Selective Experiments In Physics

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MEASUREMENT OF SMALL LENGTHS BY MICROMETER CALIPERS

OBJECT: To become familiar with the use of micrometer calipers for the accurate measurements of small lengths.

METHOD: A micrometer caliper with a millimeter scale is first studied. The pitch of the instrument and least count is determined, the zero error is checked, and the observer makes trials to become familiar with the device. Then the dimensions of several objects such as small cylinders, spheres, wires, and file cards are measured.

THEORY: One of the problems involved in the assembly line production of such articles as automobiles is that of having parts manufactured at different times and places brought together and assembled so that they fit perfectly. The workers in such industries know that many measurements must have a "tolerance." of only one or two thousandths of an inch or less. The measurement of such small distances requires some skill and special apparatus. Mass production of automobiles was not possible until these were developed.
The most widely used device for the accurate measurement of small dimensions is the micrometer caliper, such as that shown in Fig. 1. On one end of the heavy frame *F* is mounted the anvil A. and on the other end the cylindrical sleeve S. On the inside wall of S an accurate screw thread has been cut. The corresponding screw thread has been cut on the outside wall of the rod *R* and this rod is rigidly attached to the thimble T. As *R* and *T* are rotated, they advance (or recede) a distance equal to the pitch of the screw for each revolution. The total number of revolutions is indicated by the *S* scale (the scale on *S*) and the additional fraction of a revolution by the *T* scale.
The pitch of the screw for most metric micrometer calipers is ½mm and the numbers of the *S* scale represents the number of millimeters (not the number of revolutions). Since there are 50 divisions on the *T* scale, each one of these divisions represents 1/50 of a revolution or an advance of *R* amounting to 0.01mm. Since the *T* scale should be read to tenths of a division, lengths are measured to thousandths of a millimeter.
Various methods are used in making the *S* scale. There may be twenty identical divisions per centimeter, Fig. 2 (a), in which case each division represents ½mm or one revolution; for easy identification, the half-millimeter marks may be staggered. Fig 2 (b), or made somewhat shorter. Fig 2 (c); or, the half-millimeter marks may be omitted entirely. Fig 2 (d), in which case the observer must decide from an inspection of the two scales whether or not the half-millimeter point has been passed.
Referring to any one of the diagrams in Fig. 2. one can see that the *S* scale reading is 6.5mm and the *T* scale reading is 48.4 hundredths of a millimeter. The complete reading is, therefore. 6.5mm + 0.181mm or 6.984mm.
If the micrometer caliper does not read zero when the gap between *R* and *A* is closed, it is said to have a *zero error* and the reading thus taken is called the *zero reading*. The zero reading should be subtracted algebraically from all readings taken with the micrometer. Since it gives exactly the same result and saves considerable time, the zero reading should be subtracted from the average of a set of readings rather than from each individual reading.

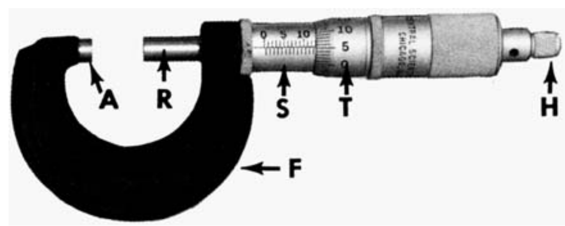

Fig. 1. Micrometer caliper.

When a micrometer caliper is to be used, the body to be measured is held lightly clamped between the anvil *A* and the rod *R*. To make sure that the pressure exerted on the body is the same for each reading and to prevent injury to the accurately cut screw threads. *R* should always be turned by means of the friction head *H*. As *R* approaches its final position, *H* should be turned slowly until the ratchet between *H* and *T* clicks once.
In the United States the metric system has not been widely adopted in manufacturing processes and the British system remains popular. A variety of micrometer calipers calibrated in British units are available. Many of these are in decimal British units and can easily be read to thousandths of an inch and estimated to a few thousandths of an inch.

APPARATUS: Several micrometer calipers; small metal cylindrical specimens; wires (gauge numbers 18, 24, and 30); spherical specimen; file cards; spherometer; watch glass.

PROCEDURE: 1. Select the micrometer caliper with the millimeter scale and thoroughly acquaint yourself with its features. Note the pitch of the screw and what the numbers on the *S* and *T* scales represent. Take about five observations of the zero reading of the instrument, closing the jaws each time with the ratchet. (Do not force the screw.) Record the zero error of this micrometer caliper.

