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Influence of Height of Wheel on the Draft of Farm Wagons.

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The Influence of Height of Wheels on the Draft of Farm Wagons.

By T. I. Mairs, Assistant in Agriculture.

SUMMARY OF RESULTS.

Numerous tests of the draft of wagons equipped with wheels of different height have been made at this Station during the past three years. The trials were made on Macadam, gravel and dirt roads in all conditions, and on meadows, pastures, cultivated fields, stubble land, etc.

The draft was determined by means of a Giddings self-recording dynamometer. The net load was in every case the same, viz: 2,000 pounds. Three sets of wheels of different heights, all with six inch tires, were used as follows:

Standard, front wheels 44 inches, rear wheels..55 inches.
Medium, front wheels 36 inches, rear wheels..40 inches.
Low, front wheels 24 inches, rear wheels....28 inches.

The following is a summary of the results:

I. For the same load, wagons with wheels of standard height drew lighter than those with lower wheels.

II. The difference in favor of the standard wheels was greater on road surfaces in bad condition than on good road surfaces.

III. Low wheels cut deeper ruts than those of standard height.

IV. The vibration of the tongue is greater in wagons with low wheels.

V. For most purposes wagons with low wheels are more convenient than those of standard height.

VI. Wagons with broad tires and wheels of standard height are cumbersome and require much room in turning.

VII. Diminishing the height of wheel to from 30 to 36 inches in front and 40 to 44 inches in the rear did not increase the draft in as great proportion as it increased the convenience of loading and unloading the ordinary farm freight.

VIII. Diminishing the height of wheels below 30 inches front and 40 inches rear, increased the draft in greater proportion than it gained in convenience.

IX. On good roads, increasing the length of rear axle so that the front and rear wheels will run in different tracks to avoid cutting ruts, did not increase the draft.

X. On sod, cultivated ground, and bad roads, wagons with the rear axle longer than the front one, drew heavier than one having both axles of the same length.

XI. Wagons with the rear axle longer than front one require wider gateways and more careful drivers, and are on the whole very inconvenient and not to be recommended for farm use.

XII. The best form of farm wagon is one with axles of equal length, broad tires and wheels 30 to 36 inches high in front and 40 to 44 inches behind.

DETAILS OF THE EXPERIMENT.

The advantages of broad tired vehicles over narrow tired ones for general farm work such as hauling feed, spreading manure, etc., has long been recognized. The work of this Station has demonstrated that under almost all conditions of

road surface the broad tired vehicles draw the lighter and are a benefit to roads, while the narrow tired ones are constantly destroying them.

The chief drawback to the use of broad tired wheels has been their unwieldiness. The rim of the wheel coming so much nearer the bed of the wagon, cramps the wagon sooner in turning and so requires more room. On the other hand, if we diminish the diameter of the wheel, to facilitate turning we necessarily increase the draft. Manufacturers have in recent years placed upon the market all sorts of so-called "handy wagons" with low wheels turning under the body. For most purposes, the greater ease with which wagons with low wheels can be loaded and unloaded is an advantage in their favor.

To study the effect of the height of wheel upon the draft and discover if possible to what extent it may be reduced without the increased draft counteracting the greater convenience in loading and unloading and in turning, has been the object of these tests.

Of course upon a perfectly rigid surface, level, or with uniform grade, the results could be computed mathematically. But as loads are not drawn over such surfaces, it becomes necessary to make actual tests.

These tests were made with three wagons under a variety of conditions. The wheels known as "Standard or high wheels" were of ordinary height, viz.: 44 inches front, 56 inches rear; those known as "medium" were 36 inches front, 40 inches rear; those known as "low" were 24 inches front, 28 inches rear. All were steel wheels with six inch tires.

The high or Standard wheels weighed 692 pounds.

The medium wheels weighed 510 pounds.

The low wheels weighed 292 pounds.

The dead weight of the wagons, exclusive of wheels and including driver and man to operate the dynamometer, was

