A PC- BASED SIMULATION PACKAGE FOR ENGINEERING STUDENTS AND PROFESSIONALS ON COMPRESSIBLE FLOW

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Abstract

Both Engineering students and practicing Engineers are involved in the design and analysis associated with fluid mechanics and thermo-dynamics problems. For them to be very efficient and proficient in handling various problems there is need for scientific data and general information in forms of tables or graphs. These must be made available in a compact form. In this paper a successful attempt was made to make available this aforementioned data in respect of compressible flow. All the equations concerned are brought together in a simplified form and programmed to generate useful data for various gases of interest on compressible flows. Analysis of compressible fluid flow becomes very easy if one has access to information as presented in this paper.

Introduction

The main aim of this compilation is to make available some of the scientific data and general information that are needed by Engineering students and practicing Engineers involved in the analysis of problems on compressible flows. The experiences gathered in the process of teaching students at the undergraduate level have gone a long way to suggest that students' problems will be minimized if theses information are successfully packaged.

Conditions of a fluid flow once known can be used in conjunction with equations relating upstream and downstream conditions to predict or in designing flow in pipeline. When analyzing compressible fluid flow given different upstream conditions, and equations relationship are employed, it could be rigorous to calculate manually. Rather a table values relating the conditions upstream and downstream can be generated for use. In this write up particular references is made to the gas with ratio of specific heats (GAMMA) 1.25.

.The paper includes computer programs that generate values for upstream and downstream relations for the following types of flow: isentropic flow, adiabatic flow, normal shock wave and oblique heats can be varied to obtain information on other gases, for instance gamma equals 1.14, 1.3, 1.35, and 1.67.

Lack of the information mentioned above in form of tables or graphs has not been helpful to students to understand quickly the issues involved in the analysis of compressible flows. The information complied and package in this paper will be very useful compendium for students working on sundry problems in the areas of Thermodynamics and Fluid mechanics.

Application Equations for Compressible Fluid Flow
Adiabatic Flow with Friction (Fanno Flow)

ISENTROPIC FLOW

$$\frac{T_0}{T} = 1 + \frac{1}{2}(Y - 1)M^2 \quad \text{......(1)}$$

$$\frac{P^0}{P} = \left[\frac{T}{T}\right]^{\frac{1}{Y-1}} \quad \text{......(2)}$$

$$\frac{P^0}{P} = \left[\frac{T}{T}\right]^{\frac{1}{Y-1}} = \left[\frac{P^0}{P}\right]^{Y} \quad \text{......(3)}$$

$$\left[\frac{A}{A}\right]=\left[\frac{A}{A}\right]=\frac{1}{M}\left(\frac{1+\frac{1}{2}(y-1)M^{2}}{\frac{1}{2}(y+1)}\right)^{\frac{y+1}{2(Y-1)}} \qquad \text{.....(4)}$$

FANNO FLOW

$$\left[\frac{T_1}{T_2}\right]=\left(\frac{1+\frac{1}{2}(y-1)M_2^2}{1+\frac{1}{2}(y-1)M_1^2}\right) \qquad \text{.....(5)}$$

$$\frac{fl}{(A/P)}=\frac{1}{y}\left(\frac{1}{M_1^2}-\frac{1}{M_2^2}\right)-\left(\frac{y+1}{2y}\right)\ln\left(\left[\frac{M_2}{M_1}\right]^2\frac{(y-1)M_1^2+2}{(y-1)M_2^2+2}\right) \qquad \text{.....(6)}$$

$$\left[\frac{V_1}{V_2}\right]=\left[\frac{P_2}{P_1}\right]=\left[\frac{M_1}{M_2}\right]\left[\frac{T_1}{T_2}\right]^{\frac{1}{2}} \qquad \text{.....(7)}$$

$$\left[\frac{P_1}{P_2}\right]=\left(\frac{P_1}{P_2}\right)\left(\frac{T_1}{T_2}\right) \qquad \text{.....(8)}$$

