Scilab Textbook Companion for The Theory of Machines by T. Bevan[1]

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Book Description

Title: The Theory of Machines

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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 2

Motion Inertia

Scilab code Exa 2.1 `find velocity and kinetic energy`

```

clc
//a) INELASTIC
//for sphere 1 ,mass=m1 and initial velocity=u1
//for sphere 2 ,mass=m2 and initial velocity=u2
m1=100//lb
u1=10//ft/s
m2=50//lb
u2=5//ft/s
v=(m1*u1+m2*u2)/(m1+m2)
//change in kinetic energy
//initial kinetic energy = ke1
ke1=(m1*(u1^2)+m2*(u2^2))/(2*32.2)
//Kinetic Energy after inelastic colision = ke2
ke2=((m1+m2)*8.333^2)/(2*32.2)
//Change in Kinetic Energy =l
l=ke1-ke2
//b) Elastic
// for a very short time bodies will have a common
    velocity given by v=8.333 ft/s
// for a very short time bodies will have a common
```

```
velocity given by v=8.333 ft/s
//immidiately after impact ends the velocities for both the bodies are given by v1 and v2
v1=2*v-u1
v2=2*v-u2
//c) Coeeficient of Restitution=0.6
e=0.6
ve1=(1+e)*v-e*u1
ve2=(1+e)*v-e*u2
ke3=(m1*(ve1^2)+m2*(ve2^2))/(2*32.2)
loss=ke1-ke3
printf("kinetic energy before collisio0n is %f ft lb\n",ke1)
printf("\n")
printf("a) INELASTIC\n")
printf("\n")
printf("velocity after collision is %f ft/s\n",v)
printf("the Kinetic Energy after collision is %f ft lb\n",ke2)
printf("the change in Kinetic Energy after collision is %f ft lb\n",l)
printf("\n")
printf("b) ELASTIC\n")
printf("\n")
printf("velocity of 1 after collision is %f ft/s\n",v1)
printf("velocity of 2 after collision is %f ft/s\n",v2)
printf("there is no loss of kinetic energy in case of elastic collision\n")
printf("\n")
printf("c) e=0.6\n")
printf("\n")
printf("velocity of 1 after collision is %f ft/s\n",ve1)
printf("velocity of 2 after collision is %f ft/s\n",ve2)
printf("the Kinetic Energy after collision is %f ft
```

```
lb\n",ke3)
printf("the change in Kinetic Energy after collision is %f ft lb\n",loss)
```

Scilab code Exa 2.2 speed of truck

```

clc
//given
m1=15//tons
u1=12//m/h
m2=5//tons
u2=8//m/h
k=2//ton/in
e1=0.5//coefficient of restitution
printf("\n")
//conservation of linear momentum
v=(m1*u1+m2*u2)/(m1+m2)
printf("velocity at the instant of  collision is %.2f mph",v)
e=(m1*m2*(88/60)^2*(u1-u2)^2)/(2*32.2*(u1+u2))
printf("\n")
printf("The difference between the kinetic energy before and during the impact is %.2f ft tons\n",e)
//energy stored in spring equals energy dissipated
//s=(1/2)*k*x^2
//s=e
//since there are 4 buffer springs ,4x^2=24 inches (2 ft=24 inches)
x=((e*12)/4)^.5
printf("Maximum deflection of the spring is %.2f in\n",x)
// maximum force acting between pair of buffer = stiffness of spring*deflection
```

```
f=k*x
printf("Maximum force acting between each buffer is
    %.2f tons\n",f)
//assuming perfectly elastic collision
//for loaded truck
v1=2*11-12
//for unloaded truck
v2=2*11-8
printf("Speed of loaded truck after impact %.2f mph\
    n",v1)
printf("speed of unloaded truck after impact %.2f
    mph\n",v2)
//if coefficient of restitution =o.5
//for loaded truck
ve1=(1+.5)*11-.5*12
//for unloaded truck
ve2=(1+.5)*11-.5*8
printf("Speed of loaded truck after impact when e
    =0.5 %.2f mph\n",ve1)
printf("Speed of unloaded truck after impact when e
    =0.5 %.2f mph\n",ve2)
//net loss of kinetic energy=(1-e^2)*energy stored
    in spring
l=(1-(e1^2))*2//ft tons
printf("Net loss of kinetic energy is %.2f ft tons\n
    ",l)
```

Scilab code Exa 2.3 Maximum twist

```

clc
//given
m1=500//lb ft^2
m2=1500//lb ft^2
k=150//lb ft^2
```

```
w1=150//rpm

N=(w1*m1)/(m1+m2)
printf("Angular velocity at the instant when speeds
    of the flywheels are equalised is given by %.2f r
    .p.m\n",N)
//kinetic energy at this instance
ke1=(1/2)*((m1+m2)/32.2)*((%pi*N)/30)^2
printf("The kinetic energy of the system at this
    instance is %.2f ft lb\n",ke1)
printf("which is almost equal to 480 ft lb \n")
//initial kinetic energy
ke0=(1/2)*((m1)/32.2)*((%pi*w1)/30)^2
printf("The initial kinetic energy of the system is
    %.2f ft lb\n",ke0)
printf("which is almost equal to 1915 ft lb \n")
//strain energy = s
s=ke0-ke1
printf("strain energy stored in the spring is %.2f
    ft lb which is approximately 1435 ft lb\n",s)

x=((1435*2)/150)^.5
printf("Maximum angular displacement is %.2f in
    radians which is equal to 250 degrees\n",x)
//na1 and na are initial and final speeds of the
    flywheel 1 and same nb1 and nb for flywheel 2
na=2*N-w1//w1=na1
nb=2*N-0//nb1=0
printf ("Speed of flywheel a and b when spring
    regains its unstrained position are %.2f rpm and
    %.2f rpm respectively\n",na,nb)
```

Scilab code Exa 2.4 Length of equivalebt pendulum

```

```

```
clc
//given
m1=150 //lb
l=3//ft
//number of oscillation per second is given by n
printf("\n")
n=(50/92.5)
printf ("number of oscillation per second = %.2f\n",
    n)
//length of simple pendulum is given by L=g/(2*%pi*n
    )^2
L=32.2/(2*%pi*n)^2
printf ("length of simple pendulum = %.2f ft\n",L)
// distance of cg from point of suspension is given
    by a
a=25/12
k=(a*(L-a))^.5//radius of gyration
moi=m1*k^2
printf("The moment of inertia of rod is %.2f lb ft^2
    ",moi)
```

Scilab code Exa 2.5 Moment of inertia

```
clc;
n1=50/84.4
n2=50/80.3

L1=(32.2*12)*(84.4/(100*%pi))^2
L2=(32.2*12)*(80.3/(100*%pi))^2
//a1(L1-a1)=k^2=a2(L2-a2) and a1+a2=30 inches
//substituting and solving for a we get
a1=141/6.8
a2=30-a1
k=(a1*(L1-a1))^.5
moi=90*(149/144)//moi=m*k^2
```

```
printf("length of equivalent simple pendulum when axis coincides with small end and big end respectively -\n")
printf("L1=%.1f in\n",L1)
printf("L2=%.1f in\n",L2)
printf("distances of cg from small end and big end centers respectively are-\n")
printf("a1=%.1f in\n",a1)
printf("a2=%.1f in\n",a2)
printf("Moment of inertia of rod =%.2f lb ft^2",moi)
```

Scilab code Exa 2.6 radius of gyration

```

clc
//given
printf("\n")
m1=150
l=8.5
g=32.2
a=83.2
n=25
//k=(a/2*%pi*n)*(g/l)^0.5
k=(14*a*((g)^0.5))/(2*%pi*n*(l^0.5))
k1=14.5/12
printf("radius of gyration is %.2f inches which is equal to %.2f ft \n",k,k1)
moi=m1*(k1^2)
printf("moment of inertia=%.2f lb ft^2",moi)
```

Scilab code Exa 2.7 Dynamical system

```
clc
```

```
printf("\n")
//given
m=2.5//lb
a=6//in
k=3.8//in
l=9//in
c=3//in
w=22500
//k^2=ab
//case a) to find equivalent dynamic system
b=(k^2)/a
ma=(2.5*6)/8.42//m*a/a+b
mb=m-ma
printf("Mass ma =%.2f lb will be situated at 6 inches from cg \n and mb =%.2f lb will be situated at %.2f inches \n from cg in the equivalent dynamical system",ma,mb,b)
printf("\n")
//if two masses are situated at the bearing centres
ma1=(2.5*6)/9
mb1=m-ma1
k1=(a*c)^.5
//t=m*((k1^2)-(k^2))*w
t=((2.5*(18-3.8^2))*22500)/(32.2*12*12)
printf("correction couple which must be applied in order that the two mass system is dynamically equivalent to the rod is given by %.2f lb ft\n",t)
```

