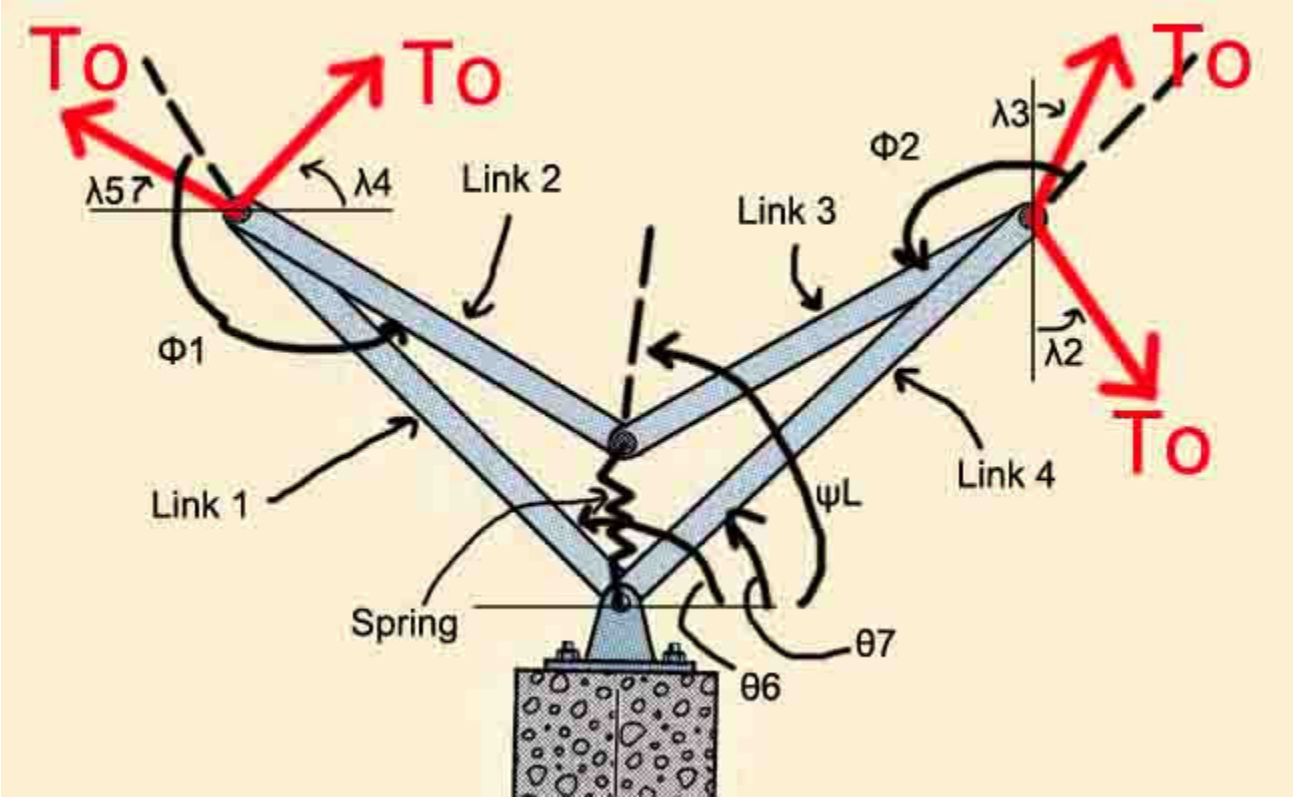


Theta6 = 100deg and Theta7 = 20deg
Link 1 is 9m long, Link 2 is 5m long, Link 3 is 7m long, Link 4 is 9m long
Lamda2 = 50deg
lamda3 = 55deg
lamda4 = 50deg
lamda5 = -20 deg

Initialization, Constants, Procedures:

```
reset()
```

```
use(plot):
Warning: 'hull' already has a value, not exported. [use]
Warning: 'Integral' seems to be proteced; not exported. [use]
Warning: 'Pyramid' seems to be proteced; not exported. [use]
```

```
iexp:=proc(theta) begin exp(I*theta) end_proc:
```

```
arr:=proc(v1,v2) begin plot::Arrow2d([Re(v1),Im(v1)],
               [Re(v2),Im(v2)],Color=mycolor,
               LineWidth=mylinewidth)
                           end_proc:
```

```
lin:=proc(v1,v2) begin plot::Line2d([Re(v1),Im(v1)],
                  [Re(v2),Im(v2)],Color=mycolor,
                   LineWidth=mylinewidth)
                           end_proc:
```

```
dtr:=float(PI/180):
```

```
L1:=9: L2:=5: L3:=7: L4:=9:
```

```
lambda2 := 50*dtr:
lambda3 := 55*dtr:
lambda4 := 50*dtr:
lambda5 := -20*dtr:
theta6:=100*dtr:
theta7:=20*dtr:
```

```
T0:=3 // Value selected for plotting convenience (all vectors scale)
```

