CHAPTER V.

ARTICLE 74.

RULES AND CALCULATIONS.

THE fundamental principle, on which are founded all rules for calculating the motion produced by a combination of wheels, and for calculating the number of cogs to be put in them, to produce any motion that is required, has been given in Art. 20; and is as follows:—

If the revolutions that the first moving wheel makes in a minute be multiplied by the number of cogs in all the driving wheels successively, and the product noted; and the revolutions of the last leading wheel be multiplied by the number of cogs in all the leading wheels successively, and the product noted; these products will be equal in all possible cases. Hence, we deduce the following simple rules:—

1st. For finding the motion of the mill-stone; the revolutions of the water-wheel, and the cogs in the wheels, being given:—

RULE.

Multiply the revolutions of the water-wheel per minute, by the number of cogs in all the driving wheels successively, and note the product; and multiply the number of cogs or rounds in all the leading wheels successively, and note the product; then divide the first product by the last, and the quotient is the number of revolutions of the stone per minute.

EXAMPLE.

Given, the revolutions of the water-wheel per minute, - - - - - -		10,4
No. of cogs in the master cog-wheel -	78	Drivers.
No. of do. in the counter cog-wheel -	48	
No. of rounds in the wallower - -	23	Leaders.
No. of do. in the trundle - -	17	

Then 10,4 the revolutions of the water-wheel, multiplied by 78, the cogs in the master-wheel, and 48, the cogs in the counter-wheel, are equal to 38937,6; and 23 rounds in the wallower, multiplied by 17 rounds in the trundle, are equal to 391, by which we divide 38937,6, and it gives 99,5, the revolutions of the stone per minute; which are the calculations for a 16 feet wheel, in the overshot table.

2d. For finding the number of cogs to be put in the wheels, to produce any number of revolutions required to the mill-stone, or to any wheel.

RULE.

Take any suitable number of cogs for all the wheels, except one; then multiply the revolutions of the first mover per minute, by all the drivers, except the one wanting (if it be a driver,) and the revolutions of the wheel required, by all the leaders, and divide the greatest product by the least, and it will give the number of cogs required in the omitted wheel, to produce the desired revolutions.

Note. If any of the wheels be for straps, take their diameters in inches and parts, and multiply and divide with them, as with the cogs.

EXAMPLE.

Given, the revolutions of the water-wheel		10,4
And the cogs in the master wheel -	78	} Drivers.
Ditto in the counter wheel - -	48	}
Rounds in the wallower - - -	23	

The number of the trundle is required, to give the stone 99 revolutions.

Then 10,4, multiplied by 78 and 48, is equal to 38937,6; and 99, multiplied by 23, is equal to 2277, by which divide 38937,6 and it gives 16,66; instead of which, I take the nearest whole number, 17, for the rounds in the trundle, and find, by rule 1st, that it produces 99,5 revolutions, as required.

For the exercise of the inexperienced, I have constructed fig. 7, Plate XI.; which I call the circle of motion, and which serves to prove the fundamental principle on which the rules are founded; the first shaft being, also, the last of the circle.

A is a cog-wheel of	20	cogs, and	is a	driver.
B	do.	24	-	leader.
C	do.	24	-	driver.
D	do.	30	-	leader.
E	do.	25	-	driver.
F	do.	30	-	leader.
G	do.	36	-	driver.
H	do.	20	-	leader.

But if we trace the circle the backward way, the leaders become drivers.

I is a strap-wheel	$14\frac{1}{2}$	inches diameter,		driver.
K	do.	30	do. -	leader.
L	cog-wheel	12 cogs	-	driver.
M	do.	29 do.	-	leader.

MOTION OF THE SHAFTS.

The upright shaft, and first driver, AH 36 revs. in a min.
BC 30 do.
DE 24 do.
FG 20 do.
HA 36 do.
M 4 do. which is the shaft of a hopper-boy.

If this circle be not so formed, as to give the first and last shafts (which are here the same) exactly the same motion, one of the shafts must break as soon as they are put in motion.

The learner may exercise the rules on this circle, until he can form a similar circle of his own; and then he need never be afraid to undertake to calculate any other combination of motion.

