Scilab Textbook Companion for Mechanical Vibration by G. K. Grover[1]

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Book Description

Title: Mechanical Vibration

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Scilab numbering policy used in this document and the relation to the above book.

Exa Example (Solved example)

Eqn Equation (Particular equation of the above book)

AP Appendix to Example(Scilab Code that is an Appednix to a particular Example of the above book)

For example, Exa 3.51 means solved example 3.51 of this book. Sec 2.3 means a scilab code whose theory is explained in Section 2.3 of the book.

Contents

List of Scilab Codes

Chapter 1

Fundamental of vibration

Scilab code Exa 1.4.2 sum of two harmonic motion

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 1.4.2\n')
//given data
//case 1
//x1=(1/2)*cos((%pi/2)*t)...x1=a*cos(W1*t)
//x2=sin(%pi*t)...x2=b*sin(W2*t)
//calculations
W1=(%pi/2)
W2=%pi
t1=2*%pi/(W1)
t2=2*%pi/(W2)
p1=[t1 t2]
T1=lcm(p1)
//case 2
//x1=2*cos((%pi*t)...x1=a*cos(W3*t)
//x2=2*cos(2*t)...x2=a*cos(W4*t)
W3=%pi
W4=2
t3=2*%pi/(W3)
```

```
t4=2*%pi/(W4)
p2=[t3 t4]
T2=lcm(p2)
//output
mprintf('Case(i)\nTime period of first wave is %f sec\nTime period of first wave is %f sec\nThe time period of combined wave is %f sec\nCase(ii)\nTime period of first wave is %f sec\nTime period of first wave is %f sec\nThe time period of combined wave is %f sec',t1,t2,T1,t3,t4,T2)
mprintf('\nNOTE: The time period of combined motion in case (ii) cannot be calculated\n since pi is a non-terminating and non recurring number.\n But SCILAB takes the value of pi to be 3.141593 and therefore\n calculates the LCM of pi and the time period of first wave in case (ii.')
```

Scilab code Exa 1.5.1 max and min amplitude of combined motion

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 1.5.1\n')
//given data
//x1=a*sin(W1*t)
//x2=b*sin(W2*t)
//calculations
a=1.90//amplitude of first wave in cm
b=2.00//amplitude of second wave in cm
W1=9.5//frequency of first wave in rad/sec
W2=10.0//frequency of second wave in rad/sec
xmax=b+a//maximum amplitude of motion in cms
xmin=abs(a-b)//minimum amplitude of motion in cms
f=abs(W1-W2)/(2*%pi)//beat frequency in Hz
t=1/f//time period of beat in sec
```

```
//output
mprintf('The maximum amplitude of motion is %4.4f cms\nThe minimum amplitude of motion is %4.4f cms\n The beat frequency is %4.4f Hz\n the time period is %4.4f sec',xmax,xmin,f,t)
```

Scilab code Exa 1.6.1 `complex number in exponential form`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 1.6.1\n')
//given data
//case 1
//a complex number is represented as Z=X+j*Y where j is imaginary
//V=3 +j*7
x1=3
y1=7
//calculations
r1=sqrt(x1^2+y1^2)
    if (y1/x1)>0 then theta1=atan(y1/x1)
    else theta1=%pi-atan(abs(y1/x1))
    end
theta1=atan(y1/x1)
//case 2
//V=-5 +j*4
x2=-5
y2=4
//calculations
r2=sqrt(x2^2+y2^2)
 if (y2/x2)>0 then theta1=atan(y2/x2)
    else theta2=%pi-atan(abs(y2/x2))
    end
//output
```

```
mprintf('case(i) V=3+j*7 is represented as V=%3.3f*e
    ^(j*(%3.3f))\ncase(ii) V=-5+j*4 is represented as
    V=%3.3f*e^(j*(%3.3f))',r1,theta1,r2,theta2)
```

Scilab code Exa 1.6.2 `complex number in rectangular form`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
    Example 1.6.2\n')
//given data
//Z=r*e^(i*theta) is represented as Z=r*cos(theta) +
    i*r*sin(theta)= x +i*y
//where r*cos(theta)=x and r*sin(theta)=y
//case 1
//V=5*e^(j*0.10)
r1=5
theta1=0.1
x1=r1*cos(theta1)
y1=r1*sin(theta1)
v1=complex(x1,y1)
//case 2
//V=17*e^(-j*3.74)
r2=17
theta2=-3.74
x2=r2*cos(theta2)
y2=r2*sin(theta2)
v2=complex(x2,y2)
//output
mprintf('case(i):V=5*e^(j*0.10) is represented as')
disp(v1)
mprintf('\ncase(ii):V=17*e^(-j*3.74) is represented
    as')
disp(v2)
mprintf('\nNOTE:complex number is represented as x+y
```

```
*i in SCILAB')
```

Scilab code Exa 1.7.1 `work done by a force on displacement`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 1.7.1\n')
//given data
Po=25//amplitude of force in N
Xo=0.05//ampliyude of displacement in m
W=20*%pi
//calculations
//case 1
t0=0
t1=1
v1=integrate('sin(W*t)*cos(W*t-%pi/6)','t',t0,t1)
WD1=Po*Xo*W*v1
//case 2
t0=0
t1=1/40
v2=integrate('sin(W*t)*cos(W*t-%pi/6)','t',t0,t1)
WD2=Po*Xo*W*v2
//output
mprintf(' (i)work done during the first second is %f N-m\n (ii)work done during the first 1/40th of second is %f N-m',WD1,WD2)
```

Scilab code Exa 1.8.2 `fourier components of periodic motion`

```
clc
clear
```

```
mprintf('Mechanical vibrations by G.K.Grover\n Example 1.8.2\n')
//given data
T=0.1//time period of periodic motion in sec
W=2*%pi/T
k=12/2//number of elements in half cycle
mprintf('\tNo of elements in one cycle 2k=12,t(j) in degrees\n')
mprintf('t(j)      f(j)           cos(t(j))       f(j)*cos(t(j))    sin(t(j))      f(j)*sin(t(j)      cos(2*t(j))      f(j)*cos(2*t(j))    sin(2*t(j))    f(j)*sin(2*t(j))    cos(3*t(j))      f(j)*cos(3*t(j)   sin(3*t(j))    f(j)*sin(3*t(j)\n')
f(1)=10/6
for j=1:6
   t(j)=j*(%pi/k)
   m(j)=cos(t(j))
   n(j)=f(j)*m(j)
   o(j)=sin(t(j))
   p(j)=f(j)*o(j)
   q(j)=cos(2*t(j))
   r(j)=f(j)*q(j)
   s(j)=sin(2*t(j))
   u(j)=f(j)*s(j)
   v(j)=cos(3*t(j))
   x(j)=f(j)*v(j)
   y(j)=sin(3*t(j))
   z(j)=f(j)*y(j)
   f(j+1)=f(j)+f(1)
mprintf('%3.0f\t',t(j)*(180/%pi))
mprintf('%3.4f\t\t',f(j))
mprintf('%3.4f\t\t',m(j))
mprintf('%3.4f\t\t',n(j))
mprintf('%3.4f\t\t',o(j))
mprintf('%3.4f\t\t',p(j))
mprintf('%3.4f\t\t',q(j))
mprintf('%3.4f\t\t',r(j))
mprintf('%3.4f\t\t',s(j))
```

