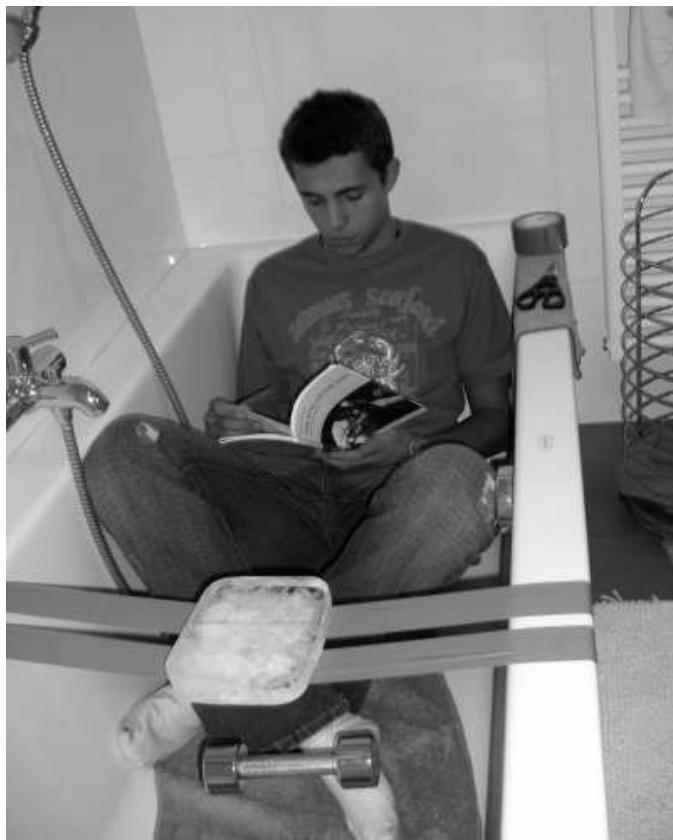


POCZTAJMY PO ANGIELSKU

Investigating how the role of pressure is misunderstood in the process of regelation of water*.

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Introduction:

The process of melting due to pressure and then re-freezing when pressure is reduced is commonly called regelation. There is a substantial amount of physics that is not clearly explained. The word "regelation" means re - freezing and does not imply that pressure plays any role in it. *Congelare* means "to freeze" in Italian. This essay reports on investigation to what extent pressure is responsible for regelation of water**.

Aspects of thermal physics will come into play in this investigation, mainly, the effects of pressure on melting point. This is because observing the effects of pressure on a body involves understanding the transport of energy and where and how it is being transferred in the form of heat.

The guiding research question is: To what extent does pressure play a role in the regelation of water.

The process of regelation:

When a substance turns from a solid to a liquid, it usually undergoes a change in volume as well. Most substances expand when this phase change takes place and some contract. In the case of water, it contracts when changing from solid to liquid.

This is well expressed by Le Chatelier's** principles:

"If a dynamic equilibrium is disturbed by changing the conditions, the position of equilibrium moves to counteract the change."

When there is an application of pressure on ice, the system counteracts by lowering the pressure on it in some way. The solution would be to decrease the volume of the ice in order to decrease the pressure it is subjected to. This occurs when the ice melts. For water, the liquid state has a higher density than when it is in a solid state. Therefore the melting point of ice will decrease when under pressure. Thus when pressure is released, the volume expands, the freezing point increases and as a result, the water "re-freezes" or regelates.

Regelation: its role in Ice-skating

I came across many textbooks and some magazines including those found in the Internet, where the topic of regelation and ice-skating is mentioned. However most of the books try to avoid the subject. Most of the Syllabusses avoid the topic.

Here is what I found:

Under the skate ice melts locally due to the high pressure of the blades as the skater moves. It is claimed that at this point the ice turns into water and as a result one skates over the "thin film of water". When the skater is no longer exerting pressure on the ice at that point, water regelates.

