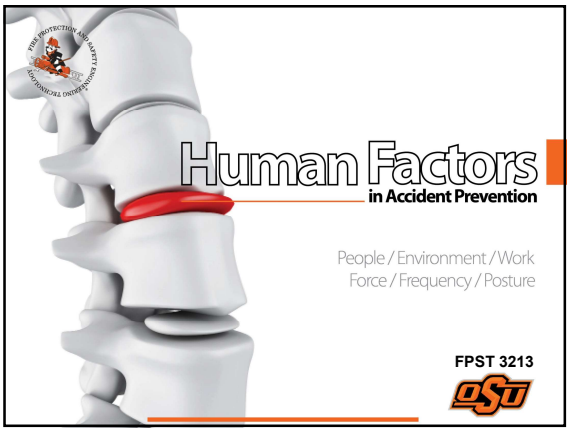


Anthropometry

Part 1

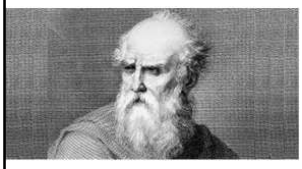
Objectives

- Know what Anthropometry is
- Know the types of measurements that can be made
- Understand how anthropometry is used for ergonomics and workplace design

Anthropometry

- From the Greek
  - Anthro- : man
  - pometry: measurements
  - Literal meaning: “measurement of humans”
- A branch of anthropology

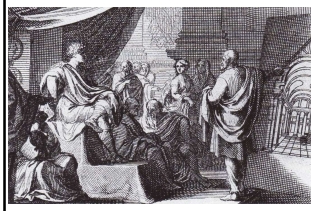
Vitruvius – 15 BC



https://www.davincilife.com/vitruvianman.html

- Vitruvius
  - Roman author, architect, civil engineer and military engineer
  - First century Roman architect and author of "De Architectura libri X” (the 10 books on Architecture).

The Vitruvian Man

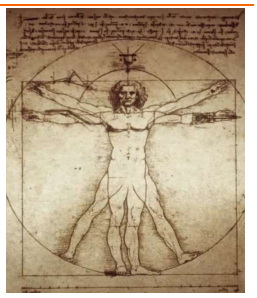


He proposed that a properly constructed temple should reflect and relate to the parts of the human body

https://www.davincilife.com/vitruvianman.html

Anthropometry

- Leonardo da Vinci
  - Vitruvian Man



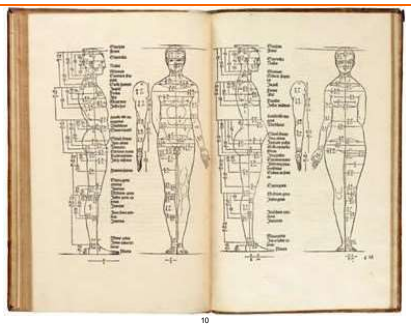
Four Books of Human Proportions

- Albrecht Dürer - 1471-1528
  - "Four Books on Human Proportion of 1528"
- Dürer's books may be regarded as the beginnings of modern scientific anthropometry

Four Books of Human Proportions

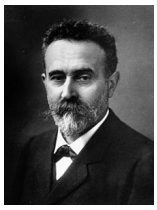
"If you wish to make a beautiful human figure, it is necessary that you probe the nature and proportions of many people: a head from one; an arm, leg from another…"

Four Books of Human Proportions



History of Anthropometry

- 1883- Alphonse Bertillon



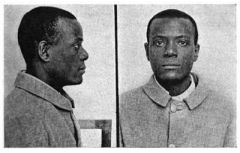
History of Anthropometry

Sir Francis Galton 1822-1911

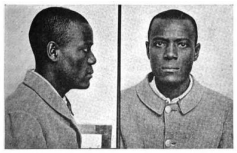
Eugenics Propaganda

- Aryan vs. non-Aryan
  - associated by many with the racial ideologies and atrocities committed by the Nazis

1903 The West Case

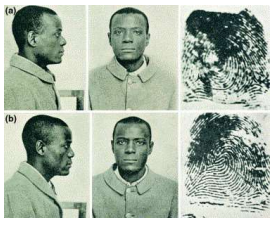


Will West



William West

1903 The West Case



Anthropometric Data

- What are some valuable ways that anthropometric data can be used?

