Tarea 4: Profesor Laboret

Para la tarea se elige la primer fila de la tabla de los valores de masa, longitud, coeficiente de rozamiento y ángulo de referencia en grados del sistema péndulo simple.

```
clear all; close all; clc
```

Se comienza definiendo los parámetros a utilizar.

```
m = 3
```

```
m = 3
```

```
b = 0.1
```

```
b = 0.1000
```

```
delta = 135
```

```
delta = 135
```

```
l = 1;
G = 10;
```

Se obtiene el modelo en espacio de estado para el sistema del péndulo linealizado a partir del modelo de Simulink.

```
[A,B,C,D] = linmod('pendulo_mod_tarea',delta*pi/180)
```

```
Warning: Extra states are being set to zero.
A = 2×2
         0    1.0000
    7.0711   -0.0333
B = 2×1
         0
    0.3333
C = 1×2
     1     0
D = 0
```

Los autovalores de la matriz A, que son los polos del sistema, son:

```
eig(A)
```

```
ans = 2×1
    2.6425
   -2.6759
```

El rango de la matriz de controlabilidad es el siguiente:

```
rank(ctrb(A,B))
```

```
ans = 2
```

Se amplían las matrices, de modo de obtener la acción integral del controlador.

```
Aa = [[A;C] zeros(3,1)]
```

```
Aa = 3×3
         0    1.0000         0
    7.0711   -0.0333         0
    1.0000         0         0
```

```
Ba = [B;0]
```

```
Ba = 3×1
         0
    0.3333
         0
```

```
eig(Aa)
```

```
ans = 3×1
         0
   -2.6759
    2.6425
```

```
rank(ctrb(Aa,Ba))
```

```
ans = 3
```

Polo triple en -4.

```
p = -4
```

```
p = -4
```

```
K = acker(Aa,Ba,[p p p])
```

```
K = 1×3
  165.2132   35.9000  192.0000
```

```
k1 = K(1)
```

```
k1 = 165.2132
```

```
k2 = K(2)
```

```
k2 = 35.9000
```

```
k3 = K(3)
```

```
k3 = 192
```

```
eig(Aa-Ba*K)
```

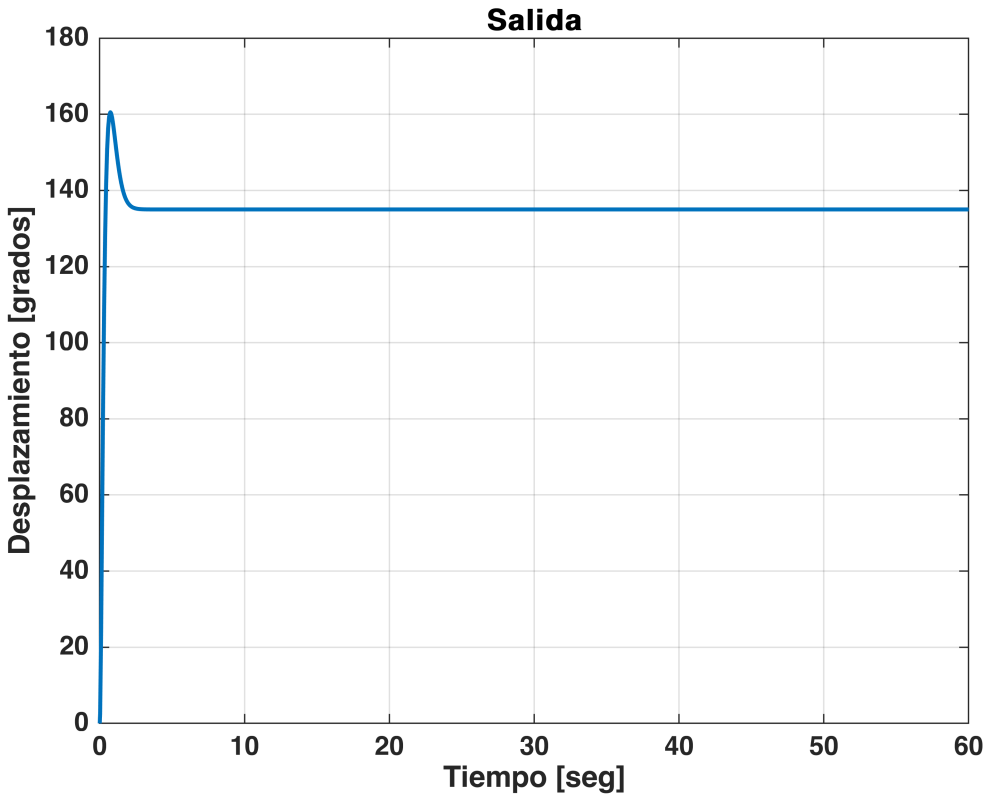
```
ans = 3×1 complex
  -4.0000 + 0.0000i
  -4.0000 + 0.0000i
  -4.0000 - 0.0000i
```

```
tscalc = 7.5/(-p)
```

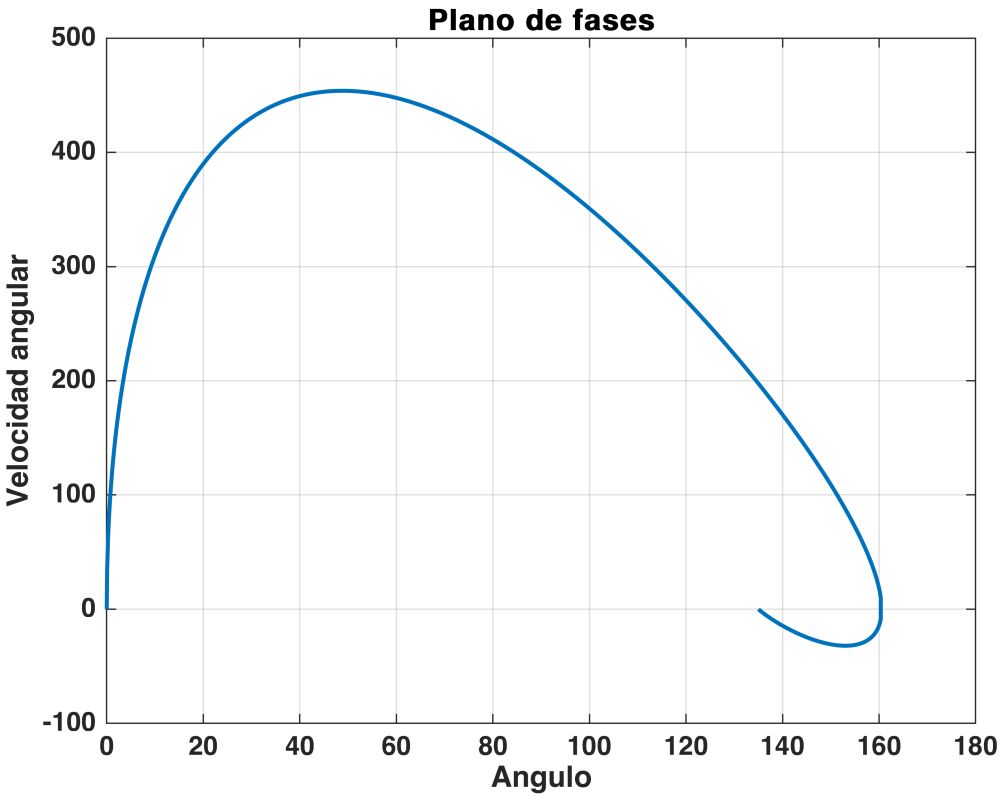
```
tscalc = 1.8750
```

```
sim('pendulo_pid_tarea')
ym1 = yout;
```

