forms require the colour parameters to be in top-down vertical order (e.g., top, middle, bottom). Note that this means that the colour parameters of the L and R commands can (if required) then be positioned intuitively (vertically) as follows:

```
\DrawRubikLayerSideL{}
{}
{}

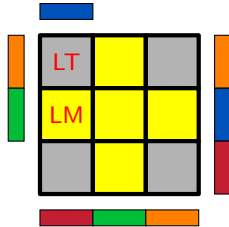
```

Extending this idea, the L and R forms are combined in the LR command, which takes six colour arguments ordered in left-right pairs,

```
\DrawRubikLayerSideLR{}{} {}{} {}{}

```

so that they can also be written vertically as left-right pairs. Use of these commands is shown in the following two examples.



```

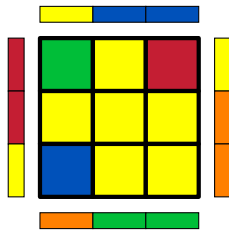
\ShowCube{3cm}{0.7}{%
  \DrawRubikLayerFace{X}{Y}{X}
    {Y}{Y}{Y}
    {X}{Y}{X}

  \DrawRubikLayerSideLTy{B}
  \DrawRubikLayerSideLTx{O}
  \DrawRubikLayerSideLM{G}

  \DrawRubikLayerSideR{O}{B}{R}
  \DrawRubikLayerSideB{R}{G}{O}

  \node (LT) at (0.5, 2.5) [red]{\small\textsf{LT}};
  \node (LM) at (0.5, 1.5) [red]{\small\textsf{LM}};
}

```



```

\ShowCube{3cm}{0.7}{%
  \DrawRubikLayerFace{G}{Y}{R}
    {Y}{Y}{Y}
    {B}{Y}{Y}

  \DrawRubikLayerSideT {Y}{B}{B}
  \DrawRubikLayerSideLR{R} {Y}
    {R} {O}
    {Y} {O}

  \DrawRubikLayerSideB {O}{G}{G}
}

```

`\DrawFaceUpSide`

IMPORTANT NOTE: If the colour configuration of the layer shown above is already known to the system (i.e., it has been specified before, and (possibly) been manipulated using the `\RubikRotation` command from RUBIKROTATION package), then the above figure could be drawn much more simply using just the single `\DrawFaceUpSide` command, as described in Section 9.4.

`\RubikSideBarWidth`
`\RubikSideBarLength`
`\RubikSideBarSep`

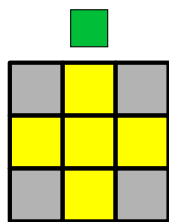
The default values (size) of the sidebars are as follows: width (0.3), length(1) and separation from the square face (0.3). Note that the default value of the length of a cubic side is 1. These sidebar values (decimal values ≥ 0 ; no units) can be changed from their default values using the three commands.

```

\RubikSideBarWidth{ }      (default = 0.3)
\RubikSideBarLength{ }    (default = 1.0)
\RubikSideBarSep{ }       (default = 0.3)

```

Values set in the document preamble will apply globally, while values set within a TikZ picture environment will apply only locally to that particular environment, as shown in the following example where we have set both the sidebar width and length to 0.7 in position MTy using the command `\DrawRubikLayerSideMTy{G}` (for the MTy code see Figure 4).



```

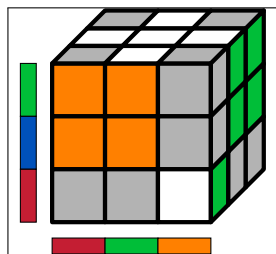
\ShowCube{3cm}{0.7}{%
  \DrawRubikLayerFace{X}{Y}{X}
                        {Y}{Y}{Y}
                        {X}{Y}{X}

  \RubikSideBarWidth{0.7}
  \RubikSideBarLength{0.7}
  \DrawRubikLayerSideMTy{G}
}

```

Note also that changing the sidebar-width or sidebar-separation values may well also change the surrounding white-space (use `\fbox` to visualise this) and may therefore require some fine-tuning of the minipage width setting in order to optimise appearance.

Since the FRONT face drawn using the `\DrawRubikCube` command is identical with that drawn using the `\DrawLayerFace` command it follows that `LayerSide` commands can also be used in conjunction with the FRONT face drawn using `\DrawRubikCube` command. This shown in the following example, where we have used the `\ShowCubeF` command as an exercise (to implement the `fbox`) and reveal the extent of the surrounding white space associated with the minipage width of 3.5cm (= 5×0.7).



```

\RubikFaceUp   {X}{W}{X}%
                {W}{W}{W}%
                {X}{W}{X}%

\RubikFaceFront{O}{O}{X}%
                {O}{O}{X}%
                {X}{X}{W}%

\RubikFaceRight{X}{G}{G}%
                {X}{G}{G}%
                {G}{X}{X}%

\ShowCubeF{3.5cm}{0.7}{%
  \DrawRubikCubeRU
  \DrawRubikLayerSideL{G}{B}{R}
  \DrawRubikLayerSideB{R}{G}{O}
}

```

Since using left and/or right sidebars (e.g., `\DrawRubikLayerSide`) in conjunction with a `\DrawRubikCube` command, will increase the width of the image, one may also have to adjust the width of the associated minipage. Note that the width of a 2D oblique view of the cube is 4 units (= width of 4 cubies). With the default sidebar width and sep settings (see above) one sidebar increases the 2D cube image width by 0.6 units (= $0.3 + 0.3$). Sidebars on both sides increase the width by 1.2 units. Note also that setting both the sidebar width and separation to 0.25 units has the convenience that the 2D width of a cube face + left and right sidebars (e.g., using `\DrawFaceUpSide`) is then exactly 5 units.

10 \ShowSequence command

`\ShowSequence` The `\ShowSequence{<separator>}{<font-code>}{<sequence>}` command typesets a comma-separated sequence of rotation codes—for code see Section 19.5. Appending an ‘F’ to the command-name (`\ShowSequenceF`) results in an fbox about the whole output (cf. the `\ShowCubeF` command). Appending an ‘f’ to the command-name (`\ShowSequencef`) results in an fbox about each element in the output (these two forms can be helpful when checking white space).

The `\ShowSequence` command takes three mandatory arguments: the first is the separator (#1), the second is the font or style code (#2), and third is a comma-separated sequence of Rubik rotation codes (#3).

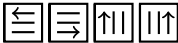
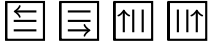




The separator (e.g., comma) used for typesetting the sequence can be specified (or just omitted—i.e., an empty bracket); the sequence can be either a named sequence (i.e., encoded as a macro) or just a comma separated sequence of rotation codes.

USAGE: The following command displays the rotation sequence F, R, U, Rp, Up, using the `\rr` encoding and comma & space separated.

```
\ShowSequence{, \ }{\rr}{F,R,U,Rp,Up} → F, R, U, R', U'
```

Remember that if you want a very long sequence to break automatically at the line-ends, then you need to include at least one space between the sequence elements, either with or without a comma; for this the separator argument needs to include a space, i.e., something like `{, \ }` or `{\ }` or just `{ }` perhaps.

For example, the following commands typeset the comma-separated rotation sequence U,D,Lp,R using different separators and fonts. For convenience, we start by encoding the sequence as the macro `\myseq`.

```
\newcommand{\myseq}{U,D,Lp,R}
\ShowSequence{,}\texttt{\myseq} → U,D,Lp,R
\ShowSequence{,}\rr{\myseq} → U,D,L',R
\ShowSequence{}{\rrh}{\myseq} → 
\ShowSequence{\ }{\rrh}{\myseq} → 
\ShowSequence{, \ }{\textRubik}{\myseq} → U , D , L' , R 
```

Trailing digits

Note that the fonts denoted by `\rr`, `\rrh`, `\Rubik` and `\textRubik` will fail for rotation codes which have a trailing digit, e.g., R2, Dp3 (so-called ‘short’ codes), since the `\ShowSequence` macro currently only reads the whole string between pairs of commas (i.e., it does not interpret each string). However, the typewriter font `\texttt` does work correctly in this case, as you would expect.

An effective ‘work-around’ for this limitation is provided by the `\RubikRotation{}` command⁶ (part of the RUBIKROTATION package), since this returns (via the Perl

⁶Using the `--shell-escape` command-line option with the L^AT_EX engine—see Section 1.2.

program `rubikrotation.pl`) an extended ('long') form of a given sequence in which any 'short' rotation codes are converted into their separate (atomic) long-form rotation codes; the associated string is `\SequenceLong`. In fact three different forms of the sequence are returned, as shown below.

For example, consider the following short-form sequence `L,R,D2,L3`, and denote it as 'seqA' as follows: `\newcommand{\seqA}{[seqA],L,R,D2,L3,<test>}`. In this case `D2,L3`, and the name 'seqA' fail to be typeset when using the `\rr` font with the `\ShowSequence` command as follows:

```
\newcommand{\seqA}{[seqA],L,R,D2,L3,<test>}
\ShowSequence{,}{\texttt}{\seqA} → [seqA],L,R,D2,L3,<test>
\ShowSequence{,}{\rr}{\seqA} → ,L,R,,,
```

However, if we now run the command `\RubikRotation{\seqA}` we shall then have at our disposal the following four strings:

```
\SequenceInfo = test
\SequenceName = seqA
\SequenceShort = L,R,D2,L3
\SequenceLong = L,R,D,D,L,L,L
```

and therefore have full control over typesetting rotation sequences. This approach therefore offers sufficient flexibility for most purposes. For example, if we now write the command `\ShowSequence{,}{\rr}{\SequenceLong}` we obtain

```
\ShowSequence{,}{\rr}{\SequenceLong} → L,R,D,D,L,L,L
```

In practice, any trailing digit is converted (modulo 4) and expanded accordingly, the details being copied to the log-file. For example, if one writes the command `\RubikRotation{[test],R,D28978}`, then since $28978 \equiv 2 \pmod{4}$ then `\SequenceLong` will be returned containing the string `R,D,D`. The associated entries in the log-file are as follows:

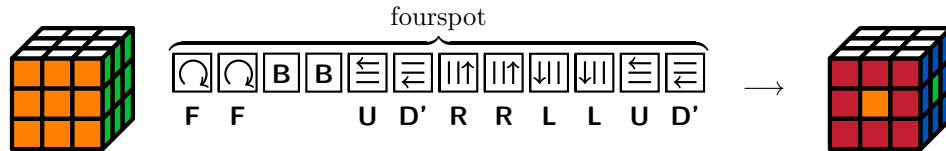
```
...rotation R OK
...Expanding D28978 (28978 = 2 mod 4) ...
...rotation D OK (= Dp3)
...rotation D OK (= Dp3)
...writing new Rubik state to file rubikstateNEW.dat
...SequenceName = test
...SequenceShort = R,D28978
...SequenceLong = R,D,D
```

11 SequenceBrace commands

`\SequenceBraceA` The `\SequenceBraceX{<name>}{<sequence>}` command is a tool for displaying a named sequence using a brace. The trailing A denotes that the brace is placed Above the sequence; the trailing B denotes the brace is Below the sequence. Appending an 'F' to the command-name (e.g., `\SequenceBraceAF`) results in a surrounding fbox (cf. the `\ShowCubeF` command). For the code see Section 19.6.

Thus `\SequenceBraceB{myseq}{U,D,L,R}` generates $\underbrace{U,D,L,R}_{\text{myseq}}$.

A typical example of its use might be:



which was generated by the following code, showing that the `\ShowSequence` command can be used as an argument for the `\SequenceBraceA` command:

```
\newcommand{\fourspot}{[fourspot],F2,B2,U,Dp,R2,L2,U,Dp}%
\noindent%
\RubikCubeSolved%
\ShowCube{1.6cm}{0.4}{\DrawRubikCubeRU}%
\RubikRotation{\fourspot}%
\quad\SequenceBraceA{\SequenceName}{%
\ShowSequence}{\Rubik}{\SequenceLong}}%
\quad$\longrightarrow$\quad%
\ShowCube{1.6cm}{0.4}{\DrawRubikCubeRU}%
```

Note (1) that the ‘fourspot’ listing is included in the RUBIKPATTERNS package, and (2) the `\RubikRotation` command requires using the `--shell-escape` command-line option with the \LaTeX engine—see Section 1.2 for details.

12 Arrows

The RUBIKCUBE package does not offer any special commands for drawing arrows since it is straightforward just to include the appropriate TikZ ‘draw’ commands in the `tikzpicture` environment (i.e., in our own `\ShowCube` environment).

In order to facilitate using the standard TikZ ‘draw’ commands the graphic grid origin of Rubik cube images is located at the bottom left corner of the FRONT face (see also Section 4 for details of the cube’s coordinate system). Similarly, single face images (e.g., drawn using the `\DrawFlatUp` or `\DrawFlatUpSide` and `LayerFace` commands etc.) have their grid origin at the bottom left corner of the face. Consequently the start and finish coordinates for any arrow or line are easy to determine.

For example, Figure 5 shows a green arrow drawn from the centre of cubie LB (0.5,0.5) to the centre of cubie MM⁷ (1.5,1.5). To do this we just include the following TikZ command, remembering that TikZ commands require a terminal semicolon.

```
\draw[->,color=green] (0.5,0.5) -- (1.5, 1.5);
```

⁷The code MM stands for x=Middle, y=Middle; see also Figure 4 on Rubik face-notation

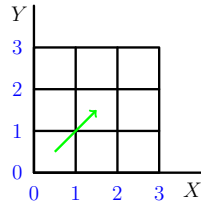
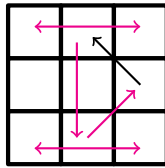


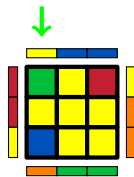
Figure 5: Grid showing the positive coordinates associated with FRONT face of a cube image, or of a face-only image.

The following example shows the cubie changes in the UP face generated by the rotation sequence **FRUR'U'F'**. The magenta arrows indicate movement *with* cubie rotations, while the black arrow indicates movement *without* rotation. This example also highlights the fact that when there are several arrows, the start and end positions often need to be offset slightly away from cubie centres.



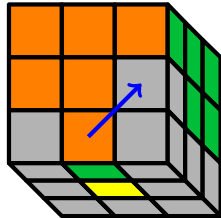
```
\ShowCube{2.5cm}{0.7}{%
\DrawRubikLayerFaceAll{W}
\draw[->,thick,color=magenta] (1.5,0.5) -- (2.4, 1.4);
\draw[->,thick] (2.5,1.5) -- (1.6, 2.4);
\draw[->,thick,color=magenta] (1.3, 2.3) -- (1.3, 0.5);
\draw[<->,thick,color=magenta] (0.5,2.6) -- (2.5, 2.6);
\draw[<->,thick,color=magenta] (0.5,0.3) -- (2.5, 0.3);
}
```

Since the coordinates shown in Figure 5 extend outwards in all directions, they can also be used as a guide for drawing arrows (or other structures) outside this 3x3 'face' square. This approach is shown in the following example, where we have changed the `tikzpicture` scale factor to 0.4 in order to generate a small figure in order to facilitate placing the figure and the code side-by-side.



```
\noindent
\ShowCube{1.8cm}{0.4}{%
\DrawRubikLayerFace{G}{Y}{R}%
{Y}{Y}{Y}%
{B}{Y}{Y}%
%
\DrawRubikLayerSideT {Y}{B}{B}
\DrawRubikLayerSideLR{R} {Y}
{R} {0}
{Y} {0}
\DrawRubikLayerSideB {0}{G}{G}
\draw[->,ultra thick,color=green] (0.5,5) -- (0.5, 4);
}
```

The following example shows an arrow on the Rubik cube. The origin of coordinates is at the bottom left corner of the FRONT face (see Section 4).



```

\RubikFaceFront{0}{0}{0}
           {0}{0}{X}
           {X}{0}{X}

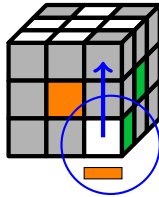
\RubikFaceRight{G}{G}{G}
           {X}{G}{G}
           {X}{X}{X}

\RubikFaceDown {X}{G}{X}
           {X}{Y}{X}
           {X}{X}{X}

\ShowCube{3cm}{0.7}{%
  \DrawRubikCubeRD
  \draw[ultra thick,->,color=blue]
        (1.5,0.5) -- (2.5, 1.5);
}

```

In the following example we use a blue circle to highlight the cubie to be rotated into the top layer.



```

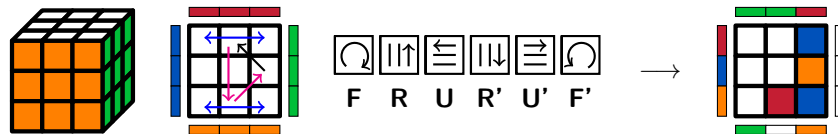
\noindent%
\RubikCubeGrey
\RubikFaceUp{X}{W}{X}
           {W}{W}{W}
           {W}{W}{X}

\RubikSliceBottomR{X}{X}{W}{G}{X}{X}
\ShowCube{2.5cm}{0.5}{%
  \DrawRubikCubeRU
  \DrawRubikLayerSideRBy{0}
  \draw[ultra thick,->,color=blue]
        (2.5,0.5) -- (2.5, 2.5);
  \draw [color=blue, thick] (2.7, 0.3) circle (1.3);
}%

```

13 Final example

We now present, as a final example, the code used to draw the front page figure⁸. This code uses the `\RubikRotation` command (from the RUBIKROTATION package), and therefore the \LaTeX engine needs to be run using the `--shell-escape` command-line switch (see Section 1.2 for details).



⁸This is a well-known sequence of order 6 used to cycle three edge cubies; it is used to generate the 'cross' configuration in the final layer when solving the cube. Here we are performing the sequence on a 'solved' cube, since this allows you to see how the three edge cubies move, and either flip (magenta arrows) or do not flip (black arrow).


```

\noindent\hfil%
\RubikCubeSolved%
\ShowCube{1.6cm}{0.4}{\DrawRubikCubeRU}%
\quad\ShowCube{1.6cm}{0.4}{%
  \DrawFlatUpSide%
  \draw[thick,->,color=magenta] (1.5,0.5) -- (2.4, 1.4);
  \draw[thick,->] (2.5,1.5) -- (1.6, 2.4);
  \draw[thick,->,color=magenta] (1.3, 2.3) -- (1.3, 0.5);
  \draw[thick,<->, color=blue] (0.5,2.6) -- (2.5, 2.6);
  \draw[thick,<->, color=blue] (0.5,0.3) -- (2.5, 0.3);
}%
\RubikRotation{F,R,U,Rp,Up,Fp}%
\quad\ShowSequence{}{\Rubik}{\SequenceLong}\quad$\longrightarrow$%
\ShowCube{1.6cm}{0.4}{\DrawFlatUpSide}%
\hfil

```

13.1 Without using \RubikRotation

If you really need to draw the above figure *without* using the RUBIKROTATION package (as we had to in order to write this particular document) then you would need to replace the commands

```

\RubikRotation{F,R,U,Rp,Up,Fp}
\ShowSequence{,}{\Rubik}{\SequenceLong} \ \ \ $\longrightarrow$
\ShowCube{2cm}{0.4}{\DrawFlatUpSide}

```

with the following commands:

```

\Rubik{F}\Rubik{R}\Rubik{U}\Rubik{Rp}\Rubik{Up}\Rubik{Fp}
\ \ \ $\longrightarrow$
\ShowCube{2cm}{0.4}{%
  \DrawRubikLayerFace{W}{W}{B}
  {W}{W}{O}
  {W}{R}{B}
  \DrawRubikLayerSideT {G}{G}{R}
  \DrawRubikLayerSideLR{R} {W}
  {B} {W}
  {O} {W}
  \DrawRubikLayerSideB {G}{W}{O}
}

```

14 Known limitations

Please contact the authors regarding any ideas for improvement, errors, problems or shortcomings etc.

- Note that the rotation hieroglyphs are optimised for a 10pt font and do not scale with document font size. However, they do work well in conjunction with the standard 11pt and 12pt document fonts sizes. Nevertheless, the font

size can of course be changed by renewing the font command (see Section 8.10 for details).

- The sidebars cannot be arbitrarily positioned (note: hidden faces can be arbitrarily positioned).

15 Future packages

Since Rubik-type cubes currently exist in a variety of sizes (from 2x2x2 to 11x11x11) other authors may well create similar packages dealing with cubes of other sizes the future. Supporting tools may also be made using various programming languages, e.g., Lua etc. Consequently the naming of such packages and tools, and even the associated CTAN directories, needs to be given some thought in order to prevent possible confusion.

In the event of new packages being made, may we suggest that a CTAN directory structure along the following lines might be appropriate.

$$\text{RUBIK} \left\{ \begin{array}{l} \text{rubiktools} \\ \text{rubik2x} \\ \text{rubik3x} \\ \dots \\ \text{rubik11x} \end{array} \right.$$

16 Change history

- Version 4.0 (March 2017)
 - Improved documentation.
 - Improved inter-hieroglyph spacing and vertical position. The Computer Modern sans bold font (10/12pt) is used for the hieroglyphs and rotation codes (see Section 19.3 for details).
 - Improved the `\ShowCube` and `\ShowCubeF` macros (see Sections 6 and 19.4).
 - Additional notation for middle slice rotations (‘m’ notation), e.g., **Rm**, **Rm’** etc (see Sections 8.3 and 19.23).
 - Additional notation for whole cube rotations (‘c’ notation), e.g., **Rc**, **Rc’** etc (see Sections 8.6 and 19.23).
 - Added Randelshofer notation (the ‘CMST’ rotations), e.g., **CR**, **MR** etc (see Sections 8.9.1 and 19.24).
 - Two new (more-intuitive) `\Draw..` commands replace earlier (now deprecated) ambiguous versions; these new versions are now consistent with the other `\DrawRubikCubeXX` commands (see Section 9.3).

`\DrawRubikCubeF` (F = flat) —replaces `\DrawRubikFlat`.

`\DrawRubikCubeSF` (SF = semi-flat) —replaces `\DrawRubikCubeFlat`.

—Six new commands for showing and annotating rotation sequences; the versions with a terminal ‘F’ also surround the object with an fbox to allow users to see the extent of any associated white space (see Sections 10 & 11):

```
\ShowSequence
\ShowSequenceF
\ShowSequencef
\SequenceBraceA
\SequenceBraceAF
\SequenceBraceB
\SequenceBraceBF
```

—A new command for setting up or allocating a ‘solved’ colour configuration. (see Section 7.3):

```
\SolvedConfig
```

—A new command for setting up a ‘starter cube’ for which the *whole* cube is allocated the default ‘grey’ colour (see Section 7.5):

```
\RubikCubeGreyAll
```

—A new supporting RUBIKPATTERNS package has been added to the Rubik bundle. It is a small macro database of well-known named Rubik patterns and associated sequences (see Section 1.3).

- Version 3.0 (September 2015)

—All rotation commands can now use the rotation-code as an argument; for example, the rotation **D** can now be typeset using the command `\rr{D}` etc (see Section 8). The new rotation commands are:

```
\rr{<rotation-code>}
\rrh{<rotation-code>}
\Rubik{<rotation-code>}
\textRubik{<rotation-code>}
```

The original rotation command formats (e.g., `\rrD`) are still supported for backwards compatibility.

— `\ShowCube` and `\ShowCubeF` are new commands for displaying a cube inside a minipage (see Sections 6 and 19.4).

— `\RubikCubeGrey` is a new command for setting up a ‘starter cube’ for which the only allocated colours are those for the centre cubies (see Section 7.5). The colour configuration matches that of the `\RubikCubeSolved`.

- Version 2.2 (January 2015)

—Fixed typos and minor errors in the documentation.

—Added the following commands to facilitate typesetting a face, as described in Section 9.3.

```

\DrawFlatUp
\DrawFlatDown
\DrawFlatLeft
\DrawFlatRight
\DrawFlatFront
\DrawFlatBack
\DrawFlatUpSide
\DrawFlatDownSide
\DrawFlatLeftSide
\DrawFlatRightSide
\DrawFlatFrontSide
\DrawFlatBackSide

```

—Changed ‘Equator’ → ‘Middle’ in all `\DrawLayer..` commands (for consistency). Hence ‘E’ → ‘M’ in all Flat commands and Slice commands. Note that although the former use of ‘Equator’ is retained for backward compatibility (for the moment) it is now deprecated.

—Fixed a conflict with the T_EX `\sb` command as used by the `url` package which resulted in reference chaos when the `url` package was used with the `RUBIKCUBE` package (internalised `\sb` to `\@sb`). Also internalised, for convenience, `\sd` to `\@sd`; `\sh` to `\@sh`; `\sc` to `\@sc`; `\sq` to `\@sq`.

- Version 2.0 (February 5, 2014)

—First release.

17 Acknowledgements

We would like to thank Peter Barta and Peter Grill for useful ideas and suggestions. We have built on some of their ideas and have acknowledged these instances in the documentation. Finally, we would like to thank Christian Tellechea for the `\@join{}` command (see Section 19.22.3), Christian Schröppel for help regarding the `forarray` package (see Section 19.5), and Herbert Kociemba for helpful comments.

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19 The code (rubikcube.sty)

The conventions we adopt regarding capital letters and the XYZ argument ordering are detailed in Section 3.

Note that it is important when using a graphics package to use a trailing % on the end of lines which break before the terminal curly bracket of a `\newcommand`. This is to prevent accumulating spurious spaces which may otherwise appear in figures and diagrams as a strange or unexpected horizontal shift or white-space.

19.1 Package heading

```
1 (*rubikcube)
2 \def\RCfileversion{4.0}%
3 \def\RCfiledate{2017/03/03}%
4 \NeedsTeXFormat{LaTeX2e}
5 \ProvidesPackage{rubikcube}[\RCfiledate\space (v\RCfileversion)]
```

The package requires TikZ—so we load it if not already loaded.

```
6 \@ifpackageloaded{tikz}{}{%
7   \typeout{---rubikcube requires the TikZ package.}%
8   \RequirePackage{tikz}}%
```

The package requires the Forarray package (see Section 19.5)—so we load it if not already loaded.

```
9 \@ifpackageloaded{forarray}{}{%
10  \typeout{---rubikcube requires the Forarray package.}%
11  \RequirePackage{forarray}}%
```

The package requires the IfThen package (see Section 19.5)—so we load it if not already loaded.

```
12 \@ifpackageloaded{ifthen}{}{%
13  \typeout{---rubikcube requires the IfThen package.}%
14  \RequirePackage{ifthen}}%
```

`\rubikcube` First we create a suitable logo

```
15 \newcommand{\rubikcube}{\textsc{rubikcube}}%
16 \newcommand{\Rubikcube}{\textsc{Rubikcube}}%
```

19.2 Colours

We have adopted the following colour allocations; these were initially defined by Peter Bartal (2011) —see Section 7. We have modified only the colour grey, which is now defined as black!30.

```
17 \definecolor{R}{HTML}{C41E33}%
18 \definecolor{G}{HTML}{00BE38}%
19 \definecolor{B}{HTML}{0051BA}%
20 \definecolor{Y}{HTML}{FFFF00}%
21 \colorlet{X}{black!30}% grey
22 \colorlet{O}{orange}%
23 \colorlet{W}{white}}%
```

19.3 The rubikfont

`\@rubikfont` We define two fonts for text associated with the Rubik glyphs (both the ‘arrow’
`\@rubikfontFNS` glyphs and the ‘letter’ glyphs), namely, (1) Computer Modern Sans (cmss), bold
`\@rubikprime` extended (bx), normal shape (n) at 10/12pt, and (2) a footnotesize (FNS) version
(8pt) for the lower-case letters [for cmss see Latex Companion (2004), p.417 &
p.354⁹]. This has the effect of keeping the size of Rubik glyphs constant in the
face of any changes in the document fonts. We make the baseline-skip values the
same, since the ‘arrow’ glyphs generated by the `\Rubik{D}`; see Section 19.22.13). We use the
cmss font apostrophe as the ‘prime’ symbol (the user has the opportunity to use
the maths `\prime` instead—see Section 8.10).

```
24 \newcommand{\@rubikfont}{\fontsize{10}{12pt}\usefont{T1}{cmss}{bx}{n}}
25 \newcommand{\@rubikfontFNS}{\fontsize{8}{12pt}\usefont{T1}{cmss}{bx}{n}}
26 \newcommand{\@rubikprime}{'}
```

19.4 ShowCube command

`\ShowCube` The macro `\ShowCube{<minipage width>}{<TikZ scale factor>}{<Draw.. cmd>}`
`\ShowCubeF` displays the cube inside a minipage, so that we can easily tailor the minipage
width (#1) and also the TikZ scale factor (#2). The `\ShowCubeF` command places
an fbox around the minipage so users can see the extent of any white space.