Anthropometry

- Anthropometry is a valuable tool for guiding the health and nutritional status of individuals and populations

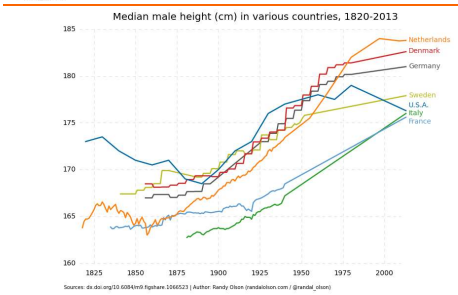
Anthropometric Data

- Furniture dimensions
- Clothing sizes
- Operator Controls
- Vehicle interiors
- Airplane seat widths
- Door heights
- Exit access
- Cell phone widths
- Shoe sizes
- Tools

Anthropometric Data

Are the body dimensions of the human population constant over the time?

Anthropometric Data



Anthropometric Data

- Tools should be adapted to accommodate different populations.
  - Reduce worker fatigue
  - Increase safety
  - Increase performance

Anthropometric Measuring Techniques

- Weight
- Height
- Posture:
  - Standing
  - Sitting
- Arm Span
- Head Length
- Head Breadth
- Ear-to-Head Height
- Reach
- Grip strength
- Limb length

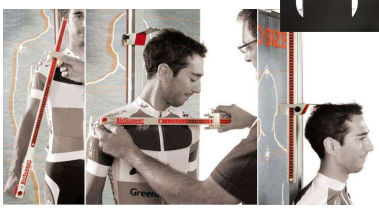
Anthropometric Measuring Tools

Anthropometric Measuring Tools

- Goniometer
  - Precision angular measurement

Anthropometric Measuring Tools

- Calipers

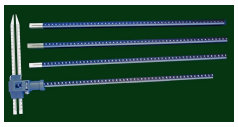


Anthropometric Measuring Tools

- Spreading caliper
  - measure distance between two points where one or both points may not be on a flat surface

Anthropometric Measuring Tools

- Anthropometer



Anthropometric Measuring Tools

- Measuring grip strength

Factors Affecting Anthropometry

Factors Affecting Anthropometry

- Human Diversity
  - Gender differences
  - Age differences
  - Growth and development
  - Environment
  - Aging – perceptual and cognitive abilities
  - Nutrition
  - Life style

Growth and Development

- At birth:
  - 7-8 pounds
  - 18" length
    - Torso represents 70%
- 20 years later
  - Body length increases three to four times
  - Weight increases 20 times
  - Linear proportions change
    - Torso accounts for only 52% of the stature

Growth and Development

At 40, we begin to shrink

- Accelerates with age
- Women shrink more than men
- Believed to occur in the intervertebral discs of the spine

Examples of Anthropometric Uses

- Driving
  - The mismatch of a heavy-vehicle operator's station to a driver could produce blind spots that limit safe operation
- Respirators
  - The misfit of a respirator could result in serious health effects in firefighting, hazardous waste cleanup
- Aircraft
  - Inadequate crew station geometry was found to be a contributor to some crew members injuries during ejection from an aircraft

Anthropometric Differences in Workgroups

- 2002 NIOSH Study
  - The increasing demands for anthropometric information for the design of machinery and PPE
  - The study identified differences in various body measurements between occupational groups in the USA.
- Fire fighter gloves
- Fire truck seatbelts
- Truck cab designs
- Fall protection harnesses

Work design or modification

Do the workers fit in the workplace?

Does the design of the equipment have any adverse effect on the worker's safety or productivity?

Work design or modification

Factors need to be considered:

1. Safe clearances or heights – examples, doorways or walkways
2. Safe reach distances – examples, equipment controls
3. Code requirements
4. Safety features – examples, machine guards
5. Workstation design for work flows.

Use of Anthropometric Data

Designing for the maximum, the average or minimum population?

Use of Anthropometric Data

- Designing for the maximum population
  - Examples, heights of doorways, sizes of an escape hatches, strength of rope ladders, strength of the workbenches
- Designing for the minimum population
  - Examples: distance of a control button from the operator, force required to operate the controls

Use of Anthropometric Data

- Designing for the average
  - There is no “average” individual
  - A person may be average on one or two body dimensions, but not all of them
  - Should only be done after careful consideration of the situation and never as an easy way out

Use of Anthropometric Data

- Designing for adjustable range
  - The obvious preferred method
  - Examples: automobile seats, office chairs, desk heights, footrests
  - Adjustable range is from XXX to XXX

