

Engineering Mathematics 1 Solved Question With Answer

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Decoding Differential Equations

A Deep Dive into Engineering Mathematics I

Engineering mathematics forms the bedrock of numerous engineering disciplines. Its core concepts, often abstract in nature, find concrete applications in designing bridges, predicting weather patterns, or even optimizing the fuel efficiency of a vehicle. This article focuses on a single yet representative solved problem from Engineering Mathematics I: solving a first-order linear differential equation, showcasing its theoretical underpinnings and practical relevance.

The Problem

Let's consider the following problem: A tank initially contains 100 liters of pure water. Brine containing 2 grams of salt per liter enters the tank at a rate of 5 liters per minute. The well-mixed solution leaves the tank at the same rate. Find the amount of salt in the tank at any time t .

Mathematical Model and Solution

This problem elegantly illustrates the application of first-order linear differential equations. We can model the amount of salt $A(t)$ in grams in the tank at time t in minutes using the following differential equation:

$$\frac{dA}{dt} = \text{Rate in} - \text{Rate out}$$

Rate in: concentration of salt in inflow \times rate of inflow $= 2 \text{ g/L} \times 5 \text{ L/min} = 10 \text{ g/min}$

Rate out: concentration of salt in outflow \times rate of outflow $= \frac{A(t)}{100} \times 5 \text{ L/min} = \frac{A(t)}{20} \text{ g/min}$

Therefore, the differential equation becomes:

$$\frac{dA}{dt} = 10 - \frac{A}{20}$$

This is a first-order linear differential equation of the form $\frac{dy}{dt} + P(t)y = Q(t)$, where $P(t) = \frac{1}{20}$ and $Q(t) = 10$. We can solve this using an integrating factor.

Integrating factor $I(t) = e^{\int P(t) dt} = e^{\int \frac{1}{20} dt} = e^{\frac{t}{20}}$

Multiplying the differential equation by the integrating factor $e^{\frac{t}{20}}$:

$$e^{\frac{t}{20}} \frac{dA}{dt} + \frac{1}{20} A e^{\frac{t}{20}} = 10 e^{\frac{t}{20}}$$

The left-hand side is the derivative of $e^{\frac{t}{20}} A$ with respect to t . Therefore:

$$\frac{d}{dt} (e^{\frac{t}{20}} A) = 10 e^{\frac{t}{20}}$$

Integrating both sides with respect to t :

$$e^{\frac{t}{20}} A = 200 e^{\frac{t}{20}} + C$$

where C is the constant of integration.

At $t = 0$, $A = 0$ (initially the tank contains pure water).

$$0 = 200 + C \implies C = -200$$

Therefore, the solution is:

$$A(t) = 200(1 - e^{-\frac{t}{20}})$$

Figure 1: Graph of $A(t) = 200(1 - e^{-\frac{t}{20}})$

Insert a graph here showing the exponential growth of $A(t)$ approaching 200 as t increases. The x-axis should represent time t and the y-axis the amount of salt $A(t)$. The graph should clearly show the asymptotic approach to 200 grams.

Practical Applications and Interpretations

This seemingly simple problem has widespread applications. Consider Chemical Engineering: Mixing tanks are common in chemical processes. Understanding salt concentration dynamics helps control reactions and product purity. Environmental Engineering: Modeling pollutant dispersion in rivers or lakes uses similar differential equations. This helps in predicting the impact of pollution and developing remediation strategies. Pharmacokinetics: Drug absorption and elimination in the body can be modeled using similar equations, aiding in drug dosage optimization. Biomedical Engineering: Modeling the diffusion of substances across cell membranes involves solving similar differential equations.

Data Visualization

Time (minutes)	Amount of Salt (grams)
0	0
10	11.758
20	16.484
30	18.559
40	19.434
50	19.760
200	200

This table illustrates the asymptotic behavior of the system, where the amount of salt approaches 200 grams as time goes to infinity.

Conclusion

This solved problem provides a glimpse into the power of engineering mathematics. While seemingly abstract, the concepts presented have tangible real-world implications across various

engineering fields The ability to formulate and solve differential equations is crucial for developing accurate models predicting system behavior and ultimately designing effective and safe engineering solutions The seemingly simple mixing tank problem reveals a sophisticated interplay of mathematical concepts and practical realities highlighting the importance of mastering engineering mathematics for tackling complex challenges

Advanced FAQs

- 1 How would the solution change if the inflow and outflow rates were different The differential equation would become more complex potentially requiring numerical methods for solution The volume of the tank would also change over time affecting the concentration calculation
- 2 What if the concentration of salt in the inflow wasn't constant This would introduce a time dependent function into the Q_t term of the differential equation making the solution more involved and potentially requiring the use of Laplace transforms
- 3 Can nonlinear differential equations be used to model similar systems Yes nonlinear equations can capture more complex behaviors such as chemical reactions with nonlinear rate laws However solving these often requires numerical techniques
- 4 How does this relate to partial differential equations This problem deals with an ordinary differential equation (ODE) However if we consider spatial variations in salt concentration within the tank a partial differential equation (PDE) would be required for a more accurate model
- 5 What are some numerical methods used to solve more complex differential equations arising in engineering problems Several numerical methods exist including Euler's method Runge-Kutta methods and finite difference methods The choice of method depends on the specific equation and desired accuracy These methods are essential when analytical solutions are intractable

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