```
% C. Petersen, H. Werkle, Dynamik der Baukonstruktionen
% 2. Auflage, Springer Vieweg, Wiesbaden, 2018
%
% ML_29_3_Einfreiheitsgradschwinger_mit_nichtlinearer_Kennlinie_2:
% Schwingungen eines Einfreiheitsgradschwingers mit nichtlinearer Kennlinie
% (Newmark-Verfahren)
%
% Version 1.0, April 2018
% Softwareentwicklung:
% Andrei Firus, M.Eng (andrei.firus@gmail.com)

% Aufbau Eingabedatei:
%   - Spalte 1: Zeitvektor des Kraftverlaufs [s]
%   - Spalte 2: Kraftvektor [N]
% ANMERKUNG: Dezimaltrennzeichen '.'

% Ausgabedateien:
% Outputdatei_1: Eingaben- und Ergebnisübersicht
% Outputdatei_2: Verschiebungszeitverlauf
% Outputdatei_3: Geschwindigkeitszeitverlauf
% Outputdatei_4: Beschleunigungszeitverlauf

%---------------------------- EINGABEBLOCK --------------------------------
m=5000;                          % Masse des EFS [kg]
d=2500;                          % Dämpfungskoeffizient [Ns/m]

k1=10^6;                         % Lineare Federzahl [N/m]
k2=0;                            % Quadratische Federzahl [N/m^2]
k3=10^8;                         % Kubische Federzahl [N/m^3]
k4=0;                            % Biquadratische Federzahl [N/m^4]

dt=0.001;                        % Berechnungszeitschritt [s]

t_ber=10;                        % Gesamtzeit der Berechnung [s]

eps=0.001;                       % relative Genauigkeit mit der die
                                 % kinetische Gleichgewichtsgleichung
                                 % erfüllt werden soll

% Integrationsparameter für das Newmark-Verfahren
alpha=1/2;
beta=1/4;

% Anfangswerte
y0=0.0;                            % Anfangsauslenkung [m]
v0=0.0;                            % Anfangsgeschwindigkeit [m/s]
%-----------------------------------------------------------------------------
% Ablesen der diskreten Lastwerte von der Eingabedatei und Generierung der
% entsprechenden Vektoren
Zeitverlauf=dlmread('Inputdatei_1.txt');
t_kraft=Zeitverlauf(:,1);
Kraft=Zeitverlauf(:,2);
%-----------------------------------------------------------------------------

%-------------------------- BERECHNUNGSBLOCK -------------------------------
% Berechnung weiterer System- und Berechnungsparameter
```

```
nt=ceil(t_ber/dt)+1;              % Anzahl Berechnungszeitschritte

% Interpolation des Kraftvektors mit Berücksichtigung des
% Berechnungzeitschrittes 'dt'
Zeit_Int=0:dt:t_kraft(length(t_kraft));
Kraft_Int = interp1(t_kraft,Kraft,Zeit_Int,'linear');
% ANMERKUNG: Je nach Anwendungsziel kann die Interpolationsmethode geändert
% werden. Für weitere Interpolationsmethoden siehe Matlab-Hilfe zur
% Funktion "interp1" (Befehl 'help interp1' in Command Window)

% Erstellung des Kraftvektors für die Berechnung (einschließlich Ergänzung
% mit Nullwerten über die Krafteinwirkungsdauer hinaus)

F=zeros(nt,1);
for i=1:1:nt
    if i<=length(Kraft_Int)
        F(i)=Kraft_Int(i);
    else
        F(i)=0;
    end
end
t_b=0:dt:dt*(nt-1);

% ANMERKUNG: Bei Berechnung freier Schwingungen mit Anfangsverschiebung
% bzw. -geschwindigkeit soll die nächste Zeile unkommentiert werden.
% Dadurch werden alle Einträge des Kraftvektors zu Null gesetzt.