Let us look at the table with Data concerning the "melting point variation with pressure"

MELTING POINT OF ICE—VARIATION WITH PRESSURE (From Tamann, 1900, by permission.)			
Pressure in kg. per sq.cm.	Temp. ° C.	Pressure in kg. per sq.cm.	Temp. ° C.
1	0.0	1410	-12.5
336	-2.5	1625	-15.0
615	-5.0	1835	-17.5
890	-7.5	2042	-20.0
1155	-10.0	2200	-22.1

2295

taken from Charles D. Hodgman ... Handbook of chemistry and physics. Cleveland, Ohio: Chemical Rubber Publishing Company, 1960. Page 2

Note: for every atmosphere exerted on ice; the melting point decreases by 0.0075°C !!!

Now, if we use this data and apply it to ice skating, it will show the nonsense more clearly. Let us exaggerate a bit: the ice-skater has a mass of 100kg and his skate blades are 0.2cm thick and 30 cm long. Thus the amount of pressure he will be exerting is a bit less than 17 atmospheres. We conclude that the decrease in melting point is very small and hardly noticeable to make a suitable "watery" surface.

It would only work if the ice temperature is close to 0°C . However most ice rinks are approximately - 7°C .

Here is another calculation:

$17 \times 0.0075 \times 0.1^{\circ}\text{C}$. This gigantic fellow will lower the melting point by 0.1°C .

Therefore to skate on -7°C ice, one would need 70 men one on top of the other.

But, what about children who ice skate with no problems weighing maybe 40kg and who even use double blade of not very sharp skates.

If the data is correct, the poor children should not enjoy ice-skating.

Some textbooks claim, that friction works simultaneously with high pressure to allow the ice under the skates to melt. It would be very hard to justify the strange logic in this "theory". Skaters are able to move very fast, therefore if it is friction that is causing the ice to melt, the ice should get an early message: get ready for instantaneous melting ! the skater is coming! If not, then by the time friction has caused the ice to melt, the skater would have moved on to the distant area of ice.

I found a literature value for the coefficient of friction between steel and ice. It is around 0.0055; therefore we see that friction plays absolutely no role being very small indeed.

One can read in many places:"The skater actually glides along a thin layer of water."

. If that is all that is required, why cant one water-skate on wet concrete for example? Why go through the hassle of constructing an ice rink when all one uses is a surface and water over it?

It is mind-boggling because, the instantaneous change of state is impossible. In fact, it would be impossible to skate if the melting took any time whatsoever, the front part of the blade would just be hitting a frictional surface and inertia would do the rest. Ha, ha.

I recommend an article by "The Scientific American" *** trying to explain the complicated physics behind ice-skating. Note that regelation is never mentioned through out the whole article.

* * * *

Regelation: Forming a Snowball

This is an explanation of how one is able to form a snowball. A textbook claims that the increase in pressure lowers the melting point of the snow so when the snow indeed melts, it moulds together in ones hand forming a snowball.

It is therefore claimed that even a child, who can form a snowball, must be generating approximately 400 atmospheres to melt the ice assuming that the ice is at 0°C. No word of possible role of the warmth of the child's hands?

This forming a snow ball could be an interesting project for students in the coming season.

Regelation: How the process is experimentally demonstrated

Many textbooks and websites claim that regelation can be demonstrated by looping a fine wire around a block of ice and attaching a heavy weight to it. The pressure exerted on the ice slowly melts it locally, permitting the wire to pass through the entire block. The wire's track will refill as soon as pressure is relieved, so the ice block will remain solid even after wire passes completely through. This experiment is possible for ice at -10 °C or even cooler.

There is no mention of the conducting of heat through the "wire" and into the ice as a reason for why the wire is able to move through the block. It claims that the reason why this is possible it because the "pressure exerted on the ice slowly melts it locally, permitting the wire to pass through..." Therefore, could it not be possible to do the same experiment using a fishing line? If there is no mention of conductivity of heat, then why is it that every experiment of this sort, requires a copper wire, which is an excellent heat conductor? Regelation might be taking place due to the heat conducted from the environment into the ice resulting in local melting and .. the gravity does the rest.

