

Scilab Textbook Companion for
Fundamentals of Turbomachinery
by W. W. Peng¹

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Book Description

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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.

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Chapter 1

Introduction

Scilab code Exa 1.1 I

```
1 clear all; clc;
2 //This numerical is Ex 1_1E, page 9.
3 Pso=20.5
4 Psc=20.5*550//converting hp to fps system
5 Qo=385
6 Qc=385/449//converting gpm to ft^3/s
7 E=0.83
8 dp=E*Psc/(Qc*144)
9 printf('The pressure rise is %g psi',dp)
10 disp("After rounding off, pressure rise is 75.8 psi")
11 dpr=75.8
12 dHw=75.8*144/62.4//62.4 is accelaration due to
    gravity in fps system
13 printf(' The head of water is %g ft of water',dHw)
14 disp("After rounding off the value of head of water
    the answer is 175 ft of water.")
15 dhwr=175//rounded off value of head of water
16 sg=0.72//specific gravity of oil
17 dHo=dhwr/sg
18 printf(' The head of oil is %g ft of oil',dHo)
19 disp("After rounding off the value of head of oil
```


the answer is 243 ft of oil.”)

Scilab code Exa 1.2 I

```
1 clear all; clc;
2 //This numerical is Ex 1_1S, page 10.
3 E=0.83//efficiency
4 Ps=15300
5 Q=87.4
6 Qs=87.4/3600//flow rate in meter cube per sec
7 rho=998
8 g=9.81
9 sg=0.72
10 dp=E*Ps/Qs
11 printf('\n The change in pressure (dp)is %g',dp)
12 dpr=523000//rounded value of dp
13 disp("The rounded off value of dp is 523kPa.")
14 dHw=dpr/(rho*g)
15 printf(' dHw is equal to %g m of water ',dHw)
16 disp("The rounded off value of dHw is 53.4 m of
    water.")
17 dHwr=53.4//rounded off value of dHw
18 disp("Thus we can determine head of oil.")
19 dHoil=dHwr/sg
20 printf(' dHoil is given by %g m of oil ',dHoil)
21 disp("The rounded off value of dHoil is 74.2 m of
    oil.")
```

Scilab code Exa 1.3 I

```
1 clear all; clc;
2 //This numerical is Ex 1_2E, page 10.
3 Q=12000
```

```

4 A=3.5
5 rho_a=0.0762
6 E=0.85
7 r=2.5//resistance of duct system
8 V=Q/(60*A)
9 printf('The air flow velocity at discharge is %0.2f
    ft/s ',V)
10 KE=(rho_a*(V^2))/(32.2*2)
11 printf('\n The product is %0.2f lb/ft^2 ',KE)
12 //PE=KE
13 Hv=KE/62.4
14 printf('\n The dynamic head is %0.3f ft ',Hv)
15 disp("The value of dynamic head in inches of water
    is 0.74.")
16 Hvi=0.74//Head in inches
17 Ht=r+Hvi
18 printf('\n The total head is %0.2f inches of water ',
    Ht)
19 p_tot=Ht*62.4
20 Ps=Q*p_tot/(60*12*E)
21 printf('\n The shaft power is %0.1f ft-lb/s ',Ps)
22 disp("The shaft power is 7.2 hp.")

```

Scilab code Exa 1.4 I

```

1 clear all; clc;
2 //This numerical is Ex 1_2S, page 11.
3 Q=340
4 A=0.325
5 V=Q/(60*A)
6 printf('The air flow velocity at discharge is %0.1f
    m/s ',V)
7 rho_a=1.22
8 Vr=17.4
9 Hd=(rho_a*(Vr^2))/2

```

```

10 printf('\n The dynamic pressure head is %0.1f Pa',Hd
    )
11 Hdr=184.7//rounded off value of Hd
12 rho_w=998//density of water=rhow
13 g=9.81
14 H=0.0635
15 dp=rho_w*g*H//static pressure head
16 printf('\n The static pressure head is %0.1f Pa',dp)
17 dpr=621.7
18 p_tot=Hdr+dpr
19 printf('\n The total pressure head is %0.1f Pa',
    p_tot)
20 p_tot=806.4
21 E=0.85//efficiency
22 Ps=Q*p_tot/(60*E)
23 printf('\n The shaft power is %g W',Ps)
24 disp("The shaft power is 5.376 kW.")

```

Scilab code Exa 1.5 I

```

1 clear all; clc;
2 //This numerical is Ex 1-3E, page 11.
3 H=295//net head in ft
4 Q=148//water flow rate
5 n=1800//rpm
6 E=0.87//efficiency
7 a=62.4//product of density and accelaration due to
    gravity
8 omega=(n*2*%pi)/60
9 dp=a*H
10 printf('The pressure is %g lb/ft^2',dp)
11 Ps=E*Q*dp
12 printf('\n Output power is equal to %0.3f lb-ft/s',
    Ps)
13 disp("The output output power can also be written as

```

```

    2.37*10^6 lb-ft/s")
14 disp("Output power in terms of horsepower is given
    by 4309hp.")
15 Psr=2370000//rounded off value of Ps
16 Torque=Psr/omega
17 printf(' The output torque is %g lb-ft.',Torque)
18 disp("The output torque can also be written as
    12.57*10^3 lb-ft")

```

Scilab code Exa 1.6 I

```

1 clear all; clc;
2 //This numerical is Ex 1_3S ,page 12.
3 H=90
4 Q=4.2//water flow rate(in m^3/s)
5 n=1800
6 E=0.87//efficiency
7 rho=998
8 g=9.81
9 omega=(n*2*%pi)/60
10 dp=rho*g*H
11 printf('The pressure is %g N/m^2',dp)
12 Ps=E*Q*dp
13 printf('\n Output power is equal to %0.3f N-m/s',Ps)
14 disp("After rounding off the value of output power
    is 3220 kW.")
15 Psr=3220000//rounded off value of Ps
16 Torque=Psr/omega
17 printf(' The output torque is %g N-m.',Torque)
18 disp("After rounding off the output torque comes out
    to be 17.1*10^3 N-m.")

```

Chapter 2

Dimensional Analysis

Scilab code Exa 2.1 DA

```
1 clear all; clc;
2 //This numerical is Ex 2_1, page 18.
3
4 //These are examples given in the book, they are used
   to teach conversions from one unit to another
5
6 rho=0.075//lbm/ft^3
7
8 V=120
9
10 RHO_c=rho/32.2//rho converted to slug/ft^3
11
12 disp("The initial value of rho was given in lb/ft^3.
   In order to convert it to slug/ft^3, we have used
   the conversion factor 1/32.2.")
13
14 printf("\nThe initial value of rho was 0.075 lb/ft^3
   after converting it is %0.5f slug/ft^3", RHO_c)
15
16 p_d=RHO_c*V^2/2
17
```

```

18 printf("\nHence the value of dynamic pressure is %0
    .2f (slug/ft^3)(ft/s)",p_d)
19
20 p_dc=p_d/(12^2)//converting slug*s/ft^2 to lbf/in^2
21
22 printf("\nThe final value of dynamic pressure is %0
    .3f lbf/in^2",p_dc)
23
24 printf("\nHence we can say that the dynamic power is
    equal to %0.3f psi.",p_dc)

```

Scilab code Exa 2.2 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_2, page 18.
3
4 // This numerical is used an example to teach
    conversion factors
5 T0=600
6 T1=550
7 Cp=0.24
8 halfVsquare=Cp*32.2*778*(T0-T1)
9 printf("\n The value of half of V^2 is %g (Btu/slug*
    R)(lbf-ft/Btu)(R)",halfVsquare)
10 printf("\n The value of half of V^2 ca also be
    written as %g lbf-ft/slug",halfVsquare)
11 printf("\n The value of half of V^2 is also equal to
    %g (ft/s)^2",halfVsquare)
12 V=sqrt(halfVsquare*2)
13 printf("\n\n The value of V is equal to %0.1f ft/s",
    V)

```

Scilab code Exa 2.3 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_3 ,page 19.
3
4 // This numerical is used an example to teach
   conversion factors
5
6 rho=0.85*62.4
7 p=50//in psi
8 g=32.2
9 disp("Since pressure is the product of density ,
   gravitaional accelaration and head, we can
   convert pressure in psi to head in ft using
   suitable conversion factors.")
10 H=p*144/( (rho/32.2)*32.2)
11 printf("The value of head H is given by %0.1f lb/ft
   ^2/((slug/ft ^3)*(ft/s ^2))",H)
12 printf("\nThus the value of H is equal to %0.1f ft",
   H)

```

Scilab code Exa 2.4 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_4 ,page 19.
3
4 //converting dynamic pressure of air from 2_1 to wg
5
6 pd=16.77//lbf/ft ^2
7 rho_w=62.4/32.2
8 g=32.2
9 disp("From pressure=density*gravitational
   accelaration *head, we can find out the value of
   head")
10 h=pd/(rho_w*g)
11 printf(" Hence the value of head H is %0.3f (lbf/ft
   ^2)/(lbf/ft ^3)",h)

```

```
12 printf("\n The value of head H can also be given by
    %0.3 f ft",h)
```

Scilab code Exa 2.5 DA

```
1 clear all; clc;
2 //This numerical is Ex 2_1E, page 29.
3 Q1=80
4 N1=1000
5 N2=1500
6 delta_p1=150
7 P_s1=8
8
9 disp("From phi_2=phi_1 we have  $Q_2/(D^3*N_2)=Q_1/(D^3*
    N_1)$ ")
10 Q2=Q1*N2/N1
11 printf(" The value of Q2 is equal to %g gpm \n",Q2)
12
13 disp("From psi_1=psi_2 we have  $\text{delta p } 2/(\rho*D^2*N_2
    ^2)=\text{delta p } 1/(\rho*D^2*N_1^2)$ ")
14 delta_p2=delta_p1*((N2/N1)^2)
15 printf(" The value of delta_p2 is equal to %g psig \
    n",delta_p2)
16
17 disp("From pi_2=pi_1 we have  $P_{s2}=P_{s1}*((N2/N1)^3)$ ")
18 P_s2=P_s1*(N2/N1)^3
19 printf(" The value of P_s2 is equal to %g hp \n",
    P_s2)
20
21 disp("The efficiencies are same at the corresponding
    points ,so  $E_1=E_2$ ")
22 E1=Q1*delta_p1*0.00223*144/(550*P_s1)
23 printf(" The value of  $E_1=E_2$  is equal to %g \n",E1)
24 disp("Thus the efficiency is equal to 87.57%")
```

Scilab code Exa 2.6 DA

```
1 clear all; clc;
2 //This numerical is Ex 2_1S ,page 29.
3 Q1=18.2
4 N1=1000
5 N2=1500
6 delta_p1=10.3
7 P_s1=6
8
9 Q2=Q1*N2/N1
10 printf("\n The value of Q2 is equal to %g m^3/h",Q2)
11
12 delta_p2=delta_p1*((N2/N1)^2)
13 printf("\n The value of delta_p2 is equal to %0.1f
    bars",delta_p2)
14
15 P_s2=P_s1*(N2/N1)^3
16 printf("\n The value of P_s2 is equal to %g kW",P_s2
    )
17
18 E1=((Q1/3600)*delta_p1*10^2)/(P_s1)
19 printf("\n The value of E1=E2 is equal to %g ",E1)
20 disp("Thus the efficiency is equal to 86.8%")
```

Scilab code Exa 2.7 DA

```
1 clear all; clc;
2 //This numerical is Ex 2_2E ,page 30.
3 P_ho=30//hydraulic output power
4 Q=5//flow rate at best efficiency point
5 g=32.2
```

```

6 rho=1.938
7 Hp=320
8 N=600
9
10 delta_pm=P_ho*550/Q
11 printf(" Value of discharge head P_m %g lb/ft^2",
        delta_pm)
12
13 Hm=delta_pm/(rho*g)
14 printf("\n Value of H_m=%0.2f ft",Hm)
15 disp("From the similarity law, H_p/H_m=((N_p/N_m)^2)
        *((D_p/D_m)^2)")
16
17 //let x=Hp/Hm
18 x=Hp/Hm
19 printf(" H_p/H_m =%0.2f",x)
20 disp("Thus (N_p/N_m)*(D_p/D_m) is equal to 2.46")
21 disp("Also the flow rate Q_p/Q_m=(N_p/N_m)*(D_p/D_m)
        ^3")
22 z=350/5//value of Q_p/Q_m
23 printf(" Hence the value of Q_p/Q_m is equal to %g",
        z)
24 disp("Thus D_p/D_m=5.33 ,N_p/N_m=0.461")
25 //Let y=N_p/N_m=0.461
26 y=0.461
27 N_m=N/y
28 printf(" Thus N_m = %g rpm",N_m)

```

Scilab code Exa 2.8 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_2S,page 30.
3 //The value given in the book for N_m is 1315,but on
  calculating the true value is found out to be
  1304.35

```

```

4
5 P_ho=22.4//hydraulic output power
6 Q=0.14//flow rate at best efficiency point
7 g=9.8
8 rho=998
9 H_p=97.5
10 N=600
11
12 delta_pm=P_ho/Q
13 printf("Value of discharge head P_m %g kPa",
        delta_pm)
14
15 H_m=delta_pm*10^3/(rho*g)
16 printf("\n Value of H_m=%g m",H_m)
17 disp("From the similarity law, H_p/H_m=((N_p/N_m)^2)
        *((D_p/D_m)^2)")
18
19 //let x=H_p/H_m
20 H_mr=16.3//rounded off value
21 x=H_p/H_mr
22 printf(" H_p/H_m =%0.2 f",x)
23 disp("Thus (N_p/N_m)*(D_p/D_m) is equal to 2.45")
24 disp("Also the flow rate Q_p/Q_m=(N_p/N_m)*(D_p/D_m)
        ^3")
25 z=9.9/0.14//value of Q_p/Q_m
26 printf(" Thus the value of Q_p/Q_m is %0.1 f",z)
27 disp("Thus D_p/D_m=5.4 ,N_p/N_m=0.46")
28 //Let y=N_p/N_m=0.461
29 y=0.46
30 N_m=N/y//where N=600 and y=0.46
31 printf(" Hence N_m = %g rpm",N_m)//value given in
        the book is 1315,but on calculating the true
        value is found out to be 1304.35

```

Scilab code Exa 2.9 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_3E,page 31.
3
4 N=1500
5 E=0.74
6 Q=250*0.00223//0.00223 is conversion factor
7 printf("Q is equal to %g",Q)
8 H=18
9 g=32.2
10 Q_o=250//before converting Q
11
12 disp("From the dimensional specific speed (N_s) and
      fig2.1 , we select a Francis type pump and
      efficiency is estimated to be equal to 74%")
13
14 N_s=N*(Q_o^0.5)/(H^0.75)
15 printf("\n N_s is equal to %0.0f rpm(gpm^0.5)/(ft
      ^0.75)",N_s)
16 disp("To find the approximate size ,Figure 2.2 has to
      be used")
17
18 omega=N*pi/30
19 printf("\n omega is equal to %0.0f",omega)
20
21 omega_s=omega*(Q^0.5)/((g*H)^0.75)
22 printf("\n omega_s is equal to %0.4f",omega_s)
23
24 disp("From figure 2.2, it is obtained that delta_s
      =3.1")
25 D=(3.1*(Q^0.5))/((g*H)^0.25)
26 printf("\n Hence D is equal to %0.3f ft",D)
27 disp("Hence D is equal to 5.7 in ")

```

Scilab code Exa 2.10 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_4E, page 31.
3
4 disp("From phi equal to  $Q_m/(D_m^3*N_m)=Q_p/(D_p^3*N_p)$ 
      and  $\psi=g*H_m/(D_m^2*N_m^2)=g*H_p/(D_p^2*N_p^2)$ , we
      have  $Q_m=Q_p*((D_m/D_p)^3)*(N_m/N_p)$  and  $H_m=H_p*((D_m/D_p)^2)*(N_m/N_p)^2$ ")
5
6 Q_p=25
7 //let x=Dm/Dp=1/5
8 x=1/5
9 N_m=3600
10 N_p=1800
11 H_p=160
12 E=0.92
13 //let y=rho*g=62.4
14 y=62.4
15
16 Q_m=Q_p*((x)^3)*(N_m/N_p)
17 printf("\n The value of Q_m is equal to %g ft^3/s",
      Q_m)
18
19 H_m=H_p*((x^2)*(N_m/N_p)^2)
20 printf("\n The value of H_m is equal to %g ft",H_m)
21
22 P_s=E*y*Q_m*H_m/550//1/550 is conversion factor
23 printf("\n The value of P_s is equal to %0.02f hp",
      P_s)

```

Scilab code Exa 2.11 DA

```

1 clear all; clc;
2 //This numerical is Ex 2_4S, page 31.
3 disp("From phi equal to  $Q_m/(D_m^3*N_m)=Q_p/(D_p^3*N_p)$ 
      and  $\psi=g*H_m/(D_m^2*N_m^2)=g*H_p/(D_p^2*N_p^2)$ , we

```

```

    have Qm=Qp*((Dm/Dp) ^ 3)*(Nm/Np) and Hm=Hp*((Dm/Dp)
    ^ 2)*(Nm/Np) ^ 2)”)
4
5 Q_p=42
6 //let x=Dm/Dp=1/5
7 x=1/5
8 N_m=3600
9 N_p=1800
10 H_p=50
11 E=0.92
12 rho=998
13 g=9.81
14 //let y=Q/60=0.011166
15 y=0.011166
16
17 Q_m=Q_p*((x) ^ 3)*(N_m/N_p)
18 printf(“\n The value of Q_m is equal to %g cmm”,Q_m)
19
20 H_m=H_p*((x ^ 2)*(N_m/N_p) ^ 2)
21 printf(“\n The value of H_m is equal to %g m”,H_m)
22
23 Q_mr=0.67//rounded off
24 P_s=E*rho*g*(y)*H_m
25 printf(“\n The value of P_s is equal to %0.1f W”,P_s
    )

```

Chapter 3

Energy Transfer in Turbomachines

Scilab code Exa 3.1 ETT

```
1 clear all; clc;
2 //This numerical is Ex 3_1E, page 43.
3 N=800
4 Q=1750//in gallon per minute
5 r_1=3
6 b_1=4
7 r_2=9
8 b_2=3
9
10 omega=N*pi/30
11 printf('\n The angular velocity is %g rad/s',omega)
12 omega_r=83.7
13 disp("After rounding off the value of angular
      velocity is 83.7 rad/s")
14
15
16 U_1=omega_r*r_1/12
17 printf(' U_1=%g',U_1)
18 disp("After rounding off the value of U_1 is 20.9 ft
```

```

    /s")
19 U_1r=20.9//rounded value of U1
20
21
22 U_2=omega_r*r_2/12
23 printf(' U_2=%g',U_2)
24 disp("After rounding off the value of U_2 is 62.7 ft
    /s")
25
26
27 A_1=2*pi*r_1*b_1/144
28 printf(' A_1=%g ft^2',A_1)
29 disp("After rounding off the value of A_1 is 0.523
    ft^2")
30
31 A_2=2*pi*r_2*b_2/144
32 printf(' A_2=%g ft^2',A_2)
33 disp("After rounding off the value of A_2 is 1.18 ft
    ^2")
34 A_1r=0.523//rounded off
35 A_2r=1.18//rounded off
36
37
38 V_r1=(Q*0.00223)/(A_1r)
39 printf(' The value of V_r1 is %g',V_r1)
40 disp("The value of V_r1 after rounding off is 7.47
    ft/s")
41
42 V_r2=(Q*0.00223)/(A_2r)
43 printf(' The value of V_r2 is %g',V_r2)
44 disp("The value of V_r2 after rounding off is 3.27
    ft/s")//actual value is 3.30,however the value
    given in the book is 3.27 ft/s

```

Scilab code Exa 3.2 ETT


```

1 clear all; clc;
2 //This numerical is Ex 3_1S ,page 43.
3 N=800
4 Q=397//in meter cube per hour
5 r_1=7.6
6 b_1=10.2
7 r_2=22.9
8 b_2=7.6
9 omega=N*pi/30
10 printf('The angular velocity is %g rad/s',omega)
11 omegar=83.7
12 disp("After rounding off the value of angular
        velocity is 83.7 rad/s")
13 U_1=omega*r_1/100
14 printf(' U_1=%g',U_1)
15 disp("After rounding off the value of U_1 is 6.36 m/
        s")
16 U_1r=6.36//rounded value of U1
17 U_2=omega*r_2/100
18 printf(' U_2=%g',U_2)
19 disp("After rounding off the value of U_2 is 19.2 m/
        s")
20 A_1=2*pi*r_1*b_1
21 printf(' A_1=%g cm^2',A_1)
22 disp("After rounding off the value of A_1 is 487 cm
        ^2")
23 A_2=2*pi*r_2*b_2
24 printf(' A_2=%g cm^2',A_2)
25 disp("After rounding off the value of A_2 is 1093.5
        cm^2")
26 A_1r=487//rounded off
27 A_2r=1093.5//rounded off
28 V_r1=(Q/3600)/(A_1r/10000)
29 printf(' The value of V_r1 is %g',V_r1)
30 disp("The value of V_r1 after rounding off is 2.26 m
        /s")
31 V_r2=(Q/3600)/(A_2r/10000)
32 printf(' The value of V_r2 is %g',V_r2)

```

```
33 disp("The value of V_r2 after rounding off is 1.01 m
/s")
```

Scilab code Exa 3.3 ETT

```
1 clear all; clc;
2 //This numerical is Ex 3_2E, page 44.
3
4 V_r1=7.47
5 U_1=20.9
6 V_r2=3.27
7 U_2=62.7
8
9 //let x=tanbeta1
10 x=V_r1/U_1
11 printf("\n The value of f1 is equal to %0.3f
degrees",x)
12 beta_f1=(atan(x))*180/%pi
13 printf("\n Thus the value of f1 is %0.2f degrees"
,beta_f1)
14
15 V_1=V_r1
16 W_1=(U_1^2+V_r1^2)^0.5
17 printf("\n Thus the value of W_1 is %0.2f ft/s",W_1)
18
19 beta_f2=beta_f1-10
20 printf("\n Hence the value of beta_f2 is equal to %0
.2f degrees",beta_f2)
21
22 //rounding of value of betaf2 to be equal to 9.6
23 beta_f2=9.6
24 W_u2=V_r2/tan(beta_f2*%pi/180)
25 printf("\n Hence the value of W_u2 is %0.1f ft/s",
W_u2)
26
```

```

27 V_u2=U_2-W_u2
28 printf("\n Hence the value of V_u2 is equal to %0.1f
      ft/s",V_u2)
29
30
31 //rounding off Wu2
32 W_u2=19.3
33 W_2=(W_u2^2+V_r2^2)^0.5
34 printf("\n The value of W_u2 is equal to %0.3f ft/s"
      ,W_2)
35
36 //rounding off Vu2
37 V_u2=43.4
38 V_2=(V_u2^2+V_r2^2)^0.5
39 printf("\n Thus he value of V_2 is equal to %0.2f ft
      /s",V_2)

```

Scilab code Exa 3.4 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_2S ,page 44.
3
4 V_r1=2.26
5 U_1=6.36
6 V_r2=1.01
7 U_2=19.2
8
9 //let x=tan(beta_1)
10 x=V_r1/U_1
11 printf("\n The value of f1 is equal to %0.3f
      degrees",x)
12 beta_f1=(atan(x))*180/%pi
13 printf("\n Thus the value of f1 is %0.1f degrees"
      ,beta_f1)
14

```

```

15 V_1=V_r1
16 W_1=(U_1^2+V_r1^2)^0.5
17 printf("\n Thus the value of W_1 is %0.2f m/s",W_1)
18
19 beta_f2=beta_f1-10
20 printf("\n Hence the value of  f2  is equal to %0.1
    f degrees",beta_f2)
21
22 //rounding of value of betaf2 to be equal to 9.6
23 beta_f2=9.6
24 W_u2=V_r2/tan(beta_f2*pi/180)
25 printf("\n Hence the value of W_u2 is %0.2f m/s",
    W_u2)
26
27 V_u2=U_2-W_u2
28 printf("\n Hence the value of V_u2 is equal to %0.2f
    m/s",V_u2)
29
30
31 //rounding off W_u2
32 W_u2=5.97
33 W_2=(W_u2^2+V_r2^2)^0.5
34 printf("\n The value of W_2 is equal to %0.3f m/s",
    W_2)
35
36 //rounding off V_u2
37 V_u2=13.23
38 V_2=(V_u2^2+V_r2^2)^0.5
39 printf("\n Thus he value of V_2 is equal to %0.2f m/
    s",V_2)

```

Scilab code Exa 3.5 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_3E, page 46.

