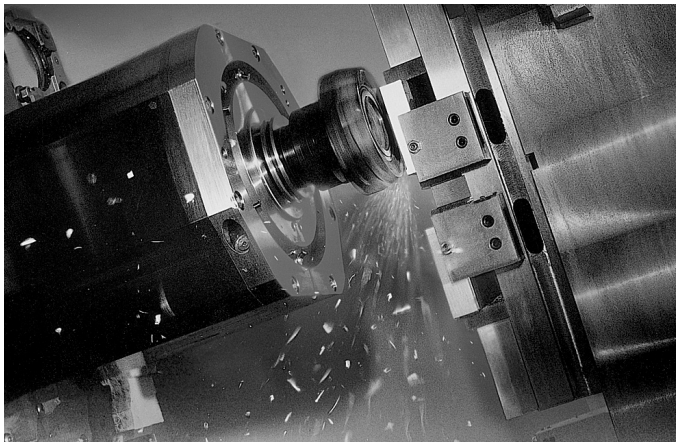


Chapter 4

Measurement

LEARNING OBJECTIVES

After studying this chapter, students will be able to:

- Measure to 1/64″ (0.5 mm) with a steel rule.
- Measure to 0.0001″ (0.002 mm) using a Vernier micrometer caliper.
- Measure to 0.001″ (0.02 mm) using Vernier measuring tools.
- Measure angles to 0°5′ using a universal Vernier bevel.
- Identify and use various types of gages found in a machine shop.
- Use a dial indicator.
- Employ the various helper measuring tools found in a machine shop.

INSTRUCTIONAL MATERIALS

Text: pages 55–80
Test Your Knowledge Questions, pages 78–80
Workbook: pages 23–32
Instructor's Resource: pages 71–92
Guide for Lesson Planning
Research and Development Ideas
Reproducible Masters:
4-1 Inch-Based Rule
4-2 Metric Rule
4-3 Inch-Based Micrometer
4-4 Inch-Based Vernier Micrometer
4-5 Metric Micrometer
4-6 Metric-Based Vernier Micrometer
4-7 25-Division Inch-Based Vernier Caliper
4-8 25-Division Metric Vernier Caliper
4-9 50-Division Inch-Based Vernier Caliper
4-10 50-Division Metric Vernier Caliper
4-11 Universal Bevel Protractor
4-12 Test Your Knowledge Questions
Color Transparencies (Binder/CD only)

GUIDE FOR LESSON PLANNING

Since this chapter is extensive, it is recommended that it be divided into four parts.

Part I—The Rule

The ability to make accurate measurements is basic to all types of skilled occupations. As a pretest, use the rules on Reproducible Masters 4-1 and 4-2 to determine a starting point for teaching measurement.

Have students read and study pages 55–57. Review the assignment and demonstrate and discuss the following:

- The various types of rules.
- How to read and use the various types of rules.
- How to make accurate measurements with a rule.
- How to handle and care for rules so they will retain their accuracy.

Part II—Micrometers

Once students become proficient with rules, introduce the micrometer caliper. Since most training centers have a limited number of the various types of micrometers, Reproducible Masters 4-3, 4-4, 4-5, and 4-7 have been provided for use as overhead transparencies or handouts.

Have students read and study pages 57–63. Review the assignment and demonstrate the following:

- The various types of micrometers.
- How to read inch- and metric-based micrometers.
- How to read inch- and metric-based Vernier micrometers.
- The proper way to use micrometers.
- The proper way to care for micrometers so they will retain their accuracy.

Allow students to examine and use micrometers. Provide various sizes of work so students can practice using and reading micrometers.

Part III—Vernier Measuring Tools

Have students read and study pages 63–67. Use Reproducible Masters 4-7, 4-8, 4-9, 4-10, and 4-11 to make overhead transparencies and handouts. Review the assignment and demonstrate the following:

- The various types of Vernier calipers.
- How to read inch- and metric-based Vernier calipers.
- How to read dial calipers.
- How to read the universal bevel protractor.
- The correct way to use Vernier and dial calipers.
- The proper way to care for Vernier measuring tools so they will retain their accuracy.

Allow students to examine and use the Vernier type tools. Provide various sizes of work so students can practice using and reading the tools.

Part IV—Gages and Dial Indicators

Have as many of the tools described in this section that are available in the shop on hand for student examination.

Have students read and study pages 67–78, paying particular attention to the illustrations. Discuss and demonstrate how the tools are used.

Technical Terms

Review the terms introduced in the chapter. New terms can be assigned as a quiz, homework, or extra credit. These terms are also listed at the beginning of the chapter.

dial indicators
gage blocks
gaging
graduations
helper measuring tools
International System of Units
metrology
micrometer caliper
steel rule
Vernier caliper

Review Questions

Assign *Test Your Knowledge* questions. Copy and distribute Reproducible Master 4-12 or have students use the questions on pages 78–80 in the text and write their answers on a separate sheet of paper.

Workbook Assignment

Assign Chapter 4 of the ***Machining Fundamentals Workbook.***

Research and Development

Discuss the following topics in class or allow students to choose topics for individual or group projects.

1. Make a large working model of the hub and thimble of a micrometer. Use different size cardboard mailing tubes.
2. Develop a working model of a Vernier caliper. Make it large enough to be used to instruct the class. The model may be of a 25- or a 50-division scale.
3. Make an enlarged section of a No. 4 rule at least ten times actual size. Use basswood, plywood, or hardboard.
4. Prepare a transparency of a No. 4 rule using several overlays that can be used on an overhead projector to teach beginners how to read a rule.
5. Design and make a series of posters showing how to read a metric micrometer.
6. Prepare a display of various types of gages. Secure samples of work checked by gage type measuring tools.
7. Arrange for someone to demonstrate how optical flats are used. Use a film or video

presentation if the actual equipment cannot be secured.

8. Invite a quality control expert from a local industry to speak to the class or grant an interview. Ask them to describe their job and the specialized measuring tools that are used on the job. Prepare questions in advance that the class would like to have answered or explained.
9. Prepare a research paper on how temperature changes can affect measuring accuracy.
   - Prepare 1.000″ (25.00 mm) long pieces of aluminum, brass, steel, plastic, and cast iron with exactly the same size cross section.
   - Record their exact lengths at room temperature with a Vernier micrometer caliper.
   - Place the sections in a freezer for 24 hours and quickly measure them again.
   - Record your findings. Place the sections in boiling water or in a heat treating furnace for 15 minutes at 200°F (93°C). Quickly measure them again. Record your findings.
   - Record a graph that will show how sizes varied under the three conditions of temperature. Using this information, have a class discussion how products can be affected by great changes in temperature and how industry takes into account this problem when certain products are designed.
10. Prepare a report or presentation on early measuring tools and some of the problems encountered before measuring standards were established.

