In the name of allah

Linear Control Systems

Hw 04

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Fall 1402

Theory Assignments

بنام خدا

سوال ۱

1. $G(s) = \dfrac{5s+5}{s^4+3s^3+3s^2+3s+2}$ → ریشه موهومی خالص جفت هستن چون ... دو ریشه ناپایدار نیست.

s^4	1	3	2
s^3	3	3	
s^2	2	2	$2s^2+2 \to s=\pm j$
s^1	$\cancel{0}$ 4	$\cancel{0}$	→ حالت خاص 2
s^0	2		

سیستم marginally Stable ← ریشه ناپایدار نداریم. (تغییر علامت نداریم) ریشه‌هایی روی محور نیز داریم (ساده).

2. $\dfrac{8s+1}{s^4+3s^3+3s^2+9s+1}$

	s^4	1	3	1
	s^3	3	9	
0^+	s^2	$\cancel{0}$ ε	1	→ حالت خاص 1
$-\infty$	s^1	$\frac{9\varepsilon-3}{\varepsilon}$	0	
	s^0	1		$\varepsilon \to 0^+$

unstable سیستم ← دو ریشه ناپایدار داریم ← دو تغییر علامت

3. $\dfrac{4}{s^4+4s^3+3s^2-4s-4}$

s^4	1	3	-4
s^3	4	-4	
s^2	4	-4	→ $4s^2-4 \to s=\pm 1$
s^1	$\cancel{0}$ ε	$\cancel{0}$ 0	→ حالت خاص 2
s^0	-4		

unstable سیستم ← یک ریشه ناپایدار ← یک تغییر علامت

4. $\dfrac{2s-1}{s^5+2s^4+2s^3+4s^2+11s+10}$ → صفر ناپایدار داریم، ریشه موهومی خالص نیست.

	s^5	1	2	11
	s^4	2	4	10
0^+	s^3	$\cancel{0}$ ε	6	→ حالت خاص 1
$+\infty$	s^2	$\frac{12-4\varepsilon}{\varepsilon}$	10	
6	s^1	α		
	s^0	10		

$\alpha = \dfrac{-10\varepsilon}{\frac{12-4\varepsilon}{\varepsilon}} + 6$

$\varepsilon \to 0^+$

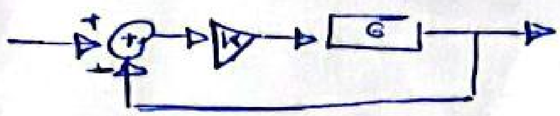
Stable سیستم ← ریشه ناپایدار نداریم ← تغییر علامت نداریم

5. $\dfrac{2}{s^6+7s^5+20s^4+30s^3+25s^2+11s+2}$

s^6	1	20	25	2
s^5	7	30	11	
s^4	$\frac{110}{7}$	$\frac{164}{7}$	$\cancel{2}$ 14	×7
s^3	$\frac{2152}{110}$	$\frac{1112}{110}$		×110
s^2	$\frac{230608}{2152}$	14		×2152
s^1	$\frac{1916006400}{230608}$			
s^0	14×2152	0		

Stable سیستم ← ریشه ناپایدار نداریم ← تغییر علامت نداریم

(سوال ۲)



$$G(s) = \frac{2s^3 + s^2 + s - 1}{s^3 - 5s^2 + 2s + 8}$$

$$H(s) = \frac{KG}{1 + KG} \to G = \frac{Z}{P} \to \underbrace{\frac{KZ}{P + KZ}}_{} = H$$

$$\to s^3 - 5s^2 + 2s + 8 + 2Ks^3 + Ks^2 + Ks - K$$

$$= (1+2K)s^3 + (K-5)s^2 + (2+K)s + (8-K)$$

s^3	$1+2K$	$2+K$
s^2	$K-5$	$8-K$
s^1	$-\frac{(1+2K)(8-K) + (2+K)(K-5)}{K-5}$	
s^0	$8-K$	

$$\to K^2 - 3K - 10 - (-2K^2 + 15K + 8)$$

$$\frac{3K^2 - 18K - 18}{K-5}$$

$$\to \begin{matrix} 1+2K \\ K-5 \end{matrix}$$

$$\to \frac{6 \pm \sqrt{36 + 24}}{2},\quad 3 \pm \sqrt{15},\quad \begin{matrix} 6,87 \\ -0,87 \end{matrix}$$

$$3K^2 - 18K - 18 = K^2 - 6K - 6 = \frac{(K - 3 - \sqrt{15})(K - 3 + \sqrt{15})}{K-5}$$

$$8-K$$

$\uparrow$

ستون اول باید هم علامت باشد

$\to$ ⊖

$K < -\frac{1}{2}$

$K < 5$

$K < -0,87$, $5 < K < 6,87$

$K > 8$

⊕

$K > -\frac{1}{2}$

$K > 5$

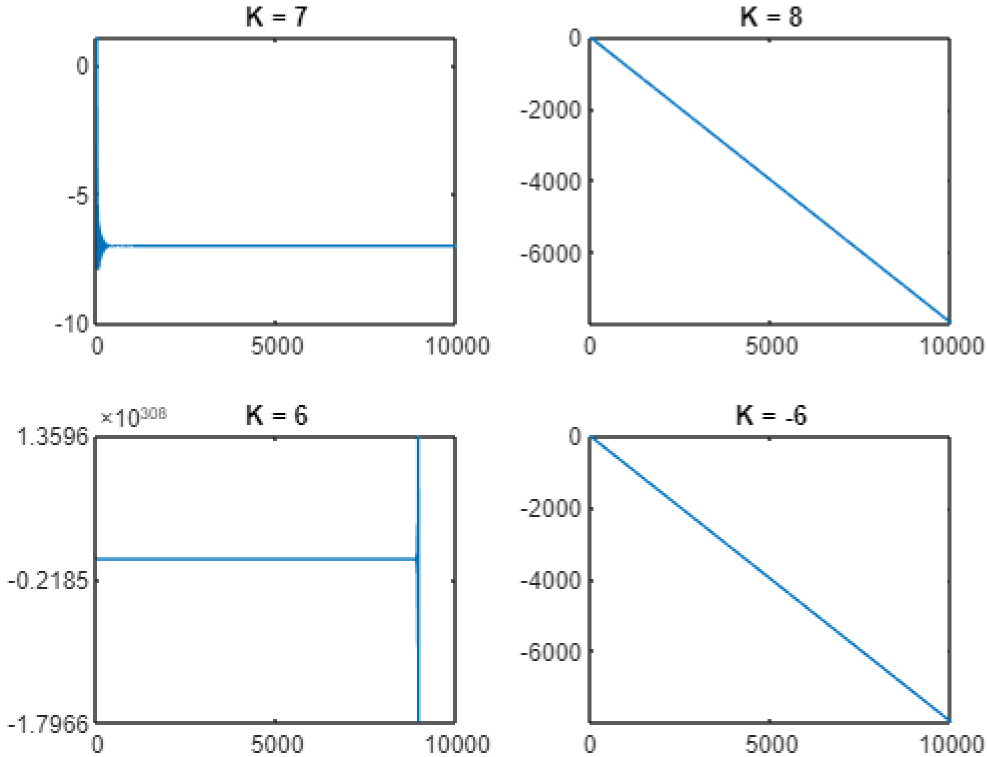
$K > 6,87$, $-0,87 < K < 5$

$K < 8$

[illegible] K موجود نیست

$$\boxed{8 > K > 6,87}$$

```
t = 0:0.01:10000;
u =  Step01(t);

K = 7;
num = [2*K K K -K];
den = [ 2*K+1 K-5 K+2 8-K];
sys = tf(num, den);
y1 = lsim(sys, u, t);

K = 8;
num = [2*K K K -K];
den = [ 2*K+1 K-5 K+2 8-K];
sys = tf(num, den);
y2 = lsim(sys, u, t);

K = 6;
num = [2*K K K -K];
den = [ 2*K+1 K-5 K+2 8-K];
sys = tf(num, den);
y3 = lsim(sys, u, t);

K = -6;
num = [2*K K K -K];
den = [ 2*K+1 K-5 K+2 8-K];
sys = tf(num, den);
y4 = lsim(sys, u, t);


figure
subplot(2,2,1)
plot(t,y1)
title("K = 7")
xlim([0 10000])
subplot(2,2,2)
plot(t,y2)
title("K = 8")
xlim([0 10000])
subplot(2,2,3)
plot(t,y3)
title("K = 6")
xlim([0 10000])
subplot(2,2,4)
plot(t,y2)
title("K = -6")
xlim([0 10000])
```



As we see, for $6.87 < K < 8$ system is stable

3) (حل

1.)
$$y(t) = \int_{-\infty}^{t} x(t-\tau)h(\tau)\,d\tau$$

$$\xrightarrow[y(t)\,max]{t=T_s} \Rightarrow \|y\|_\infty = y(T_s) = \int_0^{T_s} x(T_s-\tau)h(\tau)\,d\tau$$

ضرب x و h تغییر علامت نمی‌دهد

$$\le \int_0^{T_s} |x(T_s-\tau)||h(\tau)|\,d\tau$$

چون شرطی روی x نگذاشتیم با بیشترین شرط داری استفاده کردیم

$$\le \int_0^{\infty} |x(T_s-\tau)||h(\tau)|\,d\tau$$

h معمولاً (تا T_s و بعد از T_s) ... حجم برابر یا بیشتر خود

$$\le \int_0^{\infty} \|x\|_\infty |h(\tau)|\,d\tau$$

جای بیشترین مقدار قرار دادیم

$$\le \|x\|_\infty \int_0^{\infty} |h(\tau)|\,d\tau$$

2.) $\Rightarrow$ h(t) اگر: مثبت / منفی ، $u = a\,u(t)$: $a>0$ $\Rightarrow$ (نامساوی‌ها به مساوی تبدیل می‌شود) $\hat{}$ $Sgn(h(t))$

$$\Rightarrow \|y\|_\infty = \|x\|_\infty \int_0^{\infty} |h(\tau)|\,d\tau \Rightarrow \|S\| = \int_0^{\infty} |h(\tau)|\,d\tau$$

3) $\hookrightarrow e^{-t} > 0 \Rightarrow x = u(t)$

1. $\frac{1}{S+1} \times \frac{1}{S} = \frac{-1}{S+1} + \frac{1}{S} \Rightarrow 1 - e^{-t} \Rightarrow \|S_1\| = \frac{1}{1} = 1$ ✓

$\hookrightarrow e^{t} > 0 \Rightarrow x = u(t)$

2. $\frac{1}{S-1} \times \frac{1}{S} = (\frac{+1}{S-1} - \frac{1}{S}) \Rightarrow e^{t} - 1 \Rightarrow \|S_2\| = \frac{\infty}{1}$ = بی‌نهایت ✗

3. $\frac{1}{S^2+1} \longrightarrow \sin t \Rightarrow \|S_3\| = \int_0^{\infty} |\sin t|\,dt \Rightarrow \|S_3\| = \infty$ ✗

4. $\frac{1}{(S+1)^2} \times \frac{1}{S} = \frac{-1}{S+1} + \frac{-1}{(S+1)^2} + \frac{1}{S} \Rightarrow -e^{-t} - te^{-t} + 1 \Rightarrow \|S_4\| = \frac{1}{1} = 1$

$\hookrightarrow te^{-t} > 0 \Rightarrow x = u(t)$ $\quad e^{-t} + te^{-t} \longrightarrow \cancel{-e^{-t}} + \cancel{e^{-t}} - te^{-t} \Rightarrow$ تا بی‌نهایت جزئی صفر

5. $\frac{1}{t+1} \Rightarrow \int_0^{\infty} \frac{1}{t+1}\,dt = \int_1^{\infty} \frac{1}{u}\,du = \ln u \Big|_1^{\infty} = \ln \infty = \infty$ ✗

