

Problems on applied thermodynamics Full Version

Problems on applied thermodynamics are a fundamental aspect of engineering and physical sciences, particularly in areas such as mechanical engineering, aerospace, chemical engineering, and energy systems. These problems help students and professionals understand the practical applications of thermodynamic principles, such as energy transfer, work, heat, and entropy, in real-world systems. Addressing these problems enhances analytical skills and deepens comprehension of how thermodynamic laws govern the behavior of systems ranging from engines and refrigerators to power plants and biological processes.

In this comprehensive guide, we will explore common types of problems encountered in applied thermodynamics, their typical frameworks, and strategies to solve them effectively. This article aims to serve as both an educational resource and a reference for tackling complex thermodynamic problems with confidence.

Understanding the Core Concepts of Applied Thermodynamics

Before delving into specific problems, it's essential to revisit the foundational principles of thermodynamics that underpin problem-solving:

First Law of Thermodynamics

- Conservation of energy principle
- Energy transfer as heat and work
- Application in closed and open systems

Second Law of Thermodynamics

- Entropy and irreversibility
- Limitations on engine efficiencies
- Carnot cycle and idealized processes

Properties of Substances

- Temperature, pressure, volume
- Phase diagrams and state equations
- Property tables and charts (e.g., T-s, p-v diagrams)

Common Types of Applied Thermodynamics Problems

Applied thermodynamics problems typically fall into several categories, each requiring specific approaches:

1. Power Cycle Analysis

- Example: Rankine, Brayton, Otto, Diesel cycles
- Objective: Calculate efficiency, work output, heat transfer
- Approach:
 - Identify cycle processes
 - Use property tables or equations of state
 - Apply the first law for each process
 - Compute net work and efficiency

2. Refrigeration and Heat Pump Systems

- Example: Coefficient of performance (COP) calculations
- Approach:
 - Analyze the refrigeration cycle
 - Determine heat removed or added
 - Use the first and second laws to find COP values

3. Combustion and Fuel Analysis

- Example: Heating value calculations, air-fuel ratios
- Approach:
 - Apply conservation of mass and energy
 - Use chemical equations and property data

4. Gas and Vapor Mixture Problems

- Example: Mixture of gases at different states

- Approach:
- Use Dalton's and Dalton's law
- Apply ideal gas law or real gas equations
- Determine properties of the mixture

5. Thermodynamic Property Calculations

- Example: Enthalpy, entropy, internal energy calculations
- Approach:
- Use tables, charts, or equations
- Interpolate data when necessary

Strategies for Solving Applied Thermodynamics Problems

Effective problem-solving in applied thermodynamics involves systematic steps:

Step 1: Understand the Problem Statement

- Carefully read the problem
- Identify knowns and unknowns
- Determine what is being asked

Step 2: Draw a T-s or p-v Diagram

- Visualize the process
- Helps in understanding cycle or process paths

Step 3: List the Assumptions and Simplifications

- Idealized processes (isothermal, adiabatic, isentropic)
- Steady-flow or steady-state assumptions

Step 4: Apply Thermodynamic Laws and Equations

- Use energy balance equations
- Apply property data from tables or charts

- Incorporate entropy considerations for irreversibility

Step 5: Perform Calculations

- Interpolate property data if necessary
- Calculate work, heat transfer, efficiencies

Step 6: Verify Results

- Check units and plausibility
- Analyze whether the results align with physical expectations

Example Problems in Applied Thermodynamics

To illustrate the application of these principles, consider the following example problems:

Example 1: Power Cycle Efficiency Calculation

A steam power plant operates on an ideal Rankine cycle. The boiler pressure is 8 MPa, and the condenser pressure is 10 kPa. Assuming superheated steam at the turbine inlet at 550°C, calculate the cycle efficiency.

Solution Approach:

- Use steam tables to find enthalpy and entropy at key points
- Calculate work done by turbine and pump
- Determine heat added in boiler and rejected in condenser
- Compute efficiency as (net work output) / (heat input)

Example 2: Refrigeration Cycle COP

A vapor-compression refrigeration system has an evaporator temperature of -10°C and a condenser temperature of 30°C. Determine the coefficient of performance (COP) for cooling.

