

# Mathematical & Physical Formulas Cube Design

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|           |                                                                             |                                                                       |
|-----------|-----------------------------------------------------------------------------|-----------------------------------------------------------------------|
| Designers | André Boulouard                                                             | Walter Randelshofer                                                   |
| WebSites  | <a href="http://www.mementoslangues.fr/">http://www.mementoslangues.fr/</a> | <a href="http://www.randelshofer.ch/">http://www.randelshofer.ch/</a> |

## Introduction

A **Mathematical & Physical Formulas Cube** is a 3x3x3 **Rubik's Cube** used to display *selected* mathematical and physical formulas.

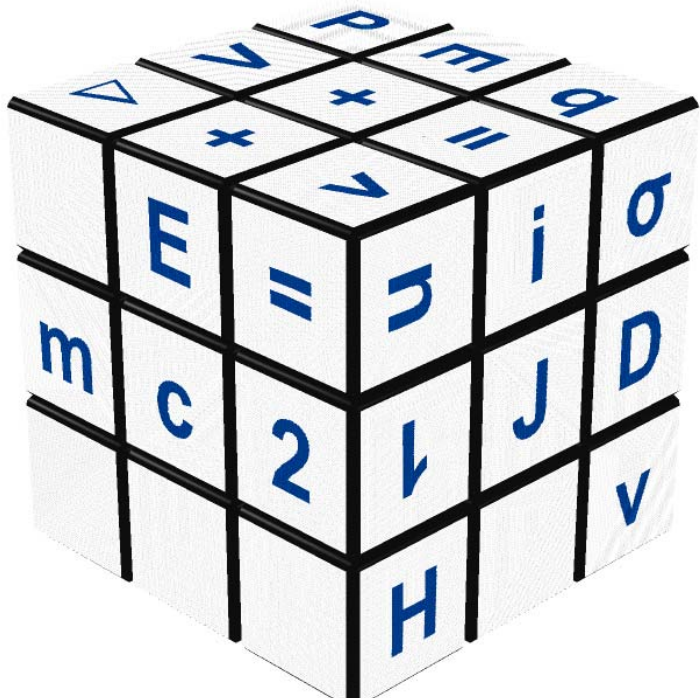
There are **Virtual Cubes** that can be *virtually* rotated and twisted on a computer screen and **Real Cubes** that can only be *physically* rotated and twisted by hand. A **Texture** is laid down on a Virtual Cube whereas real **Stickers** are stuck down on a Real Cube.

A Mathematical & Physical Formulas Cube is designed by placing letters, symbols and numbers on a texture which is then laid down on a Virtual Cube (see <http://www.randelshofer.ch/> for more details).

| Mathematical & Physical Formulas – Useful Links                                                                 |                                                                                                             |
|-----------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| <a href="http://en.wikipedia.org/wiki/Maxwell's_equations">http://en.wikipedia.org/wiki/Maxwell's_equations</a> | <a href="http://en.wikipedia.org/wiki/Lorentz_force_law">http://en.wikipedia.org/wiki/Lorentz_force_law</a> |
| <a href="http://en.wikipedia.org/wiki/Ideal_gas_law">http://en.wikipedia.org/wiki/Ideal_gas_law</a>             | <a href="http://en.wikipedia.org/wiki/Ohm's_law">http://en.wikipedia.org/wiki/Ohm's_law</a>                 |
| <a href="http://en.wikipedia.org/wiki/Euler's_identity">http://en.wikipedia.org/wiki/Euler's_identity</a>       | <a href="http://en.wikipedia.org/wiki/Photon">http://en.wikipedia.org/wiki/Photon</a>                       |

A set of *well-known* mathematical & physical formulas can be displayed on a *selected* Cube face by rotating and twisting some parts of the Cube. When this has been achieved, we say that the Cube has been *solved*.

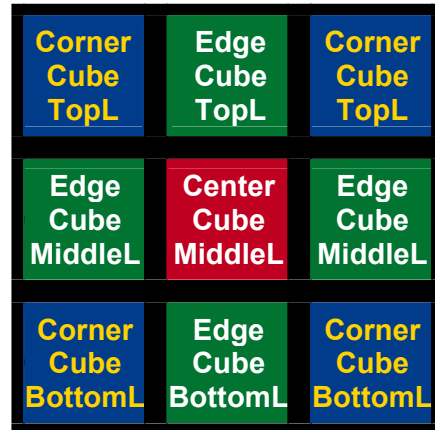
The Einstein's mass/energy equation of special relativity is shown in the following example:

| Virtual Mathematical and Physical Formulas Cube                                                                                                                                                                                                                                                                                                                                              |                                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------|
| $  \begin{array}{ccccccc}  & & P & \pi & q & & \\  & & \nabla & + & = & & \\  & & \triangle & + & > & & \\  J & \times & F & & E & = & \gamma & i & \sigma \\  R & = & = & m & c & 2 & \downarrow & J & D \\  & / & \partial B & & & & H & & v \\  & & \partial D & q & E & F & \triangle & e \\  & & 0 & & \sigma & B & \cdot & q \\  B & h & T & - & i & \partial t & & &   \end{array}  $ |  |
| Mathematical & Physical Formulas Cube Texture                                                                                                                                                                                                                                                                                                                                                | Mathematical & Physical Formulas Cube                                                |
| Download <b>CubeTwister</b> from: <a href="http://www.randelshofer.ch/">http://www.randelshofer.ch/</a>                                                                                                                                                                                                                                                                                      |                                                                                      |

