Reconciling `unicode-math` and LaTeX 2_ε

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July 20, 2015

What's unicode-math?

```
\usepackage{unicode-math}
\setmathfont{Cambria Math}
\setmathfont{Cambria Math}[
 range={\mathrel}, Colour=ForestGreen]
\setmathfont{Cambria Math}[
 range={\mathopen,\mathclose}, Colour=blue]
\setmathfont{Cambria Math}[
 range={\mathop,\mathscr}, Colour=red]

\[ F(s)=\mathscr{L}\,\bigl\{f(t)\bigr\}
   = \int_0^∞ \mathup e^{-st}f(t)
   \, \mathup d t \]
```

$$F(s) = \mathscr{L}\,\bigl\{f(t)\bigr\} = \int_0^\infty \mathrm{e}^{-st} f(t)\,\mathrm{d}t$$

Introduction

LATEX defaults

Input:

```
\[ fin = \mathit{fin} \]
```

Output:

$$fin = \mathit{fin}$$

Introduction

With unicode-math

Input:

```
\[ fin = \mathit{fin} \]
```

Output:

$$fin = fin$$

Introduction

Similarly:

Input:

```
\[ fin = \mathbf{fin} \]
```

Default:

$$fin = \mathbf{fin}$$

With `unicode-math`:

$$fin = \mathbf{fin}$$

Something needs fixing!

Contents

Overview of Unicode Mathematics

Historical and current examples
- Sidenote: symbols

TEX's methods

Unicode mathematics

- I hope you know what Unicode is
- Thousands of mathematical glyphs (≈ 2500)
- Standard LATEX names thanks to Barbara Beeton
- As a non-mathematician, very fun to scroll through seemingly endless tables like:

"2A00	"2A01	"2A02	"2A03	"2A04	"2A05	"2A06	"2A07
⨀	⨁	⨂	⨃	⨄	⨅	⨆	⨇
"2A59	"2A60	"2A61	"2A62	"2A63	"2A64	"2A65	"2A66
⩙	⩠	⩡	⩢	⩣	⩤	⩥	⩦

Extract from the symbols table

0225B	≛	≛	≛	≛	≛		\stareq
0225C	≜	≜	≜	≜	≜		\triangleq(a)
0225D	≝	≝	≝	≝	≝		\eqdef
0225E	≞	≞	≞	≞	≞		\measeq
0225F	≟	≟	≟	≟	≟		\questeq
02260	≠	≠	≠	≠	≠	≠	\ne(p)
02261	≡	≡	≡	≡	≡	≡	\equiv(p)
02262	≢	≢	≢	≢	≢	≢	\nequiv
02263	≣	≣	≣	≣	≣	≣	\Equiv
02264	≤	≤	≤	≤	≤	≤	\leq(p)
02265	≥	≥	≥	≥	≥	≥	\geq(p)
02266	≦	≦	≦	≦	≦	≦	\leqq(a)
02267	≧	≧	≧	≧	≧	≧	\geqq(a)
02268	≨	≨	≨	≨	≨	≨	\lneqq(a)

Symbols

- Access to all these symbols is nice
- All the symbols stuff is fine, $\pm$ a few naming issues
- Standardisation should be considered more rigorously

The ‘controversial’ stuff

- Alphabetic symbols are encoded individually:

"00057	"1D44A	"1D416	"1D51A	"1D4E6	"1D54E	"1D5B6
W	W	$\mathbf{W}$	$\mathfrak{W}$	$\boldsymbol{\mathcal{W}}$	$\mathbb{W}$	W

- Strong rationale: different letter shapes have different meanings in mathematics, and therefore should be distinguishable in plain text
- I.e., symbols are expressible without changing fonts
- How does this translate to LATEX?
- (This is where I went wrong.)

Alphabetic symbols

1D434	A	A	A	A	A	\mitA
1D435	B	B	B	B	B	\mitB
1D436	C	C	C	C	C	\mitC
1D437	D	D	D	D	D	\mitD
1D438	E	E	E	E	E	\mitE
1D439	F	F	F	F	F	\mitF
1D43A	G	G	G	G	G	\mitG
1D43B	H	H	H	H	H	\mitH
1D43C	I	I	I	I	I	\mitI
1D43D	J	J	J	J	J	\mitJ
1D43E	K	K	K	K	K	\mitK

Alphabetic symbols

1D700	ε	ε	ε	ε	ε	\mitepsilon
1D701	ζ	ζ	ζ	ζ	ζ	\mitzeta
1D702	η	η	η	η	η	\miteta
1D703	θ	θ	θ	θ	θ	\mittheta
1D704	ι	ι	ι	ι	ι	\mitiota
1D705	κ	κ	κ	κ	κ	\mitkappa
1D706	λ	λ	λ	λ	λ	\mitlambda
1D707	μ	μ	μ	μ	μ	\mitmu
1D708	ν	ν	ν	ν	ν	\mitnu
1D709	ξ	ξ	ξ	ξ	ξ	\mitxi
1D70A	o	o	o	o	o	\mitomicron