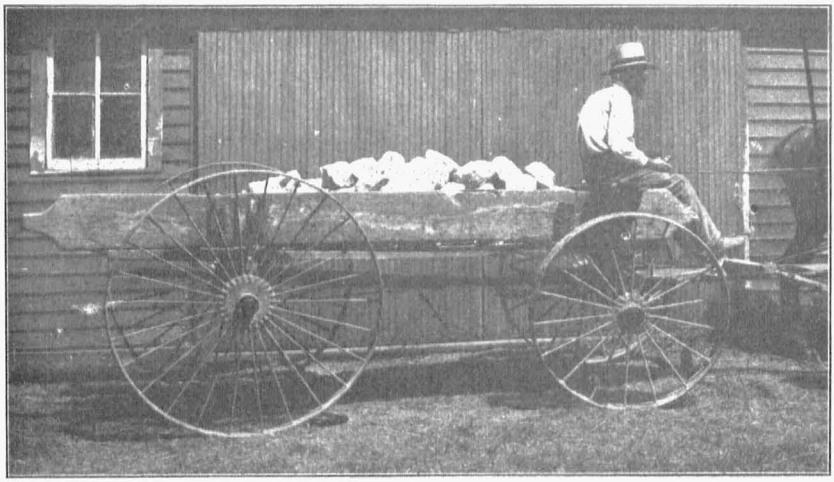

Fig. 1. WAGON EQUIPPED WITH HIGH OR STANDARD WHEELS.

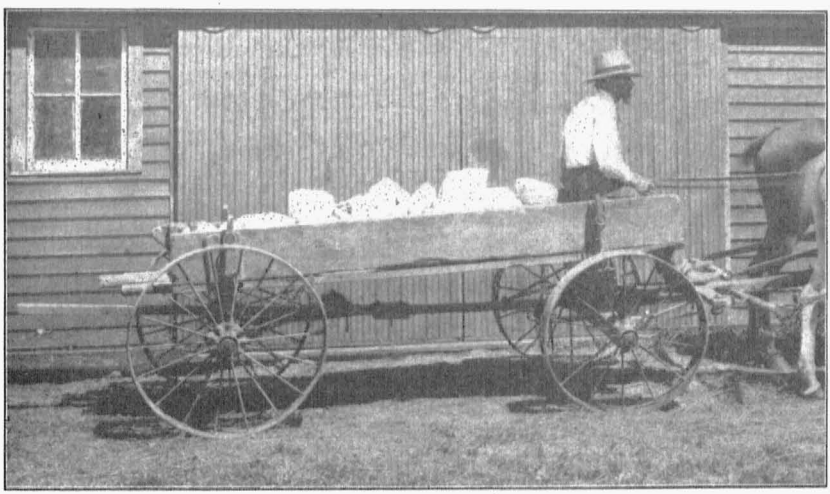

Fig. 2. WAGON EQUIPPED WITH MEDIUM WHEELS.

made the same in each case, viz: about 1070 pounds. Then a load of 2,000 pounds was placed upon each wagon and the tests made.

The actual weights of the different wagons and loads were as follows:

High ....3762 pounds.
Medium ....3580 pounds.
Low ....3362 pounds.

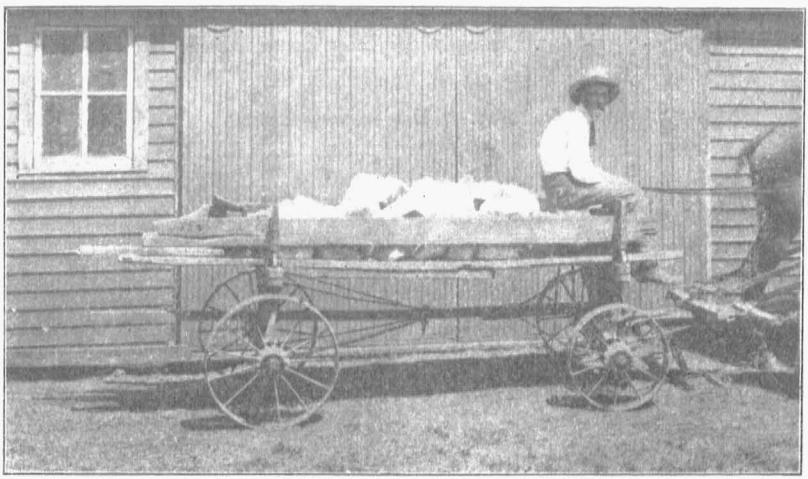

Fig. 3. WAGON EQUIPPED WITH LOW WHEELS.

A Gidding's self recording dynamometer was used for making the test.

The results were obtained by dividing the area, as determined by a planimeter, enclosed by the dynamometer autograph, the zero line and the ordinates at beginning and end, by the length of zero line. The runs were all 200 feet and return except when made purposely upon a grade.

It was found that the first two runs over any track drew heavier than later ones, but after the second run the draft was fairly uniform for any one wagon. Therefore, before each test on a road, one of the wagons was run over the track four to six times before the tests were made. On meadows and in the fields a piece of uniform ground was chosen wide enough so that all the runs could be made without running twice in the same track.

The following are detailed results of the tests made:

I. Gravel Road.

(a) Dry, sand about one inch deep, some small loose stones ranging in size up to small hen egg. Length of run 400 feet. October 15th, 1898.