Designing a Mathematical & Physical Formulas Cube that *works* is definitely not a trivial task but **Design Rules** exist that should be applied. Because it is nearly impossible to test all configurations, the placement of numbers and letters on a texture should be carefully checked at *the end* of the design process. This is carried out by applying a **Design Rules Check (DRC)** in the final design stage.

## Terminology

In a 3x3x3 **Rubik's Cube**, there are 8 *Corner Cubes*, 12 *Edge Cubes*, 6 *Center Cubes* and 6 *Cube Faces*. There are also 4 Corner Cube faces, 4 Edge Cube faces and 1 Center Cube face *per Cube Face*, as shown below.



There are 1 face per Center Cube, 2 faces per Edge Cube and 3 faces per Corner Cube.

There are also 3 horizontal *Layers* called *Top*, *Middle* and *Bottom Layers*.

| Cube Lexicon                     |                                     |                                                                  |
|----------------------------------|-------------------------------------|------------------------------------------------------------------|
| English                          | Français                            | Deutsch                                                          |
| Cube                             | Cube                                | Würfel                                                           |
| cube, cube                       | cube, petit cube                    | Würfelteil, Teil des Würfels                                     |
| face                             | face                                | Seite, Seitenfläche                                              |
| front face                       | face avant                          | vordere Seite, vorne                                             |
| back face                        | face arrière                        | hintere Seite, hinten                                            |
| left face                        | face gauche                         | linke Seite, links                                               |
| right face                       | face droite                         | rechte Seite, rechts                                             |
| top face                         | face supérieure                     | obere Seite, oben                                                |
| bottom face                      | face inférieure                     | untere Seite, unten                                              |
| sticker                          | étiquette (autocollante), plaquette | Kleber, Farbkleber                                               |
| tile                             | tuile, plaquette                    | Plättchen, Farbplättchen                                         |
| center cube, center              | cube central, centre                | Mittelwürfel, Mittelstein, Mitte                                 |
| edge cube, edge                  | cube-arête, arête                   | Kantenwürfel, Kantenstein, Kante                                 |
| corner cube, corner              | cube de coin, coin                  | Eckwürfel, Eckstein, Ecke                                        |
| layer                            | couronne                            | Schicht, Scheibe                                                 |
| top layer                        | couronne supérieure                 | obere Schicht, obere Scheibe                                     |
| middle layer                     | couronne intermédiaire              | mittlere Schicht, mittlere Scheibe, Mittelschicht, Mittelscheibe |
| bottom layer                     | couronne inférieure                 | untere Schicht, untere Scheibe                                   |
| orientation, direction           | orientation                         | Orientierung                                                     |
| to solve                         | résoudre                            | lösen, zusammen drehen                                           |
| to twist                         | pivoter                             | drehen                                                           |
| to rotate                        | tourner, effectuer une rotation     | drehen                                                           |
| clockwise                        | dans le sens horaire                | im Uhrzeigersinn                                                 |
| anticlockwise, counter-clockwise | dans le sens anti-horaire           | im Gegenuhrzeigersinn                                            |

# Mathematical & Physical Formulas

In this *particular* design, the following **15** mathematical & physical formulas can be displayed on a cube.