NORMAL SHOCKS

$$M_2^2=\left(\frac{1+\frac{1}{2}(y-1)M_1^2}{yM_1^2-\frac{1}{2}(y-1)}\right),\left[\frac{P_2}{P_1}\right]=\frac{1+yM_1^2}{1+yM_2^2} \qquad \text{.....(9)}$$

$$\frac{T_2}{T_1}=\left(\frac{1+\frac{1}{2}(y-1)M_1^2}{1+\frac{1}{2}(y-1)M_2^2}\right)=\left[\frac{P_2}{P_1}\right]^2\left[\frac{M_2}{M_1}\right]^2 \qquad \text{.....(10)}$$

$$\left[\frac{P_2}{P_1}\right]=\left(\frac{(y-1)+(y+1)\left[\frac{P_2}{P_1}\right]}{(y+1)+(y-1)\left[\frac{P_2}{P_1}\right]}\right)=\left[\frac{P_2}{P_1}\right]\Big/\left[\frac{T_2}{T_1}\right] \qquad \text{.....(11)}$$

$$\frac{(P_0)_2}{(P_1)} = \frac{(P_0)_2}{P_2}\left[\frac{P_2}{P_1}\right] = \left(1 + \frac{1}{2}(y-1)M_2^{\ 2}\right)^{\frac{Y}{y-1}}\left(\frac{1 + yM_1^{\ 2}}{1 + yM_2^{\ 2}}\right) \quad \ldots\ldots(12)$$

$$\frac{(P_0)_2}{(P_0)_1} = \frac{(P_0)_2}{P_2}\left[\frac{P_2}{P_1}\right]\frac{P_1}{(P_0)_1} = \left(\frac{(y+1)M_1^{\ 2}}{2 + (y-1)M_1^{\ 2}}\right)^{\frac{y}{y-1}}\left(\frac{(y+1)}{2Ym_1^{\ 2} - Y + 1}\right)^{\frac{1}{y-1}} \quad \ldots\ldots(13)$$

$$V_2 = \frac{\left[\frac{T_2}{T_1}\right]}{\left[\frac{P_2}{P_1}\right]} = \frac{1}{\left(\frac{P_2}{P_1}\right)} \quad \ldots\ldots(14)$$

Oblique Shock Equations

$$\frac{\text{TAN}(\beta - \theta)}{\text{TAN}\,\beta} = \frac{2 + (y-1)\,Ma_1^{\ 2}\text{SIN}^2\beta}{(y+1)\,Ma_1^{\ 2}\text{SIN}^2\beta} \quad \ldots\ldots(15)$$

$$\text{TAN}\,\theta = \frac{2\text{COT}\beta\,(Ma_1^{\ 2}\text{SIN}\beta - 1)}{Ma_1^{\ 2}(y + \text{COS}2\beta) + 2} \quad \ldots\ldots(16)$$

Equations (1-16) above were incorporated into the computer programs to generate the values of the unknown parameters: pressure ratio, velocity ratio, temperature ratio, and FL/2 (A/P). The value of gamma is the only required input for the program to run and generate the relevant data. The value of heat ratio, gamma used in the sample run is 1.25.

Results and Discussion

The application software for generating the unknown parameters for the compressible fluid flow under different conditions is attached. The value of gamma happens to be the only required input for the program to run. With this development the students of Engineering and Professional Engineers will be able to analyse problems on compressible fluid with greater level of efficiency.

Conclusion

Having carried out this exercise of developing workable computer software for compressible fluid flow and found very efficient, it can be concluded that the manual use of equations which tend to be tedious and time consuming is completely done away with. Values of parameters needed for analysis can easily be picked up from the relevant tables that are generated or square interpolation could be employed to obtain those parameters that are not directly found in the tables.

