

# Longitudinal Acceleration

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Braking

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# Grip between tyre and road

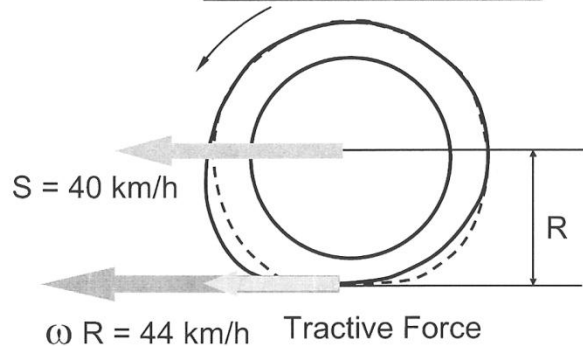
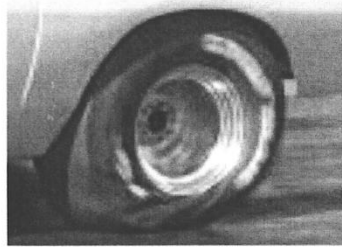
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Several mechanisms for generating  
'frictional' forces

- Hysteresis – interlocking of tyre and road
  - Adhesion – chemical bonding
  - Conventional friction- smooth surfaces rubbing
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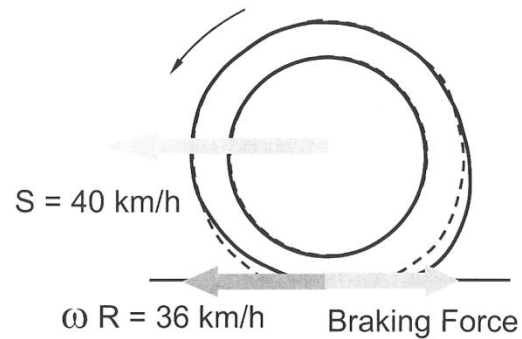
# Tyre characteristics

## Longitudinal Slip Definition



$$Sr = (44 - 40) / 40 = 10 \%$$

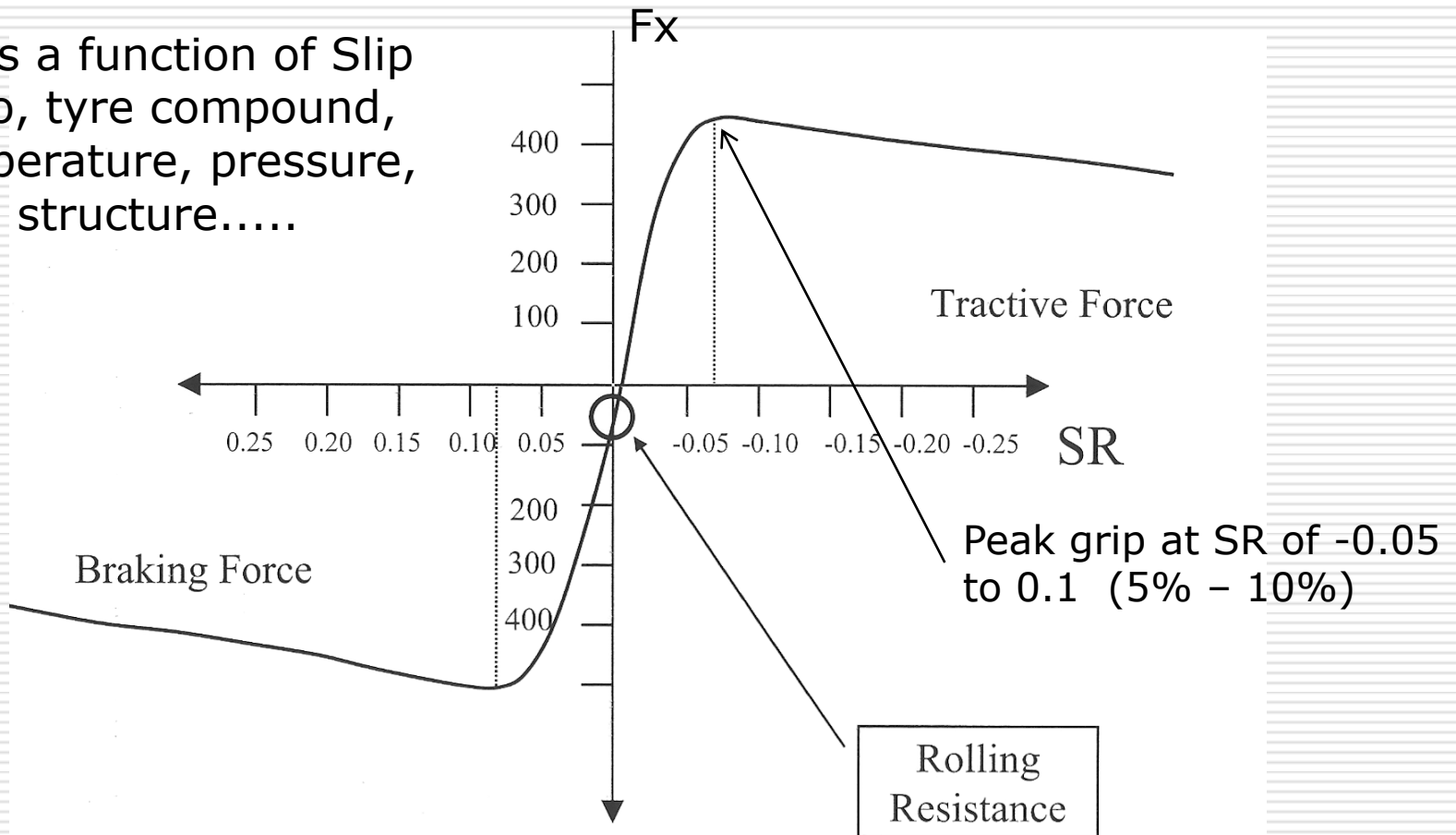
Sr is 'Slip Ratio' :