| 1 Mathematical Formula                                |                                                 |                                                                |
|-------------------------------------------------------|-------------------------------------------------|----------------------------------------------------------------|
| Name                                                  | Formula                                         | As displayed on a cube                                         |
| Euler's Identity                                      | $e^{i\pi}+1=0$                                  | $e^{i\pi}+1=0$                                                 |
| 14 Physical Formulas                                  |                                                 |                                                                |
| Names                                                 | Formulas                                        | As displayed on a cube                                         |
| Einstein's Mass/Energy Equation of Special Relativity | $E=mc^2$                                        | $E=mc^2$                                                       |
| Photon's Energy                                       | $E=h\nu$                                        | $E=h\nu$                                                       |
| Maxwell's Equations – Faraday's Law                   | $\nabla \times E = -\partial B / \partial t$    | $\nabla \times E = -\partial B / \partial t$                   |
| Maxwell's Equations – Maxwell's Law                   | $\nabla \times H = J + \partial D / \partial t$ | $\nabla \times H = J + \partial D / \partial t$                |
| Maxwell's Equations – Maxwell's Law (J=0)             | $\nabla \times H = \partial D / \partial t$     | $\nabla \times H = \partial D / \partial t$                    |
| Maxwell's Equations – Maxwell's Law (J=0)             | $\nabla \times H = \partial D / \partial t$     | $\nabla \times H = \partial D / \partial t$                    |
| Maxwell's Equations – Gauss' Law for Magnetism        | $\nabla \cdot B = 0$                            | $\nabla \cdot B = 0$                                           |
| Maxwell's Equations – Gauss' Law                      | $\nabla \cdot D = \rho$                         | $\nabla \cdot D = \rho$                                        |
| Maxwell's Equations – Gauss' Law ( $\rho=0$ )         | $\nabla \cdot D = 0$                            | $\nabla \cdot D = 0$                                           |
| Lorentz Force Law                                     | $F=q(E+v \times B)$                             | $F=qE+q v \times B$                                            |
| Lorentz Force Law ( $v=0$ )                           | $F=qE$                                          | $F=qE$                                                         |
| Electrical Conductivity Law                           | $J=\sigma(E+v \times B)$                        | $J=\sigma E+\sigma v \times B$                                 |
| Electrical Conductivity Law ( $v=0$ )                 | $J=\sigma E$                                    | $J=\sigma E$                                                   |
| Joule's Law                                           | $V=RI$                                          | $V=RI$                                                         |
| Ideal Gas Law                                         | $PV=nRT$                                        | $PV=nRT$                                                       |
| Defintions                                            | Symbols                                         | Values/Units/Symbols                                           |
| Energy                                                | $E$                                             | J                                                              |
| Mass                                                  | $m$                                             | kg                                                             |
| Speed of light                                        | $c$                                             | $m \cdot s^{-1}$                                               |
| Planck's constant                                     | $h$                                             | $6.62606896 \times 10^{-34} \text{ J} \cdot s$                 |
| Frequency                                             | $\nu$                                           | Hz                                                             |
| Gradient operator                                     | $\nabla$                                        |                                                                |
| Vector cross product operator                         | $\times$                                        |                                                                |
| Scalar cross product operator                         | $\cdot$                                         |                                                                |
| Curl operator                                         | $\nabla \times$                                 |                                                                |
| Divergence operator                                   | $\nabla \cdot$                                  |                                                                |
| Electric field                                        | $E$                                             | $V \cdot m^{-1}$                                               |
| Magnetic field                                        | $B$                                             | $V \cdot s \cdot m^{-2}$                                       |
| Partial derivative with respect to time               | $\partial / \partial t$                         |                                                                |
| Magnetizing field                                     | $H$                                             | $A \cdot m^{-1}$                                               |
| Electric flux density                                 | $D$                                             | $C \cdot m^{-2}$                                               |
| Total charge density                                  | $\rho$                                          | $C \cdot m^{-3}$                                               |
| Force                                                 | $F$                                             | N                                                              |
| Electrical charge                                     | $q$                                             | C                                                              |
| Particle instantaneous velocity                       | $v$                                             | $m \cdot s^{-1}$                                               |
| Total current density                                 | $J$                                             | $A \cdot m^{-2}$                                               |
| Electrical conductivity                               | $\sigma$                                        | $S \cdot m^{-1}$                                               |
| Voltage                                               | $V$                                             | V                                                              |
| Resistance                                            | $R$                                             | $\Omega$                                                       |
| Current                                               | $I$                                             | A                                                              |
| Absolute pressure of a gas                            | $P$                                             | Pa                                                             |
| Volume of a gas                                       | $V$                                             | $m^3$                                                          |
| Number of moles of gas                                | $n$                                             |                                                                |
| Universal gas constant                                | $R$                                             | $8.314472 \text{ J} \cdot \text{mol}^{-1} \cdot \text{K}^{-1}$ |
| Absolute temperature                                  | $T$                                             | K                                                              |

|              |          |              |              |          |              |              |          |              |
|--------------|----------|--------------|--------------|----------|--------------|--------------|----------|--------------|
| e            | i        | $\pi$        |              | E        | =            |              | E        |              |
| +            |          | 1            | m            | c        | 2            |              | =        |              |
| =            | 0        |              |              |          |              |              | h        | v            |
| $\nabla$     | $\times$ | E            | $\nabla$     | $\times$ | H            | $\nabla$     | $\times$ | H            |
| =            |          | -            | =            | J        | +            | =            |          |              |
| $\partial B$ | /        | $\partial t$ | $\partial D$ | /        | $\partial t$ | $\partial D$ | /        | $\partial t$ |
|              |          |              |              |          |              |              |          |              |
| $\nabla$     | $\cdot$  | B            | $\nabla$     | $\cdot$  | D            | $\nabla$     | $\cdot$  | D            |
| =            | 0        |              | =            | $\rho$   |              | =            | 0        |              |
| F            | =        | q            | F            | =        | q            | J            | =        | $\sigma$     |
| E            | +        | q            | E            |          |              | E            | +        | $\sigma$     |
| v            | $\times$ | B            |              |          |              | v            | $\times$ | B            |
| J            | =        | $\sigma$     |              | V        |              | P            | V        |              |
| E            |          |              |              | =        |              |              | =        |              |
|              |          |              |              | R        | I            | n            | R        | T            |