```
mprintf('%3.4f\t\t',u(j))
mprintf('%3.4f\t\t',v(j))
mprintf('%3.4f\t\t',x(j))
mprintf('%3.4f\t\t',y(j))
mprintf('%3.4f\n',z(j))
end
f(7)=f(j)-f(1)
for j=7:12
    t(j)=j*(%pi/k)
    m(j)=cos(t(j))
    n(j)=f(j)*m(j)
    o(j)=sin(t(j))
    p(j)=f(j)*o(j)
    q(j)=cos(2*t(j))
    r(j)=f(j)*q(j)
    s(j)=sin(2*t(j))
    u(j)=f(j)*s(j)
    v(j)=cos(3*t(j))
    x(j)=f(j)*v(j)
    y(j)=sin(3*t(j))
    z(j)=f(j)*y(j)
    f(j+1)=f(j)-f(1)
    mprintf('%3.0f\t',t(j)*(180/%pi))
mprintf('%3.4f\t\t',f(j))
mprintf('%3.4f\t\t',m(j))
mprintf('%3.4f\t\t',n(j))
mprintf('%3.4f\t\t',o(j))
mprintf('%3.4f\t\t',p(j))
mprintf('%3.4f\t\t',q(j))
mprintf('%3.4f\t\t',r(j))
mprintf('%3.4f\t\t',s(j))
mprintf('%3.4f\t\t',u(j))
mprintf('%3.4f\t\t',v(j))
mprintf('%3.4f\t\t',x(j))
mprintf('%3.4f\t\t',y(j))
mprintf('%3.4f\n',z(j))
end
sumf(j)=f(1)+f(2)+f(3)+f(4)+f(5)+f(6)+f(7)+f(8)+f(9)
```

```
+f(10)+f(11)+f(12)
sumcos(t(j))=m(1)+m(2)+m(3)+m(4)+m(5)+m(6)+m(7)+m(8)+m(9)+m(10)+m(11)+m(12)
sumfjcos(t(j))=n(1)+n(2)+n(3)+n(4)+n(5)+n(6)+n(7)+n(8)+n(9)+n(10)+n(11)+n(12)
sumsin(t(j))=o(1)+o(2)+o(3)+o(4)+o(5)+o(6)+o(7)+o(8)+o(9)+o(10)+o(11)+o(12)
sumfjsin(t(j))=p(1)+p(2)+p(3)+p(4)+p(5)+p(6)+p(7)+p(8)+p(9)+p(10)+p(11)+p(12)
sumcos2(t(j))=q(1)+q(2)+q(3)+q(4)+q(5)+q(6)+q(7)+q(8)+q(9)+q(10)+q(11)+q(12)
sumfjcos2(t(j))=r(1)+r(2)+r(3)+r(4)+r(5)+r(6)+r(7)+r(8)+r(9)+r(10)+r(11)+r(12)
sumsin2(t(j))=s(1)+s(2)+s(3)+s(4)+s(5)+s(6)+s(7)+s(8)+s(9)+s(10)+s(11)+s(12)
sumfjsin2(t(j))=u(1)+u(2)+u(3)+u(4)+u(5)+u(6)+u(7)+u(8)+u(9)+u(10)+u(11)+u(12)
sumcos3(t(j))=v(1)+v(2)+v(3)+v(4)+v(5)+v(6)+v(7)+v(8)+v(9)+v(10)+v(11)+v(12)
sumfjcos3(t(j))=x(1)+x(2)+x(3)+x(4)+x(5)+x(6)+x(7)+x(8)+x(9)+x(10)+x(11)+x(12)
sumsin3(t(j))=y(1)+y(2)+y(3)+y(4)+y(5)+y(6)+y(7)+y(8)+y(9)+y(10)+y(11)+y(12)
sumfjsin3(t(j))=z(1)+z(2)+z(3)+z(4)+z(5)+z(6)+z(7)+z(8)+z(9)+z(10)+z(11)+z(12)
a0=sumf(j)/(2*k)
a1=sumfjcos(t(j))/k
b1=sumfjsin(t(j))/k
a2=sumfjcos2(t(j))/k
b2=sumfjsin2(t(j))/k
a3=sumfjcos3(t(j))/k
b3=sumfjsin3(t(j))/k
disp('The fourier components of periodic motion shown in example 1.8.1 are as follows')
mprintf('\nao=%f\na1=%f\nb1=%f\na2=%f\nb2=%f\na3=%f\nb3=%f\n',a0,a1,b1,a2,b2,a3,b3)
```

Chapter 2

Undamped free vibrations of single degree of freedom system

Scilab code Exa 2.3.4 moment of inertia of flywheel

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 2.3.4\n')
//given data
M=35//mass of flywheel in Kgs
r=0.3/2 //distance of centre of mass from pivot in m
T=1.22 //time period of oscillation in sec
g=9.81//accelaration due to gravity in m/(sec^2)
//concept is as follows
//Jo=mass moment of inertia about pivot , Wn=natural
   freqency
//thetadd=theta double dot(double differentiation)
//Jo*thetadd=-M*g*r*theta ....sum of moments is = to
    zero
//Jo*thetadd +(M*g*r*theta)=0
//Wn=sqrt((M*g*r*)/Jo)=2*pi/T
//calculations
Jo=M*g*r/((2*%pi/T)^2)
```

```
Jg=Jo-M*r^2 //mass moment of inertia about geometric
    axis
//output
mprintf('Mass moment of inertia about pivot is %4.4f
    Kg-m^2\n Mass moment of inertia about geometric
   axis is %4.4f Kg-m^2',Jo,Jg)
```

Scilab code Exa 2.4.1 `natural frequency of torsional pendulum`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 2.4.1\n')
//given data
l=1 //lenght in m
d=0.005 //dia of rod im m
D=0.2 //dia of dotor in m
M=2 //mass of motor in Kg
G=0.83 *10^11 //modulus of rigidity in N/m^2
//calculations
J=M*((D/2)^2)/2 //mass moment of inertia in Kg-m^2
Ip=(%pi/32)*d^4 //section modulus in m^4
Kt=G*Ip/l //stiffness in N-m/rad
Wn=sqrt(Kt/J) //natural freqency in rad/sec
fn=Wn/(2*%pi) //natural freq in Hz
//output
mprintf(' The natural freqency of vibration of
   torsional pendulum is %4.4f rad/sec\n or %4.4f Hz
   ',Wn,fn)
mprintf('\nNOTE:In book the natural freqency of
   vibration of torsional pendulum\nis given as 36
   Hz which is wrong.')
```

Scilab code Exa 2.5.1 mass in a spring mass system

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 2.5.1\n')
//given data
k1=2000 //stiffness of spring 1 in N/m
k2=1500 //stiffness of spring 2 in N/m
k3=3000 //stiffness of spring 3 in N/m
k4=500 //stiffness of spring 4 in N/m
k5=500 //stiffness of spring 5 in N/m
fn =10 //natural frequency of system in Hz
//calculations
Ke1=1/((1/k1)+(1/k2)+(1/k3)) // effective stiffness
   of  top 3 springs in series in N/m
Ke2=k4+k5 // effective stiffness of lower 2 springs
   in parallel in N/m
Ke=Ke1+Ke2 //  total effective stiffness of sring
   system
M=Ke/(2*%pi*fn)^2 //reqired mass such that the
   natural frequency of system is 10 Hz  (in Kg)
//output
mprintf(' The mass required such that the natural
   frequency of system is 10 Hz\n is %4.4f Kg',M)
```

Scilab code Exa 2.5.2 natural frequency of torsional oscillation

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 2.5.2\n')
//given data
G=0.83*10^11//rigidity modulus in N/m^2
J=14.7 //mass moment of inertia in kg-m^2
```