Use of Anthropometric Data

- Designing for adjustable range
  - Adjustable range is from the 5th percentile female to the 95th percentile male

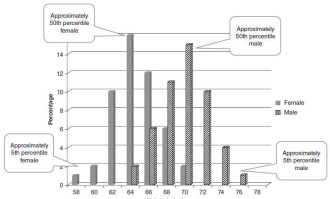


Figure 3.6 Statures with percentiles

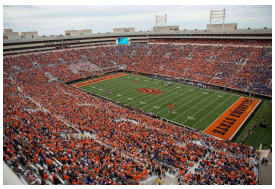
Use of Anthropometric Data

- Define the population that will use the equipment
  - Children, women, US civilians, age group, etc.
- Determine the body dimensions important in the design
  - Sitting height as a basic factor in a seat to roof dimension in automobiles
- Determine what principle should be applied
  - Design for extremes
  - Design for adjustability
  - Design for average
- Select the relevant population to be accommodated
  - Locate anthropometric tables appropriate for the population
- Allow for appropriate special clothing as applicable
- Build a full-scale mock-up

Modern Uses of Anthropometrics

Modern Uses of Anthropometrics

- Boone Pickens Stadium
  - 2016 – 60,218
  - 2017 – 56,790
  - 2016 – 12-16” wide
  - 2017 – 20” wide



Modern Uses of Anthropometrics

Modern Uses of Anthropometrics

Anthropometry Today

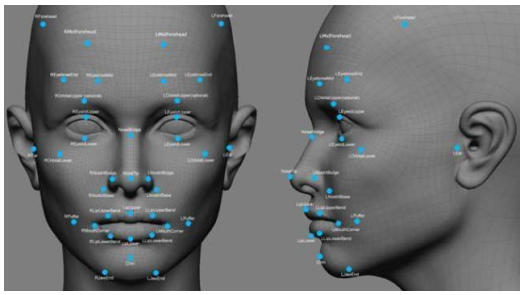
Anthropometry Today

- Biometrics
- Sports Performance – Tools to measure human movement include video, accelerometer, medical imaging, and 3-D motion capture
- Dynamic anthropometry

Anthropometry Today

- Changes in humans overtime
- Hand Geometry
- Face Location
- Multibiometrics

Facial Recognition Technology



Facial Recognition Technology

Identification → Authentication

Measurement → Match

Facial Recognition Technology

- Forensics: criminal identification and prison security
- Prevention of unauthorized access to ATMs, cellular phones, workstations, and computer networks
- Automobiles: replace keys with key-less entry and key-less ignition
- Border control and national ID cards

Biometrics in Use

BenGurion Airport:
Hand Geometry

INSPASS:
Hand Geometry

Heathrow
Airport- Iris

FacePass:
Face Verification

Grocery Store
Payment: Fingerprint

Biometrics in Use

https://www.youtube.com/watch?v=239jmYOhF9c

Anthropometric tables

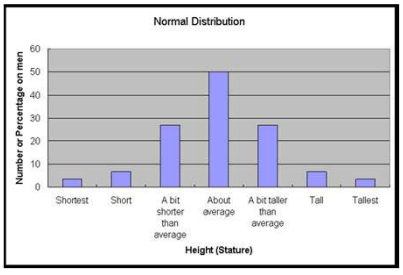
- Frequency distribution
  - Mean
  - Median
  - Standard deviation
  - Percentiles

Average Male Height Worldwide

TABLE 3.1 Height in Inches for Males Aged 20 and Over and Number of Examined Persons, Mean, Standard Error of the Mean, and Selected Percentiles, by Race and Ethnicity and Age

Race and Ethnicity	Number of Examined Persons	Mean	Standard Error of the Mean	Percentile								
				5th	10th	15th	25th	50th	75th	85th	90th	95th
All racial and ethnic groups[a]												
20 years and over	5647	69.3	0.08	64.3	65.4	66.2	67.3	69.3	71.2	72.3	73.0	74.1
20–29 years	895	69.4	0.13	64.4	65.5	66.5	67.4	69.4	71.5	72.6	73.1	74.1
30–39 years	948	69.5	0.14	64.4	65.4	66.3	67.5	69.5	71.6	72.6	73.3	74.2
40–49 years	934	69.6	0.17	64.9	66.0	66.6	67.6	69.6	71.5	72.6	73.5	74.4
50–59 years	938	69.5	0.13	64.5	65.8	66.3	67.7	69.7	71.3	72.3	72.8	74.4
60–69 years	932	68.8	0.10	63.9	64.8	65.7	66.9	69.0	70.7	71.9	72.6	73.6
70–79 years	646	68.2	0.13	63.6	64.6	65.2	66.3	68.2	70.0	70.9	71.9	72.7
80 years and over	354	67.2	0.15	62.5	63.7	64.4	65.3	67.3	69.2	69.9	70.4	71.5

Whom to Design for?