USAGE: `\ShowCube{2cm}{0.5}{\DrawRubikCubeRU}`

February 2017 (RWDN): We first require a new length variable (which will
become the minipage-width), so we can add the length 1.6pt to it (this is the width
of the TikZ ultra-thick line which is used to draw the Rubik cubes). In order for
a width of an image made up of x units to be equal to $x \times$ (scale-factor) we need
to add an extra line-width (i.e., to include the right-hand edge).

```
27 \newlength{\@showcubewidth}%
```

We can now build the two macros. We set the `\fboxsep` value to zero.

```
28 \newcommand{\ShowCube}[3]{%
29 \setlength{\fboxsep}{0cm}%
30 \setlength{\@showcubewidth}{#1}%
31 \advance\@showcubewidth by 1.6pt\relax%
32 \begin{minipage}{\the\@showcubewidth}%
33 \centering%
34 \begin{tikzpicture}[scale=#2]%
35 #3%
36 \end{tikzpicture}%
37 \end{minipage}%
38 }%
39 \newcommand{\ShowCubeF}[3]{%
40 \setlength{\fboxsep}{0cm}%
41 \setlength{\fboxrule}{0.4pt}%
42 \setlength{\@showcubewidth}{#1}%
```

⁹Note the typo in Table 7.5 (p.354): the font-series code for the Sans semi-bold condensed form is ‘sbx’ (not sbc).


```

43 \advance\@showcubewidth by 1.6pt\relax%
44 \framebox{%
45 \begin{minipage}{\the\@showcubewidth}%
46 \centering%
47 \begin{tikzpicture}[scale=#2]%
48 #3%
49 \end{tikzpicture}%
50 \end{minipage}%
51 }}%

```

19.5 ShowSequence command

`\ShowSequence` The `\ShowSequence{<separator>}{<font-code>}{<sequence>}` command typesets a comma separated sequence of rotation commands. (See Section 10). This command takes three mandatory arguments: the first is the separator (#1), the second is the font or style code (#2), and third is a comma-separated sequence of Rubik rotation commands (#3).

This command requires the `forarray` package—by Christian Schröppel—for the `\ForEachX` command) and the `ifthen` package—by David Carlisle—for the `\ifthenelse` command). These two packages are loaded at startup if not already loaded. We first need to define two variables for use by the command; these are derived from the `forarray` package.

```

52 \newcommand{\x}{\thislevelitem}
53 \newcommand{\xcount}{\thislevelcount}

```

The `\ShowSequence` command typesets a sequence of elements, and places an optional separator (#1) between them. For each element of #3 this command forms the construction #2{element of #3}. For example, if #2 = `\rr`, and an element of #3 is D, then it forms `\rr{D}` etc.

Note that in order to avoid placing a trailing comma after the final element, we identify the first element (using `\xcount`) and then place a comma in front all the remaining elements. This is because it is easy to identify the first element of a sequence, but very difficult to identify the final element.

We also create two fbox forms: the ‘F’ form places an fbox about the whole output; the ‘f’ form places an fbox about each element in the output (these forms can be helpful when checking white space.

USAGE: `\ShowSequence{,}{\rr}{R,L,Up,Dp.....}`

```

54 \newcommand{\ShowSequence}[3]{%
55 \ForEachX{,}{%
56 \ifthenelse{\xcount=1}{#2{x}}{#1#2{x}}%
57 }{#3}%
58 }%
59 \newcommand{\ShowSequenceF}[3]{%
60 \fbox{%
61 \ForEachX{,}{%
62 \ifthenelse{\xcount=1}{#2{x}}{#1#2{x}}%
63 }{#3}%

```

```

64 }}%
65 \newcommand{\ShowSequencef}[3]{%
66   \ForEachX{,}{%
67     \ifthenelse{\xcount=1}{\fbox{#2{x}}}{#1{\fbox{#2{x}}}}%
68     }{#3}%
69 }%

```

`\SequenceInfo` SEQUENCE HOLDERS: providing none of the Rubik rotation-codes has a trailing integer (e.g., R3) then the Rubik macros (`\rr`, `\rrh`, `\Rubik`, `\textRubik`) will work as expected when used as the second argument in the `\ShowSequence` command (described above). However, a problem arises when trying to process in this way any Rubik rotation-codes having a terminal integer (for example, short-codes e.g., R2, D3,...), since the `\ShowSequence` macro cannot expand short-codes into their long-code elements (e.g., R,R,D,D,D,...).

Accommodating such codes when using the `\ShowSequence` command is currently solved by using separate ‘holders’ for four derived strings, namely: `\SequenceInfo`, `\SequenceName`, `\SequenceShort` and `\SequenceLong` (for details see Section 10). These are generated automatically by the Perl RUBIKROTATION program, which returns a so-called ‘long’ version of the ‘short’ string (the argument of the `\RubikRotation` command). For example, the Perl program converts any short codes (e.g., R2, D3,...) → long form, e.g., R,R,D,D,D,... (see the RUBIKROTATION documentation for details). In order for the four ‘holders’ of these derived strings generated by the Perl program (written to the file `rubikstateNEW.dat`) to be accessible to the user they need to be defined here so that they can then be ‘redefined’ (by the Perl program) in the file `rubikstateNEW.dat`:

```

70 \newcommand{\SequenceInfo}{{}}%   %% INFO only
71 \newcommand{\SequenceName}{{}}%   %% NAME only
72 \newcommand{\SequenceShort}{{}}%  %% original SHORT seq but with NO NAME
73 \newcommand{\SequenceLong}{{}}%   %% just the LONG string & no name

```

19.6 SequenceBrace commands

`\SequenceBraceA` The `\SequenceBraceX{⟨name⟩}{⟨sequence⟩}` command is a tool for displaying a named sequence using a brace. The trailing A denotes that the brace is placed Above the sequence; B denotes the brace is Below the sequence. For usage see Section 11.

```

74 \newcommand{\SequenceBraceA}[2]{\overbrace{\mbox{#2}}^{\mbox{#1}}}%
75 \newcommand{\SequenceBraceB}[2]{\underbrace{\mbox{#2}}_{\mbox{#1}}}%
76 \newcommand{\SequenceBraceAF}[2]{\fbox{\overbrace{\mbox{#2}}^{\mbox{#1}}}}%
77 \newcommand{\SequenceBraceBF}[2]{\fbox{\underbrace{\mbox{#2}}_{\mbox{#1}}}}%

```

19.7 Face commands

Cube face notation: U, D, L, R, F, B (Singmaster)

Cubie-square notation: t, m, b, l, m, r = top, middle, bottom, left, middle, right.

We use the t, b notation for cubie-squares (facelets) to avoid confusion with cube

Face notation. We number the cubie-squares on a face 1–9 reading from left-to-right, starting top-left, ending bottom-right, as follows (see also Figure 4):

top row (1,2,3) = tl, tm, tr
middle row (4,5,6) = ml, mm, mr
bottom row (7,8,9) = bl, bm, br

`\RubikFaceUp` These 5 commands allocate a colour to each of the 9 cubie-squares in the specified face (Up, Down, Left, Right, Front, Back). Each command takes 9 arguments
`\RubikFaceDown` (colour codes) in the order 1–9 as specified above.
`\RubikFaceLeft`
`\RubikFaceRight` EXAMPLE: `\RubikFaceUp{R}{O}{Y} {G}{B}{W} {X}{R}{G}`
`\RubikFaceFront` Each of the 9 `\def{}` commands below allocates one colour to a specific cubie-square (facelet), using a simple three-letter encoding. Each letter is an initial
`\RubikFaceBack` letter of the words Up, Down, Left, Right, Front, Back, left, middle, right, top, middle, bottom.

For example, in the command `\Urt{#1}` the U stands for the Up face of the cube, while the `rt` stands for the “right-top” facelet on this face. Note that the order of the two lower-case letters (in this case `rt`) are always written in the x, y order; i.e., the first of the two lower-case letters relates to the x direction (either left, middle, or right), while the second lower-case letter relates to the y direction (either top, middle, or bottom)—this rule makes it easy to remember the order.

```

78 \newcommand{\RubikFaceUp}[9]{%
79 \def\Ult{#1}\def\Umt{#2}\def\Urt{#3}%
80 \def\Ulm{#4}\def\Umm{#5}\def\Urm{#6}%
81 \def\Ulb{#7}\def\Umb{#8}\def\Urb{#9}%
82 }
83 \newcommand{\RubikFaceFront}[9]{%
84 \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
85 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
86 \def\Flb{#7}\def\Fmb{#8}\def\Frb{#9}%
87 }
88 \newcommand{\RubikFaceRight}[9]{%
89 \def\Rlt{#1}\def\Rmt{#2}\def\Rrt{#3}%
90 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
91 \def\Rlb{#7}\def\Rmb{#8}\def\Rrb{#9}%
92 }
93 \newcommand{\RubikFaceDown}[9]{%
94 \def\Dlt{#1}\def\Dmt{#2}\def\Drt{#3}%
95 \def\Dlm{#4}\def\Dmm{#5}\def\Dr{#6}%
96 \def\Dlb{#7}\def\Dmb{#8}\def\Drb{#9}%
97 }
98 \newcommand{\RubikFaceLeft}[9]{%
99 \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
100 \def\Llm{#4}\def\Lmm{#5}\def\Lrm{#6}%
101 \def\Llb{#7}\def\Lmb{#8}\def\Lrb{#9}%
102 }
103 \newcommand{\RubikFaceBack}[9]{%
104 \def\Blt{#1}\def\Bmt{#2}\def\Brt{#3}%
105 \def\Blm{#4}\def\Bmm{#5}\def\Brm{#6}%

```

```
106 \def\Blb{#7}\def\Bmb{#8}\def\Brb{#9}%
107 }
```

`\RubikFaceUpAll` These 5 commands allocate the same colour to all 9 cubie-squares in the specified face (Up, Down, Left, Right, Front). Each command therefore takes only 1 argument (one of the colour codes).
`\RubikFaceDownAll`
`\RubikFaceLeftAll`
`\RubikFaceRightAll` For example, `\RubikFaceUpAll{R}`
`\RubikFaceFrontAll`
`\RubikFaceBackAll`

```
108 \newcommand{\RubikFaceUpAll}[1]{%
109 \def\Ult{#1}\def\Umt{#1}\def\Urt{#1}%
110 \def\Ulm{#1}\def\Umm{#1}\def\Urm{#1}%
111 \def\Ulb{#1}\def\Umb{#1}\def\Urb{#1}%
112 }
113 \newcommand{\RubikFaceFrontAll}[1]{%
114 \def\Flt{#1}\def\Fmt{#1}\def\Frt{#1}%
115 \def\Flm{#1}\def\Fmm{#1}\def\Frm{#1}%
116 \def\Flb{#1}\def\Fmb{#1}\def\Frb{#1}%
117 }
118 \newcommand{\RubikFaceRightAll}[1]{%
119 \def\Rlt{#1}\def\Rmt{#1}\def\Rrt{#1}%
120 \def\Rlm{#1}\def\Rmm{#1}\def\Rrm{#1}%
121 \def\Rlb{#1}\def\Rmb{#1}\def\Rrb{#1}%
122 }
123 \newcommand{\RubikFaceLeftAll}[1]{%
124 \def\Llt{#1}\def\Lmt{#1}\def\Lrt{#1}%
125 \def\Llm{#1}\def\Lmm{#1}\def\Lrm{#1}%
126 \def\Llb{#1}\def\Lmb{#1}\def\Lrb{#1}%
127 }
128 \newcommand{\RubikFaceDownAll}[1]{%
129 \def\Dlt{#1}\def\Dmt{#1}\def\Drt{#1}%
130 \def\Dlm{#1}\def\Dmm{#1}\def\Drp{#1}%
131 \def\Dllb{#1}\def\Dmb{#1}\def\Drb{#1}%
132 }
133 \newcommand{\RubikFaceBackAll}[1]{%
134 \def\Blt{#1}\def\Bmt{#1}\def\Brt{#1}%
135 \def\Blm{#1}\def\Bmm{#1}\def\Brm{#1}%
136 \def\Blb{#1}\def\Bmb{#1}\def\Brb{#1}%
137 }
```

Finally, we now use these commands to initialise all visible faces to the default colour grey (X)

```
138 \RubikFaceUpAll{X}%
139 \RubikFaceDownAll{X}%
140 \RubikFaceLeftAll{X}%
141 \RubikFaceRightAll{X}%
142 \RubikFaceFrontAll{X}%
143 \RubikFaceBackAll{X}%

```

19.8 RubikCubeGrey command

`\RubikCubeGrey` This command sets the face/colour configuration (state) of a 3x3x3 Rubik cube with no colours allocated except for the central cubie of each face. The colour configuration of the central cubies matches those defined for the `RubikCubeSolved` command (i.e., white opposite yellow etc). We also implement an equivalent ‘gray’ version (to be consistent with TikZ).

```
144 \newcommand{\RubikCubeGrey}{%
145 \RubikFaceUp   {X}{X}{X}{X}{W}{X}{X}{X}{X}%
146 \RubikFaceDown {X}{X}{X}{X}{Y}{X}{X}{X}{X}%
147 \RubikFaceLeft  {X}{X}{X}{X}{B}{X}{X}{X}{X}%
148 \RubikFaceRight {X}{X}{X}{X}{G}{X}{X}{X}{X}%
149 \RubikFaceFront {X}{X}{X}{X}{O}{X}{X}{X}{X}%
150 \RubikFaceBack  {X}{X}{X}{X}{R}{X}{X}{X}{X}%
151 }
152 \newcommand{\RubikCubeGray}{\RubikCubeGrey}
```

19.9 SolvedConfig command

`\SolvedConfig` This command sets the face/colour configuration (state) of a typical solved Rubik cube. Note that the order is Right, Left, Up, Down, Front, Back (i.e., X+, X-, Y+, Y-, Z+, Z-, order). We shall use this command to define solved cube configurations.

```
153 \newcommand{\SolvedConfig}[6]{%
154   \RubikFaceRightAll{#1}%
155   \RubikFaceLeftAll{#2}%
156   \RubikFaceUpAll{#3}%
157   \RubikFaceDownAll{#4}%
158   \RubikFaceFrontAll{#5}%
159   \RubikFaceBackAll{#6}%
160 }
```

19.10 RubikCubeGreyAll command

`\RubikCubeGreyAll` This command sets the face/colour configuration (state) of a 3x3x3 Rubik cube with no colours allocated. This colour configuration is the same as the startup default state—all cubies will appear grey. We implement it using the `\SolvedConfig` command (above). We also implement an equivalent ‘gray’ version (to be consistent with TikZ).

```
161 \newcommand{\RubikCubeGreyAll}{\SolvedConfig{X}{X}{X}{X}{X}{X}}%
162 \newcommand{\RubikCubeGrayAll}{\RubikCubeGreyAll}
```

19.11 RubikCubeSolved command

`\RubikCubeSolved` The first (default) command sets the face/colour configuration (state) one of the standard commercially available solved Rubik cube (white opposite yellow). The `\RubikCubeSolvedWY` argument order follows the XYZ notation. For convenience we make a copy named `\RubikCubeSolvedWB`

\RubikCubeSolvedWY (denoting the White opposite Yellow configuration), and also a different version named \RubikCubeSolvedWB (denoting the White opposite Blue configuration). These represent the two standard versions of the Rubik Cube.

```
163 \newcommand{\RubikCubeSolved}{\SolvedConfig{G}{B}{W}{Y}{0}{R}}%
164 \newcommand{\RubikCubeSolvedWY}{\RubikCubeSolved}%
165 \newcommand{\RubikCubeSolvedWB}{\SolvedConfig{R}{0}{W}{B}{G}{Y}}%
```

19.12 Slice commands

\RubikSliceTopR These 6 commands allocate the colour arguments for the 6 visible ordered facets along a horizontal slice. There are three horizontal slices to consider (Top, Middle, Bottom) and each has two viewpoints. The colour-code arguments are ordered 1–6 from left to right. The terminal L and R denote the Left (L) viewpoint and Right (R) viewpoint versions. Note that the two legacy ‘Equator’ versions (now replaced by ‘Middle’) are retained (below) to allow backward compatibility.

```
166 \newcommand{\RubikSliceTopR}[6]{%
167 \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
168 \def\Rlt{#4}\def\Rmt{#5}\def\Rrt{#6}%
169 }
170 \newcommand{\RubikSliceTopL}[6]{%
171 \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
172 \def\Flt{#4}\def\Fmt{#5}\def\Frt{#6}%
173 }
174 \newcommand{\RubikSliceMiddleR}[6]{%
175 \def\Flm{#1}\def\Fmm{#2}\def\Frm{#3}%
176 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
177 }
178 \newcommand{\RubikSliceMiddleL}[6]{%
179 \def\Llm{#1}\def\Lmm{#2}\def\Lrm{#3}%
180 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
181 }
182 \newcommand{\RubikSliceEquatorR}[6]{%
183 \def\Flm{#1}\def\Fmm{#2}\def\Frm{#3}%
184 \def\Rlm{#4}\def\Rmm{#5}\def\Rrm{#6}%
185 }
186 \newcommand{\RubikSliceEquatorL}[6]{%
187 \def\Llm{#1}\def\Lmm{#2}\def\Lrm{#3}%
188 \def\Flm{#4}\def\Fmm{#5}\def\Frm{#6}%
189 }
190 \newcommand{\RubikSliceBottomR}[6]{%
191 \def\Flb{#1}\def\Fmb{#2}\def\Frb{#3}%
192 \def\Rlb{#4}\def\Rmb{#5}\def\Rrb{#6}%
193 }
194 \newcommand{\RubikSliceBottomL}[6]{%
195 \def\Llb{#1}\def\Lmb{#2}\def\Lrb{#3}%
196 \def\Flb{#4}\def\Fmb{#5}\def\Frb{#6}%
197 }
```

19.13 Cube drawing macros

Since the three visible sides of a Rubik cube have up to 27 non-grey colours, and \TeX has only 9 macro parameters available, we are forced to draw Rubik cubes by first specifying the colours on each of the three faces, and then using a ‘`\DrawRubikCubeXY`’ command, where the trailing XY code defines the viewing direction (X = either R or L; Y = either U or D). The order of the XY code is important: X first, Y second (so it is easy to remember).

On each face the facelets are drawn in the following order: Top row (left to right), Middle row (left to right), Bottom row (left to right).

The TikZ draw cycle for each facelet square on a Rubik cube face cycles through the four corners of the facelet in the following order: lb \rightarrow lt \rightarrow rt \rightarrow rb; the code being lb (LeftBottom), lt (LeftTop), rt (RightTop), rb (RightBottom) (only need four coords); the (x,y) grid origin is at the bottom-left corner of the FRONT face.

`\DrawRubikCubeFrontFace` This ‘FrontFace’ command is an ‘internal’ command which draws and paints all the facelets on the FRONT face of a Rubik cube. It is used by all of the cube drawing macros which display the FRONT face. The 9 colours are allocated by an earlier `\RubikFaceFront` command. These Face macros are based, in part, on those of Peter Bartal (2011).

```
198 \newcommand{\DrawRubikCubeFrontFace}{%
199 % ---top row left to right
200 \draw[line join=round,line cap=round,ultra thick,fill=\Flt]%
201 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
202 \draw[line join=round,line cap=round,ultra thick,fill=\Fmt]%
203 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
204 \draw[line join=round,line cap=round,ultra thick,fill=\Frt]%
205 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
206 % -----middle row left to right
207 \draw[line join=round,line cap=round,ultra thick,fill=\Flm]%
208 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
209 \draw[line join=round,line cap=round,ultra thick,fill=\Fmm]%
210 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
211 \draw[line join=round,line cap=round,ultra thick,fill=\Frm]%
212 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
213 % ----bottom row left to right
214 \draw[line join=round,line cap=round,ultra thick,fill=\Flb]%
215 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
216 \draw[line join=round,line cap=round,ultra thick,fill=\Fmb]%
217 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
218 \draw[line join=round,line cap=round,ultra thick,fill=\Frb]%
219 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
220 }
```

19.13.1 Viewing direction

The command ‘`\DrawRubikCubeXY`’ command uses the trailing XY code to specify the view direction (X = either R or L; Y = either U or D). The order of the XY code is important: X first, Y second (so it is easy to remember).

`\DrawRubikCubeRU` This command draws and paints a Rubik cube as viewed from the Right Upper (RU) viewpoint. It starts by using the internal command `\DrawRubikCubeFrontFace` to draw the FRONT face, and then draws the UP face followed by the RIGHT face. The colours are allocated to particular facelets using the `\RubikFaceUp`, `\RubikFaceRight` and `\RubikFaceFront` commands.

The (x,y) grid origin is at the bottom-left corner of the FRONT face (see Section 4). The perspective is designed so that the 2D graphic image of the side face (RIGHT in this particular case) has its ‘horizontal’ lines running at 45 degrees. This has the useful advantage that the 2D width of the side is exactly 1-unit, and so makes it easy to determine the 2D (x,y) coordinates of any position, and hence facilitates typesetting text onto the image of the cube using TikZ commands.

```

221 \newcommand{\DrawRubikCubeRU}{%
222 \DrawRubikCubeFrontFace %% frontface
223 %%-----Up face-----
224 %%---top row
225 \draw[line join=round,line cap=round,ultra thick,fill=\Ultr]%
226 (0.66,3.66) -- (1,4) -- (2,4) -- (1.66,3.66) -- cycle;
227 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
228 (1.66,3.66) -- (2,4) -- (3,4) -- (2.66,3.66) -- cycle;
229 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
230 (2.66,3.66) -- (3,4) -- (4,4) -- (3.66,3.66) -- cycle;
231 %%---middle row
232 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
233 (0.33,3.33) -- (0.66,3.66) -- (1.66,3.66) -- (1.33,3.33) -- cycle;
234 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
235 (1.33,3.33) -- (1.66,3.66) -- (2.66,3.66) -- (2.33,3.33) -- cycle;
236 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
237 (2.33,3.33) -- (2.66,3.66) -- (3.66,3.66) -- (3.33,3.33) -- cycle;
238 %%---bottom row
239 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
240 (0,3) -- (0.33,3.33) -- (1.33,3.33) -- (1,3) -- cycle;
241 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
242 (1,3) -- (1.33,3.33) -- (2.33,3.33) -- (2,3) -- cycle;
243 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
244 (2,3) -- (2.33,3.33) -- (3.33,3.33) -- (3,3) -- cycle;
245 %%-----Right face-----
246 %%---top row
247 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
248 (3,2) -- (3, 3) -- (3.33,3.33) -- (3.33,2.33) -- cycle;
249 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
250 (3.33,2.33) -- (3.33, 3.33) -- (3.66,3.66) -- (3.66,2.66) -- cycle;
251 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
252 (3.66,2.66) -- (3.66, 3.66) -- (4,4) -- (4,3) -- cycle;
253 %%---middle row
254 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
255 (3,1) -- (3, 2) -- (3.33,2.33) -- (3.33,1.33) -- cycle;
256 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
257 (3.33,1.33) -- (3.33, 2.33) -- (3.66,2.66) -- (3.66,1.66) -- cycle;

```



```

258 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
259 (3.66,1.66) -- (3.66, 2.66) -- (4,3) -- (4,2) -- cycle;
260 %%---bottom row
261 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
262 (3,0) -- (3, 1) -- (3.33,1.33) -- (3.33,0.33) -- cycle;
263 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
264 (3.33,0.33) -- (3.33, 1.33) -- (3.66,1.66) -- (3.66,0.66) -- cycle;
265 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
266 (3.66,0.66) -- (3.66, 1.66) -- (4,2) -- (4,1) -- cycle;
267 }

```

`\DrawRubikCube` This command is equivalent to the previous `\DrawRubikCubeRU` and hence is the default form (i.e., if the trailing XY viewpoint code is accidentally omitted).

```

268 \newcommand{\DrawRubikCube}{\DrawRubikCubeRU}

```

`\DrawRubikCubeRD` This command draws and paints a Rubik cube as viewed from the Right Down (RD) viewpoint.

```

269 \newcommand{\DrawRubikCubeRD}{%
270 \DrawRubikCubeFrontFace %% frontface
271 %%-----Right face-----
272 %%---top row
273 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
274 (3,2) -- (3, 3) -- (3.33,2.66) -- (3.33,1.66) -- cycle;
275 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
276 (3.33,1.66) -- (3.33, 2.66) -- (3.66,2.33) -- (3.66,1.33) -- cycle;
277 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
278 (3.66,1.33) -- (3.66, 2.33) -- (4,2) -- (4,1) -- cycle;
279 %%---middle row
280 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
281 (3,1) -- (3, 2) -- (3.33,1.66) -- (3.33,0.66) -- cycle;
282 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
283 (3.33,0.66) -- (3.33, 1.66) -- (3.66,1.33) -- (3.66,0.33) -- cycle;
284 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
285 (3.66,0.33) -- (3.66, 1.33) -- (4,1) -- (4,0) -- cycle;
286 %%---bottom row
287 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
288 (3,0) -- (3, 1) -- (3.33,0.66) -- (3.33,-0.33) -- cycle;
289 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
290 (3.33,-0.33) -- (3.33, 0.66) -- (3.66,0.33) -- (3.66,-0.66) -- cycle;
291 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
292 (3.66,-0.66) -- (3.66, 0.33) -- (4,0) -- (4,-1) -- cycle;
293 %%-----Down face-----
294 %%---top row
295 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
296 (0.33,-0.33) -- (0, 0) -- (1,0) -- (1.33,-0.33) -- cycle;
297 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
298 (1.33,-0.33) -- (1, 0) -- (2,0) -- (2.33,-0.33) -- cycle;
299 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%

```

```

300 (2.33,-0.33) -- (2, 0) -- (3,0) -- (3.33,-0.33) -- cycle;
301 %%---middle row
302 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
303 (0.66,-0.66) -- (0.33, -0.33) -- (1.33,-0.33) -- (1.66,-0.66) -- cycle;
304 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
305 (1.66,-0.66) -- (1.33, -0.33) -- (2.33,-0.33) -- (2.66,-0.66) -- cycle;
306 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
307 (2.66,-0.66) -- (2.33, -0.33) -- (3.33,-0.33) -- (3.66,-0.66) -- cycle;
308 %%---bottom row
309 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
310 (1,-1) -- (0.66, -0.66) -- (1.66,-0.66) -- (2,-1) -- cycle;
311 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
312 (2,-1) -- (1.66, -0.66) -- (2.66,-0.66) -- (3,-1) -- cycle;
313 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
314 (3,-1) -- (2.66, -0.66) -- (3.66,-0.66) -- (4,-1) -- cycle;
315 }

```

`\DrawRubikCubeLD` This command draws and paints a Rubik cube as viewed from the Left Down (LD) viewpoint.

```

316 \newcommand{\DrawRubikCubeLD}{%
317 \DrawRubikCubeFrontFace %% frontface
318 %%-----Left face-----
319 %%---top row
320 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
321 (-1,1) -- (-1, 2) -- (-0.66,2.33) -- (-0.66,1.33) -- cycle;
322 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
323 (-0.66,1.33) -- (-0.66, 2.33) -- (-0.33,2.66) -- (-0.33,1.66) -- cycle;
324 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
325 (-0.33,1.66) -- (-0.33, 2.66) -- (0,3) -- (0,2) -- cycle;
326 %%---middle row
327 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
328 (-1,0) -- (-1, 1) -- (-0.66,1.33) -- (-0.66,0.33) -- cycle;
329 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
330 (-0.66,0.33) -- (-0.66, 1.33) -- (-0.33,1.66) -- (-0.33,0.66) -- cycle;
331 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
332 (-0.33,0.66) -- (-0.33, 1.66) -- (0,2) -- (0,1) -- cycle;
333 %%---bottom row
334 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
335 (-1,-1) -- (-1, 0) -- (-0.66,0.33) -- (-0.66,-0.66) -- cycle;
336 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
337 (-0.66,-0.66) -- (-0.66, 0.33) -- (-0.33,0.66) -- (-0.33,-0.33) -- cycle;
338 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
339 (-0.33,-0.33) -- (-0.33, 0.66) -- (0,1) -- (0,0) -- cycle;
340 %%-----Down face-----
341 %%---top row
342 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
343 (-0.33,-0.33) -- (0, 0) -- (1,0) -- (0.66,-0.33) -- cycle;
344 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
345 (0.66,-0.33) -- (1, 0) -- (2,0) -- (1.66,-0.33) -- cycle;