```
l1=0.6 //lenght of section 1 in m
l2=1.8 //lenght of section 2 in m
l3=0.25 //lenght of section 3 in m
d1=0.05 //dia of section 1 in m
d2=0.08 //dia of section 2 in m
d3=0.03 //dia of section 3 in m
//calculations
Kt1=(G/l1)*(%pi/32)*d1^4 //(%pi/32)*d^4 is the section modulus
Kt2=(G/l2)*(%pi/32)*d2^4
Kt3=(G/l3)*(%pi/32)*d3^4
Kt=1/((1/Kt1)+(1/Kt2)+(1/Kt3)) //total effective stiffness of the torsional system
Wn=sqrt(Kt/J)//natural freq in rad/sec
fn=Wn/(2*%pi) //natural freq in Hz
//output
mprintf(' The natural frequency of torsional oscillation for the given system is\n %4.4f rad/sec or %4.4f Hz.',Wn,fn)
mprintf('\nNOTE:Since the value of Kt in the textbook has been rounded of\n  to 3 decimal places,the final answer varies slightly.')
```

Chapter 3

Damped free vibrations of single degree of freedom system

Scilab code Exa 3.3.2 undamped and damped natural frequencies of system

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 3.3.2\n')
//given data
m=10 //mass of solid in Kg
Kr=3000 //stiffness of  natural rubber in N/m
Kf=12000 //stiffness of felt in N/m
Cr=100 //damping coefficient of  natural rubber in N
   -sec/m
Cf=330 //damping coefficient of felt in N-sec/m
//calculations
Ke=1/((1/Kf)+(1/Kr)) //equivalent stiffness in N/m
Ce=1/((1/Cf)+(1/Cr)) //equivalent damping
   coefficient N-sec/m
Wn=sqrt(Ke/m) // undamped natural freq in rad/sec
fn=Wn/(2*%pi) // undamped natural freq in Hz
zeta=Ce/(2*sqrt(Ke*m)) //damping factor
Wd=sqrt(1-zeta^2)*Wn //damped natural freuency in
```

```
rad/sec(eqn 3.3.16)
fd=Wd/(2*%pi) // damped natural frequency in Hz
//output
mprintf(' The undamped natural frequency is %4.4f rad/sec or %4.4f Hz\n The damped natural freuency is %4.4f rad/sec or %4.4f Hz',Wn,fn,Wd,fd)
```

Scilab code Exa 3.3.3 gun barrel recoilling

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 3.3.3\n')
//given data
m=600//mass of gun barrel in Kgs
k=294000//stiffness in N/m
x=1.3//recoil of gun in meters
//calculations
E=0.5*k*x^2//energy stored at the end of recoil
Vo=sqrt(2*E/m)//velocity of recoil
Cc=2*sqrt(k*m)//critical damping in N-sec/m
Wn=sqrt(k/m)//natural frequency of undamped vibration in rad/sec
T=2*%pi/Wn//time period of undamped vibration in sec
Trecoil=(1/4)*T//time period for recoil or outward stroke in sec
//x=(1.3+28.8*t)*e^(-22.1*t) from eqn 3.3.24
mprintf('a)the initial recoil velocity of barrel is %f m/s\nb)critical damping co-efficient of the dashpot which is engaged at\nthe end of recoil stroke is %f N-sec/m\n\nsubstituting the value for t in eqn 3.3.24,starting from t=0.1 sec\nwith an increment of 0.01sec we get the following observations\n',Vo,Cc)
t=0.1
```

```
for i=1:20
    x=(1.3 +28.8*t)*exp(-22.1*t)
    mprintf('x=%f at t=%f\n',x,t)
    t=t+0.01
end
mprintf('As x approaches the value of 0.05m,the value of t=0.22sec')
Trec=0.22
Tret=Trecoil+Trec
mprintf('\nc)Therefore time required for barrel to return to position 5cm from\n the initial position is %f sec',Tret)
```

Scilab code Exa 3.4.1 disc of torsional pendulum

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 3.4.1\n')
//given data
J=0.06 //moment of inertia of disc of pendulum in Kg-m^2
G=4.4*10^10 //rigidity modulus in N/m^2
l=0.4 //lenght of shaft in m
d=0.1 //diametre of shaft in m
a1=9 //amplitude of first oscillation in degrees
a2=6 //amplitude of second oscillation in degrees
a3=4 //amplitude of third oscillation in degrees
//calculations
delta=log(a1/a2) //logarithmic decrement eqn 3.4.1 explained in sec 3.4
zeta=delta/sqrt(4*%pi^2+delta^2) //representing zeta from eqn 3.4.1 in sec 3.4
Kt=(G/l)*(%pi/32)*d^4 //(%pi/32)*d^4 is the section modulus
```

```
C=zeta*2*sqrt(Kt*J) // torsional damping coefficient which is the damping torque at unit velocity (similar to eqn 3.3.6 in sec 3.3)
Wn=sqrt(Kt/J) // undamped natural freq in rad/sec
T=2*%pi/(sqrt(1-zeta^2)*Wn) //periodic time of vibration
fn=Wn/(2*%pi) //natural freq of undamped vibration
//output
mprintf(' a)logarithmic decrement is %4.4f\n b)damping torque at unit velocity is %4.4f N-m/rad\n c)periodic time of vibration is %4.5f sec\n frequency of vibration if the disc is removed from viscous fluid is %4.4f Hz',delta,C,T,fn)
```

Scilab code Exa 3.6.1 spring mass system with coulomb damping

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 3.6.1\n')
//given data
m=5 //mass in spring mass system )in kg)
k=980//stiffnes of spring in N/m
u=0.025//coefficient of friction
g=9.81//acceleration due to gravity
//calculations
F=u*m*g//frictional force in N
Wn=sqrt(k/m)// freq of free oscillations in rad/sec
fn=Wn/(2*%pi)// freq of free oscillations in Hz
Ai=0.05//initial amplitude in m
Ar=0.5*Ai//reduced amplitude in m
totAreduc=Ai-Ar//total reduction in amp in m
Areducpercycl=4*F/k //reduction in amplitude/cycle explained in section 3.6.2 in eqn 3.6.6
n=round(totAreduc/Areducpercycl) //number of cycles
```

```
for 50% reduction in amplitude
Treduc=n*(2*%pi/Wn)//time taken to achieve 50 %reduction
//output
mprintf(' a)The frequency of free oscillations is %4.4f rad/sec or %4.4f Hz\n b)number of cycles taken for 50 percent reduction in amplitude is %1.0f cycles\n c)time taken to achieve 50 percent reduction in amplitude is %4.4f sec',Wn,fn,n,Treduc)
```

Scilab code Exa 3.6.2 `vertical spring mass system`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 3.6.2\n')
//given data
k=9800//stiffnes of spring in N/m
m=40 //mass in spring mass system )in kg)
g=9.81//acceleration due to gravity
F=49//frictional force in N
x=0.126//total extension of spring in m
xeq=m*g/k//extension of spring at equillibrium in m
xi=x-xeq//initial extension of spring from equillibrium in m
Alosspercycl=4*F/k//reduction in amplitude/cycle explained in section 3.6.2 in eqn 3.6.6
n=int(xi/Alosspercycl)//number of complete cycles that system undergoes
Af=xi-n*Alosspercycl//amplitude at the end of n cycles
SF=k*Af//spring force acting on the upward direction for an extension of Af
if F<SF then
```

```
    disp('The spring will move up since spring force is greater than frictional force')
    Xa=Af//assigning Af to a new variable Xa
     Xb=0//assume Xb=0 at first
    //solving the quadratic equation in Xb whose roots are Xb1 and Xb2
    Xb1=(F+sqrt((-F)^2-(4*(0.5*k)*((-(1/2)*k*Xa^2)+F*Xa))))/k
    Xb2=(F-sqrt((-F)^2-(4*(0.5*k)*((-(1/2)*k*Xa^2)+F*Xa))))/k
    if  int(Xb1-Xa)==0 then
        Xb=Xb2
      else
          Xb=Xb1
      end
      finalext=xeq+Xb
      mprintf(' The final extention of spring is %f m',finalext)
    else disp('The spring will not move up since spring force is not greater than frictional force')
end
```

