Lecture 17: Circular motion

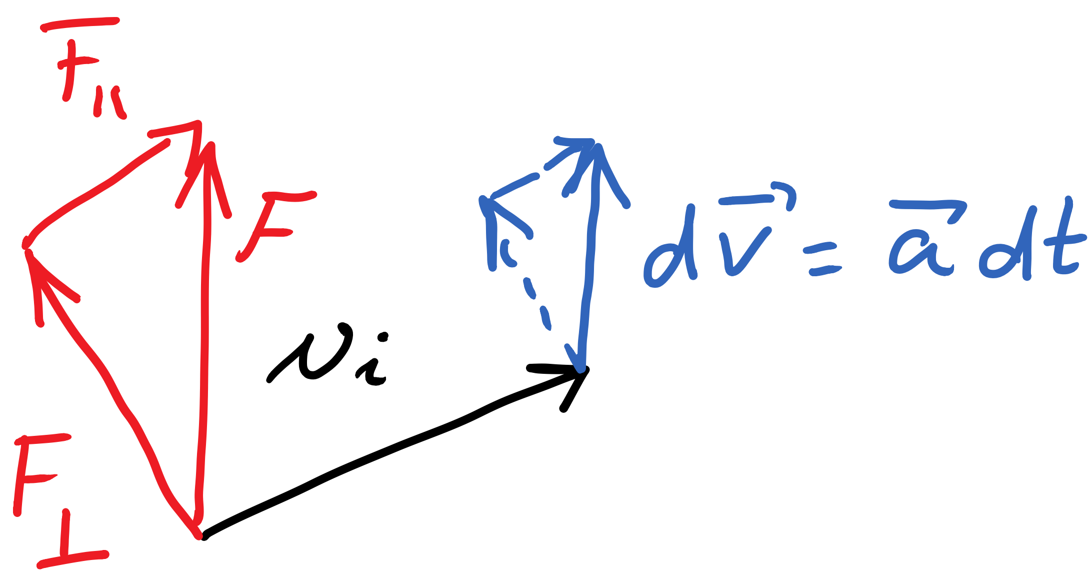
- Uniform circular motion
- Centripetal acceleration
- Problem solving with Newton's 2nd Law for circular motion

Effect of force components

Components of force parallel and perpendicular to velocity have different effects.

$F_{\parallel}$ causes change in magnitude of velocity vector (speed)

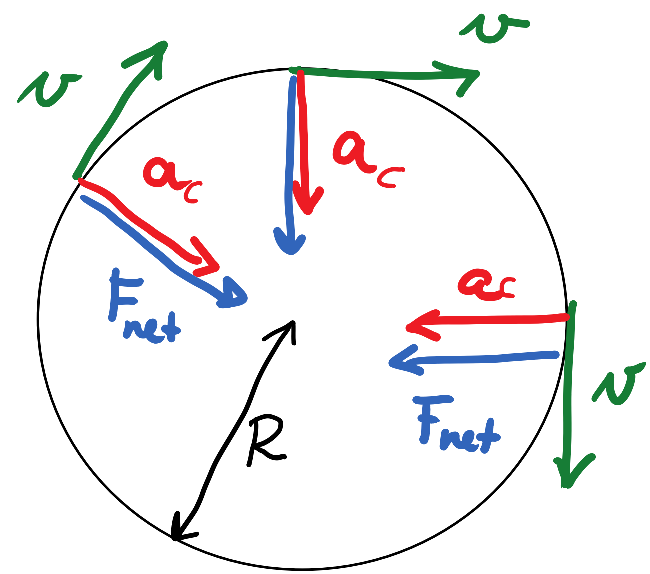
$F_{\perp}$ causes change in direction



Uniform circular motion

Motion in a circle with constant speed

Caution:
velocity is a vector and has magnitude and direction
$\Longrightarrow$ constant *speed* does not mean constant *velocity*. There will be acceleration!



