



Turbidostat Response (TURBCON)



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Model



- Schematic diagram

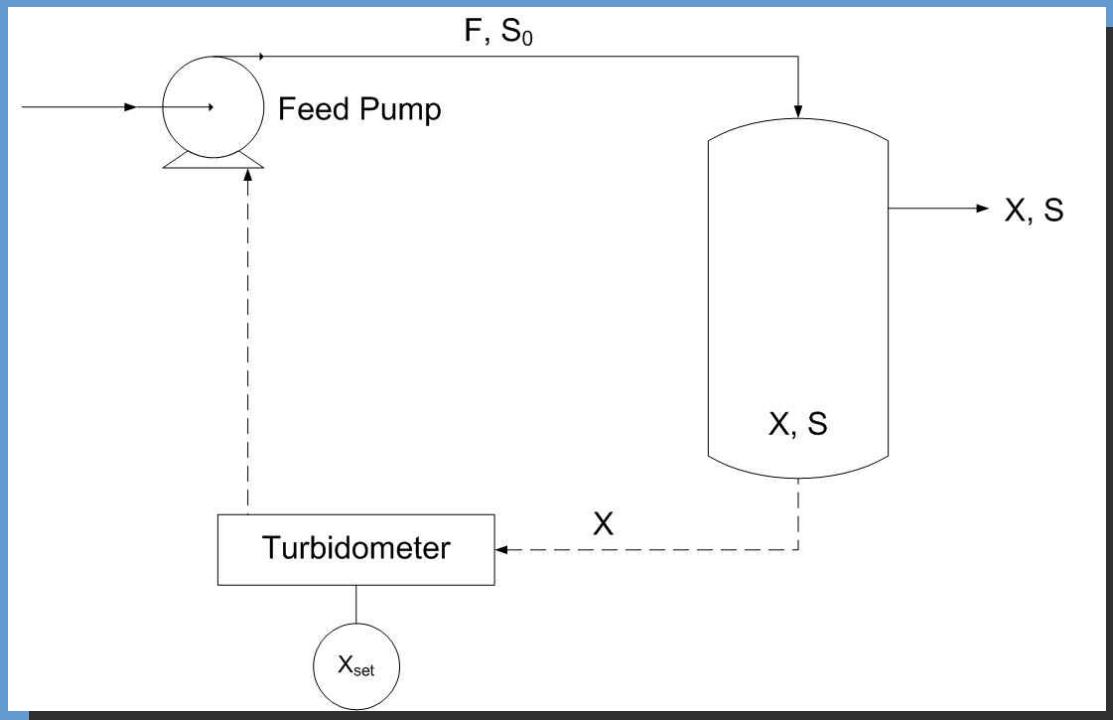


Fig. 1. Feedback control of the biomass concentration using a Turbidostat.



Model



• Dream CNU •

- For the well-mixed tank with Monod growth

$$\mu = \frac{\mu_m S}{K_s + S}$$

$$\frac{dS}{dt} = \frac{F(S_0 - S)}{V} - \frac{\mu X}{Y}$$
$$\frac{dX}{dt} = -\frac{FX}{V} + \mu X$$

➤ Luedeking-Piret kinetics

$$\frac{dP}{dt} = -\frac{FP}{V} + (B + \mu A)X$$

➤ PI control

$$F = F_0 + K_p \varepsilon + \frac{K_p}{\tau_I} \int \varepsilon dt$$

$$\varepsilon = (X - X_{set})$$



Model



Dream CNU

Symbols

A	Growth-associated constant	-
B	Nongrowth-associated constant	1/h
F	Flow rate	m ³ /h
F ₀	Normal feed flow rate	m ³ /h
K _P	Proportional controller constant	m ⁶ /(h·kg)
K _S	Saturation constant	Kg/m ³
P	Product concentration	Kg/m ³
S	Substrate concentration	Kg/m ³
V	Reactor Volume	m ³
X	Biomass concentration	Kg/m ³
Y	Yield coefficient	Kg /kg
τ _I	Integral control time constant	h

Indices

m	Refers to maximum
P	Refers to proportional control
S and set	Refers to setpoint
0	Refers to inlet stream