```

```

346 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
347 (1.66,-0.33) -- (2, 0) -- (3,0) -- (2.66,-0.33) -- cycle;
348 %%---middle row
349 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
350 (-0.66,-0.66) -- (-0.33, -0.33) -- (0.66,-0.33) -- (0.33,-0.66) -- cycle;
351 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
352 (0.33,-0.66) -- (0.66, -0.33) -- (1.66,-0.33) -- (1.33,-0.66) -- cycle;
353 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
354 (1.33,-0.66) -- (1.66, -0.33) -- (2.66,-0.33) -- (2.33,-0.66) -- cycle;
355 %%---bottom row
356 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
357 (-1,-1) -- (-0.66, -0.66) -- (0.33,-0.66) -- (0,-1) -- cycle;
358 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
359 (0,-1) -- (0.33, -0.66) -- (1.33,-0.66) -- (1,-1) -- cycle;
360 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
361 (1,-1) -- (1.33, -0.66) -- (2.33,-0.66) -- (2,-1) -- cycle;
362 }

```

`\DrawRubikCubeLU` This command draws and paints a Rubik cube as viewed from the Left Up (LU) viewpoint.

```

363 \newcommand{\DrawRubikCubeLU}{%
364 \DrawRubikCubeFrontFace %% frontface
365 %%-----Left face-----
366 %%---top row
367 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
368 (-1,3) -- (-1, 4) -- (-0.66,3.66) -- (-0.66,2.66) -- cycle;
369 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
370 (-0.66,2.66) -- (-0.66, 3.66) -- (-0.33,3.33) -- (-0.33,2.33) -- cycle;
371 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
372 (-0.33,2.33) -- (-0.33, 3.33) -- (0,3) -- (0,2) -- cycle;
373 %%---middle row
374 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
375 (-1,2) -- (-1, 3) -- (-0.66,2.66) -- (-0.66,1.66) -- cycle;
376 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
377 (-0.66,1.66) -- (-0.66, 2.66) -- (-0.33,2.33) -- (-0.33,1.33) -- cycle;
378 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
379 (-0.33,1.33) -- (-0.33, 2.33) -- (0,2) -- (0,1) -- cycle;
380 %%---bottom row
381 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
382 (-1,1) -- (-1, 2) -- (-0.66,1.66) -- (-0.66,0.66) -- cycle;
383 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
384 (-0.66,0.66) -- (-0.66, 1.66) -- (-0.33,1.33) -- (-0.33,0.33) -- cycle;
385 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
386 (-0.33,0.33) -- (-0.33, 1.33) -- (0,1) -- (0,0) -- cycle;
387 %%-----Up face-----
388 %%---top row
389 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
390 (-0.66,3.66) -- (-1, 4) -- (0,4) -- (0.33,3.66) -- cycle;
391 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%

```

```

392 (0.33,3.66) -- (0, 4) -- (1,4) -- (1.33,3.66) -- cycle;
393 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
394 (1.33,3.66) -- (1, 4) -- (2,4) -- (2.33,3.66) -- cycle;
395 %%---middle row
396 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
397 (-0.33,3.33) -- (-0.66, 3.66) -- (0.33,3.66) -- (0.66,3.33) -- cycle;
398 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
399 (0.66,3.33) -- (0.33, 3.66) -- (1.33,3.66) -- (1.66,3.33) -- cycle;
400 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
401 (1.66,3.33) -- (1.33, 3.66) -- (2.33,3.66) -- (2.66,3.33) -- cycle;
402 %%---bottom row
403 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
404 (0,3) -- (-0.33, 3.33) -- (0.66,3.33) -- (1,3) -- cycle;
405 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
406 (1,3) -- (0.66, 3.33) -- (1.66,3.33) -- (2,3) -- cycle;
407 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
408 (2,3) -- (1.66, 3.33) -- (2.66,3.33) -- (3,3) -- cycle;%
409 \ %%trailing space
410 }

```

19.14 LayerFace commands

`\DrawRubikLayerFace`
`\DrawRubikLayerFaceAll`

These two LayerFace commands each draw and paint a single face of 9 facelets. The first command takes 9 ordered colour parameters, (ordered in layers from top left to bottom right, so #1 is the place-holder for the colour of the TopLeft facelet etc.) The second command takes only one colour parameter (since All the colours are the same).

The drawing origin (0,0) = bottom left corner. The facelets are drawn from left to right. NOTE: this macro is SAME as the internal command `\DrawRubikCubeFrontFace` which is used for drawing the front face of a Rubik cube.

```

411 \newcommand{\DrawRubikLayerFace}[9]{%
412 %%-----FRONT face-----
413 %%---top row
414 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
415 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
416 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
417 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
418 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
419 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
420 %%----middle row
421 \draw[line join=round,line cap=round,ultra thick,fill=#4]%
422 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
423 \draw[line join=round,line cap=round,ultra thick,fill=#5]%
424 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
425 \draw[line join=round,line cap=round,ultra thick,fill=#6]%
426 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
427 %%---bottom row

```

```

428 \draw[line join=round,line cap=round,ultra thick,fill=#7]%
429 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
430 \draw[line join=round,line cap=round,ultra thick,fill=#8]%
431 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
432 \draw[line join=round,line cap=round,ultra thick,fill=#9]%
433 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
434 }
435 \newcommand{\DrawRubikLayerFaceAll}[1]{%
436 %%-----FRONT face-----
437 %%---top row
438 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
439 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
440 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
441 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
442 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
443 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
444 %%----middle row
445 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
446 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
447 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
448 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
449 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
450 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
451 %%---bottom row
452 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
453 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
454 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
455 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
456 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
457 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
458 }

```

19.15 DrawFlatX commands

[NOTE: These new commands (version 3.0) were modified from the earlier `\FlatUp`, `\FlatDown` etc., commands; i.e., they were reformulated as a set of `\Draw...` commands so as to make this notation consistent with the other `\Draw...` commands. Note also that, for user convenience, all of these commands have been copied (in version 4.0) to equivalent `\DrawFace...` versions associated with their two coordinate arguments set to $x = 0$, $y = 0$ —see Section 19.16]

<code>\DrawFlatUp</code> <code>\DrawFlatDown</code> <code>\DrawFlatLeft</code> <code>\DrawFlatRight</code> <code>\DrawFlatFront</code> <code>\DrawFlatBack</code>	<p>Each of these commands draws a separate (flat) face (9 facelets) (see Section 9.3). Each command (except <code>\DrawFlatFront</code>) takes two arguments, namely the X-coordinate and Y-coordinate of the bottom-left corner of the face. This (X,Y) pair of coordinates therefore allows the user to position the face in relation to the cube itself. These commands were motivated by a need to be able to show hidden faces under certain circumstances.</p>
--	--

Note that the Y-argument currently only works fully with the `\DrawFlatUp`, `\DrawFlatDown` and `\DrawFlatBack` commands, since all the other faces currently

only require $Y=0$ (this will be made more flexible in a later version).

Note also that the `\DrawFlatFront` command takes no arguments, since by definition the bottom left corner of this face is at $(0,0)$, and there seems to be no reason (just now) for this face to have the facility to be positioned otherwise.

EXAMPLE: The following command positions the Up face so that its bottom left corner is located at $(0,3)$:

```
\DrawFlatUp{0}{3}
```

These new commands are also used by the commands `\DrawRubikFlat` and `\DrawRubikCubeFlat` to draw various ‘flat’ representations of a Rubik cube.

The (x,y) variables are here encoded as (\ux, \uy) where the ‘u’ stands for Up etc. However, since we are unable to use a ‘dx, dy’ notation with the `\DrawFlatDown` command (since dx and dy are already used by the `\cube@dxdydz...` command), we encode these instead as (\ddx, \ddy) .

```
459 \newcommand{\DrawFlatUp}[2]{%
460 \pgfmathsetmacro{\ux}{#1}%
461 \pgfmathsetmacro{\uy}{#2}%
462 %%---top row
463 \draw[line join=round,line cap=round,ultra thick,fill=\Ult]%
464 (\ux + 0,\uy + 2) -- (\ux + 0,\uy + 3) -- (\ux + 1,\uy + 3)%
465 -- (\ux + 1,\uy + 2) -- cycle;
466 \draw[line join=round,line cap=round,ultra thick,fill=\Umt]%
467 (\ux + 1,\uy + 2) -- (\ux + 1,\uy + 3) -- (\ux + 2,\uy + 3)%
468 -- (\ux + 2,\uy + 2) -- cycle;
469 \draw[line join=round,line cap=round,ultra thick,fill=\Urt]%
470 (\ux + 2,\uy + 2) -- (\ux + 2,\uy + 3) -- (\ux + 3,\uy + 3)%
471 -- (\ux + 3,\uy + 2) -- cycle;
472 %%----middle row
473 \draw[line join=round,line cap=round,ultra thick,fill=\Ulm]%
474 (\ux + 0,\uy + 1) -- (\ux + 0,\uy + 2) -- (\ux + 1,\uy + 2)%
475 -- (\ux + 1,\uy + 1) -- cycle;
476 \draw[line join=round,line cap=round,ultra thick,fill=\Umm]%
477 (\ux + 1,\uy + 1) -- (\ux + 1,\uy + 2) -- (\ux + 2,\uy + 2)%
478 -- (\ux + 2,\uy + 1) -- cycle;
479 \draw[line join=round,line cap=round,ultra thick,fill=\Urm]%
480 (\ux + 2,\uy + 1) -- (\ux + 2,\uy + 2) -- (\ux + 3,\uy + 2)%
481 -- (\ux + 3,\uy + 1) -- cycle;
482 %%---bottom row
483 \draw[line join=round,line cap=round,ultra thick,fill=\Ulb]%
484 (\ux + 0,\uy + 0) -- (\ux + 0,\uy + 1) -- (\ux + 1,\uy + 1)%
485 -- (\ux + 1,\uy + 0) -- cycle;
486 \draw[line join=round,line cap=round,ultra thick,fill=\Umb]%
487 (\ux + 1,\uy + 0) -- (\ux + 1,\uy + 1) -- (\ux + 2,\uy + 1)%
488 -- (\ux + 2,\uy + 0) -- cycle;
489 \draw[line join=round,line cap=round,ultra thick,fill=\Urb]%
490 (\ux + 2,\uy + 0) -- (\ux + 2,\uy + 1) -- (\ux + 3,\uy + 1)%
491 -- (\ux + 3,\uy + 0) -- cycle;
492 }
```

```

493 %%-----
494 \newcommand{\DrawFlatDown}[2]{%
495 \pgfmathsetmacro{\ddx}{#1}%
496 \pgfmathsetmacro{\ddy}{#2}%
497 %%---top row
498 \draw[line join=round,line cap=round,ultra thick,fill=\Dlt]%
499 (\ddx + 0,\ddy + 2) -- (\ddx + 0,\ddy + 3) -- (\ddx + 1,\ddy + 3)%
500 -- (\ddx + 1,\ddy + 2) -- cycle;
501 \draw[line join=round,line cap=round,ultra thick,fill=\Dmt]%
502 (\ddx + 1,\ddy + 2) -- (\ddx + 1,\ddy + 3) -- (\ddx + 2,\ddy + 3)%
503 -- (\ddx + 2,\ddy + 2) -- cycle;
504 \draw[line join=round,line cap=round,ultra thick,fill=\Drt]%
505 (\ddx + 2,\ddy + 2) -- (\ddx + 2,\ddy + 3) -- (\ddx + 3,\ddy + 3)%
506 -- (\ddx + 3,\ddy + 2) -- cycle;
507 %%----middle row
508 \draw[line join=round,line cap=round,ultra thick,fill=\Dlm]%
509 (\ddx + 0,\ddy + 1) -- (\ddx + 0,\ddy + 2) -- (\ddx + 1,\ddy + 2)%
510 -- (\ddx + 1,\ddy + 1) -- cycle;
511 \draw[line join=round,line cap=round,ultra thick,fill=\Dmm]%
512 (\ddx + 1,\ddy + 1) -- (\ddx + 1,\ddy + 2) -- (\ddx + 2,\ddy + 2)%
513 -- (\ddx + 2,\ddy + 1) -- cycle;
514 \draw[line join=round,line cap=round,ultra thick,fill=\Drm]%
515 (\ddx + 2,\ddy + 1) -- (\ddx + 2,\ddy + 2) -- (\ddx + 3,\ddy + 2)%
516 -- (\ddx + 3,\ddy + 1) -- cycle;
517 %%----bottom row
518 \draw[line join=round,line cap=round,ultra thick,fill=\Dlb]%
519 (\ddx + 0,\ddy + 0) -- (\ddx + 0,\ddy + 1) -- (\ddx + 1,\ddy + 1)%
520 -- (\ddx + 1,\ddy + 0) -- cycle;
521 \draw[line join=round,line cap=round,ultra thick,fill=\Dmb]%
522 (\ddx + 1,\ddy + 0) -- (\ddx + 1,\ddy + 1) -- (\ddx + 2,\ddy + 1)%
523 -- (\ddx + 2,\ddy + 0) -- cycle;
524 \draw[line join=round,line cap=round,ultra thick,fill=\Drb]%
525 (\ddx + 2,\ddy + 0) -- (\ddx + 2,\ddy + 1) -- (\ddx + 3,\ddy + 1)%
526 -- (\ddx + 3,\ddy + 0) -- cycle;
527 }
528 %%-----
529 \newcommand{\DrawFlatLeft}[2]{%
530 \pgfmathsetmacro{\lx}{#1}%
531 \pgfmathsetmacro{\ly}{#2}%
532 %% NOTE: y variable coord not yet implemented
533 %%---top row
534 \draw[line join=round,line cap=round,ultra thick,fill=\Llt]%
535 (\lx + 0,2) -- (\lx + 0, 3) -- (\lx + 1,3) -- (\lx + 1,2) -- cycle;
536 \draw[line join=round,line cap=round,ultra thick,fill=\Lmt]%
537 (\lx + 1,2) -- (\lx + 1, 3) -- (\lx + 2,3) -- (\lx + 2,2) -- cycle;
538 \draw[line join=round,line cap=round,ultra thick,fill=\Lrt]%
539 (\lx + 2,2) -- (\lx + 2, 3) -- (\lx + 3,3) -- (\lx + 3,2) -- cycle;
540 %%----middle row
541 \draw[line join=round,line cap=round,ultra thick,fill=\Llm]%
542 (\lx + 0,1) -- (\lx + 0, 2) -- (\lx + 1,2) -- (\lx + 1,1) -- cycle;

```

```

543 \draw[line join=round,line cap=round,ultra thick,fill=\Lmm]%
544 (\lx + 1,1) -- (\lx + 1, 2) -- (\lx + 2,2) -- (\lx + 2,1) -- cycle;
545 \draw[line join=round,line cap=round,ultra thick,fill=\Lrm]%
546 (\lx + 2,1) -- (\lx + 2, 2) -- (\lx + 3,2) -- (\lx + 3,1) -- cycle;
547 %%----bottom row
548 \draw[line join=round,line cap=round,ultra thick,fill=\Llb]%
549 (\lx + 0,0) -- (\lx + 0, 1) -- (\lx + 1,1) -- (\lx + 1,0) -- cycle;
550 \draw[line join=round,line cap=round,ultra thick,fill=\Lmb]%
551 (\lx + 1,0) -- (\lx + 1, 1) -- (\lx + 2,1) -- (\lx + 2,0) -- cycle;
552 \draw[line join=round,line cap=round,ultra thick,fill=\Lrb]%
553 (\lx + 2,0) -- (\lx + 2, 1) -- (\lx + 3,1) -- (\lx + 3,0) -- cycle;
554 }
555 %%-----
556 \newcommand{\DrawFlatRight}[2]{%
557 \pgfmathsetmacro{\rx}{#1}% %3
558 \pgfmathsetmacro{\ry}{#2}% %0
559 %% NOTE: y variable coord not yet implemented
560 %%---top row
561 \draw[line join=round,line cap=round,ultra thick,fill=\Rlt]%
562 (\rx + 0,2) -- (\rx + 0, 3) -- (\rx + 1,3) -- (\rx + 1,2) -- cycle;
563 \draw[line join=round,line cap=round,ultra thick,fill=\Rmt]%
564 (\rx + 1,2) -- (\rx + 1, 3) -- (\rx + 2,3) -- (\rx + 2,2) -- cycle;
565 \draw[line join=round,line cap=round,ultra thick,fill=\Rrt]%
566 (\rx + 2,2) -- (\rx + 2, 3) -- (\rx + 3,3) -- (\rx + 3,2) -- cycle;
567 %%----middle row
568 \draw[line join=round,line cap=round,ultra thick,fill=\Rlm]%
569 (\rx + 0,1) -- (\rx + 0, 2) -- (\rx + 1,2) -- (\rx + 1,1) -- cycle;
570 \draw[line join=round,line cap=round,ultra thick,fill=\Rmm]%
571 (\rx + 1,1) -- (\rx + 1, 2) -- (\rx + 2,2) -- (\rx + 2,1) -- cycle;
572 \draw[line join=round,line cap=round,ultra thick,fill=\Rrm]%
573 (\rx + 2,1) -- (\rx + 2, 2) -- (\rx + 3,2) -- (\rx + 3,1) -- cycle;
574 %%----bottom row
575 \draw[line join=round,line cap=round,ultra thick,fill=\Rlb]%
576 (\rx + 0,0) -- (\rx + 0, 1) -- (\rx + 1,1) -- (\rx + 1,0) -- cycle;
577 \draw[line join=round,line cap=round,ultra thick,fill=\Rmb]%
578 (\rx + 1,0) -- (\rx + 1, 1) -- (\rx + 2,1) -- (\rx + 2,0) -- cycle;
579 \draw[line join=round,line cap=round,ultra thick,fill=\Rrb]%
580 (\rx + 2,0) -- (\rx + 2, 1) -- (\rx + 3,1) -- (\rx + 3,0) -- cycle;
581 }
582 %%-----
583 \newcommand{\DrawFlatFront}{%
584 %% This command is used /only/ by the \cmd{\DrawRubikCubeF} command.
585 %% NOTE: x, y variables not implemented as not required here
586 %%---top row
587 \draw[line join=round,line cap=round,ultra thick,fill=\Flt]%
588 (0,2) -- (0, 3) -- (1,3) -- (1,2) -- cycle;
589 %%
590 \draw[line join=round,line cap=round,ultra thick,fill=\Fmt]%
591 (1,2) -- (1, 3) -- (2,3) -- (2,2) -- cycle;
592 %%

```



```

593 \draw[line join=round,line cap=round,ultra thick,fill=\Frt]%
594 (2,2) -- (2, 3) -- (3,3) -- (3,2) -- cycle;
595 %%-----middle row
596 \draw[line join=round,line cap=round,ultra thick,fill=\Flm]%
597 (0,1) -- (0, 2) -- (1,2) -- (1,1) -- cycle;
598 %%
599 \draw[line join=round,line cap=round,ultra thick,fill=\Fmm]%
600 (1,1) -- (1, 2) -- (2,2) -- (2,1) -- cycle;
601 %%
602 \draw[line join=round,line cap=round,ultra thick,fill=\Frm]%
603 (2,1) -- (2, 2) -- (3,2) -- (3,1) -- cycle;
604 %%---bottom row
605 \draw[line join=round,line cap=round,ultra thick,fill=\Flb]%
606 (0,0) -- (0, 1) -- (1,1) -- (1,0) -- cycle;
607 %%
608 \draw[line join=round,line cap=round,ultra thick,fill=\Fmb]%
609 (1,0) -- (1, 1) -- (2,1) -- (2,0) -- cycle;
610 %%
611 \draw[line join=round,line cap=round,ultra thick,fill=\Frb]%
612 (2,0) -- (2, 1) -- (3,1) -- (3,0) -- cycle;
613 }
614 %%-----
615 \newcommand{\DrawFlatBack}[2]{%
616 \pgfmathsetmacro{\bx}{#1}%
617 \pgfmathsetmacro{\by}{#2}%
618 %%---top row
619 \draw[line join=round,line cap=round,ultra thick,fill=\Blt]%
620 (\bx + 0,\by + 2) -- (\bx + 0,\by + 3) -- (\bx + 1,\by + 3)%
621 -- (\bx + 1,\by + 2) -- cycle;
622 \draw[line join=round,line cap=round,ultra thick,fill=\Bmt]%
623 (\bx + 1,\by + 2) -- (\bx + 1,\by + 3) -- (\bx + 2,\by + 3)%
624 -- (\bx + 2,\by + 2) -- cycle;
625 \draw[line join=round,line cap=round,ultra thick,fill=\Brt]%
626 (\bx + 2,\by + 2) -- (\bx + 2,\by + 3) -- (\bx + 3,\by + 3)%
627 -- (\bx + 3,\by + 2) -- cycle;
628 %%-----middle row
629 \draw[line join=round,line cap=round,ultra thick,fill=\Blm]%
630 (\bx + 0,\by + 1) -- (\bx + 0,\by + 2) -- (\bx + 1,\by + 2)%
631 -- (\bx + 1,\by + 1) -- cycle;
632 \draw[line join=round,line cap=round,ultra thick,fill=\Bmm]%
633 (\bx + 1,\by + 1) -- (\bx + 1,\by + 2) -- (\bx + 2,\by + 2)%
634 -- (\bx + 2,\by + 1) -- cycle;
635 \draw[line join=round,line cap=round,ultra thick,fill=\Brm]%
636 (\bx + 2,\by + 1) -- (\bx + 2,\by + 2) -- (\bx + 3,\by + 2)%
637 -- (\bx + 3,\by + 1) -- cycle;
638 %%---bottom row
639 \draw[line join=round,line cap=round,ultra thick,fill=\Blb]%
640 (\bx + 0,\by + 0) -- (\bx + 0,\by + 1) -- (\bx + 1,\by + 1)%
641 -- (\bx + 1,\by + 0) -- cycle;
642 \draw[line join=round,line cap=round,ultra thick,fill=\Bmb]%

```

```

643 (\bx + 1,\by + 0) -- (\bx + 1,\by + 1) -- (\bx + 2,\by + 1)%
644 -- (\bx + 2,\by + 0) -- cycle;
645 \draw[line join=round,line cap=round,ultra thick,fill=\Brb]%
646 (\bx + 2,\by + 0) -- (\bx + 2,\by + 1) -- (\bx + 3,\by + 1)%
647 -- (\bx + 3,\by + 0) -- cycle;
648 }

```

`\DrawRubikCubeF` Draws a standard flat (F) representation of the Rubik cube (colours only). Note that `\DrawFlatFront` (below) does not take any arguments (x,y).

```

649 \newcommand{\DrawRubikCubeF}{%
650   \DrawFlatUp{0}{3}%
651   \DrawFlatDown{0}{-3}%
652   \DrawFlatLeft{-3}{0}%
653   \DrawFlatFront%
654   \DrawFlatRight{3}{0}%
655   \DrawFlatBack{6}{0}%
656 }

```

`\DrawRubikCubeSF` Draws a Rubik cube together with the three hidden faces (colours only) in a semi-flat (SF) representation. The (x,y) arguments (below) are for the bottom-left corner of the face.

```

657 \newcommand{\DrawRubikCubeSF}{%
658   \DrawRubikCube%
659   \DrawFlatDown{0}{-3}%
660   \DrawFlatLeft{-3}{0}%
661   \DrawFlatBack{4}{1}%
662 }

```

19.15.1 DrawFlatXSide commands

These six commands draw a face together with all four sidebars (colours only). We use the `\DrawFlatX` commands to draw the face. We use the `\DrawRubikLayerSideX` commands to draw the sidebars. The parameter orders for the `\DrawRubikLayerSideX` commands are as follows: Top (T) and Bottom (B) = left to right; Left (L) and Right (R) = top to bottom; (see the `\DrawRubikLayerSideX` command for details of the arguments).

Note that for user convenience, we have copied many of these commands to a `\DrawFace..` version (see Section 19.16).

`\DrawFlatUpSide` Draws the UP face together with all four sidebars (colours only).

```

663 \newcommand{\DrawFlatUpSide}{%
664   \DrawFlatUp{0}{0}%
665   \DrawRubikLayerSideT{\Brt}{\Bmt}{\Blt}%
666   \DrawRubikLayerSideL{\Llt}{\Lmt}{\Lrt}%
667   \DrawRubikLayerSideR{\Rrt}{\Rmt}{\Rlt}%
668   \DrawRubikLayerSideB{\Flt}{\Fmt}{\Frt}%
669 }

```

`\DrawFlatFrontSide` Draws the FRONT face together with all four sidebars (colours only).

```

670 \newcommand{\DrawFlatFrontSide}{%
671 \DrawFlatFront{0}{0}%
672 \DrawRubikLayerSideT{\Ulb}{\Umb}{\Urb}%
673 \DrawRubikLayerSideL{\Lrt}{\Lrm}{\Lrb}%
674 \DrawRubikLayerSideR{\Rlt}{\Rlm}{\Rlb}%
675 \DrawRubikLayerSideB{\Dlt}{\Dmt}{\Drt}%
676 }

```

`\DrawFlatRightSide` Draws the RIGHT face together with all four sidebars (colours only).

```

677 \newcommand{\DrawFlatRightSide}{%
678 \DrawFlatRight{0}{0}%
679 \DrawRubikLayerSideT{\Urb}{\Urm}{\Urt}%
680 \DrawRubikLayerSideL{\Frt}{\Frm}{\Frb}%
681 \DrawRubikLayerSideR{\Blt}{\Blm}{\Blb}%
682 \DrawRubikLayerSideB{\Drt}{\Drm}{\Drb}%
683 }

```

`\DrawFlatLeftSide` Draws the LEFT face together with all four sidebars (colours only).

```

684 \newcommand{\DrawFlatLeftSide}{%
685 \DrawFlatLeft{0}{0}%
686 \DrawRubikLayerSideT{\Ult}{\Ulm}{\Ulb}%
687 \DrawRubikLayerSideL{\Brt}{\Brm}{\Brb}%
688 \DrawRubikLayerSideR{\Flt}{\Flm}{\Flb}%
689 \DrawRubikLayerSideB{\Dlb}{\Dlm}{\Dlt}%
690 }

```

`\DrawFlatBackSide` Draws the BACK face together with all four sidebars (colours only).

```

691 \newcommand{\DrawFlatBackSide}{%
692 \DrawFlatBack{0}{0}%
693 \DrawRubikLayerSideT{\Urt}{\Umt}{\Ult}%
694 \DrawRubikLayerSideL{\Rrt}{\Rrm}{\Rrb}%
695 \DrawRubikLayerSideR{\Llt}{\Llm}{\Llb}%
696 \DrawRubikLayerSideB{\Drb}{\Dmb}{\Dlb}%
697 }

```

`\DrawFlatDownSide` Draws the DOWN face together with all four sidebars (colours only).

```

698 \newcommand{\DrawFlatDownSide}{%
699 \DrawFlatDown{0}{0}%
700 \DrawRubikLayerSideT{\Flb}{\Fmb}{\Frb}%
701 \DrawRubikLayerSideL{\Lrb}{\Lmb}{\Llb}%
702 \DrawRubikLayerSideR{\Rlb}{\Rmb}{\Rrb}%
703 \DrawRubikLayerSideB{\Brb}{\Bmb}{\Blb}%
704 }

```

19.16 DrawFace commands

We now copy the above `\DrawFlat...` commands as `\DrawFace...` commands for the purpose of user convenience, since most of the time the user wants just to draw

a particular face with or without the associated side bars. In a future version we may well, therefore, deprecate some of the above ‘Flat’ command names.

```

705 \newcommand{\DrawFaceUp}{\DrawFlatUp{0}{0}}
706 \newcommand{\DrawFaceDown}{\DrawFlatDown{0}{0}}
707 \newcommand{\DrawFaceLeft}{\DrawFlatLeft{0}{0}}
708 \newcommand{\DrawFaceRight}{\DrawFlatRight{0}{0}}
709 \newcommand{\DrawFaceFront}{\DrawFlatFront{0}{0}}
710 \newcommand{\DrawFaceBack}{\DrawFlatBack{0}{0}}
711 \newcommand{\DrawFaceUpSide}{\DrawFlatUpSide}
712 \newcommand{\DrawFaceDownSide}{\DrawFlatDownSide}
713 \newcommand{\DrawFaceLeftSide}{\DrawFlatLeftSide}
714 \newcommand{\DrawFaceRightSide}{\DrawFlatRightSide}
715 \newcommand{\DrawFaceFrontSide}{\DrawFlatFrontSide}
716 \newcommand{\DrawFaceBackSide}{\DrawFlatBackSide}

```

19.17 SideBar commands

SideBar commands draw narrow bars of colour indicating the side colours of each of the facelets forming the side of a given layer (face). Each SideBar is the length of a single facelet.

