'Nature! Out of the simplest matter it creates most diverse things, without the slightest effort, with the greatest perfection, and on everything it casts sort of fine veil. Each of its creations has its own essence, each phenomenon has separate concept, but everything is a single whole.'
—GOETHE

a toss up

PARTHA GHOSE
DIPANKAR HOME

To coin a phrase, these problems could leave you whistling in the dark

Illustration: Sibabrata Ray

WISH you a very happy 1988.

With this issue we enter the second year of Inquiry. We must take this opportunity to thank you all for the warm and enthusiastic response to our column. Over the past year it has been gratifying for us to receive such a large number of responses to the problems we have been posing. We have a pleasant surprise (we hope) for you. We have decided to offer a humble prize to Y. Raja Reddy (Tadipatri, Andhra Pradesh) who has been responding most regularly and has given the largest number of correct solutions. He will get free copies of Science Today for a year (1988). Heartiest congratulations to you, Raja. We hope you will keep it up.

In particular, we would like to mention how impressed we are by Raja's thoughtful and detailed investigation of the second problem we posed in the September issue: Why does water left in the open in cold countries in the winter freeze faster when it is initially heated to a higher temperature? Here is what Raja writes:

With the help of the following three facts we can solve the mystery of HOT FREEZE.

1. A body at a higher temperature loses heat at a faster rate than a body at a lower temperature.
2. If there is a temperature difference between the top and the bottom layers of a liquid convection currents are formed. The top layer must always be at a lower temperature than the bottom layer. Otherwise convection currents are not formed.
3. Water or any liquid cools at a faster rate when stirred. The stirring can be manual or natural as in the case of convection currents.

Since the effect is more pronounced in the case of a wooden vessel let us consider it first. According to point no. 1 above, hot water loses heat at a faster rate. All the while the cold water also loses heat, but at a slower rate. Therefore, at some point, the hot water catches up with the cold water. (A race between hare and tortoise where tortoise is given an initial lead.) Naturally hot water will have stronger convection currents than cold water (the more the difference in temperature the stronger the currents).

Now we have the following situation. The two vessels are at the same temperature. But the hot water is cooling at a faster rate because convection currents do not abruptly slow down to the speed of the currents in the cold water. (The hare has caught up with the tortoise but continues to run faster than the tortoise though at a rate slower than it did in the beginning.) As a result the cold water cannot keep up with the hot water in losing heat. So the hot water freezes first.

In a wooden vessel the only surface where heat can be given out is the surface of the liquid. The sides of the vessel do not allow the transfer of heat. This increases the temperature difference between the top and the bottom layers of the liquid. Consequently strong convection currents are formed.

In a metallic vessel heat is lost through the walls of the vessel also. This results in a reduction of the temperature difference between the top and the bottom layers. Therefore only weak currents are formed. When the hot water catches up with the cold water, the strength of currents in both of them is almost equal. Both freeze at the same time.

Here is a follow-up question. Can we observe the same effect (of hot water freezing first) in the absence of gravity (in a spaceship, for example)?

In the absence of gravity, convection currents do not form. We cannot observe the effect. That is, the cold water freezes first, or both of them freeze simultaneously.

We can use the following two experiments to confirm or refute the convection current theory.

EXPERIMENT 1

Aim: To create convection currents artificially and observe the results.

Equipment: Two identical wooden vessels, ice, salt, two identical flat bottomed stirrers, one heat-proof (thermocole) box.

Fill both vessels with water at room temperature. Slowly move the stirrer in vessel no.1 up and down until the water freezes. The stirring is identical with the convection current. If the theory is correct, the water in vessel no.1 should freeze first. Otherwise water in both vessels freeze at the same time.

