

Energy Systems

Mihir Sen

*Department of Aerospace and Mechanical Engineering
University of Notre Dame
Notre Dame, IN 46556*

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Preface

These are notes and reading material being prepared during Spring, 2009 as part of a three-credit, self-study, elective course on *Energy Systems*. The purpose is to develop textual material for a regular course on the subject to be offered in the future for mechanical and aerospace engineering seniors interested in the generation, storage and usage of energy in mechanical and thermal systems. Students would normally have taken courses in mathematics, thermodynamics, solid and fluid mechanics, and heat transfer.

This text is designed as outside-class reading to complement in-class lectures. Supplementary homework will be assigned, along with individual research projects and state of the art reviews of selected topics with in-class presentations, mid-term and final reports.

Mihir Sen
Department of Aerospace and Mechanical Engineering
University of Notre Dame

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Chapter 1

Introduction

1.1 Historical background

Fire was an early source of energy for humans; it helped keep them warm, kept away predators, and could be used to cook their food. We can only speculate how they lit their fires. One obvious source is natural, due to lightening strikes, for example. Later, rubbing one wooden stick or piece of flint against another would become a more reliable way of starting a fire.

[4, 11, 15, 17, 29, 35, 36, 39]

1.1.1 Pre-industrial

1.1.2 Water power

1.1.3 Coal

1.1.4 Steam

1.1.5 IC engines

1.1.6 Electricity

1.1.7 Potential energy storage

Springs, falling weights

1.2 Hydrocarbon energy sources

1.2.1 Coal

1.2.2 Petroleum

1.2.3 Natural gas

1.3 Climate modeling

1.3.1 Effect of Coriolis forces

1.3.2 Weather patterns

1.4 Geophysics

1.4.1 Volcanoes

1.4.2 Hydrothermal vents

[1]

1.5 Physics

1.5.1 Nuclear processes

[27]

Nuclear energy, terrestrial radioactivity

1.6 Chemistry

1.6.1 Photosynthesis

1.6.2 Combustion

1.7 Electromagnetics

1.7.1 Magnetohydrodynamic generators

1.7.2 Devices

Photovoltaic, thermoelectric, and thermionic

1.8 Electrochemical

1.8.1 Batteries

1.8.2 Fuel cells

[22]

Chapter 2

Hardware

2.1 Piping and networks

[14]

2.2 Heat exchangers

[13, 20, 21]

2.3 Boilers and condensers

[2]

2.4 Prime movers

2.5 Turbomachines

[23]

Chapter 3

Conventional energy systems

3.1 Thermal power plants

3.2 Hydroelectric power

Dams

3.3 Nuclear power plants

Types of reactors, fuel, breeding, waste, reprocessing, fusion

Chapter 4

Alternative energy systems

[3]

4.1 Solar

4.1.1 *Solar thermal*

[7]

4.1.2 *Photovoltaic*

4.2 Ocean

4.2.1 *Thermal*

Concentrated (mirrors), flat-plate collectors

4.2.2 *Wave*

4.2.3 *Tidal*

4.3 Wind

[19]

4.4 Geothermal

4.5 Biomass

Biofuels

4.6 Carbon sequestration

4.7 Synthetic fuels

Integrated Gasification Combined Cycle (IGCC)

Chapter 5

Energy storage and recovery

5.1 Mechanical

5.1.1 *Flywheels*

5.2 Thermal

[6, 30]

5.2.1 *Phase-change*

5.3 Fluidic

5.3.1 *Compressed air*

5.3.2 *Pumped water*

5.4 Chemical

5.5 Kinetic energy recovery systems

5.6 Energy harvesting

Chapter 6

Energy usage

6.1 Electrical machines

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6.2 Internal combustion engines

[8, 32, 34]

6.3 Steam and Stirling engines

[33, 37]

6.4 Propulsion

6.5 Furnaces

[2]

6.6 Air conditioning

[10, 24]

6.6.1 *Vapor compression*

6.6.2 *Absorption*

6.6.3 *Thermoelectric*

6.7 Thermal control

6.8 Buildings

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6.8.1 *Human comfort*

6.8.2 *Thermal loads*

6.8.3 *Heating and ventilation*

[10, 24]

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6.8.4 *Simulation*

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6.8.5 *Insulation*

6.9 Electrical

6.9.1 *Active and reactive loads*

6.9.2 *Demand*

6.10 Computers

6.10.1 *Data centers*

6.11 Environmental aspects

Pollutants, scrubbing

Appendix A

Review

A.1 Energy and power

A.1.1 *Units and conversion*

A.2 Thermodynamics

[16, 25]

A.2.1 *Laws*

A.2.2 *Properties*

Intensive, extensive, internal energy, enthalpy, entropy

A.2.3 *Available energy*

A.2.4 *Cycles*

Otto, Stirling, Brayton

A.2.5 *Psychrometrics*

A.3 Fluid mechanics

[9, 26, 38]

A.4 Heat transfer

[18]

A.5 Chemical kinetics

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