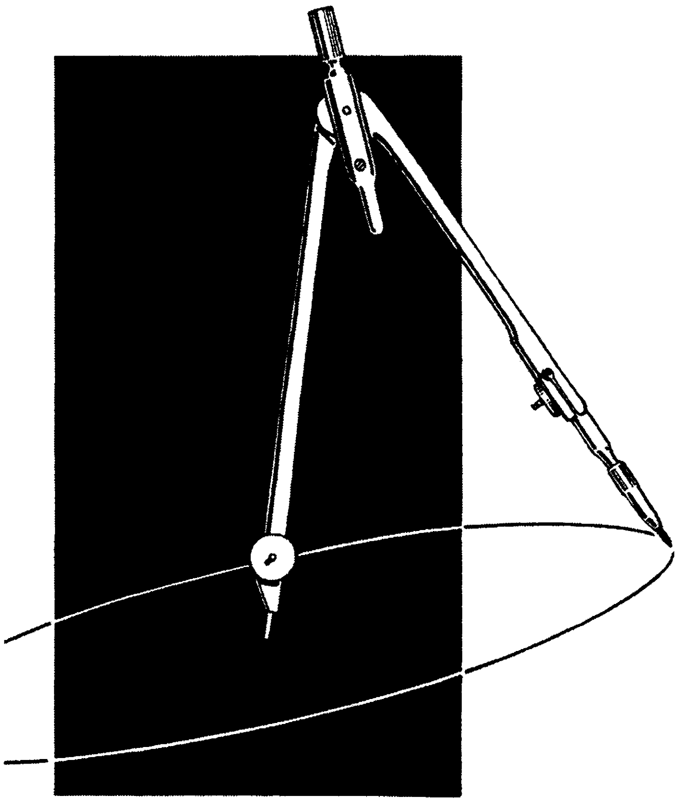
LESSON 24 DRAWING THE LEVER ESCAPEMENT

Sections 421 - 434

CHICAGO SCHOOL OF WATCHMAKING
Founded 1908 by Thomas B. Sweazey



SEC. 421—Purpose of Mechanical Drawing

It should be the aim of every watchmaker to acquire a theoretical as well as a practical knowledge of the craft. He should not be content with the simple fact that making a certain alteration will produce a definite result, but should learn through what mechanical laws that result was brought about. With this knowledge he proceeds logically with his work. He applies the correct methods to remedy the defect; thus he accomplishes it in the shortest time and in the most workmanlike manner. Without this knowledge he works on the "cut and try" plan, and while he may eventually succeed in remedying the defect, it is often at the cost of valuable time wasted in futile attempts before success is achieved. This is particularly true of the lever escapement.

The ability to make and read drawings aids greatly in developing inventive and constructive powers, and when applied to the study of the mechanism of the watch, helps the student in mastering the principles of the various actions of trains and escapements. In preparation of these lessons, it has been assumed that the student has a knowledge of elementary mathematics and that he has some understanding of mechanics as applied to watches and clocks. No attempt has been made to give a treatise on drafting. Only such elementary principles of mechanical drawing are included as will enable one to work out the various projects which the author feels will prove most beneficial. If the student has had training in mechanical drawing, the projects to be studied offer few dificulties, but for those who have not had the benefit of such training, it is necessary to give a brief description of the instruments and methods used in making various plane figures before assembling them into the completed drawings. Study diligently the lessons that follow and make all the drawings in the order in which they are given. Only such problems are given as are needed in the lessons to follow and if these are mastered thoroughly, very little dificulty will be encountered in completing the advanced work.

The purpose of this lesson is to give such instruction as will enable a student, though he may not be a draftsman, to make these drawings.

SEC. 422—Drawing Instruments Required

The drawing instruments necessary for a beginner are:

1 Drawing Board or Drafting Machine with Metric Scales

1 T Square 1 45° Triangle 1 30° Triangle	These articles are not required if drafting machine is used.

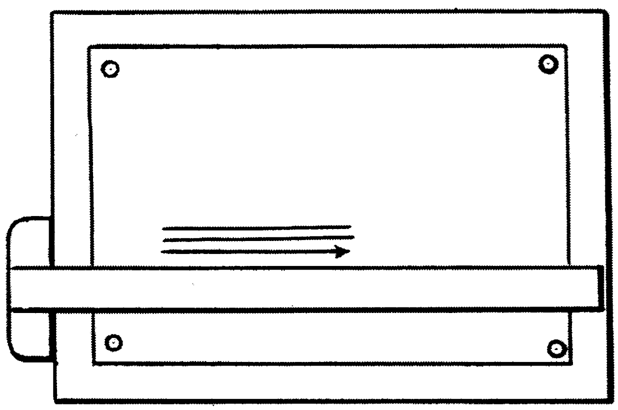
1 Metric Scale
1 Pair 6-inch Compasses with Pencil and Attachments
1 4½-inch Ruling Pen
1 Bottle Waterproof Drawing Ink
2 Hard Drawing Pencils (2H-4H)
1 Rubber Eraser
1 Art Gum Eraser
Drawing Paper
Drafting Tape (or Thumb Tacks)
1 Protractor

Sharpen pencils to fine point. In sharpening, use pencil sharpener or knife and shape lead on sand paper. KEEP YOUR PENCILS SHARP.

SEC. 423—Using the Drawing Board

A right-handed person uses the T square with the head of the T square against the left end of the board, figure 24-1. Let the pencil slant in the direction in which you are moving the hand and apply only enough pressure to make a distinct line. Draw lines as lightly as possible. The head of the T square is held against the left hand edge of the drawing board, moving parallel. In drawing horizontal lines, the upper edge of the T square is used as a straight edge. Vertical lines are drawn by means of a triangle resting against the T square, **A,** figure 24-2. **B,** figure 24-2, illustrates the method used to obtain a line making a given angle with the horizontal.

Fig. 24-1



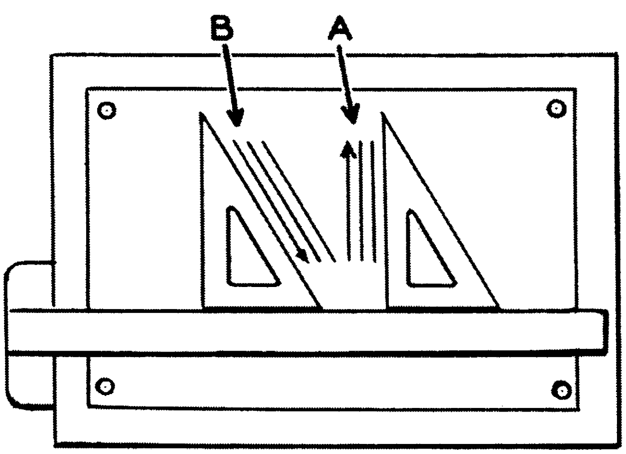
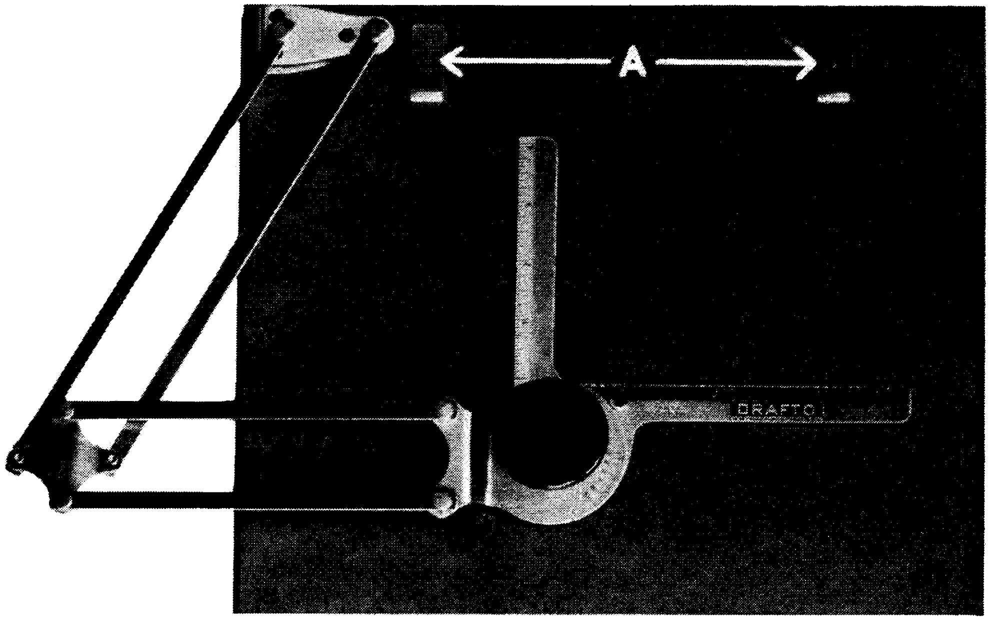


Fig. 24-2

Fig. 24-3



SEC. 424—Using the Portable Drawing Machine

The Portable Drawing Machine, figure 24-3, operates smoothly and easily and eliminates the use of triangles, thumb tacks and T square. The paper clamps, **A**, figure 24-3, hold securely one or more sheets of drawing paper. They are tightened underneath the board and do not interfere with the movement of the scales.

For our use the detachable metric scales with millimeters on one edge and half millimeters on the other are attached as in figure 24-4. The two fingers of the attaching clip are slipped over the ruling side of the integral scale. Then by pressing the two scales firmly together the detachable scale is locked rigidly and in accurate alignment. The detachable scale can be easily removed by applying slight pressure against the spring lock of the attaching clip. There are two clips on each scale permitting either edge to be used on the ruling side.