Scilab code Exa 3.7.1 time taken for complete damping

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 3.7.1\n')
//given data
fnA=12 //frequency of free vibrations of system A in Hz
fnB=15 //frequency of free vibrations of system B in Hz
TdA=4.5 //time taken by system A to damp out
```

```
    completely in sec
//calculations
TdB=fnA*TdA/fnB //time taken by system B to damp out
     completely in sec
//output
mprintf(' The time taken by system B to damp out
    completely is %4.4f sec',TdB)
```

Chapter 4

Forced vibrations of single degree of freedom system

Scilab code Exa 4.2.1 periodic torque on suspended flywheel

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.2.1\n')
//given data
//T=To*sin(W*t)
To=0.588 //maximum value of periodic torque in N-m
W=4// freqency of applied force in rad/sec
J=0.12//moment of inertia of wheel in kg-m^2
Kt=1.176//stiffness of wire in N-m/rad
Ct=0.392/1 //damping coefficient in N-m_sec/rad
//calculations
theta=To/sqrt((Kt-J*W^2)^2+(Ct*W)^2)//Equation for torsional vibration amplitude from Fig (4.2.2) and Eqn (4.2.5)
MaxDcoup=Ct*W*theta//maximum damping couple in N-m
if atan((Ct*W)/(Kt-J*W^2))>0  then
    phiD=(180/%pi)*atan((Ct*W)/(Kt-J*W^2));//from eqn 4.2.6(in degrees)
```

```
else
    phiD=180+(180/%pi)*atan((Ct*W)/(Kt-J*W^2));

end
//output
mprintf(' a)The maximum angular displacement from
   rest position is %4.4f radians\n b)The maximum
   couple applied to dashpot is %4.4f N-m\n c)angle
   by which the angular displacement lags the torque
    is %4.4f degrees',theta,MaxDcoup,phiD)
```

Scilab code Exa 4.2.2 damping factor and natural frequency of system

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.2.2\n')
//given data
Wd=9.8*2*%pi// damped natural freqency in rad/sec
Wp=9.6*2*%pi//freqency from forced vibration test in
    rad/sec
//calculations
//(Wp/Wn)=sqrt(1-2*zeta^2)...(1) from Eqn 4.2.18
   from Sec 4.2.1
//(Wd/Wn)=sqrt(1-zeta^2)...(2) from Eqn 4.2.19 from
   Sec 4.2.1
//dividing (1) by (2)
x=(Wp/Wd)
//x=[sqrt(1-2*zeta^2)]/[sqrt(1-zeta^2)]
zeta=sqrt((1-x)/(2-x))//damping factor obtained on
   simplifying the above eqn
//substituting for zeta in eqn 2 above
Wn=Wd/sqrt(1-zeta^2)//natural frequency of system in
    rad/sec
fn=Wn/(2*%pi)//natural frequency of system in Hz
```

```
//output
mprintf('The damping factor for the system is %f and\n the natural frequency is %4.4f rad/sec or %4.2f Hz',zeta,Wn,fn)
mprintf('\nNOTE:The damping factor zeta given in textbook is 0.196,which is wrong.')
```

Scilab code Exa 4.3.1 `system of beams supporting a motor`

```
clc
clear
mprintf('Mechanical vibrations b G.K.Grover\n Example 4.3.1\n')
//given data
m=1200//mass of motor in kg
mo=1//unbalanced mass on motor in kg
e=0.06//location of unbalanced mass from motor in m
Wn=2210*(2*%pi/60)//resonant freq in rad/sec
W=1440*(2*%pi/60)//operating freq
//calculations
//case 1
zeta=0.1
bet=(W/Wn)
y=(mo/m)//from eqn 4.3.2
X1=(y*e)*(bet)^2/sqrt((1-bet^2)^2+(2*zeta*bet)^2)//from eqn 4.3.2
//case 2
zeta=0
X2=(y*e)*(bet)^2/sqrt((1-bet^2)^2+(2*zeta*bet)^2)//from eqn 4.3.2
//output
mprintf('If the damping is less than 0.1 then the amplitude of \n vibration will be between %f m and %f m',X1,X2)
```

Scilab code Exa 4.3.2 single cylinder vertical petrol engine

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.3.2\n')
//given data
m=320//mass of engine in kg
mo=24//reciprocating mass on motor in kg
r=0.15//vertical stroke in m
e=r/2
delst=0.002//stati defln in m
C=490/(0.3)//damping recistance in N-sec/m
g=9.81// gravity in m/sec^2
N=480//speed in rpm in case b)
//calculation
Wn=sqrt(g/delst) //natural freqency in rad/sec
Nr=Wn/(2*%pi)*60 //resonant speed in rpm
W=(2*%pi*N/60)
bet=(W/Wn)
zeta=(C/(2*m*Wn)) //damping factor
y=(mo/m)//from eqn 4.3.2
X=(y*e)*(bet)^2/sqrt((1-bet^2)^2+(2*zeta*bet)^2)// from eqn 4.3.2
//output
mprintf(' a)speed of driving shaft at which esonance occurs is %4.4f RPM\n b)The amplitude of steady state forced vibrations when the driving shaft \n of the engine rotates at 480 RPM is %f m',Nr,X)
```

Scilab code Exa 4.4.1 mass hung from end of vertical spring

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.4.1\n')
//given data
T=0.8//time period of free vibration in sec
t=0.3//time for which the vertical distance has to
   be calculated
//y=18*sin(2*pi*t)
Y=18//max amplitude in mm
//calculations
W=2*%pi
Wn=(2*%pi/T)
bet=(W/Wn)
x=(Y/(1-bet^2))*(sin(W*t)-bet*sin(Wn*t))// from eqn
   4.4.17 explained in the same problem
//output
mprintf('The vertical distance moved by mass in the
   first 0.3 sec is %4.4f mm',x)
```

Scilab code Exa 4.4.2 support of spring mass system

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.4.2\n')
//given data
m=0.9//mass in kg
K=1960//stiffness in N/m
Y=5//amp of vibration of support in m
N=1150//frequency in cycles per min
//calculations
Wn=sqrt(K/m)
W=N*2*%pi/60//frequency of  vibration of support
bet=(W/Wn)
```

```
//case 1
zeta=0
X1=Y*(sqrt(1+(2*zeta*bet)^2)/sqrt((1-bet^2)^2+(2*zeta*bet)^2))//Eqn (4.4.6)
//case 2
zeta =0.2
X2=Y*(sqrt(1+(2*zeta*bet)^2)/sqrt((1-bet^2)^2+(2*zeta*bet)^2))//Eqn (4.4.6)
//output
mprintf('The amplitude of vibration when damping factor=0 is %4.4f mm \n If damping factor=0.2, then amplitude of vibration is %4.4f mm',X1,X2)
```

Scilab code Exa 4.4.3 spring of automobile trailer

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.4.3\n')
//given data
delst=0.1//steady state defln in m
g=9.81//acceleration due to gravity
Y=0.08//amp of vibration of automobile in m
lambda=14//wavelenght of profile in m
//calculations
Wn=sqrt(g/delst)
fn=Wn/(2*%pi)//frequency of vibration of automobile in Hz
Vc=(3600/1000)*lambda*fn//critical speed in km/hr
V=60 //speed in km/hr
W=V*(1000/3600)*(2*%pi/lambda)
bet=(W/Wn)
zeta=0
X=Y*(sqrt(1+(2*zeta*bet)^2)/sqrt((1-bet^2)^2+(2*zeta*bet)^2))//Eqn (4.4.6)
```

