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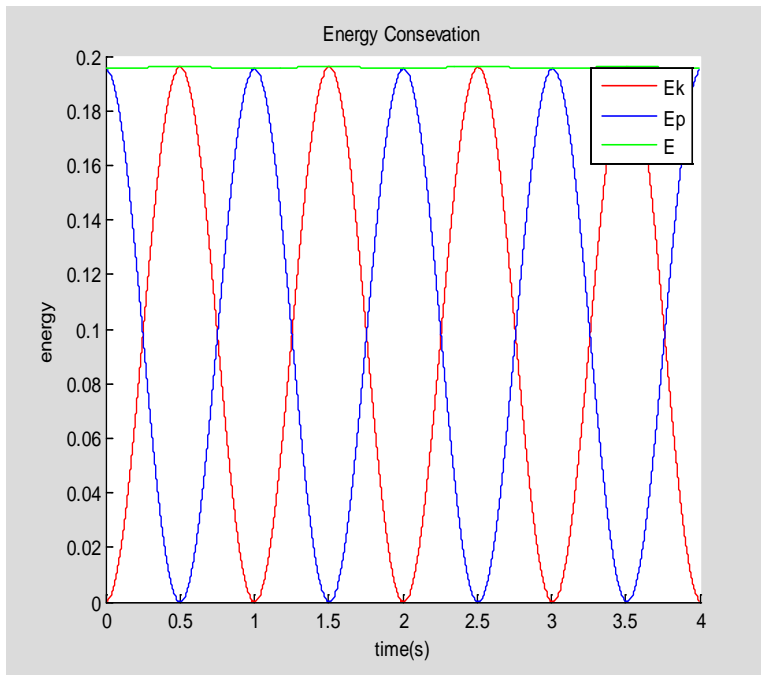
3.1

```
clear
p=0;q=4;h=0.00001;n=(q-p)/h;
theta(1)=0.2;omg(1)=0;
t(1)=0;g=9.8;l=1;
for k=1:1:n
omg(k+1)=omg(k)-(g/l)*theta(k)*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
end
Ep=(1-cos(theta)).*l.*g;
Ek=0.5.*(omg.*l).^2;
```

```

E=Ep+Ek;
hold on
plot(t,Ek,'r')
plot(t,Ep,'b')
plot(t,E,'g')
xlabel('time(s)')
ylabel('energy')
legend('Ek','Ep','E')
title('Energy Consevation')

```



可见尽管能量基本守恒，但还会存在一些波动。如果用 Verlet 法则可以完全避免这种波动。

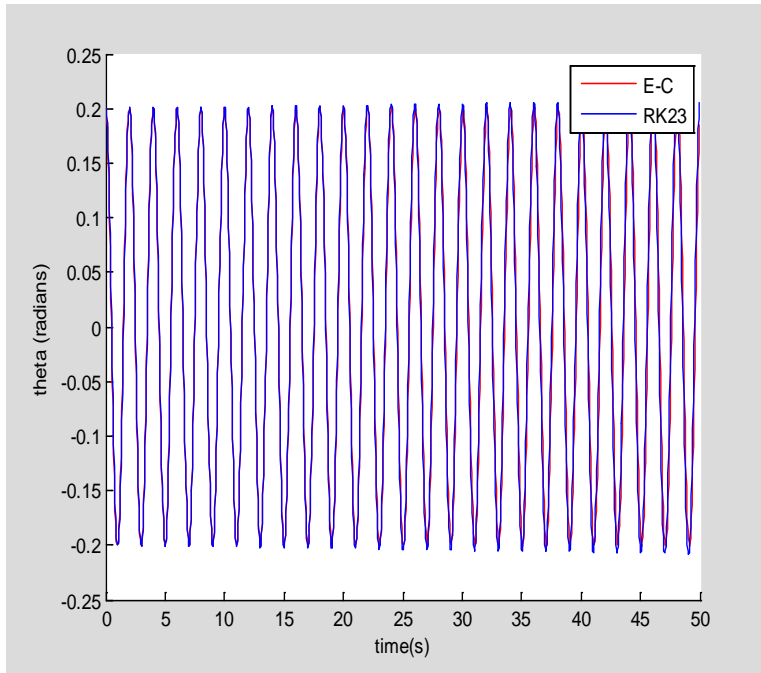
3.2

```

clear
p=0;q=50;h=0.04;n=(q-p)/h;
theta(1)=0.2;omg(1)=0;t(1)=0;
rktheta(1)=0.2;rkomg(1)=0;
g=9.8;l=1;
for k=1:1:n
omg(k+1)=omg(k)-(g/l)*theta(k)*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
end
for k=1:1:n
theta_=rktheta(k)+1/2*rkomg(k)*h;
omg_=rkomg(k)-1/2*(g/l)*rktheta(k)*h;
rktheta(k+1)=rktheta(k)+omg_*h;
rkomg(k+1)=rkomg(k)-(g/l)*theta_*h;
t(k+1)=t(k)+h;
end
hold on
plot(t,theta,'r')
plot(t,rktheta)
xlabel('time(s)')

```

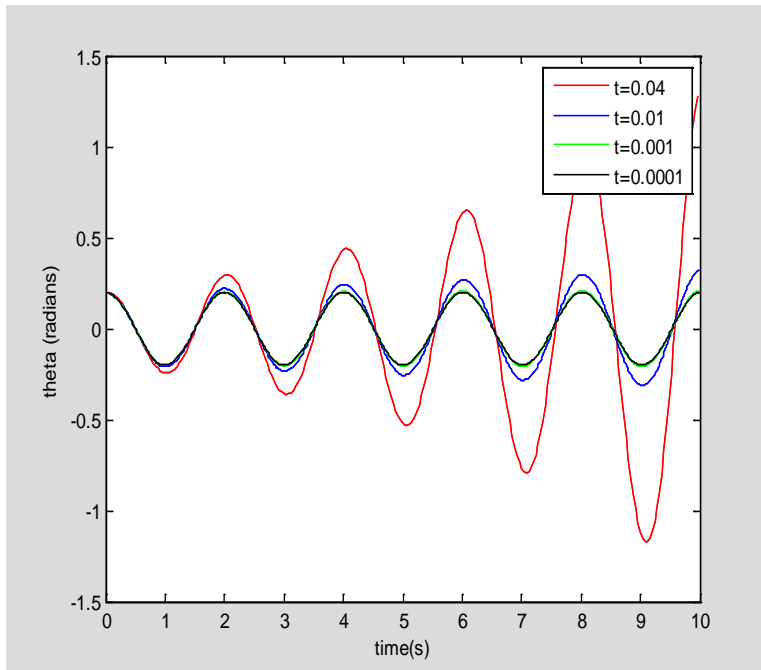
```
ylabel('theta (radians)')
legend('E-C', 'RK23')
```



可见二阶龙格库塔法很短时间内也会显示出能量增长的趋势。

3.3

```
clear
p=0;q=10;h=[0.04 0.01 0.001 0.0001];
theta(1:4,1)=0.2;omg(1:4,1)=0;t(1:4,1)=0;
g=9.8;l=1;
for kk=1:1:4
n(kk)=(q-p)/h(kk);
for k=1:1:n(kk)
omg(kk,k+1)=omg(kk,k)-(g/l)*theta(kk,k)*h(kk);
theta(kk,k+1)=theta(kk,k)+omg(kk,k)*h(kk);
t(kk,k+1)=t(kk,k)+h(kk);
end
end
hold on
plot(t(1,1:n(1)),theta(1,1:n(1)),'r')
plot(t(2,1:n(2)),theta(2,1:n(2)),'b')
plot(t(3,1:n(3)),theta(3,1:n(3)),'g')
plot(t(4,1:n(4)),theta(4,1:n(4)),'k')
hold off
xlabel('time(s)')
ylabel('theta (radians)')
legend('t=0.04','t=0.01','t=0.001','t=0.0001')
box on
```

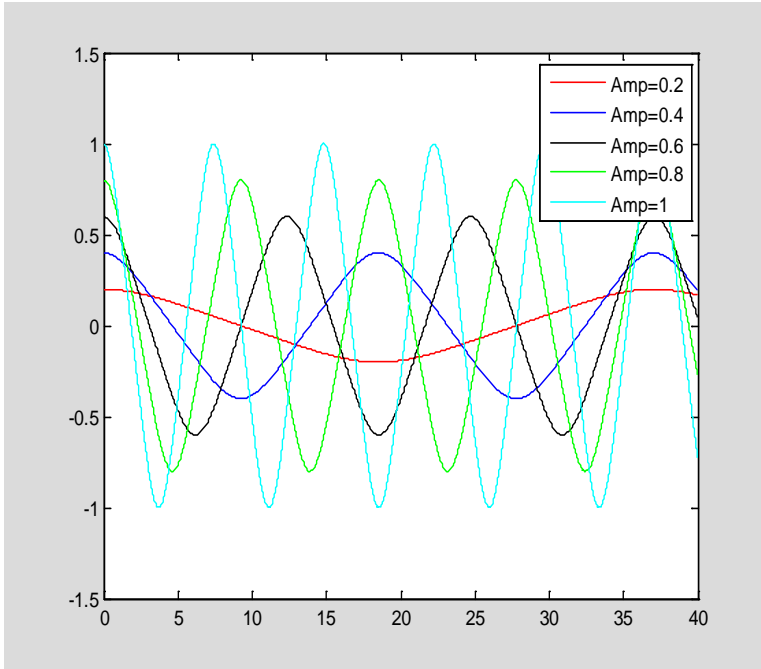


3.4

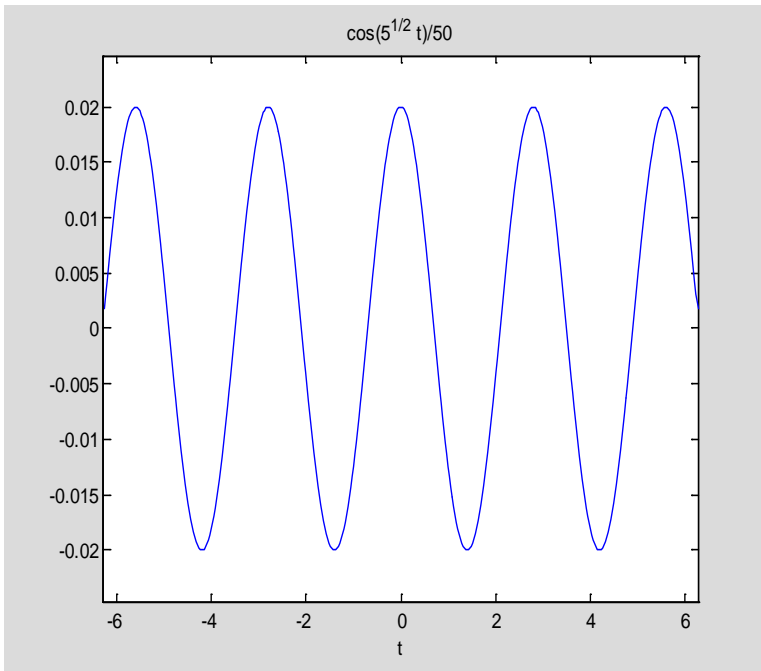
```

clear
disp('when alpha=3, amplitude decreases as periode se prolonger ')
p=0;q=40;h=0.01;n=(q-p)/h;
k=1;alpha=3;
x(1,1:5)=[0.2 0.4 0.6 0.8 1];v(1,1:5)=0;t(1,1:5)=0;
for ii=1:1:5
for kk=1:1:n
v(kk+1,ii)=v(kk,ii)-k*x(kk,ii)^alpha*h;
x(kk+1,ii)=x(kk,ii)+v(kk+1,ii)*h;
t(kk+1,ii)=t(kk,ii)+h;
end
end
hold on
plot(t(1:n,1),x(1:n,1),'r')
plot(t(1:n,2),x(1:n,2),'b')
plot(t(1:n,3),x(1:n,3),'k')
plot(t(1:n,4),x(1:n,4),'g')
plot(t(1:n,5),x(1:n,5),'c')
hold off
legend('Amp=0.2','Amp=0.4','Amp=0.6','Amp=0.8','Amp=1')
box on
  
```

when alpha=3, amplitude decreases as periode se prolonger



```
y=dsolve('D2y+5*y^1=0','y(0)=0.02,Dy(0)=0','t');
ezplot(y)
```

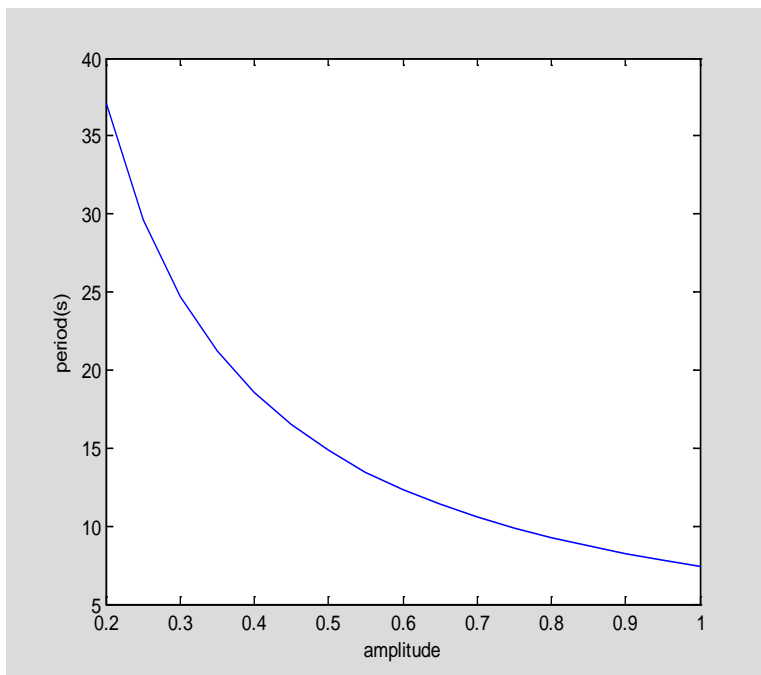


```
3.5
clear
p=0;
q=60;
h=0.01;
n=(q-p)/h;
```

```

k=1;
alpha=3;
x(1,1:17)=0.2:0.05:1;
v(1,1:17)=0;
t(1,1:17)=0;
for ii=1:1:17
    jj=1;
    for kk=1:1:n
        v(kk+1,ii)=v(kk,ii)-k*x(kk,ii)^alpha*h;
        x(kk+1,ii)=x(kk,ii)+v(kk+1,ii)*h;
        t(kk+1,ii)=t(kk,ii)+h;
        if (jj==1)&(v(kk,ii)>0&v(kk+1,ii)<0)
            T(ii)=t(kk,ii);
        end
        jj=jj+1;
    end
end
end
plot(x(1,1:17),T)
box on;
xlabel('amplitude')
ylabel('period(s)')

```



3.6

```

clear
a=0;
b=10;
h=0.01;
n=(b-a)/h;
l=1;g=9.8;
q0=sqrt(4*g/l) %q0 即为临界阻尼值
q=[1 q0 10];
theta(1,1:3)=0.2;
omg(1,1:3)=0;

