12.3: The First Law of Thermodynamics and Some Simple Processes

Learning Objectives

By the end of this section, you will be able to:

- Define the first law of thermodynamics.
- Describe how conservation of energy relates to the first law of thermodynamics.
- Identify instances of the first law of thermodynamics working in everyday situations, including biological metabolism.
- Calculate changes in the internal energy of a system, after accounting for heat transfer and work done.

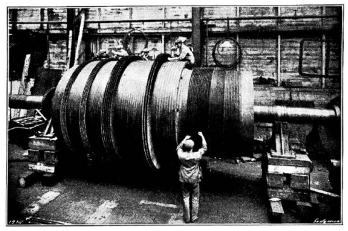

Figure 12.3.1: Beginning with the Industrial Revolution, humans have harnessed power through the use of the first law of thermodynamics, before we even understood it completely. This photo, of a steam engine at the Turbinia Works, dates from 1911, a mere 61 years after the first explicit statement of the first law of thermodynamics by Rudolph Clausius. (credit: public domain; author unknown)

One of the most important things we can do with heat transfer is to use it to do work for us. Such a device is called a **heat engine**. Car engines and steam turbines that generate electricity are examples of heat engines. Figure $12.3.2$shows schematically how the first law of thermodynamics applies to the typical heat engine.

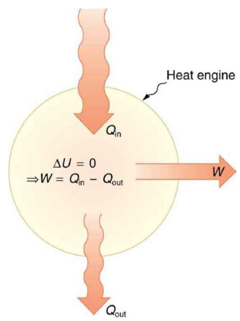

Figure 12.3.2: Schematic representation of a heat engine, governed, of course, by the first law of thermodynamics. It is impossible to devise a system where $Q_{out} = 0$, that is, in which no heat transfer occurs to the environment.

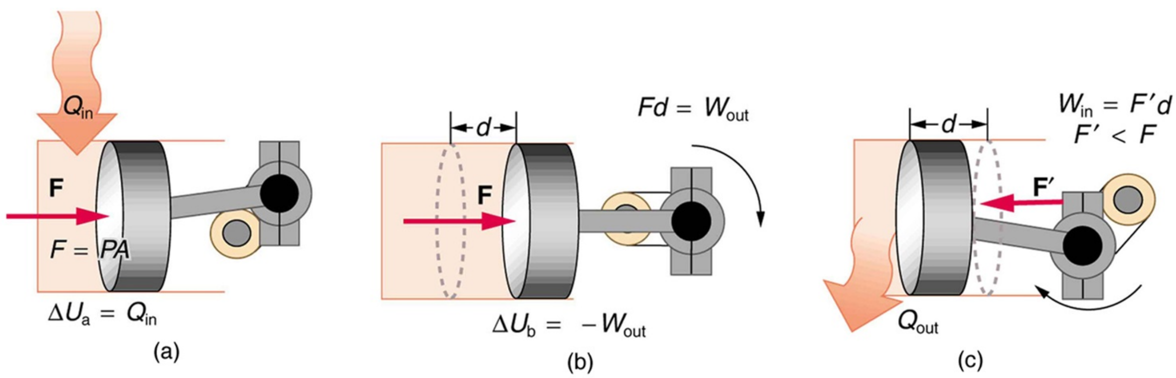

***Figure $12.3.3$:** (a) Heat transfer to the gas in a cylinder increases the internal energy of the gas, creating higher pressure and temperature. (b) The force exerted on the movable cylinder does work as the gas expands. Gas pressure and temperature decrease when it expands, indicating that the gas's internal energy has been decreased by doing work. (c) Heat transfer to the environment further reduces pressure in the gas so that the piston can be more easily returned to its starting position.*

The illustrations above show one of the ways in which heat transfer does work. Fuel combustion produces heat transfer to a gas in a cylinder, increasing the pressure of the gas and thereby the force it exerts on a movable piston. The gas does work on the outside world, as this force moves the piston through some distance. Heat transfer to the gas cylinder results in work being done. To repeat this process, the piston needs to be returned to its starting point. Heat transfer now occurs from the gas to the surroundings so that its pressure decreases, and a force is exerted by the surroundings to push the piston back through some distance. Variations of this process are employed daily in hundreds of millions of heat engines. We will examine heat engines in detail in the next section. In this section, we consider some of the simpler underlying processes on which heat engines are based.

Reversible Processes

A process by which a gas does work on a piston at constant pressure is called an **isobaric process**. Such processes are examples of a **thermodynamic process.** A thermodynamic process describes a change that happens to a gas, which results in change in its pressure P, volume V, and/or temperature TTT" id="MathJax-Element-797-Frame" role="presentation" style="position:relative;" tabindex="0">. An **isobaric** process is a thermodynamic process that takes place under constant pressure (so the v

There are three more named thermodynamic processes. These processes are given special names because, like the isobaric process, they occur under some restrictions, which gives them their special pro

An isochoric process is a thermodynamic process in which no change in volume takes place. Because the work done by a gas is proportional to the change in volume, in an isochoric process, no work is

An isothermal process is a thermodynamic process in which no change in temperature takes place. A gas expanding isothermally, for example, does work on the surrounding, but its internal energy (as re

The adiabatic process is, in some sense, the opposite of an isothermal process. In an adiabatic process, no heat transfer takes place (that is $Q = 0$). This may happen because the gas is well-insulated fron

Both isothermal and adiabatic processes are reversible in principle. A reversible process is one in which both the system and its environment can return to exactly the states they were in by following the

There must be reasons that real macroscopic processes cannot be reversible. We can imagine them going in reverse. For example, heat transfer occurs spontaneously from hot to cold and never spontaneo

Isobaric	Constant pressure	$W = P\Delta V$
Isochoric	Constant volume	$W = 0$
Isothermal	Constant temperature	$Q = W$
Adiabatic	No heat transfer	$Q = 0$

PHET EXPLORATIONS: STATES OF MATTER

Watch different types of molecules form a solid, liquid, or gas in teh States of Matter simuator. Add or remove heat and watch the phase change. Change the temperature or volume of a container and s

Summary

- One of the important implications of the first law of thermodynamics is that machines can be harnessed to do work that humans previously did by hand or by external energy supplies such as running
- There are several simple processes, used by heat engines, that flow from the first law of thermodynamics. Among them are the isobaric, isochoric, isothermal and adiabatic processes.
- These processes differ from one another based on how they affect pressure, volume, temperature, and heat transfer.
- If the work done is performed on the outside environment, work (W) will be a positive value. If the work done is done to the heat engine system, work (W) will be a negative value.
- Some thermodynamic processes, including isothermal and adiabatic processes, are reversible in theory; that is, both the thermodynamic system and the environment can be returned to their initial stat

Glossary

heat engine
: a machine that uses heat transfer to do work

isobaric process
: constant-pressure process in which a gas does work

isochoric process
: a constant-volume process

isothermal process
: a constant-temperature process

adiabatic process
: a process in which no heat transfer takes place

reversible process
: a process in which both the heat engine system and the external environment theoretically can be returned to their original states

Contributors and Attributions

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