Alphabetic symbols

1D53B	𝔻	𝔻	𝔻	𝔻	𝔻	\BbbD
1D53C	𝔼	𝔼	𝔼	𝔼	𝔼	\BbbE
1D53D	𝔽	𝔽	𝔽	𝔽	𝔽	\BbbF
1D53E	𝔾	𝔾	𝔾	𝔾	𝔾	\BbbG
1D540	𝕀	𝕀	𝕀	𝕀	𝕀	\BbbI
1D541	𝕁	𝕁	𝕁	𝕁	𝕁	\BbbJ
1D542	𝕂	𝕂	𝕂	𝕂	𝕂	\BbbK
1D543	𝕃	𝕃	𝕃	𝕃	𝕃	\BbbL
1D544	𝕄	𝕄	𝕄	𝕄	𝕄	\BbbM
1D546	𝕆	𝕆	𝕆	𝕆	𝕆	\BbbO
1D54A	𝕊	𝕊	𝕊	𝕊	𝕊	\BbbS

What does LATEX do with maths alphabets?

$$Re = \frac{\rho v \cos(\theta)}{L} \qquad \text{for } 0 \leq \theta < \pi/2$$

$$H \sim \mathbf{Hom}(Z)$$

$$\mathbf{k} = [k_x, k_y, k_z]^T \qquad \mathbf{k} \in \mathbb{R}^3$$

What are the different fonts here?

- ρv etc — `\mathnormal`
- Re — `\mathit`
- $\cos$ — `\mathrm` (actually `\operator@font`)
- 'for ...' — `\textrm`
- $(\cdot)^T$ or $(\cdot)^\mathrm{T}$ — your choice
- $\mathbf{Hom}$ — `\mathbf`
- $\mathbf{v}$ — `\mathbf` — but should it be?
- $\mathbb{R}$ — `\mathbb`

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Maths alphabet fonts

- Many many alphabet styles used in mathematics
- TeX achieved this by switching fonts
- In Unicode mathematics, these are all in the one font
- Or are they?

What's missing?

- Unicode mathematics has a few potential gaps
- To date, no provision for 'text spacing' (v maths)
- Although it's up to the font designer, symbols in UM fonts are kerned as single-letter variables.
- Ramifications:
  - Upright roman not spaced for text ($\mathrm{sin}\,x$)
  - Italic roman not spaced for text (Re)
  - Bold roman not spaced for text ($\mathbf{Hom}$)

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Unfortunately, `unicode-math` has been calling these `\mathrm`, `\mathit`, and `\mathbf` for many years.

This gives a good excuse for a talk

- Historical/interesting examples of mathematics
- How `unicode-math` works, TEX-nically
- Fixing the alphabet problem

Overview of Unicode Mathematics

Historical and current examples

Sidenote: symbols

TeX's methods

\mathrm with maths spacing

Historical example

Up to the critical point

$$\mathrm{A}_c \frac{\mathrm{D}^3}{\mathrm{P}^2} i = \mathrm{B}_c \frac{\mathrm{D}v}{\mathrm{P}}$$

After the critical point is passed the law is complex until a velocity which is $1{\cdot}325\ v_c$ is reached. Then as shown in the homologues the curve assumes a simple character again

$$\mathrm{A}\ \frac{\mathrm{D}^3}{\mathrm{P}^2} i = \left(\mathrm{B}\ \frac{\mathrm{D}v}{\mathrm{P}}\right)^{1{\cdot}723}$$

Osborne Reynolds. "An Experimental Investigation of the Circumstances Which Determine Whether the Motion of Water Shall Be Direct or Sinuous, and of the Law of Resistance in Parallel Channels". In: *Phil. Trans. R. Soc. Lond.* 174 (1883), pp. 935–982. DOI: 10.1098/rstl.1883.0029

\mathrm with maths spacing

Modern example

$$\boxed{\frac{d}{dt}U(t)^2 = 2U(t)K\left[\underline{\mathrm{e}}^{A\hat{D}(t)}\dot{X}(t) + \dot{\hat{D}}(t)G_1(t) + \frac{\hat{D}(t)}{D}G_2(t)\right]}$$

Miroslav Krstić. *Delay Compensation for Nonlinear, Adaptive, and PDE Systems*. Birkhäuser Boston, 2009. DOI: 10.1007/978-0-8176-4877-0

Also note

$$\frac{d}{dt} \quad \text{vs} \quad \frac{\mathrm{d}}{\mathrm{d}t}$$

e and e

$$\mathrm{Proj}_{\Pi}\{\tau_\theta\} = \tau_\theta \begin{cases} I, & \hat{\theta} \in \mathring{\Pi} \text{ or } \nabla_{\hat{\theta}} \mathscr{P}^T \tau \leq 0, \\ I - \frac{\nabla_{\hat{\theta}} \mathscr{P} \nabla_{\theta} \mathscr{P}^T}{\nabla_{\hat{\theta}} \mathscr{P}^T \nabla_{\theta} \mathscr{P}}, & \hat{\theta} \in \partial\Pi \text{ and } \nabla_{\hat{\theta}} \mathscr{P}^T \tau > 0, \end{cases}$$

for the vector (plant parameter) case.