High wheels, average of two runs.....158.9 pounds.
Medium wheels, average of two runs....161.9 pounds.
Low wheels, average of two runs.....185.3 pounds.

Advantage in draft of high over medium wheels, 3.0 pounds or 1.9 per cent; medium over low wheels, 23.4 pounds or 14.5 per cent; and high over low wheels 26.4 pounds or 16.6 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,290 pounds on the medium wheels or 2,332 pounds on the high ones.

The draft required for 2,000 pounds on the medium wheels would draw 2,038 pounds on the high ones.

(b) Up a grade of 1 in 44, with about one half inch of wet sand, ground frozen underneath. Length of run 250 feet. November 25th, 1898.

High wheels, average of two runs, draft..231.3 pounds.
Medium wheels, aver. of two runs, draft..236.5 pounds.
Low wheels, average of two runs, draft..291.0 pounds.

Advantage of high over medium wheels 5.2 pounds or 2.2 per cent; medium over low wheels 54.5 pounds or 23.0

per cent; high over low wheels 59.7 pounds or 25.8 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels, would draw 2,460 pounds on the medium wheels or 2,516 pounds on the high ones; and the draft required to draw 2,000 pounds on the medium wheels would draw 2,044 pounds on the high ones.

As an average of all the tests made on gravel roads, it is found that the high wheels draw 2.1 per cent lighter than the medium ones and 21.2 per cent lighter than the low ones; the medium wheels drew 18.8 per cent lighter than the low ones.

II. Macadam Street.

Slightly worn but clean and in fair condition. Length of run, 400 feet. July 27th, 1900.

High wheels, average of two runs, draft..108.0 pounds.
Medium wheels, aver. of two runs, draft..108.7 pounds.
Low wheels, average of two runs, draft..117.4 pounds.

Advantage of high over medium wheels .7 pounds or .65 per cent; medium over low wheels 8.7 pounds or 8 per cent; high over low wheels 9.4 pounds or 8.7 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,160 pounds on the medium wheesl or 2,174 pounds on the high ones; and the draft required to draw 2,000 pounds on the medium wheels would draw 2,013 pounds on the high ones.

III. Cinder Track.

Smooth, but had never been heavily rolled, consequently was not very solid and had from half an inch to one inch of loose dry cinders on top. Length of run, 600 feet. July 27th, 1900.

High wheels, average of two runs, draft..113.1 pounds.
Medium wheels, aver. of two runs, draft..114.0 pounds.
Low wheels, average of two runs, draft..120.0 pounds.

Advantage of high over medium wheels, .9 pounds or .8 per cent; high over low wheels, 6.9 pounds or 6.1 per cent; medium over low wheels, 6.0 pounds or 5.3 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,106 pounds on the medium wheel, or 2,122 pounds on the high ones, and the draft required to draw 2,000 pounds on the medium wheels would draw 2,016 pounds on the high ones.

IV. Dirt Road.

(a) Frozen solid but thawing on top, rather rough, covered with about one half inch of very sticky black mud which gathered on the wheels. Length of run 400 feet. November 23rd, 1898.

High wheels, average of two runs, draft..189.2 pounds.
Medium wheels, aver. of two runs, draft..213.4 pounds.
Low wheels, average of two runs, draft..233.8 pounds.

Advantage of high over medium wheels 24.2 pounds, or 12.8 per cent; medium over low, 20.4 pounds or 9.6 per cent; high over low, 44.6 pounds or 23.6 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,192 pounds on the medium ones, or 2,472 pounds on the high ones, and the draft required for 2,000 pounds on the medium wheels would draw 2,256 pounds on the high ones.

(b) Dry and hard, no dust or inequalities. Length of run 400 feet. August 21st, 1899.

High wheels, average of two runs, draft..130 pounds.
Medium wheels, average of two runs, draft..134 pounds.
Low wheels, average of two runs, draft..132 pounds.

Advantage of high over low wheels, 2 pounds or 1.5 per cent; high over medium wheels, 4 pounds or 3.1 per cent; low over medium, 2 pounds or 1.5 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels, would draw 2,031 pounds on the high wheels, or 1,970 pounds on the medium ones; and the draft required for 2,000 pounds on the medium wheels would draw 2062 pounds on the high, or 2,030 pounds on the low ones.

The extra weight of the medium wheels probably account for their extra draft over the low ones.

As an average then of all the tests made on dirt roads, the high wheels drew 8.0 per cent lighter than the medium ones, and 12.6 per cent lighter than the low ones; the medium wheels drew 4.0 per cent lighter than the low ones.

