MELTING AND REGELATION OF ICE

In Nature of January 4th of this year, there is a most interesting account of some experiments on melting and regelation of ice by Mr. James T. Bottomley. These experiments of Mr. Bottomley's suggested the possi bility of passing large bodies through ice in the same way as he caused the wires to pass. I accordingly placed a sixpence on a block of ice, and applied pressure to it by means of a fine steel wire about one-sixteenth of an inch in diameter. On examining the block of ice sometime afterwards, I found the sixpence had passed into the centre of the block, and that the space through which it had passed, except the small part occupied by the steel wire, was again solid ice. I tried the same experiment with a shilling, and found that it also easily passed through the ice, the experiment was then repeated with a half-crown with the same result. I did not attempt anything larger, but have no doubt much larger discs of metal might be made to pass through ice if sufficient pressure were applied. The ice in the parts of the blocks through which the coins had passed did not look very solid, but was rather full of air-bubbles; on breaking the block, however, it did not seem much weaker than the rest of the ice. Another form of the experiment was then made, a block of ice was supported on two boards placed near each other. A loop of fine wire was passed over the ice, and hung down between the two boards and a weight attached to it, as in Mr. Bottomley's experiments, pieces of wood were placed so as to stop the wire when it had passed half way though the ice. After the wire had passed into the centre of the block, the weight was removed, the wire cut, and a disc of metal half an inch in diameter was attached to one end of the wire, and a weight to the other end. In this manner the disc was drawn through the ice, leaving apparently perfect solid ice behind. The path of the disc could only be traced by its slightly cloudy appearance, it looked as if the few air-bubbles passed through by the disc had been broken up into a great number of small ones. On breaking the ice afterwards it seemed quite as strong where the disc had passed as elsewhere.

The explanation of these experiments is of course the same as for the experiments with the wires; Professor James Thomson showed that the freezing point of water is lowered by pressure, and also that ice has a tendency to melt, when forces are applied which tend to change its form. So that the ice under the coins has a tendency to melt, and has its freezing point lowered by the pressure. The under side of the coin will thus have a lower temperature than the upper; there will therefore be a transference of heat from the upper to the under side of the coin, this heat melts the ice under the coin, the water so formed passes round the edges of the coin to the upper side. This water being at a slightly lower temperature than the freezing point at ordinary pressure, a very small proportion of it will freeze and raise the temperature of the rest to the freezing point. The water arrived at the upper side of the coin, the coin being at a temperature a little below the freezing point, the water will be frozen, giving out its latent heat, which will pass through the coin and melt an equal quantity of ice on the under side, this having absorbed its latent heat of liquefaction will in turn pass to the upper side, and will there be converted into ice, giving out its latent heat to melt another quantity, and so on.

A slightly different form of the experiment was then made, a small metal cup was filled with water and laid on a piece of ice, and a heavy weight placed on the cup. After some time the water in the cup was frozen. The freezing point of the ice under the cup being, owing to the pressure, lower than that of the water in the cup, the water in the cup parted with its heat to the ice outside. A quantity of ice outside the cup was thus melted equal to the quantity of ice formed in the cup.

At first sight these experiments might seem to have an important bearing on the motion of glaciers. It might be thought, that if large bodies flowed thus easily through ice, why should not ice flow easily in its channel? But when we consider the circumstances, we find they are not so similar as might at first appear. When a body flows in this way through ice, there is not only a displacement of matter but also a displacement of heat, and the displacement of the matter cannot take place till there has been a displacement of the heat. In the preceding experiments, circumstances were most favourable for both displacements taking place quickly. The heat easily flowed through the very small thickness of the good conducting silver discs, and the water had only to flow from the one face to the other round the edges of the coins, whereas in glaciers, the ice and the rocks over which it moves are bad conductors of heat, and the distance to which the heat has to be conducted is so much greater than in the above experiments, that the exchange of heat can take place but very slowly; and when we further remember the very small difference of temperature between the freezing point of ice under pressure and not under pressure—if the lowering of the freezing point is the result of hydrostatic pressure alone, a pressure of one hundred atmospheres not lowering the temperature one degree centigrade—we can easily see that there will not be sufficient difference in temperature between the different parts of the glacier to cause the heat to flow quickly from one part to another, through such bad conductors.

In the explanation given of the passage of the coins through the ice, it has been assumed that the passage depends on the exchange of heat from the freezing ice on the one side of the coin to the melting ice on the other side. If this explanation is correct, then, if the coins had been non-conductors of heat, they would not have passed through the ice. The test was put. A shilling was placed on a block of ice, and over it a disc of a non-conductor (india-rubber), the same size as the shilling and over that another shilling; a weight of 90 lbs. was applied by means of a small steel rod. After four hours it was found that the shillings had only sunk about an eighth of an inch into the ice, most of the heat to sink it this short distance being, in all probability, got by radiation from surrounding objects; as other two shillings and non-conducting disc placed on a block of ice and similarly situated, but not under pressure, had sunk to nearly the same depth.

There is another point in these experiments in their relation to glacier motion, which requires to be noticed. In all the experiments referred to, ice at the melting point was used. Sir William Thomson showed that the freezing-point of water was lowered $0^{\circ}{\cdot}13$ C. by a pressure of 16·8 atmospheres. We should therefore expect that, if we lowered the temperature of the ice by half a degree or a degree below the freezing-point, a much greater pressure would be required to cause the coins to pass through the ice. In order to test this, a block of ice was surrounded with ice, salt, and water. After it was cooled about a degree below the freezing-point, a shilling was placed on the block of ice, and a pressure of 90 lbs. applied. On examining it three and a half hours afterwards, the shilling was found not to have entered in the slightest degree into the ice. The freezing mixture was then removed, and within an hour the shilling had passed some distance into the ice. It would therefore appear, considering the enormous resistance offered by ice at a temperature of even one degree below the freezing-point to change of state, that the motion of glaciers at the higher parts, where their temperature is below the freezing-point, is, in all probability, not caused by the melting and regelation of the ice in the same manner as in the experiments.

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