THE ARCHITECT'S MATH

A 7th-Grade Survival Workbook

200 Problems. 10 Chapters. Zero Guesswork.

Global Sovereign University

Building a Bridge to Freedom Through Education—Not Handouts

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THE ARCHITECT'S MATH: A 7th-Grade Survival Workbook

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DEDICATION

To every student who was told they were "bad at math."

You were never bad at math. You were bored by irrelevant problems.

This book gives you a reason to care.

TABLE OF CONTENTS

HOW TO USE THIS BOOK

This is not a traditional math textbook. There are no cartoons. There are no participation trophies. There are no problems about buying 47 watermelons.

Instead, you are the architect of a settlement. Every problem in this book is a real operational decision: How much fuel do you need? Can the bridge hold? Will the crops survive? How many days until the water runs out?

The math is real. The stakes are real. The skills transfer directly to the world outside your classroom.

The Structure

The book is organized into 5 Modules covering the 5 pillars of 7th-grade mathematics. Each module contains 2 chapters. Each chapter contains 20 problems and a complete answer key at the back of the book.

Module 1: The Number System (Chapters 1–2) — Survival & Logistics

Module 2: Ratios and Proportional Relationships (Chapters 3–4) — Economics

Module 3: Expressions and Equations (Chapters 5–6) — Systematizing the Settlement

Module 4: Geometry (Chapters 7–8) — Engineering & Infrastructure

Module 5: Statistics and Probability (Chapters 9–10) — Risk & Quality Control

How Each Chapter Works

1. Learning Objectives — What you will be able to do after completing this chapter.

2. Key Vocabulary — Critical mathematical terms defined in plain language.

3. Worked Examples — Step-by-step demonstrations showing exactly how to solve the type of problem you are about to face. Study these before attempting the problems.

4. The 20 Problems — Your operational challenge. These are arranged from foundational to advanced.

5. Answer Key — Located at the back of the book. Every answer includes the mathematical work, not just the final number.

The Badge System

After completing each chapter, score yourself honestly:

BRONZE (0–10 correct) — Casualty: You survived, but you are bleeding. Massive tactical blind spots.

SILVER (11–14 correct) — Liability: You recognize the theory, but your application is flawed. Under pressure, you will revert to bad habits.

GOLD (15–18 correct) — Operator: Functional competence. You understand the rules and can execute without supervision.

PLATINUM (19–20 correct) — Architect: Sovereign Mastery. You do not just know the answers; you understand the underlying architecture.

THE STANDING ORDER: If you stall out at Bronze or Silver, the chapter just did its job. It proved you lack the ammunition required for this subject. Do not guess your way to the top. Study the worked examples, review your errors, and return when you are ready to execute.

MODULE 1: THE NUMBER SYSTEM

Survival & Logistics

In the real world, numbers are not always friendly. Temperatures drop below zero. Bank accounts go into the red. Debts are negative. Surpluses are positive. A settlement that cannot compute with rational numbers—positive and negative integers, fractions, and decimals—is a settlement that will be destroyed by its own bookkeeping.

In Module 1, you will master the language of gain and loss. Chapter 1 focuses on addition and subtraction of integers: assets minus debts, temperatures rising and falling, and populations growing and shrinking. Chapter 2 scales the operations: multiplication and division of rational numbers, including fractions and decimals that govern ratios, labor rates, and expansion planning.

By the end of this module, you will handle any rational number—positive, negative, whole, fractional, or decimal—with the confidence of someone whose survival depends on the calculation. Because in this book, it does.

CHAPTER 1: ASSETS AND DEFICITS

Adding and Subtracting Integers

Theme: Settlement Founding & Resource Management

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Learning Objectives

After completing this chapter, you will be able to:

• Add and subtract positive and negative integers in real-world contexts.

• Interpret negative numbers as debts, deficits, below-zero temperatures, and below-sea-level elevations.

• Perform multi-step integer operations involving three or more terms.

• Determine net results when gains and losses occur simultaneously.

Key Vocabulary

Integer: Any positive or negative whole number, including zero. Examples: −12, 0, 45.

Positive Number: A number greater than zero, representing a gain, surplus, or asset.

Negative Number: A number less than zero, representing a loss, debt, or deficit. Written with a minus sign: −8.

Absolute Value: The distance a number is from zero on the number line, always expressed as a positive. The absolute value of −7 is 7.

Net Result: The final amount after all gains and losses are calculated. Also called the net balance.

Deficit: A shortfall; when you need more than you have. Represented as a negative number.

Worked Examples

WORKED EXAMPLE: Combining Gains and Losses

The settlement starts with 600 pounds of dried meat. Wolves raid the storehouse and destroy 185 pounds. A hunting party then returns with 90 pounds. What is the final inventory?

Step 1: Start with the initial value: 600

Step 2: Subtract the loss: 600 − 185 = 415

Step 3: Add the gain: 415 + 90 = 505

Answer: 505 pounds of dried meat.

WORKED EXAMPLE: Working with Negative Numbers (Debt)

A colonist owes the central storehouse −$60 for emergency rations. They perform guard duty and earn $45. What is their new balance?

Step 1: Write the starting balance: −60

Step 2: Add the earnings: −60 + 45

Step 3: When adding a positive to a negative, subtract the smaller absolute value from the larger: 60 − 45 = 15. Since the negative had the larger absolute value, the result is negative: −15

Answer: −$15 (the colonist still owes $15).

WORKED EXAMPLE: Temperature Drops Below Zero

The temperature at noon is 8°F. A blizzard drops the temperature by 23°F. What is the temperature now?

Step 1: Start at 8°F.

Step 2: Subtract the drop: 8 − 23

Step 3: Since 23 is larger than 8, the result crosses below zero: 8 − 23 = −15

Answer: −15°F.

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Instructions

In the real world, you cannot spend what you do not have without going into debt. Use addition and subtraction of positive and negative numbers to balance the settlement's books.

1. The First Harvest: Your settlement starts the month with 450 bushels of wheat. The colonists consume 185 bushels. How many bushels are left in the storehouse?

2. Cold Front: The temperature at sunset is 14°F. A harsh winter storm rolls in, dropping the temperature by 22°F overnight. What is the new temperature at dawn?

3. Lumber Deficit: The builders need 500 logs to finish the housing block. They currently have 320 logs, leaving them with a deficit of −180. The logging team brings in 95 logs. What is the settlement's new lumber deficit?

4. Trade Ledger: Your settlement trades with a neighboring outpost. You begin with a ledger balance of −$45 (you owe them). You sell them purified water for $115. What is your new ledger balance?

5. Water Reserves: The main cistern holds 8,000 gallons of water. A leak causes a loss of 1,250 gallons, and daily consumption uses another 400 gallons. A rainstorm then adds 850 gallons. What is the final volume of water in the cistern?

6. Tool Degradation: The blacksmith has 42 usable iron axes. During a heavy clearing operation, 15 axes break, but the smith manages to forge 8 new ones. How many functional axes remain?

7. Elevation Mapping: A scouting party starts at the settlement base camp at an elevation of 250 feet above sea level. They descend 315 feet into a deep ravine to find fresh water. What is their current elevation relative to sea level?

8. Caloric Deficit: A worker needs 2,500 calories a day to maintain their weight. Yesterday, a worker only consumed 1,800 calories, resulting in a deficit of −700 calories. Today, they consume 3,100 calories. What is their net caloric balance over the two days?

9. Debt Forgiveness: A colonist owes the central storehouse −$80 for winter supplies. They perform extra guard duty, earning $55. The settlement council then forgives $15 of the remaining debt. What is the colonist's final balance?

10. Livestock Management: The settlement begins with a herd of 84 cattle. Predators take 6, a neighboring settlement gifts you 12, and 4 die of illness. What is the final herd count?

11. Sub-Zero Logistics: The medicine must be kept at exactly −5°C. The current temperature of the icebox is 3°C. How many degrees must the temperature drop to reach the required storage level?

12. The Coal Supply: The forge requires 200 pounds of coal per week. The settlement currently has a supply of −50 pounds (they had to borrow from a private citizen). A mining team returns with 340

pounds of coal. After paying back the borrowed coal, how much surplus is left toward the weekly requirement?

13. Wall Construction: The defensive wall requires 1,200 stone blocks. The quarry team mines 450 blocks on Monday, but 35 of them are fractured and unusable. They mine another 500 blocks on Tuesday. How many blocks are still needed to finish the wall?

14. Barter Economy: You trade away 40 pounds of salted meat (−40) and in return receive 65 pounds of grain (+65). If you started the day with 100 pounds of meat and 0 pounds of grain, what is your inventory of both items now?

15. Fuel Crisis: The settlement generator has 40 gallons of diesel. It burns 12 gallons on Monday and 15 gallons on Tuesday. On Wednesday, a scavenger finds 8 gallons and adds it to the tank. How many gallons remain?

16. Trench Digging: The irrigation trench must be dug to a depth of −8 feet. The crew digs down 3 feet on the first day, and another 4 feet on the second day. How many more feet must they dig to reach the target depth?

17. Population Fluctuation: The settlement population is exactly 300. In one year, 14 people leave to start a new camp, 8 people are born, and a group of 22 refugees joins the settlement. What is the new population?

18. Financial Ruin: A trader arrives with a net worth of −$150. They sell a rare artifact for $300, but are immediately fined $50 for bringing contraband into the settlement. What is the trader's final net worth?

19. Battery Reserves: The solar battery bank is at 100% capacity. An overcast week drains 45% of the power. A brief sunny day recharges 18%, but a night of heavy machinery use drains another 30%. What is the battery's current percentage?

20. The Final Tally: At the end of the year, the settlement's gross asset value is $4,500. However, they incurred $1,200 in structural damages, owe $850 to a trade caravan, and lost $300 in spoiled crops. What is the true net worth of the settlement?

CHAPTER 2: SCALING OPERATIONS

Multiplying and Dividing Rational Numbers

Theme: Expansion, Labor Division, and Resource Burn Rates

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Learning Objectives

After completing this chapter, you will be able to:

- Multiply and divide integers, fractions, and decimals in operational contexts.
- Interpret repeated subtraction (negative rates over time) as multiplication by negative numbers.
- Convert between fractions, mixed numbers, and decimals to solve division problems.