# Some Interesting Combinations

Small greek letters only

|  |        |          |
|--|--------|----------|
|  |        | $\pi$    |
|  |        | $\sigma$ |
|  | $\rho$ | $\nu$    |

Small letters only

|   |   |   |
|---|---|---|
| e | i | q |
| m | c | q |
| v | h |   |

Operators only

|          |          |          |
|----------|----------|----------|
| $\nabla$ | $\times$ | $=$      |
| $+$      | $\cdot$  | $\Delta$ |
| $-$      | $/$      |          |

Capital letters only

|   |   |   |
|---|---|---|
| F | E | E |
| E | J | B |
| H | R | T |

Capital letters only

|   |   |   |
|---|---|---|
| J | V | E |
| E | J | B |
| H | R | B |

Capital letters only

|   |   |   |
|---|---|---|
| P | V | E |
| E | J | D |
| H | R | I |

Circumference =  $2\pi R$

|  |     |       |
|--|-----|-------|
|  | $=$ | $\pi$ |
|  | c   | 2     |
|  | R   |       |

$\Delta E = h\nu$

|     |   |          |
|-----|---|----------|
|     |   |          |
| E   |   | $\Delta$ |
| $=$ | h | $\nu$    |

Angular frequency =  $2\pi\nu$

|   |     |       |
|---|-----|-------|
| F | $=$ | $\pi$ |
|   |     | 2     |
|   |     | $\nu$ |

I seek you.

|  |   |   |
|--|---|---|
|  | i |   |
|  | c | q |
|  |   |   |

I see too.

|  |   |   |
|--|---|---|
|  | i |   |
|  | c | 2 |
|  |   |   |

See me.

|   |   |  |
|---|---|--|
| e |   |  |
| m | c |  |
|   |   |  |

# Some Interesting Combinations (cont'd)

Last 4 letters of 'ALBERT'

|   |   |   |
|---|---|---|
|   |   |   |
| E |   | B |
|   | R | T |

See me too.

|   |   |   |
|---|---|---|
| e |   |   |
| m | c | 2 |
|   |   |   |

ETH (Zurich)

|   |  |   |
|---|--|---|
|   |  | H |
| E |  |   |
|   |  | T |

quantum mechanics

|   |   |   |
|---|---|---|
| e |   | q |
| m | c |   |
|   | h |   |

First 3 letters of 'Einstein'

|   |   |  |
|---|---|--|
|   | i |  |
| E |   |  |
|   | n |  |

1999 Time Magazine

|   |   |   |
|---|---|---|
| e | i |   |
| m |   |   |
|   |   | T |

Federal Inst. of Technology

|   |   |   |
|---|---|---|
| F |   |   |
|   |   |   |
|   | I | T |

'THE0R' of 'THEORY'

|   |   |   |
|---|---|---|
|   | 0 | H |
| E |   |   |
|   | R | T |

Last 4 letters of 'Einstein'

|   |   |   |
|---|---|---|
| e | i |   |
|   |   |   |
|   | n | T |

BeRn (Switzerland)

|   |   |   |
|---|---|---|
| e |   |   |
|   |   |   |
| n | R | B |

EPR Einstein Podolsky Rosen

|   |   |  |
|---|---|--|
| P |   |  |
| E |   |  |
|   | R |  |

'1' = 'Ein' auf Deutsch

|   |   |   |
|---|---|---|
|   | i |   |
| E | = | 1 |
|   | n |   |

# Letters, Symbols and Numbers Layout

## Center Cubes Layout

There are 3 symbols, 2 letters and a blank/white laid on the 6 center cubes:  $\bullet$ ,  $+$ ,  $=$ ,  $c$ ,  $J$ , blank/white

## Corner Cubes Layout

Letters and symbols are *logically* grouped and laid out on the 8 corner cubes as follows:

- 1- Top Left (**TL**): ( $\nabla$ , F, blank/white), ( $J$ , P, e)
- 2- Top Right (**TR**): (E, H, blank/white), ( $q$ ,  $\sigma$ ,  $\pi$ )
- 3- Bottom Left (**BL**): ( $\partial B$ ,  $\partial D$ , blank/white), ( $n$ ,  $v$ ,  $=$ )
- 4- Bottom Right (**BR**): ( $\partial t$ , B, blank/white), ( $T$ , I,  $v$ )

**DRC:** Blanks have been grouped with *carefully selected* letters and/or symbols. When these letters and/or symbols are displayed on a solved Face, there should be *no* blank corner cube face on the Face.

**LOC:** There is a *maximum* of 3 blank corner cube faces on a solved Face. So, there is 1 blank corner cube face left that could be used for *Localizing/Customizing* the Cube.