% F=zeros(nt,1);

% Berechnung der Schwingungsantwort mittels Newmark-Verfahren (iterative
% inkrementelle Fassung)

% Definition der Ergebnisvektoren
y=zeros(nt,1);   % Verschiebungsvektor
v=zeros(nt,1);   % Geschwindigkeitsvektor
a=zeros(nt,1);   % Beschleunigungsvektor

% Berücksichtigung der Anfangswerte
y(1)=y0;
v(1)=v0;
a(1)=(F(1)-d*v(1)-(k1*y(1)+k2*y(1)^2+k3*y(1)^3+k4*y(1)^4))/m;

% Inkrementelle Vektoren
dy=zeros(nt-1,1);
dv=zeros(nt-1,1);
da=zeros(nt-1,1);
df=zeros(nt-1,1);
dr=zeros(nt-1,1);
for i=1:1:length(df)
    df(i)=F(i+1)-F(i);
end

% Berechnungsvorschrift
ak=1/eps;
for i=2:1:length(dy)
    while 1
```

```
    dy(i)=v(i-1)*dt+0.5*a(i-1)*dt^2+beta*da(i)*dt^2;
    y(i)=y(i-1)+dy(i);

    dv(i)=a(i-1)*dt+alpha*da(i)*dt;
    v(i)=v(i-1)+dv(i);

    dr(i)=k1*y(i)+k2*y(i)^2+k3*y(i)^3+k4*y(i)^4-(k1*y(i-1)+k2*y(i-1)^2+...
        k3*y(i-1)^3+k4*y(i-1)^4);

    da(i)=(df(i)-d*dv(i)-dr(i))/m;
    a(i)=a(i-1)+da(i);

    if abs(a(i)-ak)/abs(a(i))<eps
        break
    else
         ak=a(i);
    end
    end
end

% Extremwerte
ymax=max(y); ymin=min(y);
vmax=max(v); vmin=min(v);
amax=max(a); amin=min(a);
%------------------------- DARSTELLUNGSBLOCK -----------------------------
% Grafische Darstellung der Ergebnisse
name_fig1 = 'System und Belastung';
fig1=figure('Name',name_fig1,'NumberTitle','off');
set(fig1,'Position',[1000 50 700 900]);

subplot(2,1,1)
x_f_k_max=0.15;  % x - Achsenlimit für die Darstellung der Federkennlinie
x_f_k=-x_f_k_max:0.01:x_f_k_max;
f_f_k=k1.*x_f_k.^1+k2.*x_f_k.^2+k3.*x_f_k.^3+k4.*x_f_k.^4;
plot(x_f_k,f_f_k,'MarkerSize',3);
title('Federkennlinie');
xlabel('y [m]');
ylabel('f(y) [N]');
grid on; zoom on;

subplot(2,1,2)
plot(t_b,F,'MarkerSize',3);
title('Kraftverlauf');
xlabel('Zeit [s]');
ylabel('Kraft [N]');
grid on; zoom on;
%-------------------------------------------------------------------------

name_fig2 = 'Bewegungszeitverläufe';
fig2=figure('Name',name_fig2,'NumberTitle','off');
set(fig2,'Position',[200 300 800 500]);

subplot(3,1,1)
plot(t_b,y,'MarkerSize',3);
title('Verschiebungszeitverlauf');
xlabel('Zeit [s]');
```

```
ylabel('Verschiebung [m]');
grid on; zoom on;

subplot(3,1,2)
t_b_v_a=0:dt:dt*(length(v)-1);
plot(t_b_v_a,v,'MarkerSize',3);
title('Geschwindigkeitszeitverlauf');
xlabel('Zeit [s]');
ylabel('Geschwindigkeit [m/s]');
grid on; zoom on;

subplot(3,1,3)
plot(t_b_v_a,a,'MarkerSize',3);
title('Beschleunigungszeitverlauf');
xlabel('Zeit [s]');
ylabel('Beschleunigung [m/s^2]');
grid on; zoom on;
%--------------------------------------------------------------------------

%---------------------------- AUSGABEBLOCK --------------------------------
% Ausgabe der Ergebnisse in eine Datei
fid = fopen('Outputdatei_1_Allgemein.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_29_3: Eingaben- und Ergebnisuebersicht');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','EINGABEDATEN:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Masse des Einfreiheitsgradschwingers [kg]:');
fprintf(fid,'%d\n',m);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Lineare Federzahl [N/m]:');
fprintf(fid,'%d\n',k1);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Quadratische Federzahl [N/m^2]:');
fprintf(fid,'%d\n',k2);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kubische Federzahl [N/m^3]:');
fprintf(fid,'%d\n',k3);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Biquadratische Federzahl [N/m^4]:');
fprintf(fid,'%d\n',k4);
fprintf(fid, '%s\n', ' ');
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%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Daempfungskoeffizient [Ns/m]:');
fprintf(fid,'%d\n',d);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anfangsauslenkung [m]:');
fprintf(fid,'%d\n',y0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Anfangsgeschwindigkeit [m/s]:');
fprintf(fid,'%d\n',v0);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Berechnungszeitschritt [s]:');
fprintf(fid,'%d\n',dt);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Gesamtzeit der Berechnung [s]:');
fprintf(fid,'%d\n',t_ber);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s %s\n%s\n','Genauigkeitsschranke für die Erfüllung der',...