```
//output
mprintf(' The critical speed of automobile %4.4f km/hr\n The amplitude of vibration at 60 Km/Hr is %4.4f m',Vc,X)
```

Scilab code Exa 4.5.1 power required to vibrate spring mass dashpot

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.5.1\n')
//given data
X=0.015//amplitude of vibration of spring mass dashpot system in m
f=100//frquency  of vibration of spring mass dashpot system in Hz
zeta=0.05
fnD=22//damped natural frequency in Hz
m=0.5//mass in kg
//calculations
W=2*%pi*fnD
c=2*m*W*zeta// from Eqn 3.3.6 and Eqn 3.3.7
Epercycl=%pi*c*(2*%pi*f)*X^2//Eqn 4.5.1...energy dissipated per cycle
Epersec=Epercycl*f//energy dissipated per sec
//output
mprintf(' The power required to vibrate spring mass dashpot system with \n an amplitude of 1.5 cm and at frequency of 100 Hz is %4.4f Watts',Epersec)
mprintf('\nNOTE: slight differnce in answer compared to textbook\n is due approximation of value of pi')
```

Scilab code Exa 4.6.1 horizontal spring mass system in dry friction

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.6.1\n')
//given data
mprintf('NOTE:The mass given in textbook should be
   equal\n to 3.7 kgs and not 8.7 Kgs')
m=3.7//mass in kg
g=9.81// gravity
K=7550////stiffness of in N/m
u=0.22//coefficient of friction
Fo=19.6//amp of force in N
f=5//frequency of force
//calculations
F=u*m*g//frictional force
W=2*%pi*f
Wn=sqrt(K/m)
bet=(W/Wn)
X=(Fo/K)*sqrt(1-(4*F/(%pi*Fo))^2)/(1-bet^2)//Eqn
   4.6.2 in Sec 4.6
Ceq=4*F/(%pi*W*X)//equivalent viscous damping Eqn
   4.6.1 in Sec 4.6
//output
mprintf('\nThe amplitude of vibration of mass is %f
   m\n The equivalent viscous damping is %f N-sec/m'
   ,X,Ceq)
mprintf('\nNOTE: slight differnce in answer compared
    to textbook\n is due approximation of value of
   pi in the taxtbook')
```

Scilab code Exa 4.10.1 machine mounted on 4 identical springs

```
clc
```

```
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.10.1\n')
//given data
m=1000//mass of machine in kg
Fo=490//amp of force in N
f=180//freq inRPM
//calculations
//case a)
K=1.96*10^6//total stiffness of springs in N/m
Wn=sqrt(K/m)
W=2*%pi*f/60
bet=(W/Wn)
zeta=0
Xst1=Fo/K//amplitude of steady state
X1=Xst1*(1/(sqrt((1-bet^2)^2+(2*zeta*bet)^2)))//amp of vibration Eqn 4.2.15 in Sec 4.2.1
Ftr1=Fo*sqrt(1+(2*zeta*bet)^2)/sqrt((1-bet^2)^2+(2*zeta*bet)^2)//force transmitted,Eqn 4.10.2 in Sec 4.10.1
//case b)
K=9.8*10^4//total stiffness of springs in N/m
Wn=sqrt(K/m)
W=2*%pi*f/60
bet=(W/Wn)
zeta=0
Xst2=Fo/K//amplitude of steady state
X2=Xst2*(1/(sqrt((1-bet^2)^2+(2*zeta*bet)^2)))//amp of vibration Eqn 4.2.15 in Sec 4.2.1
Ftr2=Fo*sqrt(1+(2*zeta*bet)^2)/sqrt((1-bet^2)^2+(2*zeta*bet)^2)//force transmitted,Eqn 4.10.2 in Sec 4.10.1
//output
mprintf(' a)The amplitude of motion of machine is %f m and the maximum force transmitted\n to the foundation because of the unbalanced force when\n K=1.96*10^6 N/m is %4.4f N\n b)for same case as in a)if K=9.8*10^4 N/m then\n the amplitude of
```

```
motion of machine is %f m\n and the maximum force transmitted to the foundation because of\n the unbalanced force %4.4f N',X1,Ftr1,X2,Ftr2)
```

Scilab code Exa 4.10.2 `machine mounted on springs`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.10.2\n')
//given data
m=75//mass of machine in kg
K=11.76*10^5//stiffness of springs in N/m
zeta=0.2
mo=2//mass of piston in kg
stroke=0.08//in m
e=stroke/2//in m
N=3000//spee in c.p.m
//calculations
Wn=sqrt(K/m)
W=2*%pi*N/60
bet=(W/Wn)
y=(mo/m)
Fo=mo*W^2*e//max force exerted
X=y*e*bet^2/(sqrt((1-bet^2)^2+(2*zeta*bet)^2))//Eqn 4.3.2
Ftr=Fo*sqrt(1+(2*zeta*bet)^2)/sqrt((1-bet^2)^2+(2*zeta*bet)^2)//force transmitted,Eqn 4.10.2 in Sec 4.10.1
mprintf(' a)The amplitude of vibration of machine is %f m and the \n the vibratory force Ftr transmitted to the foundation is %5.4f N',X,Ftr)
mprintf('\nNOTE: slight differnce in answer compared to textbook\n is due approximation of values in textbook')
```

Scilab code Exa 4.10.3 `radio set isolated from machine`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.10.3\n')
// given data
m=20 //mass in kgs
k=125600 //overall eqivalent stiffness i.e 4*31400
   in N/m
c=1568 //overall damping coefficient i.e 4*392 in N-
   sec/m
n=500 //vibrating speed of machine in cpm
//y=Ysin(w*t)
Y=0.00005 //vibrating amplitude of machine in m
W=2*%pi*n/60 //vibrating frequency in rad/sec
Wn=sqrt(k/m) //natural frequency in rad/sec
bet=(W/Wn) //speed ratio
zeta=c/(2*sqrt(k*m)) //damping factor
//calculations
X=Y*sqrt((1+(2*zeta*bet)^2)/((1-bet^2)^2+(2*zeta*bet
   )^2)) //absolute amplitude of vibration of radio
   from eqn (4.4.6)
Z=Y*((bet^2)/sqrt(((1-bet^2)^2+(2*zeta*bet)^2)))//
   from eqn 4.4.11
FdynT=Z*sqrt((c*W)^2+k^2)//dynamic load total
Fdyn=FdynT/4 //dynamic load on each isolator
FdynTmax=m*W^2*X //max dynamic load on the isolators
Fdynmax=FdynTmax/4 //max dynamic load on each
   isolator
//output
mprintf('a) The amplitude of vibration of radio is
   %f metres \n b)the dynamic load on each isolator
   due to vibration is %3.3f N',X,Fdyn)
```

Scilab code Exa 4.11.1 vibrotometer

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.11.1\n')
//given data
T=2//period of free vibration in sec
f=1//vertical harmonic frequency of machine in in Hz
Z=2.5//amplitude of vibrotometer mass relative to
   vibrotometer frame in mm
//calculations
Wn=2*%pi/T
W=2*%pi*f
bet=(W/Wn)
zeta=0//for vibrotometers
Y=Z*(sqrt((1-bet^2)^2+(2*zeta*bet)^2))/bet^2//
   amplitude of vibration of machine Eqn 4.4.11 in
   Sec 4.4.2
//output
mprintf(' The amplitude of vibration of support of
   machine is %4.4f mm',Y)
```