Scilab code Exa 2.8 Find forces

```

clc
printf("\n")
m=20//lb
```

```
g=32.2
a=200//ft/s^2
w=120//rad/s^2
k=7//in
f=(m/g)*a//effective force appllied to the link
//this force acts parallel to the acceleration fg
t=(m/g)*(k/12)^2*w//couple required in order to
    provide the angular acceleration
//the line of action of F is therefore at a distance
    from G given by
x=t/f
printf("Effective force applied to the link is %.3f
    lb and the line of action of F is therefore at a
    distance from G given by %.3f ft \n",f,x)
printf("F is the resultant of Fa and Fb, using x as
    shown in figure.25 , the force F may then be
    resolved along the appropriate lines of action to
    give the magnitudes of Fa and Fb\n")
printf("From the scaled diagram shown in figure we
    get,Fa=65 lb and Fb=91 lb\n")
```

Scilab code Exa 2.9 Find force

```

clc
printf("\n")
//given
m=10//ton
m2=1000//lb
a=3//ft/s^2
//the addition to actual mass in order to allow for
    the rotational inertia of the wheels and axles
m1=2*(1000/2240)*(15/21)^2//m1=m2*k^2/r^2 and 1 ton
    =2240 lbs
M=m+m1
```

```
F=3*(10.46/32.2)//F=M.a
f=F*2240//lb
Fa=(2*1000/2240)*(3/32.2)*(15/21)^2//total tangential force required in order to provide the angular acceleration of the wheels and axles
//Limiting friction force =uW
//u*10>0.042
u=0.042/10
printf("The total tangential force required in order to provide the angular acceleration of the wheels and axles is %.4f ton\n",Fa)
printf("If there is to be pure rolling ,u>%.4f",u)
```

Scilab code Exa 2.10 Find acceleration

```

clc
//given
Ia=200//lb ft2
Ib=15//lb ft2
G=5//wb==5*wa
m=150//lb
r=8//in
printf("\n")
//the equivalent mass of the geared system referred to the circumference of the drum is given by
//Me=(1/r)^2*(Ia+(G^2*Ib))
Me=(12/r)^2*(Ia+(G^2*Ib))
M=m+Me
a=(m/M)*32.2//acceleration
//if efficiency of gearing is 90% then Me=(1/r^2)*(Ia+(G^2*Ib)/n)
n=.9
Me1=(12/r)^2*(Ia+(G^2*Ib)/n)
M1=Me1+m
```

```
a1=(m/M1)*32.2
printf("acceleration = %.2f ft/s2\n",a)
printf("acceleration when gear efficiency is 0.9= %.2f ft/s2\n",a1)
```

Scilab code Exa 2.11 Maximum acceleration

```

clc
printf("\n")
//let
//S=displacement of car from rest with uniform acceleration a, the engine torque T assumed to remain ocnstant
//v=final speed ofcar
//G=gear ratio
//r=effective radius
//n=efficiency of transmission
//M=mass of the car
//Ia and Ib=moments of inertia of road whels and engine
//formulas => F=29.5nG ; Me= 1648+$.54nG^2 ; a=32.2F/Me
//given
G1=22.5
G2=12.5
G3=7.3
G4=5.4
n=.82//for 1st ,2nd and 3rd gear
n4=.9//for 4th gear
F1=29.5*n*G1
F2=29.5*n*G2
F3=29.5*n*G3
F4=29.5*n4*G4
//on reduction and putting values we get
```

```
Me1=1648+4.54*n*G1^2
Me2=1648+4.54*n*G2^2
Me3=1648+4.54*n*G3^2
Me4=1648+4.54*n4*G4^2
a1=32.2*F1/Me1
a2=32.2*F2/Me2
a3=32.2*F3/Me3
a4=32.2*F4/Me4
printf("Maximum acceleration of car on top gear is %.2f ft/s^2 \n",a4)
printf("Maximum acceleration of car on third gear is %.2f ft/s^2 \n",a3)
printf("Maximum acceleration of car on second gear is %.2f ft/s^2 \n",a2)
printf("Maximum acceleration of car on first gear is %.2f ft/s^2 \n",a1)
```

Scilab code Exa 2.12 couple supplied

```

clc
printf("\n")
//given
I=40//lb ft2
n=500//rpm
w=%pi*n/30//angular velocity
wp=2*%pi/5//angular velocity of precession
I1=I/32.2
T=I1*w*wp//gyroscopic couple
printf("the couple supplied to the shaft= %.2f lb ft \n",T)
```

Scilab code Exa 2.13 gyroscopic reaction

```
clc
//given
printf("\n")
I=250//lb ft2
n=1600//rpm
v=150//mph
r=500//ft
w=%pi*160/3//angular velocity of rotation
wp=(150*88)/(60*500)//angular velocity of precession
//a) with three bladed screw
//T=I*w*wp
T=(250/32.2)*%pi*(160/3)*wp
//b)with two bladed air screw
//T1=2*I*w*wp*sin(o)
printf("The magnitude of gyroscopic couple is given
    by %.0f lb ft\n",T)
//Tix=T(1-cos(2o)) lb ft
//T1y=Tsin(2o)) lb ft
printf("The component gyroscopic couple in the
    vertical plane =%.0f(1-cos(2x)) lb ft\n",T)
printf("The component gyroscopic couple in the
    horizontal plane =%.0f(sin(2x)) lb ft\n",T)
```

Chapter 3

Velocity and acceleration

Scilab code Exa 3.3 Velocities

```

clc
//Given
OC=6//in
CP=24//in
N=240//rpm
X=45//degrees
XP=19//in
XC=6//in
YP=32//in
YC=9//in
//Scalling off lenghts from fig , we have
CI=2.77//in
PI=2.33//in
XI=2.33//in
YI=3.48//in
//Solution
Vc=((%pi*N)/30)*(OC/12)//changing OP into feets
printf("\nw=%.2f ft/s\n",Vc)
//w=Vc/CI=Vp/PI=Vx/XI=Vy/YI
w=Vc/CI
```

```
Vp=w*PI
Vx=w*XI
Vy=w*YI
printf("velocity of points P, X and Y \n are %.2f ft
    /s, %.2f ft/s and %.1f ft/s respectively",Vp,Vx,
    Vy)
```

Scilab code Exa 3.4 find acceleration

```

clc
printf("\n")
//Given
OC=9//inches
CP=36//inches
XC=12//inches
X=40//degrees
CM=6.98//from the scaled figure
N1=240//rpm
N2=240//rpm (instantaneous) with angular aceleration
     (ao) 100 rad/s^2
ao=100 //rad/s^2
w=(%pi*N1/30)
a=w^2*(OC/12)
printf("Centripetal acceleration = %.f ft/s^2\n",a)
Wr=w*CM/CP//rad/s^2
f1=Wr^2*(CP/12)//centripetal component of
    acceleration of p realtive to C
//Solution a)
//given from fig 58(a)
tp=296
cp=306
ox=422
f2=tp //Tangential component of acceleration of p
    realtive to C
```

```
f3=cp//acceleration of p realtive to C
fx=ox//acce;eration of x
ar=f2/(CP/12)//angular acceleration of rod
printf("Case a) \nap= %.f ft/s^2,\nax= %.f ft/s^2
   and\nar= %.1f rad/s^2 \n",f3,fx,ar)
//Solution b)
//given from fig 58(b)
oc1=474
oc=480
pt=238
pc=246
xo=452
f4=pt//Tangential component of acceleration of p
   realtive to C
f5=pc//acceleration of p realtive to C
Ar=f4/(CP/12)//angular acceleration of rod
f6=ao*(OC/12)//tangential component of acceleration
   realtive to C
Fx=xo//acce;eration of x
printf("Case b) \nap= %.f ft/s^2,\nax= %.f ft/s^2
   and\nar= %.1f rad/s^2 \n",f4,Fx,Ar)
```

Scilab code Exa 3.5 Angular acceleration of CD and BC

```

clc
//Given
AB=2.5//inches
BC=7//inches
CD=4.5//inches
DA=8//inches
N=100//rpm
X=60//degrees
w=(%pi*N)/30
//From triangle ABM we have
```

```
AM=0.14//feet
BM=0.12//feet
Vb=w*AB/12//ft/s
Vc=w*AM//ft/s
Vcb=w*BM//ft/s
fb=w^2*(AB/12)//ft/s^2
bt=Vcb^2/(BC/12)//ft/s^2
os=Vc^2/(CD/12)//ft/s^2
//By measurement from acceleration diagram
sc=19.1//ft/s^2
tq=14.4//ft/s^2
Acd=sc/(CD/12)
Abc=tq/(BC/12)
printf("\n")
printf("Vb=%.2f ft/s \nVc=%.2f ft/s\nVcb=%.2f ft/s\nfb=%.2f ft/s^2\nbt=%.2f ft/s^2\nos=%.2f ft/s^2\n",Vb,Vc,Vcb,fb,bt,os)
printf("Angular acceleration of CD(counter-clockwise)= %.1f rad/s^2 \n",Acd)
printf("Angular acceleration of BC(counter-clockwise)= %.1f rad/s^2 \n",Abc)
```

Scilab code Exa 3.6 Find the acceleration

```

clc
//Given
printf("\n")
OP=2//ft
f=4//ft/s^2
w=2 //rad/s (anticlockwise)
a=5 //rad/s^2 (anticlockwise)
Vpq=3 //ft/s
r=OP
os=w^2*r//component 1
```

```
sq=a*r//component 2
qt=f//component 3
tp=2*w*Vpq//component 4
Aqo=(os^2+sq^2)^1/2//vector addition of component(a,b)
Apq=(qt^2+tp^2)^1/2//vector addition of component(c,d)
//Apo=Apq+Aqo (vector addition)
Apo=((os-qt)^2+(sq+tp)^2)^(1/2)
printf("Acceleration of P realative to fixed point O is %.1f ft/s^2",Apo)
```