The transformed state of the actuator is

$$w(x,t) = e(x,t) - \hat{D}(t) \int_0^x K(\hat{\theta}) \mathrm{e}^{A(\hat{\theta})\hat{D}(t)(x-y)} B(\hat{\theta}) e(y,t) dy \\ - K(\hat{\theta}) \mathrm{e}^{A(\hat{\theta})\hat{D}(t)x} \tilde{X}(t),$$

\mathrm with text spacing

As indicated above in Section 2.1, D'Arcy Thompson used the Froude number to compare the walking speeds of different sized characters in *Gulliver's Travels*. This is clearly one of the major benefits of the Froude number, with the primary application being in the study of children's gait [1,2,32,41–44]. Alexander [32] showed that when dimensionless stride length was plotted as a function of dimensionless speed β where

$$\beta = v/(gL)^{1/2} = (\mathrm{Fr})^{1/2} \tag{3}$$

then data for children aged over 4 years were the same as adults. He used this empirical relationship to predict

Christopher L. Vaughan and Mark J. O'Malley. "Froude and the contribution of naval architecture to our understanding of bipedal locomotion". In: *Gait & Posture* 21.3 (2005), pp. 350–362. DOI: 10.1016/j.gaitpost.2004.01.011

\mathrm with text spacing

...sometimes

He hypothesised, and provided the necessary experimental evidence to demonstrate, that animals meet these five criteria when they travel at speeds that translate to equal values of *Fr* [31]. Evidence in support of criterion 3 has been presented in Fig. 7a, while the data for criterion 2 may be seen in Fig. 7b. At *Fr* values below 2, the phase differences lie between 0.4 and 0.5, and the animals utilise symmetri-

Christopher L. Vaughan and Mark J. O'Malley. "Froude and the contribution of naval architecture to our understanding of bipedal locomotion". In: *Gait & Posture* 21.3 (2005), pp. 350–362. DOI: 10.1016/j.gaitpost.2004.01.011

\mathrm with text spacing

$$u(y, t) = \mathrm{Re}\left(i \frac{P_x}{\rho n} \left\{ 1 - \frac{\cosh\left[(1+i)\sqrt{(n/2\nu}\ y\right]}{\cosh\left[(1+i)\sqrt{(n/2\nu}\ a\right]} \right\} e^{int} \right)$$

From the geometry of the element as it appears at time $t = \delta t$,

$$\begin{aligned} \delta\alpha &= \tan^{-1}\left(\frac{y \text{ component of } D'C'}{x \text{ component of } D'C'} \right) \\ &= \tan^{-1}\left\{ \frac{\left[v(\frac{1}{2}\delta x, -\frac{1}{2}\delta y)\, \delta t + \cdots\right] - \left[v(-\frac{1}{2}\delta x, -\frac{1}{2}\delta y)\, \delta t + \cdots\right]}{\delta x + \cdots} \right\} \end{aligned}$$

I. G. Currie. *Fundamental Mechanics of Fluids*. Third Edition. Marcel Dekker, 2003

Where is `\mathbf` used?

12. It is sometimes convenient in special problems to employ a system of rectangular axes which is itself in motion. The motion of this frame may be specified by the component velocities $\mathbf{u}$, $\mathbf{v}$, $\mathbf{w}$ of the origin, and the component rotations $\mathbf{p}$, $\mathbf{q}$, $\mathbf{r}$, all referred to the instantaneous positions of the axes. If u, v, w be the component velocities of a fluid particle at (x, y, z), the rates of change of its co-ordinates relative to the moving frame will be

$$\frac{Dx}{Dt} = u - \mathbf{u} + \mathbf{r}y - \mathbf{q}z, \quad \frac{Dy}{Dt} = v - \mathbf{v} + \mathbf{p}z - \mathbf{r}x, \quad \frac{Dz}{Dt} = w - \mathbf{w} + \mathbf{q}x - \mathbf{p}y. \quad \ldots(1)$$

After a time δt the velocities of the particle parallel to the new positions of the co-ordinate axes will have become

$$u + \left(\frac{\partial u}{\partial t} + \frac{\partial u}{\partial x}\frac{Dx}{Dt} + \frac{\partial u}{\partial y}\frac{Dy}{Dt} + \frac{\partial u}{\partial z}\frac{Dz}{Dt}\right)\delta t, \ \&c., \ \&c. \quad \ldots\ldots\ldots(2)$$

Horace Lamb. *Hydrodynamics*. Fourth Edition. Cambridge University Press, 1916

Where is `\mathbf` used?