V. Timothy and Bluegrass Sod.

(a) Moderately dry and firm, none of the wheels made appreciable ruts. The grass had been cut for hay and was being pastured at the time the tests were made. Length of run 400 feet. October 15th, 1898.

High wheels, average of two runs, draft..248.1 pounds.
Medium wheels, aver. of two runs, draft..259.9 pounds.
Low wheels, average of two runs, draft..300.6 pounds.

Advantage of high over medium wheel, 11.8 pounds or 4.8 per cent; medium over low wheels 40.7 pounds or 15.7 per cent; high over low wheels 52.5 pounds or 21.2 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels, would draw 2,314 pounds on the medium wheels, and 2,424 pounds on the high ones; and the draft

required for 2,000 pounds on the medium wheels would draw 2,096 pounds on the high ones.

(b) Wet and spongy, all the wheels cut in some, the low ones three or four inches. In turning, the low wheels cut up the ground much worse than the others.

High wheels, average of two runs, draft..325.2 pounds.
Medium wheels, aver. of two runs, draft..362.7 pounds.
Low wheels, average of two runs, draft..472.6 pounds.

Advantage of high over medium wheels 37.5 pounds or 11.5 per cent; medium over low wheels 109.9 pounds or 30.9 per cent; high over low wheels 147.4 pounds or 45.3 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2.618 pounds on the medium wheels or 2,906 pounds on the high ones, and the draft required for 2,000 pounds on the medium wheels would draw 2,230 pounds on the high ones.

(c) Dry and firm, grass had been cut for hay, up grade of 1 in 12.7. Length of run 300 feet. August 21st, 1899.

High wheels, average of two runs, draft..480 pounds.
Medium wheels, average of two runs, draft..495 pounds.
Low wheels, average of two runs, draft...510 pounds.

Advantage of high over medium wheels 15 pounds or 3.1 per cent; medium over low wheels, 15 pounds or 3.0 per cent; high over low wheel 30 pounds or 6.3 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,060 pounds on the medium wheels, or 2,125 pounds on the high ones; and the draft required for 2,000 pounds on the medium wheel would draw 2,062 pounds on the high ones.

As an average of all tests on meadow and pasture sod, the high wheels drew 6.5 per cent lighter than the medium ones, and 24.3 per cent lighter than the low ones; the medium wheels drew 16.5 per cent lighter than the low ones.

VI. Stubble Land.

Corn stubble running across the rows which were very slightly ridged by being cultivated with a spring-tooth cultivator; ground dry on top; in good condition for working. At last cultivation the ground was left as nearly level as it was possible to leave it. Length of run 400 feet. October 15, 1898.

High wheels, average of two runs, draft..335.7 pounds.
Medium wheels, average of two runs, draft. 360.1 pounds.
Low wheels, average of two runs, draft....445.6 pounds.

Advantage of high over medium wheels 24.4 pounds or 7.6 per cent; medium over low wheels 85.5 pounds or 23.7 per cent; high over low wheels 109.9 pounds or 32.7 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,476 pounds on the medium wheels or 2,654 pounds on the high ones; and the draft required for 2,000 pounds on the medium wheels would draw 2,152 pounds on the high ones.

VII. Freshly Plowed Ground.

Dry and cloddy. Length of run 400 feet. August 2, 1899.

High wheels, average of two runs, draft..475 pounds.
Medium wheels, average of two runs, draft..542 pounds.
Low wheels, average of two runs, draft....628 pounds.

Advantage of high wheels over medium wheels 67 pounds or 14.1 per cent; medium over low wheels 86 pounds or 15.9 per cent; high over low wheels 153 pounds or 32.2 per cent.

At this rate the draft required to draw 2,000 pounds on the low wheels would draw 2,318 pounds on the medium wheels or 2,644 pounds on the high ones; and the draft required for 2,000 pounds on the medium wheels would draw 2,282 pounds on the high ones.

As an average of all runs on plowed ground, the high wheels drew 10.9 per cent lighter than the medium ones, and 32.4 per cent lighter than the low ones; the medium wheels drew 19.8 per cent lighter than the low ones.

SUMMARY.