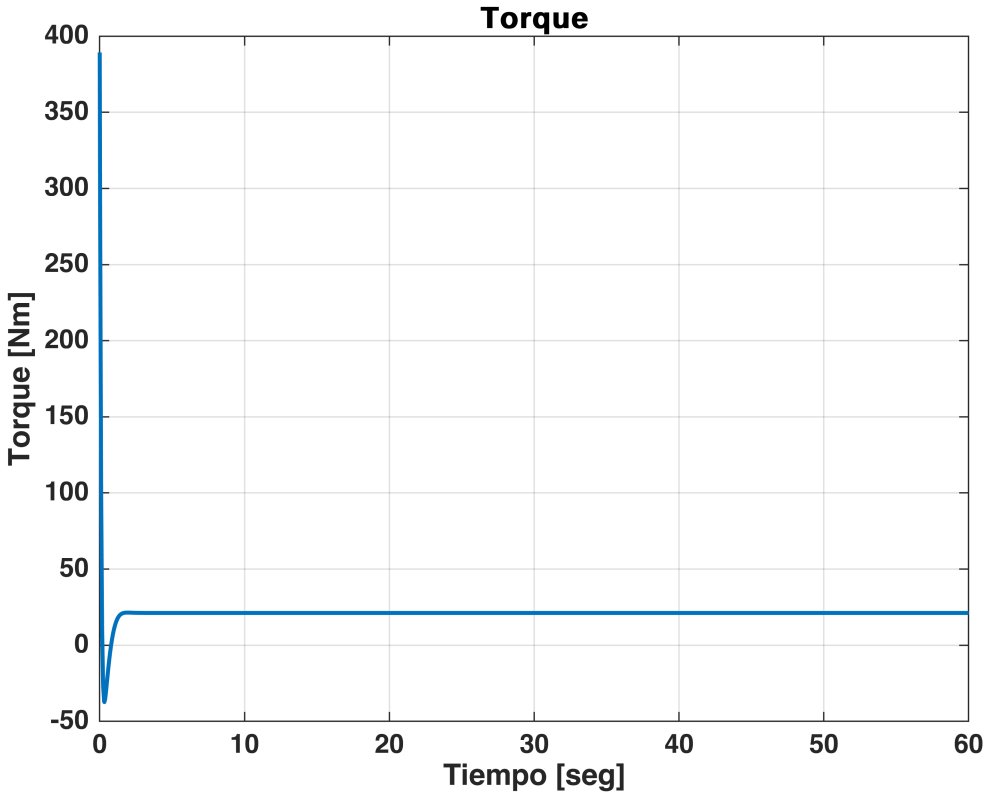
```
vel1 = velocidad;
tor1 = torque;
int1 = accint;
plot(tout,yout, 'LineWidth',1.5)
grid on
title('Salida')
xlabel('Tiempo [seg]');
ylabel('Desplazamiento [grados]')
```



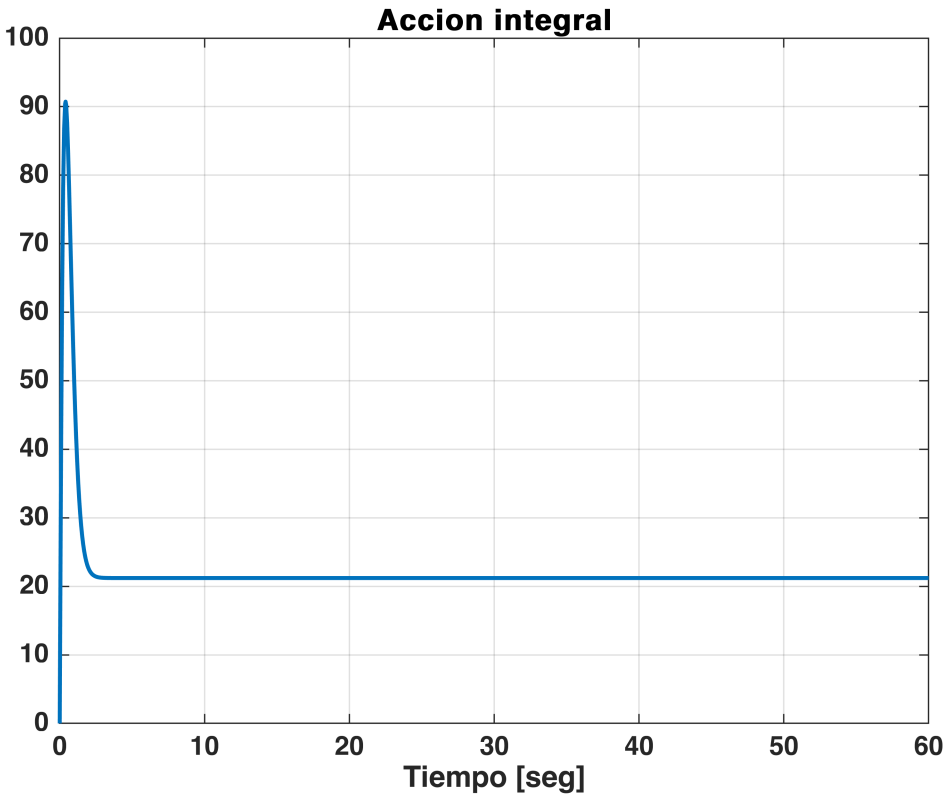

```
plot(yout,velocidad, 'LineWidth',1.5)
grid
title('Plano de fases');
xlabel('Angulo');
ylabel('Velocidad angular')
```




```
plot(tout,torque, 'LineWidth',1.5)
grid on,
title('Torque');
xlabel('Tiempo [seg]');
ylabel('Torque [Nm]')
```




```
plot(tout,-accint, 'LineWidth',1.5)
grid
title('Accion integral');
xlabel('Tiempo [seg]');
```




```
ymax = max(yout)
```

```
ymax = 160.5228
```

```
S = (ymax-delta)/delta*100
```

```
S = 18.9058
```

```
erel = (delta-yout)/delta;
efinal = erel(end)
```

```
efinal = 2.8843e-14
```

```
ind = find(abs(erel)>.02);
tss = tout(ind(end))
```

```
tss = 1.8043
```

```
yte = yout(ind(end))
```

```
yte = 137.7007
```

```
uf = torque(end)
```

```
uf = 21.2132
```

```
Intf = -accint(end)
```

```
Intf = 21.2132
```

