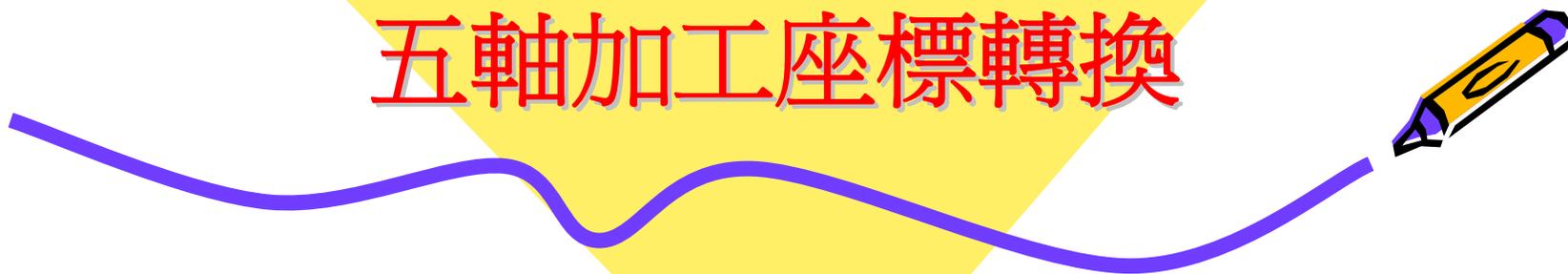


# 五軸與UG/CAM

## 第二章

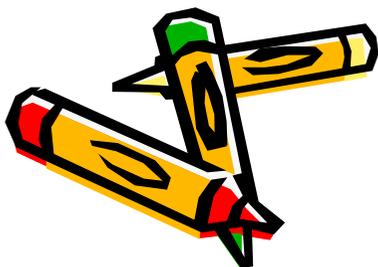
### 五軸加工座標轉換



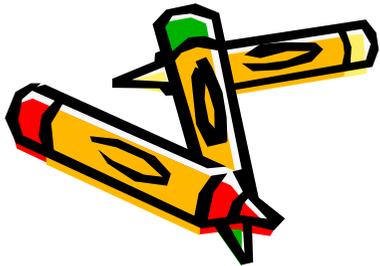
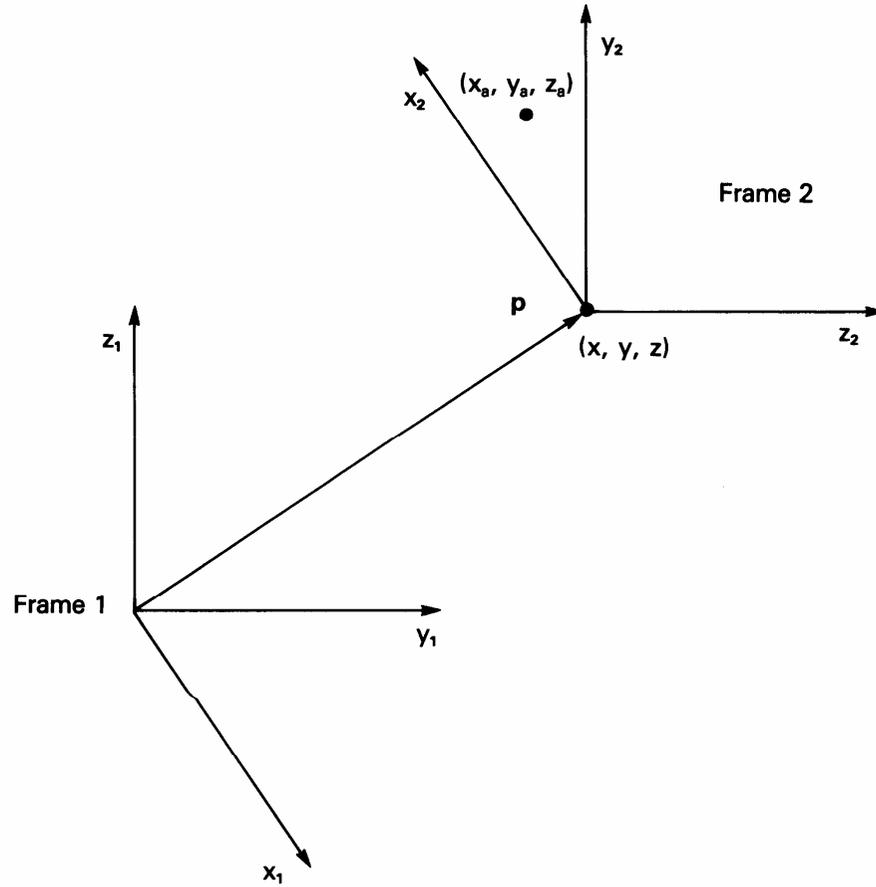
徐永源

## 學習要點

- ◆ 應用HTM (Homogeneous Transformation Matrix) 座標轉換。
- ◆ 三軸工具機座標轉換
- ◆ 五軸工具機座標轉換。
- ◆ 正逆座標轉換。

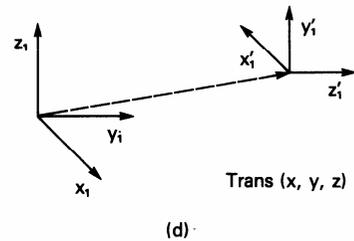
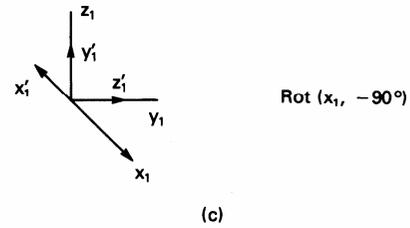
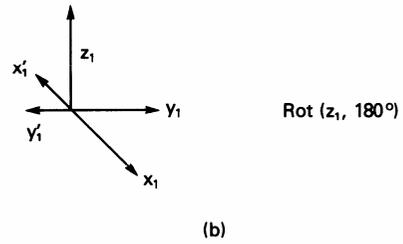
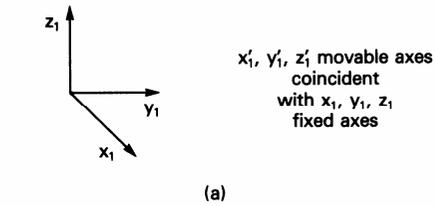