```

```

3 //the value given in the book for Um is 200.5, but on
   calculating the value comes out to be 200.3
4
5 r_t=24
6 r_h=10
7 N=1250
8 Q=53000
9
10 r_m=(0.5*(r_t^2+r_h^2))^0.5
11 printf("\n The mean radius rm is equal to %0.1f in",
   r_m)
12 disp("Converting to feet we have r_m equal to 1.53
   ft")
13
14
15 //rm in feet equals 1.53
16 r_m=1.53
17 U_m=((N*pi)/30)*r_m
18 printf(" Um = %0.1f ft/s",U_m)//the value given in
   the book for Um is 200.5, but on calculating the
   value comes out to be 200.3
19
20 A=(pi*(r_t^2-r_h^2))/144
21 printf("\n The value of A is %0.1f ft^2",A)
22
23 //rounding off A to be 10.4
24 A=10.4
25 V_a2=Q/(A*60)
26 V_a1=V_a2
27 printf("\n V_a1=V_a2 %0.1f ft/s",V_a2)
28
29 beta_f1=(atan(U_m/V_a1))*180/pi
30 beta_b1=beta_f1
31 printf("\n beta_b1=beta_f1 %0.1f degrees",beta_b1)
32
33
34 rho_w=62.4
35 rho_a=0.0762

```

```

36 g=32.2
37 H_w=2/12
38 disp("We know that  $g \cdot H_w = (\rho_w / \rho_a) \cdot g \cdot H_w = U_m V_{u2} =$ 
       $U_m \cdot (U_m - V_{a2} \cdot \tan(\beta_{f2}))$ ")
39 disp("Hence we can find out the value of  $\tan(\beta_{f2})$ .
      Thus we can determine value of  $\beta_{f2}$  .")
40 //Let  $n = U_m \cdot (U_m - V_{a2} \cdot \tan(\beta_{f2}))$  and  $m = (\rho_w /$ 
       $\rho_a) \cdot g \cdot H_w$ 
41  $m = (\rho_w / \rho_a) \cdot g \cdot H_w$ 
42 //therefore  $\tan \beta_{f2} = (U_m - m / U_m) / V_{a2}$ 
43  $\tan \beta_{f2} = (U_m - m / U_m) / V_{a2}$ 
44  $\beta_{f2} = (\text{atan}(\tan \beta_{f2})) \cdot 180 / \pi$ 
45 printf("\n Thus the value of  $\beta_{f2}$  is equal to %0.1f
      degrees", beta_f2)

```

Scilab code Exa 3.6 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_3S, page 46.
3
4 r_t=0.6
5 r_h=0.25
6 N=1250
7 Q=1500
8
9 r_m=(0.5*(r_t^2+r_h^2))^0.5
10 printf("\n The mean radius r_m is equal to %0.2f in.
      ", r_m)
11
12 U_m=((N*pi)/30)*r_m
13 printf(" On converting ,U_m = %0.1f m/s", U_m)
14
15 A=(pi*(r_t^2-r_h^2))
16 printf("\n The value of A is %0.4f m^2", A)
17

```

```

18
19 V_a2=Q/(A*60)
20 V_a1=V_a2
21 printf("\n V_a1=V_a2 %0.1f m/s",V_a2)
22
23 beta_f1=(atan(U_m/V_a1))*180/%pi
24 beta_b1=beta_f1
25 printf("\n beta_b1=beta_f1 %0.1f degrees",beta_b1)
26
27
28 rho_w=998
29 rho_a=1.22
30 g=9.8
31 H_w=5/100
32 U_m=60.2//rounding off Um
33 disp("We know that  $g \cdot H_a = (\rho_w / \rho_a) \cdot g \cdot H_w = U_m V_{a2}$ 
       $= U_m \cdot (U_m - V_{a2} \cdot \tan(\beta_{f2}))$ ")
34 disp("Hence we can find out the value of  $\tan \beta_{f2}$ ")
35 // Let  $n = U_m \cdot (U_m - V_{a2} \cdot \tan(\beta_{f2}))$  and  $m = (\rho_w /$ 
       $\rho_a) \cdot g \cdot H_w$ 
36  $m = (\rho_w / \rho_a) \cdot g \cdot H_w$ 
37 // therefore  $\tan \beta_{f2} = (U_m - m / U_m) / V_{a2}$ 
38  $\tan \beta_{f2} = (U_m - m / U_m) / V_{a2}$ 
39  $\beta_{f2} = (\text{atan}(\tan \beta_{f2})) \cdot 180 / \pi$ 
40 printf("\n Thus the value of  $\beta_{f2}$  is equal to %0
      .1f degrees",beta_f2)

```

Scilab code Exa 3.7 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_4E, page 49.
3
4 //the value of  $\Delta E_2$  slightly differs from the
      value given in the book. However the calculated
      value is correct for the given substitutions

```

```

5
6 N=120
7 r_1=1.8
8 b_1=0.3
9
10 omega=(N*pi)/30
11 printf("\n Omega is equal to %0.3f rad/s",omega)
12
13 U_1=r_1*omega
14 printf("\n U_1 is equal to %0.1f ft/s",U_1)
15
16 r_m2=(0.5*(1^2+0.4^2))^0.5
17 //rounding off the value of rm2
18 r_m2=0.761
19
20 U_2=r_m2*omega
21 printf("\n U_2 is equal to %0.2f ft/s",U_2)
22
23 A_1=2*pi*r_1*b_1
24 printf("\n A_1 is equal to %0.2f ft^2",A_1)
25
26 r_t2=1.0
27 r_h2=0.4
28 b_2=0.5
29 A_2=pi*(r_t2+r_h2)*b_2
30 printf("\n A_2 is equal to %0.2f ft^2",A_2)
31
32 disp("Assume swirl free flow at discharge that is
      V_u2=0 and f1 = b1 , f2 = b2 .")
33
34 V_m2=U_2*tan(15*(pi/180))
35 printf("\n So V_m2=U_2tan15 is equal to %0.2f ft/s",
      V_m2)
36 disp("Thus now we can determine Q")
37
38 V_m2=2.56//rounding off
39 Q=V_m2*A_2
40 disp("Q=V_m2*A_2=V_r1*A_1")

```



```

41 printf("\n Thus Q is equal to %0.2f ft^3/s",Q)
42
43 disp(" Since the value of Q,A_1 is known,we can
      determine the value of V_r1")
44 V_r1=Q/A_1
45 printf(" The value of V_r1 is equal to %0.2f ft/s",
      V_r1)
46
47 beta_f1=27
48 W_u1=V_r1/tan((beta_f1*pi)/180)
49 printf("\n W_u1 is equal to %0.2f ft/s",W_u1)
50
51 V_u1=U_1-W_u1
52 printf("\n The value of V_u1 is %0.2f ft/s",V_u1)
53
54 U_1=22.6//rounding off
55 V_u1=19.3//rounding off
56 delta_Et=U_1*V_u1
57 printf("\n delta_Et is equal to %0.1f ft^2/s^2",
      delta_Et)//the value given in the book is 437.1,
      but the actual value is as calculated for the
      given values of U1 and Vul
58
59 m=(62.4/32.2)*5.63
60 P_s=m*delta_Et
61 printf("\n Thus P_s is equal to %0.1f ft*lb/s",P_s)
      //since value of deltaEt differs from the one
      given in the book,so does the value of Ps
62 disp(" Converting P_s to hp we get 8.65hp")

```

Scilab code Exa 3.8 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_4S,page 50.
3 //the value of deltaE2 slightly differs from the

```

value given in the book. However the calculated value is correct for te given substitutions

```
4
5 N=120
6 r_1=54.8
7 b_1=9.1
8
9 omega=(N*%pi)/30
10 printf("\n Omega is equal to %0.3f rad/s",omega)
11
12 U_1=r_1*omega/100
13 printf("\n U_1 is equal to %0.1f m/s",U_1)
14
15 r_m2=(0.5*(30.5^2+ 12.2^2))^0.5
16
17 U_2=r_m2*omega/100
18 printf("\n U_2 is equal to %0.2f m/s",U_2)
19
20 A_1=2*%pi*r_1*b_1/10000
21 printf("\n A1 is equal to %0.3f m^2",A_1)
22
23 r_t2=30.5
24 r_h2=12.2
25 b_2=15.2
26 A_2=%pi*(r_t2+r_h2)*b_2/10000
27 printf("\n A_2 is equal to %0.3f m^2",A_2)
28
29 disp("Assume swirl free flow at discharge that is
      V_u2=0 and f1 = b1 , f2 = b2 .")
30
31 V_m2=U_2*tan(15*(%pi/180))
32 printf("\n So V_m2=U_2tan15 is equal to %0.3f m/s",
      V_m2)
33 disp("Thus now we can determine Q")
34
35 Q=V_m2*A_2
36 disp("Q=V_m2*A_2=V_r1*A_1")
37 printf("\n Thus Q is equal to %0.3f m^3/s",Q)
```

```

38
39 disp(" Since the value of Q,A_1 is known,we can
      determine the value of V_r1")
40 Q=0.159
41 V_r1=Q/A_1
42 printf(" The value of V_r1 is equal to %0.4f m/s",
      V_r1)//actual values are taken ,hence a 0.0005
      difference in answer is observed
43
44 beta_f1=27// fl
45 V_r1=0.508//rounding off Vr1
46 W_u1=V_r1/tan((beta_f1*%pi)/180)
47 printf("\n W_u1 is equal to %0.4f m/s",W_u1)
48
49 W_u1=0.997//rounding off
50 U_1=6.9//rounding off
51 V_u1=U_1-W_u1
52 printf("\n The value of V_u1 is %0.2f m/s",V_u1)//
      0.02 difference obtained because of substituting
      the values as they ahve been found out
53
54
55 V_u1=5.92//as substituted in the book
56 delta_Et=U_1*V_u1
57 printf("\n deltaEt is equal to %0.2f m^2/s^2",
      delta_Et)//
58
59 m=998*0.782*0.204
60 P_s=m*delta_Et
61 printf("\n Thus P_s is equal to %0.0f W",P_s)
62 disp(" Converting P_s to kW we get 6.503kW")

```

Scilab code Exa 3.9 ETT

```

1 clear all; clc;

```

```

2 //This numerical is Ex 3_5E,page 52.
3
4 //this numerical is based on numerical 3.4E
5 //values found in the book for numerical 3.4E will
   be used to solve this numerical(3.5E)
6
7 delta_Et=437.1
8 U_1=22.6
9 U_2=9.56
10 V_m2=2.56
11 V_2=2.56
12
13 V_r1=1.66
14 W_u1=3.26
15 W_1=(V_r1^2+W_u1^2)^0.5
16 printf("\n W_1 is equal to %0.2f ft/s",W_1)
17
18 W_2=(U_2^2+V_m2^2)^0.5
19 printf("\n W_2 is equal to %0.2f ft/s",W_2)
20
21 V_u1=19.3
22 V_1=(V_r1^2+V_u1^2)^0.5
23 printf("\n V_1 is equal to %0.2f ft/s",V_1)
24
25 Rt=0.5*[(U_1^2-U_2^2)+(W_2^2-W_1^2)]/(delta_Et)
26 printf("\n Thus the value Rt is equal to %0.3f",Rt)

```

Scilab code Exa 3.10 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_5S,page 53.
3
4 //this numerical is based on numerical 3_4S
5 //values found in the book for numerical 3_4S will
   be used to solve this numerical(3.5S)

```

```

6
7 delta_Et=40.85
8 U_1=6.9
9 U_2=2.92
10 V_m2=0.782
11 V_2=0.782//since V2=Vm2
12
13 V_r1=0.508
14 W_u1=0.997
15 W_1=(V_r1^2+W_u1^2)^0.5
16 printf("\n W1 is equal to %0.2f ft/s",W_1)
17
18 W_2=(U_2^2+V_m2^2)^0.5
19 printf("\n W_2 is equal to %0.2f ft/s",W_2)
20
21 Rt=0.5*[(U_1^2-U_2^2)+(W_2^2-W_1^2)]/(delta_Et)
22 printf("\n Thus the value Rt is equal to %0.3f",Rt)

```

Scilab code Exa 3.11 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_6E, page 53.
3 disp("The velocity diagram is similar to that in
   figure 3.19")
4
5 r_t=1.2
6 r_h=0.7
7 N=4800
8 V_1=600
9
10 r_m=[0.5*(r_t^2+r_h^2)]^0.5
11 printf("\n r_m is equal to %0.3f ft",r_m)
12
13 A=%pi*(r_t^2-r_h^2)
14 printf("\n A is equal to %0.2f ft^2",A)

```

```

15
16 r_m=0.982//rounding off rm
17 U=(N*pi*r_m)/30
18 printf("\n U is equal to %0.1f ft/s",U)
19
20 V_a1=V_1*cos(60*pi/180)//angle is given as 60
    degrees
21 printf("\n V_a1 is equal to %0.2f ft/s",V_a1)
22
23 V_u1=V_1*sin(60*pi/180)//angle is given as 60
    degrees
24 printf("\n V_u1 is equal to %0.1f ft/s",V_u1)
25
26 //let tan(beta_f1)=(V_u1-U)/V_a1=x
27 x=(V_u1-U)/V_a1
28 printf("\n tan( f1 ) is equal to %0.4f",x)
29 beta_f1=(atan(x))*180/pi
30 printf("\n Hence f1 = %0.2f degrees",beta_f1)
31
32 disp(" f1 = b1 . Also b2 = f2 =alpha_1=60 degrees")
33 disp("From the velocity diagram we have V_u2=W_u1=
    V_u1-U")
34 W_u1=V_u1-U
35 printf("\n Thus Wu1 = %g ft/s",W_u1)
36
37 //let l=Ps/m=U*(Vu1+Vu2)
38 V_u2=W_u1//already stated above
39 l=U*(V_u1+V_u2)
40 printf("\n P_s/m=U*(V_u1+V_u2) is equal to %g (ft/s)
    ^2",l)
41 disp("Thus we can round it off to 29*10^5 (ft/s)^2")
42
43 disp("Where m=rho*V_a1*A")
44 rho=0.085/32.2
45 m=rho*V_a1*A
46 printf("\n m= %0.2f slug/s",m)
47
48 disp("Thus we can determine P_s")

```

```

49 l=2.69*10^5//rounded off value
50 m=2.36//rounded off value
51 P_s=(l*m)/550
52 printf(" P_s =%0.0 f hp",P_s)

```

Scilab code Exa 3.12 ETT

```

1 clear all; clc;
2 //This numerical is Ex 3_6S ,page 54.
3
4 disp("The velocity diagram is similar to that in
      figure 3.19")
5
6 r_t=0.36
7 r_h=0.21
8 N=4800
9 V_1=183
10
11 r_m=[0.5*(r_t^2+r_h^2)]^0.5
12 printf("\n rm is equal to %0.3 f m",r_m)
13
14 A=%pi*(r_t^2-r_h^2)
15 printf("\n A is equal to %0.2 f m^2",A)
16
17 r_m=0.295//rounding off rm
18 U=(N*pi*r_m)/30
19 printf("\n U is equal to %0.1 f m/s",U)
20
21 V_a1=V_1*cos(60*pi/180)//angle is given as 60
      degrees
22 printf("\n V_a1 is equal to %0.2 f m/s",V_a1)
23
24 V_u1=V_1*sin(60*pi/180)//angle is given as 60
      degrees
25 printf("\n V_u1 is equal to %0.1 f m/s",V_u1)

```

```

26
27 //let tan(beta_f1)=(Vu1-U)/Va1=x
28 x=(V_u1-U)/V_a1
29 printf("\n tan( 1 ) is equal to %g m/s^2",x)
30
31 beta_f1=(atan(x))*180/%pi
32 printf("\n We have  _b1 =  _f1 = %0.2f degrees",
    beta_f1)//value in book is 6.35 degrees
    Difference is obtained because actual value of x
    is substituted. Value substituted in the book is
    not 0.111 or 0.11147.
33
34 disp("  _f1 =  _b1 . Also  _b2 =  _f2 =alpha_1=60
    degrees")
35 disp("From the velocity diagram we have V_u2=W_u1=
    V_u1-U")
36 W_u1=V_u1-U
37 printf("\n Thus W_u1 = %0.2f m/s",W_u1)
38
39 //let l=Ps/m=U*(Vu1+Vu2)
40 V_u2=W_u1//already stated above
41 l=U*(V_u1+V_u2)
42 printf("\n P_s/m=U*(V_u1+V_u2) is equal to %g (m/s)
    ^2",l)
43 disp("Thus we can round it off to 2.5*10^4 (m/s)^2")
44
45 disp("Where m=rho*V_a1*A")
46 rho=1.36
47 V_a1=91.5//rounded off
48 A=0.269//rounded off
49 m=rho*V_a1*A
50 printf("\n m= %0.1f kg/s",m)
51
52 disp("Thus we can determine P_s")
53 l=2.5*10^4//rounded off value
54 m=33.5//rounded off value
55 P_s=(l*m)
56 printf(" P_s =%0.0f W",P_s)

```


57 `disp("Thus on rounding off P_s is equal to 837kW")`

Scilab code Exa 3.13 ETT

```
1 clear all; clc;
2 //This numerical is Ex 3_7E, page 54.
3
4 //Velocity diagrams are not drawn. This is with
   Scilab team's permission.
5 //The numerical part of the question has been solved
   .
6
7 r_t=5.2
8 r_h=3.5
9 N=4500
10
11 A=%pi*(r_t^2-r_h^2)
12 printf(" A is equal to %0.2f in^2",A)
13 disp("On converting to feet we get A= 0.322 ft^2")
14
15 r_m=[0.5*(r_t^2+r_h^2)]^0.5
16 printf("\n rm is equal to %0.2f in",r_m)
17 disp(" On converting to feet we get rm =0.369ft")
18
19 r_m=0.369//in feet
20 U_m=(N*pi*r_m)/30
21 printf("\n U_m is equal to %0.0f ft/s",U_m)
22
23 disp("From inlet velocity triangle we have V_1/sin(
   _1 +pi/2)+U_m/sin(alpha_1- _1 )")
24 disp("Hence V_1=174*(sin(120)/sin(25))")
25
26 V_1=174*(sin(120*pi/180)/sin(25*pi/180))
27 printf(" V_1 = %0.2f ft/s",V_1)
28
```

```

29 alpha_1=(55*%pi)/180//radians
30 V_1=356.5//rounded off
31 V_a=V_1*cos(alpha_1)
32 printf("\n Thus V_a= %0.1 f ft/s",V_a)
33
34 rho=0.095
35 V_a=204.5//rounded off
36 A=0.322//rounded off
37 m=rho*V_a*A
38 printf("\n m= %0.3 f lb/s",m)
39
40 disp("From delta_E=U_m*V_u1 we have P_s=m*delta_E")
41 m=6.25/32.2//in lbf
42 U_m=174//rounded off
43 V_u1=356.5*sin((55*%pi)/180)
44 delta_E=U_m*V_u1
45 P_s=m*delta_E
46 printf(" P_s is equal to %0.1 f ft-lbf/s",P_s)
47 disp("On converting we get P_s = 17.9hp")

```

Chapter 4

Centrifugal Pumps

Scilab code Exa 4.1 CP

```
1 clear all; clc;
2
3 N=1750
4 r_2=0.15
5 U_2=N*%pi*r_2/30
6 printf("With U_2= %0.1 f m/s",U_2)
7
8 b_2=0.012
9
10 A_2=2*%pi*r_2*b_2
11 printf(" and A_2= %0.4 f m^2",A_2)
12
13 disp("Equations 4.3 and 4.4 can be rewritten.")
14 disp("H_a= s *(U_2/g)*(U_2-Q/(A_2*tan _b2))-kQ
      ^ 2...(4.3)")
15 disp(" _Ha / _Q =(- _s *(U_2/(g*A_2*tan _b2)))-2*
      k_Q...(4.4)")
16 disp("Thus the equations become")
17
18 disp("(27.5/9.8)*(27.5-(4.5/(1000*0.0113*tan(60))))*
      s -k*(4.5/1000)^2=60")
```

```

19 disp(" (27.5/(9.8*0.0113*tan(60)))* s +(2*(4.5/1000))
    *k=2.5*1000")
20
21 disp("from equation 4.3   s =(60+(2.025*10^-5)*k)
    /76.25")
22 disp("from equation 4.4   s =(25-(9*10^-5)*k)/1.434"
    )
23 disp("Solving for s and k we get   s =0.852 and k
    =2.642*10^5")
24
25 H_a=60
26 Q=4.5/1000
27 k=2.642*10^5
28 ETA_h=H_a/(H_a+k*(Q^2))
29 printf(" Thus ETA_h= %0.4 f" ,ETA_h)
30
31 P_s=3.2*10^3
32 rho=1000
33 g=9.8
34 ETA_oa=(rho*Q*g*H_a)/P_s
35 printf("\n ETA_oa= %0.3 f",ETA_oa)//answer given in
    the book is0.825,however the correct answer is0
    .827.
36
37 disp(" Eta_m=0.946")

```

Scilab code Exa 4.2 CP

```

1 clear all; clc;
2
3 disp("The relevant formulae are given as : ")
4 disp(" Eta_1 =((62.4*0.00223*Q_1*H_1/(550*P_s1)))*100
    ")
5 disp(" Q_2=Q_1*N_2/N_1")
6 disp(" H_2=H_1*(N_2/N_1)^2")

```

```

7 disp("P_s2=P_s1*((N_2/N_1)^3)")
8 disp("H and P_s at Q=0 are obtained with
      extrapolition")
9
10 Q_1= [0 285 435 540 785 920 1275];
11 H_1= [205 200 195 190 186 172 130];
12 P_s1=[28 31 36 42 44 49 58];
13
14 Eta_1 = zeros(1,length(Q_1));
15 Q_2=zeros(1,length(Q_1));
16 H_2=zeros(1,length(Q_1));
17 P_s2=zeros(1,length(Q_1));
18 Eta_2=zeros(1,length(Q_1));
19
20 for i = 1: length(Q_1)
21
22
23     Eta_1(i) =((62.4*0.00223*Q_1(i)*H_1(i)/(550*P_s1
      (i))))*100; //multiplied by 100 to get answer
      in percentage
24     Q_2(i) = Q_1(i)*1850/1350; //Since Q2=Q1*N2/N1
      and N2=1850 and N1=1350
25     H_2(i) = H_1(i)*((1850/1350)^2); //Since H2=H1*((
      N2/N1)^2)
26     P_s2(i)=P_s1(i)*((1850/1350)^3)
27     Eta_2(i)=Eta_1(i)
28 end
29
30 table = [Q_1'H_1'P_s1'Eta_1'Q_2'H_2'P_s2'Eta_2'];
31 disp("  Q_1(gpm)  H_1(ft)  P_s1(hp)  Eta_1(%)
      Q_2(gpm)      H_2(ft)      P_s2(hp)      Eta_2(
      %)")
32 disp(table)
33
34 figure()
35 plot(Q_1,H_1,'o',Q_1,P_s1,'d',Q_1,Eta_1,'s')
36 legend("H_1(ft)", "P_s1(hp)", "Eta_1(%)", -1)
37 xlabel("Q_1(gpm)")

```

```

38 ylabel("H_1(ft) , P_s1 (hp) , Eta_1 (%)")
39 set(gca(),"grid",[1 1])
40
41 figure(1)
42 plot(Q_2,H_2,'o',Q_2,P_s2,'d',Q_2,Eta_2,'s')
43 legend("H_2(ft)","Ps_2 (hp)","Eta_2 (%)",-1)
44 xlabel("Q_2(gpm)")
45 ylabel("H_2(ft) , Ps_2 (hp) , Eta_2 (%)")
46 set(gca(),"grid",[1 1])

```

Scilab code Exa 4.3 CP

```

1 clear all; clc;
2
3 disp("The expression  $P_s = \rho * Q * gH / \text{Eta}$  is used to
   calculate the shaft power for al finite flow rate
   conditions .For the shutoff condition ,since Eta
   is zero ,Ps has to be extrapolated. Also 0.1H is
   plotted instead of H in the same chart since its
   order of magnitude is higher than others.")
4
5 disp("The efficiency and NPSHR are read from the
   constant contours with interpolation and Ps is
   calculated with the above equation.")
6
7 Q = [40 80 120 160 200 220];
8 OneTenthH = [27 26.5 25.5 24 21.5 20];
9 eff = [30 42.5 52 56.7 57 54.5];
10 NPSHR = [5 5.5 6.1 7.3 11.5 16];
11
12 Ps = zeros(1,length(Q));
13
14 for i = 1: length(Q)
15
16

```

```

17         Ps(i)=(62.4*0.00223*Q(i)*OneTenthH(i)*10)/((
           eff(i)/100)*550); //550 is conversion factor
18
19 end
20
21 disp(" Q(gpm) 1/10H(ft) eff(%) NPSHR(ft) Ps(hp)")
22
23 table=[Q' OneTenthH' eff' NPSHR' Ps' ];
24 disp(table)
25
26 plot(Q,OneTenthH,'o',Q,NPSHR,'d',Q,Ps,'s',Q,eff,'*')
27 legend("OneTenthH(ft)", "NPSHR(ft)", "Ps(hp)", "eff(%)
           ",-1)
28 xlabel("Q(gpm)")
29 ylabel("OneTenthH(ft), NPSHR(ft) , Ps(hp) eff(%)")
30 set(gca(),"grid",[1 1])

```

Scilab code Exa 4.4 CP

```

1 clear all; clc;
2
3 disp("From figure 4.7a, H=235ft , Q=170 gpm at b.e.p.
       of 57.5%. ")
4 disp("The corresponding NPSHR is 8.7ft. From the
       steam table we have pv=3.73 psia at T=150 degrees
       Farenheit")
5 disp("Also NPSPA=pt-pf+rho*g*Z-pv is greater than or
       equal to NPSPR ")
6 disp("Thus we can determine the value of Z")
7
8 NPSHR=8.7
9 p_t=20
10 p_f=1.5*((170/50)^2)
11 p_v=3.73
12 //Let x=rho*g=62.4

```

```

13 x=62.4
14
15 Z=NPSHR-[p_t-p_f-p_v]*(144/(x))//144 is conversion
    factor
16
17 printf(" Thus the value of Zis equal to %0.1f ft",Z)

```

Scilab code Exa 4.5 CP

```

1 clear all; clc;
2
3 disp("The b.e.p. of all four trims are read as
    follows")
4 Dia=[9.25 8 7 6];
5 Q=[220 170 155 130];
6 H=[330 235 170 120];
7 Ps=[29 17 12.5 8];
8 eff=[62.5 57.5 53.5 49.5];
9 table=[Dia' Q' H' Ps' eff']
10 disp("Dia(in) Q(gpm) H(ft) Ps(hp) eff(%)")
11 disp(table)
12
13 disp("From the similarity laws Q is proportional to
    D, H proportional to D^2 and Ps proportional to D
    ^3")
14
15 disp("The performance should be")
16
17 Di=[9.25 8 7 6];
18 Q=[220 190 166 143 ];
19 H=[330 246 189 139];
20 P_s=[29 18.7 12.5 7.9];
21 eff=[62.5 62.5 62.5 62.5];
22
23 disp("Dia(in) Q(gpm) H(ft) P_s(hp) eff(%)")

```



```

24 table=[Dia'   Q'   H'           P_s'           eff']
25 disp(table)

```

Scilab code Exa 4.6 CP

```

1 clear all; clc;
2
3 disp("From figure 4.7a, we have NPSHR=8.7ft=2.65m at
      Q=170gpm for the b.e.p. condition of the 8in
      impeller.")
4
5 disp("From figure 4.18 we have deltaNPSH=0.6ft=0.18m
      and pv=69kPa at T=90 degrees celsius for water.
      ")
6 disp("The total NPSPA is equal to  $p_t - \rho * g * Z - p_f - p_v$ 
      and the total NPSPR is equal to  $\rho * g * (NPSHR -$ 
       $\text{deltaNPSH})$ ")
7 disp("To avoid cavitation, at the pump inlet, it is
      required to have  $NPSPA > NPSPR$ ")
8 disp("Hence it is required  $(p_t - \rho * g * Z - p_f - p_v) > \rho * g$ 
       $* (NPSHR - \text{deltaNPSH})$ ")
9 p_f=10
10 p_v=69
11 rho=998
12 g=9.8
13 Z=2
14 NPSHR=2.65
15 deltaNPSH=0.18
16 p_t=p_f+p_v+rho*g*(Z+NPSHR-deltaNPSH)/1000//1000 is
      conversion factor
17 printf("\n Thus p_t is equal to %0.1f kPA",p_t)

```

Scilab code Exa 4.7 CP

```

1 clear all; clc;
2
3 disp("(a) Start wit calculation of specific speed")
4
5 N=2400
6 Q=1200
7 H=450
8 N_s=(N*Q^0.5)/(H^0.75)
9 printf("Ns= %0.0 f rpm*gpm^0.5/ft^0.75",N_s)
10
11 disp("From figure 4.20 we obtain overall efficiency
      is equal to 0.76")
12 Q=1200
13 delta_p=0.00223*62.4*450
14 ETA_oa=0.76
15 P_s=(Q*delta_p)/(ETA_oa)
16 printf("Since Ps=(Q*delta_p)/(ETA_oa),P_s= %0.0 f ft-
      lbf/s",P_s)
17
18 disp("To determine the inlet configuration:")
19 N=2400
20 omega=N*%pi/30
21 printf("Omega = %0.0 frad/s",omega)
22 tau=P_s/omega
23 printf("\n = %0.0 f lbf-ft",tau)
24
25 disp("Hence the shaft diameter Dsh can be determined
      ")
26 sigma_s=10000
27 D_sh=(16*tau/(144*%pi*sigma_s))^(1/3)
28 printf("D_sh= %0.4 f ft =1.34 inches",D_sh)
29
30 disp("A pure radial inet confuguratin isbselected
      that is Dt1=Dh1=D1(see figure 4.19).The impeller
      eye area and leading edge diameters can be
      calculated from the following equations.")
31
32 disp("U_1=0.5*omega*D_1")

```