`\RubikSideBarWidth` These three commands allow the user to set the Width, Length and Separation
`\RubikSideBarLength` parameters for the sidebar (in decimal values, where 1 is equivalent to the length
`\RubikSideBarSep` of the side of a facelet).

```

717 \newcommand{\RubikSideBarWidth}[1]{\pgfmathsetmacro{\bw}{#1}}
718 \newcommand{\RubikSideBarLength}[1]{\pgfmathsetmacro{\bl}{#1}}
719 \newcommand{\RubikSideBarSep}[1]{\pgfmathsetmacro{\bs}{#1}}

```

We first set some default values

```

720 \RubikSideBarWidth{0.3}%
721 \RubikSideBarLength{1}%
722 \RubikSideBarSep{0.3}%

```

19.17.1 Allocating a colour to a single facelet sidebar

`\side@barT` Internal commands. Full length face SideBars are really multiple instances of
`\side@barB` single facelet bars, each of which is drawn using one of four internal SideBar
`\side@barL` commands—one for each of the sides which we shall call Top, Bottom, Left, Right.
`\side@barR` Each SideBar command takes two arguments: one for facelet position $\{1 | 2 | 3\}$
and one for the colour-code $\{R | O | Y | G | B | W | X\}$.

EXAMPLE: the following command allocates a colour to a single facelet sidebar on the Left of a Rubik face:

```
\side@barL{\facelet-position}{\colour-code}
```

There are three facelet positions on each of the four sides of a face, and these are numbered 1 to 3 starting from the bottom left corner (1,1). The SideBar command also implements the set (or default) Length (`\bl`), Width (`\bw`) and

Separation ($\backslash bs$) values mentioned above. $\backslash blh = \text{Half } \backslash bl = \backslash bl/2$. Note that the TikZ $\backslash pgfmathsetmacro$ commands (which do the maths) must be inside the TeX sidebar command in order to work. The start point of the TikZ $\backslash draw$ command for each bar rectangle is bottom Left corner of the bar $=(\backslash dx, \backslash dy)$

```

723 \newcommand{\side@barL}[2]{%
724 %% #1 = cubie possn no, #2 = colour
725 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
726 \pgfmathsetmacro{\dx}{0 - \bs - \bw}%
727 \pgfmathsetmacro{\dy}{#1-1+0.5-\blh}%
728 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
729 -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
730 }
731 \newcommand{\side@barR}[2]{%
732 %% #1 = cubie possn no, #2 = colour
733 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
734 \pgfmathsetmacro{\dx}{3 + \bs}%
735 \pgfmathsetmacro{\dy}{#1 -1+0.5-\blh}%
736 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bl)
737 -- (\dx+\bw,\dy+\bl) -- (\dx+\bw,\dy) -- cycle;
738 }
739 \newcommand{\side@barT}[2]{%
740 %% #1 = cubie possn no, #2 = colour
741 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
742 \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh}%
743 \pgfmathsetmacro{\dy}{3 + \bs}%
744 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
745 -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
746 }
747 \newcommand{\side@barB}[2]{%
748 %% #1 = cubie possn no, #2 = colour
749 \pgfmathsetmacro{\blh}{\bl*(0.5)}%
750 \pgfmathsetmacro{\dx}{#1 -1+0.5-\blh}%
751 \pgfmathsetmacro{\dy}{0 - \bs - \bw}%
752 \draw[fill=#2] (\dx,\dy) -- (\dx,\dy + \bw)
753 -- (\dx+\bl,\dy+\bw) -- (\dx+\bl,\dy) -- cycle;
754 }

```

19.17.2 Drawing a single facelet sidebar

$\backslash DrawRubikLayerSideX_1X_2X_3$ This command draws a single facelet sidebar using the above $\backslash sidebar$ command. The $X_1X_2X_3$ parameters refer to the options Left, Middle, Right, Top, Middle, Bottom, x , y , as follows:

X_1 is an x parameter: either $\langle L | M | R \rangle$
 X_2 is a y parameter: either $\langle T | M | B \rangle$
 X_3 is an extra parameter: either $\langle x | y \rangle$, required by corner sidebars to indicate whether the sidebar was either above or below $\langle y \rangle$, or to the left or right $\langle x \rangle$ of the associated cubie. An X_3 parameter is not

required for the sidebar of an edge cubie, since only one location is possible in these cases.

For example, the following command

```
\DrawRubikLayerSideLTy{G}
```

draws a Green sidebar above the Top Left cubie.

```
755 %%---Left side
756 \newcommand{\DrawRubikLayerSideLTx}[1]{\side@barL{3}{#1}}
757 \newcommand{\DrawRubikLayerSideLMx}[1]{\side@barL{2}{#1}}
758 \newcommand{\DrawRubikLayerSideLM}[1]{\side@barL{2}{#1}}
759 \newcommand{\DrawRubikLayerSideLBx}[1]{\side@barL{1}{#1}}
760 %%---Right side
761 \newcommand{\DrawRubikLayerSideRTx}[1]{\side@barR{3}{#1}}
762 \newcommand{\DrawRubikLayerSideRMx}[1]{\side@barR{2}{#1}}
763 \newcommand{\DrawRubikLayerSideRM}[1]{\side@barR{2}{#1}}
764 \newcommand{\DrawRubikLayerSideRBx}[1]{\side@barR{1}{#1}}
765 %%---Top side
766 \newcommand{\DrawRubikLayerSideLTy}[1]{\side@barT{1}{#1}}
767 \newcommand{\DrawRubikLayerSideMTy}[1]{\side@barT{2}{#1}}
768 \newcommand{\DrawRubikLayerSideMT}[1]{\side@barT{2}{#1}}
769 \newcommand{\DrawRubikLayerSideRTy}[1]{\side@barT{3}{#1}}
770 %%---Bottom side
771 \newcommand{\DrawRubikLayerSideLBy}[1]{\side@barB{1}{#1}}
772 \newcommand{\DrawRubikLayerSideMBy}[1]{\side@barB{2}{#1}}
773 \newcommand{\DrawRubikLayerSideMB}[1]{\side@barB{2}{#1}}
774 \newcommand{\DrawRubikLayerSideRBy}[1]{\side@barB{3}{#1}}
```

19.17.3 Drawing multiple cubie sidebars

`\DrawRubikLayerSideT` These commands allow the drawing of 3 small sidebars along one particular side
`\DrawRubikLayerSideB` (Top, Bottom, Left, Right), as indicated by the appended T, B, L, R letter code.
`\DrawRubikLayerSideL` Each command takes three ordered colour arguments, which are ordered either
`\DrawRubikLayerSideR` from left to right (the T and B forms), or from top to bottom (the L and R forms)

```
775 %%--Top side---
776 \newcommand{\DrawRubikLayerSideT}[3]{%
777 \DrawRubikLayerSideLTy{#1}%
778 \DrawRubikLayerSideMTy{#2}%
779 \DrawRubikLayerSideRTy{#3}%
780 }
781 %%--Bottom side---
782 \newcommand{\DrawRubikLayerSideB}[3]{%
783 \DrawRubikLayerSideLBy{#1}%
784 \DrawRubikLayerSideMBy{#2}%
785 \DrawRubikLayerSideRBy{#3}%
786 }
787 %%--Left side-----
788 %% colours run vertically DOWN
```

```

789 \newcommand{\DrawRubikLayerSideL}[3]{%
790   \DrawRubikLayerSideLTx{#1}%
791   \DrawRubikLayerSideLMx{#2}%
792   \DrawRubikLayerSideLBx{#3}%
793 }
794 %%--Right side-----
795 %% colours run vertically DOWN
796 \newcommand{\DrawRubikLayerSideR}[3]{%
797   \DrawRubikLayerSideRTx{#1}%
798   \DrawRubikLayerSideRMx{#2}%
799   \DrawRubikLayerSideRBx{#3}%
800 }

```

`\DrawRubikLayerSideLR` This command draws six cubie sidebars, three on each side, drawn in (L, R) pairs. The command takes six colour arguments, ordered in pairs, as shown in the following example.

```

\DrawRubikLayerSideLR{G}   {G}
                        {R}   {B}
                        {Y}   {B}

```

```

801 \newcommand{\DrawRubikLayerSideLR}[6]{%
802   \DrawRubikLayerSideLTx{#1}%
803   \DrawRubikLayerSideRTx{#2}%
804   \DrawRubikLayerSideLMx{#3}%
805   \DrawRubikLayerSideRMx{#4}%
806   \DrawRubikLayerSideLBx{#5}%
807   \DrawRubikLayerSideRBx{#6}%
808 }

```

19.18 RubikSide commands

`\RubikSideLeft` `\RubikSideRight` `\RubikSideFront` `\RubikSideBack` RubikSide commands allocate colours to the side facelets of the UP face—see Section 7.7. These facelets are the top three facelets of each side Front, Back, Left, Right.

```

809 \newcommand{\RubikSideFront}[3]{%
810   \def\Flt{#1}\def\Fmt{#2}\def\Frt{#3}%
811 }
812 \newcommand{\RubikSideRight}[3]{%
813   \def\Rlt{#1}\def\Rmt{#2}\def\Rrt{#3}%
814 }
815 \newcommand{\RubikSideLeft}[3]{%
816   \def\Llt{#1}\def\Lmt{#2}\def\Lrt{#3}%
817 }
818 \newcommand{\RubikSideBack}[3]{%
819   \def\Blt{#1}\def\Bmt{#2}\def\Brt{#3}%
820 }

```

`\RubikSideLeftAll` `\RubikSideRightAll` `\RubikSideFrontAll` `\RubikSideBackAll` These 4 commands allocate the same colour to all 3 cubiesquares in the specified face (Left, Right, Front, Back). Each command therefore takes only 1 argument (one of the colour codes).

```

For example, \RubikSideUpAll{R}
821 \newcommand{\RubikSideFrontAll}[1]{%
822 \def\Flt{#1}\def\Fmt{#1}\def\Frt{#1}%
823 }
824 \newcommand{\RubikSideRightAll}[1]{%
825 \def\Rlt{#1}\def\Rmt{#1}\def\Rrt{#1}%
826 }
827 \newcommand{\RubikSideLeftAll}[1]{%
828 \def\Llt{#1}\def\Lmt{#1}\def\Lrt{#1}%
829 }
830 \newcommand{\RubikSideBackAll}[1]{%
831 \def\Blt{#1}\def\Bmt{#1}\def\Brt{#1}%
832 }

```

19.19 NCube command

HISTORY: The essence of this command was originally developed by Peter Bartal as his command `\rubikcube` (see Bartal, 2011). We have modified it, as follows (June 2012):

- (1) adjusted to use the TikZ `\pgfmathsetmacro{ }{ }` command (suggested by Peter Grill),
- (2) renamed to `\DrawNCubeAll`.

`\DrawNCubeAll` This command draws a solved $N \times N \times N$ Rubik's cube from the RightUp viewpoint. All cubies on a given face have the same colour. The command takes four ordered arguments, as follows:

`#1` = number of cubies ($n > 0$) along each side,
`#2`, `#3`, `#4` = colours of the visible faces (in X,Y,Z order); X=Right face colour, Y=Up face colour, Z=Front face colour.

We use the `\pgfmathsetmacro{<variable-name>}{<numeric value or maths>}` command. Note that the second argument must not involve any units—just numeric values or mathematics.

```

833 \newcommand{\DrawNCubeAll}[4]{%
834 \pgfmathsetmacro{\ncubes}{#1-1}%
835 %% need to subtract 1 from the given number of cubies per side
836 %% to avoid the origin of the initial cube to be displaced
837 \foreach \x in {0,...,\ncubes}{%
838 \foreach \y in {0,...,\ncubes}{%
839 \foreach \z in {0,...,\ncubes}{%
840 \cube@dxdydz{1}{#2}{#3}{#4}{\x}{\y}{\z}%
841 }}}

```

`\cube@dxdydz` This internal command is used only by the `\DrawNCubeAll` command (see above). The original version of this command was developed by Peter Bartal (see Bartal, 2011). It was later modified (2012) by RWD Nickalls (to implement a more intuitive X, Y, Z ordering of the face colour parameters).

The cube need not be in the origin, the distances of the DOWN-behind [L] corner from the origin are taken as parameters 5,6,7. The command takes 7 ordered arguments:

- 1 - length of an edge
- 2 - X-face colour (RIGHT face)
- 3 - Y-face colour (UP face)
- 4 - Z-face colour (FRONT face)
- 5 - x-position in space
- 6 - y-position in space
- 7 - z-position in space

USAGE: `\cube@dxdydz{1}{X}{Y}{Z}{x}{y}{z}`

The original code `\pgfmathparse{#1+#5}\let\dy\pgfmathresult` was changed to the more intuitive `\pgfmathsetmacro{\dx}{#1+#5}` (suggested by Peter Grill 2011).

CHANGES: RWD Nickalls (2012): (1) added the `[line join=round,line cap=round]` options to each of the TikZ `\draw` commands, in order to improve the line joining (first two options); (2) adjusted the `\cube@dxdydz` macro to adopt the ordered XYZ face colour notation (by reassigning #2, #3, #4 to the X, Y, Z face colours, as shown above).

```

842 \newcommand{\cube@dxdydz}[7]{%
843   \pgfmathsetmacro{\dx}{#1+#5}%
844   %% calculates the 'displacement' (distance from the origin) of the
845   %% far corners of the cube along the x axis from the arguments
846   \pgfmathsetmacro{\dy}{#1+#6}%
847   %% calculates the 'displacement' (distance from the origin) of the
848   %% far corners of the cube along the y axis from the arguments
849   \pgfmathsetmacro{\dz}{#1+#7}%
850   %% calculates the 'displacement' (distance from the origin) of the
851   %% far corners of the cube along the z axis from the arguments
852   %% Draw FRONT face (using the X colour = #4)
853   \draw[line join=round,line cap=round,ultra thick,fill=#4]%
854   (#5,#6,\dz) -- (\dx,#6,\dz) -- (\dx,\dy,\dz) -- (#5,\dy,\dz) -- cycle;
855   %% The 'rectangle' command does not work with 3D coordinates,
856   %% so this is the way to draw the squares with space coordinates
857   %% Draw UP face (using the Y colour = #3)
858   \draw[line join=round,line cap=round,ultra thick,fill=#3]%
859   (#5,\dy,\dz) -- (\dx,\dy,\dz) -- (\dx,\dy,#7) -- (#5,\dy,#7) -- cycle;
860   %% Draw RIGHT face (using the X colour = #2)
861   \draw[line join=round,line cap=round,ultra thick,fill=#2]%
862   (\dx,#6,\dz) -- (\dx,#6,#7) -- (\dx,\dy,#7) -- (\dx,\dy,\dz) -- cycle;
863 }

```

19.20 Drawing single cubies

`\Cubiedx` These two commands set the value of the two length parameters `cx` and `cy`, and
`\Cubiedy` allow the user to vary the size (adjust `cy`) and horizontal viewpoint (adjust `cx`) of a

single cubie (described in more detail in the RUBIKCUBE package documentation). Note that we cannot use the names `dx`, `dy` for the variables here since these names have been allocated already (see above). However, we can use `dx`, `dy` in the command names as these will be more readily understood by the user.

```
864 \newcommand{\Cubiedx}[1]{\pgfmathsetmacro{cx}{#1}}
865 \newcommand{\Cubiedy}[1]{\pgfmathsetmacro{cy}{#1}}
```

We now set the default values (`cx=cy=0.4`)

```
866 \Cubiedx{0.4}
867 \Cubiedy{0.4}
```

`\DrawCubieRU` These four commands draw a single cubie from the RightUp, RightDown, LeftUp, LeftDown viewpoint. The viewpoint is specified using an appended two-letter XY ordered viewpoint code: either RU, RD, LU, LD. These commands take three arguments, namely three different XYZ ordered colour codes (R,O,Y,G,B,W,X).
`\DrawCubieRD` FORMAT: `\DrawCubieRU{<Xcolour>}{<Ycolour>}{<Zcolour>}`
`\DrawCubieLU` USAGE: `\DrawCubieRU{G}{B}{W}`
`\DrawCubieLD`

```
868 \newcommand{\DrawCubieRU}[3]{%
869 %% Front face (z)
870 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
871 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
872 %% Up face(y)
873 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
874 (0,1) -- (\cx, 1+\cy) -- (1+\cx,1+\cy) -- (1,1) -- cycle;
875 %% Right face(x)
876 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
877 (1,0) -- (1,1) -- (1+\cx,1+\cy) -- (1+\cx, \cy) -- cycle;
878 }
879 \newcommand{\DrawCubieRD}[3]{%
880 %% Front face (z)
881 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
882 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
883 %% Down face (y)
884 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
885 (\cx,-\cy) -- (0, 0) -- (1,0) -- (1+\cx,-\cy) -- cycle;
886 %% Right face (x)
887 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
888 (1,0) -- (1,1) -- (1+\cx,-\cy+1) -- (1+\cx, -\cy) -- cycle;
889 }
890 \newcommand{\DrawCubieLD}[3]{%
891 %% Front face (z)
892 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
893 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
894 %% Down face (y)
895 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
896 (-\cx,-\cy) -- (0, 0) -- (1,0) -- (1-\cx,-\cy) -- cycle;
897 %% Left face (x)
898 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
```

```

899 (-\cx,-\cy) -- (-\cx,-\cy+1) -- (0,1) -- (0,0) -- cycle;
900 }
901 \newcommand{\DrawCubieLU}[3]{%
902 %% Front face (z)
903 \draw[line join=round,line cap=round,ultra thick,fill=#3]%
904 (0,0) -- (0, 1) -- (1, 1) -- (1,0) -- cycle;
905 %% Up face (y)
906 \draw[line join=round,line cap=round,ultra thick,fill=#2]%
907 (-\cx,1+\cy) -- (1-\cx, 1+\cy) -- (1,1) -- (0,1) -- cycle;
908 %% Left face (x)
909 \draw[line join=round,line cap=round,ultra thick,fill=#1]%
910 (-\cx, \cy) -- (-\cx,\cy+1) -- (0,1) -- (0,0) -- cycle;
911 }

```

19.21 Text cubies

`\textCubieRU` These four commands draw a single ‘text’ cubie from the RightUp, RightDown, LeftUp, LeftDown viewpoint. They are ‘text’ forms of the `\DrawCubie` commands described above. Their size was chosen to be suitable for use with 10–12 point fonts.

As before, the viewpoint is specified using an appended two-letter XY ordered viewpoint code: either RU, RD, LU, LD. These commands take three arguments (since just three faces are visible with this cube format), namely three different XYZ ordered colour codes (R,O,Y,G,B,W,X).

FORMAT: `\textCubieRU{<Xcolour>}{<Ycolour>}{<Zcolour>}`

USAGE: `\textCubieRU{G}{B}{W}`

```

912 \newcommand{\textCubieRU}[3]{%
913 \begin{minipage}{0.66cm}
914 \centering
915 \begin{tikzpicture}[scale=0.5]
916 \Cubiedx{0.4}\Cubiedy{0.4}
917 \DrawCubieRU{#1}{#2}{#3}
918 \end{tikzpicture}%
919 \end{minipage}
920 }
921 \newcommand{\textCubieRD}[3]{%
922 \begin{minipage}{0.66cm}
923 \centering
924 \begin{tikzpicture}[scale=0.5]
925 \Cubiedx{0.4}\Cubiedy{0.4}
926 \DrawCubieRD{#1}{#2}{#3}
927 \end{tikzpicture}%
928 \end{minipage}
929 }
930 \newcommand{\textCubieLD}[3]{%
931 \begin{minipage}{0.66cm}
932 \centering
933 \begin{tikzpicture}[scale=0.5]

```

```

934 \Cubiedx{0.4}\Cubiedy{0.4}
935 \DrawCubieLD{#1}{#2}{#3}
936 \end{tikzpicture}%
937 \end{minipage}
938 }
939 \newcommand{\textCubieLU}[3]{%
940 \begin{minipage}{0.66cm}
941 \centering
942 \begin{tikzpicture}[scale=0.5]
943 \Cubiedx{0.4}\Cubiedy{0.4}
944 \DrawCubieLU{#1}{#2}{#3}
945 \end{tikzpicture}%
946 \end{minipage}
947 }

```

19.22 Rotation commands


19.22.1 Introduction

We use a special prefix notation to denote each of four different representations of the various Rubik cube rotations as follows: the name of the Rubik rotation (rr), its associated hieroglyph (rrh), and combinations of name and hieroglyph both vertical (Rubik) and horizontal (textRubik). A rotation command is a combination of a rotation-code appended to one of the four prefixes.

For example, the command `\rrhD` generates the hieroglyph (rrh) associated with the rotation-code D. In this form it is used internally, but it is also available for the user.

In version 3.0, however, all the rotation commands were also made available to the user in the much more intuitive form `stem{argument}` form, for example, `\rrh{D}`. In practice, this ‘argument’ form actually generates the original non-argument form by the use of the internal macro `\@join`. For example, `\rrh{D}` \rightarrow `join(\rrh + D)` \rightarrow `\rrhD` (see Sections 19.22.4 for details).

The hieroglyphs are of two types: ‘arrow’ glyphs (all exactly square), and ‘letter’ glyphs (mostly square, but many are rectangular); however both types are made to have the same height so they sit nicely when arranged side-by-side. A lot of special macros for handling and generating these glyphs are described below in Section 19.22.3 (and also in Section 19.22.2).

The ‘arrow’ hieroglyphs are built up in stages using TikZ. We first create a command for drawing the square (`\DrawNotationBox`; see Section 19.22.2) and then draw the contents (lines, arrows, arcs of circles). For an example, see the D form  constructed in Section 19.22.13.

The ‘letter’ hieroglyphs (glyphs for which the rotations cannot be seen from the front, and hence cannot have arrows) just give a letter representation of the rotation (say, Bw for ‘back wide’). These glyphs are therefore made using an fbox (for convenience), and therefore these are sometimes not square. Some vertical fine-tuning using the `\raisebox` command is often required to force these ‘letter’ glyphs to have the same vertical position as their ‘arrow’ cousins. For an example,

see the form $\boxed{\text{Bw}}$ constructed Section 19.22.7).

The presence of small overfilled `\hboxes` associated with these squares were originally checked using the `ltugboat.cls`, and all fixed mainly by setting the associated `minipages` \rightarrow `width = 0.6cm`, and using `TikZ scale=0.5`.

19.22.2 DrawNotationBox

`\DrawNotationBox` This internal command draws the surrounding square box of all the hieroglyphs. Note that we start at (0,0) and draw to the final point in order to make a nice corner join.

todo: ? make this a proper internal command using @ sometime.

```
948 \newcommand{\DrawNotationBox}{%
949   \draw [thick] (0,0) -- (0,1) -- (1,1) -- (1,0) -- (0,0) -- (0,1)%
950 }
```

We now define a number of points and line-segments inside the square (e.g., `\@sd`, `\@sh` ... etc.) which will be required for use in drawing the various lines and arrows. Some hieroglyphs contain either one circular arc, or two concentric arcs, and these arcs require both a centre and a start point. Note that the final argument does not use any units. For the `TikZ ARC` command see `TikZ pgfmanual` (2012) page 146 (§14.8).

todo: make a small diagram to illustrate the position of these parameters and make things a bit clearer sometime.

```
951 \pgfmathsetmacro{\@sd}{0.25} % a small horiz space
952 \pgfmathsetmacro{\@sdd}{2*\@sd} % 2x horiz space
953 \pgfmathsetmacro{\@sddd}{3*\@sd} % 3x horiz space
954 \pgfmathsetmacro{\@sh}{0.6} % height
955 \pgfmathsetmacro{\@sb}{0.2} % base
956 \pgfmathsetmacro{\@sbh}{\@sb + \@sh} % UP
957 \pgfmathsetmacro{\@scx}{\@sdd+0.2} % Start of CircleX arc
958 \pgfmathsetmacro{\@scy}{\@sd*2/3} % Start of CircleY arc
959 \pgfmathsetmacro{\@sqcx}{\@scx-0.13} %% Square CenterX coord
960 \pgfmathsetmacro{\@sqcy}{\@scy+0.25} %% Square CenterY cprrd
```

19.22.3 Some useful internal commands

<code>\@rr</code>	These internal commands are used to generate the prime, w, w-prime, s, s-prime,
<code>\@rrp</code>	a, a-prime rotation commands. The <code>\@xyz..</code> commands are used to generate the
<code>\@rrw</code>	x, y, z, u, d, l, r, f, b commands and their associated prime rotation commands.
<code>\@rrwp</code>	The <code>\@SquareLetter</code> command is used to form the separate square hieroglyph
<code>\@rrs</code>	form used for rotations with no visible representation from the front (e.g., B., Fs,
<code>\@rrsp</code>	Fsp, Fa, Fap, S, Sp, Sf, Sfp, Sb, Sbp). The <code>\@hRubik</code> is the vertical shift used
<code>\@rra</code>	to raise the box carrying the rotation rotation-code in <code>\Rubik..</code> commands not
<code>\@rrap</code>	visible from the front.
<code>\@xyzh</code>	The commands <code>\@xyzhbdf1</code> and <code>\@xyzbdf1Rubik</code> relate to the axis rotations
<code>\@xyzhp</code>	denoted as b, d, f, l; since these four letters have long upstrokes they require
<code>\@xyzRubik</code>	special fine-tuning for vertical position.
<code>\@xyzRubikp</code>	
<code>\@SquareLetter</code>	
<code>\@hRubik</code>	

The idea is that by using these internal tools taking parameters we are able to more easily standardise the size and position of all the various glyphs. For details of the rubikfont and rubikprime see Section 19.3).