$$3$$

Solve to find angles Phi1 and Phi2:

```
EqPhi:=L1*iexp(theta6)+L2*iexp(theta6+phi1)=
    L4*iexp(theta7)+L3*iexp(theta7+phi2)
```

$$5\,e^{phi1\,i+1.745329252\,i} - 1.562833599 + 8.863269777\,i = 7\,e^{phi2\,i+0.3490658504\,i} + 8.457233587 + 3.07818129\,i$$

```
assume (phi1 in R_)
```

```
assume(phi2 in R_)
```

```
EqPhi1:=Re(lhs(EqPhi))=Re(rhs(EqPhi))
```

$$5.0\cos(phi1 + 1.745329252) - 1.562833599 = 7.0\cos(phi2 + 0.3490658504) + 8.457233587$$

```
EqPhi2:=Im(lhs(EqPhi))=Im(rhs(EqPhi))
```

$$5.0\sin(phi1 + 1.745329252) + 8.863269777 = 7.0\sin(phi2 + 0.3490658504) + 3.07818129$$

```
PhiSoln:=numeric::solve({EqPhi1,EqPhi2},[phi1=2,phi2=2])
```

$$\{[phi1 = 3.695379566,\ phi2 = 2.494772348]\}$$

```
phi1:=phi1|PhiSoln
```

$$3.695379566$$

```
phi2:=phi2|PhiSoln
```

$$2.494772348$$

```
phi1/dtr
```

$$211.7296528$$

```
phi2/dtr
```

$$142.9399264$$

Solve to find tension T1 and T2 to balance forces applied at end of bar 1

```
Eq1:=T0*iexp(PI-lambda5)+T0*iexp(lambda4)+T1*iexp(theta6-PI)
  +T2*iexp(theta6+phi1)=0
```

$$T1\,(0.1736481777 - 0.984807753\,i) + T2\,(0.66561668 - 0.7462937996\,i) - 0.8907150333 + 1.272072899\,i$$

```
Eq1r:=Re(lhs(Eq1))=0
```

$$\Re(T1\ (0.1736481777 - 0.984807753\ i)) + \Re(T2\ (0.66561668 - 0.7462937996\ i)) - 0.8907150333 = 0$$

Eq1i:=Im(lhs(Eq1))=0

$$0.1736481777\ \Im(T1) + 0.66561668\ \Im(T2) - 0.984807753\ \Re(T1) - 0.7462937996\ \Re(T2) + 1.272072899 = 0$$

T12soln:=solve({Eq1r,Eq1i},{T1,T2})

$$\{[T1 = 0.3460234127,\ T2 = 1.247908478]\}$$

T1:=T1|T12soln

$$0.3460234127$$

T2:=T2|T12soln

$$1.247908478$$

Solve to find tension T3 and T4 to balance forces applied at end of bar 4

Eq4:=T0*iexp(PI/2-lambda3)+T0*iexp(-PI/2+lambda2)
+T4*iexp(theta7-PI)+T3*iexp(theta7+phi2)=0

$$T3\ (-0.9559976837 + 0.2933742127\ i) + T4\ (-0.9396926208 - 0.3420201433\ i) + \frac{3}{e^{\frac{\pi\ i}{2} - 0.872664626\ i}} + 3\ e^{\frac{\pi}{2}}$$

Eq4r:=Re(lhs(Eq4))=0

$$\Re(T4\ (-0.9396926208 - 0.3420201433\ i)) + \Re(T3\ (-0.9559976837 + 0.2933742127\ i)) + 3.0\cos\left(0.8726\right.$$

Eq4i:=Im(lhs(Eq4))=0

$$3.0\sin\left(\frac{\pi}{2} - 0.9599310886\right) - 0.9559976837\ \Im(T3) - 0.9396926208\ \Im(T4) + 0.2933742127\ \Re(T3) - 0.342$$

T34soln:=solve({Eq4r,Eq4i},{T3,T4})

$$\{[T3 = 3.022671346,\ T4 = 1.985673416]\}$$

T3:=T3|T34soln

$$3.022671346$$

T4:=T4|T34soln

$$1.985673416$$

Solve to find Spring force vector for info

EqS:=T2*iexp(theta6+phi1-PI)+T3*iexp(theta7+phi2-PI)+Ts*iexp(thetaS-PI)=0

$$2.059038107 - Ts\ e^{thetaS\ i} + 0.04453253328\ i = 0$$

EqSr:=Re(lhs(EqS))=0

$$2.059038107 - \Re(Ts\ e^{thetaS\ i}) = 0$$

EqSi:=Im(lhs(EqS))=0

$$0.04453253328 - \Im(Ts\ e^{thetaS\ i}) = 0$$

```
Tssoln:=solve({EqSr,EqSi},{Ts,thetaS})
```