Scilab code Exa 4.11.2 commercial type vibration pick up

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.11.2\n')
//given data
fn=5.75//natural frequency in Hz
```

```
zeta=0.65
ZbyY=1.01
//case 1
//substituting for (Z/Y)=1.01 and (W/Wn)=r^2 in Eqn 4.4.11 we get the quadratic eqn as follows
//0.02*r^4-0.31*r^2+1=0
//solving for r in above eqn whose rootes are r1 and r2
r1=sqrt(((0.31)+sqrt(((-0.31)^2)-4*0.02*1))/(2*0.02))
r2=sqrt(((0.31)-sqrt(((-0.31)^2)-4*0.02*1))/(2*0.02))
if r1>r2 then
    r=r1
    else r=r2
end
bet=r//bet=(W/Wn)
f1=bet*fn
//case 2
ZbyY=0.98
//substituting for (Z/Y)=0.98 and (W/Wn)=r^2 in Eqn 4.4.11 we get the quadratic eqn as follows
//0.04*r^4+0.31*r^2-1=0
//solving for r in above eqn whose rootes are r3 and r4
r3=sqrt((-0.31+sqrt(((0.31)^2)-4*0.04*-1))/(2*0.04))
r4=sqrt((-0.31-sqrt(((0.31)^2)-4*0.04*-1))/(2*0.04))
t1=real(r3)
t2=real(r4)
if t1>t2 then
    r=r3
    else r=r4
end
bet=r//bet=(W/Wn)
f2=bet*fn
mprintf('The lowest frequency beyond which the amplitude can be measured within\n (i)one percent error is %4.4f Hz\n (ii)two percent error
```

```
is %4.4f Hz',f1,f2)
```

Scilab code Exa 4.11.3 device used to measure torsional accerelartion

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 4.11.3\n')
//given data
J=0.049//moment of inertia in kg-m^2
Kt=0.98//stiffness in N-m/rad
Ct=0.11//damping coefficient in N-m_sec/rad
N=15//R.P.M
thetaRD=2//relative amplitude between ring and shaft in degrees
//calculations
W=N*2*%pi/60 //frequency of  vibrating shaft in rad/sec
Wn=sqrt(Kt/J) //natural freqency in rad/sec
zeta=(Ct/(2*sqrt(Kt*J))) //damping factor
thetaRR=(thetaRD/(57.3)) //relative amplitude in radians
bet=(W/Wn)
thetamax=thetaRR*((sqrt((1-bet^2)^2+(2*zeta*bet)^2)/bet^2))
maxacc=(W^2)*thetamax
//output
mprintf('The maximum acceleration of the shaft is %4.4f rad/(sec^2)',maxacc)
```

Scilab code Exa 4.11.4 Frahm tachometer

```
clc
```

```
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 4.11.4\n')
//given data
RF=1800//resonant frequency in rpm
L=0.050//lenght of steel reed in metres
B=0.006//width of steel reed in metres
t=0.00075//thickness of steel reed in metres
E=19.6*10^10//young's modulus in N/(m^2)
//calculations
Wn=2*%pi*RF/60//natural frequency in radians
I=(B*t^3)/12//moment of inertia in (m^4)
m=3*E*I/((Wn^2)*L^3)//required mass
//output
mprintf('The required mass M to be placed at the end
    of the reeds of Frahm tachometer is %f Kgs',m)
```

Chapter 5

Two degrees of freedom systems

Scilab code Exa 5.3.2 uniform rods pivoted at their upper ends

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 5.3.2\n')
//given data
m1=5*0.75//mass of rod 1 in kgs
m2=5*1.00//mass of rod 2 in kgs
l1=0.75//lenght of rod 1 in m
l2=1.00//lenght of rod 2 in m
K=2940//stiffness of spring in N/m
//calculations
Wn=sqrt(3*(m1+m2)*K/(m1*m2))//natural frequency in rad/sec
fn=Wn/(2*%pi)//natural frequency in Hz as solved in the textbook itself
b1=(K*l2)
b2=(K*l1-m1*l1*Wn^2/3)
x=(b2/b1)
Fmax=K*(l1*1-l2*x)/57.3//to convert into radians
```

```
//output
mprintf('The frequency of the resulting vibrations
   if the efect of gravity\n is neglected is %4.4f
   rad/sec or %4.4f Hz.\n The angular movement of CD
    is %3.3f degrees(out of phase) \n with the
   movement of AB.\n The maximum force in the spring
    is %4.4f N',Wn,fn,x,Fmax)
```

Scilab code Exa 5.3.3 shaft with 2 circular discs at the end

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 5.3.3\n')
//given data
m1=500//mass of disc 1 in Kgs
m2=1000//mass of disc 2 in Kgs
D1=1.25//outer dia of disc 1 in m
D2=1.9//outer dia of disc 2 in m
l=3.0//lenght of shaft in m
d=0.10//dia of shaft in m
G=0.83*10^11//rigidity modulus in N/m^2
//calculations
J1=m1*(D1/2)^2/2//mass moment of inertia in kg-m^2
J2=m2*(D2/2)^2/2//mass moment of inertia in kg-m^2
Ip=(%pi/32)*d^4//section modulus of shaft in m^4
Kt=G*Ip/l//stiffness in N-m/rad
Wn=sqrt(Kt*(J1+J2)/(J1*J2))//from Eqn 5.3.28,Sec
   5.3.3
fn=Wn/(2*%pi)
Kt1=2*Kt
Kt2=2*Kt*2^4
Kte=1/((1/Kt1)+(1/Kt2))
x=sqrt(Kte/Kt)//ratio of modified natural freq to
   original natural frequency
```

```
//output
mprintf('The natural frequency of the torsional vibration is\n %4.4f rad/sec or %3.3f Hz.\n The ratio of modified natural frequency to original natural frequency\n is %3.3f.Which means stiffening a system increases its natural frequency',Wn,fn,x)
```

Scilab code Exa 5.7.1 torque applied to a torsional system

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 5.7.1\n')
//given data
J1=0.735//moment of inertia of main system in Kg-m^2
Kt1=7.35*10^5//torsional stiffness
To=294//amplitude of applied torque
W=10^3//frequency of applied torque
//u=ratio of absorber mass to main mass i.e M2/M1
//Wn is exitation frequency
//calculations
W1=sqrt(Kt1/J1)
//case1
x1=0.8//where x=(W/W2)
u1=[x1^2-1]^2/x1^2//from Eqn 5.7.9,Sec 5.7.1.
//case 2
x2=1.2//where x=(W/W2)
u2=[x2^2-1]^2/x2^2//from Eqn 5.7.9,Sec 5.7.1.
if u1>u2 then
    u=u1
else
    u=u2
end
J2=u*J1//moment of inertia of absorber in Kg-m^2
```