```

```

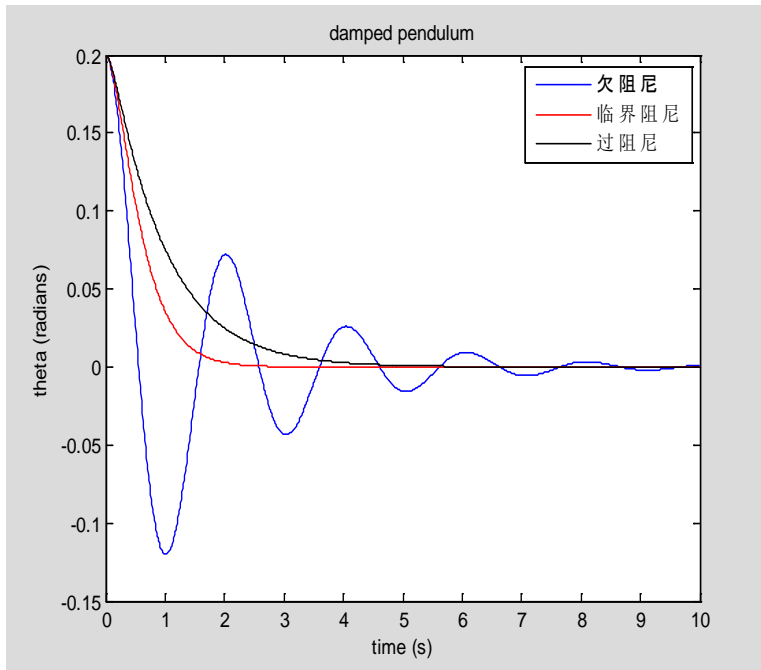
t(1,1:3)=0;
for k=1:1:3
for kk=1:1:n
omg(kk+1,k)=omg(kk,k)-g/l*theta(kk,k)*h-q(k)*omg(kk,k)*h;
theta(kk+1,k)=theta(kk,k)+omg(kk+1,k)*h;
t(kk+1,k)=t(kk,k)+h;
end
end
hold on
plot(t(1:n,1),theta(1:n,1),'b');
plot(t(1:n,2),theta(1:n,2),'r');
plot(t(1:n,3),theta(1:n,3),'k');
box on;
hold off
xlabel('time (s)')
ylabel('theta (radians)')
legend('欠阻尼','临界阻尼','过阻尼')
title('damped pendulum')

```

```

q0 =
    6.2610

```



3.7

振幅与 Omd 的关系

```

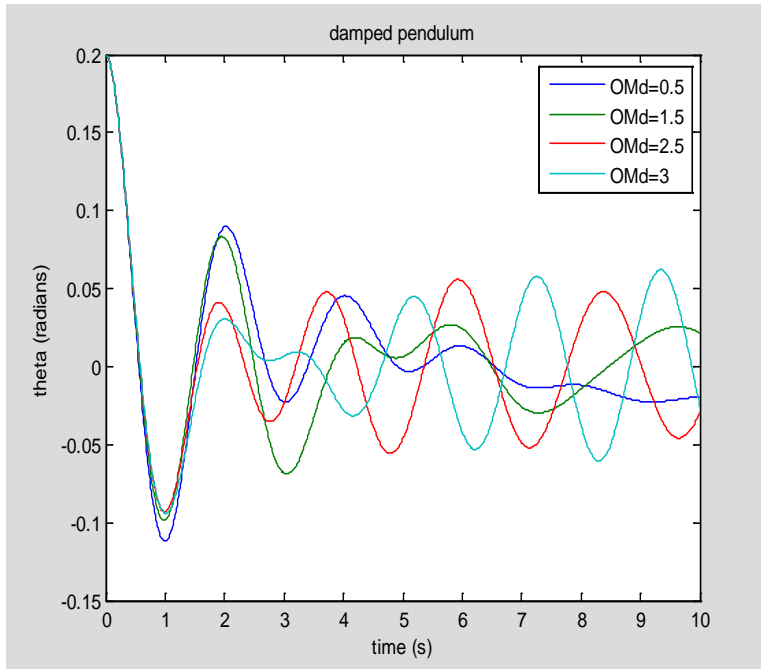
clear
a=0;b=10;h=0.01;n=(b-a)/h;
l=1;g=9.8;
fd=0.2;omgd=[0.5 1.5 2.5 3];
q=1;
theta(1,1:4)=0.2;omg(1,1:4)=0;t(1,1:4)=0;
for k=1:1:4
for kk=1:1:n

```

```

omg(kk+1,k)=omg(kk,k)-g/l*theta(kk,k)*h-
q*omg(kk,k)*h+fd*sin(omgd(k)*t(kk,k))*h;
theta(kk+1,k)=theta(kk,k)+omg(kk+1,k)*h;
t(kk+1,k)=t(kk,k)+h;
end
end
plot(t,theta)
xlabel('time (s)')
ylabel('theta (radians)')
title('damped pendulum')
legend('OMd=0.5','OMd=1.5','OMd=2.5','OMd=3')

```



振幅与 q 的关系

```

clear
a=0;b=10;h=0.01;n=(b-a)/h;
l=1;g=9.8;
fd=0.4;omgd=1;
q0=sqrt(4*g/l);
q=[1 :0.5 :3];
theta(1,1:5)=0.2;
omg(1,1:5)=0;
t(1,1:5)=0;
for k=1:1:5
for kk=1:1:n
omg(kk+1,k)=omg(kk,k)-g/l*theta(kk,k)*h-
q(k)*omg(kk,k)*h+fd*sin(omgd*t(kk,k))*h;
theta(kk+1,k)=theta(kk,k)+omg(kk+1,k)*h;
t(kk+1,k)=t(kk,k)+h;
end
end
plot(t,theta)
xlabel('time (s)')
ylabel('theta (radians)')

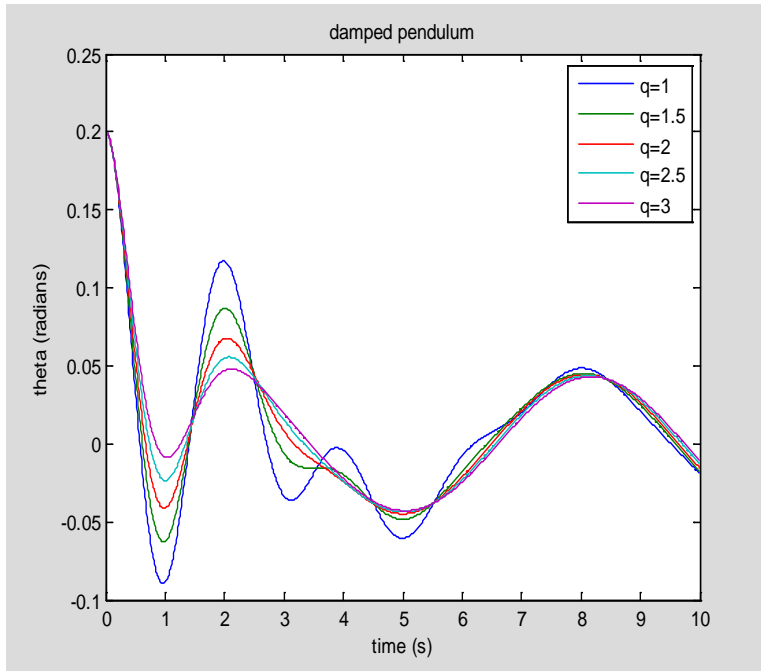
```



```

title('damped pendulum')
legend('q=1','q=1.5','q=2','q=2.5','q=3')

```



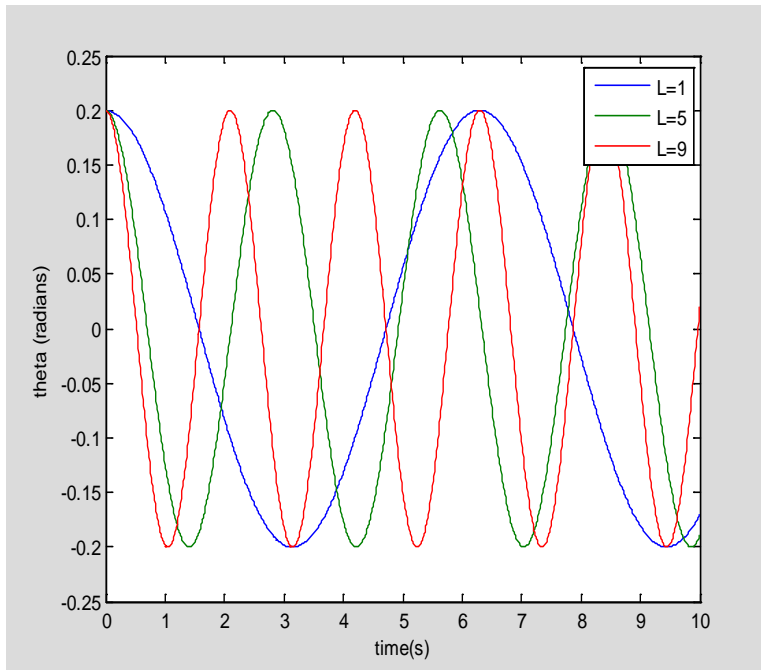
3.8

改变右端系数

```

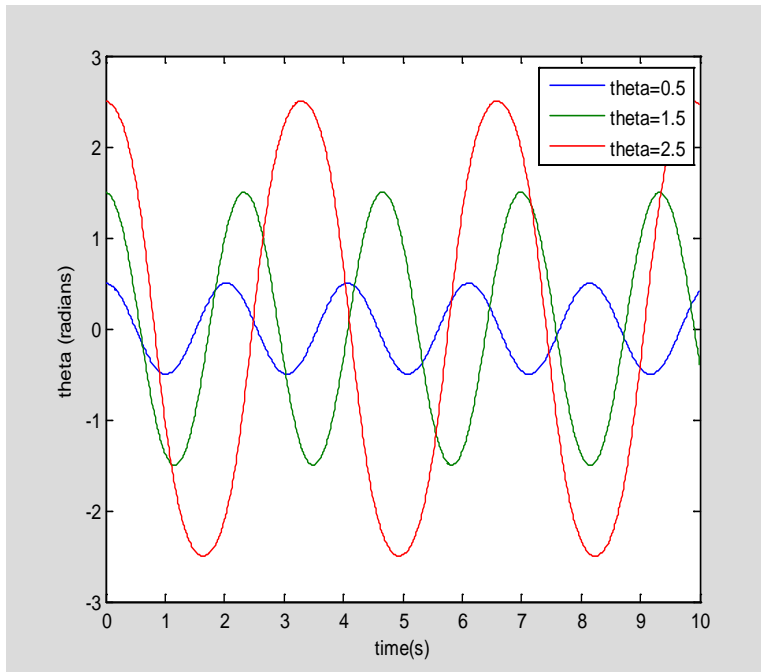
clear
a=0;b=10;h=0.01;n=(b-a)/h;
L=[1:4:9];theta(1,1:3)=0.2;omg(1,1:3)=0;t(1,1:3)=0;
for kk=1:1:3
for k=1:1:n
omg(k+1,kk)=omg(k,kk)-L(kk)*sin(theta(k,kk))*h;
theta(k+1,kk)=theta(k,kk)+omg(k+1,kk)*h;t(k+1,kk)=t(k,kk)+h;
end
end
plot(t,theta)
xlabel('time(s)')
ylabel('theta (radians)')
box on;
legend('L=1','L=5','L=9')

```



改变 theta

```
clear
a=0;b=10;h=0.01;n=(b-a)/h;
L=9.8;
theta(1,1:3)=[0.5:1:2.5];omg(1,1:3)=0;t(1,1:3)=0;
for kk=1:1:3
for k=1:1:n
omg(k+1,kk)=omg(k,kk)-L*sin(theta(k,kk))*h;
theta(k+1,kk)=theta(k,kk)+omg(k+1,kk)*h;
t(k+1,kk)=t(k,kk)+h;
end
end
plot(t,theta)
xlabel('time(s)')
ylabel('theta (radians)')
box on;
legend('theta=0.5','theta=1.5','theta=2.5')
```

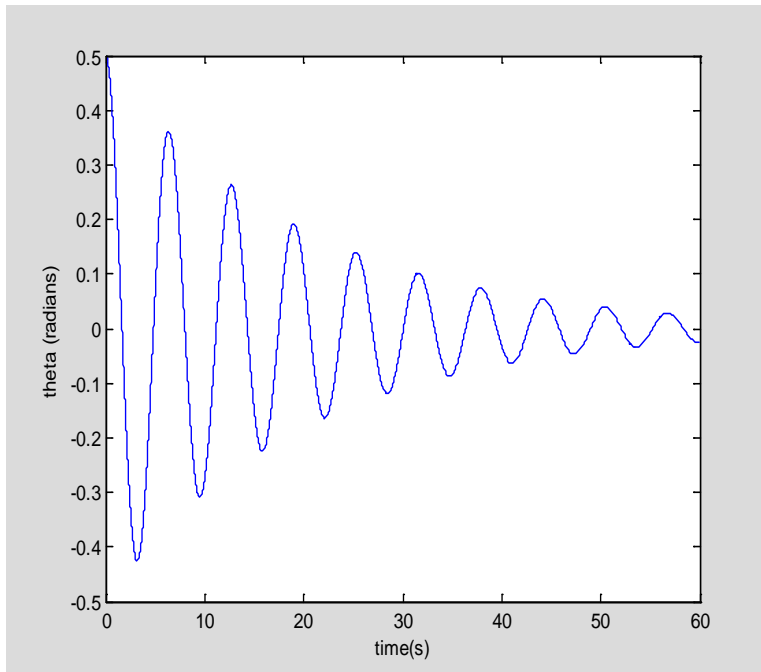


3.9

```

clear
a=0;b=60;h=0.01;n=(b-a)/h;
l=9.8;g=9.8;q=0.1;
theta(1)=0.5;omg(1)=0;t(1)=0;
for k=1:1:n
omg(k+1)=omg(k)-1/g*sin(theta(k))*h-q*omg(k)*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
end
plot(t,theta)
xlabel('time(s)')
ylabel('theta (radians)')
box on

```



3.10

```

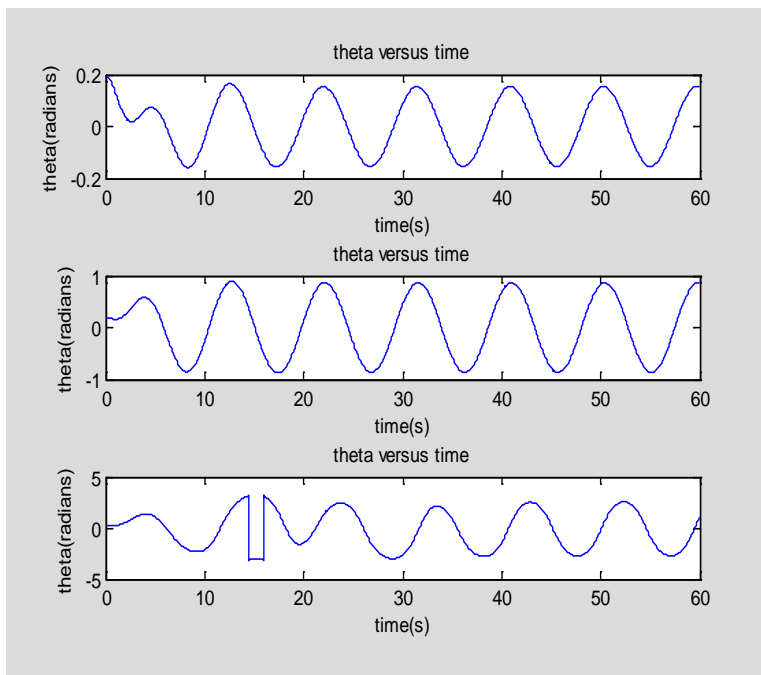
clear
a=0;b=60;h=0.04;n=(b-a)/h;
l=9.8;g=9.8;
fd=[0.1 0.5 0.99];omgd=2/3;
q=0.5;
theta(1,1:3)=0.2;omg(1,1:3)=0;t(1,1:3)=0;
for k=1:1:3
for kk=1:1:n
omg(kk+1,k)=omg(kk,k)-g/l*sin(theta(kk,k))*h-
q*omg(kk,k)*h+fd(k)*sin(omgd*t(kk,k))*h;
theta(kk+1,k)=theta(kk,k)+omg(kk+1,k)*h;
t(kk+1,k)=t(kk,k)+h;
if theta(kk+1,k)<-pi
theta(kk+1,k)=theta(kk+1,k)+2*pi;
end
if theta(kk+1,k)>pi
theta(kk+1,k)=theta(kk+1,k)-2*pi;
end
end
end
subplot(3,1,1)
plot(t(1:n,1),theta(1:n,1))
xlabel('time(s)')
ylabel('theta(radians)')
title('theta versus time')
subplot(3,1,2)
plot(t(1:n,2),theta(1:n,2))
xlabel('time(s)')
ylabel('theta(radians)')
title('theta versus time')
subplot(3,1,3)
plot(t(1:n,3),theta(1:n,3))