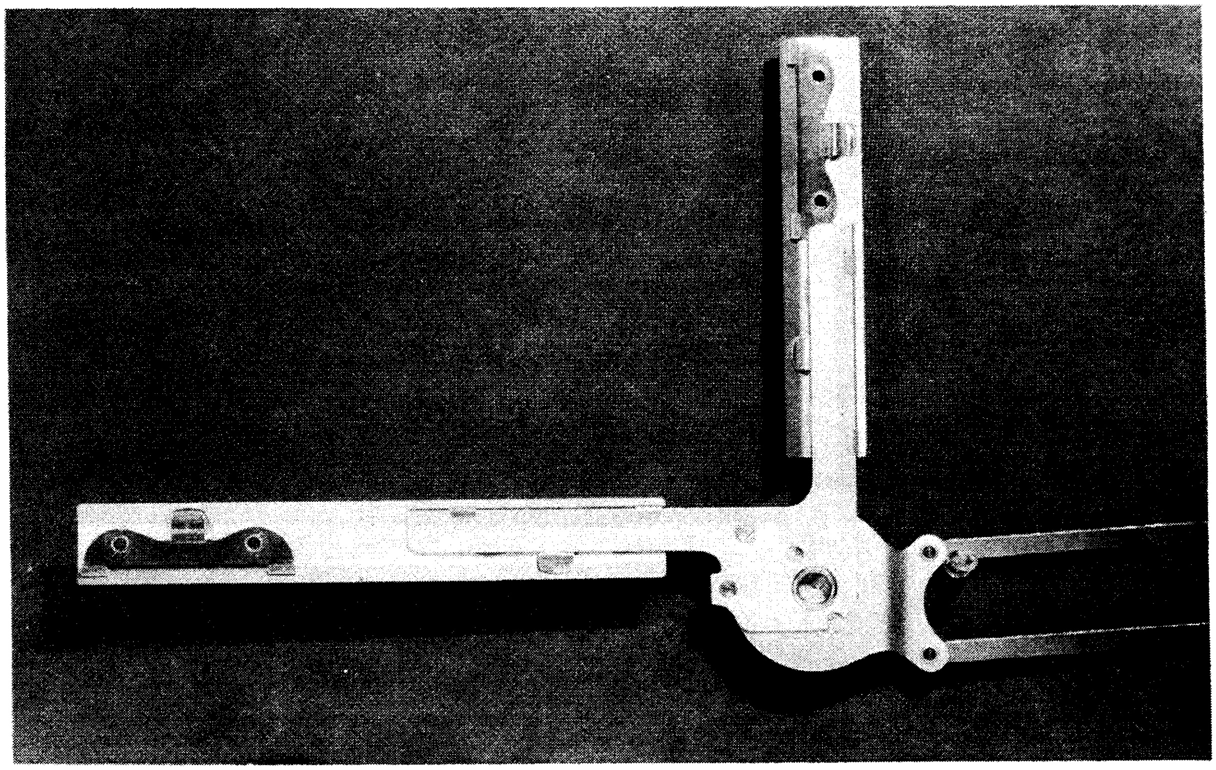


Fig. 24-4

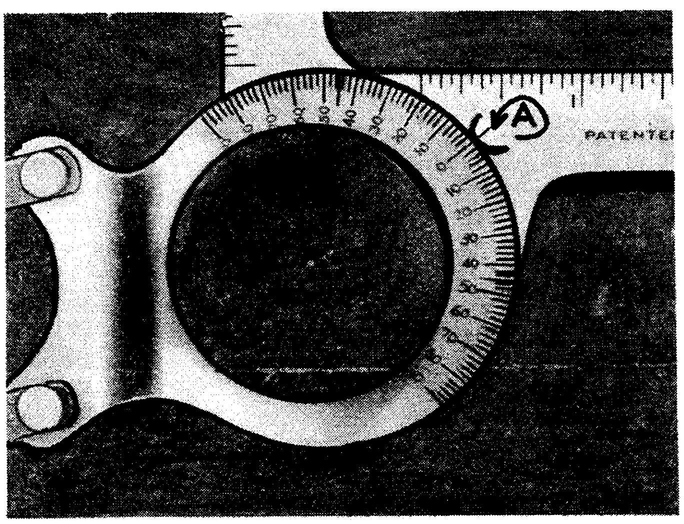


Fig. 24-5

The protractor feature, figure 24-5, is graduated to 2 degrees. To draw a horizontal line, the index on the scale **A,** figure 24-5, is set at zero. The vertical scale is used to draw vertical lines and these lines are always perpendicular to the horizontal scale.

Example: Set index **A** at **0** and draw horizontal line **AB,** figure 24-6. From point **A,** draw vertical line **AC,** using the vertical scale. Now move horizontal scale up until the index line is opposite the 30 degree marker and draw line **AD** from **A** - the angle **DAB** is an angle of 30 degrees. Using the vertical scale, draw line **AE** from **E** and the angle **EAC** is an angle of 30 degrees. When an angle of odd degrees is desired as 15 degrees, the index will have to be set midway between 14 and 16 as each graduation represents 2 degrees.

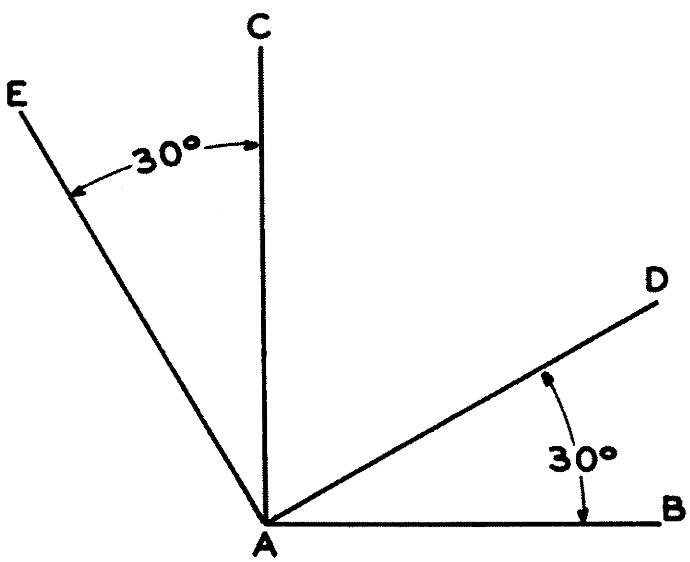


Fig. 24-6

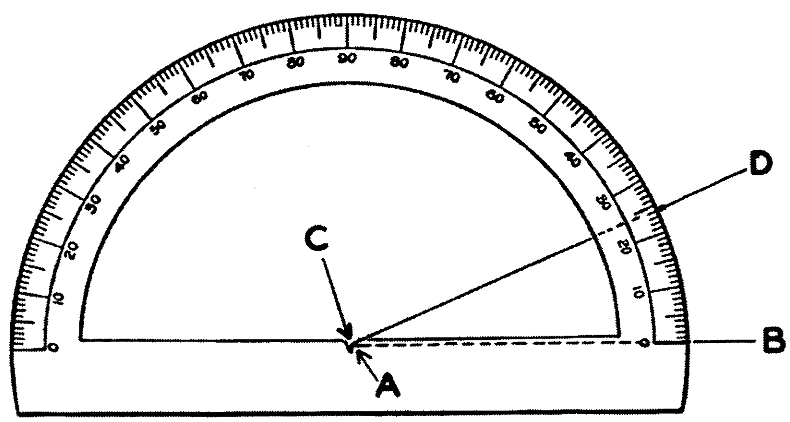


Fig. 24-7

SEC. 425—The Protractor

Figure 24-7 illustrates a protractor used for measuring and laying out angles as follows:

Problem: With **A** as center, draw an angle of 24 degrees above line **AB.** Place the center of protractor **C,** figure 24-7, directly over point **A** and the zero on the right side of protractor directly over the line **AB.** With a sharp pointed pencil, mark a dot at the 24 degree mark on the protractor scale and draw line **AD.** The angle **DAB** is an angle of 24 degrees.

SEC. 426—Geometrical Constructions

Our first drawing will consist of a series of geometrical constructions as illustrated in figures 1 through 17 of Plate 24-8.

First draw in "trim lines". These lines are drawn inside the thumb tack holes of drafting tape, and after the drawing is completed these lines are cut away. For our purpose, the horizontal trim line will be 225mm and the vertical trim line 290mm. Inside of the trim lines draw the border lines; the horizontal border line to be 215mm and the vertical border line to be 280 mm. It is not necessary to ink in the trim line. Divide the drawing paper into 3 equal vertical columns, draw and letter each figure as close as possible to the illustrations in Plate 24-8.

PLATE 24-8

Fig. 1. A **point** is that which has position but no magnitude. It is represented by a dot.

Fig. 2. A **line** is that which has but one dimension - namely length.

Fig. 3. A **straight** or **right line** has the same direction throughout its length.

Fig. 4. A **curved line** or **curve** changes its direction at each succeeding point.

Fig. 5. A **vertical line** is perfectly erect—namely is parallel with a plumb line.

Fig. 6. A **horizontal line** is one that is level throughout its length.

Fig. 7. Parallel lines are those lines which lie in the same plane.

Fig. 8. A **perpendicular** is a straight line so meeting another that the two adjacent angles formed are equal. Each of these angles is called a right angle.

Fig. 9. A **right angle** is composed of 90 equal parts called degrees.

Fig. 10. A **circle** is a plane figure bounded by a curve, all points of which are equi-distant from the center of the circle.

Fig. 10. The boundary of a circle is called the **circumference.**

Fig. 11. Any part of the circumference is called an **arc.**

Fig. 11. Any Chord passing through the center is a **diameter.**

Fig. 11. Any straight line from the center to the circumference is called a **radius.**

Fig. 12. Any straight line having its ends in the circumference is called a **chord.**

Fig. 12. Any straight line which touches a circle at but one point is a **tangent** to the circle and it is always perpendicular to a radius drawn to that point.