TEST YOUR KNOWLEDGE ANSWERS, Pages 78–80

1. 1. 3/16
   2. 11/16
   3. 1 5/16
   4. 1 13/16
   5. 2 7/16
   6. 2 13/16
   7. 3 1/16
   8. 3 7/16
   9. 3 15/16
   10. 1/32
   11. 13/32
   12. 21/32
   13. 25/32
   14. 1 3/32
   15. 1 15/32
   16. 1 25/32
   17. 2 5/32
   18. 2 17/32
   19. 2 23/32
   20. 2 29/32
   21. 3 9/32
   22. 3 7/16
   23. 3 19/32
   24. 3 29/32
   A. 300 mm
   B. 295 mm
   C. 289 mm
   D. 284 mm
   E. 278 mm
   F. 273 mm
   G. 267 mm
   H. 262 mm
   I. 251 mm
   J. 241 mm
   K. 234 mm
   L. 227 mm
   M. 214 mm
   N. 0.50 mm
   O. 5.5 mm
   P. 11.5 mm
   Q. 19.5 mm
   R. 24.0 mm
   S. 32.5 mm
   T. 36.5 mm
   U. 43.5 mm
   V. 54.5 mm
   W. 62.5 mm
   X. 74.5 mm
   Y. 83.5 mm
   Z. 88.5 mm
2. A. 8.683″
   B. 4.107″
   C. 7.500″
   D. 3.150″
   E. 8.793″
   F. 5.008″
   G. 55.78 mm
   H. 73.34 mm
   I. 71.70 mm
   J. 24.84 mm
3. mike
4. microinch
5. micrometer
6. 0.001, 0.0001, 0.01, 0.002
7. Student answers will vary but may include two of the following: it can be used to make both internal and external measurements; newer versions make both inch based and metric measurements; it has a larger measuring range.
8. 0.001, 0.02
9. Evaluate individually.
10. universal Vernier bevel protractor
11. Double end plug gage has the GO plug on one end and the NO-GO plug on the other end. The progressive or step plug gage has GO and NO-GO plugs on same end permitting gaging to be done in a single motion.
12. diameters, tolerance
13. Jo
14. a. Air pressure leakage between the plug and hole walls.
15. Continuous and balanced types.

16. Evaluate individually.
17. Optical flats
18. optical comparator
19. screw pitch gage
20. Evaluate individually. Refer to Figure 4-52.
21. Helper tools are not direct reading and require the help of a rule, micrometer, or Vernier caliper to determine the size of the measurement taken.
22. Compress the contact legs.

    Insert the gage into the hole and allow the legs to expand.

    After the proper fitting is obtained, lock the contacts into position.

    Remove the gage from the hole and make your reading with a micrometer.
23. A. 0.312″
    B. 0.625″
    C. 5.78 mm
    D. 0.375″
    E. 0.562″
    F. 9.67 mm
    G. 0.437″
    H. 0.937″
    I. 4.03 mm
    J. 0.500″
    K. 0.187″
    L. 16.07 mm

WORKBOOK ANSWERS, Pages 23–32

1. A. 1/4
   B. 7/8
   C. 1 3/8
   D. 2 1/8
   E. 2 5/8
   F. 3 1/2
   G. 5/16
   H. 11/16
   I. 1 3/16
   J. 1 11/16
   K. 2 7/16
   L. 2 15/16
   M. 3 9/16
   N. 4 1/16
2. A. 3/32
   B. 15/32
   C. 23/32
   D. 27/32
   E. 1 5/32
   F. 1 17/32
   G. 1 27/32
   H. 2 7/32
   I. 2 19/32
   J. 2 25/32
   K. 2 31/32
   L. 3 11/32
   M. 3 1/2
   N. 3 21/32
   O. 3 13/16
   P. 3 31/32
   Q. 5/64
   R. 13/64
   S. 23/64
   T. 37/64
   U. 45/64
   V. 55/64
   W. 1 3/64
   X. 1 10/64
   Y. 1 19/64
   Z. 1 27/64
   AA. 1 39/64
   BB. 1 61/64
   CC. 2 7/64
   DD. 2 15/64
   EE. 2 31/64
   FF. 2 39/64
   GG. 2 49/64
   HH. 2 63/64
   II. 2 9/64
   JJ. 3 17/64
   KK. 3 25/64
   LL. 3 33/64
   MM. 3 41/64
   NN. 3 58/64
   OO. 4 1/64
3. A. 305.0
   B. 294.0
   C. 286.0
   D. 281.0
   E. 272.0
   F. 266.0
   G. 261.0
   H. 255.0
   I. 249.0
   J. 241.0
   K. 233.0
   L. 225.0
   M. 214.0
   N. 6.5
   O. 12.5
   P. 20.5
   Q. 25.5
   R. 33.5
   S. 43.5
   T. 54.5
   U. 64.5
   V. 75.5
   W. 84.5
   X. 88.5
   Y. 93.5
   Z. 99.5
4. A. 0.856″
   B. 0.663″
5. A. 0.817″
   B. 0.532″
6. A. 0.748″
   B. 0.142″

7. A. 0.429″
   B. 0.081″
8. A. 0.357″
   B. 0.759″
9. A. 5.04 mm
   B. 12.99 mm
10. A. 1.39 mm
    B. 19.51 mm
11. A. 0.56 mm
    B. 14.61 mm
12. A. 9.62 mm
    B. 15.99 mm
13. A. 12.18 mm
    B. 13.83 mm
14. A. 0.743
    B. 4.157
15. A. 6.991
    B. 12.108
16. A. 8.475
    B. 11.708
17. A. 5.057
    B. 3.343
18. A. 75.34 mm
    B. 43.78 mm
19. A. 78.66 mm
    B. 23.66 mm
20. A. 69.28 mm
    B. 113.94 mm
21. d. Both b and c.
22. 0.001, 0.0001
23. 0.01 mm, 0.002 mm
24. Evaluate individually. Refer to Section 4.3.
25. Evaluate individually. Refer to Section 4.3.5.
26. 1/12, 5
27. go-no go
28. go-no go dimensions in one motion
29. air pressure leakage between the plug and diameter being measured
30. d. All of the above.
31. light waves
32. A measuring device that makes use of an enlarged image of the part to be inspected. The image is projected on a screen where it is superimposed on an enlarged accurate drawing of the part.
33. telescoping gage
34. the number of threads per inch or mm on a threaded section
35. The thin steel blades of a fillet and radius gage, are used to check concave and convex radii on corners or against shoulders. The gage is used for layout work and inspection, and as a template when grinding form cutting tools.
36. Measuring devices that are not direct reading but require the aid of a rule, micrometer, or Vernier caliper to determine size of measurement taken.
37. Inside caliper, telescoping gage, outside caliper, and small hole gage.
38. d. All of the above.
39. d. All of the above.
40. c. openings that are too small for a telescoping gage