```

```

xlabel('time(s)')
ylabel('theta(radians)')
title('theta versus time')

```

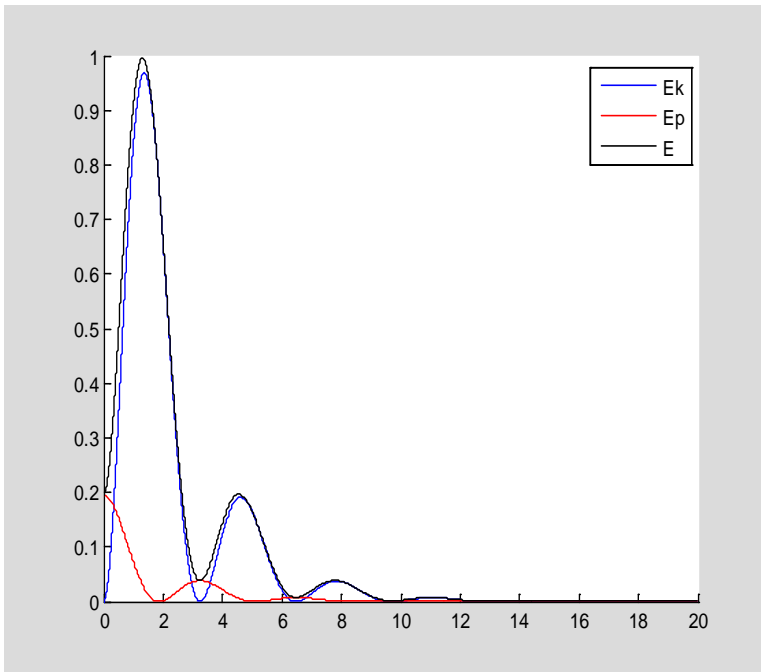


3.11

```

F=0
clear
a=0;b=20;h=0.001;n=(b-a)/h;
l=9.8;g=9.8;
fd=[0 0.5 1.2];omgd=2/3;
q=0.5;
theta(1,1:3)=0.2;omg(1,1:3)=0;t(1,1:3)=0;
for k=1:1:3
for kk=1:1:n
omg(kk+1,k)=omg(kk,k)-g/l*sin(theta(kk,k))*h-
q*omg(kk,k)*h+fd(k)*sin(omgd*t(kk,k))*h;
theta(kk+1,k)=theta(kk,k)+omg(kk+1,k)*h;
t(kk+1,k)=t(kk,k)+h;
end
end
Ek=0.5*(omg.*l).^2;
Ep=g.*(1-cos(theta));
E=Ep+Ek;
hold on
plot(t(1:n,1),Ek(1:n,1),'b')
plot(t(1:n,1),Ep(1:n,1),'r')
plot(t(1:n,1),E(1:n,1),'k')
hold off
legend('Ek','Ep','E')

```

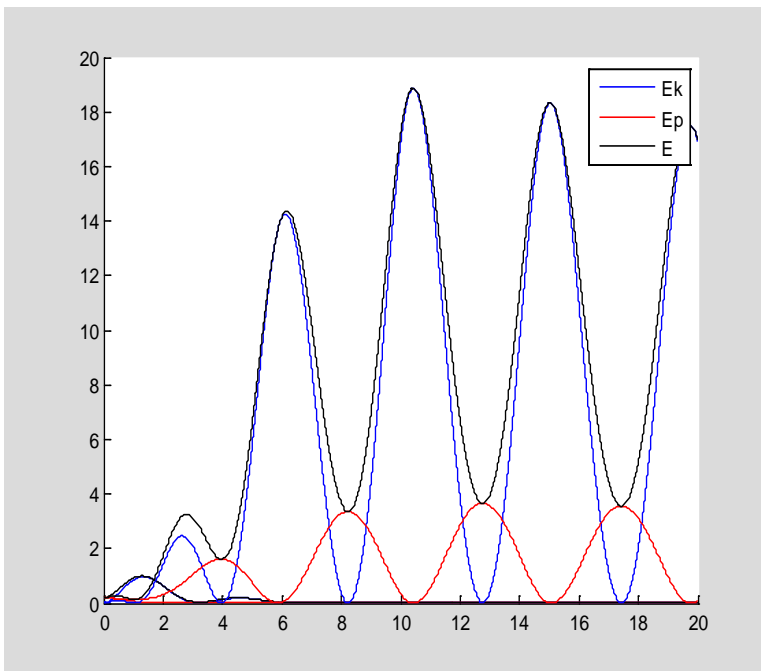


F=0.5

```

hold on
plot(t(1:n,2),Ek(1:n,2),'b')
plot(t(1:n,2),Ep(1:n,2),'r')
plot(t(1:n,2),E(1:n,2),'k')
hold off
legend('Ek','Ep','E')

```



F=1.2

```

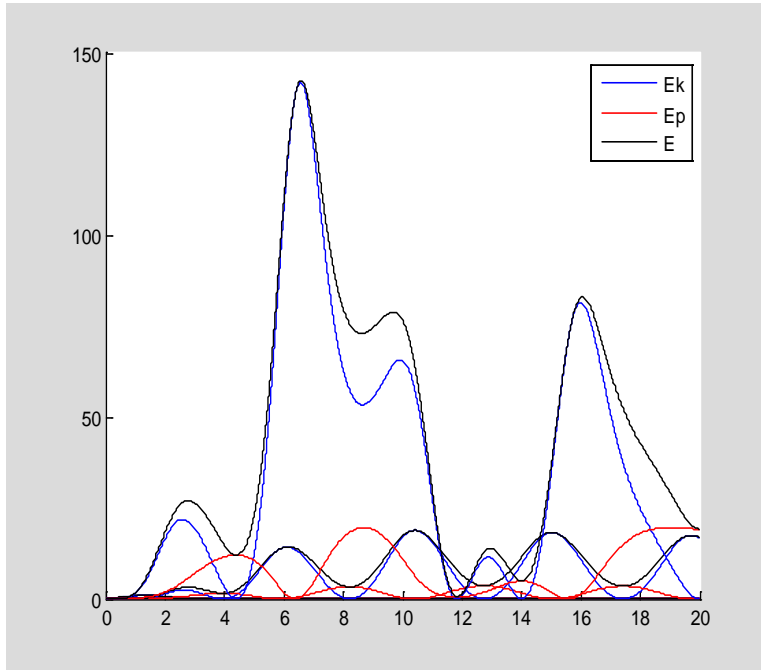
hold on

```

```

plot(t(1:n,3),Ek(1:n,3),'b')
plot(t(1:n,3),Ep(1:n,3),'r')
plot(t(1:n,3),E(1:n,3),'k')
hold off
legend('Ek','Ep','E')

```

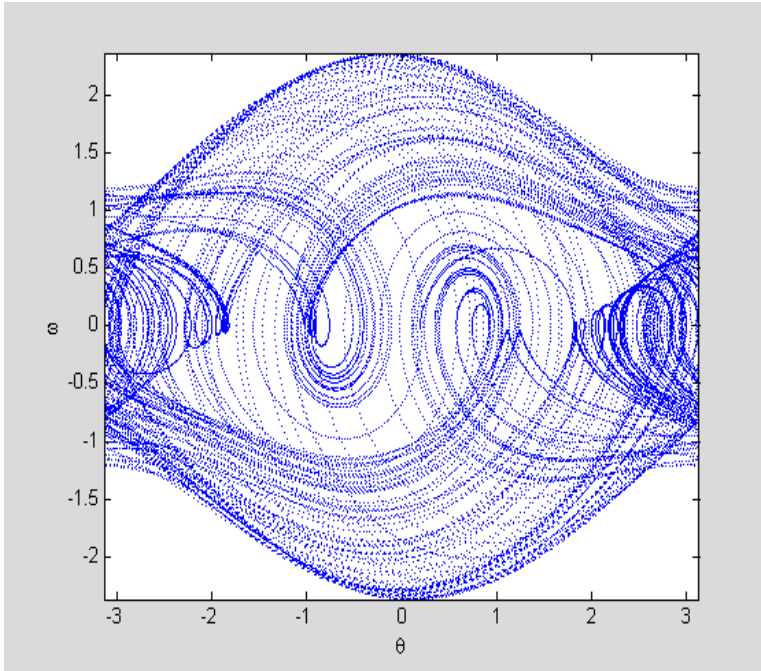


3.12

```

clear
a=0;b=1000;h=0.01*pi;n=(b-a)/h;
l=9.8;g=9.8;q=0.5;fd=1.2;omgd=2/3;
theta(1)=0.2;omg(1)=0;t(1)=0;
for k=1:1:n
omg(k+1)=omg(k)-l/g*sin(theta(k))*h-q*omg(k)*h+fd*sin(omgd*t(k))*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
if theta(k+1)>pi
theta(k+1)=theta(k+1)-2*pi;
end
if theta(k+1)< -pi
theta(k+1)=theta(k+1)+2*pi;
end
end
plot(theta,omg,'b.','markersize',2)
xlabel('\theta')
ylabel('\omega')
axis tight ,box on

```

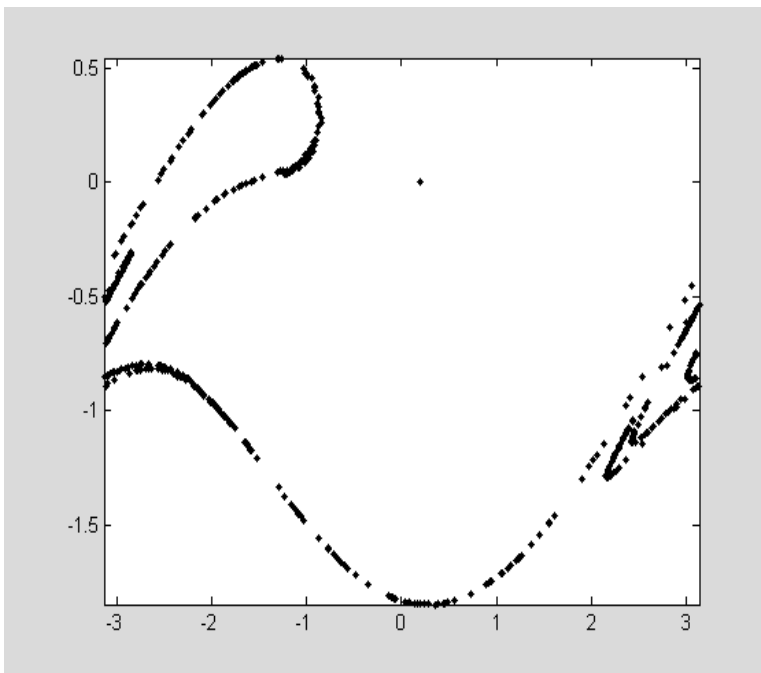


庞加莱截面 1

```

I=find(abs(rem(t,2*pi/omgd)) > 0.017);
omg(I)=NaN;
theta(I)=NaN;
plot(theta,omg,'.k');
axis tight

```



庞加莱截面 2:90° 相位差

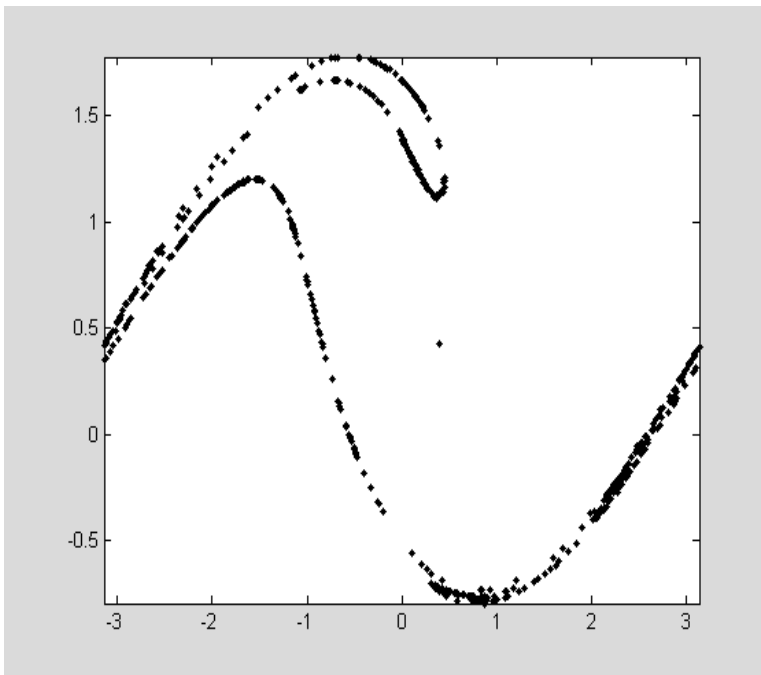
```

I=find(abs(rem((t-pi/2),2*pi/omgd)) > 0.017);
omg(I)=NaN;

```

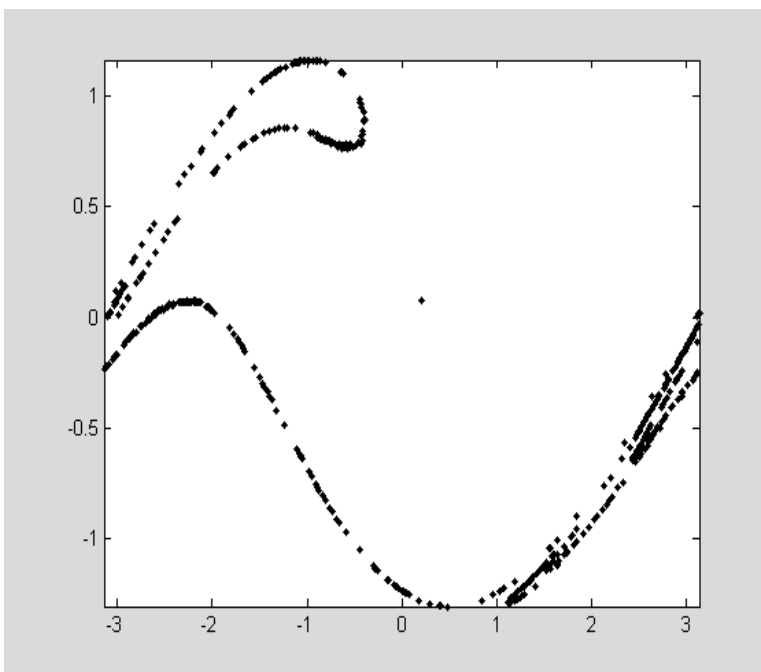


```
theta(I)=NaN;  
plot(theta,omg,'.k');  
axis tight
```



庞加莱截面 3: 45° 相位差

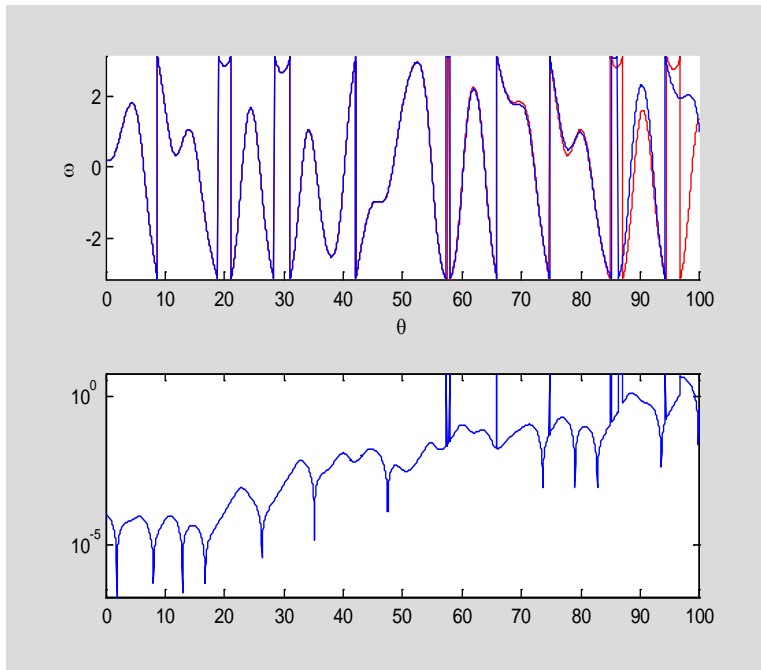
```
I=find(abs(rem((t-pi/4),2*pi/omgd)) > 0.017);  
omg(I)=NaN;  
theta(I)=NaN;  
plot(theta,omg,'.k');  
axis tight
```