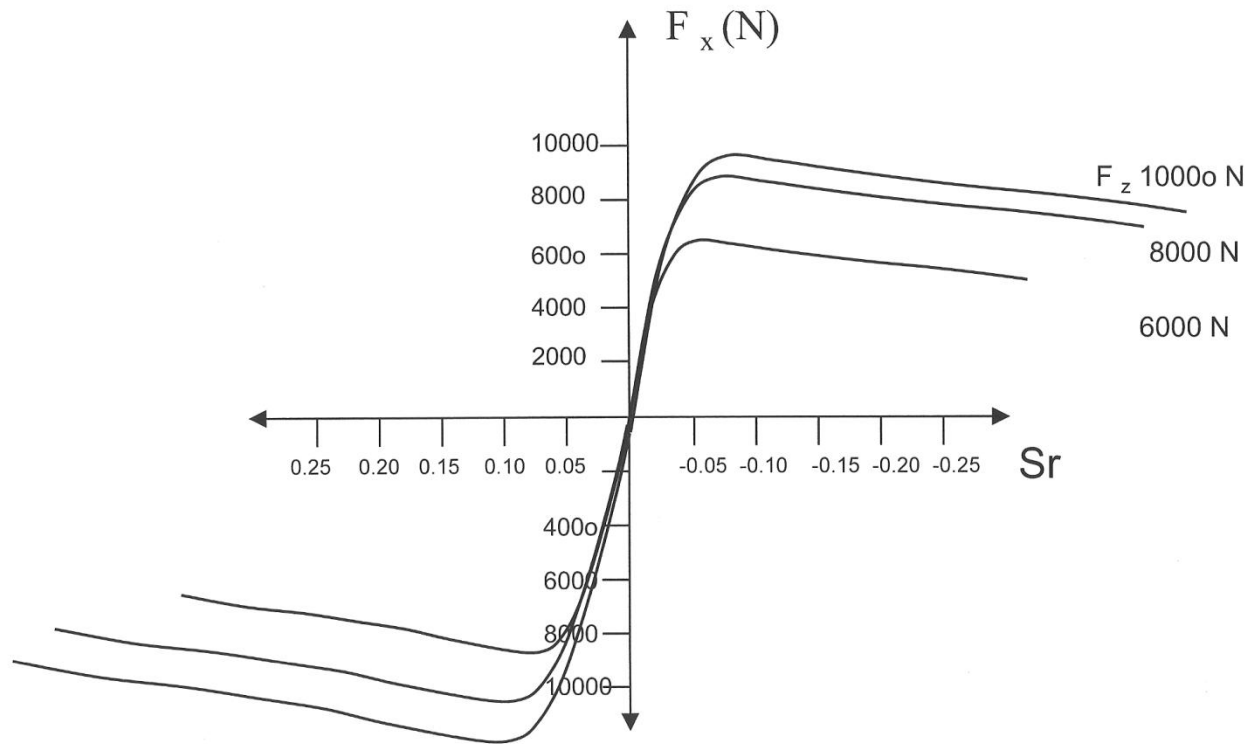
$$Sr = (40 - 36) / 40 = -10 \%$$

# Longitudinal Force , $F_x$

$F_x$ , is a function of Slip Ratio, tyre compound, temperature, pressure, road structure.....