Solution Approach:

- Find saturation pressures and enthalpies at both states

- Use refrigeration cycle equations
- Calculate COP as Q_L / W_{input}

Common Challenges and How to Overcome Them

Despite systematic approaches, students and professionals often face challenges such as:

- **Complex Property Data:** Property tables can be extensive. Use digital tools or software for quick access.
- **Interpreting Diagrams:** Practice sketching and analyzing T-s and p-v diagrams for better understanding.
- **Handling Irreversibilities:** Recognize real-world inefficiencies and include entropy generation in calculations.
- **Multiple Variables:** When multiple unknowns exist, organize data methodically and consider energy and entropy balances simultaneously.

Conclusion

Problems on applied thermodynamics are crucial for translating theoretical principles into practical engineering solutions. Mastering these problems requires a solid understanding of thermodynamic laws, familiarity with property data, and effective problem-solving strategies. By systematically analyzing each problem, drawing clear diagrams, and applying appropriate equations, engineers and students can accurately evaluate system performance, optimize designs, and troubleshoot real-world thermal systems.

Whether dealing with power cycles, refrigeration systems, combustion processes, or gas mixtures, a structured approach combined with practice will enhance proficiency. Remember, solving thermodynamics problems not only deepens theoretical knowledge but also empowers you to innovate and improve energy efficiency in various engineering applications.

For continued learning, utilize online property databases, simulation software, and practice problem sets to strengthen your applied thermodynamics skills.

Problems on Applied Thermodynamics: Navigating the Complexities of Energy Transformation

Introduction

Problems on applied thermodynamics are fundamental to understanding how energy interacts with matter in real-world systems. Whether optimizing power plants, designing efficient engines, or developing sustainable energy solutions, engineers and scientists grapple with the intricacies of

thermodynamic principles. These problems are not merely academic exercises; they are critical to advancing technology, reducing environmental impact, and ensuring energy security. This article delves into the core challenges faced in applied thermodynamics, exploring common problem types, their significance, and the innovative approaches used to solve them.

Understanding the Foundations of Applied Thermodynamics

What Is Applied Thermodynamics?

Applied thermodynamics is the branch of physics and engineering concerned with the practical application of thermodynamic principles to real systems. It bridges the gap between theoretical laws—such as the conservation of energy—and their implementation in devices like engines, refrigerators, turbines, and heat exchangers.

The core goal is to analyze energy transfer processes, optimize system efficiency, and minimize losses. To do so, practitioners rely on fundamental laws—namely, the First and Second Laws of Thermodynamics—and their application to complex systems.

Core Principles in Thermodynamic Problem-Solving

- First Law of Thermodynamics (Conservation of Energy): Energy can neither be created nor destroyed; it can only change forms.
- Second Law of Thermodynamics: Entropy of an isolated system tends to increase, setting limits on the efficiency of energy conversion processes.
- Property Relationships: Understanding properties such as pressure, temperature, volume, enthalpy, entropy, and internal energy is crucial for solving practical problems.

Common Types of Problems in Applied Thermodynamics

Applied thermodynamics problems generally fall into several categories, each presenting unique challenges.

- Power Cycle Analysis

Power cycles, such as Rankine, Brayton, or Otto cycles, form the backbone of power generation and

propulsion systems.

Typical Problem Aspects:

- Calculating thermal efficiency
- Determining work output
- Assessing heat transfer rates
- Analyzing state points and cycle parameters

Example Challenge:

Calculating the efficiency of a steam turbine cycle operating between specified pressure and temperature limits requires applying the first law to each component and understanding phase changes.

- Refrigeration and Heat Pump Systems

These systems involve transferring heat from a low-temperature source to a high-temperature sink.

Key Focus:

- Evaluating Coefficient of Performance (COP)
- Determining work input or heat transfer rates
- Analyzing cycle performance under varying conditions

Problem Example:

Designing a refrigeration cycle that maintains a specific temperature difference while optimizing energy consumption involves complex property calculations and cycle analysis.

- Combustion and Fuel Analysis

Efficient combustion processes are central to many applications, including engines and power plants.

Challenges Include:

- Balancing chemical reactions
- Calculating heat of reaction
- Analyzing exhaust composition
- Estimating fuel consumption and efficiency

Sample Issue:

Determining the adiabatic flame temperature for a fuel-air mixture requires solving energy balance equations with detailed property data.