• Determine how many whole units can be produced from a given resource (integer division with remainders).

Key Vocabulary

Rational Number: Any number that can be expressed as a fraction p/q where q is not zero. Includes integers, fractions, and terminating or repeating decimals.

Mixed Number: A number with a whole part and a fractional part: 3½ means 3 + ½.

Reciprocal: The flipped version of a fraction. The reciprocal of ¾ is 4/3. Used to convert division into multiplication.

Rate: A ratio comparing two different units. Example: 3.5 pounds per day, or $12.50 per week.

Depreciation: A decrease in value over time. Expressed as a negative rate.

Worked Examples

WORKED EXAMPLE: Multiplying a Decimal by an Integer

A heavy-labor worker requires 3.5 pounds of grain per day. The crew is deployed on a 14-day mission. How much grain must be loaded?

Step 1: Identify the rate: 3.5 pounds per day.

Step 2: Identify the duration: 14 days.

Step 3: Multiply: 3.5 × 14 = 49 pounds.

Answer: 49 pounds of grain.

WORKED EXAMPLE: Dividing a Mixed Number

A beam is 15¾ feet long. It must be cut into braces that are 1½ feet each. How many full braces can be cut?

Step 1: Convert mixed numbers to improper fractions: 15¾ = 63/4 and 1½ = 3/2.

Step 2: Divide by multiplying by the reciprocal: 63/4 × 2/3 = 126/12 = 10.5.

Step 3: You cannot use half a brace. Take the whole number only: 10.

Answer: 10 full braces.

WORKED EXAMPLE: Dividing a Negative Total Among a Group

Three merchants share a debt of −$450 equally. What is each merchant's share?

Step 1: Total debt: −$450.

Step 2: Number of merchants: 3.

Step 3: Divide: −450 ÷ 3 = −150.

Answer: −$150 per merchant.

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Instructions

Growth is not linear; it is a multiplier. Survival requires exact division of limited assets and calculating the trajectory of your deficits. Compute the following operational scenarios.

1. Ration Scaling: A heavy-labor worker requires 3.5 pounds of grain per day to maintain energy. If a logging crew is deployed on a 14-day mission, how many pounds of grain must be loaded onto their supply cart?

2. The Deep Freeze: The settlement's central heater fails. The internal temperature drops at a steady rate of −2.5°F every hour. What is the total temperature change after 6 hours?

3. Land Allocation: The Sovereign Council clears a new agricultural sector measuring exactly 12½ acres. They need to divide this land equally among 5 farming families. How many acres does each family receive?

4. Generator Efficiency: The backup diesel generator consumes 45.6 gallons of fuel over an 8-hour overnight shift. What is the exact fuel consumption rate per hour?

5. Shared Liability: A trade caravan loses valuable cargo in a storm, resulting in a debt of −$450. The 3 lead merchants agree to split the deficit equally. What integer represents each merchant's share of the debt?

6. Crop Yield Projections: An acre of modified soil yields ¾ of a ton of root vegetables. If the settlement expands its planting to 15 acres, what will be the total yield in tons?

7. Labor Optimization: A builder works 8.5 hours a day for 5 days. If a single housing frame requires 2.5 man-hours to assemble, how many complete frames can the builder finish in that week?

8. Lumber Processing: The sawmill produces a massive support beam that is 15¾ feet long. The architect orders it cut into smaller braces that are exactly 1½ feet long. How many full braces can be cut from the beam?

9. Asset Depreciation: A stockpile of untreated leather is exposed to the dampness, losing $12.50 in trade value every week. What is the total change in the stockpile's value after 4 weeks?

10. Water Distribution: A secondary cistern holds 1,200 gallons of water. The council orders ⅔ of the cistern to be pumped to the northern greenhouses. How many gallons are transferred?

11. Hauling Capacity: A reinforced transport cart can carry exactly 2¼ tons of stone. If the quarry team makes 3 fully loaded trips, how much total stone is brought into the settlement?

12. Tax Levies: To fund the new defensive perimeter, the settlement collects a total of $105.75 in silver from 15 independent merchants. If the levy was distributed equally, how much did each merchant pay?

13. Plummeting Temps: A specialized thermometer records that the temperature dropped a total of −18.6°C over a period of 3 days. What was the average change in temperature per day?

14. Medical Triage: The clinic has a jar containing 5¼ ounces of burn salve. Each standard treatment requires exactly ⅜ of an ounce. How many full treatments can the medic administer before running out?

15. Solar Yield: A newly installed solar panel array generates 2.25 kilowatts of power per hour. On a clear day with 6.5 hours of peak sunlight, what is the total power generated?

16. Drilling the Well: The engineering team is drilling a new deep-water well. The drill bites into the earth at a rate of −4.5 feet per hour. Where is the drill head relative to the surface after an 8-hour shift?

17. Perimeter Defense: A section of the perimeter trench is 40½ yards long. A steel stake must be driven into the ground every ¾ of a yard to hold the barricade wire. How many stakes are required?

18. Winter Caloric Burn: During a blizzard, a scout's body burns energy at 1.5 times the normal rate. If the standard daily burn rate is 2,500 calories, how many calories does the scout burn during the blizzard?

19. The Granary Leak: A slow rat infestation is consuming the grain reserves at a rate of −3.2 pounds per day. If left unchecked for two full weeks (14 days), what is the total loss to the food supply?

20. Profit Distribution: A successful scavenging run yields tech components that sell for a total net profit of $450.50. The 4 operators on the crew split the profit evenly. To the nearest cent, how much does each operator take home?

MODULE 2: RATIOS AND PROPORTIONAL RELATIONSHIPS

Economics

A settlement cannot survive on guesswork. If your water purifier processes 45 gallons per hour, you must know exactly how long it takes to fill a 1,200-gallon cistern. If your map says 1 inch equals 40 feet, you must know the exact length of the defensive wall.

Module 2 teaches proportional reasoning—the ability to scale relationships up and down with precision. Chapter 3 covers unit rates, proportions, and the logic of supply chains. Chapter 4 introduces percentages, tax calculations, profit margins, and scale drawings.

This is where most students get left behind in the legacy system. By framing proportional reasoning around survival and trade, the math becomes a tool instead of a chore.

CHAPTER 3: SUPPLY CHAINS AND YIELDS

Proportions, Unit Rates, and Resource Scaling

Theme: Logistics, Production, and Trade

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Learning Objectives

After completing this chapter, you will be able to:

- Calculate unit rates from given data (output per hour, cost per unit, miles per gallon).
- Set up and solve proportional relationships using cross-multiplication.
- Scale production rates to predict future output.
- Apply proportional reasoning to map scales and resource conversion ratios.

Key Vocabulary

Ratio: A comparison of two quantities, expressed as a fraction, with a colon, or in words. Example: 5 pounds of salt for every 2 pelts (5:2).

Unit Rate: A rate simplified so the denominator is 1. Example: 45 gallons per hour, $7.05 per merchant.

Proportion: An equation stating that two ratios are equal: a/b = c/d.

Cross-Multiplication: A method for solving proportions: if a/b = c/d, then a × d = b × c.

Scale: The ratio between a drawing or model and the real object. Example: 1 inch = 40 feet.

Worked Examples

WORKED EXAMPLE: Finding a Unit Rate

The filtration system purifies 180 gallons in 4 hours. What is the rate per hour?

Step 1: Set up the rate: 180 gallons ÷ 4 hours.

Step 2: Divide: 180 ÷ 4 = 45.

Answer: **45 gallons per hour.**

WORKED EXAMPLE: Solving a Proportion

A scout gathers 3.5 pounds of mushrooms in 2 hours. How long to gather 14 pounds?

Step 1: Find the unit rate: 3.5 ÷ 2 = 1.75 pounds per hour.

Step 2: Divide the target by the rate: 14 ÷ 1.75 = 8.

Answer: **8 hours.**

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Instructions

A settlement cannot survive on guesswork. You must know exactly how much your systems produce and consume per unit of time or space. Calculate the unit rates and solve the proportional relationships to keep the logistics network intact.

1. Water Purification: The settlement's primary filtration system can purify 180 gallons of water in 4 hours. What is the unit rate of purification in gallons per hour?

2. Scout Vehicles: A perimeter patrol buggy uses 6 gallons of diesel to cover 135 miles of rough terrain. At this rate, how many miles can it travel on a full 10-gallon tank?

3. Agricultural Yield: A hydroponic greenhouse produces 320 pounds of tomatoes from 8 planting beds. If the Sovereign Council authorizes the construction of 5 more identical beds, how many total pounds of tomatoes will the 13 beds produce?

4. Labor Output: A crew of 3 miners can extract 450 pounds of raw iron ore in a standard 8-hour shift. How many pounds of ore can a crew of 7 miners extract in the same amount of time?

5. Trade Exchange: The neighboring outpost trades at a strict ratio: 5 pounds of salt for every 2 cured animal pelts. If your settlement needs 45 pounds of salt for winter preservation, how many pelts must you trade?

6. Wind Turbine Power: A standard wind turbine generates 24 kilowatts of power every 3 hours of steady wind. How much power does it generate in a full 24-hour period of steady wind?

7. Medical Rations: A 50-milliliter vial of liquid antibiotic contains exactly 8 adult doses. During an outbreak, the clinic needs to treat 36 adults. How many milliliters of the antibiotic are required?

8. Masonry Metrics: An experienced builder can lay 120 stone bricks in 1.5 hours. At this unit rate, how many bricks can the builder lay in an 8-hour workday?

9. Lumber Processing: The sawmill yields 45 usable board feet of lumber from every 2 raw pine logs. If the architect needs 315 board feet to frame a new clinic, how many raw pine logs must the logging team fell?

10. Textile Production: The settlement looms weave 14 yards of heavy canvas every 4 days. If it takes 21 yards of canvas to make a heavy winter tent, how many days of weaving does it take to produce enough material for one tent?

11. Fuel Consumption: The central furnace burns through 3.5 cords of wood in 2 weeks during the dead of winter. If the winter deep-freeze lasts for 12 weeks, how many cords of wood must be stockpiled?

12. Map Scaling: On the architect's blueprint, 2 inches represents a physical distance of 15 feet. If the defensive trench is drawn as 8.5 inches long on the blueprint, what is its actual physical length?

