Review Section 4.3.2, 5.3.2, 5.3.3, 5.3.4 and 6.1 in Goldsman, D. & Goldsman, P. (2020). A First Course in Probability and Statistics. Lulu. Download link

Not all tables for these distributions are the same. Having an understanding of how probability, cumulative distribution functions, and inverse cumulative distribution functions works is more important than memorizing how to use these tables. If you have the fundamentals down, then you can use any table or software no matter how they have defined these concepts.

Be mindful when dealing with probability distributions. Different textbooks, online resources, and software tools may have slightly different ways of defining some distributions and may parameterize them differently as well. Always read the documentation!

Standard Normal Table

Quantiles

Example: If σ^2 is *known*, then a $100(1-\alpha)\%$ CI for μ is

$$\bar{X}_n - z_{\alpha/2}\sqrt{\frac{\sigma^2}{n}} \le \mu \le \bar{X}_n + z_{\alpha/2}\sqrt{\frac{\sigma^2}{n}},$$

where z_γ is the $1-\gamma$ quantile of the standard normal distribution, i.e., $z_\gamma \equiv \Phi^{-1}(1-\gamma)$.

If we want to find a 95% confidence interval, this implies that $\alpha = 0.05$ and $\frac{\alpha}{2} = 0.025$.

In order to find the correct z-value, we need to be aware that by Dave's definition and notation, this means we are looking for $1 - \frac{\alpha}{2} = 1 - 0.025 = 0.975$

When using the table, we will want to take the following steps:

1. Find an entry in the table that is close to 0.975.
2. Follow the row all the way to the left to obtain the z value to one decimal place.
3. Follow the column all the way up to obtain the z value's second decimal place.

The result is a z value of 1.96.

Standard Normal Tab

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9031	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	[illegible]616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	[illegible]93	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	[illegible]9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9924	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9958	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986

Software

R

```
> qnorm(0.975)
[1] 1.959964
```

Python

```python
import scipy.stats
scipy.stats.norm.ppf(0.975)
```

```
1.959963984540054
```

MATLAB

```
>> norminv(0.975)

ans =

    1.9600
```

Excel

```
=NORM.INV(0.975, 0, 1)
```

D	E
1.959964	

Texas Instruments Calculators

```
invNorm(0.975, 0, 1)
```

Probabilities

The probabilities given in the table are for positive z values and are the areas/probabilities to the left of those z values.

For positive z values, you can use the table directly; to find $P(Z \leq 2)$:

1. Find the z value in the left column to one decimal place.
2. Find the z value's second decimal place in the top row.
3. Find the intersection between the column and the row.

The value is 0.9772

Standard Normal Table

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9031	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	[illegible]	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	[illegible]	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9924	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9958	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986

For negative z values, you can use the symmetry of the Normal distribution. $P(Z \leq -z)$ represents the area to the left of $-z$. The area to the right of the positive z value will have the same value. So $P(Z \leq -z) = P(Z > z) = 1 - P(Z \leq z)$

To find $P(Z \leq -2)$, we use $1 - P(Z \leq 2) = 1 - 0.9772 = 0.0228$

To find the probability between $-z$ and z, $P(-z \leq Z \leq z)$, you can think of this as finding $P(Z \leq z)$ and subtracting off the tail probability of $P(Z \leq -z)$.

$$P(-z \leq Z \leq z) = P(Z \leq z) - P(Z \leq -z)$$

From above, we saw that $P(Z \leq -z) = 1 - P(Z \leq z)$. Substituting this back into the expression above:

$$P(Z \leq z) - (1 - P(Z \leq z)) = 2P(Z \leq z) - 1$$

For $P(-2 \leq Z \leq 2)$ this is $2(0.9772) - 1 = 0.9544$

It might also be worthwhile to review the [68–95–99.7](68–95–99.7) rule.

For any other types of probabilities where you are finding between two values that are not the same, you may need to sketch a drawing with the area you are looking for to figure out what values to use.