- Thermodynamic Property Calculations

Many problems involve determining specific properties at various states, which serve as inputs for cycle analysis.

Typical Tasks:

- Calculating enthalpy, entropy, and internal energy
- Using property tables or equations of state
- Interpolating data for specific conditions

Complexity:

Accurate property data are essential, especially near phase boundaries or in supercritical regions, leading to potential inaccuracies if mishandled.

Challenges and Solutions in Applied Thermodynamics Problems

While the foundational principles are straightforward, practical problems often involve complex variables, approximations, and assumptions.

- Handling Real-World Deviations

Problem:

Idealized models often assume reversible processes and neglect losses, leading to discrepancies when applying to real systems.

Solution:

- Incorporate irreversibilities and entropy generation into models.
 - Use real fluid properties rather than idealizations.
 - Employ correction factors and empirical data.
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- Dealing with Complex Property Data

Problem:

Accessing and accurately interpolating thermodynamic properties from tables or software can be challenging, especially for mixtures or supercritical fluids.

Solution:

- Utilize advanced thermodynamic software with extensive property databases.
 - Develop customized interpolation routines.
 - Validate data through experimental measurements when possible.
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- Optimization Under Constraints

Problem:

Maximizing efficiency or minimizing costs often involves multiple competing parameters and constraints.

Solution:

- Formulate problems as constrained optimization tasks.
- Use techniques such as Lagrange multipliers or numerical optimization algorithms.
- Incorporate sensitivity analysis to assess the impact of variables.

Emerging Trends and Future Directions

Applied thermodynamics continues to evolve with technological advancements and environmental considerations.

- Sustainable Energy Systems

Designing thermodynamic systems that utilize renewable resources or waste heat involves novel problem-solving approaches.

- Developing high-efficiency cycles like supercritical CO₂ cycles
- Integrating thermodynamic analysis with renewable energy sources

- Advanced Computational Tools

Simulation software and machine learning models are increasingly used to predict system behavior and optimize designs.

- Enhanced accuracy in property calculations
- Rapid analysis of complex cycles and systems

- Miniaturization and Micro-scale Applications

As devices shrink, thermodynamic principles are applied at micro and nano scales.

- Challenges in heat transfer and entropy management
- New problem types involving quantum effects

Conclusion

Problems on applied thermodynamics are at the heart of modern engineering innovation. They require a deep understanding of fundamental principles, meticulous analysis, and often creative problem-solving. From designing the next-generation power plants to developing eco-friendly refrigeration systems, tackling these challenges is crucial for sustainable development and technological progress.

As our energy landscape shifts towards greener and more efficient solutions, the importance of mastering applied thermodynamics problems only grows. Continuous advancements in computational methods, material science, and system integration promise to equip engineers and scientists with better tools to solve these complex issues. Whether addressing the efficiency of a simple heat engine or optimizing a complex combined cycle plant, the core challenges remain

rooted in understanding and applying thermodynamic principles effectively.

By embracing these problems, the engineering community not only advances scientific knowledge but also paves the way for a more sustainable and energy-efficient future.

Question What are common challenges faced when applying the first law of thermodynamics to real-world systems? Common challenges include accounting for irreversibilities, heat losses, and non-ideal behaviors of materials, which make exact energy balance calculations more complex in practical applications. How does the concept of entropy help in analyzing problems in applied thermodynamics? Entropy provides insight into the irreversibility of processes, helping engineers evaluate the efficiency of systems and identify sources of energy degradation and entropy generation. What are typical issues encountered in modeling real gas behavior in thermodynamic problems? Modeling real gases involves complexities such as deviations from ideal gas law, requiring equations of state like Van der Waals or Redlich-Kwong, which can be challenging due to their mathematical complexity and the need for accurate property data. Why is it difficult to accurately determine thermodynamic properties during phase change processes? Phase change processes involve rapid changes in properties like enthalpy and entropy, and accurate data may be limited or difficult to measure, making precise calculations challenging. What problems arise when applying thermodynamic cycles in real-world heat engines? Issues include irreversibilities, friction, heat losses, and non-ideal working fluids, which reduce efficiency compared to ideal cycle predictions. How do engineers address the problem of heat transfer losses in thermodynamic system design? Engineers use insulation, heat exchangers, regenerative processes, and optimization techniques to minimize heat transfer losses and improve system efficiency. What challenges are associated with applying thermodynamic principles to renewable energy systems? Challenges include variable energy sources, complex system interactions, and the need for accurate modeling of new or unconventional working fluids and processes, which complicate analysis and optimization. In what ways do material limitations pose problems in applied thermodynamics? Material limitations such as temperature and pressure constraints can restrict operating conditions, cause degradation, or failure of components, thus impacting the design and safety of thermodynamic systems.