In the first step, the integration takes place over the surface of the first magnet S_1, which is written for the charge model as

$$\mathbf{B}_1(\mathbf{x}_2) = \frac{\mu_0}{4\pi} \oint_{S_1} \left[\mathbf{M}_1 \cdot \hat{\mathbf{n}}_{s_1}\right] \frac{\mathbf{x}_2 - \mathbf{x}_1}{\left|\mathbf{x}_2 - \mathbf{x}_1\right|^3} \mathrm{d}s_1 \,, \tag{2.11}$$

and for the current model as

$$\mathbf{B}_1(\mathbf{x}_2) = \frac{\mu_0}{4\pi} \oint_{S_1} \left[\mathbf{M}_1 \times \hat{\mathbf{n}}_{s'_1}\right] \times \frac{\mathbf{x}_2 - \mathbf{x}_1}{\left|\mathbf{x}_2 - \mathbf{x}_1\right|^3} \mathrm{d}s'_1 \,, \tag{2.12}$$

where $\hat{\mathbf{n}}$ is the normal vector from the differential surface of integration $\mathrm{d}s$.

William S P Robertson. "Modelling and design of magnetic levitation systems for vibration isolation". PhD thesis. The University of Adelaide, 2013

Where is `\mathbf` used?

on **Grp** to the factor-commutator functor **Grp** $\to$ **Ab** $\to$ **Grp**. Moreover, p is natural, because each group homomorphism $f : G \to H$ defines the evident homomorphism f' for which the following diagram commutes:

$$\begin{tikzcd} G \arrow[r, "p_G"] \arrow[d, "f"'] & G/[G, G] \arrow[d, "f'"] \\ H \arrow[r, "p_H"] & H/[H, H]\,. \end{tikzcd} \tag{3}$$

The double character group yields a suggestive example in the category **Ab** of all abelian groups G. Let $D(G)$ denote the character group of G, so that $DG = \hom(G, \mathbf{R}/\mathbf{Z})$ is the set of all homomorphisms $t : G \to \mathbf{R}/\mathbf{Z}$ with the familiar group structure, where $\mathbf{R}/\mathbf{Z}$ is the additive group of real numbers modulo 1. Each arrow $f : G' \to G$ in **Ab** determines an arrow $Df : DG \to DG'$ (opposite direction!) in **Ab**, with $(Df)t = tf : G' \to \mathbf{R}/\mathbf{Z}$ for each t; for composable arrows,

Saunders Mac Lane. *Categories for the Working Mathematician*. 2nd ed. Springer, 1998

Overview of Unicode Mathematics

Historical and current examples

- Sidenote: symbols

TeX's methods

and the estimation error vector

$$\epsilon = \varepsilon + \mho_0 - \mho^{\mathrm{T}} \hat{\theta} \tag{9.266}$$

result in the static parametric model

$$\epsilon = \mho^{\mathrm{T}} \tilde{\theta} + \tilde{\epsilon}\,, \tag{9.267}$$

where $\tilde{\epsilon} \stackrel{\Delta}{=} \varepsilon + \mho_0 - \mho^{\mathrm{T}} \theta$ is governed by

$$\dot{\tilde{\epsilon}} = \left(A_o - \kappa_o |\omega|^2 l e_1^{\mathrm{T}}\right) \tilde{\epsilon}\,. \tag{9.268}$$

Since only $\varepsilon_1 = y - \hat{\chi}_1$ is measured, only the first component of ϵ would be implemented as the estimation error:

$$\epsilon_1 = \varepsilon_1 + \mho_{1,0} - \mho_1^{\mathrm{T}} \hat{\theta}\,. \tag{9.269}$$

Miroslav Krstić, Ioannis Kanellakopoulos, and Petar Kokotović. *Nonlinear and Adaptive Control Design*. Ed. by Simon Haykin. John Wiley and Sons, 1995. ISBN: 0-471-12732-9

Consider the class of strict-feedforward systems given by

$$\begin{aligned}
\dot{x}_1 &= x_2 + \sum_{j=2}^{n-1} \pi_j(x_j)x_{j+1} + \pi_n(x_n)u\,,\\
\dot{x}_i &= x_{i+1}\,, \qquad i = 2,\ldots,n-1\,,\\
\dot{x}_n &= u\,,
\end{aligned}$$

where $\pi_j(0) = 0$. Any system in this class is DECI.

where $A(x,t)$ is exponentially stable for each x continuous in t. Combining (6.76) and (6.78), we define $\mathcal{Y} = x + \Omega_0$ so that

$$\dot{\mathcal{Y}} = A(x,t)\mathcal{Y} + F(x,u)^{\mathrm{T}}\theta\,. \tag{6.80}$$