# 座標系統操作

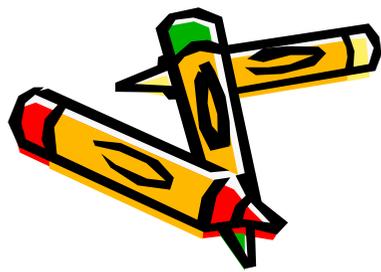
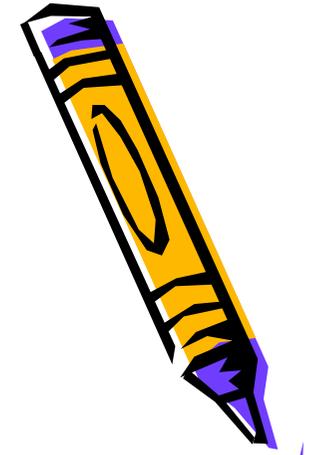
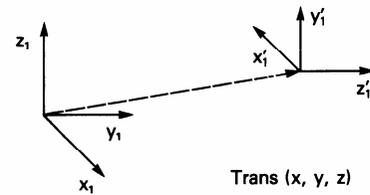
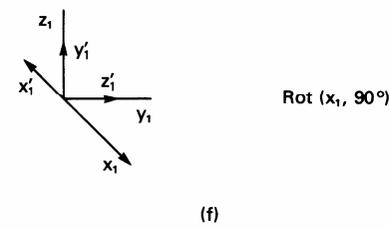
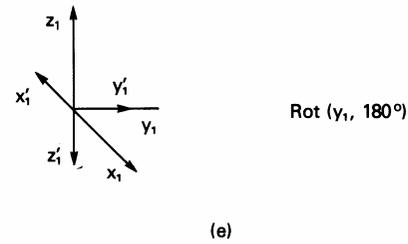
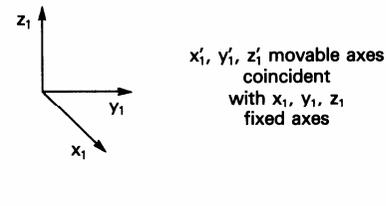


# 座標系統操作

Method 1

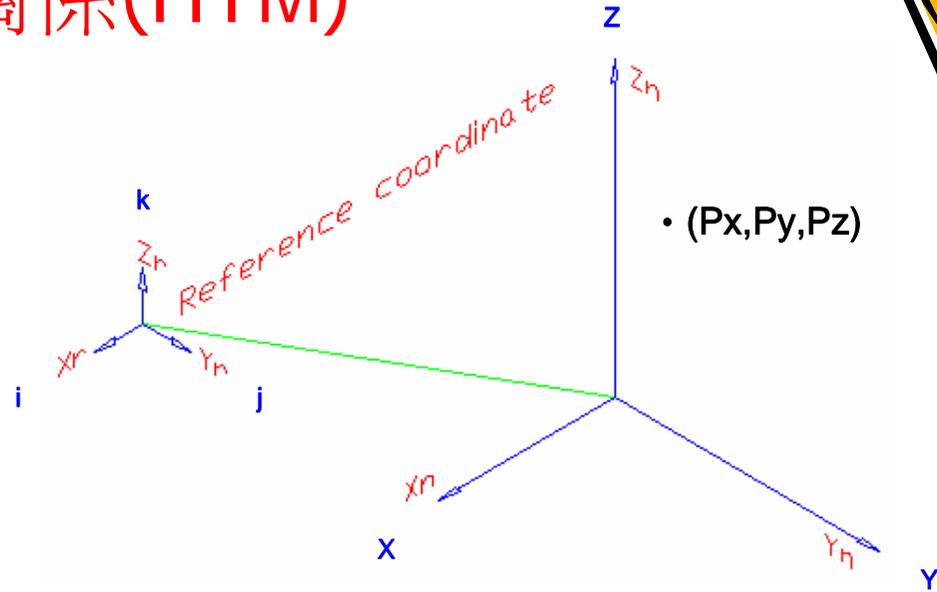


Method 2



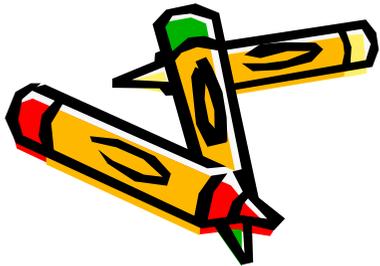
# 座標關係(HTM)

$$\begin{bmatrix} X_r \\ Y_r \\ Z_r \\ 1 \end{bmatrix} = {}^rT_n \begin{bmatrix} X_n \\ Y_n \\ Z_n \\ 1 \end{bmatrix}$$



$${}^rT_n = \begin{bmatrix} R_{3 \times 3} & P_{3 \times 1} \\ O_{1 \times 3} & P_s \end{bmatrix} = \begin{bmatrix} O_{ix} & O_{iy} & O_{iz} & P_x \\ O_{jx} & O_{jy} & O_{jz} & P_y \\ O_{kx} & O_{ky} & O_{kz} & P_z \\ 0 & 0 & 0 & P_s \end{bmatrix}$$