13. Caloric Density: A survival ration bar weighs 4 ounces and contains 1,400 calories. What is the unit rate in calories per ounce?

14. Ammunition Fabrication: The machinist can press and assemble 75 rifle cartridges in 15 minutes. How many cartridges can the machinist produce in 2.5 hours? (Hint: convert hours to minutes).

15. Seed Ratios: To properly sow a field, the agricultural manual dictates a ratio of 3 pounds of nitrogen fertilizer for every 10 pounds of wheat seed. If a farmer is planting 85 pounds of wheat seed, how much fertilizer is needed?

16. Foraging Efficiency: A scout gathers 3.5 pounds of edible mushrooms in 2 hours. At this exact rate, how long will it take the scout to gather 14 pounds of mushrooms?

17. Canning and Preserving: It takes 12 pounds of raw venison to produce 8 sealed jars of preserved meat. If hunters bring in a deer yielding 54 pounds of meat, how many jars can be preserved?

18. Water Pressure: A damaged pipe leaks 5 gallons of water every 12 minutes. If the pipe is not repaired for 3 hours, how many gallons of water are lost to the earth?

19. Smelting Iron: The forge requires 8 pounds of raw coal to smelt 5 pounds of pure iron ingots. If the blacksmith needs 40 pounds of pure iron for new tools, how much coal must be burned?

20. The Operator's Pace: A courier carrying vital intel runs 6 miles in 45 minutes. If they maintain this exact proportional pace, how many minutes will it take them to cover the remaining 8 miles to the outpost?

CHAPTER 4: THE SETTLEMENT ECONOMY

Percentages, Taxes, Margins, and Scale

Theme: Trade, Growth, and Cartography

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Learning Objectives

After completing this chapter, you will be able to:

- Calculate percentages of a given quantity (tax, markup, discount, growth, loss).
- Determine percent increase and percent decrease from original values.
- Interpret and use map scales to convert between drawing dimensions and real-world dimensions.
- Apply successive percentage changes (compound events) to find a final result.

Key Vocabulary

Percent: A ratio out of 100. 15% means 15 out of every 100.

Markup: A percentage added to the cost to set a selling price. A 15% markup on $40 adds $6.

Discount: A percentage subtracted from a price. A 20% discount on $25 saves $5.

Flat Tax: A fixed percentage applied equally to all transactions, regardless of amount.

Profit Margin: The profit divided by the original cost, expressed as a percentage.

Scale Drawing: A diagram where all dimensions are proportional to the real object, using a fixed ratio (e.g., 1 inch = 40 feet).

Worked Examples

WORKED EXAMPLE: Calculating a Percentage of a Number

The council implements a 6% flat tax on a $450 sale. How much goes to the defense fund?

Step 1: Convert the percentage to a decimal: 6% = 0.06.

Step 2: Multiply: $450 × 0.06 = $27.

Answer: **$27 goes to the defense fund.**

WORKED EXAMPLE: Percent Increase

Crop yield went from 1,200 pounds last season to 1,500 pounds this season. What is the percent increase?

Step 1: Find the difference: 1,500 − 1,200 = 300.

Step 2: Divide the difference by the original: 300 ÷ 1,200 = 0.25.

Step 3: Convert to a percentage: 0.25 × 100 = 25%.

Answer: 25% increase.

WORKED EXAMPLE: Successive Percentage Changes

6,000 crops exist. Locusts destroy 10%. Then frost destroys 20% of what remains. How many survive?

Step 1: Locust damage: 10% of 6,000 = 600. Remaining: 6,000 − 600 = 5,400.

Step 2: Frost damage: 20% of 5,400 = 1,080. Remaining: 5,400 − 1,080 = 4,320.

CRITICAL: You cannot just add 10% + 20% = 30%. The frost acts on the reduced amount, not the original.

Answer: 4,320 crops survive.

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Instructions

In an uncharted economy, numbers do not just add and subtract—they compound, they scale, and they decay. A Sovereign Architect must understand profit margins to survive trade, percentages to calculate taxes, and map scales to build the physical world. Compute the following operational scenarios.

1. Trade Markup: A neighboring outpost sells bulk medical kits for $40. Your traders buy them and mark up the price by 15% to cover the risks of transport. What is the new selling price inside your settlement?

2. Surplus Discount: The winter surplus of dried fish is initially priced at $25 per barrel. The Sovereign Council authorizes a 20% discount to clear the inventory before spring. What is the new price per barrel?

3. Crop Spoilage: A grain silo holds 800 pounds of wheat. A hidden moisture leak destroys 5% of the crop before it is caught. How many pounds are lost, and what is the remaining usable weight?

4. Population Growth: The settlement's population was 320 people at the end of last year. This year, due to an influx of refugees and new births, the population grew by 15%. What is the new total population?

5. The Flat Tax: To fund the construction of a new perimeter wall, the council implements a 6% flat tax on all trade goods. If a merchant sells $450 worth of iron tools, how much silver goes to the defense fund?

6. Yield Fluctuation: Last season, a designated farming plot produced 1,200 pounds of potatoes. This season, thanks to a newly engineered fertilizer, the yield increased to 1,500 pounds. What is the percent increase in the crop yield?

7. Scale Drawing (Distance): On the architect's map of the settlement, 1 inch represents 40 physical feet. The distance from the medical clinic to the central armory is measured at 4.5 inches on the map. What is the actual physical distance in feet?

8. Scale Drawing (Area): A blueprint shows a rectangular greenhouse measuring 3 inches wide by 5 inches long. If the map scale is 1 inch = 10 feet, what is the actual physical area of the greenhouse in square feet?

9. Equipment Failure Rate: Out of 250 solar panels installed in the northern grid, 15 failed during their first harsh winter. What percentage of the solar array failed?

10. Interest on Debt: A colonist borrows $300 from the central supply to buy a heavy plow, agreeing to a 4% simple interest rate per year. How much total money (principal plus interest) will they owe after exactly 1 year?

11. Resource Depletion: The primary coal reserve holds 5,000 tons. The settlement burns 8% of the total reserve over a single winter. How many tons of coal remain in the reserve?

12. Blueprint Conversion: The defensive wall needs to be exactly 2,400 feet long. If the architect's map uses a scale of 1 inch = 60 feet, how many inches long will the wall be drawn on the paper?

13. Protective Tariff: To protect the settlement's local blacksmiths from being undercut, a 12% tariff is placed on all imported iron goods. If a foreign trader brings in a shipment valued at $850, what is the total cost of the shipment after the tariff is applied?

14. Efficiency Upgrades: An old generator converted 60% of its fuel into usable power. The new generator converts 75% of its fuel into power. What is the absolute percentage point increase in efficiency?

15. Ration Cuts: Due to a severe drought, the standard daily water ration of 60 ounces per person must be reduced by 15%. What is the new daily water ration per person?

16. Profit Margin: A scavenger spends $120 repairing a salvaged all-terrain vehicle and sells it to a courier for $180. What is the profit margin (the profit divided by the original cost, expressed as a percentage)?

17. Scale Model Engineering: An engineer builds a 3D physical scale model of a new water tower to test wind resistance. The scale is 1 inch = 5 feet. If the actual water tower will be 45 feet tall, how tall is the scale model?

18. Hunting Success: A hunting party goes on 40 expeditions in a year. They return with major game on 28 of those trips. What is their success rate expressed as a percentage?

19. Tax Evasion Penalty: A merchant fails to pay their $150 trade tax on time. The council imposes a strict 20% late penalty on the unpaid tax. What is the total amount the merchant now owes?

20. Combined Threat: A field contains 6,000 mature crops. A swarm of locusts destroys exactly 10% of the crops. A week later, a sudden frost destroys 20% of the remaining crops. How many crops survive both events?

MODULE 3: EXPRESSIONS AND EQUATIONS

Systematizing the Settlement

Amateurs react to problems one by one. Architects write formulas so the system solves the problem automatically, no matter how the variables change.

In Module 3, you stop using fixed numbers and start using variables to build mathematical machinery. Chapter 5 teaches you to translate physical rules into algebraic expressions—the code that runs the settlement. Chapter 6 teaches you to solve that code: finding exact break-even points with equations, and determining safe operating limits with inequalities.

This is the pivot point in a student's mathematical development. After this module, you are no longer doing arithmetic. You are writing the software that runs the physical world.

CHAPTER 5: CODIFYING THE RULES

Equivalent Expressions, Combining Like Terms, and the Distributive Property

Theme: Translating Physical Rules into Mathematical Code

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Learning Objectives

After completing this chapter, you will be able to:

- Translate verbal rules and physical descriptions into algebraic expressions.
- Apply the distributive property to expand expressions like 4(3b + 2s).
- Combine like terms to simplify messy expressions into clean, professional form.
- Factor expressions by identifying the greatest common factor.

Key Vocabulary

Variable: A letter (like x, h, or w) that represents an unknown or changing quantity.

Expression: A mathematical phrase that contains numbers, variables, and operations but NO equals sign. Example: 5 + 2h.

Like Terms: Terms that have the same variable raised to the same power. 3x and 5x are like terms. 3x and 5y are not.

Distributive Property: Multiplying a number across a sum inside parentheses: a(b + c) = ab + ac.

Factoring: The reverse of distributing. Pulling out the greatest common factor: 18r + 24p = 6(3r + 4p).

Coefficient: The number multiplied by a variable. In the term 5x, the coefficient is 5.

Worked Examples

WORKED EXAMPLE: Writing an Expression from Words

"The total fuel required is 5 gallons for the generator, plus 2 gallons for every hour the spotlights run." Write this as an algebraic expression using h for hours.

Step 1: Identify the constant (does not change): 5 gallons.

Step 2: Identify the variable part: 2 gallons per hour = 2h.

Step 3: Combine: 5 + 2h.

Answer: 5 + 2h (or equivalently, 2h + 5).

WORKED EXAMPLE: Distributing and Combining Like Terms

Simplify: 5(2m + 3) − 4(m − 2).

Step 1: Distribute the 5: 5 × 2m + 5 × 3 = 10m + 15.

Step 2: Distribute the −4 (watch the negative!): −4 × m + (−4) × (−2) = −4m + 8.

Step 3: Combine: 10m + 15 − 4m + 8.