## Edge Cubes Layout

Letters, symbols and numbers are *logically* grouped and laid out on the 12 edge cubes as follows:

- 1- Top Center (**TC**): ( $\times$ , V), ( $=$ , i), (E, **ML**)
- 2- Bottom Center (**BC**): ( $/$ , 0), (R,  $\rho$ ), (h, **MR**)
- 3- Middle Left (**ML**): ( $=$ , m), (E,  $\nabla$ )
- 4- Middle Right (**MR**): (D, B), (1, 2), ( $q$ , blank/white), ( $\sigma$ , blank/white)

**DRC:** Blanks have been be paired with *carefully selected* letters. When 1 of these 2 letters ( $q$  or  $\sigma$ ) is displayed on a solved Face, there should be a *maximum* of 1 blank edge cube face on the Face.

**LOC:** There is a *maximum* of 2 blank edge cube faces on a solved Face. But there are *only* 2 blank edge cube faces. So *none* could be used for *Localizing/Customizing* the Cube.

## Letters, Symbols and Numbers Combination Table

| Letters, Symbols and Numbers Combination Table (90°, 180°)                                  |                                                                                       |                                                                                                                                                                         |
|---------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Top Left – Corner cubes                                                                     | Top Center – Edge cubes                                                               | Top Right – Corner cubes                                                                                                                                                |
| $\nabla$ , F, white, J, P, e, <b>I</b>                                                      | $\underline{\times}$ , V, $\underline{=}$ , i, E, <b>O</b> , <b>/</b> , <b>I</b>      | E, H, white, $q$ , $\sigma$ , $\pi$ , <b>=</b> , <b>—</b>                                                                                                               |
| Middle Left – Edge cubes                                                                    | Middle Center – Center cubes                                                          | Middle Right – Edge cubes                                                                                                                                               |
| $\underline{=}$ , m, E, $\nabla$ , $\pm$ , <b>—</b> , <b>\</b> , <b><math>\times</math></b> | $\bullet$ , $+$ , $=$ , $c$ , J, white                                                | D, B, 1, 2, $q$ , white, $\sigma$ , white, <b><math>\underline{=}</math></b> , <b>=</b> , <b>+</b> , <b><math>\Delta</math></b> , <b>\</b> , <b><math>\times</math></b> |
| Bottom Left – Corner cubes                                                                  | Bottom Center – Edge cubes                                                            | Bottom Right – Corner cubes                                                                                                                                             |
| $\partial B$ , $\partial D$ , white, $n$ , $v$ , $\underline{=}$ , <b>H</b> , <b>—</b>      | <b>L</b> , <b>0</b> , R, $\rho$ , h, <b><math>\times</math></b> , <b>=</b> , <b>I</b> | $\partial t$ , B, white, T, <b>I</b> , $v$ , <b><math>\Delta</math></b>                                                                                                 |

## Letters, Symbols and Numbers Orientation – Recap

| Letters, Symbols and Numbers Orientation – Recap     |                                        |                                                     |
|------------------------------------------------------|----------------------------------------|-----------------------------------------------------|
| Top Left – Corner cubes                              | Top Center – Edge cubes                | Top Right – Corner cubes                            |
| $\nabla$ , F, white, J, P, e                         | $\times$ , V, $=$ , i, E               | E, H, white, $q$ , $\sigma$ , $\pi$                 |
| Middle Left – Edge cubes                             | Middle Center – Center cubes           | Middle Right – Edge cubes                           |
| $=$ , m, E, $\nabla$ , $+$                           | $\bullet$ , $+$ , $=$ , $c$ , J, white | D, B, 1, 2, $q$ , white, $\sigma$ , white, <b>—</b> |
| Bottom Left – Corner cubes                           | Bottom Center – Edge cubes             | Bottom Right – Corner cubes                         |
| $\partial B$ , $\partial D$ , white, $n$ , $v$ , $=$ | $/$ , 0, R, $\rho$ , h                 | $\partial t$ , B, white, T, I, $v$                  |

# Solving a Mathematical & Physical Formulas Cube Step by Step

In this example, a step by step solving process is applied to the Mathematical & Physical Formulas Cube, just described before. Note that we only need to solve a *single* Face out of six. We will solve a Face for  $e=mc^2$ .