Note that the TikZ ‘thick’ line code = 0.8pt (used in \@SquareLetter).

```

961 \newcommand{\@rr}[1]{\@rubikfont #1}
962 \newcommand{\@rrp}[1]{\@rubikfont #1\@rubikprime}
963 \newcommand{\@rrw}[1]{\@rubikfont #1\@rubikfontFNS w}}
964 \newcommand{\@rrwp}[1]{\@rubikfont #1\@rubikfontFNS w}\@rubikprime}
965 \newcommand{\@rrs}[1]{\@rubikfont #1\@rubikfontFNS s}}
966 \newcommand{\@rrsp}[1]{\@rubikfont #1\@rubikfontFNS s}\@rubikprime}
967 \newcommand{\@rra}[1]{\@rubikfont #1\@rubikfontFNS a}}
968 \newcommand{\@rrap}[1]{\@rubikfont #1\@rubikfontFNS a}\@rubikprime}
969 \newcommand{\@rru}[1]{\@rubikfont #1\@rubikfontFNS u}}
970 \newcommand{\@rrup}[1]{\@rubikfont #1\@rubikfontFNS u}\@rubikprime}
971 \newcommand{\@rrd}[1]{\@rubikfont #1\@rubikfontFNS d}}
972 \newcommand{\@rrdp}[1]{\@rubikfont #1\@rubikfontFNS d}\@rubikprime}
973 \newcommand{\@rrl}[1]{\@rubikfont #1\@rubikfontFNS l}}
974 \newcommand{\@rrlp}[1]{\@rubikfont #1\@rubikfontFNS l}\@rubikprime}
975 \newcommand{\@rrr}[1]{\@rubikfont #1\@rubikfontFNS r}}
976 \newcommand{\@rrrp}[1]{\@rubikfont #1\@rubikfontFNS r}\@rubikprime}
977 \newcommand{\@rrf}[1]{\@rubikfont #1\@rubikfontFNS f}}
978 \newcommand{\@rrfp}[1]{\@rubikfont #1\@rubikfontFNS f}\@rubikprime}
979 \newcommand{\@rrb}[1]{\@rubikfont #1\@rubikfontFNS b}}
980 \newcommand{\@rrbp}[1]{\@rubikfont #1\@rubikfontFNS b}\@rubikprime}
981 \newcommand{\@rrc}[1]{\@rubikfont #1\@rubikfontFNS c}}
982 \newcommand{\@rrcp}[1]{\@rubikfont #1\@rubikfontFNS c}\@rubikprime}
983 \newcommand{\@rrm}[1]{\@rubikfont #1\@rubikfontFNS m}}
984 \newcommand{\@rrmp}[1]{\@rubikfont #1\@rubikfontFNS m}\@rubikprime}
985 \newcommand{\@xyzh}[1]{\@rubikfont #1}}
986 \newcommand{\@xyzhp}[1]{\@rubikfont #1\@rubikprime}}
987 \newcommand{\@xyzRubik}[1]{\raisebox{3.45pt}{\@rubikfont #1}}
988 \newcommand{\@xyzRubikp}[1]{\raisebox{3.45pt}{\@rubikfont #1\@rubikprime}}
989 \newcommand{\@xyzbdf1}[1]{\raisebox{-0.6pt}{\@rubikfont #1}}
990 \newcommand{\@xyzbdf1Rubik}[1]{\raisebox{3.45pt}{\raisebox{-0.6pt}{\@rubikfont #1}}}
991 \newcommand{\@SquareLetter}[1]{\setlength{\fboxsep}{2.5pt}%
992 \setlength{\fboxrule}{0.8pt}%
993 \fbox{\rule[-1pt]{0pt}{8.5pt}\raisebox{-0.5pt}{#1}}}
994 \newlength\@hRubik%
995 \setlength{\@hRubik}{0.185cm}%

```

\@tlen Feb 2017 (RWDN): We also need to define a small length for fine-tuning the default horizontal space between a pair of ‘letter’ hieroglyphs, eg B (i.e., when no additional space has been added by the user), so that this matches that between a pair of ‘arrow’ hieroglyphs. This length is inserted on both sides of the square frame. This length is used in two settings: (a) in ‘letter’ hieroglyphs (for an example, see the definition of the macro \SquareB in Section 19.22.5), and in (b) in ‘arrow’ hieroglyphs (for an example, see the definition of the macro \rrhD in Section 19.22.13).

```
996 \newcommand{\@tlen}{\hspace{1pt}}%
```

`\@join` We also require a macro for joining two strings so we can convert a rotation-code, say U, into a macro which typesets it in some form, say `\rrhU`. The following `\@join{ }{ }` command is by Christian Tellechea (many thanks!).

USAGE: `\@join{<command-stem>}{<rotation-code>}`. For example, to create the command `\rrhU` we would write `\@join{\rrh}{U}`, and hence the command `\rrh{U}` is equivalent to `\rrhU` (see Section 19.22.4).

Since this macro is also useful for processing rotation-codes in a list, which may also include macros, it is important that #2 is not detokenized.

```
997 \newcommand*\@join[2]{%
998   \csname\expandafter\@gobble\string#1#2\endcsname}
```

19.22.4 Using \@join

`\textRubik` The following four commands typeset a single rotation, where the rotation-code
`\Rubik` (e.g., U) is the argument (see Section 8.1). As an example, the format for the
`\rr` `\rrh{ }` command is `\rrh{<rotation-code>}`. In practice, these four commands are
`\rrh` really a sort of front-end for all the commands which follow this section. For ex-
 ample, the command `\rrh{U}` generates the command `\rrhU` which itself typesets
 the rotation hieroglyph for the rotation U, etc.

These four commands, which use the internal `\@join` command (see Section 19.22.3), are especially useful when typesetting a list of rotation-codes. Furthermore, it seems more intuitive to specify a rotation command using the rotation-code as an argument.

```
999 \newcommand*\Rubik[1]{\@join{\Rubik}{#1}}
1000 \newcommand*\textRubik[1]{\@join{\textRubik}{#1}}
1001 \newcommand*\rr[1]{\@join{\rr}{#1}}
1002 \newcommand*\rrh[1]{\@join{\rrh}{#1}}
```

19.22.5 Rotation B

`\rrB` These commands all draw forms which denote the B (BACK-face) rotation. Not
`\SquareB` visible from the front.
`\rrhB` Feb 2017 (RWDN): added the `\@tlen` length (= 1pt; defined above) to the
`\RubikB` `\SquareB` command, and removed the terminal `\`, space from the `rrhB`, `RubikB`,
`\textRubikB` `textRubikB` commands, and copied this action with all the subsequent Letter
 hieroglyphs (e.g., B, Bw,...). These minor changes were to improve the spacing
 between two Letter hieroglyphs, and make it match that between two square
 ‘arrow’ hieroglyphs. The same changes were made to all the ‘letter’ hieroglyphs.

```
1003 \newcommand{\rrB}{\@rr{B}}
1004 \newcommand{\SquareB}{\@tlen\@SquareLetter{\rrB}\@tlen}
1005 \newcommand{\rrhB}{\raisebox{-0.25mm}{\SquareB}}
1006 \newcommand{\RubikB}{\raisebox{\@hRubik}{\SquareB}}
1007 \newcommand{\textRubikB}{\rrhB}
```

19.22.6 Rotation Bp

`\rrBp` These commands all draw forms which denote the Bp rotation. Not visible from
`\SquareBp` the front.
`\rrhBp` 1008 `\newcommand{\rrBp}{\@rrp{B}}`
`\RubikBp` 1009 `\newcommand{\SquareBp}{\@tlen\@SquareLetter{\rrBp}\@tlen}`
`\textRubikBp` 1010 `\newcommand{\rrhBp}{\raisebox{-0.25mm}{\SquareBp}}`
1011 `\newcommand{\RubikBp}{\raisebox{\@hRubik}{\SquareBp}}`
1012 `\newcommand{\textRubikBp}{\rrhBp}`

19.22.7 Rotation Bw

`\rrBw` These commands all draw forms which denote the Bw rotation. Not visible from
`\SquareBw` the front.
`\rrhBw` 1013 `\newcommand{\rrBw}{\@rrw{B}}`
`\RubikBw` 1014 `\newcommand{\SquareBw}{\@tlen\@SquareLetter{\rrBw}\@tlen}`
`\textRubikBw` 1015 `\newcommand{\rrhBw}{\raisebox{-0.25mm}{\SquareBw}}`
1016 `\newcommand{\RubikBw}{\raisebox{\@hRubik}{\SquareBw}}`
1017 `\newcommand{\textRubikBw}{\rrhBw}`

19.22.8 Rotation Bwp

`\rrBwp` These commands all draw forms which denote the Bwp rotation. Not visible from
`\SquareBwp` the front.
`\rrhBwp` 1018 `\newcommand{\rrBwp}{\@rrwp{B}}`
`\RubikBwp` 1019 `\newcommand{\SquareBwp}{\@tlen\@SquareLetter{\rrBwp}\@tlen}`
`\textRubikBwp` 1020 `\newcommand{\rrhBwp}{\raisebox{-0.25mm}{\SquareBwp}}`
1021 `\newcommand{\RubikBwp}{\raisebox{\@hRubik}{\SquareBwp}}`
1022 `\newcommand{\textRubikBwp}{\rrhBwp}`

19.22.9 Rotation Bs

`\rrBs` These commands all draw forms which denote the Bs rotation. Not visible from
`\SquareBs` the front.
`\rrhBs` 1023 `\newcommand{\rrBs}{\@rrs{B}}`
`\RubikBs` 1024 `\newcommand{\SquareBs}{\@tlen\@SquareLetter{\rrBs}\@tlen}`
`\textRubikBs` 1025 `\newcommand{\rrhBs}{\raisebox{-0.25mm}{\SquareBs}}`
1026 `\newcommand{\RubikBs}{\raisebox{\@hRubik}{\SquareBs}}`
1027 `\newcommand{\textRubikBs}{\rrhBs}`

19.22.10 Rotation Bsp

`\rrBsp` These commands all draw forms which denote the Bsp rotation. Not visible from
`\SquareBsp` the front.
`\rrhBsp` 1028 `\newcommand{\rrBsp}{\@rrsp{B}}`
`\RubikBsp` 1029 `\newcommand{\SquareBsp}{\@tlen\@SquareLetter{\rrBsp}\@tlen}`
`\textRubikBsp` 1030 `\newcommand{\rrhBsp}{\raisebox{-0.25mm}{\SquareBsp}}`
1031 `\newcommand{\RubikBsp}{\raisebox{\@hRubik}{\SquareBsp}}`
1032 `\newcommand{\textRubikBsp}{\rrhBsp}`

19.22.11 Rotation Ba

`\rrBa` These commands all draw forms which denote the Ba rotation. Not visible from
`\SquareBa` the front.

```
\rrhBa 1033 \newcommand{\rrBa}{\@rra{B}}
\RubikBa 1034 \newcommand{\SquareBa}{\@tlen\@SquareLetter{\rrBa}\@tlen}
\textRubikBa 1035 \newcommand{\rrhBa}{\raisebox{-0.25mm}{\SquareBa}}
1036 \newcommand{\RubikBa}{\raisebox{\@hRubik}{\SquareBa}}
1037 \newcommand{\textRubikBa}{\rrhBa}
```

19.22.12 Rotation Bap

`\rrBap` These commands all draw forms which denote the Bap rotation. Not visible from
`\SquareBap` the front.

```
\rrhBap 1038 \newcommand{\rrBap}{\@rrap{B}}
\RubikBap 1039 \newcommand{\SquareBap}{\@tlen\@SquareLetter{\rrBap}\@tlen}
\textRubikBap 1040 \newcommand{\rrhBap}{\raisebox{-0.25mm}{\SquareBap}}
1041 \newcommand{\RubikBap}{\raisebox{\@hRubik}{\SquareBap}}
1042 \newcommand{\textRubikBap}{\rrhBap}
```

19.22.13 Rotation D

`\rrD` These commands all draw forms which denote the D rotation.
`\SquareD` Feb 2017 (RWDN): added the `\@tlen` length to the `\rrhD` command to im-
`\rrhD` prove the spacing between two ‘arrow’ square hieroglyphs; and also removed the
`\RubikD` terminal `\`, space. The same changes were made to all the ‘arrow’ hieroglyphs.

```
\textRubikD 1043 \newcommand{\rrD}{\@rr{D}}
1044 %%
1045 \newcommand{\SquareD}{%
1046 \begin{tikzpicture}[scale=0.5]
1047 \DrawNotationBox;
1048 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1049 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1050 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1051 \end{tikzpicture}%
1052 }
1053 \newcommand{\rrhD}{\raisebox{-0.333\height}{\@tlen\SquareD\@tlen}}
1054 %%
1055 \newcommand{\RubikD}{%
1056 {\@rubikfont%
1057 \begin{minipage}{0.6cm}
1058 \centering%
1059 \SquareD\@tlen
1060 \rrD%
1061 \end{minipage}%
1062 }}
1063 \newcommand{\textRubikD}{\rrD\@tlen,\rrhD}
```

19.22.14 Rotation Dp

`\rrDp` These commands all draw forms which denote the Dp rotation.

```
\SquareDp 1064 \newcommand{\rrDp}{\@rrp{D}}
\rrhDp    1065 %%
\RubikDp  1066 \newcommand{\SquareDp}{%
\textRubikDp 1067 \begin{tikzpicture}[scale=0.5]
1068 \DrawNotationBox;
1069 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1070 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1071 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1072 \end{tikzpicture}%
1073 }
1074 \newcommand{\rrhDp}{\raisebox{-0.333\height}{\@tlen\SquareDp\@tlen}}
1075 %%
1076 \newcommand{\RubikDp}{%
1077 {\@rubikfont%
1078 \begin{minipage}{0.6cm}
1079 \centering%
1080 \SquareDp\@tlen
1081 \rrDp%
1082 \end{minipage}%
1083 }}
1084 \newcommand{\textRubikDp}{\rrDp\@tlen, \rrhDp}
```

19.22.15 Rotation Dw

`\rrDw` These commands all draw forms which denote the Dw rotation.

```
\SquareDw 1085 \newcommand{\rrDw}{\@rrw{D}}
\rrhDw    1086 %%
\RubikDw  1087 \newcommand{\SquareDw}{%
\textRubikDw 1088 \begin{tikzpicture}[scale=0.5]
1089 \DrawNotationBox;
1090 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1091 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1092 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1093 \end{tikzpicture}%
1094 }
1095 \newcommand{\rrhDw}{\raisebox{-0.333\height}{\@tlen\SquareDw\@tlen}}
1096 %%
1097 \newcommand{\RubikDw}{%
1098 {\@rubikfont%
1099 \begin{minipage}{0.6cm}
1100 \centering%
1101 \SquareDw\@tlen
1102 \rrDw%
1103 \end{minipage}%
1104 }}
1105 \newcommand{\textRubikDw}{\rrDw\@tlen, \rrhDw}
```

19.22.16 Rotation Dwp

`\rrDwp` These commands all draw forms which denote the Dwp rotation.

```
\SquareDwp 1106 \newcommand{\rrDwp}{\@rrwp{D}}
\rrhDwp 1107 %%
\RubikDwp 1108 \newcommand{\SquareDwp}{%
\textRubikDwp 1109 \begin{tikzpicture}[scale=0.5]
1110 \DrawNotationBox;
1111 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1112 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1113 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1114 \end{tikzpicture}%
1115 }
1116 \newcommand{\rrhDwp}{\raisebox{-0.333\height}{\@tlen\SquareDwp\@tlen}}
1117 %%
1118 \newcommand{\RubikDwp}{%
1119 {\@rubikfont%
1120 \begin{minipage}{0.6cm}
1121 \centering%
1122 \SquareDwp\@
1123 \rrDwp%
1124 \end{minipage}%
1125 }}
1126 \newcommand{\textRubikDwp}{\rrDwp\,\rrhDwp}
```

19.22.17 Rotation Ds

`\rrDs` These commands all draw forms which denote the Ds rotation.

```
\SquareDs 1127 \newcommand{\rrDs}{\@rrs{D}}
\rrhDs 1128 %%
\RubikDs 1129 \newcommand{\SquareDs}{%
\textRubikDs 1130 \begin{tikzpicture}[scale=0.5]
1131 \DrawNotationBox;
1132 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1133 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1134 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1135 \end{tikzpicture}%
1136 }
1137 \newcommand{\rrhDs}{\raisebox{-0.333\height}{\@tlen\SquareDs\@tlen}}
1138 %%
1139 \newcommand{\RubikDs}{%
1140 {\@rubikfont%
1141 \begin{minipage}{0.6cm}
1142 \centering%
1143 \SquareDs\@
1144 \rrDs%
1145 \end{minipage}%
1146 }}
1147 \newcommand{\textRubikDs}{\rrDs\,\rrhDs}
```

19.22.18 Rotation Dsp

`\rrDsp` These commands all draw forms which denote the Dsp rotation.

```
\SquareDsp 1148 \newcommand{\rrDsp}{\@rrsp{D}}
\rrhDsp 1149 %%
\RubikDsp 1150 \newcommand{\SquareDsp}{%
\textRubikDsp 1151 \begin{tikzpicture}[scale=0.5]
1152 \DrawNotationBox;
1153 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1154 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1155 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1156 \end{tikzpicture}%
1157 }
1158 \newcommand{\rrhDsp}{\raisebox{-0.333\height}{\@tlen\SquareDsp\@tlen}}
1159 %%
1160 \newcommand{\RubikDsp}{%
1161 {\@rubikfont%
1162 \begin{minipage}{0.6cm}
1163 \centering%
1164 \SquareDsp\
1165 \rrDsp%
1166 \end{minipage}%
1167 }}
1168 \newcommand{\textRubikDsp}{\rrDsp\,\rrhDsp}
```

19.22.19 Rotation Da

`\rrDa` These commands all draw forms which denote the Da rotation.

```
\SquareDa 1169 \newcommand{\rrDa}{\@rra{D}}
\rrhDa 1170 %%
\RubikDa 1171 \newcommand{\SquareDa}{%
\textRubikDa 1172 \begin{tikzpicture}[scale=0.5]
1173 \DrawNotationBox;
1174 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1175 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1176 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1177 \end{tikzpicture}%
1178 }
1179 \newcommand{\rrhDa}{\raisebox{-0.333\height}{\@tlen\SquareDa\@tlen}}
1180 %%
1181 \newcommand{\RubikDa}{%
1182 {\@rubikfont%
1183 \begin{minipage}{0.6cm}
1184 \centering%
1185 \SquareDa\
1186 \rrDa%
1187 \end{minipage}%
1188 }}
1189 \newcommand{\textRubikDa}{\rrDa\,\rrhDa}
```

19.22.20 Rotation Dap

`\rrDap` These commands all draw forms which denote the Dap rotation.

```
\SquareDap 1190 \newcommand{\rrDap}{\@rrap{D}}
\rrhDap 1191 %%
\RubikDap 1192 \newcommand{\SquareDap}{%
\textRubikDap 1193 \begin{tikzpicture}[scale=0.5]
1194 \DrawNotationBox;
1195 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1196 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1197 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1198 \end{tikzpicture}%
1199 }
1200 \newcommand{\rrhDap}{\raisebox{-0.333\height}{\@tlen\SquareDap\@tlen}}
1201 %%
1202 \newcommand{\RubikDap}{%
1203 {\@rubikfont%
1204 \begin{minipage}{0.6cm}
1205 \centering%
1206 \SquareDap\@tlen
1207 \rrDap%
1208 \end{minipage}%
1209 }}
1210 \newcommand{\textRubikDap}{\rrDap\, \rrhDap}
```

19.22.21 Rotation E

`\rrE` These commands all draw forms which denote the E rotation.

```
\SquareE 1211 \newcommand{\rrE}{\@rr{E}}
\rrhE 1212 %%
\RubikE 1213 \newcommand{\SquareE}{%
\textRubikE 1214 \begin{tikzpicture}[scale=0.5]
1215 \DrawNotationBox;
1216 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1217 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1218 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1219 \end{tikzpicture}%
1220 }
1221 \newcommand{\rrhE}{\raisebox{-0.333\height}{\@tlen\SquareE\@tlen}}
1222 %%
1223 \newcommand{\RubikE}{%
1224 {\@rubikfont%
1225 \begin{minipage}{0.6cm}
1226 \centering%
1227 \SquareE\@tlen
1228 \rrE%
1229 \end{minipage}%
1230 }}
1231 \newcommand{\textRubikE}{\rrE\, \rrhE}
```

19.22.22 Rotation Ep

`\rrEp` These commands all draw forms which denote the Ep rotation.

```
\SquareEp 1232 \newcommand{\rrEp}{\@rrp{E}}
\rrhEp    1233 %%
\RubikEp  1234 \newcommand{\SquareEp}{%
\textRubikEp 1235 \begin{tikzpicture}[scale=0.5]
1236 \DrawNotationBox;
1237 \draw [thick] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1238 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1239 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1240 \end{tikzpicture}%
1241 }
1242 \newcommand{\rrhEp}{\raisebox{-0.333\height}{\@tlen\SquareEp\@tlen}}
1243 %%
1244 \newcommand{\RubikEp}{%
1245 {\@rubikfont%
1246 \begin{minipage}{0.6cm}
1247 \centering%
1248 \SquareEp\
1249 \rrEp%
1250 \end{minipage}%
1251 }}
1252 \newcommand{\textRubikEp}{\rrEp\,\rrhEp}
```

19.22.23 Rotation F

`\rrF` These commands all draw forms which denote the F rotation.

```
\SquareF 1253 \newcommand{\rrF}{\@rr{F}}
\rrhF    1254 %%
\RubikF  1255 \newcommand{\SquareF}{%
\textRubikF 1256 \begin{tikzpicture}[scale=0.5]
1257 \DrawNotationBox;
1258 \draw [thick, <-] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1259 \end{tikzpicture}%
1260 }
1261 \newcommand{\rrhF}{\raisebox{-0.333\height}{\@tlen\SquareF\@tlen}}
1262 %%
1263 \newcommand{\RubikF}{%
1264 {\@rubikfont%
1265 \begin{minipage}{0.6cm}
1266 \centering%
1267 \SquareF\
1268 \rrF%
1269 \end{minipage}%
1270 }}
1271 \newcommand{\textRubikF}{\rrF\,\rrhF}
```

19.22.24 Rotation Fp

`\rrFp` These commands all draw forms which denote the Fp rotation.

```
\SquareFp 1272 \newcommand{\rrFp}{\@rrp{F}}
\rrhFp    1273 %%
\RubikFp  1274 \newcommand{\SquareFp}{%
\textRubikFp 1275 \begin{tikzpicture}[scale=0.5]
1276 \DrawNotationBox;
1277 \draw [thick, ->] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1278 \end{tikzpicture}%
1279 }
1280 \newcommand{\rrhFp}{\raisebox{-0.333\height}{\@tlen\SquareFp\@tlen}}
1281 %%
1282 \newcommand{\RubikFp}{%
1283 {\@rubikfont%
1284 \begin{minipage}{0.6cm}
1285 \centering%
1286 \SquareFp\
1287 \rrFp%
1288 \end{minipage}%
1289 }}
1290 \newcommand{\textRubikFp}{\rrFp\,\rrhFp}
```

19.22.25 Rotation Fw

`\rrFw` These commands all draw forms which denote the Fw rotation.

```
\SquareFw 1291 \newcommand{\rrFw}{\@rrw{F}}
\rrhFw    1292 %%
\RubikFw  1293 \newcommand{\SquareFw}{%
\textRubikFw 1294 \begin{tikzpicture}[scale=0.5]
1295 \DrawNotationBox;
1296 \draw [thick, <-] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1297 \draw [thick] (\@sqcx,\@sqcy) arc[radius=0.1, start angle=-60, delta angle=360];
1298 \node (squareLab) at (0.5,0.5) {$o$};
1299 \end{tikzpicture}%
1300 }
1301 \newcommand{\rrhFw}{\raisebox{-0.333\height}{\@tlen\SquareFw\@tlen}}
1302 %%
1303 \newcommand{\RubikFw}{%
1304 {\@rubikfont%
1305 \begin{minipage}{0.6cm}
1306 \centering%
1307 \SquareFw\
1308 \rrFw%
1309 \end{minipage}%
1310 }}
1311 \newcommand{\textRubikFw}{\rrFw\,\rrhFw}
```

19.22.26 Rotation Fwp

`\rrFwp` These commands all draw forms which denote the Fwp rotation.

```
\SquareFwp 1312 \newcommand{\rrFwp}{\@rrwp{F}}
\rrhFwp 1313 %%
\RubikFwp 1314 \newcommand{\SquareFwp}{%
\textRubikFwp 1315 \begin{tikzpicture}[scale=0.5]
1316 \DrawNotationBox;
1317 \draw [thick, ->] (\@scx, \@scy) arc[radius=0.35, start angle=-60, delta angle=290];
1318 \draw [thick] (\@sqcx,\@sqcy) arc[radius=0.1, start angle=-60, delta angle=360];
1319 \end{tikzpicture}%
1320 }
1321 \newcommand{\rrhFwp}{\raisebox{-0.333\height}{\@tlen\SquareFwp\@tlen}}
1322 %%
1323 \newcommand{\RubikFwp}{%
1324 {\@rubikfont%
1325 \begin{minipage}{0.6cm}
1326 \centering%
1327 \SquareFwp\
1328 \rrFwp%
1329 \end{minipage}%
1330 }}
1331 \newcommand{\textRubikFwp}{\rrFwp\,\rrhFwp}
1332 %%
```

19.22.27 Rotation Fs

`\rrFs` These commands draw forms of the Singmaster Fs slice rotation. We need to just
`\rrhFs` make square with Fs in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikFs` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikFs` reset to defaults. Not visible from the front.

```
1333 \newcommand{\rrFs}{\@rrs{F}}
1334 \newcommand{\SquareFs}{\@tlen\@SquareLetter{\rrFs}\@tlen}
1335 \newcommand{\rrhFs}{\raisebox{-0.25mm}{\SquareFs}}
1336 \newcommand{\RubikFs}{\raisebox{\@hRubik}{\SquareFs}}
1337 \newcommand{\textRubikFs}{\rrhFs}
```

19.22.28 Rotation Fsp

`\rrFsp` These commands draw forms of the Singmaster Fsp slice rotation. We need to
`\rrhFsp` just make square with Fsp in square; adjust box height using a `\rule`; adjust
`\RubikFsp` `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no
`\textRubikFsp` need to reset to defaults. Not visible from the front.

```
1338 \newcommand{\rrFsp}{\@rrsp{F}}
1339 \newcommand{\SquareFsp}{\@tlen\@SquareLetter{\rrFsp}\@tlen}
1340 \newcommand{\rrhFsp}{\raisebox{-0.25mm}{\SquareFsp}}
1341 \newcommand{\RubikFsp}{\raisebox{\@hRubik}{\SquareFsp}}
1342 \newcommand{\textRubikFsp}{\rrhFsp}
```


19.22.29 Rotation Fa

`\rrFa` These commands draw forms of the Singmaster Fa slice rotation. We need to just
`\rrhFa` make square with Fa in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikFa` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikFa` reset to defaults. Not visible from the front.

```
1343 \newcommand{\rrFa}{\@rra{F}}
1344 \newcommand{\SquareFa}{\@tlen\@SquareLetter{\rrFa}\@tlen}
1345 \newcommand{\rrhFa}{\raisebox{-0.25mm}{\SquareFa}}
1346 \newcommand{\RubikFa}{\raisebox{\@hRubik}{\SquareFa}}
1347 \newcommand{\textRubikFa}{\rrhFa}
```

19.22.30 Rotation Fap

`\rrFap` These commands draw forms of the Singmaster Fap slice rotation. We need to
`\rrhFap` just make square with Fap in square; adjust box height using a `\rule`; adjust
`\RubikFap` `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no
`\textRubikFap` need to reset to defaults. Not visible from the front.

```
1348 \newcommand{\rrFap}{\@rrap{F}}
1349 \newcommand{\SquareFap}{\@tlen\@SquareLetter{\rrFap}\@tlen}
1350 \newcommand{\rrhFap}{\raisebox{-0.25mm}{\SquareFap}}
1351 \newcommand{\RubikFap}{\raisebox{\@hRubik}{\SquareFap}}
1352 \newcommand{\textRubikFap}{\rrhFap}
```

19.22.31 Rotation L

`\rrL` These commands all draw forms which denote the L rotation.

```
\SquareL 1353 \newcommand{\rrL}{\@rr{L}}
\rrhL    1354 %%
\RubikL  1355 \newcommand{\SquareL}{%
\textRubikL 1356 \begin{tikzpicture}[scale=0.5]
1357 \DrawNotationBox;
1358 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1359 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1360 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1361 \end{tikzpicture}%
1362 }
1363 \newcommand{\rrhL}{\raisebox{-0.333\height}{\@tlen\SquareL\@tlen}}
1364 %%
1365 \newcommand{\RubikL}{%
1366 {\@rubikfont%
1367 \begin{minipage}{0.6cm}
1368 \centering%
1369 \SquareL\
1370 \rrL%
1371 \end{minipage}%
1372 }}
1373 \newcommand{\textRubikL}{\rrL\,\rrhL}
```

19.22.32 Rotation Lp

`\rrLp` These commands all draw forms which denote the Lp rotation.

```
\SquareLp 1374 \newcommand{\rrLp}{\@rrp{L}}
\rrhLp 1375 %%
\RubikLp 1376 \newcommand{\SquareLp}{%
\textRubikLp 1377 \begin{tikzpicture}[scale=0.5]
1378 \DrawNotationBox;
1379 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1380 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1381 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1382 \end{tikzpicture}%
1383 }
1384 \newcommand{\rrhLp}{\raisebox{-0.333\height}{\@tlen\SquareLp\@tlen}}
1385 %%
1386 \newcommand{\RubikLp}{%
1387 {\@rubikfont%
1388 \begin{minipage}{0.6cm}
1389 \centering%
1390 \SquareLp\
1391 \rrLp%
1392 \end{minipage}%
1393 }}
1394 \newcommand{\textRubikLp}{\rrLp\,\rrhLp}
```