$$a_c = \frac{v^2}{R}$$

Centripetal acceleration

Directed **towards center** of the circle

Forces create centripetal acceleration

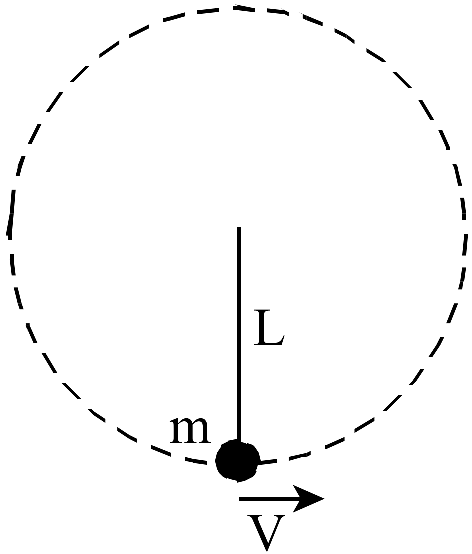
The acceleration towards the center must be created by a force that is acting towards the center.

$$\Sigma F_r = ma_c = m\frac{v^2}{R}$$

Example: http://www.walter-fendt.de/ph1i1e/carousel.htm

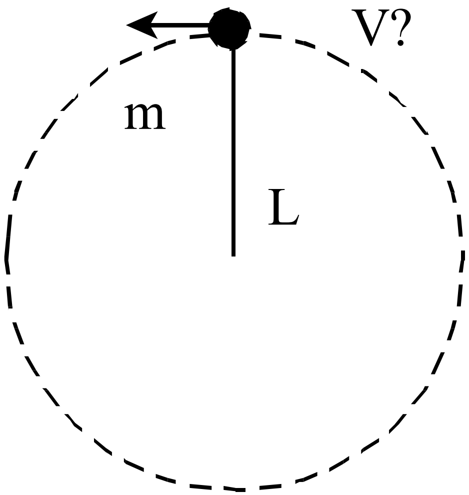
Example: ball in vertical circle

A Ball of mass *m* at the end of a string of length *L* is moving in a vertical circle. When it is at its lowest point, it has speed *V*. What is the tension in the string at that instant?



Example: ball in vertical circle- Minimum speed?

A Ball of mass *m* at the end of a string of length *L* is moving in a vertical circle. What must be its minimum speed at the highest point?

