The Four Thermoelectric Effects

Submitted by Keith P Walsh on Sat, 2005-11-26 02:57

Whilst it is generally accepted that there are only three thermoelectric effects, it is in fact possible to describe four.

The four thermoelectric effects, listed in chronological order of their discovery, are:

Effect 1 - If two different conductors are joined and the two junctions are maintained at different temperatures, an electromotive force is developed in the circuit.

Effect 2 - If a current flows in a circuit consisting of two different conductors then one of the junctions is heated and the other is cooled.

Effect 3 - When a temperature difference exists between two points in a single electrical conductor an electrical potential is established between the points.

Effect 4 - If a current passes through a conductor in which a temperature gradient exists, this current causes a flow of heat from one part to the other.

These effects are very closely related. Indeed, each of them represents a reversible effect whereby effects 1 and 2 are the reverse of each other, and effects 3 and 4 are similarly the reverse of each other.

Thomas Johann Seebeck first identified Effect 1 in 1821. He spent the rest of his scientific career measuring the size of this effect for different pairs of dissimilar conductors in contact with each other. Seebeck died in 1831.

In 1834 Jean Charles Athanase Peltier first identified Effect 2, the reverse of Effect 1. Peltier died in 1845.

Significantly later (around 1854-1855), William Thomson first deduced and demonstrated BOTH of the effects numbered 3 and 4.

Starling and Woodall partly describe Thomson's contribution thus (from "Physics", Longmans, 1950):

"He [Thomson] suggested that there must be other electromotive forces in the circuit and that these exist in the metals themselves, acting between the parts of any one metal at different temperatures. This was found to be correct. Thus if two points in the metal differ in temperature by the amount $dT$, the electromotive force in this element of the metal is $s\cdotdT$. The quantity $s$ is called the Thomson coefficient. It is taken to be positive when directed from points of lower to points of higher temperature."

As a result of the above, the four thermoelectric effects are correctly attributed the following names:

Effect 1 is the Seebeck effect.

Effect 2 is the Peltier effect - and is correctly identified as the reverse of the Seebeck effect.

Effects 3 and 4 together comprise both "directions" of the Thomson effect.

My motivation for offering this post is that some recent sources restrict the definition of the Thomson effect to that of Effect 4 only, and that this may be either the cause or the result of a further tendency to prefer that the definition of the Seebeck effect should be satisfied by that of Effect 3. (With the possible consequence of Effect 1 being rendered anonymous.)

Again, it is clear that the relationship between Effect 1 and Effect 3 must be a very close one.
However, it has been demonstrated that during his lifetime Thomas Johann Seebeck could not ever have been explicitly aware of Effect 3.

Furthermore, in the effect which Seebeck spent the greater part of his career measuring, when the junctions between the dissimilar metals are maintained at different temperatures, a net electromotive force exists in the circuit which causes a current to flow around it. Such a circuit cannot be constructed with a single conductor, and therefore the definition of Effect 3 may not serve as an adequate definition for the Seebeck effect.

Apologies if all this is obvious.

Any comments or opinions will be welcome.

I think that it’s ok to say that there are only three thermoelectric effects, so as long as people are aware that one of them, the Thomson effect, comprises both “directions” of the reversible effect.

Best regards,

Keith P Walsh