Related keywords: thermodynamic cycles, heat transfer, entropy, enthalpy, Carnot engine, refrigeration, thermal efficiency, first law, second law, real gases

Understanding Thermodynamics Dover Books On Physic

Understanding thermodynamics Dover books on physic is an essential step for students, educators, and enthusiasts seeking a comprehensive grasp of the fundamental principles governing

energy, heat, and work in physical systems. Dover Publications is renowned for its extensive collection of classic and accessible scientific texts, including their specialized offerings on thermodynamics. These books are highly valued for their clarity, depth, and affordability, making them ideal resources for anyone aiming to deepen their understanding of thermodynamics within the realm of physics. Whether you're starting your journey or looking to refine your knowledge, Dover's thermodynamics titles serve as reliable guides through complex concepts and theories.

Why Choose Dover Books for Learning Thermodynamics?

Affordable and Accessible

Dover Publications is celebrated for its budget-friendly pricing, making high-quality scientific texts accessible to a broad audience. Their thermodynamics books are often reprints of classic works or carefully curated modern texts, providing valuable insights without the hefty price tag.

Comprehensive and Well-Structured Content

These books typically cover fundamental principles, mathematical formulations, and practical applications, often presented in a clear, logical progression that benefits learners at various levels.

Authoritative and Reputable Sources

Many Dover thermodynamics titles are authored by renowned scientists and educators whose expertise lends credibility and depth to the material, ensuring readers get accurate and reliable information.

Key Titles in Dover's Thermodynamics Collection

Classic Texts and Foundational Works

Dover offers reprints of seminal works that have shaped the understanding of thermodynamics, such as:

- *Thermodynamics: An Introductory Treatment* by Richard C. Tolman
- *Introduction to Thermodynamics* by Richard E. Sonntag, Claus Borgnakke, and Gordon J. Van Wylen

These texts provide historical context and foundational theories that remain relevant today.

Modern and Specialized Publications

In addition to classics, Dover publishes contemporary texts that explore specialized topics like statistical mechanics, non-equilibrium thermodynamics, and applications in engineering and physics.

Understanding Thermodynamics Through Dover Books

The Core Principles Explained

Dover's thermodynamics books excel at breaking down complex concepts into manageable explanations, making them ideal for students new to the subject.

- **First Law of Thermodynamics:** Conservation of energy principle, relating heat added to a system to work done and change in internal energy.
- **Second Law of Thermodynamics:** Introduction to entropy, irreversibility, and the concept that energy spontaneously disperses.
- **Third Law of Thermodynamics:** Behavior of entropy as temperature approaches absolute zero.

Mathematical Foundations

Most Dover thermodynamics books include mathematical derivations and problem-solving strategies, which are essential for mastering the quantitative aspects of the field.

- Use of calculus to describe thermodynamic processes
- Formulation of state functions and equations of state
- Application of differential equations in thermodynamic cycles

Practical Applications and Examples

To bridge theory and practice, Dover's titles often feature real-world applications, such as engines, refrigerators, and atmospheric processes, demonstrating the relevance of thermodynamics principles.

How to Use Dover Books for Effective Learning

Start with Introductory Texts

If you're new to thermodynamics, begin with Dover's introductory titles that lay out fundamental concepts clearly and systematically.

Work Through Examples and Exercises

Active engagement enhances understanding. Dover books frequently include problems and solutions that help reinforce learning.

Supplement with Modern Resources

While Dover books are excellent foundational texts, supplement your study with online lectures, research papers, or interactive simulations to deepen understanding.

Additional Resources and Study Tips

Join Study Groups or Forums

Collaborative learning can clarify difficult topics and provide diverse perspectives.

Utilize Visual Aids

Diagrams, charts, and graphs included in Dover texts help visualize complex processes and relationships.

