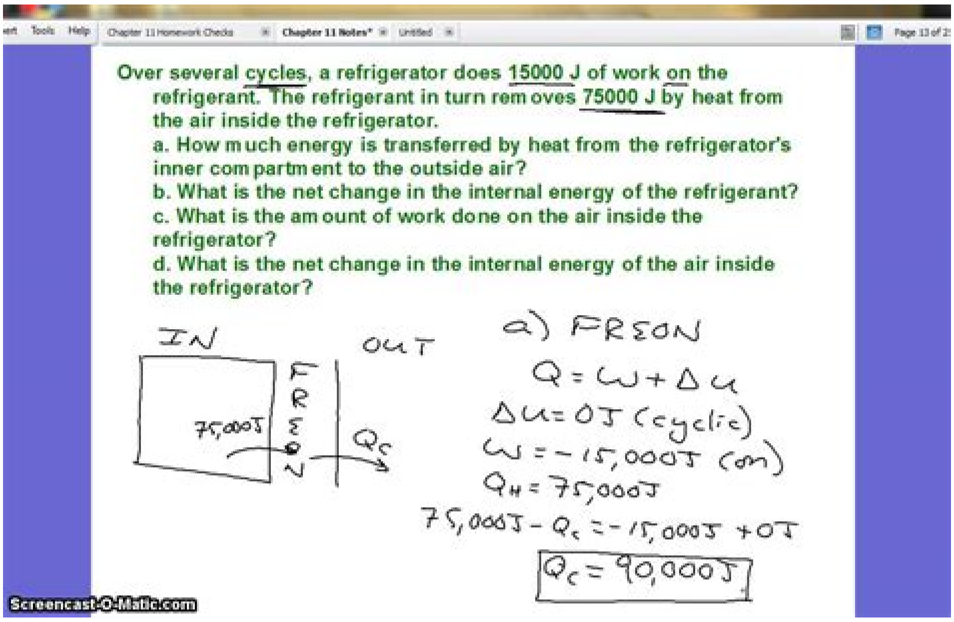
First Law Of Thermodynamics Practice Problems



First law of thermodynamics practice problems are essential for students and enthusiasts looking to deepen their understanding of thermodynamics. The first law, also known as the law of energy conservation, states that energy cannot be created or destroyed, only transformed from one form to another. This principle is foundational in various fields, including physics, chemistry, and engineering. In this article, we will explore the first law of thermodynamics, present practice problems, and provide detailed solutions to help solidify your comprehension of this crucial concept.

Understanding the First Law of Thermodynamics

The first law of thermodynamics can be mathematically expressed as:

$$\Delta U = Q - W$$

Where:
- ΔU is the change in internal energy of the system.
- Q is the heat added to the system.
- W is the work done by the system.

This equation highlights the relationship between heat transfer, work, and internal energy. When heat is added to a system, its internal energy increases unless work is done by the system. Conversely, if the system does work on its surroundings, its internal energy decreases.

Key Concepts of the First Law of Thermodynamics

To effectively solve practice problems related to the first law of thermodynamics, it’s vital to understand some key concepts:

- **Internal Energy (U):** The total energy contained within a system, including kinetic and potential energy at the molecular level.
- **Heat (Q):** The energy transfer due to a temperature difference between the system and its surroundings.
- **Work (W):** The energy transfer that occurs when a force is applied to a system, resulting in displacement.
- **Isothermal Process:** A thermodynamic process that occurs at a constant temperature.
- **Adiabatic Process:** A process where no heat is exchanged with the surroundings.

Practice Problems

To help you master the first law of thermodynamics, we will present several practice problems, each designed to test your understanding of the concepts we discussed.

Problem 1: Internal Energy Change

A gas in a closed container is heated, absorbing 500 J of heat. During this process, the gas does 200 J of work on the surroundings. Calculate the change in internal energy of the gas.

Problem 2: Work Done on the System

A piston compresses a gas, resulting in 300 J of work done on the gas. The gas releases 100 J of heat to the surroundings. What is the change in internal energy of the gas?

Problem 3: Adiabatic Process

A system undergoes an adiabatic process where it does 400 J of work on the surroundings. If the internal energy decreases by 350 J, how much heat was exchanged during this process?

Problem 4: Isothermal Expansion

A gas expands isothermally and absorbs 600 J of heat from the surroundings. If the internal energy of the gas remains constant during this process, how much work is done by the gas?

Solutions to Practice Problems

Now that we have outlined several practice problems, let’s go through the solutions step by step.

Solution to Problem 1

Given:
- $Q = 500 \, \text{J}$
- $W = 200 \, \text{J}$

Using the first law of thermodynamics:

$$\Delta U = Q - W$$

$$\Delta U = 500 \, \text{J} - 200 \, \text{J} = 300 \, \text{J}$$

The change in internal energy of the gas is 300 J.