$P_s$  is scale factor



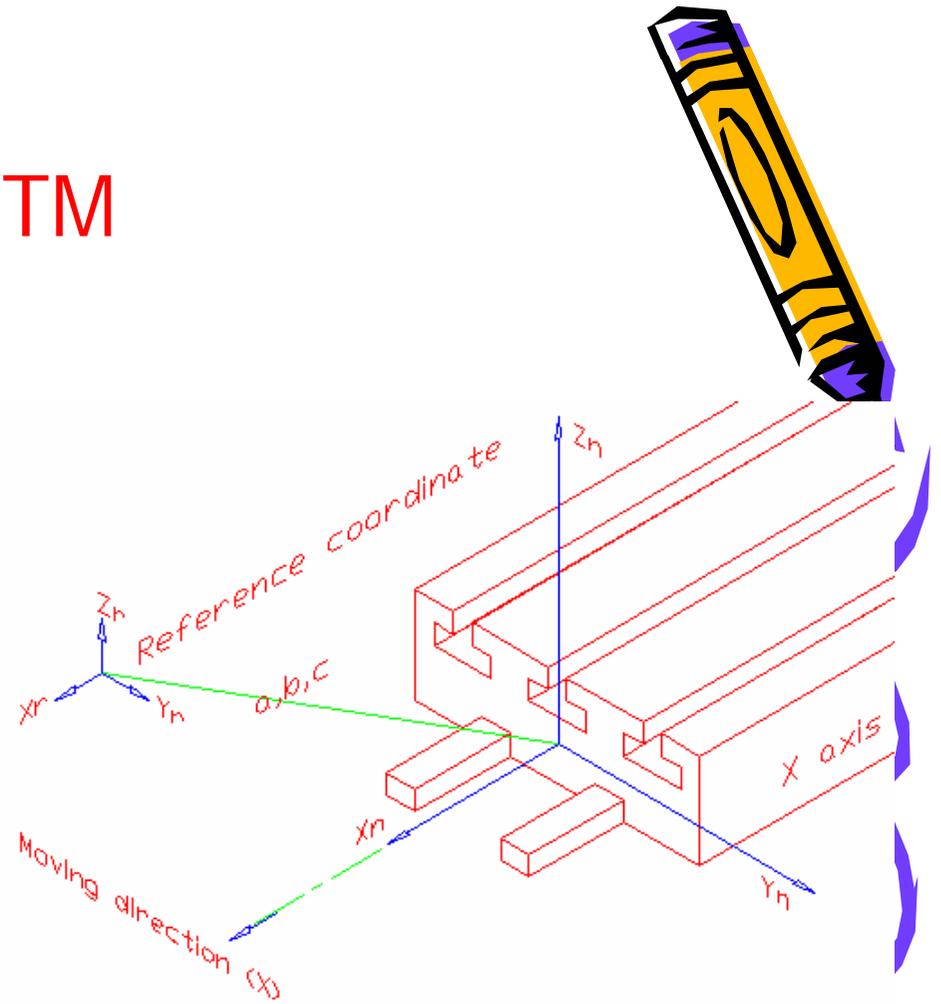
## 座標平移HTM

$${}^rT_x = \begin{bmatrix} 1 & 0 & 0 & a \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

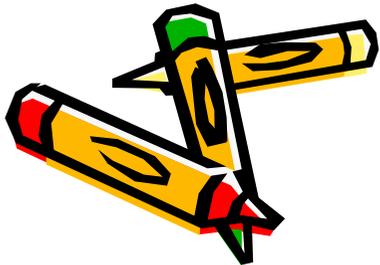
$${}^rT_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & b \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^rT_x = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & c \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

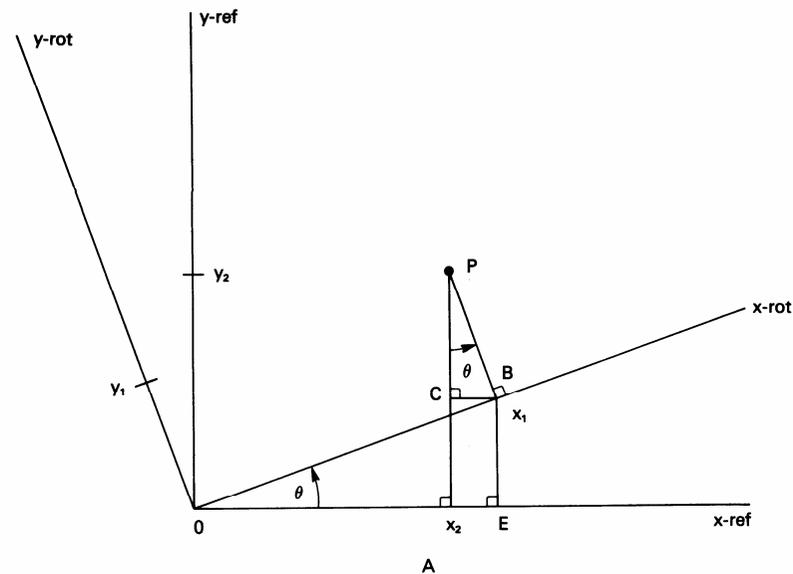
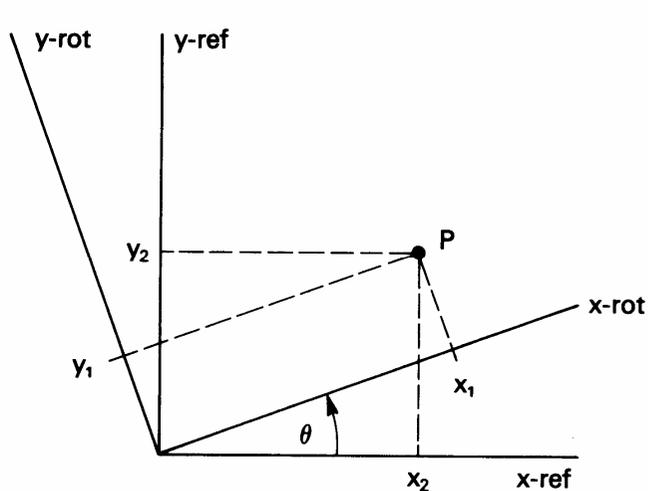
$${}^rT_x = \begin{bmatrix} 1 & 0 & 0 & X+a \\ 0 & 1 & 0 & b \\ 0 & 0 & 1 & c \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



$${}^0T_n = \prod_{m=0}^{n-1} {}^{m-1}T_m = {}^0T_1 {}^1T_2 {}^2T_3 \dots {}^{n-1}T_n$$