Kind of Road.	Condition of Road.	Kind of Wheels.	Draft required for 2000 lbs. net load
Gravel Road.	Level, dry, with sand and gravel.	High.	158.9 lbs.
		Medium.	161.9 lbs.
		Low.	185.3 lbs.
	Wet sand up grade 1—44	High.	231.3 lbs.
		Medium.	236.5 lbs.
		Low.	291.0 lbs.
Macadam Street.	In fair condition.	High.	108.0 lbs.
		Medium.	108.7 lbs.
		Low.	117.4 lbs.
Cinder Track.	Dry and not firm.	High.	113.1 lbs.
		Medium.	114.0 lbs.
		Low.	120.0 lbs.
Dirt Road.	Frozen solid, sticky mud on top.	High.	189.2 lbs.
		Medium.	213.4 lbs.
		Low.	233.8 lbs.
	Dry and in good condition.	High.	130 lbs.
		Medium.	134 lbs.
		Low.	132 lbs.
Timothy and Bluegrass Sod.	Dry and firm, level.	High.	248.1 lbs.
		Medium.	259.9 lbs.
		Low.	300.6 lbs.
	Wet and spongy.	High.	325.2 lbs.
		Medium.	362.7 lbs.
		Low.	472.6 lbs.
	Dry and firm, up grade 1—12.7	High.	480 lbs.
		Medium.	495 lbs.
		Low.	510 lbs.
Plowed Ground.	Dry across rows, small ridges.	High.	335.7 lbs.
		Medium.	360.1 lbs.
		Low.	445.6 lbs.
	Freshly plowed.	High.	475 lbs.
		Medium.	542 lbs.
		Low.	628 lbs.

If we look at these figures another way and consider the number of pounds gross and net load each pound of draft drew under the several conditions, we have the following results:

Kind of road.	Condition of road.	Kind of Wheels.	Gross Load.	Net Load.
Gravel road.	Level, dry, with sand and gravel.	High.	23.7 lbs.	12.6 lbs.
		Medium.	22.1 lbs.	12.4 lbs.
		Low.	18.1 lbs.	10.8 lbs.
	Wet sand, up grade.	High.	16.3 lbs.	8.6 lbs.
		Medium.	15.1 lbs.	8.5 lbs.
		Low.	11.6 lbs.	6.9 lbs.
Macadam Street	Fair condition.	High.	34.8 lbs.	18.5 lbs.
		Medium.	32.8 lbs.	18.4 lbs.
		Low.	28.7 lbs.	17.0 lbs.
Cinder Track.	Dry but not very firm.	High.	33.3 lbs.	17.7 lbs.
		Medium.	31.4 lbs.	17.5 lbs.
		Low.	28.0 lbs.	16.7 lbs.
Dirt Road.	Frozen solid, sticky on top.	High.	19.8 lbs.	10.6 lbs.
		Medium.	16.8 lbs.	9.4 lbs.
		Low.	14.4 lbs.	8.6 lbs.
	Dry and in good condition.	High.	28.9 lbs.	15.4 lbs.
		Medium.	26.7 lbs.	14.9 lbs.
		Low.	25.5 lbs.	15.1 lbs.
Timothy and Bluegrass Sod.	Dry and firm.	High.	15.2 lbs.	8.1 lbs.
		Medium.	13.8 lbs.	7.7 lbs.
		Low.	11.2 lbs.	6.6 lbs.
	Wet and spongy.	High.	11.6 lbs.	6.2 lbs.
		Medium.	9.9 lbs.	5.5 lbs.
		Low.	7.1 lbs.	4.2 lbs.
	Dry and firm. Up grade 1—12.7	High.	7.8 lbs.	4.2 lbs.
		Medium.	7.2 lbs.	4.0 lbs.
		Low.	6.6 lbs.	3.9 lbs.
Plowed Ground.	Across corn rows.	High.	11.2 lbs.	5.9 lbs.
		Medium.	9.9 lbs.	5.5 lbs.
		Low.	7.5 lbs.	4.5 lbs.
	Large, hard clods.	High.	7.9 lbs.	4.2 lbs.
		Medlum.	6.6 lbs,	3.7 lbs.
		Low.	5.4 lbs.	3.2 lbs.

Thus it is seen that the difference in draft between the high and medium wheels is not great, while that between the medium and low ones is very considerable, and the better the condition of the roads, the more nearly the draft of the three wagons becomes equal.

The greater ease with which wagons with wheels of medium height can be turned, and loaded and unloaded, would more than counteract their increased draft over those with wheels of normal height. It is obvious also that the lighter the net load, the less the difference in draft both absolute and relative between the different wagons.

In the low wheeled wagon, while we gained somewhat in convenience of turning and loading, we increased the draft out of proportion. Another great disadvantage of a wagon with very low wheels is the increased vibration of the tongue, which is almost if not quite as worrying on the team as the increased draft, and tends to keep the horses' necks sore. On the other wagons this vibration is not noticeable.