```
Kt2=u*Kt1// total torsional stiffness of absorber
K=Kt2/(4*0.1^2)//stiffness of each spring in N/m
b2=-(To/Kt2)//amplitude of vibration in rad
//output
mprintf('The maximum moment of inertia of absorber(J2) is %4.4f Kg-m^2 and\n %f is the stiffness of each of the four absorber springs such that\n the resonant frequencies are at least 20 percent from exitation frequency.\n The amplitude of vibration of this absorber(b2) at exitation frequency\n is %f radians',J2,K,b2)
```

Scilab code Exa 5.7.2 section of pipe in a machine

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 5.7.2\n')
//given data
W1=220*2*%pi/60//vibrating frequency at 220 RPM (in rad/sec)
W2=W1//frequency to which the spring mass system is tuned to.
M2=1//mass in spring mass system in kgs
N1=188//first resonant freq of spring mass system in cpm
N2=258//second resonant freq of spring mass system in cpm
//u=ratio of absorber mass to main mass i.e M2/M1
//calculations
K2=M2*W2^2
Wn1=N1*2*%pi/60//first resonant freq of spring mass system in rad/sec
Wn2=N2*2*%pi/60//second resonant freq of spring mass system in rad/sec
```

```
//case 1
W=Wn1
x1=(W/W2)
u1=[x1^2-1]^2/x1^2//from Eqn 5.7.9,Sec 5.7.1.
//case 2
W=Wn2
x2=(W/W2)
u2=[x2^2-1]^2/x2^2//from Eqn 5.7.9,Sec 5.7.1.
//therefore
u=(u1+u2)/2//which is equal to M2/M1
M1=M2/u// mass of main system in kgs
K1=K2/u//stiffness of main system in N/m
//now
Wn21=150*2*%pi/60//new first resonant frequency in rad/sec
Wn22=310*2*%pi/60//new second resonant frequency in rad/sec
W=Wn21
x1=(W/W2)
u1=[x1^2-1]^2/x1^2//from Eqn 5.7.9,Sec 5.7.1.
//case 2
W=Wn22
x2=(W/W2)
u2=[x2^2-1]^2/x2^2//from Eqn 5.7.9,Sec 5.7.1.
//choosing the higher value
if u1>u2 then
    u=u1
else
    u=u2
end
M3=M1*u// mass of main system in kgs
K3=K1*u//stiffness of main system in N/m
//output
mprintf(' The mass of main system required is %4.4f kgs\n stiffness of main system reqired is %5.5f N/m\n If the resonant frequencies lie outside the range of 150 to 310 rpm then\n mass of main system is %4.4f kgs\n stiffness of main system is
```

```
%5.5f N/m',M1,K1,M3,K3)
```

Chapter 6

Multi degree of freedom systems exact analysis

Scilab code Exa 6.8.2 system with rolling masses

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 6.8.2\n')
//given data
m1=250;m2=100//mass of two blocks in Kgs
c1=80;c2=60,c=20//damping coefficients in N-sec/m
F1=1000;F2=1500//amplitude of force acting on block
   1 and 2 rsptly
k=250000//stiffness of spring in N/m
W=60//frequency of applied force in rad/sec
//calculations
M=[m1,0;0,m2];
K=[k,-k;-k,k];
C=[c+c1,-c;-c,c+c2];
R=[F1;F2;0;0];
X=K-(W^2)*M
Y=W*C
G=[X,-Y;Y,X]
```

```
AB=inv(G) *R//from Eqn6.8.4 in Sec 6.8
X1=sqrt(AB(1,1)^2 +AB(3,1)^2)
X2=sqrt(AB(2,1)^2 +AB(4,1)^2)
//output
mprintf('The amplitude of vibrations are %fm for
    mass 1 and %fm for mass 2',X1,X2)
```

Chapter 7

Multi degree of freedom systems numerical methods

Scilab code Exa 7.2.1 fundamental frequency by rayleigh method

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 7.2.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
I=4*10^-7//moment of area in m^4
M1=100;M2=50//mass of discs 1 and 2 in Kgs
c=0.18//distance of disc 1 from support in m
l=0.3//distance of disc 2 from support in m
g=9.81//aceleration due to gravity in m/sec^2
//calculations
a=[(c^3/(3*E*I)),(c^2/(6*E*I)*(3*l-c));(c^2/(6*E*I)
   *(3*l-c)),(l^3/(3*E*I))]//from SOM
y1=g*(M1*a(1,1)+M2*a(1,2))
y2=g*(M1*a(2,1)+M2*a(2,2))
Wn=sqrt(g*(M1*y1+M2*y2)/(M1*y1^2+M2*y2^2))
//now to find out lower natural frequency
F1=M1*y1*Wn^2
```

```
F2=M2*y2*Wn^2
y1new=F1*a(1,1)+F2*a(1,2)
y2new=F1*a(2,1)+F2*a(2,2)
Wnnew=sqrt((F1*y1new+F2*y2new)/(M1*y1new^2+M2*y2new
    ^2))//actual natural frequency in rad/sec
//output
mprintf(' The practical natural frequency Wn is %4.4
    f rad/sec,but the lower \n natural frequency Wn‘
    is %4.4f rad/sec which is closer to the actual\n
    natural frequency',Wn,Wnnew)
```

Scilab code Exa 7.3.1 `Dunkerly method`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
    Example 7.3.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
I=4*10^-7//moment of area in m^4
M1=100;M2=50//mass of discs 1 and 2 in Kgs
c=0.18//distance of disc 1 from support in m
l=0.3//distance of disc 2 from support in m
g=9.81//aceleration due to gravity in m/sec^2
//calculations
a=[(c^3/(3*E*I)),(c^2/(6*E*I)*(3*l-c));(c^2/(6*E*I)
    *(3*l-c)),(l^3/(3*E*I))]//from SOM
y1=g*M1*a(1,1)//considering only M1 to be acting
y2=g*M2*a(2,2)//considering only M2 to be acting
W1=sqrt(g/y1)
W2=sqrt(g/y2)
Wn=sqrt(1/((1/W1^2)+(1/W2^2)))//applying Eqn 7.3.7,
    Sec7.3
//output
mprintf(' The natural frequency of transverse
```

```
vibration obtained from \n Dunkerly method is %4
.4f rad/sec which is slightly lower\n than the
correct value',Wn)
```

Scilab code Exa 7.4.1 Stodola method

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n
   Example 7.4.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
I=4*10^-7//moment of area in m^4
M1=100;M2=50//mass of discs 1 and 2 in Kgs
c=0.18//distance of disc 1 from support in m
l=0.3//distance of disc 2 from support in m
g=9.81//aceleration due to gravity in m/sec^2
//calculations
a=[(c^3/(3*E*I)),(c^2/(6*E*I)*(3*l-c));(c^2/(6*E*I)
   *(3*l-c)),(l^3/(3*E*I))]//from SOM
x1(1)=1;x2(1)=1
for i=1:10//upto 10th iteration for more perfect
   answer
F1(i)=100*x1(i)//'i' represents the dash(')
F2(i)=50*x2(i)
x1(i)=F1(i)*a(1,1)+F2(i)*a(1,2)
x2(i)=F1(i)*a(2,1)+F2(i)*a(2,2)
r=(x2(i)/x1(i))
x2(i+1)=r
x1(i+1)=1
end
x1dd=1
W1=(x1dd/x1(10))
W2=(r/x2(10))
Wn=sqrt((W1+W2)/2)//natural frequency in rad/sec
```

```
mprintf('The natural frequency of system in iilustrative example 7.2.1 obtained by\nStodala method is Wn=%f rad/sec',Wn)
mprintf('\nNOTE:The obtained answer is more near to the perfect answer \since 10 iterations/trials\nhas been carried out.In textbook only upto 3rd iteration has been carried out')
```

Scilab code Exa 7.7.2 four rotor system

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 7.7.2\n')
//given data
J(1)=100//moment of inertia of first rotor in Kg-m^2
J(2)=50//moment of inertia of second rotor in Kg-m^2
J(3)=10//moment of inertia of third rotor in Kg-m^2
J(4)=50//moment of inertia of fourth rotor in Kg-m^2
Kt(1)=10^4//stiffness of shaft between 1 and 2 in N-m/rad
Kt(2)=10^4//stiffness of shaft between 2 and 3 in N-m/rad
Kt(3)=2*10^4//stiffness of shaft between 3 and 4 in N-m/rad
To=10000//amplitude of applied torque in N-m
W=5//frequency of applied torque in rad/sec
//calculations
b(1)=-(0.789*To)/3825//twist of shaft 1 in rad
P(1)=J(1)*W^2
Q(1)=P(1)*b(1)//twisting moment of shaft 1 in N-m
R(1)=Q(1)
S(1)=R(1)/Kt(1)//twist of shaft 1 in radians
b(2)=b(1)-S(1)//twist of shaft 2 in rad
P(2)=J(2)*W^2
```