Design principles
- Design for extremes
- Design for adjustability
- Design for average

Basic statistical functions

- The examples that follow are for a Population
- If the data is a Sample then the calculation changes

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
- What is the mean?
- What is the sample standard deviation?
- What is the population standard deviation?

Problems

- Anthropomorphic measurements (feet):

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

Units

1.62 feet = 49.37 cm

1 foot = 30.48 cm

Basic statistical functions

- Median – the "middle" of a sorted list of numbers

Median

Total amount of data is an odd number

1.55
1.57
1.58
1.59
1.61
1.62
1.62
1.67
1.75
1.80
1.86
1.99
2.10

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
- What is the sample standard deviation?
- What is the population standard deviation?

Median even number

Total amount of data is an even number

1.55
1.57
1.58
1.59
1.61
1.62
1.62
1.63
1.67
1.75
1.80
1.86
1.99
2.10

Median even number

Total amount of data is an even number

the **median** is the average of the middle two **numbers**

1.55
1.57
1.58
1.59
1.61
1.62
1.62
1.63
1.67
1.75
1.80
1.86
1.99
2.10

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
- What is the sample standard deviation?
- What is the population standard deviation?

Basic statistical functions

- Mean – the average of a data set

$$\overline{x} = \frac{\sum_{i=1}^{N} x_i}{N}$$

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
  - 1.71615385
- What is the sample standard deviation?
- What is the population standard deviation?

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
  - 1.72
- What is the sample standard deviation?
- What is the population standard deviation?

Basic statistical functions

- The standard deviation is a measure of the amount of variation or dispersion of a set of values.

Standard Deviations

Standard Deviation-Sample

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

N = number of data points
X = each data point
$\overline{x}$ = Mean of the sample data points

Standard Deviation-Population

$$\sigma = \sqrt{\frac{1}{N}\sum_{i=1}^{N}(x_i - \mu)^2}$$

X_i = is an individual value
μ = is the average of the population
N = is the total number of the population

Standard Deviations

1.55	-0.17	0.0289					
1.57	-0.15	0.0225					
1.58	-0.14	0.0196					
1.59	-0.13	0.0169					
1.61	-0.11	0.0121					
1.62	-0.1	0.01					
1.62	-0.1	0.01					
1.67	-0.05	0.0025					
1.75	0.03	0.0009					
1.8	0.08	0.0064					
1.86	0.14	0.0196					
1.99	0.27	0.0729					
2.1	0.38	0.1444					
		0.3667	0.028208	0.167951		0.167907	
1.72						=STDEV.P(D3:D15)	

Problems

- Anthropomorphic measurements:

1.62	1.75
1.57	1.61
2.10	1.67
1.86	1.80
1.58	1.55
1.99	1.62
1.59	

- What is the median?
  - 1.62
- What is the mean?
  - 1.72
- What is the population standard deviation?
  - 0.17
- What is the sample standard deviation?
  - ?

Understanding Variance

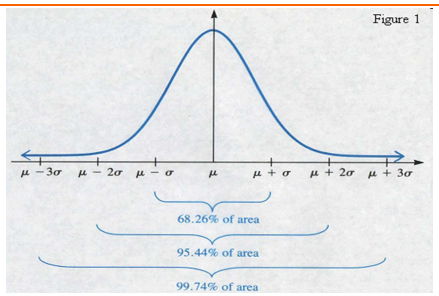
- "What is the Variance?"
  - Formally, it is the expectation of the squared deviation of a random variable from its mean
  - Informally, it measures how far a set of (random) numbers are spread out from their average value

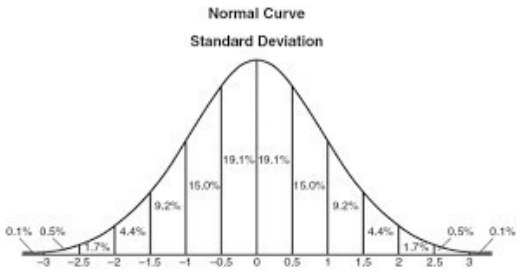
Variance

$$S^2 = \frac{\sum(x_i - \bar{x})^2}{n-1}$$

S^2 = sample variance
x_i = the value of the one observation
$\bar{x}$ = the mean value of all observations
n = the number of observations

Statistical Characteristics





Expected value – Example 1

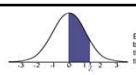
The amount of mustard dispensed from a machine is normally distributed with a mean of **0.9** ounce and a standard deviation of **0.1** ounce. If the machine is used **500** times, approximately how many times will it be expected to dispense **1** or more ounces of mustard?