19.22.33 Rotation Lw

`\rrLw` These commands all draw forms which denote the Lw rotation.

```
\SquareLw 1395 \newcommand{\rrLw}{\@rrw{L}}
\rrhLw 1396 %%
\RubikLw 1397 \newcommand{\SquareLw}{%
\textRubikLw 1398 \begin{tikzpicture}[scale=0.5]
1399 \DrawNotationBox;
1400 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1401 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1402 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1403 \end{tikzpicture}%
1404 }
1405 \newcommand{\rrhLw}{\raisebox{-0.333\height}{\@tlen\SquareLw\@tlen}}
1406 %%
1407 \newcommand{\RubikLw}{%
1408 {\@rubikfont%
1409 \begin{minipage}{0.6cm}
1410 \centering%
1411 \SquareLw\
1412 \rrLw%
1413 \end{minipage}%
1414 }}
1415 \newcommand{\textRubikLw}{\rrLw\,\rrhLw}
```

19.22.34 Rotation Lwp

`\rrLwp` These commands all draw forms which denote the Lwp rotation.

```
\SquareLwp 1416 \newcommand{\rrLwp}{\@rrwp{L}}
\rrhLwp 1417 %%
\RubikLwp 1418 \newcommand{\SquareLwp}{%
\textRubikLwp 1419 \begin{tikzpicture}[scale=0.5]
1420 \DrawNotationBox;
1421 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1422 \draw [thick,->] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1423 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1424 \end{tikzpicture}%
1425 }
1426 \newcommand{\rrhLwp}{\raisebox{-0.333\height}{\@tlen\SquareLwp\@tlen}}
1427 %%
1428 \newcommand{\RubikLwp}{%
1429 {\@rubikfont%
1430 \begin{minipage}{0.6cm}
1431 \centering%
1432 \SquareLwp\
1433 \rrLwp%
1434 \end{minipage}%
1435 }}
1436 \newcommand{\textRubikLwp}{\rrLwp\,\rrhLwp}
```

19.22.35 Rotation Ls

`\rrLs` These commands all draw forms which denote the Ls rotation.

```
\SquareLs 1437 \newcommand{\rrLs}{\@rrs{L}}
\rrhLs 1438 %%
\RubikLs 1439 \newcommand{\SquareLs}{%
\textRubikLs 1440 \begin{tikzpicture}[scale=0.5]
1441 \DrawNotationBox;
1442 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1443 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1444 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1445 \end{tikzpicture}%
1446 }
1447 \newcommand{\rrhLs}{\raisebox{-0.333\height}{\@tlen\SquareLs\@tlen}}
1448 %%
1449 \newcommand{\RubikLs}{%
1450 {\@rubikfont%
1451 \begin{minipage}{0.6cm}
1452 \centering%
1453 \SquareLs\
1454 \rrLs%
1455 \end{minipage}%
1456 }}
1457 \newcommand{\textRubikLs}{\rrLs\,\rrhLs}
```

19.22.36 Rotation Lsp

`\rrLsp` These commands all draw forms which denote the Lsp rotation.

```
\SquareLsp 1458 \newcommand{\rrLsp}{\@rrsp{L}}
\rrhLsp 1459 %%
\RubikLsp 1460 \newcommand{\SquareLsp}{%
\textRubikLsp 1461 \begin{tikzpicture}[scale=0.5]
1462 \DrawNotationBox;
1463 \draw [thick, ->] (\@sd, \@sb) -- (\@sd, \@sbh);
1464 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1465 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1466 \end{tikzpicture}%
1467 }
1468 \newcommand{\rrhLsp}{\raisebox{-0.333\height}{\@tlen\SquareLsp\@tlen}}
1469 %%
1470 \newcommand{\RubikLsp}{%
1471 {\@rubikfont%
1472 \begin{minipage}{0.6cm}
1473 \centering%
1474 \SquareLsp\
1475 \rrLsp%
1476 \end{minipage}%
1477 }}
1478 \newcommand{\textRubikLsp}{\rrLsp\,\rrhLsp}
```

19.22.37 Rotation La

`\rrLa` These commands all draw forms which denote the La rotation.

```
\SquareLa 1479 \newcommand{\rrLa}{\@rra{L}}
\rrhLa 1480 %%
\RubikLa 1481 \newcommand{\SquareLa}{%
\textRubikLa 1482 \begin{tikzpicture}[scale=0.5]
1483 \DrawNotationBox;
1484 \draw [thick, <-] (\@sd, \@sb) -- (\@sd, \@sbh);
1485 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1486 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1487 \end{tikzpicture}%
1488 }
1489 \newcommand{\rrhLa}{\raisebox{-0.333\height}{\@tlen\SquareLa\@tlen}}
1490 %%
1491 \newcommand{\RubikLa}{%
1492 {\@rubikfont%
1493 \begin{minipage}{0.6cm}
1494 \centering%
1495 \SquareLa\
1496 \rrLa%
1497 \end{minipage}%
1498 }}
1499 \newcommand{\textRubikLa}{\rrLa\,\rrhLa}
```

19.22.38 Rotation Lap

`\rrLap` These commands all draw forms which denote the Lap rotation.

```
\SquareLap 1500 \newcommand{\rrLap}{\@rrap{L}}
\rrhLap 1501 %%
\RubikLap 1502 \newcommand{\SquareLap}{%
\textRubikLap 1503 \begin{tikzpicture}[scale=0.5]
1504 \DrawNotationBox;
1505 \draw [thick, ->] (\@sd, \@sb) -- (\@sd, \@sbh);
1506 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1507 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1508 \end{tikzpicture}%
1509 }
1510 \newcommand{\rrhLap}{\raisebox{-0.333\height}{\@tlen\SquareLap\@tlen}}
1511 %%
1512 \newcommand{\RubikLap}{%
1513 {\@rubikfont%
1514 \begin{minipage}{0.6cm}
1515 \centering%
1516 \SquareLap\@tlen
1517 \rrLap%
1518 \end{minipage}%
1519 }}
1520 \newcommand{\textRubikLap}{\rrLap\, \rrhLap}
```

19.22.39 Rotation M

`\rrM` These commands all draw forms which denote the M rotation.

```
\SquareM 1521 \newcommand{\rrM}{\@rr{M}}
\rrhM 1522 %%
\RubikM 1523 \newcommand{\SquareM}{%
\textRubikM 1524 \begin{tikzpicture}[scale=0.5]
1525 \DrawNotationBox;
1526 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1527 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1528 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1529 \end{tikzpicture}%
1530 }
1531 \newcommand{\rrhM}{\raisebox{-0.333\height}{\@tlen\SquareM\@tlen}}
1532 %%
1533 \newcommand{\RubikM}{%
1534 {\@rubikfont%
1535 \begin{minipage}{0.6cm}
1536 \centering%
1537 \SquareM\@tlen
1538 \rrM%
1539 \end{minipage}%
1540 }}
1541 \newcommand{\textRubikM}{\rrM\, \rrhM}
```

19.22.40 Rotation Mp

`\rrMp` These commands all draw forms which denote the Mp rotation.

```
\SquareMp 1542 \newcommand{\rrMp}{\@rrp{M}}
\rrhMp    1543 %%
\RubikMp  1544 \newcommand{\SquareMp}{%
\textRubikMp 1545 \begin{tikzpicture}[scale=0.5]
1546 \DrawNotationBox;
1547 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1548 \draw [thick,->] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1549 \draw [thick] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1550 \end{tikzpicture}%
1551 }
1552 \newcommand{\rrhMp}{\raisebox{-0.333\height}{\@tlen\SquareMp\@tlen}}
1553 %%
1554 \newcommand{\RubikMp}{%
1555 {\@rubikfont%
1556 \begin{minipage}{0.6cm}
1557 \centering%
1558 \SquareMp\
1559 \rrMp%
1560 \end{minipage}%
1561 }}
1562 \newcommand{\textRubikMp}{\rrMp\,\rrhMp}
```

19.22.41 Rotation R

`\rrR` These commands all draw forms which denote the R rotation.

```
\SquareR 1563 \newcommand{\rrR}{\@rr{R}}
\rrhR    1564 %%
\RubikR  1565 \newcommand{\SquareR}{%
\textRubikR 1566 \begin{tikzpicture}[scale=0.5]
1567 \DrawNotationBox;
1568 %% draw three lines in the square, one with an arrow
1569 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1570 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1571 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1572 \end{tikzpicture}%
1573 }
1574 \newcommand{\rrhR}{\raisebox{-0.333\height}{\@tlen\SquareR\@tlen}}
1575 %%
1576 \newcommand{\RubikR}{%
1577 {\@rubikfont%
1578 \begin{minipage}{0.6cm}
1579 \centering%
1580 \SquareR\
1581 \rrR%
1582 \end{minipage}%
1583 }}
1584 \newcommand{\textRubikR}{\rrR\,\rrhR}
```

19.22.42 Rotation Rp

`\rrRp` These commands all draw forms which denote the Rp rotation.

```
\SquareRp 1585 \newcommand{\rrRp}{\@rrp{R}}
\rrhRp    1586 %%
\RubikRp  1587 \newcommand{\SquareRp}{%
\textRubikRp 1588 \begin{tikzpicture}[scale=0.5]
1589 \DrawNotationBox;
1590 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1591 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1592 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1593 \end{tikzpicture}%
1594 }
1595 \newcommand{\rrhRp}{\raisebox{-0.333\height}{\@tlen\SquareRp\@tlen}}
1596 %%
1597 \newcommand{\RubikRp}{%
1598 {\@rubikfont%
1599 \begin{minipage}{0.6cm}
1600 \centering%
1601 \SquareRp\
1602 \rrRp%
1603 \end{minipage}%
1604 }}
1605 \newcommand{\textRubikRp}{\rrRp\,\rrhRp}
```

19.22.43 Rotation Rw

`\rrRw` These commands all draw forms which denote the Rw rotation.

```
\SquareRw 1606 \newcommand{\rrRw}{\@rrw{R}}
\rrhRw    1607 %%
\RubikRw  1608 \newcommand{\SquareRw}{%
\textRubikRw 1609 \begin{tikzpicture}[scale=0.5]
1610 \DrawNotationBox;
1611 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1612 \draw [thick, ->] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1613 \draw [thick, ->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1614 \end{tikzpicture}%
1615 }
1616 \newcommand{\rrhRw}{\raisebox{-0.333\height}{\@tlen\SquareRw\@tlen}}
1617 %%
1618 \newcommand{\RubikRw}{%
1619 {\@rubikfont%
1620 \begin{minipage}{0.6cm}
1621 \centering%
1622 \SquareRw\
1623 \rrRw%
1624 \end{minipage}%
1625 }}
1626 \newcommand{\textRubikRw}{\rrRw\,\rrhRw}
```

19.22.44 Rotation Rwp

`\rrRwp` These commands all draw forms which denote the Rwp rotation.

```
\SquareRwp 1627 \newcommand{\rrRwp}{\@rrwp{R}}
\rrhRwp 1628 %%
\RubikRwp 1629 \newcommand{\SquareRwp}{%
\textRubikRwp 1630 \begin{tikzpicture}[scale=0.5]
1631 \DrawNotationBox;
1632 \draw [thick] (\@sd, \@sb) -- (\@sd, \@sbh);
1633 \draw [thick, <-] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1634 \draw [thick, <-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1635 \end{tikzpicture}%
1636 }
1637 \newcommand{\rrhRwp}{\raisebox{-0.333\height}{\@tlen\SquareRwp\@tlen}}
1638 %%
1639 \newcommand{\RubikRwp}{%
1640 {\@rubikfont%
1641 \begin{minipage}{0.6cm}
1642 \centering%
1643 \SquareRwp\@
1644 \rrRwp%
1645 \end{minipage}%
1646 }}
1647 \newcommand{\textRubikRwp}{\rrRwp\, \rrhRwp}
```

19.22.45 Rotation Rs

`\rrRs` These commands all draw forms which denote the Rs rotation.

```
\SquareRs 1648 \newcommand{\rrRs}{\@rrs{R}}
\rrhRs 1649 %%
\RubikRs 1650 \newcommand{\SquareRs}{%
\textRubikRs 1651 \begin{tikzpicture}[scale=0.5]
1652 \DrawNotationBox;
1653 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1654 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1655 \draw [thick,->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1656 \end{tikzpicture}%
1657 }
1658 \newcommand{\rrhRs}{\raisebox{-0.333\height}{\@tlen\SquareRs\@tlen}}
1659 %%
1660 \newcommand{\RubikRs}{%
1661 {\@rubikfont%
1662 \begin{minipage}{0.6cm}
1663 \centering%
1664 \SquareRs\@
1665 \rrRs%
1666 \end{minipage}%
1667 }}
1668 \newcommand{\textRubikRs}{\rrRs\, \rrhRs}
```


19.22.46 Rotation Rsp

`\rrRsp` These commands all draw forms which denote the Rsp rotation.

```
\SquareRsp 1669 \newcommand{\rrRsp}{\@rrsp{R}}
\rrhRsp 1670 %%
\RubikRsp 1671 \newcommand{\SquareRsp}{%
\textRubikRsp 1672 \begin{tikzpicture}[scale=0.5]
1673 \DrawNotationBox;
1674 \draw [thick,<-] (\@sd, \@sb) -- (\@sd, \@sbh);
1675 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1676 \draw [thick,<-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1677 \end{tikzpicture}%
1678 }
1679 \newcommand{\rrhRsp}{\raisebox{-0.333\height}{\@tlen\SquareRsp\@tlen}}
1680 %%
1681 \newcommand{\RubikRsp}{%
1682 {\@rubikfont%
1683 \begin{minipage}{0.6cm}
1684 \centering%
1685 \SquareRsp\
1686 \rrRsp%
1687 \end{minipage}%
1688 }}
1689 \newcommand{\textRubikRsp}{\rrRsp\,\rrhRsp}
```

19.22.47 Rotation Ra

`\rrRa` These commands all draw forms which denote the Ra rotation.

```
\SquareRa 1690 \newcommand{\rrRa}{\@rra{R}}
\rrhRa 1691 %%
\RubikRa 1692 \newcommand{\SquareRa}{%
\textRubikRa 1693 \begin{tikzpicture}[scale=0.5]
1694 \DrawNotationBox;
1695 \draw [thick,<-] (\@sd, \@sb) -- (\@sd, \@sbh);
1696 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1697 \draw [thick,->] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1698 \end{tikzpicture}%
1699 }
1700 \newcommand{\rrhRa}{\raisebox{-0.333\height}{\@tlen\SquareRa\@tlen}}
1701 %%
1702 \newcommand{\RubikRa}{%
1703 {\@rubikfont%
1704 \begin{minipage}{0.6cm}
1705 \centering%
1706 \SquareRa\
1707 \rrRa%
1708 \end{minipage}%
1709 }}
1710 \newcommand{\textRubikRa}{\rrRa\,\rrhRa}
```

19.22.48 Rotation Rap

`\rrRap` These commands all draw forms which denote the Rap rotation.

```
\SquareRap 1711 \newcommand{\rrRap}{\@rrap{R}}
\rrhRap    1712 %%
\RubikRap  1713 \newcommand{\SquareRap}{%
\textRubikRap 1714 \begin{tikzpicture}[scale=0.5]
1715 \DrawNotationBox;
1716 \draw [thick,->] (\@sd, \@sb) -- (\@sd, \@sbh);
1717 \draw [thick] (\@sdd,\@sb) -- (\@sdd, \@sbh);
1718 \draw [thick,<-] (\@sddd, \@sb) -- (\@sddd, \@sbh);
1719 \end{tikzpicture}%
1720 }
1721 \newcommand{\rrhRap}{\raisebox{-0.333\height}{\@tlen\SquareRap\@tlen}}
1722 %%
1723 \newcommand{\RubikRap}{%
1724 {\@rubikfont%
1725 \begin{minipage}{0.6cm}
1726 \centering%
1727 \SquareRap\@tlen
1728 \rrRap%
1729 \end{minipage}%
1730 }}
1731 \newcommand{\textRubikRap}{\rrRap\, \rrhRap}
```

19.22.49 Rotation S

`\rrS` These commands all draw forms which denote the S rotation. Not visible from the front.

```
\rrhS 1732 \newcommand{\rrS}{\@rr{S}}
\RubikS 1733 \newcommand{\SquareS}{\@tlen\SquareLetter{\rrS}\@tlen}
\textRubikS 1734 \newcommand{\rrhS}{\raisebox{-0.25mm}{\SquareS}}
1735 \newcommand{\RubikS}{\raisebox{\@hRubik}{\SquareS}}
1736 \newcommand{\textRubikS}{\rrhS}
```

19.22.50 Rotation Sp

`\rrSp` These commands all draw forms which denote the Sp rotation. Not visible from the front.

```
\rrhSp 1737 \newcommand{\rrSp}{\@rrp{S}}
\RubikSp 1738 \newcommand{\SquareSp}{\@tlen\SquareLetter{\rrSp}\@tlen}
\textRubikSp 1739 \newcommand{\rrhSp}{\raisebox{-0.25mm}{\SquareSp}}
1740 \newcommand{\RubikSp}{\raisebox{\@hRubik}{\SquareSp}}
1741 \newcommand{\textRubikSp}{\rrhSp}
```

19.22.51 Rotation Su

`\rrSu` These commands draw forms of the Singmaster Su slice rotation. We also need to fine-tune the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).

```
\rrhSu
\RubikSu
\textRubikSu
```

```

1742 \newcommand{\rrSu}{\@rru{S}}
1743 \newcommand{\rrhSu}{\rrhEp}%
1744 \newcommand{\RubikSu}{%
1745 {\@rubikfont%
1746 \begin{minipage}{0.6cm}
1747 \centering%
1748 \SquareEp\\
1749 \rrSu%
1750 \end{minipage}%
1751 }}
1752 \newcommand{\textRubikSu}{\rrSu\,\rrhEp}

```

19.22.52 Rotation Sup

`\rrSup` These commands draw forms of the Singmaster Sup slice rotation. We also need
`\rrhSup` to fine-tune the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
`\RubikSup`

```

1753 \newcommand{\rrSup}{\@rrup{S}}
1754 \newcommand{\rrhSup}{\rrhE}%
1755 \newcommand{\RubikSup}{%
1756 {\@rubikfont%
1757 \begin{minipage}{0.6cm}
1758 \centering%
1759 \SquareE\\
1760 \rrSup%
1761 \end{minipage}%
1762 }}
1763 \newcommand{\textRubikSup}{\rrSup\,\rrhE}

```

19.22.53 Rotation Sd

`\rrSd` These commands draw forms of the Singmaster Sd slice rotation.
`\rrhSd`

```

1764 \newcommand{\rrSd}{\@rrd{S}}
1765 \newcommand{\rrhSd}{\rrhE}%
1766 \newcommand{\RubikSd}{%
1767 {\@rubikfont%
1768 \begin{minipage}{0.6cm}
1769 \centering%
1770 \SquareE\\
1771 \rrSd%
1772 \end{minipage}%
1773 }}
1774 \newcommand{\textRubikSd}{\rrSd\,\rrhE}

```

19.22.54 Rotation Sdp

`\rrSdp` These commands draw forms of the Singmaster Sdp slice rotation.
`\rrhSdp`

```

1775 \newcommand{\rrSdp}{\@rrdp{S}}
1776 \newcommand{\rrhSdp}{\rrhEp}%
1777 \newcommand{\RubikSdp}{%

```

```

1778 {\@rubikfont%
1779 \begin{minipage}{0.6cm}
1780 \centering%
1781 \SquareEp\
1782 \rrSdp%
1783 \end{minipage}%
1784 }}
1785 \newcommand{\textRubikSdp}{\rrSdp\,\rrhEp}

```

19.22.55 Rotation Sl

`\rrSl` These commands draw forms of the Singmaster Sl slice rotation.

```

\rrhSl 1786 \newcommand{\rrSl}{\@rrl{S}}
\RubikSl 1787 \newcommand{\rrhSl}{\rrhM}%
\textRubikSl 1788 \newcommand{\RubikSl}{%
1789 {\@rubikfont%
1790 \begin{minipage}{0.6cm}
1791 \centering%
1792 \SquareM\
1793 \rrSl%
1794 \end{minipage}%
1795 }}
1796 \newcommand{\textRubikSl}{\rrSl\,\rrhM}

```

19.22.56 Rotation Slp

`\rrSlp` These commands draw forms of the Singmaster Slp slice rotation.

```

\rrhSlp 1797 \newcommand{\rrSlp}{\@rrlp{S}}
\RubikSlp 1798 \newcommand{\rrhSlp}{\rrhMp}%
\textRubikSlp 1799 \newcommand{\RubikSlp}{%
1800 {\@rubikfont%
1801 \begin{minipage}{0.6cm}
1802 \centering%
1803 \SquareMp\
1804 \rrSlp%
1805 \end{minipage}%
1806 }}
1807 \newcommand{\textRubikSlp}{\rrSlp\,\rrhMp}

```

19.22.57 Rotation Sr

`\rrSr` These commands draw forms of the Singmaster Sr slice rotation.

```

\rrhSr 1808 \newcommand{\rrSr}{\@rrr{S}}
\RubikSr 1809 \newcommand{\rrhSr}{\rrhMp}%
\textRubikSr 1810 \newcommand{\RubikSr}{%
1811 {\@rubikfont%
1812 \begin{minipage}{0.6cm}
1813 \centering%
1814 \SquareMp\

```

```

1815 \rrSr%
1816 \end{minipage}%
1817 }}
1818 \newcommand{\textRubikSr}{\rrSr\,\rrhMp}

```

19.22.58 Rotation Srp

`\rrSrp` These commands draw forms of the Singmaster Srp slice rotation.

```

\rrhSrp 1819 \newcommand{\rrSrp}{\@rrrp{S}}
\RubikSrp 1820 \newcommand{\rrhSrp}{\rrhM}%
\textRubikSrp 1821 \newcommand{\RubikSrp}{%
1822 {\@rubikfont%
1823 \begin{minipage}{0.6cm}
1824 \centering%
1825 \SquareM\
1826 \rrSrp%
1827 \end{minipage}%
1828 }}
1829 \newcommand{\textRubikSrp}{\rrSrp\,\rrhM}

```

19.22.59 Rotation Sf

`\rrSf` These commands draw forms of the Singmaster Sf slice rotation. We need to just make square with Sf in square; adjust box height using a `\rule`; adjust `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to reset to defaults. Not visible from the front.

```

1830 \newcommand{\rrSf}{\@rrf{S}}
1831 \newcommand{\SquareSf}{\@tlen\@SquareLetter{\rrSf}\@tlen}
1832 \newcommand{\rrhSf}{\raisebox{-0.25mm}{\SquareSf}}
1833 \newcommand{\RubikSf}{\raisebox{\@hRubik}{\SquareSf}}
1834 \newcommand{\textRubikSf}{\rrhSf}

```

19.22.60 Rotation Sfp

`\rrSfp` These commands draw forms of the Singmaster Sfp slice rotation. We need to just make square with Sfp in square; adjust box height using a `\rule`; adjust `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to reset to defaults. Not visible from the front.

```

1835 \newcommand{\rrSfp}{\@rrfp{S}}
1836 \newcommand{\SquareSfp}{\@tlen\@SquareLetter{\rrSfp}\@tlen}
1837 \newcommand{\rrhSfp}{\raisebox{-0.25mm}{\SquareSfp}}
1838 \newcommand{\RubikSfp}{\raisebox{\@hRubik}{\SquareSfp}}
1839 \newcommand{\textRubikSfp}{\rrhSfp}

```

19.22.61 Rotation Sb

`\rrSb` These commands draw forms of the Singmaster Sb slice rotation. We need to just make square with Sb in square; adjust box height using a `\rule`; adjust `\fboxsep`

```

\rrhSb
\RubikSb
\textRubikSb

```

(default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to reset to defaults. Not visible from the front.

```
1840 \newcommand{\rrSb}{\@rrb{S}}
1841 \newcommand{\SquareSb}{\@tlen\@SquareLetter{\rrSb}\@tlen}
1842 \newcommand{\rrhSb}{\raisebox{-0.25mm}{\SquareSb}}
1843 \newcommand{\RubikSb}{\raisebox{\@hRubik}{\SquareSb}}
1844 \newcommand{\textRubikSb}{\rrhSb}
```

19.22.62 Rotation Sbp

`\rrSbp` These commands draw forms of the Singmaster Sbp slice rotation. We need to
`\rrhSbp` just make square with Sbp in square; adjust box height using a `\rule`; adjust
`\RubikSbp` `\fboxsep` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no
`\textRubikSbp` need to reset to defaults. Not visible from the front.

```
1845 \newcommand{\rrSbp}{\@rrbp{S}}
1846 \newcommand{\SquareSbp}{\@tlen\@SquareLetter{\rrSbp}\@tlen}
1847 \newcommand{\rrhSbp}{\raisebox{-0.25mm}{\SquareSbp}}
1848 \newcommand{\RubikSbp}{\raisebox{\@hRubik}{\SquareSbp}}
1849 \newcommand{\textRubikSbp}{\rrhSbp}
```

19.22.63 Rotation U

`\rrU` These commands all draw forms which denote the U rotation.
`\SquareU` 1850 \newcommand{\rrU}{\@err{U}}
`\rrhU` 1851 %%
`\RubikU` 1852 \newcommand{\SquareU}{%
`\textRubikU` 1853 \begin{tikzpicture}[scale=0.5]
1854 \DrawNotationBox;
1855 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1856 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1857 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1858 \end{tikzpicture}%
1859 }
1860 \newcommand{\rrhU}{\raisebox{-0.333\height}{\@tlen\SquareU\@tlen}}
1861 %%
1862 \newcommand{\RubikU}{%
1863 {\@rubikfont%
1864 \begin{minipage}{0.6cm}
1865 \centering%
1866 \SquareU\
1867 \rrU%
1868 \end{minipage}}%
1869 }}
1870 \newcommand{\textRubikU}{\rrU, \rrhU}

19.22.64 Rotation Uw

`\rrUw` These commands all draw forms which denote the Uw rotation.
`\SquareUw`
`\rrhUw`
`\RubikUw`
`\textRubikUw`

```

1871 \newcommand{\rrUw}{\@rrw{U}}
1872 %%
1873 \newcommand{\SquareUw}{%
1874 \begin{tikzpicture}[scale=0.5]
1875 \DrawNotationBox;
1876 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1877 \draw [thick, <-] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1878 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1879 \end{tikzpicture}%
1880 }
1881 %
1882 \newcommand{\rrhUw}{\raisebox{-0.333\height}{\@tlen\SquareUw\@tlen}}
1883 %%
1884 \newcommand{\RubikUw}{%
1885 {\@rubikfont%
1886 \begin{minipage}{0.6cm}
1887 \centering%
1888 \SquareUw\
1889 \rrUw%
1890 \end{minipage}}%%
1891 }}
1892 %%
1893 \newcommand{\textRubikUw}{\rrUw\,\rrhUw}

```

19.22.65 Rotation Up

\rrUp These commands all draw forms which denote the Up rotation.

```

\SquareUp 1894 \newcommand{\rrUp}{\@rrp{U}}
\rrhUp    1895 %%
\RubikUp  1896 \newcommand{\SquareUp}{%
\textRubikUp 1897 \begin{tikzpicture}[scale=0.5]
1898 \DrawNotationBox;
1899 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1900 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1901 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1902 \end{tikzpicture}%
1903 }
1904 \newcommand{\rrhUp}{\raisebox{-0.333\height}{\@tlen\SquareUp\@tlen}}
1905 %%
1906 \newcommand{\RubikUp}{%
1907 {\@rubikfont%
1908 \begin{minipage}{0.6cm}
1909 \centering%
1910 \SquareUp\
1911 \rrUp%
1912 \end{minipage}}%%
1913 }}
1914 \newcommand{\textRubikUp}{\rrUp\,\rrhUp}

