附录

一、材料清单 BOM

项目号	零件号	说明	数量
1	机架		1
2	顶盖		1
3	70-35转角-1球铰-2转轴-2		3
4	圆球杆42mm		3
5	40-35转角-2球铰-1转轴		3
6	圆球杆158mm		3
7	三角板		1
8	凸轮		3

二、动学求解代码（通过执行器位置求解驱动空间参数）

```
clear;

L_tri=7.5;

%O1=(0,5,25);O2=(0,5,20);O3=(5*cos(pi/6),5*sin(pi/6),20);O4=(5*cos(pi/6),5*sin(pi/6),25)

xo=0;

yo=5;

zo=21;


xa=xo+L_tri/2;

ya=yo-L_tri/(2*3^0.5);

za=zo;

xb=xo-L_tri/2;

yb=yo-L_tri/(2*3^0.5);
```

```
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
```

```
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
```

```
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
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```
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
```

```
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
```

```
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
```

```
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
positions.rho_s=rho_s;
positions.rho_u=rho_u;
positions.rho_v=rho_v;
disp(positions);
```

三、运动学求解代码（凸轮方案运动功能设计）

```
clear;

L_tri=7.5;

%O1=(0,5,21);O2=(0,5,27);O3=(5*cos(pi/6),-5*sin(pi/6),21);O4=(5*cos(pi/6),-5*sin(pi/6),27)

for i=27:-0.5:21


  xo=0;

  yo=5;

  zo=i;


  xa=xo+L_tri/2;

  ya=yo-L_tri/(2*3^0.5);

  za=zo;

  xb=xo-L_tri/2;

  yb=yo-L_tri/(2*3^0.5);

  zb=zo;

  xc=xo;

  yc=yo+L_tri/(3^0.5);

  zc=zo;

  xg=10*cos(pi/6);

  yg=-10*sin(pi/6);

  zg=0;

  xh=-xg;

  yh=yg;

  zh=zg;

  xi=0;
```

```
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
```

```
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
```

```
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
```

```
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
```

```
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
```

```
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
```

```
  positions.zv=zv;
  positions.xs1=xs1;
  positions.ys1=ys1;
  positions.zs1=zs1;
  positions.xu1=xu1;
  positions.yu1=yu1;
  positions.zu1=zu1;
  positions.xv1=xv1;
  positions.yv1=yv1;
  positions.zv1=zv1;
  fileID=fopen('spiderhand_positions.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);

end;

for i=1/12:1/12:11/12
```

```
xo=i*5*cos(pi/6);
yo=5-i*(5*sin(pi/6)+5);
zo=21;

xa=xo+L_tri/2;
ya=yo-L_tri/(2*3^0.5);
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
```

```
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
```

```
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
```

```
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
```

```
alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
```

```
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
```

```
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
```

```
  positions.xv1=xv1;

  positions.yv1=yv1;

  positions.zv1=zv1;

  fileID=fopen('spiderhand_positions.txt','a');

  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);




end;


for i=21:0.5:26.5


  xo=5*cos(pi/6);

  yo=-5*sin(pi/6);

  zo=i;


  xa=xo+L_tri/2;

  ya=yo-L_tri/(2*3^0.5);
```

```
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;
```

```
eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
```

```
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;
```

```
syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
```

```
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
```

```
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
```

```
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
fileID=fopen('spiderhand_positions.txt','a');
dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
```

```
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);




end;


for i=27:-0.5:21


  xo=5*cos(pi/6);

  yo=-5*sin(pi/6);

  zo=i;


  xa=xo+L_tri/2;

  ya=yo-L_tri/(2*3^0.5);

  za=zo;

  xb=xo-L_tri/2;

  yb=yo-L_tri/(2*3^0.5);

  zb=zo;

  xc=xo;

  yc=yo+L_tri/(3^0.5);
```

```
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
```

```
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));
```

```
syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
```

```
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
```

```
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
```

```
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
```

```
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
fileID=fopen('spiderhand_positions.txt','a');
dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
```

```
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);



end;

for i=1/12:1/12:11/12

  xo=5*cos(pi/6)-i*2*5*cos(pi/6);
  yo=-5*sin(pi/6);
  zo=21;

  xa=xo+L_tri/2;
  ya=yo-L_tri/(2*3^0.5);
  za=zo;
  xb=xo-L_tri/2;
  yb=yo-L_tri/(2*3^0.5);
  zb=zo;
  xc=xo;
  yc=yo+L_tri/(3^0.5);
  zc=zo;
  xg=10*cos(pi/6);
  yg=-10*sin(pi/6);
  zg=0;
  xh=-xg;
  yh=yg;
```

```
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
```

```
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
```

```
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
```

```
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;
```

```
positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
```

```
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
```

```
  positions.xv=xv;
  positions.yv=yv;
  positions.zv=zv;
  positions.xs1=xs1;
  positions.ys1=ys1;
  positions.zs1=zs1;
  positions.xu1=xu1;
  positions.yu1=yu1;
  positions.zu1=zu1;
  positions.xv1=xv1;
  positions.yv1=yv1;
  positions.zv1=zv1;
  fileID=fopen('spiderhand_positions.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);



end;
```

```
for i=21:0.5:26.5

  xo=-5*cos(pi/6);
  yo=-5*sin(pi/6);
  zo=i;

  xa=xo+L_tri/2;
  ya=yo-L_tri/(2*3^0.5);
  za=zo;
  xb=xo-L_tri/2;
  yb=yo-L_tri/(2*3^0.5);
  zb=zo;
  xc=xo;
  yc=yo+L_tri/(3^0.5);
  zc=zo;
  xg=10*cos(pi/6);
  yg=-10*sin(pi/6);
  zg=0;
  xh=-xg;
  yh=yg;
  zh=zg;
  xi=0;
  yi=10;
  zi=0;

  L1=20.8;
  L2=10.8;
```

```
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
```

```
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
```

```
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
```

```
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
```

```
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
```

```
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
```

```
  positions.yu1=yu1;
  positions.zu1=zu1;
  positions.xv1=xv1;
  positions.yv1=yv1;
  positions.zv1=zv1;
  fileID=fopen('spiderhand_positions.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);



end;


for i=27:-0.5:21


  xo=-5*cos(pi/6);
  yo=-5*sin(pi/6);
  zo=i;


  xa=xo+L_tri/2;
```

```
ya=yo-L_tri/(2*3^0.5);
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
```

```
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
```

```
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;
```

```
syms xm ym zm xp yp zp xq yq zq;

eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;

eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;

eq3=zs==zm;

eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;

eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;

eq6=zp==zu;

eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;

eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;

eq9=zq==zv;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];

sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);

xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));

zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));



alpha=pi*3/4;

L6=2.5;

xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
```

```
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
```

```
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
```

```
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
fileID=fopen('spiderhand_positions.txt','a');
dispcontent=positions;
```

```
fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,positions.zv1);




end;


for i=1/12:1/12:11/12


  xo=-5*cos(pi/6)+i*(5*cos(pi/6));
  yo=-5*sin(pi/6)+i*(5*sin(pi/6)+5);
  zo=21;


  xa=xo+L_tri/2;
  ya=yo-L_tri/(2*3^0.5);
  za=zo;
  xb=xo-L_tri/2;
  yb=yo-L_tri/(2*3^0.5);
  zb=zo;
  xc=xo;
```

```
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;
```

```
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
```

```
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
```

```
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
```

```
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
```

```
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
```

```
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
fileID=fopen('spiderhand_positions.txt','a');
dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
```

```
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);



end;


for i=21:0.5:26.5


  xo=0;

  yo=5;

  zo=i;


  xa=xo+L_tri/2;

  ya=yo-L_tri/(2*3^0.5);

  za=zo;

  xb=xo-L_tri/2;

  yb=yo-L_tri/(2*3^0.5);

  zb=zo;

  xc=xo;

  yc=yo+L_tri/(3^0.5);

  zc=zo;

  xg=10*cos(pi/6);

  yg=-10*sin(pi/6);

  zg=0;

  xh=-xg;

  yh=yg;
```

```
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
```

```
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
```

```
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
```

```
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;
```

```
positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
```

```
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
```

```
  positions.xv=xv;
  positions.yv=yv;
  positions.zv=zv;
  positions.xs1=xs1;
  positions.ys1=ys1;
  positions.zs1=zs1;
  positions.xu1=xu1;
  positions.yu1=yu1;
  positions.zu1=zu1;
  positions.xv1=xv1;
  positions.yv1=yv1;
  positions.zv1=zv1;
  fileID=fopen('spiderhand_positions.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,p
ositions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positio
ns.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,
positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positio
ns.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,
positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.
xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,posi
tions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,position
s.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,p
ositions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positi
ons.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,posi
tions.zv1);



end;
```

```
fclose(fileID);
```