Solve the Cross First

|  |  |  |
|--|--|--|
|  |  |  |
|  |  |  |
|  |  |  |

Standard Rubik's Cube Solving

Then Solve the Corner Cubes

|  |  |  |
|--|--|--|
|  |  |  |
|  |  |  |
|  |  |  |

Standard Rubik's Cube Solving

Step 1

|  |   |  |
|--|---|--|
|  |   |  |
|  | c |  |
|  |   |  |

Center Cube c on Front Face

Step 2

|  |   |  |
|--|---|--|
|  | E |  |
|  | c |  |
|  |   |  |

Top Layer: Edge Cube E

Step 3

|   |   |  |
|---|---|--|
|   | E |  |
| m | c |  |
|   |   |  |

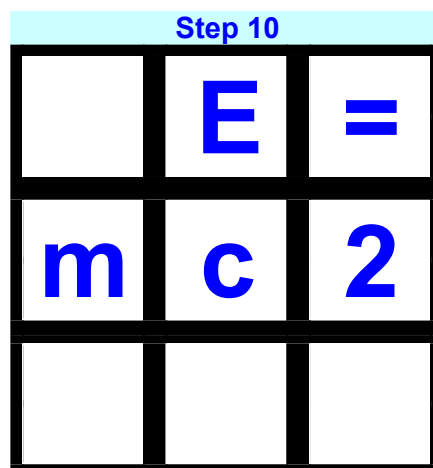
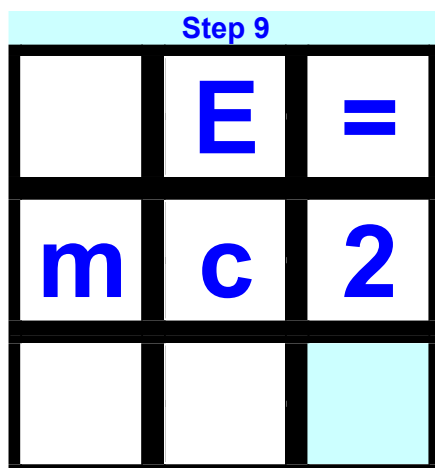
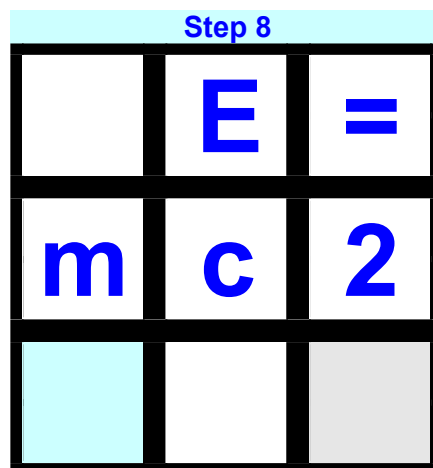
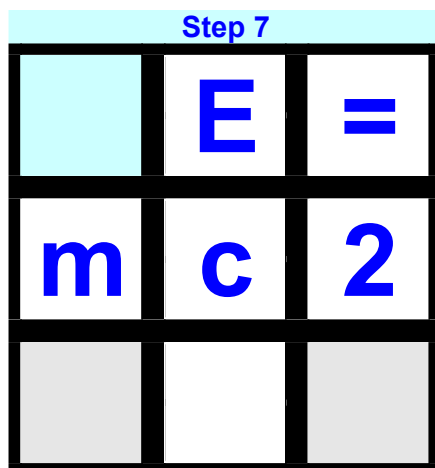
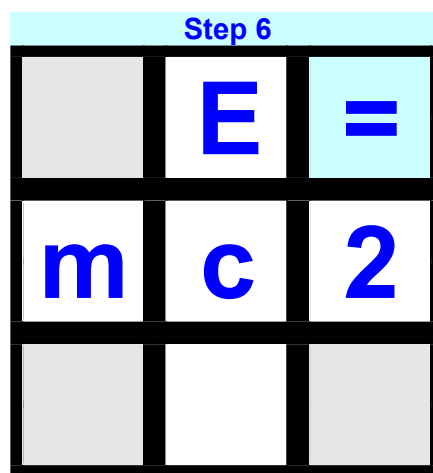
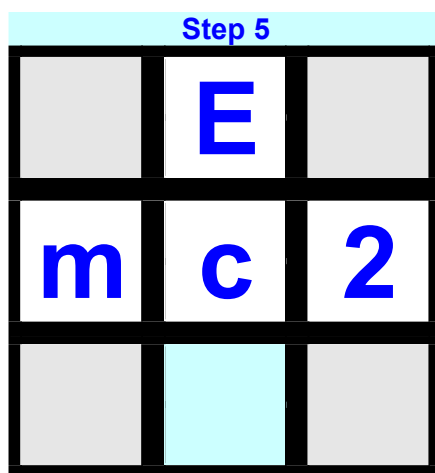
Middle Layer: Edge Cube m