A **plane** or **plane surface** is one in which the straight line connecting any two points will lie wholly within the surface. Example: The surface of a drawing board.

Fig. 13. When any two straight lines meet at a point the figure so formed is called an **angle.** The two lines are called the **sides** of the **angle.** The point of meeting of the sides is called the **vertex** of the **angle.** The **size** of the **angle** is the amount of its opening and doesn't depend on length of its sides.

Fig. 14. If the opening between the sides is greater than a right angle, the angle is an **obtuse angle.**

Fig. 15. If the opening is less than a right angle, the angle is an **acute angle.**

Fig. 16. In figure 16 is shown an **angle,** the two lines **BA** and **BC** being the sides and the point **B** the **vertex. Angles** in drawings are designated by three letters, the center letter indicating the vertex of the angle. Figure 16 would be described as the **angle ABC.**

If the circumference of a circle is divided into 360 equal parts, each one of these parts is called a **degree.** In other words, a degree is 1/360th of the circumference of a circle regardless of the diameter of that circle. For instance, a degree on the rim of a balance wheel from a man's size watch would be a very small amount if measured in inches, not to exceed 1/200th of an inch, being but 1/360th of the circumference of that wheel. If we were to take a degree on the rim of an automobile wheel, it would be larger, measured in inches rather than in hundredths of an inch. If we go still further and speak of a degree upon the circumference of the earth at the equator, it would measure about 69 miles. Hence a degree is not a **linear** measurement but an **angular** measurement, and while the angle as shown in the circle, figure 17, is 40 degrees, it would remain 40 degrees regardless of how far the lines **AG** and **BG** might be extended from the Center **G,** and also regardless of the size of any circle that might be described from the Center **G.** If we were to draw a circle as shown at **E** and another one at **C,** figure 17, using **G** as a center, the actual distance between the lines on these two arcs would vary greatly, but the angular measurements of **CGD** and **EGF** would still be the same, 40 degrees. Therefore, the size of the angle is the amount of its opening and does not depend upon the length of its sides.

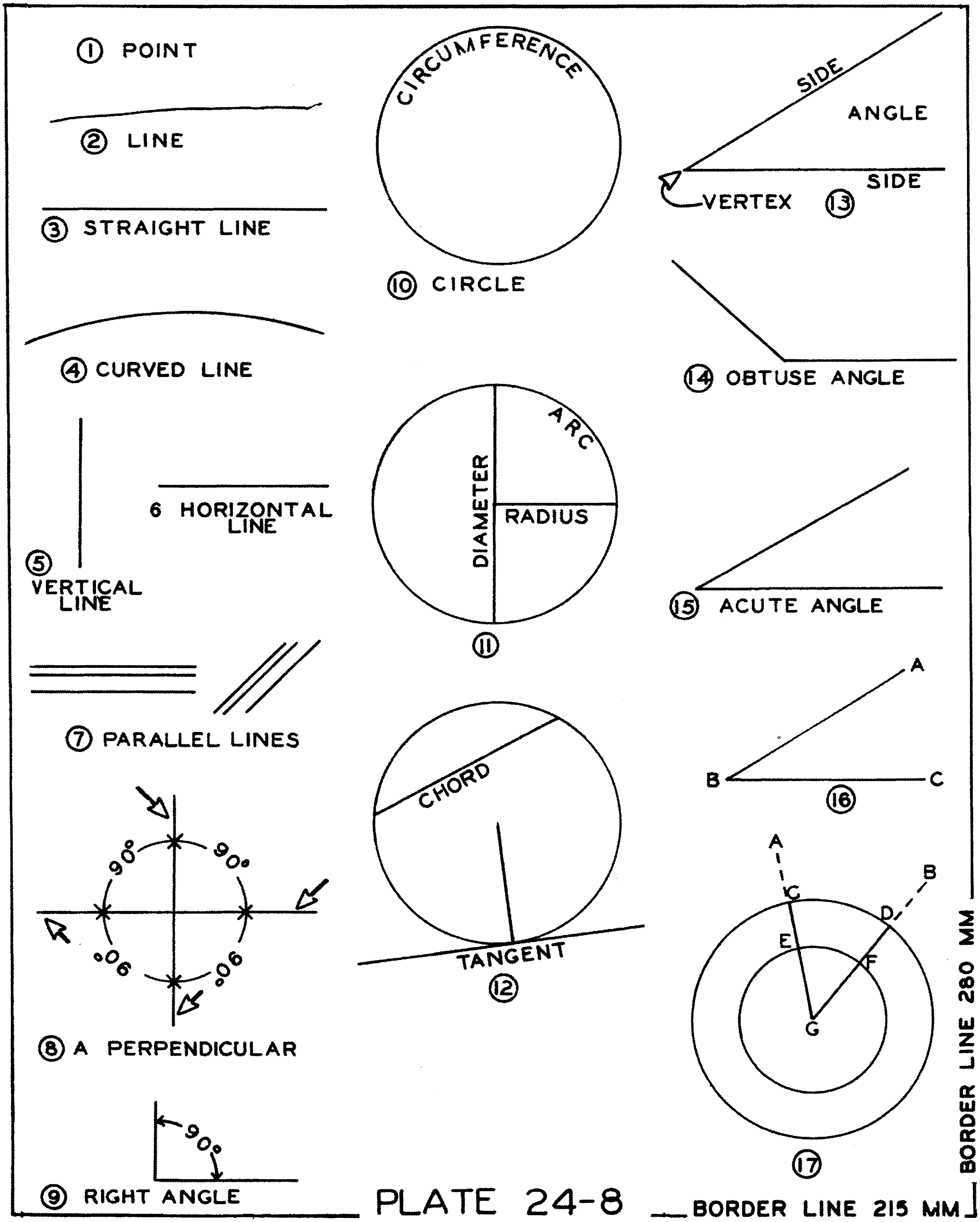

① POINT
② LINE
③ STRAIGHT LINE
④ CURVED LINE
⑤ VERTICAL LINE
6 HORIZONTAL LINE
⑦ PARALLEL LINES
90°
90°
90°
90°
⑧ A PERPENDICULAR
90°
⑨ RIGHT ANGLE
CIRCUMFERENCE
⑩ CIRCLE
ARC
DIAMETER
RADIUS
⑪
CHORD
TANGENT
⑫
SIDE
ANGLE
SIDE
VERTEX
⑬
⑭ OBTUSE ANGLE
⑮ ACUTE ANGLE
A
B
C
⑯
A
B
C
D
E
F
G
⑰
BORDER LINE 280 MM
BORDER LINE 215 MM

PLATE 24-8

ABCDEFGHIJKLMNOPQRSTUVWXYZ 1234567890

Fig. 24-9

SEC. 427—Lettering Your Drawing

In lettering your drawing, always draw horizontal and vertical guide lines as shown in figure 24-9 and sketch the letters or figures in pencil. In this way, any errors may be corrected before inking which is best done with a lettering pen and a good black drawing ink.

When you have completed the pencil drawings and lettering, proceed to ink the plate as follows:

1. Ink main center lines.
2. Ink small circles and arcs.
3. Ink large circles and arcs.
4. Ink irregular curves.
5. Ink horizontal lines.
6. Ink vertical lines.
7. Ink inclined lines.
8. Ink dotted lines.
9. Ink extension and dimension lines.
10. Ink arrow heads.
11. Letter.
12. Ink border lines.
13. Check drawing.
14. Clean with art gum and cut away trim lines.

SEC. 428—Drawing to Scale

PLATE 24-9

If you wish to show the purpose or function of certain mechanical actions, it should be possible to convey your ideas by means of free hand drawings, but if the different parts of such a drawing are to be of proper proportions and the work accurate, it is necessary to use drawing instruments and make the drawings **to scale.**

In making our drawing to scale, the actual measurements of our object can be increased or decreased in any proportion. Most of our drawings will be increased proportion because of the minuteness of the parts with which we work. This will enable the student to see clearly the proper shapes or mechanical principles involved in any part or combination of parts he desires.

Example: If we have a part such as a balance staff and we desire to draw it proportionately larger, it is necessary to predetermine the ratio. **Example:** Let 20mm. equal 1mm. Then if our staff measures 5:50mm, we would increase it twenty times and the length of the staff in our drawing would be 110mm, figure 18, Plate 24-9.

All of the figures referred to in the following text are contained in Plate 24-9.

Fig. 18 is a drawing of a balance staff which will be drawn to the scale of 1mm equals 20mm. All the necessary dimensions are given in millimeters. Keep your drawing in the upper left hand corner and inside the trim lines.

The following problems in Geometrical Constructions are essential because of their particular bearing on the work to follow. Solve these problems with great care and keep your drawings neat and accurate.

Fig. 19. To erect a perpendicular to a given line from a point on the line. Given point **A** on line **BC.** With **A** as a center and any convenient radius, describe arcs intersecting the line **BC** at points **1** and **2.** With points **1** and **2** as centers, and with a radius greater than half the distance between points **1** and **2,** describe arcs which intersect at **3.** Draw line **3-A,** which is the required perpendicular.

Fig. 20. To erect a perpendicular to a given line from a point outside the line. Given point **A** and line **BC.** With **A** as a center and any radius intersect the given line at points **1** and **2.** With points **1** and **2** as centers and any radius, describe arcs intersecting at **3.** Join **A** and **3. A-4** is the required perpendicular.