个中差距并未看破……

3.13

```
clear
a=0;b=100;h=0.04;n=(b-a)/h;
l=9.8;g=9.8;q=0.5;fd=1.2;omgd=2/3;
theta1(1)=0.2;omg1(1)=0;t(1)=0;
theta2(1)=theta1(1)+1e-4;omg2(1)=0;
for k=1:1:n
omg1(k+1)=omg1(k)-l/g*sin(theta1(k))*h-q*omg1(k)*h+fd*sin(omgd*t(k))*h;
theta1(k+1)=theta1(k)+omg1(k+1)*h;
omg2(k+1)=omg2(k)-l/g*sin(theta2(k))*h-q*omg2(k)*h+fd*sin(omgd*t(k))*h;
theta2(k+1)=theta2(k)+omg2(k+1)*h;
t(k+1)=t(k)+h;
if theta1(k+1)>pi
theta1(k+1)=theta1(k+1)-2*pi;
end
if theta1(k+1)<-pi
theta1(k+1)=theta1(k+1)+2*pi;
end
if theta2(k+1)>pi
theta2(k+1)=theta2(k+1)-2*pi;
end
if theta2(k+1)<-pi
theta2(k+1)=theta2(k+1)+2*pi;
end
end
delta=abs(theta2-theta1);
subplot(211)
hold on
plot(t,theta1,'r');
plot(t,theta2,'b');
hold off
xlabel('\theta')
ylabel('\omega')
axis tight
subplot(212)
semilogy(t,delta);
axis tight
```



进行拟合后的曲线

```

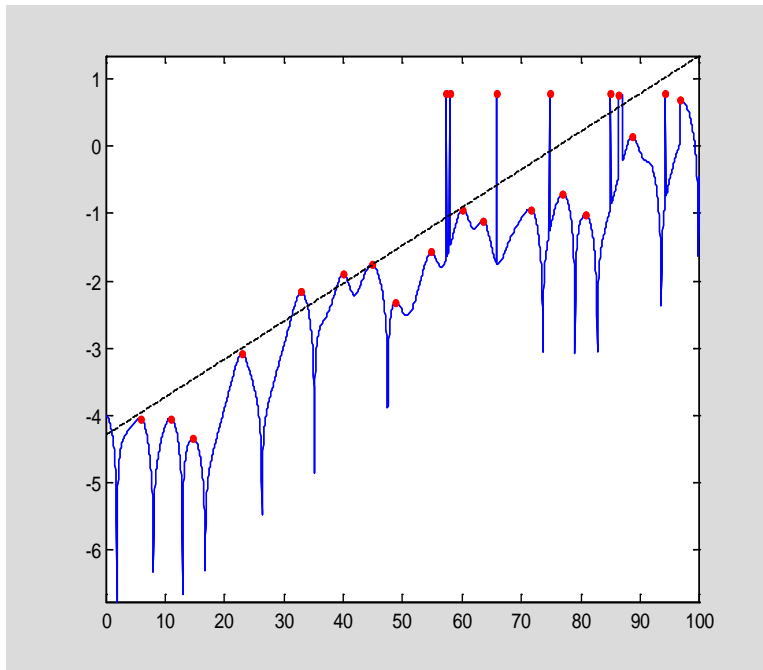
kk=1;
logdelta=log(delta)/log(10);
for k=2:1:n
if (logdelta(k)>logdelta(k-1))&&(logdelta(k)>logdelta(k+1))
xx(kk)=t(k);
yy(kk)=logdelta(k);
kk=kk+1;
end
end
w=polyfit(xx,yy,1);
xi=0:0.01:100;
yi=polyval(w,xi);
hold on
plot(t,logdelta);
plot(xx,yy,'r.','markersize',10)
plot(xi,yi,'k--')
box on
axis tight
hold off
lambda=w(1)

```

```

lambda =
    0.0565

```



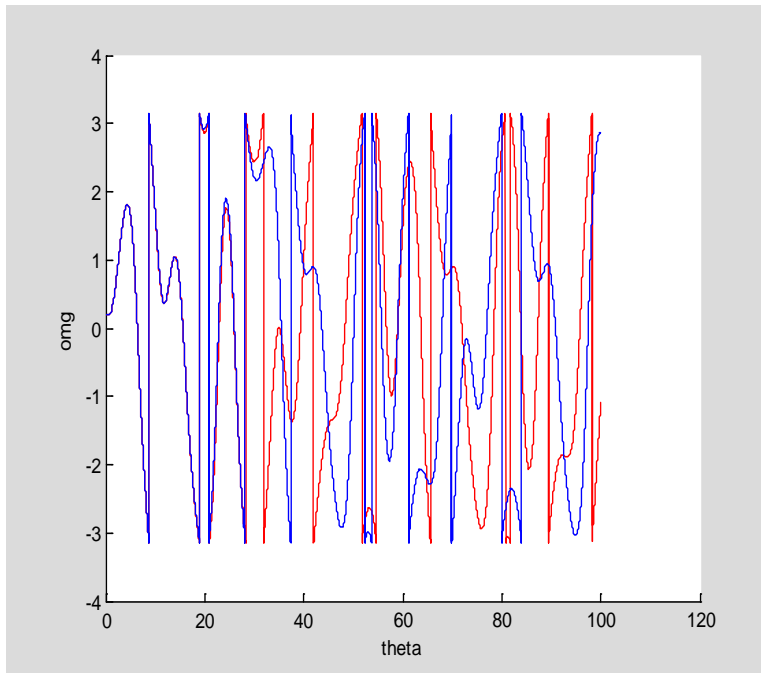
3.14

```

clear
a=0;b=100;h=0.01;n=(b-a)/h;
l=9.8;g=9.8;q=0.5;fd=1.2;omgd=2/3;
theta1(1)=0.2;omg1(1)=0;t(1)=0;
theta2(1)=theta1(1)+1e-4;omg2(1)=0;
for k=1:1:n
omg1(k+1)=omg1(k)-l/g*sin(theta1(k))*h-q*omg1(k)*h+fd*sin(omgd*t(k))*h;
theta1(k+1)=theta1(k)+omg1(k+1)*h;
omg2(k+1)=omg2(k)-l/g*sin(theta2(k))*h-
(q+0.001)*omg2(k)*h+fd*sin(omgd*t(k))*h;
theta2(k+1)=theta2(k)+omg2(k+1)*h;
t(k+1)=t(k)+h;
if theta1(k+1)>pi
theta1(k+1)=theta1(k+1)-2*pi;
end
if theta1(k+1)<-pi
theta1(k+1)=theta1(k+1)+2*pi;
end
if theta2(k+1)>pi
theta2(k+1)=theta2(k+1)-2*pi;
end
if theta2(k+1)<-pi
theta2(k+1)=theta2(k+1)+2*pi;
end
end
delta=abs(theta2-theta1);
logdelta=log(delta)/log(10);
hold on
plot(t,theta1,'r');
plot(t,theta2,'b');
hold off
xlabel('theta')

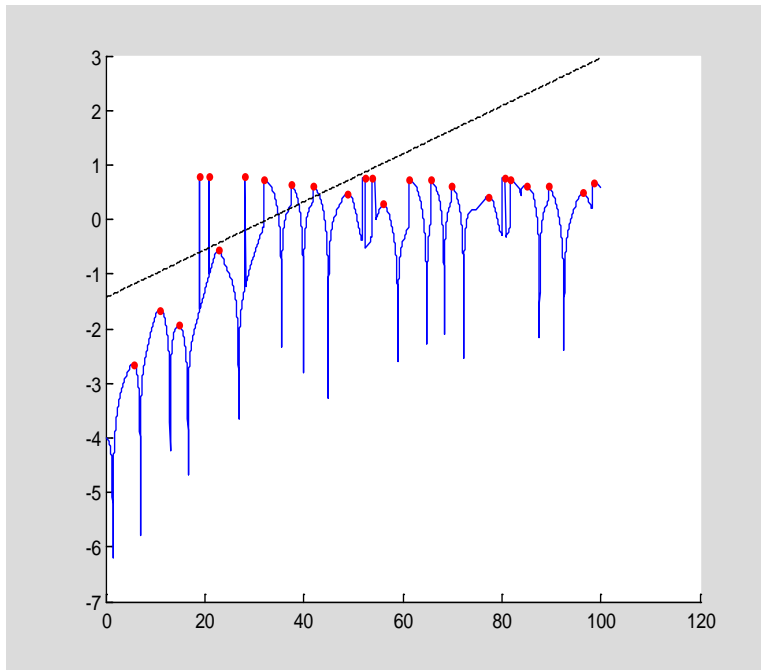
```

```
ylabel('omg')
```



```
kk=1;  
for k=2:1:n  
if (logdelta(k)>logdelta(k-1))&&(logdelta(k)>logdelta(k+1))  
xx(kk)=t(k);  
yy(kk)=logdelta(k);  
kk=kk+1;  
end  
end  
w=polyfit(xx(1:15),yy(1:15),1);  
xi=0:0.01:100;  
yi=polyval(w,xi);  
hold on  
plot(t,logdelta)  
plot(xx,yy,'r.','markersize',10)  
plot(xi,yi,'k--')  
hold off  
lambda=w(1)
```

```
lambda =  
    0.0439
```



3.15

```

clear
hold on
w=zeros(1,10001);
theta=zeros(1,10001);
t=zeros(1,10001);
theta(1)=0.2;
dt=0.06;
g=9.8;
l=9.8;
q=0.5;
F=1.2;
m=0.05;
for i=1:10000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(2/3*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;
    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
end
subplot(2,3,1)
plot(theta,w)
clear
w=zeros(1,10001);
theta=zeros(1,10001);
t=zeros(1,10001);
theta(1)=0.2;
dt=0.04;
g=9.8;

```

```

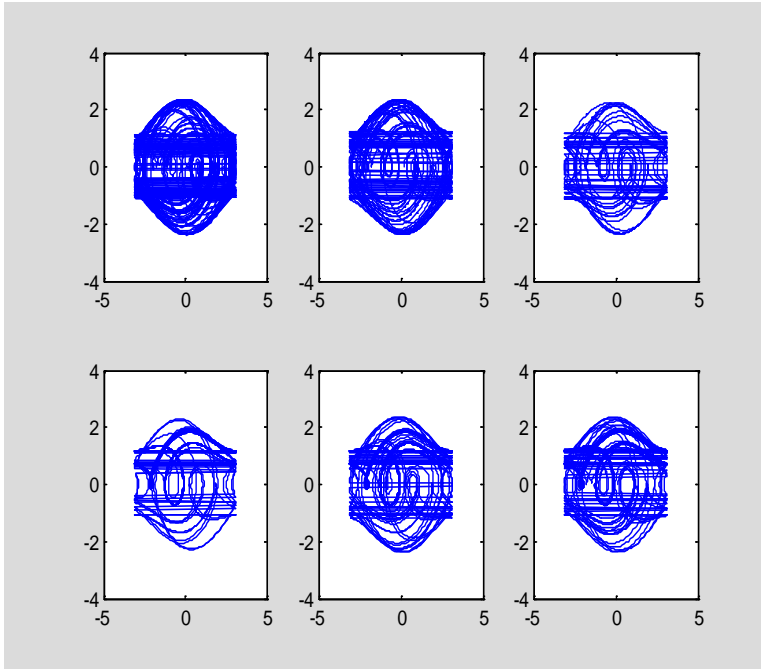
l=9.8;
q=0.5;
F=1.2;
m=0.05;
for i=1:10000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(2/3*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;
    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
end
subplot(2,3,2)
plot(theta,w)
clear
w=zeros(1,10001);
theta=zeros(1,10001);
t=zeros(1,10001);
theta(1)=0.2;
dt=0.02;
g=9.8;
l=9.8;
q=0.5;
F=1.2;
m=0.05;
for i=1:10000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(2/3*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;
    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
end
subplot(2,3,3)
plot(theta,w)
clear
w=zeros(1,10001);
theta=zeros(1,10001);
t=zeros(1,10001);
theta(1)=0.25;
dt=0.06;
g=9.8;
l=9.8;
q=0.5;
F=1.2;
m=0.05;
for i=1:10000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(2/3*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;

```

```

    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
end
subplot(2,3,4)
plot(theta,w)
clear
w=zeros(1,10001);
theta=zeros(1,10001);
t=zeros(1,10001);
theta(1)=0.3;
dt=0.06;
g=9.8;
l=9.8;
q=0.5;
F=1.2;
m=0.05;
for i=1:10000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(2/3*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;
    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
end
subplot(2,3,5)
plot(theta,w)
clear
w=zeros(1,10001);
theta=zeros(1,10001);
t=zeros(1,10001);
theta(1)=0.15;
dt=0.06;
g=9.8;
l=9.8;
q=0.5;
F=1.2;
m=0.05;
for i=1:10000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(2/3*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;
    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
end
subplot(2,3,6)
plot(theta,w)

```

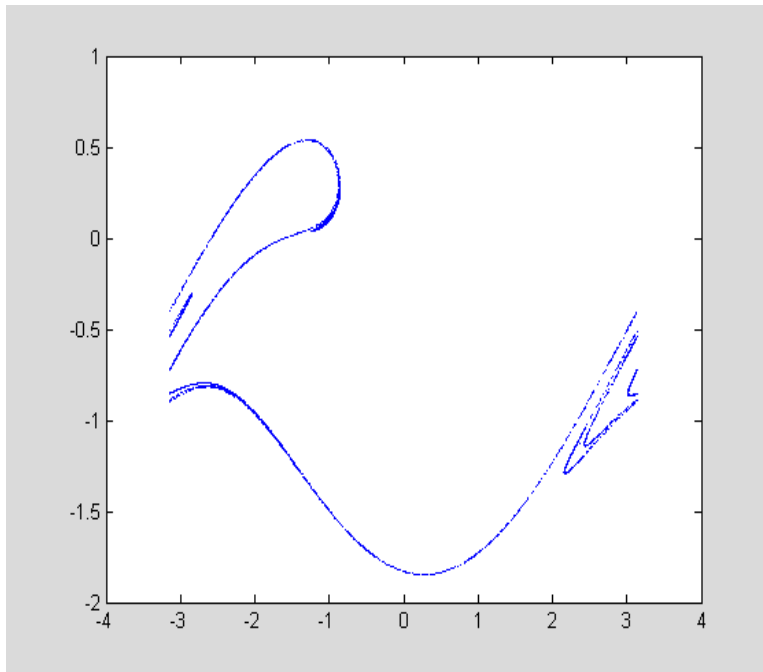



3.16

```

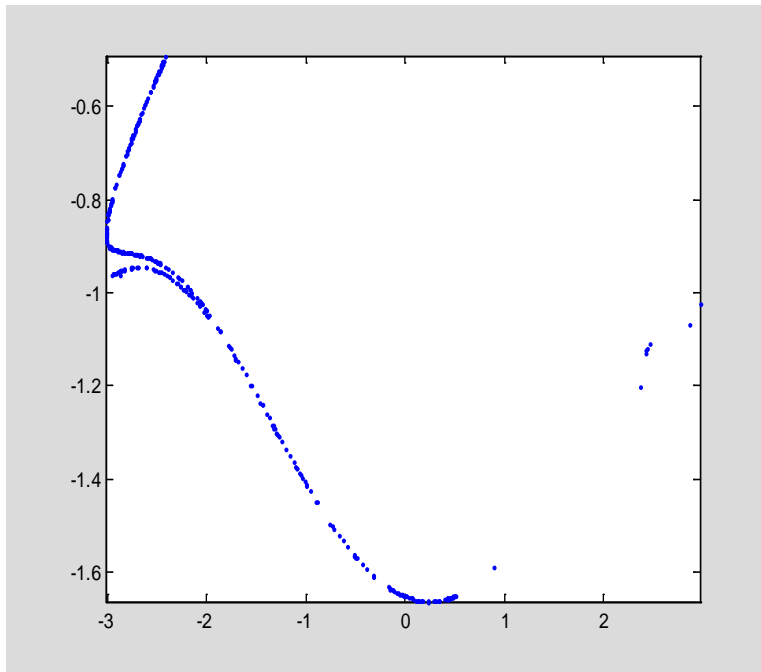
clear
a=0;b=50000;h=0.01*pi;n=(b-a)/h;
l=9.8;g=9.8;q=0.5;fd=1.2;omgd=2/3;
theta(1)=0.2;omg(1)=0;t(1)=0;
for k=1:1:n
omg(k+1)=omg(k)-1/g*sin(theta(k))*h-q*omg(k)*h+fd*sin(omgd*t(k))*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
if theta(k+1)>pi
theta(k+1)=theta(k+1)-2*pi;
end
if theta(k+1)<-pi
theta(k+1)=theta(k+1)+2*pi;
end
end
kk=1;
for k=1:1:n
if abs(t(k)/3/pi-kk)<1e-3
tt(kk)=t(k);
theta1(kk)=theta(k);
omg1(kk)=omg(k);
kk=kk+1;
end
end
end
plot(theta1,omg1,'b.','markersize',2)