```

19.22.66 Rotation Uwp

`\rrUwp` These commands all draw forms which denote the Uwp rotation.

```
\SquareUwp 1915 \newcommand{\rrUwp}{\@rrwp{U}}
\rrhUwp    1916 %%
\RubikUwp  1917 \newcommand{\SquareUwp}{%
\textRubikUwp 1918 \begin{tikzpicture}[scale=0.5]
1919 \DrawNotationBox;
1920 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1921 \draw [thick, ->] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1922 \draw [thick] (\@sb,\@sd) -- (\@sbh, \@sd);
1923 \end{tikzpicture}%
1924 }
1925 \newcommand{\rrhUwp}{\raisebox{-0.333\height}{\@tlen\SquareUwp\@tlen}}
1926 %%
1927 \newcommand{\RubikUwp}{%
1928 {\@rubikfont%
1929 \begin{minipage}{0.6cm}
1930 \centering%
1931 \SquareUwp\
1932 \rrUwp%
1933 \end{minipage}}%
1934 }}
1935 \newcommand{\textRubikUwp}{\rrUwp\,\rrhUwp}
```

19.22.67 Rotation Us

`\rrUs` These commands all draw forms which denote the Us rotation.

```
\SquareUs 1936 \newcommand{\rrUs}{\@rrs{U}}
\rrhUs    1937 %%
\RubikUs  1938 \newcommand{\SquareUs}{%
\textRubikUs 1939 \begin{tikzpicture}[scale=0.5]
1940 \DrawNotationBox;
1941 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1942 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1943 \draw [thick, <-] (\@sb,\@sd) -- (\@sbh, \@sd);
1944 \end{tikzpicture}%
1945 }
1946 \newcommand{\rrhUs}{\raisebox{-0.333\height}{\@tlen\SquareUs\@tlen}}
1947 %%
1948 \newcommand{\RubikUs}{%
1949 {\@rubikfont%
1950 \begin{minipage}{0.6cm}
1951 \centering%
1952 \SquareUs\
1953 \rrUs%
1954 \end{minipage}}%
1955 }}
1956 \newcommand{\textRubikUs}{\rrUs\,\rrhUs}
```


19.22.68 Rotation Usp

`\rrUsp` These commands all draw forms which denote the Usp rotation.

```
\SquareUsp 1957 \newcommand{\rrUsp}{\@rrsp{U}}
\rrhUs 1958 %%
\RubikUs 1959 \newcommand{\SquareUsp}{%
\textRubikUsp 1960 \begin{tikzpicture}[scale=0.5]
1961 \DrawNotationBox;
1962 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1963 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1964 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1965 \end{tikzpicture}%
1966 }
1967 \newcommand{\rrhUsp}{\raisebox{-0.333\height}{\@tlen\SquareUsp\@tlen}}
1968 %%
1969 \newcommand{\RubikUsp}{%
1970 {\@rubikfont%
1971 \begin{minipage}{0.6cm}
1972 \centering%
1973 \SquareUsp\
1974 \rrUsp%
1975 \end{minipage}%
1976 }}
1977 \newcommand{\textRubikUsp}{\rrUsp\,\rrhUsp}
```

19.22.69 Rotation Ua

`\rrUa` These commands all draw forms which denote the Ua rotation.

```
\SquareUa 1978 \newcommand{\rrUa}{\@rra{U}}
\rrhUa 1979 %%
\RubikUa 1980 \newcommand{\SquareUa}{%
\textRubikUa 1981 \begin{tikzpicture}[scale=0.5]
1982 \DrawNotationBox;
1983 \draw [thick, <-] (\@sb,\@sddd) -- (\@sbh, \@sddd);
1984 \draw [thick] (\@sb,\@sdd) -- (\@sbh, \@sdd);
1985 \draw [thick, ->] (\@sb,\@sd) -- (\@sbh, \@sd);
1986 \end{tikzpicture}%
1987 }
1988 \newcommand{\rrhUa}{\raisebox{-0.333\height}{\@tlen\SquareUa\@tlen}}
1989 %%
1990 \newcommand{\RubikUa}{%
1991 {\@rubikfont%
1992 \begin{minipage}{0.6cm}
1993 \centering%
1994 \SquareUa\
1995 \rrUa%
1996 \end{minipage}%
1997 }}
1998 \newcommand{\textRubikUa}{\rrUa\,\rrhUa}
```

19.22.70 Rotation Uap

`\rrUap` These commands all draw forms which denote the Uap rotation.

```
\SquareUap 1999 \newcommand{\rrUap}{\@rrap{U}}
\rrhUap    2000 %%
\RubikUap  2001 \newcommand{\SquareUap}{%
\textRubikUap 2002 \begin{tikzpicture}[scale=0.5]
2003 \DrawNotationBox;
2004 \draw [thick, ->] (\@sb,\@sddd) -- (\@sbh, \@sddd);
2005 \draw [thick]      (\@sb,\@sdd)  -- (\@sbh, \@sdd);
2006 \draw [thick, <-]  (\@sb,\@sd)   -- (\@sbh, \@sd);
2007 \end{tikzpicture}%
2008 }
2009 \newcommand{\rrhUap}{\raisebox{-0.333\height}{\@tlen\SquareUap\@tlen}}
2010 %%
2011 \newcommand{\RubikUap}{%
2012 {\@rubikfont%
2013 \begin{minipage}{0.6cm}
2014 \centering%
2015 \SquareUap\@tlen
2016 \rrUap%
2017 \end{minipage}%
2018 }}
2019 \newcommand{\textRubikUap}{\rrUap\, \rrhUap}
```

19.22.71 Rotations x and xp

`\rrx` These commands all draw forms which denote the x rotation.

```
\rrhx 2020 \newcommand{\rrx}{\@rr{x}}
\Rubikx 2021 \newcommand{\Rubikx}{\@xyzRubik{x}}
2022 \newcommand{\rrhx}{\@xyzh{x}}
```

`\rrxp` These commands all draw forms which denote the xp rotation.

```
\rrhxp 2023 \newcommand{\rrxp}{\@rrp{x}}
\Rubikxp 2024 \newcommand{\Rubikxp}{\@xyzRubikp{x}}
2025 \newcommand{\rrhxp}{\@xyzhp{x}}
```

19.22.72 Rotations y and yp

`\rry` These commands all draw forms which denote the y rotation.

```
\rrhy 2026 \newcommand{\rry}{\@rr{y}}
\Rubiky 2027 \newcommand{\Rubiky}{\@xyzRubik{y}}
2028 \newcommand{\rrhy}{\@xyzh{y}}
```

`\rryp` These commands all draw forms which denote the yp rotation.

```
\rrhyp 2029 \newcommand{\rryp}{\@rrp{y}}
\Rubikyp 2030 \newcommand{\Rubikyp}{\@xyzRubikp{y}}
2031 \newcommand{\rrhyp}{\@xyzhp{y}}
```

19.22.73 Rotations z and zp

`\rrz` These commands all draw forms which denote the z rotation.
`\rrhz` 2032 `\newcommand{\rrz}{\@rr{z}}`
`\Rubikz` 2033 `\newcommand{\Rubikz}{\@xyzRubik{z}}`
2034 `\newcommand{\rrhz}{\@xyzh{z}}`

`\rrzp` These commands all draw forms which denote the zp rotation.
`\rrhzp` 2035 `\newcommand{\rrzp}{\@rrp{z}}`
`\Rubikzp` 2036 `\newcommand{\Rubikzp}{\@xyzRubikp{z}}`
2037 `\newcommand{\rrhzp}{\@xyzhp{z}}`

19.22.74 Rotations u and d

`\rru` These commands all draw forms which denote the u rotation.
`\rrhu` 2038 `\newcommand{\rru}{\@rr{u}}`
`\Rubiku` 2039 `\newcommand{\Rubiku}{\@xyzRubik{u}}`
2040 `\newcommand{\rrhu}{\@xyzh{u}}`

`\rrd` These commands all draw forms which denote the d rotation.
`\rrhd` 2041 `\newcommand{\rrd}{\@rr{d}}`
`\Rubikd` 2042 `\newcommand{\rrhd}{\@xyzhbdf1{d}}`
2043 `\newcommand{\Rubikd}{\@xyzbdf1Rubik{d}}`

19.22.75 Rotations l and r

`\rrl` These commands all draw forms which denote the l rotation.
`\rrhl` 2044 `\newcommand{\rrl}{\@rr{l}}`
`\Rubikl` 2045 `\newcommand{\rrhl}{\@xyzhbdf1{l}}`
2046 `\newcommand{\Rubikl}{\@xyzbdf1Rubik{l}}`

`\rrr` These commands all draw forms which denote the r rotation.
`\rrhr` 2047 `\newcommand{\rrr}{\@rr{r}}`
`\Rubikr` 2048 `\newcommand{\Rubikr}{\@xyzRubik{r}}`
2049 `\newcommand{\rrhr}{\@xyzh{r}}`

19.22.76 Rotations f and b

`\rrf` These commands all draw forms which denote the f rotation.
`\rrhf` 2050 `\newcommand{\rrf}{\@rr{f}}`
`\Rubikf` 2051 `\newcommand{\rrhf}{\@xyzhbdf1{f}}`
2052 `\newcommand{\Rubikf}{\@xyzbdf1Rubik{f}}`

`\rrb` These commands all draw forms which denote the b rotation.
`\rrhb` 2053 `\newcommand{\rrb}{\@rr{b}}`
`\Rubikb` 2054 `\newcommand{\rrhb}{\@xyzhbdf1{b}}`
2055 `\newcommand{\Rubikb}{\@xyzbdf1Rubik{b}}`

19.23 Face(c) and Face(m) rotations

This subsection (added Nov 2016) is to accommodate some additional notation, much used on the Jaap Puzzles website (Scherphius J), which, although quite convenient, is technically ‘non-standard’. This additional notation makes available the (middle slice) rotations of the form Rm, Rmp, Lm, Lmp, ... and also the (whole cube) rotations Rc, Lc, ... (referenced to a face) as used on the Cube Lovers usenet group (1981–1997). This notation was probably invented by Singmaster (see Scherphius J).

`\@xyzhc` First we have some useful facilitating commands we shall make use of in conjunction with the Face(c) and Face(cp) notation.
`\@xyzhcp`
`\@xyzRubikc` 2056 `\newcommand{\@xyzhc}[1]{\raisebox{-1.2pt}{%`
`\@xyzRubikcp` 2057 `{\@rubikfont #1\@rubikfontFNS c}}}`
2058 `\newcommand{\@xyzhcp}[1]{\raisebox{-1.2pt}{%`
2059 `{\@rubikfont #1\@rubikfontFNS c}\@rubikprime}}}`
2060 `\newcommand{\@xyzRubikc}[1]{\raisebox{3.45pt}{%`
2061 `{\@rubikfont #1\@rubikfontFNS c}}}`
2062 `\newcommand{\@xyzRubikcp}[1]{\raisebox{3.45pt}{%`
2063 `{\@rubikfont #1\@rubikfontFNS c}\@rubikprime}}}`

19.23.1 Rotations Rc and Rcp

Whole cube rotations Rc = x, Rcp = xp.

`\rrRc` These commands all draw forms which denote the Rc rotation.
`\rrhRc` 2064 `\newcommand{\rrRc}{\@rrc{R}}`
`\RubikRc` 2065 `\newcommand{\RubikRc}{\@xyzRubikc{R}}`
2066 `\newcommand{\rrhRc}{\@xyzhc{R}}`

`\rrRcp` These commands all draw forms which denote the Rcp rotation.
`\rrhRcp` 2067 `\newcommand{\rrRcp}{\@rrcp{R}}`
`\RubikRcp` 2068 `\newcommand{\RubikRcp}{\@xyzRubikcp{R}}`
2069 `\newcommand{\rrhRcp}{\@xyzhcp{R}}`

19.23.2 Rotations Lc and Lcp

Whole cube rotations Lc = xp, Lcp = x.

`\rrLc` These commands all draw forms which denote the Lc rotation.
`\rrhLc` 2070 `\newcommand{\rrLc}{\@rrc{L}}`
`\RubikLc` 2071 `\newcommand{\RubikLc}{\@xyzRubikc{L}}`
2072 `\newcommand{\rrhLc}{\@xyzhc{L}}`

`\rrLcp` These commands all draw forms which denote the Lcp rotation.
`\rrhLcp` 2073 `\newcommand{\rrLcp}{\@rrcp{L}}`
`\RubikLcp` 2074 `\newcommand{\RubikLcp}{\@xyzRubikcp{L}}`
2075 `\newcommand{\rrhLcp}{\@xyzhcp{L}}`

19.23.3 Rotations Uc and Ucp

Whole cube rotation $Uc = y$, $Ucp = yp$.

`\rrUc` These commands all draw forms which denote the Uc rotation.
`\rrhUc` 2076 `\newcommand{\rrUc}{\@rrc{U}}`
`\RubikUc` 2077 `\newcommand{\RubikUc}{\@xyzRubikc{U}}`
2078 `\newcommand{\rrhUc}{\@xyzhc{U}}`

`\rrUcp` These commands all draw forms which denote the Ucp rotation.
`\rrhUcp` 2079 `\newcommand{\rrUcp}{\@rrcp{U}}`
`\RubikUcp` 2080 `\newcommand{\RubikUcp}{\@xyzRubikcp{U}}`
2081 `\newcommand{\rrhUcp}{\@xyzhcp{U}}`

19.23.4 Rotations Dc and Dcp

Whole cube rotations $Dc = yp$, $Dcp = y$.

`\rrDc` These commands all draw forms which denote the Dc rotation.
`\rrhDc` 2082 `\newcommand{\rrDc}{\@rrc{D}}`
`\RubikDc` 2083 `\newcommand{\RubikDc}{\@xyzRubikc{D}}`
2084 `\newcommand{\rrhDc}{\@xyzhc{D}}`

`\rrDcp` These commands all draw forms which denote the Dcp rotation.
`\rrhDcp` 2085 `\newcommand{\rrDcp}{\@rrcp{D}}`
`\RubikDcp` 2086 `\newcommand{\RubikDcp}{\@xyzRubikcp{D}}`
2087 `\newcommand{\rrhDcp}{\@xyzhcp{D}}`

19.23.5 Rotations Fc and Fcp

Whole cube rotations $Fc = z$, $Fcp = zp$.

`\rrFc` These commands all draw forms which denote the Fc rotation.
`\rrhFc` 2088 `\newcommand{\rrFc}{\@rrc{F}}`
`\RubikFc` 2089 `\newcommand{\RubikFc}{\@xyzRubikc{F}}`
2090 `\newcommand{\rrhFc}{\@xyzhc{F}}`

`\rrFcp` These commands all draw forms which denote the Fcp rotation.
`\rrhFcp` 2091 `\newcommand{\rrFcp}{\@rrcp{F}}`
`\RubikFcp` 2092 `\newcommand{\RubikFcp}{\@xyzRubikcp{F}}`
2093 `\newcommand{\rrhFcp}{\@xyzhcp{F}}`

19.23.6 Rotations Bc and Bcp

Whole cube rotation $Bc = zp$, $Bcp = z$.

`\rrBc` These commands all draw forms which denote the Bc rotation.
`\rrhBc` 2094 `\newcommand{\rrBc}{\@rrc{B}}`
`\RubikBc` 2095 `\newcommand{\RubikBc}{\@xyzRubikc{B}}`
2096 `\newcommand{\rrhBc}{\@xyzhc{B}}`

`\rrBcp` These commands all draw forms which denote the Bcp rotation.
`\rrhBcp` 2097 `\newcommand{\rrBcp}{\@rrcp{B}}`
`\RubikBcp` 2098 `\newcommand{\RubikBcp}{\@xyzRubikcp{B}}`
2099 `\newcommand{\rrhBcp}{\@xyzhcp{B}}`

19.23.7 Rotations Rm and Rmp

$Rm = Mp = Sr$ (M follows Left). We use Sr and Srp as the templates.

`\rrRm` These commands draw forms of the Rm slice rotation.
`\rrhRm` 2100 `\newcommand{\rrRm}{\@rrm{R}}`
`\RubikRm` 2101 `\newcommand{\rrhRm}{\rrhMp}%`
`\textRubikRm` 2102 `\newcommand{\RubikRm}{%`
2103 `{\@rubikfont%`
2104 `\begin{minipage}{0.6cm}`
2105 `\centering%`
2106 `\SquareMp\`
2107 `\rrRm%`
2108 `\end{minipage}%`
2109 `}}`
2110 `\newcommand{\textRubikRm}{\rrRm\,\rrhMp}`

`\rrRmp` These commands draw forms of the Rmp slice rotation.
`\rrhRmp` 2111 `\newcommand{\rrRmp}{\@rrmp{R}}`
`\RubikRmp` 2112 `\newcommand{\rrhRmp}{\rrhM}%`
`\textRubikRmp` 2113 `\newcommand{\RubikRmp}{%`
2114 `{\@rubikfont%`
2115 `\begin{minipage}{0.6cm}`
2116 `\centering%`
2117 `\SquareM\`
2118 `\rrRmp%`
2119 `\end{minipage}%`
2120 `}}`
2121 `\newcommand{\textRubikRmp}{\rrRmp\,\rrhM}`

19.23.8 Rotations Lm and Lmp

$Lm = M = Sl$ (M follows Left). We use Sl and Slp as the templates.

`\rrLm` These commands draw forms of the Lm slice rotation.
`\rrhLm` 2122 `\newcommand{\rrLm}{\@rrm{L}}`
`\RubikLm` 2123 `\newcommand{\rrhLm}{\rrhM}%`
`\textRubikLm` 2124 `\newcommand{\RubikLm}{%`
2125 `{\@rubikfont%`
2126 `\begin{minipage}{0.6cm}`
2127 `\centering%`
2128 `\SquareM\`
2129 `\rrLm%`
2130 `\end{minipage}%`

```

2131 }}
2132 \newcommand{\textRubikLm}{\rrLm\,\rrhM}

\rrLmp These commands draw forms of the Lmp slice rotation.
\rrhLmp
\RubikLmp 2133 \newcommand{\rrLmp}{\@rrmp{L}}
\textRubikLmp 2134 \newcommand{\rrhLmp}{\rrhMp}%
2135 \newcommand{\RubikLmp}{%
2136 {\@rubikfont%
2137 \begin{minipage}{0.6cm}
2138 \centering%
2139 \SquareMp\
2140 \rrLmp%
2141 \end{minipage}%
2142 }}
2143 \newcommand{\textRubikLmp}{\rrLmp\,\rrhMp}

```

19.23.9 Rotations Um and Ump

$Um = Ep = Su$ (E follows Down). We use Su and Sup as the templates.

```

\rrUm These commands draw forms of the Um slice rotation. We also need to fine-tune
\rrhUm the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
\RubikUm 2144 \newcommand{\rrUm}{\@rrm{U}}
\textRubikUm 2145 \newcommand{\rrhUm}{\rrhEp}%
2146 \newcommand{\RubikUm}{%
2147 {\@rubikfont%
2148 \begin{minipage}{0.6cm}
2149 \centering%
2150 \SquareEp\
2151 \rrUm%
2152 \end{minipage}%
2153 }}
2154 \newcommand{\textRubikUm}{\rrUm\,\rrhEp}

\rrUmp These commands draw forms of the Ump slice rotation. We also need to fine-tune
\rrhUmp the spacing between these ‘slice’ hieroglyphs (especially Fs and Bs).
\RubikUmp 2155 \newcommand{\rrUmp}{\@rrmp{U}}
\textRubikUmp 2156 \newcommand{\rrhUmp}{\rrhE}%
2157 \newcommand{\RubikUmp}{%
2158 {\@rubikfont%
2159 \begin{minipage}{0.6cm}
2160 \centering%
2161 \SquareE\
2162 \rrUmp%
2163 \end{minipage}%
2164 }}
2165 \newcommand{\textRubikUmp}{\rrUmp\,\rrhE}

```

19.23.10 Rotations Dm and Dmp

Dm = E = Sd (E follows Down). We use Sd and Sdp as the templates.

```
\rrDm These commands draw forms of the Singmaster Dm slice rotation.
\rrhDm 2166 \newcommand{\rrDm}{\@rrm{D}}
\RubikDm 2167 \newcommand{\rrhDm}{\rrhE}%
\textRubikDm 2168 \newcommand{\RubikDm}{%
2169 {\@rubikfont%
2170 \begin{minipage}{0.6cm}
2171 \centering%
2172 \SquareE\
2173 \rrDm%
2174 \end{minipage}%
2175 }}
2176 \newcommand{\textRubikDm}{\rrDm\,\rrhE}
```

```
\rrDmp These commands draw forms of the Singmaster Dmp slice rotation.
\rrhDmp 2177 \newcommand{\rrDmp}{\@rrmp{D}}
\RubikDmp 2178 \newcommand{\rrhDmp}{\rrhEp}%
\textRubikDmp 2179 \newcommand{\RubikDmp}{%
2180 {\@rubikfont%
2181 \begin{minipage}{0.6cm}
2182 \centering%
2183 \SquareEp\
2184 \rrDmp%
2185 \end{minipage}%
2186 }}
2187 \newcommand{\textRubikDmp}{\rrDmp\,\rrhEp}
```

19.23.11 Rotations Fm and Fmp

Fm = S = Sf (S follows Front). S is not visible from the front, so is represented in a square box. We use Sf and Sfp as the templates.

```
\rrFm These commands draw forms of the Fm slice rotation. We need to just make
\rrhFm square with Fm in square; adjust box height using a \rule; adjust \fboxsep
\RubikFm (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikFm reset to defaults. Not visible from the front.
2188 \newcommand{\rrFm}{\@rrm{F}}
2189 \newcommand{\SquareFm}{\@tlen\@SquareLetter{\rrFm}\@tlen}
2190 \newcommand{\rrhFm}{\raisebox{-0.25mm}{\SquareFm}}
2191 \newcommand{\RubikFm}{\raisebox{\@hRubik}{\SquareFm}}
2192 \newcommand{\textRubikFm}{\rrhFm}
```

```
\rrFmp These commands draw forms of the Fmp slice rotation. We need to just make
\rrhFmp square with Fmp in square; adjust box height using a \rule; adjust \fboxsep
\RubikFmp (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikFmp reset to defaults. Not visible from the front.
```



```

2193 \newcommand{\rrFmp}{\@rrmp{F}}
2194 \newcommand{\SquareFmp}{\@tlen\@SquareLetter{\rrFmp}\@tlen}
2195 \newcommand{\rrhFmp}{\raisebox{-0.25mm}{\SquareFmp}}
2196 \newcommand{\RubikFmp}{\raisebox{\@hRubik}{\SquareFmp}}
2197 \newcommand{\textRubikFmp}{\rrhFmp}

```

19.23.12 Rotations Bm and Bmp

$Bm = Sp = Sb$. We use Sb and Sbp as the templates.

`\rrBm` These commands draw forms of the Bm slice rotation. We need to just make
`\rrhBm` square with Bm in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikBm` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikBm` reset to defaults. Not visible from the front.

```

2198 \newcommand{\rrBm}{\@rrm{B}}
2199 \newcommand{\SquareBm}{\@tlen\@SquareLetter{\rrBm}\@tlen}
2200 \newcommand{\rrhBm}{\raisebox{-0.25mm}{\SquareBm}}
2201 \newcommand{\RubikBm}{\raisebox{\@hRubik}{\SquareBm}}
2202 \newcommand{\textRubikBm}{\rrhBm}

```

`\rrBmp` These commands draw forms of the Bmp slice rotation. We need to just make
`\rrhBmp` square with Bmp in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikBmp` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikBmp` reset to defaults. Not visible from the front.

```

2203 \newcommand{\rrBmp}{\@rrmp{B}}
2204 \newcommand{\SquareBmp}{\@tlen\@SquareLetter{\rrBmp}\@tlen}
2205 \newcommand{\rrhBmp}{\raisebox{-0.25mm}{\SquareBmp}}
2206 \newcommand{\RubikBmp}{\raisebox{\@hRubik}{\SquareBmp}}
2207 \newcommand{\textRubikBmp}{\rrhBmp}

```

19.24 Randelshofer superset ENG rotations (CMST)

(see webpage: Randelshofer.ch/rubik/patterns/doc/supersetENG_3x3.html)

This section relates to the recent Rubik notation developed by Randelshofer (see URL above), known as the “superset ENG rotations” (see Sections 8 and 8.9.1 for details).

I denote this notation as “CMST” (i.e., his C, M, S and T notation). Although this notation replicates previously existing World Cube Association notation, we include it here for completeness. Fortunately the Randelshofer notation does not conflict with existing notation.

Briefly, the CMST letters denote whole Cube, Middle, outer-Slice and wide (T) rotations associated with named faces. For example, the rotation-code MR indicates a rotation of the middle slice parallel to the RIGHT face, and in the same sense (direction) as **R** (see Section 8 for details).

First we make some useful facilitating commands for the CX1 and CX1p forms as these are handled with raised square brackets. We model these four macros on the equivalent `\@xyzh`, `\@xyzhp`, `\@xyzRubik`, `\@xyzRubikp` macros defined above.

```

2208 \newcommand{\@randhc}[1]{[\raisebox{-1.2pt}{\@rubikfont C#1}]}
2209 \newcommand{\@randhcp}[1]{[\raisebox{-1.2pt}{\@rubikfont C#1\@rubikprime}]}
2210 \newcommand{\@randRubikc}[1]{%
2211   {\raisebox{3.45pt}{[\raisebox{-1.2pt}{\@rubikfont C#1}]}]}
2212 \newcommand{\@randRubikcp}[1]{%
2213   {\raisebox{3.45pt}{[\raisebox{-1.2pt}{\@rubikfont C#1\@rubikprime}]}]}

```

In the following we create the base form of a rotation code, eg **[CR]** and then the user typesets this rotation using CR as the argument for `\rrh{}`. This works because the macro `\@join{}` is used to join `\rrh` and `CR` \rightarrow `\rrhCR` etc.

The = signs at the beginning of each new section indicate the equivalence between the Randelshofer notation and the current (World Cube Association) notation.

19.24.1 Rotations CR and CRp

Whole cube rotations $CR = Rc = x$, $CRp = Rcp = xp$.

```

\rrCR These commands all draw forms which denote the CR = Rc rotation.
\rrhCR 2214 \newcommand{\rrCR}{\@rr{CR}}
\RubikCR 2215 \newcommand{\RubikCR}{\@randRubikc{R}}
2216 \newcommand{\rrhCR}{\@randhc{R}}

\rrCRp These commands all draw forms which denote the CRp = Rcp rotation.
\rrhCRp 2217 \newcommand{\rrCRp}{\@rrp{CR}}
\RubikCRp 2218 \newcommand{\RubikCRp}{\@randRubikcp{R}}
2219 \newcommand{\rrhCRp}{\@randhcp{R}}

```

19.24.2 Rotations CL and CLp

Whole cube rotations $CL = Lc = xp$, $CLp = Lcp = x$.

```

\rrCL These commands all draw forms which denote the CL rotation.
\rrhCL 2220 \newcommand{\rrCL}{\@rr{CL}}
\RubikCL 2221 \newcommand{\RubikCL}{\@randRubikc{L}}
2222 \newcommand{\rrhCL}{\@randhc{L}}

\rrCLp These commands all draw forms which denote the CLp rotation.
\rrhCLp 2223 \newcommand{\rrCLp}{\@rrp{CL}}
\RubikCLp 2224 \newcommand{\RubikCLp}{\@randRubikcp{L}}
2225 \newcommand{\rrhCLp}{\@randhcp{L}}

```

19.24.3 Rotations CU and CUp

Whole cube rotation $CU = Uc = y$, $CUp = Ucp = yp$.

```

\rrCU These commands all draw forms which denote the CU rotation.
\rrhCU 2226 \newcommand{\rrCU}{\@rr{CU}}
\RubikCU 2227 \newcommand{\RubikCU}{\@randRubikc{U}}
2228 \newcommand{\rrhCU}{\@randhc{U}}

```

`\rrCUp` These commands all draw forms which denote the CUp rotation.
`\rrhCUp` 2229 `\newcommand{\rrCUp}{\@rrp{CU}}`
`\RubikCUp` 2230 `\newcommand{\RubikCUp}{\@randRubikcp{U}}`
2231 `\newcommand{\rrhCUp}{\@randhcp{U}}`

19.24.4 Rotations CD and CDp

Whole cube rotations $CD = Dc = yp$, $CDp = Dcp = y$.