Fig. 21. To erect a perpendicular at the end of a given line. Given line **AB.** With **B** as a center and any radius describe an arc of a circle **1-2-3.** With **1** as a center and the same radius, cut the arc at **2.** With **2** as a center and the same radius, cut the same arc at **3.** With the same radius and with points **2** and **3** as centers, describe arcs which intersect at **4.** Draw **4B** the required perpendicular.

Fig. 22. To bisect an angle. Given angle **CAB.** With **A** as a center and any convenient radius describe an arc intersecting **AC** at **1,** and **AB** at **2.** With **1** & **2** as centers and any radius describe arcs intersecting at point **3.** Draw **A3** the bisector of the given angle.

Fig. 23. To draw a tangent to a circle at a given point in the circumference. Draw radius **BA** and extend beyond circumference. Erect a perpendicular **3-4** to the radius through point **A.** This is the required tangent.

Fig. 24. To draw a line tangent to a given circle thru a given point outside the circle. Assume any point outside the circle, as **C.** Draw a line from the point **C** to the center of the circle as **CB.** Bisect this line at point **3,** illustrated by line **1-2.** With **3** as a center and radius equal to **3B,** draw arcs intersecting the circumference at points **4** & **5.** These are the points of tangency for lines drawn from point **C** through points **4** & **5.**

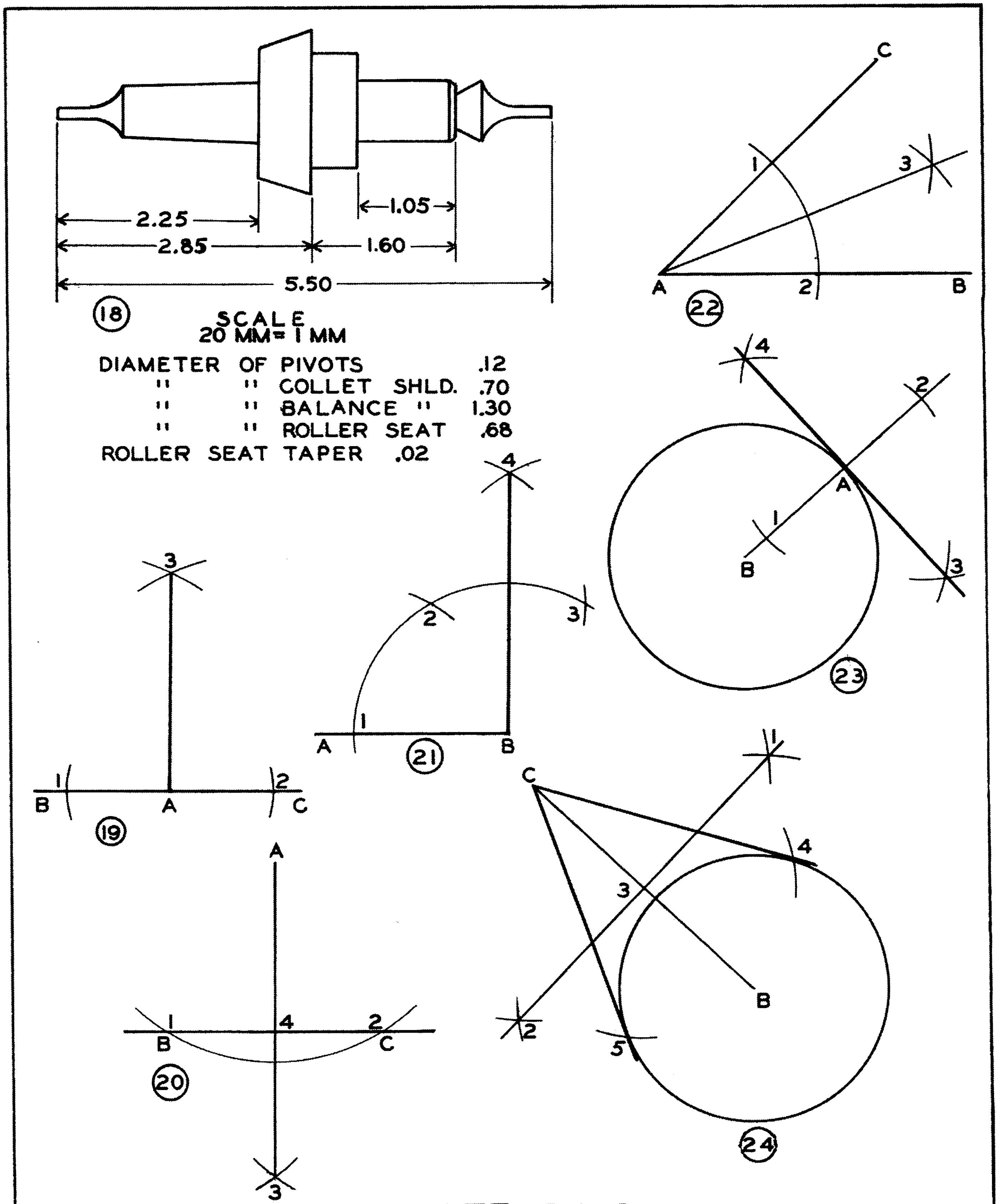

1.05
2.25
2.85
1.60
5.50
18
SCALE
20 MM= 1 MM
DIAMETER OF PIVOTS .12
" " COLLET SHLD. .70
" " BALANCE " 1.30
" " ROLLER SEAT .68
ROLLER SEAT TAPER .02
C
1
3
A
2
B
22
4
2
A
1
B
3
23
4
2
3
1
A
B
21
3
1
2
B
A
C
19
1
C
4
3
B
2
5
24
A
1
4
2
B
C
20
3

PLATE 24-9

SEC. 429—Working Lines

PLATE 24-10

Our next problem will be to draw an escape wheel containing 15 teeth. This type of escape wheel is used in most modern watches.

Many of the lines necessary in laying out an escapement are solely for the purpose of locating the several parts that constitute the finished drawing. They are called **working lines.**

In Plate 24-10 as in the preceding Plates, these lines are broken. This is done in order that they may be printed readily, but the student may use pencil lines, which he can erase when they have served their purpose. Such of these as he may desire to retain should be inked in red. The first step in drawing the escape wheel will be to draw in the border lines 280 mm and 215 mm respectively. Draw center line **AA** and divide it equally at **B.**

SEC. 430—Distance Between Escape and Pallet Center

The relative distances between the escape and the pallet centers and the pallets and balance centers may be taken at pleasure, provided it is within reasonable limits, say from escape center to pallet center, being anywhere between 30 per cent and 40 per cent of the entire distance between pallets and balance. These proportions are sometimes exceeded to accommodate other conditions, such as those existing in extra thin watches.

Decide upon the center distances between the escape and pallets and the pallets and balance. In the following instructions it will be understood that the measurements given are not from actual sizes.

Take 115 millimeters on the scale for the distance between the center of the escape wheel (point **B**) and the center of the pallets (point **C**) on center line **AA.**

SEC. 431—Relative Position of Parts

The escapement may be drawn with its parts in any relative position to each other that they assume during action. In this case, we will show them at the instant of locking on the receiving stone. In order to do this, we must find the exact point of contact of the locking corner of an escape tooth with the locking face of the receiving stone. Before we do this, however, it is well to decide what the circular impulse is to be and how it is to be proportioned between the wheel teeth and pallet stones.

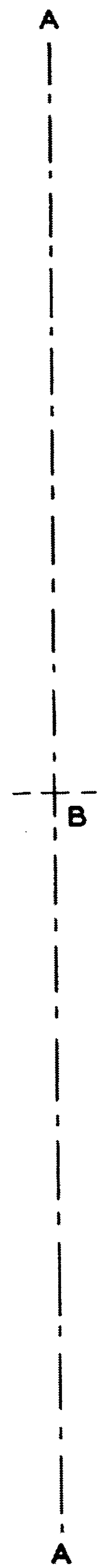
SEC. 432—Locating The Arc Of Impulse

The arc through which an escape tooth passes at each impulse is called the arc of impulse, and in an escape wheel of **15 teeth** is **12** degrees. The reason that it must be **12** degrees is that each tooth delivers two impulses —one to the receiving stone and one to the discharging stone—during each revolution of the escape wheel. There being 15 teeth in the escape wheel, we divide the entire circle (360 degrees) by twice that number, which gives us 12 degrees. This 12 degrees is not entirely taken up by impulse. A part of it is required for drop. In this case, we will give 1½ degrees for drop. The remaining 10½ degrees is what is termed active circular impulse and is divided between a pallet stone and an escape wheel tooth. We will divide this active circular impulse by giving 4½ degrees to the tooth and 6 degrees to the stone.

SEC. 433—Number of Degrees Between Escape Teeth

When the tooth of the escape wheel is locked on the receiving stone, two teeth stand between it and the locking face of the discharging stone. From the locking corner of a tooth to that of the next adjacent tooth is 24 degrees, which is divided into 2 equal impulses of 12 degrees each. From the locking corner of the tooth that is locked on the receiving stone to the locking corner of the second tooth in advance is, therefore, 48 degrees. The third tooth, which has just been released by the discharging stone, is just one impulse — 12 degrees — in advance, making an arc of 60 degrees in all between the locking corners of the pallet stones when measured from the escape wheel center. In an equi-distant locking escapement, the locking corners embrace angles of 30 degrees at each side of the line of centers, but in an equidistant center escapement these 30-degree angles of measurement pass through the centers of the stones, or, to be exact, midway between where the paths of the locking and releasing corners intersect like paths of the escape teeth. This being the case, lines drawn from the escape center 30 degrees each side of the line of centers will pass through the centers of the stones; for this is to be an equi-distant center escapement.