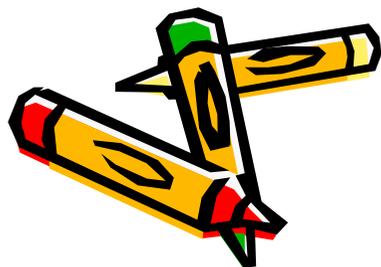


# 座標旋轉



$$x_2 = x_1 \cos \theta - y_1 \sin \theta$$

$$y_2 = x_1 \sin \theta + y_1 \cos \theta$$



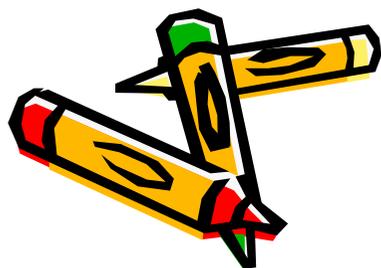
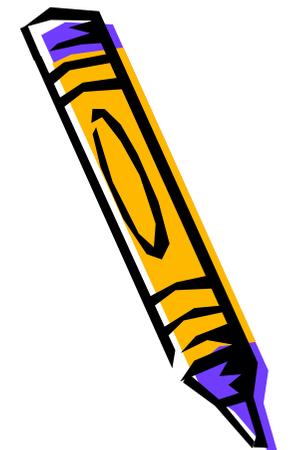
## 座標旋轉HTM

$$x_2 = x_1 \cos \theta - y_1 \sin \theta$$

$$y_2 = x_1 \sin \theta + y_1 \cos \theta$$

$$\begin{bmatrix} X_2 \\ Y_2 \\ Z_2 \\ 1 \end{bmatrix} = {}^r T_n \begin{bmatrix} X_1 \\ Y_1 \\ Z_1 \\ 1 \end{bmatrix}$$

$$\text{Rot}(z, \theta) = \begin{bmatrix} \cos \theta & -\sin \theta & 0 & 0 \\ \sin \theta & \cos \theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



## 座標旋轉HTM

$${}^rT_x = \begin{bmatrix} 1 & 0 & 0 & a \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^rT_y = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & b \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^rT_z = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & c \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

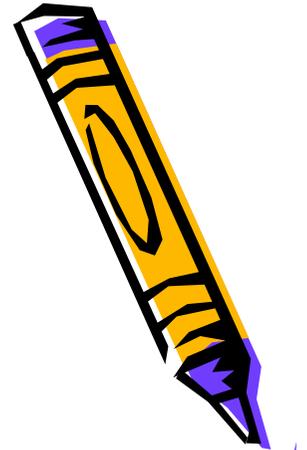
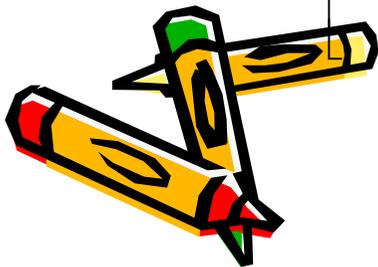
$$\text{Rot}(x, \theta) = \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & \cos \theta & -\sin \theta & 0 \\ 0 & \sin \theta & \cos \theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$$\text{Rot}(z, \theta) = \begin{bmatrix} \cos \theta & -\sin \theta & 0 & 0 \\ \sin \theta & \cos \theta & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

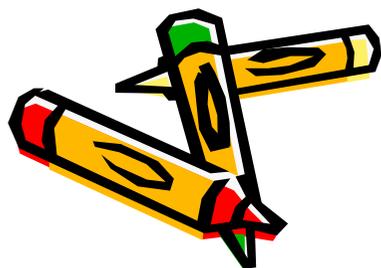
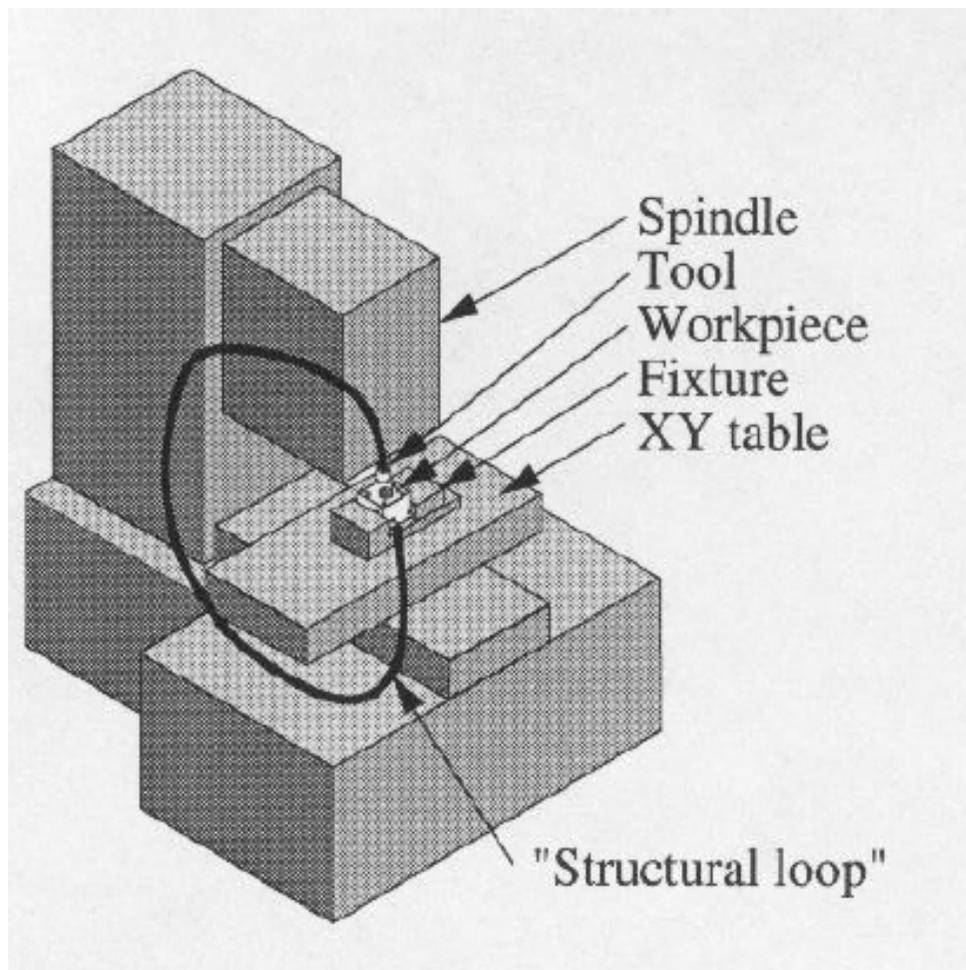
$$\text{Rot}(y, \theta) = \begin{bmatrix} \cos \theta & 0 & \sin \theta & 0 \\ 0 & 1 & 0 & 0 \\ -\sin \theta & 0 & \cos \theta & 0 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