6. $\frac{1}{t^2+1} \Rightarrow \int_0^{\infty} \frac{1}{t^2+1}\,dt = tg^{-1} t \Big|_0^{\infty} = tg^{-1} \infty = \frac{\pi}{2}$ ✓

```
t = 0:0.01:100;
u =  Step01(t);

num = [1] ;
den = [1 1];
sys = tf(num, den);
y1 = lsim(sys, u, t);

num = [1] ;
den = [1 -1];
sys = tf(num, den);
y2 = lsim(sys, u, t);

num = [1] ;
den = [1 0 1];
sys = tf(num, den);
y3 = lsim(sys, u, t);

num = [1] ;
den = [1  2 1];
sys = tf(num, den);
y4 = lsim(sys, u, t);

syms e
y5 = (-1/(e+1)^2); % s(t) = d/dt h(t)
```

y5 =

$$-\frac{1}{(e+1)^2}$$

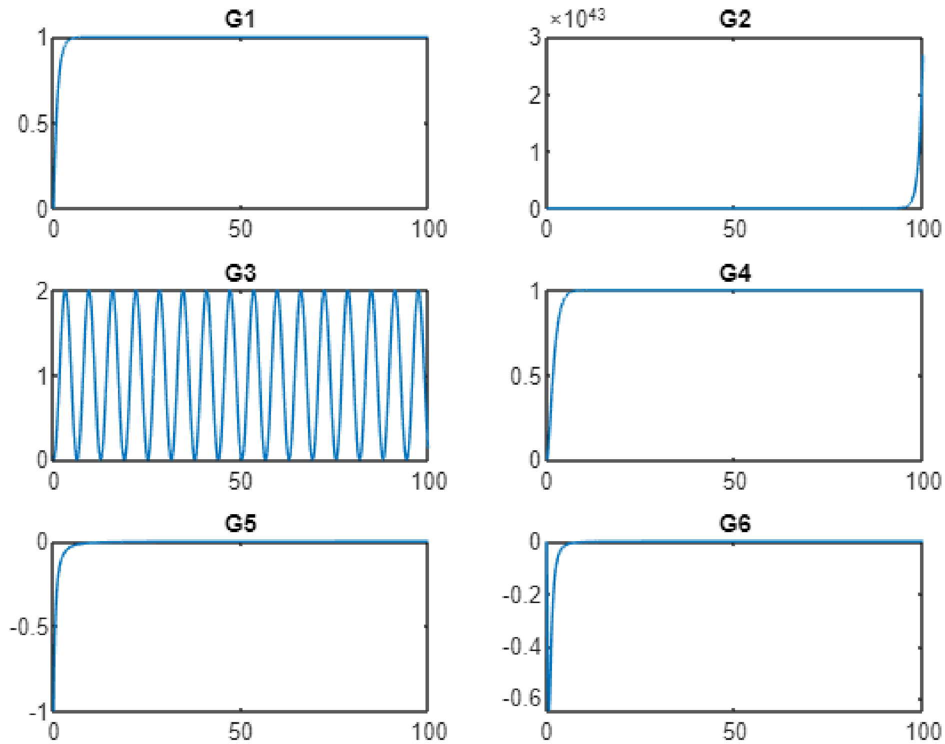
```
y6 = (-2*e/(e^2+1)^2); % s(t) = d/dt h(t)
```

y6 =

$$-\frac{2\,e}{{(e^2+1)}^2}$$

```
figure
subplot(3,2,1)
plot(t,y1)
title("G1")
xlim([0 100])
subplot(3,2,2)
plot(t,y2)
title("G2")
xlim([0 100])
subplot(3,2,3)
plot(t,y3)
title("G3")
xlim([0 100])
subplot(3,2,4)
```

```
plot(t,y4)
title("G4")
xlim([0 100])
subplot(3,2,5)
fplot(y5)
title("G5")
xlim([0 100])
subplot(3,2,6)
fplot(y6)
title("G6")
xlim([0 100])
```



9 سوال)

1) $$-0,02 < \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} \overbrace{\sin \omega_d t + \phi}^{\max 1} < 0,02$$

$$-0,02 < \frac{e^{-\zeta\omega_n t}}{\sqrt{1-\zeta^2}} < 0,02$$

$t = \frac{x}{\zeta\omega_n}$:

$$-0,02 < \frac{e^{-x}}{\sqrt{1-\zeta^2}} < 0,02$$

$$e^{-x} < 0,02\sqrt{1-\zeta^2}$$

$$\frac{e^{-x}}{0,02} < \sqrt{1-\zeta^2}$$

$$\frac{e^{-2x}}{4\,10^{-4}} < 1-\zeta^2$$

$$\zeta^2 < 1 - \frac{e^{-2x}}{4\,10^{-4}}$$

$$\zeta < \sqrt{1-\frac{e^{-2x}}{4\,10^{-4}}}$$

$x = 4 \rightarrow \zeta < 0,401$

$x = 4,2 \rightarrow \zeta < 0,661$

$x = 4,5 \rightarrow \zeta < 0,831$

$x = 4,75 \rightarrow \zeta < 0,901$

$x = 5 \rightarrow \zeta < 0,941$

$x = 6 \rightarrow \zeta < 0,992290$

$\zeta < 0,9$

در گاماهای کوچک، درصد خطا کم است ولی مقدار زمان نشست بزرگ است

در گاماهای بزرگ درصد خطا زیاد، ولی اختلاف زمان نشست کم است.

$$T_s = \frac{6}{\omega_n} \leftarrow \zeta = 1$$

2)

Scanned with CamScanner

2)

$$\frac{d}{dt}\left(1-\frac{1}{\sqrt{1-\xi^2}}e^{-\xi\omega_n t}\sin(\omega_n\sqrt{1-\xi^2}\,t+\cos^{-1}\xi)\right)$$

$$=\frac{\xi\omega_n}{\sqrt{1-\xi^2}}e^{-\xi\omega_n t}\sin \omega_d t+\phi-\frac{\omega_d}{\sqrt{1-\xi^2}}e^{-\xi\omega_n t}\cos\omega_d t+\phi$$

$$=\frac{\omega_n e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}}\left(\xi\sin\omega_d t+\phi-\sqrt{1-\xi^2}\cos\omega_d t+\phi\right)$$

$$=\frac{\omega_n e^{-\xi\omega_n t}}{\sqrt{1-\xi^2}}\sin\omega_d t+\cancel{\phi-\cos^{-1}(\xi)}$$

$$\Rightarrow t=\frac{k\pi}{\omega_n\sqrt{1-\xi^2}}\xrightarrow[\text{max over Shoot}]{k=1} t=\frac{\pi}{\omega_n\sqrt{1-\xi^2}}$$

$$\Rightarrow 1-\frac{1}{\sqrt{1-\xi^2}}e^{-\xi\omega_n\frac{\pi}{\omega_n\sqrt{1-\xi^2}}}\sin(\omega_d\frac{\pi}{\omega_d}+\cos^{-1}(\xi))$$

$$1+\frac{e^{\frac{-\xi\pi}{\sqrt{1-\xi^2}}}}{\sqrt{1-\xi^2}}\underbrace{\sin(\cos^{-1}(\xi))}_{\sqrt{1-\xi^2}}=1+\underbrace{e^{-\frac{\xi\pi}{\sqrt{1-\xi^2}}}}_{mp}$$

ب . ξ باید بین ۰ و ۱ باشد تا پاسخ پله به صورت جهش‌دار باشد، هیچ شرط اضافی روی ξ لازم نیست.

زمان پیک برابر $\frac{\pi}{\omega_n\sqrt{1-\xi^2}}$ است، برای کاهش زمان پیک (در نتیجه افزایش سرعت پاسخ) در ω_n ثابت

باید $\sqrt{1-\xi^2}$ ماکزیمم شود ولی با کاهش ξ مقدار overshoot افزایش می‌یابد

پس چون نمی‌خواهیم overshoot داشته باشیم باید $\xi=1$ باشد. در یک ω_n ثابت سریع‌ترین جواب

به ازای $\xi=1$ خواهد بود چراکه جواب میرای بحرانی سریع‌تر از فوق‌میرا است.

MATLAB Assignments

```
clc
close all
clear all
```

5 Curve Fitting Toolbox

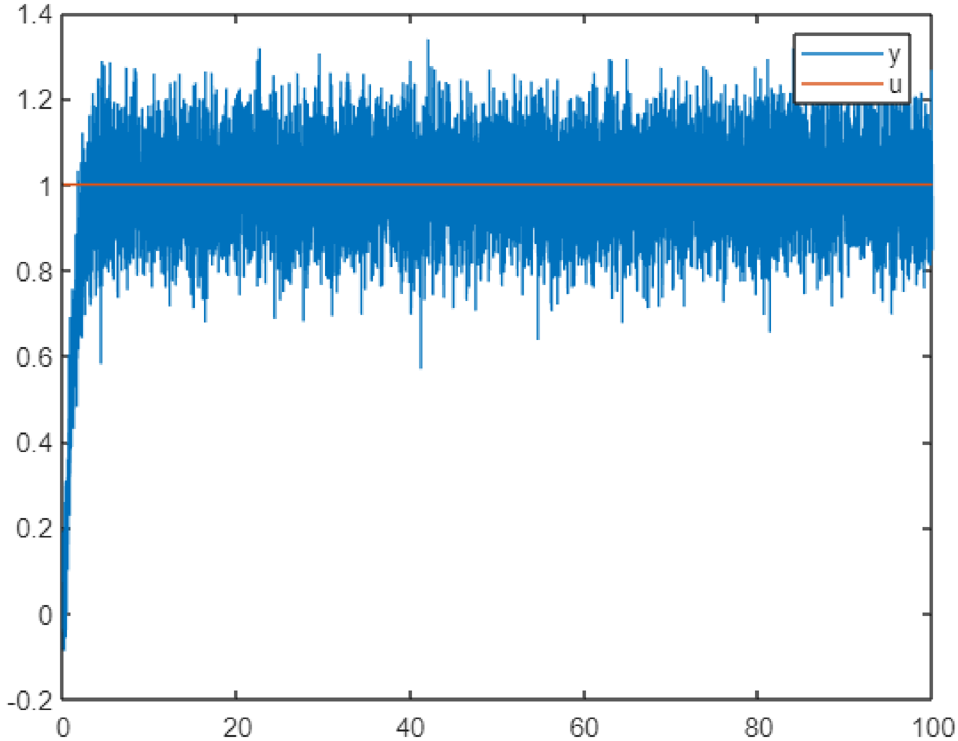
a)

$$G(s) = \frac{K}{\tau s + 1} \Rightarrow \text{step response}: \ \frac{K}{\tau s + 1} * \frac{1}{s} = \frac{-\frac{K}{\tau}}{\tau s + 1} + \frac{K}{s}$$

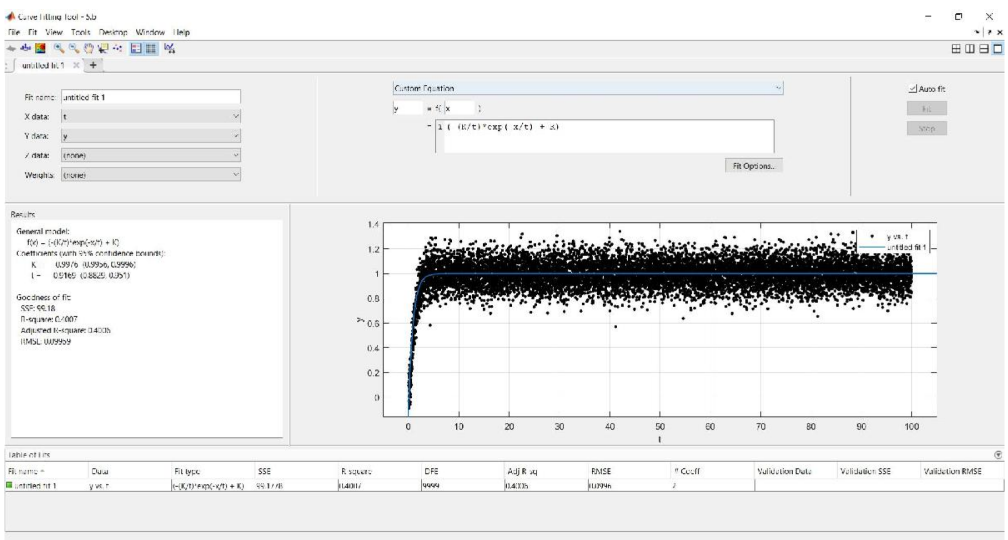
$$\Rightarrow \ = \mathrm{Ku}(t) - \frac{K}{\tau} e^{-\frac{t}{\tau}}$$

b)

```
t = out.tout;
x = out.x;
y = out.y;

figure
plot(t,y,t,x)
legend("y","u")
```



c)

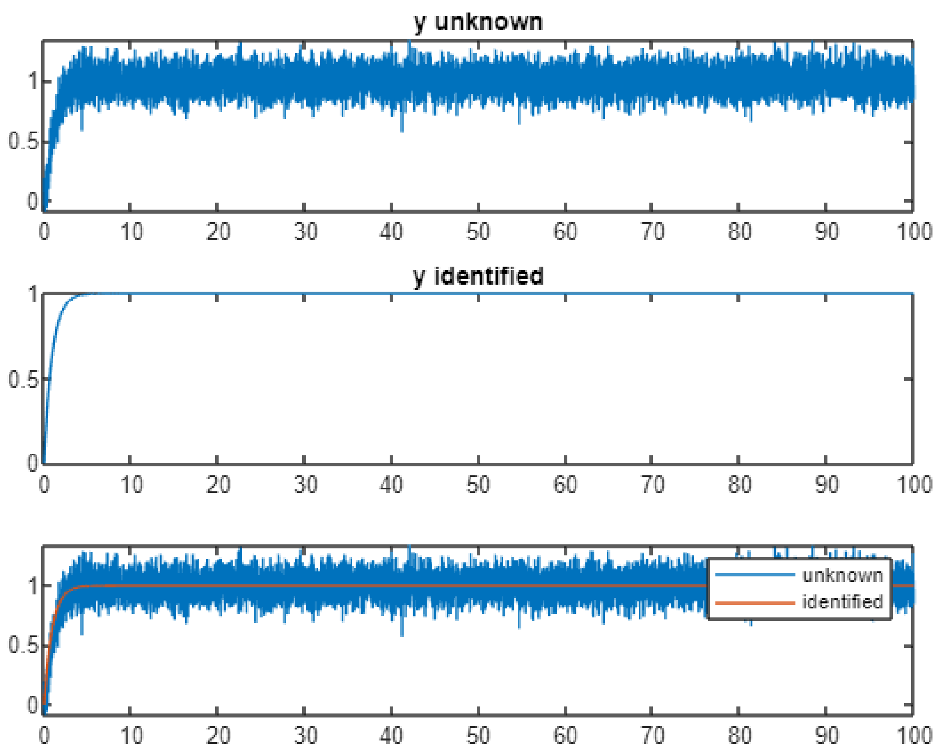


K = 0.9976 , τ = 0.9169

d)

```
K = 0.9976;
T = 0.9169;
u =  Step01(t);
```

```
num = [K] ;
den = [T 1];
sys = tf(num, den);
y1 = lsim(sys, u, t);

figure
subplot(3,1,1)
plot(t,y)
title("y unknown")
subplot(3,1,2)
plot(t,y1)
title("y identified")
subplot(3,1,3)
plot(t,y,t,y1)
legend("unknown","identified")
```



e)

$$y(t) = \mathrm{Ku}(t) - \frac{K}{\tau} e^{\frac{-t}{\tau}}$$

as we see, K is almost equal to 1.