ANSWERS FOR REPRODUCIBLE MASTERS

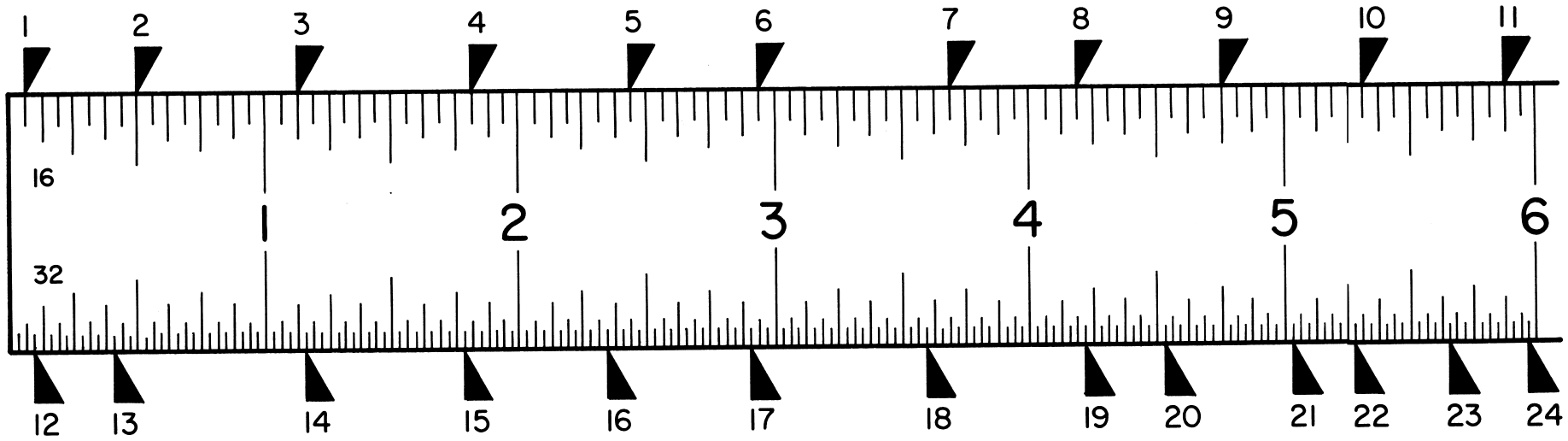
4-1 Inch-Based Rule

1. 1/16″
2. 1/4″
3. 1 1/8″
4. 1 13/16″
5. 7/16″
6. 2 15/16″
7. 2 11/16″
8. 4 3/16″
9. 4 3/4″
10. 5 5/8″
11. 5 7/8″
12. 3/32″
13. 9/32″
14. 1 5/32″
15. 1 25/32″
16. 2 11/32″
17. 2 29/32″
18. 3 19/32″
19. 4 7/32″
20. 4 17/32″
21. 5 1/32″
22. 5 9/32″
23. 5 21/32″
24. 5 31/32″

4-2 Metric Rule

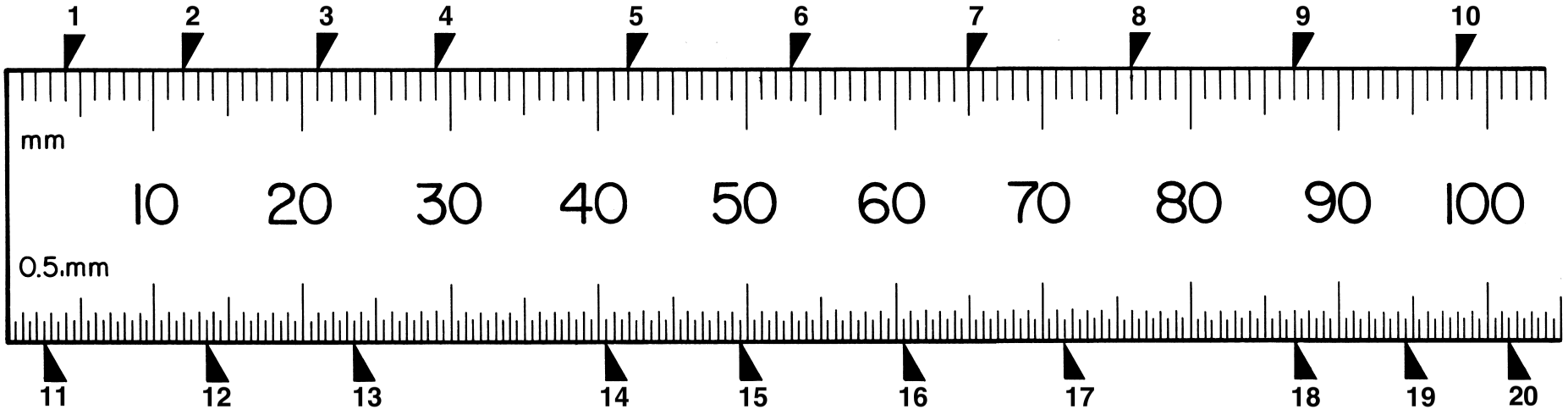
1. 4.0 mm
2. 12 mm
3. 21 mm
4. 29 mm
5. 42 mm
6. 53 mm
7. 65 mm
8. 71 mm
9. 82 mm
10. 98 mm
11. 2.5 mm
12. 13.5 mm
13. 23.5 mm
14. 40.5 mm
15. 49.5 mm
16. 60.5 mm
17. 71.5 mm
18. 87 mm
19. 94.5 mm
20. 101.5 mm

Inch-Based Rule



1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____
21. _____
22. _____
23. _____
24. _____

Metric Rule



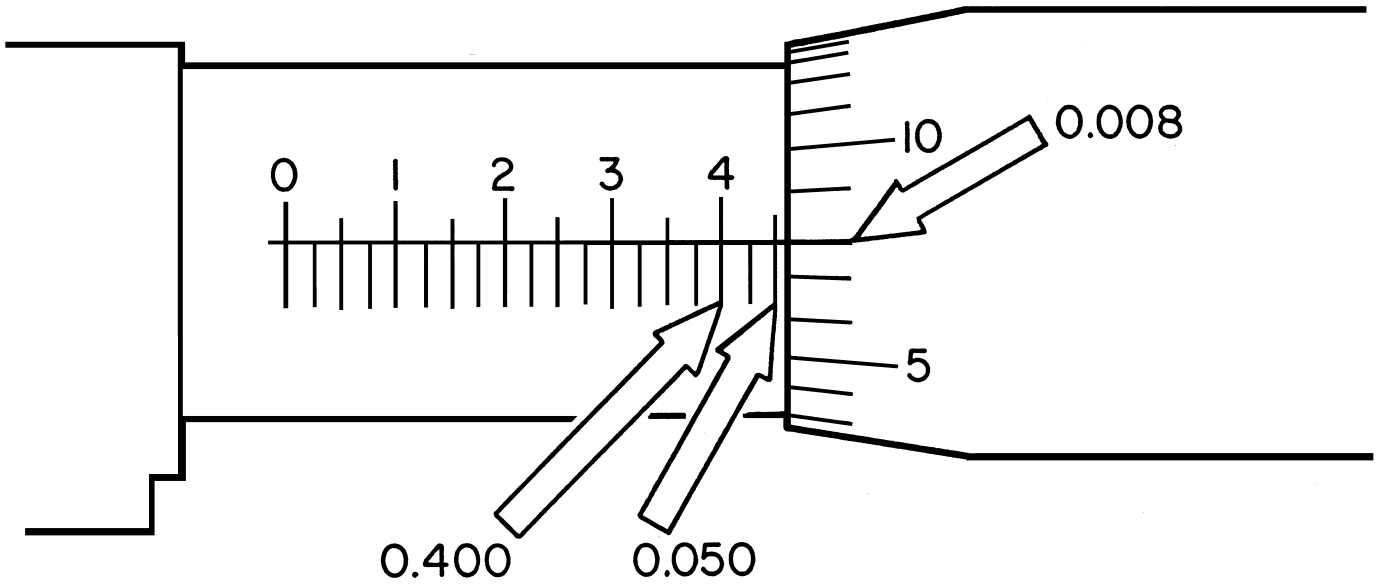
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____