The general way to do this for $P(a \leq Z \leq b)$ is to find $\Phi(b) - \Phi(a) = P(Z \leq b) - P(Z \leq a)$. You can think of this as subtracting off the area to the left of a and leaving only the area between a and b.

You can relate this back to integration. If we let $\phi(x)$ be the standard Normal PDF and $\Phi(x)$ be the standard Normal CDF then when doing the integral from a to b over the PDF we would have:

$$\int_a^b \phi(x)dx = \Phi(b) - \Phi(a)$$

Software

R

```
> pnorm(2)
[1] 0.9772499
> 1 - pnorm(2)
[1] 0.02275013
> 2*pnorm(2) - 1
[1] 0.9544997
```

Python

```
import scipy.stats
scipy.stats.norm.cdf(2)
```

```
0.9772498680518208
```

```
1 - scipy.stats.norm.cdf(2)
```

```
0.022750131948179208
```

```
2 * scipy.stats.norm.cdf(2) - 1
```

```
0.9544997361036416
```

MATLAB

```
>> [normcdf(2) 1 - normcdf(2) 2*normcdf(2) - 1]

ans =

    0.9772    0.0228    0.9545
```

Excel

=NORM.DIST(2,0,1,TRUE)

D	E	F
0.97725		

=1 - NORM.DIST(2,0,1,TRUE)

D	E	F
0.02275		

=2*NORM.DIST(2,0,1,TRUE) - 1

D	E	F
0.9545		

Texas Instruments Calculators

```
normCDF(−∞, 2, 0, 1)
normCDF(2, ∞, 0 , 1)
normCDF(-2, 2, 0, 1)
```

Student's t Distribution Table

The t-distribution is different from the standard Normal distribution table. First it contains the degrees of freedom parameter for the t-distribution, and the probabilities are in the column headings with the t-values in the table itself (this is the opposite of how the standard Normal table is presented).

Quantiles

Example: If σ^2 is *unknown*, then a $100(1-\alpha)\%$ CI for μ is

$$\bar{X}_n - t_{\alpha/2,n-1}\sqrt{\frac{S^2}{n}} \leq \mu \leq \bar{X}_n + t_{\alpha/2,n-1}\sqrt{\frac{S^2}{n}},$$

where $t_{\gamma,\nu}$ is the $1-\gamma$ quantile of the $t(\nu)$ distribution.

The same logic applies here to compute the quantiles as it did for the Normal distribution; the difference is that the t distribution has an additional parameter for degrees of freedom.

If we want to find a 95% confidence interval, this implies that $\alpha = 0.05$ and $\frac{\alpha}{2} = 0.025$.

We will assume we are using a t distribution with 19 degrees of freedom. Since this table gives probabilities above the tabulated values, we can use the value of 0.025 directly.

1. Find the row for the corresponding number of degrees of freedom.
2. Find the column with the probability desired.
3. Find the intersection between the column and the row.

The value is 2.093.

TABLE of CRITICAL VALU[illegible]STUDENT'S *t* DISTRIBUTIONS

Column headings denote probabilities (α) ***above*** tabulated values.

