

24.3: Perpetual Motion Machines

Perpetual motion machines are devices that are purported to create useful work for “nothing” by violating some physical principle. Generally they are divided into two types, perpetual motion machines of the first and second kinds. Perpetual motion machines of the first kind violate the conservation of energy, while perpetual motion machines of the second kind violate the second law of thermodynamics. It is the latter type that we address here.

We commonly hear talk of an “energy crisis”. However, it is clear to all physicists that such a crisis, if it exists, is actually an “entropy crisis”. Energy beyond the most extravagant projected needs of mankind exists in the form of internal energy of the earth. Furthermore, one cannot possibly “waste” energy, because energy can neither be created nor destroyed.

The real problem is that internal energy can only be tapped if two reservoirs of internal energy exist, one at high temperature and one at low temperature. Heat engines depend on this temperature difference to operate and if all internal energy exists at the same temperature, no conversion of internal energy to useful work is possible, at least using the Carnot cycle.

One naturally inquires as to whether some cycle exists that is more efficient than the Carnot cycle. In other words, does there exist a heat engine operating between temperatures T_2 and T_1 that extracts more work from the high temperature heat input Q_2 than ϵQ_2 ? Recall that $\epsilon = 1 - T_1/T_2$ is the thermodynamic efficiency of the Carnot engine.

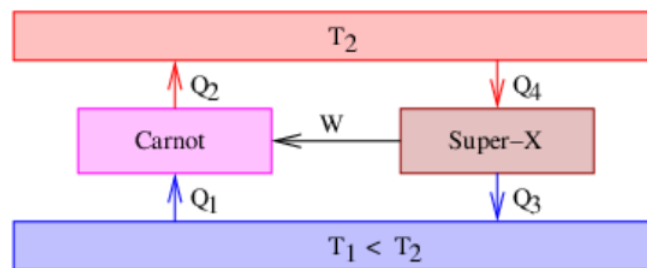


Figure 24.3.8:: Perpetual motion machine of the second kind. The Super-X machine is advertised as having a thermodynamic efficiency greater than a Carnot engine. The output of the Super-X machine runs the Carnot engine backwards as a refrigerator, resulting in net transfer of heat from the lower temperature to the higher temperature reservoir.

Let’s suppose that an inventor has presented us with the “Super-X machine”, which is purported to have a thermodynamic efficiency greater than a Carnot engine. Figure 24.3.8 shows how we could set up an experiment in our laboratory to test the inventor’s claim. The Carnot engine runs in reverse as a refrigerator, emitting heat Q_2 to the upper reservoir, absorbing Q_1 from the lower reservoir, and using the work $W = Q_2 - Q_1 = \epsilon Q_2$ from the Super-X machine. The Super-X machine is operated in heat engine mode, emitting Q_3 to the lower reservoir and absorbing $Q_4 = Q_3 + W < W/\epsilon$ from the upper reservoir. The inequality indicates that the ratio of work produced and heat extracted from the upper reservoir, W/Q_4 , is greater for the Super-X machine than for an equivalent Carnot engine.

Let us examine the net heat flow out of the upper reservoir, $Q_{\text{upper}} = Q_4 - Q_2$. Since $Q_4 < W/\epsilon = Q_2$, we find that $Q_{\text{upper}} < 0$. In other words, the Super-X machine is extracting less heat from the upper reservoir than the Carnot engine is returning to this reservoir using the work produced by the Super-X machine. The source of this energy is the lower reservoir, from which an equivalent amount of heat is being extracted. The net effect of these two machines working together is a spontaneous transfer of heat from a lower to a higher temperature, since no outside energy source or entropy sink is needed to make it operate. This is a violation of the second law of thermodynamics. Therefore, the Super-X machine, if it truly works, is a perpetual motion machine of the second kind.

Though there have been many claims, no perpetual motion machine has been convincingly demonstrated. Thus, heat engines are apparently incapable of converting all of the internal energy supplied to them to useful work, as this would require either an infinite input temperature or a zero output temperature. As we have demonstrated, this source of inefficiency is intrinsic to all heat engines and is in addition to the usual sources of inefficiency such as friction and heat loss from imperfect insulation. No heat engine, no matter how perfectly designed, can overcome this intrinsic inefficiency.

As a result of the second law of thermodynamics, we see that real heat engines, which are always less efficient than Carnot engines, produce useful work, W ,

$$W < \epsilon Q_2 \quad (\text{real heat engines}), \quad (24.3.1)$$

where Q_2 is the amount of heat energy extracted from the upper reservoir. On the other hand, refrigerators transfer heat Q_2 to the upper reservoir in the amount

$$Q_2 < W/\epsilon \quad (\text{real refrigerators}) \quad (24.3.2)$$

where W is the work done on the refrigerator.

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