```

33 disp("Q=A_1*V_1=A_e*V_e")
34 disp(" V_1=1.1*V_e")
35 disp("  _f1 =taninverse (V1/U1)")
36
37 disp(" Where A_1= _1 *pi*D_1*b_1")
38 disp(" Where A_e=pi*D_e^2/4")
39 disp(" With  _1 =Q/(A_e*U_e)=Q/(pi*omega*re^3)=27")
40 disp(" Thus we obtain re=2.8 in and selecting r1=3.2
      inches the final results are obtained as Ve=Q/(pi
      *D_e^2/4)=15.6 ft")
41 disp(" V_1=17.2 ft/s , A_1=22.4in^2, b2=1.24in with
      _1 =0.9 assumed. Also U_1=66.9 ft/s,  _f1 =14.4
      degrees,  _b1 =17 degrees and W_1=69.1 ft/s")
42
43 disp("(c) The impeller discharge is determined ")
44 omega=251
45 Q=2.676
46 //elt x=g*H=14490
47 x=14490
48 omega_s=omega*(Q^0.5)/((x)^0.75)
49 printf("\nomegas is %0.3 f",omega_s)
50
51 delta_s=9
52 D_2=delta_s*(Q^0.5)/((x)^0.25)
53 printf("\nD2= %0.4 f ft = 16.1 in",D_2)
54
55 D_2=1.342//rounded off
56 omega=251
57 U_2=D_2*omega/2
58 printf("\n U_2= %0.2 f",U_2)//in the book the answer
      has been rounded off to 168.5
59
60 disp(" Selecting  _b2 =27.5 degrees")
61 Zb=6.5*((1+0.4)/(1-0.4))*sin(((17+27.5)/2)*%pi/180)
62 printf("\nZb= %0.2 f is approximately equal to 6",Zb)
63 MUs=1-%pi*sin((27.5/6)*%pi/180)
64 printf("\nThus  s = %0.3 f",MUs)//The answer given in
      the book is 0.76,but the more accurate answer is

```

0.749

```
65
66 ETA_h=1-0.8/((1200)^0.25)
67 printf("\n ETA_h= %0.3 f",ETA_h)
68
69 disp("(3) Substituting these values into the Euler
      equation ,we obtain values of Vu2 and Vr2")
70 ETA_h=0.864
71 U_2=168.5
72 V_u2=x/(ETA_h*U_2)
73 printf("\n Vu2= %0.2 f ft/s",V_u2)//value given in
      the book is equal to 99.6,however the more
      accurate value is equal to 99.53
74
75 disp("Vu2= *(U2-Vr2/tan b2)")
76 disp("Hence we can find out the value of Vr2=19.4 ft
      /s")
77 V_r2=19.4
78 V_u2=99.6//rounded off value taken in the book
79 U_2=168.5
80 W_2=[V_r2^2+(U_2-V_u2)^2]^0.5
81 printf("W2= %0.2 f ft/s",W_2)
82
83 disp("Hence W2/W1 >1 , which is not appropriate. A
      different D2 has to be selected ,say D2=15in.")
84 disp("So we have U_2=159.6 ft/s,V_u2=106.9 ft/s ,
      V_rt=8.5 ft/s , and W_2=50.7 ft/s")
85 disp("Hence W_2/W_1=0.74, which is acceptable")
86
87 disp("The outlet dimensions are calculated as A2=Q/
      Vr2")
88 Q=1200
89 V_r2=8.5
90 A_2=(Q*0.00223)/V_r2//0.00223 is conversion factor
      to convert gallons per minute to cubic feet per
      second
91 printf("\nThus A_2= %0.3 f ft^2",A_2)
92 disp("On converting , we get A2=45.3 in^2")
```

```

93 disp("A_2= _2 *pi*D_2*b_2, where _2 =1-(Zb*t)/(pi*
      D_2*sin( _b2 )")
94 Zb=6
95 t=0.25
96 D_2=15
97 beta_b2=27.5*%pi/180//converting to radians
98 epsilon_2=1-(Zb*t)/(pi*D_2*sin(beta_b2))
99 printf("Thus _2 = %0.2f",epsilon_2)
100 A_2=45.3//in inches
101 b_2=A_2/(epsilon_2*pi*D_2)
102 printf("\nThus we can determine b_2 which is equal
      to %0.0f in",b_2)
103
104 epsilon_1=1-(6*0.25)/(pi*6.4*sin(17*%pi/180))
105 printf("\n _1= %0.2f",epsilon_1)
106 disp("b_1 has to be adjusted")
107 b_1=1.3*0.9/0.74
108 printf("\nThus b_1 is equal to %0.2f in",b_1)
109
110 disp("The blade profile is constructed by assuming a
      linear blade angle distribution")
111 disp(" b = b1 +( b2 - b1 )*(r-r1)/(r2-r1)=17+2.44(r
      -3.2)")
112 disp("where b is in degrees and r is in inches.")
113 disp("Also deltatheta can be expressed as (180/pi)*
      deltar/(r*tan b)")
114 disp("If we select deltar=0.43 in,then b ,
      deltatheta ,theta ,dL and L can be calculated and
      tabulated as follows")
115
116 r=[3.2 3.63 4.06 4.49 4.92 5.35 5.78 6.21 6.64 7.07
      7.5];
117 beta_1=[17 18.05 19.1 20.15 21.2 22.25 23.3 24.35
      25.4 26.45 27.5];
118 dthita=[25.188 20.831 17.528 14.957 12.913 11.259
      9.8993 8.768 7.8157 7.006 6.3116 ];
119 thita=[0 25.188 46.018 63.546 78.502 91.415 102.67
      112.57 121.34 129.16 136.16];

```

```

120 dL=[1.4709 1.388 1.3143 1.2484 1.1892 1.1358 1.0873
      1.0431 1.0026 0.9655 0.9314];
121 L=[0 1.471 2.859 4.173 5.422 6.611 7.747 8.834 9.877
      10.88 11.85];
122 r_2=[3.2 3.63 4.06 4.49 4.92 5.35 5.78 6.21 6.64
        7.07 7.5];
123 beta_2=[17 17.6 18.2 18.8 19.4 20 20.6 21.2 21.8
            22.4 23];
124 dthita_2=[25.19 21.4 18.46 16.12 14.22 12.65 11.34
              10.23 9.279 8.456 7.74];
125 thita_2=[0 25.2 46.6 65 81.2 95.4 108 119 130 139
             147];
126 dL_2=[1.471 1.422 1.377 1.334 1.295 1.257 1.222
          1.189 1.158 1.129 1.101];
127 L_2=[0 1.471 2.893 4.27 5.604 6.899 8.157 9.379
         10.57 11.73 12.85];
128
129 table=[r' beta_1' dthita' thita' dL' L' r_2' beta_2'
          dthita_2' thita_2' thita_2' dL_2' L_2']
130 disp("The table is in the given order:beta,dthita ,
        thita ,dL,L.r,beta ,dthita ,thita ,thita ,dL,L")
131 disp(table)
132
133 disp("The table shows that with b2 =27.5 degrees
        the blade length L=11.85 in.")
134 sigma_s=6*11.85/(%pi*15)
135 printf(" Hence the solidity is sigma_s= %0.2f which
        is too low.",sigma_s)
136
137 sigma_s=9*12.85/(%pi*15)
138 printf("\n Hence the new b2 =23 degrees and Zb=9
        are selected so that we hae final value of
        sigma_s=%0.2f.",sigma_s)
139
140 disp("The final values of the impeller outlet
        dimensions are revised:")
141 disp("A2=0.194 ft^2=27.9 in^2, b2=0.67 in , with
        mu_s=0.86, epsilon_2=0.88 , Vr2=13.8 ft/s , W2

```

=51.8 ft/s”)

Scilab code Exa 4.8 CP

```
1 clear all; clc;
2
3 disp("From example 4.7 we have Q=1200gpm,H=450 ft ,N
    =2400rpm")
4 disp("Furthermore Ns=851 rpm*(gpm^0.5)/(ft^0.75) ,D2
    =15in ,b2=0.67in ,U2=156.9 ft/s.")
5 disp("Also , b2 =23 degrees , s =0.86 ,V2=13.8 ft/s and
    Vu2=106.9 ft/s")
6 disp("Hence we have the angular momentum L=r2*Vu2 ")
7 L=15*106.9/(2*12)
8 printf(" Thus L= %0.2f dt/s^2" ,L)
9
10 disp("Fom figure 4.24 we have K3=0.46 and Ns=851.")
11 disp("Hence the volute exit velocity Vt=K3*(2*g*H
    ^0.5)")
12 V_3=0.46*sqrt(2*32.2*450)
13 printf("\n Thus Vt= %0.2f ft/s" ,V_3)
14
15 disp(" Also A_t=Q/V_t ")
16 A_t=1200*0.00223/78.3
17 printf(" At= %0.3f ft^2 which is equal to 4.92 in^2"
    ,A_t)
18 disp(" Also from Figure 4.24 we have (D3-D2)/D2=0.08"
    )
19
20 r_3=7.5*(1+0.08)
21 printf("\n r3= %0.2f" ,r_3)
22 disp(" If the trapezoid with an included angle of 30
    degrees is selected for bassic geometry of the
    volute cross section ,the dimensions from each
    section can be calculated from Athita*Vthita=(Q*
```

```

    thita)/(2*pi)")
23
24 disp(" r_c * V_thita = CL")
25 disp(" A_thita = 0.5 * h * (a + b)")
26 disp(" (a - b) / (2 * h) = tan(15)")
27 disp(" x_c = h * (2a + b) / (3 * (a + b))")
28 disp(" rc = r3 + x_c")
29
30 disp(" where b = 1.82 b2 = 1.206 in. is selected")
31 disp(" The equations are to be solved with iterations
    and performed with a spreadsheet.")
32 disp(" The initial velocity is selected as V_thita =
    V_t")
33 disp(" Then A_thita is calculated from l, a and h from
    (3) and (4), and x_c and r_c from (5) and (6)")
34 disp(" Then the improved V_thita is obtained from (2)
    and the process is repeated until the
    discrepancies of the repeated values are small
    enough.")
35 disp(" In the final design the trapezoid is modified
    by rounding off the corners and the area may be
    increased by 5 to 10 percent to accommodate the
    blockage due to the boundary layer and some
    secondary flows.") // final answers have not been
    provided in the book

```

Scilab code Exa 4.9 CP

```

1 clear all; clc;
2 // Values of tenPs0 and eff slightly vary from those
    given in the book. On calculating it was found
    out that the values given here are more accurate
    than those given in the textbook
3
4 disp(" Use the motor calibration curves to convert

```



```

        input electrical power to shaft power for the
        corresponding rotating speed. The result is
        provided below.")
5
6 Q1=[40 80 120 140 160 180 200 220];
7 dp1=[77 76 70 66 64 62 55 48];
8 Ps1=[5.2 5.6 6 6.5 7.2 7.6 7.75 7.8];
9 N1=[1775 1772 1765 1760 1755 1753 1750 1747];
10 table=[Q1' dp1' Ps1' N1'];
11 disp("    Q1    dp1(psi)    Ps1(hp)    N1(rpm)")
12 disp(table)
13
14 disp("Convert each operating condition of flow rate ,
        pressure rise and shaft power from the test
        rotating speed to the rated speed of 1750rpm.")
15 Q0 = zeros(1,length(Q1));
16 dp0 = zeros(1,length(Q1));
17 tenPs0= zeros(1,length(Q1));
18 eff=zeros(1,length(Q1));
19 for i = 1: length(Q1)
20
21
22     Q0(i)=Q1(i)*(1750/N1(i));
23     dp0(i)=dp1(i)*(1750/N1(i))*(1750/N1(i));
24     tenPs0(i)=10*Ps1(i)*(1750/N1(i))*(1750/N1(i))
           *(1750/N1(i)); //values slightly differ from
           those given in the book,however on calculation
           the values given here are more accurate than
           those given in the book
25     eff(i)=100*(Q0(i)*dp1(i)*144)/(449*550*tenPs0(i)
           /10); //since eff depends on tenPs0 ,hence they
           differ too
26 end
27
28 table2=[Q0' dp0' tenPs0' eff'];
29 disp("    Q0(gpm)    dp0(psi)    tenps(hp)
        eff(%)")
30 disp(table2)

```

```

31
32 plot(Q0,dp0,'o',Q0,tenPs0,'d',Q0,eff,'s')
33 legend("dp(psi) ", "10Ps(hp)", "Eff (%)", -1)
34 xlabel("Q(gpm)")
35 ylabel("dp(psi), 10Ps(hp), Eff(%)")
36 set(gca(),"grid",[1 1])

```

Scilab code Exa 4.10 CP

```

1 clear all; clc;
2 //Value of s differs. The one given in the book is
   incorrect. On calculation the value is equal to
   the one provided here.
3
4 disp("The dynamic pressure at the inlet is
   calculated from  $pd1 = \rho * V1^2 / 2$ ")
5
6 Q=220*0.00223//0.00223 is conversion factor
7 D=5
8 A=%pi*(D^2)/4
9 V_1=(Q*144)/(A)
10 printf(" V1=Q/A= %0.2 f ft/s",V_1)
11
12 rho=62.4
13 V_1=3.60
14 p_d1=(rho*(V_1^2))/(2*144*32.2)
15 printf(" \npd1= %0.3 f psi",p_d1)
16
17 disp("The vapor pressure of water at 80 degrees
   Farenheit is obtained from steam tables as pv
   =0.507 psia.")
18 disp("The required NPSH is designated at the
   condition such that discharge pressure drops for
   3% from the non cavitation condition.")
19

```

```

20 dpdash=0.97*70
21 printf(" Hence from the above test data,the
        correspondin dpdash= %0.2f psi",dpdash)
22
23 p_1dash=7.2+(7.5-7.2)*(67.9-67.5)/0.5
24 printf("\n p1dash can also be obtained %0.2f psia",
        p_1dash)
25
26 disp(" Also NPSPR=p1dash+pd1-pv")
27 p_1dash=7.44//rounded off
28 p_d1=0.087//rounded off
29 p_v=0.507
30 NPSPR=p_1dash+p_d1-p_v
31 printf("\n Hence NPSPR = %0.2f psia",NPSPR)
32
33 NPSPR=7.02//rounded off
34 NPSPHR=2.307*NPSPR
35 printf("\n NPSPHR= %0.2f ft",NPSPHR)
36
37 N=3500
38 Q=220
39 NPSHR=16.2
40 S=(N*(Q^0.5))/((NPSHR)^0.75)
41 printf("\n S= %0.0f rpm*(gpm^0.5)/(ft^0.75)",S)//S=
        6419 but on calculation it is found out that S
        =6429. Hence the value given here is correct.

```

Scilab code Exa 4.11 CP

```

1 clear all; clc;
2
3 disp(" With H=k*(Q^2)+3,the constant k can be
        obtained.")
4
5 H=10*144/62.4

```

```

6 printf("We have H= %0.2 f ft and Q=25gpm",H)
7
8 Q_1=25
9 k=(H-3)/(Q_1^2)
10 printf("\nThus k= %0.4 f ft/(gpm^2)",k)
11
12 disp("Thus the H/Q relationship can be tabulated and
      plotted as follows")
13
14 Q=[0 5 10 15 20 25 30];
15 Hdash = zeros(1,length(Q));
16
17 for i = 1: length(Q)
18
19
20     Hdash(i)=(0.0321*((Q(i))^2)+3);
21 end
22
23 table = [Q' Hdash'];
24 disp("  Q(gpm)  H(ft)")
25 disp(table)
26
27 plot(Q,Hdash)
28
29 xlabel("Q (gpm)")
30 ylabel("H(ft)")
31
32 disp("(b) Rewrite  $H=0.0321*(Q^2)+3$  into  $Q=5.581*((H-3)^{0.5})$ ")
33 disp("From  $Q_c=2Q$  and  $H_c=H$ , we have  $Q_c=11.16*(H_c-3)^{0.5}$  or  $Q_c^2=124.6*(H_c-3)$ ")
34 disp("Or  $H_c=0.00802*Q_c^2+3$ ")
35 disp("It is the expression of the combined system")

```

Scilab code Exa 4.12 CP

```

1 clear all; clc;
2
3 disp("The single pump performance is given as
    follows")
4 Q=[0 70 130 172 186 190 195 200];
5 H=[1600 1500 1275 920 785 540 435 285];
6 table=[Q' H'];
7 disp("  Q(gpm)  H(ft)")
8 disp(table)
9
10 disp("a) Two connected in series")
11 Q_1=[0 70 130 172 186 190 195 200];
12 H_1=[3200 3000 2550 1840 1570 1080 870 570];
13 table1=[Q_1' H_1']
14 disp("  Q-1(gpm)  H-1(ft)")
15 disp(table1)
16
17 disp("b) Two connected in parallel")
18 Q_2=[0 140 260 344 372 380 390 400];
19 H_2=[1600 1500 1275 920 785 540 435 285];
20 table2=[Q_2' H_2']
21 disp("  Q2(gpm)  H2(ft)")
22 disp(table2)
23
24 plot(Q,H,'o',Q_1,H_1,'d',Q_2,H_2,'s')
25 legend("H(ft)", "H1(ft)", "H2(ft)", -1)
26 xlabel("Q (gpm)")
27 ylabel("H(ft)")
28 set(gca(),"grid",[1 1])

```

Scilab code Exa 4.13 CP

```

1 clear all; clc;
2
3 disp("The specific speeds for all three options can

```

```

        be calculated")
4
5 N_sa=3600*(500^0.5)/(350^0.75)
6 printf("Nsa= %0.0 f rpm*(gpm^0.5)/(ft^0.75)",N_sa)
7
8 N_sb=4320*(500^0.5)/(350^0.75)
9 printf("\nNsb= %0.0 f ",N_sb)
10
11 N_sc=3600*((500^0.5)/(175^0.75))
12 printf("\nNsc= %0.0 f",N_sc)
13
14 disp("From figures 4.20 and 4.36, we oobtain Effa
        =0.75, Dsa=1.7, Effb=0.78, Dsb=1.4, Effc=0.80, Dsc
        =1.31")
15
16 D_sa=1.7
17 Q=500
18 H=350
19 D_a=D_sa*(Q^0.5)/(H^0.25)
20 printf("\nDa=Dsa*(Q^0.5)/(H^0.25)= %0.1 f in",D_a)
21
22 D_sb=1.4
23 D_b=D_sb*(Q^0.5)/(H^0.25)
24 printf("\nDb= %0.1 f in",D_b)
25
26 D_sc=1.1
27 D_c=D_sc*(Q^0.5)/(H^0.25)
28 printf("\nDc= %0.1 f in",D_c)//for Dsc=1.1 the value
        determined is correct. The value of Dc given in
        the book is incorrect.
29
30 Q=500*0.00223//conversion from gpm to cubic ft/s
31 //let x=rho*g
32 x=62.4
33 P_h=Q*x*H
34 printf("\nThe output hydraulic power is equal to %0
        .0 f ft-lbf/s = 44.3hp=33kW",P_h)
35

```

```
36 P_a=33/(0.75*0.9)
37 printf("\nThe power required for option a= %0.1f kW"
    ,P_a)
38
39 P_b=33/(0.78*0.95*0.9)
40 printf("\nThe power required for option b= %0.1f kW"
    ,P_b)
41
42 P_c=33/(0.80*0.9)
43 printf("\nThe power required for option c= %0.1f kW"
    ,P_c)
```

Chapter 5

Axial Flow Pumps and Fans

Scilab code Exa 5.1 AF

```
1 clear all; clc;
2
3 disp("From figure 5.3a, we have Cl=0.36, Cd=0.017
      and alpha=1.8 degrees at maximum L/D")
4
5 N=3500
6 C_l=0.36
7 alpha=1.8
8 C_d=0.017
9 r_t=13.25
10 r_h=3.25
11 Zb=7
12 Q=11560 //cfm
13 gamma_1=70
14 alpha=1.8
15
16 A=%pi*(r_t^2-r_h^2)
17 printf("\n A is equal to %0.1f in^2",A)
18 disp("On converting it in terms of feet we have A=
      3.6 ft^2")
19
```



```

20 r_m=[0.5*(r_t^2+r_h^2)]^0.5
21 printf("\n rm is equal to %0.2 f in",r_m)
22 disp("On converting it in terms of feet we have rm
      =0.804 ft ")
23
24 r_m=0.804//in feet
25 U_m=(N*%pi*r_m)/30
26 printf("\n Um is equal to %0.1 f ft/s",U_m)
27
28 r_m=9.65//in inches
29 s=(2*%pi*r_m)/Zb
30 printf("\n s= %0.2 f in",s)
31
32 disp("Va=V1=Q/A")
33
34 A=3.6//in square feet
35 V_1=Q/(A*60)//divided by 60 to get answer in terms
      of ft/s
36 printf("\n V1=Va= %0.2 f ft/s",V_1)
37
38 U_m=294.7//rounded off
39 V_1=53.5//rounded off
40 beta_1=(atan(U_m/V_1))*180/%pi
41 printf("\n 1 = %0.1 f degrees",beta_1)
42
43 beta_m=gamma_1+alpha
44 printf("\n m = %0.1 f degrees",beta_m)
45
46 disp("From tan m=(tan 1+tan 2)/2 , 2 =30.1
      degrees; Then Wmcos m=Va")
47 V_a=53.5//in ft/s
48 W_m=V_a/(cos(beta_m*%pi/180))
49 printf("\n So Wm= %0.1 f ft/s",W_m)
50
51 W_m=171.3//rounded off
52 rho=0.0762/32.2
53 cm=3.5
54 s=8.66//rounded off

```

```

55 disp("hence we have  $\Delta p_r = ((\rho * W_m^2) / 2) * (cm/s) * ($ 
       $C_l * \sin(\beta_m * \pi / 180) - C_d * \cos(\beta_m * \pi / 180))$ ")
56 delta_pr = ((rho * W_m^2) / 2) * (cm/s) * (C_l * sin(beta_m * pi
      / 180) - C_d * cos(beta_m * pi / 180))
57 printf("\n  $\Delta p_r = %0.4f$  lb/ft2 ", delta_pr)
58 disp("On rounding off we get  $\Delta p_r = 4.73$  lbf/ft2"
      )
59 disp("Thus  $\Delta p_r = 0.0328$  psia = 0.91 in.wg")
60
61 disp("Across the stator, from the velocity diagram,
      we have  $W_{u2} = V_a * \tan \alpha$  and  $V_2 = (V_a^2 + (U_m - W_{u2})^2)^{0.5}$ ")
62
63 beta_2 = 30.1 * pi / 180
64 V_a = 53.5 //rounded off
65 W_u2 = V_a * tan(beta_2)
66 printf(" Thus  $W_{u2}$  is equal to  $%0.0f$  ft/s", W_u2)
67
68 U_m = 294.7 //rounded off
69 V_2 = (V_a^2 + (U_m - W_u2)^2)^0.5
70 printf("\n  $V_2 = %0.0f$  ft/s", V_2)
71
72 disp("So assuming  $V_3 = V_a$ ")
73
74 V_a = 53.5 //rounded off
75 V_2 = 269 //rounded off
76 eta_s = 0.85 //efficiency
77 rho = 0.0762 / 32.2
78 delta_ps = (((eta_s * rho) / 2) * (V_2^2 - V_a^2)) / 144 //144 is
      conversion factor
79 disp("  $\Delta p_s = (((\eta_s * \rho) / 2) * (V_2^2 - V_a^2))$ ")
80 printf("\n  $\Delta p_s$  is equal to  $%0.3f$  psia", delta_ps)
81 disp("On converting the unit  $\Delta p_s = 1.12$  ft which
      is equal to 13.44 inches of water")

```

Scilab code Exa 5.2 AF

```
1 clear; clc;
2
3 disp(" a")
4 disp(" Convert: 1) Q=5 m^3/s=10595 cfm")
5 disp(" 2) rhoa=0.0761lbm/ft^3")
6
7 disp(" 3) SP=deltap/(rho_w*g)")
8 delta_ps=500
9 rho_w=1000
10 g=9.8
11 SP=delta_ps/(rho_w*g)
12 printf("Hence SP = %0.3 f m",SP)
13 disp("Thus SP= 2.01 in.wg.")
14
15 disp(" b")
16 disp(" Calculating the specific speed:Ns")
17 N_s=1500*((10575)^0.5)/(2.01)^0.75
18 printf("The value of Ns is equal to %0.2 f rpm*(cfm
    ^0.5)/(in of water^0.75)",N_s)
19
20 N=1500
21 omega=N*pi/30
22 printf("\nOmega = %0.0 f rad/s",omega)
23
24 omega_s=157*(5^0.5)/((500/1.22)^0.75)
25 printf("\nSo omegas = %0.2 f ",omega_s)
26
27 disp("From figure 5.10b,we select v=Dh/Dt=0.5 and
    the blade number Zb=6*v/(1-v)")
28 v=0.5
29 Zb=6*v/(1-v)
30 printf("Hence Zb= %0.2 f",Zb)
31
32 disp("From figure 2.2,the specific diameter obtained
    as deltas is approximately equal to 1.5")
33 D_t=1.5*(5^0.5)/((500/1.22)^0.25)
```

```

34 printf("\nHence Dt = %0.3 f m",D_t)
35
36 v=0.5
37 D_t=0.74//rounded off
38 D_h=v*D_t
39 printf("\nDh= %0.2 f m",D_h)
40
41 A=%pi*(D_t^2)*(1-v^2)/4
42 printf("\nAlso A = %0.4 f m^2",A)
43
44 D_m=((D_t^2+D_h^2)/2)^0.5
45 printf("\nDm = %0.4 f m",D_m)
46
47 A=0.322//rounded off
48 Q=5
49 V_a=Q/A
50 printf("\nVa= %0.1 f m/s",V_a)
51
52 U_m=omega*D_m/2
53 printf("\nUm = %0.2 f",U_m)
54
55 V_a=15.5//rounded off
56 PHI_m=V_a/U_m
57 printf("\nPHIm = %0.3 f",PHI_m)
58
59 disp("Now from figure 5.10c we can obtain Phim*(s/c)
      =0.65")
60 //let s/c=x
61 PHI_m=0.337//rounded off
62 x=0.65/PHI_m
63 printf("\nThus (s/c)= %0.2 f",x)
64
65 disp("Here s= pi*Dm/Zb")
66 s= %pi*D_m/Zb
67 printf("\n Thus s= %0.3 f m",s)
68
69 disp("Assuming V1=V3=Va=15.5 m/s the total head can
      be calculated from g*Ht=deltaps/rho+Va^2/2")

```

```

70 //let y=g*Ht=deltaps/rho+(Va^2)/2
71 rho_a=1.22
72 y=delta_ps/rho_a+(V_a^2)/2
73 printf("\ng*Ht = %0.0f (m/s)^2",y)
74 disp("or TP=2.59 in.wg")
75
76 disp("c")
77 ETA_h=0.77
78 V_u2=(y)/(ETA_h*U_m)//Since y=(g*Ht)
79 printf("\nVu2 is equal to %0.0f m/s",V_u2)
80
81 beta_1=(atan(U_m/V_a))*180/%pi
82 printf("\n 1= %0.2f degrees",beta_1)
83
84 beta_2=(atan(((U_m-V_u2)/V_a)))*180/%pi
85 printf("\n 2 = %0.2f degrees",beta_2)
86
87 //let m=tan m=0.5*(tan 1+tan 2)
88 beta_1=71.3//rounded off
89 beta_2=63.4//rounded off
90 m=0.5*(tan(beta_1*%pi/180)+tan(beta_2*%pi/180))
91 printf("\ntan m=0.5*(tan 1+tan 2) =%0.3f",m)
92 beta_m=(atan(m))*180/%pi
93 printf("\n m = %0.0f",beta_m)
94
95 disp("We know that Cl=2*(s/c)*(tan 1-tan 2)*cos m
    ")
96 x=1.93//rounded off
97 beta_1=71.3
98 beta_2=63.4
99 beta_m=68
100 //Let a=tan 1
101 //Let b=tan 2
102 //Letc=cos m
103 a=tan(beta_1*%pi/180)
104 b=tan(beta_2*%pi/180)
105 c=cos(beta_m*%pi/180)
106 a=2.95//rounded off

```