$${}^rT_n = \text{Trans}(x, a) \cdot \text{Trans}(y, b) \cdot \text{Trans}(z, c) \\ \cdot \text{Rot}(x, \theta_a) \cdot \text{Rot}(y, \theta_b) \cdot \text{Rot}(z, \theta_c)$$

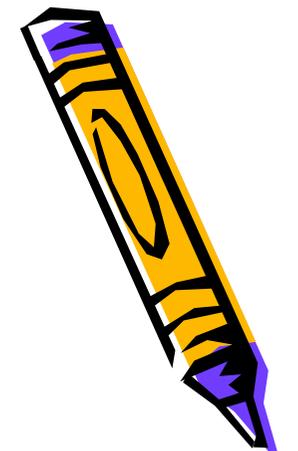
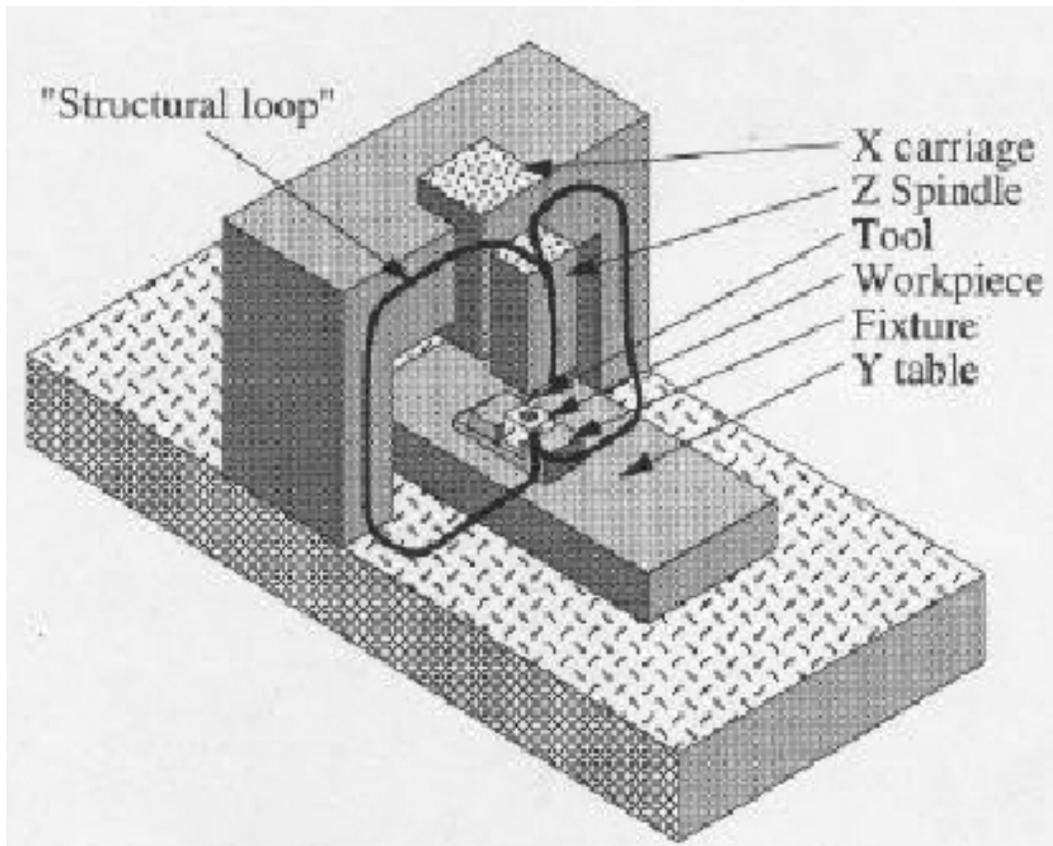
$$= \begin{bmatrix} \cos \theta_b \cos \theta_c & -\cos \theta_b \sin \theta_c & \sin \theta_b & a \\ \sin \theta_a \sin \theta_b \cos \theta_c + \cos \theta_a \sin \theta_c & -\sin \theta_a \sin \theta_b \sin \theta_c + \cos \theta_a \cos \theta_c & -\sin \theta_a \cos \theta_b & b \\ -\cos \theta_a \sin \theta_b \cos \theta_c + \sin \theta_a \sin \theta_c & \cos \theta_a \sin \theta_b \sin \theta_c + \sin \theta_a \cos \theta_c & \cos \theta_a \cos \theta_b & c \\ 0 & 0 & 0 & 1 \end{bmatrix}$$