Programming Source



Dream CNU

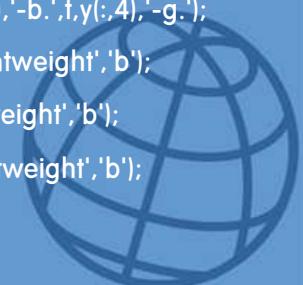
M-file

```
• function dydt=TURBCON(t,y)
• clc;
• UM=0.5; KS=0.1;      Y=0.8;
• V=1;      S0=5;       TI=10;      %Constant
• F0=0.2;   KP=0.25;    A=0.2;
• B=0.15;   XS=2.0;
• if (y(2)<0)
•     y(2)=0;
• end;
• U=UM*y(2)/(KS+y(2));
• E=y(1)-XS;           % Error
• F=F0+KP*E+KP/TI*E*t;
• y1=y(1);             % y1=X
• y2=y(2);             % y2=S
• y3=y(3);             % y3=P
• dydt=[-F*y(1)/V+U*y(1);
•       F*(S0-y(2))/V-U*y(1)/Y;
•       -F*y(3)/V+A*U*y(1)+B*y(1)];
```

Command

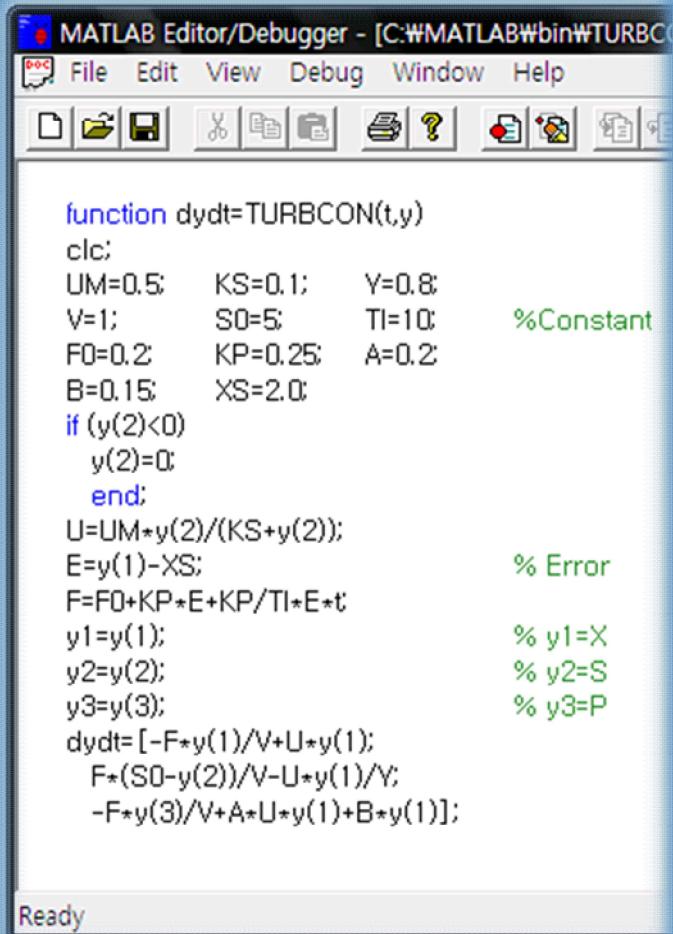
```
• y0=[1.5,1];
• t0=0;tf=20.0;
• [t,y]=ode45('TURBCON',t0:0.01:tf,y0);
• plot(t,y(:,1),'-r.',t,y(:,2),'-k.',t,y(:,3),'-b.');
• title('TURBCON','fontsize',16,'fontweight','b');
• xlabel('TIME','fontsize',12,'fontweight','b');
• ylabel('X,S,P','fontsize',12,'fontweight','b');
• h=legend('X','S','P',0);
• set(h,'fontsize',8);

• y0=[1.5,1,0.2];
• t0=0;tf=40.0;
• [t,y]=ode45('TURBCON',t0:0.01:tf,y0);
• plot(t,y(:,1),'-r.',t,y(:,2),'-k.',t,y(:,3),'-b.',t,y(:,4),'-g.');
• title('TURBCON','fontsize',16,'fontweight','b');
• xlabel('TIME','fontsize',12,'fontweight','b');
• ylabel('X,S,P,F','fontsize',12,'fontweight','b');
• h=legend('X','S','P','F',0);
• set(h,'fontsize',8);
```