四、逆运动学求解代码（电机方案运动功能设计）

```
clear;
L_tri=7.5;
%O1=(0,5,25);O2=(0,5,20);O3=(5*cos(pi/6),5*sin(pi/6),20);O4=(5*cos(pi/6),5*sin(pi/6),25)
xo=5*cos(pi/6);
yo=5*sin(pi/6);
zo=27;
x_target=0;
y_target=5;
z_target=27;
x_ball1=5;
y_ball1=10;
z_ball1=27;
x_ball2=-7;
y_ball2=-7;
z_ball2=27;
x_ball3=3;
y_ball3=6;
z_ball3=27;
x_ball4=6;
y_ball4=-4;
z_ball4=27;
xa=xo+L_tri/2;
ya=yo-L_tri/(2*3^0.5);
```

```
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;
```

```
eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
```

```
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;
```

```
syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
```

```
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
```

```
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
```

```
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
positions.rho_s=rho_s;
positions.rho_u=rho_u;
positions.rho_v=rho_v;
```

```
positions.x_target=x_target;
positions.y_target=y_target;
positions.z_target=z_target;

for i=-10:0.5:0
  positions.xo=xo+i;
  positions.yo=yo-10;
  positions.zo=zo;
  positions.xa=xa+i;
  positions.ya=ya-10;
  positions.za=za;
  positions.xb=xb+i;
  positions.yb=yb-10;
  positions.zb=zb;
  positions.xc=xc+i;
  positions.yc=yc-10;
  positions.zc=zc;
  positions.xd=xd+i;
  positions.yd=yd-10;
  positions.zd=zd;
  positions.xe=xe+i;
  positions.ye=ye-10;
  positions.ze=ze;
  positions.xf=xf+i;
  positions.yf=yf-10;
  positions.zf=zf;
  positions.xg=xg+i;
```

```
positions.yg=yg-10;
positions.zg=zg;
positions.xh=xh+i;
positions.yh=yh-10;
positions.zh=zh;
positions.xi=xi+i;
positions.yi=yi-10;
positions.zi=zi;
positions.xj=xj+i;
positions.yj=yj-10;
positions.zj=zj;
positions.xk=xk+i;
positions.yk=yk-10;
positions.zk=zk;
positions.xl=xl+i;
positions.yl=yl-10;
positions.zl=zl;
positions.xm=xm+i;
positions.ym=ym-10;
positions.zm=zm;
positions.xp=xp+i;
positions.yp=yp-10;
positions.zp=zp;
positions.xq=xq+i;
positions.yq=yq-10;
positions.zq=zq;
positions.xs=xs+i;
```

```
  positions.ys=ys-10;
  positions.zs=zs;
  positions.xu=xu+i;
  positions.yu=yu-10;
  positions.zu=zu;
  positions.xv=xv+i;
  positions.yv=yv-10;
  positions.zv=zv;
  positions.xs1=xs1+i;
  positions.ys1=ys1-10;
  positions.zs1=zs1;
  positions.xu1=xu1+i;
  positions.yu1=yu1-10;
  positions.zu1=zu1;
  positions.xv1=xv1+i;
  positions.yv1=yv1-10;
  positions.zv1=zv1;
  positions.rho_s=rho_s;
  positions.rho_u=rho_u;
  positions.rho_v=rho_v;
  positions.x_target=x_target;
  positions.y_target=y_target;
  positions.z_target=z_target;
  fileID=fopen('claw_machine.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
```

```
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);

end

for i=-10:0.5:0
   positions.xo=xo;
   positions.yo=yo+i;
   positions.zo=zo;
   positions.xa=xa;
   positions.ya=ya+i;
   positions.za=za;
   positions.xb=xb;
   positions.yb=yb+i;
   positions.zb=zb;
   positions.xc=xc;
   positions.yc=yc+i;
   positions.zc=zc;
   positions.xd=xd;
   positions.yd=yd+i;
```

```
positions.zd=zd;
positions.xe=xe;
positions.ye=ye+i;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf+i;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg+i;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh+i;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi+i;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj+i;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk+i;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl+i;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym+i;
```

```
positions.zm=zm;
positions.xp=xp;
positions.yp=yp+i;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq+i;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys+i;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu+i;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv+i;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1+i;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1+i;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1+i;
positions.zv1=zv1;
positions.rho_s=rho_s;
positions.rho_u=rho_u;
```

```
  positions.rho_v=rho_v;

  positions.x_target=x_target;

  positions.y_target=y_target;

  positions.z_target=z_target;

  fileID=fopen('claw_machine.txt','a');

  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positions.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_ball3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);


end


for i=27:-0.5:21


  xo=5*cos(pi/6);

  yo=5*sin(pi/6);

  zo=i;

  xa=xo+L_tri/2;

  ya=yo-L_tri/(2*3^0.5);
```

```
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;
```

```
eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
```

```
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;
```

```
syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
```

```
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
```

```
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
```

```
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
positions.x_target=x_target;
positions.y_target=y_target;
positions.z_target=z_target;
```

```
   disp(positions);
   fileID=fopen('claw_machine.txt','a');
   dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);




end;


for i=0:1/12:1


   xo=5*cos(pi/6)+i*(-5*cos(pi/6));
   yo=5*sin(pi/6)+i*(-5*sin(pi/6)+5);
   zo=21;


   xa=xo+L_tri/2;
   ya=yo-L_tri/(2*3^0.5);
```

```
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;
```

```
eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
```

```
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;
```

```
syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
```

```
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