Step 4: Combine like terms: (10m − 4m) + (15 + 8) = 6m + 23.

Answer: 6m + 23.

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Instructions

You cannot manage a settlement if you have to recalculate the rules every time the population changes. You must learn to write and simplify algebraic expressions. Translate the physical realities of the settlement into clean, simplified mathematical code.

Note: These are expressions, not equations. Do not solve for the variable; your goal is to simplify the code to its most efficient form.

1. The Supply Code: Write an algebraic expression for this rule: "The total fuel required is 5 gallons for the generator, plus 2 gallons for every hour (h) the spotlights are running."

2. Standardized Kits (Distributive Property): The medic packs emergency kits. Each kit contains 3 bandages (b) and 2 syringes (s). If the medic needs to pack 4 kits, write the expanded expression for the total medical supplies. (Hint: 4(3b + 2s)).

3. Consolidating Ammo (Combining Like Terms): The Northern guard post reports having 5x rounds of rifle ammo and 3y flares. The Southern post reports 2x rounds of rifle ammo and 4y flares. Write a single simplified expression for the total arsenal.

4. The Daily Ration: Write an expression for "Half of the sum of the total workers (w) and the 12 visiting merchants."

5. Tax Code Translation: A merchant sells goods for a total cost of C. The settlement charges a 5% trade tax. Write a simplified expression for the total amount the merchant pays (Cost + Tax).

6. Expanding the Perimeter: The architect designs a rectangular garden plot. The width is 5 yards. The length is unknown, but it will be x yards plus an extra 4 yards for the gate. The area is width times length: 5(x + 4). Distribute this to find the expression for the total area.

7. Factoring the Armory (Greatest Common Factor): The quartermaster has an unorganized pile of 18r rifles and 24p pistols. He wants to divide them into the largest possible number of identical weapon caches. Factor the expression 18r + 24p by pulling out the greatest common factor.

8. Resource Consumption: Initial supplies are represented by the expression (12x + 20). After a harsh week, the colonists consume (4x + 5) of those supplies. Subtract the consumed supplies from the initial supplies to write a simplified expression for what remains.

9. The Penalty Clause: A scavenging crew is penalized for damaged gear. The rule is: Deduct 3 credits for every 2 tools lost (t), but grant a flat bonus of 10 credits for returning the vehicle. The bookkeeper accidentally doubles this entire rule for a specific crew: 2(−3t + 10). Distribute to find the simplified expression.

10. Simplifying the Grid: An engineer maps a triangular section of the settlement. The three sides measure x meters, 2x meters, and x + 15 meters. Write a simplified expression for the total perimeter of the triangle.

11. Negative Debt Consolidation: Two traders merge their ledgers. Trader A owes −4m in silver and has 10 credits. Trader B owes −2m in silver and owes −5 credits. Combine their debts and credits: (−4m + 10) + (−2m − 5).

12. The "Half-Ration" Protocol: The Sovereign Council orders a 50% cut to a specific resource allocation represented by (8y + 14). Distribute the decimal 0.5 across the expression to find the new allocation rule.

13. Factoring a Deficit: The winter ledger shows a deficit expression of −6d − 15. Factor out a −3 to see the underlying daily burn rate.

14. Translating the Architect: Write the expression for: "Five less than three times the number of solar panels (p)."

15. Redundant Code: The rookie bookkeeper writes the inventory formula as 3a + 4b − a + 2b + 5a. This is sloppy. Combine the like terms to give the bookkeeper a clean, professional expression.

16. The Double Expansion: The agricultural sector runs two different greenhouse models. Model A requires 3(2x + 1) gallons of water. Model B requires 2(4x + 3) gallons. Distribute and combine both models to find the simplified expression for total water usage.

17. Subtracting Negatives (The Tax Rebate): A citizen's standard tax burden is (10x + 50). The council grants a rebate (which is a subtraction) of (2x − 15). Simplify the expression: (10x + 50) − (2x − 15).

18. The Logistics Error: An operator claims that 4(x + 3) is the exact same thing as 4x + 3. Are these expressions equivalent? (Answer Yes or No, and write the actual expanded form of the first expression).

19. Scaling the Wall: The length of the wooden palisade is (L) feet. The stone wall is twice as long as the wooden palisade minus 10 feet. Write the expression for the length of the stone wall.

20. The Master Equation: A settlement operates on this complex resource formula: 5(2m + 3) − 4(m − 2). Distribute the numbers (pay attention to the negative 4!) and combine the like terms to reveal the true, simplified core formula of the settlement.

CHAPTER 6: ESTABLISHING BOUNDARIES

Linear Equations, Inequalities, and System Limits

Theme: Break-Even Points and Carrying Capacity

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Learning Objectives

After completing this chapter, you will be able to:

• Solve one-step and two-step linear equations for an unknown variable.

• Solve equations with variables on both sides.

• Write and solve inequalities, including the rule for flipping the sign when multiplying or dividing by a negative.

• Interpret solutions in real-world contexts (maximums, minimums, break-even points).

Key Vocabulary

Equation: A mathematical statement that two expressions are equal. Contains an equals sign. Example: 5x + 12 = 72.

Inequality: A statement comparing two values using <, >, ≤, or ≥. Example: 75b + 500 ≤ 2000.

Variable: The unknown value you are solving for.

Inverse Operation: The opposite operation used to isolate the variable. Addition undoes subtraction; multiplication undoes division.

Solution: The value of the variable that makes the equation or inequality true.

Worked Examples

WORKED EXAMPLE: Solving a Two-Step Equation

The settlement requires exactly 1,200 watts. The solar array provides w watts, and the turbine provides a fixed 450 watts. Solve: w + 450 = 1200.

Step 1: Isolate the variable by subtracting 450 from both sides: w = 1200 − 450.

Step 2: Calculate: w = 750.

Answer: **w = 750 watts.**

WORKED EXAMPLE: Solving an Inequality (with Negative Division)

The cistern holds 10,000 gallons. It must never drop below 2,500. The settlement uses 300 gallons per day (d). Solve: 10000 − 300d ≥ 2500.

Step 1: Subtract 10,000 from both sides: −300d ≥ −7500.

Step 2: Divide both sides by −300. CRITICAL: When dividing by a negative, FLIP the inequality sign: d ≤ 25.

Answer: **d ≤ 25. They can go a maximum of 25 days without rain.**

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Part 1: The Exact Balance (Linear Equations)

1. The Power Grid: The settlement requires exactly 1,200 watts of power to keep the perimeter defenses active. The solar array provides w watts, and the secondary wind turbine provides a fixed 450 watts. Write and solve: $w + 450 = 1200$.

2. Medical Scavenging: A scouting team returns with 5 sealed medical boxes, plus 12 loose bandages. The quartermaster counts exactly 72 total items. If each sealed box contains x items, solve: $5x + 12 = 72$.

3. Equal Production: The Northern mine extracts $3x + 10$ pounds of coal. The Southern mine extracts $5x - 20$ pounds. Both mines extracted the exact same amount. Solve: $3x + 10 = 5x - 20$.

4. Architectural Standardization: The Sovereign Council builds 4 identical storage bunkers. Each bunker holds c crates of food and 5 crates of ammunition. The total capacity of all four bunkers combined is 68 crates. Solve: $4(c + 5) = 68$.

5. Guard Roster: Half of the total trained guards ($g/2$) are assigned to the night shift. However, 3 call in sick, leaving exactly 14 guards on duty. Solve for g: $g/2 - 3 = 14$.

6. Fuel Depletion: A heavy transport vehicle starts with 45 gallons of diesel. It burns 3 gallons for every hour (h) it drives, plus a flat 15 gallons used to power the hydraulic drill at the worksite. If the tank is completely empty, how many hours did it drive? Solve: $3h + 15 = 45$.

7. The Wall Completion: A defensive palisade must be exactly 1,000 feet long. The builders have already completed 250 feet. If they build 50 feet per day (d), how many days to finish? Solve: $50d + 250 = 1000$.

8. Trade Tariffs: A merchant sells 8 heavy pelts for p silver each. The outpost charges a flat 10-silver transaction tax. The merchant walks away with a net total of 110 silver. Solve: $8p - 10 = 110$.

9. The Deep Freeze: The greenhouse temperature starts at 70°F. The heating unit fails, and the temperature drops 4° every hour (h). The current temperature is exactly 38°F. Solve: $70 - 4h = 38$.

10. The Capital Budget: The settlement has a strict $500 tech budget. The engineer buys a central battery core for $200 and 6 identical solar panels. The budget is spent perfectly to zero. Solve: $6p + 200 = 500$.

Part 2: The Safe Operating Zones (Inequalities)

Remember the critical rule of survival math: if you divide or multiply by a negative number to solve an inequality, the threat reverses, and you must flip the inequality symbol.

11. Structural Load Limits: A transport cart can hold a maximum of 2,000 pounds. It is already loaded with a 500-pound engine block. The quartermaster wants to load supply boxes that weigh 75 pounds each (b). Solve: $75b + 500 \leq 2000$.

12. Minimum Caloric Intake: A scout must consume at least 2,400 calories before a harsh patrol. They eat a base meal of 1,000 calories and carry protein blocks at 350 calories each (p). Solve: $350p + 1000 \geq 2400$.

13. Strict Budgeting: You have no more than 150 trade credits. You must buy a $45 tool kit and y yards of canvas at $15 per yard. Solve: $15y + 45 \leq 150$.

14. The Freezing Threshold: Water freezes at 32°F. Current temperature is 50°F, dropping 3° per hour (h). When does it drop below freezing? Solve: $50 - 3h < 32$.

15. Bridge Stress Test: A wooden suspension bridge supports a maximum of 5,000 pounds. A supply truck weighs 3,200 pounds and carries c crates of iron ore at 40 pounds each. Solve: $40c + 3200 \leq 5000$.

16. Profit Thresholds: To justify the risk of a trade route, a caravan must net more than $300 in profit. They have fixed travel costs of $50. They sell goods (g) for $25 each. Solve: $25g - 50 > 300$.

17. Cistern Reserves: The main cistern holds 10,000 gallons. It must never drop below 2,500 gallons. The settlement consumes 300 gallons per day (d). Solve: $10000 - 300d \geq 2500$.