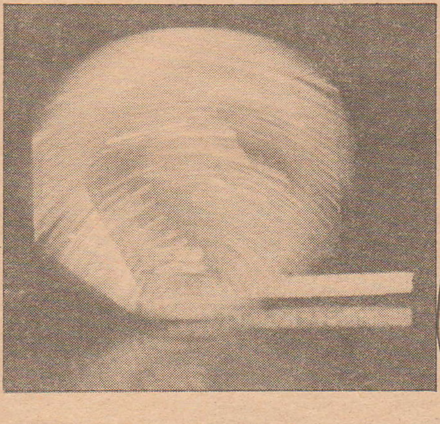
EXPERIMENT 2

Aim: To stop convection currents from forming and observe the results.

Equipment: Two small wooden vessels with a small hole at the bottom, metal lids for the vessels, ice, salt, one heat-proof (thermocole) box.

Take hot water in vessel no. 1 and cold water in vessel no. 2. Fix the metal lids and invert the vessels. Keep them on the freezing mixture. Observe which of the two waters freezes first. In this case there are no convection currents in both the vessels. Once the temperature of hot water equals the temperature of cold water both of them lose the heat at the same rate. Both of them should freeze at the same time. If the temperatures of water in the beginning differ by quite a large amount then the hot water may fail to catch up with the cold water (the tortoise is almost at the goal and the hare is at the starting point. The tortoise is given too much lead. It reaches the goal before the hare could catch up with it). Then the cold water freezes first.'

We invite your comments on Raja's analysis. We would only like to point out that it misses an important factor—water at a higher temperature loses mass at a faster rate than colder water due to faster evaporation. Hence, if you start with the same mass, by the time the temperature is equalized, the hotter water has lost more mass and so has a lower heat capacity (mass times specific heat). So it cools down faster subsequently. It would be, of course, very interesting to make a quantitative study of the relative importance of the various



factors involved. Would any one of you like to try the experiments suggested by Raja?

Pranoy Pratap Kohli from Rohtak (Haryana) has raised an interesting question concerning the invisible man problem discussed in the September issue. Pranoy argues that if the eyes of the invisible man were made of a material which acted as a black body (absorbing all the incident light) then he might be able to 'see' because of the absorption of light by his eyes. Unfortunately, mere absorption of light does not enable us to see things, it might only create a sensation. To be able to see things clearly our eyes must be good lenses which can refract light and form clear images on the retina.

Now, let's consider the solution to the first problem in the November issue (suggested by Manish. P. Pagey from Indore). Take a thick rubber band, stretch it quickly and hold it against your forehead. You will feel it distinctly warm! Why is it so? Well, first note that the quick stretching of the rubber band is an 'adiabatic' process (no exchange of heat with the surroundings can occur within this time and the work done by us in stretching the rubber band goes entirely to increase the internal energy (kinetic and potential) of the rubber molecules (the first law of thermodynamics). This raises the temperature of the band. When a gas expands rapidly, the gas itself has to do work by deriving the required energy from the internal energy of the gas molecules. Consequently the gas cools down.

This simple phenomenon of the stretching of a rubber band has another fascinating facet. A rubber band is usually a disordered tangle of long chains of molecules. The stretching produces a more ordered arrangement of these molecular chains. Now, 'entropy' is usually taken to be a measure of the disorder of a system. So one would expect the entropy of the band to decrease when stretched. But entropy cannot change in an adiabatic process. The resolution of this paradox probably lies outside the realm of standard 'equilibrium thermodynamics'. The usual connection between entropy and disorder breaks down in non-equilibrium thermodynamics, a subject that is only just beginning to be properly understood. Those of you who are interested may wish to read the pioneering work in this area done by Ilya Prigogine and his Brussels School. Prigogine was honoured for this outstanding work with a Nobel Prize.

Finally the problems for this month:

1. Place a rupee coin vertically on its edge on a table. It tends to fall down on its sides. Now, give it a push. It rolls forward steadily for a while without toppling. Why? Notice that after a while the coin starts moving in a curved path either to the left or to the right and eventually topples. It is such a common phenomenon. Have you ever thought about it?
2. People often whistle melodies through their lips when in a merry mood. What exactly happens to produce this sound? Have you ever tried whistling under water? ST