

Scilab Textbook Companion for
Gas Dynamics and Jet Propulsion
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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

Compressible Flow Fundamentals

Scilab code Exa 1.1 To calculate the work done

```
1  clc
2  clear
3
4  //Input data
5  m=0.75 //Mass of air in kg
6  T1=800 //Intial Temperature in K
7  P1=400 //Initial Pressure in kPa
8  P2=150 //Final Pressure in kPa
9  k=1.4 //Adiabatic constant
10 R=0.287 //Specific Gas constant in J/kg-K
11
12 //Calculation
13 p1=P2/P1 //pressure ratio of process
14 T2=T1*p1^((k-1)/k) //Final temperature in K
15 W=((m*R*(T1-T2))/(k-1)) //Workdone in kJ
16
17 //P-V Diagram
18 scf()
19 clf()
```

```

20 V1=(((m*R*T1)/P1)^(1/k))*10^3 //Inlet volume in cc
21 V2=(((m*R*T2)/P2)^(1/k))*10^3 //Final volume in cc
22 V = V1:(V2-V1)/100:V2 //Representing volume on
    graph, adiabatic expansion
23 P = P1*V1^k./V^k //Representing pressure on graph
24 plot(V, P) //Plotting
25 legend('P*V^k=C') //Defining curve
26 xtitle("PV Diagram", "V (cc)", "P (kPa)") //Titles
    of axes
27
28 //Output
29 printf('Workdone is %3.2f kJ',W)

```

Scilab code Exa 1.2 To calculate heat transfer internal energy change and work done

```

1  clc
2  clear
3
4  //Input data
5  V1=0.35 //Volume of gas in m^3
6  P1=110 //Initial Pressure in kPa
7  T1=300 //Intial Temperature in K
8  P2=600 //Final Pressure in kPa,missing data
9  k=1.4 //Adiabatic constant
10 Cv=718 //Specific heat at constant volume in J/kg-K
11 R=287 //Specific Gas constant in J/kg-K
12
13 //Calculation
14 dQ=0 //Heat transfer in J, Since Adiabatic process
15 m=(P1*10^3*V1)/(R*T1) //Mass of air in kg
16 p1=P2/P1 //Pressure ratio
17 T2=T1*p1^((k-1)/k) //Final temperature in K
18 dU=(m*Cv*(T2-T1))*10^-3 //Change in internal energy
    in kJ

```

```

19 dW=-dU //Workdone in kJ, Since dQ=0
20
21 //P-V Diagram
22 scf()
23 clf()
24 V1cc=V1*10^3 //Inlet volume in cc
25 V2cc=V1cc*(T2/T1)^(1/(k-1)) //Final volume in cc
26 V = V1cc:(V2cc-V1cc)/100:V2cc //Representing
    volume on graph, adiabatic expansion
27 P = P2*V1cc^k./V^k //Representing pressure on graph
28 plot(V, P) //Plotting
29 legend('P*V^k=C') //Defining curve
30 xtitle("PV Diagram", "V (cc)", "P (kPa)") //Titles
    of axes
31
32 //Output
33 printf('(A)Heat transfer is %3i J\n (B)Change in
    internal energy is %3.3f kJ\n (C)Workdone is %3.3
    f kJ\n',dQ,dU,dW)

```

Scilab code Exa 1.3 To determine temperature enthalpy drop and internal energy change

```

1 clc
2 clear
3
4 //Input data
5 P1=3.2 //Initial Pressure in bar
6 P2=1 //Final Pressure in bar
7 T1=475 //Initial temperature in K
8 Mol=44 //Molecular weight of carbondioxide in kg/mol
9 Ri=8314 //Ideal gas constant in J/mol-K
10 k=1.3 //Adiabatic constant
11
12 //Calculation

```

```

13 R=Ri/Mol // Specific gas constant in J/kg-K
14 Cp=(k*R)/(k-1) // Specific heat capacity at constant
    pressure in J/kg-K
15 Cv=Cp/k // Specific heat capacity at constant volume
    in J/kg-K
16 p1=P2/P1 // Pressure ratio
17 T2=T1*p1^((k-1)/k) // Final Temperature
18 dh=Cp*(T1-T2)*10^-3 // Enthalpy drop in kJ/kg
19 dU=Cv*(T2-T1)*10^-3 // Change in internal energy in
    kJ/kg, -ve sign indicates loss
20
21 // Output
22 printf('(A) Temperature is %3.3f K\n (B) Enthalpy drop
    is %3.3f kJ/kg\n (C) Change in internal energy is
    %3.2f kJ/kg i.e. %3.2f kJ/kg(loss)', T2, dh, dU, abs
    (dU))

```

Scilab code Exa 1.4 To determine properties at outlet and area ratio of diffuser

```

1 clc
2 clear
3
4 // Input data
5 P1=0.5 // Initial Pressure in bar
6 T1=50+273 // Initial Temperature in K
7 C1=240 // Inlet velocity in m/s
8 C2=120 // Outlet velocity in m/s, missing data
9 Cp=1005 // Specific heat capacity at constant
    pressure in J/kg-K
10 k=1.4 // Adiabatic constant
11
12 // Calculation
13 T2=T1+((C1^2-C2^2)/(2*Cp)) // Final Temperature in K
14 t1=T2/T1 // Temperature ratio

```



```

15 P2=P1*t1^(k/(k-1)) //Final Pressure in bar
16 ar=(P1*T2*C1)/(P2*T1*C2) //Ratio of outlet to inlet
    area
17
18 //Output
19 printf('(A)At outlet:\n    Temperature is %3.2f K\n
    Pressure is %3.4f bar\n (B)Ratio of outlet to
    inlet area is %3.4f',T2,P2,ar)

```

Scilab code Exa 1.5 To determine static pressure and axial force of turbojet engine

```

1  clc
2  clear
3
4  //Input data
5  m=25 //Mass flow rate of air in kg/s
6  C2=115 //Outlet velocity in m/s
7  P1=100 //Initial Pressure in kPa
8  T1=300 //Initial Temperature in K
9  C1=40 //Inlet velocity in m/s
10 R=0.287 //Specific gas constant in kJ/kg-K
11 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
12 k=1.4 //Adiabatic constant
13
14 //Calculation
15 T2=T1+((C1^2-C2^2)/(2*Cp)) //Final Temperature in K
16 t1=T2/T1 //Temperature ratio
17 P2=P1*t1^(k/(k-1)) //Final Pressure in bar
18 A1=(m*R*T1)/(P1*C1) //Area at inlet in m^2
19 A2=(m*R*T2)/(P2*C2) //Area at outlet in m^2
20 F=((P1*A1)-(P2*A2))+(m*(C1-C2))*10^-3 //Axial force
    on mouthpiece resulting from acceleration of air
    in kN

```

```

21
22 //Output
23 printf('(A) Static pressure at intake face is %3.3f
      kPa\n (B) Magnitude of axial force on mouthpiece
      resulting from acceleration of air is %3.3f kN',
      P2,F)

```

Scilab code Exa 1.6 To determine mach number at a point

```

1  clc
2  clear
3
4  //Input data
5  P=200 //Pressure in kPa
6  C=50 //Velocity of air in m/s
7  d=2.9 //Density in kg/m^3
8  Mol=32 //Molecular weight of oxygen in kg/mol
9  k=1.4 //Adiabatic constant
10 Ri=8314 //Ideal gas constant in J/mol-K
11
12 //Calculator
13 R=Ri/Mol //Specific gas constant in J/kg-K
14 T=P*10^3/(R*d) //Temperature in K
15 a=sqrt(k*R*T) //Velocity of sound in m/s
16 M=C/a //Mach number
17
18 //Output
19 printf('Mach number is %3.2f ',M)

```

Scilab code Exa 1.7 To find direction of flow

```

1  clc
2  clear

```

```

3
4 //Input data
5 Pa=1.3 //Pressure at section-A in bar
6 Ta=50+273 //Temperature at section-A in K
7 Pb=1 //Pressure at section-B in bar
8 Tb=13+273 //Temperature at section-B in K
9 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
10 R=287 //Specific gas constant in J/kg-K
11
12 //Calculation
13 ds=((Cp*log(Tb/Ta))-(R*log(Pb/Pa)))*10^-3 //The
    change in the entropy is kJ/kg
14 //+ve sign indicates A to B
15 //-ve sign indicates B to A
16
17 //Output
18 printf('The change in the entropy is %3.4f kJ/kg\n
    Since value is -ve, process must takes place from
    B to A',ds)

```

Scilab code Exa 1.8 To calculate the bulk modulus

```

1 clc
2 clear
3
4 //Input data
5 V1=8 //Intial volume in litre
6 V2=7.8 //Final volume in litre
7 P1=0.7 //Intial Pressure in MPa
8 P2=2.7 //Final Pressure in MPa
9
10 //Calculations
11 K=(P2-P1)/(log(V1/V2)) //Bulk modulus of liquid in
    kPa

```

```
12
13 //Output
14 printf('Bulk modulus of liquid is %3.3f kPa',K)
```

Scilab code Exa 1.9 To calculate mass of water to be pumped to obtain desired pressure

```
1 clc
2 clear
3
4 //Input data
5 V1=0.5 //Voume of Water required to fill pressure
        vessel in m^3
6 P=3000 //Test pressure in bar
7 dv=0.6 //Change of empty volume of container due to
        pressurisation in percentage
8 K=20000 //Bulk modulus of water in MPa
9
10 //Calculation
11 m1=V1*10^3 //Mass of water required to fill pressure
        vessel in kg
12 Vr=(P*V1)/K //Reduced volume of water due to
        compression in m^3
13 Vi=dv*V1/100 //Increased volume of container in m^3
14 V=Vr+Vi //Volume of additional water required in m^3
15 m=V*10^3 //Mass of additional water required in kg
16 mt=m1+m //Total mass of water required in litre ,
        Since 1kg=1Lit
17
18 //Output
19 printf('Mass of water to be pumped into the vesel to
        obtain the desired pressure is %3i lit ',mt)
```

Scilab code Exa 1.10 To find sonic velocity

```
1  clc
2  clear
3
4  //Input data
5  SG_oil=0.8 //Specific gravity of crude oil
6  K_oil=153036*10^4 //Bulk modulus of Oil in N/m^2
7  K_hg=2648700*10^4 //Bulk modulus of Mercury in N/m^2
8  d_steel=7860 //Density of steel in kg/m^3
9  E_steel=200*10^9 //Modulus of elasticity in Pa
10 d_hg=13600 //Density of mercury in kg/m^3
11 d_water=1000 //Density of water in kg/m^3
12
13 //Calculation
14 d_oil=SG_oil*d_water //Density of oil in kg/m^3
15 a_oil=sqrt(K_oil/d_oil) //Sonic velocity of crude
    oil in m/s
16 a_hg=sqrt(K_hg/d_hg) //Sonic velocity of mercury in
    m/s
17 a_steel=sqrt(E_steel/d_steel) //Sonic velocity of
    steel in m/s
18
19 //Output
20 printf('(A)Sonic velocity of crude oil is %3.2f m/s\
    n (B)Sonic velocity of mercury is %3.2f m/s\n (A)
    Sonic velocity of steel is %3.1f m/s\n',a_oil,
    a_hg,a_steel)
```

Scilab code Exa 1.11 To find velocity of sound

```
1  clc
2  clear
3
4  //Input data
```

```

5 T=20+273 //Temperature of medium in K
6 Cp_fr=678 //Specific heat capacity at constant
  pressure of freon in J/kg-K
7 Cv_fr=543 //Specific heat capacity at constant
  volime of freon in J/kg-K
8 T_air=0+273 //Temperature of air in K
9 Ri=8314 //Ideal gas constant in J/mol-K
10 mol_h=2 //Molecular weight of Hydrogen in kg/mol
11 mol_water=18 //Molecular weight of water in kg/mol
12 R_air=287 //Specific gas constant of air in J/kg-K
13 k=1.4 //Adiabatic constant of hydrogen
14 k_water=1.3 //Adiabatic constant of water
15
16 //Calculation
17 R_h=Ri/mol_h //Specific gas constant of hydrogen in
  J/kg-K
18 a_h=sqrt(k*R_h*T) //Velocity of sound in hydrogen in
  m/s
19 R_water=Ri/mol_water //Specific gas constant of
  water in J/kg-K
20 a_water=sqrt(k_water*R_water*T) //Velocity of sound
  in water vapour in m/s
21 k_fr=Cp_fr/Cv_fr //Adiabatic constant of feon
22 R_fr=Cp_fr-Cv_fr //Specific gas constant of freon in
  J/kg-K
23 a_fr=sqrt(k_fr*R_fr*T) //Velocity of sound in freon
  in m/s
24 a_air=sqrt(k*R_air*T_air) //Sonic Velocity of air at
  in m/s
25
26 //Output
27 printf('(A) Velocity of sound in hydrogen is %3.2f m/
  s\n (B) Velocity of sound in water vapour is %3.2f
  m/s\n (C) Velocity of sound in freon is %3.2f m/s
  \n (D) Sonic Velocity of air at %3i K is %3.4f m/s
  ',a_h,a_water,a_fr,T_air,a_air)

```

Scilab code Exa 1.12 To find highest pressure acting on surface of a body

```
1  clc
2  clear
3
4  //Input data
5  M=0.85 //Mach number
6  P=80 //Pressure in kPa
7  k=1.4 //Adiabatic Constant
8
9  //Calculation
10 Po=P*(1+(((k-1)/2)*M^2))^(k/(k-1)) //Pressure acting
    on the surface of the body in kPa
11
12 //Output
13 printf('The highest pressure acting on the surface
    of the body is %3.1f kPa',Po)
```

Scilab code Exa 1.13 To find air velocity for different types of flow

```
1  clc
2  clear
3
4  //Input data
5  P=96 //Pressure in kPa
6  T=27+273 //Temperature in K
7  dP=32 //Difference between pivot and static pressure
8  k=1.4 //Adiabatic Constant
9  R=287 //Specific Gas constant in J/kg-K
10
11 //Calculation
12 d=(P*10^3)/(R*T) //Density in kg/m^3
```

```

13 Ci=sqrt((2*(dP*10^3))/d) //Velocity of
    incompressible flow in m/s
14 pr=(dP)/P //Pressure ratio
15 p1=pr+1 //Stagnation to static pressure ratio
16 M=sqrt(((p1^((k-1)/k)-1)*2)/(k-1)) //Mach number
17 Cc=M*sqrt(k*R*T) //Velocity of compressible flow in
    m/s
18
19 //Output
20 printf('(A) Air velocity in incompressible flow is %3
    .1f m/s\n (B) Air velocity if flow is compressible
    is %3.3f m/s ',Ci,Cc)

```

Scilab code Exa 1.14 To find number of nozzles

```

1 clc
2 clear
3
4 //Input data
5 T1=200+273 //Initial Temperature in K
6 P1=1.7 //Initial Pressure in bar
7 P2=1 //Final Pressure in bar
8 C1=30 //Inlet velocity in m/s
9 m=1 //Mass flow rate in kg/s
10 D=0.025 //Nozzle diameter in m
11 k=1.4 //Adiabatic Constant
12 R=287 //Specific Gas constant in J/kg-K
13 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
14
15 //Calculation
16 p1=P2/P1 //Pressure ratio
17 T2=T1*p1^((k-1)/k) //Final temperature in K
18 E1=T1+(C1^2/(2*Cp)) //LHS of Steady flow energy
    equation

```



```

19 C2=sqrt((E1-T2)*2*Cp) //Exit velocity of the air in
    m/s
20 d2=(P2*10^5)/(R*T2) //Density at outlet in kg/m^3
21 A2=%pi*D^2/4 //Area at outlet in m^2
22 n=ceil(m/(d2*A2*C2)) //Number of nozzles to be used
23
24 //Output
25 printf('(A)Exit velocity of the air is %3.2f m/s\n (
    B)Number of nozzles to be used are %1.0f',C2,n)

```

Scilab code Exa 1.15 To find properties of a gas in vessel at a point

```

1  clc
2  clear
3
4  //Input data
5  Po=300 //Pressure in the vessel in kPa
6  To=50+273 //Temperature in vessel in K
7  M=1 //Mach number
8  k=1.667 //Adiabatic constant
9  Ri=8314 //Ideal gas constant in J/mol-K
10 Mol=4 //Molecular weight of helium in kg/mol
11
12 //Calculation
13 R=Ri/Mol //Specific gas constant in J/kg-K
14 Cp=(k*R)/(k-1) //Specific heat capacity at constant
    pressure in J/kg-K
15 p1=(2/(k+1))^(k/(k-1)) //Pressure ratio
16 Pt=Po*p1 //Pressure at test condition in kPa
17 t1=(2/(k+1)) //Temperature ratio
18 Tt=To*t1 //Temperature at test condition in K
19 at=sqrt(k*R*Tt) //Velocity of sound in m/s
20 Ct=at //Velocity of gas at test condition in m/s
21 Cmax=sqrt(2*Cp*To) //Maximum velocity due to
    expanding of gases through nozzle system in m/s

```

```

22
23 //Output
24 printf('(A)At test point:\n      Pressure is %3.2f kPa
      \n      Temperature is %3.2f K\n      Velocity is %3
      .1f m/s\n (B)Maximum velocity due to expanding of
      gases through nozzle system is %3.2f m/s',Pt,Tt,
      Ct,Cmax)

```

Scilab code Exa 1.16 To find mach number and velocity of flow

```

1  clc
2  clear
3
4  //Input data
5  T=40+273 //Temperature in K
6  p1=0.5 //Static to Stagnation pressure ratio
7  k=1.67 //Adiabatic constant
8  Ri=8314 //Ideal gas constant in J/mol-K
9  Mol=39.94 //Molecular weight of argon in kg/mol
10
11 //Calculation
12 R=Ri/Mol //Specific gas constant in J/kg-K
13 p2=1/p1 //Pressure ratio
14 M=sqrt(((p2^((k-1)/k)-1)*2)/(k-1)) //Mach number
15 C=M*sqrt(k*R*T) //Velocity in the flow in m/s
16
17 //Output
18 printf('(A)Mach number is %3.3f\n (B)Velocity in the
      flow is %3.1f m/s',M,C)

```

Scilab code Exa 1.17 To find distance covered before sonic boom is heard on ground

```

1  clc
2  clear
3
4  //Input data
5  M=2.5 //Mach number
6  h=10 //Height in km
7
8  //Calculation
9  alp=asind(1/M) //Mach cone angle in degree
10 d=10/tand(alp) //Distance the jet would cover before
    a sonic boom is heard on ground in km
11
12 //Output
13 printf('Distance the jet would cover before a sonic
    boom is heard on ground is %3.2f km',d)

```

Scilab code Exa 1.18 To calculate time elapsed to feel disturbance due to aircraft

```

1  clc
2  clear
3
4  //Input data
5  h=1100 //Height in m
6  M1=2.5 //Mach number of aircraft @h
7  T=280 //Temperature @h
8  M2=0.5 //Mach number of observer
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11
12 //Calculation
13 alp=asind(1/M1) //Mach cone angle in degree
14 a=sqrt(k*R*T) //Velocity of sound in m/s
15 C1=M1*a //Velocity of aircraft when the observer is
    stationary in m/s

```

```

16 t1=h/(C1*tand(alp)) //Time elapsed when the observer
    is stationary in sec
17 C2=(M1-M2)*a //Velocity of aircraft when the
    observer is moving in the direction of aircraft
    in m/s
18 t2=h/(C2*tand(alp)) //Time elapsed when the observer
    is moving in the direction of aircraft in sec
19 C3=(M1+M2)*a //Velocity of aircraft when the
    observer is moving in the opposite direction in m
    /s
20 t3=h/(C3*tand(alp)) //Time elapsed when the observer
    is moving in the opposite direction in sec
21
22 //Output
23 printf('(A)Time elapsed when the observer is
    stationary is %3.3f sec\n (B)Time elapsed when
    the observer is moving in the direction of
    aircraft with M=%3.1f is %3.2f sec\n (C)Time
    elapsed when the observer is moving in the
    opposite direction is %3.2f sec\n',t1,M2,t2,t3)

```

Scilab code Exa 1.19 To find mach number at a point

```

1  clc
2  clear
3
4  //Input data
5  P=200 //Pressure in kPa
6  d=2.9 //Density in kg/m^3
7  C=50 //Velocity in m/s
8  mol=32 //Molecular weight of oxygen in kg/mol
9  k=1.4 //Adiabatic constant
10 Ri=8314 //Ideal gas constant in J/mol-K
11
12 //Calculation

```

```

13 R=Ri/mol //Specific gas Constant in J/kg-k
14 T=(P*10^3)/(R*d) //Temperature in K
15 a=sqrt(k*R*T) //Velocity of sound in m/s
16 M=C/a //Mach number
17
18 //Output
19 printf('Mach number is %3.4f',M)

```

Scilab code Exa 1.20 To find Mach number

```

1 clc
2 clear
3
4 //Input data
5 C=200 //Velocity of object in m/s
6 mol=4 //Molecular weight of helium in kg/mol
7 k=1.67 //Adiabatic constant
8 Ri=8314 //Ideal gas constant in J/mol-K
9 T=288 //Temperature in K
10
11 //Calculation
12 R=Ri/mol //Specific gas Constant in J/kg-k
13 a=sqrt(k*R*T) //Velocity of sound in m/s
14 M=C/a //Mach number
15
16 //Output
17 printf('Mach number is %3.1f',M)

```

Scilab code Exa 1.21 To find speed of sound and Mach number

```

1 clc
2 clear
3

```

```

4 //Input data
5 Z1=0 //Height from sea level in m
6 Z2=11 //Height from sea level in m
7 T1=288 //Temperature @Z1 in K, from gas tables
8 T2=216.5 //Temperature @Z2 in K, from gas tables
9 C=1000*(5/18) //Velocity in m/s
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-k
12
13 //Calculation
14 a1=sqrt(k*R*T1) //Sound velocity @Z1 in m/s
15 M1=C/a1 //Mach number @Z1
16 a2=sqrt(k*R*T2) //Sound velocity @Z2 in m/s
17 M2=C/a2 //Mach number @Z2
18
19 //Output
20 printf('(A)Speed of sound at:\n      sea level is %3.2
      f\n      an altitude of %3i km is %3.2f m/s\n (B)
      Mach number at:\n      sea level is %3.2f\n      an
      altitude of %3i km is %3.2f',a1,Z2,a2,M1,Z2,M2)

```

Scilab code Exa 1.22 To find maximum possible velocity of air

```

1 clc
2 clear
3
4 //Input data
5 T=300+273 //Static Temperature in K
6 C=200 //Velocity in m/s
7 Cp=1005 //Specific heat capacity at constant
      pressure in J/kg-K
8
9 //Calculation
10 To=T+(C^2/(2*Cp)) //Stagnation Temperature in K
11 C_max=sqrt(2*Cp*To) //Maximum possible velocity

```

```

    obtained by air in m/s
12
13 //Output
14 printf('Maximum possible velocity obtained by air is
    %3.2f m/s ',C_max)

```

Scilab code Exa 1.23 To find exit velocity of air

```

1 clc
2 clear
3
4 //Input data
5 dT=37 //Temperature difference between air inside
    the tyre and nozzle exit
6 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
7
8 //Calculation
9 C=sqrt(2*Cp*dT) //Exit velocity of air in m/s
10
11 //Output
12 printf('Exit velocity of air is %3.1f m/s ',C)

```

Scilab code Exa 1.24 To find static conditions and Flight Mach number

```

1 clc
2 clear
3
4 //Input data
5 C=800*(5/18) //Velocity in m/s
6 Po=105 //Stagnation pressure in kPa
7 To=35+273 //Stagnation temperature in K

```

```

8 Cp=1005 //Specific heat capacity at constant
   pressure in J/kg-K
9 k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-k
11
12 //Calculation
13 T=To-(C^2/(2*Cp)) //Static temperature in K
14 P=Po*(T/To)^(k/(k-1)) //Static pressure in kPa
15 a=sqrt(k*R*T) //Sound Velocity in m/s
16 M=C/a //Mach number
17
18 //Output
19 printf('(A) Static conditions:\n      Pressure is %3.2f
      kPa\n      Temperature is %3.2f K\n      Sound
      Velocity is %3.2f m/s\n (B)Mach number is %3.2f',
      P,T,a,M)

```

Scilab code Exa 1.25 To find stagnation pressure and mach number

```

1 clc
2 clear
3
4 //Input data
5 C=215 //Velocity in m/s
6 T=30+273 //Static temperature in K
7 P=5 //Static pressure in bar
8 R=287 //Specific gas constant in J/kg-k
9 k=1.4 //Adiabatic Constant
10
11 //Calculations
12 a=sqrt(k*R*T) //Sound Velocity in m/s
13 M=C/a //Mach number
14 To=T*(1+(((k-1)/2)*M^2)) //Stagnation temperature in
   K
15 Po=P*(To/T)^(k/(k-1)) //Stagnation pressure in kPa

```



```

16
17 //Output
18 printf('(A) Stagnation Pressure is %3.4f bar\n (B)
    Mach number is %3.3f',Po,M)

```

Scilab code Exa 1.26 To determine different velocities stagnation enthalpy and crocco number

```

1  clc
2  clear
3
4  //Input data
5  T=400 //Static temperature in K
6  k=1.4 //Adiabatic Constant
7  Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
8  R=287 //Specific gas constant in J/kg-k
9
10 //Calculation
11 a=sqrt(k*R*T) //Sound velocity in m/s
12 C=a //Velocity of jet in m/s, Since jet has sonic
    velocity
13 To=T+(C^2/(2*Cp)) //Stagnation temperature in K
14 ao=sqrt(k*R*To) //Sound velocity at Stagnation
    condition in m/s
15 ho=(Cp*To)*10^-3 //Stagnation enthalpy in kJ/kg
16 C_max=sqrt(2*Cp*To) //Maximum velocity of jet in m/s
17 cr=C/C_max //Crocco number
18
19 //Output
20 printf('(A) Velocity of sound at %3i K is %3.3f m/s\n
    (B) Velocity of sound at stagnation condition is
    %3.3f m/s\n (C) Maximum velocity of jet is %3.3f m
    /s\n (D) Stagnation enthalpy is %3.3f kJ/kg\n (E)
    Crocco number is %3.4f',T,C,ao,C_max,ho,cr)

```

Scilab code Exa 1.27 To find stagnation conditions and mass flow rate

```
1  clc
2  clear
3
4  //Input data
5  C=250 //Velocity of air in m/s
6  D=10 //Diameter in duct in cm
7  T=5+273 //Static temperature in K
8  P=40 //Static pressure in kPa
9  k=1.4 //Adiabatic constant
10 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
11 R=287 //Specific gas constant in J/kg-k
12
13 //Calculation
14 To=T+(C^2/(2*Cp)) //Stagnation temperature in K
15 Po=P*(To/T)^(k/(k-1)) //Stagnation pressure in kPa
16 d=(P*10^3)/(R*T) //Density in kg/m^3
17 A=(%pi*D^2/4)*10^-4 //Area in m^2
18 m=d*A*C //Mass flow rate in kg/s
19
20 //Output
21 printf('(A)Stagnation pressure is %3.2f kPa\n (B)
    Stagnation temperature is %3.2f K\n (C)Mass flow
    rate is %3.4f kg/s',Po,To,m)
```

Scilab code Exa 1.28 To find stagnation conditions and velocity at dynamic condition

```
1  clc
```

```

2  clear
3
4  //Input data
5  C=300 //Velocity of air in m/s
6  P=1 //Static pressure in kPa
7  T=290 //Static temperature in K
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-k
10 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
11
12 //Calculation
13 To=T+(C^2/(2*Cp)) //Stagnation temperature in K
14 Po=P*(To/T)^(k/(k-1)) //Stagnation pressure in kPa
15 a=sqrt(k*R*T) //Sound velocity in m/s
16 Co=sqrt(k*R*To) //Sound velocity at Stagnation
    condition in m/s
17
18 //Output
19 printf('(A) Stagnation pressure and temperature are
    %3.4f bar and %3.2f K\n (B) Velocity of sound in
    the dynamic and stagnation conditions are %3.2f m
    /s and %3.2f m/s ',Po,To,a,Co)

```

Scilab code Exa 1.29 To find flow velocity for compressible and incompressible flow

```

1  clc
2  clear
3
4  //Input data
5  dP=490*(1.01325/760) //Pressure in pivot tube in bar
6  P=0.3546+1.01325 //Static pressure(absolute) in bar
7  To=25+273 //Stagnation temperature in K
8  k=1.4 //Adiabaatic constant

```

```

9 R=287 // Specific gas constant in J/kg-k
10 Cp=1005 // Specific heat capacity at constant
    pressure in J/kg-K
11
12 // Calculation
13 Po=dP+P // Stagnation pressure in bar
14 T=To*(P/Po)^((k-1)/k) // Static temperature
15 C1=sqrt(2*Cp*(To-T)) // Flow velocity for
    Compressible flow in m/s
16 di=Po/(R*To) // Density in kg/m^3
17 C2=sqrt((2*dP)/di) // Flow velocity for
    incompressible flow in m/s
18
19 // Output
20 printf('Flow velocity for:\n (A) Compressible flow is
    %3.2f m/s\n (B) Incompressible flow is %3.2f m/s'
    ,C1,C2)

```

Scilab code Exa 1.30 To find Mach number velocity and area at a point

```

1 clc
2 clear
3
4 // Input data
5 To=27+273 // Stagnation temperature in K
6 Po=8 // Stagnation Pressure in bar
7 P=5.6 // Static pressure in bar, taken from diagram
    given
8 m=2 // Mass flow rate in kg/s
9 k=1.4 // Adiabatic constant
10 Cp=1005 // Specific heat capacity at constant
    pressure in J/kg-K
11 R=287 // Specific gas constant in J/kg-k
12
13 // Calculation

```

```

14 T=To*(P/Po)^((k-1)/k) //Static temperature in K
15 a=sqrt(k*R*T) //Sound velocity in m/s
16 C=sqrt(2*Cp*(To-T)) //Velocity in m/s
17 M=C/a //Mach number
18 A=((m*R*T)/(P*10^5*C))*10^4 //Area at a point in the
    channal in cm^2
19
20 //Output
21 printf('(A)Mach number is %3.4f\n (B)Velocity is %3
    .1f m/s\n (C)Area at a point in the channal is %3
    .3f cm^2 ',M,C,A)

```

Scilab code Exa 1.31 To find velocity and mass flow rate

```

1  clc
2  clear
3
4  //Input data
5  Po=1.8 //Stagnation pressure in atm
6  To=20+273 //Stagnation temperature in K
7  P=1 //Surrounding pressure in atm
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-k
10
11 //Calculation
12 p1=0.528 //Static to Stagnation pressure ratio @Mach
    number=1, from gas tables
13 Pt=p1*Po //Critical pressure in atm, Since Pt<P the
    flow is not chocked
14 di=(Po*10^5)/(R*To) //Density in kg/m^3
15 ao=sqrt(k*R*To) //Sound velocity at Stagnation
    condition in m/s
16 Cp=(k*R)/(k-1) //Specific heat capacity at constant
    pressure in J/kg-K
17 C=sqrt(2*Cp*To*(1-(P/Po)^((k-1)/k))) //Velocity of

```

```

    air flow which will take place from chamber to
    the outside through a unit area hole in m/s
18 G=di*ao*sqrt(2/(k-1))*(P/Po)^(1/k)*sqrt((1-(P/Po)^((
    k-1)/k))) //Mass flow rate per unit area in kg/s-
    m^2
19
20 //Output
21 printf('(A) Velocity of air flow which will take
    place from chamber to the outside through a unit
    area hole is %3.3f m/s\n (B) Mass flow rate per
    unit area is %3.3f kg/s-m^2',C,G)

```

Scilab code Exa 1.32 To find various properties at one section in duct

```

1  clc
2  clear
3
4  //Input data
5  A1=465.125 //Cross sectional area at entry in cm^2
6  T1=26.66+273 //Static temperature at section -1 in K
7  P1=3.4473 //Static Pressure at section -1 in bar
8  C1=152.5 //Velocity at section -1 in m/s
9  P2=2.06838 //Static Pressure at section -2 in bar
10 T2=277.44 //Static temperature at section -2 in K
11 C2=260.775 //Velocity at section -2 in m/s
12 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
13 k=1.4 //Adiabatic constant
14 R=287 //Specific gas constant in J/kg-k
15
16 //Calculations
17 To1=T1+(C1^2/(2*Cp)) //Stagnation temperature at
    entry in K
18 To2=T2+(C2^2/(2*Cp)) //Stagnation temperature at
    exit in K

```

```

19 //here To1=To2 from answers
20 d1=(P1*10^5)/(R*T1) //Density at section-1
21 d2=(P2*10^5)/(R*T2) //Density at section-2
22 ar=(d2*C2)/(d1*C1) //Ratio of inlet to outlet area
23 A2=A1/ar //Cross sectional area at exit in cm^2
24 C_max=sqrt(2*Cp*To1) //Maximum velocity at exit in m
    /s
25 m=d1*A1*C1*10^-4 //Mass flow rate in kg/s
26 F=((P1*10^5*A1*10^-4)-(P2*10^5*A2*10^-4))+(m*(C1-C2)
    ) //Force acting on the duct wall between two
    sections in N
27
28 //Output
29 printf('(A)Maximum velocity and stagnation
    temperature at exit are %3.2f m/s and %3.2f K\n (
    B)Since Stagnation temperature %3i K at entry and
    %3i K at exit are equal, the flow is adiabatic\n
    (C)Cross sectional area at exit is %3.2f cm^2\n
    (D)Force acting on the duct wall between two
    sections is %3.2f N',C_max,To2,To1,To2,A2,F)

```

Scilab code Exa 1.33 To find various properties at one section in duct

```

1 clc
2 clear
3
4 //Input data
5 P1=250 //Static Pressure at section-1 in kPa
6 T1=26+273 //Static temperature at section-1 in K
7 M1=1.4 //Mach number at entry
8 M2=2.5 //Mach number at exit
9 k=1.4 //Adiabatic constant
10 R=287 //Specific gas constant in J/kg-k
11
12 //Calculation

```

```

13 C1=sqrt(k*R*T1)*M1 //Air velocity at entry in m/s
14 To=T1*(1+(((k-1)/2)*M1^2)) //Stagnation temperature
    in K
15 t1=(1+(((k-1)/2)*M2^2)) //Stagnation to exit
    Temperature ratio
16 T2=To/t1 //Exit temperature in K
17 C2=sqrt(k*R*T2)*M2 //Air velocity at exit in m/s
18 P2=P1*(T2/T1)^(k/(k-1)) //Exit static pressure in
    kPa
19 d2=(P2*10^3)/(R*T2) //Density at section -2 in kg/m^3
20 G=d2*C2 //)Mass flow rate through the duct per
    square metre in kg/s-m^2
21
22 //Output
23 printf('(A)At second section:\n    Temperature is %3
    .2f K\n    Pressure is %3.2f kPa\n    Velocity is
    %3.4f m/s\n (B)Mass flow rate through the duct
    per square metre is %3.1f kg/s-m^2',T2,P2,C2,G)

```

Scilab code Exa 1.34 To find maximum temperature encountered by skin

```

1  clc
2  clear
3
4  //Input data
5  M=2 //Mach number
6  h=20 //Altitude in km
7  Tc=-56 //Ambient temperature in degree Centigrade
8  Ta=-56+273 //Ambient temperature in K
9  k=1.4 //Adiabatic constant
10 R=287 //Specific gas constant in J/kg-k
11 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
12
13 //Calculation

```



```

14 a=sqrt(k*R*Ta) //Sound velocity in m/s
15 C=M*a //Velocity of flight in m/s
16 To=Tc+(C^2/(2*Cp)) //The maximum temperature
    encountered is %3.1f degree Centigrade
17
18 //Output
19 printf('The maximum temperature encountered is %3.1f
    degree Centigrade ',To)

```

Scilab code Exa 1.35 To find rate of heat transfer

```

1 clc
2 clear
3
4 //Input data
5 W=20000 //Power developed in kW
6 m=12 //Mass flow rate in kg/s
7 C1=50 //Velocity of air entering in m/s
8 T1=700+273 //Temperature of air entering in K
9 T2=298 //Temperature of air leaving in K
10 C2=125 //Velocity of air leaving in m/s
11 Cp=1.005 //Specific heat capacity at constant
    pressure in kJ/kg-K
12
13 //Calculation
14 dh=Cp*(T2-T1) //Change in enthalpy in kJ/kg
15 Q=((m*dh)+W-(m*(1/2000)*(C2^2-C1^2))) //The rate of
    heat transfer in kJ/s
16
17 //Output
18 printf('The rate of heat transfer is %3.2f kJ/s',Q)

```

Scilab code Exa 1.36 To find various properties in a nozzle

```

1  clc
2  clear
3
4  //Input data
5  mol=39.9 //Molecular weight of gas in kg/mol
6  k=1.67 //Adiabatic constant
7  Po=500 //Pressure in chamber in kPa
8  To=30+273 //Temperature in chamber in K
9  P1=80 //Pressure of nozzle at given section in kPa
10 D=0.012 //Cross section diameter of nozzle in m
11 Ri=8314 //Ideal gas constant in J/mol-K
12
13 //Calculation
14 R=Ri/mol //Specific gas constant in J/kg-K
15 p1=Po/P1 //Stagnation to static pressure ratio
16 M1=sqrt((((p1^((k-1)/k))-1)*2)/(k-1)) //Mach number
    at section
17 T1=To*((1+(((k-1)/2)*M1^2))^(-1)) //Temperature at
    section in K
18 a=sqrt(k*R*T1) //Sound Velocity in m/s
19 C1=M1*a //Gas Velocity at section in m/s
20 d=(P1*10^3)/(R*T1) //Density in kg/m^3
21 A1=%pi*D^2/4 //Cross-sectional Area
22 m=d*A1*C1 //Mass flow rate through nozzle in kg/s
23
24 //Output
25 printf('(A)At section:\n    Mach number is %3.1f\n
    Temperature is %3.1f K\n    Velocity is %3.3f
    m/s\n (B)Mass flow rate through nozzle is %3.3f
    kg/s ',M1,T1,C1,m)