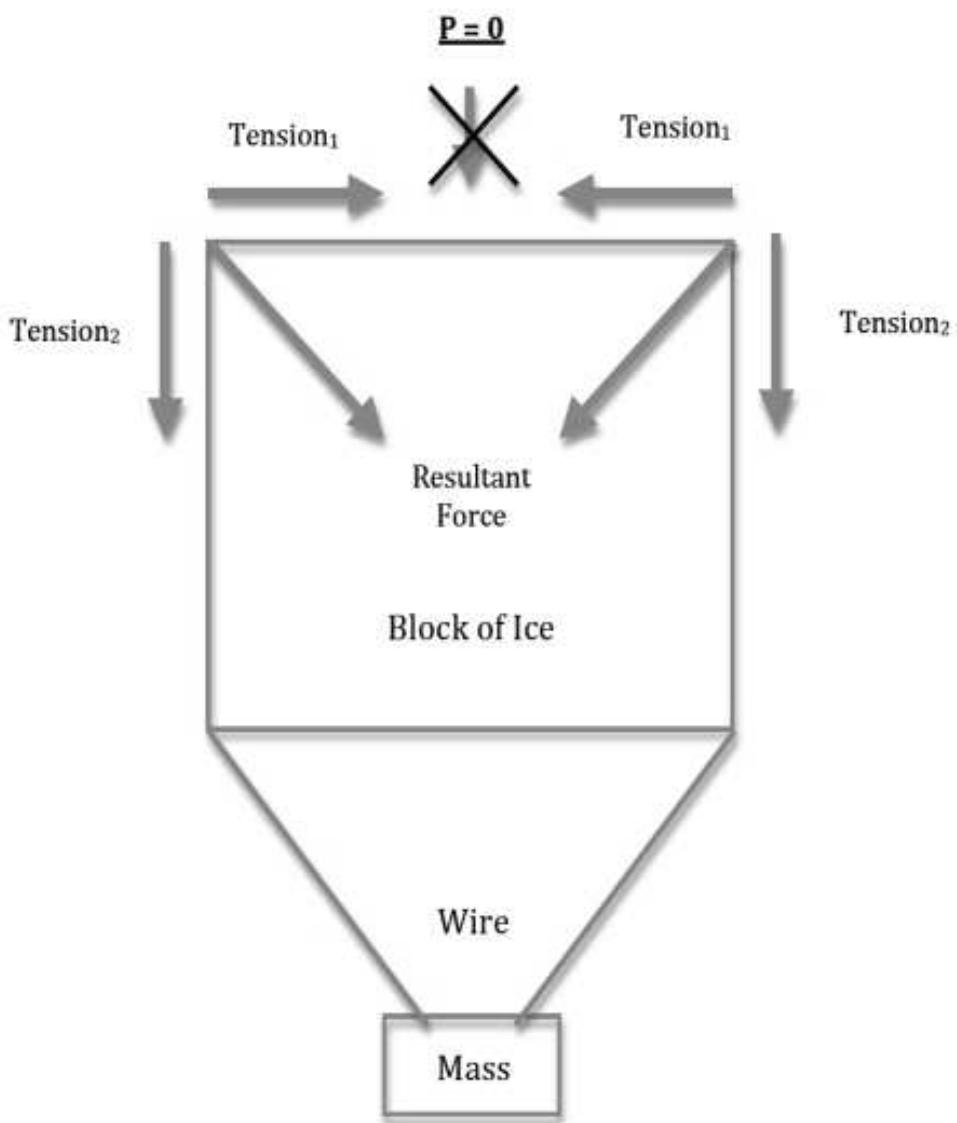


When I searched for a diagram of how the wire would behave as it moves through the ice, I noticed that the diagrams found in the textbooks were plain incorrect. See PHOTO.



