Approximating area under curve via sum of area under rectangles:

$$\int_{-\infty}^{\infty} f(x)\,dx = \sum_{k=-\infty}^{\infty} \underbrace{f(k\Delta x)}_{\text{height}} \underbrace{\Delta x}_{\text{width}}$$

Applied to convolution integral:

$$y(t) = \int_{-\infty}^{\infty} x(\tau)\,h(t-\tau)\,d\tau$$

$$= \sum_{k=-\infty}^{\infty} x(k\Delta\tau)\,h(t-k\Delta\tau)\,\Delta\tau$$

Then discretize t (or sample $y(t)$):

$$y[n] = y(nT_s) = y(n\Delta\tau)$$

$$y[n] = \sum_{k} x(k\Delta\tau)\,h((n-k)\Delta\tau)\,\Delta\tau$$

$$= \sum_{k} x[k]\,h[n-k]\,\Delta\tau$$

where:

$x[k] = x(k\Delta\tau)$

$h[k] = h(k\Delta\tau)$