References

Douglas, J. F., Gasiorek, J. M and Swaffield, J. A (1985) *Fluid Mechanics*, Second Edition

Massey, B. S., (1989) *Mechanics of Fluids*, Sixth Edition

Bosch (1976) *Automotive Handbook*

Jeje, A. B (1996) Lecture Notes on Fluid Dynamics, Mechanical Engineering Department, University of Ibadan

Source Codes

```
Option Explicit

Private Sub Cancel Button – Click ()
Dialog. Hide
Form 1. Show
End Sub

Private Sub Command 1 _ Click ()

End Sub

Private Sub Compute _ Click()
Dim Mach 1 As Double
Dim Mach2 As Double
Const pi = 22#/7#
Const gamma = 1.25
Dim counter As Double
Dim PresR As Double
Dim Results As String
Dim TempR As String
Dim DensR As Double
Dim AreaR As Single
Dim theta, thetal, theta2, theta3 As
Double
Results = " Compressible Fluid
Flow in Duct of Constant" and vbCrL and
-
  Cross-Section "and " (Isentropic
Flow) Gamma = 1.25 and vbCrL and _
vbCrLf and vbTab and Mach No. and
vbTab and vbTab and P/Po and vbTab and
vbTab and "DensR" _
and vbTab and vbTab and "T/Tc" and vbTab &
vbTab and A/At and vbTab and vbTab and
"Theta" and vbCrLf

For counter =Val(Imach 1. Text) To
Val (Imach2. Text) _
Step 0.05

frmResults. TxtResults. Text = Results

Debug. Print Results
End Sub

Private Sub OKButton_ Click()
Dialog. Hide
Form 1. Show
End Sub
```

```
TempR = 1/ ((1 + ((gamma – 1)/2)*
counter ^ 2)))
DenseR = (TempR) ^ (1/gamma- 1))
PresR = (DensR) ^ gamma
If counter = 0 Then
AreaR = 0
Else
AreaR = (1/counter) * (((+ ((gamma –
1) /2) _
* (counter ^ 2)) / ((gamma + 1) /2)) ^
((gamma + 1)/(2 * (gamma- 1))))
End If
thetal = (((gamma + 1) / (gamma- 1)) ^
0.5)
If (counter < 1 Or counter =1) Then
theta2 = 0
theta3 = 0
theta = 0
Else
theta2 = Atn (Sqr (((gamma – 1) / (gamma
+ 1 )) *
(counter ^ 2- 1 ))) * (180 /pi)
theta3 = (Atn ((counter / Sqr (counter*
counter – 1 )) * (pi / 180))_
+ Sgn ((counter) – 1) * 1.5708)
theta = (thetal * theta2) – (theta3)
End If

Results = Results and vbCrLf and vbTab and
Format_
(counter, #0.00) and vbTab and vbTab and
Format_
(PresR, ###0.000) and vbTab and vbTab
and Format _
(DensR, ###0.000) and vbTab and vbTab
and Format
(TempR, "###0.000") and vbTab and vbTab
and Format
(AreaR, ###0.000) and vbTab and vbTab
and Format _
(theta, "###0.000")
Next counter

Dialog. Hide
fir Results. Show
if counter = 0 Then
VelRl = 0
Velr = 0
PresR = 0
MaxLen = 0
Else
VelRl = (1/counter)* Sqr (TempR1)
Velr = 1/VelRl
PresR = (l / VelRl) * TempRl
```

```
Option Explicit

Private Sub CancelButton _ Click ()
Dialog 1. Hide
Form 1. Show
End Sub

Private Sub cmdCompute2_Click ()
Dim PresR, tempRl, TempR, VelRl,
VelR, _
DensR, MaxLen, counter As Double
Dim Results As String
Dim Maxlen1, Maxlen2, Maxlen3 As
Double
Const gamma = 1.25
Results = vbTab and VbTab and Adiabatic
Flow with Friction in a Pipe" _
And vbCrLf and vbTab and " of Constant
Cross – Section " and _
"(Fanno Flow). Gamma = 1.25" and
vbCrLf and vbTb and _
"Mach No. "and" Pc/P "and" T/Tc
" _
and" V'Vc "and" Fl/2(A/P) "and
vbCrLf


For counter = Val (txtMach1. Text) To
Val (txtMach2. _
Text ) Step 0.02
TempR1 = (1+ (0.5 *(gamma – 1 *
Counter ^ 2 )) _
/ (1 + (0.5 * (gamma – 1)))
TempR = 1/ TempR1
Dim Mach As Double
Dim Beta As Double
Dim Numt As Double
Dim Demt As Double
Dim theta 11 As Double
Dim Results4 As String
Dim space As String * 20
Const gamma = 1.25

Results4 = vbCrLf and vbTab and vbTab and
vbTab and Compressible Flow in a Pipe
of Constant Cross – Section " _