```

107 b=2.0//rounded off
108 c=0.374//rounded off
109 Cl=2*x*(a-b)*c//Since x=(s/c)
110 printf("\nCl= %0.2 f ",Cl)
111
112 disp("This is the cascade coefficient required.To
      use the isolated airfoil data,we obtain K=1.2
      from figure 5.9 with gamma=60 degrees. Hence we
      can determine Cli")
113
114 C_li=1.37/1.2
115 printf("\nCli= %0.2 f",C_li)
116
117 disp("d)")
118 disp("If NACA 4312 airfoil selection is selected ,at
      Alpha=12 degrees ,Cli=1.14 and Cl/Cd=L/D=12")
119 disp("Substituting the above mentioned data in Rr=
      Wmu/Um=phi*tan( m )")
120 phi=0.337
121 d=tan(beta_m*pi/180)
122 R_r=phi*d
123 printf("\n Thus Rr= %0.3 f",R_r)
124 disp("deltar is approximately=deltas is
      approximately=0.08")
125 Eta_h=0.337*((0.834-(0.337*0.08))
      /(0.337+(0.08*0.834)))+((1-0.834-(0.337*0.08))
      /(0.337+(0.08*(1-0.834))))
126 printf("\nETAh= %0.2 f",Eta_h)
127 disp("Etah=0.80 is approximately equal to 0.77")
128 disp("Also gamma=betam-alpha=68-12=56 degrees")
129 disp("c=s/1.93")
130 c=s/1.93
131 printf("\nThus c = %0.2 f m",c)
132
133 disp("e)")
134 disp("Double check the data obtained with those
      given in Figure 5.1.It is shown that Etas=0.74,Ds
      =0.35=c.")

```

```

135 SP=2.01
136 CFM=10595
137 Dt=0.35*(CFM^0.5)/(SP^0.25)
138 printf("\nHence the value of Dt= %0.1f in",Dt)
139 disp("On converting ,Dt=0.77m")
140 disp("It is close to what we have. However, some
      alternative design maybe performed with the
      selection of a little higher hub-tip ratio v and
      other available airfoil sections")

```

Scilab code Exa 5.3 AF

```

1 clear all; clc;
2
3 disp("From equation 5.11 with Vu=constant ,we have (
      Vu^2/r) dr+(Va)dVa=0 ")
4 disp("Or Vu^2lnr+Va^2/2=C")
5 disp("Or Vu^2*ln(r/rh)=(Vah^2-Va^2)/2")
6 disp("Or Va^2=Vah^2-2*Vu^2*ln(r/rh)")
7
8 V_ah=70
9 //let m=Vah^2
10 m=V_ah^2
11 printf("\n Vah^2 = %0.0f",m)
12
13 V_u=500
14 //let n=Vu^2
15 n=V_u^2
16 printf("\n Vu^2= %0.0f",n)
17
18 //let x=Vu^2*2
19 x=n*2//Since n=Vu^2
20 printf("\n 2*Vu^2= %0.0f",x)
21
22 disp("Thus Va=(4900-5000*ln(0.5r))^0.5 m/s")

```

23 `disp("and at the tip ,Vat=27.1m/s")`

Scilab code Exa 5.4 AF

```
1 clear all; clc;
2
3 disp("Assume uniform axial flow at the inlet")
4 disp("(a) At the hub")
5 disp("V_a=15.5m/s")
6
7 omega=157
8 D_h=0.37
9 U_h=0.5*omega*D_h
10 printf(" Uh= %0.2 f m/s" ,U_h)
11
12 disp("Vu2=(Vmu2*Dm)/Dh")
13 V_mu2=15
14 D_m=0.585
15 V_u2=(V_mu2*D_m)/D_h
16 printf(" Hence Vu2= %0.1 f m/s" ,V_u2)
17
18 V_a=15.5
19 disp("tan( 1 )=(Uh/Va). Hence we can determine value
      of 1 ")
20 //let x=Uh/Va
21 x=U_h/V_a
22 beta_1=(atan(x))*180/%pi
23 printf(" 1 = %0.1 f degrees" ,beta_1)
24
25 disp("tan( 2 )=(Uh-Vu2)/Va")
26 //Let y=(Uh-Vu2)/Va
27 y=(U_h-V_u2)/V_a
28 beta_2=(atan(y))*180/%pi
29 printf(" 2 = %0.2 f degrees \n" ,beta_2)
30
```



```

31 disp("(b) At the tip")
32
33 U_t=0.5*(157*0.74)
34 printf("\n Ut= %0.2 f m/s",U_t)
35
36 V_u2=(15*0.585)/0.74
37 printf("\n Vu2= %0.2 f m/s",V_u2)
38
39 //let p=atan(58.09/15.5)
40 p=(atan(58.09/15.5))*180/%pi
41 printf("\n 1 = %0.0 f degrees",p)
42
43 //let q=atan((58.09-11.86)/15.5)
44 q=atan((58.09-11.86)/15.5)*180/%pi
45 printf("\n 2 = %0.3 f degrees",q)
46 disp("On rounding off 2 =71.4")

```

Scilab code Exa 5.5 AF

```

1 clear all; clc;
2
3 disp("Since the pressure changes are small compared
      with the barometric pressure, constant densities
      are assumed that is rho3 =rho2=rhoa where rhoa=pa
      /(RTa)")
4 p_a=14.6
5 T_a=535
6 R=53.3
7 rho_a=(p_a*144)/(R*T_a)//144 is the conversion
      factor
8 printf("rhoa= %0.4 f lbm/ft ^3",rho_a)
9
10 A2=5*6.5
11 printf("\nA2 equals %g in ^2",A2)
12 disp("On converting A2=0.225ft ^2")

```

```

13
14 A3=%pi*6.065^2/4
15 printf("\nA3 equals %0.1f in^2",A3)
16 disp("On converting A3=0.2007ft^2")
17
18 disp("From  $(\rho_3*V_3^2)/2=\rho_w*g*pv_3$ , V3 can be
    calculated")
19 rho_w=62.4
20 g=32.2
21 rho_3=0.0737
22 j=sqrt(2*rho_w*g/(rho_3*12))
23 printf("V3=%0.1f * pv3^0.5 ft/s",j)
24
25 disp("The inlet flow rate can be calculated as  $Q=Q_3=$ 
     $V_3*A_3=0.2007*60*V_3=12.04*V_3$ ")
26 disp("Also the dynamic pressure can be calculated as
     $pv_2=pv_3*((A_3/A_2)^2)*(\rho_3/\rho_2)=(0.2/0.225)^2*$ 
     $pv_3=0.79pv_3$ ")
27
28 disp("The total pressure  $pt_2=ps_2+pv_2$ ")
29 disp("To correct these data to a fixed speed of 3500
    rpm,the fan laws can be used as  $Q_{dash}=Q*3500/N$ ,
     $pt_{2dash}=pt_2*((3500/N)^2)$  and  $H_{dash}=H*((3500/N)^3)$ 
    .")
30 disp("The total efficiency can be calculated as  $ETA_t$ 
     $=(\rho_w*g*pt_{2dash}*Q_{dash})/(H_{dash})$ ")
31 disp("On simplifying  $ETA_t=Q_{dash}*pt_{2dash}/(6346*H_{dash})$ 
    ")
32
33 p_v3=[2.4 2.1 1.9 1.5 1.2 0.8 0.4];
34 p_s2=[2.5 4.2 6.0 6.8 7.6 8.5 9.5];
35 N=[3450 3520 3500 3420 3430 3500 3520];
36 H=[1.1 1.25 1.49 1.55 1.67 1.72 1.81];
37
38 V_3=zeros(1,length(p_v3));
39 Q=zeros(1,length(p_v3));
40 p_v2=zeros(1,length(p_v3));
41 p_t2=zeros(1,length(p_v3));

```

```

42 Qdash=zeros(1,length(p_v3));
43 tenpt2dash=zeros(1,length(p_v3));
44 tenHdash=zeros(1,length(p_v3));
45 eta_t=zeros(1,length(p_v3));
46
47 for i = 1: length(p_v3)
48
49
50     V_3(i) = 67.4*sqrt(p_v3(i));
51     Q(i) = 12.04*V_3(i);
52     p_v2(i) =0.79*p_v3(i);
53     p_t2(i)= p_s2(i)+p_v2(i);
54     Qdash(i)= Q(i)*(3500/(N(i)));
55     tenpt2dash(i)= 10*p_t2(i)*((3500/N(i))^2);
56     tenHdash(i)= 10*H(i)*((3500/(N(i)))^3);
57     eta_t(i)= ((Qdash(i)*(tenpt2dash(i))/10)/(6346*(
        tenHdash(i))/10))*100;
58 end
59
60 disp("The table is in the order given in the book,
        that is pv3, ps2, N, H, V3, Q, pv2, pt2, Qdash,
        tenpt2dash, tenHdash and etat.")
61 table=[p_v3'  p_s2'  N'  H'  V_3'  Q'  p_v2'  p_t2'
        Qdash'  tenpt2dash'  tenHdash'  eta_t'  ];
62 disp(table)
63
64 plot(Q,tenpt2dash,'o',Q,tenHdash,'d',Q,eta_t,'s')
65 legend("tenpt2dash (inches of water)","tenHdash (hp)
        ","eta_t (%)",-1)
66 xlabel("Q(cfm)")
67 ylabel("tenpt2dash (inches of water), tenHdash (hp)
        , eta_t (%)")
68 set(gca(),"grid",[1 1])

```

Scilab code Exa 5.6 AF

```

1 clear all; clc;
2
3 disp(" Since dBt=10*[((log10^dBb)/10)+(10^dBf/10)] we
   can determine dBf")
4
5 //let x=10^(dBt/10)
6 x=10^7
7
8 //let y=10^(dBb/10)
9 y=10^6.5
10
11 //let z=x-y
12 z=x-y
13
14 disp(" dBf=10*(log (10^( dBt/10) +10^(dBb/10)))")
15 dBf=10*[log10(z)]
16 printf(" Thus dBf= %0.2 f",dBf)

```

Scilab code Exa 5.7 AF

```

1 clear all; clc;
2
3 disp("The average flow velocity V is determined as V
   =Q/A")
4 Q=7000
5 A=%pi*(1.5^2)/4
6 V=Q/A
7 printf(" Thus V = %0.2 f fpm",V)
8 disp("Thus V is approximately equal to 4000fpm")
9
10 disp("So we have 100% effective discharge duct
   length Le=[2.5+(4000-2500)/1000]*D")
11 D=1.5
12 Le=[2.5+(4000-2500)/1000]*D
13 printf("\n Since D=1.5 ft , Le is equal to %0.2 f ft",

```

```

    Le)
14
15 //let x=L1/Le
16 L1=0.75
17 x=L1/Le
18 printf("\n Since L1=0.75,L1/Le=%0.3 f",x)
19
20 disp("So the line V in figure 5.18 can be used to
    obtain SEF1=0.255in.wg")
21 disp("For the two elbows we have L2/D and C2")
22 //let y=L2/D
23 L2=3
24 y=L2/D
25 printf("\n The value of L2/D is equal to %0.2 f",y)
26 disp("From figure 5.19 a,C2=4.2")
27
28 disp("Hence we can obtain SEF2=4.2*(rho*V^2/2)")
29 rho=0.075
30 V=4000
31 SEF2=4.2*((rho/32.2)*(V/60)^2/2)*(12/62.4) //
    constants used are conversion factors
32 printf("\n SEF2 is equal to %0.2 f in.wg",SEF2)

```

Scilab code Exa 5.8 AF

```

1 clear all; clc;
2
3 disp("We have the duct resistance deltap
    =0.25*((7000/5000)^2)")
4 delta_p=0.25*((7000/5000)^2)
5 printf(" deltap %0.2 f in.wg at 7000cfm",delta_p)
6
7 disp("The density in the building can be calculated
    from rho=p/R*T")
8 p=12.5

```

```

9 R=53.3
10 T=85+460
11 rho=p*144/(R*T)//144 is convesrion factor
12 printf("\n rho= %0.5 f lbm/ft ^3",rho)
13
14 disp("So the equivalent SPe of the required fan at
      STP can be found out")
15 SPe=0.49*0.075/0.0619
16 printf("\n SPe = %0.4 f in.wg.",SPe)
17
18 disp("Form figure 5.24a, at SP=0.5,Q1=6894,N1=347,
      BHP1=0.76 and Q2=7660, N2=360, BHP2=0.88. Hence
      for Q=7000cfm we can determine Ndash")
19 Ndash=347+(360-347)*((7000-6894)/(7660-6894))
20 printf("\n Ndash is equal to %0.2 f rpm",Ndash)
21
22 BHPdash=0.76+(0.88-0.76)*0.138
23 printf("\n BHPdash= %0.4 f",BHPdash)
24
25 disp("At Sp=5/8=0.625 in.wg., Q1=6894,N1=375,BHP1
      =0.92 and Q2=7660,N2=387,BHP2=1.05,so for Q=7000
      cfm we can determine Ndbldash and BHPdbldash")
26
27 Ndbldash=375+((387-375)*0.138)
28 printf("\n Ndbldash %0.2 f rpm",Ndbldash)
29
30 BHPdbldash=0.92+(1.05-0.92)*0.138
31 printf("\n BHPdbldash %0.4 f hp",BHPdbldash)
32
33 disp("Again interpolating for SPe=0.593,we have
      values of N and BHP as mentioned below ")
34 N=348.8+(376.6-348.8)*((0.593-0.5)/(0.625-0.5))
35 printf("\n N= %0.0 frpm",N)
36 BHP=0.776+(0.938-0.776)*0.744
37 printf("\n BHP= %0.4 f hp",BHP)
38
39 disp("Correcting for the reduced air density ,the
      actual BHP is determined")

```

```
40 BHP=0.896*0.0619/0.075
41 printf("\n Actual BHP is equal to %0.4 f",BHP)
```

Scilab code Exa 5.9 AF

```
1 clear all; clc;
2
3 disp("1.Convert the system specification to Qdash
      =10000cfm with the corresponding total pressure
      loss")
4 delta_p_ldash=0.5*((10000/5000)^2)
5 printf("\n delta(pl)dash= %0.0 f in.wg.",
      delta_p_ldash)
6
7 disp("2. Draw a system line(which is a straight line
      with slope of 2 on a log-log chart)passing this
      point and intercept at 700rpm")
8
9 disp("Read the operating condition as Q=11000cfm ,
      delp=2.51 in.wg. and Ps=5.6hp")
```

Chapter 6

Centrifugal Fans Blowers and Compressors

Scilab code Exa 6.1 C

```
1 clear all; clc;
2
3 disp("Pick the data rows for the flow rates of 10241
      and 13965 cfm and list them in the first four
      columns of the table below.")
4 disp("Convert the flow rate Q, static pressure SP and
      brake horsepower BHP values for various rpm into
      300rpm based on the fan laws.")
5 disp("That is  $Q_1=Q*(300/N)$ ,  $SP_1=SP*((300/N)^2)$ ,  $BHP_1=$ 
       $BHP*((300/N)^3)$ ")
6 disp("Calculate the static efficiency using  $ETAs=(Q*$ 
       $SP)/(6346*BHP)$ ")
7 disp("The results are plotted into the chart")
8
9
10
11
12
13 Q=[10241 10241 10241 10241 10241 10241 10241 10241 13965
```



```

13965 13965 13965 13965 13965 13965 13965 ];
14 SP= [0.25 0.375 0.5 0.625 0.75 1 1.25 0.25 0.375 0.5
        0.625 0.75 1 1.25 1.5];
15 N= [300 321 341 363 385 427 466 380 396 413 428 444
        473 506 537];
16 BHP= [0.82 1.03 1.23 1.45 1.68 2.19 2.75 1.58 1.86
         2.16 2.43 2.72 3.3 3.89 4.51];
17
18 Q1= zeros(1,length(Q));
19 SP1 = zeros(1,length(Q));
20 BHP1 = zeros(1,length(Q));
21 ETA=zeros(1,length(Q));
22
23 for i = 1: length(Q)
24
25     Q1(i)=Q(i)*(300/N(i))
26     SP1(i)=SP(i)*((300/N(i))^2)
27     BHP1(i)=BHP(i)*((300/N(i))^3)
28     ETA(i)=(Q(i)*SP(i))/(6346*BHP(i))
29
30 end
31
32 // disp("      phi      psi      eff (%)      pai      N(
        rpm)      Ps(mw)      Q(m^3/s)")
33
34 table = [Q' SP' N' BHP' Q1' SP1' BHP1' ETA'];
35 disp("      Q      SP      N      BHP      Q1
        SP1      BHP1      ETA")
36 disp("      (cfm)      (in.wg)      rpm      (cfm
        )      (in.wg)")
37 disp(table)
38
39 plot(Q1,SP1,'o',Q1,BHP1,'d',Q1,ETA,'s')
40 legend("SP1(in.wg)", "BHP1(hp)", "ETA", -1)
41 xlabel("Q(cfm)")
42 ylabel("SP1(in.wg), BHP1(hp) , ETA")
43 set(gca(),"grid",[1 1])

```

Scilab code Exa 6.2 C

```
1 clear all; clc;
2
3 disp("Assume as given Na=2400 rpm")
4 disp("T1a=68 degrees Farenheit=528R, p1=14.7 psia , p2a
      =8.5 psig=23.2 psia")
5 disp("Qa=1800cfm ,Eta=0.70 Nb=3600rpm and T1b=50 to
      95 degrees Farenheit")
6
7 Q_a=1800
8 N_b=3600
9 N_a=2400
10 Q_b=Q_a*(N_b/N_a)
11 printf("\n Qb= %0.0 f cfm",Q_b)
12
13 disp("((p2/p1)_b)^((k-1)/k)-1=(T1a/T1b)*[((p2/p1)_a)
      -1]*((Nb/Na)^2)")
14 disp("On simplifying ((p2/p1)_b)=0.313*(T1a/T1b)")
15 disp("We obtain p2b=14.7*[1+0.313*(T1a/T1b)
      ]^3.5=36.6 to 39.3 psia")
16 disp("Also Psb=rho_1b*Q_b*H_i/Eta={(p_1b/(R*T_1b))*
      Qb*Cp*T_1b*[(p2/p1)^((k-1)/k)-1]}/Eta")
17 disp("Psb=[(3.5*14.7*144*2700/(550*60))*0.313*(T1a/
      T1b)]/0.7")
18 disp("Psb=271*(T1a/T1b)=257.8 to 280.6hp")
19
20 disp("From rho_0*Q_dash=rho_1*Q, we have the flow
      rate measured at the standard condition ,Q_dashb=(
      rho_1b/rho_0)*Qb=(T0/T1b)*Qb=2795 to 2568 cfm")
```

Scilab code Exa 6.3 C

```

1 clear all; clc;
2 //Answer of H_ib given in the book is 5830,however
   it is incorrect. The correct answer is found out
   to be 5837.4883
3
4 disp(" rho_a=p/(R*T)")
5 rho_a=(13.7*0.491*144)/(53.33*(-10+460))
6 printf(" rho_a= %0.5 f lbm/ft ^3",rho_a)
7
8 disp(" Qb=Q*(Nb/Na)")
9 Q=(180/0.0403)*(12000/25000)
10 printf(" q= %0.0 f cfm",Q)
11
12 disp(" Hb=Ha*((Nb/Na)^2)")
13 disp(" we obtain")
14 disp(" ((p2/p1)^((k-1)/k)_b)=[((p2/p1)^((k-1)/k)_a)
      -1]*((Nb/Na)^2)*(T1a/T1b)+1")
15 //let x=((p2/p1)^((k-1)/k)_b)
16 p2=34.5
17 p1=13.7
18 //let y=((k-1)/k)
19 y=0.2857
20 Nb=12000
21 Na=25000
22 T_1a=450
23 T_1b=535
24 x=[(p2/p1)^y-1]*((Nb/Na)^2)*(T_1a/T_1b)+1
25 printf(" ((p2/p1)^((k-1)/k)_b)=%0.4 f\n",x)
26
27 disp(" So p2b=((1.0585)^3.5)*(p1b)")
28 p_1b=30
29 p_2b=((1.0585)^3.5)*(p_1b)
30 printf(" p2b= %0.1 f in .Hg",p_2b)
31
32 disp(" H_ib=[(k*R*T_1b)/(k-1)]*[((p2/p1)^((k-1)/k)_b)
      -1]")
33 k=1.4
34 R=53.33

```

```

35 T_1b=535
36 p2=36.6
37 p1=30
38 y=0.2857
39 H_ib=[(k*R*T_1b)/(k-1)]*[((p2/p1)^y)-1]
40 printf(" H_ib=%0.4f ft-lbf/lbm",H_ib)//Answer of
    Hib given in the book is 5830,however it is
    incorrect. The correct answer is found out to be
    5837.4883 on calculating
41
42 disp(" rho_b*Qb=mb")
43 mb=(30*0.491*144)/(53.33*535)*2144
44 printf(" mb= %0.1f lbm/min",mb)
45
46 disp("Thus P_sb=mb*Hib/Eta")
47 P_sb=159.4*5830/(60*550*0.70)
48 printf(" P_sb= %0.1f hp",P_sb)

```

Scilab code Exa 6.4 C

```

1 clear all; clc;
2
3 Q_c=1000
4 N_a=3550
5 N_c=4000
6 Q_a=Q_c*(N_a/N_c)
7 printf("\n Qa=Qc*(Na/Nc)=%0.1f cfm",Q_a)
8
9 disp("H=Cp*T1*[(p2/p1)^((k-1)/k)-1]")
10 disp("Ha/Hc=((Na/Nc)^2)")
11 disp("Where ka=1.40,Cpa=0.24 Btu/lbm*degrees
    Farenheit,,T1a=530R,((ka-1)/ka)=0.2857 and kc
    =1.30")
12 disp("Cpc=0.20Btu/(lbm*degrees Farenheit),T1c=550R
    ,((kc-1)/kc)=0.2307, we have:")

```

```

13 disp(" (Cpa*T1a) * [[(p2/p1) ^ ((k-1)/k) - 1]]_a / {(Cpc*T1c)
      * [[(p2/p1) ^ ((k-1)/k) - 1]]_c} = ((3550/4000) ^ 2)")
14 //let x=(Cpa*T1a) * [[(p2/p1) ^ ((k-1)/k) - 1]]_a / {(Cpc*
      T1c) * [[(p2/p1) ^ ((k-1)/k) - 1]]_c}
15 x=((3550/4000) ^ 2)
16 printf(" Thus the value is equal to %0.3f",x)
17
18 disp(" Or")
19 disp(" (0.24*530*[(p2/p1) ^ (0.2857 - 1)]_a)
      / (0.20*550*[(19.7/17.7) ^ (0.2307) - 1]) = 0.787")
20 disp(" Hence ((p2/p1) ^ 0.2857)_a = 1 + (0.787*0.025)
      / 1.156 = 1.017")
21 disp(" p2a = 15.6 psia")

```

Scilab code Exa 6.5 C

```

1 clear all; clc;
2 //the answer of p02b given in the book is 94.1,
   however the right answer is 92.05 which is
   rounded off to 92.1 here
3
4 p_02b = 90 + 0.5 * 0.00237 * ((500) ^ 2) / 144
5 printf("\n p02b = %0.1f psia", p_02b)
6
7 //let x = T02/T01
8 x = (480 + 460) / (60 + 460)
9 printf("\n T02/T01 = %0.4f which is also = (94.1/14.7)
      ^ ((0.2857)/(Eta_p)) ", x) //answer given in the
   book is 94.1, which is substituted
10 disp("From (0.2857/Eta_p) * ln(94.1/14.7) = ln(1.807) we
      can obtain the polytropic efficiency")
11 Eta_p = (log(94.1/14.7) / log(1.807)) * 0.2857
12 printf("Eta_p = %0.4f", Eta_p)
13
14 disp("0.85 = [(4.5) ^ (0.2857) - 1] / [(4.5) ^ (0.2857/Eta_p)]")

```

```

-1")
15 disp("Thus 0.5638/((4.5^(0.2857/Eta_p))-1)")
16 disp("We have polytropic efficiency for compressor A
, Eta_pa=0.878.")
17 disp("Hence, compressor bB is moe efficient")

```

Scilab code Exa 6.6 C

```

1 clear all; clc;
2
3 disp("The specifications are N=1800 rpm=188.5 rad/s,
Q=14000 cfm=233.3 cfs ,and sp=5 in .wg")
4 N=1800
5 Q=233.3
6 sp=5
7 Ns=N*(Q^0.5)/(sp^0.75)
8 disp("Ns=%0.0 f rpm*(cfm ^0.5)/(in water ^0.75)")
9
10 disp("From Figure 5.1, selecting the air foil blade ,
we have Etas=0.80 and Ds=d2*(sp^0.25)/Q^0.5=0.33"
)
11
12 Q=14000
13 sp=5
14 Eta_s=0.8
15 P_s=Q*sp/(Eta_s*6356)
16 printf(" Ps=%0.2 f hp",P_s)//incorrectly rounded off
in the book
17
18 d2=0.33*(14000^0.5)/(5^0.25)
19 printf("\n d2=%0.0 f in",d2)
20
21 tau=(13.7*550)/(1800*%pi/30)
22 printf("\n =%0.0 f lbf-ft",tau)
23

```

```

24 tau=40
25 s_s=10000
26 ds=[(16*tau)/(%pi*s_s)]^(1/3)
27 printf("\n The shaft diameter is found out to be %0
    .2 f in",ds)
28 disp("Where s_s is the assumed maximum allowable
    shear stress of the shaft material.")
29 disp("Hence d_d is set as 0.75in and d_h=1.0in or rh
    =0.5in. Using the maximum W1 criteria ,we ave fl
    =35.2 degrees and r1=9.88 inches which is rounded
    off to 10 inches.")
30
31 disp("Also we have b1=5 inches and b1 = fl +i=37
    degrees")
32 omega=188.5
33 r2=13/12
34 U2=omega*r2
35 printf(" To determine outlet dimensions we have U2=
    %0.1 f ft/s",U2)
36
37 disp("For a straight blade we have dashb2 =52
    degrees, so try b2 =45 degrees")
38 disp("Zb=26 and mu_s=0.794")
39 disp("Since the static pressure is specified but the
    total pressure is needed in the Euler equation ,
    the discharge flow is needed.")
40 disp("Setting b2=b1=5 incheswe can determine the
    values of A2 and A3")
41
42 r2=13
43 b2=5
44 A2=2*%pi*r2*b2/144
45 printf(" A2=%0.3 f ft ^2",A2)
46
47 A2=2.83
48 A3=1.5*A2
49 printf("\n The fan discharge area A3 is set as A3
    =1.5*A2=%0.2 f ft ^2",A3)

```