```
Q(2)=P(2)*b(2)
R(2)=Q(1)+Q(2)+To//twisting moment of shaft 2 in N-m
S(2)=R(2)/Kt(2)//twist of shaft 2 in radians
b(3)=b(2)-S(2)//twist of shaft 3 in rad
P(3)=J(3)*W^2
Q(3)=P(3)*b(3)
R(3)=Q(2)+Q(3)//twisting moment of shaft 3 in N-m
S(3)=R(3)/Kt(3)//twist of shaft 3 in radians
b(4)=b(3)-S(3)//twist of shaft 4 in rad
P(4)=J(4)*W^2
Q(4)=P(4)*b(4)
R(4)=Q(3)+Q(4)//twisting moment of shaft 4 in N-m
mprintf('The amplitudes of discs are as follows\n disc1=%4.4f rad\n disc2=%4.4f rad\n disc3=%4.4f rad\n disc4=%4.4f rad',b(1),b(2),b(3),b(4))
mprintf('\nThe twists of shaft are as follows\nfirst shaft=%5.5f rad\nsecond shaft=%5.5f rad\nthird shaft=%5.5f rad',S(1),S(2),S(3))
mprintf('\nThe twisting moments of shafts are as follows\nfirst shaft=%5.5f N-m\nsecond shaft=%5.5f N-m\nthird shaft=%5.5f N-m',R(1),R(2),R(3))
mprintf('\nNOTE:The slight difference in values are due to the more accurate values\ncalculated by SCILAB')
```

Chapter 8

Critical speeds of shafts

Scilab code Exa 8.2.1 `rotor mounted midway on shaft`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 8.2.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
m=5//mass of rotor in kg
d=0.01//dia of shaft in m
I=(%pi/64)*d^4///moment of area in m^4
l=0.4//bearing span in m
e=0.02//distance of CG away from geometric centre of rotor in mm
N=3000//speed of shaft in RPM
//calculations
k=48*E*I/l^3//stiffness of shaft in N/m
Wn=sqrt(k/m)
W=2*%pi*N/60
bet=(W/Wn)
r=(bet^2*e/(1-bet^2))//from Eqn 8.2.2 in Sec 8.2
rabs=abs(r)//absolute value of displacement
Rd=k*rabs/1000//total dynamic load in bearings in N(
```

```
divide by 1000 since r is in mm)
F=Rd/2//dynamic load on each bearings in N
//output
mprintf('The amplitude of steady state vibration of shaft is %f mm\nNOTE:negetive sign shows that displacement is out of phase with centrifugal force\nThe dynamic force transmtted to the bearings is %4.4f N\n The dynamic load on each bearing is %4.4f N',r,Rd,F)
```

Scilab code Exa 8.3.1 disc mounted midway between bearings

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 8.3.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
m=4//mass of rotor in kg
g=9.81//acc due to gravity in m/sec^2
d=0.009//dia of shaft in m
I=(%pi/64)*d^4///moment of area in m^4
l=0.48//bearing span in m
e=0.003//distance of CG away from geometric centre of rotor in mm
N=760//speed of shaft in RPM
c=49//equivalent viscous damping in N-sec/m
//calculations
K=48*E*I/l^3//stiffness of shaft in N/m
Wn=sqrt(K/m)
W=2*%pi*N/60
bet=(W/Wn)
zeta=c/(2*sqrt(K*m))
r=e*(bet^2/sqrt(((1-bet^2)^2+(2*zeta*bet)^2)))//from Eqn 8.3.4 ,Sec 8.3
```

```
Fd=sqrt((K*r)^2+(c*W*r)^2)//dynamic load on bearing in N
Fs=m*g//static load in N
Fmax=Fd+Fs//maximum static load on the shaft under dynamic condition in N
smax=(Fmax*l/4)*(d/2)/I//maximum stress under dynamic condition in N/m^2
ss=(Fs*l/4)*(d/2)/I//maximum stress under dead load condition in N/m^2
Fdamp=(c*W*r)//damping force in N
Tdamp=Fdamp*r//damping torque in N-m
P=2*%pi*N*Tdamp/60//power in Watts
//output
mprintf(' The mamximum stress in the shaft under dynamic condition is %.3f N/(m^2)\n The dead load stress is %.3f N/(m^2)\n The power required to drive the shaft at 760 RPM is %4.4f Watts',smax,ss,P)
```

Scilab code Exa 8.4.1 `two critical speeds`

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 8.4.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
I=4*10^-7//moment of area in m^4
M1=100;M2=50//mass of discs 1 and 2 in Kgs
c=0.18//distance of disc 1 from support in m
l=0.3//distance of disc 2 from support in m
g=9.81//aceleration due to gravity in m/sec^2
//calculations
a=[(c^3/(3*E*I)),(c^2/(6*E*I)*(3*l-c));(c^2/(6*E*I)*(3*l-c)),(l^3/(3*E*I))]//from SOM
```

```
p=M1*a(1,1)+M2*a(2,2)//from Eqn 8.4.6 ,Sec 8.4
q=M1*M2*(a(1,1)*a(2,2)-(a(1,2)^2))//from Eqn 8.4.6 ,Sec 8.4
Wn1=sqrt((p-sqrt(p^2-4*q))/(2*q))//from Eqn 8.4.6 ,Sec 8.4
Wn2=sqrt((p+sqrt(p^2-4*q))/(2*q))//from Eqn 8.4.6 ,Sec 8.4
Nc1=Wn1*60/(2*%pi)//critical speed in RPM
Nc2=Wn2*60/(2*%pi)//critical speed in RPM
//output
mprintf(' The critical speeds for the system shown in fig 7.2.1 are %4.4f RPM and %4.4f RPM',Nc1,Nc2)
```

Scilab code Exa 8.6.1 right cantilever steel shaft with rotor at the end

```
clc
clear
mprintf('Mechanical vibrations by G.K.Grover\n Example 8.6.1\n')
//given data
E=1.96*10^11//youngs modulus in N/m^2
M=10//mass of rotor in kg
g=9.81//acc due to gravity in m/sec^2
ra=0.12//radius of gyration in m
l=0.3//lenght of steel shaft in m
b=0.06//thickness of rotor in m
I=10*10^-8//moment of inertia of section in m^4
//calculations
r=sqrt((ra^2/2)+(b^2/12))
h=3*(r^2)/l^2//from Eqn 8.6.4 ,Sec 8.6
g1=sqrt((2/h)*((h+1)-sqrt((h+1)^2-h)))//natural frequency,from Eqn 8.6.4 ,Sec 8.6
g2=sqrt((2/h)*((h+1)+sqrt((h+1)^2-h)))//natural frequency,from Eqn 8.6.4 ,Sec 8.6
```

```
W1=g1*sqrt(3*E*I/(M*l^3))//from Eqn 8.6.4 ,Sec 8.6
W2=g2*sqrt(3*E*I/(M*l^3))//from Eqn 8.6.4 ,Sec 8.6
Nc1=W1*60/(2*%pi)//critical speed in RPM
Nc2=W2*60/(2*%pi)//critical speed in RPM
//output
mprintf(' The operating speed of 10000 RPM is not
   near to either of \n the critical speeds i.e %4.4
   f RPM or %4.4f RPM.\n Therefore the operating
   speed is safe.',Nc1,Nc2)
```