Scilab code Exa 3.7 Find velocity and acceleration of ram R

```

clc
printf("\n")
//GIVEN
OC=8//inches
CP=4//inches
N=60//inches
ON=15//inches
RN=6//inches
X=120//degrees
OP=10.6
OQ=OP
//from fig 65(a)
Vq=1.56//ft/s
Vrn=0.74//ft/s
//from fig 65(b)
ftq=3.74//ft/s^2
ftrn=2.03//ft/s^2
w1=(%pi*N)/30
w=Vq/(OQ/12)
wrn=Vrn/(RN/12)
```

```
a=ftq/(OP/12)//Angular acceleration of ON
a1=ftrn/(RN/12)//angular acceleration of RN
printf("W=%.2f rad/s\nWrn=%.2f rad/s\n",w,wrn)
printf("Angular acceleration of ON= %.2f rad/s^2\
    nAngular acceleration of RN=%.2f rad/s^2\n",a,a1)
```

Scilab code Exa 3.8 Velocity and acceleration of piston

```

clc
//given
OC=3//inches
CP=9//inches
N=1200 //rpm (clockwise)
X=55 //degrees
//from the figure 66
OP=10.35//inches
PM=10.74//inches
OM=2.95//inches
PC=12.84//inches
PR=PC
RV=2.49//inches
UV=1.29//inches
OU=5.90//inches
PV=13.05//inches
OV=6.06//inches
OQ=OP
//Solution
w=(%pi*N)/30//the angular velocity of the cylinder
    line OP
Vq=w*(OP/12)//the velocity of Q
Vp=w*(PM/12)//The velocity of P
w1=Vp/(CP/12)//The angular velocity of CP
Vpq=w*(OM/12)//the velocity of sliding of the piston
     along the cylinder
```

```
fq=w^2*(OQ/12)//the centripetal acceleration of Q
Acp=w1^2*(PC/12)//The centripetal component of
    acceleration of P
Atp=w^2*(RV/12)//The tangential component of
    acceleration of P
acp=Atp/(CP/12)// The angular acceleration of the
    connecting rod CP
f=w^2*(UV/12)//component c
d=2*w*Vpq//component d
Ap=w^2*PV//the resultant acceleration of P
Apq=w^2*OV//the acceleration of P realative to Q
printf("\nThe velocity and acceleration of the
    piston along the cylinder are %.1f ft/s and %.f
    ft/s^2 respectively\nThe angular velocity and
    angular acceleration of the connecting rod cp are
     %.1f rad/s and %.f rad/s^2 respectively\nAnd the
     coriolis component of the acceleration of P is %
    .f ft/s^2\n",Vpq,f,w1,acp,d)
```

Chapter 4

Mechanisms with lower pairs

Scilab code Exa 4.1 Extreme angular velocities

```

clc
//given
rpm=1000
angle=20//degree
ang=(angle*%pi)/180
printf("\n")
w=2*%pi*rpm/60
printf("The angular velocity of the driving shaft is %.1f rad/s \n",w)
//maximum value of w1=w/cos(angle) and minimum value w2=w*cos(angle)
w1=w/cos(ang)
w2=w*cos(ang)
printf("Extreme angular velocities :-\n")
printf("maximum value of angular velocity w1=%.1f rad/s \nminimum value of angular velocity w2=%.1f rad/s\n",w1,w2)
//using equation 4.11, cos(2x)=(2*sin(angle)^2)/(2-sin(angle)^2)
x=acos((2*sin(ang)^2)/(2-sin(ang)^2))*180/(%pi)
```

```
y=360-x//for cosine inverse, angle and 360-angle are same and must be considered
x1=x/2
y1=y/2
printf("The acceleration of driven shaft is a maximum when theta =%.2f or %.2f degrees\n",x1,y1)
amax=(w^2*cos(ang)*(sin(ang)^2)*sin(x*%pi/180))/((1-((cos(x1*%pi/180)^2)*(sin(ang)^2)))^2)//maximum angular acceleration, numerically
printf("Maximum angular acceleration is %.f rad/s^2\n",amax)
```

Chapter 5

Valve diagrams and valve gears

Scilab code Exa 5.1 `find theta at admission`

```

clc
//given
s=1.125//inch
e=0.25//inch
t=2.25//inch
alpha=35//degrees
//from 5.2, we know theta+alpha=sininverse(s/t)
x=asind(s/t)
y=180-x//sin(x)=sin(180-x)=sin(y)
//at admission
p=x-alpha
//at cutoff
q=y-alpha
//from 5.3, theta+alpha=sininnverse(-e/t)
ang=asind(-e/t)
angle=abs(ang)
a=180+angle//lies in the negative region of sine
    curve
b=360-angle//lies in hte negative region of sine
    curve
```

```
//at release
r=a-alpha
//at compression
s=b-alpha
printf("Angle theta at admission, cut-off,\n release
    and compression are %.2f, %.2f, %.2f and %.2f
   degrees respectively",p,q,r,s)
```

Chapter 6

Friction

Scilab code Exa 6.1 maximum efficiency

```

clc
//given
theta=60//degrees
u1=0.15//between surfaces A annd B
u2=0.10//for the guides
phi=atand(u1)
phi1=atand(u2)
alpha=(theta+phi+phi1)/2//from 6.22, maximum
    efficiency is obtained at alpha
//from 6.23, maximum efficiency is given by nmax=(
    cos(theta+phi+phi1)+1)/(cos(theta-phi-phi1)+1)
nmax=(cos((theta+phi+phi1)*%pi/180)+1)/(cos((theta-
    phi-phi1)*%pi/180)+1)
printf("Maximum efficiency = %.4f and it is obtained
     when alpha = %.2f degrees",nmax,alpha)
```

Scilab code Exa 6.3 Power absorbed and number of collars

```
clc
//from equation 6.36 we know, M=(2/3)*u*W*(ri^3-r2
    ^3)/(r1^2-r2^2)
//given
u=0.04
W=16//tons
w=W*2240//lbs
r1=8//in
r2=6//in
N=120
P=50//lb/in^2
M=(2/3)*u*w*(r1^3-r2^3)/(r1^2-r2^2)
hp=M*2*%pi*N/(12*33000)//horse power absorbed
//from fig 137,effective bearing surface per pad is
    calsulate from the dimensions to be 58.5 in^2
A=58.5//in^2
n=w/(A*P)
x=floor(n)
printf("\n")
printf("Horsepower absorbed = %.2f\nNumber of
    collars required = %.f\n",hp,x)
```

Scilab code Exa 6.4 dimension of clutch

```
clc
//given
ratio=1.25
u=.675
P=12//hp
//W=P*%pi*(r1^2-r2^2); Total axal thrust.
//M=u*W*(r1+r2); Total friction moemnt
//reducing the two equations and using ratio=1.25(r1
    =1.25*r2) we get, M=u*21.2*r2^3
```

```
ReqM=65//lb ft
RM=ReqM*12//lb in
r2=(RM/(u*P*%pi*(1.25^2-1)))^(1/3)
r1=1.25*r2
d1=r1*2
d2=r2*2
printf("The dimensions of the friction surfaces are
   :\nOuter Diameter= %.1f in\nInner Diameter= %.1f
   in\n",d1,d2)
```

Scilab code Exa 6.5 Number of plates required

```

clc
P=20//lb/in^2
u=0.07//friction coefficient
N=3600//rpm
H=100//hp
r1=5//in
r2=0.8*r1//given
A=%pi*(r1^2-r2^2)//the area of each friction surface
W=A*P//total axial thrust on plates
M=(1/2)*u*W*(r1+r2)//friction moment for each pair
   of contacts
T=H*33000*12/(2*%pi*N)//total torque to be
   transmitted
x=(T/M)//effective friction surfaces required
printf("\nNumber of effective friction surfaces
   required= %.f\n",x)
```

Scilab code Exa 6.7 Turning moment

```

```

```
clc
//given
P=6 //tons
u=0.05
theta=60//degrees
CP=80
Stroke=16//in
OC=Stroke/2
r1=7//in
r2=15//in
r3=4.4//in
//Radius of friction circle
ro=u*r1
rc=u*r2
rp=u*r3
phi=asind(OC*sin((theta)*%pi/180)/CP)
alpha=asind((rc+rp)/CP)
//a) without friction
Qa=P/cos((phi)*%pi/180)
Xa=OC*cos((30-phi)*%pi/180)//tensile force transmitted along the eccentric rod when friction is NOT taken into account
Ma=Qa*Xa/12
//b) with friction
Qb=P/cos((phi-alpha)*%pi/180)//tensile force transmitted along the eccentric rod when friction is taken into account
Xb=OC*cos((30-(phi-alpha))*%pi/180)-(rc+ro)
Mb=Qb*Xb/12
n=Mb/Ma
printf("Turning moment applied to OC:\na)Without friction= %.2f ton.ft\nb)With friction(u=0.05)= %.2f ton.ft",Ma,Mb)
printf("\nThe efficiency of the mechanism is %.2f ",n)
```

