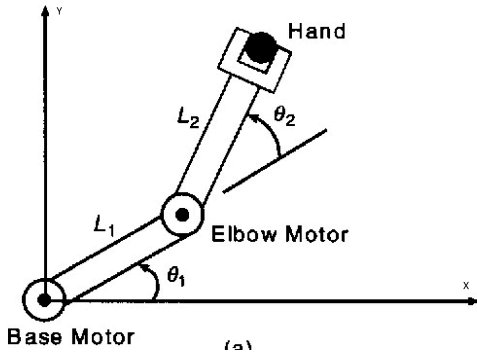


Robotic arm motion



$$x_e = L_1 \cos(\theta_1)$$

$$y_e = L_1 \sin(\theta_1)$$

$$x_h = L_1 \cos(\theta_1) + L_2 \cos(\theta_1 + \theta_2)$$

$$y_h = L_1 \sin(\theta_1) + L_2 \sin(\theta_1 + \theta_2)$$

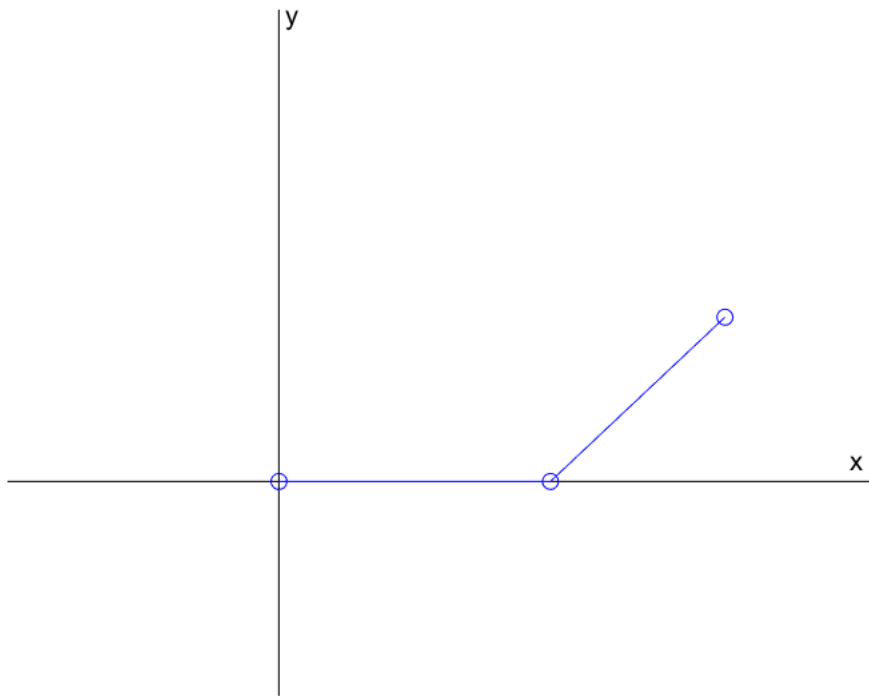
```
L1=50;  
L2=50;  
T1=-25% -30 ... 60
```

```
T1 = 0
```

```
T2=50% 0 ... 150
```

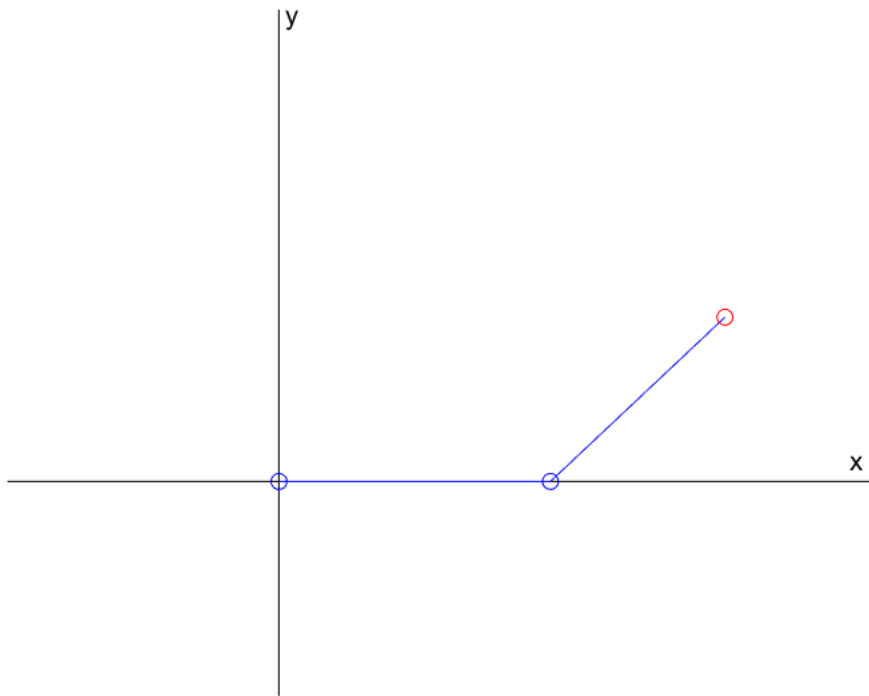
```
T2 = 50
```

```
xe=L1*cosd(T1);  
ye=L1*sind(T1);  
xh=L1*cosd(T1)+L2*cosd(T1+T2);  
yh=L1*sind(T1)+L2*sind(T1+T2);  
figure;  
set(gca,'Visible','off')  
hold on;  
plot([-50 110],[0 0],"-k")  
plot([0 0],[-50 110],"-k")  
text(105,5,"x")  
text(1,109,"y")  
plot([0 xe xh],[0 ye yh],"-b","Marker","o")  
axis([-50 110 -50 110])  
hold off
```



