

Equilibrium vs. Steady State

Equilibrium Series

Instructor's Guide

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SOPH 302

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DEVELOPED BY THE TEACHING AND LEARNING LABORATORY AT MIT
FOR THE SINGAPORE UNIVERSITY OF TECHNOLOGY AND DESIGN



Introduction

When to Use this Video

- In Soph 302, at home, in class, or in recitation.
- Prior knowledge: First and Second Law of Thermodynamics, the meaning of thermal equilibrium, and the concept of heat flow (energy per unit time).

Learning Objectives

After watching this video students will be able to:

- Identify whether a system is at equilibrium and/or steady state.
- Describe the differences and similarities between equilibrium and steady state.

Motivation

Many students confuse equilibrium and steady state and often use these terms interchangeably.

Student Experience

It is highly recommended that the video is paused when prompted so that students are able to attempt the activities on their own and then check their solutions against the video.

During the video, students will:

- Consider whether or not a metal bar is at thermal equilibrium with the air in the room.
- Consider whether or not the same metal bar, now placed on a heater for a long time is at thermal equilibrium with the room.
- Apply the concepts of thermal equilibrium and steady state to specify conditions for which the handle of a pan, which has been heated on a stove for a long time, is too hot to hold or cool to the touch.
- Analyze whether the pan on the stove and its handle are at equilibrium, steady state or both for four different cases: 1) the handle and pan are in perfect thermal contact, and both are thermally isolated from the room; 2) the handle is completely insulated from the pan, and the handle is at thermal equilibrium with the room; 3) the pan and handle are in perfect thermal contact, and heat is allowed to flow from the handle to the room; 4) the pan and handle are partially insulated from each other, and the handle can exchange heat with the room.

Key Information

Duration: 15:05

Narrator: Prof. John Lienhard

Materials Needed:

- paper
- pencil

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Video Highlights

This table outlines a collection of activities and important ideas from the video.

Time	Feature	Comments
1:29	A metal bar in a room is shown. Both the bar and the room are at 25°C.	Students are introduced to the concept of thermal equilibrium- no net transfer of energy occurs between the metal bar and the room.
3:11	The metal bar is shown and it has been left on a heater. A temperature profile for the bar is shown.	Students are presented with a contrasting situation in which the bar is not in thermal equilibrium with the room. Students are introduced to the concept of steady state temperature.
5:03	A heated pan from the introduction is shown. Students are asked to think of scenarios in which the handle is too hot to pick up or cool to the touch.	Four scenarios are presented. The first two scenarios illustrate that thermal equilibrium is a limiting case of steady state temperature.
8:34	The third scenario is presented in which heat flows from the pan body to the handle and from the handle to the room.	Students are asked to consider heat flow rates from the pan to the handle and from the handle to the room. After some initial period, the two rates are equal and students are shown that the handle reaches steady-state temperature. It is stressed that, in this scenario, the handle and the pan are not in thermal equilibrium.
11:01	The fourth scenario is presented where the pan body is insulated from the handle.	Due to the insulation, very small amounts of heat will be transferred to the handle, which dissipates to the air. In this scenario, the handle will reach steady state temperature and cool enough to hold.
13:01	The question, "Will the handle be cool enough to hold or too hot to touch?" is answered for the pan in the video.	This handle and pan are at steady state with respect to temperature. While the region of the handle closest to the pan is hot, the majority of the handle is cool enough to hold. A possible temperature profile and a thermal image are shown.

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Video Summary

In this video, viewers explore the differences and similarities between thermal equilibrium and steady state temperature. Four scenarios are presented wherein the heat transfer between a pan and its handle, and between the handle and the room are constrained in a variety of ways, and the resultant temperature profiles are discussed. Viewers are asked to: determine whether the handle is at thermal equilibrium or steady state temperature; sketch a corresponding temperature profile in the pan handle; and predict whether or not a particular pan handle will be cool enough to touch.

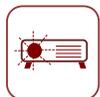
Soph 302 Materials

Pre-Video Materials

When appropriate, this guide is accompanied by additional materials to aid in the delivery of some of the following activities and discussions.



1. The Second Law of Thermodynamics



For a review of entropy and the Second Law of Thermodynamics, view the [Entropy](#) video, part of the SUTD Concept Vignette series.

Post-Video Materials



1. In small groups, ask students to list two examples of:

- A system that is at equilibrium with respect to temperature.
- A system that is at steady-state with respect to temperature.

Students should be prepared to justify their classification for each of the systems chosen to the rest of their classmates.



2. Discuss whether boiling water in an open pan on a heat source is at equilibrium, steady-state or both. Tell your students that the dominant process in this example is the vaporization of liquid water, with a net flow of water molecules from the liquid to the atmosphere. The system is not at equilibrium. However, the temperature of the boiling water remains constant at 100°C - the temperature is at steady-state.

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Additional Resources

References

The following article provided the inspiration for this video:

- Vigeant, M., Prince, M., and Nottis, K. (2011). Development of Concept Questions and Inquiry-Based Activities in Thermodynamics and Heat Transfer: An Example for Equilibrium vs. Steady State, *Chemical Engineering Education*. 45(3): 211.

The following article discusses student difficulties with the subject of this video:

- Streveler, R., Olds, B., Miller, R., and Nelson, M. (2003) Using a Delphi Study to Identify the Most Difficult Concepts for Students to Master in Thermal and Transport Science. *Proceedings of the 2003 American Society for Engineering Education Annual Conference & Exposition*, Nashville, TN.

The following textbooks may prove useful for reviewing the prerequisite information needed to understand the video:

- Oxtoby, D. W., Nachtrieb, N. H. (1990). *Principles of Modern Chemistry*. Philadelphia: Saunders College Pub.
- Bell, J. (2005). *Chemistry: A project of the American Chemical Society*. New York: W.H Freeman and Company.

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