Since θ is constant, it follows that

$$\mathcal{Y} = \Omega^{\mathrm{T}}\theta + \tilde{\epsilon}\,, \tag{6.81}$$

where $\tilde{\epsilon} \triangleq x + \Omega_0 - \Omega^{\mathrm{T}}\theta$ is exponentially decaying because it is governed by

$$\dot{\tilde{\epsilon}} = A(x,t)\tilde{\epsilon}\,, \qquad \tilde{\epsilon} \in \mathbb{R}^n\,. \tag{6.82}$$

of Σ_1 sets doubly universal for $\boldsymbol{\Sigma}_1$ sets. Now this pair can be reduced, as argued above, to yield two disjoint Σ_1 sets which are not separable even by a $\boldsymbol{\Sigma}_1 \cap \boldsymbol{\Pi}_1$ set. The same argument can be applied to actually name two disjoint Σ_{k+1} sets (Π^1_1 sets, Σ^1_{k+1} sets) not separable by $\boldsymbol{\Sigma}_{k+1} \cap \boldsymbol{\Pi}_{k+1}$ sets (by $\boldsymbol{\Sigma}^1_1 \cap \boldsymbol{\Pi}^1_1$ sets, by $\boldsymbol{\Sigma}^1_{k+1} \cap \boldsymbol{\Pi}^1_{k+1}$ sets), for $k \geqslant 1$. Similar strong forms of the negation of the second separation principle can likewise be obtained at all levels.

For some C an argument similar to the above can be applied, however. We illustrate with the case where C is finite. Here we can choose a $\Sigma_1^{[C]}$ subset of $\mathscr{N}^{n+1,0}$ universal for the $\Sigma_1^{[C]}$ subsets of $\mathscr{N}^{n,0}$, whereas the diagonal argument does prevent the existence of a $\Sigma_1^{[C]} \cap \Pi_1^{[C]}$ subset of $\mathscr{N}^{n+1,0}$ universal for $\Sigma_1^{[C]} \cap \Pi_1^{[C]}$ subsets of $\mathscr{N}^{n,0}$. So we can conclude $\overline{Sep}_{\mathrm{I}}(\Sigma_1^{[C]})$ as before. Similar arguments work, of course, at all levels of the C-arithmetical and C-analytical hierarchies with finite C.

$$\boxed{\frac{\partial |det\, g|}{\partial g_{\mu\nu}} = |det\, g| (g^{-1})^{\mu\nu},}$$

$$\frac{\partial (g^{-1})^{\kappa\lambda}}{g_{\mu\nu}} = -(g^{-1})^{\kappa\mu} (g^{-1})^{\lambda\nu},$$

$$\lightning_{(2)}^2 = |det\, \mathcal{F}| |det\, g|^{-1},$$

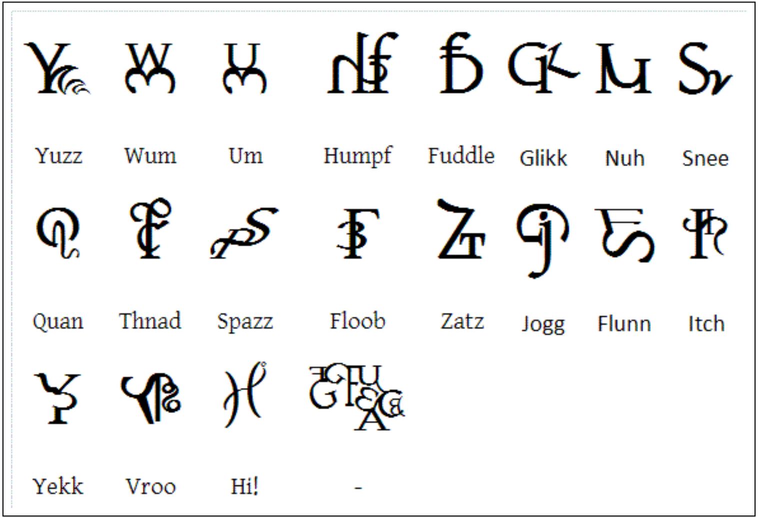
$$(g^{-1})^{\kappa\lambda} \mathcal{F}_{\mu\kappa} {}^{\star}\mathcal{F}_{\nu\lambda} = \lightning_{(2)} g_{\mu\nu},$$

$$\frac{\partial \lightning_{(1)}}{\partial g_{\mu\nu}} = -g_{\kappa\lambda} \mathcal{F}^{\#\mu\kappa} \mathcal{F}^{\#\nu\lambda},$$

$$\boxed{\frac{\partial \lightning_{(2)}}{\partial g_{\mu\nu}} = -\frac{1}{2} \lightning_{(2)} (g^{-1})^{\mu\nu},}$$

Jared Speck. "The global stability of the Minkowski spacetime solution to the Einstein-nonlinear system in wave coordinates". In: *Analysis & PDE* 7.4 (2014), pp. 771–901. DOI: 10.2140/apde.2014.7.771