Expected value

The expected value is calculated by multiplying each of the possible outcomes by the likelihood each outcome will occur and then summing all of those values.

$$E(X) = \sum_{i=1}^{n} x_i \,.\, p(x_i)$$

Standard Normal Table (Z)

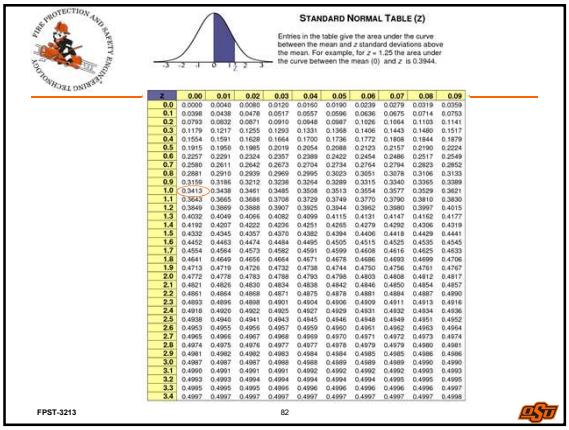


Entries in the table give the area under the curve between the mean and z standard deviations above the mean. For example, for $z = 1.25$ the area under the curve between the mean (0) and z is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0190	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	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	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	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	0.2969	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	0.3513	0.3554	0.3577	0.3529	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	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	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	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	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	0.4864	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	0.4982	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	0.4995	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

If one standard deviation is added to the mean, the result is 1.0 oz 1.0 = 0.1+0.9

1.0 is the valuable that we need to look for in the Z table



STANDARD NORMAL TABLE (Z)

Entries in the table give the area under the curve between the mean and z standard deviations above the mean. For example, for $z = 1.25$ the area under the curve between the mean (0) and z is 0.3944.

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	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	0.0596	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	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	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	0.2969	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	0.3513	0.3554	0.3577	0.3529	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
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1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
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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	0.4864	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	0.4982	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	0.4995	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

0.5 - 0.3413 (from table) = 0.1587

15.9% of the data falls at or above 1 standard deviation

Expected value

$$E(X) = \sum_{i=1}^{n} x_i \,.\, p(x_i)$$

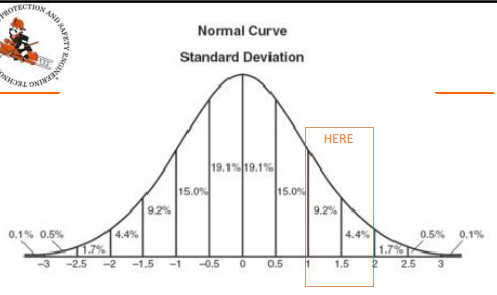
500*0.159 =79.5 or 80

It will be expected to dispense **1** or more ounces of mustard 80 times

Expected value – Example 2

A college mathematics lecture class has **184** students. The scores on the midterm exam are normally distributed with a mean of **72.3** and a standard deviation of **8.9**. How many students can be expected to receive a score between **81 and 90**?

- 1 standard deviation = 8.9
- Mean + 1 standard deviation 72.3 + 8.9 = 81.2
- 90.1 on the exam is 2 standard deviations from the mean



- Looking at the bell curve, between 1 and 2 standard deviations from the mean accounts for (9.2 + 4.4) 13.6% of the class

- Expected value = 184*(0.136) = 25 students
- It is expected that 25 students scored between 81 and 90

In class exercise

In class exercise

- Stand up straight will your arm straight down to your side.
- Place the end of the measuring tape at the top of the shoulder.
- Extend the measuring tape down the arm, until the tip of the middle finger is reached.
- Record the length of the arm (to the nearest centimeter) in the provided table.

Only one member per team needs to submit the table. This assignment is due by the end of the class period.