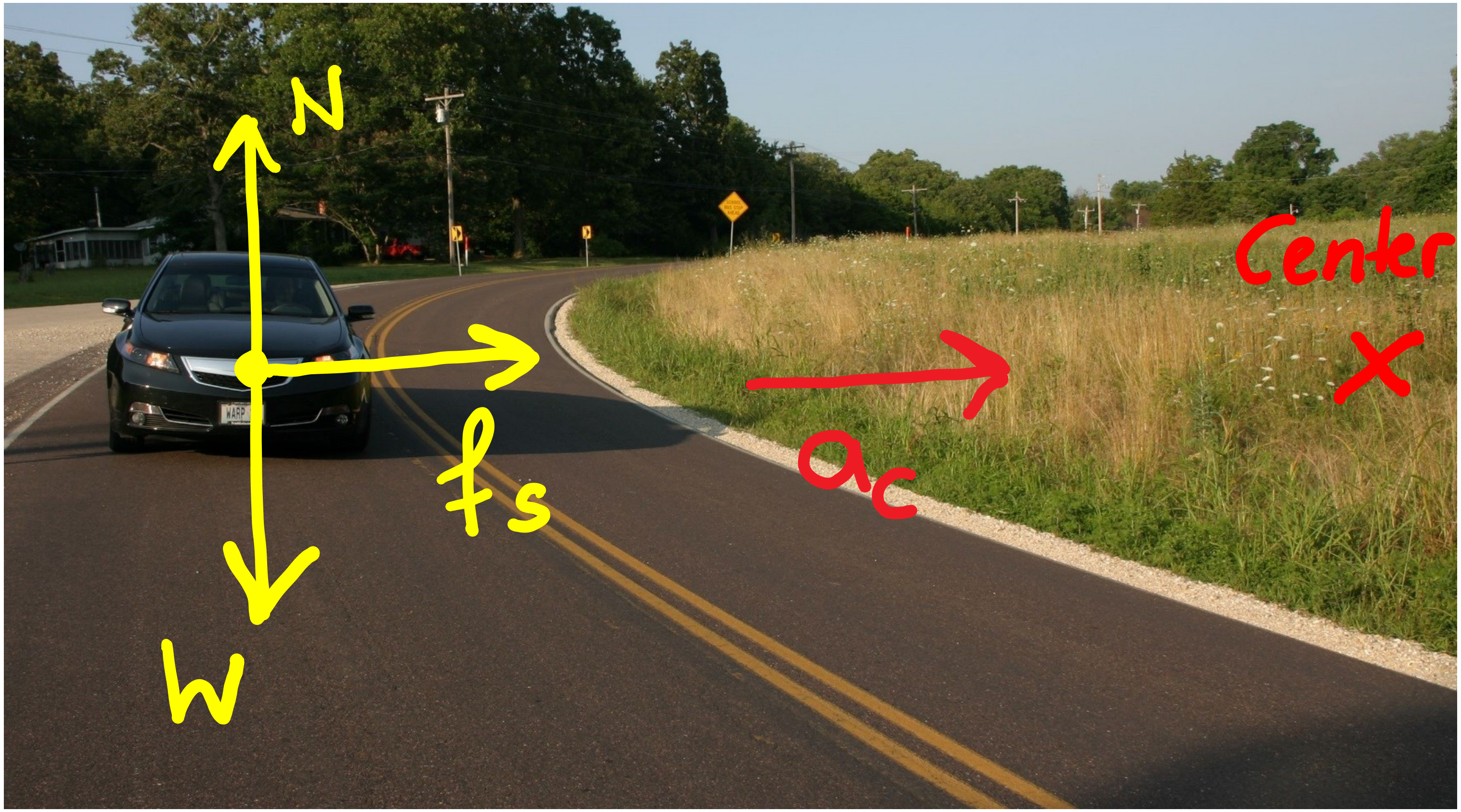


Demo: An instructor gets wet…

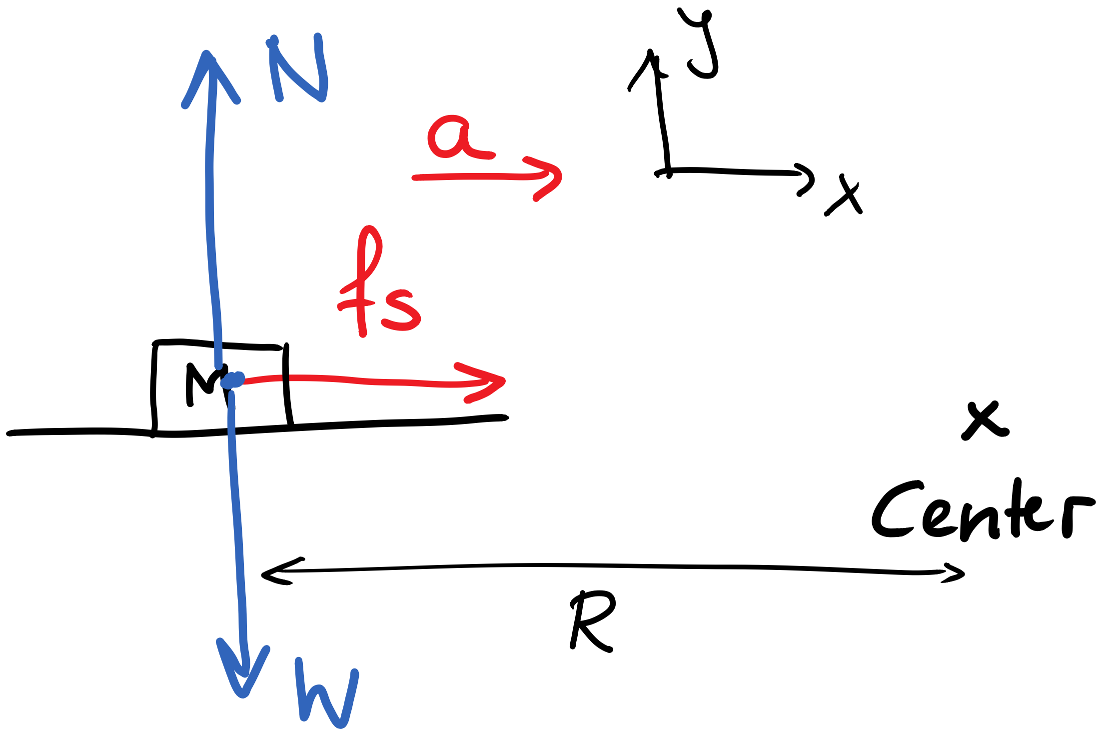
… or maybe not?

