```
function pingpong1(e,Y0,YDOT0,tmax,x0,frq,ph,g,anim,ptxt)
%PINGPONG1(E,Y0,YDOT0,TMAX,XX,FRQ,PH,G)
%     hemh 29 10 00
%     simulates a pingpong ball bouncing on a sinusoidally-vibrating bat
%     default values are given in [ ]:
%           coeff of restitution       E     [0.98]
%           initial height    (m)         Y0    [0.3]
%           initial velocity (m/s)     YDOT0 [0]
%           time for calculation (s)   TMAX  [10]
%           bat amplitude (m)          X0    [0.01]
%           bat frequency (Hz)         FRQ   [4]
%           bat sine phase (rad)       PH    [0]
%           g                             (m/s^2)     G     [9.81]
%
%try:
%pingpong1(0.9,0.1,0,10,0.02,4,0,9.81,1,'CHAOTIC_1') %chaotic
%pingpong1(0.9,0.1,0,10,0.01,5.37,0,9.81,1,'CHAOTIC_2')  %limit cycle dead zone
%pingpong1(0.9,0.1,0,20,0.01,3.5,0,9.81,1,'LIMIT_CYCLE_1')  %limit cycle 1
%pingpong1(0.9,0.1,0,10,0.01,5.3,0,9.81,1,'LIMIT_CYCLE_2')  %limit cycle 2
%pingpong1(0.9,0.1,0,10,0.01,5.36,0,9.81,1,'LIMIT_CYCLE_3')  %limit cycle 2
%pingpong1(0.9,0.1,0,10,0.01,5.301,0,9.81,1,'LIMIT_CYCLE_4')  %limit cycle 2
false start
%pingpong1(0.9,0.1,0,20,0.01,5.3918,0,9.81,1,'LIMIT_CYCLE_5')  %limit cycle 2
double freq


if nargin<1 e=0.9;end
if nargin<2 Y0=0.1;end
if nargin<3 YDOT0=0;end
if nargin<4 tmax=10;end
if nargin<5 x0=0.02;end
if nargin<6 frq=4;end
if nargin<7 ph=0;end
if nargin<8 g=9.81;end
if nargin<9 anim=1;end
if nargin<10 ptxt='CHAOTIC';end

%initialize variables
dt=tmax/5000;
om=2*pi*frq;
y0=Y0;
ydot0=YDOT0;
t0=0;
tcontact=0;
T=[];Y=[];Ydot=[];Tcontact=[];
%disp(' time (s)   bounce height (m)')
warning off
while tcontact<tmax
    tcalc=max(roots([-g/2 ydot0 y0+x0]));    %max time for ball to return to bat
    args=[y0,ydot0,t0,x0,om,ph];
        tcontact=fzero(@contact,[tcontact+10000*eps tcontact+tcalc],[],args);
    % tcontact=fzero('contact',[tcontact+100*eps tcontact+tcalc],[],0,args);
    tplot=t0+[0:dt:tcontact-t0]';
    [y,ydot]=ball(tplot,y0,ydot0,t0);
    [x,xdot]=bat(tcontact,x0,om,ph);
    [y0,ydot0]=ball(tcontact,y0,ydot0,t0);
    T=[T;tplot];
```

```
    Y=[Y;y];
    Ydot=[Ydot;ydot];
    ydot0=xdot-e*(ydot0-xdot);
    t0=tcontact;
    Tcontact=[Tcontact;tcontact];
%    disp([tcontact max(y)])
end
warning on
figure(1)
hold off
plot(T,Y,'linewidth',2)
hold on
plot(Tcontact,bat(Tcontact,x0,om,ph),'o')
plot(T,bat(T,x0,om,ph),'r','linewidth',2)
hold off
ax=axis;
axis([0 tmax ax(3:4)]);
xlabel('time (s)')
ylabel('distance (m)')
title(['pingpong ball bouncing on a sinusoidally-oscillating bat - '
ptxt],'interpreter','none')
text(0.05,0.95,['e=' num2str(e) ', y0=' num2str(Y0) 'm, ydot0=' num2str(YDOT0)
...
        'm/s, frq=' num2str(frq) 'Hz, ph=' num2str(ph) 'rad' ...
        '   red=bat, blue=ball, o=contacts'],'units','normal');

figure(gcf)

if anim==1
    figure(2)
    set(gcf,'position',[1   281   280   420])
    clf
    axes('position',[0 0 1 1])
    set(2,'doublebuffer','on')
    dt=0.02;
    t1=[0:dt:tmax];
    y1=interp1(T,Y,t1);
    b1=interp1(T,bat(T,x0,om,ph),t1);
    %plot(t1,y1,t1,b1)  %as check

    N=length(t1);
    for j=1:N
        drawball(y1(j))
        axis([-2 2 [-2 2]+1.5]*Y0)
        axis('square')
        axis('off')
        hold on
        drawbat(b1(j))
        tplot=num2str(t1(j),'%4.2f');
        text(-x0,-5*x0,['ball on bat - '
ptxt],'horizontalalign','center','interpreter','none')
        text(-x0,-7*x0,[tplot ' s'],'horizontalalign','center','fontsize',7)
        text(-x0,-
9*x0,'www.hughhunt.com','horizontalalign','center','fontsize',8)

        hold off
        drawnow
```

```
        pause(dt)
        MOV(j)=getframe(gcf);

    end
    movie2avi(MOV,['pingpong' ptxt
'.avi'],'fps',8,'compression','Indeo5','quality',65)
    eval(['print -f1 -djpeg ' ptxt])

end

function z=contact(t,args)
y0=args(1);ydot0=args(2);t0=args(3);x0=args(4);om=args(5);ph=args(6);
z=bat(t,x0,om,ph)-ball(t,y0,ydot0,t0);

function [x,xdot,xddot]=bat(t,x0,om,ph)
x=x0*sin(om*t-ph);
xdot=x0*om*cos(om*t-ph);
xddot=-x0*om^2*sin(om*t-ph);

function [y,ydot,yddot]=ball(t,y0,y0dot,t0)
g=9.81;
y=y0+y0dot*(t-t0)-0.5*g*(t-t0).^2;
ydot=y0dot-g*(t-t0);
yddot=-g;

%--------------------------------------
function drawball(yc)
a=0.04;
th=[0:10:360]/180*pi;
x=a*cos(th);
y=a*(sin(th)+1)+yc;
fill(x,y,'r','edgecolor','r')
%--------------------------------------
function drawbat(yc)
a=0.04;b=0.01;
x=[1 -1 -1 1 1]*a;
y=([1 1 -1 -1 1]-1)*b+yc;
fill(x,y,'b','edgecolor','b')
plot([1 -3]*a,[0 0]-b+yc,'b','linewidth',4)
```