18. Time Constraints: A severe storm will hit in less than 12 hours. It takes 3 hours to secure livestock, plus 1.5 hours to harvest each acre (a). Solve: $1.5a + 3 < 12$.

19. Ammunition Conservation: A guard tower is issued 120 rounds. They must keep at least 40 rounds in reserve. They fire 8 rounds per skirmish (s). Solve: $120 - 8s \geq 40$.

20. The Sovereign Standard: The settlement must maintain at least 40 guards. There are currently only 12 active guards. The training program graduates 4 new guards every week (w). Solve: $4w + 12 \geq 40$.

MODULE 4: GEOMETRY

Engineering & Infrastructure

We are taking the numbers off the ledger and putting them into the dirt. An architect who cannot calculate area starves. An architect who cannot calculate perimeter is overrun.

Chapter 7 forces you to build the physical footprint of the settlement: perimeter for fencing and walls, area for farming and solar arrays, angles for lines of sight and structural engineering. Chapter 8 extends into three dimensions: volume for storage capacity and surface area for material costs.

The physical world does not forgive measurement errors. If your perimeter calculation is short, the wall has a hole. If your volume calculation is wrong, the silo overflows or the cistern runs dry.

CHAPTER 7: BLUEPRINTING THE GRID

2D Area, Perimeter, Circumference, and Angle Relationships

Theme: Engineering the Settlement's Physical Footprint

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Learning Objectives

After completing this chapter, you will be able to:

- Calculate perimeter of rectangles, triangles, and irregular polygons.
- Calculate circumference of circles using C = 2πr.
- Calculate area of rectangles, triangles, and circles.
- Identify and use supplementary, complementary, and vertical angle relationships.
- Solve composite geometry problems combining multiple shapes.

Key Vocabulary

Perimeter: The total distance around the outside of a 2D shape.

Circumference: The perimeter of a circle. Formula: C = 2πr or C = πd.

Area: The amount of space inside a 2D shape, measured in square units.

Supplementary Angles: Two angles that sum to 180°.

Complementary Angles: Two angles that sum to 90°.

Vertical Angles: Opposite angles formed by two intersecting lines. Always equal.

Composite Shape: A figure made of two or more basic shapes combined (e.g., rectangle + semicircle).

Worked Examples

WORKED EXAMPLE: Area of a Composite Shape

A grain silo floor plan is a rectangle (20 ft × 30 ft) with a semicircle attached to one 20-ft end. Find the total area. Use π ≈ 3.14.

Step 1: Rectangle area: 20 × 30 = 600 sq ft.

Step 2: The semicircle has diameter 20, so radius = 10.

Step 3: Semicircle area: ½ × π × 10^2 = 0.5 × 3.14 × 100 = 157 sq ft.

Step 4: Total: 600 + 157 = 757 sq ft.

Answer: 757 square feet.

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Instructions

The physical world does not forgive measurement errors. If your perimeter calculation is short, the wall has a hole. If your area calculation is wrong, the crops will not fit. Use geometric formulas to design the settlement's infrastructure. Use π ≈ 3.14 where necessary.

Part 1: Perimeter and Circumference

1. The Primary Barricade: The central command center is a rectangle measuring 125 feet long and 85 feet wide. Calculate the exact perimeter to determine how many feet of reinforced steel fencing are required to enclose it.

2. The Water Reservoir: The engineers are digging a perfectly circular water catchment basin with a radius of 15 feet. Calculate the circumference of the basin.

3. The Observation Deck: A forward scout tower has a triangular platform. The three sides measure 14.5 feet, 18 feet, and 22.5 feet. What is the total perimeter of the platform?

4. Material Shortfall: The agricultural zone requires a rectangular fence that is 300 yards long and 150 yards wide. The quartermaster only has 800 yards of wire. How many more yards of wire must be scavenged to close the perimeter?

5. Irregular Defenses: An L-shaped storage bunker has six sides. Measuring clockwise, the sides are 40 ft, 20 ft, 15 ft, 30 ft, 25 ft, and 50 ft. Calculate the total perimeter.

Part 2: Area

6. Solar Array Footprint: The settlement's power grid requires a rectangular plot measuring 45 meters by 28 meters. What is the total area in square meters?

7. The Wedge Farm: A farming plot is shaped like a right triangle. The base is 60 feet and the height is 40 feet. What is the area of the farmable land?

8. The Landing Zone: The medical evacuation helicopter requires a circular landing pad with a diameter of 40 feet. Calculate the total area of the landing pad.

9. Efficiency of Space: A square housing unit has a side length of 24 feet. A rectangular housing unit is 32 feet long and 18 feet wide. Which unit provides more square footage, and by how much?

10. Yield per Square Foot: A rectangular greenhouse is 50 feet long and 20 feet wide. Every square foot yields 1.5 pounds of root vegetables. What is the total projected yield?

Part 3: Angles and Vectors

11. Supplementary Sightlines: A straight defensive wall represents a 180° angle. A guard tower's searchlight covers 115° to the left. What is the remaining angle to the right?

12. Complementary Engineering: A solar panel must be tilted to exactly 90° relative to its support strut. If the base bracket is fixed at 38°, what must the adjustable angle be?

13. Vertical Intersections: Two supply roads intersect forming an X. One acute angle is 42°. What is the vertical angle directly opposite it?

14. Triangulating a Threat: A triangle formed by command base, outpost, and scouting party has angles of 65° and 50° at the base and outpost. What is the angle at the scouting party?

15. The Sweeping Radar: A radar dish rotates a complete 360° and is programmed to pause and scan 4 equal sectors. What is the angle of each sector?

Part 4: Composite Architecture

16. The Silo Design: A grain silo's floor plan is a rectangle (20 ft by 30 ft) with a perfect semicircle attached to one 20-foot end. Calculate the total area of the floor plan.

17. Cost of Security: A square armory has an area of 400 square feet. The council mandates a heavy iron fence around the perimeter at $12 per foot. What is the total cost?

18. The Unknown Boundary: A medical tent must be exactly 540 square feet. If the length is 30 feet, what must the width be?

19. The Courtyard Path: A rectangular courtyard is 80 ft by 60 ft. A 5-foot wide stone path is built along the inside edge of the entire perimeter. What is the perimeter of the inner grassy area?

20. The Architect's Final Test: A circular guard outpost has a radius of 10 feet. A rectangular command tent is 15 ft by 20 ft. Which has a larger perimeter/circumference? Which has a larger area?

CHAPTER 8: RESOURCE STORAGE

3D Volume and Surface Area

Theme: Engineering Storage and Material Costs

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Learning Objectives

After completing this chapter, you will be able to:

- Calculate volume of rectangular prisms, cylinders, and triangular prisms.
- Calculate surface area of 3D shapes, including lateral surface area of cylinders.
- Determine material costs based on surface area and unit pricing.
- Compare efficiency of different container designs by calculating volume-to-surface-area ratios.

Key Vocabulary

Volume: The amount of 3D space inside a solid figure, measured in cubic units.

Surface Area: The total area of all the surfaces (faces) of a 3D object.

Lateral Surface Area: The surface area of the sides only, excluding the top and bottom.

Rectangular Prism: A 3D box shape. Volume = length × width × height.

Cylinder: A 3D tube shape. Volume = $\pi r^2 h$. Lateral SA = $2\pi rh$.

Triangular Prism: A 3D shape with triangular ends. Volume = (½ × base × height) × length.

Worked Examples

WORKED EXAMPLE: Volume of a Cylinder

A wheat silo has an interior radius of 8 feet and a height of 25 feet. How much grain can it store?

Step 1: Formula: $V = \pi r^2 h$.

Step 2: Substitute: $V = 3.14 \times 8^2 \times 25 = 3.14 \times 64 \times 25$.

Step 3: Calculate: $3.14 \times 1{,}600 = 5{,}024$ cubic feet.

Answer: **5,024 cubic feet.**

WORKED EXAMPLE: Total Surface Area for Material Costs

A cylindrical pressure tank (radius 3 ft, height 8 ft) needs steel plating at $5 per square foot. What is the total cost?

Step 1: Total SA = $2\pi r^2 + 2\pi rh$.

Step 2: Two circles: $2 \times 3.14 \times 9 = 56.52$ sq ft.

Step 3: Lateral: $2 \times 3.14 \times 3 \times 8 = 150.72$ sq ft.

Step 4: Total SA: $56.52 + 150.72 = 207.24$ sq ft.

Step 5: Cost: $207.24 \times \$5 = \$1{,}036.20$.

Answer: **$1,036.20.**

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Instructions

In a survival scenario, space is a finite resource, and materials cost labor. Volume dictates how much you can store. Surface area dictates how much material you must expend. Use $\pi \approx 3.14$ for all cylindrical calculations.

Part 1: Volume

1. The Subterranean Cistern: The primary underground water cistern is a rectangular prism measuring 20 feet long, 15 feet wide, and 10 feet deep. What is the maximum volume in cubic feet?

2. The Winter Silo: The main wheat silo is a cylinder with interior radius 8 feet and height 25 feet. Calculate the total volume. ($V = \pi r^2 h$).

3. Crate Optimization: A standard supply crate has a volume of 8 cubic feet. The warehouse has dimensions 40 ft × 30 ft × 12 ft. What is the maximum number of crates it can hold?

4. Diesel Reserves: A cylindrical fuel drum has a diameter of 4 feet and a height of 6 feet. What is its volume?

5. The Forward Camp: A scout's A-frame tent is a triangular prism. The triangular entrance has a base of 6 feet and a height of 5 feet. The tent is 8 feet long. What is the internal volume?

6. Agricultural Bedding: A raised farming bed is 12 ft long, 4 ft wide, and 1.5 ft deep. Soil costs $4 per cubic foot. What is the total cost to fill it?

7. Liquid Conversion: One cubic foot of water equals approximately 7.5 gallons. If a rectangular tank is 4 ft × 3 ft × 2 ft, how many gallons does it hold?

8. The Clinic Foundation: A concrete slab must be 50 ft long, 30 ft wide, and 0.5 ft thick. How many cubic feet of concrete are needed?

9. Hazardous Ventilation: A chemical storage room measures 15 ft × 15 ft × 10 ft. The extractor fan clears 250 cubic feet per minute. How many minutes to clear the room?