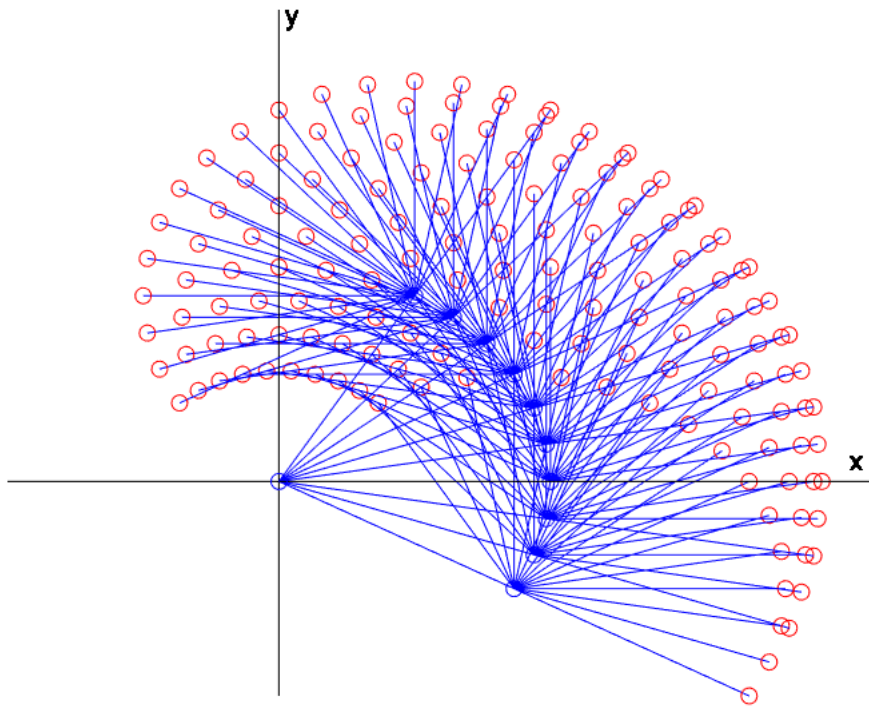
We create a function that displays the robotic arm based on information about the angles and the lengths of the two links.

```
figure;  
plotarm(T1,T2,L1,L2);
```



What is the area covered by the endpoint of the second link (hand)?

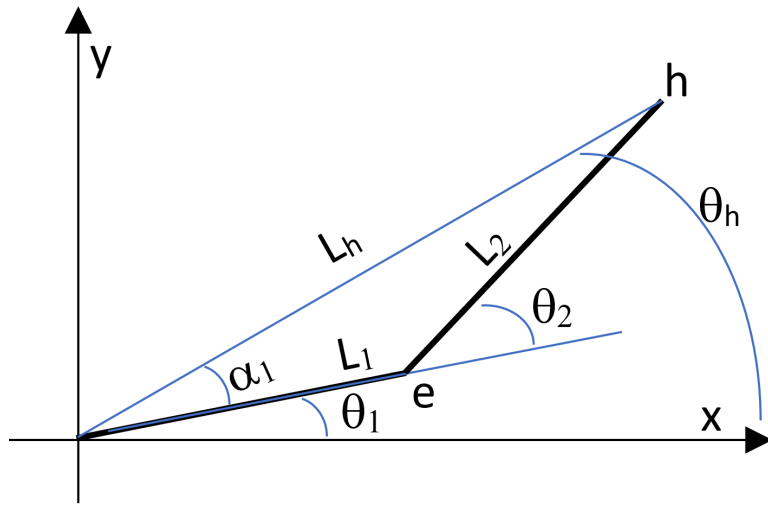
```
L1=50;
L2=50;
figure
pause on
for T1=-30:10:60
    for T2=0:10:150
        plotarm(T1,T2,L1,L2)
        pause(0.05)
    end
    pause(0.2)
end
```