Step 4

|   |   |   |
|---|---|---|
|   | E |   |
| m | c | 2 |
|   |   |   |

Middle Layer: Edge Cube 2





**Print out this page and fill in the blank faces with *your* data. Then try to design your *own* Cube.**

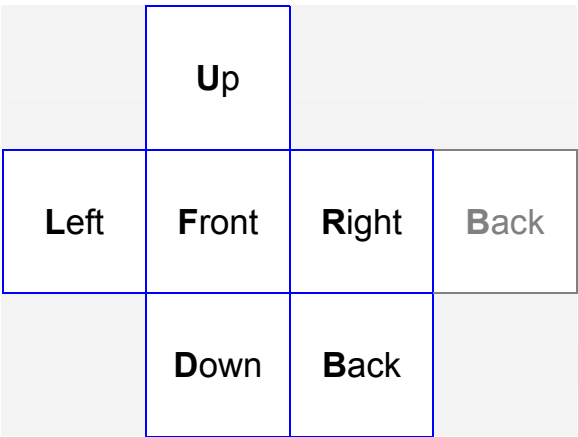
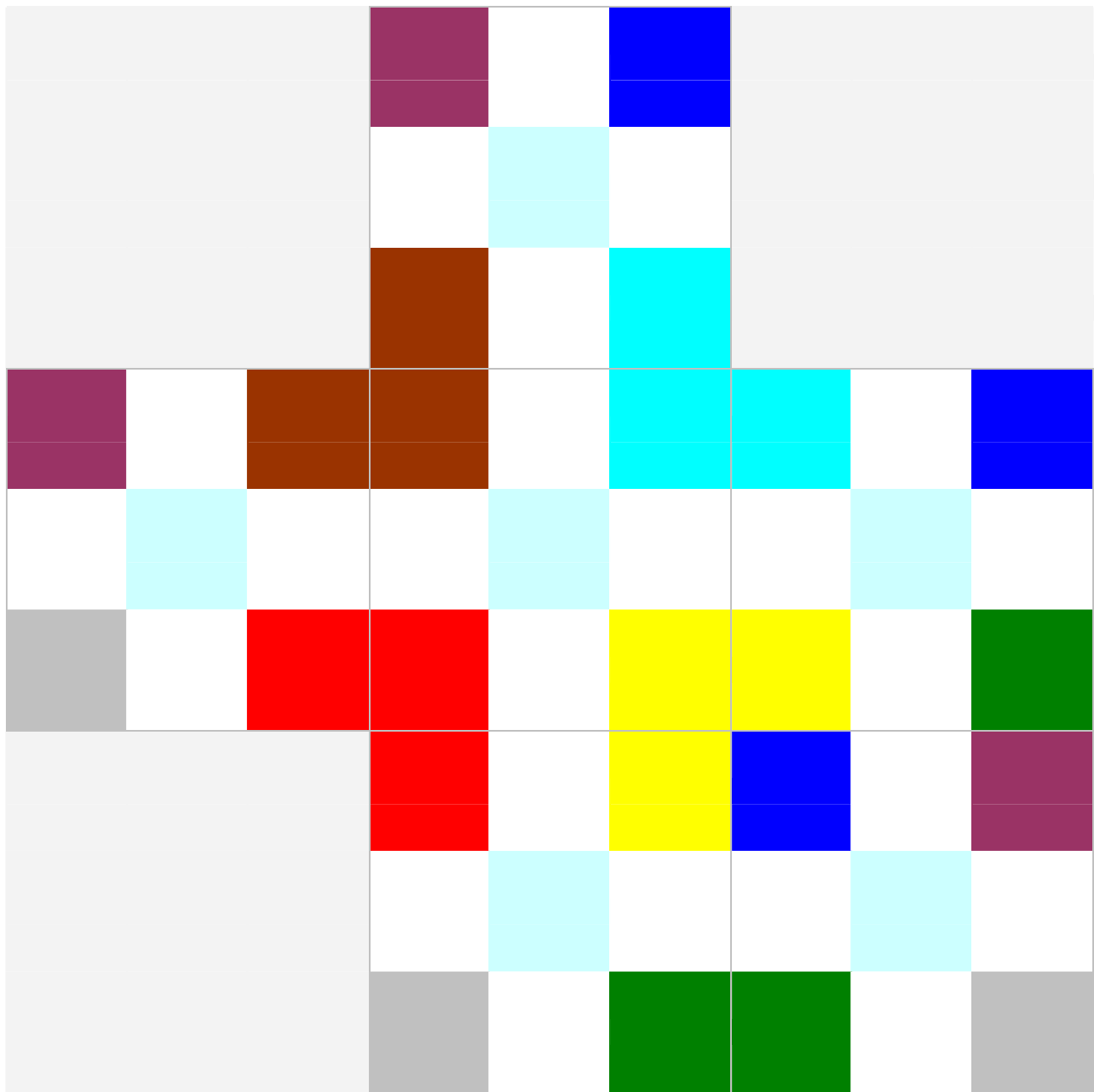
TL TC TR