d.f.	0.40	0.25	0.10	0.05	0.04	0.025	0.02	0.01	0.005	0.0025	0.001	0.0005
1	0.325	1.000	3.078	6.314	7.916	12.706	15.894	31.821	63.656	127.321	318.289	636.578
2	0.289	0.816	1.886	2.920	3.320	4.303	4.849	6.965	9.925	14.089	22.328	31.600
3	0.277	0.765	1.638	2.353	2.605	3.182	3.482	4.541	5.841	7.453	10.214	12.924
4	0.271	0.741	1.533	2.132	2.333	2.776	2.999	3.747	4.604	5.598	7.173	8.610
5	0.267	0.727	1.476	2.015	2.191	2.571	2.757	3.365	4.032	4.773	5.894	6.869
6	0.265	0.718	1.440	1.943	2.104	2.447	2.612	3.143	3.707	4.317	5.208	5.959
7	0.263	0.711	1.415	1.895	2.046	2.365	2.517	2.998	3.499	4.029	4.785	5.408
8	0.262	0.706	1.397	1.860	2.004	2.306	2.449	2.896	3.355	3.833	4.501	5.041
9	0.261	0.703	1.383	1.833	1.973	2.262	2.398	2.821	3.250	3.690	4.297	4.781
10	0.260	0.700	1.372	1.812	1.948	2.228	2.359	2.764	3.169	3.581	4.144	4.587
11	0.260	0.697	1.363	1.796	1.928	2.201	2.328	2.718	3.106	3.497	4.025	4.437
12	0.259	0.695	1.356	1.782	1.912	2.179	2.303	2.681	3.055	3.428	3.930	4.318
13	0.259	0.694	1.350	1.771	1.899	2.160	2.282	2.650	3.012	3.372	3.852	4.221
14	0.258	0.692	1.345	1.761	1.887	2.145	2.264	2.624	2.977	3.326	3.787	4.140
15	0.258	0.691	1.341	1.753	1.878	2.131	[illegible]	2.602	2.947	3.286	3.733	4.073
16	0.258	0.690	1.337	1.746	1.869	2.120	[illegible]	2.583	2.921	3.252	3.686	4.015
17	0.257	0.689	1.333	1.740	1.862	2.110	[illegible]	2.567	2.898	3.222	3.646	3.965
18	0.257	0.688	1.330	1.734	1.855	2.101	[illegible]	2.552	2.878	3.197	3.610	3.922
19	0.257	0.688	1.328	1.729	1.850	2.093	2.205	2.539	2.861	3.174	3.579	3.883
20	0.257	0.687	1.325	1.725	1.844	2.086	2.197	2.528	2.845	3.153	3.552	3.850
21	0.257	0.686	1.323	1.721	1.840	2.080	2.189	2.518	2.831	3.135	3.527	3.819
22	0.256	0.686	1.321	1.717	1.835	2.074	2.183	2.508	2.819	3.119	3.505	3.792
23	0.256	0.685	1.319	1.714	1.832	2.069	2.177	2.500	2.807	3.104	3.485	3.768
24	0.256	0.685	1.318	1.711	1.828	2.064	2.172	2.492	2.797	3.091	3.467	3.745
25	0.256	0.684	1.316	1.708	1.825	2.060	2.167	2.485	2.787	3.078	3.450	3.725
26	0.256	0.684	1.315	1.706	1.822	2.056	2.162	2.479	2.779	3.067	3.435	3.707
27	0.256	0.684	1.314	1.703	1.819	2.052	2.158	2.473	2.771	3.057	3.421	3.689
28	0.256	0.683	1.313	1.701	1.817	2.048	2.154	2.467	2.763	3.047	3.408	3.674
29	0.256	0.683	1.311	1.699	1.814	2.045	2.150	2.462	2.756	3.038	3.396	3.660
30	0.256	0.683	1.310	1.697	1.812	2.042	2.147	2.457	2.750	3.030	3.385	3.646
31	0.256	0.682	1.309	1.696	1.810	2.040	2.144	2.453	2.744	3.022	3.375	3.633
32	0.255	0.682	1.309	1.694	1.808	2.037	2.141	2.449	2.738	3.015	3.365	3.622
33	0.255	0.682	1.308	1.692	1.806	2.035	2.138	2.445	2.733	3.008	3.356	3.611
34	0.255	0.682	1.307	1.691	1.805	2.032	2.136	2.441	2.728	3.002	3.348	3.601
35	0.255	0.682	1.306	1.690	1.803	2.030	2.133	2.438	2.724	2.996	3.340	3.591
36	0.255	0.681	1.306	1.688	1.802	2.028	2.131	2.434	2.719	2.990	3.333	3.582
37	0.255	0.681	1.305	1.687	1.800	2.026	2.129	2.431	2.715	2.985	3.326	3.574
38	0.255	0.681	1.304	1.686	1.799	2.024	2.127	2.429	2.712	2.980	3.319	3.566
39	0.255	0.681	1.304	1.685	1.798	2.023	2.125	2.426	2.708	2.976	3.313	3.558
40	0.255	0.681	1.303	1.684	1.796	2.021	2.123	2.423	2.704	2.971	3.307	3.551
60	0.254	0.679	1.296	1.671	1.781	2.000	2.099	2.390	2.660	2.915	3.232	3.460
80	0.254	0.678	1.292	1.664	1.773	1.990	2.088	2.374	2.639	2.887	3.195	3.416
100	0.254	0.677	1.290	1.660	1.769	1.984	2.081	2.364	2.626	2.871	3.174	3.390
120	0.254	0.677	1.289	1.658	1.766	1.980	2.076	2.358	2.617	2.860	3.160	3.373
140	0.254	0.676	1.288	1.656	1.763	1.977	2.073	2.353	2.611	2.852	3.149	3.361
160	0.254	0.676	1.287	1.654	1.762	1.975	2.071	2.350	2.607	2.847	3.142	3.352
180	0.254	0.676	1.286	1.653	1.761	1.973	2.069	2.347	2.603	2.842	3.136	3.345
200	0.254	0.676	1.286	1.653	1.760	1.972	2.067	2.345	2.601	2.838	3.131	3.340
250	0.254	0.675	1.285	1.651	1.758	1.969	2.065	2.341	2.596	2.832	3.123	3.330
inf	0.253	0.674	1.282	1.645	1.751	1.960	2.054	2.326	2.576	2.807	3.090	3.290