```

```
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
```

```
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
positions.x_target=x_target;
positions.y_target=y_target;
positions.z_target=z_target;
```

```
   disp(positions);
   fileID=fopen('claw_machine.txt','a');
   dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);



end;

for i=21:0.5:27
   xo=0;
   yo=5;
   zo=i;

   xa=xo+L_tri/2;
   ya=yo-L_tri/(2*3^0.5);
   za=zo;
```

```
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;
```

```
eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
```

```
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
```

```
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
```

```
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
```

```
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
```

```
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
positions.x_target=x_target;
positions.y_target=y_target;
positions.z_target=z_target;
disp(positions);
```

```
fileID=fopen('claw_machine.txt','a');

dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);



end;


for i=0:0.5:3.5


  xo=0;

  yo=5;

  zo=27;

  L=L_tri-i;


  xa=xo+L/2;

  ya=yo-L/(2*3^0.5);

  za=zo;
```

```
xb=xo-L/2;

yb=yo-L/(2*3^0.5);

zb=zo;

xc=xo;

yc=yo+L/(3^0.5);

zc=zo;

xg=10*cos(pi/6);

yg=-10*sin(pi/6);

zg=0;

xh=-xg;

yh=yg;

zh=zg;

xi=0;

yi=10;

zi=0;


L1=20.8;

L2=10.8;

syms xd yd zd xe ye ze xf yf zf;

eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;

eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;

eq3=xd==xg;


eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;

eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;

eq6=xe-xh==(yh-ye)*3^0.5;
```

```
eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
```

```
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
```

```
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
```

```
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
```

```
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
```

```
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
positions.x_target=x_target;
positions.y_target=y_target;
positions.z_target=z_target;
disp(positions);
```

```
    fileID=fopen('claw_machine.txt','a');

    dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);




end;


L_tri=4;


for i=27:-0.5:21

    xo=0;

    yo=5;

    zo=i;

    x_target=xo;

    y_target=yo;

    z_target=zo;
```

```
xa=xo+L_tri/2;
ya=yo-L_tri/(2*3^0.5);
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
```

```
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
```

```
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
yv=-ys;
```

```
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
L6=2.5;
```

```
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
```

```
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
```

```
positions.ym=ym;

positions.zm=zm;

positions.xp=xp;

positions.yp=yp;

positions.zp=zp;

positions.xq=xq;

positions.yq=yq;

positions.zq=zq;

positions.xs=xs;

positions.ys=ys;

positions.zs=zs;

positions.xu=xu;

positions.yu=yu;

positions.zu=zu;

positions.xv=xv;

positions.yv=yv;

positions.zv=zv;

positions.xs1=xs1;

positions.ys1=ys1;

positions.zs1=zs1;

positions.xu1=xu1;

positions.yu1=yu1;

positions.zu1=zu1;

positions.xv1=xv1;

positions.yv1=yv1;

positions.zv1=zv1;

positions.x_target=x_target;
```

```
    positions.y_target=y_target;
    positions.z_target=z_target;
    disp(positions);
    fileID=fopen('claw_machine.txt','a');
    dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);



end;


for i=1/12:1/12:11/12


    xo=i*5*cos(pi/6);
    yo=5+i*(5*sin(pi/6)-5);
    zo=21;
    x_target=xo;
    y_target=yo;
```

```
z_target=zo;
xa=xo+L_tri/2;
ya=yo-L_tri/(2*3^0.5);
za=zo;
xb=xo-L_tri/2;
yb=yo-L_tri/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L_tri/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;
```

```
eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;
```

```
syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
yu=0;
zu=-1;
xv=xs;
```

```
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));


alpha=pi*3/4;
```

```
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
```

```
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
```

```
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
positions.xv1=xv1;
positions.yv1=yv1;
positions.zv1=zv1;
```

```
  positions.x_target=x_target;
  positions.y_target=y_target;
  positions.z_target=z_target;
  disp(positions);
  fileID=fopen('claw_machine.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,positions.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,positions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positions.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,positions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,positions.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,positions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,positions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.yu1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positions.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_ball3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);

end;

L_tri=7.5;

for i=3.5:-0.5:0
  xo=5*cos(pi/6);
  yo=5*sin(pi/6);
```

```
zo=21;
L=L_tri-i;
z_target=zo+(3.5-i)^2

xa=xo+L/2;
ya=yo-L/(2*3^0.5);
za=zo;
xb=xo-L/2;
yb=yo-L/(2*3^0.5);
zb=zo;
xc=xo;
yc=yo+L/(3^0.5);
zc=zo;
xg=10*cos(pi/6);
yg=-10*sin(pi/6);
zg=0;
xh=-xg;
yh=yg;
zh=zg;
xi=0;
yi=10;
zi=0;

L1=20.8;
L2=10.8;
syms xd yd zd xe ye ze xf yf zf;
eq1=(xd-xa)^2+(yd-ya)^2+(za-zd)^2==L1^2;