Twirling a bucket full of water in a vertical circle

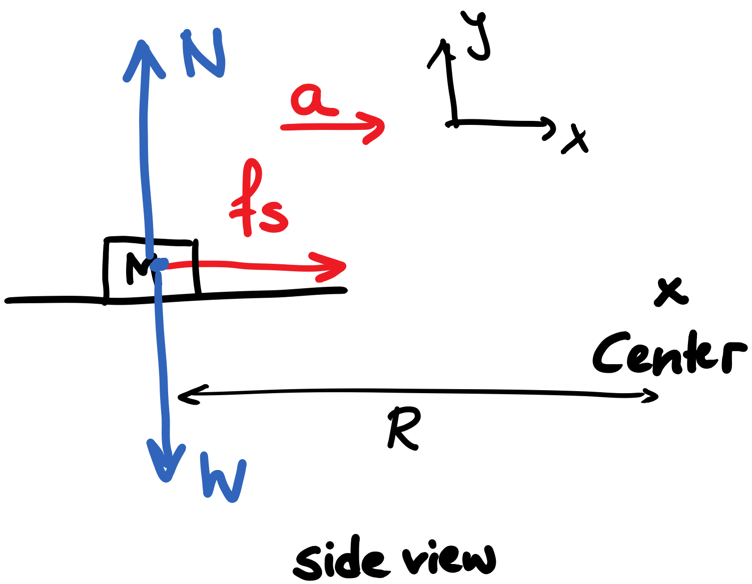
Car in flat curve



Car in flat curve



Car in flat curve worked out



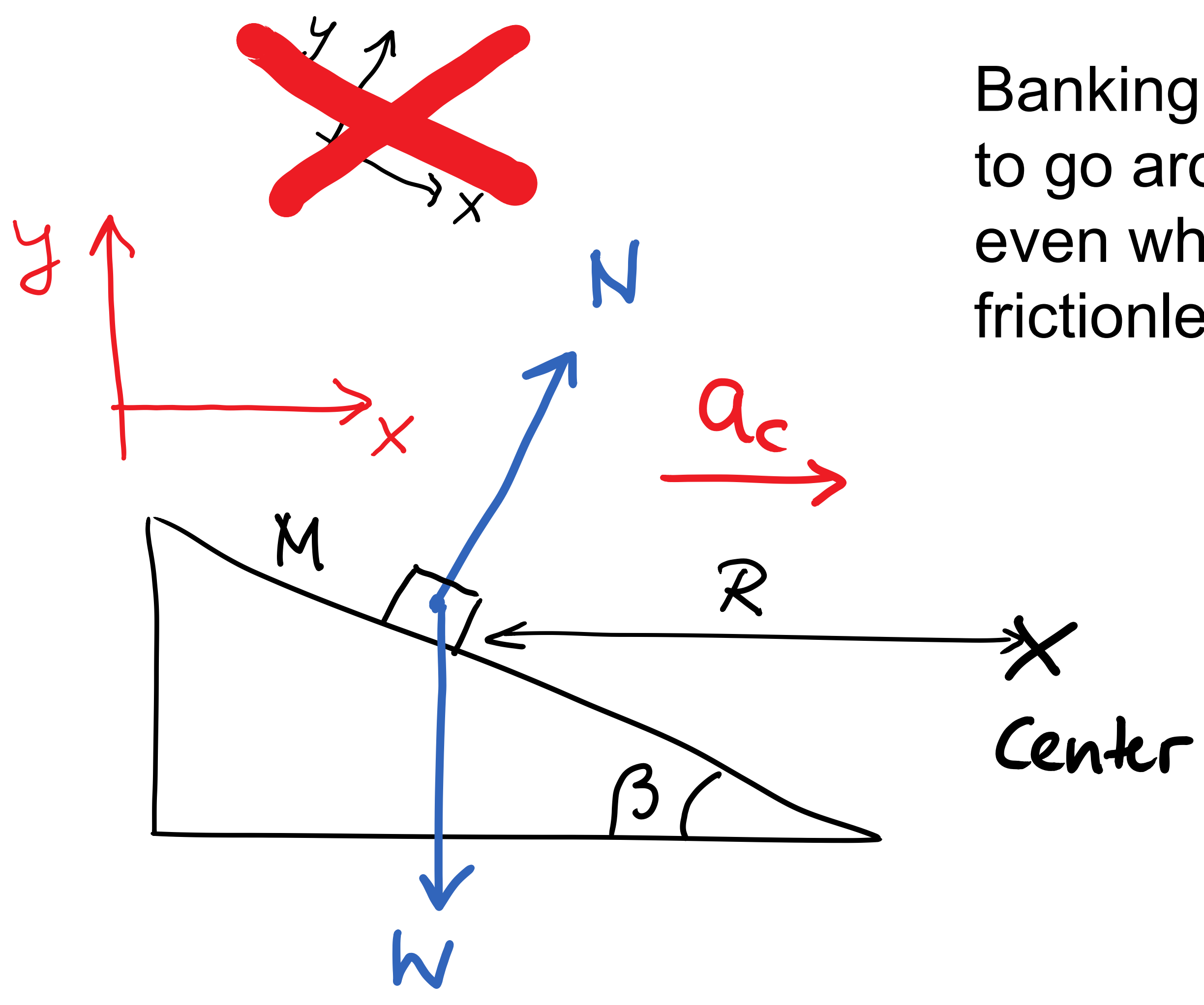
$$\Sigma F_x = ma_x$$
$$f_s = m\frac{v^2}{R}$$