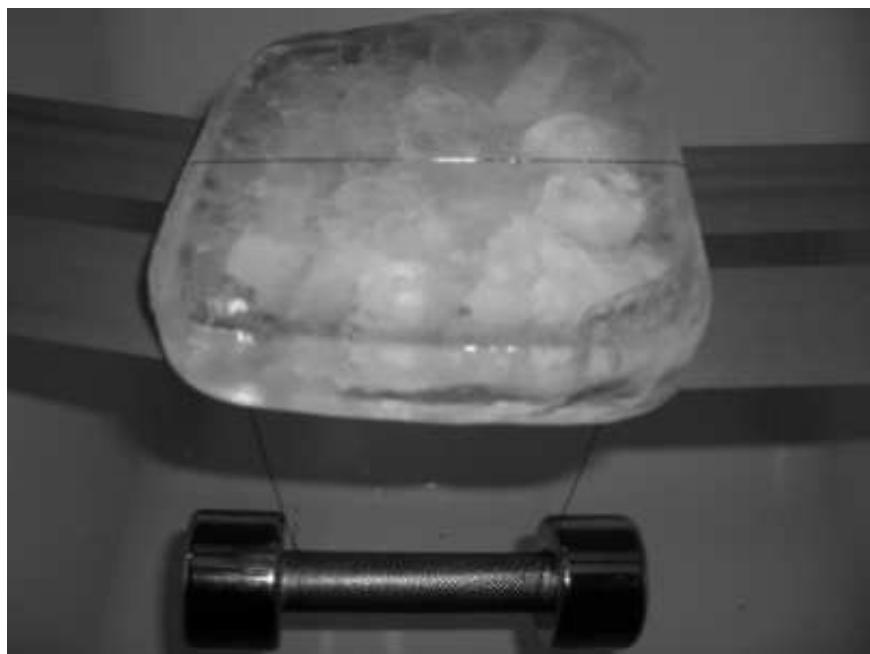
5 Eis kann durch Druck geschmolzen werden:
Unter dem Stahldraht schmilzt das Eis, wird aber nach Aufhören der Kraftwirkung gleich wieder fest. Der Stahldraht mit dem angehängten Gewichtstück wandert durch den Eisblock.

The faults in the diagrams perfectly indicate how the role of pressure is misinterpreted in regelation.



Here is a diagram scanned from one of a magazine published by a famous European University for the teachers of physics (!)

The diagram is completely wrong. It is not possible for the thin wire to move through the ice in a rectangular form. As one can see in the photographs I have taken the wire curves in the corners of the ice.





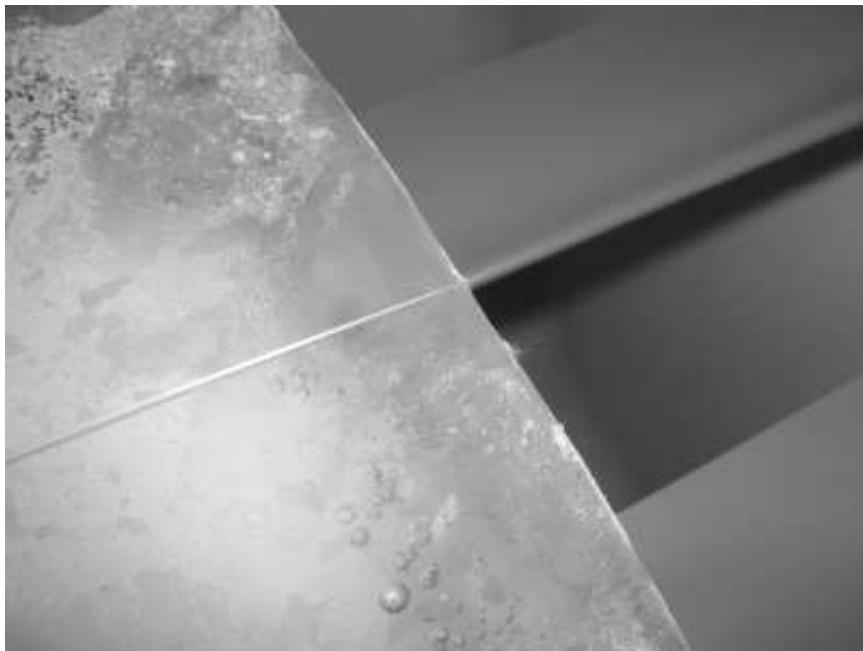
Here is what I got after about 45 minutes