```

```
eq2=(xd-xg)^2+(yd-yg)^2+(zd-zg)^2==L2^2;
eq3=xd==xg;

eq4=(xb-xe)^2+(yb-ye)^2+(zb-ze)^2==L1^2;
eq5=(xh-xe)^2+(yh-ye)^2+(zh-ze)^2==L2^2;
eq6=xe-xh==(yh-ye)*3^0.5;

eq7=(xc-xf)^2+(yc-yf)^2+(zc-zf)^2==L1^2;
eq8=(xi-xf)^2+(yi-yf)^2+(zi-zf)^2==L2^2;
eq9=xi-xf==(yi-yf)*3^0.5;

eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xd,yd,zd,xe,ye,ze,xf,yf,zf]);
xd=double(sol.xd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yd=double(sol.yd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zd=double(sol.zd(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xe=double(sol.xe(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ye=double(sol.ye(sol.yd>0 & sol.xe>-5 & sol.xf<0));
ze=double(sol.ze(sol.yd>0 & sol.xe>-5 & sol.xf<0));
xf=double(sol.xf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
yf=double(sol.yf(sol.yd>0 & sol.xe>-5 & sol.xf<0));
zf=double(sol.zf(sol.yd>0 & sol.xe>-5 & sol.xf<0));

L3=4.4;
L4=4.2;
L5=5.3;
xj=xg;
```

```
yj=yg+L3*(zd-zg)/L2;
zj=zg-L3*(yd-yg)/L2;

syms xk yk zk;
eq1=(xk-xh)^2+(yk-yh)^2+(zk-zh)^2==L3^2;
eq2=(xk-xe)^2+(yk-ye)^2+(zk-ze)^2==L3^2+L2^2;
eq3=-sin(pi/6)*(xk-xh)-cos(pi/6)*(yk-yh)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xk,yk,zk]);
xk=double(sol.xk(sol.xk>xh));
yk=double(sol.yk(sol.xk>xh));
zk=double(sol.zk(sol.xk>xh));

syms xl yl zl;
eq1=(xl-xi)^2+(yl-yi)^2+(zl-zi)^2==L3^2;
eq2=(xl-xf)^2+(yl-yf)^2+(zl-zf)^2==L2^2+L3^2;
eq3=-sin(pi/6)*(xl-xi)+cos(pi/6)*(yl-yi)==0;
eqns=[eq1,eq2,eq3];
sol=solve(eqns,[xl,yl,zl]);
xl=double(sol.xl(sol.xl<0));
yl=double(sol.yl(sol.xl<0));
zl=double(sol.zl(sol.xl<0));

xs=6*sin(pi/6);
ys=-6*cos(pi/6);
zs=-1;
xu=-6;
```

```
yu=0;
zu=-1;
xv=xs;
yv=-ys;
zv=-1;

syms xm ym zm xp yp zp xq yq zq;
eq1=(xm-xj)^2+(ym-yj)^2+(zm-zj)^2==L4^2;
eq2=(xm-xs)^2+(ym-ys)^2+(zm-zs)^2==L5^2;
eq3=zs==zm;
eq4=(xp-xk)^2+(yp-yk)^2+(zp-zk)^2==L4^2;
eq5=(xp-xu)^2+(yp-yu)^2+(zp-zu)^2==L5^2;
eq6=zp==zu;
eq7=(xq-xl)^2+(yq-yl)^2+(zq-zl)^2==L4^2;
eq8=(xq-xv)^2+(yq-yv)^2+(zq-zv)^2==L5^2;
eq9=zq==zv;
eqns=[eq1,eq2,eq3,eq4,eq5,eq6,eq7,eq8,eq9];
sol=solve(eqns,[xm,ym,zm,xp,yp,zp,xq,yq,zq]);
xm=double(sol.xm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
ym=double(sol.ym(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zm=double(sol.zm(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xp=double(sol.xp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yp=double(sol.yp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zp=double(sol.zp(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
xq=double(sol.xq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
yq=double(sol.yq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
zq=double(sol.zq(sol.ym>-3 & sol.xp>-6.3 & sol.yq<8.2));
```

```
alpha=pi*3/4;
L6=2.5;
xs1=xs+L6*cos(alpha+atan2(ym-ys,xm-xs));
ys1=ys+L6*sin(alpha+atan2(ym-ys,xm-xs));
zs1=zm;
xu1=xu+L6*cos(alpha+atan2(yp-yu,xp-xu));
yu1=yu+L6*sin(alpha+atan2(yp-yu,xp-xu));
zu1=zp;
xv1=xv+L6*cos(alpha+atan2(yq-yv,xq-xv));
yv1=yv+L6*sin(alpha+atan2(yq-yv,xq-xv));
zv1=zq;

rho_s=(xs1^2+ys1^2+zs1^2)^0.5;
rho_u=(xu1^2+yu1^2+zu1^2)^0.5;
rho_v=(xv1^2+yv1^2+zv1^2)^0.5;

positions.xo=xo;
positions.yo=yo;
positions.zo=zo;
positions.xa=xa;
positions.ya=ya;
positions.za=za;
positions.xb=xb;
positions.yb=yb;
positions.zb=zb;
```

```
positions.xc=xc;
positions.yc=yc;
positions.zc=zc;
positions.xd=xd;
positions.yd=yd;
positions.zd=zd;
positions.xe=xe;
positions.ye=ye;
positions.ze=ze;
positions.xf=xf;
positions.yf=yf;
positions.zf=zf;
positions.xg=xg;
positions.yg=yg;
positions.zg=zg;
positions.xh=xh;
positions.yh=yh;
positions.zh=zh;
positions.xi=xi;
positions.yi=yi;
positions.zi=zi;
positions.xj=xj;
positions.yj=yj;
positions.zj=zj;
positions.xk=xk;
positions.yk=yk;
positions.zk=zk;
```

```
positions.xl=xl;
positions.yl=yl;
positions.zl=zl;
positions.xm=xm;
positions.ym=ym;
positions.zm=zm;
positions.xp=xp;
positions.yp=yp;
positions.zp=zp;
positions.xq=xq;
positions.yq=yq;
positions.zq=zq;
positions.xs=xs;
positions.ys=ys;
positions.zs=zs;
positions.xu=xu;
positions.yu=yu;
positions.zu=zu;
positions.xv=xv;
positions.yv=yv;
positions.zv=zv;
positions.xs1=xs1;
positions.ys1=ys1;
positions.zs1=zs1;
positions.xu1=xu1;
positions.yu1=yu1;
positions.zu1=zu1;
```

```
  positions.xv1=xv1;
  positions.yv1=yv1;
  positions.zv1=zv1;
  positions.x_target=x_target;
  positions.y_target=y_target;
  positions.z_target=z_target;
  disp(positions);
  fileID=fopen('claw_machine.txt','a');
  dispcontent=positions;

fprintf(fileID,'[%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,%f,
%f,%f,%f,%f,%f,%f,%f,%f,%f,%f]\n',positions.xo,positions.yo,positions.zo,position
s.xa,positions.ya,positions.za,positions.xb,positions.yb,positions.zb,positions.xc,p
ositions.yc,positions.zc,positions.xd,positions.yd,positions.zd,positions.xe,positio
ns.ye,positions.ze,positions.xf,positions.yf,positions.zf,positions.xg,positions.yg,p
ositions.zg,positions.xh,positions.yh,positions.zh,positions.xi,positions.yi,position
s.zi,positions.xj,positions.yj,positions.zj,positions.xk,positions.yk,positions.zk,posi
tions.xl,positions.yl,positions.zl,positions.xm,positions.ym,positions.zm,positions.
xp,positions.yp,positions.zp,positions.xq,positions.yq,positions.zq,positions.xs,po
sitions.ys,positions.zs,positions.xu,positions.yu,positions.zu,positions.xv,positions
.yv,positions.zv,positions.xs1,positions.ys1,positions.zs1,positions.xu1,positions.y
u1,positions.zu1,positions.xv1,positions.yv1,positions.zv1,positions.x_target,positi
ons.y_target,positions.z_target,x_ball1,y_ball1,z_ball1,x_ball2,y_ball2,z_ball2,x_bal
l3,y_ball3,z_ball3,x_ball4,y_ball4,z_ball4);

end;

fclose(fileID);
```