Software

R

```
> qt(0.025, 19, lower.tail = FALSE)
[1] 2.093024
```

Python

Note that for Python you need to use $1 - 0.025 = 0.975$ as the function always returns based on the lower tail.

```
import scipy.stats
scipy.stats.t.ppf(1 - 0.025, df = 19)
```

```
2.093024054408263
```

MATLAB

MATLAB also returns the lower tail.

```
>> tinv(1 - 0.025, 19)

ans =

    2.0930
```

Excel

Excel also returns the lower tail.

```
=T.INV(1-0.025, 19)
```

D	E
2.093024	

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```
invt(0.975, 19)
```

Probabilities

It's not common (at least in ISyE 6644) to ask for probabilities for the t distribution. The table can be used, but it's not a great tool for the job. I do not believe you will be asked to do this in this course, so I will skip the explanation of how to use the table

Software

R

```
> pt(2.093, 19)
[1] 0.9749988
> 1 - pt(2.093, 19)
[1] 0.02500119
> 2*pt(2.093, 19) - 1
[1] 0.9499976
```

Python

```python
import scipy.stats
scipy.stats.t.cdf(2.093, df = 19)
```

```
0.974998810528586
```

```python
1 - scipy.stats.t.cdf(2.093, df = 19)
```

```
0.025001189471414054
```

```python
2 * scipy.stats.t.cdf(2.093, df = 19) - 1
```

```
0.9499976210571719
```

MATLAB

```
>> [tcdf(2.093, 19) 1 - tcdf(2.093, 19) 2*tcdf(2.093, 19) - 1]

ans =

    0.9750    0.0250    0.9500
```

Excel

```
=T.DIST(2.093, 19, TRUE)
```

D	E
0.974999	

```
=1 - T.DIST(2.093, 19, TRUE)
```

D	E	F
0.025001		

```
=2*T.DIST(2.093, 19, TRUE) - 1
```

D	E	F
0.949998		

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```
tCDF(−∞, 2.093, 0, 1)
tCDF(2.093, ∞, 0 , 1)
tCDF(-2.093, 2.093, 0, 1)
```

Chi-squared Distribution Table

The χ^2 table is similar to the t distribution table with degrees of freedom to the left and probabilities as the column headings. The probabilities as given are to the right of the indicated critical values.