& VbTCrLf and vbTab and vbTab and vbTab &
"                    (Oblique Shock) Heat
Ratio, Gamma = 1.31" _
And vbCrLf and vbTab and "M" and VbTab &
"10" and vbTab and "20" _
and vbTab and "30" and vbTab and "40" and
```

```
Maxlenl = counter ^ 2 * ((gamma + 1) /
_
(((gamma – 1) * (counter ^ 2)) + 2 ))
Maxlen2 = ((gamma + 1 ) / (2 * gamma))
* Log (Maxlen1)
Maxlen3 = (1- (1 /counter ^ 2)) * (1 /
gamma)
MaxLen = Abs (Malen3 – Maxlen2)
End If
Results= Results and vbCrLf and vbTab and
Format
(counter, "#0.00") and "      " and Format
_
(PresR, "###0.000") and "      " and Format
_
(TempR, "###0.000") and "      " and
format _
(VelR, "###0.000) and "       " and
Format _
(MaxLen, "###0.000)
Next counter

Dialog1. Hide
frmResults2. Show
frmResults2. TxtResults2. Text = Results
End Sub


Option Explicit

Private Sub CancelButton_ Click ()
Form 1. Show
Dailog2. Hide
End Sub
Private Sub cmdCcompute3_ Click ()
Const pi = 22#/ 7#

Dialog2. Hide
frmResults4. Show


End Sub


Option Explicit

Private Sub CancelButton_ Click ()
Dialog3. Hide
Form 1. Show
End Sub

Private Sub cmdCompute3_ Click ()
Dim Mach2 As Double
Dim PresRa, PresRal, PresRa2,
```

```
vbTab and "50" and vbTab and "60" _
and vbTab and "70" and vbTab and "80" and
vbTab and "90" and vbCrlf

For Mach = Val (txtO1. Text) To
Val  (txtO2. Text) Step 0.1
    Results4. = Results4 and vbTab and
Format (Mach, "##0.0")
For Beta =10 To 90 Step 10

Numt = 2 * (1 / Tan (beta * pi / 180))
* ((Mach ^ 2)*
(Sin (Beta * pi / 180) ^ 2) – 1)
Demt = ((Mach ^ 2) * (gamma +
Cos (2* Beta * pi /180) _
)) + 2
theta 11 = (180 / pi) * Atn (Numt /
Demt )
Results4 = Results4 and vbTab and
Format (theta11, "###0.0")
Next Beta
Results4 = Results4 and vbCrLf
Next Mach

FrmResults4. txtResults4. Text =
FrmResults4. txtResults4. Text _
And vbCrLf and Results4 and vbCrLf
(0.5 * (gamma – 1)))
PresRa = (1 + (gamma * counter ^ 2)))/ _
(1 + (gamma * Mach2 ^ 2))
TempRa = PresRa ^ 2 * ((Mach2/
counter) ^ 2)
DensRa = PresRa ^ / TemRa
PresRal = ((1 + ( 0.5 * (gamma –1) *
Mach2 ^ 2)) _
^ (gamma / (gamma – 1))) * PreRa
PresRa2 = (((gamma + 1) * counter ^ 2)
_
/ (2 + ((gamma – 1) * counter ^ 2))) ^ _
(gamma / (gamma – 1))
PresRa3 = ((gamma + 1 )) / _
((2 *gamma * (counter ^ 2)) – gamma +
1)) _
^ (1 / (gamma – 1 ))
PresRa4 = PresRa2 * PresRa3
VelRa = 1 / DensRa

Results3 = Results3 and vbCrLf and Format
_
(counter, "#0.00") and vbTab and Format _
(Mach2, "### 0. 000") and vbTab and Format
_
(PresRa, "###0.000") and vbTab and
Format _
(DensRa, "###0.000") and vbTab and
PresRa3, PresRal, PresRa2,
As Double
Dim TempRa As Double
Dim DensRa As Doble
Dim VelRa As Double
Dim counter As Double
Dim Results3 As String
Const gamma = 1.25

Results3 = vbTab and "Normal Shock
Wave in a Pipe of Constant Cross –
Section" and vbCrLf _
and " (Isentropic Flow where Mach
number is greater than 1, Gamma =
1.31)" _
and vbTCrLf and "M" and vbTab and _
"M2" and vbTab and "p2/P1" and vbTab and _
"p2/p1" and vbTab and "T2/T1 and vbTab
and _
"(Po)2/(Po)1" and vbTab and (Po)2/P1 and
vbCrLf

For counter = Val (txtNorm 1. Text) _
To Val (txtNorm2. Text) Step 0.02
Mach2 = Sqrl ((1 + (0.5 * (gamma – 1) _
* counter ^ 2)) / ((gamma * (counter ^
2)) - _
Charater6 = Val (txtNorm1. Text)
Select Case Charater6
Case Is < 1 #
MsgBox "Please enter a Mach number
greater than 1"
txtNorml .Set Focus

Case Is > 100#
MsgBox "Please enter a Mach number