五、凸轮设计

```
% 导入数据并计算
c = 15;
phi = linspace(0, 2*pi, 630);
filepath = 'C:\Users\Dell\Desktop\机设大作业\spiderhand_rho_s1.txt';
rho = readmatrix(filepath);
x = zeros(length(phi), 1);
y = zeros(length(phi), 1);
z = zeros(length(phi), 1);

for i = 1:length(phi)
    x(i) = rho(i) * cos(phi(i));
    y(i) = rho(i) * sin(phi(i));
end
%输出 solidworks 中生成凸轮需要的数据
output_data = [x, y, z] * c;
writematrix(output_data, 'closed_cam_profile.txt');
disp('闭合凸轮曲线数据已保存为 closed_cam_profile.txt');

%绘制凸轮轮廓
figure;
hold on;
plot(x, y, 'r', 'LineWidth', 2);
plot(x(1:11), y(1:11), 'blue', 'LineWidth', 2);
plot(x(71:81),y(71:81), 'green', 'LineWidth',2);
plot(x(200:221), y(200:221), 'blue', 'LineWidth', 2);
plot(x(281:291), y(281:291), 'green', 'LineWidth', 2);
plot(x(410:431), y(410:431), 'blue', 'LineWidth', 2);
```

```
plot(x(551:561), y(551:561), 'green', 'LineWidth', 2);

plot(x(620:630), y(620:630), 'blue', 'LineWidth', 2);

hold off;

axis equal;

title('凸轮轮廓');

xlabel('X');

ylabel('Y');

grid on;


%绘制 rho 与 phi 的关系图像

figure;

plot(phi, rho, 'b', 'LineWidth', 3);

title('$\rho$($\phi$)', 'Interpreter', 'latex');

xlabel('$\phi$', 'Interpreter', 'latex');

ylabel('$\rho$', 'Interpreter', 'latex');

xticks(0:0.25:2*pi);

grid on;
```