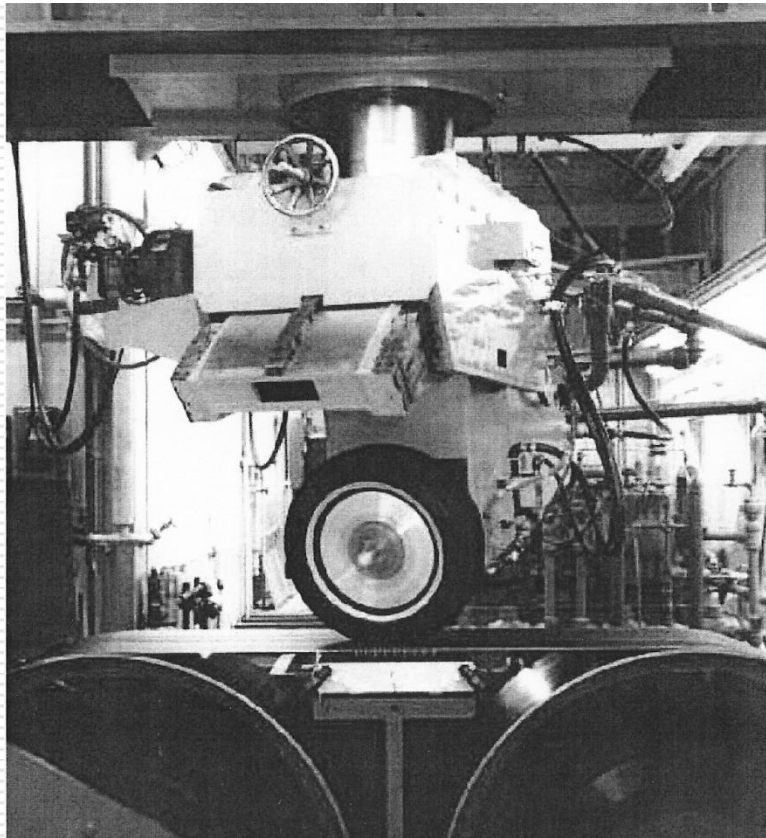


# Influence of vertical load



# Measuring the Longitudinal Friction Coefficient

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Using single tyre forces in a laboratory

[Tire Force Test.mp4](#)

# Track Test

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How could we obtain a value for the longitudinal friction coefficient of a tyre with a track test ? In your groups come up with an answer...

Clue 1

[How to make a stoppie with a van.mp4](#)

Clue 3

[Car Stoppie Fail.mp4](#)

Clue 2

[Car Stoppie 2.mp4](#)

$$\mu = F_x/F_z$$

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So, need to:

- Measure rate of deceleration and hence calculate longitudinal force  $F_x$
  - Calculate vertical load – from static load + weight transfer =  $F_z$
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# Example 1