```

Scilab code Exa 1.37 To find Mach number velocity and pressure at a section in duct

```

1  clc

```

```

2 clear
3
4 //Input data
5 mol=4 //Molecular weight of gas in kg/mol
6 k=1.3 //Adiabatic constant
7 C1=150 //Gas Velocity at section-1 in m/s
8 P1=100 //Pressure of duct at section-1 in kPa
9 T1=15+273 //Temperature at section-1 in K
10 T2=-10+273 //Temperature at section-2 in K
11 Ri=8314 //Ideal gas constant in J/mol-K
12
13 //Calculation
14 R=Ri/mol //Specific gas constant in J/kg-K
15 a1=sqrt(k*R*T1) //Sound velocity at section-1 in m/s
16 M1=C1/a1 //Mach number at section-1
17 t1=0.9955 //Static to Stagnation temperature ratio
    at entry from gas tables @M1,k=1.3
18 To=T1/t1 //Stagantion temperature in K
19 p1=0.9815 //Static to Stagnation pressure ratio at
    entry from gas tables @M1,k=1.3
20 Po=P1/p1 //Stagnation pressure in kPa
21 t2=T2/To //Static to Stagnation temperature ratio at
    exit
22 M2=0.82 //Amch number at section-2 from gas tables
    @t2,k=1.3
23 p2=0.659 //Static to Stagnation pressure ratio at
    exit from gas tables @M2,k=1.3
24 P2=Po*p2 //Pressure at section-2 in kPa
25 a2=sqrt(k*R*T2) //Sound velocity at section-2 in m/s
26 C2=M2*a2 //Gas Velocity at section-2 in m/s
27
28 //Output
29 printf('At the second point:\n    Mach number is %3
    .2f\n    Pressure is %3.3f kPa\n    Velocity is
    %3.2f m/s ',M2,P2,C2)

```

Scilab code Exa 1.38 To find mass flow rate and velocity at exit

```
1  clc
2  clear
3
4  //Input data
5  A1=10 //Inlet area in cm^2
6  C1=80 //Inlet Air velocity in m/s
7  T1=28+273 //Inlet temperature in K
8  P1=700 //Inlet Pressure in kPa
9  P2=250 //Exit pressure in kPa
10 k=1.4 //Adiabatic constant
11 R=287 //Specific gas constant in J/kg-K
12
13 //Calculation
14 a1=sqrt(k*R*T1) //Sound velocity at inlet in m/s
15 M1=C1/a1 //Mach number at inlet
16 t1=0.989 //Static to Stagnation temperature ratio at
    entry from gas tables @M1,k=1.4
17 To=T1/t1 //Stagantion temperature in K
18 p1=0.964 //Static to Stagnation pressure ratio at
    entry from gas tables @M1,k=1.4
19 Po=P1/p1 //Stagnation pressure in kPa
20 p2=P2/Po //Static to Stagnation pressure ratio
21 M2=1.335 //Mach number at exit
22 t2=0.737 //Static to Stagnation temperature ratio at
    exit from gas tables @M2,k=1.4
23 T2=To*t2 //Stagnation temperatur in K
24 a2=sqrt(k*R*T2) //Sound velocity at exit in m/s
25 C2=M2*a2 //Exit Air velocity in m/s
26 d1=(P1*10^3)/(R*T1) //Density at inlet in kg/m^3
27 m=d1*A1*C1*10^-4 //Mass flow rate in kg/s
28
29 //Output
```

```

30 printf('(A)Mass flow rate is %3.3f kg/s\n (B)
    Velocity at the exit is %3.2f m/s',m,C2)

```

Scilab code Exa 1.39 To find time required for a value of pressure decrease

```

1  clc
2  clear
3
4  //Input data
5  V=5 //Volume of air in m^3
6  Ae=10*10^-4 //Exit area in cm^2
7  To=60+273 //Temperature inside in the tank in K
8  Po1=40 //Intial total pressure in bar
9  Po2=2 //Final total pressure in bar
10 P=1 //Discharge pressure in bar
11 R=287 //Specific gas constant in J/kg-K
12
13 //Calculation
14 //Here pressure ratios P/Po1 and P/Po2 are always
    less than critical pressure ratio therefore flow
    is choked i.e. M=1 at exit
15 Gp=(0.0404184*Ae)/sqrt(To) //Mass flow rate by
    Stagnation pressure i.e. m/Po
16 //Differentiating m=(P*V)/(R*To) w.r.t. time and
    intrgrating resulting equation we get following
    expression.
17 t=-(V/(R*To*Gp))*log(Po2/Po1) //The time required
    for tank pressure to decrease from Po1 to Po2 in
    sec
18
19 //Output
20 printf('The time required for tank pressure to
    decrease from %i bar to %i bar is %3.2f sec',Po1,
    Po2,t)

```


Chapter 2

Flow through Variable Area Ducts

Scilab code Exa 2.1 To find mass flow rate temperature and pressure at throat

```
1  clc
2  clear
3
4  //Input data
5  do1=1.12 //Density of air i reservoir in kg/m^3
6  ao1=500 //Velocity of sound in reservoir in m/s
7  d=0.01 //Throat diameter in m
8  k=1.4 //Adiabatic Constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 To1=ao1^2/(k*R) //Stagnation temperature in K
13 Po1=do1*R*To1 //Stagnation pressure in Pa
14 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from gas tables @M=1
15 Pt=(Po1*p1)*10^-5 //Throat pressure in bar
16 t1=0.834 //Ratio of critical temperature to
    Stagnation temperature from gas tables @M=1
```

```

17 Tt=To1*t1 //critical temperature in K
18 d_t=(Pt*10^5)/(R*Tt) //Density of air at throat in
    kg/m^3
19 a_t=sqrt(k*R*Tt) //Sound velocity at throat in m/s
20 Ct=a_t //Air velocity t throat in m/s, Since M=1
21 A_t=%pi*d^2/4 //Throat area in m^2
22 m=d_t*A_t*Ct //Maximum mass flow rate in kg/s
23
24 //Output
25 printf('(A)Maximum mass flow rate is %3.5f kg/s\n (B
    )Pressure and temperarature at the throat are %3
    .3f bar and %3.4f K',m,Pt,Tt)

```

Scilab code Exa 2.2 To find properties at throat and exit in Convergent Divergent nozzle

```

1 clc
2 clear
3
4 //Input data
5 P1=2 //Intial pressure in bar
6 C1=170 //Initial velocity of air in m/s
7 T1=473 //Intial temperature in K
8 A1=1000 //Inlet area in mm^2
9 P2=0.95 //Exit pressure in bar
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-K
12
13 //Calculation
14 a_1=sqrt(k*R*T1) //Velocity of sound at inlet in m/s
15 M1=C1/a_1 //Inlet mach number
16 t1=0.970 //Ratio of inlet temperature to Stagnation
    temperature from gas tables @M=1
17 To1=T1/t1 //Stagnation temperature in K
18 p1=0.900 //Ratio of inlet pressure to Stagnation

```



```

    pressure from gas tables @M=1
19 Po1=P1/p1 //Stagnation pressure in bar
20 a1=1.623 //Ratio of inlet area to critical area from
    isentropic gas tables @M=1
21 At=A1/a1 //critical area in mm^2
22 p2=0.528 //Pressure ratio at critical state from
    isentropic gas tables @M=1
23 Pt=Po1*p2 //Throat pressure in bar
24 t2=0.834 //Temperature ratio at critical state from
    isentropic gas tables @M=1
25 Tt=To1*t2 //Throat temperature in K
26 a_t=sqrt(k*R*Tt) //Velocity of sound at throat in m/
    s
27 C_t=a_t //Critical velocity of air in m/s
28 p3=P2/Po1 //Pressure ratio at exit
29 M2=1.17 //Mach number at exit from isentropic gas
    tables @p3
30 t3=0.785 //Temperature ratio at exit from isentropic
    gas tables @M2
31 T2=To1*t3 //Exit temperature in K
32 a3=1.022 //Area ratio at exit from isentropic gas
    tables @M2
33 A2=At*a3 //Exit area in mm^2, wrong answer in
    textbook
34 C2=M2*sqrt(k*R*T2) //Exit velocity in m/s
35
36 //Output
37 printf('(A) Stagnation temperature and pressure are
    %3.2f K and %3.3f bar\n (B) Sonic velocity and
    mach number at entry are %3.2f m/s and %3.2f\n (C
    ) Velocity , Mach number and flow area at outlet
    section are %3.2f m/s, %3.2f and %3.2f mm^2\n (D)
    Pressure , area at throat of the nozzle are %3.5f
    bar and %3.3f mm^2 ',To1,Po1,a_1,M1,C2,M2,A2,Pt,At
    )

```

Scilab code Exa 2.3 To find properties at throat and exit maximum possible velocity of gas and type of nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po1=10 //Stagnation pressure in bar
6  To1=798 //Stagnation temperature in K
7  Pt=7.6 //Throat pressure in bar
8  m=1.5 //Mass flow rate in kg/s
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
12
13 //Calculation
14 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from isentropic gas tables @M=1,k=1.4
15 Pc=p1*Po1 //Critical pressure in bar
16 P2=Pt //Exit pressure in bar, Since Pc<P2
17 p2=P2/Po1 //Pressure ratio
18 M2=0.64 //Exit mach number from isentropic gas
    tables @p2
19 t1=0.924 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2
20 T2=t1*To1 //exit temperature in K
21 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
22 C_max=sqrt(2*Cp*To1) //Maximum possible velocity in
    m/s
23 d2=(P2*10^5)/(R*T2) //Density at exit in kg/m^3
24 At=(m/(d2*C2))*10^6 //Throat area in mm^2
25
26 //Output

```

```

27 printf('(A)At the nozzle throat/exit:\n    Pressure
    is %3.2f bar\n    Temperature is %3.2f K\n
    Velocity is %3.2f\n (B)Maximum possible velocity
    is %3.2f m/s\n (C)Type of the nozzle is a
    convergent nozzle and its throat area is %3.3f mm
    ^2 ',P2,T2,C2,C_max,At)

```

Scilab code Exa 2.4 To find properties at exit in Convergent Divergent nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po1=3.344 //Stagnation pressure in bar
6  To1=900 //Stagnation temperature in K
7  P2=1.05 //Exit pressure in bar
8  k=1.4 //Adiabatic Constant
9  R=287 //Specific gas constant in J/kg-K
10 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
11
12 //Calculation
13 p1=P2/Po1 //Pressure ratio
14 M2=1.40 //Exit mach number from gas tables @p1,k=1.4
15 t1=0.718 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
16 T2=To1*t1 //exit temperature in K
17 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
18 d2=(P2*10^5)/(R*T2) //Density at exit in kg/m^3
19 a1=1.115 //Ratio of exit area to critical area from
    isentropic gas tables @M2
20 M_2=0.6733 //Exit mach number when it acts as
    diffuser
21 t2=0.91633 //Ratio of exit temperature to Stagnation

```

```

    temperature from isentropic gas tables @M2
22 T_2=t2*To1 //exit temperature in K
23 C_2=sqrt(k*R*T_2)*M_2 //Exit velocity in m/s
24 p2=0.738 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2
25 P_2=Po1*p2 //exit pressure in bar
26 d_2=(P_2*10^5)/(R*T_2) //Density at exit in kg/m^3
27
28 //Output
29 printf('(A)At exit:\n    Temperaure is %3i K\n
    Velocity is %3.2f m/s\n    Density is %3.3f kg/m
    ^3\n (B)At diffuser:\n    Temperaure is %3.3f K\n
    Velocity is %3.3f m/s\n    Density is %3.4f
    kg/m^3\n    Pressure is %3.4f bar\n',T2,C2,d2,T_2
    ,C_2,d_2,P_2)

```

Scilab code Exa 2.5 To find mass flow rate and pressure of a CD nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po1=8 //Stagnation pressure in bar
6  To1=273+15 //Stagnation temperature in K
7  At=25 //Throat area in cm^2
8  A2=100 //Exit area in cm^2
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11
12 //Calculation
13 a1=A2/At //Area ratio
14 M2=2.94 //Exit mach number from gas tables @a1,k=1.4
15 p1=0.0298 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
16 P2=Po1*p1 //exit pressure in bar

```

```

17 M_2=0.146 //Exit mach number when it acts as
    diffuser
18 p2=0.9847 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2
19 P_2=Po1*p2 //exit pressure in bar
20 p3=0.528 //Ratio of critical pressure to Stagnation
    pressure from isentropic gas tables @M=1,k=1.4
21 Pc=(Po1*p3) //Critical pressure in bar
22 t1=0.834 //Ratio of critical temperature to
    Stagnation temperature from isentropic gas tables
    @M=1,k=1.4
23 Tt=To1*t1 //critical temperature in K
24 d_t=(Pc*10^5)/(R*Tt) //Density at critical state in
    kg/m^3
25 a_t=sqrt(k*R*Tt) //Velocity of sound at critical
    state in m/s
26 Ct=a_t //Velocity of air at critical state in m/s
27 m=d_t*At*Ct*10^-4 //Mass flow rate in kg/s
28
29 //Output
30 printf('(A)Maximum mass flow rate is %3.3f kg/s\n (B
    )As nozzle:\n    Pressure is %3.4f bar\n    Mach
    number is %3.2f\n As diffuser:\n    Pressure is
    %3.4f bar\n    Mach number is %3.3f',m,P2,M2,P_2,
    M_2)

```

Scilab code Exa 2.6 To find exit properties and force exerted on diffuser walls

```

1 clc
2 clear
3
4 //Input data
5 D1=15 //Entry diameter in cm
6 D2=30 //Exit diameter in cm

```

```

7 P1=0.96 //Inlet pressure in bar
8 T1=340 //Inlet temperature in K
9 C1=185 //INlet velocity in m/s
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-K
12
13 //Calculation
14 A1=%pi*D1^2/4 //Entry area in cm^2
15 A2=%pi*D2^2/4 //Exit area in cm^2
16 a_1=sqrt(k*R*T1) //Sound velocity in m/s
17 M1=C1/a_1 //Inlet mach number
18 p1=0.843 //Ratio of inlet pressure to Stagnation
    pressure from gas tables @M1,k=1.4
19 Po1=P1/p1 //Stagnation pressure in bar
20 t1=0.952 //Ratio of inlet temperature to Stagnation
    temperature from gas tables @M1,k=1.4
21 To1=T1/t1 //Stagnation temperature in K
22 a1=1.34 //Ratio of inlet area to critical area from
    isentropic gas tables @M1,k=1.4
23 At=A1/a1 //critical area in cm^2
24 a2=A2/At //Area ratio
25 M2=0.1088 //Exit mach number from gas tables @a2,k
    =1.4
26 p2=0.992 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
27 P2=Po1*p2 //exit pressure in bar
28 t2=0.9976 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
29 T2=To1*t2 //exit temperature in K
30 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
31 F1=P1*10^5*A1*10^-4*(1+(k*(M1^2))) //Force exerted
    at entry in kN
32 F2=P2*10^5*A2*10^-4*(1+(k*(M2^2))) //Force exerted
    at exit in kN
33 F=(F2-F1)*10^-3 //Force exerted on the diffuser
    walls in kN, wrong answer in textbook
34
35 //Output

```

```

36 printf('(A)Exit pressure is %3.3f bar\n (B)Exit
    velocity is %3.2f m/s\n (C)Force exerted on the
    diffuser walls is %3.3f kN',P2,C2,F)

```

Scilab code Exa 2.7 To find properties at inlet and exit of diffuser

```

1  clc
2  clear
3
4  //Input data
5  M1=3.6 //Inlet mach number
6  M2=2 //Exit mach number
7  m=15 //Mass flow rate in kg/s
8  P1=1.05 //Inlet pressure in bar
9  T1=313 //Inlet temperature in K
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-K
12
13 //Calculation
14 p1=11.38*10^-3 //Ratio of inlet pressure to
    Stagnation pressure from gas tables @M1,k=1.4
15 Po=P1/p1 //Stagnation pressure in bar
16 t1=0.278 //Ratio of inlet temperature to Stagnation
    temperature from gas tables @M1,k=1.4
17 To=T1/t1 //Stagnation temperature in K
18 C1=sqrt(k*R*T1)*M1 //Inlet velocity in m/s
19 d1=(P1*10^5)/(R*T1) //Density at inlet in kg/s, P1
    in Pa
20 A1=(m/(d1*C1))*10^4 //Inlet area in cm^2
21 p2=0.128 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
22 P2=Po*p2 //exit pressure in bar
23 t2=0.555 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
24 T2=To*t2 //exit temperature in K

```

```

25 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
26 d2=(P2*10^5)/(R*T2) //Density at exit in kg/s
27 A2=(m/(d2*C2))*10^4 //Exit area in cm^2
28
29 //Output
30 printf('(A)At Inlet:\n      Area is %3.1f cm^2\n
      Total pressure %3.2f bar\n      Total temperature
      is %3.1f K\n (B)At Exit:\n      Area is %3.1f cm^2\n
      n      Total pressure %3.2f bar\n      Total
      temperature is %3.2f K\n      Static temperature is
      %3.2f K\n      Static pressure is %3.2f bar',A1,Po
      ,To ,A2 ,Po ,To ,T2 ,P2)

```

Scilab code Exa 2.8 To find properties at throat and exit and maximum possible velocity of nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po=6.91 //Stagnation pressure in bar
6  To=325+273 //Stagnation temperature in K
7  P2=0.98 //exit pressure in bar
8  m=3600/3600 //Mass flow rate in kg/s
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11 Cp=1005 //Specific heat capacity at constant
      pressure in J/kg-K
12
13 //Calculation
14 p1=0.528 //Ratio of critical pressure to Stagnation
      pressure from gas tables @M=1
15 Pt=Po*p1 //critical pressure in bar
16 t1=0.834 //Ratio of critical temperature to
      Stagnation temperature from gas tables @M=1

```



```

17 Tt=To*t1 //critical temperature in K
18 at=sqrt(k*R*Tt) //Sound velocity at throat in m/s
19 Ct=at //Air velocity t throat in m/s, Since M=1
20 dt=(Pt*10^5)/(R*Tt) //Density of air at throat in kg
    /m^3, Pt in Pa
21 At=(m/(dt*Ct))*10^4 //Throat area in m^2 x10^-4
22 p2=P2/Po //Pressure ratio
23 M2=1.93 //Exit mach number from gas tables @p2,k=1.4
24 t2=0.573 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
25 T2=To*t2 //exit temperature in K
26 a2=1.593 //Ratio of exit area to critical area from
    isentropic gas tables @M2,k=1.4
27 A2=a2*At //Exit area in m^2, At in m^2 x10^-4
28 C_max=sqrt(2*Cp*To) //Maximum possible velocity in m
    /s
29
30 //Output
31 printf('(A)At throat:\n    Area is %3.2fx10^-4 m^2\n
    Pressure is %3.2f bar\n    Velocity is %3.1f
    m/s\n (B)At Exit:\n    Area is %3.3fx10^-4 m^2\n
    Mach number is %3.2f\n (C)Maximum possible
    velocity is %3.2f m/s',At,Pt,Ct,A2,M2,C_max)

```

Scilab code Exa 2.9 To find Stagnation temperature properties at exit and mass flow rate

```

1 clc
2 clear
3
4 //Input data
5 P1=2.45 //Inlet pressure in bar
6 T1=26.5+273 //Inlet temperature in K
7 M1=1.4 //Inlet mach number
8 M2=2.5 //Exit mach number

```

```

 9 k=1.3 //Adiabatic Constant
10 R=469 //Specific gas constant in J/kg-K
11
12 //Calculation
13 t1=0.773 //Ratio of inlet temperature to Stagnation
    temperature from gas tables @M1,k=1.3
14 To=T1/t1 //Stagnation temperature in K
15 t2=0.516 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.3
16 T2=To*t2 //exit temperature in K
17 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
18 a1=sqrt(k*R*T1) //Sound velocity at inlet in m/s
19 G=(P1*10^5*a1*M1)/(R*T1) //Flow rate per square
    meter of the inlet cross section in kg/s-m^2
20
21 //Output
22 printf('(A) Stagnation temperature is %3.2f K\n (B) At
    Exit:\n    Temperature is %3.3f K\n    Velocity
    is %3.2f m/s\n (C) Flow rate per square meter of
    the inlet cross section is %3.2f kg/s-m^2 ',To,T2,
    C2,G)

```

Scilab code Exa 2.10 To determine throat and exit conditions mass flow rate through nozzle

```

1 clc
2 clear
3
4 //Input data
5 Po=1000 //Stagnation pressure in kPa
6 To=800 //Stagnation temperature in K
7 k=1.4 //Adiabatic Constant
8 M2=2 //Exit mach number
9 At=20 //Throat area in cm^2
10 R=287 //Specific gas constant in J/kg-K

```

```

11
12 // Calculation
13 t1=0.834 //Ratio of critical temperature to
    Stagnation temperature from isentropic gas tables
    @M=1,k=1.4
14 Tt=To*t1 //critical temperature in K
15 at=sqrt(k*R*Tt) //Velocity of sound at critical
    state in m/s
16 Ct=at //Velocity of air at critical state in m/s,
    Since M=1
17 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from isentropic gas tables @M=1,k=1.4
18 Pt=Po*p1 //Critical pressure in bar
19 dt=(Pt*10^3)/(R*Tt) //Density at critical state in
    kg/m^3, Pt in Pa
20 m=dt*At*10^-4*Ct //Mass flow rate in kg/s, At in m^2
21 p2=0.128 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
22 P2=Po*p2 //exit pressure in kPa
23 t2=0.555 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
24 T2=To*t2 //exit temperature in K
25 a2=1.687 //Ratio of exit area to critical area from
    isentropic gas tables @M2,k=1.4
26 A2=At*a2 //Exit area in cm^2
27 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
28 d2=P2*10^3/(R*T2) //Density at exit in kg/m^3, P2 in
    Pa
29
30 //Output
31 printf('(A)At throat:\n    Temperature is %3.1f K\n
    Velocity is %3.2f m/s\n    Pressure is %3i kPa
    \n (B)At Exit:\n    Temperature is %3i K\n
    Pressure is %3i kPa\n    Area is %3.2f m^2\n
    Mass flow rate is %3.4f kg/s',Tt,Ct,Pt,T2,P2,A2,m
    )

```

Scilab code Exa 2.11 To find properties at throat and test section mass flow rate and Power required in nozzle of wind tunnel

```

1  clc
2  clear
3
4  //Input data
5  M2=2 //Exit mach number
6  At=1000 //Throat area in cm2
7  Po=0.69 //Stagnation pressure in bar
8  To=310 //Stagnation temperature in K
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11 Cp=1.005 //Specific heat capacity at constant
    pressure in kJ/kg-K
12
13 //Calculation
14 t1=0.834 //Ratio of critical temperature to
    Stagnation temperature from isentropic gas tables
    @M=1,k=1.4
15 Tt=To*t1 //critical temperature in K
16 at=sqrt(k*R*Tt) //Velocity of sound at critical
    state in m/s
17 Ct=at //Velocity of air at critical state in m/s,
    Since M=1
18 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from isentropic gas tables @M=1,k=1.4
19 Pt=Po*p1 //Critical pressure in bar
20 dt=(Pt*105)/(R*Tt) //Density at critical state in
    kg/m3, Pt in Pa
21 m=dt*At*10-4*Ct //Mass flow rate in kg/s, At in m2
22 p2=0.128 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
23 P2=Po*p2 //exit pressure in bar

```

```

24 t2=0.555 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
25 T2=To*t2 //exit temperature in K
26 C2=sqrt(k*R*T2)*M2 //Exit velocity in m/s
27 d2=(P2*10^5)/(R*T2) //Density at exit in kg/m^3, P2
    in Pa
28 A2=(m/(d2*C2))*10^4 //Exit area in cm^2
29 P=m*Cp*(To-T2) //Power required to drive the
    compressor in kW
30
31 //Output
32 printf('(A)At throat:\n    Temperature is %3.2f K\n
    Velocity is %3.2f m/s\n    Pressure is %3.3f
    bar\n    At Test section:\n    Temperature is %3
    .2f K\n    Velocity is %3.3f m/s\n    Pressure is
    %3.3f bar\n (B)Area of cross section at test
    section is %3i cm^2\n (C)Mass flow rate is %3.3f
    kg/s\n (D)Power required to drive the compressor
    is %3.2f kW',Tt,Ct,Pt,T2,C2,P2,A2,m,P)

```

Scilab code Exa 2.12 To find cross section at throat and exit

```

1  clc
2  clear
3
4  //Input data
5  Po=10 //Stagnation pressure in bar
6  To=100+273 //Stagnation temperature in K
7  m=15 //mass flow rate in kg/s
8  P2s=1 //Back pressure in isentropic state in bar
9  eff=0.95 //efficiency of diverging nozzle
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-K
12 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K

```

```

13
14 // Calculation
15 // case I: isentropic
16 t1=0.834 //Ratio of critical temperature to
    Stagnation temperature from isentropic gas tables
    @M=1,k=1.4
17 Tt=To*t1 //critical temperature in K
18 at=sqrt(k*R*Tt) //Velocity of sound at critical
    state in m/s
19 Ct=at //Velocity of air at critical state in m/s,
    Since M=1
20 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from isentropic gas tables @M=1,k=1.4
21 Pt=Po*p1 //Critical pressure in bar
22 dt=(Pt*10^5)/(R*Tt) //Density at critical state in
    kg/m^3, Pt in Pa
23 At=(m/(dt*Ct))*10^4 //Throat area in cm^2
24 p2=P2s/Po //Pressure ratio
25 M2s=2.15 //Exit mach number from gas tables (
    isentropic state) @p2,k=1.4
26 t2=0.519 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2s,k=1.4
27 T2s=t2*To //exit temperature in K
28 a2s=sqrt(k*R*T2s) //Velocity of sound at exit in m/s
29 C2s=M2s*a2s //Exit air velocity in m/s
30 d2s=(P2s*10^5)/(R*T2s) //Density at exit in kg/m^3,
    P2 in Pa
31 A2s=(m/(d2s*C2s))*10^4 //Exit area in cm^2
32 //case II: isentropic upto throat
33 T2=To-(eff*(To-T2s)) //Exit tempareture in K
34 C2=sqrt(2*Cp*(To-T2)) //Exit air velocity in m/s
35 P2=P2s //Exit pressure in bar, Since it is diffuser
36 d2=(P2*10^5)/(R*T2) //Density at exit in kg/m^3, P2
    in Pa
37 A2=(m/(d2*C2))*10^4 //Exit area in cm^2
38
39 //Output
40 printf('(A)The nozzle cross section at throat in

```

both cases is 3.2 f cm^2 \n (B)The nozzle cross section at exit in case I is 3.3 f cm^2 and in case II is 3.2 f cm^2 ,At ,A2s ,A2)

Scilab code Exa 2.13 To find ratio of areas velocity and back pressure in CD nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po=600 //Stagnation pressure in kPa
6  To=40+273 //Stagnation temperature in K
7  P2=100 //exit pressure in kPa
8  k=1.4 //Adiabatic Constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 p1=P2/Po //pressure ratio
13 M2=1.82 //Exit mach number from gas tables @p2,k=1.4
14 ar=1.461 //Ratio of nozzle exit area to nozzle
    throat area from gas tables @M2
15 t1=0.602 //Ratio of exit temperature to Stagnation
    temperature from isentropic gas tables @M2,k=1.4
16 T2=To*t1 //exit temperature in K
17 C2=sqrt(k*R*T2)*M2 //Exit air velocity in m/s
18 p2=3.698 //Ratio of static pressures after shock to
    before shock from normal shock gas tables @M2
19 Py=p2*P2 //The back pressure at which normal shock
    acts at the exit plane of the nozzle in kPa
20
21 //Output
22 printf('(A)Ratio of nozzle exit area to nozzle
    throat area is %3.3f\n (B)The discharge velocity
    from nozzle is %3.2f m/s\n (C)The back pressure

```

at which normal shock acts at the exit plane of the nozzle is %3.1f kPa',ar,C2,Py)

Scilab code Exa 2.14 To find how duct acts

```
1 clc
2 clear
3
4 //Input data
5 ar=2 //Ratio of nozzle exit area to nozzle throat
    area
6 Po=700 //Stagnation pressure in kPa
7 P2=400 //exit pressure in kPa
8
9 //Calculation
10 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from gas tables @M=1
11 Pt=Po*p1 //critical pressure in bar
12 p2=P2/Po //Pressure ratio
13 M2=0.93 //Exit mach number from gas tables @p2,k=1.4
14
15 //Output
16 printf('Since pressure decreases from %3i kPa to %3
    .1f kPa from inlet to throat, it acts as nozzle\n
    Since exit pressure %3i kPa is above critical
    pressure %3.1f kPa, it acts as diffuser with M=%3
    .2f\n Hence the duct acts as Venturi ',Po,Pt,P2,Pt
    ,M2)
```

Scilab code Exa 2.15 To find mass flow rate static and stagnation conditions and entropy change of subsonic diffuser

```
1 clc
```



```

2 clear
3
4 //Input data
5 A1=0.15 //Inlet area in m^2
6 C1=240 //Inlet velocity in m/s
7 T1=300 //Inlet temperature in K
8 P1=0.7 //Inlet pressure in bar
9 C2=120 //Exit velocity in m/s
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-K
12 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
13
14 //Calculations
15 a1=sqrt(k*R*T1) //Velocity of sound at inlet in m/s
16 M1=C1/a1 //Inlet mach number
17 d1=(P1*10^5)/(R*T1) //Density at inlet in kg/s, P1
    in Pa
18 m=d1*A1*C1 //Mass flow rate in kg/s
19 t1=0.913 //Ratio of inlet temperature to Stagnation
    temperature from gas tables @M1,k=1.4
20 To=T1/t1 //Stagnation temperature in K
21 p1=0.727 //Ratio of inlet pressure to Stagnation
    pressure from gas tables @M1,k=1.4
22 Po=P1/p1 //Stagnation pressure in bar
23 T2=To-(C2^2/(2*Cp)) //Exit temperature in K
24 t2=T2/To //Temperature ratio
25 M2=0.33 //Exit mach number from gas tables @t2,k=1.4
26 p2=0.927 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
27 P2=Po*p2 //exit pressure in bar
28 d2=(P2*10^5)/(R*T2) //Density at exit in kg/s, P2 in
    Pa
29 A2=(m/(d2*C2)) //Exit area in m^2
30 ds=0 //Entropy change in kJ/kg-K, since process is
    isentropic
31
32 //Output

```

```

33 printf('(A)Mass flow rate is %3.3f kg/s\n (B)
    Stagnation pressure at exit is %3.4f bar\n (C)
    Stagnation Temperature at exit is %3.3f K\n (D)
    Static exit pressure is %3.3f bar\n (E)Entropy
    change is %3i kJ/kg-K\n (F)Exit area is %3.3f m^2
    ',m,Po,To,P2,ds,A2)

```

Scilab code Exa 2.16 To find throat area reservoir conditions and mass flow rate

```

1  clc
2  clear
3
4  //Input data
5  A2=645 //Exit area in mm^2
6  M2=2 //Exit mach number
7  P2=1 //exit pressure in bar
8  T2=185 //Exit temperature in K
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11
12 //Calculation
13 t1=0.555 //Ratio of exit temperature to Stagnation
    temperature from gas tables @M2,k=1.4
14 To=T2/t1 //Stagnation temperature in K
15 p1=0.128 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
16 Po=P2/p1 //Stagnation pressure in bar
17 a1=1.687 //Ratio of exit area to critical area from
    isentropic gas tables @M2,k=1.4
18 At=A2/a1 //Critical area in mm^2
19 d2=(P2*10^5)/(R*T2) //Density at exit in kg/s, P2 in
    Pa
20 C2=sqrt(k*R*T2)*M2 //Exit air velocity in m/s
21 m=d2*A2*C2*10^-6 //Mass flow rate in kg/s, A2 in m^2

```

```

22
23 //Output
24 printf('(A)Throat area is %3.2f mm^2\n (B)Reservoir
      pressure is %3.4f bar\n (C)Reservoir temperature
      is %3.2f K\n (D)Mass flow rate is %3.4f kg/s',At,
      Po,To,m)

```

Scilab code Exa 2.17 To find throat conditions ratio of velocities and mass flow rate

```

1  clc
2  clear
3
4  //Input data
5  Po=20 //Stagnation pressure in kPa
6  To=1000 //Stagnation temperature in K
7  P2=3 //exit pressure in bar
8  A2=100 //Exit area in cm^2
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11 Cp=1005 //Specific heat capacity at constant
      pressure in J/kg-K
12
13 //Calculations
14 p1=P2/Po //Pressure ratio
15 M2=1.9 //Exit mach number from gas tables @p1,k=1.4
16 t1=0.581 //Ratio of exit temperature to Stagnation
      temperature from isentropic gas tables @M2,k=1.4
17 T2=To*t1 //exit temperature in K
18 C2=M2*sqrt(k*R*T2) //Exit velocity in m/s
19 a1=1.555 //Ratio of exit area to critical area from
      isentropic gas tables @M2,k=1.4
20 At=A2/a1 //critical area in cm^2
21 p1=0.528 //Ratio of critical pressure to Stagnation
      pressure from gas tables @M=1

```

```

22 Pt=Po*p1 //critical pressure in bar
23 t1=0.834 //Ratio of critical temperature to
    Stagnation temperature from gas tables @M=1
24 Tt=To*t1 //critical temperature in K
25 at=sqrt(k*R*Tt) //Sound velocity at throat in m/s
26 Ct=at //Air velocity t throat in m/s, Since M=1
27 dt=(Pt*10^5)/(R*Tt) //Density of air at throat in kg
    /m^3, Pt in Pa
28 m=dt*At*10^-4*Ct //Mass flow rate in kg/s, At in m^2
29 C_max=sqrt(2*Cp*To) //Maximum possible velocity in m
    /s
30 cr=C2/C_max //Ratio of velocities
31
32 //Output
33 printf('(A)At Throat:\n      Area is %3.2f cm^2\n
    Pressure is %3.2f bar\n      Temperature is %3i K\n
    (B)Exit velocity is %3.4f times C_max in m/s\n (
    C)Mass flow rate is %3.2f kg/s',At,Pt,Tt,cr,m)

```

Scilab code Exa 2.18 To find mass flow rate and exit conditions

```

1  clc
2  clear
3
4  //Input data
5  Po=7 //Stagnation pressure in bar
6  To=100+273 //Stagnation temperature in K
7  At=12 //Critical area in cm^2
8  A2=25.166 //Exit area in cm^2
9  k=1.4 //Adiabatic Constant
10 R=287 //Specific gas constant in J/kg-K
11
12 //Calculation
13 a1=A2/At //Ratio of areas
14 //subsonic

```

```

15 M2=0.29 //Exit mach number from gas tables @a1,k=1.4
16 p1=0.943 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
17 P2=Po*p1 //exit pressure in bar
18 t1=0.983 //Ratio of exit temperature to Stagnation
    temperature from gas tables @M2,k=1.4
19 T2=To*t1 //Exit temperature in K
20 C2=M2*sqrt(k*R*T2) //Exit air velocity in m/s
21 //supersonic
22 M_2=2.25 //Exit mach number from gas tables @a1,k
    =1.4
23 p2=0.0865 //Ratio of exit pressure to Stagnation
    pressure from isentropic gas tables @M2,k=1.4
24 P_2=Po*p2 //exit pressure in bar
25 t2=0.497 //Ratio of exit temperature to Stagnation
    temperature from gas tables @M2,k=1.4
26 T_2=To*t2 //Exit temperature in K
27 C_2=M_2*sqrt(k*R*T_2) //Exit air velocity in m/s
28 d2=(P2*10^5)/(R*T2) //Density at exit in kg/s, P2 in
    Pa
29 m=d2*A2*10^-4*C2 //Mass flow rate in kg/s, A2 in m^2
30
31 //Output
32 printf('(A)Maximum mass flow rate is %3.3f kg/s\n (B
    )Subsonic exit condition:\n    Temperature is %3
    .3f K\n    Velocity is %3.2f m/s\n    Pressure is
    %3.3f bar\n    Mach number is %3.2f\n
    Supersonic exit condition:\n    Temperature is %3
    .3f K\n    Velocity is %3.2f m/s\n    Pressure is
    %3.4f bar\n    Mach number is %3.2f\n',m,T2,C2,
    P2,M2,T_2,C_2,P_2,M_2)

```

Scilab code Exa 2.19 To find mach number change in stagnation pressure entropy change and static temperature and efficiency of nozzle