Quantiles

Example: A $100(1-\alpha)\%$ CI for σ^2 is

$$\frac{(n-1)S^2}{\chi^2_{\frac{\alpha}{2},n-1}} \leq \sigma^2 \leq \frac{(n-1)S^2}{\chi^2_{1-\frac{\alpha}{2},n-1}},$$

where $\chi^2_{\gamma,\nu}$ is the $1-\gamma$ quantile of the $\chi^2(\nu)$ distribution.

Notice the difference with the use of $\frac{\alpha}{2}$ for the left side and $1-\frac{\alpha}{2}$. This is because the χ^2 distribution is not symmetric and its support is only positive values (since the distribution results from squaring Normal random variables, it can only take on positive values).

We will assume we are using a χ^2 distribution with 4 degrees of freedom. Since this table gives probabilities above the tabulated values, we can use the value of 0.025 directly. We typically in this course will use critical values from this table for hypothesis testing purposes, so if the test statistic is less than the critical value, we will fail to reject the null hypothesis; otherwise, the test statistic is above the critical value and we reject the null hypothesis. This means we are always interested in the upper tail probability here and that is why this table is designed this way.

For a hypothesis test with an $\alpha = 0.05$ we can read this from the table by doing the following:

1. Find the row for the corresponding number of degrees of freedom.
2. Find the column with the probability desired.
3. Find the intersection between the column and the row.

The value is 9.49.

Percentage Points of the Chi-Square Distribution

Degrees of Freedom	Probability of a larger value of x ²								
	0.99	0.95	0.90	0.75	0.50	0.25	0.10	0.05	0.01
1	0.000	0.004	0.016	0.102	0.455	1.32	2.71	3.84	6.63
2	0.020	0.103	0.211	0.575	1.386	2.77	4.61	5.99	9.21
3	0.115	0.352	0.584	1.212	2.366	4.11	6.25	7.81	[illegible]
4	0.297	0.711	1.064	1.923	3.357	5.39	7.78	9.49	[illegible]
5	0.554	1.145	1.610	2.675	4.351	6.63	9.24	11.07	[illegible]
6	0.872	1.635	2.204	3.455	5.348	7.84	10.64	12.59	16.81
7	1.239	2.167	2.833	4.255	6.346	9.04	12.02	14.07	18.48
8	1.647	2.733	3.490	5.071	7.344	10.22	13.36	15.51	20.09
9	2.088	3.325	4.168	5.899	8.343	11.39	14.68	16.92	21.67
10	2.558	3.940	4.865	6.737	9.342	12.55	15.99	18.31	23.21
11	3.053	4.575	5.578	7.584	10.341	13.70	17.28	19.68	24.72
12	3.571	5.226	6.304	8.438	11.340	14.85	18.55	21.03	26.22
13	4.107	5.892	7.042	9.299	12.340	15.98	19.81	22.36	27.69
14	4.660	6.571	7.790	10.165	13.339	17.12	21.06	23.68	29.14
15	5.229	7.261	8.547	11.037	14.339	18.25	22.31	25.00	30.58
16	5.812	7.962	9.312	11.912	15.338	19.37	23.54	26.30	32.00
17	6.408	8.672	10.085	12.792	16.338	20.49	24.77	27.59	33.41
18	7.015	9.390	10.865	13.675	17.338	21.60	25.99	28.87	34.80
19	7.633	10.117	11.651	14.562	18.338	22.72	27.20	30.14	36.19
20	8.260	10.851	12.443	15.452	19.337	23.83	28.41	31.41	37.57
22	9.542	12.338	14.041	17.240	21.337	26.04	30.81	33.92	40.29
24	10.856	13.848	15.659	19.037	23.337	28.24	33.20	36.42	42.98
26	12.198	15.379	17.292	20.843	25.336	30.43	35.56	38.89	45.64
28	13.565	16.928	18.939	22.657	27.336	32.62	37.92	41.34	48.28
30	14.953	18.493	20.599	24.478	29.336	34.80	40.26	43.77	50.89
40	22.164	26.509	29.051	33.660	39.335	45.62	51.80	55.76	63.69
50	27.707	34.764	37.689	42.942	49.335	56.33	63.17	67.50	76.15
60	37.485	43.188	46.459	52.294	59.335	66.98	74.40	79.08	88.38

