

How to Use the Z Table to Calculate Probabilities

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How to Use the Z Table (With Detailed Examples)

The **Z Table**, often formally referred to as the **Standard Normal Table**, serves as a cornerstone in the field of **statistics**. It provides a comprehensive list of probabilities associated with the **standard normal distribution**, allowing researchers to quantify the likelihood of specific outcomes within a data set. By mapping raw data points to a standardized scale, this tool enables the calculation of the **area under the curve**, which represents the **probability** of a random variable falling within a designated range. This capability is essential for professionals in **economics**, engineering, and the social sciences who rely on objective data to make informed predictions.

At its core, the **Z Table** functions as a reference guide for interpreting **z-scores**. A **z-score** acts as a standardized metric that describes the position of a specific observation in relation to the average of the entire group. Because many natural phenomena follow a bell-shaped curve, or **normal distribution**, the table offers a universal method for comparing disparate datasets. For example, it allows a scientist to compare the relative height of a plant in one region to a different species in another by normalizing their measurements against their respective averages.

Effective **data analysis** requires more than just raw numbers; it requires context. The **Z Table** provides this context by converting raw scores into cumulative probabilities. Whether one is conducting academic research or optimizing industrial processes, the ability to determine where a value sits within the broader distribution is a vital skill. This tutorial will explore the mathematical foundations of the **z-score**, the structure of the table itself, and practical applications through detailed, step-by-step examples.

Understanding the Mathematical Foundation of Z-Scores

To utilize the **Z Table** effectively, one must first master the calculation of the **z-score**. This value indicates precisely how many **standard deviations** an individual data point is from the **population mean**. If a **z-score** is positive, the value is above the average; if it is negative, the value resides below the average. This normalization is what allows different types of data to be compared on a single, standardized scale known as the **standard normal distribution**.

The mathematical formula used to derive this value is straightforward but profound in its utility. It accounts for both the central tendency of the data and the degree of variation within the population. By subtracting the mean from the observed value and dividing by the standard deviation, we effectively strip away the original units of measurement, leaving a pure number that reflects the data point's relative standing.

The specific formula is expressed as:

$$\text{z-score} = (x - \mu) / \sigma$$

Where the components are defined as follows:

x: This represents the individual data value or the specific observation being analyzed.

μ : This denotes the **population mean**, which is the arithmetic average of all points in the set.

σ : This signifies the **population standard deviation**, measuring the amount of dispersion or spread in the data.

By applying this formula, any **normal distribution** can be converted into a standard form where the mean is zero and the standard deviation is one. This transformation is what makes the **Z Table** a universally applicable tool. Once a **z-score** is calculated, the table reveals the cumulative **probability** associated with that score, facilitating a deeper understanding of the dataset's characteristics.

Navigating the Structure of the Standard Normal Table

The **Z Table** is typically presented as a grid of numbers that may appear daunting at first glance. However, its organization is highly logical. The leftmost column of the table lists the **z-score** up to the first decimal place (the tenths position). The top row of the table provides the second decimal place (the hundredths position). By finding the intersection of the appropriate row and column, a user can locate the exact cumulative probability for their calculated score.

It is important to distinguish between the two primary types of tables: the "positive" table and the "negative" table. The negative table provides probabilities for scores that fall below the mean, while the positive table covers scores above the mean. Most modern statistical software handles these calculations automatically, but understanding how to read the manual table is a fundamental skill for any student or professional engaged in **statistics**. This manual lookup process reinforces the relationship between the **area under the curve** and the resulting probability.

When you look up a value in the **Z Table**, the number you find represents the total area to the left of that **z-score**. In practical terms, this tells you the percentage of the population that falls below that specific value. For instance, a **z-score** of 0.00 corresponds to a probability of 0.5000, or 50%, confirming that exactly half of the data in a **normal distribution** lies below the mean. As the **z-score** increases, the cumulative probability approaches 1.000 (100%), while a decreasing negative score approaches 0.000.