10. Composite Storage: A bunker has a lower section (20 × 20 × 10 ft) and a smaller upper section (10 × 10 × 5 ft) stacked on top. What is the total volume?

Part 2: Surface Area

11. Resin Waterproofing: A rectangular munitions chest is 3 ft long, 2 ft wide, and 1.5 ft high. It must be coated on all six sides. Calculate the total surface area.

12. Thermal Insulation: The cylindrical water tower (radius 10 ft, height 30 ft) must be wrapped in insulation on the sides only. Calculate the lateral surface area. (Lateral SA = $2\pi rh$).

13. Radar-Absorbent Paint: A guard shack is 10 ft long, 8 ft wide, and 9 ft tall. The four walls and flat roof must be painted (not the floor). What is the total surface area to paint?

14. Canvas Fabrication: An A-frame tent has triangular front and back (base 6 ft, height 4 ft each) and two slanted rectangular sides (5 ft × 10 ft each). No floor canvas needed. How many square feet of canvas?

15. Pressure Tank Costs: A fully sealed cylindrical tank (radius 3 ft, height 8 ft) needs steel plating at $5 per square foot. Calculate total SA and total cost.

16. Medical Packaging: A sheet of cardboard has 150 square inches. A pill box is 4 in × 3 in × 2 in. What is the surface area of one box? Can the sheet make exactly two boxes?

17. Solar Heat Gain: A battery enclosure (5 ft × 4 ft × 3 ft) sits in the sun. Only the top and four sides absorb radiation (not the bottom). What is the exposed surface area?

18. Pipe Wrapping: A cylindrical steam pipe has a diameter of 2 feet and is 50 feet long. It must be wrapped entirely in a fire-retardant sleeve. Calculate the lateral surface area.

19. The Efficiency Test: Crate A is a cube (4 × 4 × 4 ft). Crate B is a rectangular prism (8 × 4 × 2 ft). Calculate the volume and surface area of both. Which requires less wood to build while holding the same volume?

20. The Architect's Challenge: A cylindrical watchtower (radius 5 ft, height 40 ft) must be coated on the lateral sides plus the flat circular roof (not the bottom). One bucket of sealant covers 300 sq ft. How many whole buckets must be purchased?

MODULE 5: STATISTICS AND PROBABILITY

Risk & Quality Control

A leader must be able to look at a small set of data and accurately predict the behavior of the entire system. In survival conditions, you do not have the time or resources to inspect every single crop, ask every single citizen, or test every single battery. You must take a sample, analyze the data, and make an inference about the whole.

Chapter 9 teaches you to gather, analyze, and interpret data—identifying bias, calculating measures of center, and making predictions from samples. Chapter 10 enters the realm of calculated risk: probability models, expected value, and compound events.

We leave the realm of absolute certainty and enter the realm of odds. Certainty is an illusion; everything is a matter of probability. Survival exists in the fractions between 0 and 1.

CHAPTER 9: POPULATION METRICS

Statistics, Random Sampling, and Inferences

Theme: Data-Driven Decision Making

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Learning Objectives

After completing this chapter, you will be able to:

- Distinguish between random (unbiased) and biased samples.
- Use sample data to make proportional inferences about a larger population.
- Calculate mean, median, mode, and range from data sets.
- Identify outliers and explain their effect on measures of center.
- Choose the appropriate measure of center for a given context.

Key Vocabulary

Random Sample: A subset chosen so that every member of the population has an equal chance of being selected.

Biased Sample: A sample that systematically favors certain members of the population over others.

Inference: A conclusion about a population based on data from a sample.

Mean: The average: sum of all values divided by the count of values.

Median: The middle value when data is arranged in order. Less affected by outliers.

Mode: The value that appears most frequently. Useful for sizing and manufacturing.

Range: The difference between the highest and lowest values. Measures variability.

Outlier: A data point that is significantly different from the rest. Can distort the mean.

Worked Examples

WORKED EXAMPLE: Making an Inference from a Sample

40 ears of corn are inspected from a field of 2,000. Six are infected with fungus. Predict total infections.

Step 1: Find the infection rate in the sample: 6/40 = 0.15 = 15%.

Step 2: Apply to the total population: 0.15 × 2,000 = 300.

Answer: **An estimated 300 ears of corn are infected.**

WORKED EXAMPLE: Mean vs. Median: Choosing the Right Metric

Daily lumber yields over 7 days: 45, 42, 48, 12, 46, 50, 44. Which is the better measure of a typical day?

Step 1: Calculate the mean: (45+42+48+12+46+50+44) ÷ 7 = 287 ÷ 7 = 41.

Step 2: Arrange in order: 12, 42, 44, 45, 46, 48, 50. The median (middle value) is 45.

Step 3: The "12" was an equipment failure. It drags the mean down but does not affect the median.

Answer: **The median (45) is the better measure. The mean (41) is distorted by the outlier.**

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Instructions

In survival conditions, you do not have the time or resources to inspect every single crop, ask every single citizen, or test every single battery. You must take a sample, analyze the data, and make an inference about the whole. But beware: a biased sample will feed you a lie, and bad data leads to dead settlements.

Part 1: The Integrity of the Sample

1. The Pulse of the Settlement: The council wants to know if citizens believe winter rations are sufficient. The surveyor only asks citizens in line at the medical clinic. Is this random or biased? Why?

2. Quality Control: The quartermaster tests a shipment of 5,000 rifle cartridges by randomly selecting 50 from 10 different crates. Is this a valid random sample?

3. Agricultural Testing: An engineer tests moisture levels in the eastern farming sector. All 10 soil samples are taken within 5 feet of the irrigation trench. Is this data reliable for the whole sector?

4. The Labor Vote: To determine which project to prioritize, the architect pulls 40 names from a blind lottery box containing all 400 citizens' names. Is this biased or unbiased?

5. The Missing Metric: Five citizens report daily caloric intake: 1,200; 1,400; 1,350; 1,500; and 8,000 (a hoarder). Will the mean accurately represent the group, or will the outlier distort the truth?

Part 2: Inferences

6. Crop Viability: An agricultural scout randomly inspects 40 ears of corn from a field of 2,000. Six are infected with fungus. Predict the total number of infected ears in the entire field.

7. Battery Degradation: The tech division tests 60 salvaged solar batteries. 15 cannot hold a full charge. If the stockpile totals 1,200 batteries, infer how many are likely defective.

8. The Flu Outbreak: The medic randomly surveys 25 citizens and finds 4 showing symptoms. The population is 350. Predict how many citizens are likely infected.

9. Seed Germination: A farmer plants 50 test tomato seeds. After two weeks, 42 have sprouted. If the farmer plants 800 seeds total, how many can they expect to sprout?

10. Ammunition Reliability: A guard test-fires 20 flares from an old cache. 3 fail to ignite. If there are 140 flares total, predict how many are reliable.

Part 3: Measures of Center and Variability

11. The Median Truth: Daily lumber yield over 7 days: 45, 42, 48, 12, 46, 50, 44. The "12" was an equipment failure. Should the foreman use mean or median? Calculate both.

12. The Range of Volatility: Wind turbine output over 5 hours: 14, 28, 8, 35, 12 kilowatts. Calculate the range. Is this a reliable primary power source?

13. Target Averages: A scavenging team must average 40 pounds of scrap per day over 5 days. For the first four days: 35, 42, 38, and 45 pounds. How much on day five to hit the target mean?

14. The Mode of Supply: Boot sizes requested by recruits: 9, 10, 10, 11, 9, 10, 12, 10, 8. Calculate the mode. Why is it more useful than the mean here?

15. Comparing Populations: Team A brings back 12, 14, 15, 13, and 16 pounds of meat over 5 days. Team B brings back 2, 25, 4, 30, and 9 pounds. Both average 14 pounds. Which team is better for steady planning?

Part 4: Applied Wilderness Statistics

16. The Mark and Recapture Protocol: Scouts catch, tag, and release 30 fish. A week later, they catch 50 fish and find 10 are tagged. Estimate the total fish population.

17. Surveying the Threat: Out of 15 hostile vehicles spotted, 6 were heavily armored. If command estimates 80 total hostile vehicles, infer how many are heavily armored.

18. The Outlier Effect: Daily water consumption for a week: 300, 310, 290, 305, 315, 300, and 850 gallons. Identify the outlier. If removed, what is the new mean?

19. Predicting Labor Needs: 5 randomly selected wall sections need an average of 12 replacement spikes each. The entire wall has 45 sections. Infer total spikes needed.

20. The Sovereign's Call: System Alpha filters an average of 50 gallons/hour (range: 20–80). System Beta filters 40 gallons/hour (range: 38–42). If consistent planning is your priority, which system do you authorize?

CHAPTER 10: RISK ASSESSMENT

Probability Models, Expected Outcomes, and Compound Events

Theme: Calculating the Odds of Survival

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Learning Objectives

After completing this chapter, you will be able to:

• Calculate theoretical and experimental probability.

- Determine the probability of compound events (independent and dependent).
- Build sample spaces and count outcomes using the counting principle.
- Calculate expected value and use it to evaluate risk.
- Compute complementary probability (the chance something does NOT happen).

Key Vocabulary

Probability: A number between 0 (impossible) and 1 (certain) that represents the likelihood of an event.

Theoretical Probability: Based on known possibilities: favorable outcomes ÷ total possible outcomes.

Experimental Probability: Based on observed data: times it happened ÷ times you tried.

Complementary Event: The opposite of an event. P(not A) = 1 − P(A).

Independent Events: Two events where the outcome of one does not affect the other. Multiply their probabilities.

Dependent Events: Two events where the first outcome changes the probability of the second.

Expected Value: The predicted average outcome over many trials: probability × value of outcome.

Sample Space: The set of all possible outcomes.

Worked Examples

WORKED EXAMPLE: Independent Compound Events

Generator A has a 10% chance of failing. Generator B has a 20% chance. What is the probability both fail?

Step 1: These are independent events (one does not affect the other).

Step 2: Multiply: 0.10 × 0.20 = 0.02.

Step 3: Convert: 0.02 = 2%.

Answer: **2% chance that both generators fail on the same night.**

WORKED EXAMPLE: Expected Value

A scouting mission costs $50. There is a 20% chance of finding tech worth $400. Is it a good risk?

Step 1: Expected payout: 0.20 × $400 = $80.