```



改变摆长 l:

```
clear
a=0;b=5000;h=0.01*pi;n=(b-a)/h;
l=7;g=9.8;q=0.5;fd=1.2;omgd=2/3;
theta(1)=0.2;omg(1)=0;t(1)=0;
for k=1:1:n
omg(k+1)=omg(k)-l/g*sin(theta(k))*h-q*omg(k)*h+fd*sin(omgd*t(k))*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
if theta(k+1)>pi
theta(k+1)=theta(k+1)-2*pi;
end
if theta(k+1)<-pi
theta(k+1)=theta(k+1)+2*pi;
end
end
kk=1;
for k=1:1:n
if abs(t(k)/3/pi-kk)<1e-3
tt(kk)=t(k);
thetal(kk)=theta(k);
omg1(kk)=omg(k);
kk=kk+1;
end
end
plot(thetal,omg1,'b.','markersize',2)
box on,axis tight
```

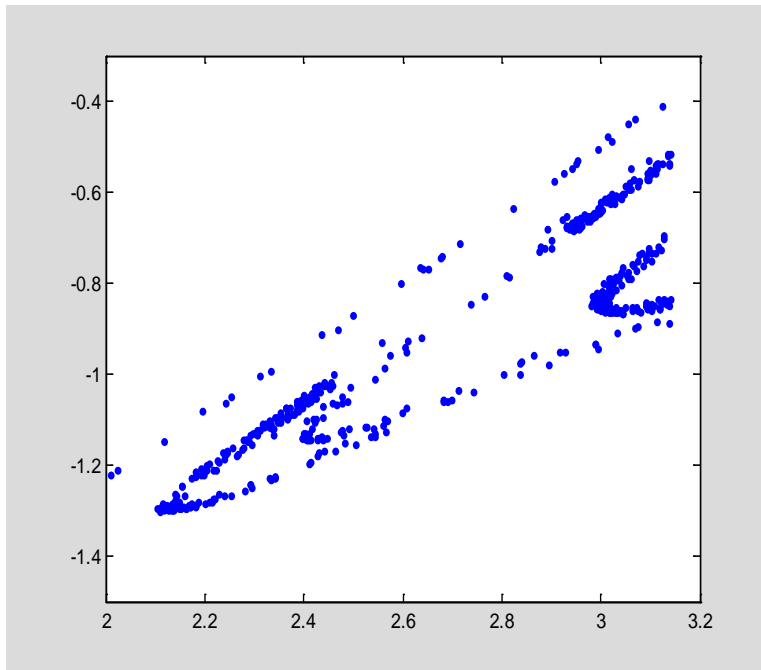


3.17

```

clear
w=zeros(1,400001);
theta=zeros(1,400001);
t=zeros(1,400001);
theta(1)=0.2;
dt=0.04;
g=9.8;
l=9.8;
q=0.5;
F=1.2;
m=0.05;
n=1;
W=2/3;
hold on
for i=1:400000
    w(i+1)=w(i)-g/l*sin(theta(i))*dt-q*w(i)*dt+F*sin(W*t(i))*dt;
    theta(i+1)=theta(i)+w(i+1)*dt;
    if theta(i+1)>pi
theta(i+1)=theta(i+1)-2*pi;
    end
    if theta(i+1)<-pi
theta(i+1)=theta(i+1)+2*pi;
    end
    t(i+1)=t(i)+dt;
    if t(i)>=2*n*pi/W && t(i)<=2*n*pi/W+0.04
        plot(theta(i),w(i),'b.')
    end
    n=n+1;
end
end
axis ([2,3.2,-1.5,-0.3])
box on;

```



3.18

```

clear all
l=9.8;
g=9.8;

omega(1)=0;
theta(1)=0.2;
t(1)=0;
q=1/2;
Omega=2/3;
dt=0.01;
hold on
box on

F=1.4;
n=1;
for i=1:2000/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;
    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

    if t(i)<n*2*pi/Omega+0.01 && t(i)>n*2*pi/Omega-0.01
        plot(theta(i),omega(i),'bo','MarkerSize',6)
    end
end

```

```

        n=n+1;
    end
end
legend('1.4')

F=1.44;
n=1;
for i=1:2000/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;
    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

    if t(i)<n*2*pi/Omega+0.01 && t(i)>n*2*pi/Omega-0.01
        plot(theta(i),omega(i),'g.','MarkerSize',5)
        n=n+1;
    end
end
legend('1.44')

F=1.465;
n=1;
for i=1:2000/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;
    t(i+1)=t(i)+dt;

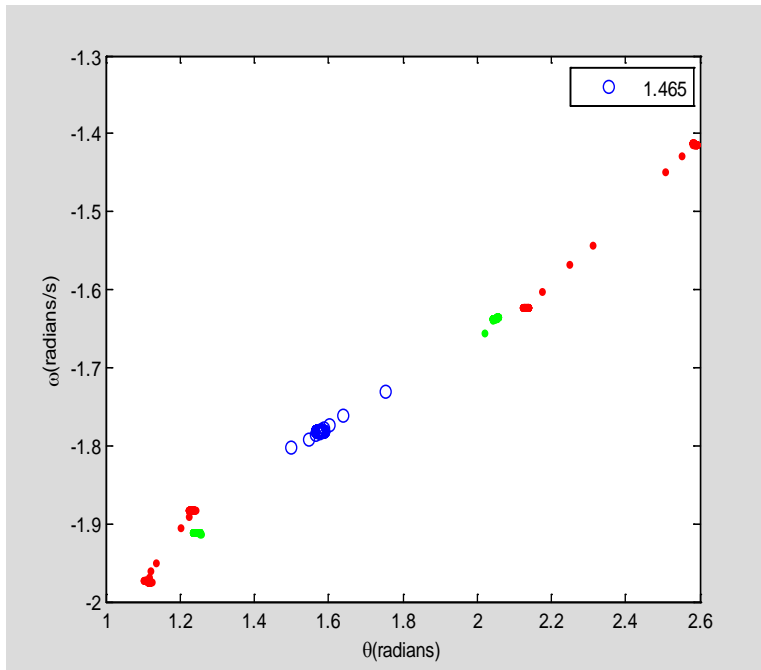
    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

    if t(i)<n*2*pi/Omega+0.01 && t(i)>n*2*pi/Omega-0.01
        plot(theta(i),omega(i),'r.','MarkerSize',5)
        n=n+1;
    end
end

ylabel('\omega(radians/s)')
xlabel('\theta(radians)')
legend('1.465')

```

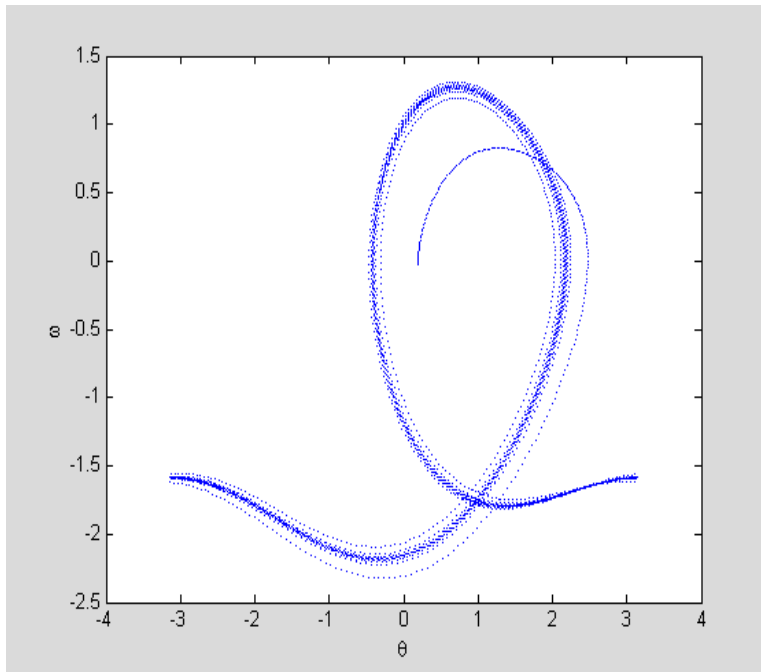


3.19

```

clear
a=0;b=5000;h=0.01*pi;n=(b-a)/h;
l=9.8;g=9.8;q=0.5;fd=1.4;omgd=2/3;
theta(1)=0.2;omg(1)=0;t(1)=0;
for k=1:1:n
omg(k+1)=omg(k)-l/g*sin(theta(k))*h-q*omg(k)*h+fd*sin(omgd*t(k))*h;
theta(k+1)=theta(k)+omg(k+1)*h;
t(k+1)=t(k)+h;
if theta(k+1)>pi
theta(k+1)=theta(k+1)-2*pi;
end
if theta(k+1)<-pi
theta(k+1)=theta(k+1)+2*pi;
end
end
kk=1;
for k=1:1:n
if abs(t(k)/0.01/pi-kk)<1e-3
tt(kk)=t(k);
theta1(kk)=theta(k);
omg1(kk)=omg(k);
kk=kk+1;
end
end
end
plot(theta1,omg1,'b.','markersize',2)
xlabel('\theta')
ylabel('\omega')

```

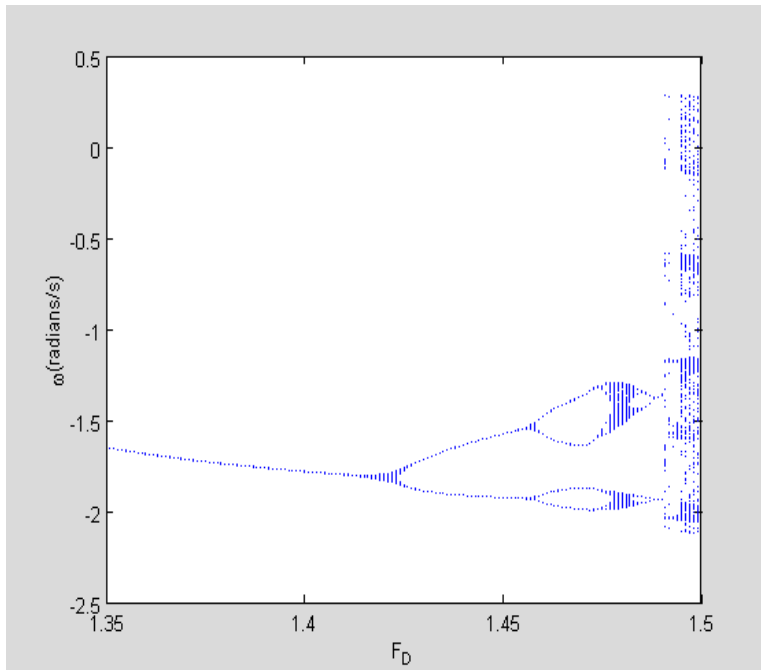


3.20

```

clear
a=0;b=1300*pi;h=0.01*pi;n=(b-a)/h;
l=9.8;g=9.8;q=0.5;fd=[1.35:0.001:1.5];omgd=2/3;
p=length(fd);
mm=1;
theta(1,1:p)=0.2;omg(1,1:p)=0;t(1,1:p)=0;
for k=1:1:n
omg(k+1,1:p)=omg(k,1:p)-1/g*sin(theta(k,1:p))*h-
q*omg(k,1:p)*h+fd.*sin(omgd*t(k,1:p))*h;
theta(k+1,1:p)=theta(k,1:p)+omg(k+1,1:p)*h;
t(k+1,1:p)=t(k,1:p)+h;
% theta(theta>pi)=theta(theta>pi)-2*pi;
% theta(theta<-pi)=theta(theta<-pi)+2*pi;
if rem(k,30)==0
    theta1(mm,1:p)=theta(k,1:p);
    mm=mm+1;
end
end
for ii=1:1:mm-1
    for jj=1:1:p
        while theta1(ii,jj)<-pi
            theta1(ii,jj)=theta1(ii,jj)+2*pi;
        end
        while theta1(ii,jj)>pi
            theta1(ii,jj)=theta1(ii,jj)-2*pi;
        end
    end
end
end
plot(fd,theta1(300:400,1:p),'r.','markersize',4)

```



3.21

```
clear all
l=9.8;
g=9.8;
dt=0.01;
```

```
omega(1)=0;
theta(1)=0.2;
t(1)=0;
q=1/3;
Omega=2/3;
```

```
subplot(3,1,1)
hold on
box on
for F=1.35:0.0005:1.5
    n=20;
    for i=1:1000/dt
        omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
        theta(i+1)=theta(i)+omega(i+1)*dt;
        t(i+1)=t(i)+dt;

        if theta(i+1)>pi
            theta(i+1)=theta(i+1)-2*pi;
        end

        if theta(i+1)<-pi
            theta(i+1)=theta(i+1)+2*pi;
        end

        if t(i)<n*2*pi/Omega+0.02 && t(i)>n*2*pi/Omega-0.02
```



```

        plot(F,omega(i),'b.','MarkerSize',4)
        n=n+1;
    end
end
end

ylabel('\omega(radians/s)')
xlabel('F_D')
title('q=1/3')

subplot(3,1,2)
hold on
box on
q=1/2;
Omega=3/5;
for F=1.35:0.0005:1.5
    n=20;
    for i=1:1000/dt
        omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
        theta(i+1)=theta(i)+omega(i+1)*dt;
        t(i+1)=t(i)+dt;

        if theta(i+1)>pi
            theta(i+1)=theta(i+1)-2*pi;
        end

        if theta(i+1)<-pi
            theta(i+1)=theta(i+1)+2*pi;
        end

        if t(i)<n*2*pi/Omega+0.02 && t(i)>n*2*pi/Omega-0.02
            plot(F,omega(i),'b.','MarkerSize',4)
            n=n+1;
        end
    end
end
end

ylabel('\omega(radians/s)')
xlabel('F_D')
title('\Omega=3/5')

subplot(3,1,3)
hold on
box on
q=1/2;
Omega=2/3;
for F=1.35:0.0005:1.5
    n=20;
    for i=1:1000/dt
        omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
        theta(i+1)=theta(i)+omega(i+1)*dt;
        t(i+1)=t(i)+dt;

        if theta(i+1)>pi