```

1  clc
2  clear
3
4  //Input data
5  T1=335 //Inlet temperature in K
6  P1=655 //Inlet pressure in kPa
7  C1=150 //Inlet velocity in m/s
8  P2=138 //Exit pressure in kPa
9  T2=222 //Exit temperature in K
10 m=9 //Mass flow rate in kg/s
11 Mol=32 //Molar mass of oxygen in kg/mol
12 Ri=8314 //Ideal gas constant in J/kg-k
13 k=1.4 //Adiabatic Constant
14 Cp=915 //Specific heat capacity at constant pressure
    in J/kg-K
15
16 //Calculation
17 R=Ri/Mol //Specific gas constant in J/kg-K
18 a1=sqrt(k*R*T1) //Sound velocity at inlet in m/s
19 M1=C1/a1 //Inlet mach number
20 t1=0.964 //Ratio of inlet temperature to Stagnation
    temperature from gas tables @M1,k=1.4
21 To1=T1/t1 //Stagnation temperature at inlet in K
22 p1=0.881 //Ratio of inlet pressure to Stagnation
    pressure at entry from gas tables @M1,k=1.4
23 Po1=P1/p1 //Stagnation pressure at entry in kPa
24 t2=0.834 //Ratio of critical temperature to
    Stagnation temperature from gas tables @M=1
25 Tt=To1*t2 //critical temperature in K
26 C2=sqrt(C1^2+(2*Cp*(T1-T2))) //Exit velocity in m/s,
27 a2=sqrt(k*R*T2) //Sound velocity at exit in m/s
28 M2=C2/a2 //Exit mach number
29 p2=0.208 //Ratio of exit pressure to Stagnation
    pressure at exit from isentropic gas tables @M2,k
    =1.4
30 Po2=P2/p2 //Stagnation pressure at exit in kPa
31 SPC=(Po1-Po2) //Change in the stagnation pressure
    between inlet and exit in kPa

```

```

32 ds=R*log(Po1/Po2) //Change in entropy in J/kg-K
33 T2s=T1*((P2/P1)^((k-1)/k)) //Exit temperature at
    isentropic state in K
34 eff=((T1-T2)/(T1-T2s))*100 //Nozzle efficiency in
    percent
35
36 //Output
37 printf('(A)Exit mach number is %3.2f\n (B)Change in
    the stagnation pressure between inlet and exit is
    %3.2f kPa\n (C)Change in entropy is %3.3f J/kg-K
    \n (D)Static temperature at throat is %3.1f K\n (
    E)Nozzle efficiency is %3.2f percent ',M2,SPC,ds,
    Tt,eff)

```

Scilab code Exa 2.20 To find pressure rise coefficient and ratio of area

```

1  clc
2  clear
3
4  //Input data
5  C1=200 //Inlet velocity in m/s
6  Po1=400 //Stagnation pressure at entry in kPa
7  To1=500 //Stagnation temperature at inlet in K
8  C2=100 //Exit velocity in m/s
9  eff=0.9 //Nozzle efficiency
10 k=1.4 //Adiabatic Constant
11 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
12
13 //Calculation
14 T1=To1-(C1^2/(2*Cp)) //Inlet temperature in K
15 t1=T1/To1 //Temperature ratio
16 P1=Po1*t1^(k/(k-1)) //Inlet pressure in kPa
17 To2s=(eff*(To1-T1))+T1 //Exit Stagnation temperature
    at isentropic state in K

```

```

18 To2=To2s //Exit Stagnation temperature in K, Since
    adiabatic
19 T2=To2-(C2^2/(2*Cp)) //Exit temperature in K
20 t2=To2s/T1 //Temperature ratio
21 Po2=P1*t2^(k/(k-1)) //Stagnation pressure at exit in
    kPa
22 t3=T2/To2 //Temperature ratio
23 P2=Po2*t3^(k/(k-1)) //Exit pressure in kPa
24 Cpr=(P2-P1)/(Po1-P1) //Pressure raise coefficient
25 ar=(P1*T2*C1)/(P2*T1*C2) //Ratio of exit to inlet
    area
26
27 //Output
28 printf('(A) Pressure raise coefficient is %3.3f\n (B)
    Ratio of exit to inlet area is %3.3f',Cpr,ar)

```

Scilab code Exa 2.21 To find area at throat and exit Mach number total pressure loss and entropy change

```

1 clc
2 clear
3
4 //Input data
5 Po1=4.9 //Stagnation pressure at entry in bar
6 P2=1.4 //Exit pressure in bar
7 To=810 //Stagnation temperature in K
8 m=1 //Mass flow rate in kg/s
9 eff=0.9 //Nozzle efficiency
10 k=1.4 //Adiabatic Constant
11 R=287 //Specific gas constant in J/kg-K
12 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
13
14 //Calculations
15 t1=0.834 //Ratio of critical temperature to

```



```

    Stagnation temperature from gas tables @M=1
16 Tt=To*t1 //critical temperature in K
17 at=sqrt(k*R*Tt) //Sound velocity at critical state
    in m/s
18 Ct=at //Air velocity t throat in m/s, Since M=1
19 p1=0.528 //Ratio of critical pressure to Stagnation
    pressure from gas tables @M=1
20 Pt=Po1*p1 //critical pressure in bar
21 dt=(Pt*10^5)/(R*Tt) //Density of air at throat in kg
    /m^3, Pt in Pa
22 At=(m/(dt*Ct))*10^4 //Throat area in cm^2
23 p2=P2/Po1 //Pressure ratio
24 T2s=To*p2^((k-1)/k) //Exit temperature in K (at
    isentropic state)
25 T2=To-(eff*(To-T2s)) //Exit temperature in K
26 d2=(P2*10^5)/(R*T2) //Density at exit in kg/m^3, P2
    in Pa
27 C2=sqrt(2*Cp*(To-T2)) //Exit air velocity in m/s
28 A2=(m/(d2*C2))*10^4 //Exit area in cm^2
29 a2=sqrt(k*R*T2) //Sound velocity at exit in m/s
30 M2=C2/a2 //Exit mach number
31 p3=0.332 //Static to stagnation pressure ratio at
    exit from isentropic gas tables @M2,k=1.4
32 Po2=P2/p3 //stagnation pressure in bar
33 TPL=Po1-Po2 //Loss in total pressure is %3.3f bar
34 ds=R*log(Po1/Po2) //Increase in entropy in kJ/kg-K
35
36 //Output
37 printf('(A)Throat and exit area are %3.2f cm^2 and
    %3.3f cm^2\n (B)Exit mach number is %3.2f\n (C)
    Loss in total pressure is %3.3f bar\n (D)Increase
    in entropy is %3.2f kJ/kg-K',At,A2,M2,TPL,ds)

```

Scilab code Exa 2.22 To find required throat and exit area of nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po=3.5 //Stagnation pressure in bar
6  To=425+273 //Stagnation temperature in K
7  P2=0.97 //Exit pressure in bar
8  m=18 //Mass flow rate in kg/s
9  Kd=0.99 //Coefficient of discharge
10 eff=0.94 //Nozzle efficiency
11 k=1.33 //Adiabatic Constant
12 Cp=1110 //Specific heat capacity at constant
    pressure in J/kg-K
13
14 //Calculations
15 Pt=Po*(2/(k+1))^(k/(k-1)) //critical pressure in bar
16 Tt=To*(2/(k+1)) //critical temperature in K
17 R=Cp/(k/(k-1)) //Specific gas constant in J/kg-K
18 m_s=m/Kd //Isentropic mass
19 at=sqrt(k*R*Tt) //Sound velocity at throat in m/s
20 Ct=at //Air velocity t throat in m/s, Since M=1
21 dt=(Pt*10^5)/(R*Tt) //Density of air at throat in kg
    /m^3, Pt in Pa
22 At=(m_s/(dt*Ct))*10^4 //Throat area in cm^2
23 p2=P2/Po //Pressure ratio
24 T2s=To*p2^(1/(k/(k-1))) //Exit temperature in K (at
    isentropic state)
25 T2=To-(eff*(To-T2s)) //Exit temperature in K
26 d2=(P2*10^5)/(R*T2) //Density at exit in kg/m^3, P2
    in Pa
27 C2=sqrt(2*Cp*(To-T2)) //Exit air velocity in m/s
28 A2=(m_s/(d2*C2))*10^4 //Exit area in cm^2
29
30 //Output
31 printf('Throat area and Exit area of nozzle are %3.1
    f cm^2 and %3.1 f cm^2 ',At,A2)

```

Chapter 3

Flow Through Constant Area Duct Adiabatic Flow

Scilab code Exa 3.1 To find length of pipe

```
1  clc
2  clear
3
4  //input data
5  M1=0.25 //Mach number at entrance
6  M2=1 //Mach number at exit
7  D=0.04 //inner tube diameter in m
8  f=0.002 //frictional factor
9
10 //calculation
11 X1=8.537 //frictional constant fanno parameter at
    entry from gas tables @M1=0.25
12 X2=0 //frictional constant fanno parameter at exit
    from gas tables @M2=1
13 X=X1-X2 //overall frictional constant fanno
    parameter i.e. (4*f*L)/D
14 L=(X*D)/(4*f) //Length of the pipe in m
15
16 //output
```

```
17 printf('(A)Length of the pipe is %3.3f m',L)
```

Scilab code Exa 3.2 To find length of required duct and length required to obtain critical condition

```
1 clc
2 clear
3
4 //input data
5 M1=0.1 //Mach number at entrance
6 M2=0.5 //Mach number at a section
7 M3=1 //Mach number at critical condition
8 D=0.02 //Diameter of duct in m
9 f=0.004 //Frictional factor
10
11 //calculation
12 X1=66.922 //frictional constant fanno parameter from
    gas tables @M1=0.1
13 X2=1.069 //frictional constant fanno parameter from
    gas tables @M2=0.5
14 X3=0 //frictional constant fanno parameter from gas
    tables @M3=1
15 X4=X1-X3 ////frictional constant fanno parameter
    from M2=0.1 to M3=1
16 L1=(X4*D)/(4*f) //Length of the pipe in m
17 X5=X2-X3 //frictional constant fanno parameter from
    M2=0.5 to M3=1
18 L2=(X5*D)/(4*f) //Addition length of the pipe
    required to accelerate into critical condition in
    m
19 L=L1-L2 //Length of the pipe required to accelerate
    the flow from M1=0.1 to M2=0.5 in m
20
21 //output
22 printf('(A)Length of the pipe required to accelerate
```

the flow from $M_1=0.31$ to $M_2=0.31$ is 0.33 m/s
(B) Additional length required to accelerate into critical condition is 0.35 m', M_1, M_2, L, L_2)

Scilab code Exa 3.3 To find length of pipe and mass flow rate

```
1  clc
2  clear
3
4  //input data
5  D=0.05 //inner pipe diameter in m
6  Po=10 //Stagnation Pressure at reservoir in bar
7  To=400 //Stagnation temperature at reservoir in K
8  f=0.002 //frictional factor
9  M1=3 //Mach number at entrance
10 M2=1 //Mach number at end of pipe
11 R=287 //Gas constant in J/kg-K
12 k=1.4 //Adiabatic constant
13
14 //calculation
15 X1=0.522 //frictional constant fanno parameter from
    gas tables @M1=3
16 X2=0 //frictional constant fanno parameter from gas
    tables @M2=1
17 X=X1-X2 //overall frictional constant fanno
    parameter
18 L=(X*D)/(4*f) //Length of the pipe in m
19 p1=0.0272 //Pressure ratio from gas tables (M=3,k
    =1.4,isentropic)
20 P1=p1*Po //Static pressure at entrance in bar
21 t1=0.3571 //Temperature ratio from gas tables (M=3,k
    =1.4,isentropic)
22 T1=t1*To //Static temperature at entrance in K
23 d1=(P1*10^5)/(R*T1) //Density of air in kg/m^3, P1
    in Pa
```

```

24 a1=sqrt(k*R*T1) //Sound velocity in m/s
25 C1=a1*M1 //air velocity in m/s
26 A1=(%pi*D^2)/4 //Cross sectional area of pipe in m^2
27 m=d1*A1*C1 //Mass flow rate in kg/s
28
29 //output
30 printf('(A)Length of the pipe is %3.2f m\n (B)Mass
    flow rate is %3.4f kg/s',L,m)

```

Scilab code Exa 3.4 To find temperature velocity at a section and distance between two sections

```

1  clc
2  clear
3
4  //input data
5  C1=235 //Velocity at entrance in m/s
6  P1=13 //Static Pressure at entry in bar
7  P2=10 //Static Pressure at a point in duct in bar
8  T1=543 //Static temperature at entry in Kelvin
9  D=0.15 //inner duct diameter in m
10 f=0.005 //frictional factor
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13
14 //calculation
15 a1=sqrt(k*R*T1) //Sound velocity in m/s
16 M1=C1/a1 //Mach number at entry
17 p1=2.138 //Static Pressure ratio from gas tables (
    fanno flow tables ,k=1.4,M=0.5)
18 Pt=P1/p1 //Static critical pressure in bar
19 t1=1.143 //Static temperature ratio from gas tables
    (fanno flow tables ,k=1.4,M=0.5)
20 Tt=T1/t1 //Static critical temperature in K
21 c1=0.534 //Velocity ratio from gas tables (fanno

```

```

    flow tables ,k=1.4,M=0.5)
22 Ct=C1/c1 //Critical velocity in m/s
23 p2=1.644 //Pressure ratio from gas tables (fanno
    flow tables ,k=1.4)
24 M2=0.64 //Mach number from gas tables (fanno flow
    tables ,k=1.4,p2)
25 c2=0.674 //Velocity ratio from gas tables (fanno
    flow tables ,k=1.4,p2)
26 C2=Ct*c2 //Air velocity at P2 in m/s
27 t2=1.109 //Temperature ratio from gas tables (fanno
    flow tables ,k=1.4,p2)
28 T2=t2*Tt //Satic temperature at P2 is K
29 X1=1.06922 //frictional constant fanno parameter
    from gas tables @M1
30 X2=0.353 //frictional constant fanno parameter from
    gas tables @M2
31 X=X1-X2 //overall frictional constant fanno
    parameter
32 L=(X*D)/(4*f) //Length of the pipe in m
33
34 //output
35 printf('(A)Temperature and velocity at section of
    the duct where the pressure has dropped to %3i
    bar due to friction are %3.1f K and %3.2f m/s\n (
    B)The distance between two section is %3.3f m',P2
    ,T2,C2,L)

```

Scilab code Exa 3.5 To find length of pipe and properties of air at exit

```

1 clc
2 clear
3
4 //input data
5 P1=120 //Static pressure at entrance in bar
6 T1=313 //Static temperature at entry in Kelvin

```

```

7 M1=2.5 //Mach number at entrance
8 M2=1.8 //Mach number at exit
9 D=0.2 //inner pipe diameter in m
10 f=0.01/4 //frictional factor
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13
14 //calculation
15 a1=sqrt(k*R*T1) //Sound velocity in m/s
16 C1=a1*M1 //air velocity in m/s
17 p1=0.292 //Static Pressure ratio from gas tables (
    fanno flow tables ,k=1.4,M=2.5)
18 Pt=P1/p1 //Static critical pressure in kPa
19 t1=0.533 //Static temperature ratio from gas tables
    (fanno flow tables ,k=1.4,M=2.5)
20 Tt=T1/t1 //Static critical temperature in K
21 c1=1.826 //Velocity ratio from gas tables (fanno
    flow tables ,k=1.4,M=2.5)
22 Ct=C1/c1 //Critical velocity in m/s
23 X1=0.432 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1=3
24 X2=0 //frictional constant fanno parameter from gas
    tables @M2=1
25 X3=X1-X2 //overall frictional constant fanno
    parameter
26 L1=(X3*D)/(4*f) //Maximum length of the pipe in m
27 p2=0.474 //Static Pressure ratio from gas tables (
    fanno flow tables ,k=1.4,M=1.8)
28 P2=Pt*p2 //Static pressure in kPa
29 t2=0.728 //static temperature ratio from gas tables
    (fanno flow tables ,k=1.4,M=1.8)
30 T2=Tt*t2 //Static temperature in K
31 c2=1.536 //Velocity ratio from gas tables (fanno
    flow tables ,k=1.4,M=1.8)
32 C2=c2*Ct //Critical velocity in m/s
33 X4=0.242 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M=1.8
34 X5=X4-X2 //overall frictional constant fanno

```



```

parameter
35 L2=(X5*D)/(4*f) //Length between sonic and outlet
    section
36 L=L1-L2 //Length of the pipe in m
37
38 //output
39 printf('(A)Maximum length of the pipe is %3.2f m\n (
    B)Properties of air at sonic condition:\n
    Pressure is %3i kPa\n    Temperature is %3.2f K\n
    Velocity is %3.1f m/s\n (C)Length of the pipe
    is %3.1f m\n (D)Properties of air at M2=%3.1f:\n
    Pressure is %3i kPa\n    Temperature is %3.2f
    K\n    Velocity is %3.2f m/s\n',L1,Pt,Tt,Ct,L,M2
    ,P2,T2,C2)

```

Scilab code Exa 3.6 To find mach number properties at a section and critical section and length of the duct

```

1  clc
2  clear
3
4  //input data
5  M1=0.25 //Mach number at entrance
6  ds=0.124 //Change in entropy in kJ/kg-K
7  P1=700 //Static pressure at entrance in bar
8  T1=333 //Static temperature at entry in Kelvin
9  D=0.05 //inner pipe diameter in m
10 f=0.006 //frictional factor
11 k=1.4 //Adiabatic constant
12 R=0.287 //Gas constant in kJ/kg-K
13
14 //calculation
15 p1=exp(ds/R) //Ratio of Stagnation pressure at inlet
    to outlet
16 t1=0.987 //Ratio of Static Temperature to Stagnation

```

```

    temperature at entry from gas tables @M1
17 To1=T1/t1 //Stagnation temperature at entry in K
18 p2=0.957 //Ratio of Static pressure to Stagnation
    pressure at entry from gas tables @M1
19 Po1=P1/p2 //Stagnation pressure at entry in kPa
20 Po2=Po1/p1 //Stagnation pressure at exit in kPa
21 a1=sqrt(k*R*10^3*T1) //Sound velocity in m/s, R in J
    /kg
22 C1=a1*M1 //air velocity in m/s
23 p3=4.3615 //Static Pressure ratio from gas tables (
    fanno flow tables ,k=1.4,M=0.25)
24 Pt=P1/p3 //Static critical pressure in kPa
25 t1=1.185 //Static temperature ratio from gas tables
    (fanno flow tables ,k=1.4,M=0.25)
26 Tt=T1/t1 //Static critical temperature in K
27 c1=0.272 //Velocity ratio from gas tables (fanno
    flow tables ,k=1.4,M=0.25)
28 Ct=C1/c1 //Critical velocity in m/s
29 p4=2.4065 //Pressure ratio at entry from gas tables
    @M1,k
30 Pot=Po1/p4 //Stagnation pressure at critical state
    in kPa
31 X1=8.537 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k
32 p5=Po2/Pot //Pressure ratio
33 M2=0.41 //Mach number at exit from gas tables @p5
34 p6=2.629 //Pressure ratio at exit from gas tables
    @p5
35 P2=Pt*p6 //Exit pressure in kPa
36 t2=1.161 //Temperature ratio at exit from gas tables
    @p5
37 T2=Tt*t2 //Exit temperature in K
38 c2=0.4415 //Velocity ratio at exit from gas tables
    @p5
39 C2=Ct*c2 //Exit velocity in m/s
40 X2=2.141 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k
41 X3=X1-X2 //overall frictional constant fanno

```

```

parameter
42 L=(X3*D)/(4*f) //Length of the pipe in m
43
44 //output
45 printf('(A)Mach number at exit(section 2) is %3.2f \
n (B)Properties at exit(section 2):\n Pressure
is %3.2f kPa\n Temperature is %3i K\n
Velocity is %3.3f m/s\n (C)Length of the duct is
%3.3f m',M2,P2,T2,C2,L)

```

Scilab code Exa 3.7 TO find final pressure and velocity of duct

```

1 clc
2 clear
3
4 //input data
5 M1=0.25 //Initial Mach number
6 M2=0.75 //Final mach number
7 P1=1.5 //Inlet pressure in bar
8 T1=300 //Inlet temperature in K
9 k=1.4 //Adiabatic constant
10 R=0.287 //Gas constant in kJ/kg-K
11
12 //calculation
13 a1=sqrt(k*R*10^3*T1) //Sound velocity in m/s, R in J
/kg
14 C1=a1*M1 //air velocity in m/s
15 p1=4.3615 //Pressure ratio at entry from gas tables
@M1,k
16 Pt=P1/p1 //Static critical pressure in kPa
17 c1=0.272 //Velocity ratio from gas tables (fanno
flow tables ,k=1.4,M1)
18 Ct=C1/c1 //Critical velocity in m/s
19 p2=1.385 //Pressure ratio at exit from gas tables
@M2,k

```

```

20 P2=Pt*p2 //Exit pressure in bar
21 c2=0.779 //Velocity ratio at exit from gas tables
    @M2,k
22 C2=Ct*c2 //Exit velocity in m/s
23
24 //output
25 printf('Final pressure and velocity are %3.4f bar
    and %3.2f m/s ',P2,C2)

```

Scilab code Exa 3.8 To find inlet mach number mass flow rate and exit temperature

```

1  clc
2  clear
3
4  //input data
5  T1=333 //Inlet temperature in K
6  D=0.05 //inner duct diameter in m
7  f=0.005/4 //frictional factor
8  L=5 //Length of the pipe in m
9  Pt=101 //Exit pressure in kPa, Pt=P2 Since flow is
    choked
10 M2=1 //Mach number at exit since pipe is choked
11 k=1.4 //Adiabatic constant
12 R=0.287 //Gas constant in kJ/kg-K
13
14 //calculation
15 X=(4*f*L)/D //frictional constant fanno parameter
16 M1=0.6 //Inlet mach number
17 t1=1.119 //Temperature ratio at entry from fanno
    flow gas tables @M1,k
18 Tt=T1/t1 //Static critical temperature in K
19 at=sqrt(k*R*10^3*Tt) //Sound velocity in m/s, R in J
    /kg
20 Ct=at //air velocity in m/s

```

```

21 d_t=Pt/(R*Tt) //Density at exit in kg/m^3
22 At=%pi*D^2/4 //Critical area in m^2
23 m=d_t*At*Ct //Mass flow rate in kg/s
24
25 //output
26 printf('(A)Mach number at inlet is %3.1f \n (B)Mass
    flow rate is %3.5f kg/s\n (C)Exit temperature is
    %3.3f K',M1,m,Tt)

```

Scilab code Exa 3.9 To find length diameter of the duct pressure at exit Stagnation pressure lose and to verify exit mach number

```

1  clc
2  clear
3
4  //input data
5  m=8.25 //Mass flow rate in kg/s
6  M1=0.15 //Mach number at entrance
7  M2=0.5 //Mach number at exit
8  P1=345 //Static pressure at entrance in kPa
9  T1=38+273 //Static temperature at entry in Kelvin
10 f=0.005 //frictional factor
11 k=1.4 //Adiabatic constant
12 R=0.287 //Gas constant in kJ/kg-K
13
14 //calcu;ation
15 d1=(P1*10^3)/(R*10^3*T1) //Density of air in kg/m^3,
    P1 in Pa
16 a1=sqrt(k*R*10^3*T1) //Sound velocity in m/s, R in J
    /kg
17 C1=a1*M1 //air velocity in m/s
18 A1=m/(d1*C1) //Inlet area in m^2
19 D=(sqrt((4*A1)/(%pi)))*10^3 //inner duct diameter in
    mm
20 p1=7.3195 //Static Pressure ratio from gas tables (

```

```

    fanno flow tables ,k=1.4,M=0.15)
21 Pt=P1/p1 //Static critical pressure in kPa
22 t1=1.1945 //Static temperature ratio from gas tables
    (fanno flow tables ,k=1.4,M=0.15)
23 Tt=T1/t1 //Static critical temperature in K
24 c1=0.164 //Velocity ratio from gas tables (fanno
    flow tables ,k=1.4,M=0.15)
25 Ct=C1/c1 //Critical velocity in m/s
26 p2=0.984 //Pressure ratio at entry from gas tables (
    fanno flow tables ,k=1.4,M=0.15)
27 Po1=P1/p2 //Stagnation pressure at entry in kPa
28 p3=3.928 //Stagnation pressure ratio at entry from
    gas tables (fanno flow tables ,k=1.4,M=0.15)
29 Pot=Po1/p3 //Stagnation pressure at critical state
    in kPa
30 X1=28.354 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k
31 p5=2.138 //Pressure ratio at exit from gas tables (
    fanno flow tables ,k=1.4,M2)
32 P2=Pt*p5 //Exit pressure in kPa
33 t2=1.143 //Temperature ratio at exit from gas tables
    (fanno flow tables ,k=1.4,M2)
34 T2=Tt*t2 //Exit temperature in K
35 c2=0.534 //Velocity ratio at exit from gas tables (
    fanno flow tables ,k=1.4,M2)
36 C2=Ct*c2 //Exit velocity in m/s
37 p6=1.34 //Stagnation pressure ratio at exit from gas
    tables (fanno flow tables ,k=1.4,M2)
38 Po2=Pot*p6 //Stagnation pressure at exit in kPa
39 SPL=Po1-Po2 //Stagnation Pressure lose in kPa
40 X2=1.069 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k
41 X3=X1-X2 //overall frictional constant fanno
    parameter
42 L=(X3*D*10^-3)/(4*f) //Length of the duct in m
43
44 //verification
45 a2=sqrt(k*R*10^3*T2) //Sound velocity in m/s, R in J

```

```

    /kg
46 M2_v=C2/a2 //air velocity in m/s
47
48 //output
49 printf('(A)Length of the duct is %3.2f m\n (B)
    Diameter of the duct is %3i mm\n (C)Pressure and
    diameter at exit are %3.2f kPa, and %3i mm
    respectively\n (D)Stagnation Pressure lose is %3i
    kPa\n (E)Using exit velocity %3.2f m/s,
    temperature %3.2f K Mach number is found to be %3
    .2f ',L,D,P2,D,SPL,C2,T2,M2_v)

```

Scilab code Exa 3.10 To find length of the pipe Mach number percent of stagnation pressure loss and length required to reach choking condition

```

1  clc
2  clear
3
4  //input data
5  M1=0.25 //Mach number at entrance
6  f=0.01/4 //frictional factor
7  D=0.15 //inner pipe diameter in m
8  p1=0.8 //Stagnation pressure ratio at exit to entry
    when loss in stagnation pressure is 20%
9  M3=0.8 //Mach number at a section
10
11 //calculation
12 p2=2.4065 //Ratio of Stagnation pressure at entry
    from gas tables @M1,k=1.4
13 X1=8.537 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1
14 p3=p1*p2 //Ratio of Stagnation pressure at exit
15 M2=0.32 //Exit mach number at p1=0.8
16 X2=4.447 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2

```

```

17 L1=(X1*D)/(4*f) //Length of the pipe in m
18 L2=(X2*D)/(4*f) //Length of the pipe in m
19 L=L1-L2 //Overall length of the duct in m
20 p4=1.038 //Stagnation pressure ratio from M=1 to M3
21 PL=(1-(p4/p2))*100 //Percentage of stagnation
    pressure from inlet to section at which M3 in
    percent
22
23 //output
24 printf('(A)Length of the pipe is %3.2f m\n (B)Mach
    number at this exit is %3.2f\n (C)Percentage of
    stagnation pressure from inlet to section at
    which M=%3.1f is %3.2f percent\n (D)Maximum
    length to reach choking condition is %3.3f m',L,
    M2,M3,PL,L1)

```

Scilab code Exa 3.11 To find length of the pipe and mass flow rate

```

1  clc
2  clear
3
4  //input data
5  D=0.3 //inner duct diameter in m
6  P1=10 //Static pressure at entrance in bar
7  T1=400 //Static temperature at entry in Kelvin
8  M1=3 //Mach number at entrance
9  M2=1 //Mach number at exit
10 k=1.3 //Adiabatic constant
11 R=287 //Specific Gas constant in J/kg-K, wrong
    printing in question
12 f=0.002 //frictional factor
13
14 //calculation
15 p1=0.233 //Pressure ratio from gas tables (M=3,k
    =1.4,isentropic)

```



```

16 Pt=P1/p1 //Static pressure at entrance in bar
17 t1=0.489 //Temperature ratio from gas tables (M=3,k
    =1.4,isentropic)
18 Tt=T1/t1 //Static temperature at entrance in K
19 X1=0.628 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.3
20 L1=(X1*D)/(4*f) //Length of the pipe in m
21 d_t=(Pt*10^5)/(R*Tt) //Density at critical state in
    kg/m^3, Pt in Pa
22 at=sqrt(k*R*Tt) //Sound velocity in m/s, R in J/kg
23 Ct=at //air velocity in m/s
24 At=(%pi*D^2)/4 //Critical area in m^2
25 m=d_t*At*Ct //Mass flow rate in kg/s
26
27 //output
28 printf('(A)Length of the pipe is %3.2f m\n (B)Mass
    flow rate is %3.3f kg/s',L1,m)

```

Scilab code Exa 3.12 To find length and Mach number of given pipe and at required section

```

1  clc
2  clear
3
4  //input data
5  M1=0.25 //Mach number at entrance
6  f=0.04/4 //frictional factor
7  D=0.15 //inner duct diameter in m
8  p1=0.9 //Stagnation pressure ratio at exit to entry
    when loss in stagnation pressure is 10%
9  ds=190 ///Change in entropy in J/kg-K
10 k=1.3 //Adiabatic constant
11 R=287 //Specific Gas constant in J/kg-K, wrong
    printing in question
12

```

```

13 //calculation
14 p2=2.4064 //Ratio of stagnation pressures at inlet
    to critical state from gas tables fanno flow
    tables @M1,k=1.3
15 X1=8.537 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.3
16 p3=p1*p2 //Ratio of stagnation pressures at exit to
    critical state from gas tables fanno flow tables
    @M1,k=1.3
17 M2=0.28 //Mach number at p1=0.9 from gas tables @p3
18 X2=6.357 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k=1.3
19 X3=X1-X2 //overall frictional constant fanno
    parameter
20 L1=(X3*D)/(4*f) //Length of the pipe in m
21 p4=exp(ds/R) //Ratio of Stagnation pressure at entry
    to Stagnation pressure where ds=190
22 p5=p1/p4 //Ratio of Stagnation pressures where ds
    =190 to critical state
23 M3=0.56 //Mach number where ds=190
24 X4=0.674 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M3,k=1.3
25 X5=X1-X4 //overall frictional constant fanno
    parameter
26 L2=(X5*D)/(4*f) //Length of the pipe in m
27
28 //output
29 printf('(A)Length of the pipe is %3.3f m\n (B)Length
    of the pipe would require to rise entropy by %3i
    J/kg-K is %3.5f m\n (C)Mach number is %3.2f',L1,
    ds ,L2 ,M3)

```

Scilab code Exa 3.13 To find length of the pipe percent of stagnation pressure change and entropy change

```

1  clc
2  clear
3
4  //input data
5  Po1=200 //Stagantion pressure at inlet in kPa
6  To1=303 //Stagnation temperature at inlet in K
7  M1=0.2 //Inlet Mach number from diagram
8  D=0.025 //inner tude diameter in m(missing data)
9  M2=0.8 //Outlet Mach number
10 f=0.005/4 //frictional factor
11 R=287 //Gas constant in J/kg-K
12
13 //calculation
14 t1=0.992 //Static to Stagnation temperature ratio at
    entry from gas tables (M1,k=1.4,isentropic)
15 T1=To1*t1 //Static temperature in K
16 p1=0.973 //Static to Stagnation pressure ratio at
    entry from gas tables (M1,k=1.4,isentropic)
17 P1=Po1*p1 //Static pressure in kPa
18 p2=2.964 //Stagnation pressure ratio at inlet to
    critical state from gas tables (M1,k=1.4,fanno
    flow)
19 Pot=Po1/p2 //Stagnation pressure at critical state
    in kPa
20 X1=14.533 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
21 p3=1.038 //Stagnation pressure ratio at outlet to
    critical state from gas tables (M1,k=1.4,fanno
    flow)
22 Po2=Pot*p3 //Stagnation pressure at exit in kPa
23 X2=0.073 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k=1.4
24 X3=X1-X2 //overall frictional constant fanno
    parameter
25 L1=(X3*D)/(4*f) //Length of the pipe in m
26 SPL=(1-(p3/p2))*100 //Percentage decrease in
    stagnation pressure in percent
27 ds=R*log(Po1/Po2) //Change of entropy in kJ/kg-K

```

```

28
29 //output
30 printf('(A)Length of the pipe is %3.1f m\n (B)
    Percentage decrease in stagnation pressure is %3
    .2f percent\n (C)Change of entropy is %3.3f kJ/kg
    -K',L1,SPL,ds)

```

Scilab code Exa 3.14 To find maximum length of pipe and conditions of air at exit

```

1  clc
2  clear
3
4  //input data
5  D1=0.03 //Inlet duct diameter in m
6  D2=0.015 //Throat diameter of duct in m
7  Po1=750 //Stagantion pressure at inlet in kPa
8  To1=450 //Stagnation temperature at inlet in K
9  f=0.02/4 //frictional factor
10 L=0.25 //Length of the duct in m
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13
14 //calculation
15 ar=(D1/D2)^2 //Ratio of areas
16 M1=2.94 //Mach number at inlet from gas tables (ar,k
    =1.4,isentropic)
17 p1=0.0298 //Static to Stagnation pressure ratio at
    entry from gas tables (M1,k=1.4,isentropic)
18 P1=Po1*p1 //Static pressure at inlet in kPa
19 t1=0.367 //Static to Stagnation temperature ratio at
    entry from gas tables (M1,k=1.4,isentropic)
20 T1=To1*t1 //Static temperature at inlet in K
21 a1=sqrt(k*R*T1) //Sound velocity in m/s
22 C1=a1*M1 //Air velocity at inlet in m/s

```

```

23 X1=0.513 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
24 p2=0.226 //Static to Critical pressure ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
25 Pt=P1/p2 //Critical pressure in kPa
26 c1=1.949 //Static to Critical velocity ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
27 Ct=C1/c1 //Critical velocity in m/s
28 t2=0.439 //Static to Critical temperature ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
29 Tt=T1/t2 //Critical temperature in K
30 L1=(X1*D1)/(4*f) //Length of the pipe from inlet to
    critical state in m
31 L2=L1-L //Length of the pipe from required point to
    critical state in m
32 X2=(4*f*L2)/D2 //frictional constant fanno parameter
33 M2=2.14 //Mach number at inlet from gas tables (X2,k
    =1.4,fanno flow)
34 p3=0.369 //Static to Critical pressure ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
35 P2=Pt*p3 //Exit pressure in kPa
36 c2=1.694 //Static to Critical velocity ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
37 C2=Ct*c2 //Exit velocity in m/s
38 t3=0.623 //Static to Critical temperature ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
39 T2=t3*Tt //Exit temperature in K
40
41 //output
42 printf('(A)Maximum length of the pipe is %3.4f m\n (
    B)Condition of air at exit:\n    Pressure is %3.2
    f kPa\n    Velocity is %3.2f m/s\n    Temperature
    is %3.2f K\n',L1,P2,C2,T2)

```

Scilab code Exa 3.15 To find Maximum and required length of the pipe and properties of air at a section

```

1  clc
2  clear
3
4  //input data
5  f=0.002 //frictional factor
6  C1=130 //Air velocity at inlet in m/s
7  T1=400 //Inlet temperature at inlet in K
8  P1=250 //Inlet pressure at inlet in kPa
9  D=0.16 //Inlet duct diameter in m
10 p1=0.8 //Stagnation pressure ratio at exit to entry
    when loss in stagnation pressure is 20%
11 L1=35 //Length of duct from inlet to required
    section
12 k=1.4 //Adiabatic constant
13 R=287 //Gas constant in J/kg-K
14
15 //calculation
16 a1=sqrt(k*R*T1) //Sound velocity in m/s
17 M1=C1/a1 //Mach number at inlet
18 p2=0.9295 //Static to Stagnation pressure ratio at
    entry from gas tables (M1,k=1.4,isentropic)
19 Po1=P1/p2 //Stagantion pressure at inlet in kPa
20 Po2=0.8*Po1 //Stagantion pressure at outlet in kPa
21 p3=1.89725 //Stagnation pressure ratio at inlet to
    critical state from gas tables (M1,k=1.4,fanno
    flow)
22 Pot=Po1/p3 //Stagnation pressure at critical state
    in kPa
23 X1=4.273 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
24 p4=3.33725 //Static Pressure ratio from gas tables (

```

```

    fanno flow tables ,k=1.4,M=0.5)
25 Pt=P1/p4 //Static critical pressure in kPa
26 t1=1.175 //Static temperature ratio from gas tables
    (fanno flow tables ,k=1.4,M=0.5)
27 Tt=T1/t1 //Static critical temperature in K
28 c1=0.347 //Velocity ratio from gas tables (fanno
    flow tables ,k=1.4,M=0.5)
29 Ct=C1/c1 //Critical velocity in m/s
30 p5=Po2/Pot //Pressure ratio
31 M2=0.43 //Mach number at p1=0.8
32 X2=1.833 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k=1.4
33 X3=X1-X2 //overall frictional constant fanno
    parameter
34 L2=(X3*D)/(4*f) //Length of the pipe in m, (from
    required section to critical state)
35 L3=(X1*D)/(4*f) //Length of the pipe in m, (from
    required inlet to critical state)
36 L4=L3-L1 //Length of the pipe in m
37 X4=(4*f*L3)/D //frictional constant fanno parameter
38 M3=0.39 //Mach number at L1=35m
39 p6=2.767 //Static to Critical pressure ratio at
    outlet from gas tables ,fanno flow tables @M3,k
    =1.4
40 P2=Pt*p6 //Exit pressure in kPa
41 t2=1.1645 //Static to Critical temperature ratio at
    outlet from gas tables ,fanno flow tables @M3,k
    =1.4
42 T2=Tt*t2 //Exit temperature in K
43 c2=0.42087 //Static to Critical velocity ratio at
    outlet from gas tables ,fanno flow tables @M3,k
    =1.4
44 C2=Ct*c2 //Exit velocity in m/s
45
46 //output
47 printf('(A)Length of pipe required for p=%3.1f m is
    %3.3f m\n (B)Properties of air at section %3i
    from inlet:\n    Temperature is %3.3f K\n

```

```

Pressure is %3.2f kPa\n      Velocity is %3.1f m/s\n
n (C)Maximum length of the pipe is %3.2f m',p1,L2
,L1,T2,P2,C2,L3)