```

50 disp("Hence we have  $V_3=Q/A_3=54.8$  ft/s")
51
52 sp=62.4*5/12
53 rho=0.00237
54 V3=54.8
55 tp=sp+(0.5)*rho*(V3^2)
56 printf(" tp=%0.2f lbf/ft^2",tp)
57
58 disp("Also  $\text{Eta}_t=\text{Eta}_s*(tp/sp)=\text{Eta}_{imp}*\text{Eta}_v*\text{Eta}_m$ 
    and assuming  $\text{Eta}_v*\text{Eta}_m=0.95$ ")
59 Eta_imp=((0.8*29.5)/26)/(0.95)
60 printf(" So we hae  $\text{Eta}_{imp}= %0.4f$ ",Eta_imp)
61
62 disp("So from the Euler equation , we have
    ( $29.5/0.00237$ )= $154.8*(204.2-(82.4/\tan b_2))$ ")
63 disp("  $b_2 =33.6$  degrees")
64 disp("Since  $Z_b$  and  $\mu_s$  are related to  $b_2$  ,we have
    to repeat the calculations")
65 disp("The new alues  $Z_b=20$  and  $\mu_s=0.781$  and  $b_2$ 
    = $33.9$  degrees are obtained")
66 disp("Hence the final values are 20 and  $b_2 =33.9$ 
    degrees")
67
68 disp("From equation (6.12) we have  $(d/dr)=(1/(2*\tan f_1)*[2*(r/r_1)*(1/r_1)])$ ")
69 disp("Hence  $\tan \text{dash}_b2=[dr/(r*d )_{r2}]=\tan f_1*((r_1/r_2)^2)$ ")
70 tan_beta_dashb2=tan((35.2*%pi/180)*[(10/13)^2])
71 printf(" Thus the value of  $\tan \text{dash}_b2= %0.3f$ ",
    tan_beta_dashb2)//Answer f=given in the book is
    0.417,however the more correct answer is 0.380
72 betab2dash=((atan(tan_beta_dashb2))*180/%pi)
73 printf("\n  $\text{dash}_b2 = %0.1f$  degrees",betab2dash)//
    Since value of  $\tan 'b_2$  is different ,  $'b_2$  is
    different
74 disp("This value is smaller than  $b_2$  which is
    expected from 6.13c")

```


Scilab code Exa 6.7 C

```
1 clear all; clc;
2
3 disp("Inlet Configuration selection: Mr1,t=0.75 and
      fl =25 degrees")
4 M_r1t=0.75
5 beta_f1=25*%pi/180
6 M_1t=M_r1t*sin(beta_f1)
7 printf(" M_1t=%0.3 f",M_1t)
8
9 disp("T1=To1/(1=((k-1))*(M_1t^2)/2)")
10 T1=530/(1+0.2*(0.317^2))
11 printf("\n Thus the value of T1= %0.1 fR",T1)
12
13 a1=(1.4*53.33*32.2*519.6)^0.5
14 printf("\n a1= %0.2 f ft/s",a1)//answer provided here
      is more accurate
15
16 V_1t=0.317*1117.6
17 printf("\n V1=%0.1 f ft/s",V_1t)
18
19 W_1t=0.75*1117.6
20 printf("\n W_1t= %0.1 f ft/s",W_1t)
21
22 U_1t=[(838.2^2)-(354.3^2)]^0.5
23 printf("\n U_1t= %0.1 f ft/s",U_1t)
24
25 omega=1623
26 U_1t=759.6
27 r_1t=U_1t/omega
28 printf("\n So we have r_1t= %0.3 f ft=5.6 in",r_1t)
29
30 //let x=k/k-1
```

```

31 x=3.5
32 po1=14.7
33 T_1=519.6
34 T_o1=530
35 p1=po1*[(T_1/T_o1)^x]
36 printf("\n So we have p1= %0.1f psia",p1)
37
38 p1=13.7
39 R=53.33
40 T1=519.6
41 rho1=(p1*144)/(R*T_1)
42 printf("\n rho1= %0.4f lbm/ft ^3",rho1)
43
44 m=17
45 rho1=0.0713
46 V1=354.3
47 A1=m/(rho1*V1)
48 printf("\n A1= %0.3f ft ^2=96.9 in ^2, assuming
         uniform inlet flow.\n\n",A1)
49
50 disp("From pi*[(r_1t ^2)-(r_1h ^2)]=A1")
51 disp("We have r_1h={[(r_1t ^2)-A1]/pi}^0.5=0.72 in")
52 disp("U_1h=97.0 ft/s")
53
54 disp(" f1 ,h=taninverse(V_1h/U_1h)")
55 V_1h=354.3
56 U_1h=97
57 beta_f1h=(atan(V_1h/U_1h))*180/%pi
58 printf(" f1 = %0.1f degrees",beta_f1h)
59
60 disp("(B) Outlet Configuration From")
61
62 Cp=0.24
63 To1=530
64 //let y=(k-1)/k=0.2857
65 y=0.2857
66 //let m=po2/po1
67 m=2.5

```

```

68 H_ad=Cp*To1*778*[(m)^(y)-1]
69 printf(" H_ad=H_ad=Cp*To1*778[(po2/po1)^((k-1)/k)-1]
        %0.0f ft-lbf/lbm ",H_ad)
70
71 m=17
72 rho1=0.0713
73 Q1=m/rho1
74 printf("\n Q1=%0.1f ft^3/s",Q1)
75
76 N=15500
77 H_ad=29614
78 Q1=238.4
79 Ns=N*(Q1^0.5)/((H_ad)^0.75)
80 printf("\n We obtain specific speed %0.0f rpm*{(ft
        ^3/s)^0.5}(ft-lbf/lbm)^0.75 ",Ns)
81
82 disp("Fom figure 6.7 we have estimated Eta_c=0.87
        and Ds=D2*(H_ad)/(Q1^0.5)=1.50")
83 D2=1.5*(238.4^0.5)/(29614^0.25)
84 printf("\n D2=%0.4f ft=21.2 inches or r2=10.6 in.
        and U2=r2*omega=1433.7 ft/s",D2)
85
86 disp("Referring to figure 6.16c,we have T_sso3=T_o1
        *(po3/po1)^((k-1)/k)")
87 //((k-1)/k)=x
88 x=0.2857
89 T_o1=530
90 //let l=po3/po1
91 l=2.5
92 T_sso3=T_o1*(l^x)
93 printf(" T_sso3= %0.1f R ",T_sso3)
94 disp("From Eta_c=(T_sso3-(T_o1))/(To3-To1) we have
        To2=To3")
95 //let l=To2/To3
96 l=(1/0.87)*(688.6-530)+530
97 printf(" To2/To3 %0.1fR",l)
98 disp("Also from Etam=U2*Vu2/[Cp*(T_o2-T_o1)]")
99

```

```

100 Vu2=0.95*0.24*778*32.2*(712.3-530)/(1433.7)
101 printf(" With the estimated Eta_m=0.95,Vu2=%0.1 f ft/
    s",Vu2)
102
103 disp("Flow coefficient    =Vm2/U2=0.30 ")
104 Vm2=0.3*1433.7
105 printf(" Vm2=%0.1 f ft/s",Vm2)
106
107 disp("W2=[Vm2^2+(U2-Vu2)^2]^0.5=827.9 ft/s")
108 disp("V2=[Vu2^2+Vm2^2]^0.5=844.1 ft/s")
109
110 W1t=838.2
111 W2=827.9
112 Df=W1t/W2
113 printf(" Hence we have diffusion factor Df=%0.3 f.
    The value is less than 1.9 which is okay.",Df)
114
115 disp("The impeller efficiency can be estimated from
    the losses fraction X=(1-Eta_imp)/(1-Eta_c) is
    approximately =0.6 ")
116 Eta_imp=1-0.6*(1-0.87)
117 printf("\n Eta_imp %0.3 f",Eta_imp)
118
119 disp("Hence from Eta_imp=(T_so2-T_o1)/(T_o2-T_o1),we
    have T_so2=T_o1+Eta_imp*(To2-T_o1)=698R and po2=
    po1*(T_so2/T_o1)^(k/(k-1))")
120 po1=14.7
121 T_so2=698.1
122 T_o1=530
123 //Let x=(k/(k-1))
124 x=3.5
125 po2=po1*(T_so2/T_o1)^x
126 printf(" po2=%0.2 f psia ",po2)
127
128 disp("Then from the energy equation we have T2=T_o2-
    V2^2/(2*Cp)=653.0R")
129 disp("Hence p2=p02*(T2/To2)^(k/(k-1))=28.4 psia and
    rho2=p2/(R*T2)=0.117lbm/ft^3")

```

```

130
131 disp(" Selecting Zb=16 and using the Stanitz formula
      for the slip coefficient we have Vdash_u2=Vu2
      +0.63*pi*U2/Zb")
132 Vu2=726.3
133 U2=1433.7
134 Zb=16
135 Vdash_u2=Vu2+0.63*pi*U2/Zb
136 printf(" Vdash_u2= %0.1f ft/s",Vdash_u2)
137
138 disp(" tan _b2=Vm2/(U2-Vdash_u2)")
139 Vm2=430.1
140 U2=1433.7
141 Vdash_u2=903.6
142 tan_beta_b2=Vm2/(U2-Vdash_u2)
143 printf(" tan _b2=%0.2f ",tan_beta_b2)
144
145 betab2=(atan(tan_beta_b2))*180/pi
146 printf("\n _b2 = %0.0f degrees",betab2)
147
148 disp(" With blade thickness t=0.15,contraction factor
      is determined")
149 Zb=16
150 t=0.15
151 betab2=39*pi/180
152 D2=21.3
153 epsilon2=1-[(Zb*t)/(sin(betab2))]/(pi*D2)
154 printf(" Thus epsilon2= %0.2f",epsilon2)
155
156 disp(" Hence from the mass equation we can determine
      b2")
157 b2=17/(0.117*430.1*pi*1.765*0.94)
158 printf(" b2=%0.4f=0.78 inch",b2)

```

Scilab code Exa 6.8 C

```

1 clear all; clc;
2
3 disp("Using figure 6.7 the specific speed  $N_s=N(V1$ 
       $^0.5)/(H_{ad}^0.75)$  should be calculated based on
      the inlet volumetric flow rate  $V1$  and the
      adiabatic head per stage  $H_{ad}$ ")
4 p1=14.7
5 R=53.3
6 T1=530
7 rho1=p1*144/(R*T1)//144 is conversion factor.the
      actual formula is rho1=p1/(R*T1)
8 printf(" From rho1=p1/(R*T1) =%0.3 f lbm/ft ^3, we
      have V1",rho1)
9
10 V1=100/0.075
11 printf("\n Thus V1= %0.0 f ft ^3/s.",V1)
12
13 disp("Also from equation (A.3), we have total
      adiabatic head  $H_{ad} =C_p*T1*[(p_e/p_i)^{((k-1)/k)}-1]$ 
      ")
14 Cp=0.24
15 T1=530
16 p_e=50
17 p_i=14.7
18 //Let y= (k-1)/k
19 y=0.2857
20 H_ad=Cp*T1*778*[{(p_e/p_i)^(y)}-1]//778 is conversion
      factor
21 printf(" Thus H_ad = %0.0 f lbf-ft/lbm \n",H_ad)
22
23 disp("The specific speeds for different number of
      stages are calculated as follows ")
24
25 Ns=4800*(1333^0.5)/(41436^0.75)
26 printf(" For n=1 , Ns=4800*(1333^0.5)/(41436^0.75)=
      %0.0 f ",Ns)
27
28 Ns=4800*(1333^0.5)/(13812^0.75)

```

```

29 printf("\n For n=3 , Ns=4800*(1333^0.5)/(13812^0.75)
    =%0.2 f " ,Ns)
30
31 Ns=4800*(1333^0.5)/(10359^0.75)
32 printf("\n For n=4 , Ns=4800*(1333^0.5)/(10359^0.75)
    =%0.0 f " ,Ns)
33
34 Ns=4800*(1333^0.5)/(6906^0.75)
35 printf("\n For n=6 , Ns=4800*(1333^0.5)/(6906^0.75)=
    %0.0 f " ,Ns)
36
37 Ns=4800*(1333^0.5)/(5179^0.75)
38 printf("\n For n=8 , Ns=4800*(1333^0.5)/(5179^0.75)=
    %0.0 f " ,Ns)
39
40 disp("Reading the curves in figure 6.7,the best
    efficient point is around Ns=280 with Eta=0.90")
41 disp("ds=D*(H_ad^0.25)/(V1^0.5)=0.7")
42 disp("Hence 8 stage mixed flow impellers are
    selected.")
43
44 D=0.7*(1333^0.5)/((41436/8)^0.25)
45 printf(" The impeller diameter is calculated to be =
    %0.1 f ft" ,D)
46
47 m=100
48 H_ad=41436
49 Eta=0.9
50 Ps=m*H_ad/(Eta*550)//converting units
51 printf("\n The total required shaft power Ps=m*H_ad
    /(Eta)=%0.0 f hp" ,Ps)

```

Scilab code Exa 6.9 C

```

1 clear; clc;

```

```

2
3 m = 100;
4 disp("The inlet specific volume is calculated from
      the ideal gas equation")
5 R=53.3
6 T1=580
7 p1=65
8 nu1=(R*T1)/(144*p1)
9 printf(" nu1=%0.3 f ft ^3/lbm=",nu1)
10
11 disp("Q1=m*v1=4594 cfm")
12
13 R=53.3
14 T1=580
15 //let y=(n/(n-1))
16 y=2.625
17 p2=250
18 p1=65
19 H_oa=R*T1*(y)*[(p2/p1)^(1/y)-1]
20 printf(" The overall adiabatic head is calculated as
      H_o/a= %0.0 f ft-lbf/lbm",H_oa)
21
22 y=(0.75*1.4)/(1.4-1)
23 printf("\n Where n/(n-1)=(Eta_p*k)/(k-1)=%0.3 f",y)
24
25 disp("From figure 6.7 , a centrifugal compressor
      with speed N=10000rpm is appropriate for the
      present application")
26
27 disp("To use figure 6.7,the specific speed can be
      calculated from Ns=N*(V1^0.5)/(H_ad^0.75)")
28 V1=4954/60
29 printf(" Where V1= %0.1 f cfs",V1)
30 disp("H_ad=(H_o/a)/Eta_s is the head for each stage
      .")
31 disp("Selecting the number of stages to be 2,4, and
      6,the head for each stage and specific speed can
      be calculated ,then the total-to-total adiabatic

```



```

    efficiencies can be read ")
32 disp("The required shaft horse power can be
    calculated with the volumetric and mechanical
    efficiencies assumed to be 0.98 and 0.95
    respectively")
33 disp("That is  $P_s = (m \cdot (H_o/a)) / (33000 \cdot \eta_{ad} \cdot \eta_v \cdot \eta_m)$ ")
34
35 H_oa=54417
36 V1=82.6
37  $\eta_v=0.98$ 
38  $\eta_m=0.95$ 
39 N=10000
40
41 StageNo=[2 4 6];
42  $\eta_{ad}=[0.72 \ 0.83 \ 0.87]$ ;
43
44
45 H_ad= zeros(1,length(StageNo));
46 Ns = zeros(1,length(StageNo));
47 Ps = zeros(1,length(StageNo));
48
49 for i = 1: length(StageNo)
50
51     H_ad(i) =H_oa/(StageNo(i));
52     Ns(i) =N*(V1^0.5)/(H_ad(i)^0.75);
53     Ps(i) = (m*H_oa)/(33000* $\eta_{ad}(i)$ * $\eta_v$ * $\eta_m$ );
54
55 end
56
57 disp(" StageNo      H_ad          Ns           $\eta_{ad}$ 
    Ps")
58 disp("          (ft-lbf/lbm)          (
    hp)")
59 table = [StageNo' H_ad' Ns'  $\eta_{ad}$ ' Ps'];
60 disp(table)

```

Scilab code Exa 6.10 C

```
1 clear all; clc;
2
3 disp("From table 6.1 at 1.25 SP, the rotating speeds
      for Q1=11172cfm and Q2=12103cfm are N1=474rpm and
      N2=483 rpm respectively")
4 Ns=474+[(483-474)*(12000-11172)]/[12103-11172]
5 printf(" Hence the rotating speed for the selected
      fan is determined by inetrpolation %0.0f rpm\n\n"
      ,Ns)
6
7 disp("Select a few data points around 482 rpm from
      table 6.1 as:")
8 Q=[14896 12103 11172 11172 10241 7448];
9 N=[490 448 436 474 466 360];
10 SP=[1.0 1.0 1.0 1.25 1.25 0.75];
11 BHP=[3.66 2.67 2.40 2.97 2.75 1.2];
12
13 disp(" Q(cfm)    N(rpm)    SP(in.wg)    BHP(hp)")
14 table=[Q' N' SP' BHP']
15 disp(table)
16
17 disp("Convert them into condition of 482 rpm
      according to the similarity laws, resulting in")
18 Q1=[14653 13021 12350 11360 10593 9972];
19 SP1=[0.967 1.16 1.22 1.29 1.34 1.34];
20 BHP1=[3.5 3.20 3.24 3.12 3.04 2.88];
21 table1=[Q1' SP1' BHP1']
22 disp(" Q(cfm)    SP(in.wg)    BHP(hp)")
23 disp(table1)
24
25 disp("The system curve can be calculated from the
      following table")
```

```

26
27 Q2=[10000 11000 12000 13000 14000];
28 H2=[0.87 1.05 1.25 1.47 1.70];
29
30 sqrQ2 = zeros(1,length(Q2));
31
32 for i = 1: length(Q2)
33
34     sqrQ2(i) = [Q2(i)]^2;
35
36
37 end
38
39
40 table2=[Q2' H2']
41 disp("  Q(cfm)  H(in.wg)")
42 disp(table2)
43
44 disp("The system curve can be calculated from H
      versus Q^2. It is plotted as shown.")
45 //The system curve has not been provided in the book
      for this numerical. However they have mentioned
      that the parameters for the curve are H and Q^2,
      and as such has been plotted here.
46 plot(sqrQ2,H2)
47 xlabel("Q^2 ")
48 ylabel("H")
49 set(gca(),"grid",[1 1])
50 xtitle("System curve: H versus Q squared")

```

Chapter 7

Axial Flow Compressors

Scilab code Exa 7.1 AFC

```
1 clear all; clc;
2
3 disp("From (poe/poi)=[(Toi+ns*deltaTo)]^(k*eff*p/(k
  -1))")
4 disp("From the above mentioned equation we can find
  out the value of deltaTo")
5 delta_To=((8^(1/(3.5*0.87)))-1)*530/7
6 printf("deltaTo= %0.1f degrees Farenheit",delta_To)
7
8 Q=450
9 r_m1=9
10 b=3
11 V_a1=(Q*144)/(2*pi*r_m1*b)
12 printf("\n Thus Va1 = %0.0f fps",V_a1)
13
14 N=12000
15 U=(N*pi*9)/(30*12)
16 printf("\n N= %0.1f fps",U)
17
18 disp("deltaho=U*Va*(tan 1 - tan 2) and R=( /2)*(
  tan 1+tan 2")
```

```

19 //let y= tan 1-tan 2
20 y=[(0.24*778*74.2*32.2)/(942.5*382)]
21 printf("\n Thus tan 1-tan 2= %0.2f",y)
22
23 //let x=tan 1+tan 2
24 x=(0.5*2*942.5/382)
25 printf("\n Thus tan 1+tan 2= %0.3f",x)
26
27 disp("Hence we get tan 1=1.853")
28 tanbeta1=1.853
29 beta_1=(atan(tanbeta1))*180/%pi
30 printf("\n The value of 1 = %0.1f degrees",beta_1)
31 disp("Also tan 2=0.613")
32 tanbeta2=0.613
33 beta_2=(atan(tanbeta2))*180/%pi
34 printf("\n The value of 2 = 1 = %0.1f degrees",
        beta_2)
35
36 disp("Ps=m*Cp*ns*deltaTo/etam")
37 P_s=(0.075*450*0.24*778*7*74.2)/(550*0.95)
38 printf("\n The total power required is Ps= %0.0f hp"
        ,P_s)
39
40 disp("The adiabatic efficiency is given as ((poe/poi
        )^(((k-1)/k))-1/((Toe/Toi)-1)")
41 ETA_ad=0.811/0.979
42 printf("\n Thus adiabatic efficiency is %0.4f",
        ETA_ad)//answer given in the book is 0.827,but
        this is more accurate
43
44 disp("ETAc=ETAm*ETAad")
45 ETA_m=0.95
46 ETA_ad=0.827
47 ETA_c=ETA_m*ETA_ad
48 printf(" Hence ETAc= %0.3f ",ETA_c)
49 disp(" Thus ETAc=78.6%")

```

Scilab code Exa 7.2 AFC

```
1 clear all; clc;
2
3 r_h=15
4 r_t=24
5 r_m=((r_h^2+r_t^2)/2)^0.5
6 printf("rm= %0.0f in",r_m)
7
8 N=6000
9 r_m=20
10 U_m=N*pi*r_m/(12*30)
11 printf("\n U_m= %0.2f ft/s",U_m)
12
13 disp("We have  $\psi = \lambda \phi (\tan m_1 - \tan m_2)$ ")
14 //let x=tan m1-tan m2
15 x=(0.24*778*32.2*35)/(0.92*1047.2*450)
16 printf("\n Hence we can find out  $\tan m_1 - \tan m_2 = %0.3f$ ",x)
17
18 disp("From equation 7.2B for  $R_m=0.5$  we have  $m_1 = m_2$ ")
19 disp("We get values of  $\tan m_1 + \tan m_2 = 2.325$  and  $\tan m_1 - \tan m_2 = 2.325$ ")
20
21 disp("Hence we have  $\tan m_1 - \tan m_2 = 0.485$ ")
22
23 tanalpham1=0.92
24 alphas_1=((atan(tanalpham1)))*180/pi
25 printf("\n Thus  $m_1 = %0.1f$  degrees",alphas_1)
26
27 tanalpham2=1.405
28 alphas_2=((atan(tanalpham2)))*180/pi
```

```

29 printf("\n Thus  m2 = %0.2f degrees",alphan_2)
30
31 disp("To determine the flow angles at the hub and
      tip, we use the free vortex condition of  $V_{ur} = \text{const}$ 
      , or  $r \tan h = r_t \tan t = r_m \tan m$ . Hence the flow
      angles can be determined.")
32
33 tanalphah1=0.92*20/15
34 printf("\n tan h1= %0.3f",tanalphah1)
35 alpha_h1=((atan(tanalphah1)))*180/%pi
36 printf("\n Thus  h1 = %0.1f degrees",alpha_h1)
37
38 tanalphat1=0.92*20/24
39 printf("\n\n tan t1= %0.3f",tanalphat1)
40 alpha_t1=((atan(tanalphat1)))*180/%pi
41 printf("\n Thus  t1 = %0.1f degrees",alpha_t1)
42
43 tanalphah2=1.405*20/15
44 printf("\n\n tan h2= %0.3f",tanalphah2)
45 alpha_h2=((atan(tanalphah2)))*180/%pi
46 printf("\n Thus  h1 = %0.1f degrees",alpha_h2)
47
48 tanalphat2=1.405*20/24
49 printf("\n\n tan t2= %0.3f",tanalphat2)
50 alpha_t2=((atan(tanalphat2)))*180/%pi
51 printf("\n Thus  h1 = %0.1f degrees",alpha_t2)
52
53 disp("The degree of reaction at the hub and tip can
      be determined.")
54 Rh=1-((1-0.5)/((15/20)^2))
55 Rt=1-((1-0.5)/((24/20)^2))
56 printf("\n Rh= %0.2f",Rh)
57 printf("\n Rt= %0.2f",Rt)

```

Scilab code Exa 7.3 AFC

```

1 clear all; clc;
2
3 disp("From the previous numerical we have m1 = m2
      =54.5 degrees , tan m1=1.405")
4 disp(" m2 = m1 =42.6 degrees . Thus tan m2=0.92")
5
6 disp("tan m1 -tan m2 =1.55(1+1.5*(s/c)) ,thus we can
      determine s/c")
7 //let x= s/c
8 x=[1.55/(1.405-0.92) -1]/1.5
9 printf("Thus (s/c)= %0.2 f" ,x)
10
11 disp(" Also b/c=3,we have c=(rt-rh)/3")
12 rt=24
13 rh=15
14 c=(rt-rh)/3
15 printf("\n c= %0.0 f in" ,c)
16
17 s=1.47*c
18 printf("\n Hence we determine s to be equal to %0.1 f
      in" ,s)
19
20 rm=20
21 Zb=2*pi*rm/s
22 printf("\n Zb= %0.0 f" ,Zb)
23
24 disp("The blade angles can be estimated from b1 =
      m1 -i and b2 = m2 - ")
25 disp("Where i=3 degrees and =m* *((s/c)^0.5)")
26
27 //let n=a/c
28 n=0.5
29 disp("m=0.23*((2*(a/c))^2)+0.1*( m2 /50)")
30 disp(" = m1 - m2 ")
31 thita=11.9
32 m=0.23+(0.1*42.6/50)//for circular blade
33 printf("\n m= %0.3 f" ,m)
34 m=0.315

```



```

35 x=1.47
36 delta=m*thita*(x^0.5)
37 printf("\n    = %0.1f degrees",delta)
38
39 beta_b1=54.5-3
40 printf("\n  b1 = %0.1f degrees",beta_b1)
41
42 beta_b2=42.6-4.5
43 printf("\n  b2 = %0.1f degrees",beta_b2)

```

Scilab code Exa 7.4 AFC

```

1  clear all; clc;
2
3  disp("We have psia=lamda*psi=lambda*phi*(tan m1 -
      tan m2) and R=0.5* (tan 1+tan 2) we can
      obtain the values of tan 1 and tan 2")
4  //let x=tan m1-tan m2
5  x=0.35/(0.92*0.5)
6  printf("\n tan m1-tan m2= %0.3f",x)
7
8  //let y=tan 1+tan 2
9  y=2*0.5/0.5
10 printf("\nThus tan 1+tan 2= %0.3f",y)
11
12 disp("Hence tan 1=1.38")
13 tanbeta1=1.38
14 beta_1=((atan(tanbeta1)))*180/%pi
15 printf("\nThus the value of 1 is equal to %0.1f
      degrees",beta_1)
16
17 disp("tan 2=0.619")
18 tanbeta2=0.619
19 beta_2=((atan(tanbeta2)))*180/%pi
20 printf("\nThus the value of 1 is equal to %0.1f

```

```

    degrees",beta_2)
21
22 disp("For each stage we have  $\psi=C_p \cdot \Delta T_{os} / ((U_m)^2)$ ")
23 delta_T_os=0.35*(920^2)/6012
24 printf("\nHence  $\Delta T_{os} = %0.1 f$  R",delta_T_os)
25
26 Cp=0.24*778*32.2
27 printf("\nWhere  $C_p = %0.0 f$  ft-lbf/slug",Cp)
28
29 disp("For overall compressor form equation 47.4 we
    have  $(P_{oe}/P_{oi}) = [(1 + \Delta T_{oe}/T_{oi})]^{(k \cdot \text{eff} \cdot p / (k-1))}$ ")
30 delta_T_oe=530*[(4.5^(0.2857/0.9))-1]
31 printf("\nThus  $\Delta T_{oe} = %0.0 f$  R",delta_T_oe)
32
33 disp("The number of stages can be calculated as  $n_s = \Delta T_{oe} / \Delta T_{os}$ ")
34 delta_T_oe=324
35 delta_T_os=49.3
36 ns=delta_T_oe/delta_T_os
37 printf("\nThus  $n_s = %0.2 f$ ",ns)
38 disp("ns is approximately equal to 7")
39
40 disp("Hence the actual values are: ")
41 delta_T_oe=7*49.3
42 printf("deltaToe= %0.1 f R",delta_T_oe)
43
44 //let f=poe/poi
45 f=(1+(345.1/530))^(0.9*3.5)
46 printf("\n poe/poi= %0.2 f",f)
47
48 disp("The adiabatic efficiency is given as  $((P_{oe}/P_{oi})^{((k-1)/k)} - 1 / ((T_{oe}/T_{oi}) - 1))$ ")
49 //let k-1/k=d
50 d=0.2857
51 f=4.85
52

```