```

```

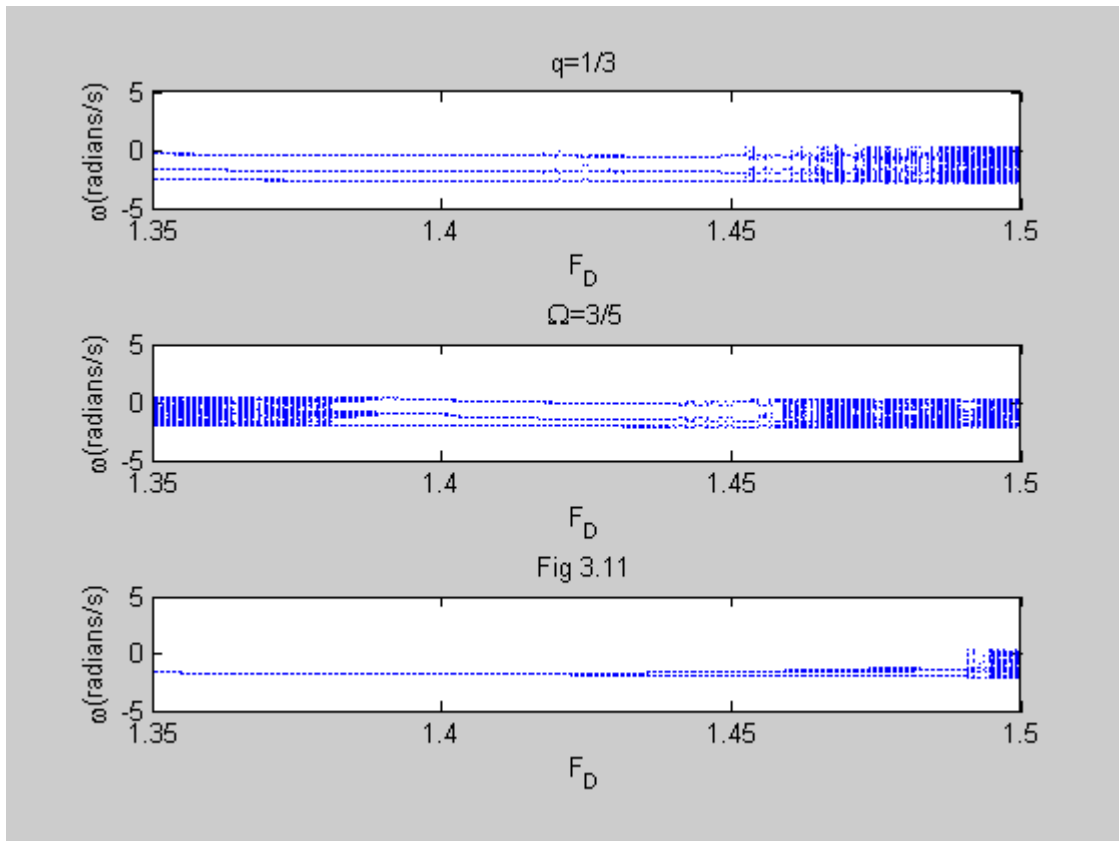
    theta(i+1)=theta(i+1)-2*pi;
end

if theta(i+1)<-pi
    theta(i+1)=theta(i+1)+2*pi;
end

if t(i)<n*2*pi/Omega+0.02 && t(i)>n*2*pi/Omega-0.02
    plot(F,omega(i),'b.','MarkerSize',4)
    n=n+1;
end
end
end

ylabel('\omega(radians/s)')
xlabel('F_D')
title('Fig 3.11')

```



3.22

```

u=2.5:0.001:4;
X=ones(250,1501);
X(1,:)=0.6*X(1,:);
tic
for j=1:250
    X(j+1,:)=u.*(X(j,:)-X(j,:).^2);
end

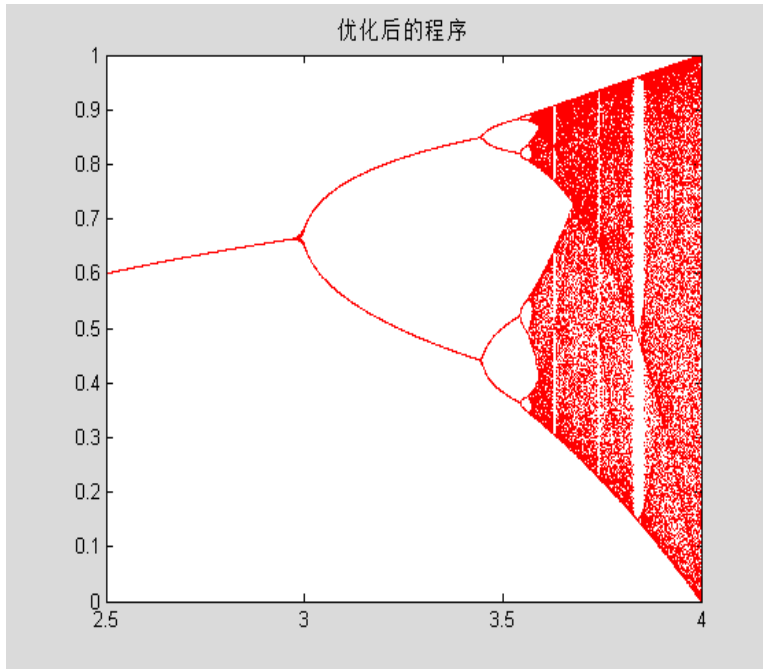
```

```

plot(u,X(150:end,:), 'r.', 'markersize', 2)
toc
title('优化后的程序')

```

Elapsed time is 0.037843 seconds.



费根鲍姆常数为 $4.2/0.9=4.6667$

3.23

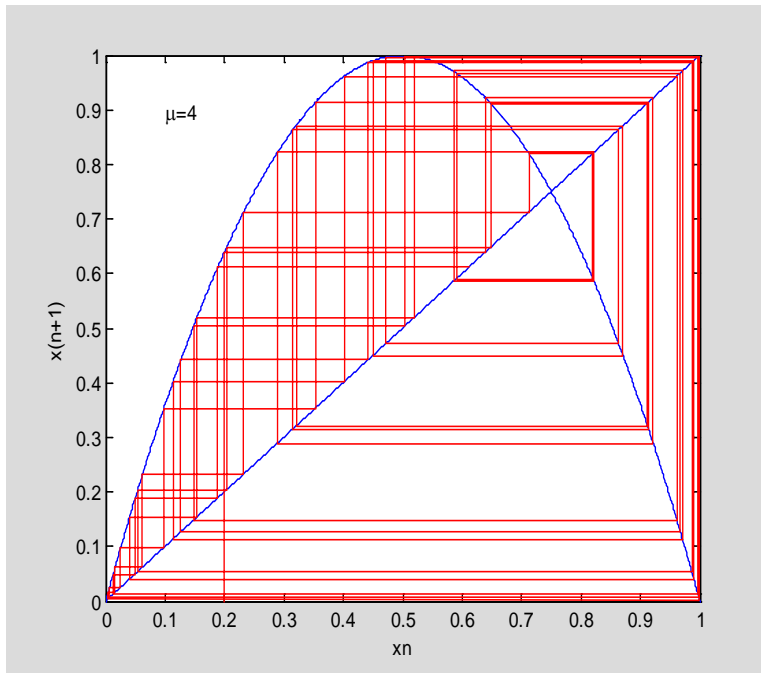
```

clear
figure
box on

for mu=1.5:0.1:4
x=0:0.001:1;
y=mu.*x.*(1-x);
xx(1)=0.2;yy(1)=0;
for k=1:1:100
if rem(k,2)==0
xx(k+1)=yy(k);
yy(k+1)=yy(k);
else
xx(k+1)=xx(k);
yy(k+1)=xx(k+1)*mu*(1-xx(k+1));
end
end
plot(x,y)
hold on
plot(x,x)
plot(xx,yy, 'r')
xlabel('xn')
ylabel('x(n+1)')
text(0.1,0.9,['\mu=' num2str(mu)])
hold off

```

end



```
clear all
x(1)=0.5;
n(1)=1;

subplot(2,2,1)
hold on
box on
mu=3.2;
for i=1:50
    x(i+1)=mu*x(i)*(1-x(i));
    n(i+1)=i+1;
    plot(n(i),x(i),'bo','MarkerSize',4)
end
plot(n,x,'-b')
xlabel('n')
ylabel('x')
title('logistic map x vs n, \mu=3.2')

subplot(2,2,2)
hold on
box on
mu=3.5;
for i=1:50
    x(i+1)=mu*x(i)*(1-x(i));
    n(i+1)=i+1;
    plot(n(i),x(i),'ko','MarkerSize',4)
end
plot(n,x,'-k')
xlabel('n')
ylabel('x')
```

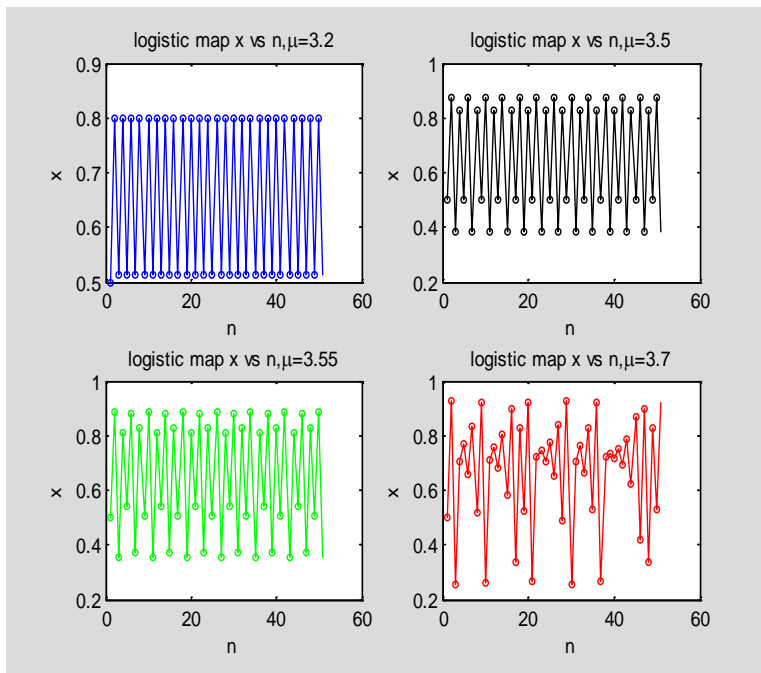
```

title('logistic map x vs n,\mu=3.5')

subplot(2,2,3)
hold on
box on
mu=3.55;
for i=1:50
    x(i+1)=mu*x(i)*(1-x(i));
    n(i+1)=i+1;
    plot(n(i),x(i),'go','MarkerSize',4)
end
plot(n,x,'-g')
xlabel('n')
ylabel('x')
title('logistic map x vs n,\mu=3.55')

subplot(2,2,4)
hold on
box on
mu=3.7;
for i=1:50
    x(i+1)=mu*x(i)*(1-x(i));
    n(i+1)=i+1;
    plot(n(i),x(i),'ro','MarkerSize',4)
end
plot(n,x,'-r')
xlabel('n')
ylabel('x')
title('logistic map x vs n,\mu=3.7')

```



3.24 伪随机序列

```

A
clear all

```

```

x(1)=0.5;
n=8;

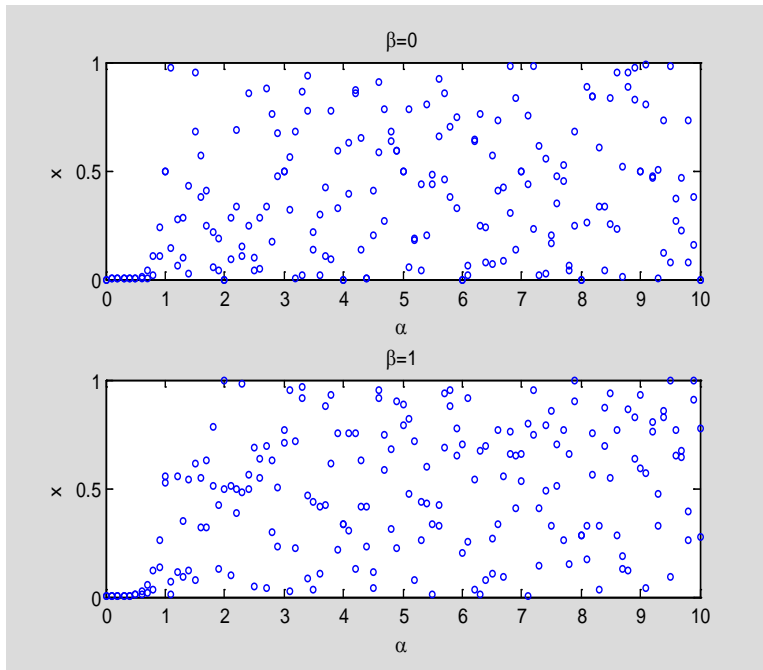
subplot(2,1,1)
hold on
box on
b=0;
for a=0:0.1:10
    for i=1:20
        x(i+1)=mod((a*x(i)*2^(n)+b),2^n)/(2^n);
        if mod(i,8)==0
            plot(a,x(i),'bo','MarkerSize',4)
        end
    end
end

xlabel('\alpha')
ylabel('x')
title('\beta=0')

subplot(2,1,2)
hold on
box on
b=1;
for a=0:0.1:10
    for i=1:20
        x(i+1)=mod((a*x(i)*2^(n)+b),2^n)/(2^n);
        if mod(i,8)==0
            plot(a,x(i),'bo','MarkerSize',4)
        end
    end
end

xlabel('\alpha')
ylabel('x')
title('\beta=1')

```



B

```

clear all
x(1)=0.5;
n=8;
subplot(2,1,1)
hold on
box on
b=0;
for a=0:0.1:10
    for i=1:20
        x(i+1)=mod((a*(x(i)*2^(n))-mod(x(i)*2^(n),1))+b),2^n)/(2^n);
        if mod(i,8)==0
            plot(a,x(i),'bo','MarkerSize',4)
        end
    end
end

xlabel('\alpha')
ylabel('x')
title('\beta=0')

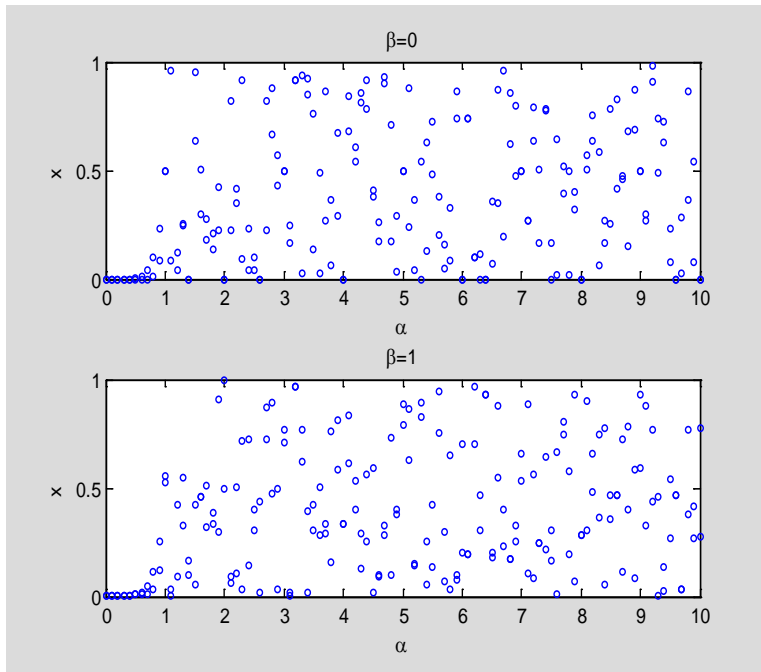
subplot(2,1,2)
hold on
box on
b=1;
for a=0:0.1:10
    for i=1:20
        x(i+1)=mod((a*(x(i)*2^(n))-mod(x(i)*2^(n),1))+b),2^n)/(2^n);
        if mod(i,8)==0
            plot(a,x(i),'bo','MarkerSize',4)
        end
    end
end
end