Courtesy `http://math.stackexchange.com/a/1250067/2961`



Dr. Seuss. *On Beyond Zebra!* Random House, 1955

Courtesy `http://math.stackexchange.com/a/1197641`

Overview of Unicode Mathematics

Historical and current examples

Sidenote: symbols

TeX's methods

Setting up maths in plain (Xe/Lua)TeX

Define some fonts:

```
\font\Urm = "[texgyrepagella-regular.otf]:color=AA00AA"
\font\Ubf = "[texgyrepagella-bold.otf]   :color=0000FF"
\font\Uit = "[texgyrepagella-italic.otf] :color=00AA00"
\font\Umm = "[texgyrepagella-math.otf]   :color=FF0000"
```

Which produces: rm **bf** *it* mm

(*Remember: red is the maths font in particular*)

Now set up some maths families

```
\newfam\Urmfam
\newfam\Ubffam
\newfam\Uitfam

\textfont\Urmfam\Urm
\textfont\Ubffam\Ubf
\textfont\Uitfam\Uit
\textfont1\mm
```

(`\textfont1` *just means default symbols*)

Switching to these fonts?

```
$$
 a + b + c \quad α + β + γ
$$
$$
{\fam\Urmfam abcαβγ} \quad
{\fam\Uitfam abcαβγ} \quad
{\fam\Ubffam abcαβγ}
$$
```

$$a + b + c \quad + +$$

$$abc \quad abc\alpha\beta\gamma \quad \mathbf{abc}$$

(*What's going on with symbols?*)

Remap to Unicode

```
\Umathcode`\a = 7 1 "1D44E\relax
\Umathcode`\b = 7 1 "1D44F\relax
\Umathcode`\c = 7 1 "1D450\relax
\Umathcode`\α = 7 1 "1D6FC\relax
\Umathcode`\β = 7 1 "1D6FD\relax
\Umathcode`\γ = 7 1 "1D6FE\relax
```

$$a + b + c \quad \alpha + \beta + \gamma$$

("*1D44E is Unicode Plane 1 mathematical small a*)

Remap to elsewhere in Unicode

```
\Umathcode`\a = 7 1 "1D482\relax
\Umathcode`\b = 7 1 "1D483\relax
\Umathcode`\c = 7 1 "1D484\relax
\Umathcode`\α = 7 1 "1D736\relax
\Umathcode`\β = 7 1 "1D737\relax
\Umathcode`\γ = 7 1 "1D738\relax
```

$$\boldsymbol{a} + \boldsymbol{b} + \boldsymbol{c} \quad \boldsymbol{\alpha} + \boldsymbol{\beta} + \boldsymbol{\gamma}$$

(`"`*1D44E is Unicode Plane 1 mathematical small a*)

Rundown so far

- Maths is not like text
- In text, an input char, say ‘ascii a’ (U+97) is represented at the same code-point in the current font
- In maths, an input char is (luckily!) mapped to whatever code-point we like!
- In this case, input char U+97 $\rightarrow$ font glyph U+1D44E

But what about alphabets?

Traditional TEX

This is very different than traditional TEX maths where we have a number of maths fonts with different shapes in ascii slots:

- e.g., input char $\mathtt{A}_{65} \rightarrow A_{65}$ maths font (`\mathnormal`)
- e.g., input char $\mathtt{A}_{65} \rightarrow \mathbf{A}_{65}$ bold font (`\mathbf`)
- e.g., input char $\mathtt{A}_{65} \rightarrow \mathcal{A}_{65}$ cal font (`\mathcal`)

But what about alphabets?

Unicode mathematics

Now we need to map within the same font:

- e.g., input char $\texttt{A}_{65} \rightarrow A_{\text{1D434}}$ maths font (`\mathnormal`)
- e.g., input char $\texttt{A}_{65} \rightarrow \mathbf{A}_{\text{1D400}}$ maths font (`\mathbf`)
- e.g., input char $\texttt{A}_{65} \rightarrow \mathcal{A}_{\text{1D49C}}$ maths font (`\mathcal`)

But what about alphabets?

Unicode mathematics

The naive approach (up until now):

- Ignore classical TEX maths; Unicode is the future!
- `\mathcal` maps to calligraphic range.
- `\mathfrak` maps to fraktur range.
- `\mathbf` maps to bold upright symbols. (Maybe okay?)
- `\mathit` maps to math italic symbols. (Not okay!)

Impedance mismatch between what TEX users use and what Unicode mathematics provides.

Kerning

The big problem here:

- `\mathbf` traditionally uses a *text* font (why not?)
- `\mathit` traditionally uses a *text* font (needed!)
- `\mathtt` traditionally uses a *text* font
- `\mathsf` traditionally uses a *text* font

Where is `\mathbf` used?

- It's not just one thing!
- Single symbols with math-like spacing
- Multi-letter names with text-like spacing

Unicode only provides for the first.
LATEX sort of only provides the second.

What about `\mathit`?

LATEX defines:

- `\mathnormal` — italic symbols with maths spacing
- `\textit` — italic letters with text spacing and text behaviour
- `\mathit` — italic w. text spacing and maths behaviour

These could all be separate fonts. Unicode only provides for the `\mathnormal` case.