Example 1: Analyzing College Entrance Exam Performance

Consider a scenario involving standardized testing, a common application for **data analysis**. The scores on a specific college entrance exam are known to be **normally distributed**, featuring a **population mean** (μ) of 82 and a **population standard deviation** (σ) of 8. A researcher wants to determine the percentage of students who scored less than 84 on this exam. This requires a two-

step process involving the **z-score** formula and the **Z Table**.

Step 1: Calculate the Z-Score

First, we must determine how the score of 84 relates to the rest of the distribution. By applying the formula:

$$z\text{-score} = (x - \mu) / \sigma = (84 - 82) / 8 = 2 / 8 = 0.25$$

This result tells us that a score of 84 is exactly 0.25 **standard deviations** above the mean. Since the value is positive, we know the score is better than the average student's performance, but we need the **Z Table** to find the exact percentile.

Step 2: Locate the Probability in the Z Table

Next, we reference the **Z Table** to identify the percentage that corresponds to a **z-score** of 0.25:

z	0	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	0.9131	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

By finding the row labeled 0.2 and the column labeled 0.05, we find the intersection at 0.5987. This indicates that approximately **59.87%** of students scored less than 84 on the exam. This type of analysis is crucial for admissions departments when setting benchmarks for acceptance.

Example 2: Determining Probabilities Above a Specific Value

In biological **statistics**, we often need to find the proportion of a population that exceeds a certain

threshold. Suppose the heights of plants in a botanical garden are **normally distributed** with a mean (μ) of 26.5 inches and a **population standard deviation** (σ) of 2.5 inches. The goal is to calculate what percentage of these plants are taller than 26 inches.

Step 1: Calculate the Z-Score

We begin by calculating the **z-score** for a height of 26 inches:

$$z\text{-score} = (x - \mu) / \sigma = (26 - 26.5) / 2.5 = -0.5 / 2.5 = \mathbf{-0.2}$$

The negative result signifies that 26 inches is slightly below the **population mean**. Specifically, it is 0.2 **standard deviations** below the average height.

Step 2: Consult the Z Table and Adjust for Direction

We look up the value of **-0.2** in the **Z Table**:

z	0	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
-3.0	0.0013	0.0013	0.0013	0.0012	0.0012	0.0011	0.0011	0.0011	0.0010	0.0010
-2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
-2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
-2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
-2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
-2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
-2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
-2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
-2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
-2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
-2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
-1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
-1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
-1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
-1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
-1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
-1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
-1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
-1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
-1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
-1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
-0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611
-0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
-0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
-0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
-0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
-0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
-0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
-0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
-0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
-0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641

The table shows that 0.4207, or 42.07%, of the plants are shorter than 26 inches. However, our objective is to find the percentage of plants **greater** than 26 inches. Since the total **area under the curve** is 100%, we subtract the table value from 1:

$$100\% - 42.07\% = \mathbf{57.93\%}$$

Thus, approximately **57.93%** of the plants in the garden are taller than 26 inches. This subtraction step is vital whenever you are looking for values "greater than" or "at least" a certain number.

Example 3: Calculating Probabilities Between Two Bounds

A common task in **data analysis** is finding the **probability** that a value falls within a specific range.

Imagine a marine biology study focusing on a dolphin species where the weights are **normally distributed**. The mean weight (μ) is 400 pounds, and the **standard deviation** (σ) is 25 pounds. We want to find the percentage of dolphins weighing between 410 and 425 pounds.