I omit showing the work for finding the motion of the several shafts in this circle, and the wheels to produce said motion; but leave it for the practice of the learner, in the application of the foregoing rules.

EXAMPLES.

1st. Given, the first mover AH 36 revolutions per minute, and first driver A 20 cogs, leader B 24; required, the revolutions of shaft BC. Answer, 30 revolutions per minute.

2dly. Given, first mover 36 revolutions per minute, drivers 20—24—25, and leaders 24—30—30; required, the revolutions of the last leader. Answer, 20 revolutions per minute.

3dly. Given, first mover 20 revolutions per minute, and first driver, strap-wheel, $14\frac{1}{2}$ inches, cog-wheel 12, and leader, strap-wheel, 30 inches, cog-wheel 29; required, the revolutions of the last leader, or last shaft. Answer, 4 revolutions.

4thly. Given, first mover 36 revolutions, driver A 20, C 24, leader B 24, D 30; required, the number of leader F, to produce 20 revolutions per minute. Answer, 30 cogs.

5thly. Given, first mover 36 revolutions per minute, driver A 20, C 24, E 25, driver pulley $14\frac{1}{2}$ inches diameter, L 12, and leader B 24, D 30, F 30, M 29; required the diameter of the strap-wheel K, to give the shaft 4, four revolutions per minute. Answer, 30 inches diameter.

The learner may, for exercise, work the above questions, and every other than he can propose on the circle.

ARTICLE 75.

The following are the proportions for finding the circumference of a circle, its diameter being given, or the diameter by the given circumference; namely:

As 1 is to 3,1416, so is the diameter to the circumference; and as 3,1416 is to 1, so is the circumference to the diameter: Or, as 7 is to 22, so is the diameter to the circumference; and as 22 is to 7, so is the circumference to the diameter. The last proportion makes the diameter a little too large; it, therefore, suits mill-wrights best for finding the pitch circle; because the sum of the distances, from centre to centre, of all the cogs in a wheel, makes the circle too short, especially where the number of cogs is few, because the distance is taken in straight lines, instead of on the circle. In a wheel of 6 cogs only, the circle will be so much too short, as to give the diameter $\frac{2}{22}$ parts of the pitch or distance of the cogs too short. Hence, we deduce the following

RULES FOR FINDING THE PITCH CIRCLE.

Multiply the number of cogs in the wheel, by the quarters of inches in the pitch, and that product by 7, and divide by 22, and the quotient is the diameter in quarters of inches, which is to be reduced to feet.

EXAMPLE.

Given, 84 cogs $4\frac{1}{2}$ inches pitch; required the diameter of the pitch circle.

Then, by the rule, 84 multiplied by 18, and by 7, is equal to 10584; which, divided by 22, is equal to $481\frac{2}{22}$ quarter inches, equal to 10 feet $\frac{1}{4}\frac{2}{22}$ inches, for the diameter of the pitch circle required.

ARTICLE 76.

A true and expeditious method of finding the diameter of the pitch circle, is to find it in measures of the pitch itself that you use.

RULE.

Multiply the number of cogs by 7, and divide by 22, and you have the diameter of the pitch circle, in measures of the pitch, and 22d parts of said pitch.

EXAMPLE.

Given, 78 cogs; required, the diameter of the pitch circle. Then, by the rule,

```
     78
      7
    ———
22)546(24 18/22  { Measures of the pitch for the diameter
   44            {        of the circle required.
   ———
   106
    88
   ———
    18
```

Half of which diameter, $12\frac{9}{22}$ of the pitch, is the radius, or half diameter, by which the circle is to be swept.

To use this rule, set a pair of compasses to the pitch, and screw them fast, so as not to be altered until the wheel is pitched; divide the pitch into 22 equal parts; then step 12 steps, on a straight line with the pitch compasses, and 9 of these equal parts of the pitch, make the radius that is to describe the circle.

To save the trouble of dividing the pitch for every wheel, the workman may mark the different pitch which he commonly uses, on the edge of his two-foot rule, (or make a little rule for the purpose,) and carefully divide them there, where they will always be ready for use. See plate IV. fig. 35.

By these rules, I have calculated the following table of the radii of pitch circles of the different wheels commonly used, from 6 to 136 cogs.

