Thermodynamics Laws (1st and 2nd)

by

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Heat is often produced as a by-product during energy transformations. This energy is transferred into the surroundings and is not usually recoverable as a useful form of energy. The efficiency of systems is defined as the ratio of the useful energy output to the total energy input. The efficiency of natural and human-made systems varies due to the amount of heat that is not recovered as useful work.

P4.11a Calculate the energy lost to surroundings when water in a home water heater is heated from room temperature to the temperature necessary to use in a dishwasher, given the efficiency of the home hot water heater.

P4.2D Explain why all the stored energy in gasoline does not transform to mechanical energy of a vehicle.

P4.2f Identify and label the energy inputs, transformations, and outputs using qualitative or quantitative representations in simple technological systems (e.g., toaster, motor, hair dryer) to show energy conservation.

Items:

1- Thermodynamics.

2- First Law of Thermodynamics.

3- Second Law of Thermodynamics.

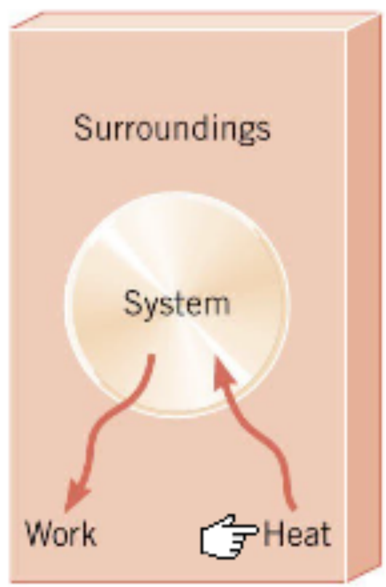
4- Heat Engine and Refrigeration Process.

5- Efficiency.

Thermodynamics

Thermodynamics is a branch of physics that deals with the relationships between heat and other forms of energy.

The collections of objects that we are studying the heat is called a system. Everything around the system is called the surroundings.



(a)

First Law of Thermodynamics

Heat (Q) and work (W) change the internal energy (ΔU) of the system.

The quantity of heat energy transferred to a system is equal to the work done by the system plus the change in the internal energy of the system.

First Law of Thermodynamic
$\Delta U = Q - W$

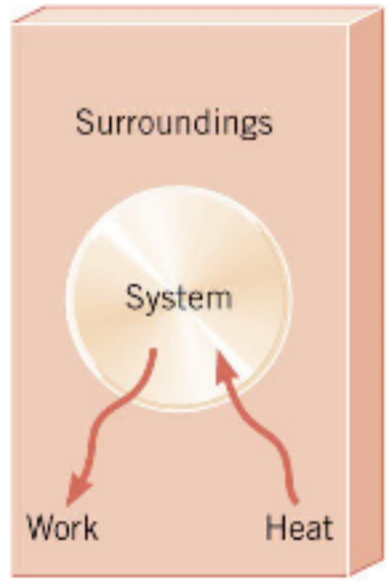
Heat is positive when the system gains heat from its surrounding ($Q > 0$).

Heat is negative when the system loses heat to the surrounding ($Q < 0$).

Work is positive when it is done by the system ($W > 0$).

Work is negative when it is done on the system ($W < 0$).

Example 1: *System gains energy from its surrounding*



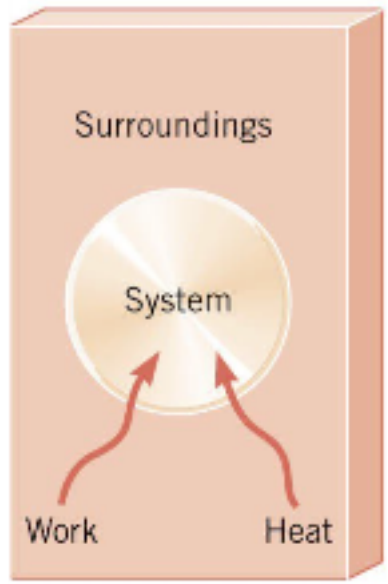
(a)

In this figure (a), the system gains (absorbs in)1500 J of heat. So, Q = +1500 J. A 2200 J of work is done by the system (out) on its surrounding. So, W = + 2200 J. The change of the internal energy is:

$$\Delta U = Q - W = (+1500\ J) - (+\ 2200\ J) = -700\ J$$

The minus sign indicates that the internal energy decreased, as expected.