Considering draft, convenience, etc., it is believed that the most suitable height for wheels of a farm wagon, especially with wide tires, is 32-26 inches in front and 36-42 inches in the rear.

WHY SHOULD LOW WHEELS DRAW HEAVIER THAN HIGH ONES BEARING THE SAME LOAD?

1st. The power required to overcome the axle friction diminishes as the diameter of the wheel increases, the diameter of the axle remaining the same.

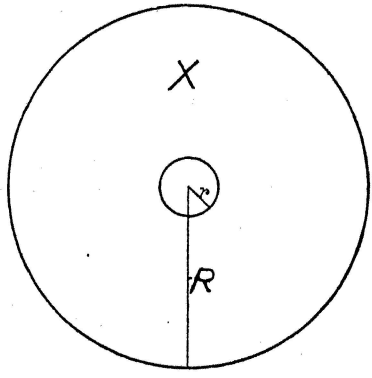

Fig. 4.

Let X. be any wheel with a radius R. and the radius of whose axle is r. Now since axle friction is resistance to be overcome on the circumference of the axle, and the power is to be applied at the circumference of the wheel, we may take O. the center of the wheel as a fulcrum.

Then R : r : : axle friction : power. $R P = r F$.

$P = \frac{r F}{R}$ or $P \propto \frac{r}{R}$ where F is axle friction and P the power weight.

Hence, the power required to overcome axle friction increases as the diameter of the axle increases or the diameter of the wheel decreases. But in the tests made, the diameter of the axle remains constant, so the power required to over-

come friction increases as the diameter of the wheel decreases.

2d. The power required to draw a high wheel over an obstruction is less than that required for a low wheel bearing the same weight.

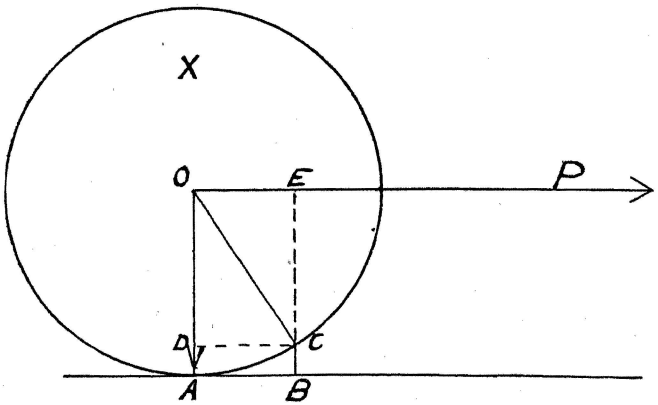

Fig. 5.

Let the wheel X be drawn along the level surface A B and meet an obstruction C B, the wheel touching the horizontal surface at A. Let P represent the power required and W the weight to be raised, including wheel and load. Let the power act parallel to the surface of the road. Draw the vertical line E C and the horizontal C D. Then the power acting in the direction of O P on the lever arm E C is balanced by the weight acting in the direction O A on the lever arm C D.

$$W \times C\,D = P \times E\,C$$

$$P = W\frac{C\,D}{E\,C}$$

$$E\,C = O\,D$$

$$P = W\frac{C\,D}{O\,D}$$

$$\frac{C\,D}{O\,D} = \text{Tan. } C\,O\,D$$

$$P = W \text{ Tan. } C\,O\,D$$

The power required to draw a wheel over an obstruction is equal to the weight multiplied by the tangent of the angle between the vertical and the line drawn from the center of the wheel to the point of obstruction. But for obstructions of the same height this angle is greater in low wheels.

This is the problem which would apply to obstructions and inequalities on macadam and other hard surfaces.

Solving this without the application of trigonometry we may start with the equation.

$$P = W \frac{CD}{OD}$$

$$OD = R - CB$$

$$CD = \sqrt{R^2 - OD^2} = \sqrt{R^2 - (R - CB)^2}$$

$$P = W \frac{\sqrt{R^2 - (R - CB)^2}}{R - CB} = W \frac{\sqrt{R^2 - (R^2 + CB^2 - 2R\,CB)}}{R - CB}$$

$$P = W \frac{\sqrt{2R\,CB - CB^2}}{R - CB} = W \frac{\sqrt{CB\,(2R - CB)}}{R - CB}$$

Putting this formula into words:

The power required to raise a wheel over an obstruction is equal to the square root of the height of obstruction into diameter minus height of obstruction, multiplied by weight and divided by radius minus height of obstruction.

Since $\frac{\sqrt{2R - CB}}{R - CB}$ decreases as the wheels get larger, it follows that the larger wheels must draw lighter.