Scilab code Exa 6.8 horizontal force

```
clc
stroke=4//in
d=11.5//in
ds=4//in
dp=14//in
theta=%pi
u1=.25
T1=350//lb
u2=0.1
k=%e^(u1*theta)
T2=T1/k
Tor=(T1-T2)*(dp/2)//total resisting torque
//total resisting torque is also given by P*(r+2*(
    cos%pi/6))+u2*R*(ds/2)
//equating and putting values we get the following
    quadratic equation
p=[1 -1.163D3 3.342D5]
a=roots(p)
printf("\nP=%.1f",a)
printf("\nThe larger of two values is inadmissible.
    \n It corresponds to a negative sign in front of
    the second term on the \n right hand side of
    equation (1)")
```

Chapter 7

Belt rope and chain drive

Scilab code Exa 7.1 Maximum horsepower

```
clc
//given-belt is perfectly elastic and massless
u=0.3
v=3600//ft/min
V=v/60//ft/sec
theta=165//degrees
x=theta*%pi/180
k=%e^(u*x)//k=T1/T2=e^(u*x)
To=500//lb
T1=2*k*To/(k+1)
T2=T1/k
T=T1-T2//effective tension
H=T*V/550//horsepower transmitted
printf("\nThe horse-power transmitted = %.2f\n",H)
```

Scilab code Exa 7.2 Maximum horsepower

```
clc
w=1.2//lb/ft^2
u=0.3
v=3600//ft/min
V=v/60//ft/sec
theta=165//degrees
g=32.2//ft/s^2
x=theta*%pi/180
k=%e^(u*x)//k=T1/T2=e^(u*x)
To=500//lb
//Solution a)Vertical drive
Tc=w*V^2/g//equation 7.5
//solution a)
H=2*(k-1)*(To-Tc)*V/((k+1)*550)
Vmax=(To*g/(3*w))^(1/2)
Hmax=2*(k-1)*(To-Tc)*Vmax/((k+1)*550)
//Solution b)
To1=To+Tc
//from equation 7.15 2/To1^2=1/Tt^2+1/Ts^2
//T1/T2=k
T2=367 //lb - from trail and error
T1=k*T2
Tt=T1+Tc
Ts=T2+Tc
HP=(T1-T2)*V/550
printf("\nSolution a)\nHorsepower transmitted= %.1f\nMaximum Horsepower transmitted= %.1f (at velocit = %.1f ft/s^2)Solution b)\nTt=%.f lb\nTs=%.f lb\nHorsepower transmitted= %.1f",H,Hmax,Vmax,Tt,Ts,HP)
```

Chapter 8

Brakes and dynamometer

Scilab code Exa 8.1 Braking trrques

```
clc
//given
dia=12//in
r=dia/2
CQ=7//in
OC=6//in
OH=15//in
u=0.3
P=100//lb
phi=atan(u)
x=r*sin(phi)//in inches;radius of friction circle
a=5.82//from figure
Tb=P*OH*x/a//braking torque
printf("\nThe braking torque of the drum Tb= %.2f lb
    in\n",Tb)
```

Scilab code Exa 8.2 Braking troque applied to the drum

```
clc
//given

OH=15//in
l=OH
u=0.3
P=100//lb
phi=atan(u)
dia=12 //in
r=dia/2;
//according to fig 170(b)
//for clockwise rotation
a=6//from figure
x=r*sin(phi)//in inches;radius of friction circle
Tb=P*l*x/a//braking torque on the drum
//for counter clockwise rotation
a1=5.5//in
Tb1=P*l*x/a1//braking torque on the drum
//according to figure 172(a)
//for clockwise rotation
a2=6.48//from figure
x=r*sin(phi)//in inches;radius of friction circle
Tb2=P*l*x/a2//braking torque on the drum
//for counter clockwise rotation
a3=6.38//in
Tb3=P*l*x/a3//braking torque on the drum
T1=ceil(Tb1)
T2=ceil(Tb2)
T3=ceil(Tb3)
printf("\nbraking torque on drum\nWhen dimensions
   are measured from fig 170(b)\nFor clockwise
   rotation= %.f lb in\nFor counter clockwise
   rotation= %.f lb in\nWhen dimensions are measured
    from fig 171(a)\nFor clockwise rotation= %.f lb
   in\nFor counter clockwise rotation= %.f lb in",Tb
   ,T1,T2,T3)
```

Scilab code Exa 8.3 Magnitude of force

```

clc
//given
u=.35
Tb=500//lb.ft
rd=10//in
phi=atan(u)
x=rd*sin(phi)
//F*OD=R*a=R1*a
//R=R1
//2*R*x=Tb
OD=24//in
a=11.5//inches; From figure
F=Tb*a*12/(OD*2*x)
//from figure
HG=4//in
GK=12//in
HL=12.22//in
P=F*HG/GK
Fhd=HL*P/HG
printf("\na) Magnitude of P = %.f lb",P)
printf("\nb) Magnitude of Fhd = %.f lb",Fhd)
```

Scilab code Exa 8.4 force required to support load

```

clc
//given
u=.3
theta=270*%pi/180
```

```
l=18//in
a=4//in
Di=15//in
Do=21//in
w=.5//tons
W=w*2204//lb
Q=W*Di/Do//required tangential braking force on the drum
k=%e^(u*theta)//k=T1/T2
p=Q*a/(l*(k-1))
printf("Least force required , P = %.f lb",p)
```

Scilab code Exa 8.5 `Effort applied`

```

clc
//given
n=12
u=.28
a=4.5//in
b=1//in
l=21//in
r=15//in
Tb=4000//lb
theta=10*%pi/180
//k=Tn/To
k=((1+u*tan(theta))/(1-u*tan(theta)))^n
Q=Tb*(12/r)
P=Q*(a-b*k)/(l*(k-1))//from combining 8.6 with k=e^u*theta
printf("The least effort required = P = %.1f lb",P)
```

Scilab code Exa 8.6 `minimum distance`

```
clc
//given
w=9.5 //ft
h= 2 //ft
x=4 //ft
v=30//mph
V=1.46667*v//ft/s
u1=.1
u2=.6
g=32.2//ft/s^2
//a) rear wheels braked
fa1=(u1*(w-x)*g)/(w+u1*h)
fa2=(u2*(w-x)*g)/(w+u2*h)
sa1=V^2/(2*fa1)
sa2=V^2/(2*fa2)
//b) front wheels braked
fb1=u1*x*g/(w-u1*h)
fb2=u2*x*g/(w-u2*h)
sb1=V^2/(2*fb1)
sb2=V^2/(2*fb2)
//c) All wheels braked
fc1=u1*g
fc2=u2*g
sc1=V^2/(2*fc1)
sc2=V^2/(2*fc2)
k1=(x+u1*h)/(w-x-u1*h)//Na/Nb
k2=(x+u2*h)/(w-x-u2*h)//Na/Nb
printf("\nCoefficient of friction = 0.1\na) Minimum
    distance in which car may be stopped when the
    rear brakes are applied = %.f ft\nb) Minimum
    distance in which car may be stopped when the
    front brakes are applied = %.f ft\nc) Minimum
    distance in which car may be stopped when all
    brakes are applied = %.f ft\nCoefficient of
    friction = 0.6\na) Minimum distance in which car
    may be stopped when the rear brakes are applied =
    %.f ft\nb) Minimum distance in which car may be
    stopped when the front brakes are applied = %.f
```

```
    ft\nc) Minimum distance in which car may be
    stopped when all brakes are applied = %.f ft\n",
    sa1,sb1,sc1,sa2,sb2,sc2)
printf("Required ration of Na/Nb\nFor u1 = 0.1 -> %
    .3f\nFor u2 = 0.6 -> %.2f\n",k1,k2)
```

Chapter 9

CAMS

Scilab code Exa 9.5 Draw diagram

```
clc
//given
alpha=55*%pi/180
N=1200//rpm
lift=.5//in
rn=.125//in ; noseradius
rmin=1.125//in ; minimum radius
OQ=rmin+lift-rn
OP=(OQ^2-1)/(2*(1-OQ*cos(alpha)))//from triangle opq
    fig 201(a)
PQ=OP+rmin-rn
phi=asin(OQ*sin(alpha)/PQ)
x1=[0:.0001:phi]
x2=[phi:.0001:alpha]
y1=4.477*(1-cos(x1))//from 9.6
y2=1.5*cos(alpha-x2)-1//from 9.9
v1=%pi*N*4.477*sin(x1)/(30*12)//from 9.7
v2=15.71*sin(alpha-x2)//from 9.10
f1=(%pi*N/30)^2*(4.477/12)*cos(x1)//from 9.8
f2=-1974*cos(alpha-x2)//from 9.11
a=[0:.0001:phi]
```

```
b=[phi:.0001:alpha]
p=[0:.0001:phi]
q=[phi:.0001:alpha]
subplot(3,1,3)
subplot(311)
plot(x1,y1,x2,y2)
xtitle("","angle","displacement")
subplot(312)
plot(a,v1,b,v2)
xtitle("","angle","velocity")
subplot(313)
plot(p,f1,q,f2)
xtitle("","angle","acceleration")
```