```

Scilab code Exa 3.16 To find exit mach number and inlet temperature and pressure

```

1  clc
2  clear
3
4  //input data
5  D=0.3 //inner pipe diameter in m
6  Q=1000 //Discharge in m^3/min
7  P2=150 //Exit pressure in kPa
8  T2=293 //Exit temperature in K
9  L1=50 //Length of the pipe in m
10 f=0.005 //frictional factor
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13
14 //calculation
15 A=%pi*D^2/4 //Area of duct in m^2
16 C2=Q/(A*60) //Exit air velocity in m/s
17 a2=sqrt(k*R*T2) //Sound velocity in m/s
18 M2=C2/a2 //Exit mach number
19 p1=1.54 //Static to Critical pressure ratio at
      outlet from gas tables ,fanno flow tables @M2,k
      =1.4
20 Pt=P2/p1 //Critical pressure in kPa
21 t1=1.10 //Static to Critical temperature ratio at
      outlet from gas tables ,fanno flow tables @M2,k
      =1.4
22 Tt=T2/t1 //Critical temperature in K
23 X1=0.228 //frictional constant fanno parameter from
      gas tables ,fanno flow tables @M2,k=1.4

```



```

24 L2=(X1*D)/(4*f) //Length of the pipe in m
25 L2=L1+L2 //Overall length of pipe from inlet to
    critical state in m
26 X2=(4*f*L2)/D //frictional constant fanno parameter
    for M1
27 M1=0.345 //Inlet Mach number from gas tables fanno
    flow tables @X2,k=1.4
28 p2=3.14 //Static to Critical pressure ratio at inlet
    from gas tables ,fanno flow tables @M1,k=1.4
29 P1=Pt*p2 //Static pressure at inlet in kPa
30 t2=1.17 //Static to Critical temperature ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
31 T1=Tt*t2 //Static temperature at inlet in K
32
33 //output
34 printf('(A)Mach number at the exit is %3.3f\n (B)
    Inlet pressure and temperature are %3.3f kPa and
    %3.2f K',M2,P1,T1)

```

Scilab code Exa 3.17 To find Static and Stagnation conditions velocity length and mass flow rate of air in pipe

```

1  clc
2  clear
3
4  //input data
5  D=0.0254 //inner pipe diameter in m
6  f=0.003 //frictional factor
7  M1=2.5 //Inlet Mach number
8  To1=310 //Stagnation temperature at inlet in K
9  P1=0.507 //Static pressure at inlet in kPa
10 M2=1.2 //Exit mach number
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13

```

```

14 //calculation
15 t1=0.4444 //Static to Stagnation temperature ratio
    at entry from gas tables (M1,k=1.4,isentropic)
16 T1=To1*t1 //Static temperature at inlet in K
17 p1=0.05853 //Static to Stagnation pressure ratio at
    entry from gas tables (M1,k=1.4,isentropic)
18 Po1=P1/p1 //Stagantion pressure at inlet in kPa
19 a1=sqrt(k*R*T1) //Sound velocity at inlet in m/s, R
    in J/kg
20 C1=a1*M1 //air velocity at inlet in m/s
21 c1=2.95804 //Static to Critical velocity ratio at
    inlet from gas tables ,isothermal tables @M1,k=1.4
22 Ctt=C1/c1 //Critical velocity at isothermal state in
    m/s
23 p2=0.33806 //Static to Critical pressure ratio at
    inlet from gas tables ,isothermal @M1,k=1.4
24 Ptt=P1/p2 //Critical pressure at isothermal state in
    bar
25 p3=3.61691 //Stagnation pressure ratio at inlet to
    isothermal state from gas tables ,isothermal
    tables @M1,k=1.4
26 Pott=Po1/p3 //Critical pressure at isothermal state
    in K
27 t2=1.968748 //Stagnation temperature ratio at inlet
    to isothermal state from gas tables ,isothermal
    tables @M1,k=1.4
28 Tott=To1/t2 //Critical temperature at isothermal
    state in K
29 X1=1.28334 //frictional constant fanno parameter
    from gas tables ,fanno flow tables @M1,k=1.4
30 c2=1.4186 //Static to Critical velocity ratio at
    exit from gas tables ,isothermal tables @M2,k=1.4
31 C2=Ctt*c2 //Exit velocity in m/s
32 p4=0.7043 //Static to Critical pressure ratio at
    inlet from gas tables ,isothermal @M2,k=1.4
33 P2=Ptt*p4 //Exit pressure in bar
34 p5=1.07026 //Stagnation pressure ratio at inlet to
    isothermal state from gas tables ,isothermal

```

```

    tables @M2,k=1.4
35 Po2=Pott*p5 //Stagnation pressure at exit in bar
36 t3=1.127 //Stagnation temperature ratio at inlet to
    isothermal state from gas tables ,isothermal
    tables @M2,k=1.4
37 To2=Tott*t3 //Stagnation temperature at exit in bar
38 T2=T1 //Exit temperature in K, Since isothermal flow
39 X2=0.19715 //frictional constant fanno parameter
    from gas tables ,fanno flow tables @M2,k=1.4
40 X3=X1-X2 //Overall frictional constant fanno
    parameter
41 L1=(X3*D)/(4*f) //Length of the pipe in m
42 d1=(P1*10^5)/(R*T1) //Density of air in kg/m^3, P1
    in Pa
43 A1=(%pi*D^2)/4 //Cross sectional area of pipe in m^2
44 m=d1*A1*C1 //Mass flow rate in kg/s
45
46 //output
47 printf('At M=%3.1f :\n (A) Static pressure and static
    temperature are %3.5f bar and %3.3f K
    respectively\n (B) Stagnation pressure and
    temperature are %3.4f bar and %3.3f K
    respectively\n (C) Velocity of air is %3.3f m/s\n
    (D) Distance of the section from innlet is %3.3f m
    \n (E) Mass flow rate is %3.5f kg/s ',M2,P2,T2,Po2,
    To2,C2,L1,m)

```

Scilab code Exa 3.18 To find length of pipe and properties of air at a section and limiting mach number

```

1  clc
2  clear
3
4  //input data
5  D=0.12 //inner duct diameter in m

```

```

6 f=0.004 //frictional factor
7 M1=0.4 //Inlet Mach number
8 P1=300 //Static pressure at inlet in kPa
9 T1=310 //Static temperature at inlet in K
10 M2=0.6 //Exit mach number
11 k=1.4 //Adiabatic constant
12
13 //calculation
14 p1=2.118 //Static to Critical pressure ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
15 Pt=P1/p1 //Critical pressure in kPa
16 X1=1.968 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
17 p2=1.408 //Static to Critical pressure ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
18 P2=Pt*p2 //Exit pressure in kPa
19 X2=0.299 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k=1.4
20 X3=X1-X2 //Overall frictional constant fanno
    parameter
21 L1=(X3*D)/(4*f) //Length of the pipe in m
22 T2=T1 //Exit temperature in K, Since isothermal flow
23 Ttt=T1 //Critical temperature at critical state ,
    Since isothermal flow
24 Mtt=1/sqrt(k) //Limiting Mach number
25 L2=(X1*D)/(4*f) //Length of the duct required to
    attain limiting mach number in m
26
27 //output
28 printf('(A)Length of the duct required to chnage the
    mach number to %3.1f is %3.4f m\n (B)Pressure
    and temperature at M=%3.1f is %3i kPa and %3i K
    respectively\n (C)Length of the duct required to
    attain limiting mach number is %3.3f m\n (D)State
    of air at limiting mach number %3.3f is subsonic
    ',M2,L1,M2,P2,T2,L2,Mtt)

```

Scilab code Exa 3.19 To find diameter of pipe

```
1  clc
2  clear
3
4  //input data
5  m=0.32 //Mass flow rate in kg/s
6  L=140 //Length of the pipe in m
7  P1=800 //Inlet pressure in N/m^2, wrong units in
      textbook
8  T1=288 //Inlet temperature in K
9  P2=600 //Outlet pressure in N/m^2, wrong units in
      textbook
10 f=0.006 //frictional factor
11 R=287 //Gas constant in J/kg-K
12
13 //calculation
14 //Using Adiabatic Equation  $d=1/((((((\pi*(d/2)^2)^2)
      /(2*m^2*R*T))*(P1^2-P2^2))-(\log(P1/P2)))/(2*f*L))$ 
      and converting into 5th degree polynomial of d
15 a=( $\pi^2*(P1^2-P2^2)$ )/(32*m^2*R*T1) //Coefficient of
      power 5
16 b=log(P1/P2) //Coefficient of power 1
17 c=2*f*L //Coefficient of constant
18 p5=poly([-c -b 0 0 0 a], 'd', 'coeff') //Solving
      polynomial of degree 5
19 d=roots(p5,"e") //Command to find roots
20
21 //output
22 disp("Possible values for diameter of pipe are:\n")
      //Displays whatever within paranthesis
23 disp([d]) //To display roots
24 printf('\nTherefore Diameter of the pipe is 0.7 m')
```

Scilab code Exa 3.20 To determine required inlet conditions

```
1  clc
2  clear
3
4  //input data
5  Q=225/60 //Discharge in m3/s
6  T2=293 //Exit temperature in K
7  P2=1.25 //Exit pressure in bar
8  L1=30 //Length of the pipe in m
9  D=0.15 //Duct diameter in m
10 f=0.02/4 //frictional factor
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13
14 //calculation
15 A=%pi*D^2/4 //area in m2
16 C2=Q/A //Exit air velocity in m/s
17 a2=sqrt(k*R*T2) //Exit sound velocity in m/s
18 M2=C2/a2 //Exit mach number
19 p1=1.703 //Static to Critical pressure ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
20 Pt=P2/p1 //Critical pressure in bar
21 c1=0.654 //Static to Critical velocity ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
22 Ct=C2/c1 //Critical velocity in m/s
23 t1=1.114 //Static to Critical temperature ratio at
    outlet from gas tables ,fanno flow tables @M2,k
    =1.4
24 Tt=T2/t1 //Critical temperature in K
25 X1=0.417 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
```

```

26 X2=(4*f*L1)/D //frictional constant fanno parameter
27 X3=X1+X2 //overall frictional constant fanno
    parameter
28 M1=0.32 //Mach number at entrance
29 p2=3.385 //Static to Critical pressure ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
30 P1=Pt*p2 //Static pressure at inlet in bar
31 c2=0.347 //Static to Critical velocity ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
32 C1=Ct*c2 //Air velocity at inlet in m/s
33 t2=1.176 //Static to Critical temperature ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
34 T1=Tt*t2 //Static temperature at inlet in K
35
36 //output
37 printf('Required Inlet Condition:\n      Pressure is
    %3.4f bar\n      Velocity is %3.3f m/s\n
    Temperature is %3.1f K',P1,C1,T1)

```

Scilab code Exa 3.21 To find mach number at sections and mean value of friction

```

1  clc
2  clear
3
4  //input data
5  D1=0.134 //Inlet duct diameter in m
6  Po1=7 //Stagnation pressure at inlet in bar
7  P1=0.245 //Static pressure at 5*D1 i.e. L1 in bar
8  P2=0.5 //Static pressure at 33*D1 i.e. L2 in bar
9  D2=0.0646 //throat diameter in m
10 L1=5*D1 //Length of nozzle till section-1 in m
11 L2=33*D1 //Length of nozzle till section-2 in m
12
13 //calculation

```

```

14 ar=(D1/D2)^2 //Ratio of areas
15 p1=P1/Po1 //Pressure ratio
16 APR1=p1*ar //Area Pressure ratio i.e. (A1*P1)/(At*
    Po1)
17 M1=2.54 //Mach number at inlet from isentropic gas
    tables @APR1
18 X1=0.44 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
19 APR2=0.3073 //Area Pressure ratio i.e. (A2*P2)/(At*
    Po1)
20 M2=1.54 //Exit mach number
21 X2=0.151 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k=1.4
22 X3=X1-X2 //overall frictional constant fanno
    parameter
23 L3=L2-L1 //Length of the nozzle (Section-1 to
    Section-2) in m
24 f=(X3*D1)/(4*L3) //frictional factor
25
26 //output
27 printf('(A)Mach number at %3.3f m and %3.3f m are %3
    .2f and %3.2f respectively\n (B)Mean value of
    friction between two sections is %3.5f',L1,L2,M1,
    M2,f)

```

Chapter 4

Flow Through Constant Area Ducts Rayleigh Flow

Scilab code Exa 4.1 To find heat transferred per unit mass flow and temperature change

```
1  clc
2  clear
3
4  //input data
5  Pa=1*10^5 //Pressure of dry air in Pa
6  To1=288 //Total stagnation temperature at inlet in K
7  M1=1 //Mach number at inlet of pipe
8  M2=0.8 //Mach number at exit o pipe
9  Cp=1.005 //Specific heat of dry air in kJ/kg-K
10
11 //calculation
12 t1=0.834 //Temperature ratio at entry, i.e.entry
    static temperature to total temperature from gas
    tables at isentropic ,M1=1 & adiabatic constant
    =1.4
13 T1=t1*To1 //Static temperature at entry in Kelvin
14 t2=0.964 //Temperature ratio at critical state, i.e.
    exit stagnation temperature to critical state
```

```

    temperature from gas tables at Rayleigh , M2=0.8 &
    adiabatic constant=1.4
15 To2=t2*To1 //Total stagnation temperature at exit in
    K
16 t3=1.025 //Temperature ratio at exit , i.e. exit
    static temperature to total temperature from gas
    tables at isentropic ,M1=1 & adiabatic constant
    =1.4
17 T2=t3*T1 //Static temperature at exit in Kelvin
18 q=Cp*(To1-To2) //The heat transferred per unit mass
    flow in kJ/kg
19 dT=To1-T2 //Change in temperature in K
20
21 //output
22 printf('(A)The heat transferred per unit mass flow
    is %3.3f kJ/kg (rejected)\n (B)Change in
    temperature is %3.3f K',q,dT)

```

Scilab code Exa 4.2 To calculate flow properties at the exit

```

1 clc
2 clear
3
4 //input data
5 M1=3 //Mach number at entry
6 P1=1 //Static Pressure at entry in atm
7 T1=300 //Static Temperature at entry in K
8 q=300 //The heat transferred per unit mass flow in
    kJ/kg
9 R=287 //Gas constant in J/kg-K
10 Cp=1.005 //Specific heat of dry air in kJ/kg-K
11
12 //calculation
13 t1=2.8 //Temperature ratio at entry from gas tables
    (M=3,k=1.4,isentropic)

```

```

14 To1=t1*T1 //Total stagnation temperature at inlet in
    K
15 p1=0.0272 //Pressure ratio at entry from gas tables
    (M=3,k=1.4,isentropic)
16 Po1=P1/p1 //Stagnation Pressure at entry in atm
17 p2=0.176 //Static Pressure ratio at critical state
    from gas tables (Rayleigh,k=1.4,M=3)
18 Pt=P1/p2 //Static critical pressure in atm
19 p3=3.424 //Stagnation Pressure ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=3)
20 Pot=Po1/p3 //Stagnation critical pressure in atm
21 t2=0.281 //Static temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=3)
22 Tt=T1/t2 //Static critical temperature in K
23 t3=0.654 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=3)
24 Tot=To1/t3 //Stagnation critical temperature in K
25 To2=(q/Cp)+To1 //Stagnation exit temperation in K
26 t4=(To2/Tot) //Stagnation Temperature ratio at exit
27 M2=1.6 //Mack number at exit from gas tables (
    Rayleigh,t4)
28 p4=0.524 //Static Pressure ratio at exit from gas
    tables (Rayleigh,t4=0.866,M=1.6)
29 P2=p4*Pt //Static Pressure at exit in atm
30 p5=1.176 //Stagnation Pressure ratio at exit from
    gas tables (Rayleigh,t4=0.866,M=1.6)
31 Po2=p5*Pot //Stagnation Pressure at exit in atm
32 t5=0.702 //Static temperature ratio at exit from gas
    tables (Rayleigh,t4=0.866,M=1.6)
33 T2=t5*Tt //Static exit temperature in K
34 d2=P2*101325/(R*T2) //density of air at exit in kg/m
    ^3, P2 in N/m^2
35
36 //outpur
37 printf('(A)The Mach numer at exit is %3.1f\n (B)
    Static Pressure at exit is %3.3f atm\n (C)Static
    exit temperature is %3.2f K\n (D)density of air
    at exit is %3.4f kg/m^3\n (E)Stagnation exit

```

temperation is %3.2f K\n (F) Stagnation Pressure
at exit is %3.2f atm', M2, P2, T2, d2, To2, Po2)

Scilab code Exa 4.3 To find mass flow rate per unit area Final temperature and heat added per kg of air flow

```
1  clc
2  clear
3
4  //input data
5  M1=2 //Mach number at entry
6  P1=1.4 //Static Pressure at entry in bar
7  T1=323 //Static Temperature at entry in K
8  Cp=1.005 //Specific heat of dry air in kJ/kg-K
9  k=1.4 //Adiabatic constant
10 R=287 //Gas constant in J/kg-K
11
12 //calculation
13 t1=0.555 //Temperature ratio at entry from gas
    tables (M=2,k=1.4,isentropic)
14 To1=T1/t1 //Total stagnation temperature at inlet in
    K
15 p1=0.364 //Pressure ratio at entry from gas tables
    (M=2,k=1.4,isentropic)
16 Po1=P1/p1 //Stagnation Pressure at entry in bar
17 t2=0.529 //Static temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=2)
18 Tt=T1/t2 //Static critical temperature in K
19 t3=0.793 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=2)
20 Tot=To1/t3 //Stagnation critical temperature in K
21 To2=Tot //Stagnation exit temperation in K
22 q=Cp*(To2-To1) //The heat transferred per unit mass
    flow in kJ/kg
23 a1=sqrt(k*R*T1) //Sound velocity in m/s
```

```

24 C1=M1*a1 //Air velocity in m/s
25 d1=(P1*10^5)/(R*T1) //density of air in kg/m^3
26 ma=d1*C1 //Mass flow rate per unit area in kg/s-m^3
27
28 //output
29 printf('(A)Mass flow rate per unit area is %3.2f kg/
      s-m^2\n (B)Final temperaturure is %3.3f K\n (C)Heat
      added is %3.2f kJ/kg',ma,Tt,q)

```

Scilab code Exa 4.4 To calculate pressure and Mach number after combustion in combustion chamber

```

1  clc
2  clear
3
4  //input data
5  C1=100 //Air velocity into combustion chamber in m/s
6  P1=3 //Static Pressure at entry in bar
7  T1=318 //Static Temperature at entry in K
8  q=630 //The heat transferred per unit mass flow in
      kJ/kg
9  Cp=1.005 //Specific heat of dry air in kJ/kg-K
10 k=1.4 //Adiabatic constant
11 R=287 //Gas constant in J/kg-K
12
13 //calculation
14 a1=sqrt(k*R*T1) //Sound velocity in m/s
15 M1=C1/a1 //Mach number at entry
16 t1=0.985 //Temperature ratio at entry from gas
      tables (M1,k=1.4,isentropic)
17 To1=T1/t1 //Total stagnation temperature at inlet in
      K
18 p1=0.947 //Pressure ratio at entry from gas tables
      (M1,k=1.4,isentropic)
19 Po1=P1/p1 //Stagnation Pressure at entry in bar

```

```

20 To2=(q/Cp)+To1 //Stagnation exit temperation in K
21 p2=2.163 //Static Pressure ratio at critical state
    from gas tables (Rayleigh ,k=1.4,M=0.28)
22 Pt=P1/p2 //Static critical pressure in bar
23 p3=2.206 //Stagnation Pressure ratio at critical
    state from gas tables (Rayleigh ,k=1.4,M=0.28)
24 Pot=Po1/p3 //Stagnation critical pressure in bar
25 t2=0.310 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh ,k=1.4,M=0.28)
26 Tot=To1/t2 //Stagnation critical temperature in K
27 t3=(To2/Tot) //Stagnation Temperature ratio at exit
28 M2=0.7 //Mack number at exit from gas tables (
    Rayleigh ,t3)
29 p4=1.423 //Static Pressure ratio at exit from gas
    tables (Rayleigh ,t3,M2)
30 P2=p4*Pt //Static Pressure at exit in bar
31
32 //output
33 printf('(A) Pressure after combustion is %3.3f bar\n
    (B)Mach number after combustion is %3.1f',P2,M2)

```

Scilab code Exa 4.5 To find total temperature static pressure at exit Stagnation pressure and exponent of polytropic equation

```

1 clc
2 clear
3
4 //input data
5 M1=3 //Mach number at entry
6 To1=295 //Total stagnation temperature at inlet in K
7 P1=0.5 //Static Pressure at entry in bar
8 M2=1.5 //Mack number at exit
9 Cp=1.005 //Specific heat of dry air in kJ/kg-K
10 R=287 //Gas constant in J/kg-K
11

```

```

12 // calculation
13 p1=0.0272 //Pressure ratio at entry from gas tables
      (M=3,k=1.4,isentropic)
14 Po1=P1/p1 //Stagnation Pressure at entry in bar
15 t1=0.357 //Temperature ratio at entry from gas
      tables (M=3,k=1.4,isentropic)
16 T1=t1*To1 //Static temperature at entry in Kelvin
17 p2=0.176 //Static Pressure ratio at critical state
      from gas tables (Rayleigh,k=1.4,M=3)
18 Pt=P1/p2 //Static critical pressure in bar
19 p3=3.424 //Stagnation Pressure ratio at critical
      state from gas tables (Rayleigh,k=1.4,M=3)
20 Pot=Po1/p3 //Stagnation critical pressure in bar
21 t2=0.654 //Stagnation temperature ratio at critical
      state from gas tables (Rayleigh,k=1.4,M=3)
22 Tot=To1/t2 //Stagnation critical temperature in K
23 t3=0.280 //Static temperature ratio at critical
      state from gas tables (Rayleigh,k=1.4,M=3)
24 Tt=T1/t3 //Static critical temperature in K
25 p4=0.578 ////Static Pressure ratio at exit from gas
      tables (Rayleigh,M=1.5)
26 P2=p4*Pt //Static Pressure at exit in bar
27 p5=1.122 //Stagnation Pressure ratio at exit from
      gas tables (Rayleigh,M=1.5)
28 Po2=p5*Pot //Stagnation Pressure at exit in bar
29 t4=0.753 ////Static temperature ratio at exit from
      gas tables (Rayleigh,M=1.5)
30 T2=t4*Tt //Static exit temperature in K
31 t5=0.909 //Stagnation temperature ratio at exit from
      gas tables (Rayleigh,M=1.5)
32 To2=t5*Tot //Total stagnation temperature at exit in
      K
33 q=Cp*(To1-To2) //The heat transferred per unit mass
      flow in kJ/kg
34 SPC=Po1-Po2 //Change in stagnation pressure in bar
35 n=log(Po1/Po2)/(log(Po1/Po2)-log(To1/To2)) //
      Exponent of polytropic equation
36 qmax=Cp*(Tot-To1) //Maximum possible heat transfer

```

```

    in kJ/kg
37 ds=Cp*log(T2/T1)-(R*log(P2/P1)) //Change in entropy
    in kJ/kg-K
38
39 //output
40 printf('(A)Total temperature at exit is %3.2f K\n (B
    )Static pressure at exit is %3.3f bar \n (C)
    Change in stagnation pressure is %3.2f bar\n (D)
    Exponent of polytropic equation is %3.2f',To2,P2,
    SPC,n)

```

Scilab code Exa 4.6 To determine Mach number pressure temperature of gas at entry and amount of heat added and maximum heat can be added

```

1 clc
2 clear
3
4 //input data
5 M2=0.9 //Mack number at exit
6 P2=2.5 //Static Pressure at exit in bar
7 T2=1273 //Static exit temperature in K
8 t1=3.74 //ratio of stagnation temperatures at and
    exit entry
9 Cp=1.218 //Specific heat of dry air in kJ/kg-K
10 k=1.3 //Adiabatic constant
11
12 //calculation
13 t2=0.892 //Temperautre ratio at exit from gas
    tables (isentropic ,k=1.3,M=0.9)
14 To2=T2/t2 //Total stagnation temperature at exit in
    K
15 To1=To2/t1 //Total stagnation temperature at inlet
    in K
16 p1=1.12 //Static pressure ratio at critical state
    from gas tables (Rayleigh ,k=1.3,M=1.5)

```



```

17 Pt=P2/p1 //Static critical pressure in bar
18 t3=1.017 //Static temperature ratio at critical
    state from gas tables (Rayleigh,k=1.3,M=1.5)
19 Tt=T2/t3 //Static critical temperature in K
20 t4=0.991 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.3,M=1.5)
21 Tot=To2/t4 //Stagnation critical temperature in K
22 t5=To1/Tot //Ratio of stagnation temperature at
    entry and critical state
23 M1=0.26 //Mach number at entry from gas tables (
    Rayleigh,t5,k=1.3)
24 p2=2.114 //Static Pressure ratio at entry from gas
    tables (Rayleigh,t5,k=1.3)
25 P1=Pt*p2 //Static Pressure at entry in bar
26 t6=0.302 //Static temperature ratio at entry from
    gas tables (Rayleigh,t5,k=1.3)
27 T1=Tt*t6 //Static temperature at entry in Kelvin
28 q=Cp*(To2-To1) //The heat transferred per unit mass
    flow in kJ/kg
29 qmax=Cp*(Tot-To1) //Maximum possible heat transfer
    in kJ/kg
30
31 //output
32 printf('(A)Mach number at entry is %3.2f\n (B)
    Pressure at entry is %3.3f bar \n (C)Temperature
    of gas is %3i K\n (D)Amount of heat added is %3.2
    f kJ/kg\n (E)Maximum heat that can be heated is
    %3.3f kJ/kg',M1,P1,T1,q,qmax)

```

Scilab code Exa 4.7 To determine Mach number pressure temperature and velocity of gas at exit

```

1 clc
2 clear
3

```

```

4 //input
5 P1=0.343 //Static Pressure at entry in bar
6 T1=310 //Static temperature at entry in Kelvin
7 C1=60 //Velocity at entrance in m/s
8 q=1172.5 //The heat transferred per unit mass flow
    in kJ/kg
9 Cp=1.005 //Specific heat of dry air in kJ/kg-K
10 k=1.4 //Adiabatic constant
11 R=287 //Gas constant in J/kg-K
12
13 //calculation
14 a1=sqrt(k*R*T1) //Sound velocity in m/s
15 M1=C1/a1 //Mach number at entry
16 t1=0.9943 //Temperature ratio at entry from gas
    tables (M=0.17,k=1.4,isentropic)
17 To1=T1/t1 //Total stagnation temperature at inlet in
    K
18 p1=2.306 //Static Pressure ratio at critical state
    from gas tables (Rayleigh,k=1.4,M=0.17)
19 Pt=P1/p1 //Static critical pressure in bar
20 t2=0.154 //Static temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=0.17)
21 Tt=T1/t2 //Static critical temperature in K
22 t3=0.129 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=0.17)
23 Tot=To1/t3 //Stagnation critical temperature in K
24 c1=0.0665 //Velocity ratio at critical state from
    gas tables (Rayleigh,k=1.4,M=0.17)
25 Ct=C1/c1 //Critical velocity in m/s
26 To2=(q/Cp)+To1 //Stagnation exit temperation in K
27 t4=To2/Tot //Ratio of stagnation temperature at exit
    and critical state
28 M2=0.45 //Mach number at exit from gas tables (
    Rayleigh,t4,k=1.4)
29 p2=1.87 //Static Pressure ratio at exit from gas
    tables (Rayleigh,t4,k=1.4)
30 P2=p2*Pt //Static Pressure at exit in bar
31 t5=0.7075 //Static temperature ratio at exit from

```

```

    gas tables (Rayleigh ,t4 ,k=1.4)
32 T2=t5*Tt //Static exit temperature in K
33 c2=0.378 //Velocity ratio at critical state from gas
    tables (Rayleigh ,k=1.4,t4)
34 C2=Ct*c2 //exit velocity in m/s
35
36 //output
37 printf('At exit conditions :\n (A)Mach number is %3
    .2f\n (B)Pressure is %3.3f bar\n (C)Temperature
    is %3.2f K\n (D)Exit velocity is %3.2f m/s ',M2,P2
    ,T2,C2)

```

Scilab code Exa 4.8 To find Mach number pressure and temperature after cooling

```

1  clc
2  clear
3
4  //input data
5  M1=2 //Mach number at entry
6  To1=523 //Total stagnation temperature at inlet in K
7  Po1=6 //Stagnation Pressure at entry in bar
8  To2=423 //Stagnation exit temperation in K
9
10 //calculation
11 t1=0.555 //Temperature ratio at entry from gas
    tables (M=2,k=1.4,isentropic)
12 T1=t1*To1 //Static temperature at entry in Kelvin
13 p1=0.128 //Pressure ratio at entry from gas tables
    (M=2,k=1.4,isentropic)
14 P1=Po1*p1 //Static Pressure at entry in bar
15 p2=0.364 //Static pressure ratio at critical state
    from gas tables (Rayleigh ,k=1.4,M=2)
16 p3=1.503 //Stagnation pressure ratio at critical
    state from gas tables (Rayleigh ,k=1.4,M=2),

```

```

    printing mistake in textbook
17 t2=0.529 //Static Temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=2)
18 t3=0.793 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M=2)
19 t4=(To2/To1)*t3 //Ratio of stagnation temperature at
    exit and critical state
20 M2=3.15 //Mach number at exit from gas tables (
    Rayleigh,t4,k=1.4)
21 p4=0.161 //Static Pressure ratio at exit from gas
    tables (Rayleigh,t4,k=1.4), printing mistake in
    textbook
22 t5=0.258 //Static temperature ratio at exit from
    gas tables (Rayleigh,t4,k=1.4)
23 P2=(p4/p2)*P1 //Static Pressure at exit in bar
24 T2=(t5/t2)*T1 //Static exit temperature in K
25
26 //output
27 printf('After Cooling :\n (A)Mach number is %3.2f\n
    (B)Pressure is %3.4f bar\n (C)Temperature is %3.2
    f K',M2,P2,T2)

```

Scilab code Exa 4.9 To determine heat added per kg of air flow maximum possible heat transfer and heat transfer required to get maximum static temperature

```

1  clc
2  clear
3
4  //input data
5  M2=0.8 //Mack number at exit
6  t1=4 //Ratio of stagnation temperature at exit and
    entry
7  T1=288 //Atmospheric temperature in K
8  P1=1 //Atmospheric Pressure in atm

```

```

9 Cp=1.005 //Specific heat of dry air in kJ/kg-K
10
11 //calculation
12 t2=0.964 //Ratio of stagnation temperature at exit
    and critical state from gas tables
13 t3=t2/t1 //Ratio of stagnation temperature at entry
    and critical state
14 M1=0.24 ////Mach number at entry from gas tables (
    Rayleigh ,t3,k=1.4)
15 t5=0.988 //Temperature ratio at entry from gas
    tables (M1,k=1.4,isentropic)
16 To1=T1/t5 //Total stagnation temperature at inlet in
    K
17 To2=t1*To1 //Stagnation exit temperation in K
18 Tot=To1/t3 //Stagnation critical temperature in K
19 q=Cp*(To2-To1) //The heat transferred per unit mass
    flow in kJ/kg
20 qmax=Cp*(Tot-To1) //Maximum possible heat transfer
    in kJ/kg
21 t6=0.9775 //Ratio of stagnation temperature for
    maximum static temperature (M=1/sqrt(k),Rayleigh)
22 To3=Tot*t6 //maximum stagnation temperature in K
23 q_req=Cp*(To3-To1) //Heat transfer required to get
    maximum static temperature in kJ/kg
24
25 //output
26 printf('(A)Heat added per kg of air flow is %3.2f kJ
    /kg\n (B)Maximum possible heat transfer is %3.2f
    kJ/kg\n (C)Heat transfer required to get maximum
    static temperature is %3.1f kJ/kg',q,qmax,q_req)

```

Scilab code Exa 4.10 To find exit properties Maximum stagnation temperature percentage of pressure loss and initial mach number

```
1 clc
```

```

2  clear
3
4  //input data
5  T1=560 //Static Temperature at entry in K
6  P1=0.6 //Static Pressure at entry in bar
7  C1=75 //Air velocity into combustion chamber in m/s
8  mp=30 //air fuel ratio
9  CV=92000 //Calorific value of fuel in kJ/kg
10 Cp=1.005 //Specific heat of dry air in kJ/kg-K
11 k=1.4 //Adiabatic constant
12 R=287 //Gas constant in J/kg-K
13
14 //calculation
15 a1=sqrt(k*R*T1) //Sound velocity in m/s
16 M1=C1/a1 //Mach number at entry
17 t1=0.9949 //Temperature ratio at entry from gas
    tables (M1,k=1.4,isentropic)
18 To1=T1/t1 //Total stagnation temperature at inlet in
    K
19 p1=0.982 //Pressure ratio at entry from gas tables
    (M1,k=1.4,isentropic)
20 Po1=P1/p1 //Stagnation Pressure at entry in bar
21 q=CV/(mp+1) //The heat transferred per unit mass
    flow in kJ/kg of gas, mp+1=total amount of fuel=
    mf+ma
22 p2=2.317 //Static Pressure ratio at critical state
    from gas tables (Rayleigh,k=1.4,M1)
23 Pt=P1/p2 //Static critical pressure in bar
24 p3=1.246 //Stagnation Pressure ratio at critical
    state from gas tables (Rayleigh,k=1.4,M1)
25 Pot=Po1/p3 //Stagnation critical pressure in bar
26 t2=0.137 //Static temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M1)
27 Tt=T1/t2 //Static critical temperature in K
28 t3=0.115 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M1)
29 Tot=To1/t3 //Stagnation critical temperature in K
30 To2=(q/Cp)+To1 //Stagnation exit temperation in K

```

```

31 t4=To2/Tot //Ratio of stagnation temperature at exit
    and critical state
32 M2=0.33 //Mach number at exit from gas tables (
    Rayleigh ,t4,k=1.4)
33 p4=2.0825 //Static Pressure ratio at exit from gas
    tables (Rayleigh ,t4,k=1.4)
34 P2=p4*Pt //Static Pressure at exit in bar ,
    miscalculation in textbook
35 p5=1.186 //Stagnation Pressure ratio at exit from
    gas tables (Rayleigh ,t4,k=1.4)
36 Po2=Pot*p5 //Stagnation Pressure at exit in bar
37 t5=0.472 //Static temperature ratio at exit from
    gas tables (Rayleigh ,t4,k=1.4)
38 T2=t5*Tt //Static exit temperature in K
39 C2=M2*sqrt(k*R*T2) //exit velocity in m/s
40 SPL=((Po1-Po2)/Po1)*100 //Percentage of pressure
    loss in combustion chamber in %
41
42 //output
43 printf('(A)At exit:\n    Pressure is %3.5f bar \n
    Temperature is %3i K \n    Velocity is %3.2f m
    /s \n    Mach number is %3.2f \n (B)Maximum
    stagnation temperature available is %3.2f K\n (C)
    Percentage of pressure loss in combustion chamber
    is %3.1f percent\n (D)Intial Mach number is %3.2
    f \n' ,P2 ,T2 ,C2 ,M2 ,Tot ,SPL ,M1)

```

Scilab code Exa 4.11 To find Mach number and percentage drop in pressure

```

1 clc
2 clear
3
4 //input data
5 To1=473 //Total stagnation temperature at inlet in K

```

```

6 To2=673 //Stagnation exit temperation in K
7 M1=0.5 //Mach number at entry
8
9 //calculation
10 t1=0.6914 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh,k=1.4,M1)
11 p1=1.7778 //Static pressure ratio at critical state
    from gas tables (Rayleigh,k=1.4,M1)
12 t2=(To2/To1)*t1 //Stagnation temperature ratio at
    exit
13 M2=0.867 //Mach number at exit from gas tables (
    Rayleigh,t2,k=1.4)
14 p2=1.16 //Static pressure ratio at exit from gas
    tables (Rayleigh,k=1.4,M2)
15 p=p2/p1 //ratio of static pressures at outlet and
    inlet
16 PL=(1-p)*100 //pressure loss in %
17
18 //output
19 printf('(A)Mach number is %3.3f\n (B)Percentage drop
    in pressure is %3.1f percent',M2,PL)

```

Scilab code Exa 4.12 To find inlet mach number and percentage loss in static pressure

```

1 clc
2 clear
3
4 //input data
5 t1=3 //Stagnation temperature ratio
6 M2=0.8 //Mach number at exit
7
8 //calculation
9 t2=0.964 //Ratio of stagnation temperature at exit
    and critical state (Rayleigh,M2,k=1.4)

```



```

10 p1=1.266 //Static Pressure ratio at exit from gas
    tables (Rayleigh,M2,k=1.4)
11 t3=t2/t1 //Stagnation temperature ratio at critical
    state
12 M1=0.29 //Mach number at entry from gas tables (
    Rayleigh,t3,k=1.4)
13 p2=2.147 //Static pressure ratio at critical state
    from gas tables (Rayleigh,k=1.4,M1)
14 p=p1/p2 //ratio of static pressures at exit and
    entry
15 PL=(1-p)*100 //Percentage loss in static pressure in
    %
16
17 //output
18 printf('(A)Mach number at entry is %3.2f\n (B)
    Percentage loss in static pressure is %3i percent
    ',M1,PL)

```

Scilab code Exa 4.13 To find inlet and exit mach number

```

1 clc
2 clear
3
4 //input data
5 To1=300 //Total stagnation temperature at inlet in K
6 To2=310 //Stagnation exit temperature in K
7 G=1300 //Mass velocity in kg/m2-s
8 P1=105*103 //Static Pressure at entry in Pa
9 Cp=1.005 //Specific heat of dry air in kJ/kg-K
10 R=287 //Gas constant in J/kg-K
11
12 //calculation
13 T1=((( -2*P12*Cp)+sqrt((( -2*P12*Cp)2+(8*G2*R2*
    P12*Cp*To1))))/(2*G2*R2) //Static temperature
    in K