A TABLE

OF THE

PITCH CIRCLES OF THE COG-WHEELS

COMMONLY USED,

From 6 to 136 cogs, both in measures of the pitch, and in feet, inches, and parts.

Cogs in the wheel.	Radius of the pitch circle in measures of the pitch and 22 parts and tenths of parts of said pitch.		Radius of the pitch circle of the wheels in column 1, taken in inches, quarters, and 22 parts of a quarter, when the pitch is 2¼ inches, for bolting gears, &c.	Cogs in the wheel.	Radius of the pitch circle in measure of the pitch and 22 parts of said pitch.		Radius of the pitch circle of the wheels in the 4th column taken in feet, inches, quarters, and 22 parts of a quarter, when the pitch is 4¼ inches, for large gears, &c.	Ditto, when the pitch is 4½ inches.
No.	Pitch.	22 parts.	inches. quarters. 22 parts.	No.	Pitch.	22 parts.	feet. inches. quarters. 22 parts.	feet. inches. quarters. 22 parts.
6	1	.	2:2: 0	33	5	5 1-2	1:10:1: 51-2	1:11:2:11
7	1	3.5	2:3:12	34	5	9	1:10:3:21	2: 0:1: 8
8	1	6.7	3:1: 3	35	5	12 1-2	1:11:2:141-2	2: 1:0: 5
9	1	10.2	3:2:13	36	5	16	2: 0:1: 8	2: 1:3: 2
10	1	13.6	4:0: 3	37	5	19 1-2	2: 1:0: 11-2	2: 2:1:21
11	1	17.1	4:1:17	38	6	1	2: 1:2:17	2: 3:0:10
12	1	20.5	4:3: 5	39	6	4 1-2	2: 2:1:101-2	2: 3:3:15
13	2	1.9	5:0:17	40	6	8	2: 3:0: 4	2: 4:2:12
14	2	5.3	5:2: 8	42	6	15	2: 4:1:13	2: 6:0: 6
15	2	8.8	5:3:20	44	7		2: 5:3: 0	2: 7:2: 0
16	2	12.2	6:1:11	48	7	14	2: 8:1:18	2:10:1:10
17	2	15.7	6:3: 2	52	8	4	2:11:0:14	3: 1:0:20
18	2	19.1	7:0:15	54	8	11	3: 0:2: 1	3: 2:2:14
19	3	0.6	7:2: 6	56	8	20	3: 1:3:10	3: 4:0: 8
20	3	4.1	7:3:18	60	9	13	3: 4:2: 6	3: 6:3:18
21	3	7.5	8:1: 9	66	10	11	3: 8:2:11	3:11:1: 0
22	3	11.	8:3: 0	72	11	10	4: 0:2:16	4: 3:2: 4
23	3	14.5	9:0:13	78	12	9	4: 4:2:21	4: 7:3: 8
24	3	18.	9:2: 4	84	13	8	4: 8:3: 4	5: 0:0:12
25	3	21.5	9:3:17	88	14	0	4:11:2: 0	5: 3:0: 0
26	4	3.	10:1: 8	90	14	7	5: 0:3: 9	5: 4:1:16
27	4	6.5	10:2:21	96	15	6	5: 4:3:14	5: 8:2:20
28	4	10.	11:0:12	104	16	13	5:10:1: 6	6: 2:1:18
29	4	13.5	11:2: 3	112	17	18	6: 3:2:20	6: 8:0:16
30	4	17.	11:3:16	120	19	2	6: 9:0:12	7: 1:3:14
31	4	20.5	12:1: 7	128	20	8	7: 2:2: 4	7: 7:2:12
32	6	2.	12:2:20	136	21	14	7: 7:3:18	8: 1:1:10
1	2		3	4	5		6	7

Use of the foregoing Table.

Suppose you are making a cog-wheel with 66 cogs; look for the number in the 1st or 4th column, and against it, in the 2d or 5th column, you find 10, 11; that is, 10 steps of the pitch (you use) in a straight line, and 11 of 22 equal parts of said pitch added, make the radius that is to describe the pitch circle.