Para probar la robustez del controlador, se simulará con variaciones de 10% en el valor de masa.

```
m = 3*1.1
```

```
m = 3.3000
```

```
b = 0.1
```

```
b = 0.1000
```

```
delta = 135
```

```
delta = 135
```

```
l = 1;
G = 10;
[A,B,C,D] = linmod('pendulo_mod_tarea',delta*pi/180)
```

```
Warning: Extra states are being set to zero.
A = 2×2
         0    1.0000
    7.0711   -0.0303
B = 2×1
         0
    0.3030
C = 1×2
     1     0
D = 0
```

```
eig(A)
```

```
ans = 2×1
    2.6440
   -2.6743
```

```
rank(ctrb(A,B))
```

```
ans = 2
```

```
Aa = [[A;C] zeros(3,1)]
```

```
Aa = 3×3
         0    1.0000         0
    7.0711   -0.0303         0
    1.0000         0         0
```

```
Ba = [B;0]
```

```
Ba = 3×1
         0
    0.3030
         0
```

```
eig(Aa)
```

```
ans = 3×1
         0
   -2.6743
    2.6440
```

```
rank(ctrb(Aa,Ba))
```

```
ans = 3
```

```
p = -4
```

```
p = -4
```

```
K = acker(Aa,Ba,[p p p])
```

```
K = 1×3
  181.7345   39.5000  211.2000
```

```
k1 = K(1)
```

```
k1 = 181.7345
```

```
k2 = K(2)
```

```
k2 = 39.5000
```

```
k3 = K(3)
```

```
k3 = 211.2000
```

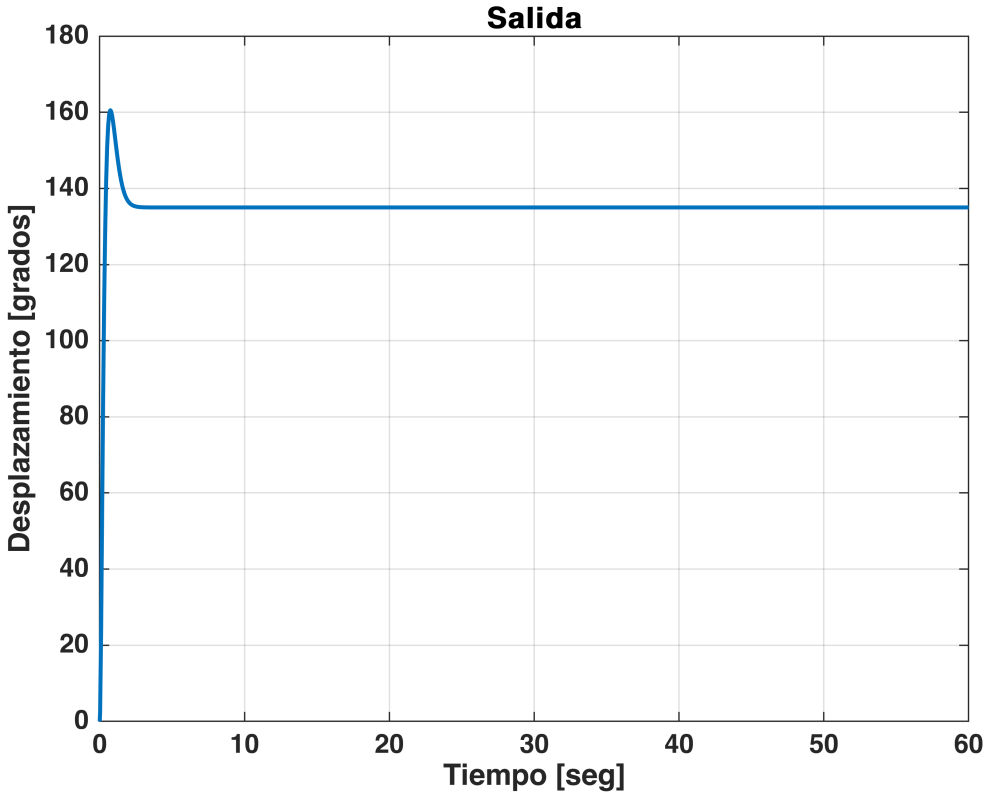
```
eig(Aa-Ba*K)
```

```
ans = 3×1 complex
  -4.0000 + 0.0000i
  -4.0000 - 0.0000i
  -3.9999 + 0.0000i
```