Solution to Problem 2

Given:
- $W = 300 \, \text{J}$ (work done on the gas, so it is positive)
- $Q = -100 \, \text{J}$ (heat released, so it is negative)

Using the first law of thermodynamics:

$$\Delta U = Q - W$$

$$\Delta U = -100 \, \text{J} - 300 \, \text{J} = -400 \, \text{J}$$

The change in internal energy of the gas is -400 J.

Solution to Problem 3

Given:
- Work done by the system, $W = 400 \, \text{J}$ (positive since work is done on surroundings)
- Change in internal energy, $\Delta U = -350 \, \text{J}$

Using the first law of thermodynamics:

$$\Delta U = Q - W$$

Rearranging to find Q:

$$Q = \Delta U + W$$

$$Q = -350 \, \text{J} + 400 \, \text{J} = 50 \, \text{J}$$

The heat exchanged during this process is 50 J.

Solution to Problem 4

Given:
- Heat absorbed, $Q = 600 \, \text{J}$
- Change in internal energy is zero since it's an isothermal process, $\Delta U = 0$

Using the first law of thermodynamics:

$$\Delta U = Q - W$$

Rearranging to find W:

$$0 = 600 \, \text{J} - W$$

Thus:

$$W = 600 \, \text{J}$$

The work done by the gas is 600 J.

Conclusion

By practicing problems related to the **first law of thermodynamics**, students can gain a more profound understanding of energy conservation and its applications in various processes. These practice problems not only enhance problem-solving skills but also prepare students for advanced topics in thermodynamics and related fields. With consistent practice, mastering the first law becomes an achievable goal, paving the way for deeper exploration into the fascinating world of thermodynamics.

Frequently Asked Questions

What is the first law of thermodynamics and how is it applied in practice problems?

The first law of thermodynamics states that energy cannot be created or destroyed, only transformed from one form to another. In practice problems, we apply this principle by accounting for the energy input and output in a system, often using the equation $\Delta U = Q - W$, where ΔU is the change in internal energy, Q is heat added to the system, and W is work done by the system.

How do you calculate the work done by a gas during expansion in a first law of thermodynamics problem?

Work done by a gas during expansion can be calculated using the formula $W = P\Delta V$, where P is the pressure and ΔV is the change in volume. If the process is isothermal, you can also use $W = nRT \ln(Vf/Vi)$ for an ideal gas, where n is the number of moles, R is the ideal gas constant, and Vf and Vi are the final and initial volumes, respectively.

What is the significance of internal energy in first law of thermodynamics practice problems?

Internal energy is a key concept in the first law of thermodynamics, representing the total energy contained within a system. It is significant because changes in internal energy (ΔU) can indicate how much energy is added or removed from the system, allowing for the analysis of various thermodynamic processes.

How can you determine if a reaction is exothermic or endothermic using the first law of thermodynamics?

You can determine if a reaction is exothermic or endothermic by observing the sign of Q in the first law of thermodynamics equation $\Delta U = Q - W$. If Q is positive, the system absorbs heat (endothermic). If Q is negative, the system releases heat (exothermic).

What types of problems commonly arise in the context of the first law of thermodynamics?

Common problems include calculating the change in internal energy for a system, determining the work done during gas expansion or compression, analyzing heat transfer in calorimetry, and solving for the final temperature or pressure of a gas after energy changes.

Can you give an example of a first law of thermodynamics practice problem involving heat and work?

Sure! If a gas in a piston receives 500 J of heat (Q) and does 300 J of work (W) on the surroundings, what is the change in internal energy (ΔU)? Using the first law: $\Delta U = Q - W = 500 \text{ J} - 300 \text{ J} = 200 \text{ J}$. Thus, the internal energy increases by 200 J.

What role does heat capacity play in first law of thermodynamics problems?

Heat capacity relates to how much heat is required to change the temperature of a system. In first law problems, it helps to quantify the amount of heat (Q) absorbed or released during temperature changes, which is essential for calculating changes in internal energy.

How do you approach a first law of thermodynamics problem involving a cyclic process?

In a cyclic process, the system returns to its initial state, so the change in internal energy (ΔU) over one complete cycle is zero. Therefore, any heat added to the system (Q) must equal the work done by the system (W) throughout the cycle, leading to the equation $Q = W$.

What is an isothermal process and how does it relate to the first law of thermodynamics?

An isothermal process occurs at constant temperature. In this context, the internal energy change (ΔU) for an ideal gas is zero. Thus, the first law simplifies to $Q = W$, meaning all heat added to the system is converted to work done by the system.

How can you use the first law of thermodynamics to analyze heating a gas in a closed container?

When heating a gas in a closed container, you can use the first law to analyze the energy changes. If heat (Q) is added to the gas, it can increase the internal energy (ΔU) and potentially do work (W) on the container walls, depending on whether the gas expands. The relationship $\Delta U = Q - W$ helps determine how much energy goes into increasing the internal energy versus doing work.

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