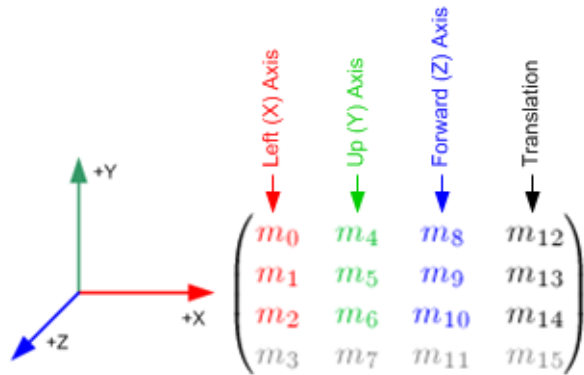In[441]:= **(\*matrix transformations, rotation, translation, scaling\*)**



In[442]:= **Clear["Global`\*"];**

In[443]:= **M = {{xx, yx, zx, ox}, {xy, yy, zy, oy}, {xz, yz, zz, oz}, {xo, yo, zo, oo}}; M // MatrixForm**

Out[443]//MatrixForm=

$$\begin{pmatrix} xx & yx & zx & ox \\ xy & yy & zy & oy \\ xz & yz & zz & oz \\ xo & yo & zo & oo \end{pmatrix}$$

**s; (\*scale\*)**
**S = {{sx, 0, 0, 0}, {0, sy, 0, 0}, {0, 0, sz, 0}, {0, 0, 0, 1}};**
**S // MatrixForm**

Out[445]//MatrixForm=

$$\begin{pmatrix} sx & 0 & 0 & 0 \\ 0 & sy & 0 & 0 \\ 0 & 0 & sz & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In[446]:= **$\gamma$;(\*rotation of z-axis\*)**
**R$\gamma$ = PadRight[RotationMatrix[$\gamma$, z], {4, 4}];**
**R$\gamma$[[4, 4]] = 1;**
**R$\gamma$ // MatrixForm**

Out[449]//MatrixForm=

$$\begin{pmatrix} Cos[\gamma] & -Sin[\gamma] & 0 & 0 \\ Sin[\gamma] & Cos[\gamma] & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In[450]:= **$\alpha$;(\*rotation of x-axis\*)**
**R$\alpha$ = PadRight[RotationMatrix[$\alpha$, x], {4, 4}];**
**R$\alpha$[[4, 4]] = 1;**
**R$\alpha$ // MatrixForm**

Out[453]//MatrixForm=

$$\begin{pmatrix} 1 & 0 & 0 & 0 \\ 0 & Cos[\alpha] & -Sin[\alpha] & 0 \\ 0 & Sin[\alpha] & Cos[\alpha] & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In[454]:= **β;(\*rotation of y-axis\*)**
**Rβ = PadRight[RotationMatrix[β, y], {4, 4}];**
**Rβ[[4, 4]] = 1;**
**Rβ // MatrixForm**

Out[457]//MatrixForm=

$$\begin{pmatrix} Cos[\beta] & 0 & Sin[\beta] & 0 \\ 0 & 1 & 0 & 0 \\ -Sin[\beta] & 0 & Cos[\beta] & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

**t; (\*translation\*)**
**T = {{1, 0, 0, tx}, {0, 1, 0, ty}, {0, 0, 1, tz}, {0, 0, 0, 1}};**
**T // MatrixForm**

Out[459]//MatrixForm=

$$\begin{pmatrix} 1 & 0 & 0 & tx \\ 0 & 1 & 0 & ty \\ 0 & 0 & 1 & tz \\ 0 & 0 & 0 & 1 \end{pmatrix}$$

In[460]:= **M.S // MatrixForm**

Out[460]//MatrixForm=

$$\begin{pmatrix} sx\,xx & sy\,yx & sz\,zx & ox \\ sx\,xy & sy\,yy & sz\,zy & oy \\ sx\,xz & sy\,yz & sz\,zz & oz \\ sx\,xo & sy\,yo & sz\,zo & oo \end{pmatrix}$$

In[461]:= **M.Rγ // MatrixForm**

Out[461]//MatrixForm=

$$\begin{pmatrix} xx\,Cos[\gamma] + yx\,Sin[\gamma] & yx\,Cos[\gamma] - xx\,Sin[\gamma] & zx & ox \\ xy\,Cos[\gamma] + yy\,Sin[\gamma] & yy\,Cos[\gamma] - xy\,Sin[\gamma] & zy & oy \\ xz\,Cos[\gamma] + yz\,Sin[\gamma] & yz\,Cos[\gamma] - xz\,Sin[\gamma] & zz & oz \\ xo\,Cos[\gamma] + yo\,Sin[\gamma] & yo\,Cos[\gamma] - xo\,Sin[\gamma] & zo & oo \end{pmatrix}$$