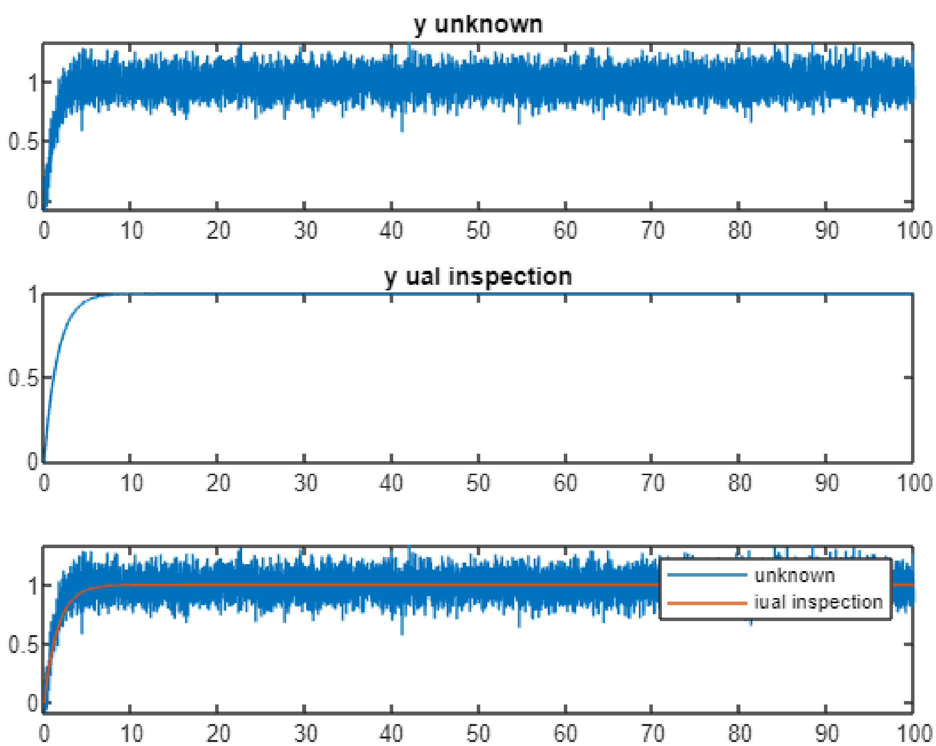
Also, in A = B, the output reaches its final value of 0.95.

$$y(4) = 1 - \frac{1}{\tau} e^{-\frac{4}{\tau}} = 0.95$$

K = 1

τ = 1.573

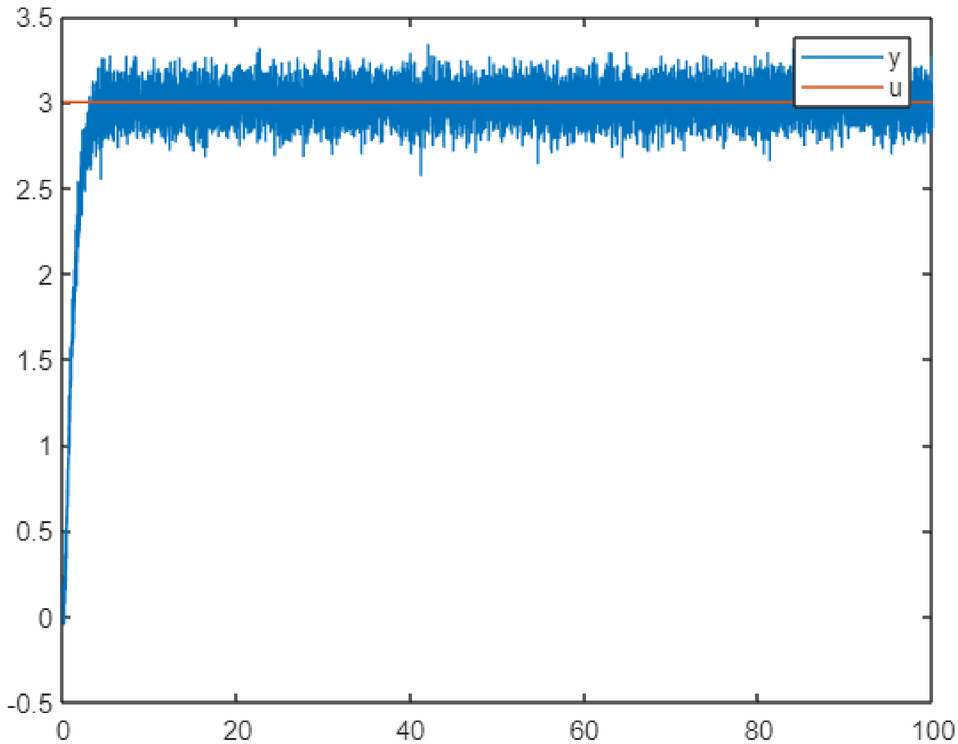
```
K = 1;
T = 1.573;
u =  Step01(t);

num = [K] ;
den = [T 1];
sys = tf(num, den);
y2 = lsim(sys, u, t);

figure
subplot(3,1,1)
plot(t,y)
title("y unknown")
subplot(3,1,2)
plot(t,y2)
title("y ual inspection")
subplot(3,1,3)
plot(t,y,t,y2)
legend("unknown","iual inspection")
```

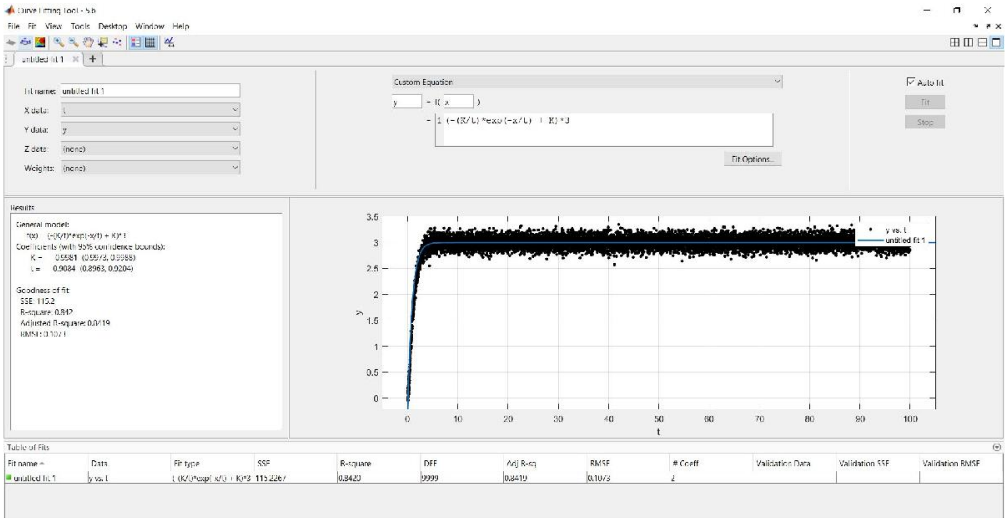


f)

$$y(t) = \mathrm{AKu}(t) - \frac{\mathrm{AK}}{\tau} e^{\frac{-t}{\tau}}, u(t) = \mathrm{Au}(t), A = 3$$

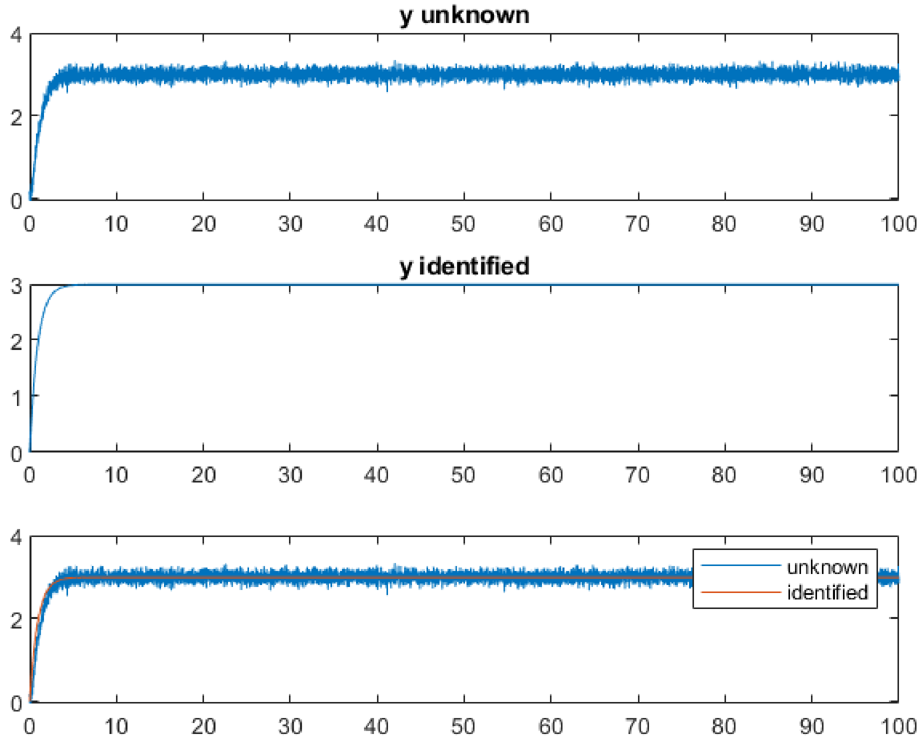
```
t = out.tout;
x = out.x;
y = out.y;

figure
plot(t,y,t,x)
legend("y","u")
```





K = 0.9981 ,τ = 0.9084

```
K = 0.9981;
T = 0.9084;
u =  Step01(t);

num = [K] ;
den = [T 1];
sys = tf(num, den);
y1 = lsim(sys, 3*u, t);

figure
subplot(3,1,1)
plot(t,y)
title("y unknown")
subplot(3,1,2)
plot(t,y1)
title("y identified")
subplot(3,1,3)
plot(t,y,t,y1)
legend("unknown","identified")
```



g)

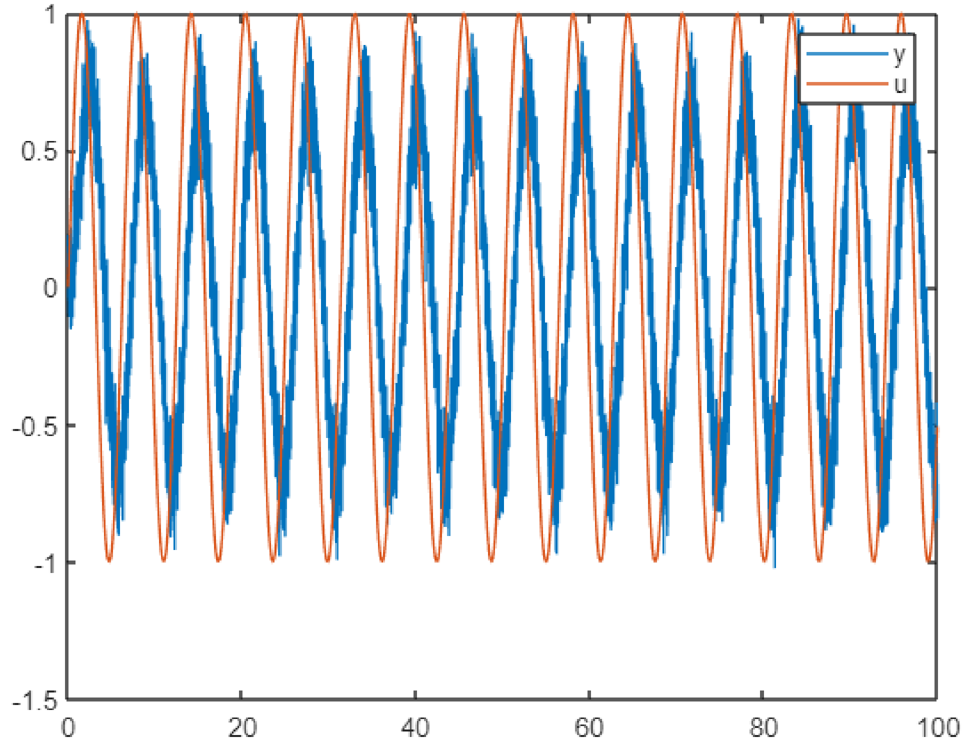
sinusoidal respons

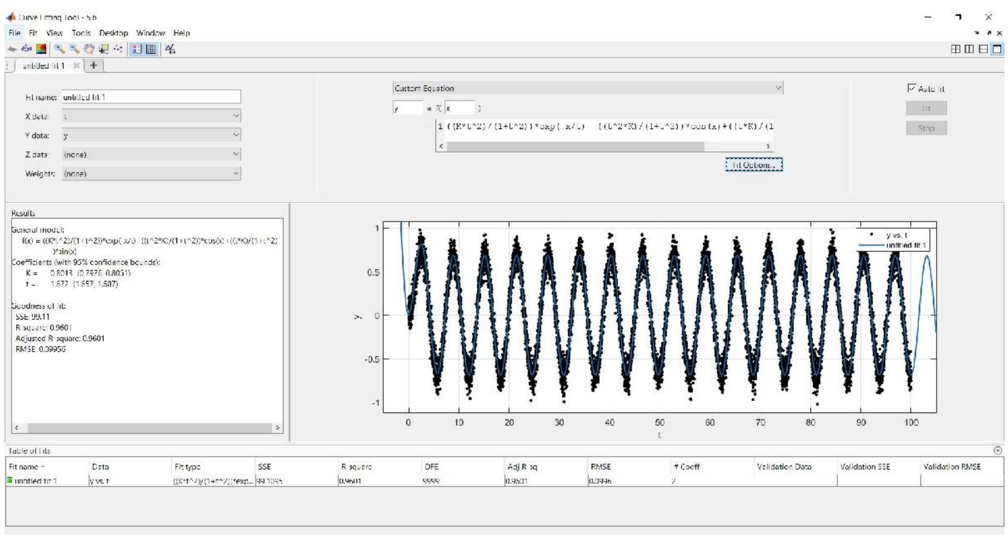
$$\frac{K}{\tau s+1}\cdot\frac{a}{s^2+a^2}=\frac{\frac{K\tau^2 a}{1+\tau^2 a}}{\tau s+1}+\frac{-\frac{a\tau^2 K}{1+\tau^2 a}s+\frac{a\ \tau K}{1+\tau^2 a}}{s^2+a^2}$$