六、仿真代码

（一）、蜘蛛手

1. 主代码块

功能：对蜘蛛手的运动仿真

```
import numpy as np
import matplotlib.pyplot as plt
import mode

with open('spiderhand.txt', 'r') as file:
    data = []
    for line in file:
```

```
        line_data = line.strip().split()  # 去掉换行符并按空格分割
        data.append([float(i) for i in line_data])  # 转换为浮动类型

# 创建一个三维图形
fig = plt.figure()
ax = fig.add_subplot(111, projection='3d')

# 设置图形属性
ax.set_xlabel('X')
ax.set_ylabel('Y')
ax.set_zlabel('Z')

angle_sum = 0
# 开始绘制循环
while True:
    # 清空当前坐标轴

    for para in data:
        ax.clear()
        coords = np.array(para).reshape(-1, 3)

        point_o = coords[0]
        # 定义三条路径
        line_1 = coords[1:19:3]

        line_2 = coords[2:19:3]

        line_3 = coords[3:19:3]

        line_sum = [line_1, line_2, line_3]


        for line in line_sum:
            for i in range(len(line)):
                ax.scatter(line[i][0], line[i][1], line[i][2], color='r
', s=3)  # 绘制点
            for i in range(2):
                ax.plot([line[i][0], line[i + 1][0]], [line[i][1], line
[i + 1][1]], [line[i][2], line[i + 1][2]],color='#00FFFF', linewidth=1)
  # 绘制线


            for i in range(2,len(line) - 1):
                ax.plot([line[i][0], line[i + 1][0]], [line[i][1], line
[i + 1][1]], [line[i][2], line[i + 1][2]], color='black', linewidth=1)
 # 绘制线
```

```
        # 绘制两点连接线
        for i in range(-1, 2):
            ax.plot([line_sum[i][-1][0], line_sum[i + 1][-1][0]],
                    [line_sum[i][-1][1], line_sum[i + 1][-1][1]],
                    [line_sum[i][-1][2], line_sum[i + 1][-1][2]], color
='b', linewidth=1)

        for i in range(-1, 2):
            ax.plot([line_sum[i][0][0], line_sum[i + 1][0][0]],
                    [line_sum[i][0][1], line_sum[i + 1][0][1]],
                    [line_sum[i][0][2], line_sum[i + 1][0][2]], color='
orange', linewidth=1)


        mode.plot_triangle_and_circle_3d(ax,[line_sum[0][2][0], line_su
m[0][2][1],line_sum[0][2][2]],
                [line_sum[1][2][0], line_sum[1][2][1],line_sum[1][2]
[2]],
                [line_sum[2][2][0], line_sum[2][2][1],line_sum[2][2]
[2]])


        for i in range(-1,2):
            angle_new = mode.calculate_angle(line_sum[i][2] - line_sum
[i][1], line_sum[i][3] - line_sum[i][2])
            if angle_sum:
                # 精度
                if abs(abs(angle_sum) - abs(angle_new)) > 0.0001:
                    angle_sum = angle_new
                    print(angle_sum)
            else:
                angle_sum = angle_new
                print(angle_new)

        # 绘制原点

        ax.scatter(point_o[0], point_o[1], point_o[2], color='r', s=5)

        ax.set_xlim([-20, 20])  # 设置 x 轴的范围
        ax.set_ylim([-20, 20])  # 设置 y 轴的范围
        ax.set_zlim([-5, 35])  # 设置 z 轴的范围
        # 更新图形
        plt.draw()
        ax.invert_zaxis()  # 反转Z轴方向
        plt.pause(0.01)  # 暂停0.1秒, 允许更新
```

