

More information about this function can be found at :
http://googology.wikia.com/wiki/Veblen_function

Every non-zero ordinal $\alpha < \Gamma_0$, where Γ_0 is the smallest ordinal α such that $\varphi_\alpha(0) = \alpha$, can be uniquely written in normal form for the Veblen hierarchy:
 $\alpha = \varphi_{\beta_1}(\gamma_1) + \varphi_{\beta_2}(\gamma_2) + \dots + \varphi_{\beta_k}(\gamma_k)$,
 where
 $\varphi_{\beta_1}(\gamma_1) \geq \varphi_{\beta_2}(\gamma_2) \geq \dots \geq \varphi_{\beta_k}(\gamma_k)$ $\gamma_m < \varphi_{\beta_m}(\gamma_m)$ for $m \in \{1, \dots, k\}$

Now we will see how we can find the fundamental sequence of an ordinal written in this normal form.

From the rule defining addition of a limit ordinal :

$$\alpha + \lim(f) = \lim(n \mapsto \alpha + f(n))$$

we deduce the fundamental sequence :

$$(\alpha + \beta)[n] = \alpha + \beta[n]$$

if β is a limit ordinal.

In particular, we have :

$$(\varphi_{\beta_1}(\gamma_1) + \varphi_{\beta_2}(\gamma_2) + \dots + \varphi_{\beta_k}(\gamma_k))[n] = \varphi_{\beta_1}(\gamma_1) + \dots + \varphi_{\beta_{k-1}}(\gamma_{k-1}) + (\varphi_{\beta_k}(\gamma_k)[n]),$$

where $\varphi_{\beta_1}(\gamma_1) \geq \varphi_{\beta_2}(\gamma_2) \geq \dots \geq \varphi_{\beta_k}(\gamma_k)$ and $\gamma_m < \varphi_{\beta_m}(\gamma_m)$ for $m \in \{1, 2, \dots, k\}$,

Then, $\varphi_0(\gamma)$ is ω^γ .

For $\gamma = 0$ it is 1.

From the rule of multiplication by a limit ordinal :

$$\alpha \cdot \lim(f) = \lim(n \mapsto \alpha \cdot f(n))$$

we deduce the fundamental sequence :

$$(\alpha \cdot \beta)[n] = \alpha \cdot \beta[n] \text{ if } \beta \text{ is a limit ordinal.}$$

In particular, for ω :

$$(\alpha \cdot \omega)[n] = \alpha \cdot \omega[n] = \alpha \cdot n$$

Then we have :

$$\varphi_0(\gamma + 1) = \omega^{\gamma+1} = \omega^\gamma \cdot \omega = \varphi_0(\gamma) \cdot \omega$$

So the corresponding fundamental sequence is :

$$\varphi_0(\gamma + 1)[n] = (\varphi_0(\gamma) \cdot \omega)[n] = \varphi_0(\gamma) \cdot n$$

If γ is a limit ordinal, the fundamental sequence can be defined canonically:

$$\varphi_0(\gamma)[n] = \varphi_0(\gamma[n])$$

Then, $\varphi_{\beta+1}(\gamma)$ is the $1 + \gamma$ -th fixed point of the function $\xi \mapsto \varphi_\beta(\xi)$, or more simply the function φ_β .

In particular, $\varphi_{\beta+1}(0)$ is the least fixed point of this function, which is $\varphi_\beta^\omega(0)$. A fundamental sequence of this ordinal is $\varphi_{\beta+1}(0)[n] = \varphi_\beta^n(0)$, which can also be written $\varphi_{\beta+1}(0)[0] = 0$ and $\varphi_{\beta+1}(0)[n+1] = \varphi_\beta(\varphi_{\beta+1}(0)[n])$.

$\varphi_{\beta+1}(\gamma+1)$ is the fixed point of φ_β that follows $\varphi_{\beta+1}(\gamma)$. It is $\varphi_\beta^\omega(\varphi_{\beta+1}(\gamma) + 1)$. This can also be written $\varphi_{\beta+1}(\gamma+1)[0] = \varphi_{\beta+1}(\gamma) + 1$ and $\varphi_{\beta+1}(\gamma+1)[n+1] = \varphi_\beta(\varphi_{\beta+1}(\gamma+1)[n])$.

If γ is a limit ordinal, the fundamental sequence can be defined canonically:

$$\varphi_{\beta+1}(\gamma)[n] = \varphi_{\beta+1}(\gamma[n]).$$

Finally, if β is a limit ordinal, we can define canonically:

$$\varphi_\beta(0)[n] = \varphi_{\beta[n]}(0) \text{ if } \beta < \varphi_\beta(0)$$

and

$$\varphi_\beta(\gamma + 1)[n] = \varphi_{\beta[n]}(\varphi_\beta(\gamma) + 1)$$

Let us recap now the results we obtained.

The fundamental sequences for the Veblen functions $\varphi_\beta(\gamma) = \varphi(\beta, \gamma)$ are :

1. $(\varphi_{\beta_1}(\gamma_1) + \varphi_{\beta_2}(\gamma_2) + \cdots + \varphi_{\beta_k}(\gamma_k))[n] = \varphi_{\beta_1}(\gamma_1) + \cdots + \varphi_{\beta_{k-1}}(\gamma_{k-1}) + (\varphi_{\beta_k}(\gamma_k)[n])$, where $\varphi_{\beta_1}(\gamma_1) \geq \varphi_{\beta_2}(\gamma_2) \geq \cdots \geq \varphi_{\beta_k}(\gamma_k)$ and $\gamma_m < \varphi_{\beta_m}(\gamma_m)$ for $m \in \{1, 2, \dots, k\}$,
2. $\varphi_0(0) = 1$,
3. $\varphi_0(\gamma + 1)[n] = \varphi_0(\gamma)n$
4. $\varphi_{\beta+1}(0)[0] = 0$ and $\varphi_{\beta+1}(0)[n+1] = \varphi_\beta(\varphi_{\beta+1}(0)[n])$,
5. $\varphi_{\beta+1}(\gamma+1)[0] = \varphi_{\beta+1}(\gamma) + 1$ and $\varphi_{\beta+1}(\gamma+1)[n+1] = \varphi_\beta(\varphi_{\beta+1}(\gamma+1)[n])$,
6. $\varphi_\beta(\gamma)[n] = \varphi_\beta(\gamma[n])$ for a limit ordinal $\gamma < \varphi_\beta(\gamma)$,
7. $\varphi_\beta(0)[n] = \varphi_{\beta[n]}(0)$ for a limit ordinal $\beta < \varphi_\beta(0)$,
8. $\varphi_\beta(\gamma + 1)[n] = \varphi_{\beta[n]}(\varphi_\beta(\gamma) + 1)$ for a limit ordinal β .

From these fundamental sequences, we can retrieve the initial definition of the function φ .

1. This does not concern the definition of the φ function but the definition of addition
2. and
3. are equivalent to $\varphi_0(\gamma) = \omega^\gamma$.
4. $\varphi_{\beta+1}(0) = \lim(n \mapsto \varphi_\beta^n(0)) = \varphi_\beta^\omega(0)$ which is the least fixed point of φ_β .
5. $\varphi_{\beta+1}(\gamma + 1) = \lim(n \mapsto \varphi_\beta^n(\varphi_{\beta+1}(\gamma) + 1))$, which is the least fixed point of φ_β strictly greater than $\varphi_{\beta+1}(\gamma)$, so $\varphi_{\beta+1}(\gamma)$ is the $1 + \gamma$ -th fixed point of φ_β .