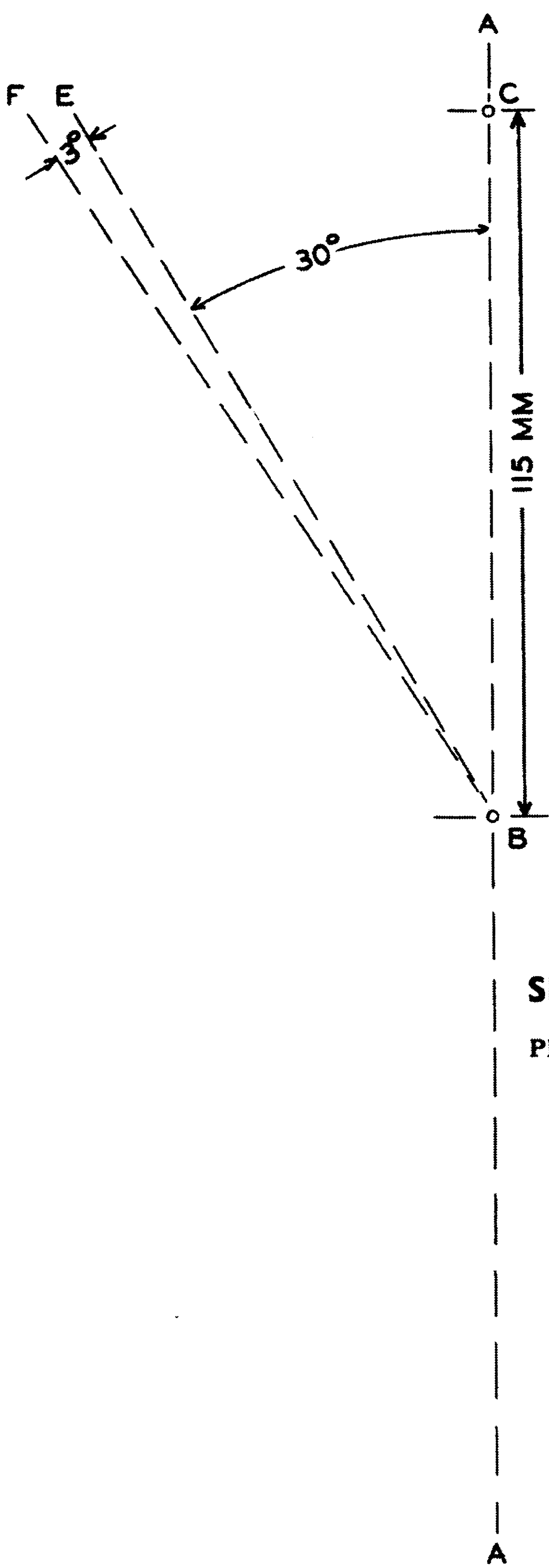
The foregoing has been gone into minutely in order that the student may understand clearly why we use 30 degrees from each side of the line of centers to determine the location of the pallet stones. It must be understood, however, that this only applies to pallets spanning 2½ teeth of a 15-tooth escape wheel.



BORDER LINE 280 MM

PLATE 24-10

BORDER LINE 215 MM



SEC. 434—Drawing an Escape Wheel

PLATE 24-11. From **B** draw line **E,** 30 degrees to the left of the line of centers. Inasmuch as this line runs through the center of the stone, and that the locking corner is half the angle—6 degrees—to the left of this point, draw a line, **F,** 3 degrees to the left of **E.**

PLATE 24-11

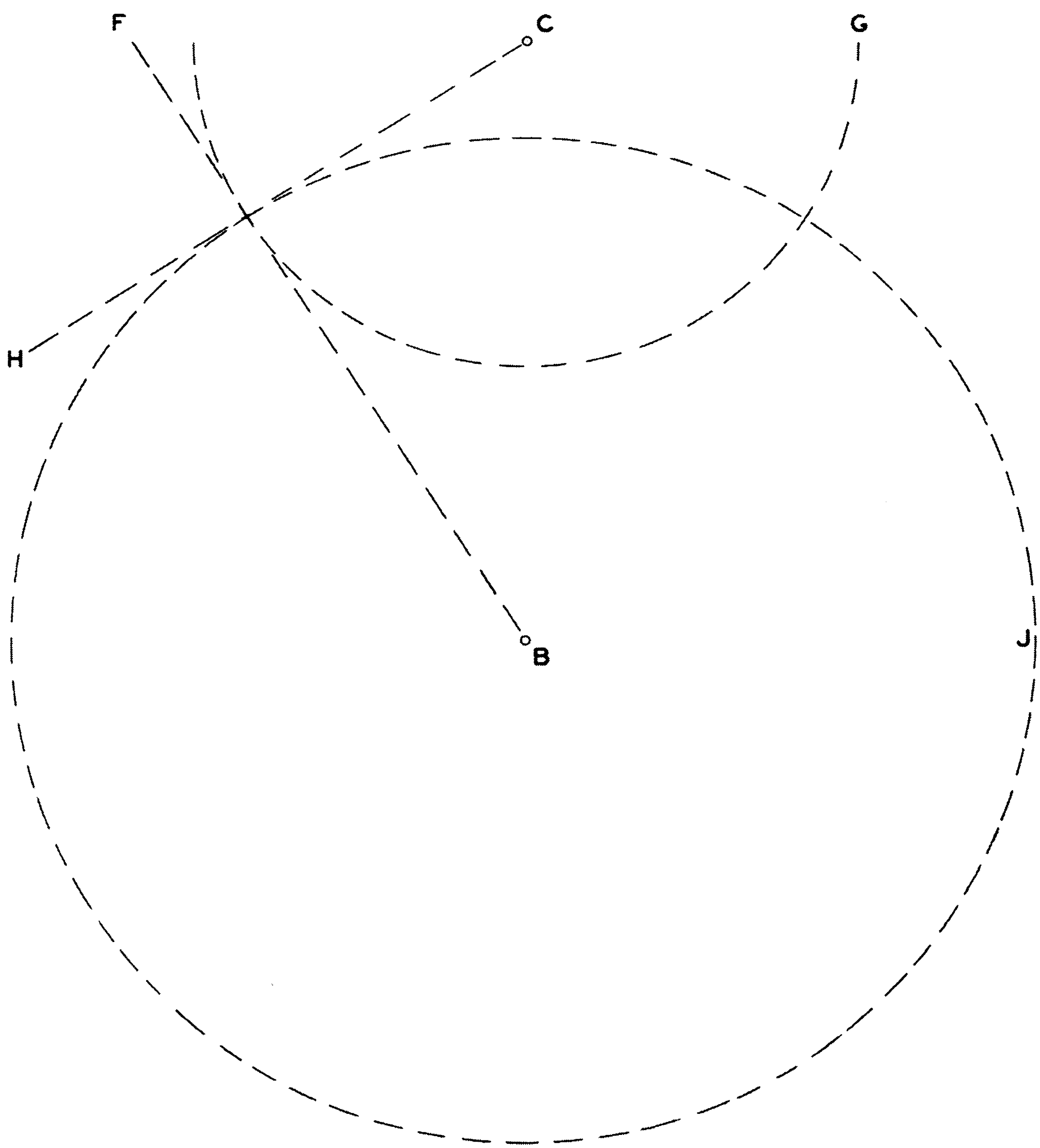


PLATE 24-12. The circular path of the receiving stone locking is tangent to this line. From **C** as a center draw an arc **G** tangent to line **FB.** At the intersection of arc **G** and line **F** from **C** draw line **H.** This line will form a right angle with line **F.**

With **B** as a center describe the circle **J** thru the intersection of lines **H** and **F.** This circle is called the primitive diameter of the escape wheel, and would be its diameter if the wheel were trimmed down to the locking corners.

PLATE 24-12

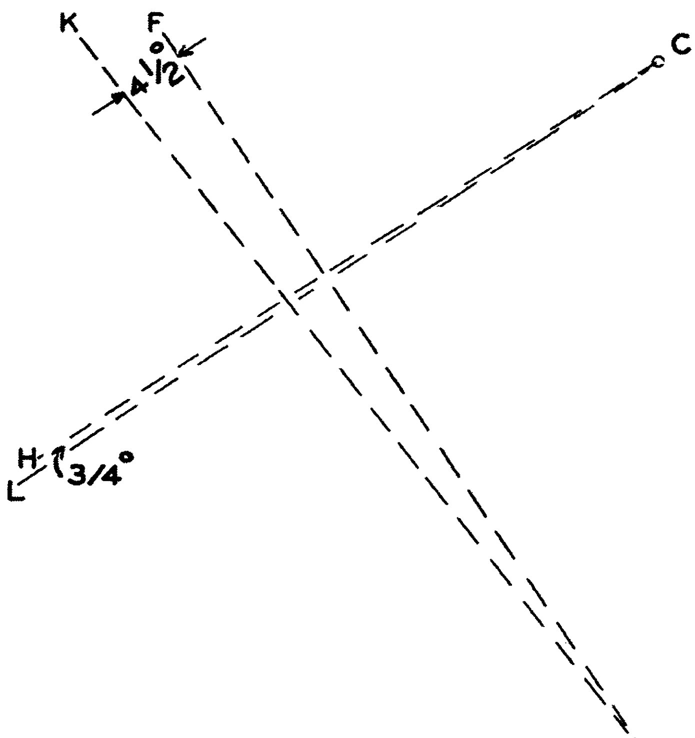


PLATE 24-13. The circular impulse, or rather that portion of it assigned to the wheel tooth, being 4½ degrees measured from the center **B**, draw line **K** that amount to the left of **F**. Upon this line will fall the releasing corner of the tooth. We will now decide upon the amount of lock, which should be as light as possible, consistent with safety, say ¾ degree. From **C** draw line **L**, ¾ degrees below **H**. Where this line intersects line **F** will mark the locking corner of the pallet stone.