## 三軸工具機機構開迴路



## 三軸工具機機構閉迴路



## 三軸工具機座標關係HTM

習作 請試推右圖三軸工具機之機器與刀具座標關係式

答案如下

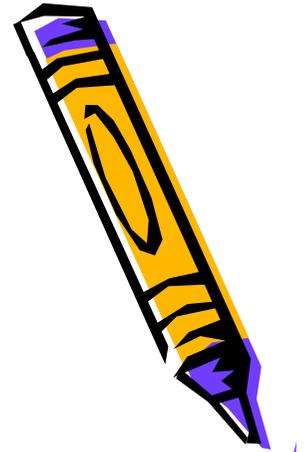
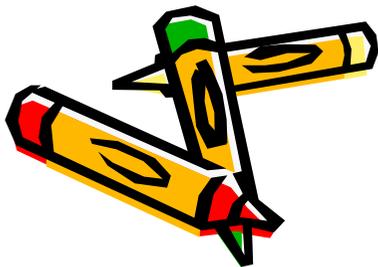
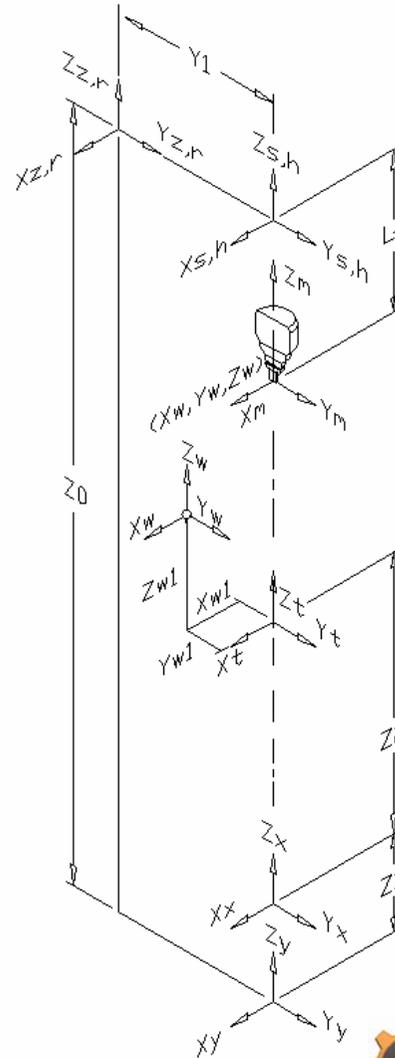
$$\begin{bmatrix} X_w \\ Y_w \\ Z_w \\ 1 \end{bmatrix} = {}^w T_m \begin{bmatrix} X_m \\ Y_m \\ Z_m \\ 1 \end{bmatrix}$$

$${}^w T_m = \begin{bmatrix} 1 & 0 & 0 & -X_{w1} \\ 0 & 1 & 0 & Y_{w1} \\ 0 & 0 & 1 & -L_t + Z_0 - Z_1 - Z_2 - Z_{w1} \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

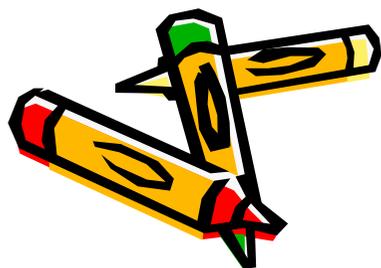
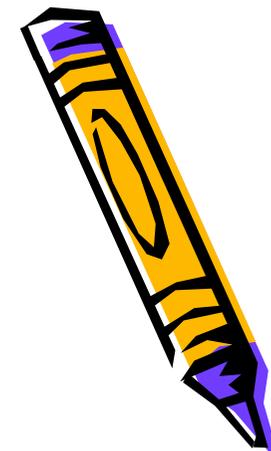
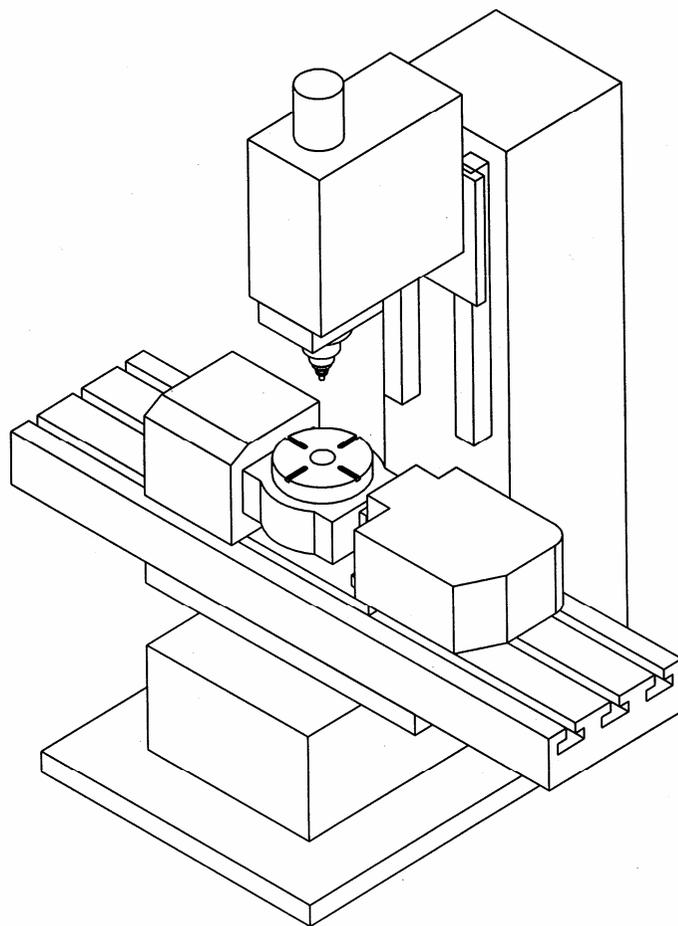
$$X_w = -X_{w1} + X_m$$

$$Y_w = Y_{w1} + Y_m$$

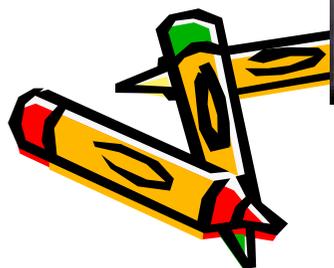
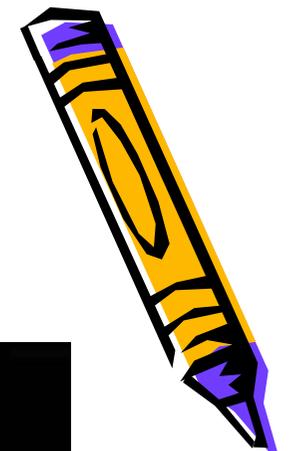
$$Z_w = -L_t + Z_0 - Z_1 - Z_2 - Z_{w1} + Z_m$$



