

Thermodynamics
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Lecture No 23
Heat and Work Interactions for a System

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Heat vs. work

System = air + heating coil

$m = C$
 $12V \quad 10A \quad t = 60s$

${}_1R_2 = 0$
 ${}_1N_2 = -V \times I \times t = -12 \times 10 \times 60 = -7.2 \text{ kJ}$
 $\Delta U = {}_1R_2 - {}_1N_2 = 0 - (-7.2) = 7.2 \text{ kJ}$

System = air only

${}_1R_2 = V \times I \times t = 7.2 \text{ kW}$
 ${}_1N_2 = 0$
 $\Delta U = {}_1R_2 - {}_1N_2 = 7.2 \text{ kW}$

$W \rightarrow R$
 $N = -V \times I \times t = -7.2 \text{ kJ}$
 $\Delta U = 0$
 $\Delta U = Q - W \Rightarrow Q = W$
 $Q = -7.2 \text{ kW}$

Correction: The unit for Q and W here is kJ (and not kW) as t has been multiplied

Figure 1.

Let us look at distinctions between heat and work.

Consider a stationary rigid insulated chamber as shown in top left hand corner of Fig. 1. There is a heating coil inside. Consider a system which includes the contents of the rigid chamber and the heating coil. The coil is connected to a battery of 12 V which sends in a current of 10 A for 60 s through the coil. Is it a work interaction or heat interaction for the system?

For answering this question, we need to consider what is crossing the boundary of the system. In this case, the voltage of the battery is pushing current across the boundary of the system. The battery is doing work on the system (actually the coil which is the part of the system) which is $W = VIt = 12 \times 10 \times 60 = 7.2 \text{ kJ}$. Since this is work done on the system it is negative, i.e. $W = -7.2 \text{ kJ}$. The work interaction is negative here. What about the heat interaction?

As mentioned before, the chamber is insulated. The heating coil heats the contents of the chamber. But there is no heat transfer across the boundary of the system as it is insulated. The

only heat transfer is between the heating coil and other contents of the system. But all these are internal to the system. Any heat transfer or work transfer has to happen across the boundary. Hence in this case, the heat transfer is 0. We can calculate change in internal using the first law in integrated form, $Q - W = \Delta U$ (there are no changes in potential and kinetic energy). Hence, $\Delta U = 0 - (-7.2 \text{ kJ}) = 7.2 \text{ kJ}$. The internal energy of the system increased by 7.2 kJ.

What if we exclude the heating coil from the system?

The current is still flowing through the coil. However, it is not crossing the boundary of the system. Hence, the work interaction for the system is zero (there is also no shaft work, gravitational work, electric work or magnetic work). As the current flows through the coil, it becomes hot as the battery is doing work on the coil. The work done by the battery on the coil is again $W = VIt = 7.2 \text{ kJ}$. Assuming steady state operation of the coil, ΔU for the coil would be 0. Hence, the first law written for the coil implies $Q = W = -7.2$. It means the coil loses 7.2 kJ of heat to the surroundings which is our system. The heat crosses the boundary of our system. Hence, there is a heat interaction. The heat transfer across the walls of the rigid chamber is zero as the walls are insulated. Hence, for such a system (which excludes heating coil), there is a heat interaction, but no work interaction. The change in internal can be calculated in the similar fashion. The first law in the integrated form is $\Delta U = Q - W$. Here, $\Delta U = Q = 7.2 \text{ kJ}$ as $W=0$.

Hence, whether a system has work interaction or heat interaction or both the interactions depends on the choice of the system. The formulae need to be written consistently according to the definition of the system.