$$\Sigma F_y = ma_y$$
$$N + (-W) = 0$$
$$N = mg$$

Maximum speed if: $f_s = f_{s\,max} = \mu N = \mu mg$

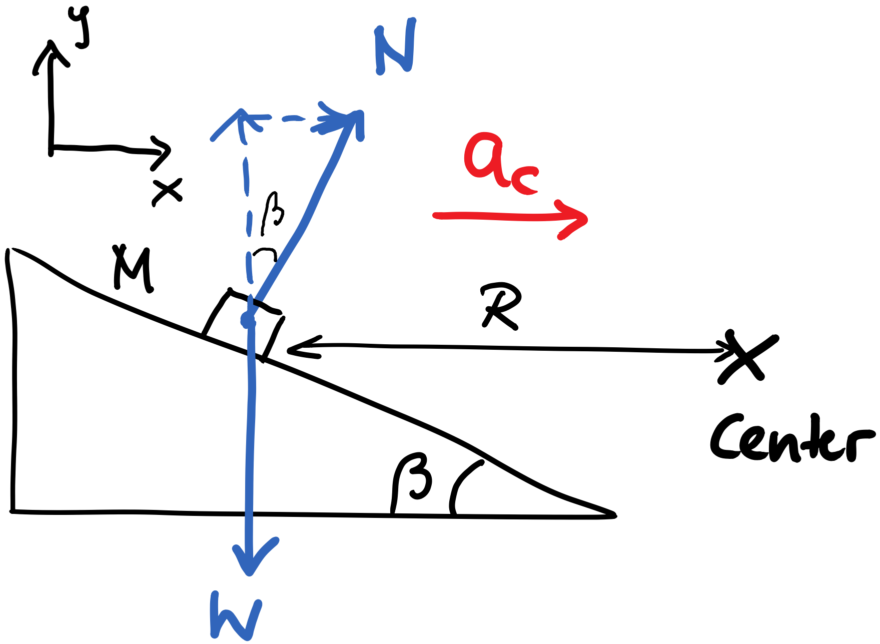
$$\boxed{v_{max} = \sqrt{\mu g R}}$$

Car in banked curve



Banking makes it possible to go around the curve even when the road is frictionless.