```

53 ETA_ad=((f^(d))-1)/((345.1/530))
54 printf("\nETAad= %0.4 f",ETA_ad)
55 //let r=ETAd*100
56 r=ETA_ad*100
57 printf("\n Thus ETAad= %0.2 f percent",r)

```

Scilab code Exa 7.5 AFC

```

1 clear all; clc;
2
3 disp("Assume constant axial flow velocity Va=500 ft/
   s , no prewhirl and hence V1=Va for the first
   stage and frre vortex conditions for all stages."
   )
4
5 disp("1. First Stage")
6
7 T1=530-((500^2)/(2*6012))
8 printf("T1= %0.1 f R",T1)
9
10 p1=14.7*((509.2/530)^3.5)
11 printf("\n p1= %0.2 f psia",p1)
12
13 rho_1=(12.78*144)/(53.33*509.2)
14 printf("\n rho_1= %0.5 f lm/ft ^3",rho_1)
15
16 disp("With a selected nu=rh/rt=0.45, A=m/(rho_1*Va)"
   )
17 m=65
18 rho_1=0.0677
19 Va=500
20 A=m/(rho_1*Va)
21 printf("\n A= %0.2 f ft ^2 = 276.5 in ^2",A)
22
23 disp("A=pi*(r_t ^2)*(1-nu ^2)")

```

```

24 A=276.5
25 nu=0.45
26 r_t=sqrt(A/(%pi*(1-(nu^2))))
27 printf("\n r_t= %0.1 f in",r_t)
28
29 disp("rm=7.6 in")
30
31 disp("Ut=rt*omega")
32 N=15000
33 omega=N*%pi/30
34 rt=10.5/12//in feet
35 Ut=rt*omega
36 printf("\n Ut %0.1 f ft/s",Ut)
37
38 rh=4.7/12//in feet
39 Uh=rh*omega
40 printf("\n Uh= %0.1 f ft/s",Uh)
41
42 rm=7.6/12//in feet
43 Um=rm*omega
44 printf("\n Um= %0.1 f ft/s",Um)//answer given in the
    book is 996.6,however 994.8 is more accurate
45
46 disp("Without inlet whirl flow ,we have Wt=(Ut^2+Va
    ^2)^0.5")
47 Ut=1374.4
48 Va=500
49 Wt=sqrt(Ut^2+Va^2)
50 printf("\n Thus Wt = %0.0 ft/s",Wt)
51
52 Uh=615.2
53 Va=500
54 Wh=sqrt(Uh^2+Va^2)
55 printf("\n Thus Wh = %0.1 ft/s",Wh)
56
57 Um=996.6//This is the answer substituted in the book
    ,although as mentioned earlier 994.8 is more
    accurate.

```

```

58 Va=500
59 Wm=sqrt(Um^2+Va^2)
60 printf("\n Thus Wm = %0.1 ft /s", Wm)
61
62 tanbeta1m=Um/Va
63 printf("\n tan 1m= %0.2 f", tanbeta1m)
64
65 beta1m=((atan(tanbeta1m)))*180/%pi
66 printf("\n 1m = %0.1 f degrees", beta1m)
67
68 disp("With a1=(k*R*T1)^0.5=1309 ft/s, the relative
      Mach numbers can be determined.")
69 Wt=1463
70 a1=1309
71 M_rt=Wt/a1
72 printf("\n M_rt= %0.2 f", M_rt)
73
74 Wh=792.8
75 M_rh=Wh/a1
76 printf("\n M_rh= %0.3 f", M_rh)
77
78 Wm=1115.0
79 M_rm=Wm/a1
80 printf("\n M_rm= %0.2 f", M_rm)
81
82 disp("Hence the relative flow at the leading edge is
      transonic, and a supersonic blade might be needed
      .")
83 disp("From the previous sum, to achieve a pressure
      ratio of 4.5, we have deltaTos=324/7=46.3R.")
84 disp("So deltaTos=45R is selected at the first stage
      .")
85 disp("From Cp*deltaTos=lambda*Um*Va*(tan 1m-tan 2m
      ), with lambda=0.95, we obtain tan 2m=1.42. Thus
      2m =54.8 degrees")
86
87 tanbeta1=1.99
88 tanbeta2=1.42

```

```

89 Va=500
90 Um=996.6
91 R=(Va/(2*Um))*(tanbeta1+tanbeta2)
92 printf("\n R=(Va/(2*Um))*(tanbeta1+tanbeta2)= %0.3 f"
    ,R)
93
94 disp("We have nu=(1-R)^0.5")
95 nu=sqrt(1-R)
96 printf("\n nu= %0.2 f",nu)
97
98 disp("This is less than the selected value and is
    acceptable.")
99 beta1=63.3
100 beta2=54.8
101 deHaller=cos(beta1*pi/180)/cos(beta2*pi/180)
102 printf("\n Also checking the deHaller number W2/W1=
    cos 1/cos 2=%0.2 f >0.70,it is also acceptable",
    deHaller)
103
104 disp("Before proceeding to the next stages ,the
    following parameters have to be specified. The
    summation of deltaTos should add upto 324degrees.
    So the following arrangement is chosen")
105 Stage_number=[1 2 3 4 5 6 7 ];
106 deltaTos_R=[45 46 47 47 47 47 45];
107 lambda=[0.95 0.93 0.90 0.89 0.88 0.86 0.85];
108 R=[0.855 0.8 0.7 0.63 0.60 0.55 0.5];
109 table=[Stage_number' deltaTos_R' lambda' R']
110 disp("The table from left to right has values of
    Stagenumber deltaTos lamdbda and R")
111 disp(table)
112
113 disp(" 2.Second Stage")
114
115 To1=530+45
116 printf("To1= %0.0 f R",To1)
117
118 po1=14.7*((1+(0.9*45/530))^3.5)

```

```

119 printf("\n po1= %0.0f psia",po1)
120
121 disp("With the specified values of deltaTos ,lamda
      and R, equations 7.1 and 7.2A can be solved for
      tan 1 and tan 2.")
122 disp("Hence 1 =62.1 degrees and 2 =52.4 degrees ,
      where W2/W1=0.76 > 0.70")
123 beta1=62.1*%pi/180 //converting to radians
124 V1=[(Va^2)+(Um-(Va*tan(beta1)))^2]^0.5
125 printf(" Also we have V1=[(Va^2)+(Um-(Va*tan(beta1)))
      ^2]^0.5= %0.2f ft/s",V1)//answer in the book is
      502.6, however the value found out here is more
      accurate
126
127 Cp=6012
128 V1=502.6
129 T1=To1-((V1^2)/(2*Cp))
130 printf("\nT1= %0.0f R",T1)
131
132 po1=19
133 T1=554
134 To1=575
135 p1=po1*((T1/To1)^3.5)
136 printf("\np1= %0.1f psia",p1)
137
138 disp("rho1= p1/(R*T1)= 0.0813 lb_m/ft^3")
139
140
141
142 disp("A=m/(rho1*Va)=230")
143 disp("A is also = 2*pi*r_m*b")
144 disp("Where b=rt-rh and rm is the same as that for
      the first stage. Hence we have rt=10 in ,rh=5.2 in
      and nu=0.52, which is greater than nu_min(0.447)
      ")
145
146 disp("3. Third to Seventh stage")
147 disp("The calculation procedure for these stages

```

```

    will be similar to the second stage. The
    calculations have not been repeated in the book,
    and hence the same is done here.")
148 disp("The results are as follows")
149
150 Stagenumber=[1 2 3 4 5 6 7];
151 To1=[530 575 621 668 715 762 809];
152 po1=[14.7 19 24.3 30.5 37.9 46.3 55.9];
153 rt=[10.5 10 9.6 9.3 9.1 8.9 8.8];
154 rh=[4.7 5.2 5.6 5.9 6.1 6.3 6.5];
155 rm=[7.6 7.6 7.6 7.6 7.6 7.6 7.6 ];
156 beta1=[63.3 62.1 59.7 57.5 56.5 54.7 52.4];
157 beta2=[54.9 52.3 47.2 43.2 41.4 38 34.8]
158 table2=[Stagenumber' To1' po1' rt' rh' rm' beta1'
           beta2']
159 disp("Stageno. To1      po1      rt      rh      rm
           beta1      beta2")
160 disp(table2)
161
162 disp("The final discharge stagnation pressure can
           also be checked with the flow across the last
           stage such that poe=po3=po1(1+ETAs*(deltaTos/To1)
           )^(k/(k-1))")
163 po1=55.9*(1+(0.9*45/809))^3.5
164 printf("po1= %0.1f psia",po1)
165 //let n=poe/poi
166 n=66.3/14.7
167 printf("\n This checks with poe/poi = %0.2f",n)

```

Scilab code Exa 7.6 AFC

```

1 clear all; clc;
2
3 disp("We have psi=lambda*[1-      *(tan 1+tan 2)] and
           R=0.5+[( /2)*(tan 2-tan 1)]")

```



```

4 disp("We have  $\tan \alpha + \tan \beta = (1 - \psi/\lambda) = 1.01$ ")
5 disp("  $\tan \alpha - \tan \beta = (1 - 2R)/\lambda = -0.545$ , or  $\psi = \lambda$ 
       $\ast(1 - 1.01\lambda)$  and  $R = 0.5 + 0.272\lambda$  Hence  $\psi = 0.495$ , assuming  $\lambda$  to be constant we can
      determine the values of  $\psi$  and  $R$ ")
6
7 lambda=0.9
8 //Let  $(\tan \alpha + \tan \beta) = x$ 
9 x=1.01
10 psi_dash=0.495
11 psi_dash=lambda*[1-(psi_dash*(x))]
12 printf("\n psi_dash= %0.2 f",psi_dash)
13
14 //Let  $0.5*(\tan \beta - \tan \alpha) = y$ 
15 y=0.272
16 R_dash=0.5+[(psi_dash*0.272)]
17 printf("\n R_dash= %0.3 f",R_dash)

```

Chapter 8

Gas Turbines

Scilab code Exa 8.1 GT

```
1 clear all; clc;
2
3 disp("From  $\eta_{Ad} = \frac{1 - ((p_{0e}/p_{0i})^{(\eta_{As}*(k-1)/k)})}{1 - ((p_{0e}/p_{0i})^{(k-1)/k})}$ ")
4  $\eta_{Ad} = \frac{1 - ((14.7/200)^{(0.85/3.5)})}{1 - (14.7/200)^{0.2857}}$ 
5 printf("\n  $\eta_{Ad} =$  %0.3 f",  $\eta_{Ad}$ )
6
7 disp("  $T_{soe}/T_{0i} = ((p_{0e}/p_{0i})^{((k-1)/k)})$ ")
8 //let  $T_{soe}/T_{0i} = w$ 
9  $w = (14.7/200)^{0.2857}$ 
10 printf("\n  $T_{soe}/T_{0i} =$  %0.4 f", w)
11
12  $T_{soe} = 0.4743 * (1800 + 460)$ 
13 printf("\n  $T_{soe} =$  %0.0 f R",  $T_{soe}$ )
14
15 disp("  $\eta_{Ad} = (T_{0i} - T_{0e}) / (T_{0i} - T_{soe}) = 0.893$ ")
16  $T_{0i} = T_{soe} / w$  //since  $T_{soe}/T_{0i} = w$ 
17  $T_{0e} = T_{0i} - (\eta_{Ad} * (T_{0i} - T_{soe}))$ 
18 printf(" Thus  $T_{0e} =$  %0.0 f R=739 degrees Farenheit",
     $T_{0e}$ )
```

```

19
20 disp(" Also for impulse turbine , we have  $2 = 3$  .
      Hence from  $\Delta H_0 = U_m \cdot (V_{u2} - V_{u3}) = U_m \cdot [U_m + V_a \cdot \tan^2 - (U_m - V_a \cdot \tan(3)) ] = 2 \cdot U_m \cdot V_a \cdot \tan$  ")
21 delta_h0=2*750*400*tan(50*%pi/180)
22 printf("\n delta_h0= %g is approximately equal to
      7.15*10^5 ((ft/s)^2)",delta_h0)
23 //Let 0.24*778*32.2*delta_T0=u
24 u=7.15*10^5
25 delta_T0=u/(0.24*778*32.2)
26 printf("\n\n Or 0.24*778*32.2*delta_T0=7.15*10^5,we
      have temperature rise per stage = %0.0f degrees
      Farenheit",delta_T0)
27
28 n_s=(1800-739)/119
29 printf("\n Hence the number of stages n_s= %0.2f is
      approximately equal to 9",n_s)

```

Scilab code Exa 8.2 GT

```

1 clear all; clc;
2
3 disp(" Referring to figure 8.3,we have  $T_{s2} = T_{01} \cdot ((p_2/p_{01})^{((k-1)/k)})$ ")
4 T_01=2860
5 p2=180
6 p01=250
7 k=1.4 //k=(Cp/Cv)
8 T_s2=T_01*((p2/p01)^((k-1)/k))
9 printf(" T_s2= %0.0f R",T_s2)
10
11 disp(" From  $\Delta s = (h_2 - h_{s2}) / ((V_2^2) / 2)$ ,we have  $C_p \cdot (T_2 - T_{s2}) = \Delta s \cdot (V_2^2) / 2$ . Combining with  $C_p \cdot (T_{02} - T_2) = ((V_2^2) / 2)$ , where  $T_{02} = T_{01}$ , we have  $C_p \cdot (T_{02} - T_{s2}) = (1 + \Delta s) \cdot ((V_2^2) / 2)$ ")

```

```

12 disp("V2=[2*Cp*(T_02-T_s2)/(1+epsilon_s)]^0.5")
13 T_02=T_01
14 Cp=0.24*778*32.2
15 epsilon_s=0.07
16 T_s2=2604
17 V2=[2*Cp*(T_02-T_s2)/(1+epsilon_s)]^0.5
18 printf(" V2= %0.0 f ft/s",V2)
19
20 V2=1696
21 alpha2=65*%pi/180//converting to radians
22 V_u2=V2*sin(alpha2)
23 printf("\n Hence we have V_u2=V2*sin( 2 ) = %0.0 f ft
    /s",V_u2)
24
25 Va=V2*cos(alpha2)
26 printf("\n Va=V2*cos(alpha2)= %0.1 f ft/s",Va)
27
28 disp("T2=T_02-(V_2^2)/(2*Cp)")
29 T_02=2860
30 V2=1696
31 Cp=0.24*778*32.2
32 T2=T_02-(V2^2)/(2*Cp)
33 printf(" Hence we have T2= %0.0 f R ",T2)
34
35 disp(" Since V1=Va, we have T1=T_01-((V1^2)/(2*Cp))")
36 V1=716.8
37 T_01=2860//2860R
38 T1=T_01-((V1^2)/(2*Cp))
39 printf("T1= %0.0 f R",T1)
40
41 disp("From delta_E=Cp*delta_T0s=U*(V_u2+V_u3)=U*V_u2
    , we have U=Ps/(m*V_u2)")
42 Ps=375*550*32.2//converting unit of Ps
43 m=3
44 V_u2=1537
45 U=Ps/(m*V_u2)
46 printf("U=%0.0 f ft/s",U)
47

```

```

48 disp("  =Va/U")
49 Va=716.8
50 U=1440
51 phi=Va/U
52 printf("  =%0.3 f" ,phi)
53
54 tanbeta3=U/Va
55 printf("\n tan 3= %0.2 f",tanbeta3)
56
57 beta3=((atan(tanbeta3))*180/%pi)
58 printf("\n 3 = %0.1 f degrees",beta3)
59
60 alpha3=0
61 phi=0.498
62 alpha2=65*%pi/180
63 R=1+((phi/2)*(tan(alpha3)-tan(alpha2)))
64 printf("\n R= %0.3 f",R)
65
66 disp(" Also from the velocity diagram in figure 8.4 ,
        we have tan 2=tan 2 -(1/ )=0.136,so 2 =7.8
        degrees")
67 disp(" Similarly we have W3=Va/ cos 3 =1606 ft/s and
        W2=Va/ cos 2 =723.5 ft/s")
68 disp(" Across the rotor we have h2+(W2^2)/2=h3+(W3^2)
        /2. Hence T3=T2+(W2^2)-(W3^2)/(2*Cp)=2450R")
69 disp(" We have Ts3=T3- r *(W3^2)/(2*Cp)=2424R")
70 disp(" Also p3=p2*(Ts3/T2)^(k/(k-1))=136.9 psia")
71 ETAs=(1+(0.12*(1606^2)+0.07*(1696^2)*(2450/2621))
        /(2*0.24*778*32.2*(2817-2450)))^-1
72 printf(" From equation 8.2 we have ETAs= %0.4 f",ETAs
        )
73
74 //Let j=0.498/2
75 j=0.498/2
76 //Let k=0.12*[(sec(63.5*%pi/180))^2]
77 k=0.12*[(sec(63.5*%pi/180))^2]
78 //Let l=0.07*(2450/2621)*[(sec(65*%pi/180))^2]
79 l=0.07*(2450/2621)*[(sec(65*%pi/180))^2]

```

```

80 //let m=tan(63.5*%pi/180)+tan(7.8*%pi/180)
81 m=tan(63.5*%pi/180)+tan(7.8*%pi/180)
82
83 ETAs=[1+((j*(k+1))/m)]^-1
84 printf("\n From equation 8.3 we have ETAs= %0.4 f",
      ETAs)
85
86 disp("Also ETAs can be calculated from ETAs=(T_01-
      T_03)/(T_01-T_ss03)")
87 disp("We have T_03=T3+V3^2/(2*Cp)")
88 disp("p03=p3*(T_03/T3)^(k/(k-1))")
89 disp("T_ss03=T_01*(p_03/(p_01)*((k-1)/k))")
90 ETAs=(2860-2493)/(2860-2450)
91 printf(" Hence we have ETAs= %0.3 f",ETAs)

```

Scilab code Exa 8.3 GT

```

1 clear all; clc;
2
3 disp("Use the velocity diagram shown in figure 8.2
      or 8.4")
4 disp("We have Vatan 2=Vatan 2-Um")
5 disp("Or tan 2=tan 2-Um/Va")
6
7 tanbeta2=tan(75*%pi/180)-1200/500
8 printf(" Thus tan 2= %0.2 f",tanbeta2)
9 beta2=((atan(tanbeta2))*180/%pi)
10 printf("\n Thus 2 = %0.2 f",beta2)
11
12 disp("Also Vatan 3=Vatan 3+Um")
13 disp("tan 3=tan 3+Um/Va")
14 tanbeta3=tan(10*%pi/180)+1200/500
15 printf(" tan 3= %0.2 f",tanbeta3)
16 beta3=((atan(tanbeta3))*180/%pi)
17 printf("\n 3 = %0.2 f",beta3)

```

```

18
19 disp("From  $C_p \Delta T_0 = \Delta E = U_m (V_{u2} + V_{u3}) = U_m V_a (\tan \alpha_2 + \tan \alpha_3)$ ")
20 deltaE=1200*500*(tan(75*%pi/180)+tan(10*%pi/180))
21 printf(" Thus  $C_p \Delta T_0 = \Delta E = %g = 2.34 \times 10^6$  ((ft/s)^2)",deltaE)
22
23 deltaT0s=(2.34*(10^6))/(0.24*778*32.2)
24 disp("  $\Delta T_0 = (2.34 \times 10^6) / (0.24 \times 778 \times 32.2)$ ")
25 printf(" Thus  $\Delta T_0 = %0.2f$  R which is rounded off to 890R",deltaT0s)
26
27 disp("Hence neglecting leakage and mechanical losses, we have shaft power output  $P_s = m C_p \Delta T_0$ ")
28 Ps=50*2.34*(10^6)/(32.2*550)
29 printf("\n Hence we have  $P_s = %0.2f$  hp which is rounded off to 6607hp",Ps)
30
31 disp("The degree of reaction at the mean radius can be determined from equation 8.5A")
32 R=(500/(2*1200))*(tan(68.8*%pi/180)-tan(53.1*%pi/180))
33 printf("\n Thus  $R = %0.3f$ ",R)
34
35 disp("To determine the radii the flow area  $A_2$  can be determined from  $m = \rho_2 A_2 V_a$ . The density  $\rho_2$  can be determined from  $p_2$  and  $T_2$  which can be calculated as follows.")
36 disp("From  $C_p T_0 = C_p T_2 + V_2^2/2$  and  $V_2 = V_a / \cos \alpha_2$ ")
37 V2=500/(cos(75*%pi/180))
38 printf("\n  $V_2 = %0.0f$  ft/s",V2)
39
40 T2=2000-(1932^2)/(2*0.24*778*32.2)
41 printf("\n Thus we have  $T_2 = %0.0f$  degrees Fahrenheit = 2150R",T2)
42
43 disp("From the definition of loss coefficient  $e$  we have  $T_{s2} = T_2 - s V_2^2 / (2 C_p)$ ")

```

```

44 Ts2=1690-(0.08*(1932^2))/(2*.24*778*32.2)
45 printf("\n Ts2= %0.2f degrees Farenheit which is
    equal to 2125.2R",Ts2)
46
47 //Let x= P2/p01
48 x=(2125.2/2460)^(1.4/0.4)
49 printf("\n and P2/p01= %0.2f",x)
50
51
52 P2=200*0.60
53 printf("\n P2= %0.0f psia",P2)
54
55 disp("Hence the density can be calculated as rho2=p2
    /(R*T2)")
56
57 rho2=120*144/(53.3*2150)
58 printf("\n Thus ro2=%0.3f lbm/ft^3",rho2)
59
60 A2=50/(0.151*500)
61 printf("\n A2=m/(rho2*Va)=%0.3f ft^2",A2)
62
63 //let y=rt^2-rh^2
64 y=0.662/%pi
65 printf("\n rt^2-rh^2=A2/pi=%0.3f",y)
66
67 rm=30*1200/(8000*%pi)
68 printf(" and rm= %0.2f ft",rm)
69
70 disp("rt^2+rh^2=2*rm^2=4.09ft^2")
71 disp("and 1.466ft , rh=1.393ft")
72 rt=1.466
73 rh=1.393
74 b=rt-rh
75 printf(" b= %0.3f ft=0.88in",b)

```

Scilab code Exa 8.4 GT

```
1 clear all; clc;
2
3 disp("For  $N/(T01^{1/2})=40$ , the following data of  $p02/p01$ ,  $\gamma/p01$  and  $\text{Eta}$  can be obtained from figure 8.9 a")
4 //let  $x=p02/p01$ 
5  $x=[0.70 \ 0.75 \ 0.8];$ 
6 //let  $y= \gamma/p01$ 
7  $y=[8.7 \ 5.3 \ 2.2];$ 
8  $\text{Eta}=[0.81 \ 0.64 \ 0.41];$ 
9 //let  $z=Ps/(p01*((T01)^{1/2}))$ 
10  $z=[0.066 \ 0.040 \ 0.017];$ 
11 //let  $i=m*((T01)^{1/2})/p01$ 
12  $i=[2.48 \ 2.34 \ 2.0];$ 
13  $\text{table}=[x' \ y' \ \text{Eta}' \ z' \ i'];$ 
14 disp(" The columns of the table are in the order  $p02/p01$   $\gamma/p01$   $\text{Eta}$   $Ps/(p01*((T01)^{1/2}))$  and  $m*((T01)^{1/2})/p01$ ")
15 disp(table)
16
17 disp("The power and mass flow rate have to be obtained with the following manipulations. ")
18 disp("Frm  $Ps= \dot{m} \omega$ , we obtain:")
19 disp(" $Ps/(p01*((T01)^{0.5}))= \dot{m} \pi / (30 \cdot 550 \cdot p01 \cdot ((T01)^{0.5}))$ ")
20 disp("Also from  $Ps/\dot{m}=\text{Eta} \cdot Cp \cdot T01 [1 - (p02/p01)^{((k-1)/k)}]$  we obtain")
21 disp(" $m*((T01)^{0.5})/p01 = \{ [Ps/(p01 \cdot T01^{0.5})] / (\text{Eta} \cdot Cp) \} \cdot [1 - (p02/p01)^{((k-1)/k)}]^{-1}$ ")
22 disp("Where  $(k-1)/k=0.40/1.4$ ")
23
24 //Let  $j=(k-1)/k=0.40/1.4$ 
25  $j=0.40/1.4$ 
26 printf("Thus= $(k-1)/k$  %0.4 f", j)
27
28 disp("And  $Cp= 0.24 \cdot \text{Btu} / (1 \text{bm} \cdot \text{R})$ ")
```

```

29 Cp=0.24*778/(550)
30 printf("Thus Cp= %0.4 f hp-s/(lbm*R)",Cp)

```

Scilab code Exa 8.5 GT

```

1 clear all; clc;
2
3 disp("From Um=rm*omega")
4 disp("We have rm=30*Um/(N*pi)")
5 rm=30*850/(8000*pi)
6 printf(" Thus rm= %0.2 f ft=12.1 in",rm)
7
8 disp("rm=(rt^2+rh^2/2)^0.5 or rt^2+rh^2=293.8")
9 disp("Combined with b=rt-rh=4 in ,we have rt^2-4rt
      -138.9=0,thus rt=13.95 in")
10
11 disp("and rh=9.95 in")
12
13 disp("To find the number of stages required the
      exhaust air temperature can be estimated as T0e=
      T0i*(p0e/p0i)^((k-1)/k)")
14 T0e=1400*(14.7/60)^0.2857
15 printf(" Thus T0e= %0.1 f R",T0e)
16
17 disp("The maximum energy available per unit mass of
      air is delta_Hs=Cp*(T0i-T0e)")
18 delta_Hs=0.24*(1400-936.7)
19 printf(" delta_Hs= %0.1 f Btu/lbm",delta_Hs)
20
21 disp("The maximum energy transfer per stage with an
      impulse turbine is deltaEi=2*Um^2")
22 delta_Ei=2*(850^2)/(32.2*778)
23 printf(" delta_Ei= %0.2 f Btu/lbm",delta_Ei)
24
25 disp("Hence the required number of stages is ETAsi=

```

```

    delta_Hs/delta_Ei")
26 ETAsi=111.2/57.68
27 printf(" ETAsi= %0.2f which is approximately equal
    to 2",ETAsi)
28
29 disp("With the reaction turbine stages ,it will be
    delta_Er=Um^2")
30 delta_Er=850^2/(32.2*778)
31 printf(" delta_Er= %0.2f Btu/lbm",delta_Er)
32 disp("And ETAsi=3.85 is approximatly equal to 4")

```

Scilab code Exa 8.6 GT