Step 1: Find the Z-Scores for Both Values

We must calculate two distinct **z-scores** to define the boundaries of our range:

For 410 pounds: $z = (410 - 400) / 25 = 10 / 25 = 0.4$

For 425 pounds: $z = (425 - 400) / 25 = 25 / 25 = 1.0$

Step 2: Use the Z Table to Find Cumulative Percentages

First, we find the cumulative **probability** for the lower bound ($z = 0.4$):

z	0	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	0.9131	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	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706

The table gives us a value of 0.6554. Next, we find the probability for the upper bound ($z = 1.0$):

z	0	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	0.9131	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	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706

The table gives us a value of 0.8413. To find the percentage of dolphins between these two weights, we subtract the smaller area from the larger area:

$$0.8413 - 0.6554 = \mathbf{0.1859}$$

Consequently, approximately **18.59%** of the dolphin population weighs between 410 and 425 pounds. This method of subtraction allows analysts to isolate specific segments of a **normal distribution**.

Practical Applications of the Z Table in Various Fields

The **Z Table** is not merely an academic exercise; it is a functional tool used daily across multiple industries. In **economics**, for instance, analysts use it to assess market risks and the likelihood of price fluctuations. By understanding the distribution of historical returns, investment firms can estimate the **probability** of a portfolio losing a certain amount of value over a given period, which is fundamental to risk management.

In manufacturing and quality control, the **Z Table** helps engineers maintain product standards. If a machine produces parts with a specific diameter, the **standard deviation** of those diameters allows the team to calculate how many parts will likely fall outside acceptable tolerances. This application of **statistics** ensures that companies can minimize waste and maintain high levels of customer satisfaction by predicting failure rates before they occur.

Furthermore, in the medical field, the **Z Table** is used to interpret clinical test results. Growth charts for children, for example, are based on **normal distributions** of height and weight for specific age groups. When a pediatrician tells a parent that their child is in the "90th percentile," they are essentially reporting a result derived from a **z-score**. This standardized approach allows healthcare providers to monitor development accurately over time.

Assumptions and Limitations of Using the Z Table

While the **Z Table** is incredibly powerful, its accuracy depends on several key assumptions. The most critical requirement is that the underlying data must follow a **normal distribution**. If the data is heavily skewed or contains significant outliers, the **z-score** calculations may lead to incorrect conclusions. Analysts often use visual tools like histograms or formal tests like the Shapiro-Wilk test to verify normalcy before proceeding with these statistical methods.

Another limitation involves the size of the sample. The **Z Table** is technically designed for situations where the population parameters (the mean and **standard deviation**) are known. When these values are unknown and must be estimated from a small sample size, statisticians often turn to the t-distribution instead. However, as the sample size increases, the t-distribution becomes nearly identical to the **standard normal distribution**, making the **Z Table** appropriate for large-scale **data analysis**.

Finally, it is essential to remember that **statistics** provide probabilities, not certainties. A **Z Table** can tell you that there is a 95% chance an event will occur, but it cannot guarantee the outcome of a single trial. Recognizing these nuances is what distinguishes a skilled researcher from one who simply follows a formula. By combining the **Z Table** with critical thinking and rigorous data collection, analysts can unlock deep insights into the world around them.

Conclusion: The Enduring Value of Statistical Standardization

In conclusion, the **Z Table** remains an indispensable asset in the toolkit of anyone working with data. By bridging the gap between raw measurements and cumulative **probability**, it allows for a level of comparison and prediction that would otherwise be impossible. From comparing exam scores to calculating the weights of marine life, the versatility of the **z-score** ensures its continued relevance in an increasingly data-driven world.

Mastering the use of the **Z Table** involves understanding the **standard normal distribution**, accurately calculating **z-scores**, and correctly interpreting the table's values based on the direction of the inquiry. While modern computers can perform these tasks in milliseconds, the conceptual understanding gained from manual calculation is invaluable. It provides a foundation for more advanced **statistics**, such as hypothesis testing and confidence intervals.

As you continue to explore the field of **data analysis**, the **Z Table** will serve as a reliable guide. Whether you are an economist predicting market trends or a student preparing for a test, the ability to interpret the **area under the curve** is a skill that will serve you well. By following the examples and principles outlined in this guide, you are now better equipped to use this essential tool to make informed, data-backed decisions.

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