Scilab code Exa 9.7 Angular velocity and angular frequency

```

clc
//given
N=600//rpm
BC=3//in
rmin=1.125//in
rf=39/8//in
OP=rf-rmin
OM1=0.79//in;given
NZ1=2.66//in
w=N*%pi/30
vb=w*OM1
Vang=vb/BC
at=w^2*NZ1
fBC=at/BC
OM2=.52//in
NZ2=3.24//in
af=w*OM2/BC
angf=w^2*NZ2/BC
```

```
printf("\nWhen theta = 25 degrees\nangular velocity = %.1f rad/s\nangular acceleration = %.f rad/s^2\nWhen theta = 45 degrees\nangular velocity = %.1f rad/s\nangular acceleration = %.f rad/s^2",Vang,fBC,af,angf)
```

Chapter 10

Toothed gearing

Scilab code Exa 10.1 Toothed gearing

```
clc
//given
Teeth=48
pitch=.75 //in
D=Teeth*pitch/%pi
printf("The pitch diameter is %.3f in",D)
```

Scilab code Exa 10.2 circular pitch

```
clc
//given
T=48//teeth
pd=4//diametral pitch
D=T/pd//pitch diameter
p=%pi/pd//the circular pitch
```

```
printf("\nThe pitch diameter = %.f in\nThe circular
    pitch = %.4f in\n",D,p)
```

Scilab code Exa 10.3 pitch module

```

clc
//given
T=48
m=6//mm ; module
D=m*T
p=%pi*m
dia=D/10//cm
P=p*0.0393700787//inches
printf("\nPitch diameter = %.1f cm\nCircular pitch =
    %.4f in\n",dia,P)
```

Scilab code Exa 10.4 smallest number of teeth

```

clc
//given
phi=20*%pi/180
//Solution a)
ar=1
t1=2*ar/sin(phi)^2//from equation 10.7
T1=ceil(t1)
//Solution b)
aw=1
t2=2*aw/((1+3*sin(phi)^2)^(1/2)-1)//from euation
    10.6
T2=ceil(t2)
//solution c)
```

```
t=1
T=3
A=(t/T)*(t/T+2)
t3=2*aw*(t/T)/((1+A*sin(phi)^2)^(1/2)-1)//from 10.5
T3=ceil(t3)
printf("\nSmallest number of teeth theoretically
    required in order to avoid interference on a
    pinion which is to gear with\na) A rack , t= %.f\
    nb) An equal pinion , t=  %.f\nc) A wheel to give
     a ratio of 3 to 1 , t= %.f\n",T1,T2,T3)
```

Scilab code Exa 10.5 Addendum required

```

clc
//given
t=25
phi=20*%pi/180
//let pitch be 1
R=t/(2*%pi)//R=t*p/(2*%pi)
Larc=1.6//1.6*p
//AB=Larc*cos(phi)
AB=Larc*cos(phi)
Ra=(4.47+13.97)^(1/2)//by simplifying AB+2{(Ra^2-R
    ^2*cos(phi)^2)-R*sin(phi)} and using p =1
Addendum=Ra-R
//writing p in place of p=1
printf("\nAddendum required = %.2fp",Addendum)
```

Scilab code Exa 10.6 length of arc contact

```

clc
```

```
//let module be 1
m=1
t1=28
t2=45
r=t1*m/2
R=t2*m/2
ra=r+m
Ra=R+m
phi1=14.5*%pi/180
//10.8 => AB =(ra^2-r^2*cos(phi)^2)^(1/2)+(Ra^2-R^2*
    cos(phi)^2)^(1/2)-(r+R)*sin(phi)
//AB=A+B-C
A=m*(ra^2-r^2*cos(phi1)^2)^(1/2)
B=m*(Ra^2-R^2*cos(phi1)^2)^(1/2)
C=m*(r+R)*sin(phi1)
AB=A+B-C
p=%pi*m
ABp=AB/%pi
arc1=ABp/cos(phi1)//length of arc of contact
phi2=20*%pi/180
//10.8 => AB =(ra^2-r^2*cos(phi)^2)^(1/2)+(Ra^2-R^2*
    cos(phi)^2)^(1/2)-(r+R)*sin(phi)
a=m*(ra^2-r^2*cos(phi2)^2)^(1/2)
b=m*(Ra^2-R^2*cos(phi2)^2)^(1/2)
c=m*(r+R)*sin(phi2)
ab=a+b-c
abp=ab/%pi
arc2=abp/cos(phi2)//length of arc of contact
printf("\nLength of path of contact\nWhen phi = 14.5
     degrees = %.3fm\nWhen phi = 20 degrees = %.2fm\
    nLength of arc of contact\nWhen phi = 14.5
    degrees = %.2fp\nWhen phi = 20 degrees = %.3fp\n"
    ,AB,ab,arc1,arc2)
```

Chapter 11

Gear Trains

Scilab code Exa 11.1 `find gear train`

```

clc
//given
Ns=26//rpm of spindle
N1=4//rpm of lead screw
//the only wheel in the set of which 13 is a factor
    is that with 65 teeth
T1=65
T2=25//to satisfy the Ns/n1 ratio and to select from
     given set
T3=75//to satisfy the Ns/n1 ratio and to select from
     given set
T4=T1*T3*N1/(Ns*T2)
//solution b
Ns1=35
N1=4
Tb1=105//to satisfy the Ns/n1 ratio and to select
    from given set
Tb2=30//to satisfy the Ns/n1 ratio and to select
    from given set
Tb3=100//to satisfy the Ns/n1 ratio and to select
```

```
from given set
Tb4=Tb1*Tb3*N1/(Ns1*Tb2)
printf("\na) The change wheel used will have %.f, %.f, %.f and %.f teeths\nb) The change wheel used will have %.f, %.f, %.f and %.f teeths",T1,T2,T3,T4,Tb1,Tb2,Tb3,Tb4)
```

Scilab code Exa 11.2 Overall ratio

```

clc
//given
v=15//ft/min
d=2//ft
N=450//rpm
N1=d*v/(2*%pi)//rpm of barrel
s=N/N1//total reduction speed required
//With a minimum number of teeth = 20
T=20
T1=T*(s)^(1/3)
R=(T1/T)^3
printf("\nIf the minimum number of teeth is fixed at 20, the might be as follow ( %.f / 20 )^3 = %.1f\nThis is sufficiently close to the required ratio\n",T1,R)
```

Scilab code Exa 11.3 Find number of teeth

```

clc
//given
d=7//in; central distance
k1=2*7*7//T1+t1/(2*7)=7
```

```
k2=2*7*5//T2+t2/(2*5)=7
G=9/1
t1=(-(k1+k2)+((k1+k2)^2+4*(G-1)*(k1*k2))^(1/2))/(2*(
   G-1))
a=ceil(t1)
b=floor(t1)
T1=k1-a
T2=k2-a
T3=k2-b
G1=T1*T2/(a*a)
G2=T1*T3/(a*b)
dp=a/d
//case b)
tb1=23//let t1 = 23
Tb1=k1-tb1
Gb1=Tb1/tb1
Gb2=G/Gb1
tb2=k2/(Gb2+1)
p=ceil(tb2)
Tb2=k2-p
l=Tb1-1
m=tb1+1
n=Tb2+1
o=p-1
Gb2=l*n/(m*o)
printf("\na) No of teeth = %.f, %.f, %.f, %.f\nG = %
   .2f\n\nb) No of teeth = %.f, %.f, %.f, %.f\nG = %
   .2f\n\n",T1,T2,a,b,G2,l,m,n,o,Gb2)
```

Scilab code Exa 11.5 Find ratio

```

clc
//given
Tb=27
```

```
Tc=30
Td=24
Te=21
k=Te*Tb/(Tc*Td)//k=Nd/Ne
//by applying componendo and dividendo , using Ne=0
    and reducing we get
a=(1-k)//where a = Nd/Na
b=1/a
printf("\nThe ratio of the speed of driving shaft to
    the speed of driven shaft\n\nNa/Nd = %.2f",b)
```

Scilab code Exa 11.6 speed of driven shaft

```

clc
//given
Tb=75
Tc=18
Td=17
Te=71
N1=500//rpm
k=Tb*Td/(Tc*Te)//k=Ne/Nb
//case a)
//using componendo and dividendo , Nb=0 and reducing
    we get
a=1-k//a=Ne/Na
Na=N1
Ne=Na*a
//case b)
Na1=500//given
Nb1=100//given
Ne1=k*(Nb1-Na1)+Na1
printf("\ncase a) Ne= %.3f rpm\ncase b) Ne= %.1f rpm
    \n",Ne,Ne1)
```

Scilab code Exa 11.8 `Diameter of bicycle wheel`

```
clc
//given
Td=23
Ta=19
Tb=20
Tc=22
k=Td*Ta/(Tb*Tc)
//using componendo and dividendo , Nc=0 and reducing
   we get
a=1/k-1//a=Nd/Ne
b=1/a//- denotes opposite direction
d=5280*12/(%pi*5*b)
p=ceil(d)
printf("\nThe diameter must be = %.1f in\nThe
   numbers of teeths are therefore suitable for a
   cyclometer for bicycle with %.f inches wheels",d,
   p)
```