Homework 1

Create a script that draws the boundary of the area covered by the hand of the robotic arm.

How can we determine the angles $T1$ and $T2$ knowing the position of the endpoint of the second link (hand)?



$$\tan(\theta_h) = \frac{y_h}{x_h},$$

$$\theta_h = \arctan\left(\frac{y_h}{x_h}\right)$$

$$L_h = \sqrt{x_h^2 + y_h^2}$$

$$\cos \alpha_1 = \frac{L_1^2 + L_h^2 - L_2^2}{2L_1L_h}$$

$$\alpha_1 = \arccosd\left(\frac{L_1^2 + L_h^2 - L_2^2}{2L_1L_h}\right)$$

$$\theta_1 = \theta_h - \alpha_1$$

$$\cos(\theta_1 + \theta_2) = \frac{x_h - x_e}{L_2}$$

$$\theta_2 = \arccosd\left(\frac{x_h - x_e}{L_2}\right) - \theta_1$$

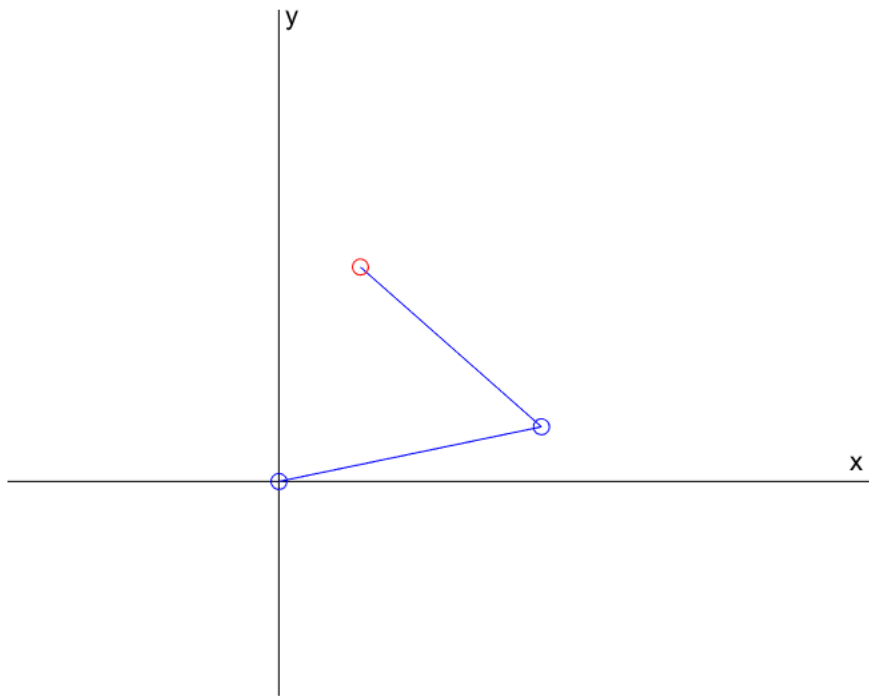
xh=15

xh = 15

yh=50

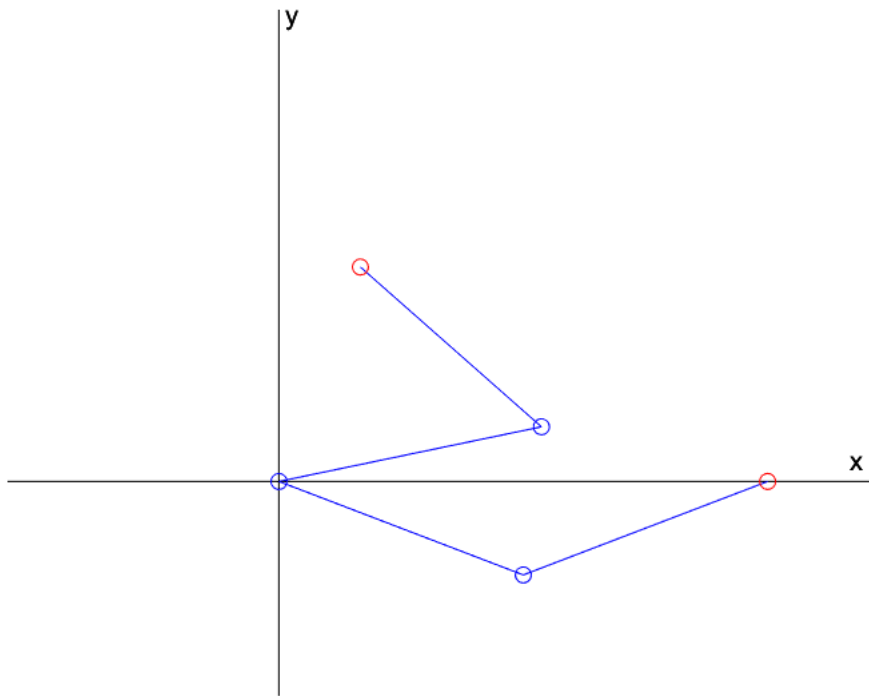
yh = 50

```
Th=atand(yh/xh);
Lh=sqrt(xh*xh+yh*yh);