    'kinetischen','Gleichgewichtsbedingung:');
fprintf(fid,'%d\n',eps);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Integrationsparameter fuer das Newmark-Verfahren:');
fprintf(fid,'%s \t %.4f\n','alpha=',alpha);
fprintf(fid,'%s \t %.4f\n','beta=',beta);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kraftzeitverlauf: siehe Dateiende');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','ERGEBNISSE:');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Verschiebung [m]:');
fprintf(fid,'%d\n',ymax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Verschiebung [m]:');
fprintf(fid,'%d\n',ymin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Maximale Geschwindigkeit [m/s]:');
fprintf(fid,'%d\n',vmax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Geschwindigkeit [m/s]:');
fprintf(fid,'%d\n',vmin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
```

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fprintf(fid,'%s\n','Maximale Beschleunigung [m/s^2]:');
fprintf(fid,'%d\n',amax);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Minimale Beschleunigung [m/s^2]:');
fprintf(fid,'%d\n',amin);
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fprintf(fid,'%s\n','Kraftzeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Kraft [N]');
for ii=1:1:length(Kraft)
    fprintf(fid,'%d \t %d\n',t_kraft(ii), Kraft(ii));
end
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Verschiebungen=[t_b' y];
fid = fopen('Outputdatei_2_Verschiebungen.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_29_3: Verschiebungszeitverlauf');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Verschiebungszeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Verschiebung [m]');
for ii=1:1:length(y)
    fprintf(fid,'%d \t %d\n',Ergebnis_Verschiebungen(ii,:));
end
fclose(fid);

%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%
Ergebnis_Geschwindigkeiten=[t_b_v_a' v];
fid = fopen('Outputdatei_3_Geschwindigkeiten.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_29_3: Geschwindigkeitszeitverlauf');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Geschwindigkeitszeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Geschwindigkeit [m/s]');
for ii=1:1:length(v)
```

```
    fprintf(fid,'%d \t %d\n',Ergebnis_Geschwindigkeiten(ii,:));
end
fclose(fid);
%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%%

Ergebnis_Beschleunigung=[t_b_v_a' a];
fid = fopen('Outputdatei_4_Beschleunigungen.txt', 'w');
fprintf(fid,...
    '%s\n','C. Petersen, H. Werkle, Dynamik der Baukonstruktionen');
fprintf(fid,...
    '%s\n','2. Auflage, Springer Vieweg, Wiesbaden, 2018');
fprintf(fid,...
    '%s\n','Softwareentwicklung: Andrei Firus (andrei.firus@gmail.com)');
fprintf(fid,'%s\n','Programm ML_29_3: Beschleunigungszeitverlauf');
fprintf(fid, '%s\n', ' ');
fprintf(fid,...
    '%s\n','-------------------------------------------------------------');
fprintf(fid, '%s\n', ' ');
fprintf(fid,'%s\n','Beschleunigungszeitverlauf:');
fprintf(fid,'%s \t %s\n','Zeit [s]', 'Beschleunigung [m/s^2]');
for ii=1:1:length(a)
    fprintf(fid,'%d \t %d\n',Ergebnis_Beschleunigung(ii,:));
end
fclose(fid);
%-------------------------------------------------------------------------
```