less than 100"
txtNorml SetFocus
KeepFocus  = True

Case Is = Val ("")
MsgBox "Please enter a Mach number
greater than 1"
txtNormL. SetFocus
KeepFocus = True

End Select
End Sub

Private Sub Isentropic Flow _Click ()
Dialog. Show
Form 1. Hide
End Sub
```

```
Format _
(TempRa, "###0.000) and vbTab and
Format _
(PresRa4, "###0.000") and vbTab and
vbTab and Format _
(PresRal, :###0.000")
Next counter


Dialog3. Hide
frmResults3. Show
frmResults3. TxtResults3. Text = Results3

End Sub

Dialog3. Hide
frmResults3. Show
frmResults3. TxtResults3. Text = Results3

End Sub

Private Sub txtNorml _ LostFocus()
Dim Charater6 As Single
End
End Sub


Private Sub cmdClose _ Click ()
FrmResults. Hide
Dialog. Show
End Sub

Private Sub cmdPrint _ Click ()
Dim cancel As Boolean
Dim copy As Integer
On Error Go To errorhandler
cancel = False
CommonDialog1. Show Printer
CommonDialog1. Flags =
        Cd1PDNoSelection Or _
        Cd1PDNoPageNums Or _
        Cd1PDNCollate
CommonDialog1.CancelError = True
CommonDialog1.PrinterDefault = True
CommonDialog1.Copies = 1
If cancel = False Then
Add actual print routines here
For copy =1 To
CommonDialog1.Copies
        FrmResults.PrintForm
        Printer.ScaleMode = 5
        Printer.CurrentX = 2.25
        Printer.CurrentY= 2.25
        Printer.Print txtResults.Text
        Printer.EndDoc
```

```
Private Sub FannoFlow _ Click ()
Dialog1. Show
Form1. Hide
End Sub

Private Sub ObliqueShock _ Click ()
Dialog2. Show
Form1. Hide
End Sub

Private Sub PlaneShock _ Click ()
Dialog3. Show
Form1. Hide
End Sub


Private Sub PlaneShock _ Click ()
Dialog3. Show
Form 1. Hide
End Sub

Private Sub Command5 _ Click ()
Private Sub cmdClose _ Click ()
frmResults2. Hide
Dialog1. Show
End Sub

private Sub Command2 _ Click ()

End Sub

Private Sub cmdClose3 _ Click ()
frmResults3. Hide
Dialog3. Show
End Sub

Private Sub cmdPrint3 _ Click()
Dim copy As Integer
On Error Go To errorhandler
cancel = False
CommonDialog1.ShowPrinter
CommonDialog1. Flags =
cd1PDHidePrintToFile Or _
            cd1PDNoSelection Or _
            cd1PDNoPageNums Or _
            cd1PDCollate
CommonDialog1.CancelError = True
CommonDialog1.PrinterDefault = True
CommonDialog1.Copies =1
If cancel = False Then
For copy = 1 To
CommonDialog1.Copies
        Printer.ScaleMode =5
        Printer.CurrentX = 2.25
```

```
Next copy
End If
Exit Sub

errohandler
If Err. Number = cd1Cancel Then
Cancel = True
Resume Next
End if
End Sub


End Sub


Private Sub cmdCancel4 _ Click ()
FrmResults4.Hide
Dialog2. Show
End Sub


Private Sub cmdPrint _ Click()
Dim cancel As Boolean
Dim copy As Integer
On Error Go To errorhandler
cancel = False
CommonDialog1.Flags =
Cd1PDHidePrintToFile Or _
        cd1PDNoSelection Or _
        cd1PDNoPageNums Or _
        cd1PDCollate
CommonDailog1.CancelError = True
CommonDialog1.PrinterDefault = True
CommonDialog1.Copies =1
If cancel = False Then
For copy = 1 To
CommonDialog1.Copies
        Printer.ScaleMode =5
        Printer.CurrentX =2.25
        Printer.CurrentY =2.25
        Printer.Print txtResults. Text
        Printer.EndDoc
Next copy
End If
Exit sub

errorhandler
If Err.number = cd1Cancel Then
Cancel = True
Resume Next
End If
End Sub
        Printer.CurrentY = 2.25
        Printer.Print txtResults. Text
        Printer.EndDoc
Next copy
End If
Exit Sub

errohandler:
If Err. Number = cd1Cnacel Then
cancel =True
Resume Next
End If
```