Step 2: Net expected profit: $80 − $50 = $30.

Step 3: Since the expected profit is positive, the mission is mathematically sound over time.

Answer: **Yes. Expected net profit is $30 per mission.**

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Instructions

Certainty is an illusion; everything is a matter of odds. A probability of 0 means the event is impossible. A probability of 1 (or 100%) means it is guaranteed. Survival exists in the fractions between 0 and 1. Calculate the odds, model the risks, and decide if the operation is mathematically viable.

Part 1: Theoretical vs. Experimental Probability

1. The Theoretical Defect: A shipment of 12 solar regulators arrives. 3 are from a defective batch. If the engineer picks one at random, what is the probability of picking a defective one (as a fraction and percentage)?

2. The Experimental Weather: A scout records weather for 60 consecutive days and notes hail on 15 of them. Based on this data, what is the probability of hail tomorrow?

3. The Germination Model: Out of 500 wheat seeds planted, 420 sprouted. If the farmer plants 2,000 seeds next season, how many can they expect to sprout?

4. The Complementary Threat: The meteorologist calculates a 12% chance of a severe freeze tonight. What is the probability that the walls will NOT be breached?

5. Divergent Data: The manual claims a 5% theoretical failure rate for a water pump under stress. In 100 actual tests, the pump failed 9 times. What is the experimental probability, and is it higher or lower than theoretical?

Part 2: Compound Events

6. Independent Redundancy: Generator A has a 10% chance of failing overnight. Generator B has a 20% chance. What is the probability that both fail on the same night?

7. Dependent Draw: A box contains 10 flares: 8 good, 2 duds. A guard pulls one, pockets it, then pulls a second without replacing the first. What is the probability both drawn are duds?

8. The Logistics Matrix: A supply truck has 3 possible routes (River, Ridge, Valley) and 2 possible departure times (Dawn, Dusk). How many total unique combinations are possible?

9. The Access Code: The armory requires a 3-digit code. Each digit can be 0–9. How many possible codes exist? What is the probability of guessing correctly on the first try?

10. The Uniform Risk: A fair 6-sided die selects which agricultural sector gets extra fertilizer. What is the probability the chosen sector is represented by a number greater than 4?

Part 3: Expected Value

11. The Scavenging Wager: A mission costs $50 in fuel. There is a 20% chance of finding tech worth $400. What is the expected payout? Subtract the cost—is this a mathematically sound risk?

12. Medical Triage: A pouch contains 5 bandages, 3 antiseptics, and 2 tourniquets (10 items). What is the probability of pulling an antiseptic or a tourniquet?

13. Predicting the Harvest: The probability model: 50% chance of high yield (800 lbs), 30% average yield (500 lbs), 20% low yield (200 lbs). Calculate the expected yield.

14. The Weak Link: A reinforced bridge has a 98% chance of holding. A second, older bridge has an 85% chance. What is the probability the transport crosses both safely?

15. Quality Control Blind Draw: An inspector tests 200 canned rations. 15 are improperly sealed. What is the percentage chance a colonist grabs a safe ration?

Part 4: The Architect's Mastery

16. The Triple Threat: Outer wall: 10% failure. Inner trench: 10% failure. Steel door: 10% failure. What is the probability an invader breaches all three consecutively?

17. The Rescue Odds: A lost scout is in one of 4 equal zones. Team Alpha searches 1 zone. Team Beta searches 1 of the remaining 3. What is the combined probability of finding the scout?

18. The Simulation Game: A digital coin is flipped 3 times. What is the probability of exactly three Heads in a row?

19. Forming the Council: There are 4 engineers and 6 medics. A 2-person committee is selected at random. What is the probability it consists of exactly two medics?

20. The Sovereign Principle: Revisit the Triple Threat (Problem 16). Calculate the exact percentage of all three defenses failing. Then calculate the complementary probability—the mathematical guarantee that at least one defense will hold. This number is why we build redundancies.

ANSWER KEY

Every answer includes the mathematical work. If your answer is correct but your method is wrong, you got lucky. Lucky is not sovereign.

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Chapter 1: Assets and Deficits

1. 265 bushels (450 − 185)

2. −8°F (14 − 22)

3. −85 logs (−180 + 95)

4. $70 (−45 + 115)

5. 7,200 gallons (8,000 − 1,250 − 400 + 850)

6. 35 axes (42 − 15 + 8)

7. −65 feet (250 − 315 = −65, or 65 feet below sea level)

8. −100 calories (Day 1: −700. Day 2: 3,100 − 2,500 = +600. Net: −700 + 600 = −100)

9. −$10 (−80 + 55 = −25. Then −25 + 15 = −10. They still owe $10)

10. 86 cattle (84 − 6 + 12 − 4)

11. A drop of 8°C (3 − (−5) = 8)

12. 290 pounds surplus (−50 + 340 = 290)

13. 285 blocks needed (450 − 35 + 500 = 915 mined. 1,200 − 915 = 285)

14. 60 lbs meat, 65 lbs grain (100 − 40 = 60 meat. 0 + 65 = 65 grain)

15. 21 gallons (40 − 12 − 15 + 8)

16. 1 foot (Dug: −3 + (−4) = −7 feet. Target: −8. Need: −1 more foot)

17. 316 people (300 − 14 + 8 + 22)

18. $100 (−150 + 300 − 50)

19. 43% (100 − 45 + 18 − 30)

20. $2,150 (4,500 − 1,200 − 850 − 300)

Chapter 2: Scaling Operations

1. 49 pounds (3.5 × 14)

2. −15°F (−2.5 × 6)

3. 2.5 acres (12.5 ÷ 5)

4. 5.7 gallons per hour (45.6 ÷ 8)

5. −$150 (−450 ÷ 3)

6. 11.25 tons (0.75 × 15)

7. 17 frames (8.5 × 5 = 42.5 hrs. 42.5 ÷ 2.5 = 17)

8. 10 full braces (15.75 ÷ 1.5 = 10.5, round down to 10)

9. −$50.00 (−12.50 × 4)

10. 800 gallons (1,200 × 2/3)

11. 6.75 tons (2.25 × 3)

12. $7.05 (105.75 ÷ 15)

13. −6.2°C per day (−18.6 ÷ 3)

14. 14 treatments (5.25 ÷ 0.375)

15. 14.625 kilowatts (2.25 × 6.5)

16. −36 feet (36 feet below surface) (−4.5 × 8)

17. 54 stakes (40.5 ÷ 0.75)

18. 3,750 calories (2,500 × 1.5)

19. −44.8 pounds (−3.2 × 14)

20. $112.63 (450.50 ÷ 4 = 112.625, rounded)

Chapter 3: Supply Chains and Yields

1. 45 gallons per hour (180 ÷ 4)

2. 225 miles (135 ÷ 6 = 22.5 mpg. 22.5 × 10)

3. 520 pounds (320 ÷ 8 = 40 lbs/bed. 40 × 13)

4. 1,050 pounds (450 ÷ 3 = 150 lbs/miner. 150 × 7)

5. 18 pelts (45 ÷ 5 = 9 groups. 9 × 2)

6. 192 kilowatts (24 ÷ 3 = 8 kW/hr. 8 × 24)

7. 225 milliliters (50 ÷ 8 = 6.25 ml/dose. 6.25 × 36)

8. 640 bricks (120 ÷ 1.5 = 80/hr. 80 × 8)

9. 14 logs (45 ÷ 2 = 22.5 board ft/log. 315 ÷ 22.5)

10. 6 days (14 ÷ 4 = 3.5 yds/day. 21 ÷ 3.5)

11. 21 cords (3.5 ÷ 2 = 1.75/wk. 1.75 × 12)

12. 63.75 feet (15 ÷ 2 = 7.5 ft/in. 7.5 × 8.5)

13. 350 calories per ounce (1,400 ÷ 4)

14. 750 cartridges (75 ÷ 15 = 5/min. 2.5 hrs = 150 min. 5 × 150)

15. 25.5 pounds (3 ÷ 10 = 0.3 lbs fert/lb seed. 0.3 × 85)

16. 8 hours (3.5 ÷ 2 = 1.75 lbs/hr. 14 ÷ 1.75)

17. 36 jars (12 lbs ÷ 8 jars = 1.5 lbs/jar. 54 ÷ 1.5)

18. 75 gallons (3 hrs = 180 min. 180 ÷ 12 = 15 cycles. 15 × 5)

19. 64 pounds of coal (8 ÷ 5 = 1.6 lbs coal/lb iron. 1.6 × 40)

20. 60 minutes (45 ÷ 6 = 7.5 min/mile. 7.5 × 8)

Chapter 4: The Settlement Economy

1. $46 (15% of 40 = 6. 40 + 6)

2. $20 (20% of 25 = 5. 25 − 5)

3. 40 lbs lost; 760 lbs remaining (5% of 800 = 40)

4. 368 people (15% of 320 = 48. 320 + 48)

5. $27 (6% of 450 = 27)

6. 25% increase (300 ÷ 1,200 = 0.25)

7. 180 feet (4.5 × 40)

8. 1,500 square feet (3 in = 30 ft, 5 in = 50 ft. 30 × 50)

9. 6% (15 ÷ 250 = 0.06)

10. $312 (4% of 300 = 12. 300 + 12)

11. 4,600 tons (8% of 5,000 = 400. 5,000 − 400)

12. 40 inches (2,400 ÷ 60)

13. $952 (12% of 850 = 102. 850 + 102)

14. 15 percentage points (75 − 60)

15. 51 ounces (15% of 60 = 9. 60 − 9)

16. 50% (Profit $60. 60 ÷ 120 = 0.50)

17. 9 inches (45 ÷ 5)

18. 70% (28 ÷ 40)

19. $180 (20% of 150 = 30. 150 + 30)

20. 4,320 crops (10% of 6,000 = 600 → 5,400. 20% of 5,400 = 1,080 → 4,320)

Chapter 5: Codifying the Rules

1. 5 + 2h

2. 12b + 8s

3. 7x + 7y

4. ½(w + 12) or 0.5(w + 12)

5. 1.05C

6. 5x + 20

7. 6(3r + 4p)

8. 8x + 15

9. −6t + 20

10. 4x + 15

11. −6m + 5

12. 4y + 7

13. −3(2d + 5)

