Brake lockup reduces the brake force on an axle, and results in loss of ability to control the vehicle. It is desired to bring both axles up to the lockup point at the same time. This is defined by a proportional line, the slope of which is the ratio between the maximum front axle force and the maximum rear axle force. The slope of the proportional line is also known as desired β. The desired β is a function of the vehicle's static and dynamic weight distribution of the front and rear axles.

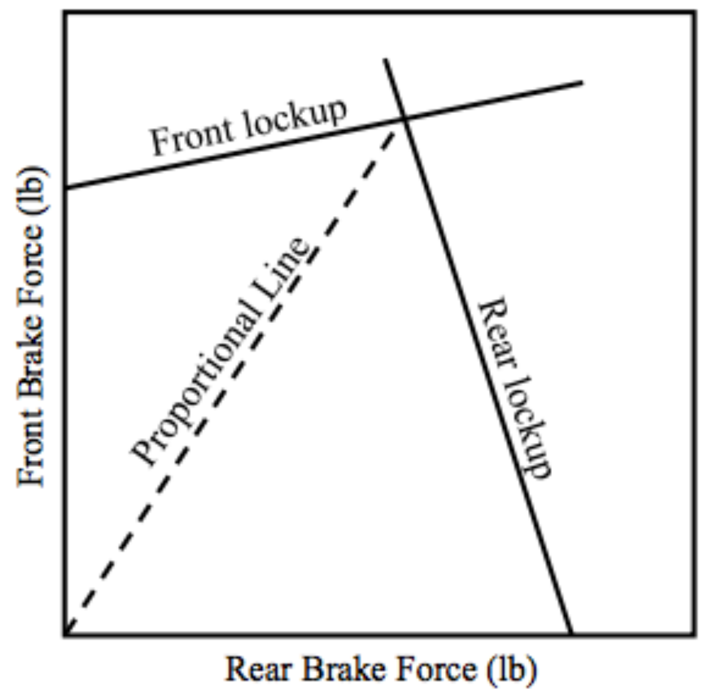

Figure 1: Maximum braking forces on the front and rear axles

During braking, a dynamic load transfer from the rear to the front axle occurs such that the load on an axle is the algebraic sum of the static and dynamic load contributions. The dynamic load transfer can be calculated as:

$$W_d = \frac{h}{L}\frac{W}{g}D_x \quad (1)$$

where, $\boldsymbol{h}$ is the height of the vehicle's center of gravity , $\boldsymbol{L}$ is the wheel base, $\boldsymbol{W}$ is the vehicle weight, $\boldsymbol{g}$ is the gravitational acceleration, and $\boldsymbol{D_x}$ is the deceleration. The front axle static load (W_{fs}) is calculated by:

$$W_{fs} = \frac{c}{L}W \qquad (2)$$

while the rear axle static load (W_{rs}) is:

$$W_{rs} = \frac{b}{L}W \qquad (3)$$

where, $\boldsymbol{c}$ is the distance from the CG to the rear axle and $\boldsymbol{b}$ is the distance between the CG and front axle. Thus the loads on the front and rear axles during braking can be calculated such as:

$$W_f = W_{fs} + W_d \qquad (4)$$

$$W_r = W_{rs} + W_d \qquad (5)$$

Thus, the maximum braking force on the front and rear axles are:

$$F_{maxf} = D_x W_f \qquad (6)$$

$$F_{maxr} = D_x W_r \qquad (7)$$

And the desired **β** can be determined by the ratio between the maximum forces, such that

$$\beta_{desired} = \frac{F_{maxf}}{F_{maxr}} \tag{8}$$

However, the actual **β** depends on the design of the actual braking system, i.e. the front and rear rotor diameters, the number of pistons in the front and rear calipers, the number of brake rotors in the front and rear, the implementation of the balance bar and proportion value, and the size of the brake pads. To simplify the problem, you are required to design the braking system, specifically the number of pistons in the front and rear calipers, the caliper piston diameter (assume all pistons in the front and the rear are the same size), and the front and rear rotor radii, to achieve an actual **β** equal to the value of the desired **β**. The actual **β** is calculated as:

$$\beta_{actual} = \frac{G_f}{G_r} \tag{9}$$

where, $\mathbf{G_f}$ is the front brake gain and $\mathbf{G_r}$ is the rear brake gain and can be calculated using Eqs 10 and 11, respectively.

$$G_f = 2D_x A_p R_{fe} N_{pf} \tag{10}$$

$$G_r = 2D_x A_p R_{re} N_{pr} \tag{11}$$

where, $\boldsymbol{A_p}$ is the caliper piston area, $\boldsymbol{R_{fe}}$ is the effective front rotor radius, $\boldsymbol{R_{fr}}$ is the effective rear rotor radius, $\boldsymbol{N_{pf}}$ and $\boldsymbol{N_{pr}}$ are the number of brakes in the front and rear, respectively. The effective radius can be calculated using Eq 12.

$$R_{xe} = R_{front\ rotor} - \frac{Brake\ Pad\ Height}{2} \tag{12}$$

Write a well-structured VBA sub to determine the number of caliper pistons (1, 2, or 3), the piston diameter (0.25”-0.5” with increment of 0.0625”), the front rotor radius (4”-6” with increment of 0.25”), and the rear rotor radius (3”-4” with increment of 0.25”). Use Arrays to tracks all your inputs and outputs. You are given the following vehicle parameters:

Parameter	Symbol	Value
Vehicle weight	W	600 lb
Wheel base length	L	68 in
CG height	H	12 in
Deceleration	D_x	1.3g
Front weight distribution	n/a	45%
Rear weight distribution	n/a	55%