$$\Rightarrow \frac{K\tau^2 a}{1+\tau^2 a^2}\ e^{\frac{-t}{\tau}}-\frac{a\ \tau^2 K}{1+\tau^2 a^2}\cos(\mathrm{at})+\frac{\tau K}{1+\tau^2 a^2}\sin(\mathrm{at})$$

$$a=1\Rightarrow\ \frac{K\tau^2}{1+\tau^2}\ e^{\frac{-t}{\tau}}-\frac{\tau^2 K}{1+\tau^2}\cos(t)+\frac{\tau K}{1+\tau^2}\sin(t)$$

```
t = out.tout;
x = out.x;
y = out.y;

figure
plot(t,y,t,x)
legend("y","u")
```



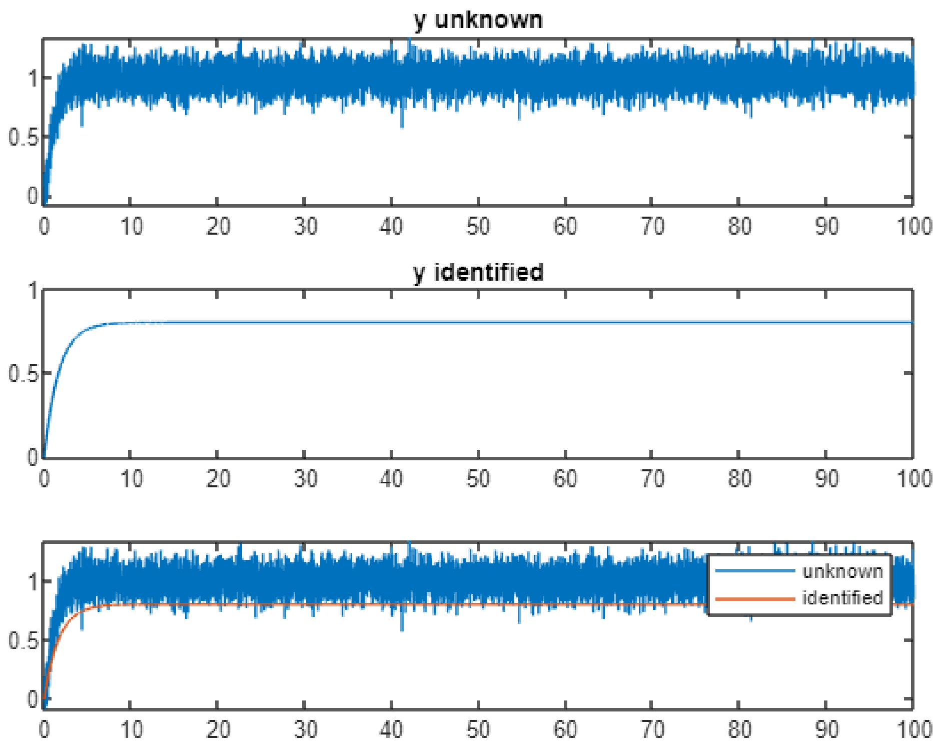


K = 0.8013 , τ = 1.672

step respons

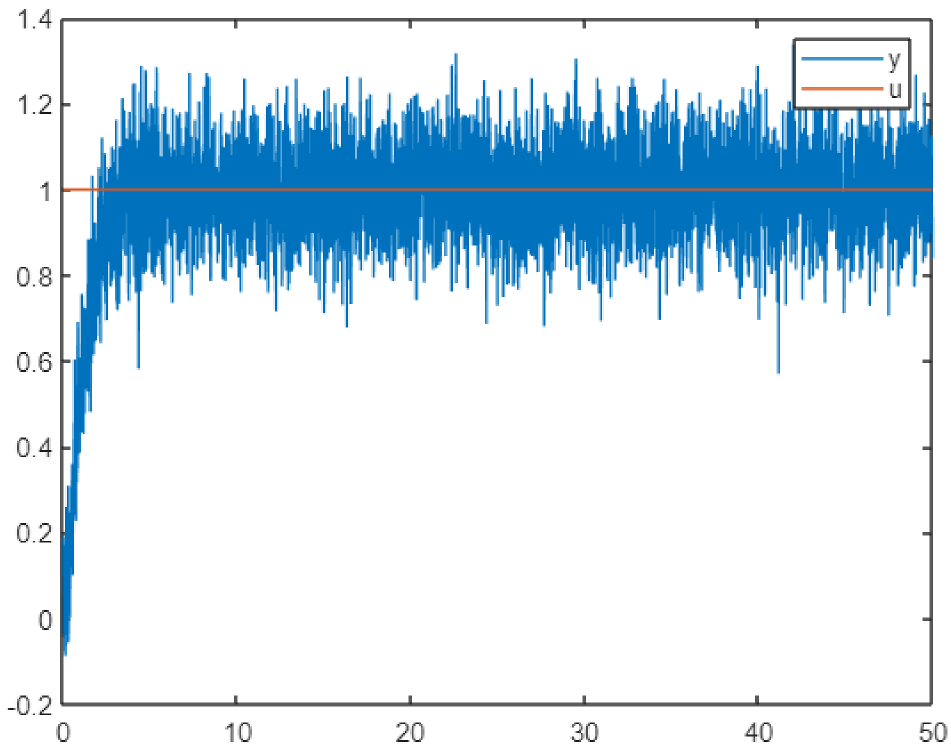
```
t = out.tout;
x = out.x;
y = out.y;

K = 0.8013;
T = 1.672;
```

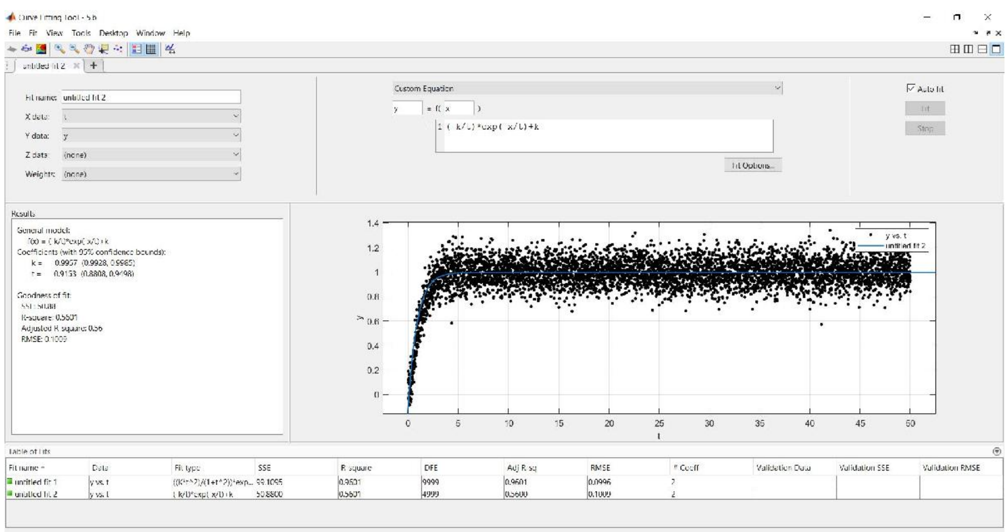
```
u =  Step01(t);

num = [K] ;
den = [T 1];
sys = tf(num, den);
y1 = lsim(sys, u, t);

figure
subplot(3,1,1)
plot(t,y)
title("y unknown")
subplot(3,1,2)
plot(t,y1)
title("y identified")
subplot(3,1,3)
plot(t,y,t,y1)
legend("unknown","identified")
```



h)

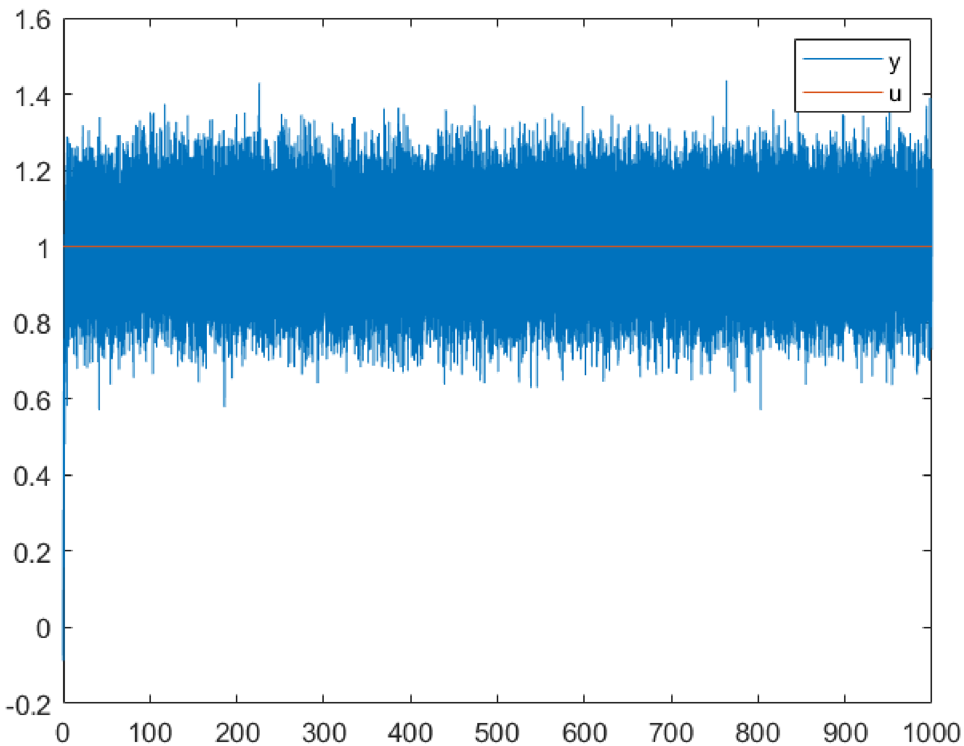
```
t = out.tout;
x = out.x;
y = out.y;

figure
plot(t,y,t,x)
legend("y","u")
```

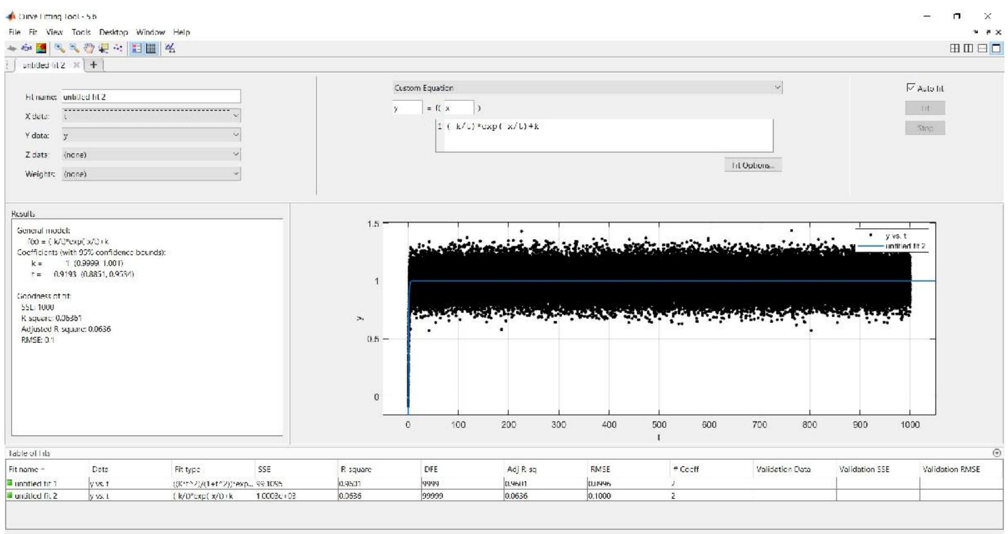




K = 0.9957 , τ = 0.9153

```
t = out.tout;
x = out.x;
y = out.y;

figure
plot(t,y,t,x)
legend("y","u")
```