```

```

xlabel('\alpha')
ylabel('x')
title('\beta=1')

```

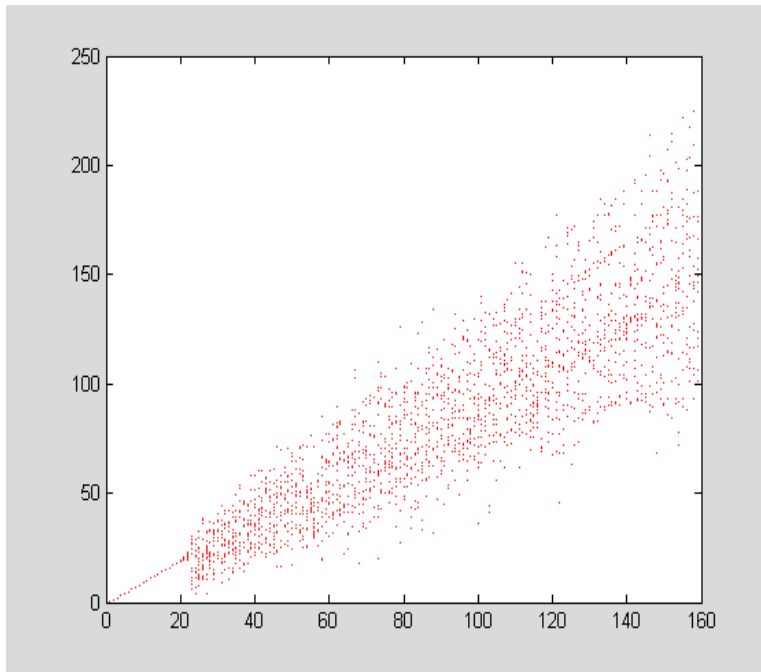


3.25

```

clear
xgm=10;b=8/3;
r=1:160;
x(1,1:160)=1;y(1,1:160)=0;z(1,1:160)=0;t(1)=0;
h=0.001;n=50/h;
for k=1:1:n
x(k+1,1:160)=x(k,1:160)+xgm*(y(k,1:160)-x(k,1:160))*h;
y(k+1,1:160)=y(k,1:160)-x(k,1:160).*z(k,1:160)*h+r.*x(k,1:160)*h-
y(k,1:160)*h;
z(k+1,1:160)=z(k,1:160)+x(k,1:160).*y(k,1:160)*h-b*z(k,1:160)*h;
t(k+1)=t(k)+h;
end
plot(r,z(30000:1000:45000,1:160),'r.','markersize',2)

```

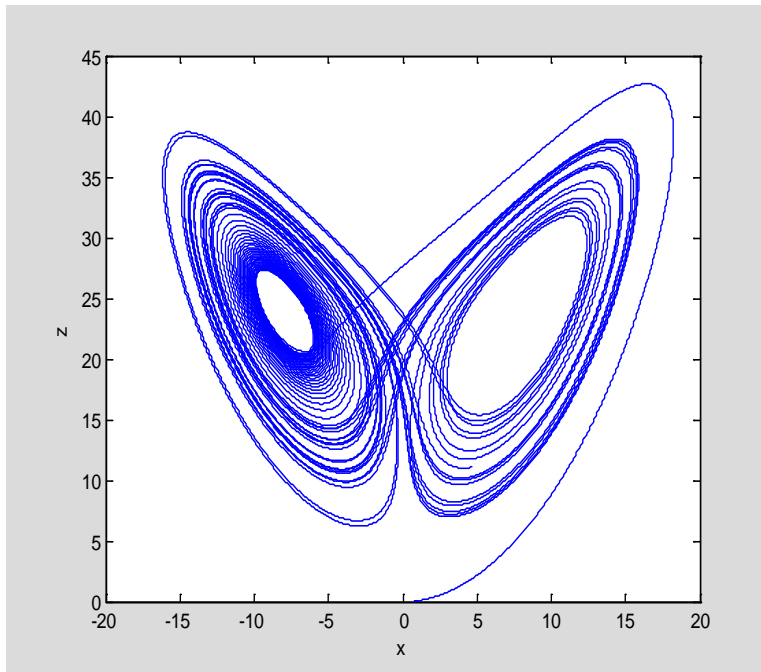



3.26

```

clear
xgm=10;b=8/3;r=25;
p=0;q=50;h=0.0001;n=(q-p)/h;
t(1)=0;x(1)=1;y(1)=0;z(1)=0;
for k=1:1:n
x(k+1)=x(k)+xgm*(y(k)-x(k))*h;
y(k+1)=y(k)-x(k)*z(k)*h+r*x(k)*h-y(k)*h;
z(k+1)=z(k)+x(k)*y(k)*h-b*z(k)*h;
t(k+1)=t(k)+h;
end
plot(x,z)
xlabel('x')
ylabel('z')

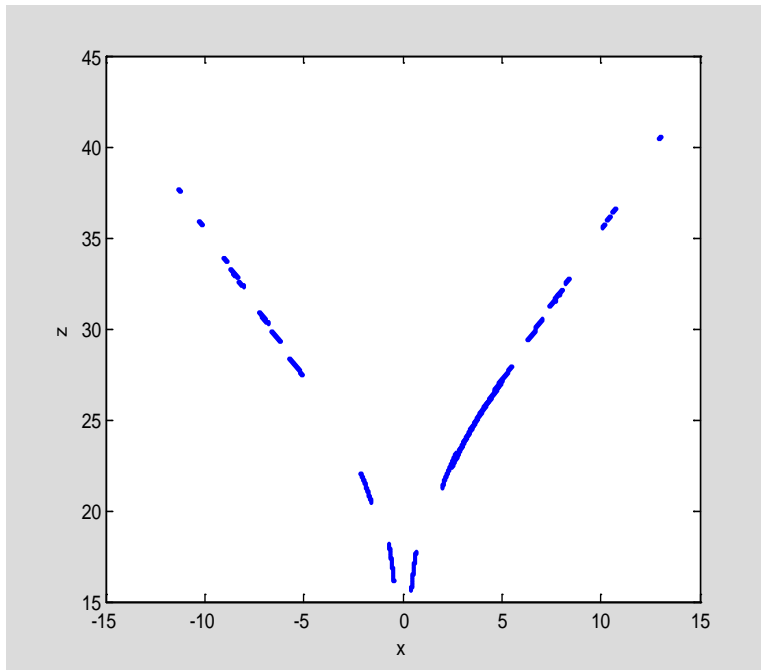
```



```

clear
xgm=10;b=8/3;r=25;
p=0;q=50;h=0.00001;n=(q-p)/h;
t(1)=0;x(1)=0;y(1)=1;z(1)=1;
for k=1:1:n
x(k+1)=x(k)+xgm*(y(k)-x(k))*h;
y(k+1)=y(k)-x(k)*z(k)*h+r*x(k)*h-y(k)*h;
z(k+1)=z(k)+x(k)*y(k)*h-b*z(k)*h;
t(k+1)=t(k)+h;
end
plot(x(abs(y)<1e-1),z(abs(y)<1e-1),'b.','markersize',4)
xlabel('x')
ylabel('z')

```



3.27

```

clear all
delta=10;
b=8/3;

dt=0.0001;

r=25;
subplot(2,1,1)
hold on
box on
x(1)=1;
y(1)=0;
z(1)=0;
for i=1:100/dt
    x(i+1)=x(i)+delta*(y(i)-x(i))*dt;
    y(i+1)=y(i)+(-x(i)*z(i)+r*x(i)-y(i))*dt;
    z(i+1)=z(i)+(x(i)*y(i)-b*z(i))*dt;

    if x(i)>-0.01&&x(i)<0.01
        plot(y(i),z(i),'b.','MarkerSize',5)
    end
end

x1(1)=0;
y1(1)=1;
z1(1)=1;
for i=1:100/dt
    x1(i+1)=x1(i)+delta*(y1(i)-x1(i))*dt;
    y1(i+1)=y1(i)+(-x1(i)*z1(i)+r*x1(i)-y1(i))*dt;
    z1(i+1)=z1(i)+(x1(i)*y1(i)-b*z1(i))*dt;

```

```

        if x1(i)>-0.01&&x1(i)<0.01
            plot(y1(i),z1(i),'r.','MarkerSize',5)
        end
    end

xlabel('y')
ylabel('z')

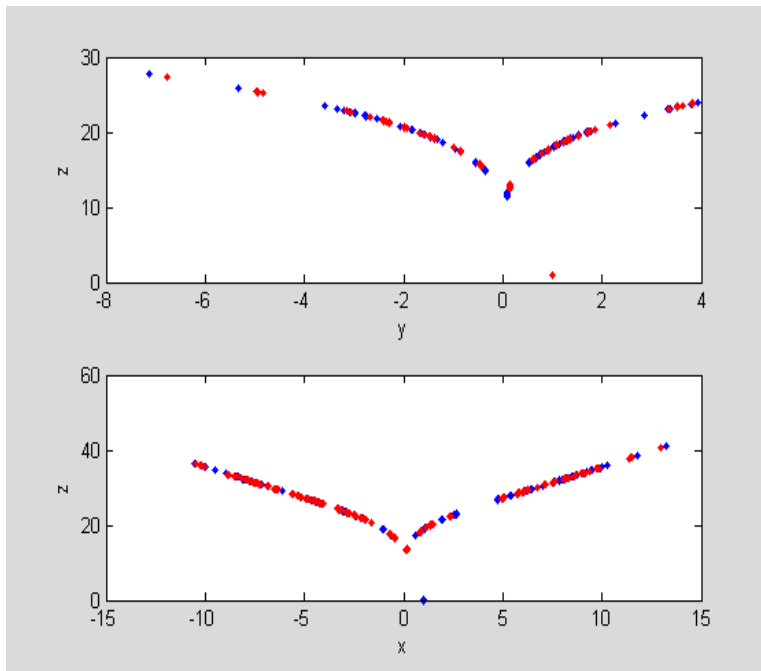
subplot(2,1,2)
hold on
box on

for i=1:100/dt
    if y(i)>-0.01&&y(i)<0.01
        plot(x(i),z(i),'b.','MarkerSize',5)
    end
end

for i=1:100/dt
    if y1(i)>-0.01&&y1(i)<0.01
        plot(x1(i),z1(i),'r.','MarkerSize',5)
    end
end

xlabel('x')
ylabel('z')

```



3.28

```

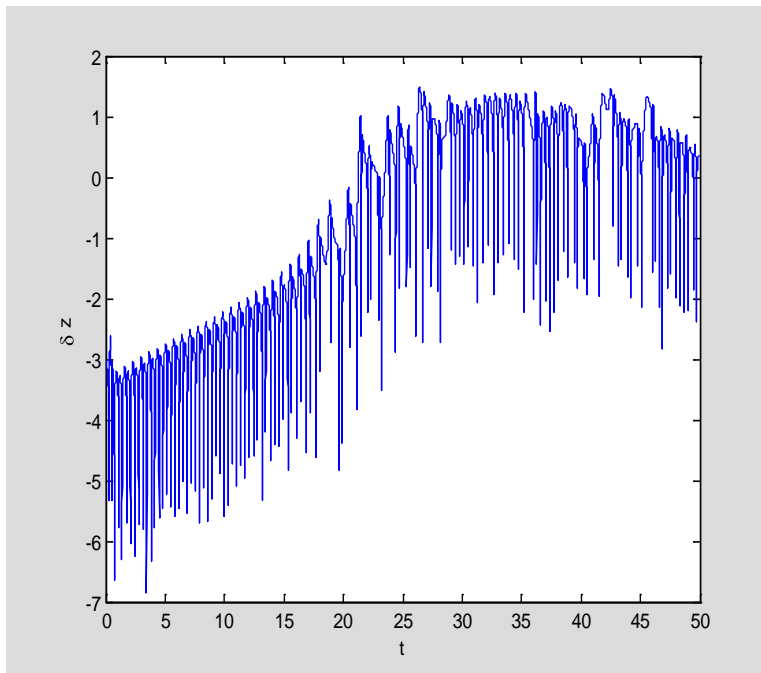
clear
xgm=10;b=8/3;r=24;
p=0;q=50;h=0.001;n=(q-p)/h;
t(1)=0;x(1)=1;y(1)=0;z(1)=0;
xx(1)=1;yy(1)=0;zz(1)=0.001;

```

```

for k=1:1:n
x(k+1)=x(k)+xgm*(y(k)-x(k))*h;
y(k+1)=y(k)-x(k)*z(k)*h+r*x(k)*h-y(k)*h;
z(k+1)=z(k)+x(k)*y(k)*h-b*z(k)*h;
xx(k+1)=xx(k)+xgm*(yy(k)-xx(k))*h;
yy(k+1)=yy(k)-xx(k)*zz(k)*h+r*xx(k)*h-yy(k)*h;
zz(k+1)=zz(k)+xx(k)*yy(k)*h-b*zz(k)*h;
t(k+1)=t(k)+h;
end
deltaz=abs(zz-z);
logdeltaz=log(deltaz)/log(10);
plot(t,logdeltaz)
xlabel('t')
ylabel('\delta z')

```



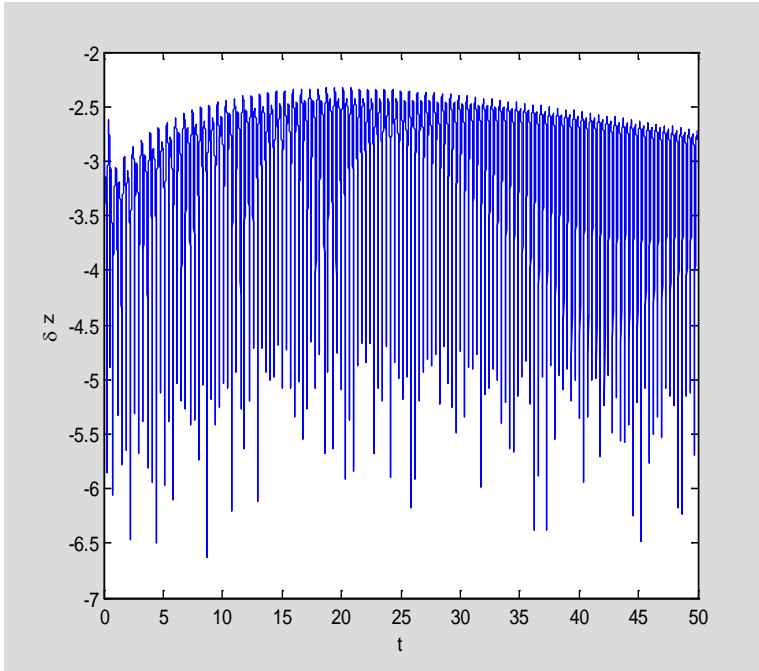
3.29

```

clear
xgm=10;b=8/3;r=22;
p=0;q=50;h=0.001;n=(q-p)/h;
t(1)=0;x(1)=1;y(1)=0;z(1)=0;
xx(1)=1;yy(1)=0;zz(1)=0.001;
for k=1:1:n
x(k+1)=x(k)+xgm*(y(k)-x(k))*h;
y(k+1)=y(k)-x(k)*z(k)*h+r*x(k)*h-y(k)*h;
z(k+1)=z(k)+x(k)*y(k)*h-b*z(k)*h;
xx(k+1)=xx(k)+xgm*(yy(k)-xx(k))*h;
yy(k+1)=yy(k)-xx(k)*zz(k)*h+r*xx(k)*h-yy(k)*h;
zz(k+1)=zz(k)+xx(k)*yy(k)*h-b*zz(k)*h;
t(k+1)=t(k)+h;
end
deltaz=abs(zz-z);
logdeltaz=log(deltaz)/log(10);
plot(t,logdeltaz)