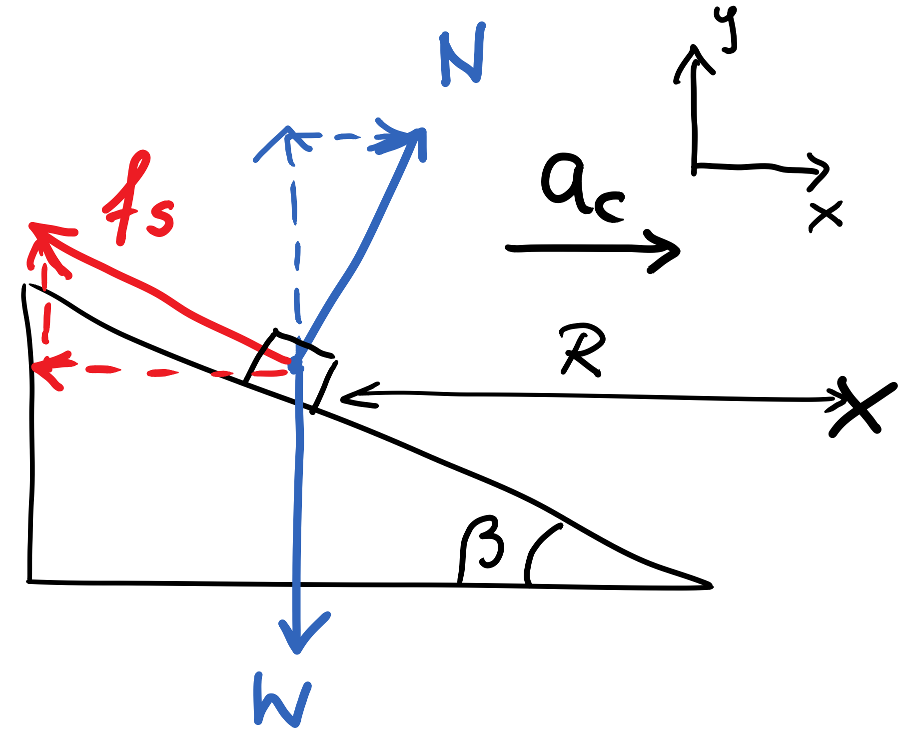
Car in banked curve: design speed



$v = v_D$: no friction

Car in banked curve with friction

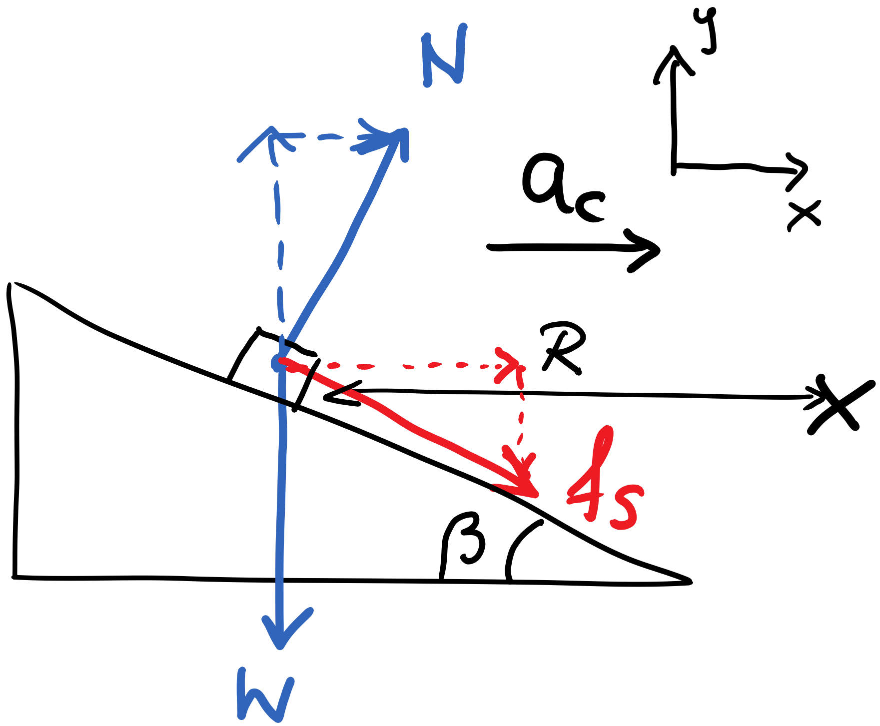
Going slower than design speed



$v < v_D$ f_s up incline

Car in banked curve with friction

Going faster than design speed



$v > v_D$ $\quad$ f_s down incline