`\rrCD` These commands all draw forms which denote the CD rotation.
`\rrhCD` 2232 `\newcommand{\rrCD}{\@rr{CD}}`
`\RubikCD` 2233 `\newcommand{\RubikCD}{\@randRubikc{D}}`
2234 `\newcommand{\rrhCD}{\@randhc{D}}`

`\rrCDp` These commands all draw forms which denote the CDp rotation.
`\rrhCDp` 2235 `\newcommand{\rrCDp}{\@rrp{CD}}`
`\RubikCDp` 2236 `\newcommand{\RubikCDp}{\@randRubikcp{D}}`
2237 `\newcommand{\rrhCDp}{\@randhcp{D}}`

19.24.5 Rotations CF and CFp

Whole cube rotations $CF = Fc = z$, $CFp = Fcp = zp$.

`\rrCF` These commands all draw forms which denote the CF rotation.
`\rrhCF` 2238 `\newcommand{\rrCF}{\@rr{CF}}`
`\RubikCF` 2239 `\newcommand{\RubikCF}{\@randRubikc{F}}`
2240 `\newcommand{\rrhCF}{\@randhc{F}}`

`\rrCFp` These commands all draw forms which denote the CFp rotation.
`\rrhCFp` 2241 `\newcommand{\rrCFp}{\@rrp{CF}}`
`\RubikCFp` 2242 `\newcommand{\RubikCFp}{\@randRubikcp{F}}`
2243 `\newcommand{\rrhCFp}{\@randhcp{F}}`

19.24.6 Rotations CB and CBp

Whole cube rotation $CB = Bc = zp$, $CBp = Bcp = z$.

`\rrCB` These commands all draw forms which denote the CB rotation.
`\rrhCB` 2244 `\newcommand{\rrCB}{\@rr{CB}}`
`\RubikCB` 2245 `\newcommand{\RubikCB}{\@randRubikc{B}}`
2246 `\newcommand{\rrhCB}{\@randhc{B}}`

`\rrCBp` These commands all draw forms which denote the CBp rotation.
`\rrhCBp` 2247 `\newcommand{\rrCBp}{\@rrp{CB}}`
`\RubikCBp` 2248 `\newcommand{\RubikCBp}{\@randRubikcp{B}}`
2249 `\newcommand{\rrhCBp}{\@randhcp{B}}`

19.24.7 Rotations MR and MRp

MR = Rm = Mp = Sr (M follows Left). We use Sr and Srp as the templates.

```
\rrMR These commands draw forms of the MR middle slice rotation.
\rrhMR 2250 \newcommand{\rrMR}{\@rr{MR}}
\RubikMR 2251 \newcommand{\rrhMR}{\rrhMp}%
\textRubikMR 2252 \newcommand{\RubikMR}{%
2253 {\@rubikfont%
2254 \begin{minipage}{0.6cm}
2255 \centering%
2256 \SquareMp\
2257 \rrMR%
2258 \end{minipage}%
2259 }}
2260 \newcommand{\textRubikMR}{\rrMR\,\rrhMp}
```

```
\rrMRp These commands draw forms of the MRp slice rotation.
\rrhMRp 2261 \newcommand{\rrMRp}{\@rrp{MR}}
\RubikMRp 2262 \newcommand{\rrhMRp}{\rrhM}%
\textRubikMRp 2263 \newcommand{\RubikMRp}{%
2264 {\@rubikfont%
2265 \begin{minipage}{0.6cm}
2266 \centering%
2267 \SquareM\
2268 \rrMRp%
2269 \end{minipage}%
2270 }}
2271 \newcommand{\textRubikMRp}{\rrMRp\,\rrhM}
```

19.24.8 Rotations ML and MLp

ML = Lm = M = Sl (M follows Left). We use Sl and Slp as the templates.

```
\rrML These commands draw forms of the ML slice rotation.
\rrhML 2272 \newcommand{\rrML}{\@rr{ML}}
\RubikML 2273 \newcommand{\rrhML}{\rrhM}%
\textRubikML 2274 \newcommand{\RubikML}{%
2275 {\@rubikfont%
2276 \begin{minipage}{0.6cm}
2277 \centering%
2278 \SquareM\
2279 \rrML%
2280 \end{minipage}%
2281 }}
2282 \newcommand{\textRubikML}{\rrML\,\rrhM}
```

```
\rrMLp These commands draw forms of the MLp slice rotation.
\rrhMLp 2283 \newcommand{\rrMLp}{\@rrp{ML}}
\RubikMLp 2284 \newcommand{\rrhMLp}{\rrhMp}%
\textRubikMLp
```

```

2285 \newcommand{\RubikMLp}{%
2286 {\@rubikfont%
2287 \begin{minipage}{0.6cm}
2288 \centering%
2289 \SquareMp\\
2290 \rrMLp%
2291 \end{minipage}%
2292 }}
2293 \newcommand{\textRubikMLp}{\rrMLp\,\\rrhMp}

```

19.24.9 Rotations MU and MUp

MU = Um = Ep = Su (E follows Down). We use Su and Sup as the templates.

```

\rrMU These commands draw forms of the MU slice rotation.
\rrhMU
\RubikMU
\textRubikMU
2294 \newcommand{\rrMU}{\@rr{MU}}
2295 \newcommand{\rrhMU}{\rrhEp}%
2296 \newcommand{\RubikMU}{%
2297 {\@rubikfont%
2298 \begin{minipage}{0.6cm}
2299 \centering%
2300 \SquareEp\\
2301 \rrMU%
2302 \end{minipage}%
2303 }}
2304 \newcommand{\textRubikMU}{\rrMU\,\\rrhEp}

```

```

\rrMUp These commands draw forms of the MUp slice rotation.
\rrhMUp
\RubikMUp
\textRubikMUp
2305 \newcommand{\rrMUp}{\@rrp{MUp}}
2306 \newcommand{\rrhMUp}{\rrhE}%
2307 \newcommand{\RubikMUp}{%
2308 {\@rubikfont%
2309 \begin{minipage}{0.6cm}
2310 \centering%
2311 \SquareE\\
2312 \rrMUp%
2313 \end{minipage}%
2314 }}
2315 \newcommand{\textRubikMUp}{\rrMUp\,\\rrhE}

```

19.24.10 Rotations MD and MDp

MD = Dm = E = Sd (E follows Down). We use Sd and Sdp as the templates.

```

\rrMD These commands draw forms of the Randelshofer MD slice rotation.
\rrhMD
\RubikMD
\textRubikMD
2316 \newcommand{\rrMD}{\@rr{MD}}
2317 \newcommand{\rrhMD}{\rrhE}%
2318 \newcommand{\RubikMD}{%
2319 {\@rubikfont%

```

```

2320 \begin{minipage}{0.6cm}
2321 \centering%
2322 \SquareE\
2323 \rrMD%
2324 \end{minipage}%
2325 }}
2326 \newcommand{\textRubikMD}{\rrMD\,\rrhE}

```

```

\rrMDp These commands draw forms of the Randelshofer MDp slice rotation.
\rrhMDp 2327 \newcommand{\rrMDp}{\@rrp{MD}}
\RubikMDp 2328 \newcommand{\rrhMDp}{\rrhEp}%
\textRubikMDp 2329 \newcommand{\RubikMDp}{%
2330 {\@rubikfont%
2331 \begin{minipage}{0.6cm}
2332 \centering%
2333 \SquareEp\
2334 \rrMDp%
2335 \end{minipage}%
2336 }}
2337 \newcommand{\textRubikMDp}{\rrMDp\,\rrhEp}

```

19.24.11 Rotations MF and MFp

MF = Fm = S = Sf (S follows Front). MF = S is not visible from the front, so is represented in a square box. We use Sf and Sfp as the templates.

```

\rrMF These commands draw forms of the MF slice rotation. We need to just make
\rrhMF square with MF in square; adjust box height using a \rule; adjust \fboxsep
\RubikMF (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikMF reset to defaults. Not visible from the front.
2338 \newcommand{\rrMF}{\@rr{MF}}
2339 \newcommand{\SquareMF}{\@tlen\@SquareLetter{\rrMF}\@tlen}
2340 \newcommand{\rrhMF}{\raisebox{-0.25mm}{\SquareMF}}
2341 \newcommand{\RubikMF}{\raisebox{\@hRubik}{\SquareMF}}
2342 \newcommand{\textRubikMF}{\rrhMF}

```

```

\rrMFp These commands draw forms of the MFp slice rotation. We need to just make
\rrhMFp square with MFp in square; adjust box height using a \rule; adjust \fboxsep
\RubikMFp (default=3pt); adjust \fboxrule (default=0.4pt); bounded by {} so no need to
\textRubikMFp reset to defaults. Not visible from the front.
2343 \newcommand{\rrMFp}{\@rrp{MF}}
2344 \newcommand{\SquareMFp}{\@tlen\@SquareLetter{\rrMFp}\@tlen}
2345 \newcommand{\rrhMFp}{\raisebox{-0.25mm}{\SquareMFp}}
2346 \newcommand{\RubikMFp}{\raisebox{\@hRubik}{\SquareMFp}}
2347 \newcommand{\textRubikMFp}{\rrhMFp}

```

19.24.12 Rotations MB and MBp

MB = Bm = Sp = Sb. We use Sb and Sbp as the templates.

`\rrMB` These commands draw forms of the MB slice rotation. We need to just make
`\rrhMB` square with MB in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikMB` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikMB` reset to defaults. Not visible from the front.

```
2348 \newcommand{\rrMB}{\@rr{MB}}
2349 \newcommand{\SquareMB}{\@tlen\@SquareLetter{\rrMB}\@tlen}
2350 \newcommand{\rrhMB}{\raisebox{-0.25mm}{\SquareMB}}
2351 \newcommand{\RubikMB}{\raisebox{\@hRubik}{\SquareMB}}
2352 \newcommand{\textRubikMB}{\rrhMB}
```

`\rrMBp` These commands draw forms of the MBp slice rotation. We need to just make
`\rrhMBp` square with MBp in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikMBp` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikMBp` reset to defaults. Not visible from the front.

```
2353 \newcommand{\rrMBp}{\@rrp{MB}}
2354 \newcommand{\SquareMBp}{\@tlen\@SquareLetter{\rrMBp}\@tlen}
2355 \newcommand{\rrhMBp}{\raisebox{-0.25mm}{\SquareMBp}}
2356 \newcommand{\RubikMBp}{\raisebox{\@hRubik}{\SquareMBp}}
2357 \newcommand{\textRubikMBp}{\rrhMBp}
```

19.24.13 Rotations T (wide)

$TR = R_w$ (We use R_w and R_{wp} as the templates).

We first set up some useful T and Tp macros for use with (L,R,U,D,F,B) slightly more general than before. As before the rubikfont command needs to be delimited using two curly brackets to contain the font expression.

```
2358 \newcommand{\@rrT}[1]{\@rubikfont T#1}
2359 \newcommand{\@rrhT}[1]{\@join{\rrh#1}{w}}%
2360 \newcommand{\@textRubikT}[1]{\@rrT{#1}\,\@join{\rrh#1}{w}}
2361 %
2362 \newcommand{\@RubikT}[1]{%
2363 {\@rubikfont%
2364 \begin{minipage}{0.6cm}
2365 \centering%%
2366 \@join{\Square#1}{w}\%
2367 \@rrT{#1}%%
2368 \end{minipage}%
2369 }}
2370 %%
2371 \newcommand{\@rrTp}[1]{\@rubikfont T#1\@rubikprime}
2372 \newcommand{\@rrhTp}[1]{\@join{\rrh#1}{wp}}%
2373 \newcommand{\@textRubikTp}[1]{\@rrTp{#1}\,\@join{\rrh#1}{wp}}
2374 %%
2375 \newcommand{\@RubikTp}[1]{%
2376 {\@rubikfont%
2377 \begin{minipage}{0.6cm}
2378 \centering%%
2379 \@join{\Square#1}{wp}\%
```

```

2380 \@rrTp{#1}%%
2381 \end{minipage}%
2382 }}

\rrTL These commands draw forms of the TL = Lw wide slice rotation.
\rrhTL 2383 \newcommand{\rrTL}{\@rrT{L}}% = rrLw
\RubikTL 2384 \newcommand{\rrhTL}{\@rrhT{L}}
\textRubikTL 2385 \newcommand{\textRubikTL}{\@textRubikT{L}}
2386 \newcommand{\RubikTL}{\@RubikT{L}}

\rrTlp These commands draw forms of the Tlp = Lwp wide slice rotation.
\rrhTlp 2387 \newcommand{\rrTlp}{\@rrTp{L}}
\RubikTlp 2388 \newcommand{\rrhTlp}{\@rrhTp{L}}
\textRubikTlp 2389 \newcommand{\textRubikTlp}{\@textRubikTp{L}}
2390 \newcommand{\RubikTlp}{\@RubikTp{L}}

\rrTR These commands draw forms of the TR = Rw wide slice rotation.
\rrhTR 2391 \newcommand{\rrTR}{\@rrT{R}}
\RubikTR 2392 \newcommand{\rrhTR}{\@rrhT{R}}
\textRubikTR 2393 \newcommand{\textRubikTR}{\@textRubikT{R}}
2394 \newcommand{\RubikTR}{\@RubikT{R}}

\rrTRp These commands draw forms of the TRp = Rmp wide slice rotation.
\rrhTRp 2395 \newcommand{\rrTRp}{\@rrTp{R}}
\RubikTRp 2396 \newcommand{\rrhTRp}{\@rrhTp{R}}
\textRubikTRp 2397 \newcommand{\textRubikTRp}{\@textRubikTp{R}}
2398 \newcommand{\RubikTRp}{\@RubikTp{R}}

\rrTU These commands draw forms of the TU = Uw wide slice rotation.
\rrhTU 2399 \newcommand{\rrTU}{\@rrT{U}}
\RubikTU 2400 \newcommand{\rrhTU}{\@rrhT{U}}
\textRubikTU 2401 \newcommand{\textRubikTU}{\@textRubikT{U}}
2402 \newcommand{\RubikTU}{\@RubikT{U}}

\rrTUp These commands draw forms of the TUp = Uwp wide slice rotation.
\rrhTUp 2403 \newcommand{\rrTUp}{\@rrTp{U}}
\RubikTUp 2404 \newcommand{\rrhTUp}{\@rrhTp{U}}
\textRubikTUp 2405 \newcommand{\textRubikTUp}{\@textRubikTp{U}}
2406 \newcommand{\RubikTUp}{\@RubikTp{U}}

\rrTD These commands draw forms of the TD = Dw wide slice rotation.
\rrhTD 2407 \newcommand{\rrTD}{\@rrT{D}}
\RubikTD 2408 \newcommand{\rrhTD}{\@rrhT{D}}
\textRubikTD 2409 \newcommand{\textRubikTD}{\@textRubikT{D}}
2410 \newcommand{\RubikTD}{\@RubikT{D}}

\rrTDp These commands draw forms of the TDp = Dwp wide slice rotation.
\rrhTDp 2411 \newcommand{\rrTDp}{\@rrTp{D}}
\RubikTDp 2412 \newcommand{\rrhTDp}{\@rrhTp{D}}
\textRubikTDp

```



```

2413 \newcommand{\textRubikTDp}{\@textRubikTp{D}}
2414 \newcommand{\RubikTDp}{\@RubikTp{D}}

\rrTF These commands draw forms of the TF = Fw wide slice rotation.
\rrhTF
\RubikTF 2415 \newcommand{\rrTF}{\@rrT{F}}
2416 \newcommand{\rrhTF}{\@rrhT{F}}
\textRubikTF 2417 \newcommand{\textRubikTF}{\@textRubikT{F}}
2418 \newcommand{\RubikTF}{\@RubikT{F}}

\rrTFp These commands draw forms of the TFp = Fwp wide slice rotation.
\rrhTFp 2419 \newcommand{\rrTFp}{\@rrTp{F}}
\RubikTFp 2420 \newcommand{\rrhTFp}{\@rrhTp{F}}
\textRubikTFp 2421 \newcommand{\textRubikTFp}{\@textRubikTp{F}}
2422 \newcommand{\RubikTFp}{\@RubikTp{F}}

\rrTB These commands draw forms of the TB = Bw wide slice rotation. NOTE we just
\rrhTB use the letters TB in a square
\RubikTB 2423 \newcommand{\rrTB}{\@rrT{B}}
\textRubikTB 2424 \newcommand{\SquareTB}{\@tlen\@SquareLetter{\rrTB}\@tlen}
2425 \newcommand{\rrhTB}{\raisebox{-0.25mm}{\SquareTB}}
2426 \newcommand{\textRubikTB}{\rrhTB}
2427 \newcommand{\RubikTB}{\raisebox{\@hRubik}{\SquareTB}}

\rrTBp These commands draw forms of the TBp = Bwp wide slice rotation. NOTE we
\rrhTBp just use the letters 'TB' in a square
\RubikTBp 2428 \newcommand{\rrTBp}{\@rrTp{B}}
\textRubikTBp 2429 \newcommand{\SquareTBp}{\@tlen\@SquareLetter{\rrTBp}\@tlen}
2430 \newcommand{\rrhTBp}{\raisebox{-0.25mm}{\SquareTBp}}
2431 \newcommand{\textRubikTBp}{\rrhTBp}
2432 \newcommand{\RubikTBp}{\raisebox{\@hRubik}{\SquareTBp}}

```

19.24.14 Rotations SR and SRp (opposite slices)

opposite slices in same direction SR = Rs (both rotating in R direction)

```

\rrSR These commands draw forms of the SR opposite slice rotation.
\rrhSR 2433 \newcommand{\rrSR}{\@rr{SR}}
\RubikSR 2434 \newcommand{\rrhSR}{\rrhRs}%
\textRubikSR 2435 \newcommand{\RubikSR}{%
2436 {\@rubikfont%
2437 \begin{minipage}{0.6cm}
2438 \centering%
2439 \SquareRs\
2440 \rrSR%
2441 \end{minipage}%
2442 }}
2443 \newcommand{\textRubikSR}{\rrSR\,\rrhRs}

```

`\rrSRp` These commands draw forms of the SRp opposite slice rotation.

```

\rrhSRp 2444 \newcommand{\rrSRp}{\@rrp{SR}}
\RubikSRp 2445 \newcommand{\rrhSRp}{\rrhRsp}%
\textRubikSRp 2446 \newcommand{\RubikSRp}{%
2447 {\@rubikfont%
2448 \begin{minipage}{0.6cm}
2449 \centering%
2450 \SquareRsp\\
2451 \rrSRp%
2452 \end{minipage}}%
2453 }}
2454 \newcommand{\textRubikSRp}{\rrSRp\,\rrhRsp}

```

19.24.15 Rotations SL and SLp

SL = Ls (both rotating in L direction)

`\rrSL` These commands draw forms of the SL opposite slice rotation.

```

\rrhSL 2455 \newcommand{\rrSL}{\@rr{SL}}
\RubikSL 2456 \newcommand{\rrhSL}{\rrhLs}%
\textRubikSL 2457 \newcommand{\RubikSL}{%
2458 {\@rubikfont%
2459 \begin{minipage}{0.6cm}
2460 \centering%
2461 \SquareLs\\
2462 \rrSL%
2463 \end{minipage}}%
2464 }}
2465 \newcommand{\textRubikSL}{\rrSL\,\rrhLs}

```

`\rrSLp` These commands draw forms of the SLp opposite slice rotation.

```

\rrhSLp 2466 \newcommand{\rrSLp}{\@rrp{SL}}
\RubikSLp 2467 \newcommand{\rrhSLp}{\rrhLsp}%
\textRubikSLp 2468 \newcommand{\RubikSLp}{%
2469 {\@rubikfont%
2470 \begin{minipage}{0.6cm}
2471 \centering%
2472 \SquareLsp\\
2473 \rrSLp%
2474 \end{minipage}}%
2475 }}
2476 \newcommand{\textRubikSLp}{\rrSLp\,\rrhLsp}

```

19.24.16 Rotations SU and SUp

SU = Us (both rotating in U direction)

`\rrSU` These commands draw forms of the SU opposite slice rotation.

```

\rrhSU 2477 \newcommand{\rrSU}{\@rr{SU}}
\RubikSU
\textRubikSU

```

```

2478 \newcommand{\rrhSU}{\rrhUs}%
2479 \newcommand{\RubikSU}{%
2480 {\@rubikfont%
2481 \begin{minipage}{0.6cm}
2482 \centering%
2483 \SquareUs\
2484 \rrSU%
2485 \end{minipage}%
2486 }}
2487 \newcommand{\textRubikSU}{\rrSU\,\rrhUs}

```

`\rrSU` These commands draw forms of the SUp opposite slice rotation.

```

\rrhSUp 2488 \newcommand{\rrSUp}{\@rrp{SU}}
\RubikSUp 2489 \newcommand{\rrhSUp}{\rrhUsp}%
\textRubikSUp 2490 \newcommand{\RubikSUp}{%
2491 {\@rubikfont%
2492 \begin{minipage}{0.6cm}
2493 \centering%
2494 \SquareUsp\
2495 \rrSUp%
2496 \end{minipage}%
2497 }}
2498 \newcommand{\textRubikSUp}{\rrSUp\,\rrhUsp}

```

19.24.17 Rotations SD and SDp

SD = Ds (both rotating in D direction)

`\rrSD` These commands draw forms of the SD opposite slice rotation.

```

\rrhSD 2499 \newcommand{\rrSD}{\@rr{SD}}
\RubikSD 2500 \newcommand{\rrhSD}{\rrhDs}%
\textRubikSD 2501 \newcommand{\RubikSD}{%
2502 {\@rubikfont%
2503 \begin{minipage}{0.6cm}
2504 \centering%
2505 \SquareDs\
2506 \rrSD%
2507 \end{minipage}%
2508 }}
2509 \newcommand{\textRubikSD}{\rrSD\,\rrhDs}

```

`\rrSDp` These commands draw forms of the SDp opposite slice rotation.

```

\rrhSDp 2510 \newcommand{\rrSDp}{\@rrp{SD}}
\RubikSDp 2511 \newcommand{\rrhSDp}{\rrhDsp}%
\textRubikSDp 2512 \newcommand{\RubikSDp}{%
2513 {\@rubikfont%
2514 \begin{minipage}{0.6cm}
2515 \centering%
2516 \SquareDsp\

```

```

2517 \rrSDp%
2518 \end{minipage}%
2519 }}
2520 \newcommand{\textRubikSDp}{\rrSDp\,\rrhDsp}

```

19.24.18 Rotations SF and SFp

SF = Fs is not visible from the front, so is represented in a square box. Both rotating in the F direction We use Fs and Fsp as the templates.

`\rrSF` These commands draw forms of the SF opposite slice rotation. We need to just
`\rrhSF` make square with SF in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikSF` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikSF` reset to defaults. Not visible from the front.

```

2521 \newcommand{\rrSF}{\@rr{SF}}
2522 \newcommand{\SquareSF}{\@tlen\@SquareLetter{\rrSF}\@tlen}
2523 \newcommand{\rrhSF}{\raisebox{-0.25mm}{\SquareSF}}
2524 \newcommand{\RubikSF}{\raisebox{\@hRubik}{\SquareSF}}
2525 \newcommand{\textRubikSF}{\rrhSF}

```

`\rrSFp` These commands draw forms of the SFp opposite slice rotation. We need to just
`\rrhSFp` make square with SFp in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikSFp` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikSFp` reset to defaults. Not visible from the front.

```

2526 \newcommand{\rrSFp}{\@rrp{SF}}
2527 \newcommand{\SquareSFp}{\@tlen\@SquareLetter{\rrSFp}\@tlen}
2528 \newcommand{\rrhSFp}{\raisebox{-0.25mm}{\SquareSFp}}
2529 \newcommand{\RubikSFp}{\raisebox{\@hRubik}{\SquareSFp}}
2530 \newcommand{\textRubikSFp}{\rrhSFp}

```

19.24.19 Rotations SB and SBp

SB = Bs is not visible from the front, so is represented in a square box. Both rotating in the B direction We use Bs and Bsp as the templates.

`\rrSB` These commands draw forms of the SB opposite slice rotation. We need to just
`\rrhSB` make square with SB in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikSB` (default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to
`\textRubikSB` reset to defaults. Not visible from the front.

```

2531 \newcommand{\rrSB}{\@rr{SB}}
2532 \newcommand{\SquareSB}{\@tlen\@SquareLetter{\rrSB}\@tlen}
2533 \newcommand{\rrhSB}{\raisebox{-0.25mm}{\SquareSB}}
2534 \newcommand{\RubikSB}{\raisebox{\@hRubik}{\SquareSB}}
2535 \newcommand{\textRubikSB}{\rrhSB}

```

`\rrSBp` These commands draw forms of the SBp opposite slice rotation. We need to just
`\rrhSBp` make square with SBp in square; adjust box height using a `\rule`; adjust `\fboxsep`
`\RubikSBp`
`\textRubikSBp`

(default=3pt); adjust `\fboxrule` (default=0.4pt); bounded by `{}` so no need to reset to defaults. Not visible from the front.

```

2536 \newcommand{\rrSBp}{\@rrp{SB}}
2537 \newcommand{\SquareSBp}{\@tlen@SquareLetter{\rrSBp}\@tlen}
2538 \newcommand{\rrhSBp}{\raisebox{-0.25mm}{\SquareSBp}}
2539 \newcommand{\RubikSBp}{\raisebox{\@hRubik}{\SquareSBp}}
2540 \newcommand{\textRubikSBp}{\rrhSBp}

```

19.25 Axis rotations (textRubik versions)

For completeness we include a `\textRubik` version of all the axis rotation codes (making them equal to their hieroglyphic `\rrh` version). Obviously this list must go at the end of this file. While these commands are perhaps strictly unnecessary, the motivation is to allow users to include them in a `\ShowSequence` command when using the `\textRubik` font argument.

```

2541 \newcommand{\textRubikx}{\rrhx}
2542 \newcommand{\textRubikxp}{\rrhxp}
2543 \newcommand{\textRubiky}{\rrhy}
2544 \newcommand{\textRubikyp}{\rrhyp}
2545 \newcommand{\textRubikz}{\rrhz}
2546 \newcommand{\textRubikzp}{\rrhzp}
2547 \newcommand{\textRubikl}{\rrhl}
2548 \newcommand{\textRubikr}{\rrhr}
2549 \newcommand{\textRubiku}{\rrhu}
2550 \newcommand{\textRubikd}{\rrhd}
2551 \newcommand{\textRubikf}{\rrhf}
2552 \newcommand{\textRubikb}{\rrhb}
2553 \newcommand{\textRubikLc}{\rrhLc}
2554 \newcommand{\textRubikLcp}{\rrhLcp}
2555 \newcommand{\textRubikRc}{\rrhRc}
2556 \newcommand{\textRubikRcp}{\rrhRcp}
2557 \newcommand{\textRubikUc}{\rrhUc}
2558 \newcommand{\textRubikUcp}{\rrhUcp}
2559 \newcommand{\textRubikDc}{\rrhDc}
2560 \newcommand{\textRubikDcp}{\rrhDcp}
2561 \newcommand{\textRubikFc}{\rrhFc}
2562 \newcommand{\textRubikFcp}{\rrhFcp}
2563 \newcommand{\textRubikBc}{\rrhBc}
2564 \newcommand{\textRubikBcp}{\rrhBcp}
2565 \newcommand{\textRubikCL}{\rrhCL}
2566 \newcommand{\textRubikCLp}{\rrhCLp}
2567 \newcommand{\textRubikCR}{\rrhCR}
2568 \newcommand{\textRubikCRp}{\rrhCRp}
2569 \newcommand{\textRubikCU}{\rrhCU}
2570 \newcommand{\textRubikCUp}{\rrhCUp}
2571 \newcommand{\textRubikCD}{\rrhCD}
2572 \newcommand{\textRubikCDp}{\rrhCDp}
2573 \newcommand{\textRubikCF}{\rrhCF}

```

2574 `\newcommand{\textRubikCFp}{\rrhCFp}`
 2575 `\newcommand{\textRubikCB}{\rrhCB}`
 2576 `\newcommand{\textRubikCBp}{\rrhCBp}`

— End of this package —

2577 `\rubikcube`

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<code>\textRubikLap</code>	1500	<code>\textRubikSL</code>	2455	<code>\TR</code>	25
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