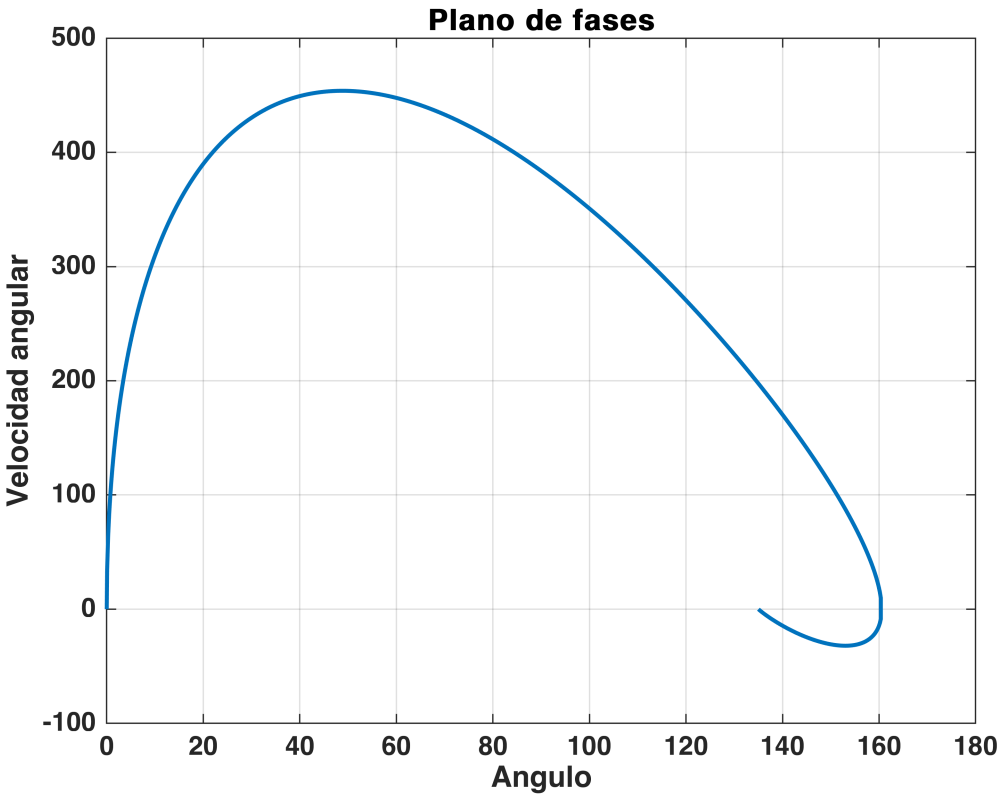
```
tscalc = 7.5/(-p)
```

```
tscalc = 1.8750
```

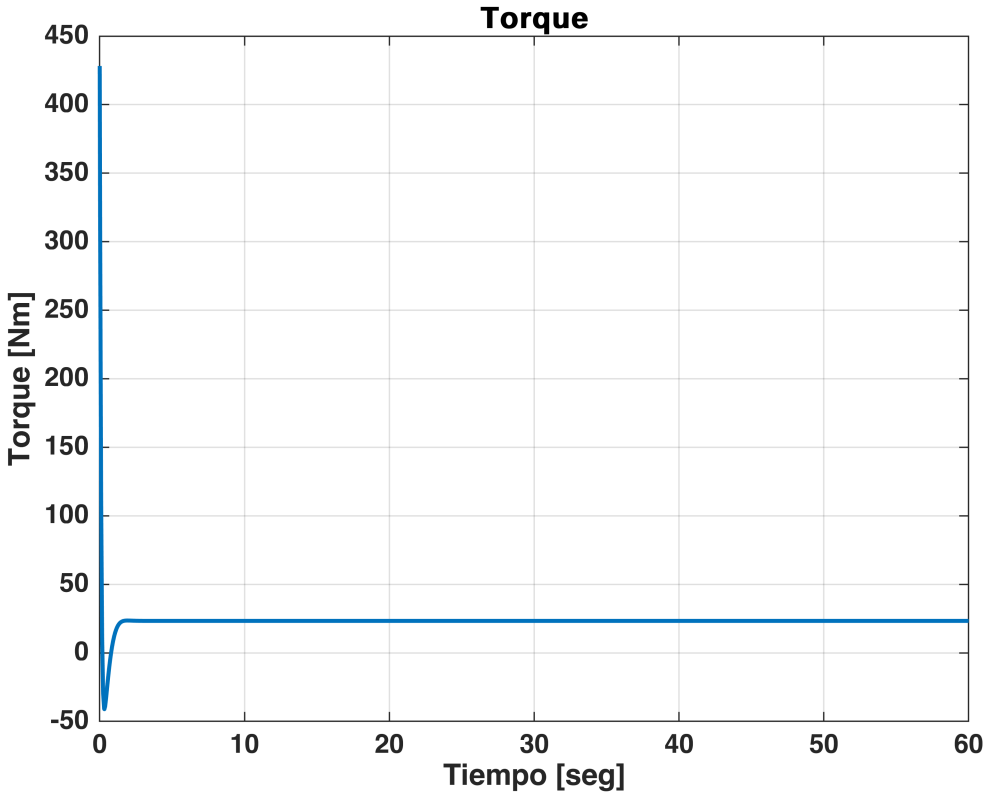
```
sim('pendulo_pid_tarea')
ym2 = yout;
vel2 = velocidad;
tor2 = torque;
int2 = accint;
plot(tout,yout, 'LineWidth',1.5)
grid on
title('Salida')
xlabel('Tiempo [seg]');
ylabel('Desplazamiento [grados]')
```




```
plot(yout,velocidad, 'LineWidth',1.5)
grid
title('Plano de fases');
xlabel('Angulo');
ylabel('Velocidad angular')
```




```
plot(tout,torque, 'LineWidth',1.5)
grid on,
title('Torque');
xlabel('Tiempo [seg]');
ylabel('Torque [Nm]')
```




```
plot(tout,-accint, 'LineWidth',1.5)
grid
title('Accion integral');
xlabel('Tiempo [seg]');
ymax = max(yout)
```

```
ymax = 160.5228
```

```
S = (ymax-delta)/delta*100
```

```
S = 18.9058
```

```
erel = (delta-yout)/delta;
efinal = erel(end)
```

```
efinal = 2.9474e-14
```

```
ind = find(abs(erel)>.02);
tss = tout(ind(end))
```

```
tss = 1.8043
```

```
yte = yout(ind(end))
```

```
yte = 137.7007
```

```
uf = torque(end)
```

```
uf = 23.3345
```

```
Intf = -accint(end)
```

```
Intf = 23.3345
```

```
m = 3*0.9
```

```
m = 2.7000
```

```
b = 0.1
```

```
b = 0.1000
```

```
delta = 135
```

```
delta = 135
```

```
l = 1;
G = 10;
[A,B,C,D] = linmod('pendulo_mod_tarea',delta*pi/180)
```

```
Warning: Extra states are being set to zero.
A = 2×2
         0    1.0000
    7.0711   -0.0370
B = 2×1
         0
    0.3704
C = 1×2
     1     0
D = 0
```

```
eig(A)
```

```
ans = 2×1
    2.6407
   -2.6777
```

```
rank(ctrb(A,B))
```

```
ans = 2
```

```
Aa = [[A;C] zeros(3,1)]
```

```
Aa = 3×3
         0    1.0000         0
    7.0711   -0.0370         0
    1.0000         0         0
```

```
Ba = [B;0]
```

```
Ba = 3×1
         0
    0.3704
         0
```

```
eig(Aa)
```

```
ans = 3×1
         0
   -2.6777
    2.6407
```

```
rank(ctrb(Aa,Ba))
```

```
ans = 3
```

```
p = -4
```

```
p = -4
```

```
K = acker(Aa,Ba,[p p p])
```

```
K = 1×3
  148.6919   32.3000  172.8000
```

```
k1 = K(1)
```

```
k1 = 148.6919
```

```
k2 = K(2)
```

```
k2 = 32.3000
```

```
k3 = K(3)
```

```
k3 = 172.8000
```