Similarly `\mathrm`

LATEX defines upright roman letters:

- `\textrm` — with text spacing and text behaviour
- `\mathrm` — with text spacing and maths behaviour

These could all be separate fonts. Unicode only provides for ???.

Up to the font designer.

This is $\LaTeX\,2_\varepsilon$+amsmath

- `\mathnormal`
- `\mathit`
- `\mathrm`
- `\mathbf`
- `\mathsf`
- `\mathtt`
- `\mathcal`
- `\mathfrak`

`\boldsymbol` / `bm` allowed for bold in many cases too.

Categories of alphabets in Unicode

Unambiguous:

- bb, bbit, scr, bfscr, cal, bfcal, frak, bffrak

Ambiguous:

- rm, it, tt, bfup, bfit, sfup, sfit, bfsfup, bfsfit, bfsf

I called these `\mathrm`, `\mathit`, etc., and that was ...

...a poor decision

As discussed:

- '`\mathit`' ALWAYS (in practice) used for Re, Fr, ...
  So `unicode-math`'s definition for `\mathit` is no good.
- 'bf' might be for $\mathbf{a} \times \mathbf{b}$ or $\mathbf{Hom}(\cdot)$
  So UM's definition for `\mathbf` (and `\mathrm`, `\mathsf`, `\mathtt`) potentially wrong.
- So what to do?

Switching to symbol ranges

- ALL mapping ranges are defined with new commands `\symbb`, `\symcal`, `\symbf`, etc. etc.
- ALL traditional LATEX font switches are given alias names `\mathtextrm`, `\mathtextit`, `\mathtextbf`, etc.
- Unambiguous ranges: `\mathfrak` := `\symfrak`
- By default: `\mathbf` := `\mathtextbf` (i.e., as per LATEX 2_{ε})
- Package options (`mathbf=sym`) to switch

Tell me about these symbol ranges

- `\symliteral` switches to ‘literal’ input syntax.
- `\symbf` follows TeX or ‘ISO’ conventions with upright latin and italic greek letters.
- `\symsf` switches to upright or italic sans serif according to a package option.

Tell me about these symbol ranges

Continued

- `\symbfit`, `\symbfup`, `\symsfit`, `\symsfup` can be used where needed.
- Why is `\symtt` not aliased to `\mathtt`?
  Few slots; if you want your code font and your typewriter maths font to match, you're better off sticking with traditional `\mathtt`.
- There is no contextual math style yet;
  `\symbf{\symsf{X}}` does NOT produce `\symbfsf{X}`.
  It probably should.

Undoing the mapping for `\DeclareMathAlphabet`

- Latest version of `unicode-math` ‘fixes’ `\DeclareMathAlphabet`.
- This is what allows the distinction between `\mathXYZ` and `\symXYZ`.
- Necessary for using character shapes outside of Unicode.
- Requires some care hacking the NFSS.
- ‘User-level’ interface `\setmathfontface`.

```
\documentclass{article}
\usepackage{unicode-math}
\setmathfont{texgyrepagella-math.otf}[Scale=0.85]
\setmathfontface\mathchor{texgyrechorus-mediumitalic.otf}
\setoperatorfont\mathchor
\begin{document}
\[
   (\sin x)^2 + (\cos x)^2 = 1
\]
\end{document}
```

$$(\sin x)^2 + (\cos x)^2 = 1$$

13.7.C. EXERCISE. Suppose

$$0 \to \mathscr{F} \to \mathscr{G} \to \mathscr{H} \to 0 \tag{13.7.1.1}$$

is an exact sequence of quasicoherent sheaves on a scheme X, where $\mathscr{H}$ is a locally free quasicoherent sheaf, and suppose $\mathscr{E}$ is a quasicoherent sheaf. By left-exactness of $\mathcal{H}om$ (Exercise 2.5.H),

$$0 \to \mathcal{H}om(\mathscr{H}, \mathscr{E}) \to \mathcal{H}om(\mathscr{G}, \mathscr{E}) \to \mathcal{H}om(\mathscr{F}, \mathscr{E}) \to 0$$

is exact except possibly on the right. Show that it is also exact on the right. (Hint: this is local, so you can assume that X is affine, say $\operatorname{Spec} A$, and $\mathscr{H} = \widetilde{A^{\oplus n}}$, so (13.7.1.1) can be written as $0 \to M \to N \to A^{\oplus n} \to 0$. Show that this exact sequence splits, so we can write $N = M \oplus A^{\oplus n}$ in a way that respects the exact sequence.) In particular, if $\mathscr{F}$, $\mathscr{G}$, $\mathscr{H}$, and $\mathscr{O}_X$ are all coherent, and $\mathscr{H}$ is locally free, then we have an exact sequence of coherent sheaves

$$0 \to \mathscr{H}^\vee \to \mathscr{G}^\vee \to \mathscr{F}^\vee \to 0.$$

Ravi Vakil. *Foundations of Algebraic Geometry*. Lecture Notes. Stanford University, 2015.
URL: http://math.stanford.edu/~vakil/216blog/

