GENERAL

answers to investigation 4 exponential decay

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Introduction

Exponential decay is a fascinating concept that appears in countless areas of science, engineering, and everyday life. From the cooling of a hot cup of coffee to the fading of a radio signal, the mathematics behind exponential decay allows us to predict how a quantity decreases over time. In many educational settings, teachers design investigations that challenge students to apply their knowledge of exponential functions to real-world scenarios. One such challenge, commonly known as **Investigation 4: Exponential Decay**, asks students to solve a series of problems that test their understanding of decay models, logarithmic transformations, and data analysis.

In this article, we provide **answers to Investigation 4 exponential decay**along with detailed explanations that illuminate the reasoning behind each solution. Whether you are a student preparing for exams, a teacher looking for a reference guide, or simply a curious mind, this comprehensive walkthrough will help you master the concepts and techniques required to tackle exponential decay problems confidently.

1. Understanding Exponential Decay

Before diving into the specific problems of Investigation 4, it is essential to revisit the fundamentals of exponential decay. The general form of an exponential decay function is:

1. y = y0 e–kt (continuous decay)
2. y = y0 (1/2)t/T½ (discrete decay with half life)

where:

- y is the remaining quantity at time t.
- y0 is the initial quantity.
- k is the decay constant, a positive number that determines the rate of decay.
- T½ is the half life, the time required for the quantity to reduce to half its original value.

These equations are mathematically equivalent because the decay constant and the half life are related by the equation **k = ln(2)/T_½**. Mastery of these relationships is critical for solving the problems in Investigation 4.

2. The Investigation 4 Problem Statement

Investigation 4 typically presents a set of scenarios that involve measuring or predicting the decay of a substance or signal. A typical problem set might look like this:

1. Determine the half life of a radioactive sample given two measurements.
2. Predict the remaining amount of a drug in a patient’s bloodstream after a certain period.
3. Find the decay constant from a graph of natural logarithm of concentration versus time.
4. Apply the decay model to estimate the time required for a pollutant to fall below a safety threshold.

Each question tests a different facet of exponential decay: algebraic manipulation, logarithmic transformation, data interpretation, and real world application. The following sections provide step by step solutions and insights for each

problem.

3. Step by Step Solutions

Problem 1: Determining the Half Life

Suppose a radioactive sample starts with a mass of 12.0 /g. After 3 hours, the mass reduces to 8.0 /g. Find the half life.

1. Set up the decay equation: 8.0 = 12.0 /e–k·3.
2. Divide both sides by 12.0: 8.0/12.0 = e–3k !’ 0.6667 = e–3k.
3. Take the natural logarithm: ln(0.6667) = –3k !’ k = –ln(0.6667)/3 "H 0.1438 /h–1.
4. Convert the decay constant to half life: T½ = ln(2)/k "H 0.6931 / 0.1438 "H 4.82 /h.

Thus, the half life is approximately **4.8 hours**.

Problem 2: Predicting Remaining Drug Amount

A patient receives a 500 mg dose of a medication that decays with a half life of 6 hours. How much drug remains in the bloodstream after 18 hours?

1. Compute the decay constant: k = ln(2)/6 "H 0.1155 /h–1.
2. Apply the decay formula: y = 500 /e–0.1155·18.
3. Calculate the exponent: –0.1155·18 = –2.079.
4. Compute the remaining amount: y "H 500 /e–2.079 "H 500 /· /0.124 "H 62 /mg.

After 18 hours, roughly **62 /mg** of the drug remains.

Problem 3: Finding the Decay Constant from a Log Graph

A scientist plots the natural logarithm of concentration (ln C) against time and obtains a straight line with slope –0.045 /min–1. What is the decay constant, and what does this slope tell us?

1. The slope of ln /C vs. time is equal to the negative decay constant: –k = –0.045 /min–1.
2. Thus, k = 0.045 /min–1.
3. Interpretation: For each minute, the concentration decreases by a factor of e–0.045 "H 0.956.

So the decay constant is **0.045 /min^{–1}**, indicating a moderate rate of decay.

Problem 4: Estimating Time to Reach a Safety Threshold

A pollutant initially present at 100 mg/m3 has a decay constant of 0.02 day–1. Determine how many days it will take for the concentration to drop below 5 /mg/m3.

1. Set up the inequality: 5 –0.02t.
2. Divide both sides by 100: 0.05 –0.02t.
3. Take natural logs: ln(0.05) !’ t > –ln(0.05)/0.02.
4. Compute: ln(0.05) "H –2.9957; thus t > 2.9957 / 0.02 "H 149.78 /days.

It will take approximately **150 days** for the pollutant to fall below the safety threshold.

4. Common Mistakes and How to Avoid Them

Students often stumble on exponential decay problems due to misunderstandings about the decay constant, misuse of logarithms, or misinterpretation of graph slopes. Below are common pitfalls and strategies to circumvent them:

- Confusing k and T½: Remember that k = ln(2)/T½. If you have one, you can always compute the other.

- Ignoring Units: Decay constants are per unit time (e.g., h–1, min–1). Always keep track of units when converting between k and T½.
- Using log base 10 instead of natural log: Exponential decay formulas use the natural logarithm. If you see log10, convert it to ln by multiplying by ln(10).
- Misreading graph slopes: The slope of ln /y vs. x is negative k. A positive slope indicates growth, not decay.
- Failing to account for initial values: Always start with y0 before applying the exponential factor.

By keeping these reminders in mind, you can reduce errors and improve problem solving accuracy.

5. Real World Applications of Exponential Decay

Exponential decay is not just a classroom exercise; it is a powerful tool for modeling real phenomena. Some prominent applications include:

- Radioactive Dating: Determining the age of fossils and geological formations by measuring the remaining activity of isotopes.
- Pharmacokinetics: Predicting how drugs are metabolized and cleared from the human body to design dosing regimens.
- Environmental Science: Estimating how pollutants dissipate in air, water, or soil over time.
- Population Dynamics: Modeling the decline of endangered species populations under certain conditions.
- Finance: Calculating the present value of cash flows that decay over time due to discounting.

Understanding the mathematics behind exponential decay equips professionals across disciplines to make informed decisions based on predictive models.

6. Further Resources for Mastery

To deepen your grasp of exponential decay and related topics, consider exploring the following resources:

1. Textbooks – “Mathematical Methods for Physics and Engineering” by Riley, Hobson, and Bence offers comprehensive coverage of exponential functions.
2. Online Courses – Khan Academy’s “Exponential and Logarithmic Functions” series provides interactive lessons and practice problems.
3. Software Tools – Graphing calculators or programs like Desmos and GeoGebra can help visualize decay curves and test hypotheses.
4. Research Papers – Look for case studies in journals such as the Journal of Environmental Quality or Pharmacology & Therapeutics that apply exponential decay models.
5. Community Forums – Platforms like Stack Exchange’s Mathematics and Physics communities offer peer support for challenging problems.

Conclusion

Exponential decay is a cornerstone of scientific modeling, and mastering it empowers you to solve a wide array of practical problems. By dissecting each step in Investigation 4, we have illuminated the path from raw data to meaningful conclusions, while highlighting common pitfalls and real world contexts. Whether you are a student refining your skills or a professional applying decay models, the principles outlined here remain universally applicable. Keep practicing, keep questioning, and let the elegance of exponential decay guide your analytical journey.

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