Example 2: *System loses energy to its surrounding*



(b)

In this figure (b), the system gains (absorb in) 1500 J of heat. So, Q = +1500 J.

A 2200 J of work is done on the system (in). So, W = -2200 J.

The change of the internal energy is:

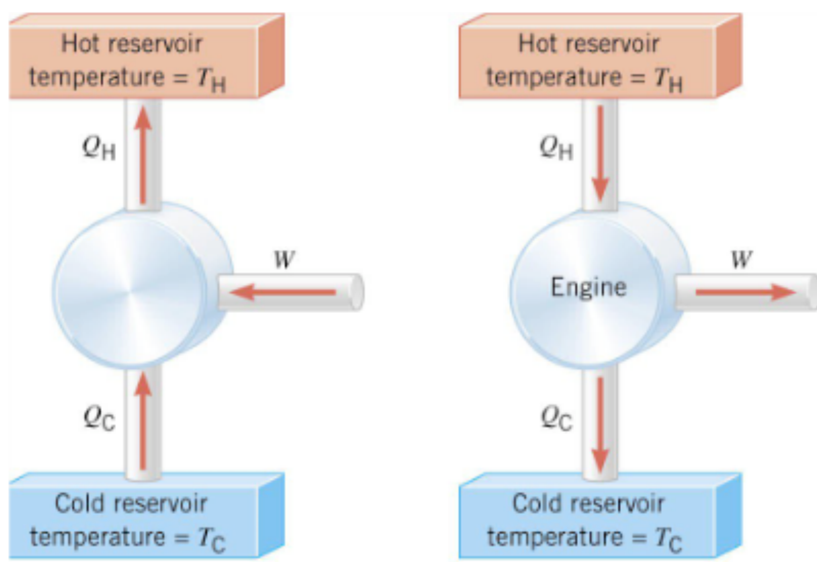
$$\Delta U = Q - W = (+1500\ J) - (-\ 2200\ J) = +\ 3700\ J$$

The positive sign indicates that the internal energy has increased, as expected.

Second Law of Thermodynamics

Naturally, heat flows spontaneously from hot objects to cold objects (Engine Process).

Heat does not flow spontaneously from a cold object to a hot object. However, if work is used, heat can flow from cold to hot. Refrigerators, air conditioners and heat pumps are devices that do just that (Refrigeration process).



Refrigeration Process

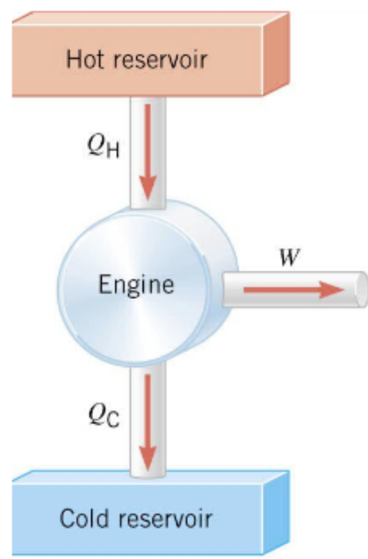
Engine Process

Heat Engine: A heat engine is any device that uses heat to perform work.

The essential features of a steam engine are:

1. A hot reservoir gives heat to the engine. The input heat is (Q_H).
2. A part of the input heat is used to perform work (W) by the engine.
3. The rest of Q_H is rejected to a cold reservoir. The rejected heat is (Q_C).
4. The principle of conservation of energy is applied in heat engine:

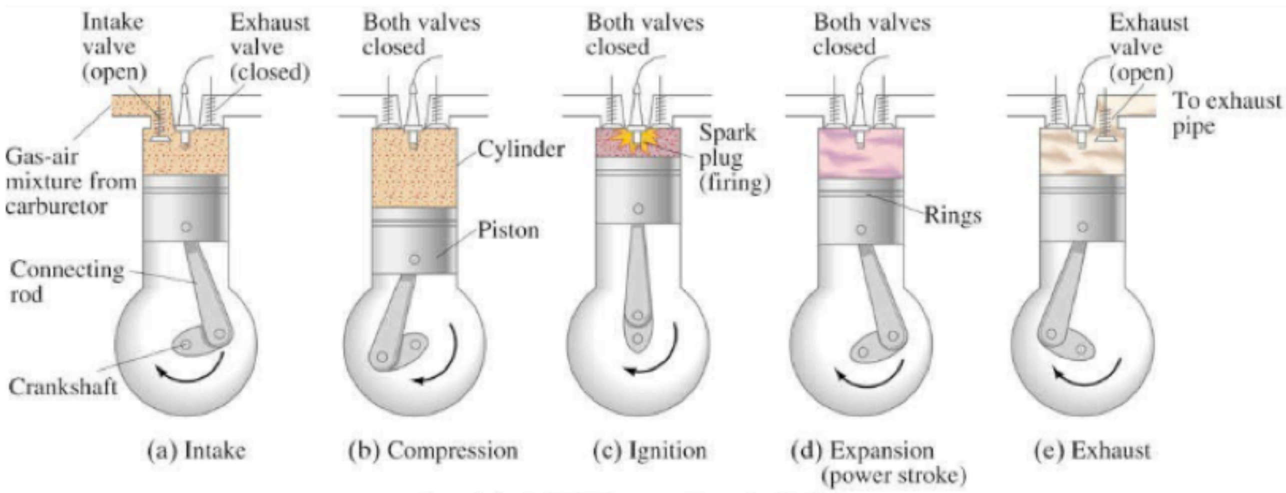
$$Q_H = W + Q_C$$



Efficiency (e) of a heat engine: The efficiency (e) of a heat engine is defined as the ratio of work W done by the engine to the input heat Q_H

$$e = \text{Work done} / \text{Input heat} = W / Q_H$$

Example 3: *The automobile engine is a type of heat engine.*



All the thermal energy from the combustion of gasoline does not transform to mechanical energy of a vehicle.

If the heat input (from burning gasoline) into an automobile engine is 11400 Joules. It can produce 2500 Joules of mechanical work.

We can calculate the efficiency (*e*) of the engine:

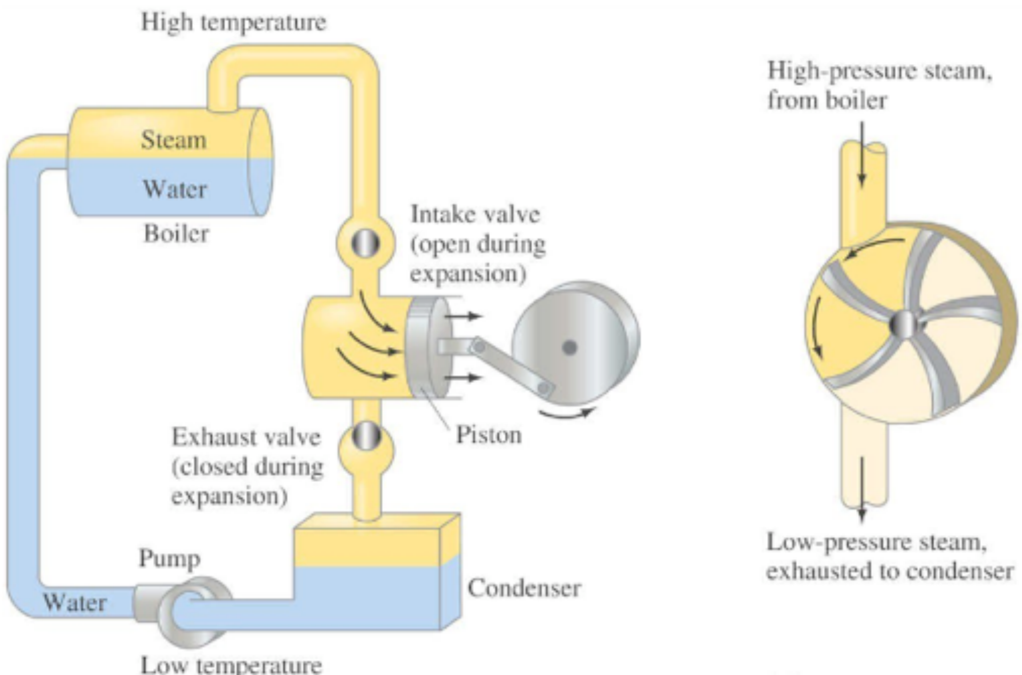
$$e = W/Q_H$$

$$= 2500/11400$$

$$= 0.22 \text{ or } 22\%.$$

That means less than one-quarter of the input heat is converted into work.

