U-SIT And Think News Letter - 77

Unified Structured Inventive Thinking is a problem-solving methodology for creating unconventional perspectives of a problem, and discovering innovative solution concepts, when conventional methodology has waned. Heuristic Innovation is an extension of USIT with continued simplification.

Subject Keys

PD = Problem definition
H = Heuristics
T = Theory
M = Metaphors
A = Analysis
BH = Brain hemispheres
EX = Examples

Dear Readers:

. A request has been received for more lectures on heuristics. This mini-lecture was sparked by that request.

. If you have favorite or unusual heuristics that you use in creative problem solving please share them with this audience. Select one and submit a description of it along with an example of how you use it.

Mini USIT Lecture – 77

Heuristics

SIMPLIFICATION

This lecture is designed to call attention to how extensively we use the simplification heuristic in solving complex physical problems. Using a demonstration problem, the lecture, in this case, challenges one not so much to recall information but to apply the information already available to analyze a process we have known about for many years – namely, the freezing of water. It makes evident how simplification aids in extracting major effects but glosses over more subtle ones. Furthermore, we are (or can be) aware of both trends and continue to perfect our mental models in steps of increasing detail as we work to understand a problem. It shows the value of understanding major effects before delving into more subtle ones.

A Gedanken Ice Cube

Water is an amazing material. It rises in the air as invisible vapor, condenses into white clouds, is released as clear rain drops, as hail stones having mixed clear and white areas, and as white snow flakes. Its physical properties have various anomalies, we'll make use of one of them.

I'll start this problem description by asking you to do a gedanken experiment (a hands-free mental exercise). This has to do with making ice cubes. Please stay put and think this through before going to your refrigerator and looking at an ice cube.

First, we'll mentally make an ice cube. Imagine slowly filling an empty ice-cube tray with clear water from the cold-water tap. You can run the water awhile to let it get good and cold if you like, but it's not necessary. Now, without spilling any water, carry the tray to the refrigerator and gently place it on a shelf in the freezer compartment. While you're reading this sentence the water will have frozen. (See the advantage of gedanken experiments? No wasted time.) Now take the tray out of the refrigerator and remove a cube of ice for inspection. What do you see; that is, how would you describe the appearance of the ice cube? You probably see some clear and some opaque ice. If so, where is it clear and where is it opaque?

The following figures represent generalized features that crudely characterize a home-made ice cube. The figures are composed of two possible characteristics: regions of mostly clear ice and regions of mostly opaque ice; you can see through the former but not the latter. Cracks, which are common in ice cubes, are not considered at this point.

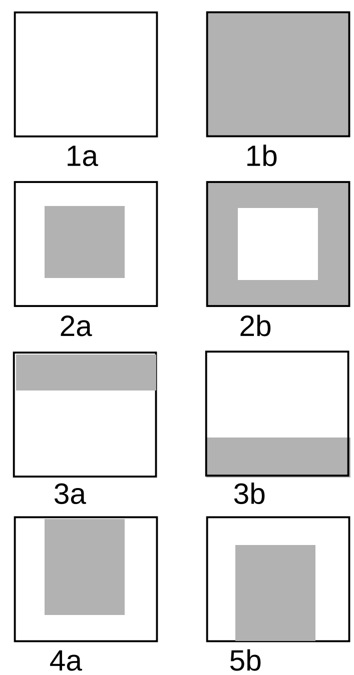
Which of the following figures best describe what you are seeing in your gedanken ice cube? For simplicity an ice cube is represented as a square. Its clear regions are shown as white while its opaque regions as grey. Contrary to this simplification, the two regions in a real home-made ice cube will not be uniformly clear or opaque. Let's not quibble about that detail. And don't worry about the amount of clear versus opaque ice in a particular cube. The relative amounts are not important. Simply imagine where clear and opaque ice may occur as illustrated in Figs. 1-4.

Figures !: (1a) ice cube is all clear;
(1b) ice cube is all opaque.

Figures 2: (2a) opaque ice surrounded by clear ice,
(2b) clear ice surrounded by opaque ice.

