```
> with(linalg):
Warning, new definition for norm
Warning, new definition for trace
> read `c:\\lang\\maplev4\\bin.win\\dh2.txt`;
> A1 := DH2(1,1,1,0,270);
```

$$A1 := \begin{bmatrix} c_1 & 0 & -s_1 & 0 \\ s_1 & 0 & c_1 & 0 \\ 0 & -1 & 0 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

```
> Z0:=vector([ 0, 0, 1] );  Z1 := vector([A1[1,3], A1[2,3], A1[3,3]]
  );
```

$$Z0 := [0, 0, 1]$$

$$Z1 := [-s_1, c_1, 0]$$

```
> P01:= vector([A1[1,4], A1[2,4], A1[3,4]] );
```

$$P01 := [0, 0, d_1]$$

```
> A2 := DH2(2,1,1,0,270);
```

$$A2 := \begin{bmatrix} c_2 & 0 & -s_2 & 0 \\ s_2 & 0 & c_2 & 0 \\ 0 & -1 & 0 & d_2 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

```
> T02 := multiply( A1, A2 );
```

$$T02 := \begin{bmatrix} c_1 c_2 & s_1 & -c_1 s_2 & -s_1 d_2 \\ s_1 c_2 & -c_1 & -s_1 s_2 & c_1 d_2 \\ -s_2 & 0 & -c_2 & d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

```
> Z2 := vector([T02[1,3], T02[2,3], T02[3,3]] );
```

$$Z2 := [-c_1 s_2, -s_1 s_2, -c_2]$$

```
> A3 := DH2(3,0,1,0,0);
```

$$A3 := \begin{bmatrix} 1 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & d_3 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

```
> T03:=multiply(A1,A2,A3);
```

$$T03 := \begin{bmatrix} c_1 c_2 & s_1 & -c_1 s_2 & -c_1 s_2 d_3 - s_1 d_2 \\ s_1 c_2 & -c_1 & -s_1 s_2 & -s_1 s_2 d_3 + c_1 d_2 \\ -s_2 & 0 & -c_2 & -c_2 d_3 + d_1 \\ 0 & 0 & 0 & 1 \end{bmatrix}$$

```
> P03:= vector([T03[1,4], T03[2,4], T03[3,4]] );
```

$$P03 := [-c_1 s_2 d_3 - s_1 d_2, -s_1 s_2 d_3 + c_1 d_2, -c_2 d_3 + d_1]$$

```
> J11 := crossprod(Z0,P03);
```

$$J11 := [\, s_1\, s_2\, d_3 - c_1\, d_2,\ -c_1\, s_2\, d_3 - s_1\, d_2,\ 0\,]$$

```
> P13 := evalm( P03 - P01);
```

$$P13 := [\, -c_1\, s_2\, d_3 - s_1\, d_2,\ -s_1\, s_2\, d_3 + c_1\, d_2,\ -c_2\, d_3\,]$$

```
> J21 := crossprod(Z1,P13);
```

$$J21 := [\, -c_1\, c_2\, d_3,\ -s_1\, c_2\, d_3,\ -s_1\,(-s_1\, s_2\, d_3 + c_1\, d_2) - c_1\,(-c_1\, s_2\, d_3 - s_1\, d_2)\,]$$

```
> simplify(J21[3]);
```

$$s_1^{\,2}\, s_2\, d_3 + c_1^{\,2}\, s_2\, d_3$$

```
> J21[3] := s[2]*d[3];
```

$$J21_3 := s_2\, d_3$$

```
> J31 := evalm( Z2 );
```

$$J31 := [\, -c_1\, s_2,\ -s_1\, s_2,\ -c_2\,]$$

```
> Jtop := augment( J11, J21, J31 );
```

$$Jtop := \begin{bmatrix} s_1\, s_2\, d_3 - c_1\, d_2 & -c_1\, c_2\, d_3 & -c_1\, s_2 \\ -c_1\, s_2\, d_3 - s_1\, d_2 & -s_1\, c_2\, d_3 & -s_1\, s_2 \\ 0 & s_2\, d_3 & -c_2 \end{bmatrix}$$

```
> J12 := evalm(Z0);
```

$$J12 := [\, 0,\ 0,\ 1\,]$$

```
> J22 := evalm( Z1 );
```

$$J22 := [\, -s_1,\ c_1,\ 0\,]$$

```
> J32 := vector([ 0, 0, 0] );
```

$$J32 := [\, 0,\ 0,\ 0\,]$$

```
> Jbot := augment( J12, J22, J32 );
```

$$Jbot := \begin{bmatrix} 0 & -s_1 & 0 \\ 0 & c_1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

```
> J := stack( Jtop, Jbot );
```

$$J := \begin{bmatrix} s_1\, s_2\, d_3 - c_1\, d_2 & -c_1\, c_2\, d_3 & -c_1\, s_2 \\ -c_1\, s_2\, d_3 - s_1\, d_2 & -s_1\, c_2\, d_3 & -s_1\, s_2 \\ 0 & s_2\, d_3 & -c_2 \\ 0 & -s_1 & 0 \\ 0 & c_1 & 0 \\ 1 & 0 & 0 \end{bmatrix}$$

```
> theta1 := 0; theta2 := 270*Pi/180; d[1]:=5; d[2]:=2; d[3]:=4;
  c[1]:=cos(theta1);s[1]:=sin(theta1);c[2]:=cos(theta2);s[2]:=sin(th
  eta2);
> read `c:\\lang\\maplev4\\bin.win\\subJ.txt`;
> AnswerA := subJ(J);
```

$$AnswerA := \begin{bmatrix} -2. & 0 & 1. \\ 4. & 0 & 0 \\ 0 & -4. & 0 \\ 0 & 0 & 0 \\ 0 & 1. & 0 \\ 1. & 0 & 0 \end{bmatrix}$$

```
> J := stack( Jtop, Jbot ):
> theta1 := 90*Pi/180; theta2 := 60*Pi/180; d[1]:=5; d[2]:=2;
  d[3]:=4;
  c[1]:=cos(theta1);s[1]:=sin(theta1);c[2]:=cos(theta2);s[2]:=sin(th
  eta2);

> AnswerB := subJ(J);
```

$$AnswerB := \begin{bmatrix} 3.464101616 & 0 & 0 \\ -2. & -2. & -.8660254040 \\ 0 & 3.464101616 & -.5000000000 \\ 0 & -1. & 0 \\ 0 & 0 & 0 \\ 1. & 0 & 0 \end{bmatrix}$$

```
> J := stack( Jtop, Jbot ):
> theta1 := 180*Pi/180; theta2 := 135*Pi/180; d[1]:=5; d[2]:=2;
  d[3]:=4;
  c[1]:=cos(theta1);s[1]:=sin(theta1);c[2]:=cos(theta2);s[2]:=sin(th
  eta2);

> AnswerC := subJ(J);
```

$$AnswerC := \begin{bmatrix} 2. & -2.828427124 & .7071067810 \\ 2.828427124 & 0 & 0 \\ 0 & 2.828427124 & .7071067810 \\ 0 & 0 & 0 \\ 0 & -1. & 0 \\ 1. & 0 & 0 \end{bmatrix}$$

```
>
```