# 五軸工具機座標轉換



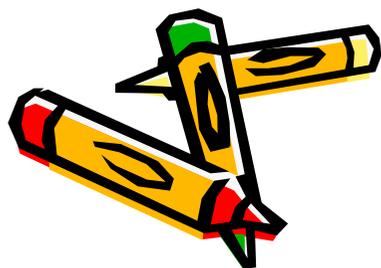
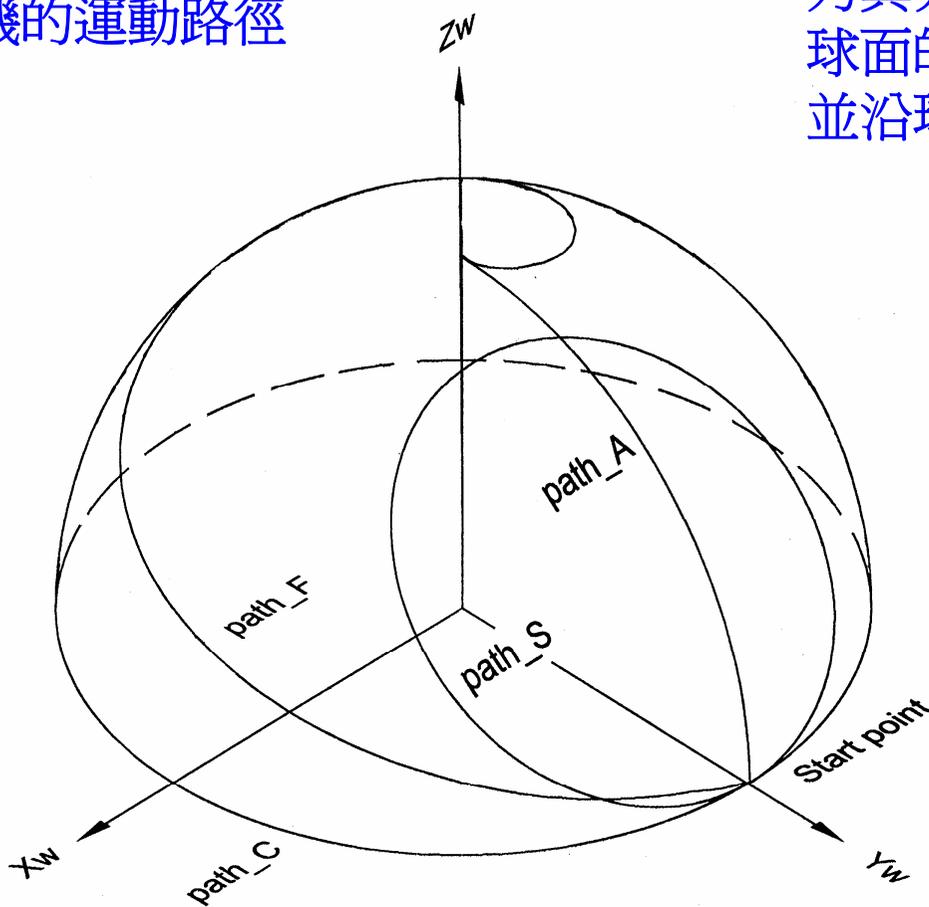
# 五軸工具機座標轉換



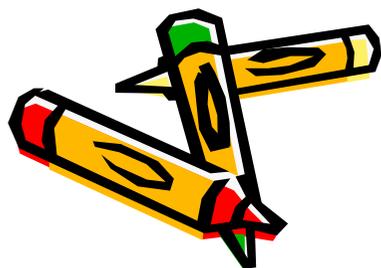
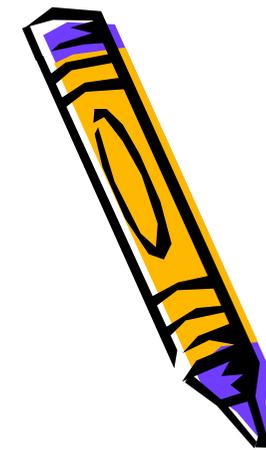
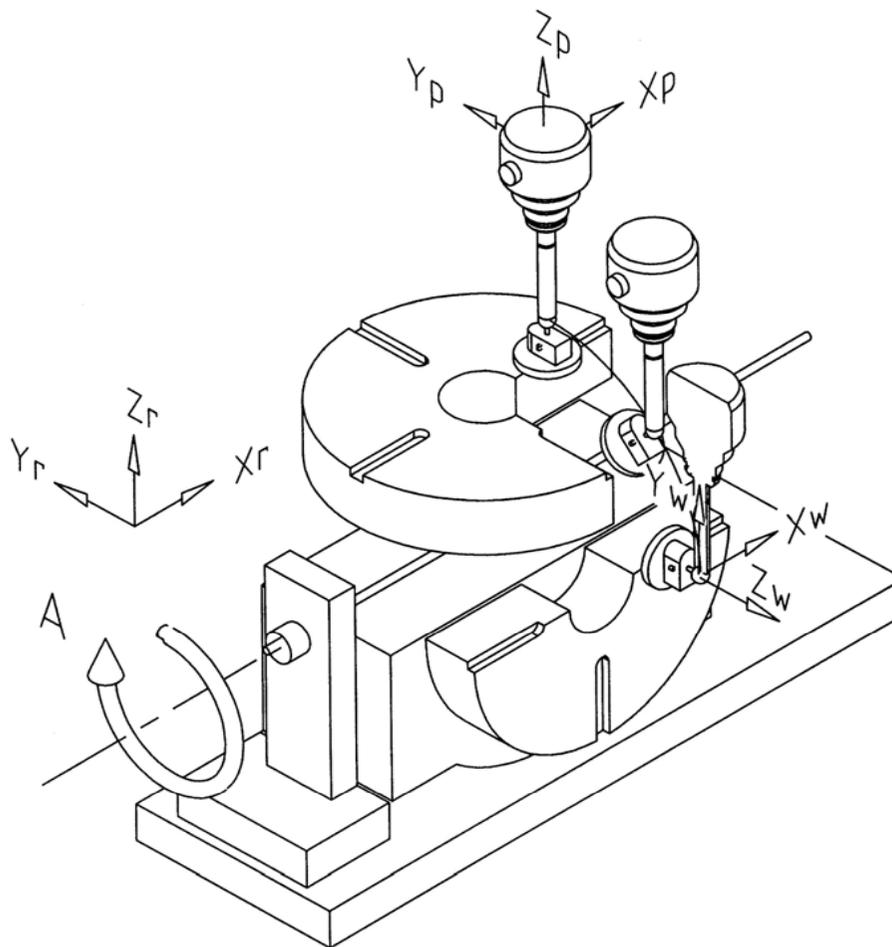
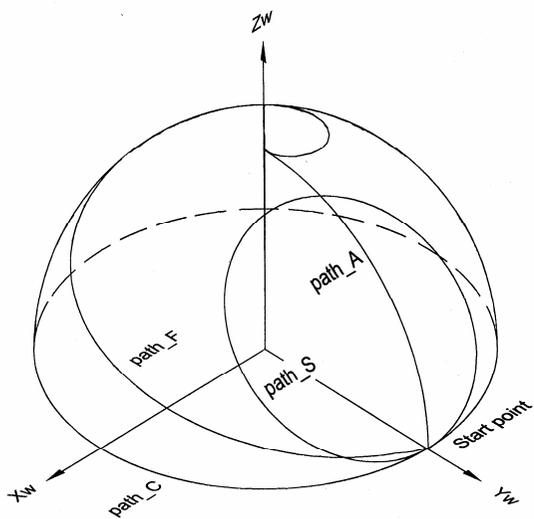
## 五軸工具機座標轉換