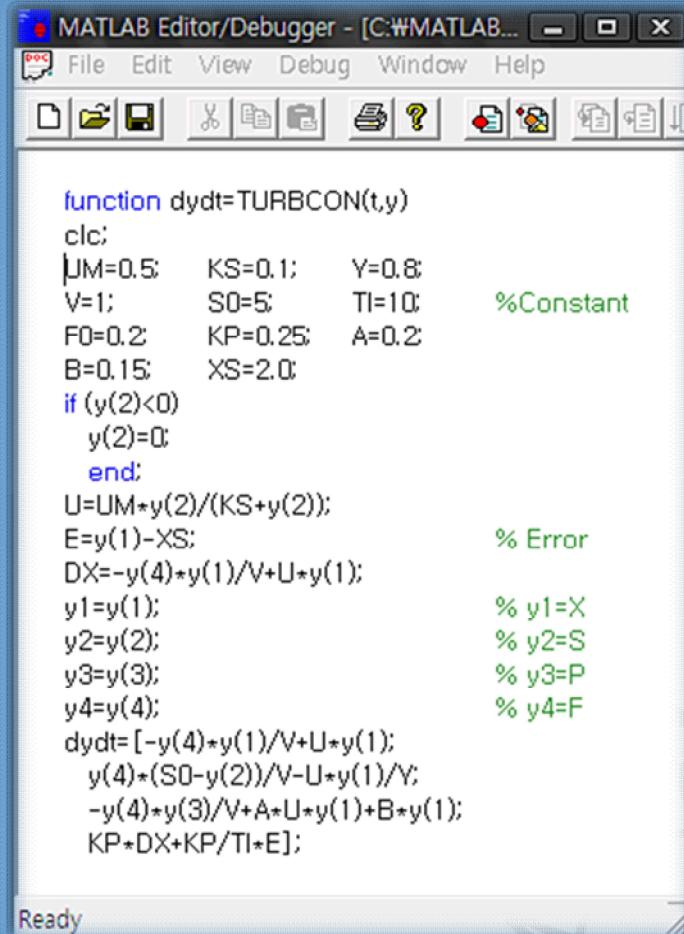


Matlab Programming

- M-file



```
function dydt=TURBCON(t,y)
clc;
UM=0.5; KS=0.1; Y=0.8;
V=1; S0=5; TI=10; %Constant
F0=0.2; KP=0.25; A=0.2;
B=0.15; XS=2.0;
if (y(2)<0)
    y(2)=0;
end;
U=UM*y(2)/(KS+y(2));
E=y(1)-XS; % Error
F=F0+KP*E+KP/TI*E*t;
y1=y(1); % y1=X
y2=y(2); % y2=S
y3=y(3); % y3=P
dydt=[-F*y(1)/V+U*y(1);
      F*(S0-y(2))/V-U*y(1)/Y;
      -F*y(3)/V+A*U*y(1)+B*y(1)];
```