Adiabatic Flow with Friction in a Pipe of Constant Cross- Section (Fanno Flow). Gamma = 1.25

Mach No	Pc/P	T/Tc	V/Vc	FL/2(A/P)
1.00	1.000	1.000	1.000	0.000
1.02	1.022	0.996	1.018	0.001
1.04	1.045	0.991	1.035	0.002
1.06	1.067	0.986	1.053	0.005
1.08	1.090	0.982	1.070	0.008
1.10	1.113	0.977	1.087	0.012
1.12	1.136	0.973	1.104	0.017
1.14	1.159	0.968	1.121	0.022
1.16	1.183	0.963	1.138	0.028
1.18	1.205	0.958	1.155	0.34
1.20	1.229	0.953	1.172	0.041
1.22	1.253	0.949	1.188	0.048
1.24	1.276	0.944	1.205	0.055
1.26	1.300	0.939	1.221	0.063
1.28	1.325	0.934	1.237	0.071
1.30	1.349	0.929	1.253	0.079
1.32	1.373	0.924	1.269	0.088
1.34	1.398	0.919	1.284	0.096
1.36	1.423	0.914	1.300	0.105
1.38	1.448	0.909	1.315	0.114
1.40	1.473	0.904	1.331	0.123
1.42	1.498	0.899	1.346	0.132
1.44	1.523	0.893	1.361	0.141
1.46	1.549	0.888	1.376	0.150
1.48	1.575	0.883	1.391	0.159
150	1.601	0.878	1.406	0.168
1.52	1.627	0.873	1.420	0.178
1.54	1.653	0.868	1.435	0.187
1.56	1.680	0.863	1.449	0.196
1.58	1.706	0.857	1.463	0.205
1.60	1.733	0.852	1.477	0.215
1.62	1.760	0.847	1.491	0.224
1.64	1.787	0.842	1.505	0.233
1.66	1.815	0.837	1.518	0.242
1.68	1.842	0.832	1.532	0.251
1.70	1.870	0.826	1.545	0.260
1.72	1.898	0.821	1.559	0.269
1.74	1.926	0.816	1.572	0.278
1.76	1.954	0.811	1.585	0.287
1.78	1.883	0.806	1.598	0.296
1.80	2.012	0.801	1.611	0.305
1.82	2.040	0.796	1.623	0.314
1.84	2.070	0.790	1.636	0.322
1.86	2.099	0.785	1.648	0.331
1.88	2.128	0.780	1.661	0.339
1.90	2.158	0.775	1.673	0.348
1.92	2.188	0.770	1.685	0.356
1.94	2.218	0.765	1.697	0.364
1.96	2.248	0.760	1.709	0.373
1.98	2.279	0.755	1.720	0.381