```

```

14 t1=T1/To1 //Temperature ratio at entry
15 M1=1.4 //Mach number at entry from gas tables (
    isentropic ,t1 ,k=1.4)
16 t2=0.934 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh ,k=1.4,M1)
17 Tot=To1/t2 //Stagnation critical temperature in K
18 t3=To2/Tot //Stagnation temperature ratio at exit
    from gas tables (Rayleigh ,k=1.4,M1)
19 M2=1.26 //Mach number at exit from gas tables (
    Rayleigh ,t3 ,k=1.4)
20
21 //output
22 printf('(A)The inlet mach number is %3.2f \n (B)The
    exit mach number is %3.2f',M1,M2)

```

Scilab code Exa 4.14 To find properties at exit and sonic condition and heat required to accelerate gas from inlet to sonic condition

```

1  clc
2  clear
3
4  //input data
5  k=1.3 //Adiabatic constant
6  R=466 //Gas constant in J/kg-K
7  P1=0.345 //Static Pressure at entry in Pa
8  T1=312 //Static Temperature at entry in K
9  C1=65.5 //Entry velocity in m/s
10 q=4592 //The heat transferred per unit mass flow in
    kJ/kg
11
12 //calculation
13 a1=sqrt(k*R*T1) //Sound velocity in m/s
14 M1=C1/a1 //Mach number at entry
15 t1=0.9965 //Temperature ratio at entry from gas
    tables (M1,k=1.3,isentropic)

```

```

16 To1=T1/t1 //Total stagnation temperature at inlet in
    K
17 p1=2.235 //Static Pressure ratio at critical state
    from gas tables (Rayleigh ,k=1.3,M1)
18 Pt=P1/p1 //Static critical pressure in bar
19 c1=0.051 //Velocity ratio at critical state from gas
    tables (Rayleigh ,k=1.3,M1)
20 Ct=C1/c1 //Critical velocity in m/s
21 t2=0.112 //Static temperature ratio at critical
    state from gas tables (Rayleigh ,k=1.3,M1)
22 Tt=T1/t2 //Static critical temperature in K
23 t3=0.098 //Stagnation temperature ratio at critical
    state from gas tables (Rayleigh ,k=1.3,M1)
24 Tot=To1/t3 //Stagnation critical temperature in K
25 Cp=(k*R)/(k-1) //Specific heat of dry air in kJ/kg-K
26 To2=(q/Cp)+To1 //Stagnation exit temperation in K
27 t4=(To2/Tot) //Stagnation Temperature ratio at exit
28 M2=0.60 //Mack number at exit from gas tables (
    Rayleigh ,t4)
29 p2=1.567 //Static Pressure ratio at exit from gas
    tables (Rayleigh ,t4 ,k=1.4)
30 P2=p2*Pt //Static Pressure at exit in bar
31 t5=0.884 //Static temperature ratio at exit from
    gas tables (Rayleigh ,t4 ,k=1.4)
32 T2=t5*Tt //Static exit temperature in K
33 c2=0.564 //Velocity ratio at critical state from gas
    tables (Rayleigh ,k=1.4,t4)
34 C2=Ct*c2 //exit velocity in m/s
35 qmax=Cp*(Tot-To1)/10^3 //Maximum possible heat
    transfer in kJ/kg
36
37 //output
38 printf('(A)Heat required to accelerate the gas from
    the inlet condition to sonic condition is %3.2f
    kJ/kg\n (B)The pressure and temperature at sonic
    condition are %3.3f bar and %3.2f K respectively\n
    (C)The properties at exit are:\n Pressure is
    %3.3f bar\n Temperature is %3.2f K\n

```

Velocity is %3i m/s ', qmax , Pt , Tt , P2 , T2 , C2)

Chapter 5

Normal and Oblique Shock

Scilab code Exa 5.1 To find Mach number before shock properties after shock density increase loss of stagnation pressure and entropy change of air in pipe

```
1  clc
2  clear
3
4  //Input data
5  Px=150 //Pressure before the shock in kPa
6  Tx=25+273 //Temperature before the shock in K
7  Py=350 //Pressure just after the shock in kPa
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculations
12 p1=Py/Px //Pressure ratio
13 Mx=1.4638 //Mach number before the shock
14 My=0.716 //Mach number after the shock from gas
    tables @Mx
15 t1=1.294 //Temperature ratio after and before the
    shock from gas tables @p1
16 Ty=t1*Tx //Temperature ratio after the shock in K
17 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
```

```

        in m/s
18 Cx=ax*Mx //Velocity of gas before the shock in m/s
19 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
20 Cy=ay*My //Velocity of gas after the shock in m/s
21 p2=0.942 //Stagnation pressure ratio after and
    before the shock from gas tables @p1
22 ds=R*log(1/p2) //Change in entropy in J/kg-K
23 p3=3.265 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @p1
24 Poy=p3*Px //Stagnation pressure after shock in kPa
25 Pox=Poy/p2 //Stagnation pressure before shock in kPa
26 pr_loss=Pox-Poy //Loss of stagnation pressure of air
    in kPa
27 dd=(1000/R)*((Py/Ty)-(Px/Tx)) //Increase in density
    of air in kg/m^3
28
29 //Output
30 printf('(A)Mach number before shock is %3.4f\n (B)
    After shock:\n    Mach number is %3.3f\n
    Static temperature is %3.3f K\n    Velocity is %3
    .2f m/s\n (C)Increase in density of air is %3.2f
    kg/m^3\n (D)Loss of stagnation pressure of air is
    %3.2f kPa\n (E)Change in entropy is %3.3f J/kg-K
    ',Mx,My,Ty,Cy,dd,pr_loss,ds)

```

Scilab code Exa 5.2 To find properties across normal shock and entropy change

```

1 clc
2 clear
3
4 //Input data
5 Tx=350 //Temperature before the shock in K
6 Px=137.8 //Pressure before the shock in kPa

```

```

7 Cx=750 //Velocity before the shock in m/s
8 k=1.4 //Adiabatic constant
9 R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
    in m/s
13 Mx=Cx/ax //Mach number before the shock
14 My=0.577 //Mach number after the shock from gas
    tables @Mx
15 p1=4.5 //Static pressure ratio after and before the
    shock from gas tables @My
16 Py=Px*p1 //Static pressure after shock in kPa
17 t1=1.687 //Temperature ratio after and before the
    shock from gas tables @My
18 Ty=Tx*t1 //Temperature ratio after the shock in K
19 p2=5.641 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @My
20 Poy=Px*p2 //Stagnation pressure after shock in kPa
21 p3=0.721 //Stagnation pressure ratio after and
    before the shock from gas tables @My
22 Pox=Poy/p3 //Stagnation pressure before shock in kPa
23 ds=R*log(1/p3) //Change in entropy in J/kg-K
24 t2=0.555 //Static to Stagnation temperature ratio
    before shock from isentropic gas tables @Mx,k=1.4
25 Tox=Tx/t2 //Stagnation temperature before shock in
    K
26 p4=0.128 //Static to Stagnation pressure ratio from
    isentropic gas tables @Mx,k=1.4
27 Pox=Px/p4 //Stagnation pressure in kPa
28 t4=0.937 //Static to Stagnation temperature ratio
    before shock from normal shock gas tables @Mx,k
    =1.4 (Tox=Toy Checked)
29 Toy=Ty/t4 //Stagnation temperature after shock in K
30 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
31 Cy=(My*ay) //Velocity of gas after the shock in m/s
32

```

```

33 //Output
34 printf('(A)At inlet to shock:\n      Stagnation
      pressure is %3.1f kPa\n      Stagnation temperature
      is %3.2f K\n      Mach number is %3.0f\n (B)After
      shock:\n      Stagnation pressure is %3.2f kPa\n
      Stagnation temperature is %3.2f K\n      Static
      pressure is %3.1f kPa\n      Static temperature is
      %3.2f K\n      Mach number is %3.3f\n      Velocity
      is %3.2f m/s\n (C)Change in entropy across the
      shock is %3.2f J/kg-K',Pox,Tox,Mx,Poy,Toy,Py,Ty,
      My,Cy,ds)

```

Scilab code Exa 5.3 To find properties downstream of shock

```

1  clc
2  clear
3
4  //Input data
5  Tx=0+273 //Temperature before the shock in K
6  Px=60 //Pressure before the shock in kPa
7  Cx=497 //Air Velocity before the shock in m/s
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
      in m/s
13 Mx=Cx/ax //Mach number before the shock
14 My=0.70109 //Mach number after the shock from gas
      tables @Mx
15 p1=2.45833 //Static pressure ratio after and before
      the shock from gas tables @My
16 Py= p1*Px //Static pressure after shock in kPa
17 t1=1.32022 //Temperature ratio after and before the
      shock from gas tables @My

```



```

18 Ty=Tx*t1 //Temperature ratio after the shock in K
19 p2=3.41327 //Stagnation pressure after shock to
    Static pressure before shock from gas tables @My
20 Poy=p2*Px //Stagnation pressure after shock in kPa
21 p3=0.92979 //Stagnation pressure ratio after and
    before the shock from gas tables @My
22 Pox=Poy/p3 //Stagnation pressure before shock in kPa
23 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
24 Cy=ay*My //Velocity of air after the shock in m/s
25
26 //Output
27 printf('After shock:\n      (A)Mach number is %3.5f\n
        (B) Velocity is %3.3f m/s\n      (C) Stagnation
        pressure is %3.3f kPa\n',My,Cy,Poy)

```

Scilab code Exa 5.4 To find velocities across shock and stagnation pressure change

```

1  clc
2  clear
3
4  //Input data
5  Px=30 //Pressure before the shock in kPa
6  Tx=-30+273 //Temperature before the shock in K
7  pr=2.6 //Pressure ratio across the shock wave
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 Mx=1.54 //Mach number before the shock from gas
    tables @pr
13 My=0.687 //Mach number after the shock from gas
    tables @Mx
14 t1=1.347 //Temperature ratio after and before the

```

```

    shock from gas tables @My
15 Ty=t1*Tx //Temperature ratio after the shock in K
16 p1=3.567 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @My
17 Poy=p1*Px //Stagnation pressure after shock in kPa
18 p2=0.917 //Stagnation pressure ratio after and
    before the shock from gas tables @My
19 Pox=Poy/p2 //Stagnation pressure before shock in kPa
20 dP=Pox-Poy //Change in stagnation pressure in kPa
21 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
    in m/s
22 Cx=(Mx*ax) //Air Velocity before the shock in m/s
23 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
24 Cy=(My*ay) //Velocity of air after the shock in m/s
25
26 //Output
27 printf('(A) Velocities upstream and downstream of
    shock wave are %3.2f m/s and %3.2f m/s
    respectively\n (B) Change in stagnation pressure
    is %3.3f kPa',Cx,Cy,dP)

```

Scilab code Exa 5.5 To find properties downstream of shock

```

1 clc
2 clear
3
4 //Input data
5 Mol=39.9 //Molar mass of a gas in kg/mol
6 k=1.67 //Specific heat ratio
7 Mx=2.5 //Mach number before the shock
8 Px=40 //Pressure before the shock in kPa
9 Tx=-20+273 //Temperature before the shock in K
10
11 //Calculation

```

```

12 My=0.554 //Mach number after the shock from gas
    tables @Mx
13 p1=7.567 //Static pressure ratio after and before
    the shock from gas tables @My
14 Py=p1*Px //Static pressure after shock in kPa
15 t1=2.805 //Temperature ratio after and before the
    shock from gas tables @My
16 Ty=Tx*t1 //Temperature ratio after the shock in K
17
18 //Output
19 printf('Downstream the normal shock:\n    Mach
    number is %3.3f\n    Pressure is %3.2f kPa\n
    Temperature is %3.3f K',My,Py,Ty)

```

Scilab code Exa 5.6 To find pressure acting on front of the body

```

1  clc
2  clear
3
4  //Input data
5  Mx=2 //Mach number before the shock
6  Px=50 //Pressure before the shock in kPa
7
8  //Calculation
9  p1=6.335 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @Mx
10 Poy=p1*Px //Stagnation pressure after shock in kPa
11
12 //Output
13 printf('Pressure acting on the front of the body is
    %3.2f kPa',Poy)

```

Scilab code Exa 5.7 To find mass flow rate and properties at exit of CD nozzle

```
1  clc
2  clear
3
4  //Input data
5  Po=800 //Pressure in reservoir in kPa
6  To=40+273 //Temperature in reservoir in K
7  M2a=2.5 //Mach number at exit from diagram
8  At=25 //Throat Area in cm2
9  Ax=40 //Area just before the shock in cm2
10 Ay=40 //Area just after the shock in cm2
11 k=1.4 //Adiabatic constant
12 R=287 //Specific gas constant in J/kg-K
13
14 //Calculation
15 t1=0.834 //Ratio of critical temperature and
    stagnation temperature from gas tables @M=1
16 Tt=To*t1 //Critical temperature in K
17 p1=0.528 //Ratio of critical pressure and stagnation
    pressure from gas tables @M=1
18 Pt=Po*p1 //Critical pressure in kPa
19 dt=Pt*103/(R*Tt) //Density in kg/m3, Pt in Pa
20 at=sqrt(k*R*Tt) //Velocity of sound at throat in m/s
21 Ct=at //Air Velocity of sound at throat in m/s
22 m=dt*At*10-4*Ct //Mass flow rate in kg/s
23 p2=0.0585 //Ratio of exit to stagnation pressure
    from isentropic gas tables @M2=2.5
24 a1=2.637 //Ratio of exit to critical area from
    isentropic gas tables @M2=2.5
25 A2=a1*At //Exit area in cm2
26 a2=Ax/At //Area ratio
27 M=1.94 //Mach number upstream of shock from gas
    tables @a2
28 p3=0.140 //Ratio of upstram of shock to stagnation
    pressures from isentropic gas tables @M
29 Px=p3*Po //Pressure upstram of shock in kPa
```

```

30 t2=0.570 //Ratio of upstram of shock to stagnation
    temperature from isentropic gas tables @M
31 Tx=t2*To //Temperature upstram of shock in K
32 My=0.588 //Mach number downstream of shock from
    normal shock gas tables @M
33 p4=4.225 //Static pressure ratio after and before
    the shock from gas tables @My
34 Py=Px*p4 //Static pressure after shock in kPa
35 t3=1.639 //Temperature ratio after and before the
    shock from gas tables @My
36 Ty=Tx*t3 //Temperature ratio after the shock in K
37 p5=2.338 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @My
38 Poy=p5*Px //Stagnation pressure after shock in kPa
39 p6=0.749 //Stagnation pressure ratio after and
    before the shock from gas tables @My
40 Pox=Poy/p6 //Stagnation pressure before shock in kPa
41 //Here At2=Aty, Po2=Poy, Toy=To2=To1=To
42 p7=0.79 //Static to stagnation pressure ratio after
    shock from isentropic gas tables @My
43 Po2=Py/p7 //Stagnation pressure at exit in kPa
44 t4=0.935 //Static to stagnation temperature ratio
    after shock from isentropic gas tables @My
45 To2=Ty/t4 //Stagnation temperature in K (checked)
46 a3=1.2 //Ratio of areas after shock i.e. (Ay/At2)
47 At2=Ay/a3 //Critical area after shock in cm^2
48 a4=A2/At2 //Ratio of areas
49 M2b=0.31 //Mach number at exit from gas tables @a4(
    as per section-b)
50 p8=0.936 //Static to stagnation pressure ratio at
    exit from isentropic gas tables @M2b
51 P2=Po2*p8 //Exit pressure in kPa
52 t5=0.981 //Static to stagnation temperature ratio
    after shock from isentropic gas tables @M2b
53 T2=To2*t5 //Exit temperature in K
54
55 //Output
56 printf('CASE-I:\n      (A)Mass flow rate is %3.2f kg/s

```

```

\n      (B)Exit area is %3.1f cm^2\n CASE-II:\n
(A)Temperature is %3.3f K\n      (B)Pressure is %3
.1f kPa',m,A2,T2,P2)

```

Scilab code Exa 5.8 To find properties upstream of wave front

```

1  clc
2  clear
3
4  //Input data
5  Px=1 //Pressure before the shock in bar
6  Tx=17+273 //Temperature before the shock in K
7  Cx=500 //Air Velocity before the shock in m/s
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
    in m/s
13 Mx=Cx/ax //Mach number before the shock
14 My=0.715 //Mach number after the shock from gas
    tables @Mx
15 p1=2.335 //Static pressure ratio after and before
    the shock from gas tables @My
16 Py=p1*Px //Static pressure after shock in bar
17 t1=1.297 //Temperature ratio after and before the
    shock from gas tables @My
18 Ty=Tx*t1 //Temperature ratio after the shock in K
19 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
20 Cy=ay*My //Velocity of air after the shock in m/s
21 C_y=Cx-Cy //Velocity of air in m/s
22 M_y=C_y/ay //Mach number impared upstream of the
    wave front
23 t2=0.939 //Static to stagnation temperature ratio

```

```

    after shock from isentropic gas tables @M_y
24 T_oy=Ty/t2 //Stagnation temperature of air in K
25
26 //Output
27 printf('(A) Pressure is %3.3f bar\n (B) Temperature is
    %3.2f K\n (C) Velocity of air is %3.2f m/s\n (D)
    Stagnation temperature is %3.2f K\n (E) Mach
    number is %3.3f ',Py,Ty,C_y,T_oy,M_y)

```

Scilab code Exa 5.9 To find properties downstream of shock total head pressure ratio entropy change strength of shock

```

1  clc
2  clear
3
4  //Input data
5  Mx=3 //Mach number before the shock
6  Tx=27+273 //Temperature before the shock in K
7  Px=1 //Pressure before the shock in bar
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 My=0.475 //Mach number after the shock from gas
    tables @Mx
13 p1=10.333 //Static pressure ratio after and before
    the shock from gas tables @My
14 Py=p1*Px //Static pressure after shock in bar
15 t1=2.679 //Temperature ratio after and before the
    shock from gas tables @My
16 Ty=Tx*t1 //Temperature ratio after the shock in K
17 p2=12.061 //Stagnation pressure after shock to
    Static pressure before shock from gas tables @My
18 Poy=p2*Px //Stagnation pressure after shock in bar
19 p3=0.328 //Stagnation pressure ratio after and

```

```

    before the shock from gas tables @My
20 Pox=Poy/p3 //Stagnation pressure before shock in kPa
21 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
22 Cy=ay*My //Velocity of air after the shock in m/s
23 ds=R*log(1/p3) //Change in entropy in J/kg-K
24 e=(Py-Px)/Px //Strength of shock
25
26 //Output
27 printf('(I)Downstream of the shock:\n    (A)Pressure
    is %3.3f bar\n    (B)Temperature is %3.1f K\n
    (C)Gas velocity is %3.2f m/s\n    (D)Mach
    number is %3.3f\n (II)Total head pressure ratio
    is %3.3f\n (III)Entropy change across the shock
    is %3.3f J/kg-K\n (IV)Strength of the shock is %3
    .3f ',Py,Ty,Cy,My,p3,ds,e)

```

Scilab code Exa 5.10 To determine Mach number across shock and area at shock

```

1  clc
2  clear
3
4  //Input data
5  a1=0.4 //Ratio of throat area to exit area
6  p1=0.8 //Ratio of static pressure to Stagnation
    pressure at inlet
7  At=1 //Throat area in m^2
8
9  //Calculation
10 a2=1/a1 //reciprocal of a1 to find in gas tables
11 //Pox=Po1=Po, Poy=Po2
12 a2p2=a2*p1 //Area pressure ratio i.e. (A2*P2)/(At2*
    Po2)
13 M2=0.28 //Exit mach number from gas tables @a2p2

```



```

14 a3=2.166 //Ratio of exit area to throat area after
    shock from gas tables @a2p2
15 p2=0.947 //Static to stagnation pressure ratio at
    exit from gas tables @a2p2
16 p3=a2/a3 //Stagnation pressure ratio after and
    before shock
17 Mx=1.675 //Mach number before the shock @p3
18 My=0.647 //Mach number after the shock from gas
    tables @Mx
19 a4=1.14 //Ratio of area after shock to throat area
    after shock from isentropic gas tables @My
20 a5=1.315 //Ratio of area before shock to throat area
    before shock from isentropic gas tables @My
21 Ax=a5*At //Area at shock in m^2
22
23 //Output
24 printf('(A)Mach number across the shock: Mx=%3.3 f (
    My=%3.3 f)\n (B)Area at shock is %3.3 f m^2 ',Mx,My,
    Ax)

```

Scilab code Exa 5.11 To find Mach number across shock Static pressure and area at shock

```

1  clc
2  clear
3
4  //Input data
5  a1=1/3 //Ratio of throat area to exit area
6  p1=0.4 //Ratio of static pressure to Stagnation
    pressure at inlet
7
8  //Calculation
9  a2=1/a1 //reciprocal of a1 to find in gas tables
10 //we know Pox=Po1=Po, Poy=Po2, At=Atx and Aty=At2
11 a2p2=a2*p1 //Area pressure ratio i.e. (A2*P2)/(At2*

```

```

    Po2)
12 M2=0.472 //Exit mach number from gas tables @a2p2
13 a3=1.397 //Ratio of exit area to throat area after
    shock from gas tables @a2p2
14 p2=0.858 //Static to stagnation pressure ratio at
    exit from gas tables @a2p2
15 p3=a3/a2 //Stagnation pressure ratio after and
    before shock
16 Mx=2.58 //Mach number before the shock @p3
17 My=0.506 //Mach number after the shock from gas
    tables @Mx
18 p4=9.145 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @My
19 a4=2.842 //Ratio of area before shock to throat area
20 p5=0.051 //Ratio of Pressure before shock to
    Stagnation pressure at entry
21
22 //Output
23 printf('At section where shock occurs:\n    (A)Mach
    number Mx=%3.2f and My=%3.3f\n    (B) Static
    Pressure is %3.3f*Po1 (units depend on Po1)\n
    (C)Area of cross section is %3.3f*At (units
    depend on At)',Mx,My,p5,a4)

```

Scilab code Exa 5.12 To find properties at various sections

```

1  clc
2  clear
3
4  //Input data
5  Po=300 //Pressure in reservoir in kPa
6  To=500 //Temperature in reservoir in K
7  At=1 //Throat area in m^2
8  Ax=2 //Area just before the shock in m^2
9  Ay=2 //Area just after the shock in m^2

```

```

10 A2=3 //Exit area in m^2
11
12 //Calculation
13 a1=Ax/At //Area ratio
14 Mx=2.2 //Mach number upstream of shock
15 p1=0.0935 //Ratio of pressure before shock to
    stagnation pressure before shock from gas tables
    @Mx
16 Px=p1*Po //pressure before shock in kPa
17 t1=0.50 //Ratio of temperature before shock to
    stagnation pressure before shock from gas tables
    @Mx
18 Tx=t1*To //temperature before shock in K
19 My=0.547 //Mach number downstream of shock
20 p2=5.480 //Static pressure ratio after and before
    the shock from gas tables @My
21 Py=Px*p2 //Static pressure after shock in kPa
22 t2=1.857 //Temperature ratio after and before the
    shock from gas tables @My
23 Ty=t2*Tx //Temperature ratio after the shock in K
24 p3=6.716 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @My
25 Poy=Px*p3 //Stagnation pressure after shock in kPa
26 Po2=Poy //Exit stagnation pressure in kPa, Since
    total pressure remains same after shock
27 t3=0.943 //Static to stagnation pressure after shock
    from isentropic gas tables @My
28 Toy=Ty/t3 //Stagnation pressure after shock in K
29 To2=Toy //Exit stagnation temperature in K, Since
    temperature remains after shock
30 a2=1.255 //Ratio of area after shock to throat area
    after shock from isentropic gas tables @My
31 Aty=Ay/a2 //Throat area after shock in m^2
32 At2=Aty //Throat area at exit in m^2
33 a3=A2/At2 //Areas ratio
34 M2=0.33 //Exit mach number from gas tables @a3
35 p4=0.927 //Static to Stagnation pressure at exit
    from gas isentropic gas tables @a3

```

```

36 P2=Po2*p4 //Exit pressure in kPa
37 t4=0.978 //Static to Stagnation temperature at exit
    from gas isentropic gas tables @a3
38 T2=To2*t4 //Exit temperature in K
39
40 //Output
41 printf('(A) Pressure at section (x) Px=%3.2f kPa\n (B
    ) Pressure at section (y) Px=%3.3f kPa\n (C)
    Stagnation pressure at section (y) Poy=%3.2f kPa\
n (D) Throat area of cross section at section (y)
    Aty=%3.4f m^2\n (E) Stagnation pressure at exit
    Po2=%3.2f kPa\n (F) Throat area of cross section
    at exit At2=%3.4f m^2\n (G) Static Pressure at
    exit P2=%3.2f kPa\n (H) Stagantion temperature at
    exit To2=%3i K\n (I) Temperature at exit T2=%3i k'
    ,Px ,Py ,Poy ,Aty ,Po2 ,At2 ,P2 ,To2 ,T2)

```

Scilab code Exa 5.13 To find mass flow rate and properties at throat and exit at various sections of CD nozzle

```

1  clc
2  clear
3
4  //Input data
5  Po1=500 //Stagnation pressure in kPa
6  To1=600 //Stagnation temperature in K
7  C1=100 //inlet velocity in m/s
8  A1=0.01 //Inlet Area in m^2
9  A2=0.01 //Exit Area in m^2
10 Mx=1.2 //Mach number before the shock
11 Ax=37.6 //Area just before the shock in cm^2
12 Ay=37.6 //Area just after the shock in cm^2
13 Px=109.9 //Pressure before the shock in kPa
14 Poy=350 //Stagnation pressure after shock in kPa
15 k=1.4 //Adiabatic constant

```

```

16 R=287 // Specific gas constant in J/kg-K
17 Cp=1005 // Specific heat capacity at constant volume
    in J/kg-K
18
19 // Calculation
20 T1=To1+(C1^2/(2*Cp)) // Inlet static temperature in K
21 ai_1=sqrt(k*R*T1) // Velocity of sound at inlet in m/
    s
22 M1=C1/ai_1 // Inlet Mach number
23 p1=0.973 // Static to Stagnation pressure ratio at
    entry from gas tables @M1
24 P1=Po1*p1 // Inlet static pressure in kPa
25 d1=P1*10^3/(R*T1) // Density at inlet in kg/m^3, P1
    in Pa
26 m=d1*A1*C1 // Mass flow rate at inlet in kg/s
27 p2=0.528 // Ratio of critical pressure to stagnation
    pressure from gas tables @M=1
28 Pt=Po1*p2 // Critical pressure in kPa
29 t1=0.834 // Ratio of critical temperature to
    stagnation temperature from gas tables @M=1
30 Tt=t1*To1 // critical temperature in K
31 ai_t=sqrt(k*R*Tt) // Velocity of sound at critical
    state in m/s
32 Ct=ai_t // Velocity of air at critical state in m/s
33 a1=2.964 // Ratio of inlet area to critical area from
    gas tables @M=1
34 At=A1/a1 // critical area in m^2
35 dt=Pt/(R*Tt) // Density at critical state in kg/m^3
36 mt=dt*At*Ct // Mass flow rate at critical state in
    kg/s
37 // Sub-division (a)
38 a2=1.030 // Ratio of area after shock to critical
    area from gas tables @Mx
39 Ay_a=At*a2 // Area after shock in cm^2
40 p3=0.412 // Ratio of upstream of shock to stagnation
    pressures from isentropic gas tables @Mx
41 Px_a=Po1*p3 // Pressure upstream of shock in kPa
42 t2=0.776 // Ratio of upstream of shock to stagnation

```

```

    temperature from isentropic gas tables @Mx
43 Tx_a=To1*t2 //Temperature upstram of shock in K
44 My_a=0.84 //Mach number downstream of shock from
    normal shock gas tables @Mx
45 p4=1.497 //Static pressure ratio after and before
    the shock from gas tables @My
46 Py_a=Px_a*p4 //Static pressure after shock in kPa
47 t3=1.099 //Temperature ratio after and before the
    shock from gas tables @My
48 Ty_a=Tx_a*t3 //Temperature ratio after the shock in
    K
49 p5=2.407 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @My
50 Poy_a=Px_a*p5 //Stagnation pressure after shock in
    kPa
51 a3=1.204 //Ratio of area after shock to throat area
    after shock from isentropic gas tables @My
52 At2_a=(Ay_a/a3)*10^4 //Throat area at exit in m^2,
    calculation mistake in textbook
53 a4=A2/At2_a //Ratio of areas to find gas tables
54 M2_a=0.2 //Exit mach number at section-A from gas
    tables @a4
55 p5=0.973 //ratio of exit pressure to stagnation
    pressure after shock from gas tables
56 P2_a=p5*Poy_a //exit pressure in kPa
57 //Sub-division (b)
58 a5=Ax/At //Ratio of area before shock to critical
    area
59 Mx_b=1.4 //Mach number at section-B from gas tables
    @a5
60 p6=0.314 //Ratio of upstram of shock to stagnation
    pressures from isentropic gas tables @Mx_b
61 Px_b=Po1*p6 //Pressure upstram of shock in kPa
62 t4=0.718 //Ratio of upstram of shock to stagnation
    temperature from isentropic gas tables @Mx_b
63 Tx_b=To1*t4 //Temperature upstram of shock in K
64 p20=3.049 //Stagnation pressure ratio after shock to
    Static pressure before shock from gas tables

```

```

65 Poy_b=Px_b*p20 //Stagnation pressure after shock in
    kPa
66 My_b=0.735 //Mach number downstream of shock from
    normal shock gas tables @Mx_b
67 p7=2.085 //Static pressure ratio after and before
    the shock from gas tables @My_b
68 Py_b=Px_b*p7 //Static pressure after shock in kPa
69 t5=1.260 //Temperature ratio after and before the
    shock from gas tables @My_b
70 Ty_b=Tx_b*t5 //Temperature after the shock in K
71 a6=1.071 //Ratio of area after shock to throat area
    after shock from isentropic gas tables My_b=0.735
72 At2_b=Ay/a6 //Throat area at exit in m^2
73 a7=A2/At2_b //Ratio of areas
74 M2_b=0.21 //Exit mach number at section-B from gas
    tables @a7
75 p8=0.9697 //ratio of exit pressure to stagnation
    pressure after shock from gas tables
76 P2_b=p8*Poy_b //exit pressure in kPa
77 //Sub-division (c)
78 p9=Px/Po1 //Ratio of upstram of shock to stagnation
    pressures
79 Mx_c=1.65 //Mach number at section-B from gas tables
    @p9
80 a8=1.292 //Ratio of area before shock to critical
    area from gas tables @p9
81 Ax_c=At*a8*10^4 //Area before shock in cm^2
82 t6=0.647 //Ratio of upstram of shock to stagnation
    temperature from isentropic gas tables @p9
83 Tx_c=To1*t6 //Temperature upstram of shock in K
84 My_c=0.654 //Mach number downstream of shock from
    normal shock gas tables @Mx_c
85 p10=3.0095 //Static pressure ratio after and before
    the shock from gas tables @My_c
86 Py_c=Px*p10 //Pressure downstram of shock in kPa
87 t7=1.423 //Temperature ratio after and before the
    shock from gas tables @My_c
88 Ty_c=Tx_c*t7 //Temperature after the shock in K

```

```

89 p12=4 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @Mx_c
90 Poy_c=Px*p12 //Stagnation pressure after shock in
    kPa
91 a9=1.136 //Ratio of area after shock to throat area
    after shock from gas tables My_c=0.654
92 At2_c=Ax_c/a9 //Throat area at exit in m^2
93 a8=A2/At2_c //Ratio of areas
94 M2_c=0.23 //Exit mach number at section-B from gas
    tables @a8
95 p11=0.964 //ratio of exit pressure to stagnation
    pressure after shock from gas tables
96 P2_c=p11*Poy_c //exit pressure in kPa
97 //Sub-division (D)
98 p13=Poy/Po1 //Pressure ratio , Since Pox=Po1
99 Mx_d=2.04 //Mach number upstream of shock from gas
    tables @p13
100 My_d=0.571 //Mach number downstream of shock from
    gas tables @p13
101 p14=4.688 //Static pressure ratio after and before
    the shock from gas tables @My_d
102 t8=1.72 //Temperature ratio after and before the
    shock from gas tables @My_d
103 p15=5.847 //Stagnation pressure after shock to
    Static pressure before shock from gas tables
    @Mx_d
104 p16=0.120 //Ratio of upstram of shock to stagnation
    pressures from isentropic tables @Mx_d
105 Px_d=Po1*p16 //Pressure upstram of shock in kPa
106 t9=0.546 //Ratio of upstram of shock to stagnation
    temperature from isentropic gas tables @Mx_d
107 Tx_d=To1*t9 //Temperature upstram of shock in K
108 p21=4.688 //Static pressure ratio after and before
    the shock from gas tables
109 Py_d=Px_d*p21 //Pressure downstram of shock in kPa
110 t12=1.72 //Ratio of upstram of shock to stagnation
    temperature from isentropic gas tables
111 Ty_d=Tx_d*t12 //Temperature after the shock in K

```



```

112 a9=1.745 //Ratio of area before shock to throat area
      from isentropic gas tables
113 Ax_d=At*a9*10^4 //Area before shock in cm^2
114 a10=1.226 //Ratio of area after shock to throat area
      after shock from isentropic tables @My_d
115 At2_d=(Ax_d/a10) //Throat area at exit in cm^2
116 a11=A2/At2_d //Ratio of areas
117 M2_d=0.29 //Exit mach number at section-B from gas
      tables @a11
118 p17=0.943 //ratio of exit pressure to stagnation
      pressure after shock from gas tables
119 P2_d=p17*Poy //exit pressure in kPa
120 //Sub-division (e)
121 a12=Ax/At //Ratio of areas
122 Mx_e=2.62 //Mach number upstream of shock from gas
      tables @a12
123 t10=0.421 //Ratio of upstram of shock to stagnation
      temperature from isentropic gas tables
124 Tx_e=To1*t10 //Temperature upstram of shock in K
125 p18=0.0486 //Ratio of upstram of shock to stagnation
      pressures from isentropic tables @Mx_e
126 Px_e=p18*Po1 //Pressure upstram of shock in kPa
127 My_e=0.502 //Mach number downstream of shock from
      gas tables @Mx_e
128 p19=7.842 //Static pressure ratio after and before
      the shock from gas tables @My_e
129 Py_e=Px_e*p19 //Pressure downstream of shock in kPa
130 P2_e=Py_e //Exit pressure in kPa
131 t11=2.259 //Temperature ratio after and before the
      shock from gas tables @My_d
132 Ty_e=Tx_e*t11 //Temperaure downstream of shock in K
133 T2_e=Ty_e //Exit temperature in K
134
135 //Output
136 printf('At throat:\n      Mass flow rate is %3.2f kg/s
      \n      Area at throat is %3.5f m^2\n      Pressure
      is %3i kPa\n      Temperature is %3.1f K\n
      Velocity is %3.1f m/s\n (a)At section (A):\n

```

Pressure upstream is %3i kPa\n Temperature
 upstream is %3.1f K\n Mack number downstream
 is %3.2f\n Pressure downstream is %3.3f kPa\n
 Temperature downstream is %3.3f K\n
 Stagnation pressure downstream is %3.1f kPa\n
 Area is %3.3f cm²\n At exit:\n Mach number
 is %3.1f\n Pressure is %3.1f kPa\n (b)At
 section (B):\n Pressure upstream is %3i kPa\n
 Temperature upstream is %3.1f K\n Mack
 number upstream is %3.1f\n Mack number
 downstream is %3.3f\n Pressure downstream is
 %3.2f kPa\n Temperature downstream is %3.2f K\
 n Stagnation pressure downstream is %3.1f kPa\
 n Area is %3.3f cm²\n At exit:\n Mach
 number is %3.2f\n Pressure is %3.1f kPa\n (c)
 At section (C):\n Area upstream is %3.2f cm²\n
 Temperature upstream is %3.1f K\n Mack
 number upstream is %3.2f\n Mack number
 downstream is %3.3f\n Pressure downstream is
 %3.2f kPa\n Temperature downstream is %3.2f K\
 n Stagnation pressure downstream is %3i kPa\
 Area is %3.4f cm²\n At exit:\n Mach
 number is %3.2f\n Pressure is %3.1f kPa\n (d)
 At section (D):\n Pressure upstream is %3i kPa
 \n Temperature upstream is %3.1f K\n Area
 upstream is %3.3f cm²\n Mack number upstream
 is %3.2f\n Mack number downstream is %3.2f\n
 Pressure downstream is %3.2f kPa\n
 Temperature downstream is %3.2f K\n Area is %3
 .3f cm²\n At exit:\n Mach number is %3.2f\n
 Pressure is %3.2f kPa\n (e)At section (E):\n
 Pressure upstream is %3.1f kPa\n
 Temperature upstream is %3.1f K\n Mack number
 upstream is %3.2f\n Mack number downstream is
 %3.3f\n Pressure downstream is %3.1f kPa\n
 Temperature downstream is %3.2f K\n At exit:\n
 Temperature is %3.2f K\n Pressure is %3.1f
 kPa\n ',m,At,Pt,Tt,Ct,Px_a,Tx_a,My_a,Py_a,Ty_a,

```

Poy_a , At2_a , M2_a , P2_a , Px_b , Tx_b , Mx_b , My_b , Py_b ,
Ty_b , Poy_b , At2_b , M2_b , P2_b , Ax_c , Tx_c , Mx_c , My_c ,
Py_c , Ty_c , Poy_c , At2_c , M2_c , P2_c , Px_d , Tx_d , Ax_d ,
Mx_d , My_d , Py_d , Ty_d , At2_d , M2_d , P2_d , Px_e , Tx_e ,
Mx_e , My_e , Py_e , Ty_e , T2_e , P2_e )

