

$$a_0 s^n + a_1 s^{n-1} + \dots + a_n = 0$$

$s^n$	$a_0$	$a_2$	$a_4$	$a_6 \dots$	$b_1 = \frac{a_1 a_2 - a_0 a_3}{a_1}$	$c_1 = \frac{b_1 a_3 - a_1 b_2}{b_1}$
$s^{n-1}$	$a_1$	$a_3$	$a_5$	$a_7 \dots$	$b_2 = \frac{a_1 a_4 - a_0 a_5}{a_1}$	$c_2 = \frac{b_1 a_5 - a_1 b_3}{b_1}$
$s^{n-2}$	$b_1$	$b_2$	$b_3$	$b_4 \dots$	$b_3 = \frac{a_1 a_6 - a_0 a_7}{a_1}$	$c_3 = \frac{b_1 a_7 - a_1 b_4}{b_1}$
$s^{n-3}$	$c_1$	$c_2$	$c_3$	$c_4 \dots$	$\vdots$	$\vdots$
$\vdots$						
$s^2$	$e_1$	$e_2$				
$s^1$	$f_1$					
$s^0$	$g_1$					

Routh's criteria

- # of roots with positive real parts is equal to # of changes in sign of the coefficients of the first column in the table
- necessary and sufficient condition for all roots to have negative real parts is for coefficients  $a_n$  to be positive and all terms in first column of table are positive

$$x(t) \neq \sum e^{st}$$

if 1 root has + real part  $\Rightarrow$  system unstable!

ex  $a_0 s^3 + a_1 s^2 + a_2 s + a_3 = 0$

$s^3$	$a_0$	$a_2$
$s^2$	$a_1$	$a_3$
$s^1$	$\frac{a_1 a_2 - a_0 a_3}{a_1}$	0
$s^0$	$a_3$	0

$$\frac{a_1 a_2 - a_0 a_3}{a_1} < 0 \Rightarrow \text{unstable}$$

$$a_1 a_2 - a_0 a_3 < 0$$

ex  $s^4 + 2s^3 + 3s^2 + 4s + 5 = 0$

$s^4$	1	3	5
$s^3$	2	4	0

2 roots with pos real parts

$$\begin{array}{c|cc}
 s^3 & 2 & 4 & 0 \\
 s^2 & 1 & 5 & \\
 s^1 & -6 & 0 & 0 \\
 s^0 & 5 & 0 & 0
 \end{array}$$

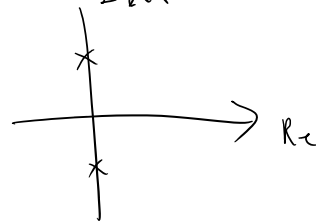
parts  
unstable!

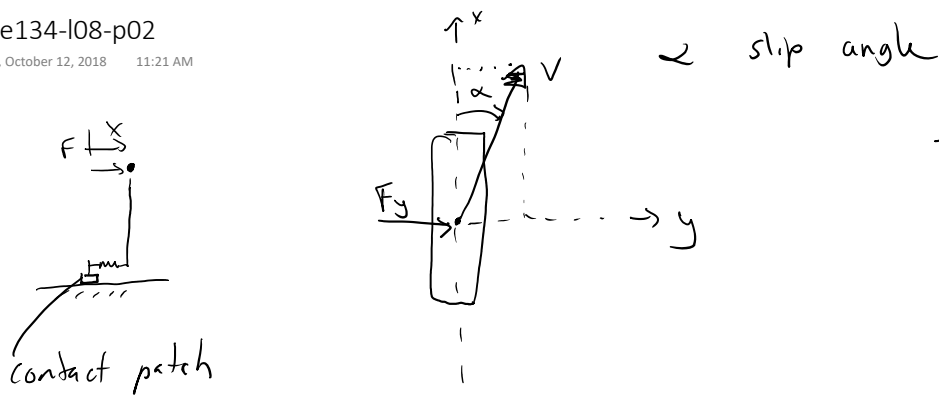
ex  $s^3 + 2s^2 + s + 2 = 0$

neutrally  
stable!

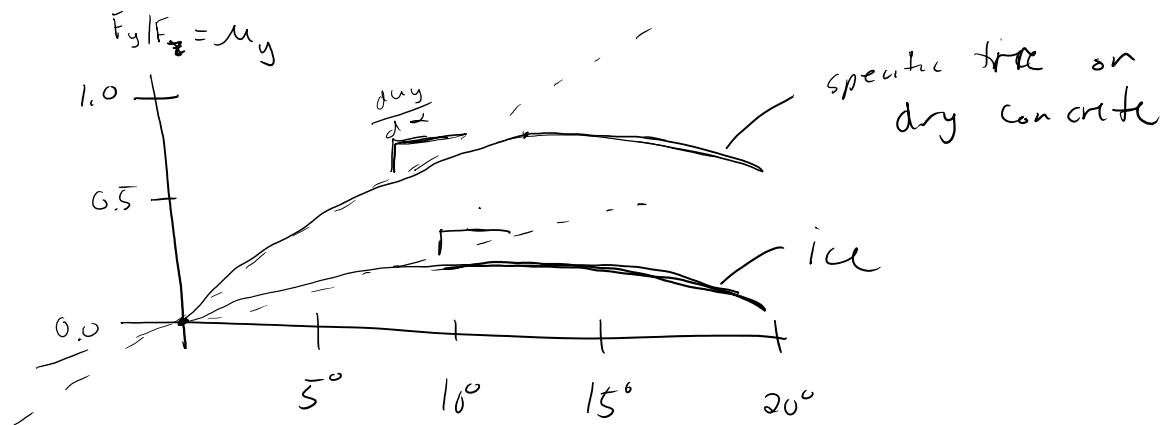
$$\begin{array}{cc}
 s^3 & 1 \quad 1 \\
 s^2 & 2 \quad 2 \\
 s^1 & 0 \approx \epsilon \quad 0 \\
 s^0 & \frac{4 \cdot 2 - 2 \cdot 2}{4} = 2
 \end{array}$$

zero  $\Rightarrow$  indicates root  $s = \pm j$   
Im





- scrub torque
- camber angle



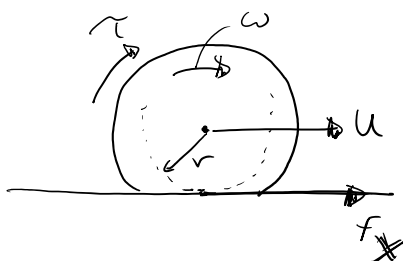
typ. auto  $\alpha$   
0 10°  
Cornering coefficient

$$\frac{F_y}{F_z} = \frac{d\mu_y}{d\alpha} \alpha \Rightarrow F_y = \underbrace{\frac{d\mu_y}{d\alpha}}_{C_\alpha} F_z \alpha$$

$C_\alpha$  cornering coeff.

$$F_y = C_\alpha \alpha$$

Longitudinal Force



$r$ : dynamic rolling radius

Long. slip

$$\overline{\text{Braking}} \\ S_B = \frac{U - r\omega}{U}$$

ang. vel,  $\omega$ , of wheel is less  
than the free rolling case

brakes locked  $S_B = 1$

free rolling  $S_B = 0$

$U = r\omega \Rightarrow$  free rolling

$$\overline{\text{accel}} \\ S_D = \frac{r\omega - U}{r\omega}$$

ang vel,  $\omega$ , of wheel is  
greater than the free rolling  
case.