2.00	2.309	0.750	1.732	0.389
2.02	2.340	0.745	1.744	0.397
2.04	2.371	0.740	1.755	0.405
2.06	2.403	0.735	1.766	0.412
2.08	2.434	0.730	1.777	0.420
2.10	2.466	0.725	1.788	0.428
2.12	2.498	0.720	1.799	0.435
2.14	2.530	0.715	1.810	0.443
2.16	2.562	0.711	1.821	0.450
2.18	2.595	0.706	1.831	0.457
2.20	2.628	0.701	1.842	0.465
2.22	2.661	0.696	1.852	0.472
2.24	2.694	0.691	1.863	0.479
2.26	2.727	0.687	1.873	0.486
2.28	2.761	0.682	1.883	0.493
2.30	2.795	0.677	1.893	0.500
2.32	2.829	0.673	1.903	0.506
2.34	2.863	0.668	1.912	0.513
2.36	2.898	0.663	1.922	0.520
2.38	2.933	0.659	1.932	0.526
2.40	2.968	0.654	1.941	0.533
2.42	3.003	0.650	1.950	0.539
2.44	3.038	0.645	1.960	0.545
2.46	3.074	0.640	1.969	0.552
2.48	3.110	0.636	1.978	0.558
2.50	3.146	0.632	1.987	0.564
2.52	3.182	0.627	1.996	0.570
2.54	3.219	0.623	2.004	0.576
2.56	3.255	0.618	2.013	0.582
2.58	3.292	0.614	2.022	0.587
2.60	3.330	0.610	2.030	0.593
2.62	3.367	0.605	2.039	0.599
2.64	3.405	0.601	2.047	0.604
2.66	3.443	0.597	2.055	0.610
2.68	3.481	0.593	2.063	0.615
2.70	3.519	0.589	2.071	0.621
2.72	3.558	0.584	2.079	0.626
2.74	3.597	0.580	2.087	0.631
2.76	3.636	0.576	2.095	0.636
2.78	3.675	0.572	2.103	0.642
2.80	3.715	0.568	2.111	0.647
2.82	3.754	0.564	2.118	0.652
2.84	3.794	0.560	2.126	0.657
2.86	3.835	0.556	2.133	0.661
2.88	3.785	0.552	2.140	0.666
2.90	3.916	0.548	2.148	0.671
2.92	3.957	0.545	2.155	0.676
2.94	3.998	0.541	2.162	0.680
2.96	4.040	0.537	2.169	0.685
2.98	4.081	0.533	2.176	0.690
3.00	4.123	0.529	2.183	0.694
3.02	4.165	0.526	2.190	0.698