Practice Regularly

Consistent problem-solving builds proficiency and confidence in applying thermodynamic principles.

Conclusion: Embracing Thermodynamics with Dover Books

Understanding thermodynamics through Dover books on physics offers a solid foundation and a pathway to mastery in this vital scientific discipline. Their combination of clarity, affordability, and authoritative content makes them ideal for learners at all levels. By carefully studying these texts, engaging with exercises, and exploring practical applications, students and enthusiasts can develop a comprehensive understanding of how energy operates within physical systems. Whether you're embarking on your academic journey or seeking to refine your knowledge, Dover's thermodynamics titles are invaluable resources that can guide you through the fascinating world of heat, work, and energy transformations in physics.

Thermodynamics Dover Books on Physics: An In-Depth Exploration

When delving into the expansive world of physics, few subjects are as foundational and as universally applicable as thermodynamics. Its principles underpin everything from engines and refrigerators to the behaviors of stars and the evolution of the universe. For students, educators, and

enthusiasts eager to master this essential field, Dover Publications has long been a trusted source of comprehensive, accessible, and affordable texts. Their series of Thermodynamics Dover Books on Physics stands out as an invaluable collection, blending rigorous academic content with clarity and pedagogical insight.

In this article, we will explore the significance of these works, analyze their content, evaluate their strengths and limitations, and provide guidance on how best to leverage them for mastering thermodynamics.

Overview of Dover's Contribution to Physics Literature

Dover Publications has established a reputation for curating a diverse catalog of scientific texts that are both affordable and authoritative. Their physics series includes classic texts, problem compilations, and introductory guides. Specifically, in the realm of thermodynamics, Dover offers a variety of titles that cater to different levels of expertise, from beginners to advanced researchers.

What makes Dover books particularly appealing is their commitment to quality content presented with clarity, often including historical context, illustrative figures, and comprehensive problem sets. This approach makes complex topics more digestible and encourages active learning.

Core Titles in the Thermodynamics Dover Series

The series encompasses several key titles, each providing a unique perspective or focus area within thermodynamics:

- "Thermodynamics and Statistical Mechanics" by Walter Greiner
- "Introduction to Thermodynamics" by Richard E. Sonntag and Gordon J. Van Wylen
- "Heat and Thermodynamics" by Mark W. Zemansky and Richard D. Drake
- "Statistical Thermodynamics" by K. Huang
- "Classical Thermodynamics" by Herbert B. Callen

While all these titles are valuable, this review will primarily focus on the foundational texts, especially those that serve as excellent starting points for students.

Key Features and Content Analysis

Comprehensiveness and Pedagogical Approach

Dover's thermodynamics books are renowned for their comprehensive coverage. They typically begin with fundamental principles?definitions of temperature, heat, work, and the laws of

thermodynamics?and gradually build towards more complex topics like entropy, free energies, and thermodynamic cycles.

Most titles employ a step-by-step pedagogical approach:

- Clear explanations of concepts with historical notes to contextualize their development.
- Mathematical derivations that explain the underlying principles without overwhelming the reader.
- Worked examples demonstrating problem-solving techniques.
- Problem sets at the end of chapters to reinforce understanding and practice application.

This structure ensures that learners can follow the logical progression of ideas while actively engaging with the material.

Mathematical Rigor and Accessibility

Dover books strike a fine balance between mathematical rigor and accessibility:

- For beginners: They introduce concepts with minimal mathematical prerequisites, focusing on intuitive understanding.
- For advanced readers: They delve into detailed derivations, statistical mechanics foundations, and thermodynamic potentials, suitable for graduate-level study or research.

The clarity of mathematical presentation allows readers to grasp complex derivations and apply the principles confidently.

Historical Context and Evolution of Ideas

Many titles include historical notes that trace the evolution of thermodynamic concepts, from Carnot's heat engine to modern statistical mechanics. This enriches the reading experience, providing insight into how ideas developed and their relevance today.

Visual Aids and Illustrations

Illustrations play a key role in Dover thermodynamics books:

- Diagrams of thermodynamic cycles, such as Carnot, Otto, and Rankine engines.
- Graphs depicting state functions and phase diagrams.
- Conceptual sketches that clarify abstract ideas.

These visual elements are crucial for understanding complex processes and are typically well-integrated into the text.