11. _____
12. _____
13. _____
14. _____
15. _____
15. _____
17. _____
18. _____
19. _____
20. _____

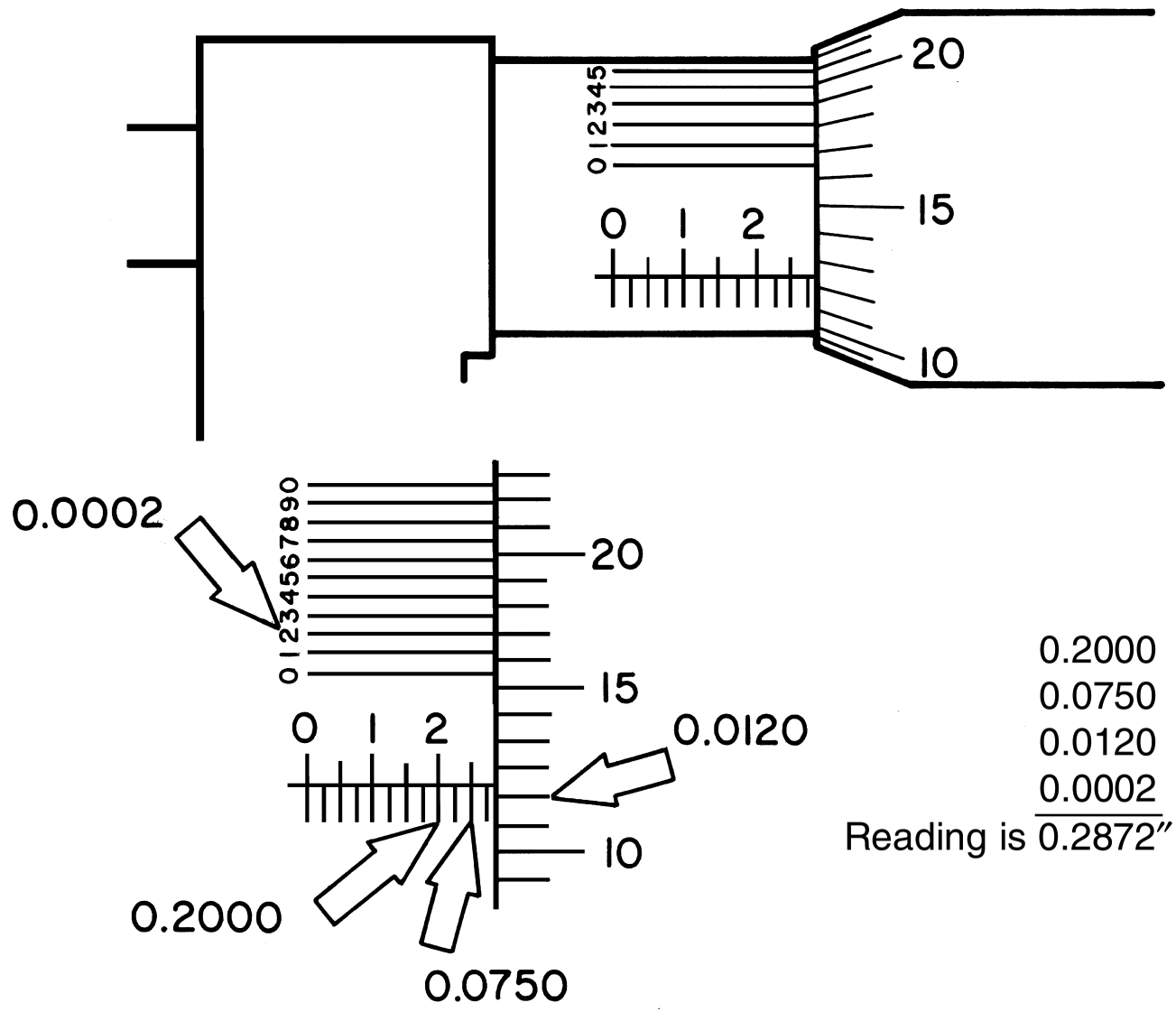
Inch-Based Micrometer

The reading is composed of:

4 Large graduations or 4 x 0.100 = 0.400
2 Small graduations or 2 x 0.025 = 0.050
8 Graduations on the thimble or 8 x 0.001 = 0.008
0.458″.