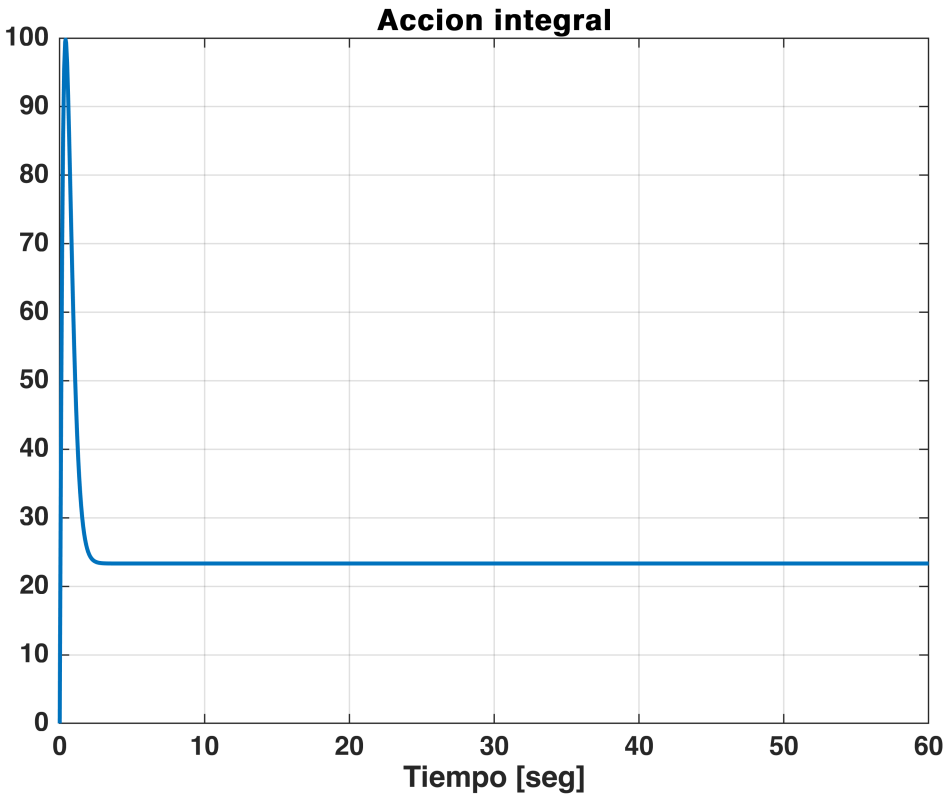
```
eig(Aa-Ba*K)
```

```
ans = 3×1 complex
  -4.0000 + 0.0000i
  -4.0000 + 0.0000i
  -4.0000 - 0.0000i
```

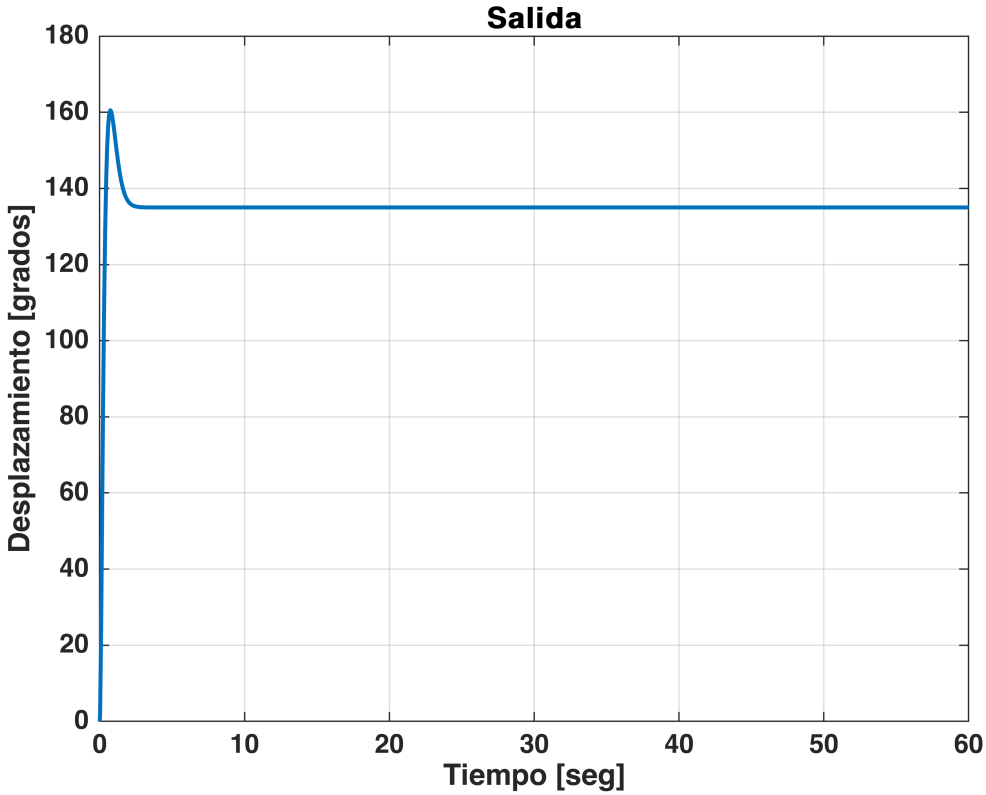
```
tscalc = 7.5/(-p)
```

```
tscalc = 1.8750
```