PLATE 24-14. We may now decide upon the arc of vibration of the fork and pallets. Let it be 10 degrees. Of this, ¾ degree will be for slide, ¾ degree for lock, leaving 8½ for active impulse—sometimes called lift. This amount should be divided between the tooth and stone in about the same proportion as the circular impulses bear each other. We will give 5 degrees to the stone, 3½ degrees to the tooth. From **C**, 5 degrees below **L**, draw line **M** and from the same center, 3½ degrees above line **H**, draw line **N**. From **B**, draw line **O**, 6 degrees to the right of line **F** (or 3° from **E**.)

From **B** as a center, through the intersection of lines **N** and **G**, draw circle **P**. This circle will embrace the diameter of the escape wheel over points.

From **C** as a center through the intersection of circle **P** with line **O**, draw arc **Q**. This will be the path of the releasing corner of the stone.

The student cannot be too strongly urged to make himself familiar with the principles involved in locating these few lines, for they embody the fundamental principle of the lever escapement.

At this point it may be well to give a simple way whereby the true diameter of an escape wheel may be found. In spanning an escape wheel with a micrometer gauge we do not get its true measurement for the reason that the gauge must necessarily bridge two teeth, which leaves us short of its true measurement by the height of the arc between these teeth. The process of measuring this accurately is somewhat complicated but can be closely approximated by simple addition. To illustrate: Let us assume that the apparent diameter of the wheel is 7.55 mm. Write it this way and add:

$$\begin{array}{r} 7.55 \\ .0755 \\ .00755 \\ \hline 7.63305 \end{array}$$

Then 7 63 mm is the true diameter of the escape wheel.

PLATE 24-13

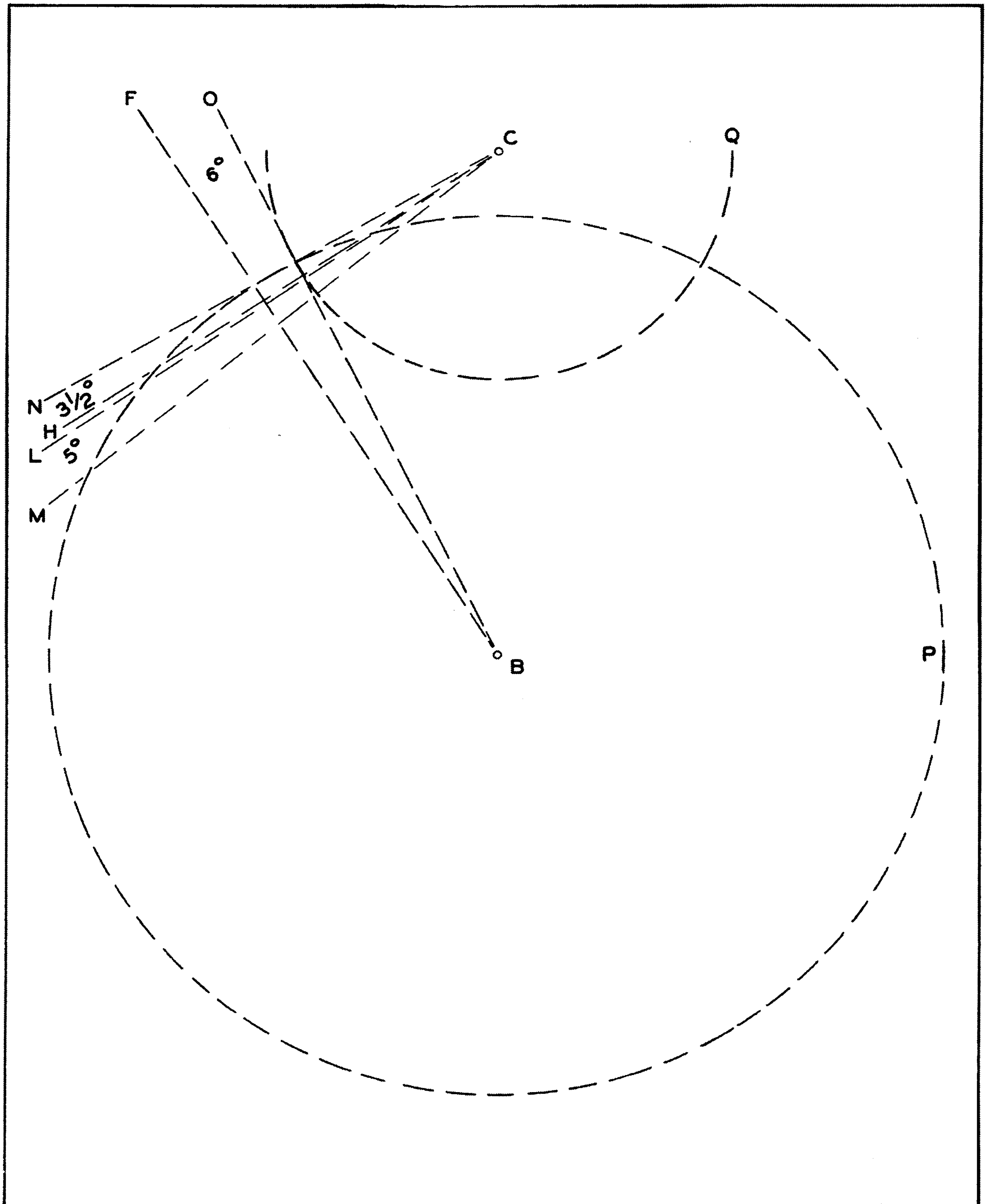


PLATE 24-14

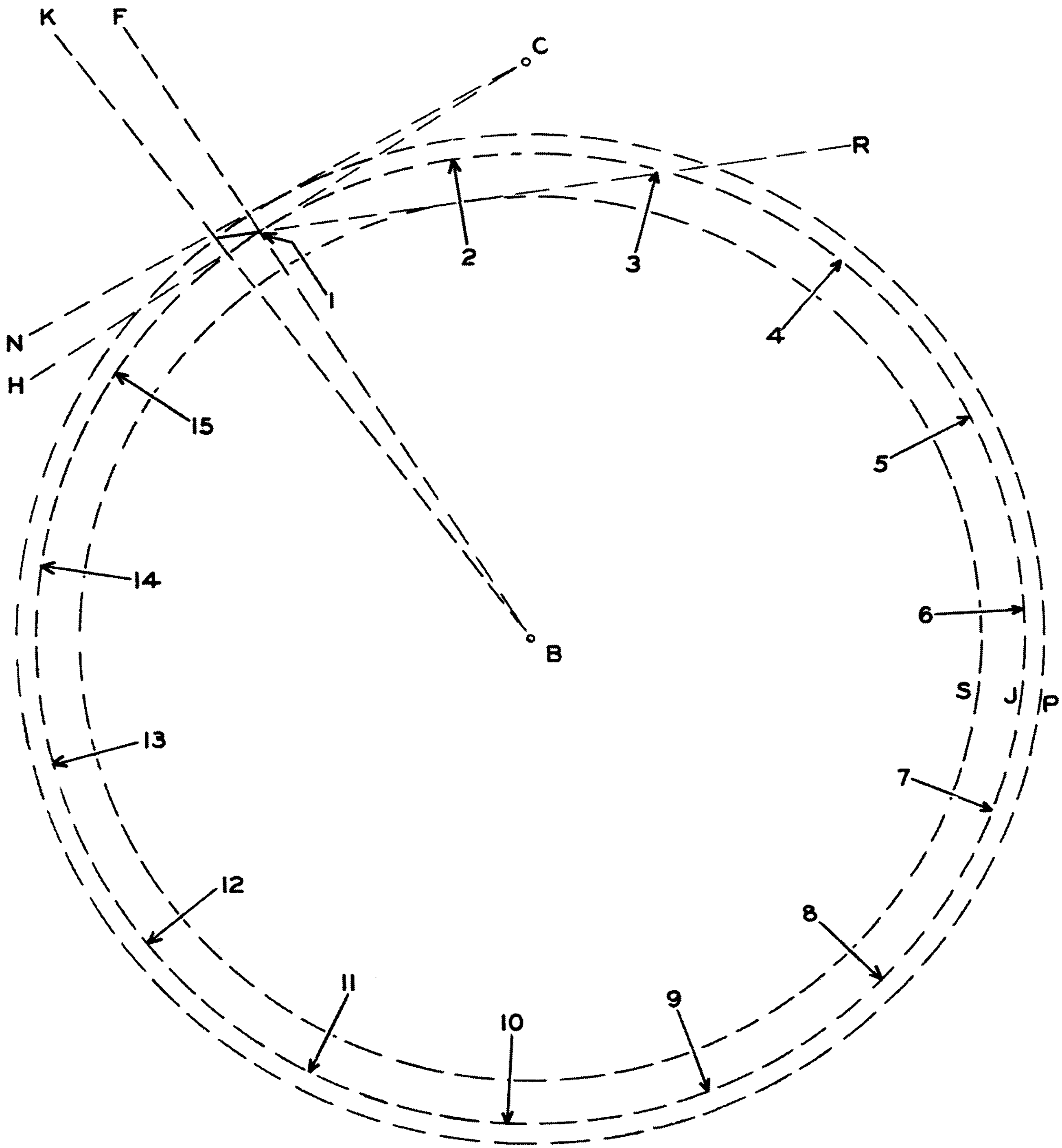


PLATE 24-15. The impulse face of a tooth is formed by drawing a full line from the intersection of lines **P** and **K** to the intersection of lines **H** and **F.** Extend this line to the right to **R.** Its use is to aid in drawing the impulse faces of the other teeth. From the locking corner of the impulse face just drawn in, mark off circle **J** into **15** equal spaces, **1, 2, 3, etc.** These will be the locking corners of the teeth.