```

Scilab code Exa 5.14 To estimate the difference in mercury in limbs of U tube manometer at various velocities

```

1  clc
2  clear
3
4  //Input data
5  T=300 //Temperature in K
6  P=1.01325*10^5 //Absolute pressure in Pa
7  k=1.4 //Adiabatic constant
8  R=287 //Specific gas constant in J/kg-K
9  C_1=60 //Velocity of air in m/s
10 C_2=200 //Velocity of air in m/s
11 C_3=500 //Velocity of air in m/s
12 d_hg=13600 //Density of mercury in kg/m^3
13 g=9.81 //Acceleration due to gravity in m/s^2
14
15 //Calculation
16 a=sqrt(k*R*T) //Sound velocity in m/s
17 M_1=C_1/a //Mach number
18 dP1=(P*C_1^2)/(2*R*T) //Difference in mercury levels
    in Pa
19 dP1_hg=(dP1/(d_hg*g))*1000 //Difference in mercury
    levels in mm of Hg
20 M_2=C_2/a //Mach number
21 p1=(1+((k-1)/2)*M_2^2)^(k/(k-1)) //Stagnation to
    static pressure ratio
22 Po=p1*P //Stagnation pressure in Pa
23 dP2=abs(Po-P) //Difference in mercury levels in Pa

```

```

24 dP2_hg=(dP2/(d_hg*g))*1000 //Difference in mercury
    levels in mm of Hg
25 M_3=C_3/a //Mach number & M_3=Mach number just
    before shock
26 My=0.723 //Mach number just after shock
27 p1=2.2530 //Ratio of pressure after shock to before
    shock from gas tables @My
28 Py=p1*P //Pressure after shock in Pa
29 p2=0.706 //Ratio of pressure after shock to
    Stagnation pressure from gas tables @My
30 Po=Py/p2 //Stagnation pressure in Pa
31 dP3=Po-Py //Difference in mercury levels in Pa
32 dP3_hg=(dP3/(d_hg*g))*1000 //Difference in mercury
    levels in mm of Hg
33
34 //Output
35 printf('Difference in mercury levels at velocity
    equal to:\n    (A)%2i m/s is %3.3f mm of Hg\n
    (B)%3i m/s is %3.1f mm of Hg\n    (C)%3i m/s is
    %3i mm of Hg',C_1,dP1_hg,C_2,dP2_hg,C_3,dP3_hg)

```

Scilab code Exa 5.15 To estimate Mach number and properties across the normal shock of tube

```

1  clc
2  clear
3
4  //Input data
5  Px=16 //Pressure before the shock in kPa
6  Poy=70 //Stagnation pressure after shock in kPa
7  To=300+273 //Stagnation temperature in K
8  k=1.4 //Adiabatic constant
9
10 //Calculation
11 p1=Poy/Px //Pressure ratio

```

```

12 Mx=1.735 //Mach number upstream of shock
13 My=0.631 //Mach number downstream of shock
14 p2=0.84 //Ratio of stagnation pressures after and
    before shock from gas tables
15 t1=1.483 //Temperature ratio after and before shock
    from gas tables
16 Tx=To/(1+((k-1)/2)*Mx^2) //Temperature upstream of
    shock in K
17 Ty=Tx*t1 //Temperature downstream of shock in K
18 Pox=Poy/p2 //Stagnation pressure before shock in kPa
19
20 //Output
21 printf('(A)Mach number of the tunnel is Mx=%3.3f (My
    =%3.3f)\n (B)Upstream of the tube:\n    Static
    temperature is %3i K\n    Total pressure is %3.1f
    kPa\n (C)Downstream of the tube:\n    Static
    temperature is %3i K\n    Total pressure is %3i
    kPa',Mx,My,Tx,Pox,Ty,Poy)

```

Scilab code Exa 5.16 To find Mach number and velocity in pitot tube

```

1  clc
2  clear
3
4  //Input data
5  Py=455 //Pressure downstream of shock in kPa
6  Ty=65+273 //Temperature downstream of shock in K
7  dP=65 //Difference between dynamic and static
    pressure in kPa
8  k=1.4 //Adiabatic constant
9  R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 Poy=dP+Py //Stagnation pressure after shock in kPa
13 p1=Py/Poy //Pressure ratio

```

```

14 My=0.44 //Mach number downstream of shock from
    isentropic gas tables @pl
15 Mx=3.8 //Mach number upstream of shock from normal
    shock gas tables @My
16 t1=3.743 //Temperature ratio after and before the
    shock from gas tables @My
17 Tx=Ty/t1 //Temperature before the shock in K
18 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
    in m/s
19 Cx=Mx*ax //Air Velocity before the shock in m/s
20
21 //Output
22 printf('(A)Mach number is Mx=%3.1f (My=%3.2f)\n (B)
    Velocity is %3.2f m/s',Mx,My,Cx)

```

Scilab code Exa 5.17 To find shock speed and air velocity inside the shock

```

1 clc
2 clear
3
4 //Input data
5 k=1.4 //Adiabatic constant
6 Px=1.01325 //Pressure before the shock in bar
7 Tx=15+273 //Temperature before the shock in K
8 Py=13.789 //Pressure just after the shock in bar
9 R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 p1=Py/Px //Pressure ratio
13 Mx=3.47 //Mach number upstream of shock from normal
    shock gas tables @pl
14 My=0.454 //Mach number downstream of shock from
    isentropic gas tables @pl
15 t1=3.213 //Temperature ratio after and before the
    shock from gas tables @Mx

```

```

16 Ty=Tx*t1 //Temperature downstream of shock in K
17 p2=15.574 //Stagnation pressure after shock to
    Static pressure before shock from gas tables @Mx
18 Poy=Px*p2 //Stagnation pressure after shock in bar
19 ax=sqrt(k*R*Tx) //Velocity of sound before the shock
    in m/s
20 Cx=Mx*ax //Velocity of air before the shock in m/s
21 Csh=Cx //Since Csh=Cx, see dig.
22 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
23 Cy=My*ay //Velocity of air after the shock in m/s
24 C_y=Cx-Cy //Air velocity just inside the shock in m/
    s
25 P_y=Py //Pressure of air in bar, Since a powerful
    explosion creates a brief but intense blast wind
    as it passes
26 a_y=sqrt(k*R*Ty) ////Velocity of sound after the
    shock in m/s
27 M_y=C_y/a_y //Mach number
28
29 //Output
30 printf('(A) Shock speed is %3.2f m/s\n (B) Air
    velocity just inside the shock is %3.2f m/s',Cx,
    C_y)

```

Scilab code Exa 5.18 To compute speed of wave pressure and temperature of air at rest

```

1 clc
2 clear
3
4 //Input data
5 T=300 //Temperature in K
6 P=1.5 //Pressure in bar
7 C_y=150 //Air velocity just inside the shock in m/s

```

```

8 k=1.4 //Adiabatic constant
9 R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 ax=sqrt(k*R*T) //Velocity of sound before the shock
    in m/s
13 Mx=sqrt(((C_y*(k+1))/(2*ax))+1) //Mach number before
    the shock
14 My=0.79 ////Mach number after the shock from normal
    shock gas tables
15 Cx=Mx*ax //Velocity of gas before the shock in m/s
16 p1=1.775 //Stagnation pressure ratio after and
    before the shock from gas tables @My
17 Py=P*p1 //Pressure just after the shock in bar
18 t1=1.1845 //Temperature ratio after and before the
    shock from gas tables @My
19 Ty=T*t1 //Temperature ratio after the shock in K
20 ay=sqrt(k*R*Ty) //Velocity of sound after the shock
    in m/s
21 Csh=My*ay //Speed of the wave in m/s
22
23 //Output
24 printf('(A)Speed of the wave is %3.1f m/s\n (B)At
    rest condition:\n    Pressure is %3.4f bar\n
    Temperature is %3.2f K',Csh,Py,Ty)

```

Scilab code Exa 5.19 To find Mach number pressure temperature at exit and diffuser efficiency

```

1 clc
2 clear
3
4 //Input data
5 Mx=2 //Mach number before the shock
6 a1=3 //Diffuser area ratio

```



```

7 Pox=0.1 //Stagnation pressure before shock in bar
8 Tx=300 //Temperature before the shock in K
9 k=1.4 //Adiabatic constant
10
11 //Calculation
12 t1=0.555 //Static to stagnation temperature ratio
    before shock from isentropic gas tables @Mx,k=1.4
13 Tox=Tx/t1 //Stagnation temperature before shock in K
14 p1=0.128 //Static to stagnation pressure ratio
    before shock from isentropic gas tables @Mx,k=1.4
15 Px=Pox*p1 //Pressure before the shock in bar
16 My=0.577 //Mach number after the shock
17 p2=4.5 //Pressure ratio after and before the shock
    from gas tables @Mx
18 Py=Px*p2 //Pressure just after the shock in bar
19 t2=1.687 //Temperature ratio after and before the
    shock from gas tables @Mx
20 Ty=Tx*t2 //Temperature ratio after the shock in K
21 p3=0.721 //Stagnation pressure ratio after and
    before shock from gas tables @Mx
22 Poy=Pox*p3 //Stagnation pressure after shock in kPa
23 a2=1.2195 //Ratio of area after shock to throat area
    after shock from gas tables @My
24 a3=a2*a1 //Ratio of exit area to throat area at exit
25 M2=0.16 //Exit mach number from gas tables @a3
26 t3=0.9946 //Static to stagnation temperature ratio
    at exit from isentropic gas tables @Mx
27 T2=Tox*t3 //Exit Temperature in K, Since Tox=Toy=T02
    in case of diffuser
28 p4=0.982 //Static to stagnation pressure ratio at
    exit from isentropic gas tables @Mx
29 P2=Poy*p4 //Exit pressure in bar, Calculation
    mistake in textbook
30 eff=(((Tox/Tx)*(Poy/Pox)^((k-1)/k))-1)/(((k-1)/2)*
    Mx^2))*100 //Diffuser efficiency including shock
    in percent
31
32 //Output

```

```

33 printf('(A)At the diffuser exit:\n    Mach number is
    %3.2f\n    Pressure is %3.3f bar\n
    Temperature is %3.2f K\n (B)Diffuser efficiency
    including shock is %3.3f percent ',M2,P2,T2,eff)

```

Scilab code Exa 5.20 To find length of duct across shock mass flow rate entropy change across and downstream of shock

```

1  clc
2  clear
3
4  //Input data
5  k=1.3 //Adiabatic constant
6  R=287 //Specific gas constant in J/kg-K
7  P1=1 //Inlet pressure in bar
8  T1=400 //Inlet temperature in K
9  D=0.3 //Duct diameter in m
10 M1=2 //Mach number at entry
11 Mx=1.5 //Mach number upstream of shock
12 M2=1 //Mach number at outlet
13 f=0.003 //Friction factor
14
15 //Calculation
16 d1=P1*10^5/(R*T1) //Density at inlet in kg/m^3
17 a1=sqrt(k*R*T1) //Velocity of sound at inlet in m/s
18 C1=M1*a1 //Gas velocity at inlet in m/s
19 A1=%pi*D^2/4 //Inlet Area of the duct in m^2
20 m=d1*C1*A1 //Mass flow rate in kg/s
21 p1=0.131 //Static to Stagnation pressure ratio at
    entry from gas tables (M1,k=1.4,isentropic)
22 Po1=P1/p1 //Stagantion pressure at inlet in bar
23 t1=0.625 //Static to Stagnation temperature ratio at
    entry from gas tables (M1,k=1.4,isentropic)
24 To1=T1/t1 //Stagnation temperature at inlet in K
25 p2=0.424 //Static to Critical pressure ratio at

```

```

    inlet from gas tables ,fanno flow tables @M1,k=1.4
26 Pt1=P1/p2 //Critical pressure in bar
27 p3=1.773 //Stagnation pressure ratio at entry to
    critical state from gas tables ,fanno flow tables
    @M1,k=1.4
28 Pto1=Po1/p3 //Stagnation pressure at critical state
    in bar
29 t2=0.719 //Static to Critical temperature ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
30 Tt1=T1/t2 //Critical temperature in K
31 X1=0.357 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
32 p4=0.618 //Ratio of Static pressure before shock to
    critical pressure at entry from gas tables (fanno
    flow ,Mx,k=1.4)
33 Px=Pt1*p4 //pressure before shock in bar
34 t3=0.860 //Ratio of Static temperature before shock
    to critical temperature at entry from gas tables
    (fanno flow ,Mx,k=1.4)
35 Tx=Tt1*t3 //Temperature before shock in K
36 p5=1.189 //Ratio of Stagnation pressure before shock
    to Stagnation pressure at critical state at
    entry from gas tables (fanno flow ,Mx,k=1.4)
37 Pox=Pto1*p5 //Stagnation pressure at critical state
    in bar
38 Xx=0.156 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @Mx,k=1.4
39 X3=X1-Xx //Overall frictional constant fanno
    parameter upstream of duct
40 L1=(X3*D)/(4*f) //Length upstream of duct in m
41 My=0.7 //Mach number downstream of shock from gas
    tables @Mx
42 p6=2.413 //Static pressure ratio after and before
    the shock from gas tables @My
43 Py=Px*p6 //Pressure after shock in bar
44 t4=1.247 //Temperature ratio after and before the
    shock from gas tables @My
45 Ty=Tx*t4 //temperature after shock in K

```

```

46 p7=0.926 //Stagnation pressure ratio after and
    before the shock from gas tables @My
47 Poy=Pox*p7 //Stagnation pressure after shock in bar
48 p8=1.479 //Ratio of pressure after shock to pressure
    at critical state from gas tables @My
49 Pt=Py/p8 //Critical pressure in bar
50 p9=1.097 //Ratio of Stagnation pressure after shock
    to Stagnation pressure at critical state from gas
    tables @My
51 Pot=Poy/p9 //Stagnation pressure at critical state
    in bar
52 t5=1.071 //Ratio of temperature after shock to
    temperature at critical state from gas tables @My
53 Tt=Ty/t5 //Critical temperature in K
54 Xy=0.231 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @My,k=1.4
55 X2=0 //frictional constant fanno parameter from gas
    tables ,fanno flow tables @M=1,k=1.4
56 X4=Xy-X2 //Overall frictional constant fanno
    parameter downstream of duct
57 L2=(X4*D)/(4*f) //Length downstream of duct in m
58 ds1=R*log(Po1/Pox) //Change of entropy upstream of
    the shock in J/kg-K
59 ds2=R*log(Pox/Poy) //Change of entropy across the
    shock in J/kg-K
60 ds3=R*log(Poy/Pot) //Change of entropy downstream of
    the shock in J/kg-K
61
62 //Output
63 printf('(A)Length of the duct upstream and
    downstream of the duct is %3.3f m and %3.3f m
    respectively\n (B)Mass flow rate of the gas is %3
    .3f kg/s\n (C)Change of entropy:\n    Upstream of
    the shock is %3.2f J/kg-K\n    Across the shock
    is %3.3f J/kg-K\n    Downstream of the shock is
    %3.4f J/kg-K',L1,L2,m,ds1,ds2,ds3)

```

Scilab code Exa 5.21 To find length across the shock properties of air at exit and mass flow rate through the duct

```

1  clc
2  clear
3
4  //Input data
5  P1=0.685 //Inlet pressure in bar
6  T1=310 //Inlet temperature in K
7  D=0.6 //Duct diameter in m
8  M1=3 //Mach number at entry
9  Mx=2.5 //Mach number upstream of shock
10 M2=0.8 //Mach number at outlet
11 f=0.005 //Friction factor
12 k=1.4 //Adiabatic constant
13 R=287 //Specific gas constant in J/kg-K
14
15 //Calculation
16 d1=P1*10^5/(R*T1) //Density at inlet in kg/m^3
17 a1=sqrt(k*R*T1) //Velocity of sound at inlet in m/s
18 C1=M1*a1 //Air velocity at inlet in m/s
19 A1=%pi*D^2/4 //Inlet Area of the duct in m^2
20 m=d1*C1*A1 //Mass flow rate in kg/s
21 p1=0.218 //Static to Critical pressure ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
22 Pt1=P1/p1 //Critical pressure in bar
23 t1=0.428 //Static to Critical temperature ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
24 Tt1=T1/t1 //Critical temperature in K
25 X1=0.522 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
26 p2=0.292 //Ratio of Static pressure before shock to
    critical pressure at entry from gas tables (fanno
    flow ,Mx,k=1.4)

```

```

27 Px=Pt1*p2 //pressure before shock in bar
28 t2=0.533 //Ratio of Static temperature before shock
    to critical temperature at entry from gas tables
    (fanno flow ,Mx,k=1.4)
29 Tx=Tt1*t2 //Temperature before shock in K
30 Xx=0.432 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @Mx,k=1.4
31 X3=X1-Xx //Overall frictional constant fanno
    parameter upstream of duct
32 L1=(X3*D)/(4*f) //Length upstream of duct in m
33 My=0.513 //Mach number downstream of shock from gas
    tables @Mx
34 p3=7.125 //Static pressure ratio after and before
    the shock from gas tables @My
35 Py=Px*p3 //Pressure after shock in bar
36 t3=2.138 //Temperature ratio after and before the
    shock from gas tables @My
37 Ty=Tx*t3 //temperature after shock in K
38 p4=2.138 //Ratio of pressure after shock to pressure
    at critical state from gas tables @My
39 Pt=Py/p4 //Critical pressure in bar
40 t4=1.143 //Ratio of temperature after shock to
    temperature at critical state from gas tables @My
41 Tt=Ty/t4 //Critical temperature in K
42 p5=1.289 //Ratio of pressure at exit to pressure at
    critical state from gas tables @M2
43 P2=Pt*p5 //Exit pressure in bar
44 t5=1.064 //Ratio of temperature at exit to
    temperature at critical state from gas tables @M2
45 T2=Tt*t5 //Exit temperature in K
46 Xy=1.069 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @My,k=1.4
47 X2=0.073 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M2,k=1.4
48 X4=Xy-X2 //Overall frictional constant fanno
    parameter downstream of duct
49 L2=(X4*D)/(4*f) //Length downstream of duct in m
50

```

```

51 //Output
52 printf('(A) Length L1 and L2 are %3.1f m and %3.2f m
    respectively\n (B) State of air at exit:\n
    Pressure is %3.3f bar\n    Temperature is %3.1f K
\n (C) Mass flow rate through the duct is %3.2f kg
/s ',L1,L2,P2,T2,m)

```

Scilab code Exa 5.22 To find properties after shock and exit and exit Mach number

```

1  clc
2  clear
3
4  //Input data
5  At=24 //Throat area in cm^2
6  A2=50 //Exit area in cm^2
7  Po=700 //Stagnation pressure in kPa
8  To=100+273 //Stagnation temperature in K
9  Ax=34 //Area before the shock in cm^2
10 Ay=34 //Area after the shock in cm^2
11
12 //Calculation
13 a1=Ax/At //Ratio of areas
14 Mx=1.78 //Mach number upstream of shock from gas
    tables @a1
15 t1=0.61212 //Ratio of temperature before shock to
    critical state from isentropic gas tables @Mx
16 Tx=To*t1 //temperature before shock in K
17 p1=0.179 //Ratio of pressure before shock to
    critical state from isentropic gas tables @Mx
18 Px=Po*p1 //pressure before shock in kPa
19 My=0.621 //Mach number downstream of shock from gas
    tables @Mx
20 p2=3.5298 //Static pressure ratio after and before
    the shock from gas tables @My

```

```

21 Py=Px*p2 //Pressure after shock in kPa
22 t2=1.51669 //Temperature ratio after and before the
    shock from gas tables @My
23 Ty=Tx*t2 //temperature after shock in K
24 p3=4.578 //Ratio of Stagnation pressure after the
    shock to static pressure before shock from gas
    tables @My
25 Po2=Px*p3 //Stagnation pressure at exit in bar
26 a2=1.16565 //Ratio of area after shock to critical
    area across shock from isentropic gas tables @My
27 At2=Ay/a2 //critical area at exit in cm^2
28 a3=A2/At2 //Ratio of areas
29 M2=0.36 //Exit mach number from gas tables (a3,k
    =1.4,isentropic)
30 p4=0.914 //Static to Stagnation pressure ratio at
    exit from gas tables (a3,k=1.4,isentropic)
31 P2=Po2*p4 //Stagnation pressure ratio at exit in kPa
32 t3=0.975 //Static to Stagnation temperature ratio at
    exit from gas tables (a3,k=1.4,isentropic)
33 T2=To*t3 //Stagnation temperature at exit in K
34
35 //Output
36 printf('(A) Properties of fluid just after shock:\n
    Mach number My=%3.3f\n    Temperature is %3.2f
    K\n    Pressure is %3.2f kPa\n (B) Exit mach
    number is %3.2f\n (C) Properties of fluid at exit
    :\n    Pressure is %3i kPa\n    Temperature is %3
    .3f K',My,Ty,Py,M2,P2,T2)

```

Scilab code Exa 5.23 To find length diameter of pipe and properties at pipe exit

```

1 clc
2 clear
3

```



```

4 //Input data
5 D=0.4 //Duct diameter in m
6 Po=12 //Stagnation pressure in kPa
7 To=600 //Stagnation temperature in K
8 f=0.0025 //Friction factor
9 M1=1.8 //Mach number at entry
10 M2=1 //Mach number at outlet
11 Mx=1.22 //Mach number upstream of shock
12
13 //Calculations
14 A2=%pi*D^2/4 //Exit area in cm^2
15 p1=0.174 //Static to Stagnation pressure ratio at
    entry from gas tables (M1,k=1.4,isentropic)
16 P1=Po*p1 //Inlet pressure in bar
17 t1=0.607 //Static to Stagnation temperature ratio at
    entry from gas tables (M1,k=1.4,isentropic)
18 T1=To*t1 //Inlet temperature in K
19 a1=1.094 //Ratio of area at exit to critical area
    across shock from isentropic gas tables @M1,k=1.4
20 Ax=A2/a1 //Area before the shock in cm^2
21 Dt=sqrt((Ax*4)/(%pi))*10^2 //Duct diameter at throat
    in cm
22 p2=0.474 //Static to Critical pressure ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
23 Pt=P1/p2 //Critical pressure in bar
24 t2=0.728 //Static to Critical temperature ratio at
    inlet from gas tables ,fanno flow tables @M1,k=1.4
25 Tt=T1/t2 //Critical temperature in K
26 X1=0.242 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @M1,k=1.4
27 p3=0.788 //Ratio of Static pressure before shock to
    critical pressure at entry from gas tables (fanno
    flow ,Mx,k=1.4)
28 Px=Pt*p3 //pressure before shock in bar
29 t3=0.925 //Ratio of Static temperature before shock
    to critical temperature at entry from gas tables
    (fanno flow ,Mx,k=1.4)
30 Tx=Tt*t3 //Temperature before shock in K

```

```

31 Xx=0.039 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @Mx,k=1.4
32 X3=X1-Xx //Overall frictional constant fanno
    parameter upstream of duct
33 L1=(X3*D)/(4*f) //Length upstream of duct in m
34 My=0.83 //Mach number downstream of shock from gas
    tables @Mx
35 p4=1.57 //Static pressure ratio after and before the
    shock from gas tables @My
36 Py=Px*p4 //Pressure after shock in bar
37 t4=1.141 //Temperature ratio after and before the
    shock from gas tables @My
38 Ty=Tx*t4 //temperature after shock in K
39 p5=1.2375 //Ratio of pressure after shock to
    pressure at critical state from gas tables @My
40 Pt=Py/p5 //Critical pressure in bar
41 t5=1.055 //Ratio of temperature after shock to
    temperature at critical state from gas tables @My
42 Tt=Ty/t5 //Critical temperature in K
43 Xy=0.049 //frictional constant fanno parameter from
    gas tables ,fanno flow tables @My,k=1.4
44 X2=0 //frictional constant fanno parameter from gas
    tables ,fanno flow tables @M=1,k=1.4
45 X4=Xy-X2 //Overall frictional constant fanno
    parameter downstream of duct
46 L2=(X4*D)/(4*f) //Length downstream of duct in m
47 L=L1+L2 //Length of duct in m
48
49 //Output
50 printf('(A)Length of the pipe is %3.2f m\n (B)
    Diameter of the nozzle throat is %3.3f cm\n (C)At
    the pipe exit:\n    Pressure is %3.3f bar\n
    Temperature is %3.2f K',L,Dt,Pt,Tt)

```

Scilab code Exa 5.24 To estimate amount of heat added in two pipe section and properties

```
1  clc
2  clear
3
4  //Input data
5  Po=700 //Stagnation pressure in kPa
6  To=500+273 //Stagnation temperature in K
7  a1=3.5 //Ratio of exit area to throat area
8  m=5.5 //Mass flow rate in kg/s
9  Cp=1.005 //Specific heat capacity at constant
    pressure in kJ/kg-K
10 k=1.4 //Adiabatic constant
11
12 //Calculation
13 My=1/sqrt(k) //Mach number downstream of shock
14 M2=2.8 //Mach number at outlet from gas tables @a1
15 t1=0.389 //Static to Stagnation temperature ratio at
    exit from gas tables (M1,k=1.4,isentropic)
16 T2=To*t1 //Exit temperature in K
17 p1=0.0369 //Static to Stagnation pressure ratio at
    exit from gas tables (M1,k=1.4,isentropic)
18 P2=Po*p1 //exit pressure in kPa
19 p2=0.2 //Ratio of pressure at exit to pressure at
    critical state at exit from Rayleigh flow gas
    tables @M2
20 Pt2=P2/p2 //Exit pressure at critical state in kPa
21 t2=0.315 //Ratio of temperature at exit to
    temperature at critical state at exit from
    Rayleigh flow gas tables @M2
22 Tt2=T2/t2 //Exit temperature at critical state in K
23 t3=0.674 //Ratio of Stagnation temperature at exit
    to stagnation temperature at critical state at
    exit from Rayleigh flow gas tables @M2
24 Tto2=To/t3 //Exit stagnation temperature at critical
    state in K
25 Mx=1.2 //Mach number upstream of shock from gas
```

```

    tables @My
26 p3=0.796 //Ratio of Static pressure before shock to
    critical pressure at exit from gas tables (
    Rayleigh flow ,Mx,k=1.4)
27 Px=Pt2*p3 //Static pressure before shock in kPa
28 t4=0.912 //Ratio of Static temperature before shock
    to critical temperature at exit from gas tables (
    Rayleigh flow ,Mx,k=1.4)
29 Tx=Tt2*t4 //Static temperature before shock in K
30 t5=0.978 //Ratio of Stagnation temperature before
    shock to critical Stagnation temperature at exit
    from gas tables (Rayleigh flow ,Mx,k=1.4)
31 Tox=Tto2*t5 //Stagnation temperature before shock in
    K
32 p4=1.513 //Static pressure ratio after and before
    the shock from gas tables @Mx
33 Py=Px*p4 //Pressure after shock in kPa
34 t6=1.128 //Temperature ratio after and before the
    shock from gas tables @Mx
35 Ty=Tx*t6 //temperature after shock in K
36 t7=0.875 //Ratio of Temperature after the shock to
    Stagnation temperature after shock from gas
    tables @Mx
37 Toy=Ty/t7 //Stagnation temperature after shock in K,
38 p5=1.207 //Ratio of pressure after shock to pressure
    at critical state from gas tables @My
39 Pt=Py/p5 //Critical pressure in kPa
40 t8=1.028 //Ratio of temperature after shock to
    temperature at critical state from gas tables @My
41 Tt=Ty/t8 //Critical temperature in K
42 t9=0.978 //Ratio of Stagnation temperature after
    shock to Stagnation temperature at critical state
    from gas tables @My
43 Tot=Toy/t9 //Stagnation temperature at critical
    state in K, calculation mistake in textbbok
44 q1=Cp*(Tox-To) //Amount of heat added in upstream of
    shock in kJ/s
45 q2=Cp*(Tot-Toy) //Amount of heat added in downstream

```

```

    of shock in kJ/s
46 Q=m*(q1+q2) //Amount of heat added in two pipe
    section in kJ/s
47
48 //Output
49 printf('(A)Amount of heat added in two pipe section
    is %3.2f kJ/s\n (B)Properties:\n Upstream of
    shock:\n    Pressure is %3.1f kPa\n
    Temperature is %3.3f K\n    Stagnation
    temperature is %3.2f K\n    Mach number is %3.1f\n
    n Downstream of shock:\n    Pressure is %3.3f kPa
    \n    Temperature is %3.3f K\n    Stagnation
    temperature is %3.1f K\n    Mach number is %3.3f\n
    n At the throat:\n    Pressure is %3.2f kPa\n
    Temperature is %3.3f K\n    Stagnation
    temperature is %3.2f K\n At the exit:\n
    Pressure is %3.2f kPa\n    Temperature is %3.2f K
    \n    Mach number is %3.2f ',Q,Px,Tx,Tox,Mx,Py,Ty,
    Toy,My,Pt,Tt,Tot,P2,T2,M2)

```

Scilab code Exa 5.25 To find deflection angle Downstream Mach number Static pressure and total pressure loss through the shock

```

1  clc
2  clear
3
4  //Input data
5  M1=2.8 //Inlet mach number
6  sig=42 //Shock wave angle in degree
7  Px=1 //Pressure upstream of shock in bar(Assuming)
8  k=1.4 //Adiabatic constant
9
10 //Calculations
11 Mx=M1*sind(sig) //Mach number before the shock
12 My=0.601 //Mach number after the shock from gas

```

```

    tables @Mx
13 p1=3.98 //Static pressure ratio after and before the
    shock from gas tables @Mx
14 Py=Px*p1 //Pressure after shock in bar
15 p2=4.994 //Stagnation pressure after shock to Static
    pressure before shock from gas tables @Mx
16 Poy=Px*p2 //Stagnation pressure after shock in bar
17 p3=0.788 //Stagnation pressure ratio after and
    before the shock from gas tables @Mx
18 Pox=Poy/p3 //Stagnation pressure before shock in kPa
19 dP1=Pox-Poy //Total pressure loss in bar
20 def=atand(((M1^2*sind(2*sig))-(2/tand(sig)))/(2+(M1
    ^2*(k+cosd(2*sig))))) //Deflection angle in
    degree
21 M2=My/(sind(sig-def)) //Downstream mach number
22
23 //Output
24 printf('(A) Deflection angle is %3i degree\n (B)
    Downstream mach number is %3.3f\n (C) Static
    pressure is %3.3f bar\n (D) Total pressure loss is
    %3.3f bar ',def,M2,Py,dP1)

```

Scilab code Exa 5.26 To determine static pressure temperature behind wave Mach number and Wedge angle

```

1  clc
2  clear
3
4  //Input data
5  M1=2 //Inlet mach number
6  sig=40 //Shock wave angle in degree
7  Px=0.5 //Pressure upstream of shock in bar
8  Tx=273 //Temperature upstream of shock in K
9  k=1.4 //Adiabatic constant
10

```

```

11 //Calculation
12 Mx=M1*sind(sig) //Mach number before the shock
13 My=0.796 //Mach number after the shock from gas
    tables @Mx
14 p1=1.745 //Static pressure ratio after and before
    the shock from gas tables @Mx
15 Py=p1*Px //Pressure after shock in bar
16 t1=1.178 //Static temperature ratio after and before
    the shock from gas tables @Mx
17 Ty=Tx*t1 //Temperature after shock in K
18 Ws=atand(((M1^2*sind(2*sig))-(2/tand(sig)))/(2+(M1
    ^2*(k+cosd(2*sig))))) //Wedge semi angle in
    degree
19 W=2*Ws //Wedge angle in degree
20
21 //Output
22 printf('(A) Static pressure is %3.4f bar\n (B)
    Temperature behind the wave is %3.2f K\n (C)Mach
    number of flow passing over wedge is %3.3f\n (D)
    Wedge angle is %3.2f degree ',Py,Ty,Mx,W)

```

Scilab code Exa 5.27 To find property ratios at strong and weak shock at wedge

```

1 clc
2 clear
3
4 //Input data
5 def=15
6 M1=2
7 k=1.4
8
9 //Calculation
10 //Using relation def=atand(((M1^2*sind(2*sig))-(2/
    tand(sig)))/(2+(M1^2*(k+cosd(2*sig))))) and

```

```

    converting into 6th degree polynomial of  $\sin(\text{sig})=x$ 
11 C=((2*tand(def))+((M1^2)*k*tand(def))+((M1^2)*tand(
    def))) //Constant value for convenience
12 D=(2*M1^2*tand(def)) //Constant value for
    convenience
13 a=4 //Value of constant in polynomial
14 b=0 //Coefficient of power 1 i.e.  $x^1$ 
15 c=(4+C^2+(8*M1^2)) //Coefficient of power 2 i.e.  $x^2$ 
16 d=0 //Coefficient of power 3 i.e.  $x^3$ 
17 e=(4*(M1^4))+((2*C*D))+((8*M1^2)) //Coefficient of power
    4 i.e.  $x^4$ 
18 f=0 //Coefficient of power 5 i.e.  $x^5$ 
19 g=(4*M1^4)+D^2 //Coefficient of power 6 i.e.  $x^6$ 
20 p4=poly([a b -c -d e f -g], 'x', 'c') //Expression for
    solving 6th degree polynomial
21 disp('Values for sine of wave angle are:\n')
22 disp(roots(p4))
23 sig1=asind(0.9842) //Strong shock wave angle in
    degree, nearer to 90 degree
24 sig2=asind(0.7113) //Weak shock wave angle in degree
    , nearer to 45 degree
25 //(a) Strong Shock Wave
26 Mx_1=M1*sind(sig1) //Mach number before the shock of
    stong shock wave
27 My_1=0.584 //Mach number after the shock from gas
    tables @Mx_1
28 p1=4.315 //Static pressure ratio after and before
    the shock from gas tables @Mx_1
29 t1=1.656 //Static temperature ratio after and before
    the shock from gas tables @Mx_1
30 d1=p1/t1 //Density ratio after and before the shock
    of stong shock wave
31 M2_1=My_1/(sind(sig1-def)) //Exit mach number of
    stong shock wave
32 Mx_2=M1*sind(sig2) //Mach number before the shock of
    weak shock wave
33 My_2=0.731 //Mach number after the shock from gas

```



```

    tables @Mx_2
34 p2=2.186 //Static pressure ratio after and before
    the shock from gas tables @Mx_2
35 t2=1.267 //Static temperature ratio after and before
    the shock from gas tables @Mx_2
36 d2=p2/t2 //Density ratio after and before the shock
    of weak shock wave
37 M2_2=My_2/(sind(sig2-def)) //Exit mach number of
    weak shock wave
38
39 //Output
40 printf('\nStrong Shock Wave:\n    (A)Wave angle is
    %3.1f degree\n    (B)Pressure ratio is %3.3f\n
    (C)Density ratio is %3.3f\n    (D)Temperature
    ratio is %3.3f\n    (E)Downstream Mach number is
    %3.3f\n Weak Shock Wave:\n    (A)Wave angle is %3
    .1f degree\n    (B)Pressure ratio is %3.3f\n    (
    C)Density ratio is %3.3f\n    (D)Temperature
    ratio is %3.3f\n    (E)Downstream Mach number is
    %3.3f ',sig1,p1,d1,t1,M2_1,sig2,p2,d2,t2,M2_2)

```

Scilab code Exa 5.28 To find deflection angle final Mach number and temperature of gas

```

1  clc
2  clear
3
4  //Input data
5  k=1.3 //Adiabatic constant
6  P1=0.345 //Inlet pressure in bar
7  T1=350 //Inlet temperature in K
8  M1=1.5 //Inlet mach number
9  P2=0.138 //Exit pressure in bar
10
11 //Calculation

```

```

12 p1=0.284 //Pressure ratio at entry from gas tables
    @M1,k=1.3
13 Po=P1/p1 //Stagnation Pressure in bar
14 t1=0.748 //Temperature ratio at entry from gas
    tables @M1,k=1.3
15 To=T1/t1 //Stagnation temperature in K
16 p2=P2/Po //Pressure ratio
17 M2=2.08 //Final Mach number from isentropic gas
    tables @p2
18 t2=0.606 //Temperature ratio at exit from gas tables
    @M2,k=1.3
19 T2=To*t2 //The temperature of the gas in K
20 w1=12.693 //Prandtl Merger function at M1
21 w2=31.12 //Prandtl Merger function at M2
22 def=w2-w1 //Deflection Angle in degree
23
24 //Output
25 printf('(A) Deflection Angle is %3.3f degree\n (B)
    Final Mach number is %3.2f\n (C)The temperature
    of the gas is %3.3f K',def,M2,T2)