```

```
xlabel('t')
ylabel('\delta z')
```

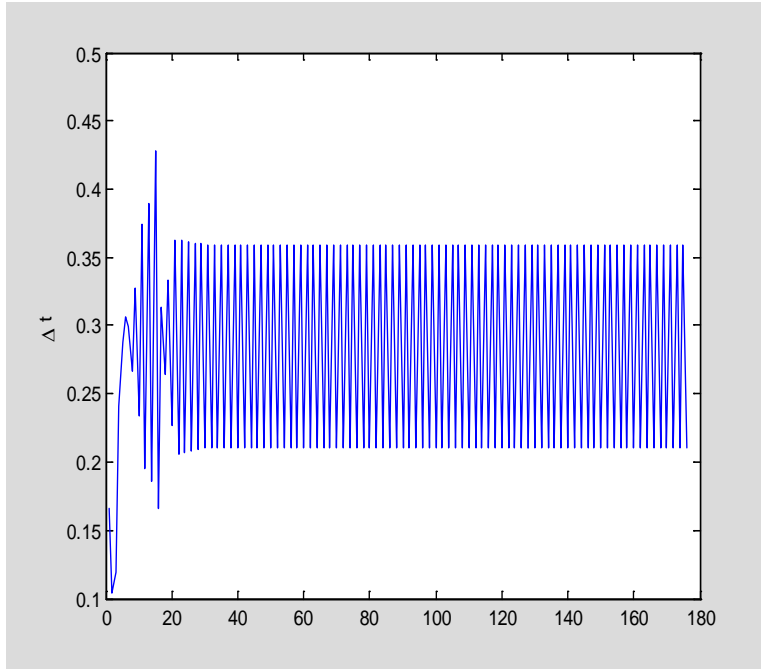


李雅普诺夫指数为负数

3.30

```
clear
xgm=10;b=8/3;r=163;
p=0;q=50;h=0.0001;n=(q-p)/h;
t(1)=0;x(1)=1;y(1)=0;z(1)=0;
for k=1:1:n
x(k+1)=x(k)+xgm*(y(k)-x(k))*h;
y(k+1)=y(k)-x(k)*z(k)*h+r*x(k)*h-y(k)*h;
z(k+1)=z(k)+x(k)*y(k)*h-b*z(k)*h;
t(k+1)=t(k)+h;
end

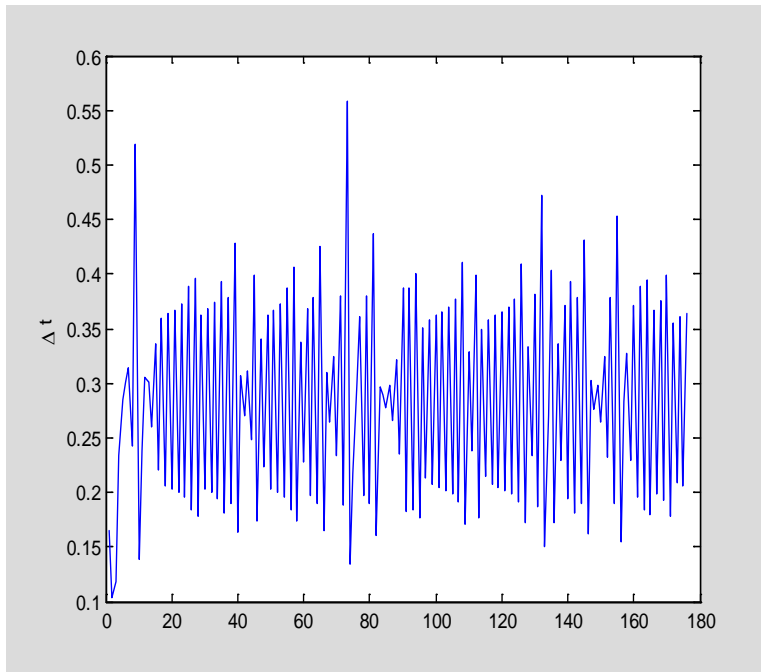
kk=1;
for k=2:1:n-1
if (z(k)>z(k-1))&(z(k)>z(k+1))
tt(kk)=t(k);
kk=kk+1;
end
end
for ii=(kk-1):-1:2
tt(ii)=tt(ii)-tt(ii-1);
end
plot(tt)
ylabel('\Delta t')
```



Δt 在 0.3 附近，由于欧拉法出现一些震荡

```
clear
xgm=10;b=8/3;r=165;
p=0;q=50;h=0.0001;n=(q-p)/h;
t(1)=0;x(1)=1;y(1)=0;z(1)=0;
for k=1:1:n
x(k+1)=x(k)+xgm*(y(k)-x(k))*h;
y(k+1)=y(k)-x(k)*z(k)*h+r*x(k)*h-y(k)*h;
z(k+1)=z(k)+x(k)*y(k)*h-b*z(k)*h;
t(k+1)=t(k)+h;
end

kk=1;
for k=2:1:n-1
if (z(k)>z(k-1))&(z(k)>z(k+1))
tt(kk)=t(k);
kk=kk+1;
end
end
for ii=(kk-1):-1:2
tt(ii)=tt(ii)-tt(ii-1);
end
plot(tt)
ylabel('\Delta t')
```



高的峰值就是 hiccup 出现的位置

3.31

```
clear all
x(1)=0.2;
y(1)=0;
vx(1)=0.5;
vy(1)=0.4;
dt=0.01;
hold on
box on

theta=0:pi/20:2*pi;
X=0.2*sin(theta);
Y=0.2*cos(theta);
plot(X,Y,'r-','LineWidth',4)

for i=1:100/dt

    flagx=1;
    flagy=1;
    x(i+1)=x(i)+vx(i)*dt;
    y(i+1)=y(i)+vy(i)*dt;

    if x(i+1)>1
        vx(i+1)=-vx(i);
        flagx=0;
    end

    if x(i+1)<-1
        vx(i+1)=-vx(i);
        flagx=0;
    end
end
```



```

end

if y(i+1)>1
    vy(i+1)=-vy(i);
    flagy=0;
end

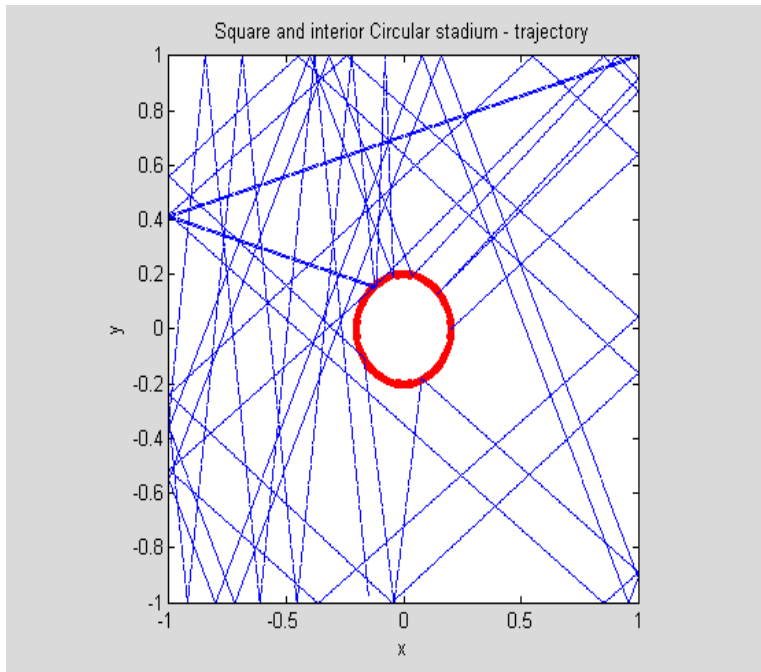
if y(i+1)<-1
    vy(i+1)=-vy(i);
    flagy=0;
end

if sqrt(x(i+1)^2+y(i+1)^2)<0.2
    cos1=x(i)./sqrt(x(i)^2+y(i)^2);
    sin1=y(i)./sqrt(x(i)^2+y(i)^2);
    vx(i+1)=vx(i).*sin1.*sin1-vx(i).*cos1.*cos1-vy(i).*cos1.*sin1-
vy(i).*sin1.*cos1;
    vy(i+1)=-vx(i).*sin1.*cos1-vx(i).*cos1.*sin1+vy(i).*cos1.*cos1-
vy(i).*sin1.*sin1;
    flagx=0;
    flagy=0;
end

if flagx==1
    vx(i+1)=vx(i);
end
if flagy==1
    vy(i+1)=vy(i);
end
plot(x(i),y(i),'b.','MarkerSize',3)

end
axis equal
axis([-1,1,-1,1])
xlabel('x')
ylabel('y')
title('Square and interior Circular stadium - trajectory')

```



3.32

```
clear all
l=9.8;
g=9.8;
dt=0.04;
```

```
omega(1)=0;
theta(1)=0.2;
t(1)=0;
q=1/2;
Omega=2/3;
```

```
subplot(2,2,1)
hold on
box on
```

```
F=0.5;
for i=1:100/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;

    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end
end
```

```

end
plot(abs(fft(abs(theta))))
axis([0,100,0,1000])
title('F=0.5')

subplot(2,2,2)
hold on
box on

F=0.95;
for i=1:100/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;

    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

end
plot(abs(fft(abs(theta))))
axis([0,100,0,3000])
title('F=0.95')

subplot(2,2,3)
hold on
box on

F=1.2;
for i=1:100/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;

    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

end
plot(abs(fft(abs(theta))))
axis([0,100,0,3000])
title('F=1.2')

subplot(2,2,4)
hold on

```

```

box on

F=1.44;
for i=1:100/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;

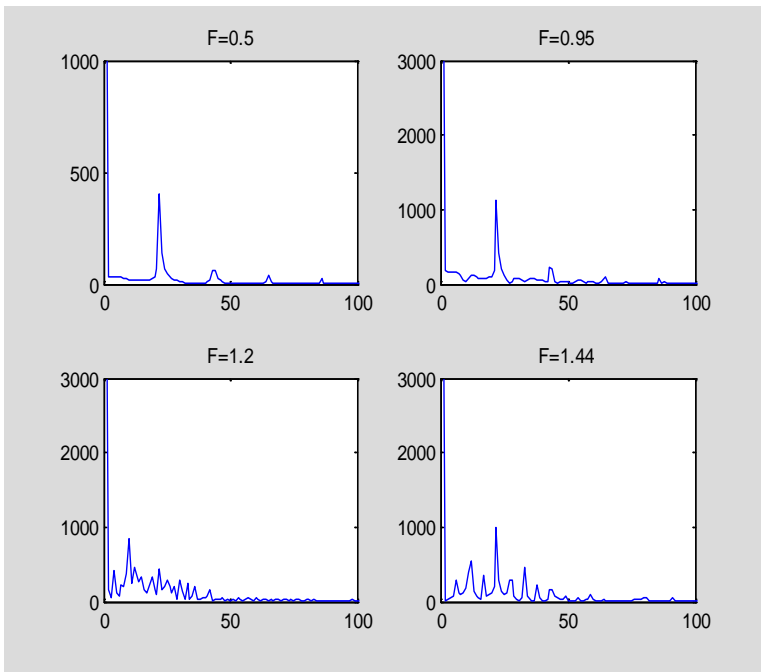
    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

end
plot(abs(fft(abs(theta))))
axis([0,100,0,3000])
title('F=1.44')

```



3.33

%

3.34

%

3.35

clear all

```

l=9.8;
g=9.8;
dt=0.04;

omega(1)=0;
theta(1)=0.2;
t(1)=0;
q=1/2;
Omega=2/3;

hold on
box on

F=1.424;
for i=1:100/dt
    omega(i+1)=omega(i)-g/l*sin(theta(i))*dt-
q*omega(i)*dt+F*sin(Omega*t(i))*dt;
    theta(i+1)=theta(i)+omega(i+1)*dt;

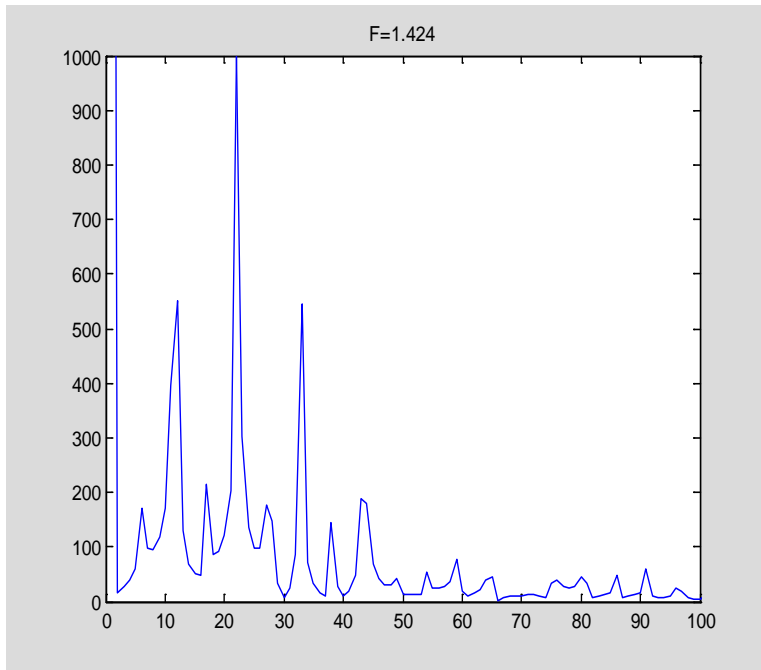
    t(i+1)=t(i)+dt;

    if theta(i+1)>pi
        theta(i+1)=theta(i+1)-2*pi;
    end

    if theta(i+1)<-pi
        theta(i+1)=theta(i+1)+2*pi;
    end

end
plot(abs(fft(abs(theta))))
axis([0,100,0,1000])
title('F=1.424')

```



3.36

%

3.37

```
clear all
delta=10;
b=8/3;
x(1)=1;
y(1)=0;
z(1)=0;
dt=0.0001;

subplot(2,2,1)
hold on
box on
r=25;
for i=1:30/dt
    x(i+1)=x(i)+delta*(y(i)-x(i))*dt;
    y(i+1)=y(i)+(-x(i)*z(i)+r*x(i)-y(i))*dt;
    z(i+1)=z(i)+(x(i)*y(i)-b*z(i))*dt;
end
plot(abs(fft(z)))
axis([0,1000,0,40000])
title('r=25')

subplot(2,2,2)
hold on
box on
r=160;
for i=1:30/dt
    x(i+1)=x(i)+delta*(y(i)-x(i))*dt;
```

```

        y(i+1)=y(i)+(-x(i)*z(i)+r*x(i)-y(i))*dt;
        z(i+1)=z(i)+(x(i)*y(i)-b*z(i))*dt;

    end
    plot(abs(fft(z)))
    axis([0,1000,0,80000])
    title('r=163')

    subplot(2,2,3)
    hold on
    box on
    r=163.8;
    for i=1:30/dt
        x(i+1)=x(i)+delta*(y(i)-x(i))*dt;
        y(i+1)=y(i)+(-x(i)*z(i)+r*x(i)-y(i))*dt;
        z(i+1)=z(i)+(x(i)*y(i)-b*z(i))*dt;

    end
    plot(abs(fft(z)))
    axis([0,1000,0,80000])
    title('r=163.8')

    subplot(2,2,4)
    hold on
    box on
    r=26;
    for i=1:30/dt
        x(i+1)=x(i)+delta*(y(i)-x(i))*dt;
        y(i+1)=y(i)+(-x(i)*z(i)+r*x(i)-y(i))*dt;
        z(i+1)=z(i)+(x(i)*y(i)-b*z(i))*dt;

    end
    plot(abs(fft(z)))
    axis([0,1000,0,80000])
    title('r=26')

```