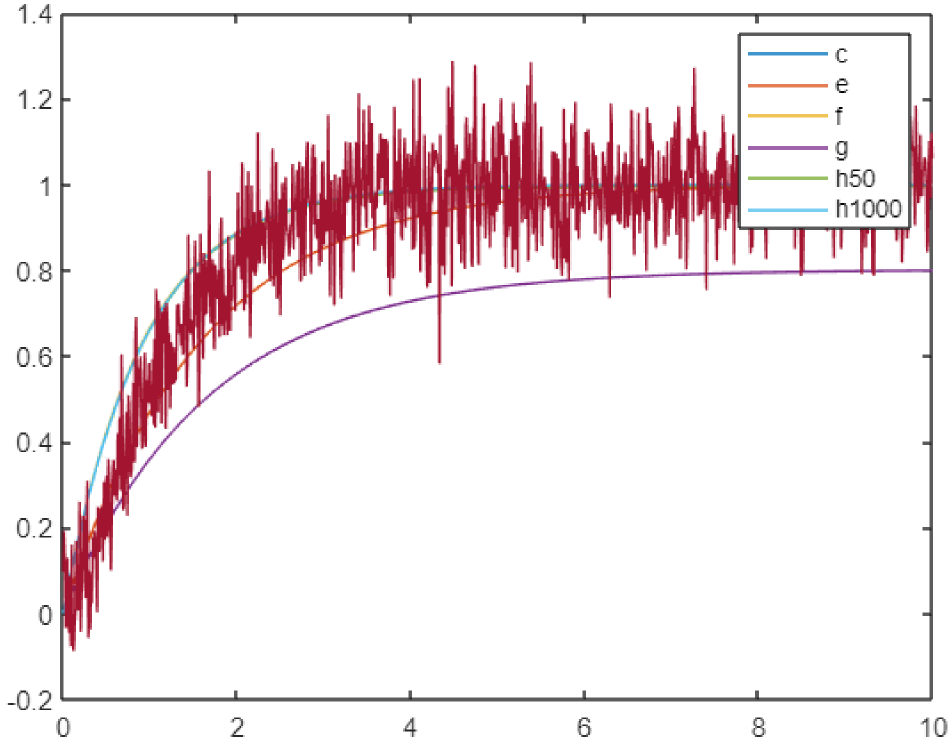


K = 1 , τ = 0.9193

j)

```
u =  Step01(t);


K = 0.9976;
T = 0.9169;
num = [K] ;
```

```
den = [T 1];
sys = tf(num, den);
y1 = lsim(sys, u, t);

K = 1;
T = 1.573;
num = [K] ;
den = [T 1];
sys = tf(num, den);
y2 = lsim(sys, u, t);

K = 0.9981;
T = 0.9084;
num = [K] ;
den = [T 1];
sys = tf(num, den);
y3 = lsim(sys, u, t);

K = 0.8013;
T = 1.672;
num = [K] ;
den = [T 1];
sys = tf(num, den);
y4 = lsim(sys, u, t);

K = 0.9957;
T = 0.9153;
num = [K] ;
den = [T 1];
sys = tf(num, den);
y5 = lsim(sys, u, t);

K = 1;
T = 0.9193;
num = [K] ;
den = [T 1];
sys = tf(num, den);
y6 = lsim(sys, u, t);

figure
plot(t,y1,t,y2,t,y3,t,y4,t,y5,t,y6,t,y)
legend("c","e","f","g","h50","h1000")
xlim([0 10])
```

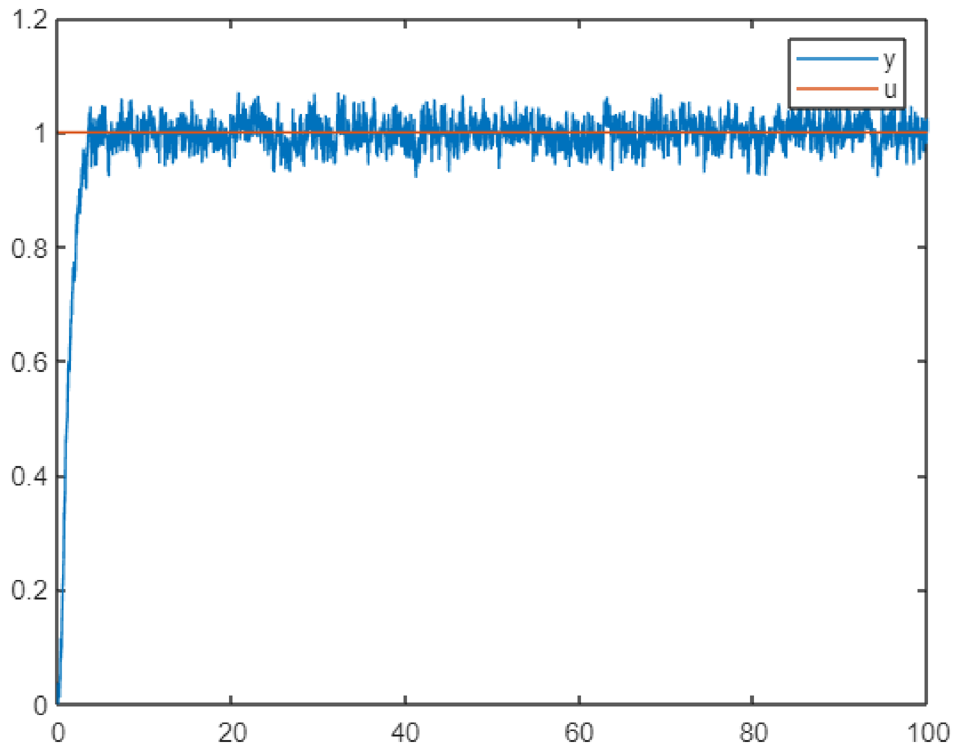


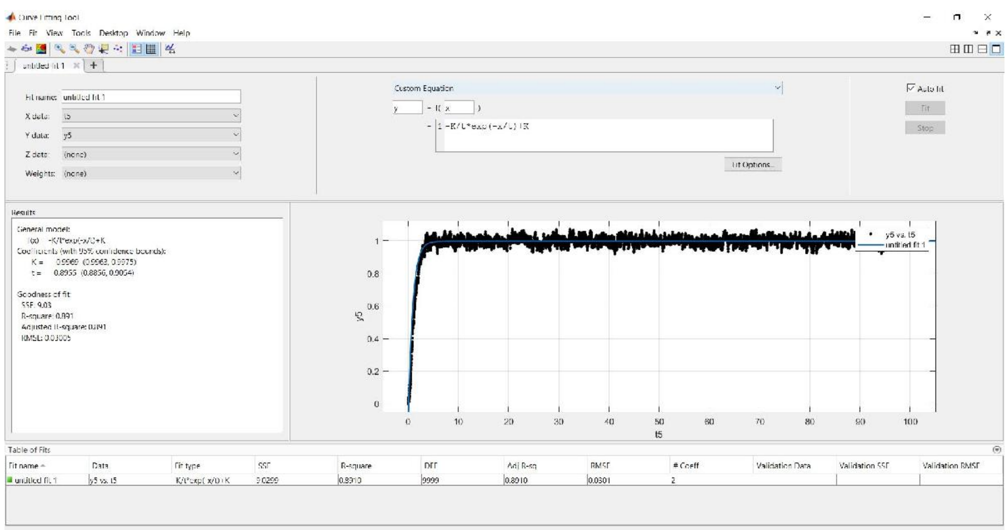
as we see,c,f,h50 &h1000 are good approximation.

Bonus

i)

```
% t5 = out.tout;
% x5 = out.x;
% y5 = out.y;

figure
plot(t5,y5,t5,x5)
legend("y","u")
```





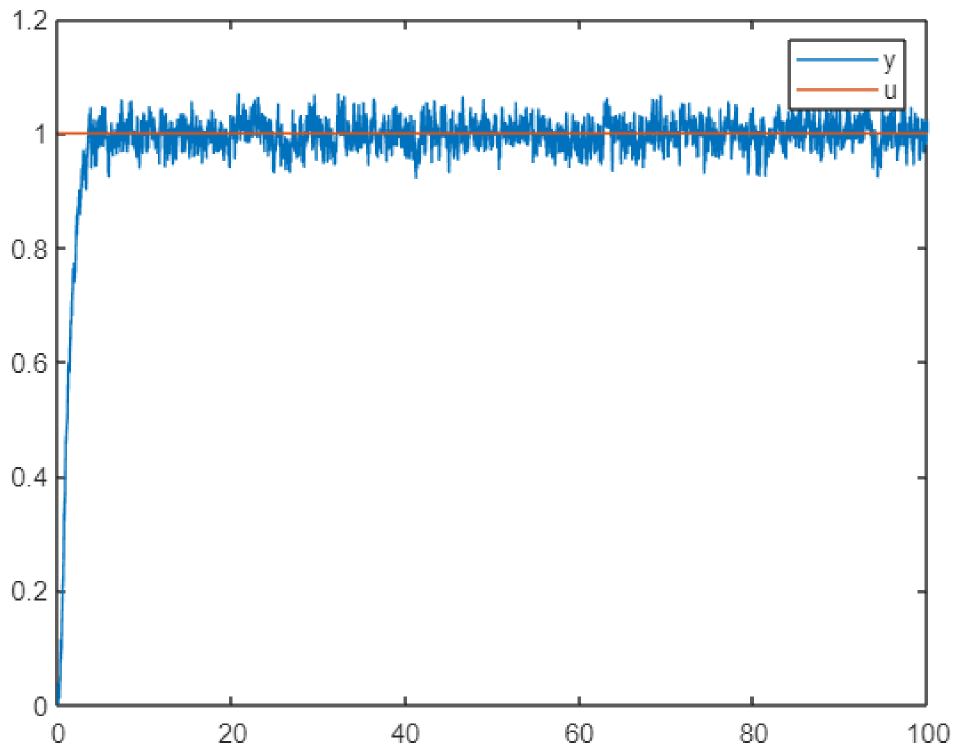
K = 0.9969 , τ = 0.8955

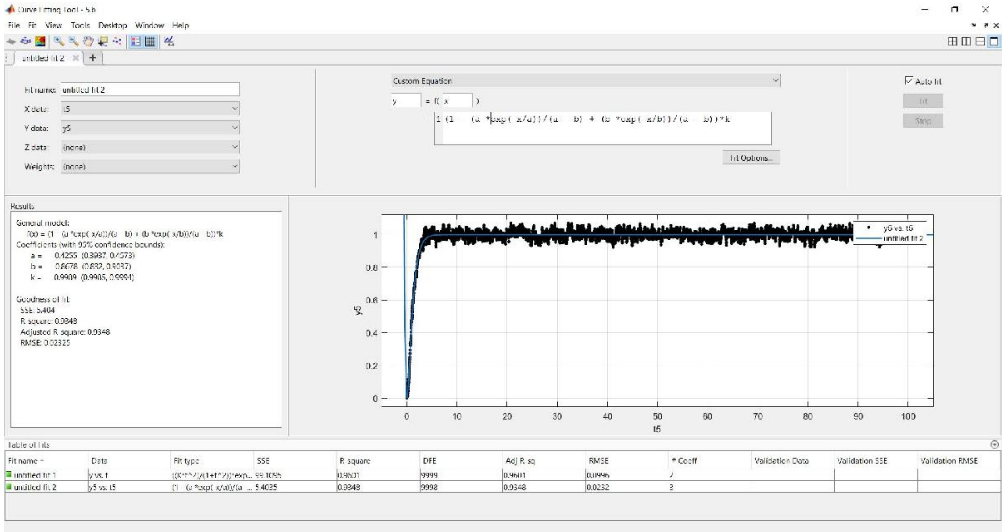
k)

$$G(s) = \frac{K}{(\tau_1 s + 1)(\tau_2 s + 1)} \Rightarrow \text{step response} : \frac{K}{(\tau_1 s + 1)(\tau_2 s + 1)} * \frac{1}{s} = -\frac{\frac{K\tau_1}{1 - \frac{\tau_2}{\tau_1}}}{\tau_1 s + 1} - \frac{\frac{K\tau_2}{1 - \frac{\tau_1}{\tau_2}}}{\tau_2 s + 1} + \frac{K}{s}$$

$$\Rightarrow \ = \mathrm{Ku}(t) - \frac{K\tau_1}{\tau_1 - \tau_2} e^{-\frac{t}{\tau_1}} - \frac{K\tau_2}{\tau_2 - \tau_1} e^{-\frac{t}{\tau_2}}$$

```
figure
plot(t5,y5,t5,x5)
legend("y","u")
```