## Find Static Wheel Loads

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### ☐ **Data:**

☐  $L = 2.5\text{m}$

☐  $M_{\text{usf}} = 76\text{ kg}$

☐  $M_{\text{usr}} = 82\text{ kg}$

☐  $a = 1.35\text{ m}$

☐  $b = 1.15\text{ m}$

☐  $M_{\text{tot}} = 800\text{ kg}$

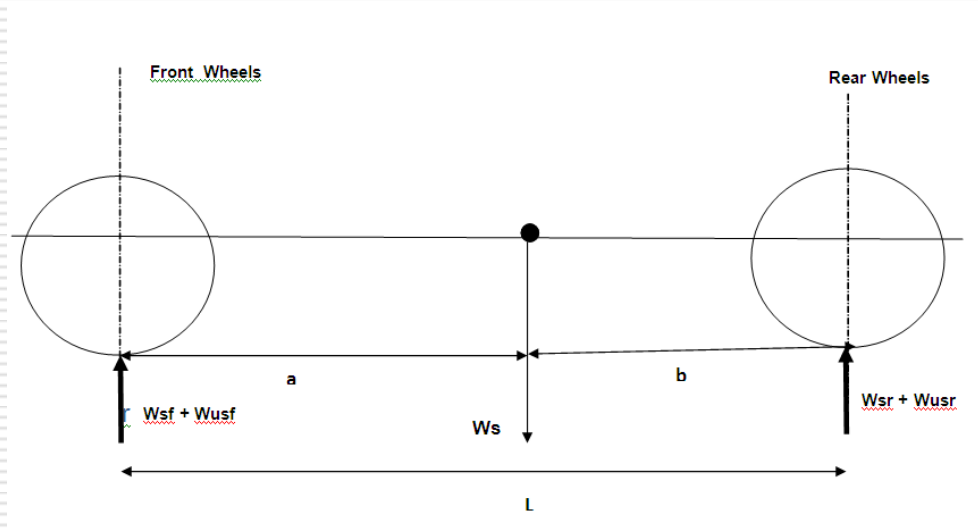
☐  $H = 0.375\text{m}$

☐  $a_x = 1.4g$

☐  $r = 0.275$

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# Static Load Distribution



For Sprung Mass element take moments about Rear wheel  $W_{sf} \times L = W_s \times b$

Front sprung load  $W_{sf} = \frac{W_s \times b}{L}$

# Static Load Distribution

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$$\frac{642 \text{ g} \times 1.15}{2.5} = 2897.09\text{N}$$

$$\text{Musf} = 76 \times 9.81 = 745.56\text{N}$$

$$\text{Total front load} = 3642.46\text{N}$$

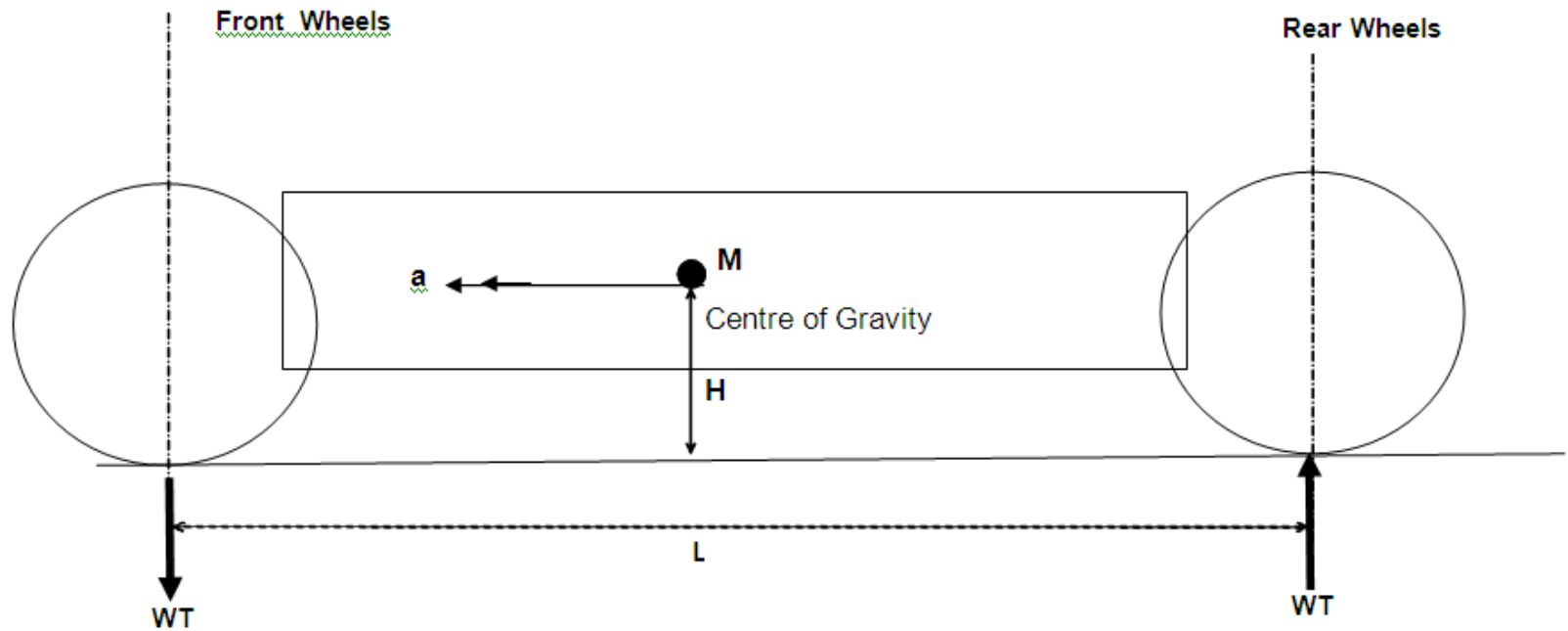
$$\text{Total weight} = 7848\text{N}$$

So static mass distribution is  
46.4% at the front

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# Simple Weight Transfer

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Simple, rigid car with no suspension