Scilab code Exa 11.10 `Find the ratio`

```
clc
//given
s1=26
s2=24
s3=23
sr=31
i1=70
i2=72
```

```
i3=61
ir=71
t=1500//lb in
k1=-i3/s3//Ns3−Ni2/(Ni3−Ni2)=k
//S3 is fixed thus
k2=1-(1/k1)//k2=Ni3/Ni2
k3=-i2/s2//k3=Ns2−Ni3/(Ni2−Ni3)
k4=(1/k2-1)*k3+1//k4=Ns2/Ni3  ; reducing using k2
    and k3
k5=-i1/s1//Ns1−Nf/(Ni1−Nf)
k6=(1-k5)/(1-k5/k4)//k6=Ns1/Nf
printf("\n Ns1/Nf = %.2f",k6)
```

Chapter 12

Dynamics of Machines

Scilab code Exa 12.2 `Torque exerted`

```

clc
//given
ne=31
na=25
nb=90
nc=83
Ta=10 //lbft
//Ne-Nf/(Nc-Nf)=-83/31
k=114/83//k=Nc/Nf As Ne = 0, on simplification we get Nc/Nf= 114/83
j=-90/25//j=Na/Nb
//Nc=Nb, Thus Na/Nc=-90/25
//Na/Nf=(Na/Nc)*(Nc/Nf) ie Na/Nf=k*j
//Tf*Nf=Ta*Na
Tf=Ta*k*j
printf("\nTorque exerted on driven shaft = %.1f lb.ft\n",Tf)
```

Scilab code Exa 12.3 Torque exerted on crankshaft

```

clc
//given
D=9//in
stroke=24//in
d=2//in
l=60//in
CP=l
N=120
theta=40//degrees
x=theta*%pi/180
P1=160//lb/in^2
P2=32//lb/in^2
OC=stroke/2
F=%pi*(D/2)^2*P1-%pi*(D/2)^2*P2+%pi*(d/2)^2*P2
//Ft*Vc=F*Vp; Where Vc and Vp are velocities of crank and pin respectively
//Vp/Vc=IP/IC=OM/OC - From similar triangles  ; fig 274
n=CP/OC
OM=OC*(sin(x) + (sin(2*x)/(2*n)))//from 3.11
T=F*OM/12//torque exerted on crankshaft
Torque=floor(T)
printf("The torque exerted on crankshaft= F*OM = %.f lb ft",Torque)
```

Scilab code Exa 12.4 Total force

```

clc
//given
AB=12.5//in
IB=10.15//in
```

```
IA=10.75//in
IX=2.92//in
IY=5.5//in
w=3//lb
Fi=5//lb
Fa1=9//lb
Fb1=(Fa1*IA-w*IY-Fi*IX)/IB
//From the polygon of forces
Fa2=7.66//lb
Fb2=3.0//lb
Fa=(Fa1^2+Fa2^2)^(1/2)
Fb=(Fb1^2+Fb2^2)^(1/2)
printf("\nThe total force applied to the link AB at
   the pin A = Fa = %.2f lb\nThe total force applied
    to the link AB at the pin B = Fb = %.2f lb\n",Fa
   ,Fb)
```

Scilab code Exa 12.5 Inertia torque

```

clc
//given
CP=60//in
l=CP/12
a=41
cg=19
g=32.2//ft/s^2
m1=580//lb
Mr=500//lb
n=5//from example 12.3
x=40*%pi/180
N=120
r=1//ft
k=25
w=N*%pi/30
```

```
Rm=m1+(cg/CP)*Mr
fp=w^2*r*(cos(x)+cos(2*x)/n)
Fp=-Rm*fp/g
OM=0.7413//ft -from example 12.3
Tp=Fp*OM//from 12.6
L=a+k^2/a//length for simple equivalent pendulum
L1=L/12
Tc=-Mr*(a/12)*(l-L1)*w^2*sin(2*x)/(g*2*n^2)//from
    12.10
Tw=-Mr*a*cos(x)/(n*12)
T=Tp+Tc+Tw
printf("\nTp= %.f lbft\nTc = %.1f lbft\nTw = %.1f
    lbft\nTotal torque exerted on the crankshaft due
    to the inertia of the moving parts = Tp+Tc+tw = %
    .1f lbft",Tp,Tc,Tw,T)
```

Scilab code Exa 12.6 Torque exerted

```

clc
//given
AB=2.5//in
BC=7//in
CD=4.5//in
AD=8//in
ED=2.3//from figure
N=180
w=N*%pi/30
m=3//lb
k=3.5//radius of gyration
g=32.2//ft/s^2
QT=1.35//inches from figure
alpha=w^2*(QT/CD)
Torque=m*(k/12)^2*alpha/g
Torque1=Torque*12
```

```
Tadd=m*ED//additional torque
Tc=Tadd+Torque1//total torque
Fc1=Tc/CD
//link BC
M=5//lb
gA=1.8//in
fg=w^2*(gA/12)
F=M*fg/g
OaG=5.6//in
Kg=2.9//in
GZ=Kg^2/OaG
//scaled from figure
IB=9//in
IC=5.8//in
IX=2.49//in
IY=1.93//in
Fb1=(Fc1*IC+F*IX+M*IY)/IB
Tor=Fb1*AB
//from force polygon
Fc2=1//lb
Fb2=15.2//lb
Fb=(Fb1^2+Fb2^2)^(1/2)
Fc=(Fc1^2+Fc2^2)^(1/2)
printf("\nThe torque which must be exerted on AB in
    order to overcome the inertia of the links = Fb1*
    AB = %.1f lb.in\nThe total force applied to the
    link BC \nAt pin C = %.2f lb\nAt pin B = %.1f lb\
    n",Tor,Fc,Fb)
```

Scilab code Exa 12.7 Actual speed

```

clc
//given
N=210//rpm
```

```
w=N*%pi/30
F=50
p1=F*120/(N*2)//N*p=F*120
p2=floor(p1)//no of poles must be a whole number ; P2=P/2
p=2*p2
N1=F*120/p
n=3//no of impulse per second
Ks=n/(6*p)//equation 12.13
printf("\nKs = %.4f\n\nActual speed = %.1f rpm\nNumber of poles = %.f",Ks,N1,p)
```

Scilab code Exa 12.8 Weight of fly wheel

```

clc
//given
N=120//rpm
k=3.5//ft
Ef=2500//ft lb
Ks=.01
g=32.2//ft/s^2
w=%pi*N/30//angular velocity
W=g*Ef/(w^2*k^2*Ks*2240)//Weight of flying wheel
printf("\nWeight of flying wheel, W = %.2f tons",W)
```

Scilab code Exa 12.9 Fluctuation of speed

```

clc
//given
N=270//rpm
ihp=35.8
```

```
k=2.25//ft
g=32.2//ft/s^2
ke=1.93//from table on p 440
E=ihp*33000/N
Ef=ke*E
w=%pi*N/30
W=1000//lb
MOI=2*W*k^2//moment of inertia of both wheel
ks=Ef*g/(MOI*w^2)//formula for ks
p=ks/2
printf("The fluctuation speed is therefore %.4f or %.3f on either side of the mean speed",ks,p)
```

Scilab code Exa 12.10 Moment of inertia

```

clc
//given
ihp=25
N=300//rpm
Ks=2/100//given
u=2.3//work done by gases during expansion is u(2.3) times that during compression
E=ihp*33000/N//indicated work done per revolution
E1=E*2//indicated work done per cycle
We=E1/(1-1/u)//work done by gases during expansion
AB=We*2/%pi//the maximum torque from fig 290
AC=E/(2*%pi)//mean turning moment
CB=AB-AC//maximum excess turning moment
Ef=(CB/AB)^2*We//fluctuation of energy
Ke=Ef/E
w=%pi*N/30//angular speed
g=32.2//ft/s^2
moi=g*Ef/(w^2*Ks)//moment of inertia
printf("Moment of inertia of the flywheel = %.f lb
```

```
ft^2",moi)

//answer is not EXACT due to the approximations in
   calculations done by the author of the book
```

Scilab code Exa 12.11 Percentage variation

```

clc
//given
N=100//rpm
ke=1.93//As per given figure
l=15//1 inch of fig = 15 ton ft
x=40//degrees; 1 inch = 40 degree
I=150//ton ft^2
w=%pi*N/30//angular speed
E=l*x*%pi/180//energy
Ef=E*ke//fluctuation energy
Ks=Ef*g/(w^2*I)//from equation 12.14
p=Ks*100/2//dummy variables
q=p*2//dummy variables
printf("The total fluctuation of speed is %.2f
   percent and the variation in speed is %.2f
   percent on either side of \n the mean speed",q,p)
```