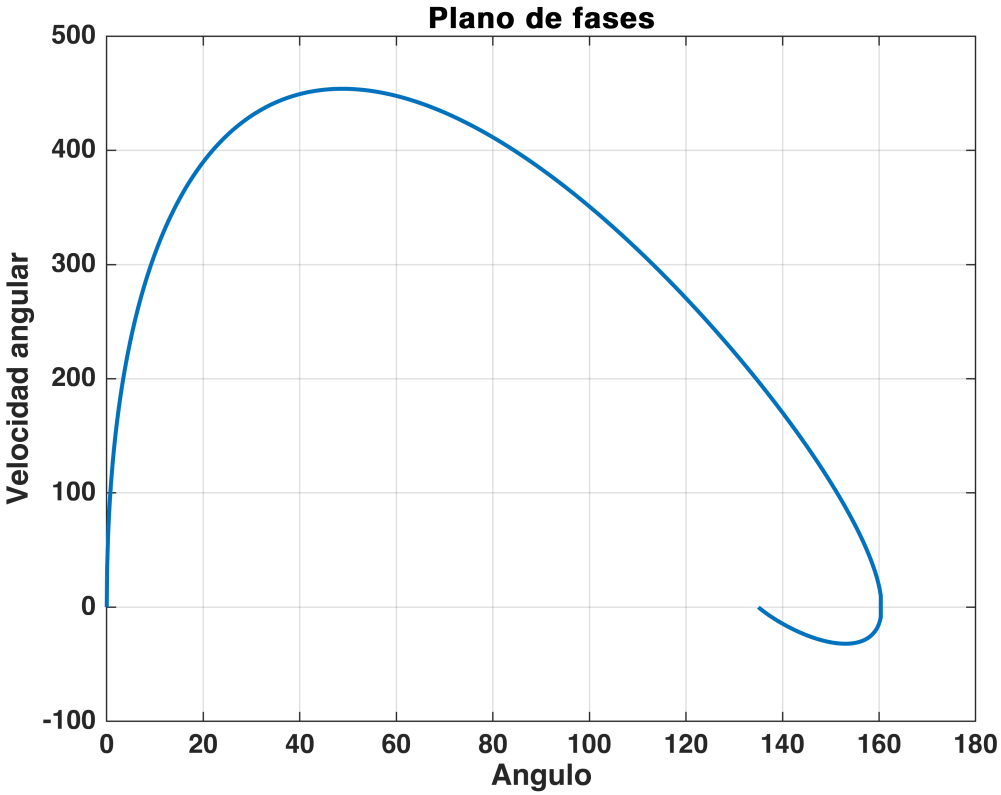
```
sim('pendulo_pid_tarea')
```



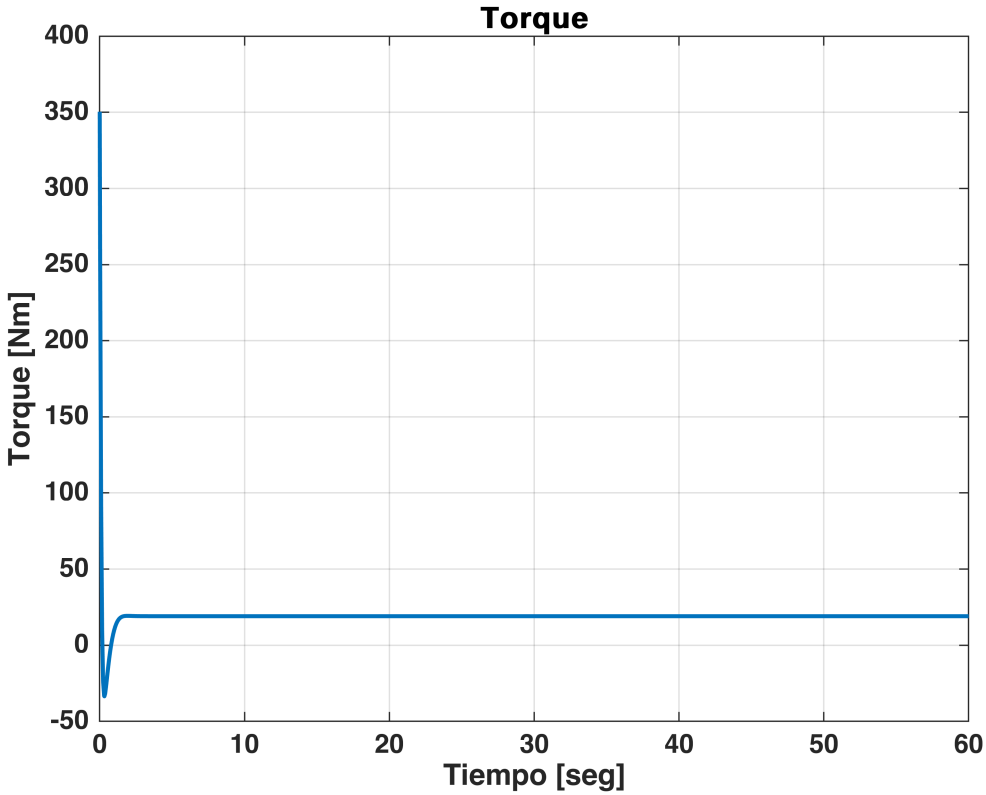

```
ym3 = yout;
vel3 = velocidad;
tor3 = torque;
int3 = accint;
plot(tout,yout, 'LineWidth',1.5)
grid on
title('Salida')
xlabel('Tiempo [seg]');
ylabel('Desplazamiento [grados]')
```



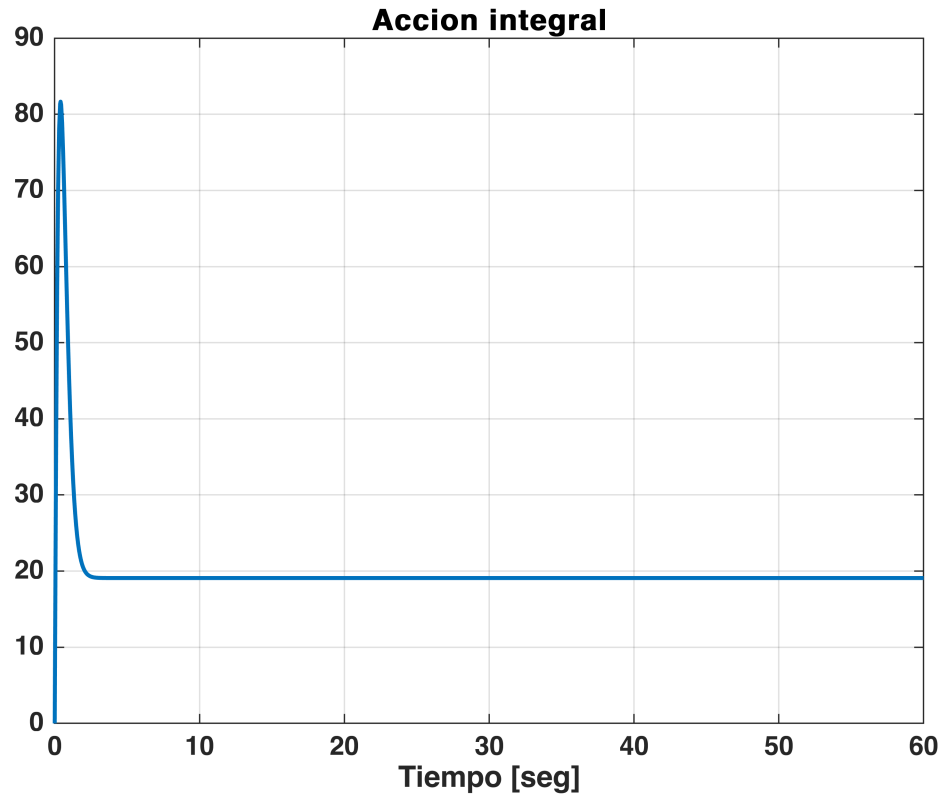

```
plot(yout,velocidad, 'LineWidth',1.5)
grid
title('Plano de fases');
xlabel('Angulo');
ylabel('Velocidad angular')
```




```
plot(tout,torque, 'LineWidth',1.5)
grid on,
title('Torque');
xlabel('Tiempo [seg]');
ylabel('Torque [Nm]')
```




```
plot(tout,-accint, 'LineWidth',1.5)
grid
title('Accion integral');
xlabel('Tiempo [seg]');
```




```
ymax = max(yout)
```

```
ymax = 160.5228
```

```
S = (ymax-delta)/delta*100
```

```
S = 18.9058
```

```
erel = (delta-yout)/delta;
efinal = erel(end)
```

```
efinal = 2.9053e-14
```

```
ind = find(abs(erel)>.02);
tss = tout(ind(end))
```

```
tss = 1.8043
```

```
yte = yout(ind(end))
```

```
yte = 137.7007
```

```
uf = torque(end)
```