3d. The resistance to penetration offered by sand, gravel, loose earth or mud, is greater for small wheels.

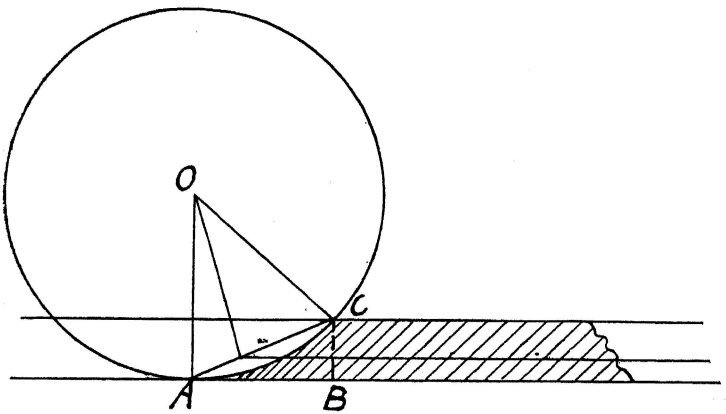

Fig. 6.

Let A B be the bottom of the rut cut by the wheel whose center is O and let C H be the surface over which the load is to be drawn. Now the resistance offered is to the arc A C and may be taken as acting perpendicularly to the plane of the road or vertically, and offered to the weight which is to pass over it. For the sake of simplicity it may be supposed that the medium penetrated is homogeneous. Then the resistance is nothing at C and increases until it reaches a maximum at A, and may be represented by an isosceles triangle whose center of gravity one-third the distance from bottom of rut to surface of road is also the center of resistance. The arc A C may for most practical purposes be assumed to be identical with the chord A C. The center of resistance then will be on the chord A C, one-third the distance from A to C E. The problem now becomes the same as the preceding one with height of obstruction equal to one-third the depth of the rut cut. But the smaller the wheel, the deeper it will penetrate for the same weight.

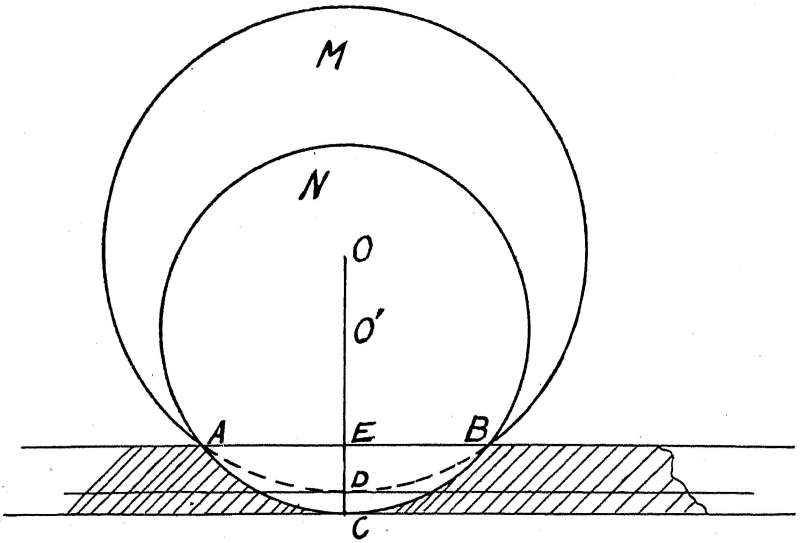

Fig. 7.

Let M and N be two wheels, each bearing the same and having the same width of tire. For simplicity we will suppose them not rolling but resting upon the surface. Then if it requires an arc whose chord is A B to support the weight on the high wheel, it will sink to the depth E D. On the low wheel it will require an arc whose cord is the same and it will sink to a depth E C. But F C is greater than E D, so the low wheel must sink deeper.

When the medium penetrated is not homogeneous but increases with depth, we can not represent the resistance by a triangle, but by a figure something like figure 8, so that the center of pressure is less than one-third the distance from base to apex.

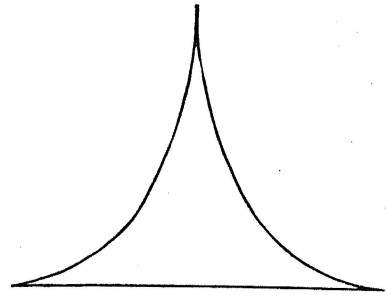

Fig. 8.

In practice the differences would not be so great as in the problems here given, because with the same net load, the gross load becomes greater as the wheels are made higher, owing to the extra weight of the wheel.

INFLUENCE OF UNEQUAL LENGTHS OF AXLE ON DRAFT OF WAGONS.