**ML MC MR**

**BL BC BR**

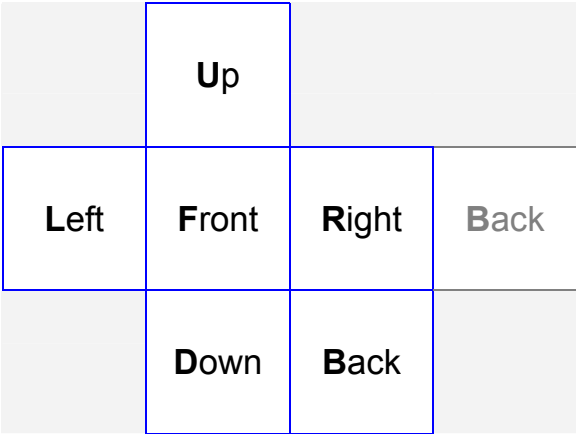
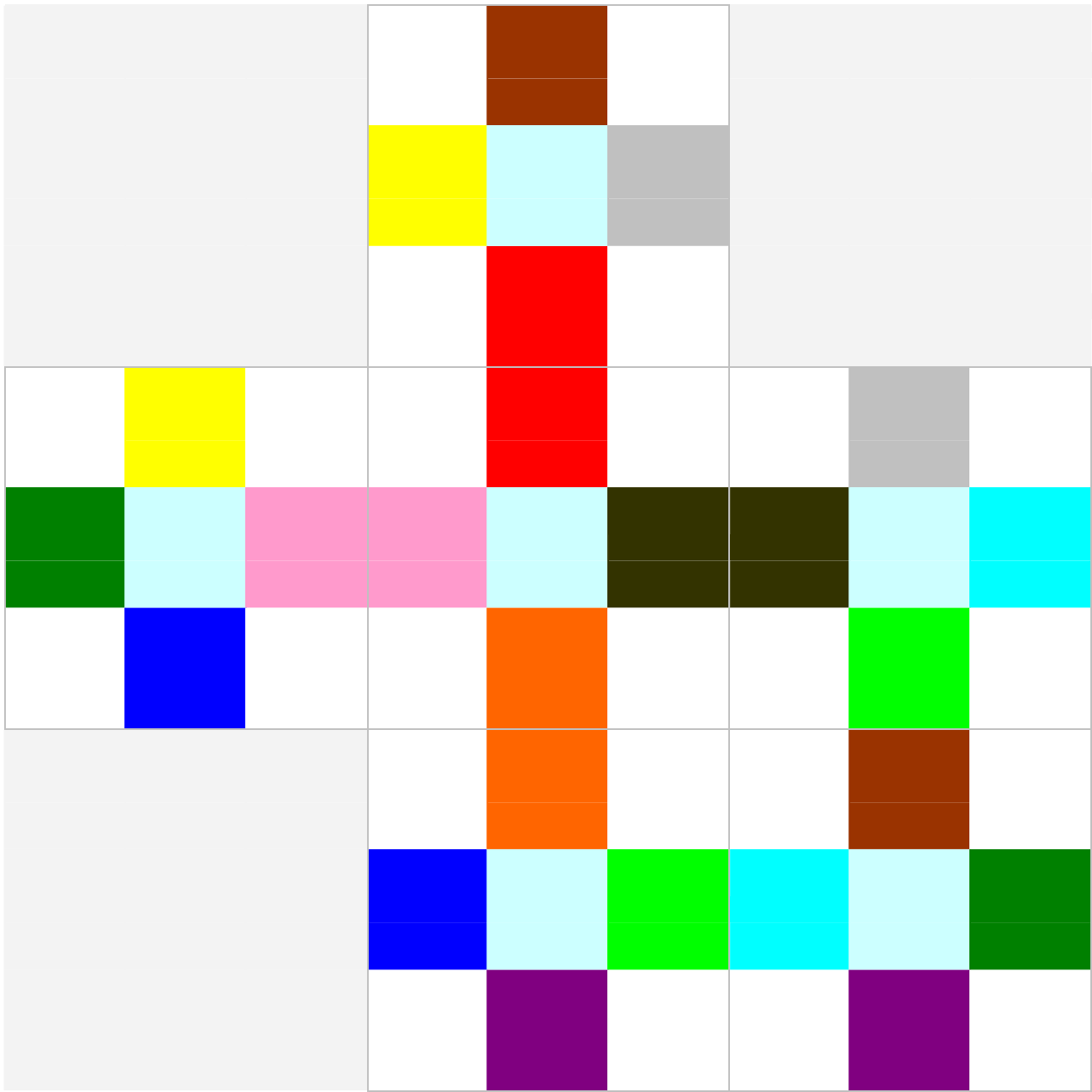
# Corner Cubes Final Check

There are 8 Corner Cubes and 3 faces per Corner Cube. In the diagram below, each Corner Cube is displayed in 8 different colors and with the same color applied to each of its 3 faces. This diagram can be used as a convenient *visual aid* to check Design Rules (DRC).



# Edge Cubes Final Check

There are 12 Edge Cubes and 2 faces per Edge Cube. In the diagram below, each Edge Cube is displayed in 12 different colors and with the same color applied to each of its 2 faces. This diagram can be used as a convenient *visual aid* to check Design Rules (DRC).



# Texture Template

This is a texture template that can be printed out and used for writing down numbers and letters by hand *prior to* texture design. All is needed are pencil, rubber...and time.