To divide the circle **J** into 15 equal arcs from the intersection of line **F** with arc **J** with **B** as a center, mark point **2** 24 degrees below line **F.** With **B** as a center mark point **3** 24 degrees from point **2.** With **B** as a center mark point **4** 24 degrees from point **3** and so on until you have 15 equal arcs.

PLATE 24-15

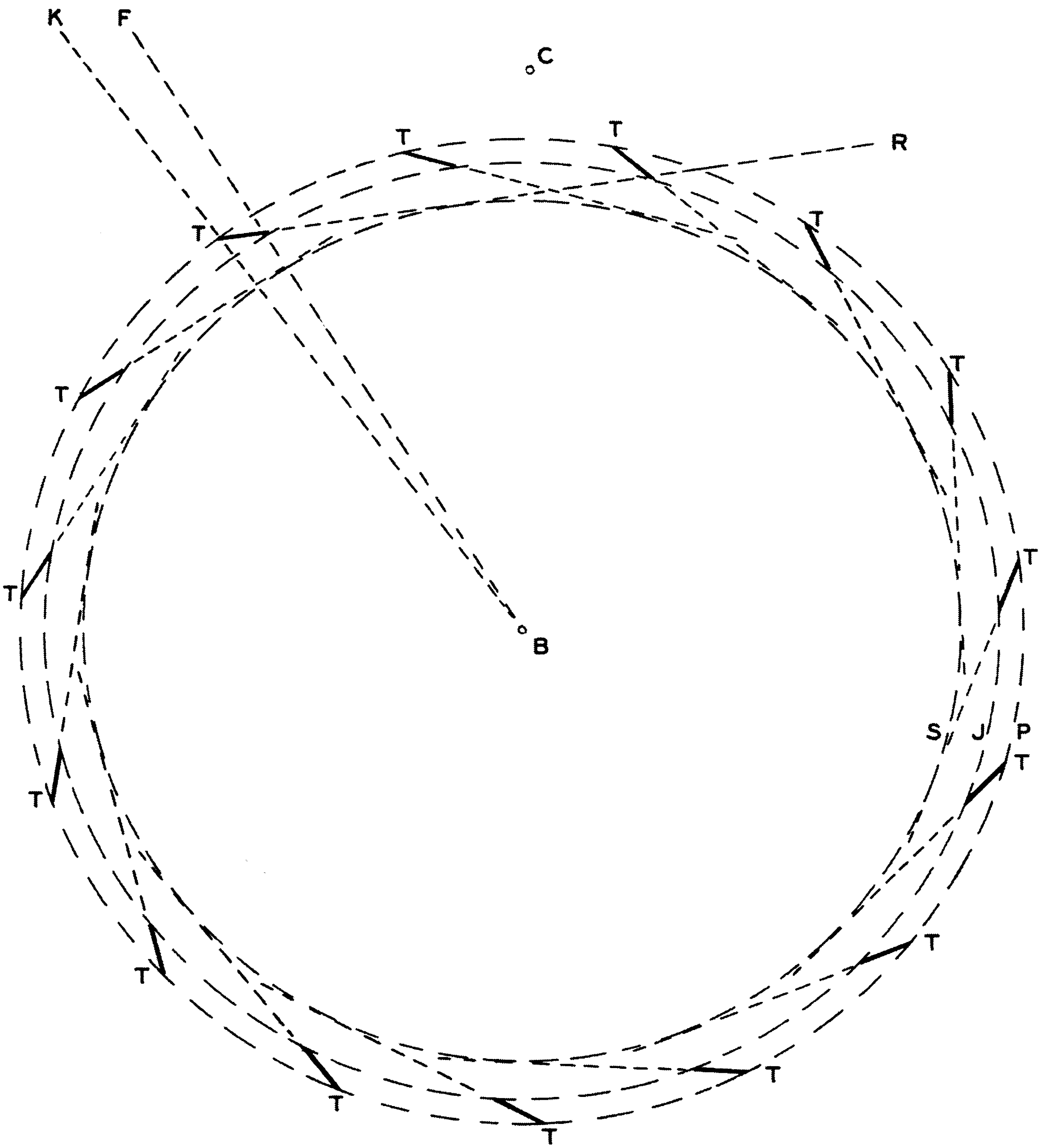


PLATE 24-16. From these points with dividers set to the length of the impulse face already drawn in, mark points **T, T, T,** etc., on circle **P.**
These points will embrace the length of the impulse for the other teeth, being guided by the tangential circle **S.**

PLATE 24-16

PLATE 24-17. We will now draw the hub, arms and rim of the escape wheel.

The dimensions of these are more or less a matter of taste.

Taking the full radius of the wheel (approx. 100 mm) as a basis, we will draw in the wheel to certain proportions, as follows:

For the hub 20%
For the inside rim 73%
For the outside rim 80%
For the thickness of the arms 8%

Setting the compass at **20 mm**, draw a circle for the wheel hub from center **B.**

Setting the compass at **73 mm,** draw a circle for the inside of the rim.

Setting the compass at **80 mm,** draw a circle for the outside of the wheel rim.

Setting the compass at **4 mm,** draw a circle to be used as a guide in drawing the arms of the wheel. Draw two lines parallel to each other and tangent to this circle.

At right angles to these lines and tangent to the same circle, draw two more parallel lines.

These will form the arms of the escape wheel.