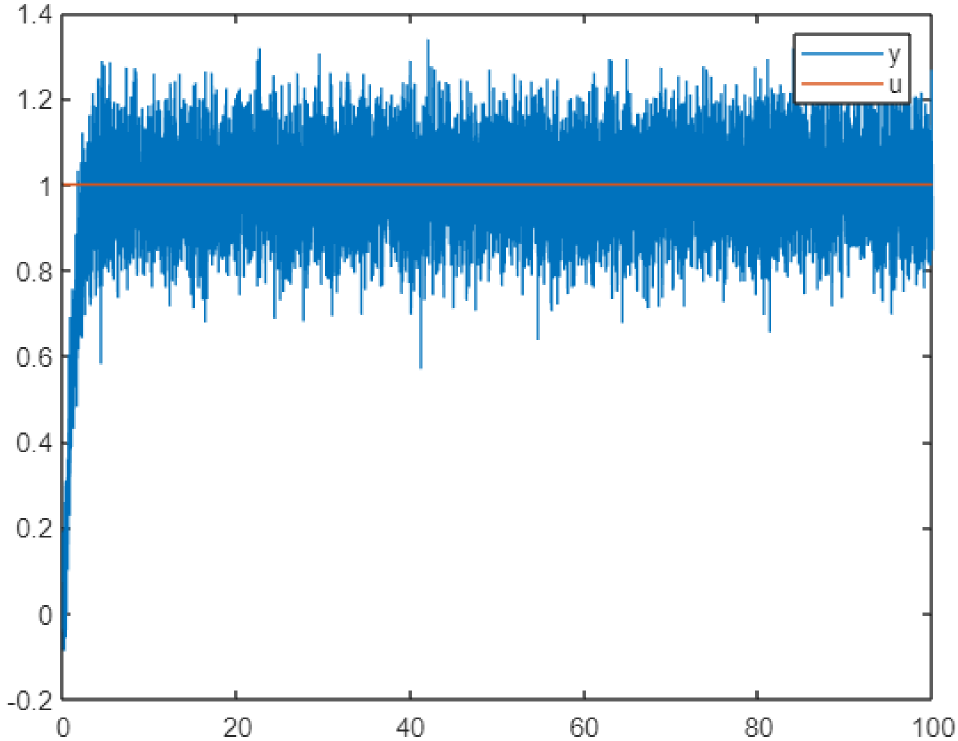
K = 0.9989 , τ_1 = 0.8678, τ_2 = 0.4255

6 System Identification Toolbox

```
clc
close all
clear all
```

a)

```
t = out.tout;
x = out.x;
y = out.y;

figure
plot(t,y,t,x)
legend("y","u")
```

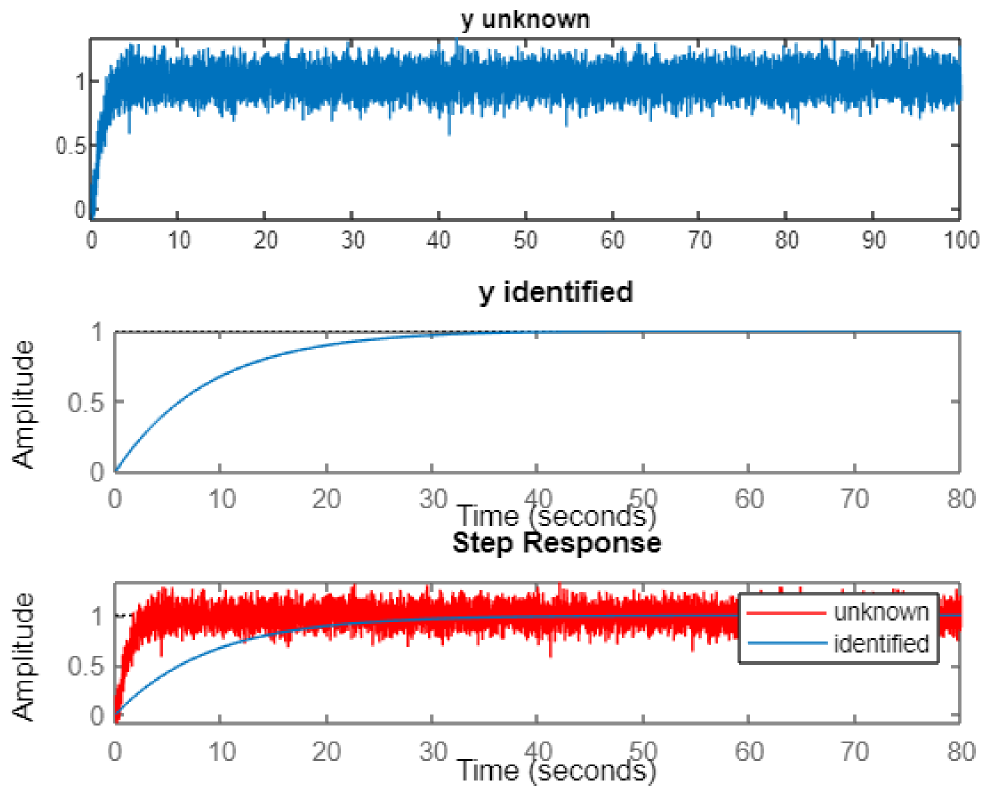


b)

```
Gb = tf(tf1.Numerator , tf1.Denominator)
```

```
Gb =

    0.1127
  ----------
  s + 0.1128

Continuous-time transfer function.
```

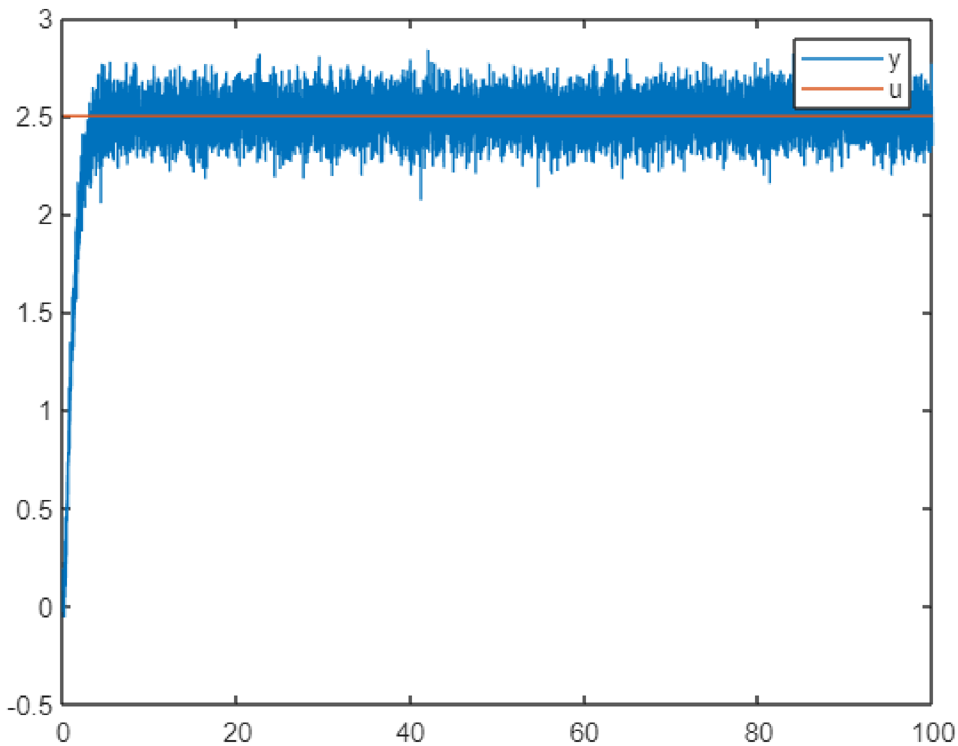
```
figure
subplot(3,1,1)
plot(t,y)
title("y unknown")
subplot(3,1,2)
step(Gb)
title("y identified")
subplot(3,1,3)
hold on
plot(t,y,"Color","r")
step(Gb)
legend("unknown","identified")
```



c)

A = 2.5

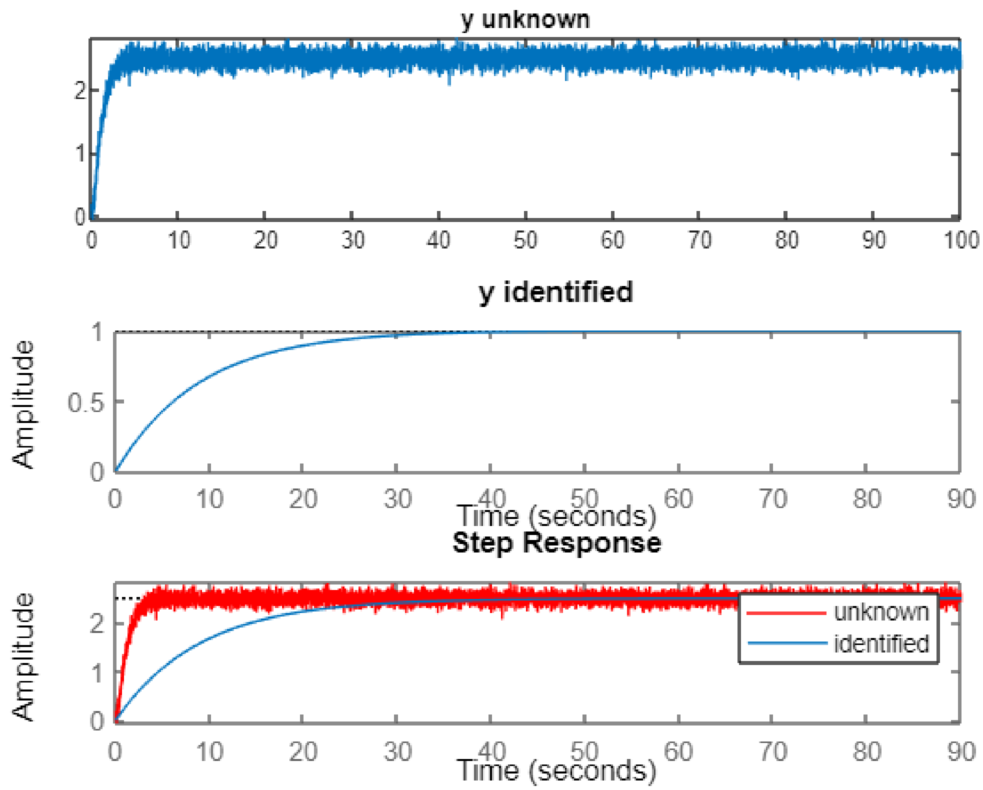
```
% t1 = out.tout;
% x1 = out.x;
% y1 = out.y;

figure
plot(t1,y1,t1,x1)
legend("y","u")
```




```
Gc1 = tf(tf2.Numerator , tf2.Denominator)
```

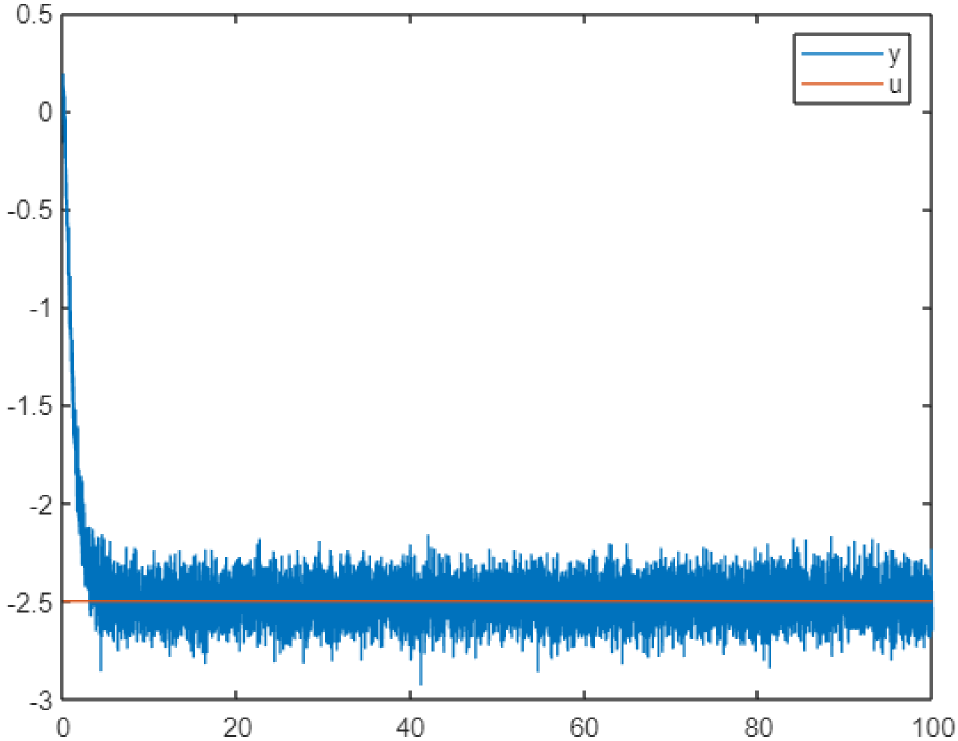
```
Gc1 =
 
    0.1116
  ----------
  s + 0.1116
 
Continuous-time transfer function.
```

```
figure
subplot(3,1,1)
plot(t1,y1)
title("y unknown")
subplot(3,1,2)
step(Gc1)
title("y identified")
subplot(3,1,3)
hold on
plot(t1,y1,"Color","r")
step(2.5*Gc1)
legend("unknown","identified")
```