In[462]:= **M.Rα // MatrixForm**

Out[462]//MatrixForm=

$$\begin{pmatrix} xx & yx\,Cos[\alpha] + zx\,Sin[\alpha] & zx\,Cos[\alpha] - yx\,Sin[\alpha] & ox \\ xy & yy\,Cos[\alpha] + zy\,Sin[\alpha] & zy\,Cos[\alpha] - yy\,Sin[\alpha] & oy \\ xz & yz\,Cos[\alpha] + zz\,Sin[\alpha] & zz\,Cos[\alpha] - yz\,Sin[\alpha] & oz \\ xo & yo\,Cos[\alpha] + zo\,Sin[\alpha] & zo\,Cos[\alpha] - yo\,Sin[\alpha] & oo \end{pmatrix}$$

In[463]:= **M.Rβ // MatrixForm**

Out[463]//MatrixForm=

$$\begin{pmatrix} xx\,Cos[\beta] - zx\,Sin[\beta] & yx & zx\,Cos[\beta] + xx\,Sin[\beta] & ox \\ xy\,Cos[\beta] - zy\,Sin[\beta] & yy & zy\,Cos[\beta] + xy\,Sin[\beta] & oy \\ xz\,Cos[\beta] - zz\,Sin[\beta] & yz & zz\,Cos[\beta] + xz\,Sin[\beta] & oz \\ xo\,Cos[\beta] - zo\,Sin[\beta] & yo & zo\,Cos[\beta] + xo\,Sin[\beta] & oo \end{pmatrix}$$

In[464]:= **M.T // MatrixForm**

Out[464]//MatrixForm=

$$\begin{pmatrix} xx & yx & zx & ox + tx\,xx + ty\,yx + tz\,zx \\ xy & yy & zy & oy + tx\,xy + ty\,yy + tz\,zy \\ xz & yz & zz & oz + tx\,xz + ty\,yz + tz\,zz \\ xo & yo & zo & oo + tx\,xo + ty\,yo + tz\,zo \end{pmatrix}$$

In[465]:= **T.Rβ.Rα.Rγ.S // MatrixForm**

Out[465]//MatrixForm=

$$\begin{pmatrix} sx\,(Cos[\beta]\,Cos[\gamma] + Sin[\alpha]\,Sin[\beta]\,Sin[\gamma]) & sy\,(Cos[\gamma]\,Sin[\alpha]\,Sin[\beta] - Cos[\beta]\,Sin[\gamma]) & sz\,Cos[\alpha]\,S \\ sx\,Cos[\alpha]\,Sin[\gamma] & sy\,Cos[\alpha]\,Cos[\gamma] & -sz\,Sin[ \\ sx\,(-Cos[\gamma]\,Sin[\beta] + Cos[\beta]\,Sin[\alpha]\,Sin[\gamma]) & sy\,(Cos[\beta]\,Cos[\gamma]\,Sin[\alpha] + Sin[\beta]\,Sin[\gamma]) & sz\,Cos[\alpha]\,C \\ 0 & 0 & 0 \end{pmatrix}$$

In[466]:= **S.Rγ.Rα.Rβ.T // MatrixForm**

Out[466]//MatrixForm=

$$
\begin{pmatrix}
\text{sx}\,\text{Cos}[\beta]\,\text{Cos}[\gamma] - \text{sx}\,\text{Sin}[\alpha]\,\text{Sin}[\beta]\,\text{Sin}[\gamma] & -\text{sx}\,\text{Cos}[\alpha]\,\text{Sin}[\gamma] & \text{sx}\,\text{Cos}[\gamma]\,\text{Sin}[\beta] + \text{sx}\,\text{Cos}[\beta]\,\text{Sin}[\alpha] \\
\text{sy}\,\text{Cos}[\gamma]\,\text{Sin}[\alpha]\,\text{Sin}[\beta] + \text{sy}\,\text{Cos}[\beta]\,\text{Sin}[\gamma] & \text{sy}\,\text{Cos}[\alpha]\,\text{Cos}[\gamma] & -\text{sy}\,\text{Cos}[\beta]\,\text{Cos}[\gamma]\,\text{Sin}[\alpha] + \text{sy}\,\text{Sin}[\beta] \\
-\text{sz}\,\text{Cos}[\alpha]\,\text{Sin}[\beta] & \text{sz}\,\text{Sin}[\alpha] & \text{sz}\,\text{Cos}[\alpha]\,\text{Cos}[\beta] \\
0 & 0 & 0
\end{pmatrix}
$$