Figures 3: (3a) opaque ice at the top,
(3b) opaque ice at the bottom.

Figures 4: (4a) opaque ice at the top surrounded on the sides and bottom by clear ice,
(4b) opaque ice at the bottom surrounded by clear ice on the top an sides.



Figures 1-4. These figures are for recognizing the main features of a gedanken ice cube. The amount of clear ice relative to opaque is immaterial. The interest here is if both regions are present how are they arranged?

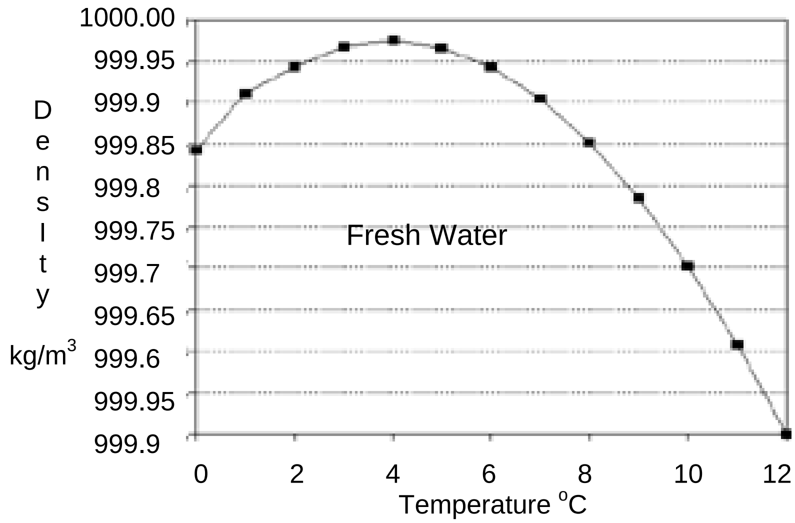
Here's the interesting part of this experiment. You've made your ice cube, examined it, and selected a representative figure to describe it. Now explain why the clear tap water froze into the arrangement you observed.

Done yet? Go ahead and work on it awhile and then I'll give you three clues.

Three clues

1. Liquid water has its greatest density at 4 °C (39.2 °F). This phenomenon is referred to the anomalous expansion of water. It's counterintuitive to our general understanding of most liquids, which contract on cooling. Water contracts on cooling down to 4 °C, but it expands on cooling below 4 °C (see Fig. 5). Said another way, from 4 °C, water expands with heating or cooling. Witness floating ice bergs protruding above water.

Figure 5. Density of fresh water as a function of temperature.



2. The solubility of air in water is much greater than its solubility in ice, by a factor of about 1000. As tiny ice particles begin to form in water at its freezing temperature, they accrete water molecules on their surfaces but exclude gaseous molecules – most of them but not all. Air molecules don't actually come out of the ice in this process, they simply never get in.

The accretion process occurs as molecules in the surrounding water momentarily adsorb onto a surface, diffuse a short distance on the surface, and then either give up thermal energy and become part of the growing solid phase or retain their energy and go back into solution. During freezing most of the water molecules join the solid phase while most of the gas molecules are re-dissolved.

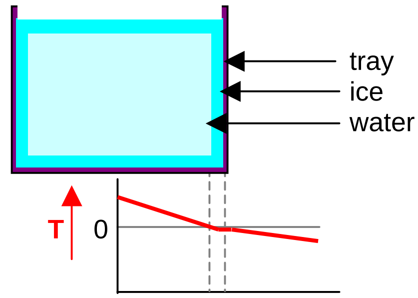
3. The viscosity of water increases as it cools. It increases by 13% between 4 °C and 0 °C.
Given these three phenomena of water you can figure out if water will freeze with clear and/or opaque regions and, if both, where they will be. You are also equipped to explain why ice cubes that have formed in ice-cube trays sometimes have a bump at the center of their tops. (An extra credit question.)

So what should we expect to see in our gedanken ice cube? Since it's not convenient to have our heads in the refrigerator to watch while the ice forms we'll do a gedanken explanation of the phenomenon of forming ice cubes.