The use of wagons with axles of unequal lengths has been suggested by some, to increase the rolling surface, prevent the cutting of ruts and preserve the road surface.

To give a concrete test to the feasibility of this plan both as regards convenience and draft, the Experiment Station had constructed a wagon with the rear axle enough longer than the front one so that the inner edge of the rear wheels ran just outside the track of the front wheels. Having tires six inches wide, a strip twelve inches wide was rolled on each side of the road.

In making the draft tests, the same wheels were used on each wagon, being changed from the one with axles of unequal lengths to the one of equal length and vice versa.

The tests were made with the same dynamometer and the results obtained in the same manner as in the preceding experiment. The dead weight of the two wagons was made the same, then a net load of 2,000 pounds added to each, making the total weight of each about 3,500 pounds.

The following are the detailed results of the experiment:

I. Dirt Road.

In good condition, no mud or dust, worn smooth. Length of run 400 feet. August 4th, 1899.

Ordinary wagon, average of two runs, draft 133.9 pounds.

Wagon with long rear axle, average of two runs, draft 133.9 pounds.

Thus the average draft of both wagons on good level dirt road was the same.

II. Meadow, Timothy and Bluegrass Sod.

Grass had been cut for hay, ground dry and firm. Length of run 400 feet. August 4th, 1899.

Ordinary wagon, average of two runs, draft 238.2 pounds.

Wagon with long rear axle, average of two runs, draft 263.1 pounds.

Advantage in favor of ordinary wagon 24.9 pounds or 10.5 per cent.

The draft required to draw 2,000 pounds on the wagon with long rear axle would draw 2,210 pounds on the ordinary wagon.

III. Pasture, Timothy and Bluegrass Sod.

Wet and spongy, grass short, wheels did not cut in. Length of run 400 feet. April 28th, 1899.

Ordinary wagon, average of two runs, draft 308.5 pounds.

Wagon with long rear axle, average of two runs, draft 327.8 pounds.

Advantage of ordinary wagon 19.3 pounds or 6.2 per cent.

The draft required to draw 2,000 pounds on the wagon with long rear axle would draw 2,124 pounds on an ordinary wagon.

IV. Freshly Plowed Ground.

In good condition for working; no large hard clods. Length of run 400 feet. April 28th, 1899.

Ordinary wagon, average of two runs, draft 582.7 pounds.

Wagon with long rear axle, average of two runs, draft 619.2 pounds.

Advantage in favor of ordinary wagon 36.5 pounds or 6.2 per cent.

The draft required to draw 2,000 pounds on the wagon with long rear axle, would draw 2,126 pounds on the ordinary one.

V. Corn Stubble.

Unplowed corn ground, following the rows the way it was laid by, dry on top. Length of run 400 feet. April 28th, 1899.

Ordinary wagon, average of two runs, draft 398.5 pounds.

Wagon with long rear axle, average of two runs, draft 434.9 pounds.

Advantage in favor of ordinary wagon 36.4 pounds or 9.1 per cent.

The draft required for 2,000 pounds on the wagon with long rear axle, would draw 2,182 pounds on the ordinary one.

SUMMARY.

Kind and condition of road.	Kind of Wagon.	Draft required (net load) for 2000 pounds.	Per cent difference.
Dirt Road in good condition.	Ordinary. Long axle.	133.9 lbs. 133.9 lbs.	0.0
Timothy & Bluegrass Sod, dry and firm.	Ordinary. Long axle.	238.2 lbs. 263.1 lbs.	10.5
Timothy & Bluegrass wet and spongy.	Ordinary. Long axle.	308.5 lbs. 327.8 lbs.	6.2
Freshly Plowed Ground.	Ordinary. Long axle.	582.7 lbs. 619.2 lbs.	6.2
Unplowed Corn Ground.	Ordinary. Long axle.	398.5 lbs. 434.9 lbs.	9.1

Thus on a uniform rigid surface there is practically no difference in the draft, whereas on surfaces where the front wheels mash down the inequalities and form a hard smooth track for the rear wheels of the ordinary wagon there is considerable difference. Where the ground is so soft, however, that the front wheels do not make a firm track, the difference is not so great.

Perhaps a greater disadvantage than the increased draft of the wagon with a long axle, is its unwieldiness. The rear axle extending out six inches beyond the front one on each side is constantly striking gates, sides of buildings, other vehicles, and whatever the driver attempts to come near. It is very inconvenient in loading and unloading grain and whatever must be shoveled in and out of the wagon.

Taken altogether it is not believed that the benefits the roads would receive from one axle being longer than the other would begin offset the inconvenience it would be to its users.