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Spontaneous rotation of a block of ice on a flat surface of a warm metal column

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Summary

We have discovered that a block of ice placed on a flat surface of a warm brass column rotates slowly without any external mechanical driving force.

Description of the Phenomenon

A column of brass, whose radius and height are 8cm and 16cm, respectively, is placed with its flat surface set horizontally. After it is warmed at least to the room temperature, a flat bottomed block of home-made ice, whose radius and height are 10cm and 4cm, respectively, is placed on the flat surface of the brass column. As the block of ice melts, it begins to rotate about the vertical axis spontaneously. The direction of the rotation does not change by itself. However, it reverses instantaneously if we gently tap the ice block to the opposite direction. The rotation period is typically about 20 seconds. The rotation stops when the brass column cools or when the ice block melts and the brass surface becomes exposed.

The Importance of Bubbles between the Ice and the Brass Surface

If we use a block of factory-made ice which contains no bubbles, the ice does not rotate. However, if we drill non-through holes on the bottom surface of the ice block so that air bubbles shall be supplied between the ice and brass surface as the ice block melts, the ice rotates. The behavior of the air bubbles observed when the ice rotates and that observed when the ice rotation is blocked are quite different. When the ice rotates, the air bubbles tend to elongate radially and are nearly stationary relative to the brass surface. When the ice is anchored and does not rotate, the air bubbles flow outward, deforming and moving randomly. The observed behaviors above imply a crucial role played by the bubbles in the physics of this phenomenon.

The Importance of Heat Supply

We measured temperature distribution within the brass column, and found a strong positive correlation between the vertical temperature difference in the column and the angular velocity of the ice rotation. We also conducted a similar experiment using a column of stainless steel, whose thermal conductivity is considerably smaller than brass, the rotation period tends to be quite longer. These observations imply that the flux of heat supplied by the heat conduction in the column of metal is crucial to the emergence of the phenomenon.

Future Directions

Presently, we have no concrete idea on the dynamics of the phenomenon, even though the strong relationship between the heat supply and the angular velocity suggests that the phenomenon may be interpreted as a kind of heat engine. In the near future, we will conduct more experiments with parameters being better controlled, and with the results of such additional experiments, we will investigate physics of the phenomenon from various aspects.

Keywords: bubble, ice, rotation, heat engine, phase change, spontaneous motion