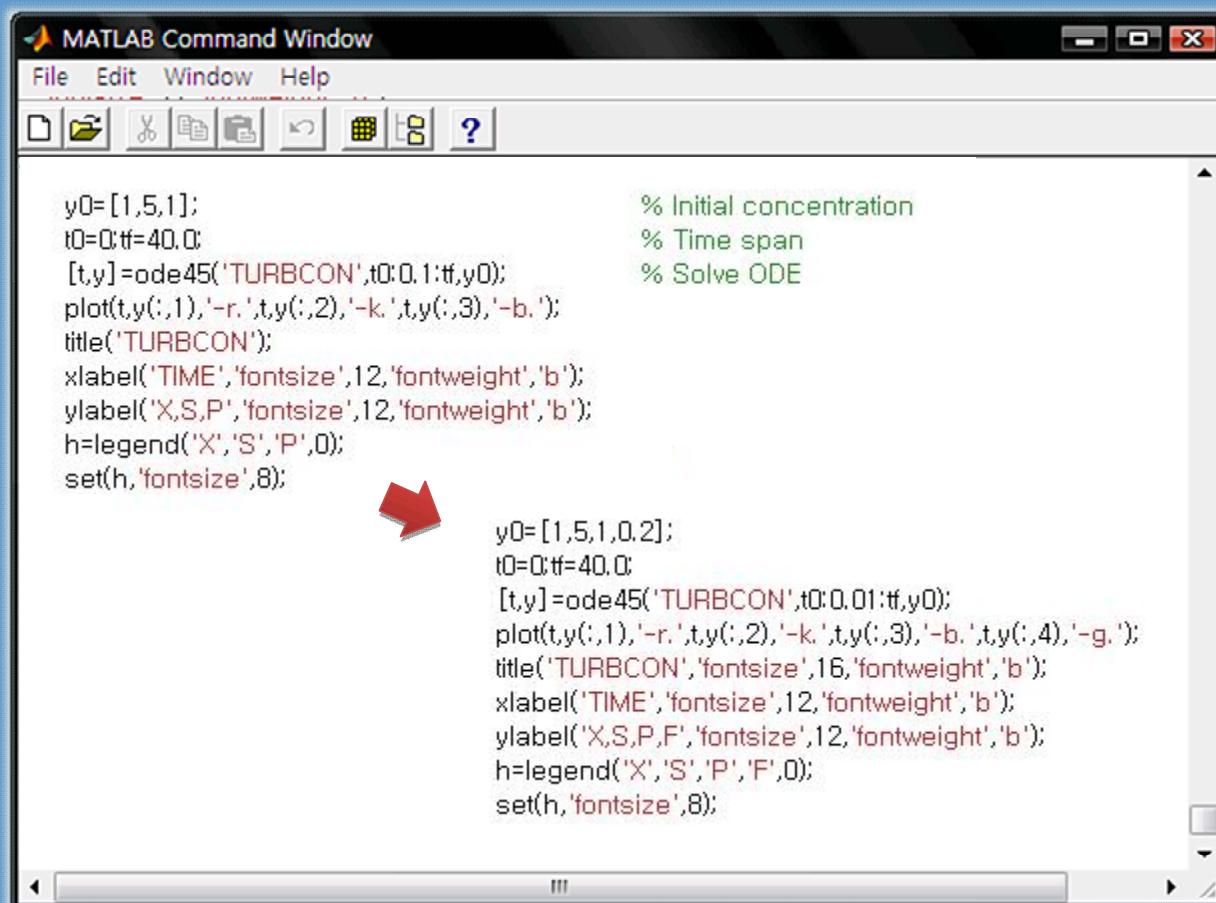


```
function dydt=TURBCON(t,y)
clc;
UM=0.5; KS=0.1; Y=0.8;
V=1; S0=5; TI=10; %Constant
F0=0.2; KP=0.25; A=0.2;
B=0.15; XS=2.0;
if (y(2)<0)
    y(2)=0;
end;
U=UM*y(2)/(KS+y(2));
E=y(1)-XS; % Error
DX=-y(4)*y(1)/V+U*y(1);
y1=y(1); % y1=X
y2=y(2); % y2=S
y3=y(3); % y3=P
y4=y(4); % y4=F
dydt=[-y(4)*y(1)/V+U*y(1);
      y(4)*(S0-y(2))/V-U*y(1)/Y;
      -y(4)*y(3)/V+A*U*y(1)+B*y(1);
      KP*DX+KP/TI*E];
```



Matlab Programming

- Command



A screenshot of the MATLAB Command Window. The window title is "MATLAB Command Window". The menu bar includes File, Edit, Window, and Help. The toolbar contains icons for file operations like Open, Save, and Print. The code in the command window is:

```
y0=[1,5,1]; % Initial concentration
t0=0;tf=40.0; % Time span
[t,y]=ode45('TURBCON',t0:0.1:tf,y0); % Solve ODE
plot(t,y(:,1),'-r.',t,y(:,2),'-k.',t,y(:,3),'-b.');
title('TURBCON');
xlabel('TIME','fontsize',12,'fontweight','b');
ylabel('X,S,P','fontsize',12,'fontweight','b');
h=legend('X','S','P',0);
set(h,'fontsize',8);
```

An arrow points from the bottom of the first code block to the top of the second code block, indicating a modification or continuation.