Strengths of Dover Thermodynamics Books

- **Affordability:** Dover's pricing makes high-quality scientific texts accessible to a broad audience, including students and independent learners.
- **Authoritativeness:** Many titles are written by renowned physicists, offering reliable and academically rigorous content.
- **Historical and Theoretical Depth:** Their inclusion of historical context and derivations enriches comprehension.
- **Comprehensive Problem Sets:** End-of-chapter questions range from straightforward applications to challenging problems, fostering mastery.
- **Durability and Quality:** Printed on quality paper with durable covers, these books are built to last.

Limitations and Considerations

While Dover books are exceptional resources, potential limitations include:

- **Lack of Modern Pedagogical Features:** Unlike contemporary textbooks, some titles may lack online supplement materials, interactive content, or multimedia aids.
- **Density of Material:** The comprehensive nature may be daunting for absolute beginners without supplementary instruction.
- **Variable Depth:** Some titles lean heavily on classical thermodynamics and may not cover the latest developments in non-equilibrium thermodynamics or quantum thermodynamics.
- **Formatting and Layout:** Older editions may have less reader-friendly formatting compared to modern textbooks.

How to Maximize Learning with Dover Thermodynamics Books

To optimize your understanding of thermodynamics using Dover publications, consider the following strategies:

Start with Introductory Titles

Begin with foundational texts that prioritize clarity and basic principles, such as "Introduction to Thermodynamics" by Sonntag and Van Wylen, before progressing to more advanced or specialized books.

Engage Actively with Problems

Work through the exercises provided. Attempt all problems, verify solutions, and revisit challenging questions to deepen understanding.

Complement Reading with Practical Application

Apply concepts to real-world problems or experiments. If possible, perform simple experiments or simulations to see thermodynamics in action.

Supplement with Modern Resources

While Dover books are comprehensive, supplement your study with online lectures, software simulations, or recent journal articles for contemporary developments.

Review Historical Context

Understanding the evolution of ideas can enhance conceptual clarity and appreciation for the subject's depth.

Conclusion: An Essential Asset for Thermodynamics Study

The Thermodynamics Dover Books on Physics series offers a treasure trove of knowledge for anyone serious about understanding this central branch of physics. Their combination of rigorous content, pedagogical clarity, historical richness, and affordability makes them stand out among scientific literature.

Whether you're a student embarking on your first thermodynamics course, an educator seeking reliable teaching materials, or an enthusiast eager to deepen your understanding, these books serve as invaluable companions. While they may not replace interactive or multimedia resources, their depth and clarity provide a solid foundation upon which to build a comprehensive understanding of thermodynamics.

In embracing Dover's thermodynamics titles, you gain access to some of the most respected classical texts in the field, ensuring your journey into the energetic and entropic intricacies of the universe is both enlightening and enduring.

Question What are the key topics covered in Dover's 'Thermodynamics' books on physics? **Answer** Dover's 'Thermodynamics' books typically cover fundamental concepts such as the laws of thermodynamics, entropy, thermodynamic cycles, statistical mechanics, and applications to real-world systems, providing a comprehensive understanding suitable for students and enthusiasts.

Are Dover's thermodynamics books suitable for beginners or advanced students? Dover's thermodynamics books are generally designed to cater to both beginners and intermediate students, offering clear explanations and detailed derivations, making complex topics accessible while also providing depth for those with foundational knowledge. How do Dover's thermodynamics books compare to other standard texts in the field? Dover's thermodynamics books are known for their affordability, clarity, and thorough coverage, often serving as excellent supplementary texts alongside more comprehensive or advanced titles, making them popular among students and educators. Can Dover's 'Thermodynamics' books help in preparing for physics exams or research? Yes, Dover's thermodynamics books provide fundamental principles, practice problems, and detailed explanations that can aid in exam preparation and offer a solid foundation for further research in physics. Are there specific Dover books on thermodynamics that focus on statistical mechanics or classical thermodynamics? Yes, Dover offers separate titles focusing on classical thermodynamics and statistical mechanics, allowing readers to choose books that align with their specific interests or academic needs within the field.

Related keywords: thermodynamics, physics books, Dover publications, heat transfer, entropy, thermodynamic cycles, statistical mechanics, classical thermodynamics, physical chemistry, energy conservation

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