A1=acosd((L1*L1+Lh*Lh-L2*L2)/2/L1/Lh);
T1=Th-A1;
xe=L1*cosd(T1);
ye=L1*sind(T1);
T2=acosd((xh-xe)/L2)-T1;
figure;
plotarm(T1,T2,L1,L2);
```



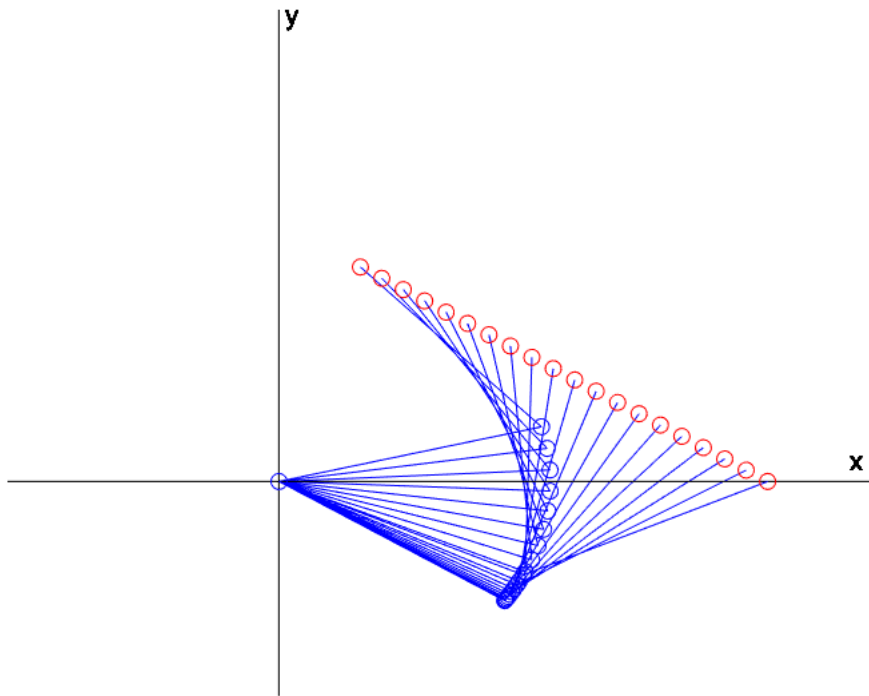
Create a script that draws the robotic arm for two different hand positions (xh0,yh0 and xh1,yh1)

```
L1=50;  
L2=50;  
figure;  
xh0=15;  
yh0=50;  
[T10,T20]=getT(xh0,yh0,L1,L2);  
plotarm(T10,T20,L1,L2);  
xh1=90;  
yh1=0;  
[T11,T21]=getT(xh1,yh1,L1,L2);  
plotarm(T11,T21,L1,L2);
```



Define a linear trajectory between the two hand positions with 20 points

```
x=linspace(xh0,xh1,20);
y=linspace(yh0,yh1,20);
figure
hold off
for i=1:length(x)
    [T1i,T2i]=getT(x(i),y(i),L1,L2);
    plotarm(T1i,T2i,L1,L2);
    pause(0.2)
end
```



Homework 2

Define a non-linear (e.g. arc) trajectory between the two hand positions