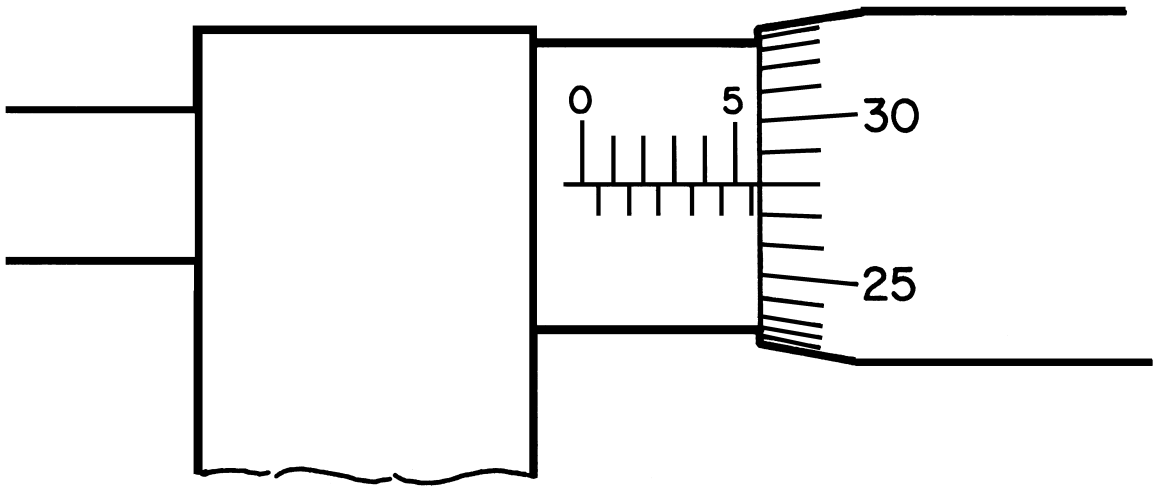


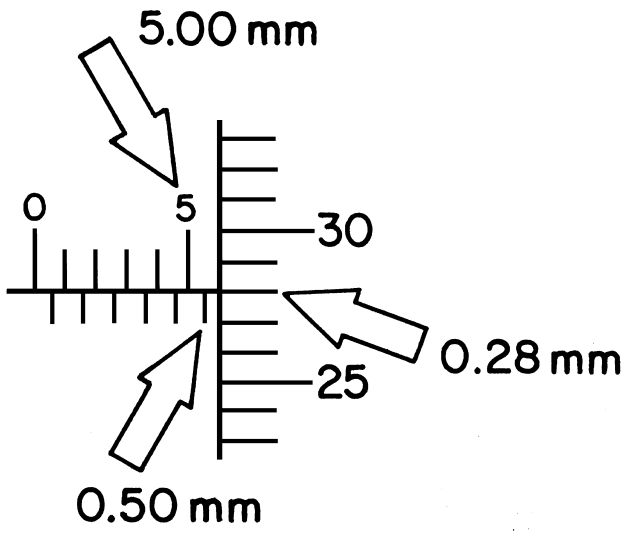
Inch-Based Vernier Micrometer



0.2000
0.0750
0.0120
0.0002
Reading is 0.2872″

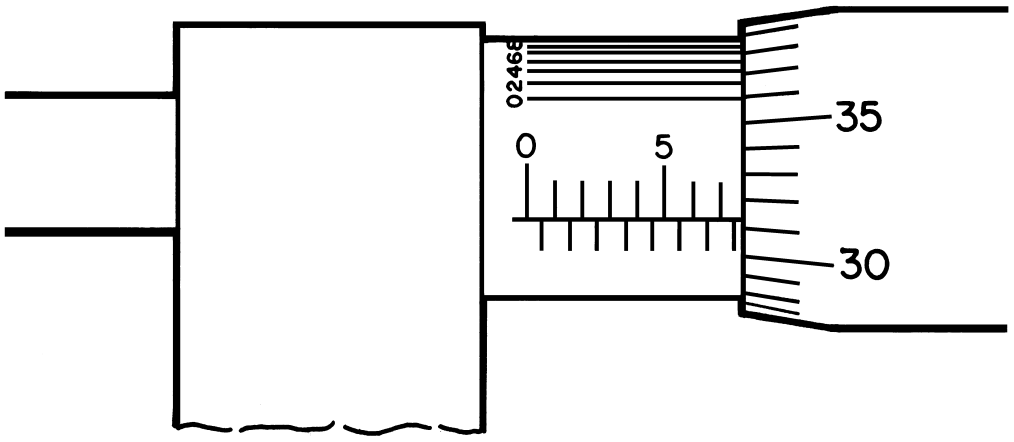
Metric Micrometer

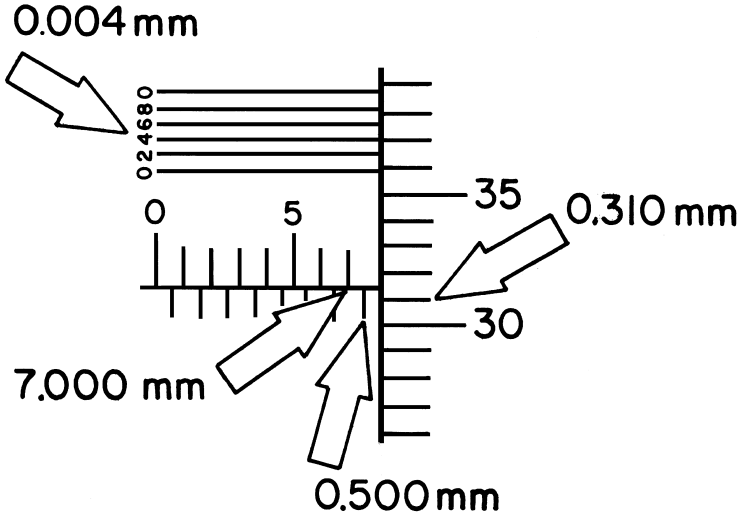




5.00
0.50
0.28
Reading is 5.78 mm

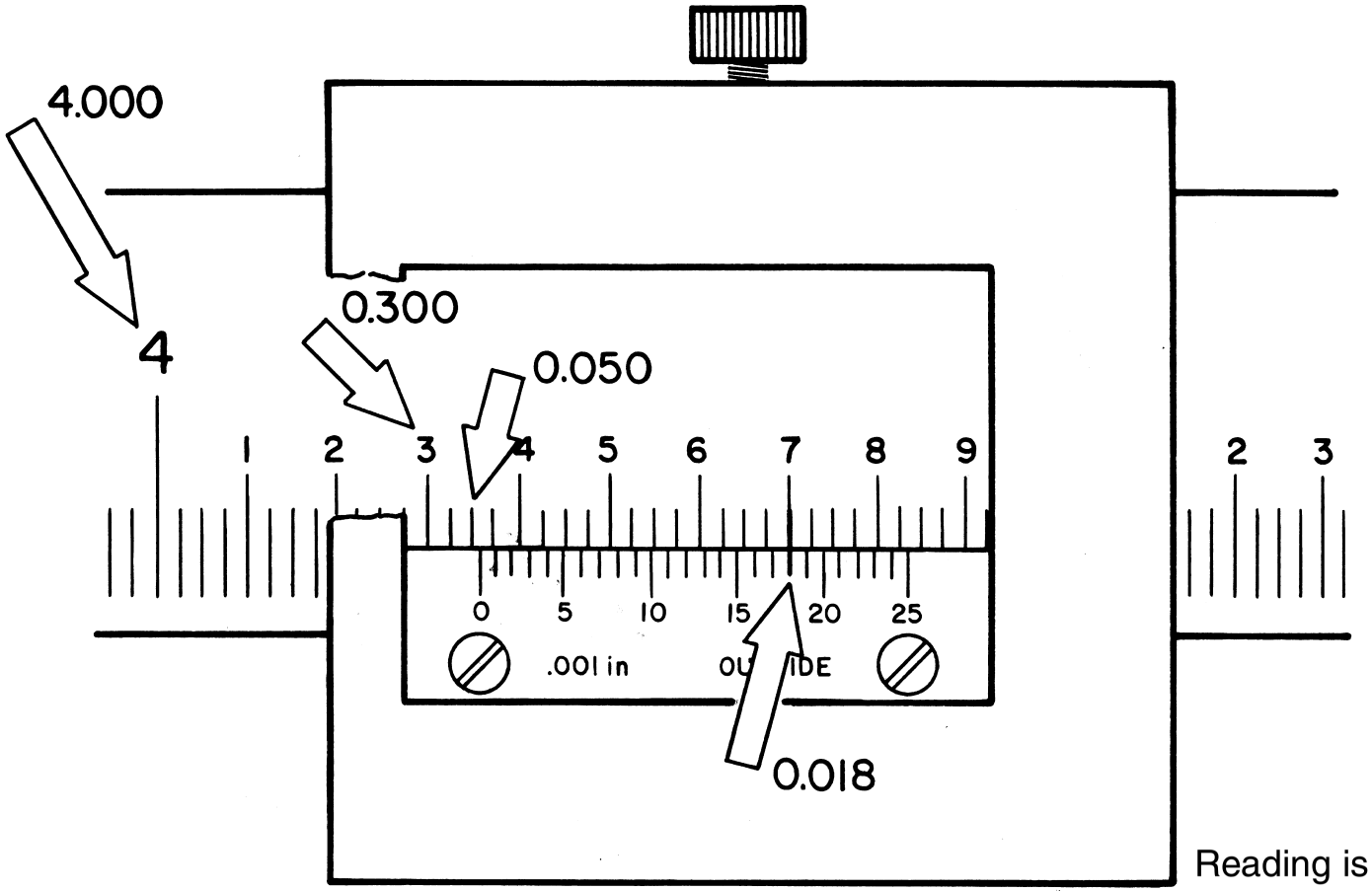
Metric-Based Vernier Micrometer



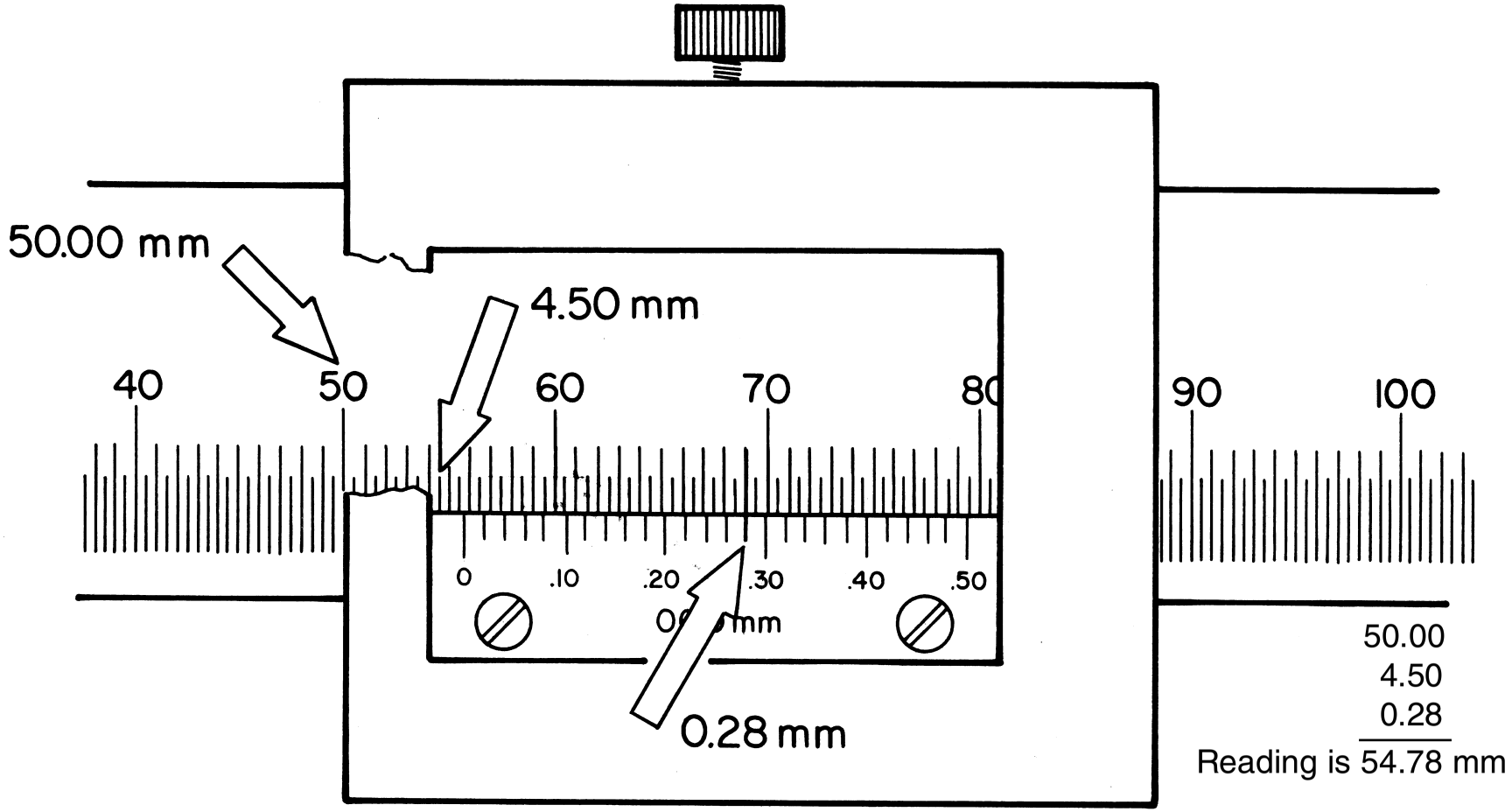