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Over turning moment =  $MaH$

Reaction moment =  $WT \times L$

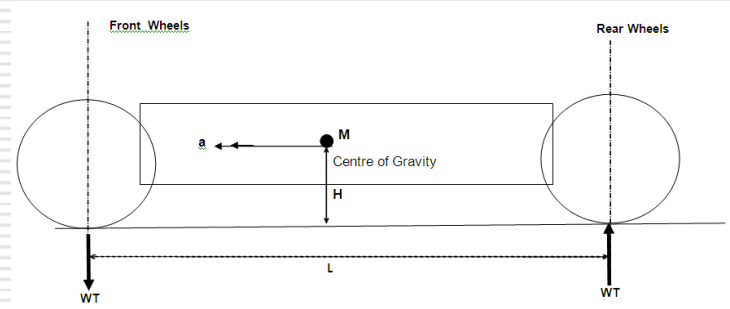
For equilibrium:-

Reaction = Overturning moment

$$WT \times L = MaH$$

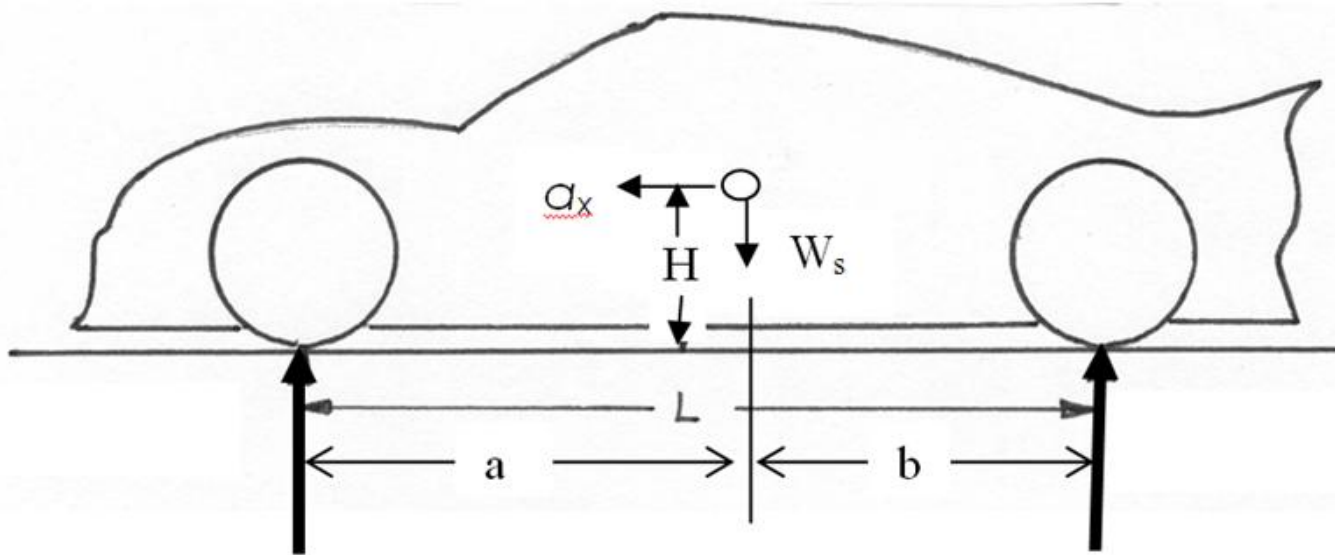
Giving

$$WT = \frac{MaH}{L}$$



# Load Distribution

Axle loads for the braking vehicle



$$W_{fb} = W_{usf} + \frac{W_s \times b}{L} + \text{Weight Transfer}$$

$$W_{rb} = W_{usr} + \frac{W_s \times a}{L} - \text{Weight Transfer}$$

# Static + Weight Transfer

The braking vehicle shown is assumed to be on level ground and aerodynamic effects are ignored the total reaction at the front axle of the braking vehicle is given by :

$$W_{fb} = W_{usf} + \frac{W_s \times b}{L} + \frac{W_s \times a_x \times H}{L \times g} + \frac{W_{us} \times a_x \times r}{L \times g}$$