A = -2.5

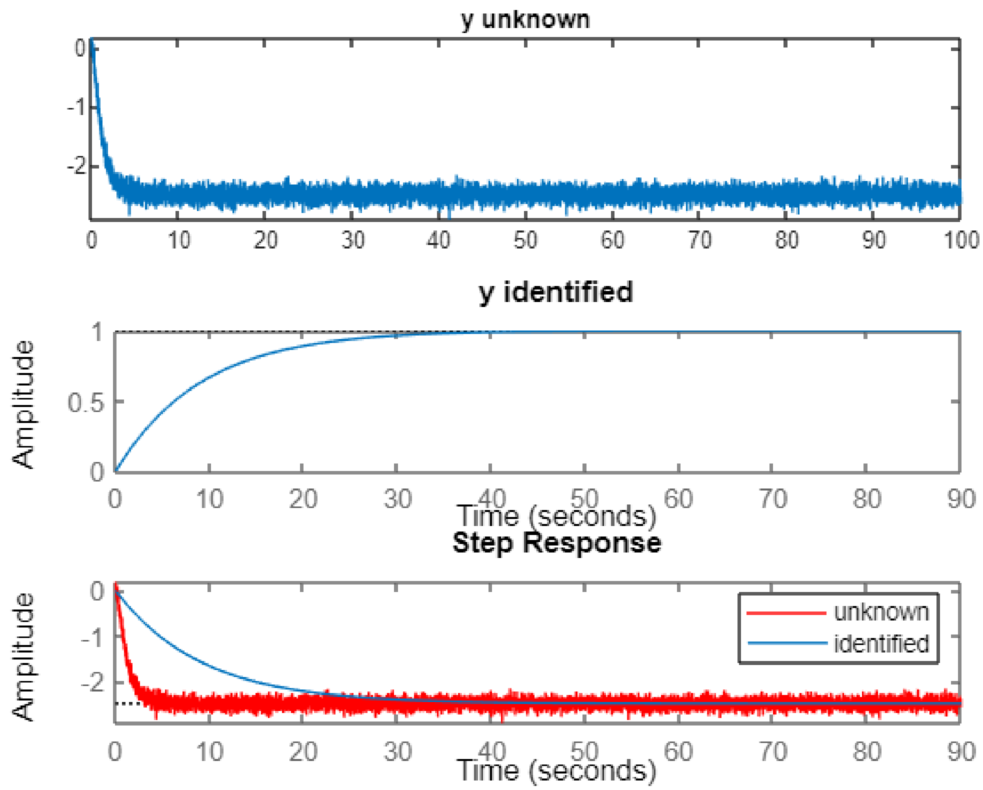
```
% t2 = out.tout;
% x2 = out.x;
% y2 = out.y;

figure
plot(t2,y2,t2,x2)
legend("y","u")
```




```
Gc2 = tf(tf3.Numerator , tf3.Denominator)
```

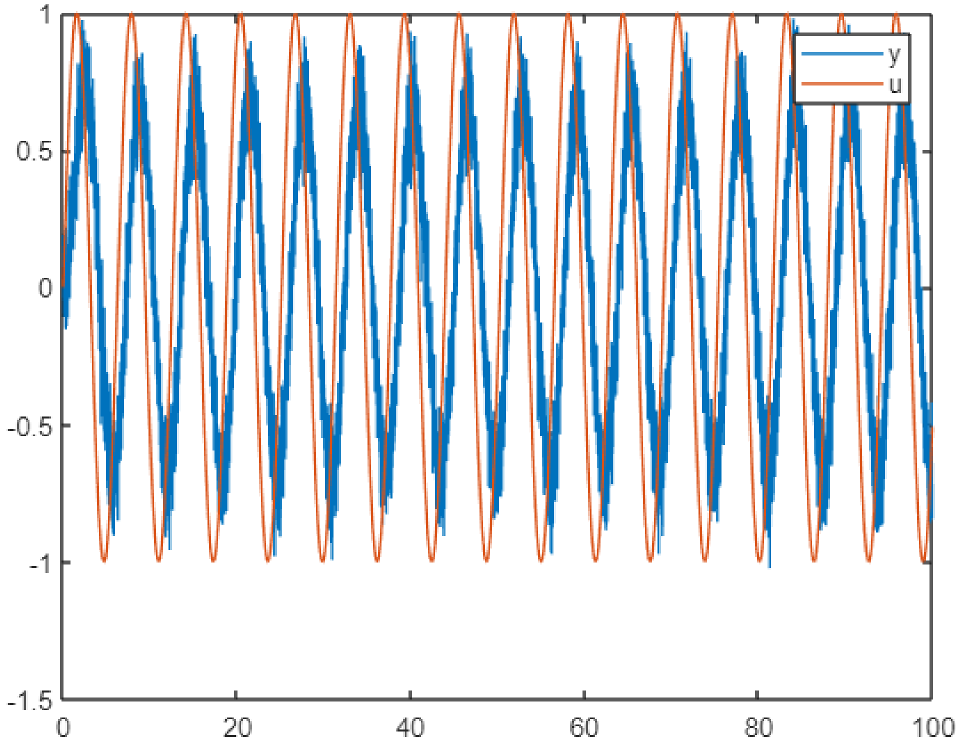
```
Gc2 =

   0.1101
  --------
  s + 0.11

Continuous-time transfer function.
```

```
figure
subplot(3,1,1)
plot(t2,y2)
title("y unknown")
subplot(3,1,2)
step(Gc2)
title("y identified")
subplot(3,1,3)
hold on
plot(t2,y2,"Color","r")
step(-2.5*Gc2)
legend("unknown","identified")
```



d)

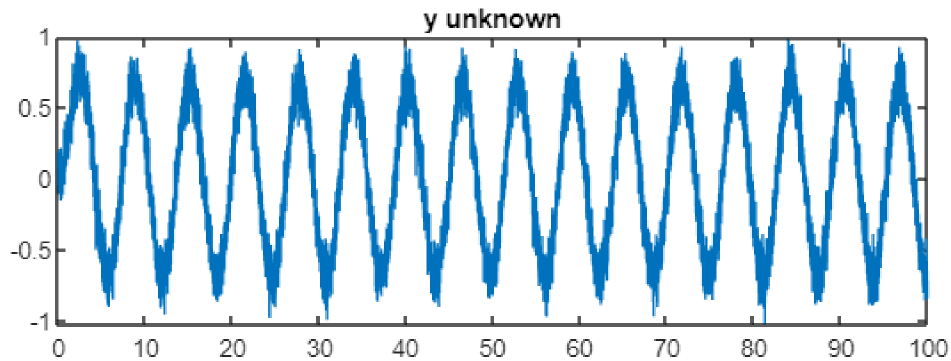
```
% t3 = out.tout;
% x3 = out.x;
% y3 = out.y;

figure
plot(t3,y3,t3,x3)
legend("y","u")
```

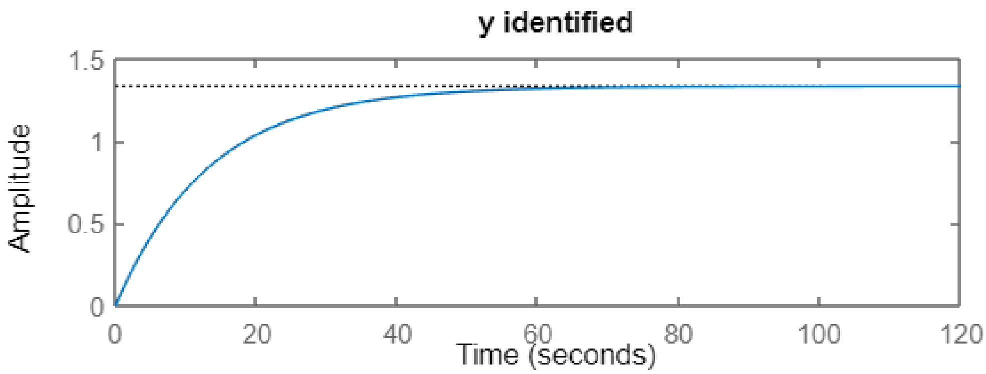



```
Gd = tf(tf4.Numerator , tf4.Denominator)
```

```
Gd =

    0.1006
  -----------
  s + 0.07537

Continuous-time transfer function.
```

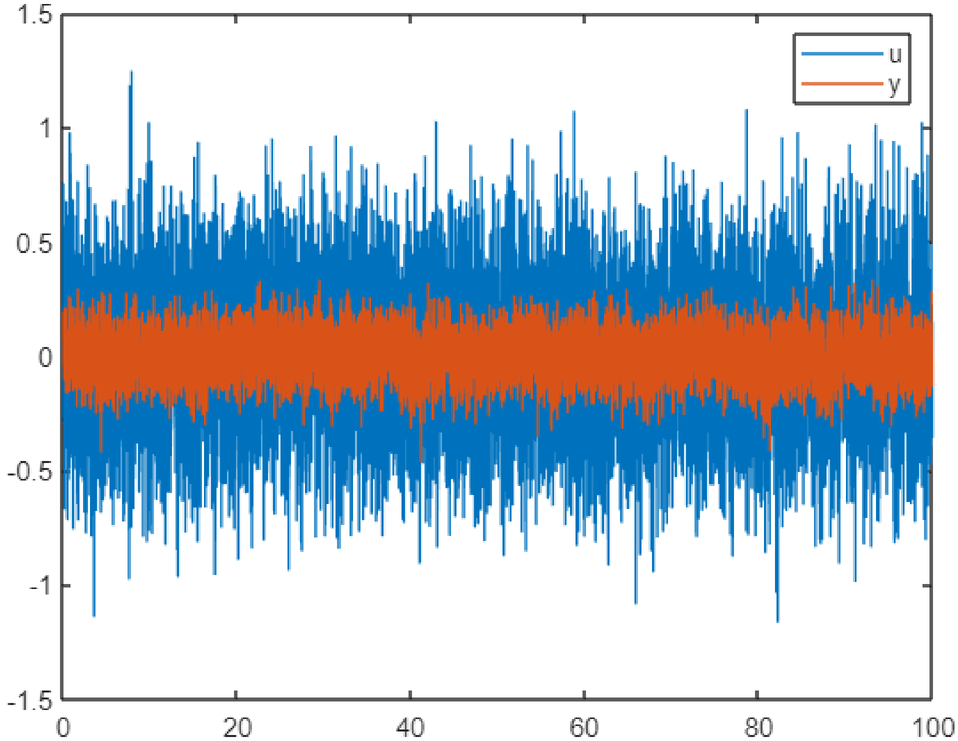
```
figure
subplot(2,1,1)
plot(t3,y3)
title("y unknown")
subplot(2,1,2)
step(Gd)
title("y identified")
```





e)

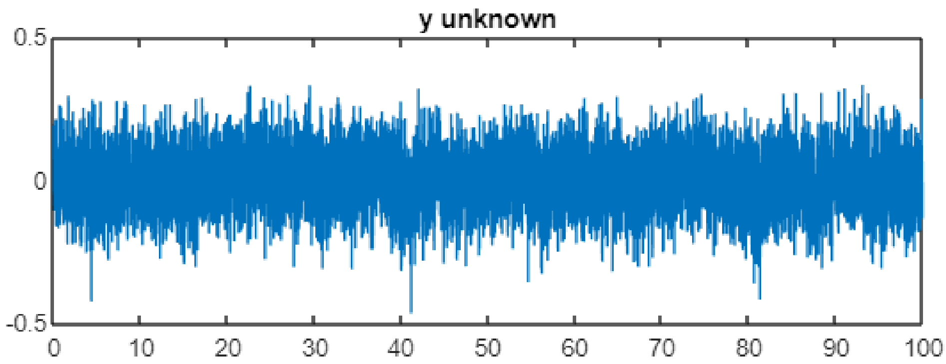
```
% t4 = out.tout;
% x4 = out.x;
% y4 = out.y;

figure
plot(t4,x4,t4,y4)
legend("u","y")
```

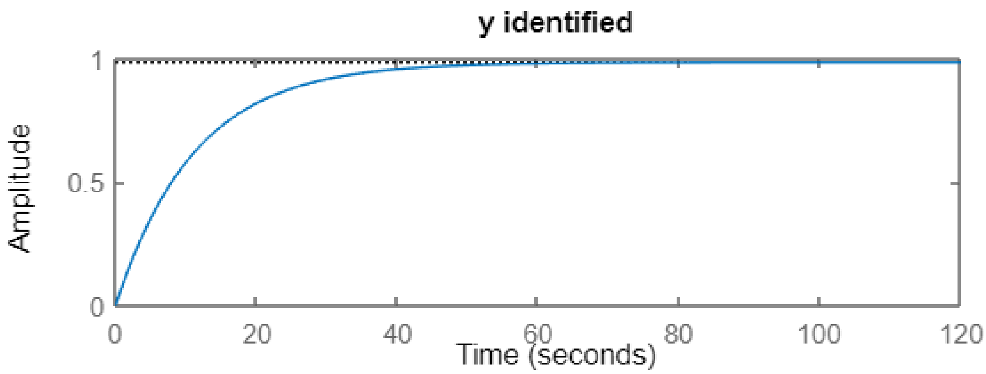



```
Ge = tf(tf5.Numerator , tf5.Denominator)
```

```
Ge =

    0.08783
  -----------
  s + 0.08898

Continuous-time transfer function.
```