{[Ts = 2.059519622, thetaS = 0.02162446218]}

First generate the bars: B1 thru B4

```
mylinewidth:=2:
mycolor:=RGB::Blue:

B1:=lin(0,L1*iexp(theta6)):
B4:=lin(0,L4*iexp(theta7)):
B2:=lin(L1*iexp(theta6),L1*iexp(theta6)+L2*iexp(theta6+phi1)):
B3:=lin(L4*iexp(theta7),L4*iexp(theta7)+L3*iexp(theta7+phi2)):
```

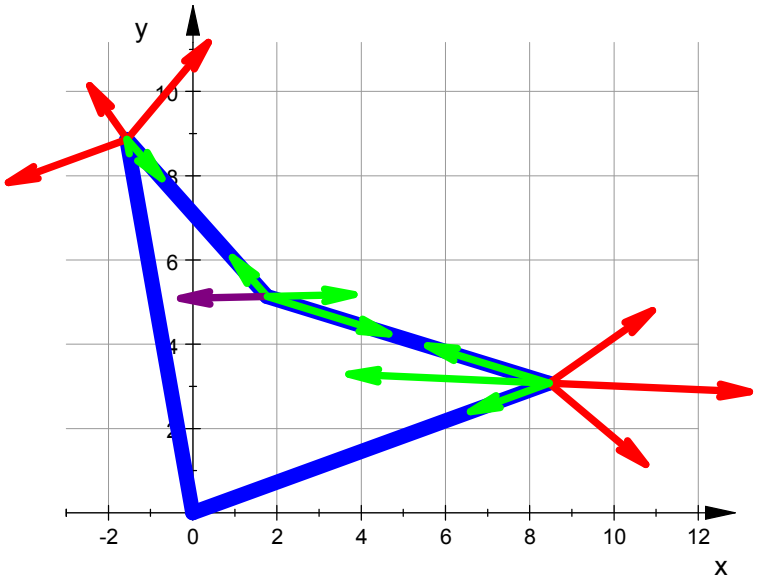
Now generate the applied forces of magnitude T0

```
mylinewidth:=1:
mycolor:=RGB::Red:
AT04:=arr(L1*iexp(theta6),L1*iexp(theta6)+T0*iexp(lambda4)):

AT05:=arr(L1*iexp(theta6),L1*iexp(theta6)+T0*iexp(PI-lambda5)):
AT0405:=arr(L1*iexp(theta6),L1*iexp(theta6)+T0*iexp(PI-lambda5)
  +T0*iexp(lambda4)):
AT02:=arr(L4*iexp(theta7),L1*iexp(theta7)+T0*iexp(-PI/2+lambda2)):
AT03:=arr(L4*iexp(theta7),L1*iexp(theta7)+T0*iexp(PI/2-lambda3)):
AT0304:=arr(L4*iexp(theta7),L1*iexp(theta7)
   +T0*iexp(PI/2-lambda3)+T0*iexp(-PI/2+lambda2)):

