

**E30 Effective Wheel Rates (This page has been updated!)**

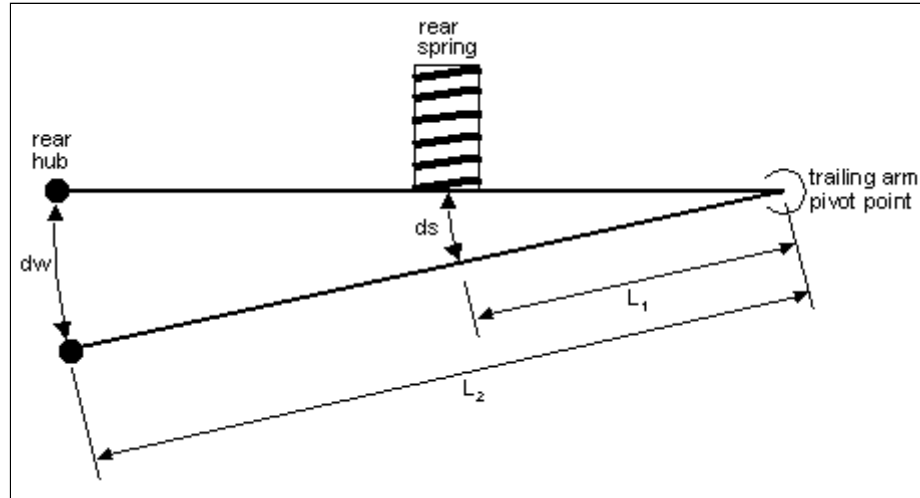


Figure 1

Figure 1 shows the layout of an E30 rear trailing arm. We are looking down the axis of rotation of the trailing arm (i.e. along the pivot points). This axis is rotated 15° (in a horizontal plane) relative to the chassis but for our purpose here that does not matter.

In order to calculate the "effective" rear wheel rate we perform a balance of torque's about the trailing arm axis of rotation. A "moment balance" in engineering parlance. There is one important aspect of calculating moments (torque's) that we need to keep in mind. Refer to Figure 2 below:

The 200 lb force creates a torque about the

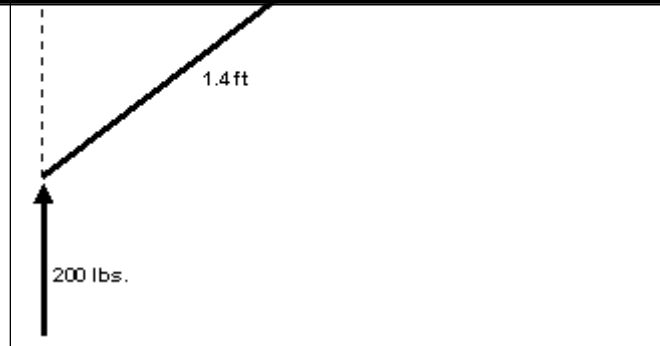


Figure 2

Rather, this torque is equal to the applied force times the *perpendicular distance from the line of force to center of rotation* of the rod:

$$\text{Torque} = 200 \times 1.0 = 200 \text{ ft. lbs.}$$

When measuring the distances L1 and L2 as shown in Figure 1, it is necessary to remember this detail concerning the definition of torque. When I initially tried to determine the effective wheel rate on my E30 M3 I forgot about this. As I was calculating the distance L2 shown in Figure 1, I measured from the rear contact patch to the trailing arm bushing. This is equivalent to using 1.4 ft. to calculate the torque in Figure 2 - which we just learned is incorrect. It has been too many years since I took the class at UCLA I suppose 8^)

Now we need to consider which torque's act on the E30 rear trailing arm. Let us examine a moment balance (balance of torque's) about an axis through the trailing arm bushings. Any force acting ON the trailing arm AT the bushings contributes no torque and cancels out. Thus we are left with the torque caused by the tire contact patch (F2 acting through the rear hub) and the torque caused by the rear spring (F1 acting through the spring perch). As long as the trailing arm is not moving these torque's balance each other out. In other words  $F_1(L_1) = F_2(L_2)$ . A sketch of the torque balance around the trailing arm axis is shown below in Figure 3:

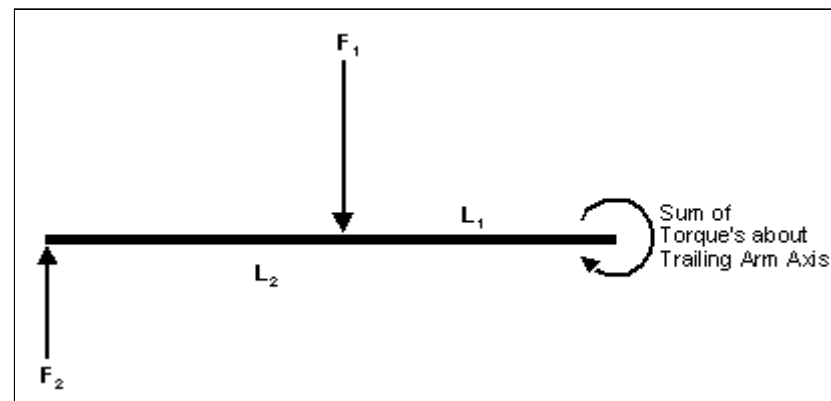


Figure 3

compress a given spring by one inch, how much resistance does it offer? If a spring that is compressed 1" pushes back with a force of 500 lbs than that spring is rated as 500 lbs/in (assuming it is linear).

What we want to do here is determine a similar rate for the rear wheel. How much force does it take to push the rear wheel up a distance of one inch? The force required will be equal to the "effective rear wheel rate". A torque balance on the trailing arm will help us answer this question.

If we push up on the trailing arm and displace it by 1 inch ( $dw = 1$ " in Figure 1) - how far does this compress the spring ( $ds$  in Figure 1)? From similar triangles we calculate  $ds$  as:

$$L1/(ds) = L2/(dw) \text{ which leads to: } ds = (L1/L2)dw$$

We will call the spring rate of the rear spring  $k1$  (lbs/in). The force exerted on the trailing arm by the compressed spring is:

$$F1 = k1(ds) = k1(L1/L2)dw$$

Now use the moment balance on the trailing arm to calculate  $F2$ :

$$F2 = (L1/L2)F1 = k1(L1/L2)^2dw$$

Divide through by  $dw$  to yield the "effective rear wheel rate":

$$\text{Wheel Rate} = F2/dw = k1(L1/L2)^2$$

The nice thing about this equation is that it applies to any type of suspension, not just the E30 trailing arms. All you need to know is the length of the two lever arms  $L1$  and  $L2$ . Thus we can also use this equation to calculate the "effective front wheel rate". The front wheel rate is closer to the spring rate than on the rear, but it is still not exactly equal to the spring rate.

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### Summary of Results

For the BMW E30 chassis we get the following table. If you know your spring rates then you can calculate your wheel rates using the yellow formulas.

Front	<del>14.5"</del>	<del>12.5"</del>	wheel rate = <del>0.74</del> x spring rate
Rear	<del>15.0"</del>	<del>11.0"</del>	wheel rate = <del>0.54</del> x spring rate

**Ed. Note:** *The numbers in the table are now known to be incorrect.*

I recently undertook a series of careful measurements of the front and rear suspension "motion ratios". That is, how far does the spring perch move for every inch of wheel movement? I also took the photograph of the rear trailing arm shown elsewhere in "Tech Articles" and measured the lever-arm lengths from the photo. Both these sets of data contradict the measurements shown in the above table, which were obtained with the suspension installed on the car. All of the theory and equations on this page are perfectly fine, it's the measurements of lever arm lengths that are off. The new measurements are shown on the [next page](#) >>