Similarly for the rear

$$W_{rb} = W_{usr} + \frac{W_s \times a}{L} - \frac{W_s \times a_x \times H}{L \times g} - \frac{W_{us} \times a_x \times r}{L \times g}$$

$W_s$  = Total sprung weight =  $M_s \times g$

$W_{us}$  = Total unsprung weight =  $M_{us} \times g$

Suffix f or r denotes front or rear

## Vertical load Example 2

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- **Data:**

- $L = 2.5\text{m}$

- $M_{\text{usf}} = 80\text{ kg}$

- $M_{\text{usr}} = 80\text{ kg}$

- $a = 1.25\text{ m}$

- $b = 1.25\text{ m}$

- $M_{\text{tot}} = 1200\text{ kg}$

- $H = 0.35\text{m}$

- $a_x = 1.2g$

- $r = 0.28$

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# Giving

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$$W_{fb} = W_{usf} + \frac{W_s \times b}{L} + \frac{W_s \times a_x \times H}{L \times g} + \frac{W_{us} \times a_x \times r}{L \times g}$$

Can also be written as :

$$W_{fb} = M_{usf} \times g + \frac{M_s \times g \times b}{L} + \frac{M_s \times a_x \times H}{L} + \frac{M_{us} \times a_x \times r}{L}$$

$$W_{fb} = 80 \times g + \frac{1040 \times g \times 1.25}{2.5} + \frac{(1040 \times 1.2g \times 0.35)}{2.5} + \frac{(160 \times 1.2g \times 0.28)}{2.5}$$

$$= 784.8 + 5101.2 + 1714 + 210.95$$

$$= 7810.95 \text{ N ie } 66.35\% \text{ of total weight}$$

Now repeat the calculation for  
Example 1

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# Answers to Example 1

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$$M_s = 800 - (76 + 82) = 642 \text{ kg}$$

$$M_{us} = (76 + 82) = 158 \text{ kg}$$

$$W_{fb} = 745.56 + 2897.09 + 1322.58 + 238.69$$

$$W_{fb} = 5203.93 \text{ N}$$

$$W_{rb} = 804.42 + 3400.93 - 1322.58 - 238.69$$

$$W_{rb} = 2644.08 \text{ N}$$

Total 7848N

Front is 66.31% of Total weight when braking at 1.4g

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# Average coefficient of friction

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We know  $F_z$  so in Example 2

$$\begin{aligned} F_x &= Ma \\ &= 1200 \times 1.2g \end{aligned}$$

$$F_z = 1200g$$

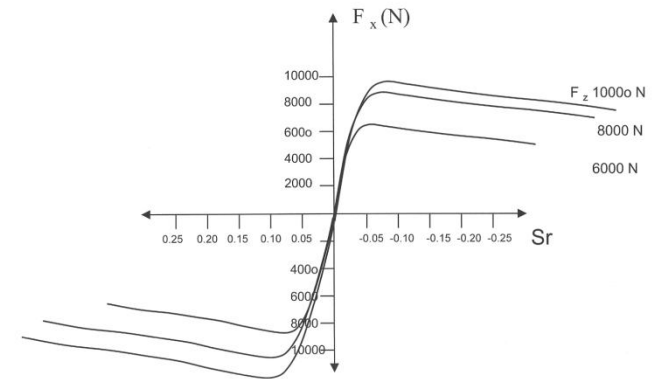
So the average  $\mu$  for Example 2  
 $= 1.2$

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But, in practice individual braking force will be modified as the  $\mu$  is dependent on vertical load.

$$F_{xf} + F_{xr} = \mu_f F_{zf} + \mu_r F_{zr}$$



# Back to the original question ...

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How could we obtain a value for the longitudinal friction coefficient of a tyre with a track test ? In your groups come up with an answer...

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# Individual Tyre $\mu$

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To find the  $\mu$  for an individual wheel we would need to determine the vertical load by calculation and then, the braking force it is capable of transmitting from the rate of deceleration achieved.

With only one pair of wheels braking..

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