From `\mathnormal` to `\mathXYZ`

As discussed above, we have default mapping set up

- e.g., input char $\texttt{A}_{65} \rightarrow A_{\mathsf{1D434}}$ maths font

When we switch to `\mathXYZ` (such as `\mathit`), we need to undo this mapping so we can revert to

- e.g., input `\mathbf{`$\texttt{A}_{65}$`}` $\rightarrow \mathbf{A}_{65}$ bold maths font

Inside the NFSS

Briefly

```
\cs_set:Npn \use@mathgroup #1 #2
 {
  \mode_if_math:T
   {
    \math@bgroup
      \cs_if_eq:cNF {M@\f@encoding} #1 {#1}
      \__um_switchto_literal:
      \mathgroup #2 \relax
    \math@egroup
   }
 }
```

Downside to this approach

- All this symbol remapping doesn't come for free.
- The literals mapping is probably not yet complete, but it current reads:

```
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```

- This adds approx 100$\times$ overhead to the font switch. (hundreds of microseconds per)

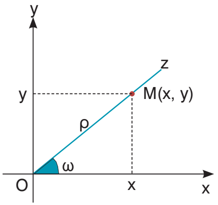
Summary

Σε ορθοκανονικό σύστημα αξόνων Oxy, αν είναι $\omega = x\hat{O}z$, και M(x, y) είναι ένα οποιοδήποτε σημείο της πλευράς Oz, διαφορετικό από το O, τότε:

$$\rho = OM = \sqrt{x^2 + y^2} \text{ και } ημω = \frac{y}{\rho},\ συνω = \frac{x}{\rho},\ εφω = \frac{y}{x}.$$

Π.χ. αν M(1, 2), τότε $\rho = \sqrt{1^2 + 2^2} = \sqrt{5}$,

$$ημω = \frac{2}{\sqrt{5}} = \frac{2\sqrt{5}}{5}, \quad συνω = \frac{1}{\sqrt{5}} = \frac{\sqrt{5}}{5}, \quad εφω = \frac{2}{1} = 2.$$



(*Thanks to Apostolos Syropoulis for the reference.*)

```
\setmainfont{Kurier-Regular.otf}
\setmathfont{texgyrepagella-math.otf}[Scale=0.85]

\[
  \mathrm{ημ}(ω) = \frac{y}{ρ}
\]
```

$$\boxed{\mathrm{ημ}(\omega) = \frac{y}{\rho}}$$

But probably `\mathrm` should now be called `\mathup`!
(My friend Nino says 'rm' means remove; cf. GNU/Linux.)

‘Sha’

Now introduce

$$\text{Ш}_p(x) = \sum_{k=-\infty}^{\infty} \delta(x - kp)\,,$$

so that, simply,

$$\rho_p = \text{Ш}_p * \rho\,.$$

Ш_p is the star of the show. Bracewell calls it the “shah function”, after the Cyrillic letter, and this has caught on. It’s also referred to as the *Dirac comb* (with spacing p).

Brad Osgood. *The Fourier Transform and its Applications*. Lecture Notes. Stanford University, 2008

7.1. **Visible Ш Table 1.** Table 1 on page 11 lists sixteen pairs of newforms f and g (of equal weights and levels) along with at least one prime q such that there is a prime $\mathfrak{q} \mid q$ with $f \equiv g \pmod{\mathfrak{q}}$. In each case, $\mathrm{ord}_{s=k/2} L(g, k/2) \geq 2$ while $L(f, k/2) \neq 0$. The notation is as follows. The first column contains a label whose structure is

[Level]k[Weight][GaloisOrbit]

Neil Watkins, William Dummigan, and Mark Stein. “Constructing elements in Shafarevich-Tate groups of modular motives”. In: *Number theory and algebraic geometry* 303 (2003)

```
\setmathfont{texgyrepagella-math.otf}[Scale=0.85]
\setmathfontface\mathcyr{Charter Roman}

\[
  ρ_p = \mathcyr{Ш}_p \ast ρ \qquad
  \dot{\mathcyr{y}} = A(x,t)\mathcyr{y} +F(x,u)θ
  \qquad y = mx+c
\]
```

$$\rho_p = \text{Ш}_p \ast \rho \qquad \dot{\text{y}} = A(x,t)\text{y} + F(x,u)\theta \qquad y = mx + c$$

New commands to differentiate maths and text

Input characters: ‘`abc ffi`’

`\textrm` abc ffi	`\textit` *abc ffi*	`\textbf` **abc ffi**	`\textsf` abc ffi	`\texttt` `abc ffi`
`\mathrm` abcffi	`\mathit` abcffi	`\mathbf` $\mathbf{abcffi}$	`\mathsf` abcffi	`\mathtt` $\mathtt{abcffi}$
`\symup` abcffi	`\symit` $abcffi$	`\symbf` $\mathbf{abcffi}$	`\symsf` abcffi	`\symtt` $\mathtt{abcffi}$

fin