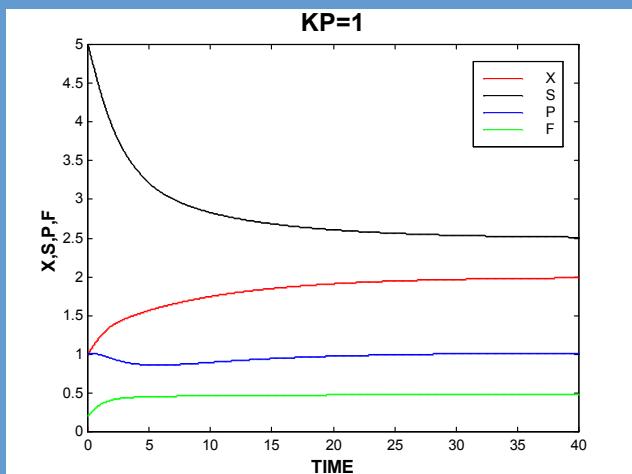
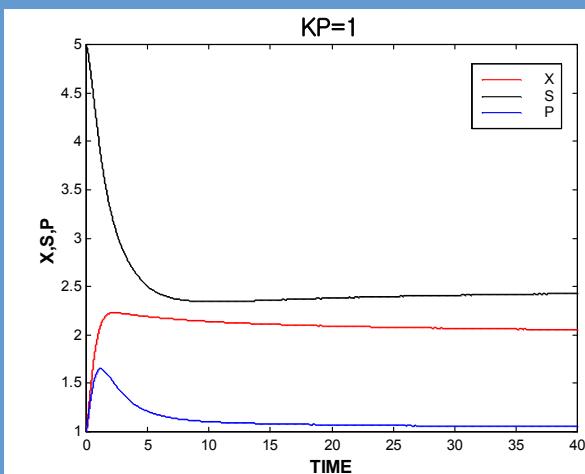
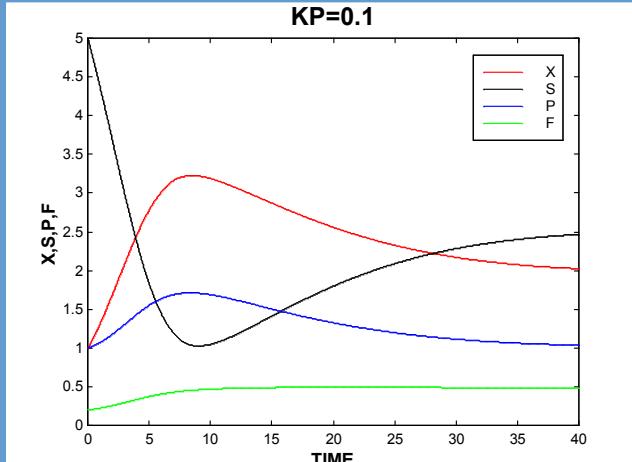
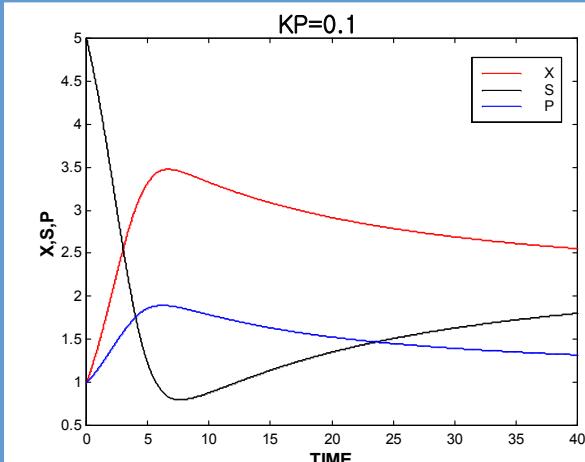
```
y0=[1,5,1,0.2];
t0=0;tf=40.0;
[t,y]=ode45('TURBCON',t0:0.01:tf,y0);
plot(t,y(:,1),'-r.',t,y(:,2),'-k.',t,y(:,3),'-b.',t,y(:,4),'-g.');
title('TURBCON','fontsize',16,'fontweight','b');
xlabel('TIME','fontsize',12,'fontweight','b');
ylabel('X,S,P,F','fontsize',12,'fontweight','b');
h=legend('X','S','P','F',0);
set(h,'fontsize',8);
```