The 3d, 6th, and 7th columns, contain the radius in feet, inches, quarters, and 22 parts of a quarter; which may be made use of in roughing out timber, and fixing the centres that the wheels are to run in, so that they may gear to the right depth; but on account of the difference in the parts of the same scales or rules, and the difficulty of setting the compasses exactly, they can never be true enough for the pitch circles.

RULE COMMONLY PRACTISED.

Divide the pitch into 11 equal parts, and take in your compasses 7 of those parts, and step, on a straight line, counting 4 cogs for every step, until you come up to the number in your wheel; if there be an odd one at last, take ¼ of a step—if 2 be left, take ½ of a step—if 3 be left, take ¾ of a step, for them; and these steps, added, make the radius or sweep-staff of the pitch circle: but on account of the difficulty of making these divisions sufficiently exact, there is little truth in this rule—and where the number of cogs is few, it will make the diameter too short, for the reason formerly mentioned.

The following geometrical rule is more true, and, in some instances, more convenient.

RULE.

Draw the line AB, Plate IV. fig. 34, and draw the line O,22 at random; then take the pitch in your compasses, and beginning at the point 22, step 11 steps towards A, and 3½ steps to point X, towards O, draw the line AC through the point X; draw the line DC parallel to AB, and, without having altered your compasses, begin at point O, and step both ways, as you did on AB; then, from the respective points, draw the cross lines parallel to O,22; and the distance from the point, where they cross the line AC, to the line AB, will be the radius of the pitch circles for the number of cogs respectively, as in the figure. If the number of cogs be odd, say 21, the radius will be between 20 and 22.

This will also give the diameter too short, if the wheels have but few cogs; but, where the number of cogs is above twenty, the error is imperceptible.

All these rules are founded on the proportion, that, as 22 is to 7, so is the circumference to the diameter.

ARTICLE 77.

CONTENTS OF GARNERS, HOPPERS, &C. IN BUSHELS.

A Table of English dry Measure.

Solid Inches.				
3.36	Pint.			
268.8	8	Gall.		
537.6	16	2	Peck.	
2150.4	64	8	4	Bushel.

The bushel contains 2150, 4 solid inches. Therefore, to measure the contents of any garner, take the following

RULE.

Multiply its length in inches, by its breadth in inches, and that product by its height in inches, and divide the last product by 2150,4, and it will give the bushels it contains.

But to shorten the work decimally, because 2150,4 solid inches, make 1,244 solid feet, multiply the length, breadth, and height, in feet, and decimal parts of a foot, by each other, and divide by 1,244, and it will give the contents in bushels.

EXAMPLE.

Given, a garner 6,25 feet long, 3,5 feet wide, 10,5 feet high; required its contents in bushels. Then, 6,25

24

multiplied by 3,5 and 10,5, is equal to 229,687; which, divided by 1,244, gives 184 bushels and 6 tenths.

To find the contents of a hopper, take the following

RULE.

Multiply the length by the width at the top, and that product by one-third of the depth, measuring to the very point, and divide by the contents of a bushel, either in inches or decimals, and the quotient will be the contents in bushels.

EXAMPLE.

Given, a hopper, 42 inches square at the top, and 24 inches deep; required, the contents in bushels.

Then 42 multiplied by 42, and that product by 8, is equal to 14112 solid inches: which, divided by 2150,4, the solid inches in a bushel, gives 6,56 bushels, or a little more than 6½ bushels.

To make a garner to hold any given quantity, having two of its sides given, pursue the following

RULE.

Multiply the contents of 1 bushel by the number of bushels the garner is to hold; then multiply the given sides into each other, and divide the first by the last product, and the quotient will be the side wanted, in the same measure by which you have wrought in.

EXAMPLE.

Given, two sides of a garner 6,25 by 10,5 feet; required, the other side, to hold 184,6 bushels.

Then, 1,244 multiplied by 184,6 is equal to 229,642; which, divided by the product of the two sides 65,625, the quotient is 3,5 feet for the side wanted.

To make a hopper to hold any given quantity, having the depth given.

RULE.

Divide the inches contained in the bushels it is to hold, by 1-3d the depth in inches; and the quotient will be the square of one of the sides, at the top, in inches.