Example 4: *Steam engine is an example of heat engine:*

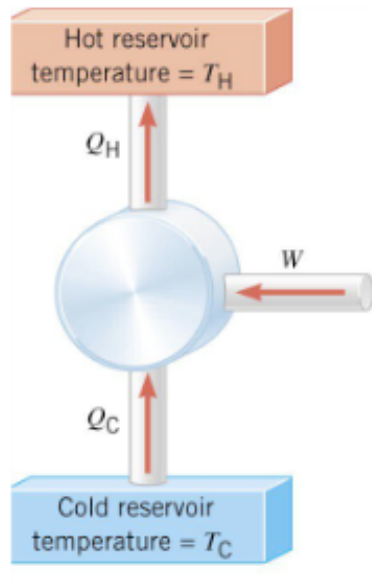


(a) Reciprocating type

(b) Turbine (boiler and condenser not shown)

Refrigeration Process: Refrigerators and air conditioners are devices that use work to make heat flow from cold to hot, against its natural tendency.

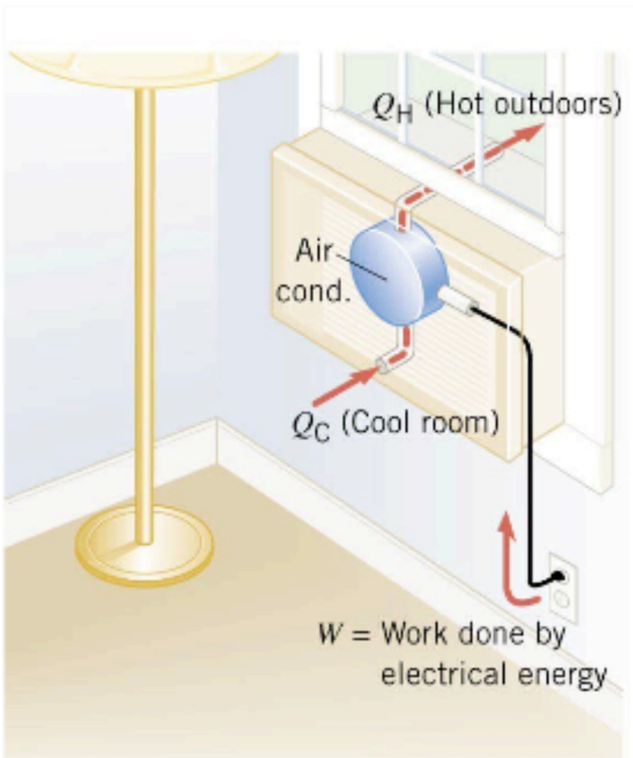
$$Q_H = W + Q_C$$

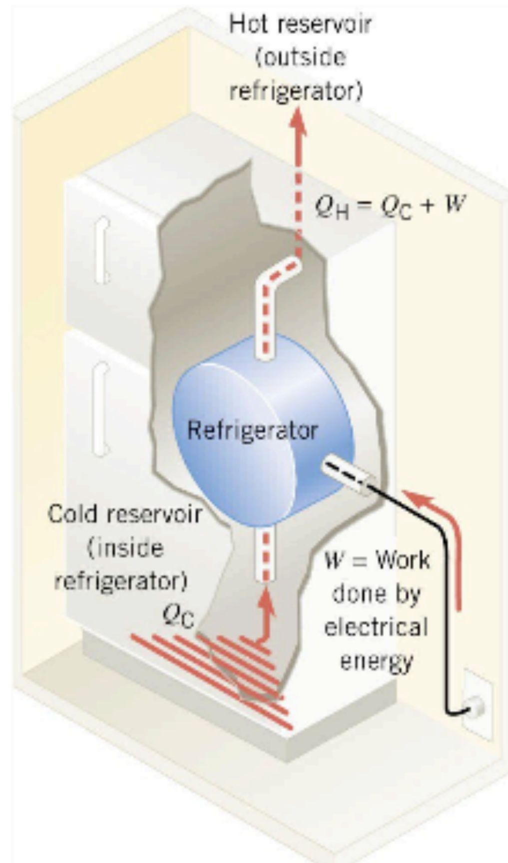


Refrigeration Process

Some people think that it is possible to cool the kitchen by leaving the refrigerator door open or cool the bedroom by putting an air conditioner on the floor by the bed. This is a common misconception about refrigerators and air conditioners.

Example 5: Air conditioners and refrigerators are examples of the refrigeration process.





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The edition was dedicated to the memory of Stella Kupferberg, Director of the Photo Department: "We miss you, Stella, and shall always remember that a well-chosen photograph should speak for itself, without the need for a lengthy explanation"

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