Changing Parameters



- Set K_p in the range 0.1 to 1

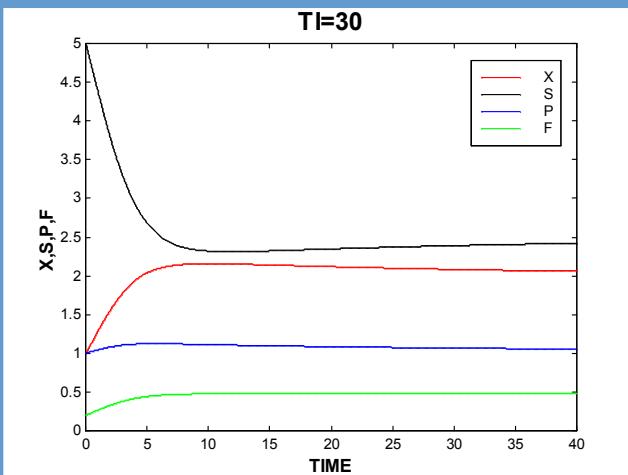
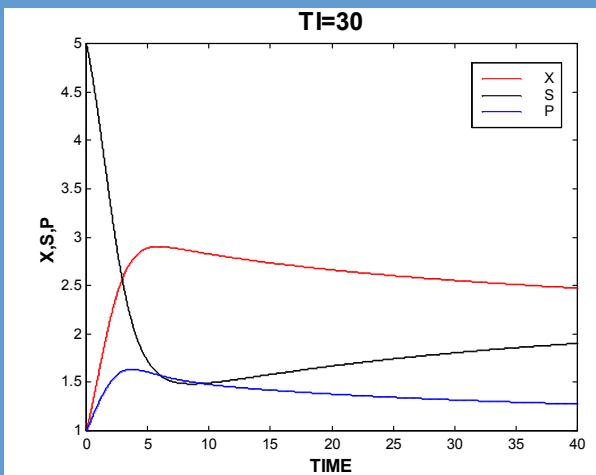
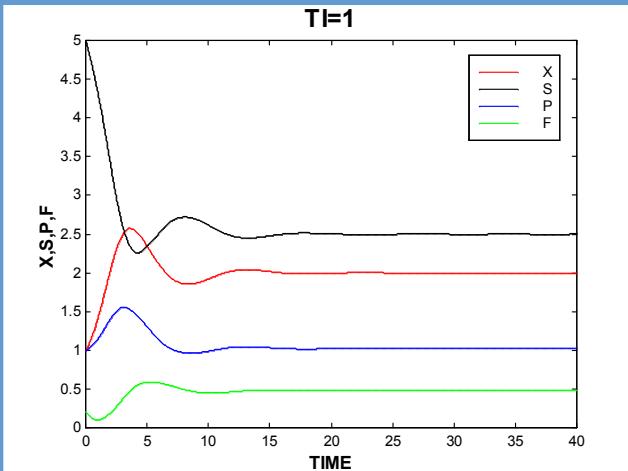
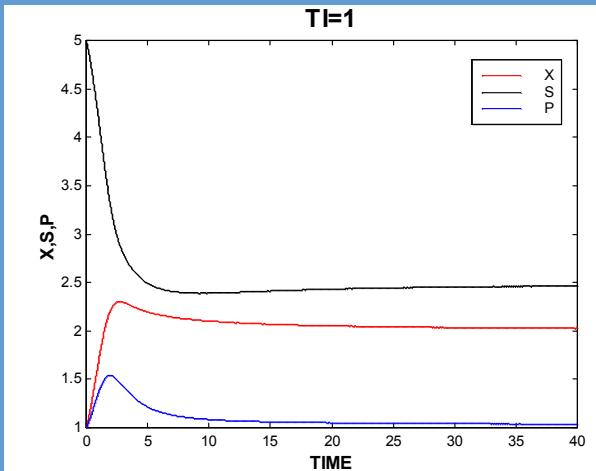