3.04	4.208	0.522	2.196	0.703
3.06	4.250	0.518	2.203	0.707
3.08	4.293	0.515	2.210	0.711
3.10	4.336	0.511	2.216	0.716
3.12	4.380	0.507	2.223	0.720
3.14	4.423	0.504	2.229	0.724
3.16	4.467	0.500	2.235	0.728
3.18	4.511	0.497	2.242	0.732
3.20	4.556	0.493	2.248	0.736
3.22	4.600	0.490	2.254	0.740
3.24	4.645	0.487	2.260	0.744
3.26	4.690	0.483	2.266	0.748
3.28	4.735	0.480	2.272	0.752
3.30	4.781	0.476	2.278	0.755
3.32	4.827	0.473	2.284	0.759
3.34	4.873	0.470	2.289	0.763
3.36	4.919	0.467	2.295	0.766
3.38	4.966	0.463	2.301	0.770
3.40	5.012	0.460	2.306	0.773
3.42	5.059	0.457	2.312	0.777
3.44	5.107	0.454	2.317	0.780
3.46	5.154	0.451	2.323	0.784
3.48	5.202	0.448	2.328	0.787
3.50	5.250	0.444	2.333	0.790
3.52	5.298	0.441	2.339	0.794
3.54	5.347	0.438	2.344	0.797
3.56	5.396	0.435	2.349	0.800
3.58	5.445	0.432	2.354	0.803
3.60	5.494	0.429	2.359	0.807
3.62	5.543	0.426	2.364	0.810
3.64	5.593	0.424	2.369	0.813
3.66	5.643	0.421	2.374	0.816
3.68	5.693	0.418	2.379	0.819
3.70	5.744	0.415	2.383	0.822
3.72	5.795	0.412	2.388	0.825
3.74	5.846	0.409	2.393	0.828
3.76	5.897	0.407	2.397	0.830
3.78	5.949	0.404	2.402	0.833
3.80	6.000	0.401	2.407	0.836
3.82	6.052	0.398	2.411	0.839
3.84	6.105	0.396	2.415	0.842
3.86	6.157	0.393	2.420	0.844
3.88	6.210	0.390	2.424	0.847
3.90	6.263	0.388	2.429	0.850
3.92	6.316	0.385	2.433	0.852
3.94	6.370	0.383	2.437	0.855
3.96	6.424	0.380	2.441	0.858
3.98	6.478	0.378	2.445	0.860
4.00	6.532	0.375	2.449	0.863
4.02	6.587	0.373	2.454	0.865
4.04	6.641	0.370	2.458	0.868
4.06	6.696	0.368	2.462	0.870

4.08	6.752	0.365	2.465	0.872
4.10	6.807	0.363	2.469	0.875
4.12	6.863	0.360	2.473	0.877
4.14	6.919	0.358	2.477	0.879
4.16	6.976	0.356	2.481	0.882
4.18	7.032	0.353	2.485	0.884
4.20	7.089	0.351	2.488	0.886
4.22	7.146	0.349	2.492	0.888
4.24	7.204	0.346	2.496	0.891
4.26	7.261	0.344	2.499	0.893
4.28	7.319	0.342	2.503	0.895
4.30	7.377	0.340	2.506	0.897
4.32	7.436	0.338	2.510	0.899
4.34	7.494	0.335	2.513	0.901
4.36	7.553	0.333	2.517	0.903
4.38	7.612	0.331	2.520	0.906
4.40	7.672	0.329	2.524	0.908
4.42	7.731	0.327	3.527	0.910
4.44	7.791	0.325	2.530	0.912
4.46	7.851	0.323	2.533	0.913
4.48	7.912	0.321	2.537	0.915
4.50	7.973	0.319	2.540	0.917
4.52	8.034	0.317	2.543	0.919
4.54	8.095	0.315	2.546	0.921
4.56	8.156	0.313	2.549	0.923
4.58	8.218	0.311	2.552	0.925
4.60	8.280	0.309	2.556	0.927
4.62	8.342	0.307	2.559	0.929
4.64	8.405	0.305	2.562	0.930
4.66	8.468	0.303	2.565	0.932
4.68	8.531	0.301	2.568	0.934
4.70	8.594	0.299	2.570	0.936
4.72	8.657	0.297	2.573	0.937
4.74	8.721	0.295	2.576	0.939
4.76	8.785	0.294	2.579	0.941
4.78	8.850	0.292	2.582	0.942
4.80	8.914	0.290	2.585	0.944
4.82	8.979	0.288	2.587	0.946
4.84	9.044	0.286	2.590	0.947
4.86	9.109	0.285	2.593	0.949
4.88	9.175	0.283	2.596	0.950
4.90	9.241	0.281	2.598	0.952
4.92	9.307	0.279	2.601	0.954
4.94	9.374	0.278	2.603	0.955
4.96	9.440	0.276	2.606	0.957
4.98	9.507	0.274	2.609	0.958
5.00	9.574	0.273	2.611	0.960