Chapter 13

Governors

Scilab code Exa 13.1 Equilibrium speed

```

clc
//given
//all lengths are in inches
W=120//lb
w=15//lb
AB=12
BF=8
BC=12
BE=6.5
g=35230//inches rpm
//at Minimum radius
AF=(AB^2-BF^2)^(1/2)
CE=(BC^2-BE^2)^(1/2)
k2=(BE*AF)/(CE*BF)
N2=(((W/2)*(1+k2)+w)*g/(w*AF))^(1/2)
//At MAximum radius
BF1=10
BE1=8.5
AF1=(AB^2-BF1^2)^(1/2)
CE1=(BC^2-BE1^2)^(1/2)
```

```
k1=(BE1*AF1)/(CE1*BF1)
N1=(((W/2)*(1+k1)+w)*g/(w*AF1))^(1/2)
printf("\nN1 (corresponding maximum radius) = %.1f
   rpm\nN2 (corresponding minimum radius) = %.1f rpm
   ",N1,N2)
```

Scilab code Exa 13.2 Weight of ball

```

clc
//given
BG=4//in
//solution a
w=15//lb
W=120//lb
k=.720
BD=10.08//in
CE=BD
DG=BD+BG
//by equating quations 13.2 and 13.10 and reducing,
   we get
w1=(W/2*(1+k))/(((W/2*(1+k)+w)*DG/(BD*w))-1)
printf("\nWeight of ball = %.3f lb\n",w1)
//solution b
CD=6.5//in
BC=12//in
BF=10//in
AB=12//in
CG=(DG^2+CD^2)^(1/2)
gama=atan(CD/DG)
bita=asin(CD/BC)
alpha1=asin(BF/AB)
bita1=asin(8.5/BC)
gama1=gama+bita1-bita
F=((w1+W/2)*8.471*(tan(alpha1)+tan(bita1)))/(CG*cos(
```

```
gama1))-(w1*tan(gama1))
printf("F1= %.1f lb",F)
r1=CG*sin(gama1)+1.5//radius of rotation
N1=(30/%pi)*(F*32.2*12/(w1*r1))^(1/2)
printf("\nr1= %.2f in\nN1= %.1f rpm",r1,N1)
```

Scilab code Exa 13.3 Rate of stiffness

```

clc
//given
w=3//lb
g=32.2
N2=300
w2=(N2*%pi/30)
r2=3/12//ft
N1=1.06*N2
r1=4.5/12//ft
a=4//in
b=2//in
ro=3.5/12//ft
F2=w*w2^2*r2/g
F1=F2*N1^2*r1/(N2^2*r2)
p=2*a^2*(F1-F2)/(b^2*(r1-r2))
Fc=F2+(F1-F2)*(.5/1.5)
N=(Fc*g/(ro*w))^(1/2)*30/%pi
Ns=ceil(N)
printf("N = %.f rpm",Ns)
```

Scilab code Exa 13.4 Equivalent stifness

```

clc
```

```
//given
w=5//lb
g=32.2
N2=240//rpm
w2=(N2*%pi/30)
r2=5/12//ft
N1=1.05*N2
r1=7/12//ft
a=6//in
b=4//in
pb=3/2
F2=w*w2^2*r2/g
F1=F2*N1^2*r1/(N2^2*r2)
p=2*(a/b)^2*((F1-F2)/(r1*12-r2*12)-4*pb)
printf("Equivalent stiffness; p = %.f lb/in",p)
```

Scilab code Exa 13.5 stiffness of governor spring

```

clc
//given
w=3//lb
W=15//lb
g=32.2
r2=2.5/12//ft
N2=240//rpm
w2=N*%pi/30
F2=w*w2^2*r2/g
a=4.5//in
b=2//in
sleevelift=0.5
r1=r2*12+a*sleevelift/b//the increase of radius for
   a scleeve lift is 0.5 in
N1=1.05*N2
F1=(N1/N2)^2*(r1/(r2*12))*F2
```

```
//a) at minimum radius
S2=(F2*a/b-w)*2-W
//b) At maximum radius
DB=r1-r2*12
BI=1.936//in
AD=a
BI=b
S1=2*(F1*AD/BI-w*(DB+BI)/BI)-W
k=(S1-S2)/sleevelift
printf("Stiffness of the spring is %.1f lb/in",k)
//answer wrong in the book
```

Scilab code Exa 13.6 Governor effort and power

```

clc
//given
c=0.01
W=120//lb
w=15//lb
k=.720
h=8.944//in
Q=c*(W+2*w/(1+k))
x=(2*c/(1+2*c))*(1+k)*h
P=Q*x
printf("Governor power = Q*x = %.3f in lb",P)
```

Scilab code Exa 13.7 Governor power

```

clc
//given
r=6//in
```

```
a=6//in
b=4//in
//from example 4(using conditions and calculating
   constants A and B) we get F=11.1r-14.6
//when r=6 , F= 52
F=52//lb
inc=2*.01*52//increase neglecting very small values
F1=F+inc
F2=2*a*inc/b//Force required to prevent the sleeve
   from rising
F3=F2/2//Force is uniformly distributed
r2=-14.6/(F1/r-11.1)//from equation 1
x=r2-r//increase in radius of rotation
lift=b*x/a//sleeve lift
P=F3*lift//governor power
printf("Governor power = %.3f in lb",P)
```

Scilab code Exa 13.10 Coefficient of insensitiveness

```

//given
fs=3//lb
W=90//lb
w=15//lb
//fb=(fs/2)*(1+k)*(r/h) From equation 13.31
k=1//All the arms are of equal length
//fb=fs*(r/h)
//comparing the above result with the one obtained
   from example 8 , F=(W+w)*(r/h), we get
   coefficient of insensitiveness = k = (N1-N2)/N =
   fs/(W+w)
k=fs/(W+w)
K=k*100
printf("Coefficient of insensitiveness = %.3f",k)
```

Scilab code Exa 13.11 Coefficients

```

//given
a=4.5//in
b=2//in
r1=2.5//in
r2=4.5//in
F2=12.25//lb
F1=25.4//lb
fs=1.5//lb
fb=(fs/2)*(b/a)
//At minimum radii
k1=fb/F2
//At maximum radii
k2=fb/F1
printf("Coefficient of insensitiveness\nAt minimum
    radii = %.4f\nAt maximum radii = %.4f\n",k1,k2)
```

Chapter 14

Balancing

Scilab code Exa 14.1 Balance weights

```
clc
//given
W=200//lb
r=9//in
b1=15//in
bm=b1
l=10//in
d=50//in
//case a
ma=d+l
Bm1=W*r*l/(d*bm)//From 14.2
B11=W*r*ma/(d*b1)//from 14.3
//case b
mb=d-l
Bm2=W*r*l/(d*bm)//from 14.2
B12=W*r*mb/(d*b1)//from 14.3
printf("\na) Bm= %.f lb ; B1= %.f lb\nb) Bm= %.f lb
    ; B1= %.f lb",Bm1,B11,Bm2,B12)
```

Scilab code Exa 14.2 position and magnitude

```

clc
//given
Wa=200//lb
Wb=300//lb
Wc=240//lb
W1=260//lb
ra=9//in
rb=7//in
rc=10//in
r1=12//in
R=24//in
alpha=45*%pi/180
bita=75*%pi/180
gama=135*%pi/180
Hb=Wa*ra+Wb*rb*cos(alpha)-Wc*rc*cos(gama-bita)-W1*r1
    *cos(bita)//horizontal component after resolving
Vb=Wb*rb*sin(alpha)+Wc*rc*sin(gama-bita)-W1*r1*sin(
    bita)//vertical component after resolving
Bb=(Hb^2+Vb^2)^(1/2)
B=Bb/R
theta=atand(Vb/Hb)
printf("\nBalance weight required = %.1f lb\ntheta =
     %.2f degrees",B,theta)
```

Scilab code Exa 14.5 Balanced weight

```
clc
//given
W=180//lb
```

```
R=150//lb
c=.5;
g = 9.81;
N=300//rpm
r=7.5/12//ft
Bb=(W+c*R)*r*12
b=6//in
B=Bb/b
w=(%pi*N)/30
Uf=(1/2)*(R/g)*w^2*r
a=floor(Uf)
printf("Balance weight required = %.1f lb\n The
    resultant unbalanced force = %.f lb\n",B,a)
```

Scilab code Exa 14.12 Resultant primary

```

clc
//given
N=1500 //rpm
R=4//lb
g=32.2//ft/s^2
w=%pi*N/30
stroke=5//in
r=stroke/2
l=9//in
b=3.5//in
B=(3/2)*R*r/b//primary force
n=l/r
F=(3/2)*R*w^2*r/(g*12*n)//secondary force
printf("\nResultant primary force = %.2f lb\
    nResultant secondary force = %.f lb",B,F)
```

Scilab code Exa 14.13 Maximum and minimum secondary force

```

clc
//given
g=32.2//ft/s^2
n=2000//rpm
R=6//lb
r=3//in
L=11//in
w=%pi*n/30
n=L/r
//minimum secondary force
F1=2*R*w^2*r/(g*n*12)
a=floor(F1)
//maximum secondary force
F2=6*R*w^2*r/(g*n*12)
b=floor(F2)
printf("\nMinimum secondary force = %.f lb\nMaximum
    secondary force = %.f lb",a,b)
```