Changing Parameters



Dream CNU

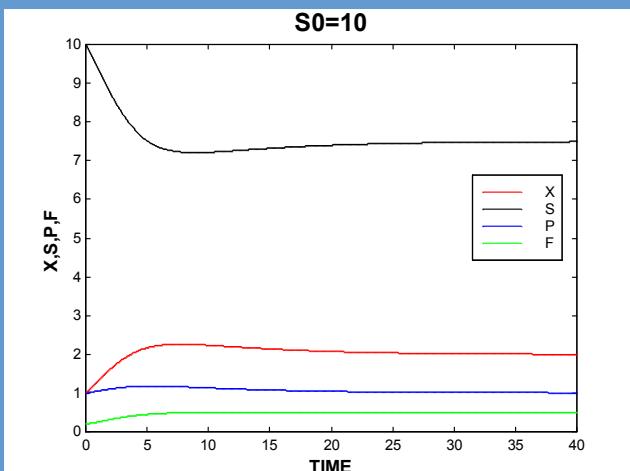
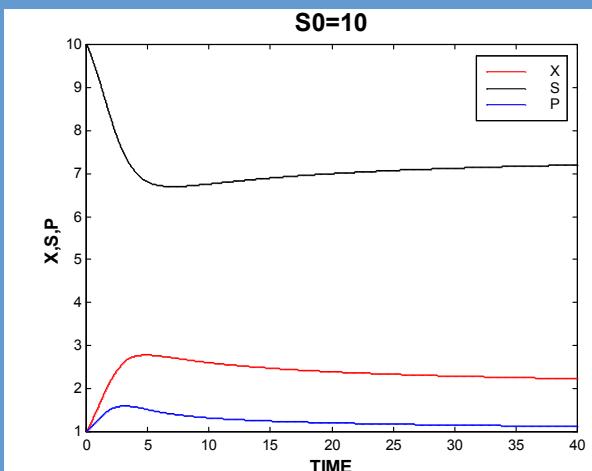
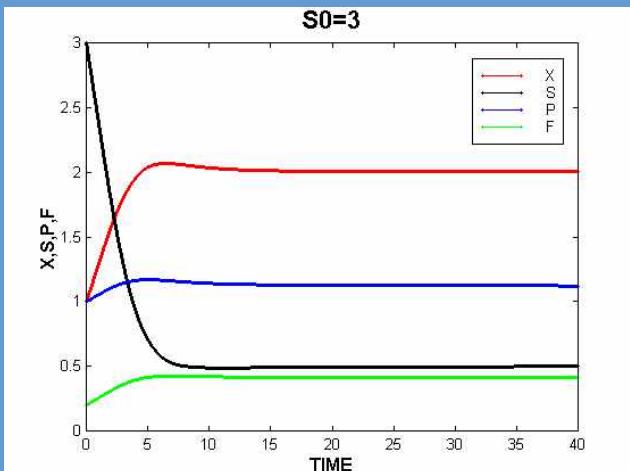
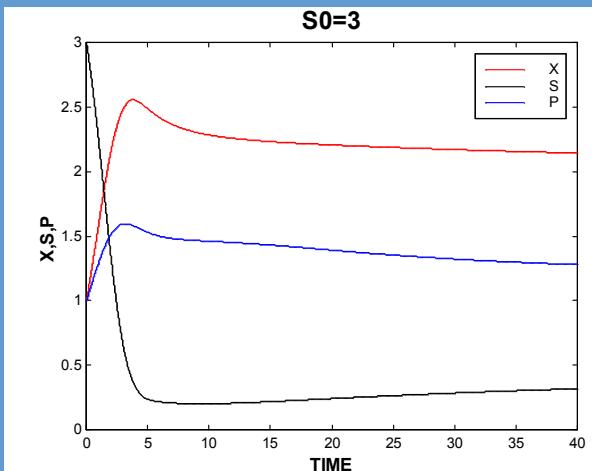
- Vary τ_1 in the range 1 to 30



Changing Parameters



- Vary S_0 in the range 3 to 10



Conclusion



• Dream CNU •

- K_p 의 값이 클수록, τ_I 값이 작을 수록 최종값에 빨리 도달한다.
- S_0 의 양이 많아질수록 반응 용기의 기질의 농도는 증가하나 생성물 농도(P)와 생장 농도(X) 변화에는 거의 영향을 미치지 않는다.

