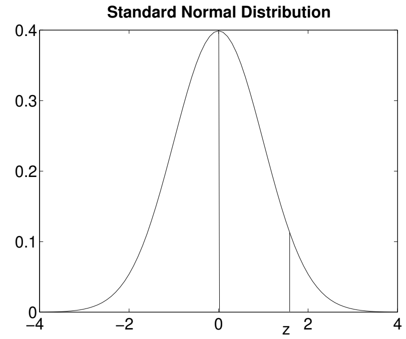
22.4UC2 Using C++ Programs to Create Tables

The following table contains the data of the standard normal distribution (Z-distribution) for values between 0.00 and 3.99:



z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	nan	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0597	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1218	0.1256	0.1293	0.1331	0.1369	0.1406	0.1443	0.1481	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4178
1.4	0.4193	0.4207	0.4222	0.4237	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4358	0.4370	0.4382	0.4394	0.4406	0.4418	0.4430	0.4441
1.6	0.4452	0.4463	0.4474	0.4485	0.4495	0.4505	0.4516	0.4526	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4679	0.4686	0.4693	0.4700	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4762	0.4767
2.0	0.4773	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4865	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4983	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998
3.5	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.6	0.4998	0.4998	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.7	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.8	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.5000
3.9	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

Such data can be created using the following C++ program:

```
#include <iostream.h>
#include <iomanip.h>
#include <math.h>

double PI=3.14159;
double fun(double);
double integrate(double, double);

main(){

  double a=0;
  double result;
  double input=0;

  cout.setf(ios::fixed);

  cout << "z\t";

  /* Here starts the generation of data */

  // First line, 0.00 0.01 0.02 0.03 etc.
  cout.precision(2);
  for(double i = 0.00; i < 0.09; i += 0.01)
    {
      cout << i << "\t";
    }
  cout << 0.09 << endl;

  // Output of one line of data
  for(double i = 0.00; i <= 4.00; i += 0.1)
    {
      cout.precision(1);
      cout << i << "\t";

      cout.precision(4);
      for(double j = 0.00; j < 0.09; j = j+0.01)
        {
          cout << integrate(0,i+j) <<"\t";
        }
      cout << integrate(0,i+0.09) << endl;
    }
}

/* The following function calculates the area under a function fun.
The area is calculated between a and b.
The method used to calculate the integral is called the
Composite Simpson Rule.
*/

double integrate(double a,double b)
{
```

```
  double steps = 10000;
  double m = (b-a)*steps;

  double even = 0, odd = 0;
  double h = (b-a)/(2*m);
  double x;

  for(int k = 1; k < m; k++)
    {
      x = a+h*2*k;
      even += fun(x);
    }

  for(int k = 1; k < m+1; k++)
    {
      x = a+h*(2*k-1);
      odd += fun(x);
    }

  return h*(fun(a) + fun(b) + 2*even + 4*odd)/3;
}

/* The following code defines the function over which we intergrate;
here it is the density function for the standard normal distribution.
*/

double fun(double x)
{
  return exp(-(x*x)/2)/sqrt(2*PI);
}
```

The method for integration in this program is called the *Composite Simpson Rule.* To approximate the integral

$$\int_a^b f(x)\,dx$$

one sub-divides the interval $[a,b]$ into $2m$ sub-intervals of equal length and evaluates the function at the points $f(a)$, $f(x_k)$, $f(b)$, where

$$x_k = a + kh, \qquad k = 0, \ldots, 2m$$

and h the interval length $(b-a)/(2m)$, so that

$$\int_a^b f(x)\,dx \approx \frac{h}{3}\left(f(a)+f(b)\right) + \frac{2h}{3}\sum\nolimits_{k=1}^{m-1} f(x_{2k}) + \frac{4h}{3}\sum\nolimits_{k=1}^{m} f(x_{2k-1})\,.$$

The Composite Simpson Rule has good convergence properties.