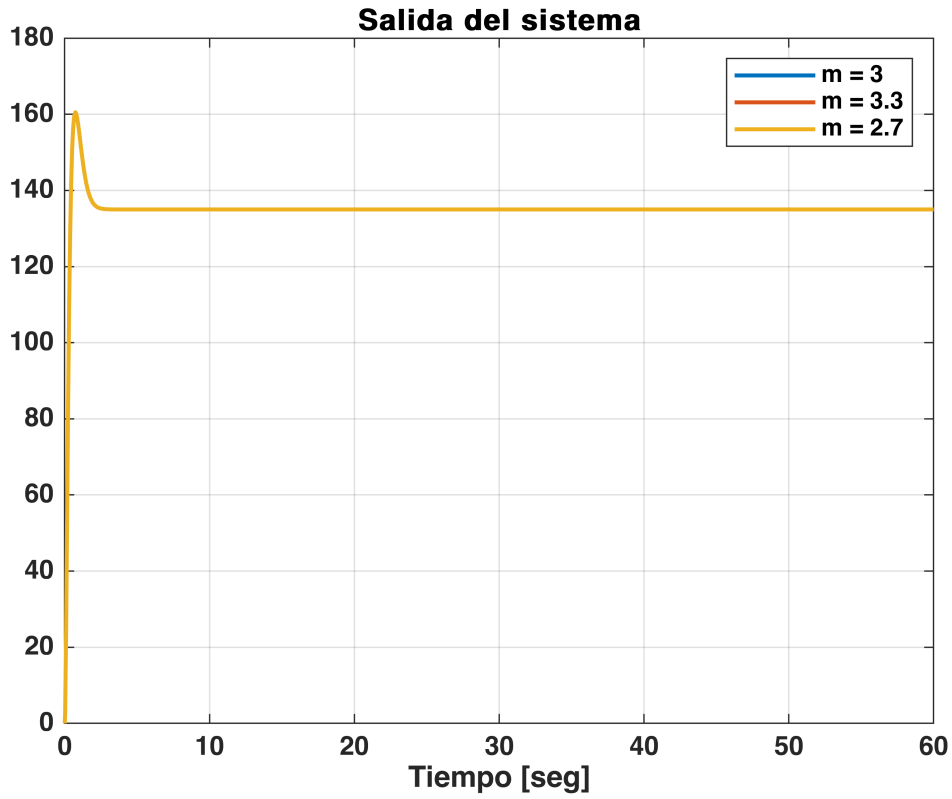
```
uf = 19.0919
```

```
Intf = -accint(end)
```

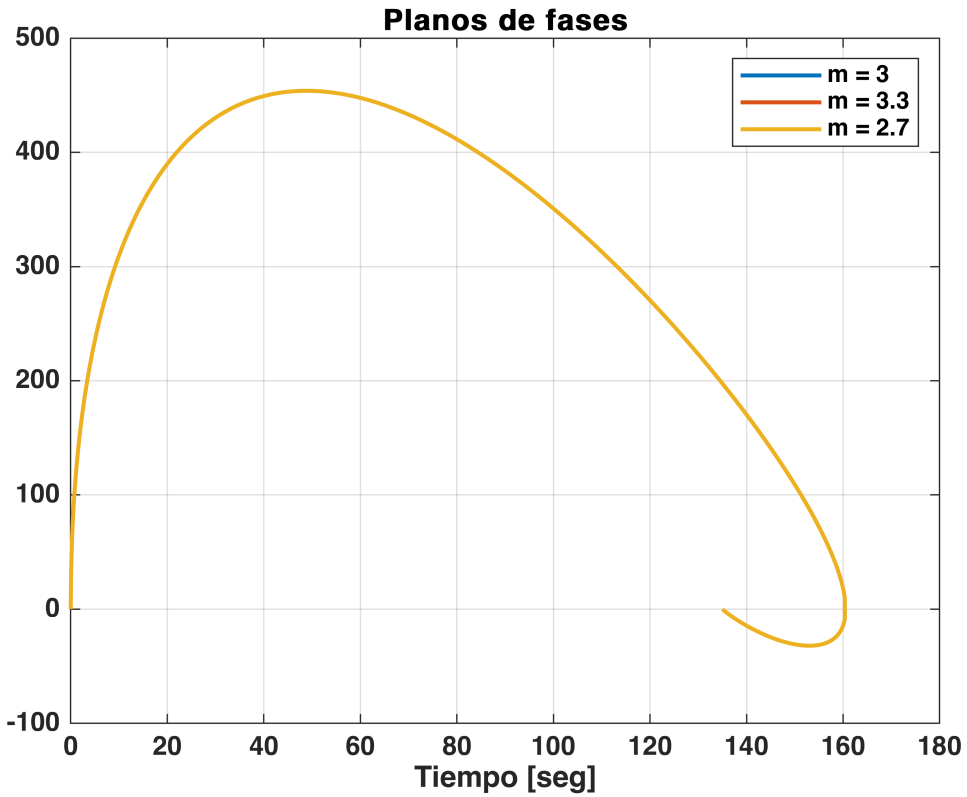
```
Intf = 19.0919
```

Se comparan las señales obtenidas:

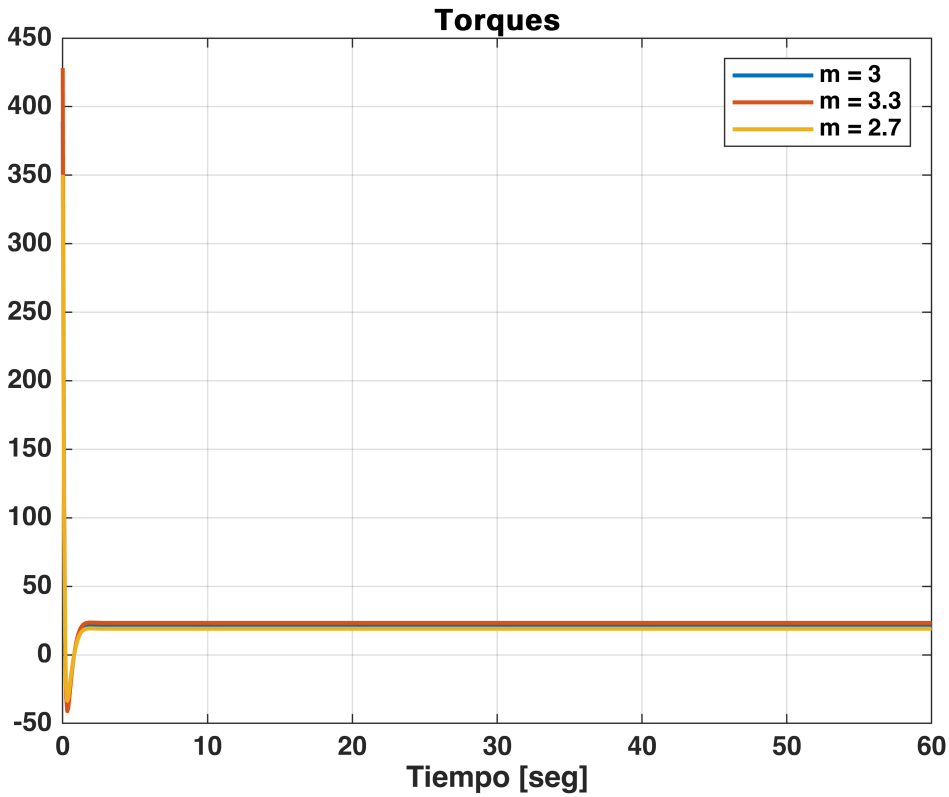
```
plot(tout,ym1,"LineWidth",1.5)
hold on;
plot(tout,ym2,"LineWidth",1.5)
plot(tout,ym3,"LineWidth",1.5)
grid;
hold off;
title('Salida del sistema')
xlabel('Tiempo [seg]')
legend('m = 3','m = 3.3','m = 2.7')
```



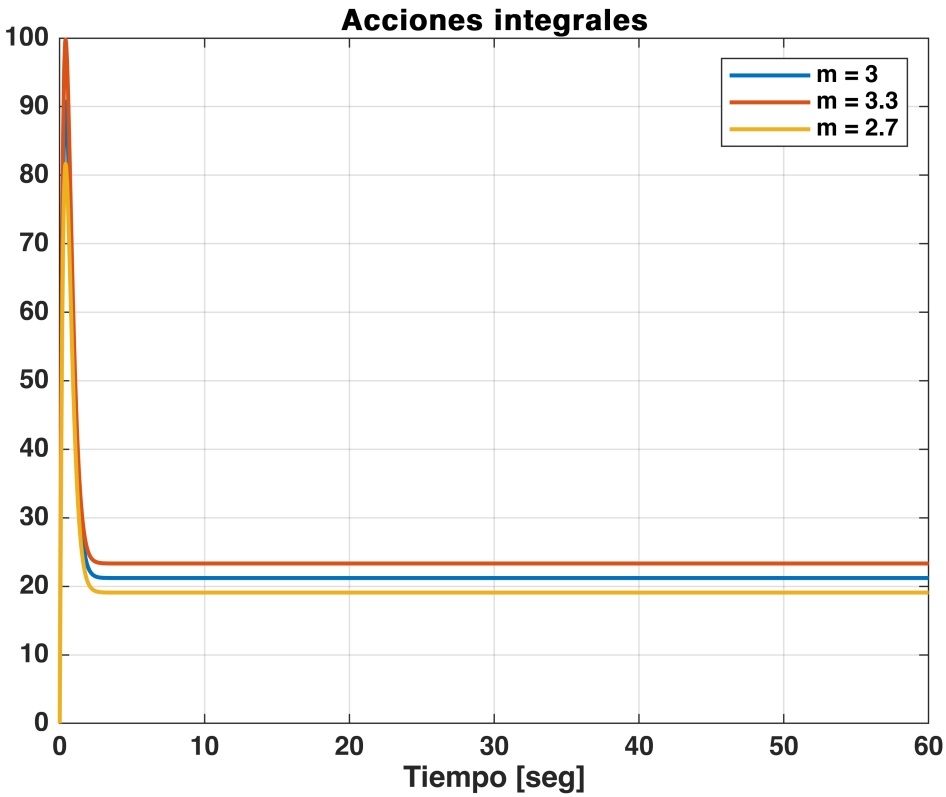

```
plot(ym1,vel1,"LineWidth",1.5)
hold on;
plot(ym2,vel2,"LineWidth",1.5)
plot(ym2,vel2,"LineWidth",1.5)
grid;
hold off;
title('Planos de fases')
xlabel('Tiempo [seg]')
legend('m = 3','m = 3.3','m = 2.7')
```




```
plot(tout,tor1,"LineWidth",1.5)
hold on;
plot(tout,tor2,"LineWidth",1.5)
plot(tout,tor3,"LineWidth",1.5)
grid;
hold off;
title('Torques')
xlabel('Tiempo [seg]')
legend('m = 3','m = 3.3','m = 2.7')
```




```
plot(tout,-int1,"LineWidth",1.5)
hold on;
plot(tout,-int2,"LineWidth",1.5)
plot(tout,-int3,"LineWidth",1.5)
grid;
hold off;
title('Acciones integrales')
xlabel('Tiempo [seg]')
legend('m = 3','m = 3.3','m = 2.7')
```


Acciones integrales
m = 3
m = 3.3
m = 2.7
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50
60
Tiempo [seg]