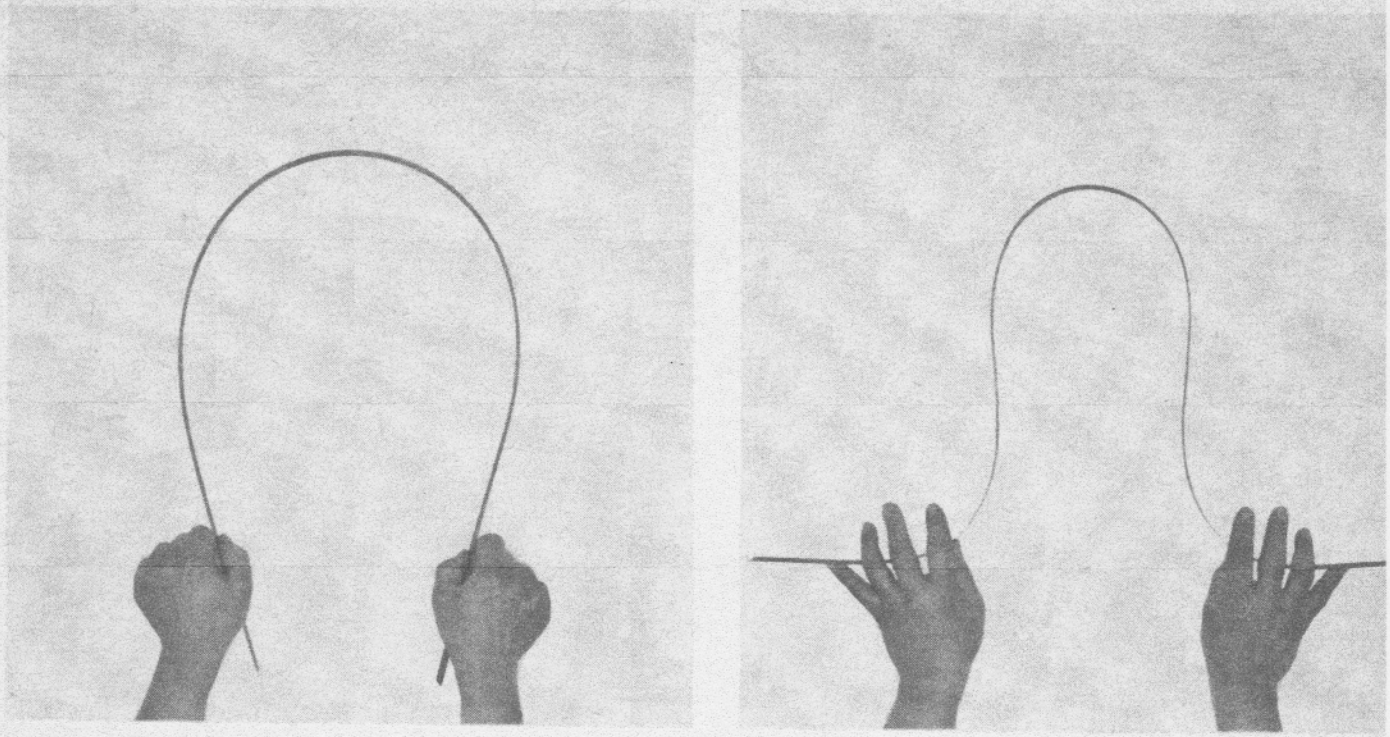

STRIP OF SPRING STEEL is used to demonstrate that a sine-generated curve is the curve of minimum total work. The strip is bent into various configurations by holding it firmly at two points and allowing the length between the fixed points to assume an un-

garded as being in a steady state, the form it assumes should be such as to avoid concentrating variations in *any* property at the expense of another property.

For example, variations in depth and velocity are inherent in all river channels, whether they are straight or curved. Even a reach, or length of channel, that is quite straight has a more or less uneven bed that consists of alternating deeps and shallows. Although this is not so obvious in a period of high flow, it becomes quite apparent at low flow, when the shallow sections tend to ripple in the sunlight as water backs up behind each hump in the bed before pouring over its downstream slope. To a trout fisherman this fast reach is known as a riffle. Alternating with the riffles are deeps, which the fisherman would call pools, through which the water flows slower and more smoothly.

The alternation of riffles and pools in a trout stream at low flow is noteworthy for another reason. The humps in the stream bed that give rise to the riffles tend to be located alternately on each side of the stream [*see top illustration on page 69*]. As a consequence the stream at low flow seems to follow a course that wanders successively from one side of the channel to the other, in a manner having an obvious similarity to meandering.

The analogy between this temporary sinuosity and full-scale meandering is strengthened by the fact that the riffles occur at roughly equal intervals along the channel. Moreover, the spacing of the riffles is correlated with the width of the channel. Successive riffles are located at intervals equal to about five to seven times the local channel width, or roughly twice the wavelength of a typical meander. This surprisingly consistent ratio seems even more remarkable when one realizes that each meander contains two riffles, one at each point of inflection. This observation led us to hypothesize that the same mechanism that causes meanders must also be at work in straight channels, and that a detailed study of the form and the hydraulic properties of two segments of channel that differ only in their degree of curvature might shed some light on the formation of meanders.

Obtaining Meander Profiles

In order to test this hypothesis it was necessary to obtain accurate data for all the pertinent hydraulic factors: depth, velocity, water-surface profile and bed profile. For several years we had attempted to measure such factors in small rivers near Washington just after every heavy rainstorm, when there was a rapid increase in streamflow. The water level changed so quickly in such storms, however, that there was never enough time to measure all the hydraulic factors in detail through a succession of two riffles and an intervening pool. Then in 1959 we tried another strategy: we decided to measure a small stream in Wyoming, named Baldwin Creek, in early June, a period of maximum runoff from melting snow. Measurements were made in two places, a meandering reach and a straight reach, that were comparable in all outward aspects except sinuosity. The stream was about 20 feet wide and was nearly overflowing its banks, so that we could just barely walk in it wearing chest-high rubber waders.

Robert M. Myrick, an engineer with the Geological Survey, and one of us (Leopold) began a series of measurements in the midafternoon of June 19, surveying water-surface and bed profiles with a level and a rod, and making velocity and depth measurements with a current meter and a rod. When darkness came, we lighted lanterns and continued our measurements. At about daybreak we slept for a few hours and then resumed the survey, grateful that the melting snow had kept the stream at a steady high flow for such a long time.

Several days later we were able to sit down under a tree and plot the profiles, velocities and depths on graph paper. What emerged was a quite unexpected contrast between meandering reach and straight reach [*see bottom illustration on page 69*]. The slope of the water surface in the meandering reach