Chapter 15

Vibrations

Scilab code Exa 15.1 frequency

```
//to find the frequencies of the free longitudinal ,
   transverse and torsional vibrations
clc
//given
W=.3*2240//lb
l=36//in
D=3//in
k=15//in
A=%pi*(D/2)^2
E=30*10^6//youngs modulus
C=12*10^6
g=32.2//ft/s^2
d=W*l/(A*E)
Fl=187.8/(d)^(1/2)
I=%pi*(d/2)^4
d1=W*(l^3)*64/(3*E*%pi*(3^4))
Ft=187.8/(d1)^(1/2)
j=%pi*3^4/32
q=C*j/l
Ftor=(1/(2*%pi))*(q*g*12/(W*k^2))^(1/2)
F1=Ftor*60
```

```
printf("\na) Frequency of Longitudinal vibrations =
    %.f per min\nb) Frequency of the transverse
    vibrations = %.f per min\nc) Frequency of the
    torsional vibration = %.f per min",Fl,Ft,F1)
```

Scilab code Exa 15.2 Natural frquency

```
//To find the natural frequencies of the
    longitudinal , transverse and torsional vibration
    of the system
clc
//given
l1=3//ft
l2=2//ft
l=l1+l2//ft
W=.5*2240//lb
k=20//in
d=2//in
Wa=2*W/5
E=30*10^6
A=%pi*(d/2)^2
d1=Wa*l1*12/(A*E)
N1=187.8/(d1)^(1/2)
I=%pi*(d)^4/64
d2=W*(l1*12)^3*(l2*12)^3/(3*E*(l*12)^3*I)
N2=187.8/(d2)^(1/2)
C=12*10^6//given
g=32.2//given
J=%pi*d^4/32
q=C*J*((1/(l1*12))+(1/(l2*12)))
n=(1/(2*%pi))*(q*g*12/(W*k^2))^(1/2)
N3=n*60
printf("\na)Longitudinal vibration = %.f per min\nb)
    Transverse Vibration = %.f per min\nc)Torsional
    Vibration = %.f per min\n",N1,N2,N3)
```

Scilab code Exa 15.3 Natural transverse vibration

```
//to find frequency of the natural transverse
    vibration
clc
//given
l=10//ft
d=4//in
E=30*10^6//youngs modulus
d1=0.0882//inches; maximum deflection as shown in
    the figure
N=207/(d1)^(1/2)//From 15.20
printf("\nFrequency of natural transverse vibration
    = %.f per min",N)
```

Scilab code Exa 15.4 Resistance offered

```
//To find the resistance offered by the dashpot
clc
//given
m=50//lb
k=100//lb/in
g=32.2//ft/s
d=m/k//static deflection
n=(1/(2*%pi))*(g*12/d)^(1/2)
//part 2
b=g*12/d
a=(b/20.79)^(1/2)
nd=(1/(2*%pi))*((b-(a/2)^2))^(1/2)
A=nd/n
```

```
printf("\nFrequency of free vibrations = %.3f per sec\nFrequency of damped vibrations = %.3f per sec \nThe ratio of the frequencies of damped and free vibrationsis %.3f \n",n,nd,A)
```

Scilab code Exa 15.5 `Ratio`

```
//To find the ratio nd/n
clc
//given
//damping torque is directly proposrtional to the angular velocity
C=12*10^6//Modulus of rigidity
l=3//ft
d=1//in
g=32.2//ft/s^2
I=500//lb ft^2 ; moment of inertia
J=%pi*d^4/32
q=C*J/(l*12)
n=(1/(2*%pi))*(q*g*12/(I*12^2))^(1/2)
//part 2
b1=(q*g*12/(I*12^2))
a1=(b1/10.15)^(1/2)//by reducing equation 15.28
nd=(1/(2*%pi))*(b1-(a1/2)^2)^(1/2)
A=nd/n
printf("\nThe frequency of natural vibration = %.2f per sec\nThe frequency of damped vibration = %.2f per sec\nThe ratio nd/n = %.3f\n",n,nd,A)
```

Scilab code Exa 15.6 `Find the amplitude`

```
//to  find the amplitude if the period of the applied force coincided with the natural period of vibration of the system
clc
//given
m=20//lb
k=50//lb/in
F=30//lb
w=50//sec^-1
g=32.2//ft/s^2
d=m/k
x=F/k//extension of the spring
b=g*12/d
a=(b/30.02)^(1/2)//from equation 15.28
D=1/((1-w^2/b)^2+a^2*w^2/b^2)^(1/2)
Af=D*x//amplitude of forced vibration
D=(b/a^2)^(1/2)//At resonance
A=D*x//amplitude at resonance
printf("\nAmplitude of forced vibrations = %.3f in\nAmplitude of the forced vibrations at resonance = %.2f in",Af,A)
```

Scilab code Exa 15.7 Fraction

```
//to find the fraction of the applied force transmitted at 1200 rpm and the amplitude of forced vibrations of the machines at resonance
clc
//given
e=1/30
n=1200//rpm
w=%pi*n/30
m=3//lb
g=32.2//ft/s^2
stroke=3.5//in
```

```
r=stroke/2
k=(1+1/e)^(1/2)//nf/n=k
d=(k/187.7)^2
W=200//lb ; given
s=W/d//combined stiffness
p=1/14.1//As a^2/b=1/198
T=((1+p^2*k^2/((1-k^2)^2+p^2*k^2)))^(1/2)//actual
    value of transmissibility
F=(m/g)*w^2*r/12//maximum unbalanced force
    transmitted on the machine
Fmax=F*T//maximum force transmitted to the
    foundation
//case b
E=((1+p^2)/(p^2))^(1/2)
Nreso=215.5//rpm
Fub=F*(Nreso/n)^2
Ftmax=E*Fub
D=E//dynamic magnifier
del=Fub/152//static deflection
A=del*D
printf("\na) Maximum force transmitted at 1200 rpm =
    %.f lb\nb) The amplitude of the forced
    vibrations of the machine at resonance = %.3f in\
    n    Force transmitted = %.f lb\n",Fmax,A,Fub)
```

Scilab code Exa 15.8 Frequency

```
//To find the frequency of the natural torsional
    oscillations of the system
clc
//given
l1=11//in
l2=10//in
l3=15//in
l4=4//in
```

```
l5=10//in
d1=3//in
d2=5//in
d3=3.5//in
d4=7//in
d5=5//in
I1=1500//lb ft^2
I2=1000//lb ft^2
leq=3//in from 15.49
g=32.2//ft/s^2
C=12*10^6
J=%pi*leq^4/32
l=l1+l2*(leq/d2)^4+l3*(leq/d3)^4+l4*(leq/d4)^4+l5*(
   leq/d5)^4
la=I2*l/(I1+I2)
qa=C*J/la
n=(1/(2*%pi))*(qa*g*12/(I1*12^2))^(1/2)
printf("\nThe frequency of the natural torsional
   oscillation of the system = %.1f per sec",n)
```

Scilab code Exa 15.9 frequencies of the free torsional

```
//To find the frequencies of the free torsional
   vibrations of the system
clc
//given
Ia=2.5//ton ft^2
Ib=7.5//ton ft^2
Ic=3//ton ft^2
g=32.2//ft/s^2
AB=9.5//ft
BC=25//ft
d=8.5//in
C=11.8*10^6//lb/in^2
k=Ic/Ia//la/lc=k
```

```
lc1=(25.6+(25.6^2-4*114.1)^(1/2))/2//from 1 and 2 ,
    reducing using quadratic formula
lc2=(25.6-(25.6^2-4*114.1)^(1/2))/2//from 1 and 2 ,
    reducing using quadratic formula
la1=lc1*k
la2=lc2*k
J=%pi*d^4/32
q=C*J/(lc1*12)//torsional stiffness
IC=Ic*2240*12^2/(g*12)//moment of inertia
nc=(1/(2*%pi))*(q/IC)^(1/2)//fundamental frequency
    of vibration
a1=nc*60
a=floor(a1)
n=16*(lc1/lc2)^(1/2)
b=n*60
printf("\nFundamental frequency of vibration = %.f
    per min\nTwo node frequency = %.f per min\n",a,b)
```

Scilab code Exa 15.11 natural frequencies

```
//to find the natural frequencies of the torsional
    vibration of the system when inertia is neglected
     and when it is taken into account
clc
//given
g=32.3//ft/s^2
l2=25.5//in
d1=2.75//in
d2=3.5//in
C=12*10^6//modulus of rigidity
G=1/0.6//given speed ratio
Ib=54//lb in^2
Ic=850//lb in^2
Id=50000//lb in^2
Id1=Id/G^2//15.62
```

```
Ia=1500//lb in^2
la=Id1/(Id1+Ia)*66.5
J=%pi*d1^4/32
q=C*J/la//torsional stiffness
n=(1/(2*%pi))*(q*g*12/Ia)^(1/2)
nf=n*60//for minutes
//case b)
Ib1=Ib+Ic/(G^2)
a=63.15//in; distance of the node from rotor A (
    given)
b=3.661//in; distance of the node from rotor A (
    given)
N1=n*(la/a)^(1/2)
N2=n*(la/b)^(1/2)
N1f=N1*60//for minutes
N2f=N2*60//for minutes
printf("\na) The frequency of torsional vibrations n
     = %.1f per sec or %.f per min\nb) The
    fundamental frquency = %.1f per sec or %.f per
    min\n    and the two node frequency = %.f per sec
    or %.f per min",n,nf,N1,N1f,N2,N2f)
```