想像  
五軸工具機的運動路徑

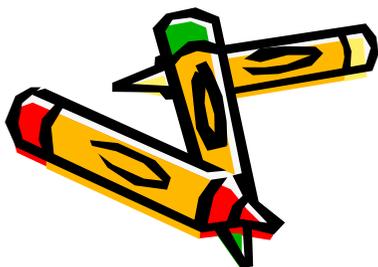
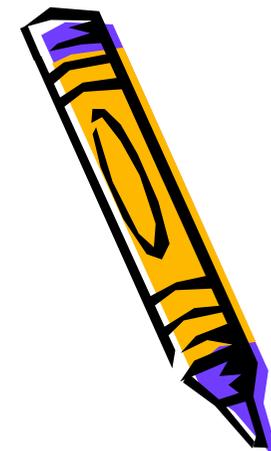
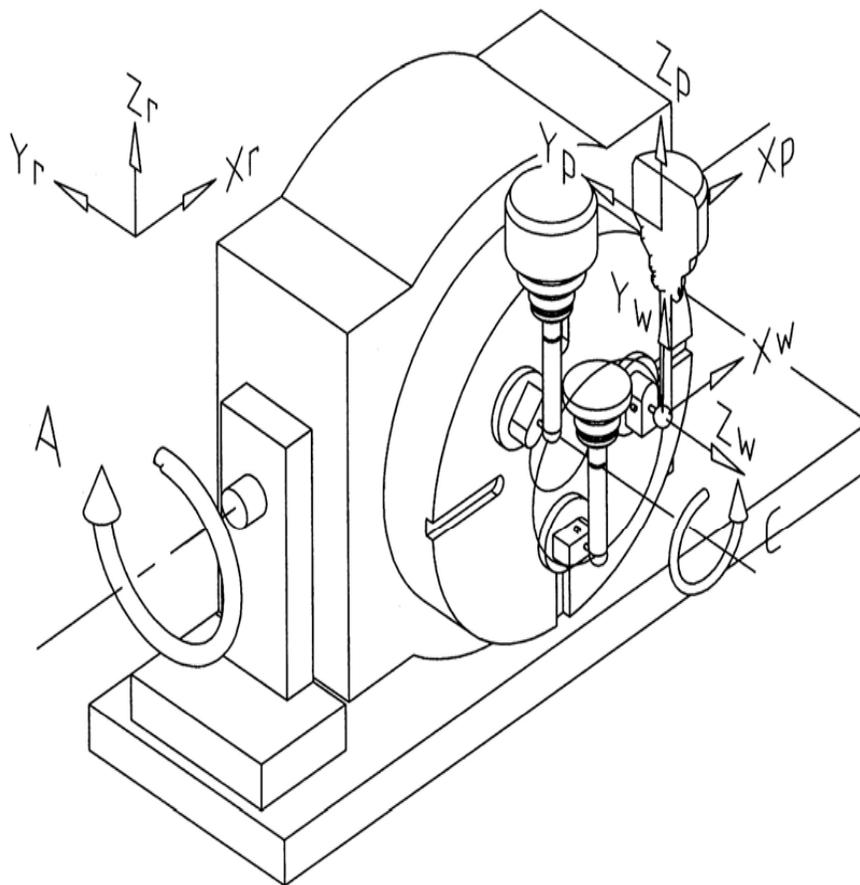
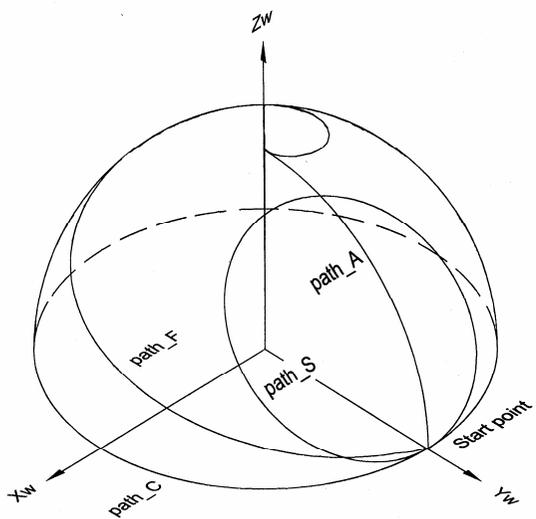
刀具方向保持為  
球面的法線方向上  
並沿球面上路徑運動



# PATH\_A座標轉換



# PATH\_C座標轉換



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