FOTO ZREGELOWANEGO BLOKU

One sees a big difference between the behaviour of the wire and the fishing line in both of my experiments. During the first 20 minutes, the copper wire had already begun cutting deeply into the corners of the block of ice. The nylon string does not seem to have begun much melting.





Already from this, one can say that since copper conducts heat much better than nylon, the ice began melting much quicker. The energy released during regelation is conducted by the copper wire downwards, to do the melting job; much better than when the nylon fishing line is used. Presumably, it could not transmit thermal energy from the part of the fishing line not touching the ice like the copper wire. Therefore it is indeed the low conductivity of the fishing line that effected the melting of the ice in the experiment.

The last photograph of the fishing line experiment shows that even after 3 hours, the nylon string has not moved substantially:



To sum up, this is what happens: Firstly, the thermal energy from outside is transferred by the wire into the ice, causing it to turn into a liquid. When regelation takes place, energy (latent heat of solidification) is released into the wire again and the cycle continues.

After looking into the tables of data I found the following:

If thermal conductivity, in arbitrary unit, is expressed for copper wire as 400. the same size of fishing line will be characterised by 0.024 Therefore, one can say that nylon cannot conduct thermal energy for the regelation to take place. This explains why we have such a difference between how the two materials behave when attempting to melt through the block

After 3 hours, the nylon line stopped melting through the block of ice therefore I ended my experiment here.



Conclusion:

To recapitulate, I did a substantial amount of research into the subject and I found how common it was to talk about pressure in relation to regelation. Pressure was even incorporated into the definition of regelation. From straight - forward research and a bit of logical thinking, I found many contradictions and plain faults in these claims of how pressure is directly responsible for regelation. I conjured up an experiment to prove whether it is indeed pressure or something else.

In my results, the transfer of heat energy inside the wire caused regelation. Copper is incomparably a better conductor than nylon, however, if it was pressure that was responsible for the regelation taking place, then it should not have necessarily mattered what material is "touching" to the block of ice. Yet, as we have seen in my photos, changing the material from copper to nylon affected the regelation greatly. The fact that the nylon string stopped melting through the ice locally and just got stuck is critical because it proves once again that if only pressure was responsible, the nylon string that can withstand heavier loads than the copper wire should be better to demonstrate the effect of REGELATION.