2. Take about nine observations each of the diameter and the length of a small cylindrical specimen. recording your

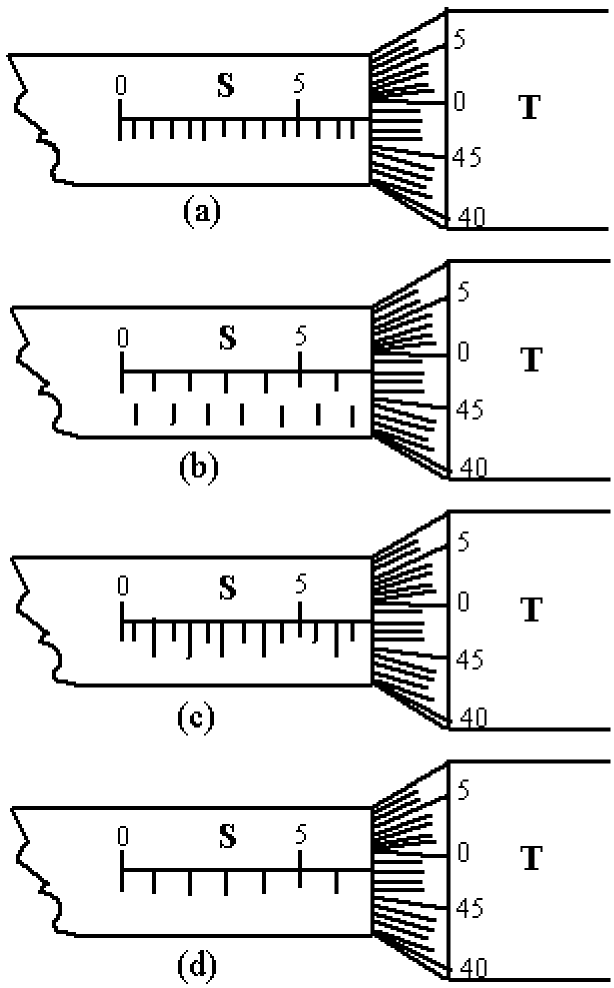

Fig. 2. Four methods of marking the micrometer scale.

observations in tabular form. These readings should not all be taken at the same position, but should be so distributed over the cylinder that good average values can be obtained. Be sure to estimate each reading to a fraction of a division on the *T* scale. Again the friction head *H* should be used to approach the final position until the ratchet clicks. This insures equal pressure and prevents injury to the screw threads.

3. Correct the observed value's for any appreciable zero error and obtain the average values of the diameter and length of the cylinder. Calculate the volume of the specimen, being careful to record the result to the proper number of significant figures. Estimate the uncertainty of this result and express it as a percentage of the volume.

4. In the same manner measure the diameter of a spherical specimen and calculate its volume. Again estimate the percentage error of your result.

5. Make several measurements of the diameters of the wire specimens. Compare the average diameters observed with the standard values found in wire tables and note the percentage difference for each wire.

6. Measure the thickness of one file card, recording the values at several card locations. Note the average thickness. Take a tightly held stack of 25 of these cards and make several measurements of the thickness of the stack. Calculate the thickness of one card from these observations and compare this value with the observation for one card.

OPTIONAL EXERCISES: 1. Determine thee masses of the specimens studied and calculate their densities (density = mass/volume). Compare these densities with the values found in tables.

2. A spherometer is a special form of micrometer screw. Examine the scales on a spherometer, determine the pitch of the screw and the least count. Use the spherometer to measure the radius of curvature of a spherical surface "watch glass," as follows: Place the instrument on a plane surface and note the reading when the tip of the screw just touches the surface. Then place the spherometer over the inverted watch glass and take a reading when all of the points are in contact with the glass. If *a* is the difference between these two readings and *S* is the length of one side of the triangular base, the radius *R* can be computed from the equation

$$R = \frac{S^2}{6a} + \frac{a}{2}$$

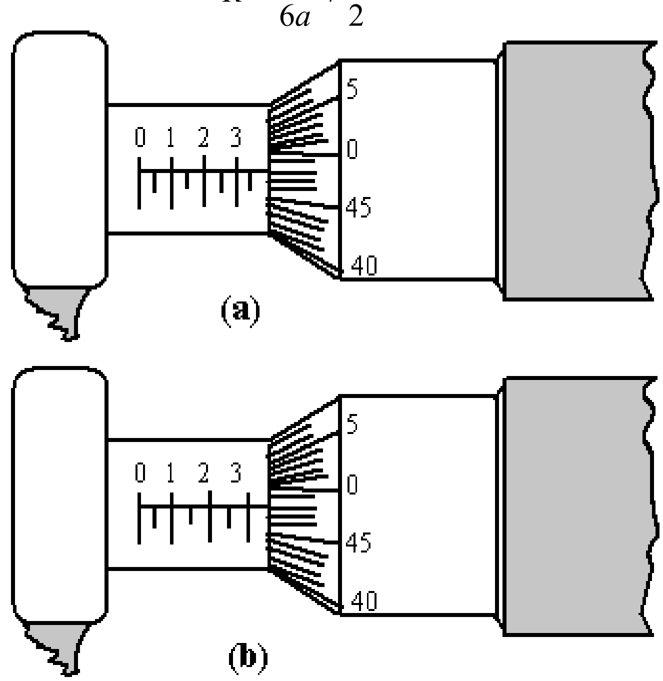

Fig. 3. Reading on micrometer calipers.

QUESTIONS: 1. State whether each of the following would be likely to produce systematic or random errors in this experiment and explain why: (a) the micrometer. is closed by twisting the thimble *T* rather than the friction head *H*; (b) the faces of the anvil *A* and the rod *R* are not parallel; (c) the corners of the cylinder are slightly rounded; (d) the end faces of the cylinder are parallel to each other but are not quit perpendicular to the side.

2. State some of the errors that are likely to be made in the measurement of the diameter of a fine wire by the use of a micrometer caliper. Which of these errors are likely to be the more serious?

3. A cheaply manufactured micrometer caliper obviously is not as accurately calibrated as an expensively made instrument. Are the errors made in the use of the cheap instrument classified as random or systematic? Explain,

4. Although micrometer calipers are used today for accurately making measurements of small distances, the idea was first thought of by a French astronomer, William Gascoigne, in 1638, as an aid in measuring the size of the sun and planets. Explain how the micrometer caliper could be of help in measuring such large bodies.

5. If in this experiment the percentage error in the measurement of the diameter of the cylinder and the diameter of the sphere where the same, would these errors cause equal percentage errors in the calculations of the volumes of these specimens?

6. Show how the barrel and thimble of a micrometer caliper could be marked so that the instrument could be used to read accurately to 0.001 inch.

7. What are the readings represented by the settings of the micrometer caliper show n in Fig. 3?

8. Make rough drawings to show a micrometer caliper set at (a) 1.098cm; (b) 1.049cm.