```

Chapter 6

Aircraft Propulsion

Scilab code Exa 6.1 To calculate thrust and specific thrust of jet propulsion

```
1  clc
2  clear
3
4  //Input data
5  eff_com=0.8 //Compressor efficiency
6  eff_t=0.85 //Turbine efficiency
7  pr=4 //Pressure ratio including combustion pressure
   loss(Po2s/Po1)
8  eff_c=0.98 //Combustion efficiency
9  eff_m=0.99 //Mechanical transmission efficiency
10 eff_n=0.9 //Nozzle efficiency
11 Tmax=1000 //Maximum cycle temperature in K
12 To3=Tmax //Stagnation temperature before turbine
   inlet in K
13 w=220 //mass flow rate in N/s
14 Cp_air=1005 //Specific heat capacity at constant
   pressure in J/kg-K
15 k=1.4 //Adiabatic constant for air
16 Cp_gas=1153 //Specific heat capacity at constant
   pressure in J/kg-K
```

```

17 k_gas=1.3 //Adiabatic constant
18 To1=15+273 //Inlet Stagnation temperature of
    compressor in K
19 Po1=1 //Inlet Stagnation pressure in bar
20 Poe=Po1 //Exit stagnation pressure in bar, Since
    exit at ambient conditions
21 g=9.81 //Acceleration due to gravity in m/s^2
22
23 //Calculation
24 To2s=To1*(pr)^((k-1)/k) //Exit Stagnation
    temperature of compressor at isentropic process
    in K
25 To2=((To2s-To1)/eff_com)+To1 //Exit Stagnation
    temperature of compressor in K
26 Wc=(Cp_air*(To2-To1)) //Work given to compressor in
    J/kg, Cp in J/kg-K
27 To4=To3-(Wc/Cp_gas*eff_m) //Exit Stagnation
    temperature of turbine in K
28 To4s=To3-((To3-To4)/eff_t) //Exit Stagnation
    temperature of turbine at isentropic process in K
29 Po2=Po1*pr //Exit Stagnation pressure of compressor
    in bar
30 Po3=Po2 //Exit Stagnation pressure of combustion
    chamber in bar, Since the process takes place at
    constant pressure process
31 p1=(To3/To4s)^(k_gas/(k_gas-1)) //Stagnation
    Pressure ratio of inlet and outlet of turbine
32 Po4s=Po3/p1 //Stagnation Pressure at outlet of
    turbine at isentropic process in bar
33 pr_n=Po4s/Poe //Pressure ratio of nozzle
34 Toes=To4/((pr_n)^((k_gas-1)/k_gas)) //Exit
    Stagnation temperature of nozzle at isentropic
    process in K
35 Toe=To4-((To4-Toes)*eff_n) //Exit Stagnation
    temperature of nozzle in K
36 Cj=sqrt(2*Cp_gas*(To4-Toe)) //Jet velocity in m/s
37 m=w/g //Mass flow rate of air in kg/s
38 F=m*Cj*10^-3 //Thrust in kN

```

```

39 Fs=(F*10^3)/m //Specific thrust in Ns/kg, F in N
40 Is=F/w //Specific impulse in sec
41
42 //Output
43 printf('(A)Thrust is %3.3f kN\n (B)Specific thrust
    is %3.2f Ns/kg',F,Fs)

```

Scilab code Exa 6.2 To find thrust developed thrust power and propulsive efficiency

```

1  clc
2  clear
3
4  //Input data
5  u=800*(5/18) //Flight velocity in m/s
6  Pe=60 //Ambient pressure in kPa
7  Pn=300 //Pressure entering nozzle in kPa
8  Tn=200+273 //Temperature entering nozzle in K
9  m=20 //Mass flow rate of air in kg/s
10 Cp=1005 //Specific heat capacity at constant
    pressure in J/kg-K
11 k=1.4 //Adiabatic constant for air
12
13 //Calculation
14 Te=Tn*(Pe/Pn)^((k-1)/k) //Exit temperature of nozzle
    in K
15 Cj=sqrt(2*Cp*(Tn-Te)) //Jet velocity in m/s
16 F=m*(Cj-u) //Thrust in N
17 P=F*u*10^-3 //Thrust power in kW
18 eff=((2*u)/(Cj+u))*100 //Propulsive efficiency in
    percent
19
20
21 //Output
22 printf('(A)Thrust developed is %3.1f N\n (B)Thrust

```

developed is %3.2f kW\n (C) Propulsive efficiency
is %3.3f percent ',F,P,eff)

Scilab code Exa 6.3 To determine specific thrust and thrust specific fuel consumption for turbojet engine

```
1  clc
2  clear
3
4  //Input data
5  Mi=0.8 //Inlet mach number
6  h=10000 //Altitude in m
7  pr_c=8 //Pressure ratio of compressor
8  To3=1200 //Stagnation temperature at turbine inlet
   in K
9  eff_c=0.87 //Compressor efficiency
10 eff_t=0.9 //Turbine efficiency
11 eff_d=0.93 //Diffuser efficiency
12 eff_n=0.95 //Nozzle efficiency
13 eff_m=0.99 //Mechanical transmission efficiency
14 eff_cc=0.98 //Combustion efficiency
15 pl=0.04 //Ratio of combustion pressure loss to
   compressor delivery pressure
16 k=1.4 //Adiabatic constant of air
17 R=287 //Specific gas constant in J/kg-K
18 k_g=1.33 //Adiabatic constant of gas
19 Cp_a=1005 //Specific heat capacity at constant
   pressure of air in J/kg-K
20 Cp_g=1100 //Specific heat capacity at constant
   pressure of gas in J/kg-K
21 CV=43000000 //Calorific value in J/kg (Assume)
22
23 //Calculation
24 Ti=223.15 //Inlet temperature in K from gas tables
25 Pi=26.4 //Inlet pressure in kPa from gas tables
```

```

26 ai=sqrt(k*R*Ti) //Sound velocity in m/s
27 Ci=ai*Mi //Velocity of air in m/s,
28 u=Ci //Flight velocity in m/s, Since it is reaction
    force of Ci
29 t1=0.886 //Ratio of static to stagnation temperature
    a entry from gas tables at M=0.8
30 To1s=Ti/t1 //Stagnation temperature at inlet of
    compressor at isentropic process in K
31 To1=((To1s-Ti)/eff_d)+Ti //Stagnation temperature at
    inlet of compressor in K
32 p1=(To1s/Ti)^(k/(k-1)) //Pressure ratio i.e. (Po1s/
    Pi)
33 Po1s=Pi*p1 //inlet Stagnation pressure of compressor
    at isentropic process in kPa
34 Po1=Po1s //Inlet Stagnation pressure of compressor
    in kPa
35 Po2=pr_c*Po1 //Exit Stagnation pressure of
    compressor in kPa
36 To2s=To1s*(Po2/Po1)^((k-1)/k) //Exit Stagnation
    temperature of compressor at isentropic process
    in K
37 To2=((To2s-To1)/eff_c)+To1 //Exit Stagnation
    temperature of compressor in K
38 P_los=p1*Po2 //combustion pressure loss in kPa
39 Po3=Po2-P_los //Exit Stagnation pressure of
    combustion chamber in kPa
40 To4=To3-((Cp_a*(To2-To1))/(eff_m*Cp_g)) //Exit
    Stagnation temperature of turbine in K
41 To4s=To3-((To3-To4)/eff_t) //Exit Stagnation
    temperature of turbine at isentropic process in K
42 p1=(To3/To4s)^(k_g/(k_g-1)) //Pressure ratio i.e. (
    Po3/Po4s)
43 Po4s=Po3/p1 //Stagnation Pressure at outlet of
    turbine at isentropic process in kPa
44 Poe=Pi //Exit stagnation pressure in kPa, Since exit
    is at ambient conditions
45 pr_n=Po4s/Poe //Pressure ratio of nozzle
46 Toes=To4/((pr_n)^((k_g-1)/k_g)) //Exit Stagnation

```

```

    temperature of nozzle at isentropic process in K
47 Toe=To4-((To4-Toes)*eff_n) //Exit Stagnation
    temperature of nozzle in K
48 Cj=sqrt(2*Cp_g*(To4-Toe)) //Jet velocity in m/s
49 Fs=Cj-u //Specific thrust in Ns/kg
50 f=((Cp_g*To3)-(Cp_a*To2))/((eff_cc*CV)-(Cp_g*To3))
    //Fuel-air ratio
51 TSFC=(f/Fs)*10^5 //Thrust specific fuel consumption
    in kg/s-N x10^-5
52
53 //Output
54 printf('(A) Specific thrust is %3.2f Ns/kg\n (B)
    Thrust specific fuel consumption is %3.3fx10^-5
    kg/s-N',Fs,TSFC)

```

Scilab code Exa 6.4 To estimate properties at exit and propulsive efficiency of a turbojet aircraft

```

1 clc
2 clear
3
4 //Input data
5 u=300 //Flight velocity in m/s
6 Pi=35 //Inlet pressure in kPa
7 Ti=-40+273 //Inlet temperature in K
8 pr_c=10 //Pressure ratio of compressor
9 T3=1100+273 //Inlet turbine temperature in K
10 m=50 //Mass flow rate of air in kg/s
11 k=1.4 //Adiabatic constant of air
12 Cp=1005 //Specific heat capacity at constant
    pressure of air in J/kg-K
13 R=287 //Specific gas constant in J/kg-K
14
15 //Calculation
16 ai=sqrt(k*R*Ti) //Sound velocity at diffuser in m/s

```



```

17 C1=u //Velocity of air in m/s, Since it is reaction
    force of u
18 T1=Ti+(C1^2/(2*Cp)) //Temperature at inlet of
    compressor in K
19 P1=Pi*((T1/Ti)^(k/(k-1))) //Inlet pressure of
    compressor in kPa
20 P2=pr_c*P1 //Exit pressure of compressor in kPa
21 P3=P2 //Exit pressure of combustion chamber in kPa,
    Since the process takes place at constant
    pressure process
22 T2=T1*(P2/P1)^((k-1)/k) //Exit temperature of
    compressor in K
23 T4=T3-(T2-T1) //Exit temperature of turbine in K
24 P4=P3/((T3/T4)^(k/(k-1))) //Pressure at outlet of
    turbine in kPa
25 Pe=Pi //Exit pressure in kPa, Since exit is at
    ambient conditions
26 pr_n=P4/Pe //Pressure ratio of nozzle
27 Te=T4/((pr_n)^((k-1)/k)) //Exit temperature of
    nozzle in K
28 Cj=sqrt(2*Cp*(T4-Te)) //Jet velocity in m/s
29 sig=u/Cj //Jet speed ratio
30 eff_prop=((2*sig)/(1+sig))*100 //Propulsive
    efficiency of the cycle in %
31
32 //Output
33 printf('(A)Temperature and pressure of gases at
    turbine exit is %3.2f K and %3i kPa\n (B) Velocity
    of gases is %3.2f m/s\n (C) Propulsive efficiency
    of the cycle is %3.2f percent ',T4,P4,Cj,eff_prop
    )

```

Scilab code Exa 6.5 To calculate absolute velocity drag overall and turbine efficiency of jet

```

1  clc
2  clear
3
4  //Input data
5  n=2 //Number of jets
6  D=0.25 //Diameter of turbojet in m
7  P=3000 //Net power at turbojet in W
8  mf_kWh=0.42 //Fuel consumption in kg/kWh
9  CV=49000 //Calorific value in kJ/kg
10 u=300 //Flight velocity in m/s
11 d=0.168 //Density in kg/m^3
12 AFR=53 //Air fuel ratio
13
14 //Calculatioon
15 mf=mf_kWh*P/3600 //Mass flow rate of fuel in kg/s
16 ma=AFR*mf //Mass flow rate of air in kg/s
17 m=ma+mf //Mass flow rate of gas in kg/s
18 Q=m/d //Volume flow rate in m^3/s
19 Cj=(Q*4)/(2*pi*D^2) //Jet velocity in m/s
20 Ca=Cj-u //Absolute Jet velocity in m/s
21 F=((m*Cj)-(ma*u))*10^-3 //Thrust in kN
22 eff=((F*u)/(mf*CV))*100 //Overall efficiency in %
23 eff_prop=((2*u)/(Cj+u))*100 //Propulsive efficiency
    of the cycle in %
24 eff_ther=(eff/eff_prop)*100 //Efficiency of turbine
    in %
25
26 //Output
27 printf('(A) Absolute velocity of jet is %3.3f m/s\n (
    B) Resistance of the plane is %3.4f kN\n (C)
    Overall efficiency is %3.2f percent\n (D)
    Efficiency of turbine is %3.3f percent',Ca,F,eff,
    eff_ther)

```

Scilab code Exa 6.6 To Calculate propulsive and thrust power total fuel consumption and propulsive thermal and overall efficiency

```

1  clc
2  clear
3
4  //Input data
5  u=900*(5/18) //Flight velocity in m/s
6  ma=3000/60 //Mass flow rate of air in kg/s
7  dh=200 //Enthalpy drop of nozzle in kJ/kg
8  eff_n=0.9 //Nozzle efficiency
9  AFR=85 //Air fuel ratio
10 eff_cc=0.95 //Combustion efficiency
11 CV=42000 //Calorific value in kJ/kg
12
13 //Calculation
14 mf=ma/AFR //Mass flow rate of fuel in kg/s
15 m=ma+mf //Mass flow rate of gas in kg/s
16 Cj=sqrt(2*eff_n*dh*10^3) //Jet velocity in m/s
17 sig=u/Cj //Jet speed ratio
18 F=((m*Cj)-(ma*u))*10^-3 //Thrust in kN
19 Pt=F*u //Thrust power in kW
20 Pp=0.5*((m*Cj^2)-(ma*u^2))*10^-3 //Propulsive power
    in kW
21 HS=eff_cc*mf*CV //Heat supplied in kW
22 eff_ther=(Pp/HS)*100 //Efficiency of turbine in %
23 eff_prop=(Pt/Pp)*100 //Propulsive efficiency of the
    cycle in %
24 eff=(Pt/HS)*100 //Overall efficiency in %
25
26 //Output
27 printf(' (A) Propulsive power is %3.2f kW\n (B) Thrust
    power is %3.1f kW\n (C) Propulsive efficiency is
    %3.3f percent\n (D) Thermal efficiency is %3.2f
    percent\n (E) Total fuel consumption is %3.3f kg/s
    \n (F) Overall efficiency is %3.3f percent ',Pp,Pt,
    eff_prop,eff_ther,mf,eff)

```

Scilab code Exa 6.7 To find specific thrust jet velocity TSFC and propulsive thermal and overall efficiency

```

1  clc
2  clear
3
4  //Input data
5  M=0.8 //Mach number
6  CV=42800 //Calorific value in kJ/kg
7  h=10 //Altitude in km
8  F=50 //Thrust in kN
9  ma=45 //Mass flow rate of air in kg/s
10 mf=2.65 //Mass flow rate of fuel in kg/s
11
12 //Calculation
13 m=ma+mf //Mass flow rate of gas in kg/s
14 a=299.6 //Sound velocity in m/s, from gas tables
15 T=233.15 //Inlet temperature in K
16 u=a*M //Flight velocity in m/s
17 Cj=((F*10^3)+(ma*u))/m //Jet velocity in m/s
18 sig=u/Cj //Jet speed ratio
19 Fs=F*10^3/m //Specific thrust in Ns/kg, F in N
20 TSFC=mf*3600/(F*10^3) //Thrust specific fuel
    consumption in kg/N-hr, F in N
21 Pt=F*u //Thrust power in kW
22 Pp=0.5*((m*Cj^2)-(ma*u^2))*10^-3 //Propulsive power
    in kW
23 HS=mf*CV //Heat supplied in kW
24 eff_ther=(Pp/HS)*100 //Efficiency of turbine in %
25 eff_prop=(Pt/Pp)*100 //Propulsive efficiency of the
    cycle in %
26 eff=(Pt/HS)*100 //Overall efficiency in %
27
28 //Output

```

```

29 printf('(A) Specific thrust is %3.2f N/kg\n (B) Thrust
    specific fuel consumption is %3.4f kg/N-hr\n (C)
    Jet velocity is %3.3f m/s\n (D) Thermal efficiency
    is %3.2f percent\n (E) Propulsive efficiency is
    %3.3f percent\n (F) Overall efficiency is %3.2f
    percent ',Fs,TSFC,Cj,eff_ther,eff_prop,eff)

```

Scilab code Exa 6.8 To calculate fuel air and pressure ratios and Mach number of jet

```

1  clc
2  clear
3
4  //Input data
5  Mi=0.8 //Inlet mach number
6  h=10 //Altitude in km
7  To3=1200 //Stagnation temperature before turbine
    inlet in K
8  dTc=175 //Stagnation temperature rise through the
    compressor in K
9  CV=43000 //Calorific value in kJ/kg
10 eff_c=0.75 //Compressor efficiency
11 eff_cc=0.75 //Combustion efficiency
12 eff_t=0.81 //Turbine efficiency
13 eff_m=0.98 //Mechanical transmission efficiency
14 eff_n=0.97 //Nozzle efficiency
15 Is=25 //Specific impulse in sec
16 k=1.4 //Adiabatic constant of air
17 R=287 //Specific gas constant in J/kg-K
18 Cp=1005 //Specific heat capacity at constant
    pressure of air in J/kg-K
19 g=9.81 //Acceleration due to gravity in m/s^2
20
21 //Calculation
22 Ti=223.15 //Inlet temperature in K from gas tables

```

```

23 ai=sqrt(k*R*Ti) //Sound velocity in m/s
24 Toi=(1+((0.5*(k-1)*Mi^2))*Ti //Stagnation
    temperature at diffuser inlet in K
25 To1=Toi //Inlet Stagnation temperature of compressor
    in K, since hoi=h01
26 To2=dTc+To1 //Exit Stagnation temperature of
    compressor in K
27 pr_c=(1+(eff_c*((To2-To1)/To1)))^(k/(k-1)) //
    Compressor pressure ratio
28 f=((Cp*To3)-(Cp*To2))/((eff_cc*CV*10^3)-(Cp*To3)) //
    Fuel-air ratio, calculation mistake in textbook
29 dTt=dTc/(eff_m*(1+f)) //Temperature difference
    across turbine
30 pr_t=1/((1-(dTt/(To3*eff_t)))^(k/(k-1))) //Turbine
    pressure ratio
31 To4=To3-dTc //Exit Stagnation temperature of turbine
    in K
32 u=ai*Mi //Flight velocity in m/s
33 sig=1/(((Is*g)/u)+1) //Jet speed ratio
34 Ce=u/sig //Exit velocity in m/s
35 Cj=Ce //Jet velocity in m/s, Since Cj is due to exit
    velocity
36 Te=To4-(Ce^2/(2*Cp)) //Exit temperature in K
37 Tes=To4-((To4-Te)*eff_n) //Exit temperature in K, (
    At isentropic process)
38 pr_n=(To4/Te)^(k/(k-1)) //Nozzle pressure ratio
39 ae=sqrt(k*R*Te) //Exit Sound velocity in m/s
40 Me=Ce/ae //Exit mach number
41
42 printf('(A)Fuel-air ratio is %3.5f \n (B)Compressor ,
    turbine , nozzle pressure ratio are %3.3f, %3.3f,
    %3.2f respectively\n (C)Mach number at exhaust
    jet is %3.3f',f,pr_c,pr_t,pr_n,Me)

```

Scilab code Exa 6.9 To determine air flow rate thrust power thrust produced specific thrust and specific impulse

```

1  clc
2  clear
3
4  //Input data
5  D=2.5 //Diameter in m
6  u=500*(5/18) //Flight velocity in m/s
7  h=8000 //Altitude in m
8  sig=0.75 //Jet speed ratio
9  g=9.81 //Acceleration due to gravity in m/s^2
10
11 //Calculation
12 d=0.525 //from gas tables
13 A=%pi*D^2*0.25 //Area of flow in m^2
14 Cj=u/sig //Jet velocity in m/s
15 Vf=(u+Cj)/2 //Velocity of flow in m/s
16 ma=d*A*Vf //Mass flow rate of air in kg/s
17 F=ma*(Cj-u)*10^-3 //Thrust in kN
18 P=F*u //Thrust power in kW
19 Fs=F*10^3/ma //Specific thrust in Ns/kg
20 Is=Fs/g //Specific impulse in sec
21
22 //Output
23 printf('(A)Flow rate of air through the propeller is
    %3.3f m/s\n (B)Thrust produced is %3.3f kN\n (C)
    Specific thrust is %3.2f N-s/kg\n (D) Specific
    impulse is %3.3f sec\n (E)Thrust power is %3.1f
    kW',ma,F,Fs,Is,P)

```

Scilab code Exa 6.10 To calculate pressure rise pressured developed by compressor and air standard efficiency of the engine

```

1  clc

```

```

2 clear
3
4 //Input data
5 h=3000 //Altitude in m
6 Pi=0.701 //Inlet pressure in bar
7 Ti=268.65 //Inlet temperature in K
8 u=525*(5/18) //Flight velocity in m/s
9 eff_d=0.875 //Diffuser efficiency
10 eff_c=0.79 //Compressor efficiency
11 C1=90 //Velocity of air at compressor in m/s
12 dTc=230 //Temperature rise through compressor
13 k=1.4 //Adiabatic constant of air
14 Cp=1005 //Specific heat capacity at constant
    pressure of air in J/kg-K
15 R=287 //Specific gas constant in J/kg-K
16
17 //Calculation
18 ai=sqrt(k*R*Ti) //Sound velocity in m/s
19 Mi=u/ai //Inlet mach number
20 Toi=(1+((0.5*(k-1)*Mi^2)))*Ti //Stagnation
    temperature at diffuser inlet in K
21 To1=Toi //Inlet Stagnation temperature of compressor
    in K, since hoi=ho1
22 T1=To1-(C1^2/(2*Cp)) //Temperature at inlet of
    compressor in K
23 P1=Pi*((1+(eff_d*((T1/Ti)-1)))^(k/(k-1))) //Inlet
    pressure of compressor in bar
24 dPc=P1-Pi //Pressure rise through inlet diffuser in
    bar
25 pr_c=((eff_c*dTc)/To1+1)^(k/(k-1)) //Pressure
    ratio of compressor
26 P=Cp*(dTc) //Power required by the compressor in kW
    /(kg/s)
27 eff=1-(1/pr_c)^((k-1)/k) //Air standard efficiency
28
29 //Output
30 printf('(A) Pressure rise through diffuser is %3.4f
    bar\n (B) Pressure developed by compressure is %3

```



```
.4 f bar\n (C) Air standard efficiency of the
engine is %3.4 f', dPc, P1, eff)
```

Scilab code Exa 6.11 To estimate diameter power output AFR and absolute velocity of the jet

```
1  clc
2  clear
3
4  //Input data
5  h=9500 //Altitude in m
6  u=800*(5/18) //Flight velocity in m/s
7  eff_prop=0.55 //Propulsive efficiency of the cycle
8  eff_o=0.17 //Overall efficiency
9  F=6100 //Thrust in N
10 d=0.17 //Density in kg/m^3
11 CV=46000 //Calorific value in kJ/kg
12
13 //Calculation
14 mf=(F*u)/(eff_o*CV*10^3) //Mass flow rate of fuel in
    kg/s
15 Cj=((2*u)/(eff_prop))-u //Jet velocity in m/s, wrong
    calculation in textbook
16 Ca=Cj-u //Absolute Jet velocity in m/s
17 ma=(F-(mf*Cj))/(Ca) //Mass flow rate of air in kg/s
18 m=ma+mf //Mass flow rate of gas in kg/s
19 f=ma/mf //Air fuel ratio
20 Q=m/d //Volume flow rate in m^3/s
21 Dj=sqrt((4*Q)/(pi*Cj))*10^3 //Diameter of jet in mm
    , Cj value wrong in textbook
22 P=((F*u)/eff_prop)*10^-3 //Power output of engine in
    kW
23
24 //Output
25 printf('(A) Diamter of the jet is %3.1 f mm\n (B) Power
```

```

    output is %3.1f kW\n (C) Air-fuel ratio is %3.3f\n
    n (D) Absolute velocity of the jet is %3i m/s\n',
    Dj,P,f,Ca)

```

Scilab code Exa 6.12 To determine jet velocity thrust specific thrust TSFC thrust power and efficiencies

```

1  clc
2  clear
3
4  //Input data
5  u=960*(5/18) //Flight velocity in m/s
6  ma=40 //Mass flow rate of air in kg/s
7  AFR=50 //Air fuel ratio
8  sig=0.5 //Jet speed ratio , for maximum thrust power
9  CV=43000 //Calorific value in kJ/kg
10
11 //Calculation
12 mf=ma/AFR //Mass flow rate of fuel in kg/s
13 m=ma+mf //Mass flow rate of gas in kg/s
14 Cj=u/sig //Jet velocity in m/s
15 F=((m*Cj)-(ma*u))*10^-3 //Thrust in kN
16 Fs=F*10^3/m //Specific thrust in Ns/kg, F in N
17 Pt=F*u //Thrust power in kW
18 eff_prop=((2*sig)/(1+sig))*100 //Propulsive
    efficiency of the cycle in %
19 eff_ther=((0.5*m*(Cj^2-u^2))/(mf*CV*10^3))*100 //
    Efficiency of turbine in %
20 eff=(eff_prop/100)*(eff_ther/100)*100 //Overall
    efficiency in %
21 TSFC=mf*3600/(F*10^3) //Thrust specific fuel
    consumption in kg/Nhr
22
23 //Output
24 printf(' (A) Jet velocity is %3.1f m/s\n (B) Thrust is

```

```

%3.3f kN\n (C) Specific thrust is %3.2f N-s/kg\n (
D) Thrust power is %3.2f kW\n (E) propulsive,
thermal and overall efficiency is %3.2f, %3.2f
and %3.3f respectively\n (F) Thrust specific fuel
consumption is %3.4f kg/Nhr',Cj,F,Fs,Pt,eff_prop,
eff_ther,eff,TSFC)

```

Scilab code Exa 6.13 To jet velocity fuel rate TSFC propulsive power and efficiencies

```

1  clc
2  clear
3
4  //Input data
5  u=960*(5/18) //Flight velocity in m/s
6  ma=54.5 //Mass flow rate of air in kg/s
7  dh=200 //Change of enthalpy for nozzle in kJ/kg
8  Cv=0.97 //Velocity coefficient
9  AFR=75 //Air fuel ratio
10 eff_cc=0.93 //Combustion efficiency
11 CV=45000 //Calorific value in kJ/kg
12
13 //Calculation
14 mf=ma/AFR //Mass flow rate of fuel in kg/s
15 Cj=Cv*sqrt(2*dh*10^3) //Jet velocity in m/s
16 F=ma*(Cj-u) //Thrust in kN
17 TSFC=mf*3600/(F) //Thrust specific fuel consumption
    in kg/Nhr
18 HS=mf*eff_cc*CV //Heat supplied in kJ/s
19 Pp=0.5*ma*(Cj^2-u^2)*10^-3 //Propulsive power in kW
20 Pt=F*u //Thrust power in kW
21 eff_p=Pt/(Pp*10^3) //Propulsive efficiency of the
    cycle
22 eff_t=Pp/HS //Efficiency of turbine
23 eff_o=Pt*10^-3/HS //Overall efficiency

```

```

24
25 //Output
26 printf('(A)Exit velocity of the jet is %3.2f m/s\n (
    B)Fuel rate is %3.4f kg/s\n (C)Thrust specific
    fuel consumption is %3.5f kg/Nhr\n (D)Thermal
    efficiency is %3.3f\n (E)Propulsive power is %3.2
    f kW\n (F)Propulsive efficiency is %3.4f\n (G)
    Overall efficiency is %3.5f',Cj,mf,TSFC,eff_t,Pp,
    eff_p,eff_o)

```

Scilab code Exa 6.14 To find absolute jet velocity volume of air compressed diameter power output and air fuel ratio of the jet

```

1  clc
2  clear
3
4  //Input data
5  u=750*(5/18) //Flight velocity in m/s
6  h=10000 //Altitude in m
7  eff_p=0.5 //Propulsive efficiency of the cycle
8  eff_o=0.16 //Overall efficiency
9  d=0.173 //Density in kg/m^3
10 F=6250 //Thrust in N
11 CV=45000 //Calorific value in kJ/kg
12
13 //Calculation
14 sig=eff_p/(2-eff_p) //Jet speed ratio
15 Cj=u/sig //Jet velocity in m/s
16 Ca=Cj-u //Absolute Jet velocity in m/s
17 ma=F/Ca //Mass flow rate of air in kg/s
18 Q=ma*60/d //Volume flow rate in m^3/min
19 A=Q/(Cj*60) //Area of flow in m^2
20 D=sqrt((4*A)/(%pi))*10^3 //Diameter in mm
21 Pt=F*u //Thrust power in W
22 Pp=(Pt/eff_p)*10^-3 //Propulsive power in kW

```

```

23 eff_t=eff_o/eff_p //Efficiency of turbine
24 HS=Pp/eff_t //Heat supplied in kJ/s
25 mf=HS/CV //Mass flow rate of fuel in kg/s
26 AFR=ma/mf //Air fuel ratio
27
28 //Output
29 printf('(A) Absolute velocity of the jet is %3.2f m/s
        \n (B) Volume of air compressed per minute is %3.2
        f m^3/min\n (C) Diameter of the jet is %3i mm\n (D
        ) Power unit of the unit is %3.3f kW\n (E) Air fuel
        ratio is %3.1f ',Ca,Q,D,Pp,AFR)

```

Scilab code Exa 6.15 To estimate AFR nozzle thrust propeller thrust and mass flow rate

```

1  clc
2  clear
3
4  //Input data
5  P1=0.56 //Inlet pressure of compressor in bar
6  T1=260 //Temperature at inlet of compressor in K
7  pr_c=6 //Pressure ratio of compressor
8  eff_c=0.85 //Compressor efficiency
9  u=360*(5/18) //Flight velocity in m/s
10 D=3 //Propeller diameter in m
11 eff_p=0.8 //Efficiency of propeller
12 eff_g=0.95 //Gear reduction efficiency
13 pr_t=5 //Expansion ratio
14 eff_t=0.88 //Turbine efficiency
15 T3=1100 //temperature at turbine inlet in K
16 eff_n=0.9 //Nozzle efficiency
17 Cp=1005 //Specific heat capacity at constant
        pressure of air in J/kg-K
18 CV=40000 //Calorific value in kJ/kg
19 k=1.4 //Adiabatic constant of air

```

```

20 R=287 // Specific gas constant in J/kg-K
21
22 // Calculation
23 P2=pr_c*P1 // Exit pressure of compressor in bar
24 T2s=T1*(pr_c)^((k-1)/k) // Exit temperature of
    compressor at isentropic proces in K
25 T2=T1+((T2s-T1)/eff_c) // Exit temperature of
    compressor in K
26 Wc=Cp*(T2-T1)*10^-3 // Power input to compressor in
    kJ/kg of air
27 C1=u // Air velocity in m/s, since C1 is resultant of
    u
28 C=C1/eff_p // Average velocity in m/s
29 C2=(2*C)-C1 // Exit velocity from compressor in m/s
30 Ap=0.25*pi*D^2 // Area of propeller passage in m^2
31 Q=Ap*C // Quantity of air inducted in m^3/s
32 mf=((T3-T2)*Cp)/((CV*10^3)-(Cp*T3)) // Mass flow rate
    of fuel in kg/s
33 f=mf // Fuel consumption in kg/kg of air
34 AFR=1/mf // Air fuel ratio
35 P3=P2 // Exit pressure of combustion chamber in bar,
    Since process is at constant pressure
36 P4=P3/pr_t // Exit pressure of turbine in bar
37 T4s=T3/((pr_t)^((k-1)/k)) // Exit temperature of
    turbine at isentropic proces in K, wrong
    calculation
38 T4=T3-(eff_t*(T3-T4s)) // Exit temperature of turbine
    in K
39 Po=(1+f)*Cp*(T3-T4)*10^-3 // Power output per kg of
    air in kJ/kg of air
40 Pa=Po-Wc // Power available for propeller in kJ/kg of
    air
41 Pe=P1 // Exit pressure in bar, Since exit is at
    ambient conditions
42 Tes=T4/((P4/Pe)^((k-1)/k)) // Exit temperature of
    nozzle at isentropic proces in K
43 Cj=sqrt(2*Cp*eff_n*(T4-Tes)) // Jet velocity in m/s
44 Fs=((1+f)*Cj)-u // Specific thrust in Ns/kg, F in N

```

```

45 Pp=((0.5*P1*10^5*Q*(C2^2-C1^2))/(R*T1))*10^-3 //
    Propulsive power by propeller in kJ/s
46 Ps=Pp/eff_g //Power supplied by the turbine in kW
47 ma=Ps/Pa //Air flow rate in kg/s
48 Fj=ma*Cj*10^-3 //Jet thrust in kN, calculation
    mistake
49 Fp=(Pp*eff_p)/u //Thrust produced by propeller in kN
50
51 //Output
52 printf('(A) Air fuel ratio is %3.2f\n (B) Thrust
    produced by the nozzle is %3.3f kN\n (C) Thrust by
    the propeller is %3.3f kN\n (D) mass flow rate
    through the compressor is %3.2f kg/s ', AFR, Fj, Fp,
    ma)

```

Scilab code Exa 6.16 To find various parameters of ramjet engine through out its operation

```

1  clc
2  clear
3
4  //Input data
5  M1=1.5 //Mach number
6  h=6500 //Altitude in m
7  D=0.5 //Diameter in m
8  To4=1600 //Stagnation temperature at nozzle inlet in
    K
9  CV=40000 //Calorific value in kJ/kg
10 k=1.4 //Adiabatic constant of air
11 R=287 //Specific gas constant in J/kg-K
12 eff_d=0.9 //Diffuser efficiency
13 eff_cc=0.98 //Combustion efficiency
14 eff_n=0.96 //Nozzle efficiency
15 pr_1=0.02 //Pressure ratio i.e. Stagnation pressure
    loss to Exit presure of compressor

```

```

16 Cp=1005 //Specific heat capacity at constant
    pressure of air in J/kg-K
17
18 //Calculation
19 P1=0.44 //Inlet pressure of compressor in bar
20 T1=245.9 //Temperature at inlet of compressor in K
21 a1=314.5 //Sound velocity at compressor in m/s
22 d1=0.624 //Density at compressor in kg/m^3
23 A1=0.25*pi*D^2 //Area at diffuser inlet in m^2
24 u1=M1*a1 //Flight velocity in m/s
25 ma=d1*A1*u1 //Mass flow rate of air in kg/s
26 To2=T1*(1+(((k-1)/2)*M1^2)) //Stagnation temperature
    at compressor inlet in K
27 To1=To2 //Stagnation temperature at compressor
    outlet in K, (It is in case of diffuser)
28 pr_d=((eff_d*(((k-1)/2)*M1^2))+1)^(k/(k-1)) //
    Pressure ratio of diffuser
29 P2=pr_d*P1 //Exit pressure of compressor in bar
30 Po2=P2 //Stagnation pressure at exit of compressor
    in bar
31 Po3=(Po2-(pr_l*Po2)) //Stagnation pressure at exit
    of combustion chamber in bar
32 Poe=P1 //Exit stagnation pressure in kPa, Since exit
    is at ambient conditions
33 pr_n=Po3/Poe //Pressure ratio of nozzle
34 p1=1/pr_n //Inverse of pr_n to find in gas tables
35 M4s=1.41 //Mach number at turbine exit from gas
    tables
36 T4s=To4/(1+((0.5*(k-1)*M4s^2))) //Exit temperature
    of turbine at isentropic process in K
37 To3=To4 //Stagnation temperature at inlet turbine in
    K,
38 T4=To3-(eff_n*(To3-T4s)) //Exit temperature of
    turbine in K
39 C4=sqrt(2*Cp*(To4-T4)) //Flight velocity of air in m
    /s
40 a4=sqrt(k*R*T4) //Sound velocity in m/s
41 Me=C4/a4 //Nozzle jet mach number

```



```

42 f=(Cp*(To3-To2))/(eff_cc*CV*10^3) //Fuel air ratio
43 mf=ma*f //Mass flow rate of fuel in kg/s
44 m=ma+mf //Mass flow rate of gas in kg/s
45 eff_i=(1/(1+((2/(k-1))*(1/M1^2))))*100 //Efficiency
    of the ideal cycle in %
46 sig=u1/C4 //Jet speed ratio
47 eff_p=((2*sig)/(1+sig)) //Propulsive efficiency in %
48 F=((m*C4)-(ma*u1))*10^-3 //Thrust in kN
49
50 //Output
51 printf('(A)Efficiency of the ideal cycle is %3i
    percent\n (B)Flight speed is %3.3f m/s\n (C)Air
    flow rate is %3.3f kg/s\n (D)Diffuser pressure
    ratio is %3.4f\n (E)Fuel air ratio is %3.5f\n (F)
    Nozzle pressure ratio is %3.2f\n (G)Nozzle jet
    mach number is %3.3f\n (H)Propulsive efficiency
    is %3.4f percent\n (I)Thrust is %3.3f kN',eff_i,
    C4,ma,pr_d,f,pr_n,Me,eff_p,F)

```

Scilab code Exa 6.17 To find power input power output Fuel air ratio Exit Mach number thrust and thrust power developed in the jet

```

1 clc
2 clear
3
4 //Input data
5 ma=18 //Mass flow rate of air in kg/s
6 Mi=0.6 //Inlet mach number
7 h=4600 //Altitude in m
8 Pi=55 //Inlet pressure in
9 Ti=-20+273 //Inlet temperature in K
10 eff_d=0.9 //Diffuser efficiency
11 pr_d=5 //Diffuser pressure ratio
12 T3=1000+273 //Inlet turbine temperature in K
13 Pe=60 //Exit pressure in kPa