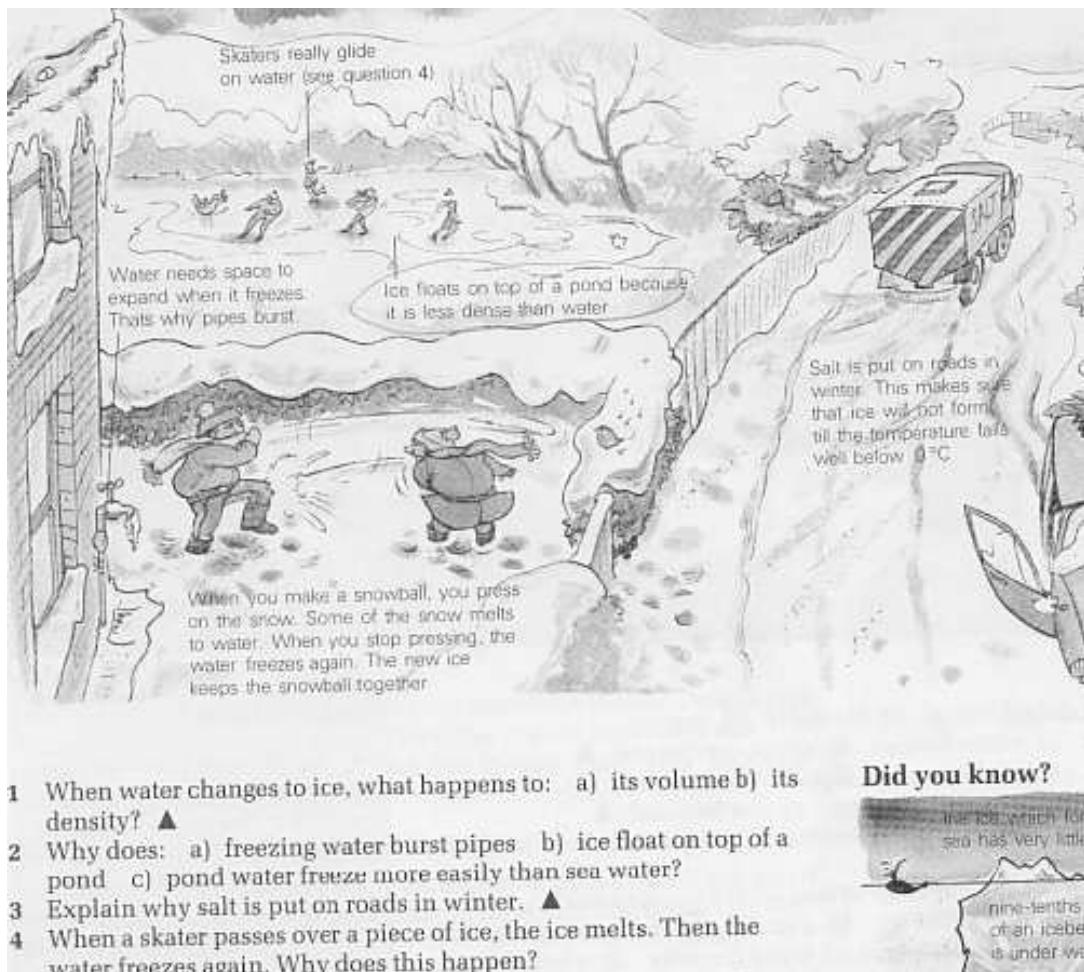
I am pleased with what I have seen. How nicely nature bends the "wire" inside the ice block, I would like to find the equation for this shape including all the constants, and identifying variables. Nature knew how to do it. At this moment I do not.

And here is one photo of the regelation experiment with "explanation" taken from a Physics textbook

What is written here? "One can melt (ice) by pressure: ice melts under the steel wire, but immediately after the force stops acting it freezes again. The wire along with the hanging load travels through the ice block"

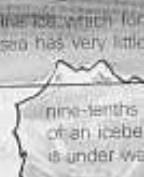
And the last picture I'd like to present taken from 1995 issue of Oxford University Press "Starting Science". One can ask: why do we feed the children with such low value information?

See? On the very top: "Skaters really glide on water"



- 1 When water changes to ice, what happens to: a) its volume b) its density? ▲
- 2 Why does: a) freezing water burst pipes b) ice float on top of a pond c) pond water freeze more easily than sea water?
- 3 Explain why salt is put on roads in winter. ▲
- 4 When a skater passes over a piece of ice, the ice melts. Then the water freezes again. Why does this happen?

Did you know?



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* This is an abbreviated version of my Extended Essay - an independent study required by the International Baccalaureate Diploma Program.

** The readers could be astonished reading in the WEBSTER NEW WORD DICTIONARY of American Language - World Press New York-London 1951:

regelation – freezing together as of pieces of moist ice under pressure at a temperature above the freezing point. (W.D.)

Dash and Scientific American