```

1 clear all; clc;
2
3 disp("From figure 8.14c we have P1=620hp at N=18400
    rpm. Pick a point on the curve of N/(T01^0.5)
    =18400/(530^0.5)=800")
4 disp("In figure 8.14a, say p02/p01=5")
5 disp("So we have")
6
7 disp("m(T01^0.5)/p01    ETAc    p02( psia)    m(lbm/s)
    p03( psia)    p03/p04")
8 disp("    5.7            0.85        73.5        3.64
    71.5            4.86")
9
10 disp(" where p02=5*14.7")
11 p02=5*14.7
12 printf(" Thus p02= %0.2 f", p02)
13
14 disp("m=5.7*14.7/(530^0.5)")
15 m=5.7*14.7/(530^0.5)
16 printf(" m= %0.2 f", m)
17
18 disp(" 73.5-2")

```

```

19  p03=73.5-2
20  printf(" m= %0.2 f psia",p03)
21
22  //Let i=p03/p04
23  i=71.5/14.7
24  printf("\n p03/p04= %0.2 f",i)
25
26  disp("Then from figure 8.14b,with p03/p04 and m3=m2
      we have")
27  disp("m(T01^0.5)/p01      T03(R)      N/(T03^0.5)
      ETAt")
28  disp(" 2.56                2528          366
      0.87")
29
30  disp(" where T03=(2.56*71.5/3.64)^2")
31  T03=(2.56*71.5/3.64)^2
32  printf(" T03= %0.2 f",T03)
33
34  disp("N/T03=18400/(2528^0.5)")
35  //let k=N/T03
36  k=18400/(sqrt(2528))
37  printf(" Thus T03= %0.2 f",k)
38
39  disp("So from equations (8.1),(7.4) and(8.11) we
      have:")
40  disp("delta_T034=ETAt*T03*[1-(p04/p03)^((k-1)/k)]")
41  delta_T034=0.87*2528*[1-(4.86)^(-0.248)]
42  printf(" delta_T034 = %0.0 f R",delta_T034)
43
44  disp("delta_T012=(T01/ETAc)*[(p02/p01)^((k-1)/k)-1]"
      )
45  delta_T012=(530/0.85)*[(5^0.2857)-1]
46  printf(" delta_T012= %0.0 fR",delta_T012)
47
48  P0=3.64*(0.28*713-0.24*(364/0.95))
49  printf(" \n and P0=3.64*(0.28*713-0.24*(364/0.95))=
      %0.0 f Btu/s=554hp, which is less than P1",P0)
50

```

```

51 disp("So we pick another point on the same curve ,
      say p02/p01=5.2, and repeat the calculations ")
52
53 disp("m(T01^0.5)/p01  ETAc  p02(psia)  m(lbm/s)  p03
      (psia)  p03/p04  m(T01^0.5)/p01  T03(R)  N/(T03
      ^0.5)  ETAt")
54 disp(" 5.6          0.88   76.4          3.57
      74.4          5.06   2.55          2824   346
      0.85")
55
56 delta_T034=0.85*2824*[1-(5.06^(-0.248))]
57 printf("\n The new delta_T034= %0.2fR",delta_T034)//
      the book has rounded off the value to 794R,the
      value calculated in this code is more accurate
58
59 delta_T012=(530/0.88)*[(5.2^0.2857)-1]
60 printf("\n delta_T012= %0.0fR",delta_T012)
61
62 P0=3.57*(0.28*794-0.24*362/0.95)
63 printf("\n Net output power P0= %0.0f Btu/s=660hp,
      which is much greater than P1 \n\n",P0)
64
65 disp("Pick another point say p02/p01=5.15")
66
67 disp("m(T01^0.5)/p01  ETAc  p02(psia)  m(lbm/s)  p03
      (psia)  p03/p04  m(T01^0.5)/p01  T03(R)  N/(T03
      ^0.5)  ETAt")
68 disp(" 5.65          0.87   75.7          3.61
      73.7          5.01   2.55          2710   353
      0.86")
69
70 delta_T034=0.86*2710*[1-(5.01^(-0.248))]
71 printf("\n\n From new values delta_T034= %0.0f R",
      delta_T034)
72
73 delta_T012=(530/0.87)*[(5.15^(0.2857))-1]
74 printf("\n and delta_T012= %0.0f R",delta_T012)
75

```

```

76 P0=3.61*(0.28*768-0.24*(364/0.95))
77 printf("also P0= %0.1 f Btu/s =628hp",P0)
78
79 disp("P0 is close to P1")
80 disp("So the running point is around p02/p01=5.15, m
      (T01^0.5)/p01=5.65")
81 disp("and N/(T01^0.5)=800 on the compressor
      characteristics")
82 disp("It is not too close to the surge line and
      hence is safe.")

```

Scilab code Exa 8.7 GT

```

1 clear all; clc;
2
3 disp("Velocity diagrams at the rotor inlet and
      outlet are given.")
4
5 disp("Velocities at the rotor inlet can be
      calculated .")
6
7 r2=5/12
8 N=15000
9 U2=r2*N*%pi/30
10 printf(" U2=r2*N*pi/30 = %0.1 f ft/s",U2)
11
12 alpha2=85*%pi/180//converting to radians
13 V2=U2/sin(alpha2)
14 printf("\n V2= %0.0 f ft/s",V2)
15
16 Vr2=U2/(tan(alpha2))
17 printf("\n Vr2=W2= %0.1 f ft/s",Vr2)
18
19 disp("Hence from Cp(T02-T2)=V2^2/2, where T02=T01,
      we have")

```

```

20 T02=2000
21 V2=657
22 Cp=0.24*778*32.2
23 T2=T02-(V2^2)/(2*Cp)
24 printf("\n T2=T02-(V2^2)/(2*Cp) =%0.1 fR",T2)
25
26 disp("From  $n = (T2-T2\_dash) / ((V2^2)/(2*Cp))$ , we have
      ")
27 T2=1964.1
28 epsilon_n=0.08
29 V2=657
30 T2_dash=T2-epsilon_n*V2^2/(2*Cp)
31 printf(" T2_dash=T2-epsilon_n*V2^2/(2*Cp)= %0.1 fR",
      T2_dash)
32
33 p01=50
34 T2_dash=1961.2
35 T01=2000
36 //let i=(k/(k-1))
37 i=3.5
38 p2=p01*(T2_dash/T01)^i
39 printf("\n p2= %0.1 f psia",p2)
40
41 p2=46.7
42 R=53.3
43 T2=1964.1
44 rho2=p2*144/(R*T2)//conversion factor=144
45 printf("\n rho2= %0.3 f lb ,/ft ^3",rho2)
46
47 rho2=0.064
48 Vr2=57.3
49 A2=(2*pi*5*2/144)
50 m=rho2*Vr2*A2
51 printf("\n So the mass flow rate m=rho2*Vr2*A2= %0.2
      f lbm/s",m)
52
53 disp("Assuming whirl-free flow at the rotor outlet
      under the design condition , we have")

```

```

54 U2=654.5
55 delta_E=(U2)^2
56 printf("\n delta_E=U2*Vu2=U2^2 %g ((ft/s)^2)
           =428370/(32.2*550)=24.2hp/(lbm/s)",delta_E)
57
58 m=1.60
59 delta_E=24.2//after converting to new units
60 Ps=m*delta_E
61 printf("\n Ps= %0.1 f hp",Ps)
62
63 rm3=2.06/12
64 Um3=rm3*N*pi/30
65 printf("\n Um3= %0.2 f ft/s",Um3)
66
67 beta3=30*pi/180//converting to radians
68 V3=Um3/(tan(beta3))
69 printf("\n V3 = %0.0 f ft/s",V3)
70
71 W3=Um3/sin(beta3)
72 printf("\n W3 = %0.2 f ft/s",W3)//the value has been
           rounded off to 539.2 in the book,however the
           value found here is more accurate
73
74 disp("The turbine efficiency can be determined from
           equations 8.12 and 8.13. Without detailed
           calculations wthe result is given as ETAt=0.691")
75
76 disp("The exhaust pressure/temperature can be
           determined from te following calculations with
           the help of figure 8.21")
77 delta_E=428370/(32.2*778)
78 printf(" From Cp(T01-T03)=delta_E= %0.1 fBtu/lbm",
           delta_E)
79
80 disp("(T01-T03)/(T01-T3dash)=Etat=0.691")
81
82 T03=2000-(17.1/0.24)
83 printf(" T03= %0.0 f R",T03)

```



```

84
85 T01=2000
86 T03=1929
87 ETAt=0.691
88 T3_dash=T01-(T01-T03)/ETAt
89 printf("\n T3_dash=T01-(T01-T03)/ETAt %0.0 fR =",
      T3_dash)
90
91 //let i=k/(k-1)
92 i=3.5
93 p01=50
94 T3_dash=1897
95 T01=2000
96 p3=p01*(T3_dash/T01)^i
97 printf("\n p3=p01*(T3_dash/T01)^i= %0.1 f psia",p3)
98
99 T2=1964.4
100 p3=41.6
101 p2=46.7
102 // Let l=(k-1)/k
103 l=0.2857
104 T3_dbldash=T2*(p3/p2)^(1)
105 printf("\n T3_dbldash=T2*(p3/p2)^(1/i)=%0.2 fR",
      T3_dbldash)//answer given in the book is 1900.3 R
      ,however the value tabulated here is more
      accurate
106
107 T3_dbldash=1900.3
108 epsilon_r=0.45
109 W3=539.2
110 Cp=0.24*32.2*778
111 T3=T3_dbldash+epsilon_r*(W3^2)/(2*Cp)
112 printf("\n T3= %0.1 f R",T3)

```

Chapter 9

Steam Turbines

Scilab code Exa 9.1 ST

```
1 clear all; clc;
2
3 rm=8/12
4 N=7500
5 U=rm*N*%pi/30
6 printf("The peripheral velocity is calculated as U=
   %0.1f ft/s\n\n",U)
7
8 disp("From equation 9.1 we have  $U/V_1 = \sin 1/4$ ")
9 //let x= U/V1
10 alpha1=70*%pi/180
11 x=(sin(alpha1))/4
12 printf("\n Thus  $U/V_1 = %0.4f$ ",x)
13
14 V1=U/x
15 printf("\n Thus  $V_1 = %0.1f$  ft/s",V1)
16
17 disp("From velocity diagram at station1 we have
    $V_1 \sin 1 - W_1 \sin 1 = U$  and  $V_1 \cos 1 = W_1 \cos 1$  or
    $W_1 \sin 1$ ")
18 //let y=  $W_1 \sin 1$ 
```

```

19 V1=2228.8
20 U=523.6
21 y=V1*sin(alpha1)-U
22 printf("\n Hence W1sin 1= %0.1f ft/s",y)
23
24 //Let z=W1cos 1
25 z=V1*cos(alpha1)
26 printf("\n Thus W1cos 1= %0.1f ft/s",z)
27
28 disp("Hence tan 1=2.06")
29 tanbeta1=2.06
30 beta1=(atan(tanbeta1))*180/%pi
31 printf("\n Thus beta1= %0.1f degrees and W1=1746 ft/
    s",beta1)
32
33 disp("At station 2 we have W2sin 2-V2sin 2=U and
    V2cos 2=W2cos 2 ,with W2=W1=1746ft/s and 1 = 2
    =64.1 degrees")
34 //Let l=V2sin 2
35 l=1746*sin(64.1*%pi/180)-523.6
36 printf(" Thus V2sin 2=%0.0f ft/s",l)
37
38 //m=V2cos 2
39 m=1746*cos(64.1*%pi/180)
40 printf("\n V2cos 2 %0.2f ft/s",m)
41
42 disp("Hence tan 2 =1.373")
43 tanalpha2=1.373
44 alpha2=((atan(tanalpha2))*180/%pi)
45 printf(" Hence 2 = %0.2f degrees",alpha2)
46
47 disp("Hence V2=1295.2 ft/s")
48
49 disp("At station 3 we have V3sin 3-W3sin 3=U=523.6
    ft/s")
50 disp(" Also W3cos 3=V3cos 3")
51 //let n=V3cos 3
52 V3=1295.2

```

```

53 alpha3=53.9*%pi/180
54 n=V3*cos(alpha3)
55 printf(" Thus W3cos 3= %0.1f ft/s",n)
56
57 disp("Hence tan 3=0.685")
58 tanbeta3=0.685
59 beta3=((atan(tanbeta3))*180/%pi)
60 printf(" Hence 3 = %0.1f degrees",beta3)
61
62 disp("Thus W3=925.1 ft/s")
63
64 disp(" Also W4=W3=925.1 ft/s")
65 disp(" 4 = 3 =34.4 degrees")
66 disp(" And V4=VaV1cos 4")
67 beta4=34.4*%pi/180
68 //let y=Va*V1
69 y=925.0848
70 V4=y*cos(beta4)
71 printf(" Thus V4= %0.1f ft/s",V4)
72 disp(" 4 =0 degrees")
73
74 disp("From these velocities ,the energy transfers of
       the rotors can be calculated")
75
76 U=523.6
77 V1=2228.8
78 alpha1=70*%pi/180
79 V2=1295.2
80 alpha2=53.9*%pi/180
81 delta_E1=U*(V1*sin(alpha1)+V2*sin(alpha2))
82 printf(" Thus delta_E1= %0.1f ((ft/s)^2)",delta_E1)
83
84 delta_E1=1.643*(10^6)/(32.2*778)//converting units
       from (ft/s)^2 to Btu/lb
85 printf("\n On converting to Btu/lb we have delta_E1=
       %0.1f Btu/lb",delta_E1)
86
87 V3=1295.2

```

```

88 alpha3=alpha2
89 delta_E2=U*(V3*sin(alpha3))
90 printf("\n delta_E2=%0.1f ((ft/s)^2)",delta_E2)
91 delta_E2=0.546*(10^6)/(32.2*778)
92 printf("\n On converting to Btu/lb we have delta_E2=
    %0.1f Btu/lb",delta_E2)
93
94 delta_Ec=65.6+21.8
95 printf("\n Hence the total energy transfer is
    delta_Ec= %0.1f Btu/lb",delta_Ec)
96 disp("To compare with that calculated with equation9
    .3, we have delta_Ec=8*U^2")
97 delta_Ec=8*(U^2)
98 printf(" delta_Ec= %0.2f ((ft/s)^2)",delta_Ec)
99 delta_Ec=2.19*10^6/(32.2*778) //converting units
100 printf("\n On converting we have delta_Ec= %0.2f Btu
    /lb",delta_Ec)//answer given in the book is 87.5,
    however 87.42 is more accurate
101
102 disp("The difference is due to round off error.")
103 disp("The static enthalpies and pressure at stations
    1,2,3 and 4 are same for the ideal case and can
    be calculated from h1=h01-((V1)^2)/2 ")
104 disp("Where h01=h0i=1405Btu/lb from the Mollier
    diagram for p0i=3000 psia ,T01=950 degrees
    Farenheit")
105 //let l=(V1^2)/2
106 V1=2228.8
107 l=(V1^2)/(2*32.2*778)
108 printf(" Thus (V1^2)/2 = %0.0f Btu/lb",l)
109
110 disp("Hence we have h1=1306 Btu/lb and p1=1400psia")

```

Scilab code Exa 9.2 ST

```

1 clear; clc;
2
3 disp("To use Figure 9.8, with  $Q_f = U^2 / \Delta H_s = 2 * g_c$ 
      *lambda^2 * R_H")
4 disp("The value of R_H can be estimated with
      equation 8.4.")
5 disp("Using k=1.3 for steam and assuming  $\eta_{a,p} = 0.90$ 
      we have  $\eta_{a,d} = [1 - (p_e / p_i)^{(\eta_{a,p} * (k-1) / k)}] / [1 - (p_e / p_i)^{(k-1) / k}] = 0.931$ ")
6
7  $\eta_{a,d} = 0.931$ 
8  $\eta_{a,p} = 0.90$ 
9  $R_H = \eta_{a,d} / \eta_{a,p}$ 
10 printf(" R_H= $\eta_{a,d} / \eta_{a,p} =$  %0.3 f", R_H)
11
12 disp("For impulse stages, the optimal efficiencies
      occur at  $\lambda = U / V_2 = \sin^2 / 2 = 0.47$  with  $\alpha_2 = 70$ 
      degrees")
13  $Q_f = 2 * 25052 * (0.47^2) * 1.035$ 
14 printf(" So  $Q_f$  can be calculated as %0.0 f", QF)
15
16 disp("From figure 9.8, the efficiency can be
      estimated as  $\eta = 83\%$ ")
17
18 disp("From the Mollier diagram in figure A1 we have
       $h_i = 1525$  Btu/lbm,  $h_{se} = 1150$  Btu/lbm, with  $s_i = s_{es}$ 
      = 1.8 Btu/lb-R")
19  $\Delta H_s = 1525 - 1150$ 
20 printf(" Hence  $\Delta H_s =$  %0.0 f Btu/lbm",  $\Delta H_s$ )
21
22  $\sum U^2 = 11455 * 375$ 
23 printf("\n So we have  $U^2 =$  %0.0 f ((ft/s)^2)",
       $\sum U^2$ )
24
25 disp("With 10 identical stages, we have  $U^2 = 429562$ ")
26  $\text{sqrU} = 429562$ 
27  $U = \text{sqrt}(\text{sqrU})$ 
28 printf(" Thus  $U =$  %0.0 f ft/s", U)

```

```

29
30 omega=3600*%pi/30
31 D=2*U/omega
32 printf("\n The turbine diameter D= %0.3 f ft",D)//The
    answer has been incorrectly rounded off to 3.47
    in the book. A more accurate answer is provided
    here.

```

Scilab code Exa 9.3 ST

```

1 clear all; clc;
2
3 disp("The tangential velocity at the rotor mean
    radius is Um")
4 rm=1.5
5 N=3600
6 Um=rm*N*%pi/30
7 printf("Um=rm*N*pi/30= %0.1 f",Um)
8
9 disp("From the velocity diagram in figure 8.11 for
    the impulse stages we have delta_h0")
10 disp("delta_h0=delta_Et=UmVu2-UmVu3/g_c=UmVu2/g_c
    =2*((Um)^2)/g_c")
11 Um=565.5
12 gc=32.2
13 delta_h0=2*((Um)^2)/gc
14 printf("\n delta_h0= %0.0 f lbf-ft/lbm=25.5 Btu/lbm",
    delta_h0)
15
16 disp("From the Mollier diagram in appendix A, we
    have hoi=1565 Btu/lbm")
17 disp("For the stages with constant mean radi, we have
    hoi-hoe=n_s*delta_hoe or hoe=hoi-n_s*delta_hoe")
18 h_oe=1565-(12*25.5)
19 printf(" hoe= %0.0 f Btu/lbm.",h_oe)

```

```

20
21 disp(" Also from  $ETA_{ad}=(h_{oi}-h_{oe})/(h_{oi}-h_{soe})$ , we have
       $h_{soe}=h_{oi}-(h_{oi}-h_{oe})/ETA_{ad}$ ")
22 h_soe=1565-306/0.85
23 printf(" hsoe= %0.0 f Btu/lbm",h_soe)
24
25 disp("From  $s_{soe}=S_{oi}=1.69$  Btu/(lbm-R),we have  $p_{oe}=50$ 
      psia and  $T_{oe}=450$  degrees Farenheit")
26 disp(" Also from given efficiencies we have  $P_s=ETA_v*
      ETAm*m*n_s*delta_{ho}$ ")
27 Ps=0.92*0.90*7*12*19863/550
28 printf(" Ps=%0.0 f hp",Ps)

```

Scilab code Exa 9.4 ST

```

1 clear all; clc;
2
3 disp("Based on the law of Willian we have  $m_t=0.5+
      CP_s$ ")
4 C=(7-0.5)/2512
5 printf(" Where C= %0.4 f lbm/(hp-s)\n",C)
6
7 disp("So we have  $SR=mt/P_s=0.5/P_s+(2.6*10^{-3})$ ")
8 disp("And  $HR=Q_h*SR$ ")
9
10
11 disp("OR at full load ,")
12 SR_1=(0.5/2512)+(2.6*10^-3)
13 printf("\n SR_1= %0.4 f lbm/(hp-s)=10.1 lbm/(hp-h)",
      SR_1)
14
15 HR_1=1750*10.1
16 printf("\n HR_1=%0.0 f Btu/(hp-h)",HR_1)
17
18

```



```

19 disp(" at 50% load ,")
20 SR_2=(0.5/1256)+(2.6*10^-3)
21 printf("\n SR_2= %0.4 f lbm/(hp-s)=10.8 lbm/(hp-h)",
        SR_2)
22
23 HR_2=1750*10.8
24 printf("\n HR_2=%0.0 f Btu/(hp-h)",HR_2)

```

Scilab code Exa 9.5 ST

```

1 clear all; clc;
2
3 disp("To calculate the thermal efficiency ,the units
      have to be consistant. With hp=0.707 Btu/s=2545
      Btu/h, we have ETAth=Ps+Qe/Qin")
4 ETA_th=(2512*0.707+1259*7)/(7*1750)
5 printf(" Thus ETA_h= %0.3 f",ETA_th)
6
7 ETA_th=2512*0.707/(7*1750)
8 printf("\n For the simple shaft power system ,we have
      ETA_th= %0.3 f",ETA_th)
9
10 ETA_th=2545/17675
11 printf("\n From the heat rate ,ETA_th=2545/HR %0.3 f",
        ETA_th)

```

Scilab code Exa 9.6 Steam Turbines

```

1 clear all; clc;
2
3 disp("The enthalpies at various points have t be
      determined first. For the steam turbine cycle ,fro

```

```

    the Mollier diagram or steam tables ,we have h1=
    hf1=83.6")
4
5 h2=83.6+(0.0185*(1000-1.5)*144)/(778*0.80)
6 printf(" h2=h1+nu*deltap/ETA_p =%0.1 f Btu/lbm",h2)
7
8 disp("h3=1447 Btu/lbm")
9
10 disp(" s_s4=s3=1.61 Btu/(lbm-R)")
11
12 disp(" hs4=925 Btu/lbm")
13
14 disp(" Hence from ETAst=(h3-h4)/(h3-hs4) we have h4=
    h3-(h3-hs4)*ETAst")
15 h3=1447
16 hs4=925
17 ETA_st=0.85
18 h4=h3-(h3-hs4)*ETA_st
19 printf(" h4= %0.0 f Btu/lbm",h4)
20
21 h4=1003
22 h2=87.9
23 h1=83.6
24 ETA_ths=[(h3-h4)-(h2-h1)]/(h3-h2)
25 printf("\n The thermal efficiency of the steam
    turbine cycle is then obtained as ETA_th,s=(Wst-
    Wp)/(Qin,s)=%0.4 f ",ETA_ths)//it has been rounded
    off to 32.3 in the book
26
27 disp("For the gas turbine cycle , an ideal gas with
    constant Cp is assumed for the working gas. With
    Cp=0.24 Btu/(lbm-R) and k=1.4 we have T6")
28 T5=540
29 //Let n=p6/p5 and m= (k-1)/k
30 n=15
31 m=0.2857
32 ETAc=0.82
33 T6=T5+[T5*({(n)^(m)}-1)]/ETAc

```

```

34 printf("\n T6= %0.0fR=849 degrees Farenheit",T6)
35
36 T7=2560
37 //let b=(1/15)^0.2857
38 b=0.461
39 ETA_gt=0.85
40 T8=T7-T7*[1-b]*ETA_gt
41 printf("\n T8=%0.0f R= 928 degrees Farenheit",T8)
42
43 disp("Which should be greater than T3")
44 T7=2560
45 T8=1388
46 T6=1309
47 T5=540
48 ETA_thg=[(T7-T8)-(T6-T5)]/(T7-T6)
49 printf("\n The thermal efficiency of the gas turbine
        is obtained as %0.3f=32.2 percent",ETA_thg)
50
51 disp("From the energy balance equation across the
        HRSG, we have m_g*Cp*(T8-T9)")
52 disp("ms/mg=[Cp*(T8-T9)]/(h3-h2)")
53 //let x=ms/mg
54 Cp=0.24
55 T8=928
56 T9=450
57 h3=1447
58 h2=87.9
59 x=[Cp*(T8-T9)]/(h3-h2)
60 printf("\n Thus ms/mg=%0.3f",x)
61
62 disp("Hence the thermal efficiency of the combined
        cycle is obtained as ETA_th,c=[(Wgt-Wc)+(ms/mg)*(
        Wst-Wp)]/[Cp*(T7-T6)]")
63 ETA_thc=[0.24*(1172-769)+0.084*(439.7)]/(0.24*1251)
64 printf("\n ETA_th,c= %0.3f=44.5 percent",ETA_thc)

```

Chapter 10

Hydraulic Turbines

Scilab code Exa 10.1 HT

```
1 clear all; clc;
2 //the values of omegas and energycoefficient differ
   from the ones given in the book
3 //the reasons for the same are mentioned in the code
   below
4 H=85
5 Q=16
6 E=0.9//efficiency
7 g=9.8
8 rho=998
9
10 P_o=E*rho*Q*g*H/1000
11 printf("The estimated power (Po) is equal to %0.0f
   kW",P_o)
12
13
14 disp("From figure 10.11,a Francis Turbine is
   selected. Then with the synchronous speed of 16
   poles N is determined")
15 N=120*60/16
16 printf("N is equal to %grpm",N)
```

```

17
18
19 N_s=(N*Q^0.5)/H^0.75
20 printf("\nWe have value of Ns equal to %0.1f rpm(m
    ^3/s)^0.5",N_s)
21
22
23 Ksigma=2.11
24 n=450/60
25 g=9.8
26 sigma=(Ksigma*n*Q^0.5)/((g*H)^0.75)
27 printf("\n Value of sigma is equal to %0.2f",sigma)
28
29
30 omega=(%pi*N)/30
31 V=16
32 omega_s=(omega*V^0.5)/((g*H)^0.75)//Answer given in
    the book is 1.33,this is because H has been
    wrongly substituted as 75. The correct
    substitution(H=85),gives the answer equal to
    1.2157.
33 thita=1.9
34 K=1.054
35 printf("\n Value of omegas is equal to %g",omega_s)
36
37
38 disp("From figure 10.10 we have thita=1.9 for nq=Ns
    =64.3")
39 disp(" Since K*D*(g*H)^0.25/Q^0.5=thita , we can
    determine D.")
40
41 D=(thita*(Q^0.5))/(((g*H)^0.25)*K)
42 printf("\n Value of D is equal to %0.2f m ",D)
43
44
45 disp("From figure 10.9 we have efficiency=0.95,which
    is close to the original estimation")
46 D=1.34//value of D is approximately equal to 1.34

```

```

47 k_phi=(%pi^2)/4
48 k_psi=(%pi^2)/2
49 flowcoeff=Q/(k_phi*n*(D^3))
50 printf("The flow coefficient is equal to %0.3f",
        flowcoeff)
51
52
53 energycoeff=(g*H)/(k_psi*(n^2)*(D^2))
54 printf("\nThe energy coefficient is equal to %0.4f",
        energycoeff)//Answer given in the book is 1.47,
        this is because H has been wrongly substituted as
        75. The correct substitution (H=85), gives the
        answer equal to 1.6713.

```

Scilab code Exa 10.2 HT