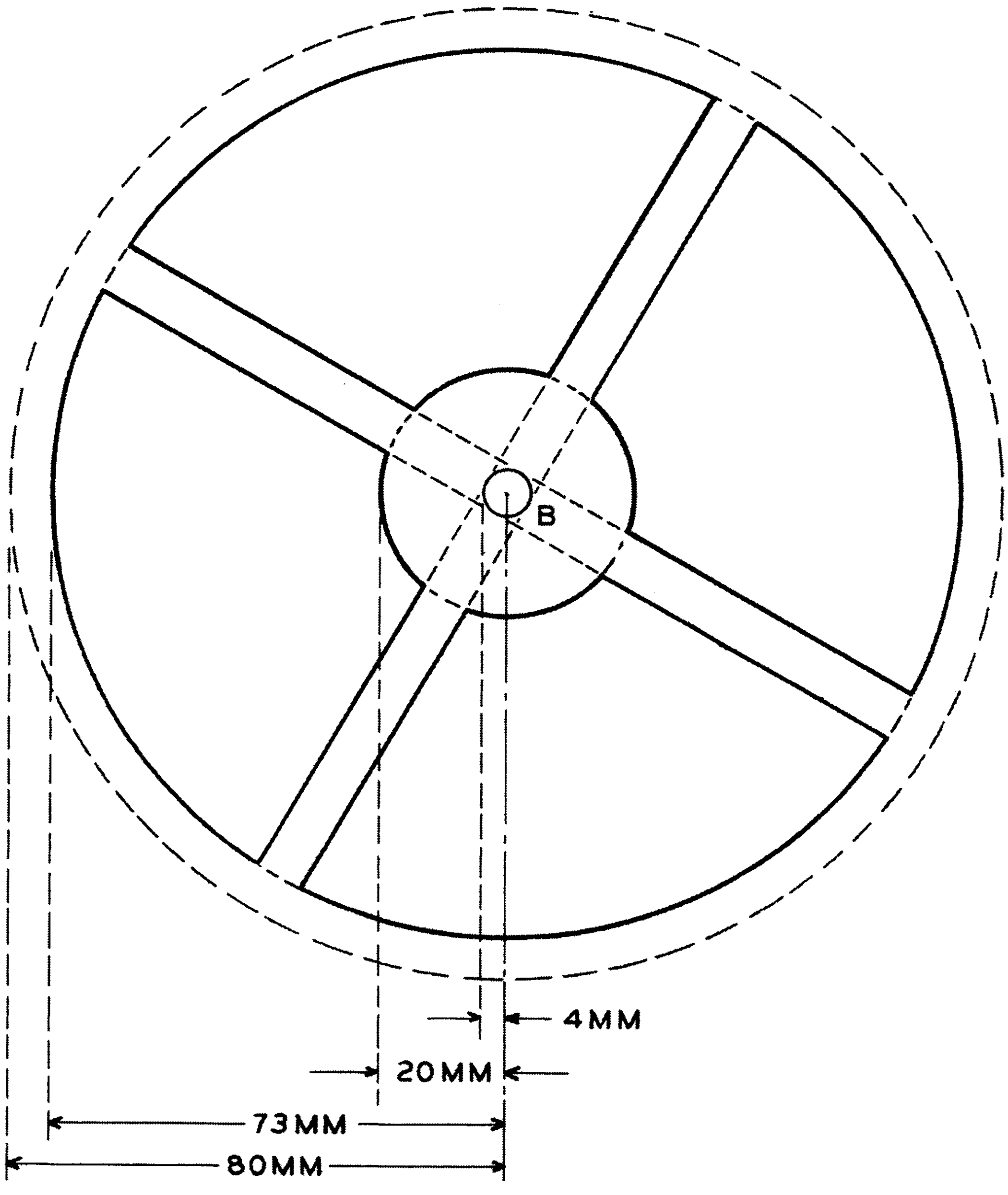


PLATE 24-17

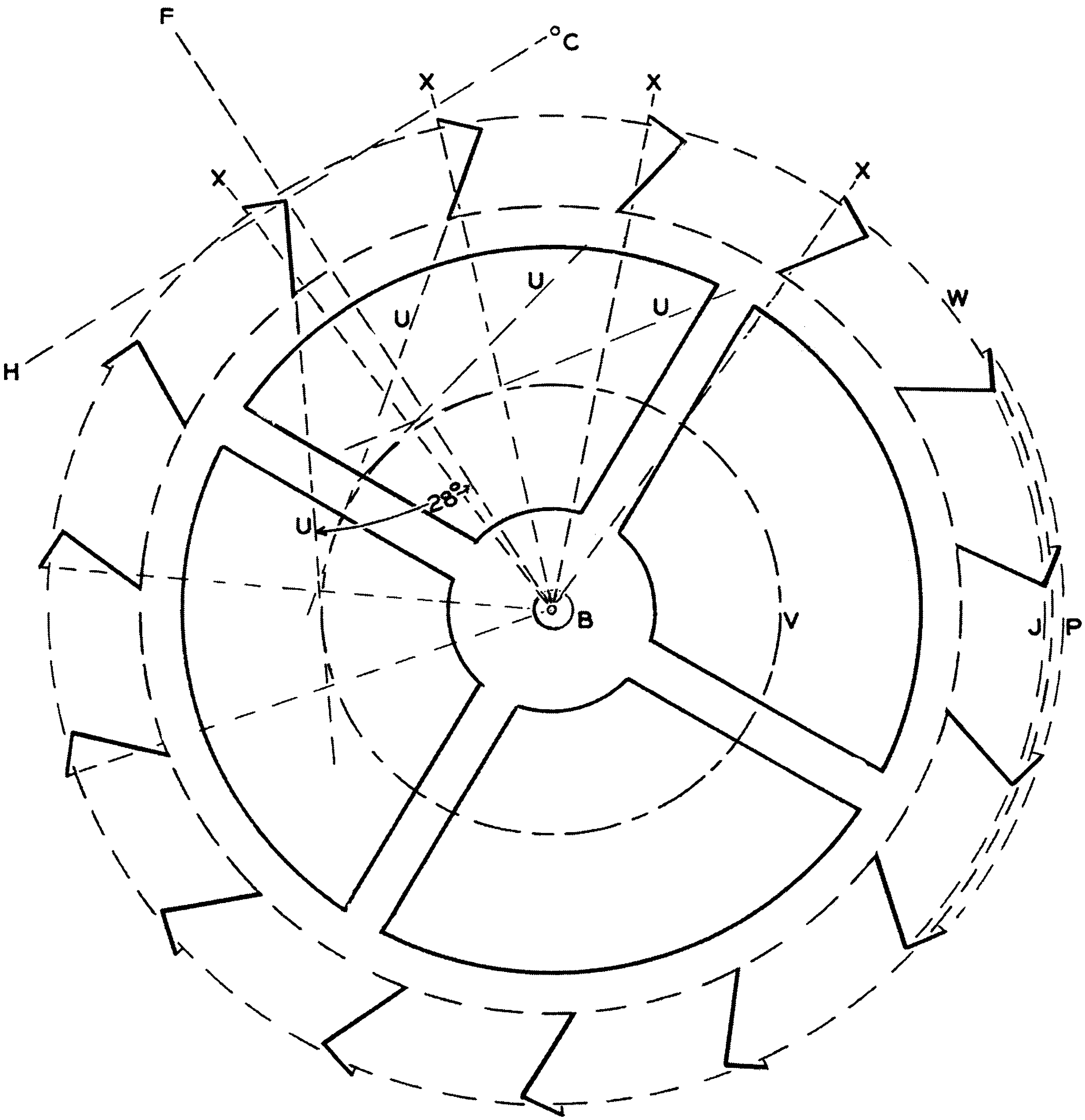


PLATE 24-18

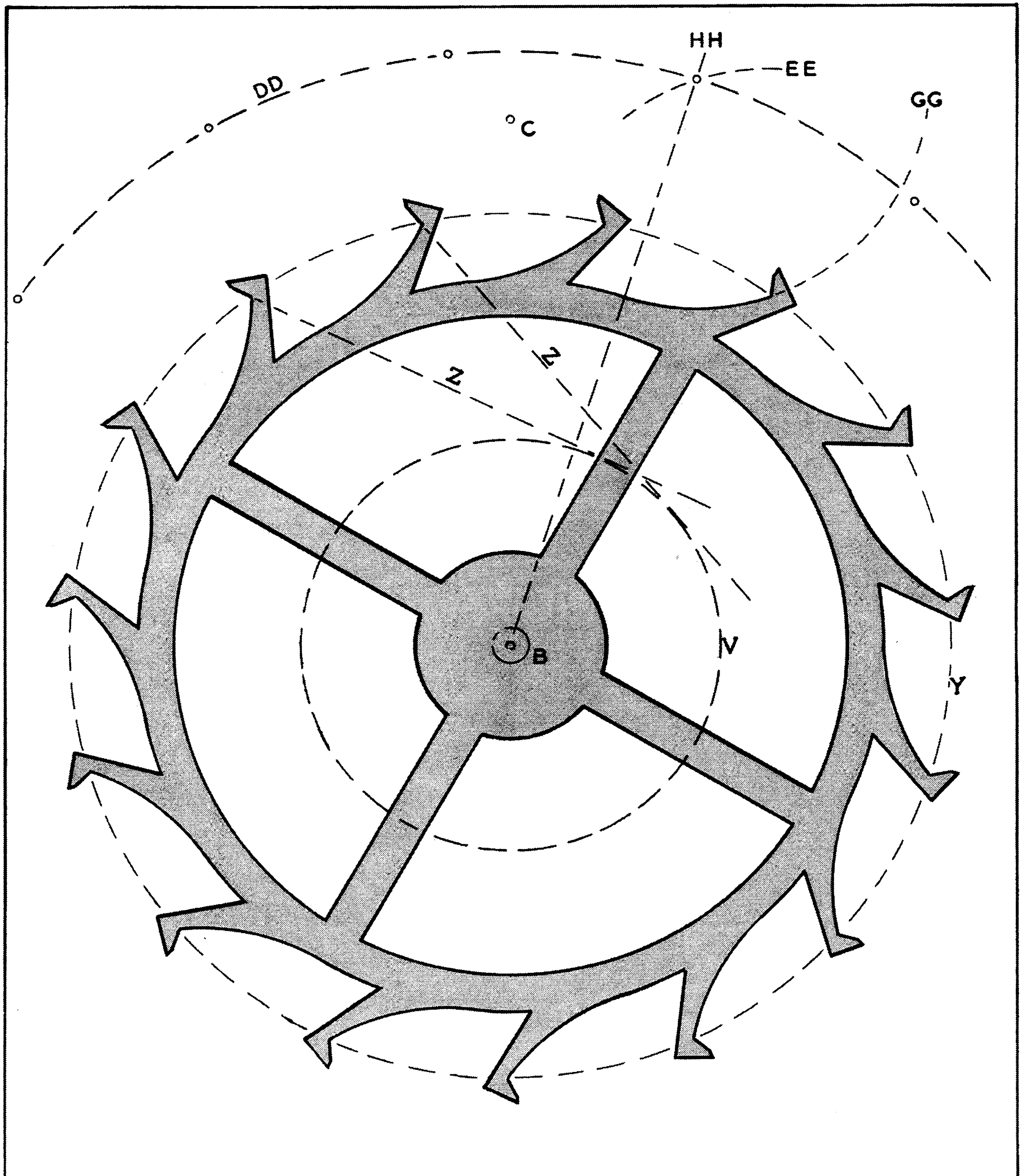


PLATE 24-19

PLATE 24-18. The angle at which the locking face of the tooth should be formed may now be determined. This angle is frequently placed at 24 degrees from a radial line to the center of the wheel but 28 degrees will be found better for the purpose, especially for an equi-distant center escapement. The reasons for this are that an unpoised fork requires increased draft for the pallet stones, and with this increased draft the locking face of the wheel tooth almost coincides with the locking face of the stone; furthermore, as the slide takes place on the discharging stone, the angle between the face decreases, with the result that when the oil becomes viscid, resistance is produced by adhesion.

On the receiving stone, the greater the slide the more the divergence, but on the discharging stone, the greater the slide the less the divergence.

With the intersection of the lines **HC** and **FB** as a center, draw line **U,** forming an angle of 28 degrees with **FB.**

This is the locking angle of the wheel tooth.

Draw circle **V** tangent to **U.** It will be a guide for forming the locking faces of the other teeth.

From the points marked **1, 2, 3,** etc. (Plate 24-15) draw lines tangent to circle **V.** These will be the locking faces of the teeth.

Draw circle **W** halfway between circles **J** and **P.**

From the points marked **T, T, T,** etc., (Plate 24-16) draw radial lines **X** to circle **W.** These form the toes of the teeth.

PLATE 24-19. From the points where these lines touch the circle **W,** draw lines in a direction that would make a tangent with circle **V,** as at **Z.** These form the under side of the club.

The next step is to form the backs of the teeth. In doing this, care should be taken that they are so shaped that when the train of the watch is reversed they will not contact the releasing corners of the pallet stones in such a manner as to wedge the guard pin against the roller.

Draw a circle **DD,** 1.3 the radius of the wheel, which will be approximately 130 mm.

Draw a circle 95% of the wheel radius, which will be 95 mm. (Circle **Y**).

With the dividers set at 50 mm, which is the difference between the radius of circle **DD** and the outside of the wheel rim, draw arc **EE** from the intersection of circle **Y** and line **Z.**

Using the same radius from the intersection of arc **EE** and circle **DD,** draw an arc **GG** from intersection of circle **Y** and line **Z** tangent to the outside of the wheel rim.

The point of tangency is located at the intersection of a line drawn from **HH** to center **B.** Draw similar arcs for the other teeth from similar points on circle **DD.** These arcs will form the backs of the teeth.

This completes the directions for drawing the escape wheel which may now be inked in as shown. Clean with art gum and print in ink your name and student number in lower right hand corner.