```

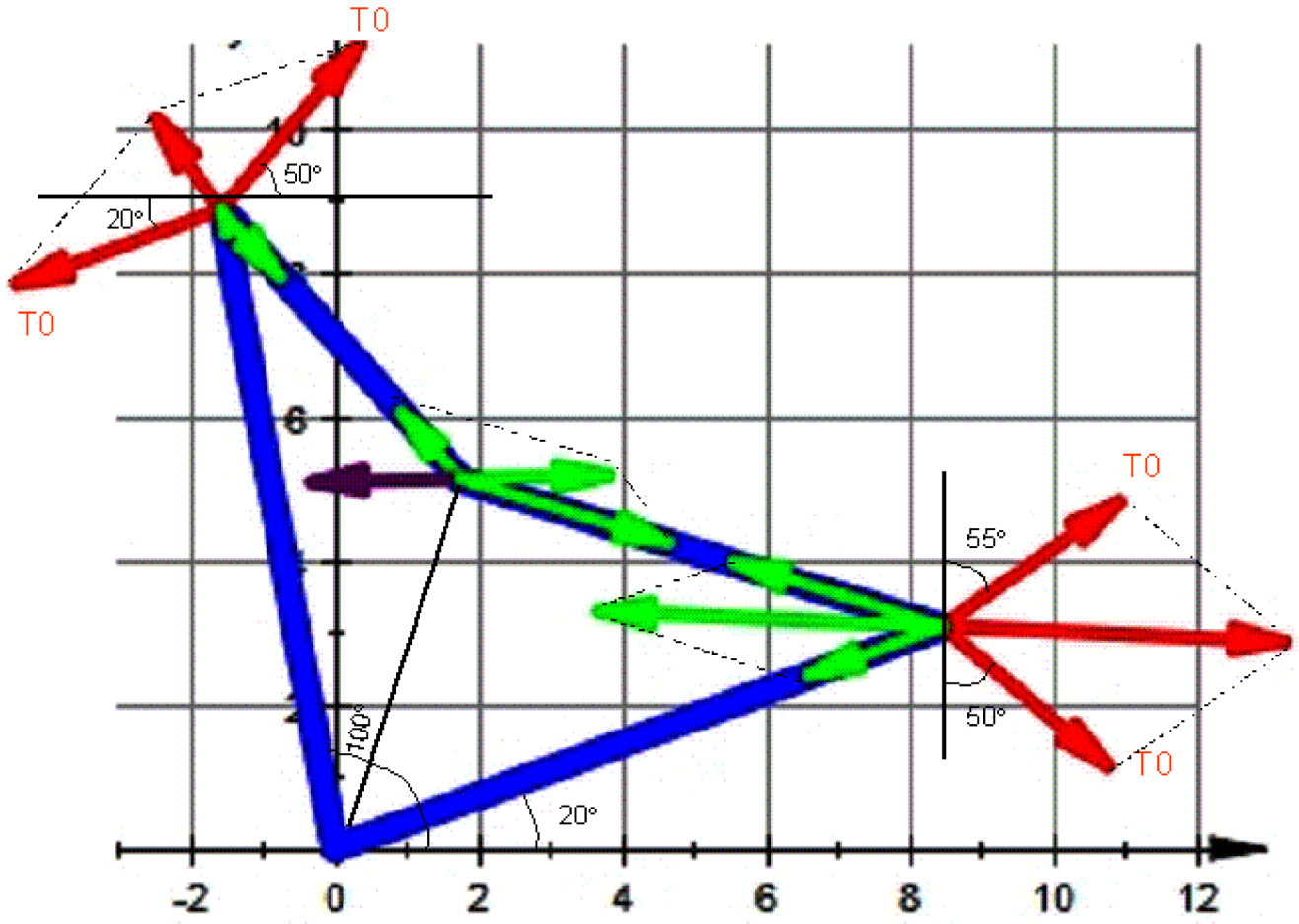
Now generate the vectors for tension in the bars

```
mycolor:=RGB::Green:

AT1:=lin(L1*iexp(theta6),L1*iexp(theta6)+T1*iexp(theta6-PI)):
AT2:=arr(L1*iexp(theta6),L1*iexp(theta6)+T2*iexp(theta6+phi1)):
AT3:=arr(L4*iexp(theta7),L4*iexp(theta7)+T3*iexp(theta7+phi2)):
AT4:=arr(L4*iexp(theta7),L4*iexp(theta7)+T4*iexp(theta7-PI)):
AT2A:=arr(L1*iexp(theta6)+L2*iexp(theta6+phi1),
L1*iexp(theta6)+L2*iexp(theta6+phi1)+T2*iexp(theta6+phi1-PI)):

AT3A:=arr(L4*iexp(theta7)+L3*iexp(theta7+phi2),
L4*iexp(theta7)+L3*iexp(theta7+phi2)+T3*iexp(theta7+phi2-PI)):
AT34:=arr(L4*iexp(theta7),L4*iexp(theta7)
   +T3*iexp(theta7+phi2)+T4*iexp(theta7-PI)):
ATS:=arr(L1*iexp(theta6)+L2*iexp(theta6+phi1),
 L1*iexp(theta6)+L2*iexp(theta6+phi1)-T2*iexp(theta6+phi1-PI)
  -T3*iexp(theta7+phi2-PI)):
ATSOpp:=arr(L1*iexp(theta6)+L2*iexp(theta6+phi1),
 L1*iexp(theta6)+L2*iexp(theta6+phi1)+T2*iexp(theta6+phi1-PI)
```

```
   +T3*iexp(theta7+phi2-PI)):
mycolor:=RGB::Violet:
ATS:=arr(L1*iexp(theta6)+L2*iexp(theta6+phi1),
 L1*iexp(theta6)+L2*iexp(theta6+phi1)-T2*iexp(theta6+phi1-PI)
   -T3*iexp(theta7+phi2-PI)):
plot([B1,B2,B3,B4,AT02,AT03,AT04,AT05,AT0304,AT0405,
AT1,AT2,AT3,AT4,AT34, AT2A,AT3A,ATS,ATSOpp],
Scaling=Constrained,ViewingBoxXRange =-3..12,
                        XGridVisible,YGridVisible)
```



Above result was transferred to powerpoint to add annotations,
and then cut/pasted below:


T0
50°
20°
T0
6
T0
55°
50°
T0
100°
20°
-2
0
2
4
6
8
10
12