```

1 clear all; clc;
2
3 disp("From  $\psi=(g*H)/(\omega^2*D^2)$  and  $N=30*\omega/\pi$  we get  $N=172.7/(\psi^{0.5})$ ")
4 disp("Also from  $\phi=Q/(\omega*D^3)$  and  $\psi=Ps/(\rho*\omega^3*D^5)$  we get  $Q=0.353*\phi*N$  and  $Ps=0.0087*N^3*\psi$ ")
5 disp("Pick the points along 80% gate opening curve, read the values for  $\phi$ ,  $\psi$ , and efficiency from figure 10.14")
6
7 phi=[0.158 0.151 0.14 0.127 0.108 0.092 0.076
      0.066];
8 psi= [0.093 0.083 0.071 0.06 0.048 0.04 0.03 0.025];
9 E= [55 56.5 58 62.5 69 71.5 67.5 60]; //efficiency
10 pai= [0.0078 0.0067 0.0058 0.0045 0.0034 0.0025
        0.0015 0.001];
11
12 N = zeros(1, length(phi));

```

```

13 Ps = zeros(1,length(phi));
14 Q = zeros(1,length(phi));
15
16 for i = 1: length(phi)
17
18
19     N(i) = 172.7/sqrt(psi(i));
20     Ps(i) = 0.0087*N(i)^3*pai(i)*10^-3;
21     Q(i) = 0.353*phi(i)*N(i);
22 end
23
24 disp("      phi      psi      eff (%)      pai      N(rpm
      )      Ps(mw)      Q(m^3/s)")
25
26 table = [phi' psi' E' pai' N' Ps' Q'];
27 disp(table)
28
29 plot(N,Ps,'o',N,Q,'d',N,E,'s')
30 legend("Ps (mw)", "Q (m^3/s)", "Eff (%)", -1)
31 xlabel("N (rpm)")
32 ylabel("Ps (mW), Q (m^3/s) , eff (%)")
33 set(gca(),"grid",[1 1])

```

Scilab code Exa 10.3 HT

```

1 clear all; clc;
2 D=3
3 dn=0.08
4 H=350
5 En=0.82
6 CVb=0.95
7 Em=0.90
8 Ev=0.96
9 g=9.8
10

```

```

11 V2=(2*En*g*H)^0.5
12 printf(" The jet flow velocity is equal to %0.0f m/s
    ",V2)
13
14 Um=0.5*V2
15 printf("\n Optimum wheel tangential velocity is Um
    is equal to %0.1f m/s",Um)
16
17 N=(60*Um)/(%pi*D)
18 printf("\n The rotating speed N is equal to %0.1f
    rpm",N)
19
20 disp("Under the maximum utilization factor condition
    ,we have beta3=90 degrees")
21 disp(" Since delta Emax=(1+CVb)*U(V2-U),we get the
    equation delta Emax=1.95*(U^2)")
22 delta_E_max=(1+CVb)*Um*(V2-Um)
23 printf(" The value of deltaEmax is equal to %g N-m/
    kg",delta_E_max)
24
25 An=(%pi/4)*(dn^2)
26 Q=V2*An
27 printf("\n The flow rate is %0.3f m^3/s",Q)
28
29 m=998*Q
30 Ps=Em*Ev*m*delta_E_max/1000
31 printf("\n The total shaft power output is %0.1f kW"
    ,Ps)
32
33 Ns=(N*(Q^0.5))/(H^0.75)
34 printf("\n The specific speed can be calculated as
    %0.2f rpm((m^3/s)^0.5)/(m^0.75)",Ns)
35
36 omega=%pi*N/30
37 omega_s=omega*(Q^0.5)/((g*H)^0.75)
38 printf("\n In non dimensional form , omegas is equal
    to %0.3f",omega_s)

```

Scilab code Exa 10.4 HT

```
1 clear all; clc;
2 H=80
3 Q=63
4 Es=0.97
5 N=400
6 V3=25
7 Dh3=2
8 rh3=1/12
9 g=32.2
10
11 Ksigma=2.11
12 n=N/60
13 sigma=(Ksigma*n*(Q^0.5))/((g*H)^0.75)
14 printf(" The value of sigma is equal to %0.2f ",
        sigma)
15
16 disp("We have thita=2.4. Thita is also equal to Kt*
        D2*((g*H)^0.25)/(Q^0.5)")
17 thita=2.4
18 Kt=1.054
19 D2=(thita*(Q^0.5))/(Kt*((g*H)^0.25))
20 printf(" Thus the value of D2 is %0.1f ft",D2)
21
22 D2r=2.5//rounded off D2
23 U2=(D2r*N*%pi)/60
24 printf("\n U2 is equal to %0.2f ft/s",U2)
25
26 V2=(2*g*H*Es)^0.5
27 printf("\n The inlet flow velocity V2 is equal to %0
        .2f ft/s",V2)
28
29 disp("From the inlet velocity diagram for alpha2=20
```

```

degrees we have Vr2=V2*sinalpha2")
30 alpha2=20
31 Vr2=V2*(sin(alpha2*pi/180))
32 printf(" Vr2 is equal to %0.2f ft/s",Vr2)
33
34 tanbeta2=Vr2/(V2*(cos(alpha2*pi/180))-U2)
35 printf("\n The value of tanbeta2 is %0.2f",tanbeta2)
36 beta2=(atan(tanbeta2))*180/pi
37 printf("\n Thus value of beta2 is %0.1f degrees",
beta2)
38
39 disp("Selecting the incidence i=2.2 degrees we have
betab2=62 degrees")
40
41 disp("A2=Q/Vr2=(%pi*D2*b2) From this equation we can
determine the value of b2.")
42 A2=Q/Vr2
43 printf(" A2 is equal to %0.2f ft^2",A2)
44 b2=A2/(%pi*D2)
45 printf("\n b2 is equal to %0.2f ft",b2)
46 disp("Thus b2= 4 inches")
47
48 disp("At the outlet with rh3=1 inch , setting gamma
=15 degrees and V3=25")
49 gamma1=15
50 A3=Q/V3
51 printf(" The value of A3 is equal to %g ft^2",A3)
52 rt3=((A3*(cos(gamma1*pi/180)))/%pi+(rh3^2))^0.5
53 printf("\n The value of rt3 is %0.2f ft",rt3)
54 disp("On converting the value of rt3 from feet to
inches we get rt3=10.6inches")
55
56 rt3c=10.6//converted value of rt3
57 rh3c=1//converted value in inches
58 rm3=((((rt3c^2+ rh3c^2)/2)^0.5)/12)
59 printf(" The mean radius rm3 is equal to %0.3f ft",
rm3)
60 Um3=26.3

```

```

61  tanbetam3=V3/Um3
62  printf("\n The value of tanbetam3 %0.2f",tanbetam3)
63  betam3=atan(tanbetam3)*180/%pi
64  printf("\n The value of betam3 whih is equal to
        betabm3 if no deviation is assumed is equal to
        %0.2f degrees",betam3)
65  disp("On rounding off we get the value og betam3
        =43.6 degrees")

```

Scilab code Exa 10.5 HT

```

1  clear all; clc;
2  disp("To use figure 10.21 we need the dimensional
        power specific speed. So the shaft power has to
        be estimated from figure 10.9 where the non
        dimensional omegas is needed.")
3
4  Ve=5
5  H1=0.7
6
7  H=80
8  Q=63
9  Es=0.97
10 N=400
11 V3=25
12 Dh3=2
13 rh3=1/12
14 g=32.2
15
16 omega=N*%pi/30
17 omega_s=omega*(Q^0.5)/((g*H)^0.75)
18 printf(" The value of omegas is %0.2f",omega_s)
19
20 disp("We have efficiency=0.95")
21 E=0.95

```

```

22 rho=1.9378
23 Ps=E*rho*g*Q*H/550//conversion factor =1/550
24 printf(" The value of Ps %0.2f hp",Ps)
25
26 Nsp=N*(Ps^0.5)/(80^1.25)
27 printf("\nThe value of Nsp is equal to %0.2f rpm(hp
    ^0.5)/ft^1.25",Nsp)
28
29 disp("From figure 10.21, we obtain sigma
    approximately equal to 0.1 or NSPHavail/H is
    greater than or equal to 0.1")
30 disp("NSPHavail =Ha-Z+Hl+Ve^2/(2*g)) and NSPH avail
    is greater than or equal to 8 ft.")
31 disp("At T=70 degrees farenheit we have the value of
    Ha equal to")
32 Ha=14.7*144/62.4
33 printf(" %0.2f ft.",Ha)
34 Hv=0.363*144/62.4
35 printf("\n The value of Hv is equal to %0.2f ft",Hv)
36 K=(Ve^2)/(2*g)
37 NPSHavail=8
38 printf("\n The value of (Ve^2)/(2*g) is equal to %0
    .2f ft",K)
39 //In the book the value of Zmax is directly stated
40 //I have used the given formulæ and substiuted the
    values in it
41 //let NPSHavail=8
42 //then from the given formula we can find out the
    value of Zmax
43
44 NPSH_avail=8
45 H_vr=0.84//rounded off value
46 Kr=0.39//rounded off value
47 H_ar=33.9//rounded off value
48 Z =H_ar-NPSH_avail+Hl+Kr-H_vr//Kr= rounded off value
    of (Ve^2)/(2*g)
49 printf("\n The value of Zmax is equal to %0.1f ft",Z
    )

```


Chapter 11

Wind Turbines

Scilab code Exa 11.1 WT

```
1 clear all; clc;
2
3 Pe=1.5
4 Eg=0.96//generator efficiency
5 Em=0.94//transmission efficiency
6 P=Pe/(Eg*Em)
7 printf('\n The power is equal to %0.3f MW',P)
8 disp("After converting to W the magnitude of power
      is equal to 1.662*10^6 W")
9
10 Cp=0.47//from figure 11.10
11 V=13
12 rho=1.222
13 disp(" Since  $P=C_p(0.5*\rho*A*V^3)$ , thus on
      substituting the values we get  $P=630.9A$ ")
14  $A=P*10^6/(C_p*0.5*\rho*V^3)$ // Since  $P=C_p*(0.5*\rho*A*V^3)$ 
15 printf(' On substituting the value of P in  $P=630.9A$ 
      we get A equal to %g',A)
16
17 disp("After rounding off ,the area is equal to 2634.7
```

```

    m^2")
18 Ar=2634.7//rounded off A
19 //A=R^2*pi
20 R=sqrt(A/%pi)
21 printf(' The Radius is equal to %g m',R)
22
23 disp(" After rounding off the ,area is equal to 28.9m"
    )
24 Rr=28.9//rounded off
25 D=2*Rr
26 printf(' The Diameter is equal to %g m',D)
27
28 omega=(V/R)*5.3// In the book diameter has been
    incorrectly substituted in place of radius(R).
    That is the reason why this particular answer
    doesn't match with the one given in the book.
29 printf('\n Omega is equal to %0.2f rad/s',omega)
30 N=(omega*30)/%pi//since N is proportional to omega
    and the answer for omega doesnt match with the
    answer given in the book(because of the
    aforementioned reason), the answer of N doesn't
    match either.
31 printf('\n RPM is equal to %g rpm',N)

```

Scilab code Exa 11.2 WT

```

1 clear all; clc;
2
3 V= 40*(5280/3600)
4 printf('V is equal to %0.2f ft/s',V)
5 N=80
6 omega=(N*pi)/30
7 printf('\n\nomega is equal to %0.2f rad/s',omega)
8 rt=15
9 rh=1

```

```

10 Vt=(rt*omega)/V//tip velocity ratio
11 printf('\n\nThe tip velocity ratio is equal to %0.2f
    ',Vt)
12
13 Zb=12/Vt
14 printf('\n \n Optimum number of blades is equal to
    %0.2f ',Zb)
15 disp("On approximating ,the optimum number of blades
    is equal to 5")
16
17 rm=[(rt^2+rh^2)/2]^0.5
18 printf('\n\nThe mean radius is equal to %0.2f ft',rm)
19
20 Um=rm*omega
21 printf('\n\nThe blade peripheral velocity at the
    mean radius is equal to %0.1f ft/s',Um)
22
23 disp(" Assuming V1=V")
24 beta_1=(atan(Um/V))*180/%pi
25 printf('\n\nThe relative flow angle at the inlet is
    equal to %0.1f degrees ',beta_1)
26
27 beta_2=65
28 tanbetam=0.5*(tan(beta_1*%pi/180)+tan(beta_2*%pi
    /180))
29 printf('\n\nThe value of tan of beta m is equal to
    %0.3f ',tanbetam)
30 beta_m=(atan(tanbetam))*180/%pi
31 printf('\n \n Mean relative flow angle (betam) is
    equal to %0.2f degrees ',beta_m)
32
33 Wm=V/cos(beta_m*%pi/180)
34 printf('\n\nThe relative flow velocity (Wm) is equal
    to %0.1f ft/s ',Wm)
35
36 rho=0.0763
37 gc=32.2
38 c=1.2

```



```

39 C1=0.28
40 Cd=0.015
41 F_um=(rho*Wm^2*c*(C1*cos(beta_m*pi/180)-Cd*sin(
    beta_m*pi/180))/(2*32.2))
42 printf('\n\nThe tangential force (Fum), is equal to
    %0.2f lb/ft ',F_um)
43
44 delta_r=14//rt-rh=deltar
45 Z_br=5//approximated value of Zb
46 P_s=rm*F_um*delta_r*omega*Z_br/550
47 printf('\n\nPs is approximately equal to %0.1f hp',
    P_s)
48
49 A=%pi*rt^2
50 A_r=707//rounding of A=706.9 to 707
51 P_smax=((8/27)*(rho/gc)*707*58.67^3)/550
52 printf('\n\nFrom the actuator theory, the maximum
    possible shaft power will be equal to %0.1f hp.',
    P_smax)

```

Scilab code Exa 11.3 WT

```

1 clear all; clc;
2
3 V= 40//in mph
4 V=58.9//in mph
5 //more accurately
6 V= 40*(5280/3600)
7 a=0.27
8 V1=V*(1-a)
9 printf('V1 is equal to %0.1f ft/s',V1)
10
11 N=60
12 D=50
13 U=(N*pi/30)*(D/2)

```

```

14 printf('\nU is equal to %0.1f ft/s',U)
15
16 //from velocity triangle
17 A=90+45
18 printf('\nA is equal to %g degrees',A)
19
20 //from cosine law
21 W=(U^2+V1^2-2*U*V1*cos(A*pi/180))^0.5
22 printf('\nW is equal to %0.1f ft/s',W)
23
24 //from sine law
25 sinB=V1*(sin(A*pi/180))/W
26 printf('\nsinB is equal to %0.4f ft/s',sinB)
27
28 B=asin(sinB)*180/pi
29 printf('\nB is equal to %0.1f degrees',B)
30
31 setting_angle=85
32 alpha=B-(90-setting_angle)
33 printf('\nalpha is equal to %0.1f degrees',alpha)
34
35 //from figure
36 C1=0.58
37 Cd=0.027
38 rho=0.0763
39 gc=32.2
40 c=1.2
41 Wr=189.8//rounded off W
42 Fu=rho*Wr^2*c*(C1*sin(B*pi/180)-Cd*cos(B*pi/180))
    /(2*gc)
43 printf('\nFu is equal to %0.3f lb/ft',Fu)
44
45 disp("After rounding off the tangential force (Fu)
    is equal to 3.38 lb/ft")

```

Chapter 12

Review on Thermodynamics and Compressible Flow

Scilab code Exa 12.1 A

```
1 clear all; clc;
2
3 disp("Assuming steady state flow, an adiabatic
      process and negligible difference between the
      inlet/outlet flow velocities.")
4 T1=25+273
5 p2=600
6 p1=120
7 k=1.4
8 T_s2=T1*((p2/p1)^((k-1)/k))
9 printf(" T_s2= %0.0 f K", T_s2)
10
11 disp("With constant Cp assumed, we have Eta_c=(Ts2-
      T1)/(T2-T1)")
12 T_s2=472
13 T1=298
14 T2=503
15 Eta_c=(T_s2-T1)/(T2-T1)
16 printf(" Eta_c=%0.4 f=84.8 percent", Eta_c)
```

```

17
18 //let w_c/m=x
19 Cp=1.004
20 T1=298
21 T2=503
22 T1=298
23 x=Cp*T1*((T2/T1)-1)
24 printf("\n w_c/m=Cp*T1*((T2/T1)-1) %0.1 f kJ/kg",x)

```

Scilab code Exa 12.2 A

```

1 clear all; clc;
2
3 disp("The gas density at the inlet can be calculated
      as rho1=p1/(R*T1)")
4 p1=14.7
5 R=35.11
6 T1=30+460
7 rho_1=p1*144/(R*T1)
8 printf(" rho1= %0.3 f lbm/ft ^3",rho_1)
9
10 m=0.123*150/60
11 printf("\n Hence we have mass flow rate m= %0.3 f lbm
        /s",m)
12 disp("Neglecting the mechanical and leakage and
      assuming ideal gas with constant Cp,we can obtain
      T2")
13
14 T1=490
15 p2=40
16 p1=14.7
17 k=1.29
18 Eta_c=0.87
19 T2=T1*(1+[(p2/p1)^((k-1)/k)-1]/[Eta_c])
20 printf(" T2=%0.0 fR",T2)

```

```

21
22 //let -w_c/m=x
23 Cp=0.2007
24 T2=632
25 T1=490
26 x=Cp*(T2-T1)
27 printf("\n -w_c/m=%0.1 f Btu/lbm",x)
28
29 omega_c=0.307*28.5*778/550
30 printf("\n -omega_c=%0.1 f hp",omega_c)
31
32 disp("For an isothermal process , we have -wc/m=pl*v1
      *ln(p2/p1)")
33 p1=14.7
34 v1=144/0.123
35 p2=40
36 x=p1*v1*log(p2/p1)
37 printf(" Thus -wc/m= %0.2 f lbf-ft/lbm",x)
38
39 wc=0.307*17227/550
40 printf("\n Hence -wc= %0.1 f hp",wc)

```

Scilab code Exa 12.3 A

```

1 clear all; clc;
2
3 disp("From the stam Mollier diagram ,we have h1=1528
      Btu/lbm,s1=1.82 Btu/(lbm_R at 250 psia and 1000
      degrees Farenheit)")
4 disp("Hence at p2=10 psia ,we have hs2=1165 btu/lbm,
      where ss2=s1")
5 disp("From Eta_t=(h1-h2)/(h1-hs2) we have")
6
7 h2=1528-0.85*(1528-1165)
8 printf("\n h2= %0.2 f Btu/lbm",h2)

```

```

9
10 m=1.2
11 h1=1528
12 h2=1219.5
13 w_t=m*(h1-h2)
14 printf("\n wt= %0.2 f Btu/s",w_t)//Wrongly rounded
    off in the book. A more accurate answer is 370.2.
15
16 w_t=370.3*778/550//converting units
17 printf("\n On converting units , we have wt= %0.1 f hp
    ",w_t)//Since the basic value of w_t differs from
    that given in the book,so does the converted
    value.

```

Scilab code Exa 12.4 A

```

1 clear all; clc;
2
3 disp("From  $T_2/T_1=T_3/T_4=(p_2/p_1)^{((k-1)/k)}$ , we have
     $T_2=901$  R")
4 disp("  $T_4=1264.6$ R")
5 disp("From  $\eta_c=(T_2-T_1)/(T_2-T_1)$  we have  $T_2=980.2$ ")
6 disp("Hence  $w_c=C_p*(T_2-T_1)=149.4$ hp/(lbm/s)")
7 disp("From  $\eta_t=(T_3-T_4)/(T_3-T_4)$ , we have  $T_4=1374.5$ R
    we hence  $w_t=249.7$ hp/(lbm/s)")
8 disp("w=w_t-w_c")
9 w_t=249.7
10 w_c=149.4
11 w=w_t-w_c
12 printf(" w=%0.1 f hp/(lbm/s)",w)
13 disp("  $q_{in}=C_p*(T_3-T_2)=383.5$ hp/(lbm/s)")
14 w=100.2
15 q_in=383.5
16 Eta_th=w/q_in
17 printf(" Eta_th=w/qin %0.2 f =26 percent",Eta_th)

```

Scilab code Exa 12.5 A

```
1 clear all; clc;
2
3 disp("From  $\text{Eta}_{hx}=(T_{dash}-T_2)/(T_4-T_{dash4})$ ,  $T_4dash$ 
   = $T_2$ ")
4
5 disp("we have  $T_2dash=T_2+\text{Eta}_{hx}*(T_4-T_2)$ ")
6 T_2=980.2
7 Eta_hx=0.7
8 T_4=1374.5
9 T_2=980.2
10 T_2dash=T_2+Eta_hx*(T_4-T_2)
11 printf(" T_2dash=%0.1 f R",T_2dash)
12
13 Cp=0.339
14 T_3=2110
15 T_2dash=1256.2
16 q_in=Cp*(T_3-T_2dash)
17 printf("\n q_in %0.1 f hp/(lbm/s)",q_in)
18
19 Eta_th=99.8/289.4
20 printf("\n Eta_th=%0.4 f=34.6 percent",Eta_th)//in
   the book the value of Eta_th is rounded off to
   34.6 and hence the same is done here.
```

Scilab code Exa 12.6 A

```
1 clear all; clc;
2
3 disp("referring to figure A-14a,  $V_a=650\text{mph}=953\text{ft/s}$ ")
```

```

4 Ta=510
5 Va=953
6 Cp=0.24*778*32.2
7 T01=Ta+Va^2/(2*Cp)
8 printf(" T01=%0.1 f R" ,T01)
9
10 disp("from Eta_i=(Ts01-Ta)/(T01-Ta),we have Ts01=Ta+
      Eta_i (T01-Ta)=577.9R")
11 pa=10.5
12 Ts01=577.9
13 Ta=510
14 //let x=k/(k-1)
15 x=3.5
16 p01=pa*(Ts01/Ta)^(x)
17 printf(" p01=%0.1 f psia",p01)
18
19 p03=5*16.3
20 printf("\n p03=p02=%0.1 f psia",p03)
21
22 T01=585.5
23 Ts02=T01*(5^0.2857)
24 printf("\n Ts02=%0.1 f R",Ts02)
25
26 disp("From Eta_c= (Ts02-T01)/(T02-T01),we have T)2=
      T01 +(Ts02-T01)/Eta_c=1012.7R")
27 disp("For the turbojet w_c=w_t is assumed,we have
      T04=T03-(T02-T01)")
28 T03=1810
29 T02=1012.7
30 T01=585.5
31 T04=T03-(T02-T01)
32 printf(" T04= %0.1 f R",T04)
33
34 disp("From Eta_t=(T03-T04)/(T03-Ts04)=1318.9R and
      p04=p03*(T_s04/T_03)^3.5=26.9 psia")
35
36 disp("To check whether the flow is choked at the
      nozzle exit,we calculate te choking condition

```



```

    from Tc=2*T_04/(k+1)”)
37 T_04=1382.8
38 k=1.4
39 Tc=2*T_04/(k+1)
40 printf(” Tc= %0.1 f R” ,Tc)
41
42 T04=1382.8
43 Tc=1152.3
44 Eta_n=0.92
45 T_sc=T04-(T04-Tc)/Eta_n
46 printf(”\n T_sc= %0.1 f R” ,T_sc)
47
48 p04=26.9
49 Tsc=1132.3
50 T04=1382.8
51 pc=p04*(Tsc/T04)^3.5
52 printf(”\n pc= %0.2 f psia” ,pc)
53
54 disp(” Since pc>pa the flow is choked at the nozzle
    exit plane ,and hence we have T5=Tc=1152.3R, ps=pc
    =13.36 psia”)
55
56 k=1.4
57 R=53.33
58 T5=1152.3
59 Vj=(k*R*T5*32.2)^0.5//conversion factor=32.2
60 printf(” Vj= %0.1 f ft/s” ,Vj)
61
62 p5=13.36
63 rho5=p5*144/(R*T5)//144 = conversion factor
64 printf(”\n rho5 %0.4 f lbn/ft^3” ,rho5)
65
66 disp(”m=rho*V*A”)
67
68 A5=60/(0.0313*1664.4)
69 printf(” A5= %0.2 f ft^2” ,A5)
70
71 disp(”F=m*(Vj-Va)+A5*(p5-pa)”)

```

```

72 F=60*(1664.4-953)/32.2+1.15*(13.36-10.5)*144
73 printf(" F= %0.1 f lbf",F)

```

Scilab code Exa 12.7 A

```

1 clear all; clc;
2
3 disp(" Referring to figure A-12 and assuming pure
      saturated liquid at the condenser outlet ,we have
      h9=hf=93 Btu/lbm from the steam table")
4 disp(" With p8=p9=2 psia and p6=100 psia ,we have h6=
      h9+delta_p*144/(Eta_p*rho)")
5 h9=93
6 delta_p=100-2
7 Eta_p=0.8
8 rho=62.4*778
9 h6=h9+delta_p*144/(Eta_p*rho)
10 printf(" h6=%0.1 f Btu/lbm",h6)
11
12 disp(" Assuming T6 to be approximately equal to T9
      =585 R with the definition of boiler efficiency
      Eta_b=(h7-h6)*m_w/[Cp*(T4-T5)*m_g]")
13 h7=0.75*0.24*(1374.5-585)/0.10+93.4
14 printf(" h7= %0.2 f Btu/lbm",h7)
15
16 disp(" Assuming p6 to be approximately equal to p7
      =100 psia ,we obtain s8s=s7=1.908 Btu/lbmR and h8s
      =1120 btu/lbm from the steam table")
17 disp(" From the definition of turbine efficiency ,
      Eta_t=(h7-h8)/(h7-h8s) we can determine the value
      of h8")
18 h8=1514.5-0.84*(1514.5-1120)
19 printf(" h8=%0.0 f Btu/lbm",h8)
20 disp(" Or w_t=h7-h8=331.4 Btu/lbm , w_p=0.4 Btu/lbm")
21

```

```

22 disp("Hence the additional power output from the
    steam power plant per unit mass flow rate of gas
    through the gas turbine is  $\Delta w = (w_t - w_p) * m_w$ 
     $*/m_g$ ")
23 delta_w=331*0.1
24 printf(" delta_w= %0.1f Btu/lbm=hp/(lbm/s)",delta_w)
25
26 Eta_th=(99.8+46.8)/(382.6)
27 printf("\n The new thermal efficiency = %0.3f =38.3
    percent",Eta_th)

```

Scilab code Exa 12.8 A

```

1 clear all; clc;
2
3 disp("We have  $h_4=104$  Btu/lbm,  $h_2=h_1=53$  Btu/lbm,  $p_4=p_1$ 
    =20psia,  $s_4=s_3=0.226$  Btu/lbm-R and  $h_3=122$  Btu/
    lbm")
4 h4=104
5 hs3=122
6 Eta_c=0.75
7 h_3dash=h4+(hs3-h4)/Eta_c
8 printf("h_3dash=%0.0f Btu/lbm",h_3dash)
9
10 w_i=h_3dash-h4
11 printf("\n The compressor work required per unit
    mass is  $w_i = %0.0f$  Btu/lbm",w_i)
12
13 h1=53
14 qi=h4-h1
15 printf("\n The heat absorbed by the evaporator per
    unit mass = $q_i = %0.0f$  Btu/lbm",qi)
16
17 beta1=qi/w_i
18 printf("\n The coefficient of performance beta= %0.1

```

```
        f",beta1)
19
20 m=10
21 Pc=m*w_i
22 printf("\n The total compressor power required Pc=%0
        .0 f=240 Btu/s=340 hp",Pc)
23
24 qi=51
25 Qr=m*qi
26 printf("\n The refrigeration capacity is Qr= %0.0 f
        Btu/s=153 tons",Qr)
```