2. 模块 mode

功能：画出给定三点的外接圆

```
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
import math
def calculate_angle(v1, v2):
    """
    计算两个三维向量 v1 和 v2 的夹角（以度为单位）
    :param v1: 第一个三维向量 (x1, y1, z1)
    :param v2: 第二个三维向量 (x2, y2, z2)
    :return: 夹角（单位：度）
    """
    # 计算点积
    dot_product = np.dot(v1, v2)

    # 计算模长
    magnitude_v1 = np.linalg.norm(v1)
    magnitude_v2 = np.linalg.norm(v2)

    # 计算夹角的余弦值
    cos_theta = dot_product / (magnitude_v1 * magnitude_v2)

    # 防止数值误差导致的溢出，限制范围
    cos_theta = np.clip(cos_theta, -1.0, 1.0)

    # 计算夹角（弧度）
    theta_rad = np.arccos(cos_theta)

    # 转换为度
    theta_deg = np.degrees(theta_rad)

    return theta_deg

def calculate_circle_3d(p1, p2, p3):
    """
    计算三维空间中通过三点的圆心、半径和法向量
    :param p1, p2, p3: 三个点的坐标 (x, y, z)
    :return: 圆心 center, 半径 radius, 法向量 normal
    """
    # 转换为 numpy 数组
    p1, p2, p3 = np.array(p1), np.array(p2), np.array(p3)

    # 向量定义
```

```
    v1 = p2 - p1
    v2 = p3 - p1

    # 法向量（平面法向量）通过叉积计算
    normal = np.cross(v1, v2)
    normal = normal / np.linalg.norm(normal)  # 单位化

    # 三角形边的中点
    mid1 = (p1 + p2) / 2
    mid2 = (p1 + p3) / 2

    # 两边中垂线的方向
    dir1 = np.cross(normal, v1)
    dir2 = np.cross(normal, v2)

    # 解方程找到中垂线的交点，即圆心
    A = np.array([dir1, -dir2, normal]).T  # 系数矩阵
    b = mid2 - mid1
    t = np.linalg.solve(A, b)
    center = mid1 + t[0] * dir1  # 圆心坐标

    # 计算半径
    radius = np.linalg.norm(center - p1)
    return center, radius, normal


def plot_triangle_and_circle_3d(ax, p1, p2, p3):
    """
    绘制给定三点构成的三角形，并画出外接圆
    :param p1, p2, p3: 三个点的坐标 (x, y, z)
    """
    # 计算圆心和半径
    center, radius, normal = calculate_circle_3d(p1, p2, p3)

    # 绘制圆
    # 生成圆的参数方程
    # 选择一个与normal 垂直的向量作为基向量u
    u = np.array([1, 0, 0]) if abs(normal[0]) < 1 else np.array([0, 1,
0])

    # 计算两个基向量 v1 和 v2，确保它们垂直于法向量并且平行于圆的平面
    v1 = np.cross(normal, u)
    v1 = v1 / np.linalg.norm(v1)  # 单位化
    v2 = np.cross(normal, v1)  # 另一垂直向量

    # 生成圆上的点
```

```
    theta = np.linspace(0, 2 * np.pi, 100)
    circle_points = np.array([
        center + radius * (np.cos(t) * v1 + np.sin(t) * v2)
        for t in theta
    ])

    # 绘制圆
    ax.plot(circle_points[:, 0], circle_points[:, 1], circle_points[:,
2], color='grey', linestyle='--', linewidth=2)

    # 绘制圆心
    ax.scatter(center[0], center[1], center[2], color='red')
```

（二）、抓娃娃机

1. 主代码块

功能：对娃娃机的运动仿真

```
import numpy as np
import matplotlib.pyplot as plt
import mode
import mode_ball
with open('claw_machine.txt', 'r') as file:
    data = []
    for line in file:
        line_data = line.strip().split()  # 去掉换行符并按空格分割
        data.append([float(i) for i in line_data])  # 转换为浮动类型

# 创建一个三维图形
fig = plt.figure()
ax = fig.add_subplot(111, projection='3d')

# 设置图形属性
ax.set_xlabel('X')
ax.set_ylabel('Y')
ax.set_zlabel('Z')

ax.set_xlim([-20, 20])  # 设置 x 轴的范围
ax.set_ylim([-20, 20])  # 设置 y 轴的范围
ax.set_zlim([-15, 30])  # 设置 z 轴的范围
# 开始绘制循环
while True:
    # 清空当前坐标轴
```

```
    for para in data:
        ax.clear()
        coords = np.array(para).reshape(-1, 3)

        ball = coords[23:]
        point_o = coords[0]
        # 定义三条路径
        line_1 = coords[1:19:3]

        line_2 = coords[2:19:3]

        line_3 = coords[3:19:3]
        target = coords[22]

        line_sum = [line_1, line_2, line_3]

        for line in line_sum:
            x = line[:,0]
            y = line[:,1]
            z = line[:,2]
            ax.scatter(x,y,z, color='r', s=3)  # 绘制点
            ax.plot(x,y,z, color='black', linewidth = 1)  # 绘制线


        # 绘制两点连接线
        for i in range(-1, 2):
            ax.plot([line_sum[i][-1][0], line_sum[i + 1][-1][0]],
                    [line_sum[i][-1][1], line_sum[i + 1][-1][1]],
                    [line_sum[i][-1][2], line_sum[i + 1][-1][2]], color
='#FF5733', linewidth=1)

        for i in range(-1, 2):
            ax.plot([line_sum[i][0][0], line_sum[i + 1][0][0]],
                    [line_sum[i][0][1], line_sum[i + 1][0][1]],
                    [line_sum[i][0][2], line_sum[i + 1][0][2]], color='
orange', linewidth=1)


        mode.plot_triangle_and_circle_3d(ax,[line_1[2][0], line_1[2][1],
line_1[2][2]],
                    [line_2[2][0], line_2[2][1],line_2[2][2]],
                    [line_3[2][0], line_3[2][1],line_3[2][2]])

        # 追踪球
        mode_ball.plot_sphere(ax,[target[0], target[1], target[2]],4 /
(3 ** 0.5))
```

```
        mode_ball.plot_xy_plane_1(ax,0,0,line_1[2][2])

        for i in ball:
            mode_ball.plot_sphere(ax, i, 4 / (3 ** 0.5))
        mode_ball.plot_xy_plane(ax,ball[0][0],ball[0][1],ball[0][2])

        # 绘制原点
        ax.scatter(point_o[0], point_o[1], point_o[2], color='r', s=5)
        ax.set_xlim([-30, 30])  # 设置 x 轴的范围
        ax.set_ylim([-30, 30])  # 设置 y 轴的范围
        ax.set_zlim([-15, 40])  # 设置 z 轴的范围
        # 更新图形
        plt.draw()
        ax.invert_zaxis()  # 反转Z轴方向
        plt.pause(0.1)  # 暂停0.1秒，允许更新
```