```

```

14 eff_c=0.81 //Compressor efficiency
15 eff_t=0.85 //Turbine efficiency
16 eff_n=0.915 //Nozzle efficiency
17 CV=46520 //Calorific value in kJ/kg
18 Cp=1005 //Specific heat capacity at constant
    pressure of air in J/kg-K
19 k=1.4 //Adiabatic constant
20 R=287 //Specific gas constant in J/kg-K
21
22 //Calculation
23 Ci=Mi*sqrt(k*R*Ti) //Velocity of air in m/s,
24 u=Ci //Flight velocity in m/s, Since it is reaction
    force of Ci
25 T1=Ti+(Ci^2/(2*Cp)) //Temperature at inlet of
    compressor in K
26 P1s=Pi*(T1/Ti)^(k/(k-1)) //Inlet pressure of
    compressor at isentropic process in kPa
27 P1=Pi+(eff_d*(P1s-Pi)) //Inlet pressure of
    compressor in kPa
28 P2=P1*pr_d //Outlet pressure of compressor in kPa
29 T2s=T1*(pr_d)^((k-1)/k) //Outlet temperature of
    compressor at isentropic process in K
30 T2=T1+((T2s-T1)/eff_c) //Exit temperature of
    compressor in K
31 Wc=Cp*(T2-T1)*10^-3 //Workdone on compressor in kJ/
    kg of air
32 Pc=ma*Wc //Power input in kW
33 Pt=Pc //Power out put of turbine for isentropic
    process in kW
34 f=(T3-T2)/((CV*10^3/Cp)-T3) //Fuel air ratio
35 Wt=Wc //Workdone by the turbine in kJ/kg of air
36 T4=T3-(Wt*10^3/Cp) //Exit temperature of turbine in
    K
37 T4s=T3-((T3-T4)/eff_t) //Exit temperature of turbine
    at isentropic process in K
38 P3=P2 //Exit pressure of combustion chamber in kPa,
    Since the process takes place at constant
    pressure process

```

```

39 P4=P3*(T4s/T3)^(k/(k-1)) //Pressure at outlet of
    turbine in kPa
40 pr_n=P4/Pe //Pressure ratio of nozzle
41 Tes=T4/(pr_n)^((k-1)/k) //Exit temperature of nozzle
    at isentropic process in K
42 Te=T4-(eff_n*(T4-Tes)) //Exit temperature of nozzle
    in K
43 Cj=sqrt(2*Cp*(T4-Te)) //Jet velocity in m/s
44 Ce=Cj //Flight velocity in m/s
45 ae=sqrt(k*R*Te) //Sound velocity at nozzle in m/s
46 Me=Ce/ae //Nozzle jet mach number
47 F=ma*(((1+f)*Cj)-u) //Thrust in N
48 P=F*u*10^-3 //Thrust power in kW
49
50 //Output
51 printf('(A)Power input of compressor is %3.2f kW\n (
    B)Power output of turbine is %3.2f kW\n (C)F/A
    ratio on mass basis is %3.4f\n (D)Exit mach
    number is %3.3f\n (E)Thrust is %3.2f N\n (F)
    Thrust power is %3.1f kW',Pc,Pt,f,Me,F,P)

```

Chapter 7

Rocket Propulsion

Scilab code Exa 7.1 To find thrust of the motor of a rocket

```
1  clc
2  clear
3
4  //input data
5  mp=12 //flow rate in kg/s
6  Ae=335*10^-4 //exit area in m^2
7  Ce=2000 //exhaust velocity in m/s
8  h=10 //altitude in km
9  Pe=1*10^5 //exhaust pressure in Pa
10 P0=1*10^5 //p0=atmospheric pressure in Pa at h=0.
11 P10=0.25*10^5 //atmospheric pressure in Pa using gas
    tables
12
13 //calculations
14 Fs=mp*Ce*10^-3 //thrust of motor at sea level since
    pe=p0 in kN
15 F10=((mp*Ce) + Ae*(Pe-P10))*10^-3 //thrust of motor
    at altitude of 10km in kN
16
17 //output
18 printf('(A)thrust of motor at sea level is %3i kN ('
```

upwards) \n (B) thrust of motor at an altitude 10
 km is %3.4f kN',Fs,F10)

Scilab code Exa 7.2 To calculate area ratio thrust characteristic velocity
 thrust coefficient exit velocity and possible maximum velocity

```

1  clc
2  clear
3
4  //input data
5  P0=38*10^5 //combustion chamber pressure in Pa
6  T0=3500 //combustion chamber temperature in K
7  ma=41.67 //oxidizer flow rate in kg/s
8  MR=5 //mixture ratio
9  k=1.3 //adiabatic constant
10 R=287 //gas constant in J/kg-K
11 Pamb=0.0582*10^5 //ambient pressure in Pa
12 Pe=Pamb //exhaust pressure at sea level in Pa
13
14 //calculation
15 mf=ma/MR //mass flow of fuel in kg/s
16 mp=mf+ma //propellant mass flow in kg/s
17 Cp=(k*R)/(k-1) //specific heat at constant pressure
    in J/kg-k
18 p=P0/Pe //ratio of pressures at combustion chamber
    and exhaust
19 Me=(((p^((k-1)/k))-1)*2)/(k-1)^0.5 //Mach number
20 t=1/(1+(((k-1)/2)*Me^2)) //ratio of exhaust
    temperature to combustion temperature
21 Te=t*T0 //exhaust temperature in Kelvin
22 a=(1/Me)*(((2/(k+1))+(((k-1)/(k+1))*Me^2))^((k+1)
    /(2*(k-1)))) //ratio of areas at exit section and
    throat section of the nozzle
23 Ce=(k*R*Te)^0.5*Me //exit velocity in the exhaust in
    m/s

```

```

24 Cj=Ce //average effective jet velocity in m/s, since
    Pe=Pamb
25 P1=P0*(2/(k+1))^(k/(k-1)) //pressure at throat
    section in Pa
26 T1=T0*(2/(k+1)) //temperature at throat section in K
27 d1=P1/(R*T1) //density of fuel at throat section in
    kg/m^3
28 C1=(k*R*T1)^0.5 //velocity at throat section in m/s
29 A1=(mp/(d1*C1))*10^4 //nozzle throat area in cm^2
30 Ae=a*A1 //exit area in cm^2
31 F=(mp*Ce)*10^-3 //thrust in kN
32 Cmax1=(2*Cp*T0)^0.5 //maximum possible velocity in m
    /s
33 Cf=(F*10^3)/(P0*A1*10^-4) //thrust coefficient , F in
    kN and A1 in m^2
34 Cch1=Cj/Cf //characteristic velocity in m/s
35
36 //output
37 printf('(A)nozzle throat area is %3.2f cm^2 \n (B)
    thrust is %3.1f kN \n (C)thrust coefficient is %3
    .2f \n (D)characteristic velocity is %3i m/s \n (
    E)exit velocity in exhaust is %3i m/s\n (F)
    maximum possible exhaust velocity is %3i m/s\n',
    A1 ,F ,Cf ,Cch1 ,Ce ,Cmax1)

```

Scilab code Exa 7.3 To estimate thrust per unit area and specific impulse

```

1 clc
2 clear
3
4 //input data
5 a=3 //exit area to throat area ratio
6 T0=2973 //combustion chamber temperature in K
7 P0=20*10^5 //combustion chamber pressure in Pa
8 k=1.3 //adiabatic constant

```

```

9 R=248 //gas constant in J/kg-K
10 Pamb=1*10^5 //ambient pressure in Pa
11 Me=2.52 //mach number for k=1.3 and a=3 using gas
    tables
12 g=9.81 //acceleration due to gravity in m/s^2
13
14 //calculation
15 p=1/((1+(((k-1)/2)*Me^2))^(k/(k-1))) //ratio of
    pressures at exhaust and combustion chamber
16 Pe=p*P0 //exhaust pressure in Pa
17 t=1/(1+(((k-1)/2)*Me^2)) //ratio of exhaust
    temperature to combustion temperature
18 Te=t*T0 //exhaust temperature in Kelvin
19 Ce=(k*R*Te)^0.5*Me //exit velocity in the exhaust in
    m/s
20 M=(Pe*Ce)/(R*Te) //propellant mass flow per unit
    area of exit in kg/m^2-s
21 Fa=((M*Ce)+(Pe-Pamb))*10^-3 //thrust per unit area
    of exit in N/m^2
22 Is=(Fa*10^3)/(M*g) //specific impulse in sec
23
24 //output
25 printf('(A)thrust per unit area of exit is %3.2f kN/
    m^2 \n (B)specific impulse is %3.2f sec',Fa,Is)

```

Scilab code Exa 7.4 To find specific impulse specific propellant consumption effective and absolute jet velocity of rocket

```

1 clc
2 clear
3
4 //input data
5 mp=5 //propellent flow rate in kg/s (missing data)
6 de=0.10 //nozzle exit diameter in m
7 Pe=1.02*10^5 //nozzle exit pressure in Pa

```

```

8 Pamb=1.013*10^5 //ambient pressure in Pa
9 P0=20 //thrust chamber pressure in Pa
10 F=7000 //thrust in N
11 u=1000 //rocket speed in m/s
12 g=9.81 //acceleration due to gravity in m/s^2
13
14 //calculation
15 Cj=F/mp //effective jet velocity in m/s
16 Ca=Cj-u //absolute jet velocity in m/s
17 wp=mp*g //weight flow rate of propellant in N/s
18 Is=F/(wp) //specific impulse in sec
19 SPC=1/Is //specific propellant consumption in sec^-1
20
21 //output
22 printf('(A)effective jet velocity is %3i m/s \n (B)
    specific impulse is %3.2f sec \n (C)specific
    propellant consumption is %3.3f s^-1 \n (D)
    absolute jet velocity is %3i m/s ',Cj,Is,SPC,Ca)

```

Scilab code Exa 7.5 To find propulsive efficiency thrust and thrust power of rocket

```

1 clc
2 clear
3
4 //input data
5 Cj=2700 //average effective jet velocity in m/s
6 u=1350 //forward flight velocity in m/s
7 mp=78.6 //propellant mass flow in kg/s
8
9 //calculation
10 s=u/Cj //effective jet speed ratio
11 np=(2*s)/(1+s^2) //propulsive efficiency
12 F=Cj*mp*10^-3 //thrust in kN
13 Pt=F*u*10^-3 //Thrust power in MW, F in N

```



```

14
15 //output
16 printf('(A) thrust is %3.2f kN \n (B) Thrust power is
    %3.3f MW \n (C) propulsive efficiency is %3.1f',F,
    Pt,np)

```

Scilab code Exa 7.6 To find velocity and maximum height that rocket will reach

```

1  clc
2  clear
3
4  //input data
5  mi=15000 //mass of the rocket in kg
6  mp=125 //propellant mass flow in kg/s
7  Cj=2000 //velocity of gases coming out in m/s
8  t=70 //time interval in sec
9  t0=0 //lower limit in integration in sec
10 t1=70 //upper limit in integration in sec
11 g=9.81 //acceleration due to gravity in m/s^2
12
13 //calculation
14 u=(-Cj*(log(1-((mp*t)/mi))))-(g*t) //velocity
    attained in 70 sec in m/s
15 h1=(integrate('((-2000*(log(1-((125*t)/15000))))-(g*
    t))', 't', t0, t1))*10^-3 //distance travelled
    through 70 sec obtained by integrating u w.r.t
    time with intervals 0 to 70 in km
16 h2=(u^2/(2*g))*10^-3 //distance reached after fuel
    last i.e. after 70 sec due to kinetic energy by
    using KE=PE in km
17 h=h1+h2 //maximum height the rocket will reach in km
18
19 //output
20 printf('(A) velocity attained in %i sec is %3.2f m/s\

```

n (B)maximum height the rocket will reach is %3.3
f km',t,u,h)

Scilab code Exa 7.7 To determine thrust coefficient propellant weight flow coefficient SPC and characteristic velocity of rocket

```
1  clc
2  clear
3
4  //input data
5  A1=18*10^-4 //throat area in m^2
6  P0=25*10^5 //combustion chamber pressure in Pa
7  Is=127.42 //specific impulse in sec
8  wp=44.145 //weight flow rate of propellant in N/s
9  g=9.81 //acceleration due to kravity in m/s^2
10
11 //calculation
12 F=Is*wp //thrust in N
13 mp=wp/g //propellant mass flow in kg/s
14 Cj=F/mp //average effective jet velocity in m/s
15 Cf=F/(P0*A1) //thrust coefficient
16 Cw=wp/(P0*A1)/10^-3 //propellant weight flow
    coefficient *10^-3
17 SPC=(wp/F)/10^-3 //specific propellant consumption
    in sec^-1 *10^-3
18 Cch1=Cj/Cf //characteristic velocity in m/s
19
20 //output
21 printf('(A)thrust coefficient is %3.2f \n (B)
    propellant weight flow coefficient is %3.2f*10^-3
    \n (C)specific propellant consumption is %3.2f
    *10^-3 s^-1 \n (D)characteristic velocity is %3.0
    f m/s ',Cf,Cw,SPC,Cch1)
```

Scilab code Exa 7.8 To find various parameters of rocket projectile during its operation

```

1  clc
2  clear
3
4  //input data
5  m1=200 //internal mass in kg
6  m2=130 //mass after rocket operation in kg
7  m3=110 //payload,non-propulsive structure, etc in kg
8  tp=3 //rocket operation duration in sec
9  Is=240 //specific impulse in sec
10 g=9.81 //acceleration due to gravity in m/s^2
11
12 //calculation
13 MR=m2/m1 //mass ratio
14 Mp=m1-m2 //mass of propellant in kg
15 mp=Mp/tp //propellant flow rate in kg/s
16 wp=mp*g //weight flow rate of propellant in N/s
17 IMF=(m2-m3)/(m1-m3) //initial mass fraction
18 PMF=1-IMF //propellant mass fraction
19 F=Is*wp //thrust in N
20 TWRi=F/(m1*g) //initial thrust to weight ratio
21 TWRf=F/(m2*g) //final thrust to weight ratio
22 av=F/m2 //Maximum acceleration of the vehicle in m/
    s^2
23 Cj=Is*g //effective exhaust velocity in m/s
24 It=Is*Mp*g*10^-3 //total impulse in kN-s, units of
    the answer given in the book is wrong
25 IWR=(It*10^3)/((m1-m3)*g) //impulse to weight ratio,
    It in N-s
26
27 //output
28 printf('(A)mass ratio is %3.2f \n (B)propellant mass

```

fraction is %3.3f \n (C) propellant flow rate is %3.1f kg/s \n (D) thrust is %3.1f N \n (E) thrust to weight ratio is %3.2f (initial) and %3.2f (final) \n (F) acceleration of the vehicle is %3.2f m/s² \n (G) effective exhaust velocity is %3.1f m/s \n (H) total impulse is %3.3f kN-s \n (I) impulse to weight ratio is %3.2f', MR, PMF, mp, F, TWRi, TWRf, av, Cj, It, IWR)

Scilab code Exa 7.9 To propulsive power engine output and efficiencies

```

1  clc
2  clear
3
4  //input data
5  u=2800 //rocket speed in m/s
6  Cj=1400 //effective exhaust velocity in m/s
7  mp=5 //propellant flow rate in kg/s
8  q=6500 //heat of propellant per kg of propellant
      mixture in kJ/kg
9
10 //calculation
11 s=u/Cj //effective jet speed ratio
12 np=(2*s)/(1+s^2) //propulsive efficiency
13 F=Cj*mp*10^-3 //thrust in kN
14 Pt=F*10^3*u*10^-6 //Thrust power in MW, F in N
15 Pe=Pt/np //engine output in MW
16 nth=Pe*10^3/(mp*q) //thermal efficiency, Pe in kW
17 no=np*nth //overall efficiency
18
19 //output
20 printf('(A) propulsive efficiency is %3.1f \n (B)
      propulsive power is %3.1f MW \n (C) engine output is
      %3.1f MW \n (D) thermal efficiency is %3.4f \n (E)
      overall efficiency is %3.3f', np, Pt, Pe, nth, no)

```

Scilab code Exa 7.10 To find thrust specific impulse and efficiencies

```
1  clc
2  clear
3
4  //input data
5  Cj=1250 //effective exhaust velocity in m/s
6  s=0.8 //effective jet speed ratio i.e. flight to jet
    speed ratio
7  ma=3.5 //oxidizer flow rate in kg/s
8  mf=1 //fuel flow rate in kg/s
9  g=9.81 //acceleration due to gravity in m/s^2
10 q=2500*10^3 //heat of propellant per kg of
    propellant mixture in J/kg
11
12 //calculation
13 u=s*Cj //flight velocity in m/s
14 mp=ma+mf //propellant mass flow in kg/s
15 F=Cj*mp*10^-3 //thrust in kN
16 wp=mp*g //weight flow rate of propellant in N/s
17 Is=(F*10^3)/(wp) //specific impulse in sec,F in N
18 np=(2*s)/(1+s^2) //propulsive efficiency
19 nth=0.5*mp*((Cj^2+u^2)/(mp*q)) //thermal efficiency
20 no=np*nth //overall efficiency
21
22 //output
23 printf('(A) thrust is %3.3f kN\n (B) specific impulse
    is %3.2f sec\n (C) propulsive efficiency is %3.4f
    \n (D) thermal efficiency is %3.4f \n (E) overall
    efficiency is %3.1f',F,Is,np,nth,no)
```

Scilab code Exa 7.11 To find specific impulse SPC effective and actual jet velocity and efficiencies

```

1  clc
2  clear
3
4  //input data
5  mp=193 //propellant flow rate in kg/s
6  P1=27*10^5 //pressure at throat section in Pa
7  T1=3000 //temperature at throat section in K
8  de=0.6 //nozzle exit diameter in m
9  Pe=1.1*10^5 //exhaust pressure in Pa
10 Pamb=1.013*10^5 //ambient pressure in Pa
11 F=380*10^3 //thrust of motor in N
12 u=694.44 //flight velocity in m/s
13 g=9.81 //acceleration due to gravity in m/s^2
14 q=6500*10^3 //heat of propellant per kg of
    propellant mixture in J/kg
15
16 //calculation
17 Ae=(%pi*0.6^2)/4 //exit area in m^2
18 Cj=F/mp //average effective jet velocity in m/s
19 Ce=(F-((Pe-Pamb)*Ae))/mp //exhaust velocity in m/s,
    wrong answer in textbook
20 wp=mp*g //weight flow rate of propellant in N/s
21 Is=(F)/(wp) //specific impulse in sec
22 SPC=(wp/F)/10^-3 //specific propellant consumption
    in sec^-1 *10^-3
23 Pt=F*u*10^-6 //Thrust power in MW
24 Pl=(0.5*mp*((Cj-u)^2))*10^-6 //Power loss in exhaust
    in MW
25 Pe=Pt+Pl //engine output in MW
26 np=Pt/Pe //propulsive efficiency
27 nth=Pe*10^3/(mp*q*10^-3) //thermal efficiency and Pe
    ,q in kW
28 no=np*nth //overall efficiency
29
30 //output

```

```

31 printf('(A) effective jet velocity is %3.4f m/s\n (B)
    Actual jet velocity is %3.4f m/s\n (C) specific
    impulse is %3.1f sec\n (D) specific propellant
    consumption is %3.4f*10^-3 sec^-1\n (E) propulsive
    efficiency is %3.5f \n (D) thermal efficiency is
    %3.3f \n (E) overall efficiency is %3.5f',Cj,Ce,Is
    ,SPC,np,nth,no)

```

Scilab code Exa 7.12 To find propellant flow rate thrust developed and height attained during powered and coasting flights

```

1  clc
2  clear
3
4  //input data
5  m1=3600 //internal mass in kg
6  Cj=2070 //average effective jet velocity in m/s
7  tp=80 //rocket operation duration in sec
8  g=9.81 //acceleration due to gravity in m/s^2
9
10 //calculation
11 up=2*Cj //flight velocity in m/s
12 MR=1/exp((up+(g*tp))/Cj) //mass ratio
13 m2=MR*m1 //mass after rocket operation in kg
14 PMF=1-MR //propellant mass fraction
15 Mp=m1-m2 //mass of propellant in kg
16 mp=Mp/tp //propellant flow rate in kg/s
17 F=Cj*mp*10^-3 //thrust in kN
18 Zp=((1+((1-(1/PMF))*log(1/MR)))*Cj*tp)-(0.5*g*tp^2)
    )*10^-3 //powered altitude gain in km
19 Zc=((0.5*up^2)/g)*10^-3 //coasting altitude gain in
    km
20 Z=Zp+Zc //maximum altitude in km
21
22 //output

```

```

23 printf('(A)flow rate of propellant is %3.2f kg/s\n (
    B)thrust developed is %3.3f kN\n (C) altitude
    gains during powered and coasting flights are %3
    .3f km and %3.3f km respectively ',mp,F,Zp,Zc)

```

Scilab code Exa 7.13 To find effective jet velocity mass ratio and propellant mass fraction maximum slight speed Altitude gain during powered and coasting flights

```

1  clc
2  clear
3
4  //input data
5  s=0.2105 //effective jet speed ratio
6  Is=203.88 //specific impulse in sec
7  tp=8 //rocket operation duration i.e. burn out time
    in sec
8  g=9.81 //acceleration due to kravity in m/s^2
9
10 //calculation
11 Cj=g*Is //average effective jet velocity in m/s
12 up=s*Cj //maximum flight speed in m/s
13 MR=1/exp((up+(g*tp))/Cj) //mass ratio
14 PMF=1-MR //propellant mass fraction
15 Zp=(((1+((1-(1/PMF))*log(1/MR)))*Cj*tp)-(0.5*g*tp^2)
    )*10^-3 //powered altitude gain in km
16 Zc=((0.5*up^2)/g)*10^-3 //coasting altitude gain in
    km
17 Z=Zp+Zc //maximum altitude in km
18
19 //output
20 printf('(A)effective jet velocity is %3i m/s\n (B)
    mass ratio and propellant mass fraction are %3.2f
    and %3.2f respectively\n (C)maximum flight speed
    is %3.2f m/s\n (D))altitude gains during powered

```


and coasting flights are %3.3f km and %3.3f km
respectively ',Cj,MR,PMF,up,Zp,Zc)

Scilab code Exa 7.14 To find orbital and escape velocities of a rocket

```
1  clc
2  clear
3
4  //input data
5  R0=6341.6*10^3 //radius of earth at mean sea-level
   in m
6  g=9.809 //acceleration due to gravity in m/s^2
7  Z1=0 //altitude at sea-level in m
8  Z2=300*10^3 //altitude above sea-level in m
9
10 //calculation
11 uorb1=R0*sqrt(g/(R0+Z1)) //orbit velocity of a
   rocket at mean sea level in m/s
12 uesc1=sqrt(2)*uorb1 //escape velocity of a rocket at
   mean sea level in m/s
13 uorb2=R0*sqrt(g/(R0+Z2)) //orbit velocity of a
   rocket at an altitude of 300 km in m/s
14 uesc2=sqrt(2)*uorb2 //escape velocity of a rocket at
   an altitude of 300 km in m/s
15
16 //output
17 printf('(A)orbit and escape velocities of a rocket
   at mean sea level are %3i m/s and %3i m/s\n (B)
   orbit and escape velocities of a rocket at an
   altitude of 300 km are %3.1f m/s and %3.2f m/s',
   uorb1,uesc1,uorb2,uesc2 )
```

Chapter 8

Two Marks Questions and Answers

Scilab code Exa 8.1.34 To find Mach angle

```
1  clc
2  clear
3
4  //Input data
5  C=500 //Airplane velocity in m/s
6  T=20+273 //Temperature in K
7  k=1.4 //Adiabatic constant
8  R=287 //Specific gas constant in J/kg-K
9
10 //Calculation
11 a=sqrt(k*R*T) //Sound velocity in m/s
12 M=C/a //Mach number
13 alp=asind(1/M) //Mach angle in degree
14
15 //Output
16 printf('Mach angle is %3.3f degree',alp)
```

Scilab code Exa 8.1.35 To find values of back pressure

```
1  clc
2  clear
3
4  //Input data
5  a1=2.2 //Area ratio (A/At)
6  Po=10 //Stagnation Pressure in bar
7
8  //Calculation
9  //Two values of mach number at a1 from gas tables
10
11 M1=0.275 //Mach number from gas tables
12 p1=0.949 //Presure ratio (P/Po)
13 P1=Po*p1 //back pressure in bar
14
15 M2=2.295 //Mach number from gas tables
16 p2=0.0806 //Presure ratio (P/Po)
17 P2=Po*p2 //back pressure in bar
18
19 //Output
20 printf('(A)When M=%3.3f, back pressure is %3.2f bar\
      n (B)When M=%3.3f, back pressure is %3.3f bar ',M1
      ,P1 ,M2 ,P2)
```

Scilab code Exa 8.1.37 To find temperature at nose of aircraft

```
1  clc
2  clear
3
4  //Input data
5  M=0.8 //Mach number
6  T=20+273 //Temperature in K
7  k=1.4 //Adiabatic constant
8
```

```

9 //Calculation
10 To=T*(1+(((k-1)/2)*M^2)) //Temperature of air at
    nose of aircraft in K
11 To1=To-273 //Temperature of air at nose of aircraft
    in degree Centigrade
12
13 //Output
14 printf('Temperature of air at nose of aircraft is %3
    .1f degree Centigrade',To1)

```

Scilab code Exa 8.1.38 To determine stagnation pressure and stagnation temperature

```

1 clc
2 clear
3
4 //Input data
5 P=1 //Pressure in bar
6 T=400 //Temperature in K
7 C=400 //Air velocity in m/s
8 k=1.4 //Adiabatic constant
9 R=287 //Specific gas constant in J/kg-K
10 Cp=1005 //Specific heat capacity at constnat
    pressure in J/kg-K
11
12 //Calculation
13 To=T+(C^2/(2*Cp)) //Stagnation Temperature in K
14 Poi=P+((P*C^2)/(R*T*2)) //Stagnation Pressure (if it
    is incompressible) in bar
15 Poc=P*(To/T)^(k/(k-1)) //Stagnation Pressure (if it
    is compressible) in bar
16
17 //Output
18 printf('(Stagnation Temperature is %3.1f K\n (C)
    Stagnation Pressure:\n If it is incompressible

```

```
is %3.4f bar\n    If it is compressible is %3.4f
bar ',To,Poi,Poc)
```

Scilab code Exa 8.1.39 To calculate bulk modulus of elasticity of a liquid

```
1  clc
2  clear
3
4  //Input data
5  v1=8 //Intial volume in litres
6  P1=0.7 //Intial pressure in MPa
7  v2=7.8 //Final volume in litres
8  P2=2.7 //Final pressure in MPa
9
10 //Calculation
11 k=(P2-P1)/(log(v1/v2)) //Bulk modulus of elasticity
    of a liquid in MPa
12
13 //Output
14 printf('Bulk modulus of elasticity of a liquid is %3
    .3f MPa',k)
```

Scilab code Exa 8.1.40 To find highest possible velocity

```
1  clc
2  clear
3
4  //Input data
5  To=15+273 //Air Temperature in K
6  Cp=1005 //Specific heat capacity at constnat
    pressure in J/kg-K
7
8  //Calculation
```

```

9 Cmax=sqrt(2*Cp*To) //Highest possible velocity in m/
  s
10
11 //Output
12 printf('Highest possible velocity is %3.2 f m/s',Cmax
  )

```

Scilab code Exa 8.3.10 To find the length of the pipe

```

1 clc
2 clear
3
4 //Input data
5 M=0.25 //mach number
6 D=0.04 //Diamter in m
7 f=0.002 //frictional factor
8
9 //Calculation
10 X=8.483 //fanno parameter from gas tables at M
11 Lmax=(X*D)/(4*f) //Lenggh of the pipe in m
12
13 //Output
14 printf('Length of the pipe is %3.3 f m',Lmax)

```

Scilab code Exa 8.3.15 To find length of the pipe to achieve deceleration

```

1 clc
2 clear
3
4 //Input data
5 M=3 //mach number
6 D=0.04 //Diamter in m
7 f=0.002 //frictional factor

```

```

8
9 // Calculation
10 X=0.522 //fanno parameter from gas tables at M
11 L=(X*D)/(4*f) //Lenggh of the pipe in m
12
13 //Output
14 printf('Lenggh of the pipe is %3.2f m',L)

```

Scilab code Exa 8.3.31 To find maximum possible amount of heat transfer of combustion chamber

```

1 clc
2 clear
3
4 //Input data
5 M=0.2 //Mach number
6 To=120+273 //Stagnation Temperature in K
7 Cp=1005 //Specific heat capacity at constnat
   pressure in J/kg-K
8
9 // Calculation
10 t1=0.174 //Temperature ratio (To/Tot) from Rayleigh
   gas tables
11 Tot=To/t1 //Critical stagnation temperature in K
12 q=Cp*(Tot-To)*10^-3 //Maximum amount of heat
   transfer in kJ/kg
13
14 //Output
15 printf('Maximum amount of heat transfer is %3.2f kJ/
   kg',q)

```

Scilab code Exa 8.3.32 To find increase in specific entropy of the fluid

```

1  clc
2  clear
3
4  //Input data
5  p1=0.75 //Pressure ratio (Po2/Po1) Since Stagnation
        pressure drop is 25%
6  Cp=1150 //Specific heat capacity at constnat
        pressure in J/kg-K
7  k=1.33 //Adiabatic constant
8
9  //Calculation
10 ds=((k-1)/k)*Cp*log(1/p1) //Increase in entropy in J
        /kg-K
11
12 //Output
13 printf('Increase in entropy is %3.2f J/kg-K',ds)

```

Scilab code Exa 8.3.33 To pipe maximum heat transfer in a pipe

```

1  clc
2  clear
3
4  //Input data
5  Mi=2.2 //Inlet Mach number
6  T=100+273 //Temperature in K
7  Cp=1005 //Specific heat capacity at constnat
        pressure in J/kg-K
8
9  //Calculation
10 t1=0.508 //Temperature ratio (To/Tot) from
        isentropic gas tables @Mi
11 To=T/t1 //Stagnation Temperature in K
12 t2=0.756 //Temperature ratio (To/Tot) from Rayleigh
        gas tables @Mi
13 Tot=To/t2 //Critical stagnation temperature in K

```



```

14 q=Cp*(Tot-To)*10^-3 //Maximum amount of heat
    transfer in kJ/kg
15
16 //Output
17 printf('Maximum amount of heat transfer is %3.4f kJ/
    kg ',q)

```

Scilab code Exa 8.5.16 To find pressure acting on the front of the body

```

1 clc
2 clear
3
4 //Input data
5 Mx=1.5 //Mach number
6 P=40 //Static pressure in kPa
7
8 //Calculation
9 p1=3.413 //Pressure ratio in (Poy/Px) from normal
    shock gas tables @Mx
10 Poy=p1*P //Pressure acting on front of the body in
    kPa
11
12 //Output
13 printf('Pressure acting on front of the body is %3.1
    f kPa ',Poy)

```

Scilab code Exa 8.5.17 To find strength of shock wave

```

1 clc
2 clear
3
4 //Input data
5 M=2 //Mach number at shock

```

```

6
7 //Calculation
8 p1=4.5 //Pressure ratio (Py/Px) from normal shock
      gas tables @M
9 e=p1-1 //Strength of shock wave
10
11 //Output
12 printf('Strength of shock wave is %3.1f',e)

```

Scilab code Exa 8.5.20 To find irreversibility of duct

```

1 clc
2 clear
3
4 //Input data
5 Mx=7 //mach number upstream of shock
6 P=2 //pressure @Mx in bar
7 T=57+273 //Temperature @Mx in K
8 R=287 //Specific gas constant in J/kg-K
9
10 //Calculation
11 p1=0.72 //Pressure ratio (Poy/Pox) from normal shock
      gas tables @Mx
12 ds=R*log(1/p1) //Irreversibility in J/kg-K
13
14 //Output
15 printf('Irreversibility is %3.2f J/kg-K',ds)

```

Scilab code Exa 8.5.21 To find mach number and air velocity of pitot tube

```

1 clc
2 clear

```

```

3
4 //Input data
5 Px=45 //Static pressure in kPa
6 T=-20+273 //Static temperature in K
7 Poy=395 //Stagnation pressure in kPa
8 k=1.4 //Adiabatic constant
9 R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 p1=Poy/Px //Pressure ratio
13 Mx=2.536 //Mach number from normal shock gas tables
    @p1
14 Cx=Mx*sqrt(k*R*T) //Air velocity in m/s
15
16 //Output
17 printf('Mach number is %3.3f\n Air velocity is %3i m
    /s ', Mx, Cx)

```

Scilab code Exa 8.5.22 To find properties downstream of the shock

```

1 clc
2 clear
3
4 //Input data
5 Cx=750 //velocity upstream of shock in m/s
6 Px=1 //Pressure upstream of shock in bar
7 Tx=10+273 //Temperature upstream of shock in K
8 k=1.4 //Adiabatic constant
9 R=287 //Specific gas constant in J/kg-K
10
11 //Calculation
12 Mx=Cx/sqrt(k*R*Tx) //Mach number upstream of shock
13 My=0.545 //Mach number downstream of shock from
    normal shock gas tables, Mistake in textbook
14 t1=1.875 //Temperature ratio (Ty/Tx)

```

```

15 Ty=Tx*t1 //Static temperature downstream of shock in
    K
16 p1=5.583 //Pressure ratio (Py/Px)
17 Py=Px*p1 //Static pressure downstream of shock in
    bar
18 Cy=My*sqrt(k*R*Ty) //velocity downstream of shock in
    m/s
19
20 //Output
21 printf('Downstream of shock:\n    Velocity is %3.3f
    m/s\n    Pressure is %3.3f bar\n    Temperature
    is %3.3f K',Cy,Py,Ty)

```

Scilab code Exa 8.6.41 To find propulsive efficiency for an optimum thrust power

```

1 clc
2 clear
3
4 //Calculation
5
6 //Differentiating  $P=m*(C_j-u)*u$  and equating it to
    zero we get jet speed ratio as 0.5
7 sig=0.5 //Jet speed ratio
8 eff_max=((2*sig)/(1+sig)) //Propulsive efficiency
    for optimum thrust power, wrong notation in
    textbook.
9
10 //Output
11 printf('Propulsive efficiency for optimum thrust
    power is %3.3f',eff_max)

```

Scilab code Exa 8.6.42 To find propulsive efficiency

```

1  clc
2  clear
3
4  //Input dat
5  u=1200*(5/18) //Flight velocity in m/s
6  Cj=800 //Effective jet velocity in m/s
7
8  //Calculation
9  sig=u/Cj //jet speed ratio
10 eff=((2*sig)/(1+sig))*100 //Propulsive efficiency in
    %
11
12 //Output
13 printf('Propulsive efficiency is %3.1f percent ',eff)

```

Scilab code Exa 8.7.42 To find thrust of the rocket

```

1  clc
2  clear
3
4  //Input data
5  m=5 //Propellant rate in kg/s
6  Pamb=1.013 //Ambient pressure in bar
7  Pe=1.02 //Nozzle exit pressure in bar
8  D=0.1 //Nozzle exit diameter in m
9  Ce=1400 //Exit jet velocity in m/s
10
11 //Calculation
12 Ae=%pi*D^2/4 //Exit area in m^2
13 F=(m*Ce)+((Pe-Pamb)*Ae) //Thrust in N
14
15 //Output
16 printf('Thrust is %3i N',F)

```

Scilab code Exa 8.7.44 To find the thrust developed

```
1  clc
2  clear
3
4  //Input data
5  Is=230 //Specific Impulse in sec
6  m=1 //Propellent flow in kg/s
7  g=9.81 //Acceleration due to gravity in m/s^2
8
9  //Calculation
10 F=m*Is*g //Thrust in N
11
12 //Output
13 printf('Thrust is %3.1f N',F)
```

Scilab code Exa 8.7.45 To find the jet velocity of a rocket

```
1  clc
2  clear
3
4  //Input data
5  u=1500 //Flight velocity in m/s
6  eff=0.75 //Propulsive efficiency
7
8  //calculation
9  //Converting relation  $eff=(2*sig)/(1+sig^2)$  into 2nd
    degree polynomial of sig
10 sig=((2-(sqrt(4-(4*eff*eff))))/(2*eff)) //Jet speed
    ratio
11 Cj=u/sig //Jet velocity in m/s
12
```

```
13 //Output
14 printf('Jet velocity is %3.2f m/s',Cj)
```

Scilab code Exa 8.7.46 To calculate thrust propulsive efficiency and thrust power of a rocket

```
1 clc
2 clear
3
4 //Input data
5 Cj=2700 //Jet velocity in m/s
6 u=1350 //Flight velocity in m/s
7 m=78.6 //Propellent flow in kg/s
8
9 //Calculation
10 F=m*Cj*10^-3 //Thrust in kN
11 P=F*u*10^-3 //Thrust power in MW
12 sig=u/Cj //Jet speed ratio
13 eff=((2*sig)/(1+sig^2))*100 //Propulsive efficiency
    in %
14
15 //Output
16 printf('Thrust is %3.1f kN\n Thrust power is %3.2f
    MW\n Propulsive efficiency is %3i percent',F,P,
    eff)
```

Scilab code Exa 8.7.47 To determine orbital velocity and escape velocity of a rocket

```
1 clc
2 clear
3
4 //Input data
```

```

5 D=12683*1000 //Diameter of Earth in m
6 g=9.81 //Acceleration due to gravity in m/s
7 h=500*1000 //Altitude in m
8
9 //Calculation
10 Uorb=(D/2)*sqrt(g/((D/2)+h)) //Orbital velocity in m
    /s
11 Uesc=sqrt(2)*Uorb //Escape velocity in m/s
12
13 //Output
14 printf('Orbital velocity is %3.2f m/s\n Escape
    velocity is %3.2f m/s',Uorb,Uesc)

```

Scilab code Exa 8.7.48 To determine propulsive efficiency and propulsive power of a rocket

```

1 clc
2 clear
3
4 //Input data
5 u=10080*(5/18) //Flight velocity in m/s
6 Cj=1400 //Jet velocity in m/s
7 m=5 //Propellent flow in kg/s
8
9 //calculation
10 F=m*Cj*10^-3 //Thrust in kN
11 P=F*u*10^-3 //Thrust power in MW
12 sig=u/Cj //Jet speed ratio
13 eff=((2*sig)/(1+sig^2)) //Propulsive efficiency
14
15 //Output
16 printf('Propulsive power is %3.1f MW\n Propulsive
    efficiency is %3.1f',P,eff)

```
