



# Thermodynamic Fundamentals with Renewable Energy Concepts and Application

An Online Continuing Education Course for Engineers

**Course Number: M-6026**

**Credit: 6 Hours / 6 PDH / 6 CPD**

# Thermodynamic Fundamentals with Renewable Energy Concepts and Application

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Thermodynamics occurs around us all the time. Whether it is how your home remains cool during the summer or how your automobile's engine powers your car, thermodynamic concepts are integral to enabling society's quality of life. This course is for engineers who are not mechanical or chemical engineers and who are not familiar with thermodynamic concepts. Additionally, this course is a refresher for those who may want to relearn thermodynamics fundamentals.

This course includes renewable energy concepts and applications that generate heat, such as solar, geothermal, biomass combustion, and methane (or biogas) production via a biodigester. This includes, for example, how to perform fundamental calculations for renewable energy applications such as estimating the size of a solar reflector, the biogas production rate of a biodigester, and the cost per kW-hr for a solar energy plant. The economics of renewable energy will be explored, such as the calculation of the cost to generate power and the payback period for investing in a renewable energy project.

The course will provide a straightforward and practical examination of thermodynamics with common rules, underlying principles, and calculations. Preliminary planning calculations are presented based on conventional assumptions, approximations, and estimations. Theories, laws, charts, equations, tables, diagrams, and other information will be presented and be explained for real-world residential and commercial examples, such as a solar water heater, an R-410a and residential air condition system, a swamp cooler, geothermal power generation, and a Stirling Engine powered by biomass and concentrated solar energy. The ideal versus actual performance of thermodynamics systems like a refrigeration system and a steam turbine or power cycle will be calculated. The amount of electrical power required for a residential air conditioner's compressor will be calculated.

Thermodynamics-related technologies will be presented, such as solar reflectors and biodigesters. Any reference to vendors or original equipment manufacturers is not intended to be an endorsement but a means to provide examples of thermodynamic systems that represent the concepts presented. English and S.I. units will be shown, and not all example problems will display both units as well as unit conversions. Information is prioritized to deliver the optimal amount of content.

## Specific Knowledge Obtained

- Fundamentals for Thermodynamics (definitions, units, basic laws, properties of thermodynamic systems, etc.)
- First Law of Thermodynamics
- Saturated and Superheated Steam
- Ideal Gas (i.e., atmospheric air relationship with work and heat)
- Thermodynamic Processes
- Thermodynamic Devices (turbines, pumps, compressors, expansion valves, etc.)
- Closed and Open Thermodynamic Systems
- Second Law of Thermodynamics
- Thermodynamic Cycles (steam power cycle, Stirling Engine, etc.)
- Refrigeration and HVAC cycles
- Psychrometrics (i.e., study of atmospheric air) and psychrometric chart
- Solar Energy concepts, including applications and economic cost analysis
- Biomass and Natural Gas concepts and applications like calculating biomass consumption per hour and cost per kW-hr; thermodynamic concepts such as heating value (H.V.)

### Acronym list

British Thermal Unit	BTU
Coefficient of linear expansion	$\alpha$
Coefficient of volumetric expansion	$\beta$
Coefficient of Performance	COP
Density	$\rho$
Direct Normal Irradiance	DNI
Efficiency (from 0% to 100%)	$\eta$
Enthalpy	H
Entropy	S
Fluidized Bed Combustion	FBD
Heat or Thermal Energy	Q
Heat Capacity or Specific Heat	c
Heating Value	HV
High or Hot Temperature	T <sub>H</sub>
International System of Units	SI
Irradiance	I
Low or Cold Temperature	T <sub>L</sub>
Molecular Weight	MW
Pound Mass	lbm, lb <sub>m</sub> , or lb
Ratio of Specific Heats	k
Solar Reflector or Collector Axis Length	a
Solar Reflector or Collect Cross Length	b
Specific Enthalpy	h
Specific Entropy	s

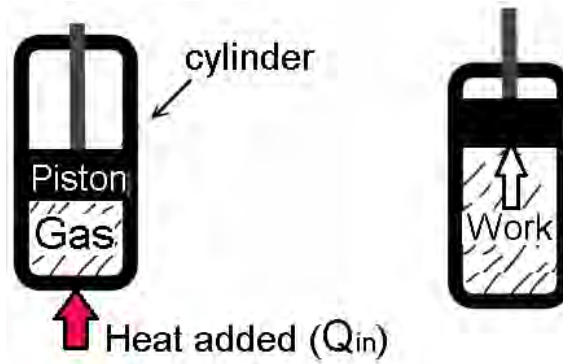
Specific Heat for constant pressure	$C_p$
Specific heat for constant volume	$C_v$
Specific Internal Energy	$u$
Internal Energy	$U$
Work	$W$

## ***Introduction***

Energy encompasses both heat and work as it is the capacity to perform work or produce heat. Heat is energy in transit and is referred to as thermal energy, whereas work is the act of changing energy from one form to another as it is transferred from a thermodynamic system to its surroundings. Energy is just converted from one form to another and is never destroyed. Hence, conservation of energy always applies. Energy comes in many forms, such as potential, kinetic, chemical, and electrical energy. The transfer of energy as heat occurs at the molecular level as a result of a temperature difference. The natural phenomenon is for heat to transfer from a colder object to a warmer object.

Heat is capable of being transferred or transmitted through solids and fluids by conduction, through fluids by convection, and through empty space by radiation. Heat is represented by the symbol  $Q$ . Common units for measuring heat are the British Thermal Unit (BTU or Btu) in the English system of units and the calorie in the S.I. system (International System of Units). Conduction, convection, and radiation are not presented in this course and would be learned in a heat transfer course.

When defining work, the nuance is how the thermodynamic system is defined since work is produced when it exits the system to its surroundings. Examine a piston and cylinder with a gas such as air in it in Figure 1 below. The gas alone is identified as a thermodynamic system for this example. When heat is added to the gas, it heats up and expands. Assume almost no heat escapes since the cylinder is almost perfectly insulated. The expanding gas raises the piston. This is work created by the gas onto the piston, and the piston's potential energy (or height) increases since it is lifted by the gas. The thermal energy from the gas is converted to kinetic energy (i.e., motion) and potential energy (i.e., height above the ground) of the piston via the work delivered from the gas to the piston. The maximum potential energy of the piston is when kinetic energy is zero and when it reaches its highest height in the cylinder.



**Figure 1. Gas is heated (image on the left), and the piston is lifted from expanded gas (image on the right)**

Another example of energy conversion is the chemical energy from gasoline for an automobile engine. The gasoline's chemical energy is converted to thermal energy when the mixture of gasoline and air is combusted. Ultimately through a series of energy conversions, the automobile's kinetic energy increases. Thermodynamics is the science that deals with heat and work and those properties of matter that relate to heat and work. Like any science, thermodynamics includes experimental observation. There are three laws of thermodynamics that guide what to expect when an experiment is observed. These laws are the foundation for this course.

### ***Thermodynamic Properties***

Before covering the... of thermodynamics are presented along... these properties is essential to understand... these properties describe measurable character... properties will be discussed in order to... properties will be thermodynamic state... dynamics. A least two thermodynam... is defined by at more properties is kno... A change of one or cycle consists of multip... a new state. A manner, such as a stea... heat in a cyclical

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A thermodynamic syste... boundary of the system. A substance ca... which are solid, liquid, and vapor also ca... within a control volume as both a liquid a... also called the control volume. The control volume has therm... properties. It also can have heat, work, and/or mass