Analysis

We began making our ice cubes with cold tap water (an optional choice). I just checked my cold tap water and its temperature was 10 °C (50 °F) after running a minute or so. Thus, it has to cool from 10 °C to 0 °C (50 °F to 32 °F) to begin the freezing process. While warmer than 4 °C, the water in the tray initially contracts and becomes denser as it cools. As a result of the tray resting on a solid shelf, the bottom water may cool more quickly; liquid-to-tray-to-shelf thermal conductivity should be greater than liquid-to-air conductivity (for good refrigerator design). The coldest water will be forming at the water-to-tray and water-to-air interfaces, i.e., the outsides of the volume of water. The warmer water will be in the center. The denser water will tend to move slowly to the bottom and displace the less dense, colder water toward the top. How far it actually moves will depend on how much the water's viscosity increases as it turns to ice (which is affected by the cooling rate in the refrigerator).

Figure 6. Temperature profile of a freezing volume of water in a cell of an ice tray. Water temperature is above freezing in the center of the liquid volume, decreases to the freezing point at the ice surface, remains at this temperature through the thickness of the ice (while liquid is still present), and drops below freezing in the tray's surroundings.



As the temperature of the water falls below 4 °C, first at the surfaces, water on all six sides will begin to expand becoming less dense and tend to rise as a result of its buoyancy. This buoyancy is a potential driver for convective flow, which the increasing viscosity of colder water tends to counteract.

The picture created so far is that warmer water, yet to freeze, is always surrounded by colder water as long as heat is flowing from the water to the ice-cube's surroundings. All thermal gradients driving the heat flow are directed outwards radially from the center of the volume of water.

The liquid water at the tray's walls, just reaching 0 °C, will be less dense than the more central water and will tend partly to flow towards the top and partly to collect on surfaces as freezing proceeds. Particles of ice not attached to surfaces form a viscous slush. Thus, as ice forms it will begin to encase the warmer, viscous slush it surrounds.

By the way, if you are old enough you probably can remember turning the hand-crank of a freezer for making home-made ice cream. If so, you have experienced the increase in viscosity of freezing liquid.

Note: You may find cause to differ with what you have just read. Make note of your differences. More discussion and analysis are coming.
After deciding what your gedanken ice cube looks like, look at a real one. Better yet, make one.

To be continued.

Other Interests

1. Have a look at the USIT textbook, "Unified Structured Inventive Thinking – How to Invent", details may be found at the Ntelleck website: www.u-sit.net
2. See also "Heuristic Innovation", which further simplifies USIT.

Publications	Language	Translators	Available at …
1. Textbook: Unified Structured Inventive Thinking – How to Invent	English	Ed Sickafus (author)	www.u-sit.net
2. eBook: Unified Structured Inventive Thinking – an Overview	English	Ed Sickafus (author)	www.u-sit.net
	Japanese	Keishi Kawamo, Shigeomi Koshimizu and Toru Nakagawa	www.osaka-gu.ac.jp/php/nakagawa/TRIZ/
	Korean	Yong-Taek Park	www.ktriza.com/www/usit/register_form.htm
"Pensamiento Inventivo Estructurado Unificado – Una Apreciación Global"	Spanish	Juan Carlos Nishiyama y Carlos Eduardo Requena	www.u-sit.net
3. eBook "Heuristic Innovation – Engaging both brain hemispheres in rapidly solving technical problems for multiple solution concepts"	English	Ed Sickafus (author)	www.u-sit.net
4. U-SIT and Think Newsletter	English	Ed Sickafus (Editor)	www.u-sit.net
	Japanese	Toru Nakagawa and Hideaki Kosha	www.osaka-gu.ac.jp/php/nakagawa/TRIZ/
	Korean	Yong-Taek Park	www.ktriza.com.
Mini-lectures from NL_01 through NL_67	Spanish	Juan Carlos Nishiyama y Carlos Eduardo Requena	www.u-sit.net click on Registration

Please send your feedback and suggestions to Ntelleck@u-sit.net and visit www.u-sit.net

To be creative, U-SIT and think.