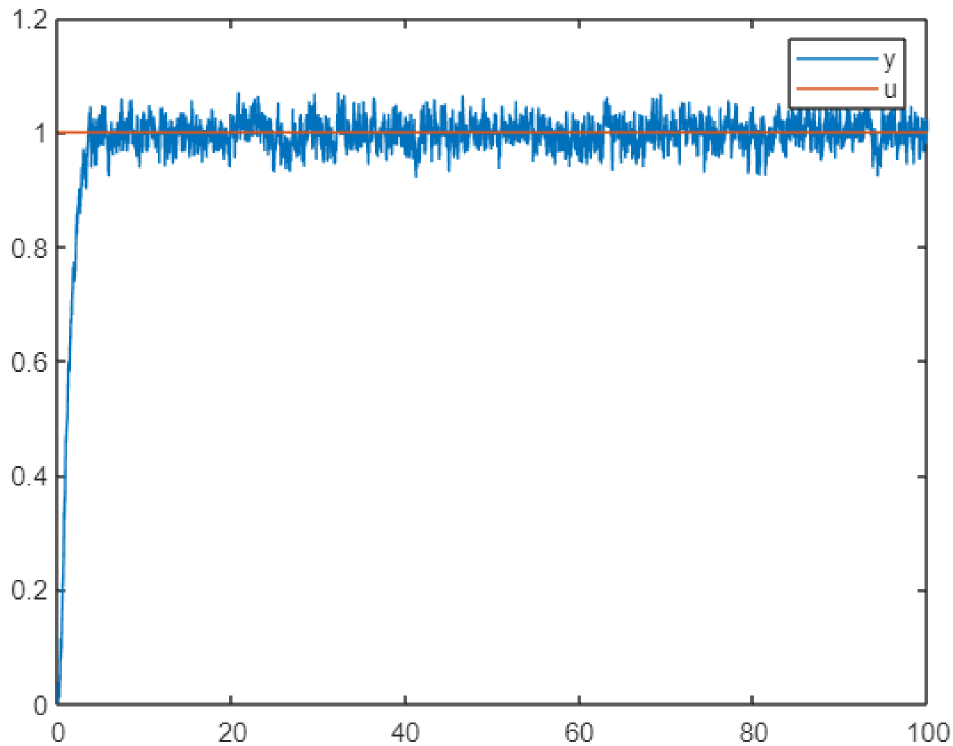
```
figure
subplot(2,1,1)
plot(t4,y4)
title("y unknown")
subplot(2,1,2)
step(Ge)
title("y identified")
```





f)

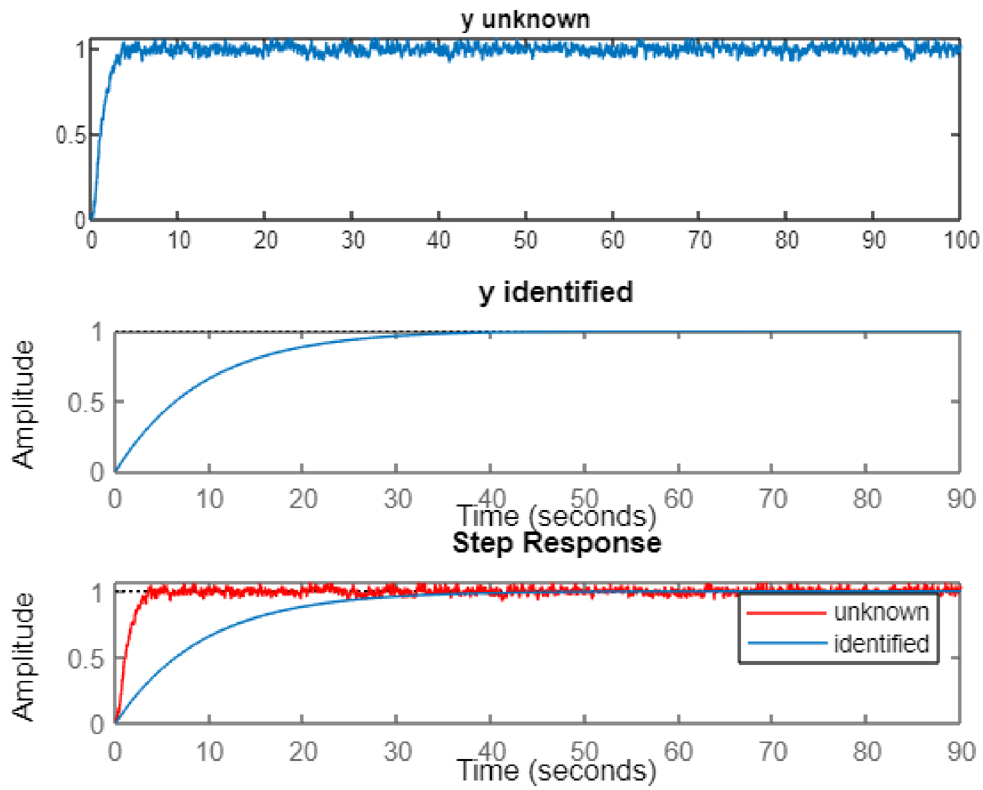
```
% t5 = out.tout;
% x5 = out.x;
% y5 = out.y;

figure
plot(t5,y5,t5,x5)
legend("y","u")
```




```
Gf = tf(tf6.Numerator , tf6.Denominator)
```

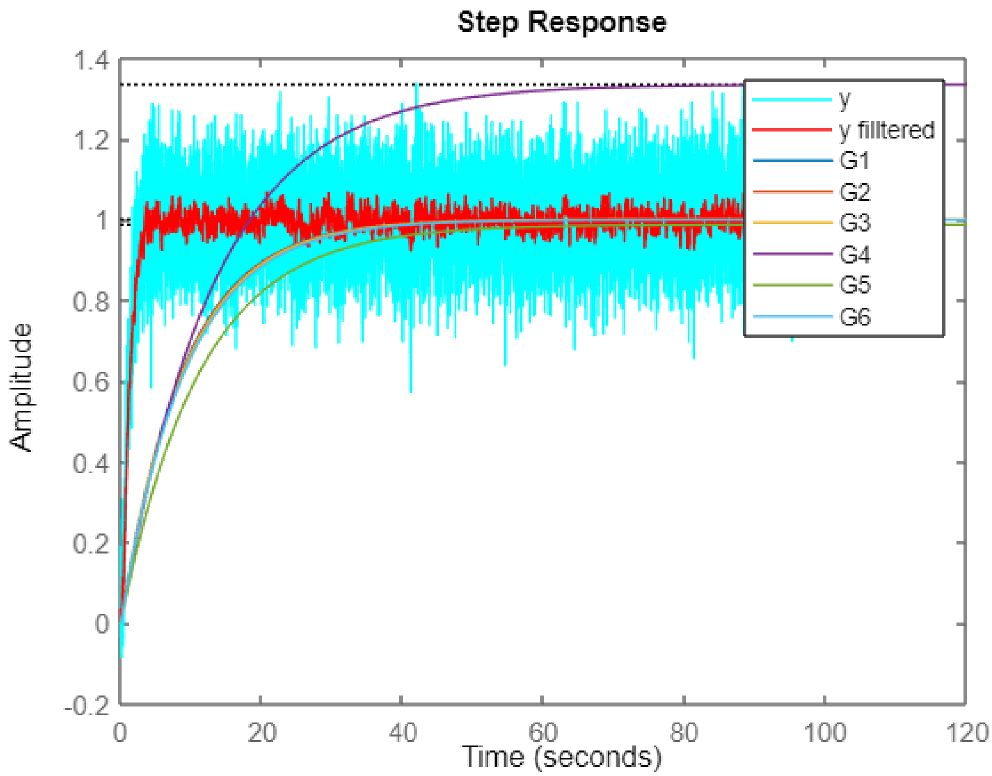
```
Gf =

    0.1076
  ----------
  s + 0.1077

Continuous-time transfer function.
```

```
figure
subplot(3,1,1)
plot(t5,y5)
title("y unknown")
subplot(3,1,2)
step(Gf)
title("y identified")
subplot(3,1,3)
hold on
plot(t5,y5,"Color","r")
step(Gf)
legend("unknown","identified")
```



g)

```
G1 = tf(tf1.Numerator , tf1.Denominator);
G2 = tf(tf2.Numerator , tf2.Denominator);
G3 = tf(tf3.Numerator , tf3.Denominator);
G4 = tf(tf4.Numerator , tf4.Denominator);
G5 = tf(tf5.Numerator , tf5.Denominator);
G6 = tf(tf6.Numerator , tf6.Denominator);

close all
hold on
plot(t,y,'c')
plot(t5,y5,'r')
step(G1)
step(G2)
step(G3)
step(G4)
step(G5)
step(G6)
legend("y","y filltered","G1","G2","G3","G4","G5","G6")
```

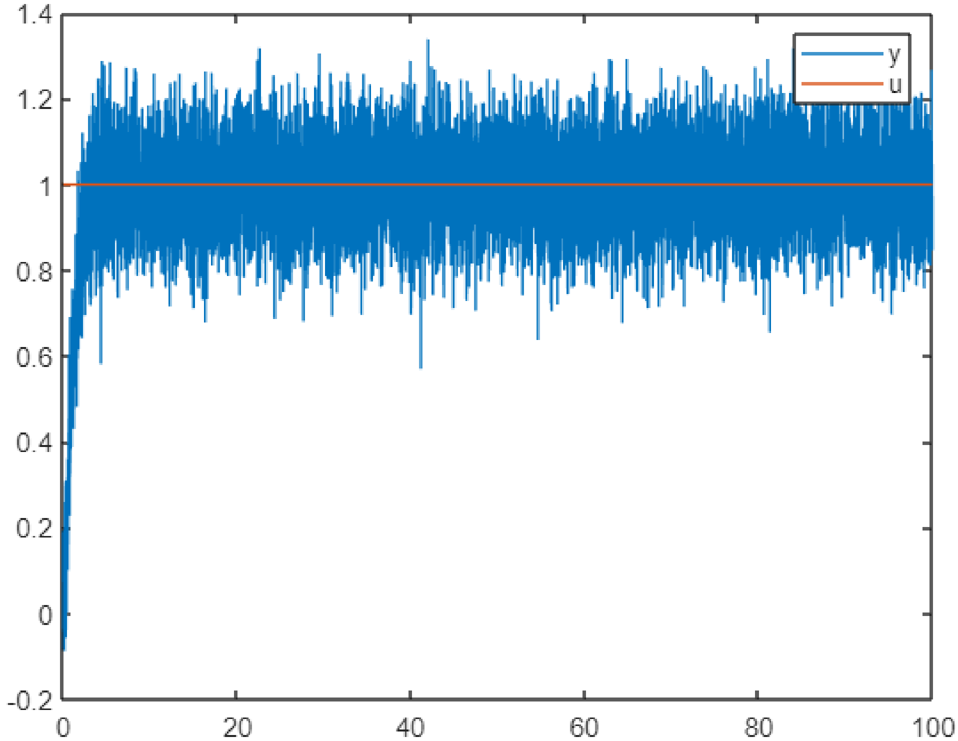


Except for the two approximations G5 and G4, the other approximations have the same and better performance.

h)

the best method is G1(part b):

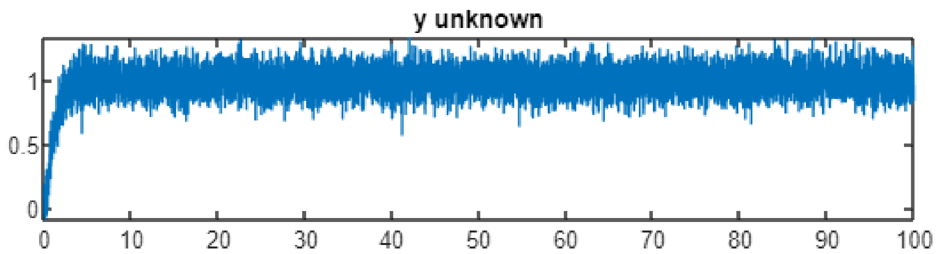
```
figure
plot(t,y,t,x)
legend("y","u")
```

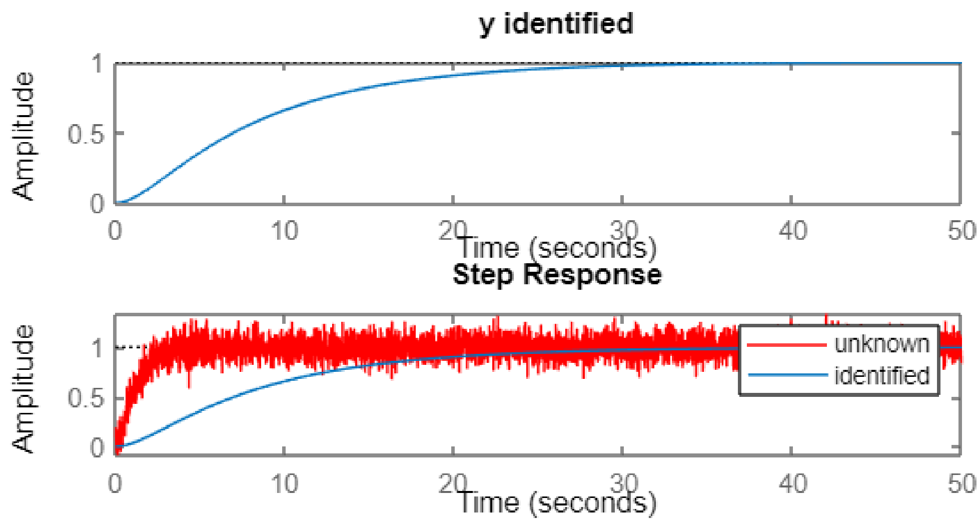



```
Gh = tf(tf7.Numerator , tf7.Denominator)
```

```
Gh =

          0.08766
  ------------------------
  s^2 + 0.8126 s + 0.08775

Continuous-time transfer function.
```

```
figure
subplot(3,1,1)
plot(t,y)
title("y unknown")
subplot(3,1,2)
step(Gh)
title("y identified")
subplot(3,1,3)
hold on
plot(t,y,"Color","r")
step(Gh)
legend("unknown","identified")
```






```
function [u] = Step01(C)
u = C;
s = length(C);
for i=1:s
    if C(i)>=0
        u(i)=1;
    else
        u(i)=0;
    end
end
end
function [u] = Step00(C)
u = C;
s = length(C);
for i=1:s
    if C(i)>0
        u(i)=1;
    else
        u(i)=0;
    end
end
end
```