2. 模块 mode

功能：画出给定三点的外接圆

```
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D
import math
def calculate_angle(v1, v2):
    """
    计算两个三维向量 v1 和 v2 的夹角（以度为单位）
    :param v1: 第一个三维向量 (x1, y1, z1)
    :param v2: 第二个三维向量 (x2, y2, z2)
    :return: 夹角（单位：度）
    """
    # 计算点积
    dot_product = np.dot(v1, v2)

    # 计算模长
    magnitude_v1 = np.linalg.norm(v1)
    magnitude_v2 = np.linalg.norm(v2)

    # 计算夹角的余弦值
    cos_theta = dot_product / (magnitude_v1 * magnitude_v2)

    # 防止数值误差导致的溢出，限制范围
    cos_theta = np.clip(cos_theta, -1.0, 1.0)

    # 计算夹角（弧度）
```

```python
    theta_rad = np.arccos(cos_theta)

    # 转换为度
    theta_deg = np.degrees(theta_rad)

    return theta_deg

def calculate_circle_3d(p1, p2, p3):
    """
    计算三维空间中通过三点的圆心、半径和法向量
    :param p1, p2, p3: 三个点的坐标 (x, y, z)
    :return: 圆心 center, 半径 radius, 法向量 normal
    """
    # 转换为 numpy 数组
    p1, p2, p3 = np.array(p1), np.array(p2), np.array(p3)

    # 向量定义
    v1 = p2 - p1
    v2 = p3 - p1

    # 法向量（平面法向量）通过叉积计算
    normal = np.cross(v1, v2)
    normal = normal / np.linalg.norm(normal)  # 单位化

    # 三角形边的中点
    mid1 = (p1 + p2) / 2
    mid2 = (p1 + p3) / 2

    # 两边中垂线的方向
    dir1 = np.cross(normal, v1)
    dir2 = np.cross(normal, v2)

    # 解方程找到中垂线的交点，即圆心
    A = np.array([dir1, -dir2, normal]).T  # 系数矩阵
    b = mid2 - mid1
    t = np.linalg.solve(A, b)
    center = mid1 + t[0] * dir1  # 圆心坐标

    # 计算半径
    radius = np.linalg.norm(center - p1)
    return center, radius, normal


def plot_triangle_and_circle_3d(ax, p1, p2, p3):
    """
    绘制给定三点构成的三角形，并画出外接圆
```

```
    :param p1, p2, p3: 三个点的坐标 (x, y, z)
    """
    # 计算圆心和半径
    center, radius, normal = calculate_circle_3d(p1, p2, p3)

    # 绘制圆
    # 生成圆的参数方程
    # 选择一个与normal 垂直的向量作为基向量u
    u = np.array([1, 0, 0]) if abs(normal[0]) < 1 else np.array([0, 1,
0])

    # 计算两个基向量 v1 和 v2，确保它们垂直于法向量并且平行于圆的平面
    v1 = np.cross(normal, u)
    v1 = v1 / np.linalg.norm(v1)  # 单位化
    v2 = np.cross(normal, v1)  # 另一垂直向量

    # 生成圆上的点
    theta = np.linspace(0, 2 * np.pi, 100)
    circle_points = np.array([
        center + radius * (np.cos(t) * v1 + np.sin(t) * v2)
        for t in theta
    ])

    # 绘制圆
    ax.plot(circle_points[:, 0], circle_points[:, 1], circle_points[:,
2], color='grey', linestyle='--', linewidth=2)

    # 绘制圆心
    ax.scatter(center[0], center[1], center[2], color='red')
```

3. 模块 mode_ball

功能：绘制球的轮廓、所有球的初始平面以及抓娃娃机的平面。

```python
import numpy as np
import matplotlib.pyplot as plt
from mpl_toolkits.mplot3d import Axes3D


def plot_sphere(ax, center, radius):
    """
    在 3D 坐标系中绘制一个以给定中心和半径的球
    :param ax: 3D 坐标轴
    :param center: 球心 (x0, y0, z0)
    :param radius: 球的半径
    """
    u = np.linspace(0, 2 * np.pi, 100)  # 方位角
    v = np.linspace(0, np.pi, 100)  # 极角


    # 使用球坐标公式生成球面上的点
    x = center[0] + radius * np.outer(np.cos(u), np.sin(v))
    y = center[1] + radius * np.outer(np.sin(u), np.sin(v))
    z = center[2] + radius * np.outer(np.ones(np.size(u)), np.cos(v))


    # 绘制球面
    ax.plot_surface(x, y, z, color='b', alpha=0.3)  # 绘制透明的球面
    ax.scatter(center[0], center[1], center[2], color='r', s=3)  # 绘制
点


def plot_xy_plane(ax,x0, y0, z0):# 解包输入点的坐标


    # 创建网格数据
    x = np.linspace(-30,  + 30, 100)
    y = np.linspace(-30,  + 30, 100)
    X, Y = np.meshgrid(x, y)


    # Z 值为 z0，表示平面高度
    Z = np.full(X.shape, z0)


    # 绘制XY 平面
    ax.plot_surface(X, Y, Z, alpha=0.3, color='yellow')


def plot_xy_plane_1(ax,x0, y0, z0):# 解包输入点的坐标
```

```python
# 创建网格数据
x = np.linspace(-30,  + 30, 100)
y = np.linspace(-30,  + 30, 100)
X, Y = np.meshgrid(x, y)

# Z 值为 z0，表示平面高度
Z = np.full(X.shape, z0)

# 绘制 XY 平面
ax.plot_surface(X, Y, Z, alpha=0.3, color='green')
```