14. 3p − 5

15. 7a + 6b

16. 14x + 9

17. 8x + 65

18. No. 4(x + 3) = 4x + 12, not 4x + 3.

19. 2L − 10

20. 6m + 23 (10m + 15 − 4m + 8. Note: −4 × −2 = +8)

Chapter 6: Establishing Boundaries

1. w = 750 watts

2. x = 12 items per box

3. x = 15 (10 = 2x − 20 → 30 = 2x)

4. c = 12 crates (4c + 20 = 68 → 4c = 48)

5. g = 34 guards (g/2 = 17)

6. h = 10 hours (3h = 30)

7. d = 15 days (50d = 750)

8. p = 15 silver (8p = 120)

9. h = 8 hours (−4h = −32)

10. p = $50 per panel (6p = 300)

11. b ≤ 20 (Maximum 20 boxes)

12. p ≥ 4 (At least 4 blocks. 350p ≥ 1,400)

13. $y \leq 7$ ($15y \leq 105$)

14. $h > 6$ (After 6 hours, it freezes. Remember: flip the sign when dividing by -3)

15. $c \leq 45$ ($40c \leq 1{,}800$)

16. $g > 14$ (Must sell at least 15 goods. $25g > 350$)

17. $d \leq 25$ (Maximum 25 days. Flip sign when dividing by -300)

18. $a < 6$ ($1.5a < 9$)

19. $s \leq 10$ (Maximum 10 skirmishes. $-8s \geq -80$, flip sign)

20. $w \geq 7$ (At least 7 weeks. $4w \geq 28$)

Chapter 7: Blueprinting the Grid

1. 420 feet (125 + 125 + 85 + 85)

2. 94.2 feet (2 × 3.14 × 15)

3. 55 feet (14.5 + 18 + 22.5)

4. 100 yards (P = 900. 900 − 800 = 100)

5. 180 feet (40 + 20 + 15 + 30 + 25 + 50)

6. 1,260 square meters (45 × 28)

7. 1,200 square feet (½ × 60 × 40)

8. 1,256 square feet (3.14×20^2)

9. Equal: both 576 sq ft ($24^2 = 576$. 32 × 18 = 576)

10. 1,500 pounds (1,000 sq ft × 1.5)

11. 65° (180 − 115)

12. 52° (90 − 38)

13. 42° (Vertical angles are always equal)

14. 65° (180 − 65 − 50)

15. 90° (360 ÷ 4)

16. 757 sq ft (Rectangle 600 + Semicircle 157)

17. $960 (Side = $\sqrt{400} = 20$. Perimeter = 80. 80 × $12)

18. 18 feet (540 ÷ 30)

19. 240 feet (Inner: 70 × 50. Perimeter: 70+70+50+50)

20. Tent has larger perimeter (70 ft vs. 62.8 ft). Outpost has larger area (314 sq ft vs. 300 sq ft).

Chapter 8: Resource Storage

1. 3,000 cubic feet (20 × 15 × 10)

2. 5,024 cubic feet (3.14 × 64 × 25)

3. 1,800 crates (14,400 ÷ 8)

4. 75.36 cubic feet (3.14 × 4 × 6)

5. 120 cubic feet (0.5 × 6 × 5 = 15. 15 × 8)

6. $288 (Volume = 72. 72 × $4)

7. 180 gallons (24 cu ft × 7.5)

8. 750 cubic feet (50 × 30 × 0.5)

9. 9 minutes (2,250 ÷ 250)

10. 4,500 cubic feet (4,000 + 500)

11. 27 sq ft (2(6) + 2(4.5) + 2(3))

12. 1,884 sq ft (2 × 3.14 × 10 × 30)

13. 404 sq ft (Roof 80 + Walls 324)

14. 124 sq ft (Triangles 24 + Rectangles 100)

15. SA: 207.24 sq ft. Cost: $1,036.20 (56.52 + 150.72 = 207.24. 207.24 × 5)

16. Box SA: 52 sq in. Yes, 150 sq in makes two boxes (104 sq in needed)

17. 74 sq ft (Top 20 + Sides 54)

18. 314 sq ft (2 × 3.14 × 1 × 50)

19. Crate A requires less wood. Both hold 64 cu ft. Cube SA = 96. Rectangle SA = 112.

20. 5 buckets (Roof 78.5 + Lateral 1,256 = 1,334.5. 1,334.5 ÷ 300 = 4.45 ⟶ round up to 5)

Chapter 9: Population Metrics

1. Biased. Clinic patients are more likely sick or weak, skewing their opinion on rations.

2. Valid. Random selection across multiple crates ensures unbiased representation.

3. Biased. Soil near the trench is much wetter than the rest of the sector.

4. Unbiased. Every citizen had an equal chance of being selected.

5. Distorted. Mean is 2,690 (inaccurate). Median is 1,400 (truthful). The outlier of 8,000 destroys the mean.

6. 300 infected ears (6/40 = 15%. 0.15 × 2,000)

7. 300 defective (15/60 = 1/4. 1,200 × 0.25)

8. 56 infected citizens (4/25 × 350)

9. 672 sprouted seeds (42/50 = 84%. 0.84 × 800)

10. 119 reliable flares (17/20 worked. 17 × 7)

11. Mean = 41. Median = 45. Use the median—the outlier (12) drags the mean down.

12. Range = 27 (35 − 8). No, it is highly volatile and unreliable.

13. 40 pounds (Total needed: 200. Have: 160. 200 − 160 = 40)

14. Mode = 10. The quartermaster needs to know which exact size to manufacture the most of.

15. Team A is better. Both average 14, but Team A's yields are steady and predictable.

16. 150 fish (30/P = 10/50. 10P = 1,500)

17. 32 armored vehicles (6/15 = x/80. 15x = 480)

18. Outlier: 850. New mean: 303.3 gallons (1,820 ÷ 6)

19. 540 spikes (12 × 45)

20. System Beta. Lower average but near-zero variability. Alpha's range (20–80) is dangerous for planning.

Chapter 10: Risk Assessment

1. 3/12 = 1/4 = 25%

2. 15/60 = 1/4 = 25%

3. 1,680 seeds (420/500 = 84%. 0.84 × 2,000)

4. 88% (100% − 12%)

5. Experimental: 9% (9/100). Higher than the theoretical 5%.

6. 2% (0.10 × 0.20 = 0.02)

7. 1/45 (2/10 × 1/9 = 2/90)

8. 6 combinations (3 routes × 2 times)

9. 1,000 codes (10^3). Probability: 1/1,000 = 0.1%.

10. 1/3 or 33.3% (Numbers 5 and 6: 2/6)

11. Expected payout: $80. Net profit: $30 ($80 − $50). Yes, mathematically sound.

12. 50% (5/10 = 1/2)

13. 590 lbs (400 + 150 + 40)

14. 83.3% (0.98 × 0.85 = 0.833)

15. 92.5% (185/200)

16. 0.1% (0.10 × 0.10 × 0.10 = 0.001)

17. 50% (2 zones searched out of 4 = 2/4 = 1/2)

18. 1/8 = 12.5% (1/2 × 1/2 × 1/2)

19. 1/3 or 33.3% (6/10 × 5/9 = 30/90)

20. Total failure: 0.1%. Complementary (at least one holds): 99.9%. That is the math of survival.

GLOSSARY

Absolute Value: The distance a number is from zero, always positive.

Biased Sample: A sample that systematically favors certain outcomes.

Circumference: The distance around a circle. $C = 2\pi r$.

Coefficient: The number multiplied by a variable (e.g., 5 in 5x).

Complementary Angles: Two angles that sum to 90°.

Complementary Event: The opposite of an event. P(not A) = 1 − P(A).

Cross-Multiplication: Solving proportions: if a/b = c/d, then ad = bc.

Cylinder: A 3D tube shape. $V = \pi r^2 h$.

Deficit: A shortfall, represented as a negative number.

Dependent Events: Events where one outcome affects the next.

Depreciation: Decrease in value over time.

Discount: A percentage subtracted from a price.

Distributive Property: a(b + c) = ab + ac.

Equation: A statement that two expressions are equal (has = sign).

Expected Value: Probability × value of outcome.

Expression: Numbers, variables, and operations with NO equals sign.

Factoring: Pulling out the greatest common factor from terms.

Flat Tax: A fixed percentage applied equally to all transactions.

Independent Events: Events where one outcome does not affect the other.

Inequality: A comparison using <, >, ≤, or ≥.

Inference: A conclusion about a population based on sample data.

Integer: Any positive or negative whole number, including zero.

Inverse Operation: The opposite operation used to isolate a variable.

Lateral Surface Area: Area of the sides only (excludes top and bottom).

Like Terms: Terms with the same variable to the same power.

Markup: A percentage added to cost to set a selling price.

Mean: The average of a data set.

Median: The middle value when data is arranged in order.

Mixed Number: A number with a whole and fractional part (e.g., 3½).

Mode: The most frequently occurring value in a data set.

Negative Number: A number less than zero, indicating loss or debt.

Net Result: The final amount after all gains and losses.

Outlier: A data point significantly different from the rest.

Percent: A ratio out of 100.

Perimeter: The distance around the outside of a 2D shape.

Probability: A number from 0 to 1 representing the likelihood of an event.

Profit Margin: Profit divided by cost, as a percentage.

Proportion: An equation stating two ratios are equal.

Random Sample: A subset where every member has an equal chance of selection.

Range: Highest value minus lowest value in a data set.

Rate: A ratio comparing two different units.

Rational Number: Any number expressible as a fraction p/q (q ≠ 0).

Reciprocal: The flipped version of a fraction (e.g., ¾ becomes 4/3).

Rectangular Prism: A 3D box. V = l × w × h.

Sample Space: The set of all possible outcomes of an experiment.

Scale Drawing: A proportional diagram of a real object.

Supplementary Angles: Two angles that sum to 180°.

Surface Area: Total area of all surfaces of a 3D object.

Triangular Prism: A 3D shape with triangular ends. V = (½bh) × length.

Unit Rate: A rate with denominator 1 (e.g., 45 gallons per hour).

Variable: A letter representing an unknown or changing quantity.

Vertical Angles: Opposite angles formed by intersecting lines. Always equal.

Volume: The amount of 3D space inside a solid, in cubic units.

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