7.000
.500
.310
.004
Reading is 7.814 mm

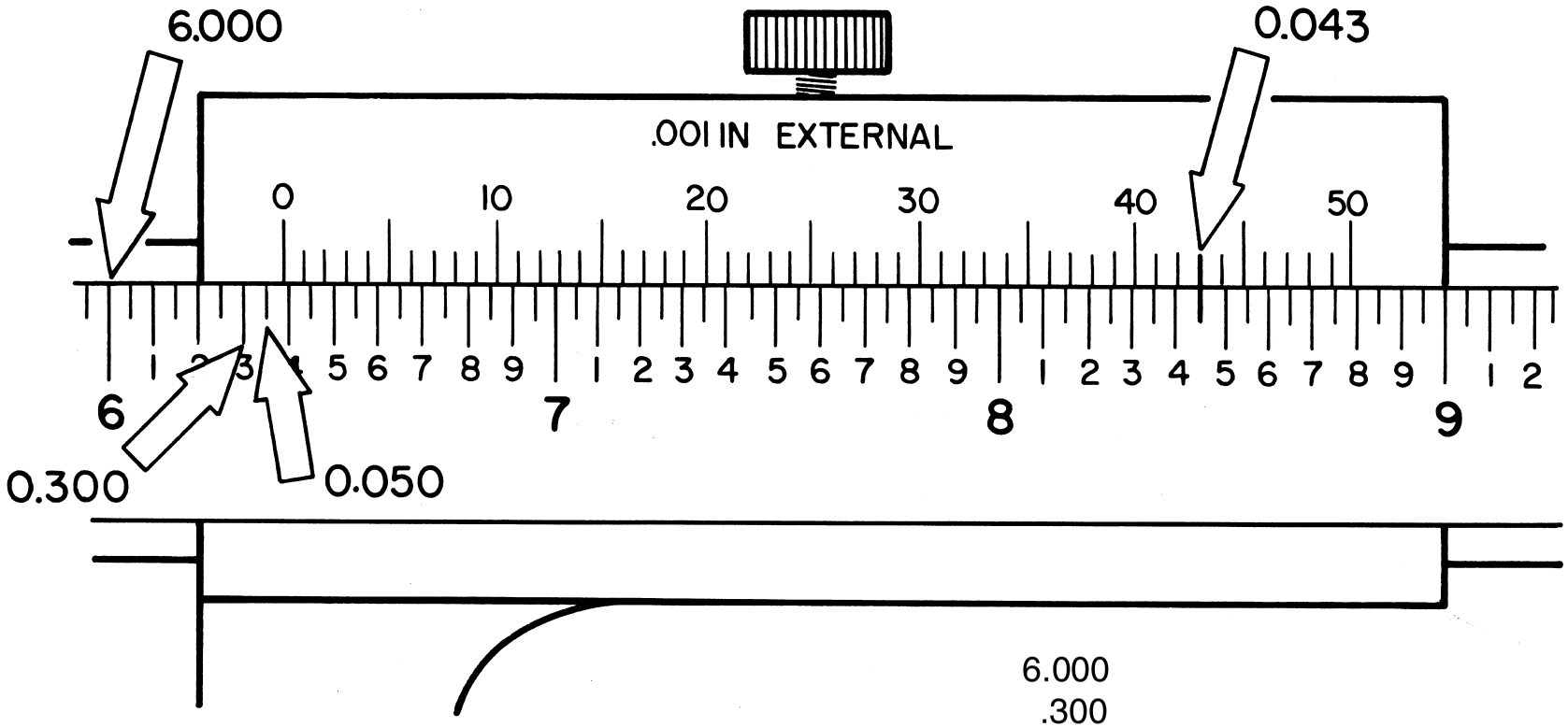
25-Division Inch-Based Vernier Caliper



25-Division Metric Vernier Caliper

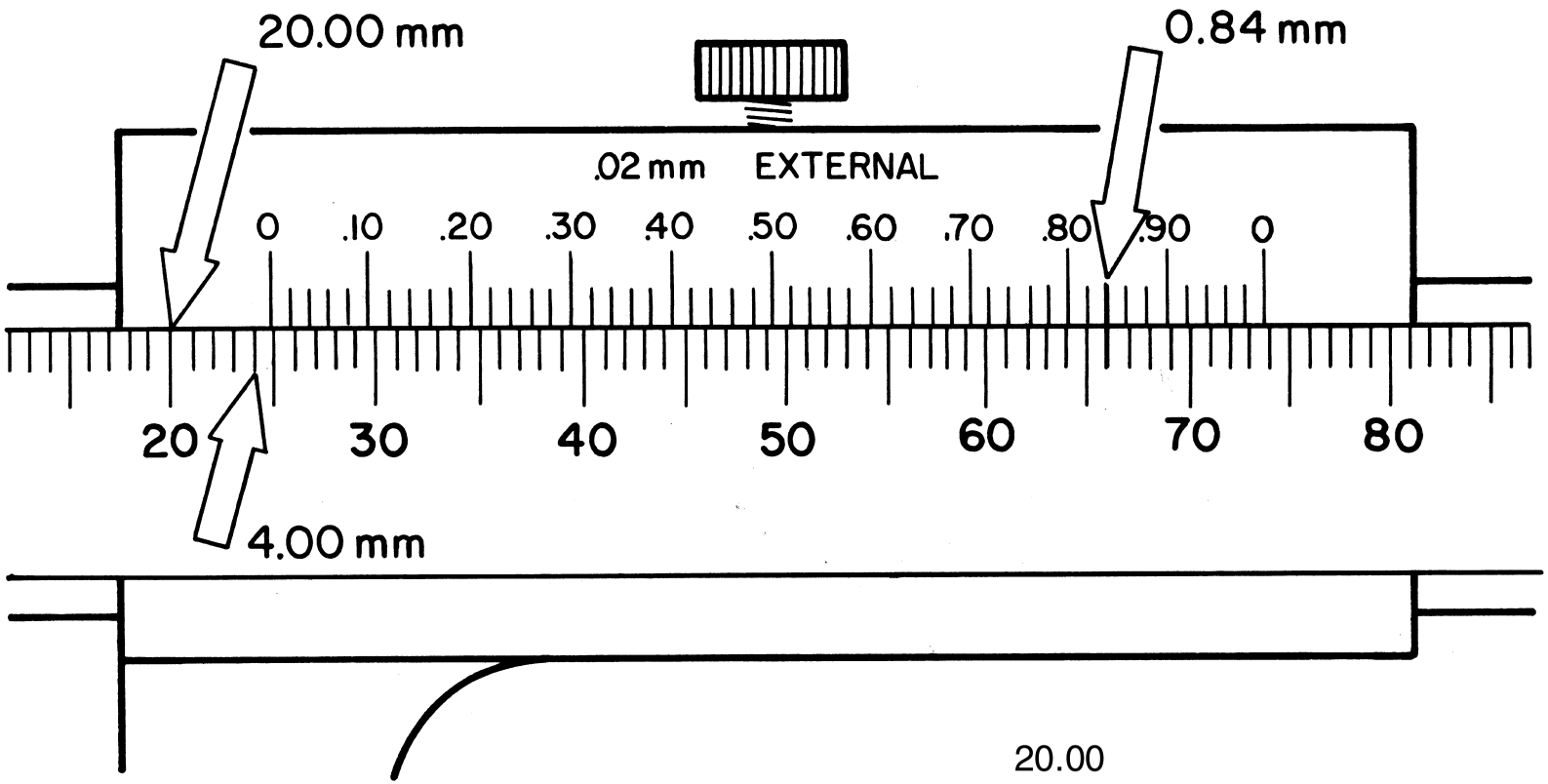


50-Division Inch-Based Vernier Caliper



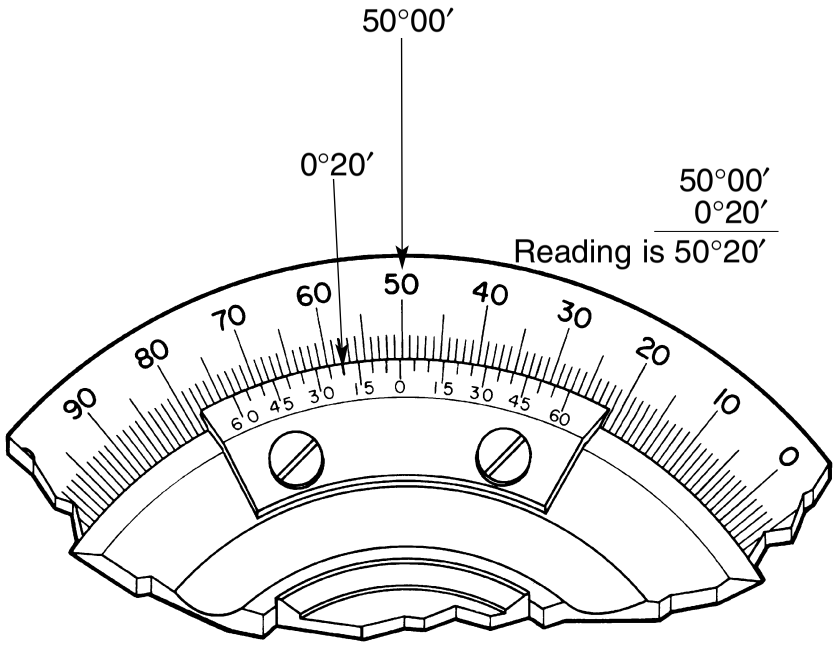
6.000
.300
.050
.043
Reading is 6.393″

50-Division Metric Vernier Caliper



20.00
4.00
0.84
Reading is 24.84 mm

Universal Bevel Protractor



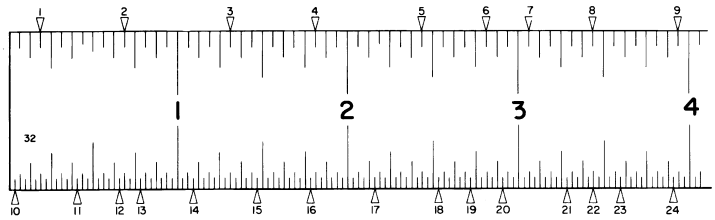
To read the protractor, note the number of degrees that can be read up to the “0” on the Vernier plate. To this, add the number of minutes indicated by the line beyond the “0” on the Vernier plate that aligns exactly with a line on the dial.

The “0” is past the 50° mark, and the Vernier scale aligns at the 20′ mark. Therefore, the measurement is 50°20′.