Software

R

```
> qchisq(0.05, 4, lower.tail = FALSE)
[1] 9.487729
```

Python

For Python you will need to use 1 minus the value from the table since Python always returns lower tailed. Notice when using the wrong value, it actually matches the value for 0.95 from the table above.

```
import scipy.stats
scipy.stats.chi2.ppf(0.05, df = 4)
```

```
0.7107230213973239
```

```
scipy.stats.chi2.ppf(1 - 0.05, df = 4)
```

```
9.487729036781154
```

MATLAB

MATLAB needs to be treated the same as Python.

```
>> chi2inv(1-0.05, 4)

ans =

    9.4877
```

Excel

Excel also needs to be treated the same way.

```
=CHISQ.INV(1-0.05, 4)
```

D	E
9.487729	

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invχ^2(0.95, 4)

Probabilities

It's not common (at least in ISyE 6644) to ask for probabilities for the χ^2 distribution. The table can be used, but it's not a great tool for the job. I do not believe you will be asked to do this in this course, so I will skip the explanation of how to use the table. Since the distribution is not symmetric, the same "tricks" that worked for the standard Normal and t distribution don't work.

Software

R

```
> # P(X <= 9.49)
> pchisq(9.49, 4)
[1] 0.9500469
> # P(X > 9.49)
> pchisq(9.49, 4, lower.tail = FALSE)
[1] 0.04995313
> # P(5 <= X <= 9.49)
> pchisq(9.49, 4) - pchisq(5, 4)
[1] 0.2373444
```

Python

```
import scipy.stats
# P(X <= 9.49)
scipy.stats.chi2.cdf(9.49, df = 4)
```

```
0.9500468687767051
```

```
# P(X > 9.49)
1 - scipy.stats.chi2.cdf(9.49, df = 4)
```

```
0.04995313122329492
```

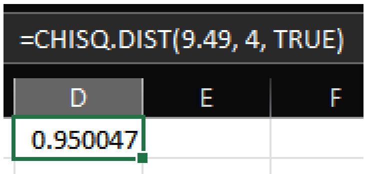
```
# P(5 <= X <= 9.49)
scipy.stats.chi2.cdf(9.49, df = 4) - scipy.stats.chi2.cdf(5, df = 4)
```

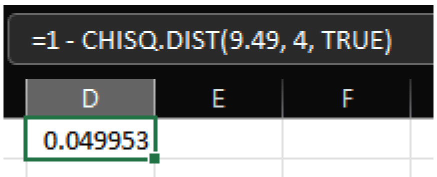
```
0.23734436396035086
```

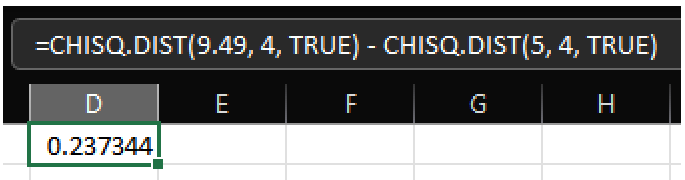
MATLAB

```
>> [chi2cdf(9.49, 4) 1 - chi2cdf(9.49, 4) chi2cdf(9.49, 4) - chi2cdf(5, 4)]

ans =

    0.9500    0.0500    0.2373
```

Excel







Texas Instruments Calculators

χ^2`CDF(0, 9.49, 4)`

χ^2`CDF(9.49, ` ∞`, 4)`

χ^2`CDF(5, 9.49, 4)`