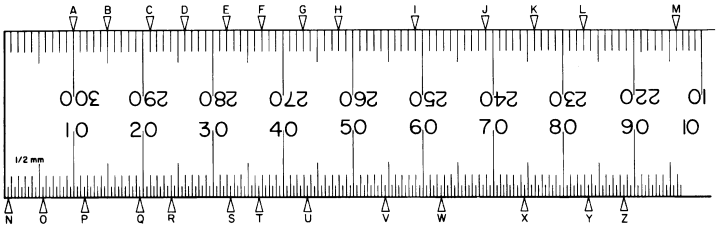
Measurement

Name: _____ Date: _____ Score: _____

1. Make readings from the rules shown below.



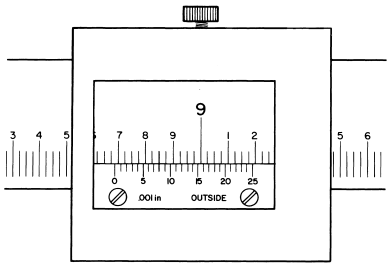
1. _____
2. _____
3. _____
4. _____
5. _____
6. _____
7. _____
8. _____
9. _____
10. _____
11. _____
12. _____
13. _____
14. _____
15. _____
16. _____
17. _____
18. _____
19. _____
20. _____
21. _____
22. _____
23. _____
24. _____



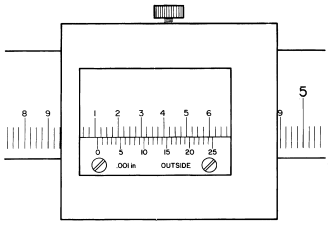
A. _____
B. _____
C. _____
D. _____
E. _____
F. _____
G. _____
H. _____
I. _____
J. _____
K. _____
L. _____
M. _____
N. _____
O. _____
P. _____
Q. _____
R. _____
S. _____
T. _____
U. _____
V. _____
W. _____
X. _____
Y. _____
Z. _____

Name: _____

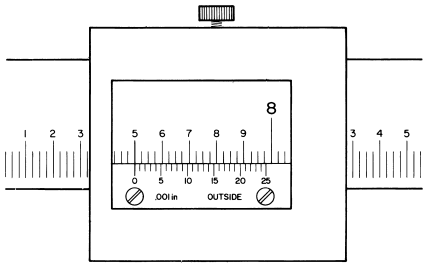
2. Make readings from the Vernier scales shown below.



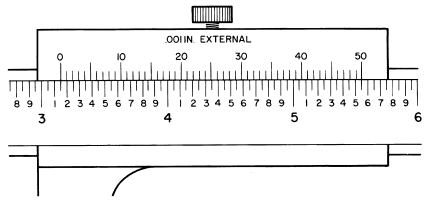
A. _____



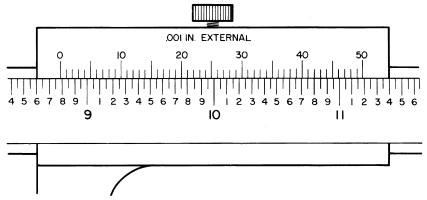
B. _____



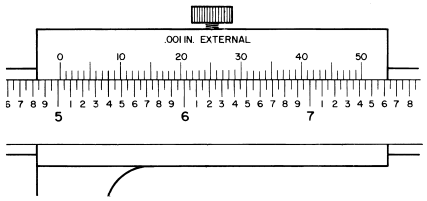
C. _____



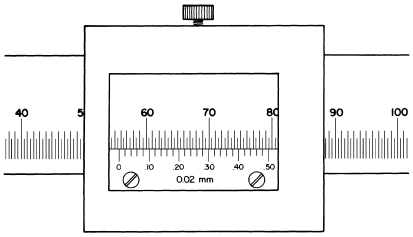
D. _____



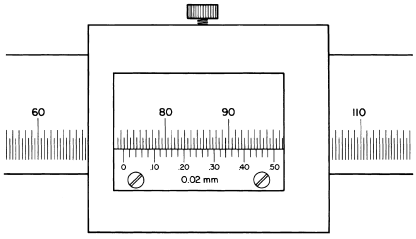
E. _____



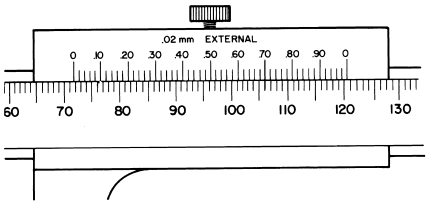
F. _____



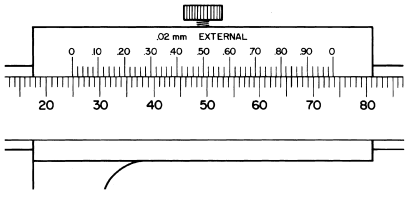
G. _____



H. _____



I. _____



J. _____

(continued)

Name: _____

- Answer the following questions as they pertain to measurement.

3. The micrometer is nicknamed _____. 3. _____
4. One-millionth part of a standard inch is known as a _____. 4. _____
5. One-millionth part of a meter is known as a _____. 5. _____
6. A micrometer is capable of measuring accurately to the _____ and _____ part of standard inch and (in metric versions) to _____ and _____ millimeters. 6. _____
7. The Vernier caliper has several advantages over the micrometer. List two of them.

_____

_____

8. A Vernier caliper can measure to the _____ part of the inch and (in the metric version) to _____ millimeters. 8. _____
9. List six precautions that must be observed when using a micrometer or Vernier caliper.

_____

_____

_____

_____

_____

_____

10. The Vernier-type tool for measuring angles is called a _____. 10. _____
11. How does a double-end cylindrical plug gage differ from a step plug gage? _____

_____

_____

_____

12. A ring gage is used to check whether _____ are within the specified _____ range. 12. _____
13. Gage blocks are often referred to as _____ blocks. 13. _____

Name: _____

14. An air gage employs air pressure to measure deep internal openings and hard-to-reach shaft diameters. It operates on the principle of: 14. _____
    a. Air pressure leakage between the plug and hole walls.
    b. The amount of air pressure needed to insert the tool properly in the hole.
    c. Amount of air pressure needed to eject the gage from the hole.
    d. All of the above.
    e. None of the above.
15. The dial indicator is available in two basic types. List them.

    _____

    _____

16. What are some uses for the dial indicator? _____

    _____

    _____

    _____

17. Name the measuring device that employs light waves as a measuring standard.

    _____

18. The _____ is used for production inspection. An enlarged image of the part is projected on a screen where it is superimposed upon an accurate drawing. 18. _____
19. The pitch of a thread can be determined with a _____. 19. _____

20. Of what use are fillet and radius gages? _____

    _____

    _____

21. What are helper measuring tools? _____

    _____

    _____

22. How is a telescoping gage used? _____

    _____

    _____

    _____

    _____

Name: _____

23. Make readings from the micrometer illustrations.

A. _____ G. _____

B. _____ H. _____

C. _____ I. _____

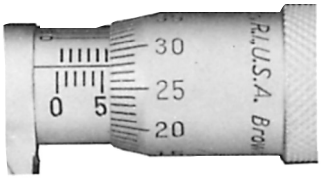
D. _____ J. _____

E. _____ K. _____

F. _____ L. _____

A

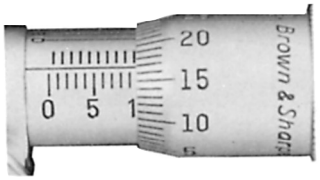
B



C

D

E



F

G

H

I

J

K

L