Answer on Question #60162, Physics / Mechanics | Relativity |

18. A turn of radius 20 m is banked for the vehicles going at a speed of 36 km/h. If the coefficient of static friction between the road and the tyre is 0.4, what are the possible speeds of a vehicle so that it neither slips down nor skids up?

Solution:

Given:

$v = 36\frac{km}{hr} = 10\ m/s,$

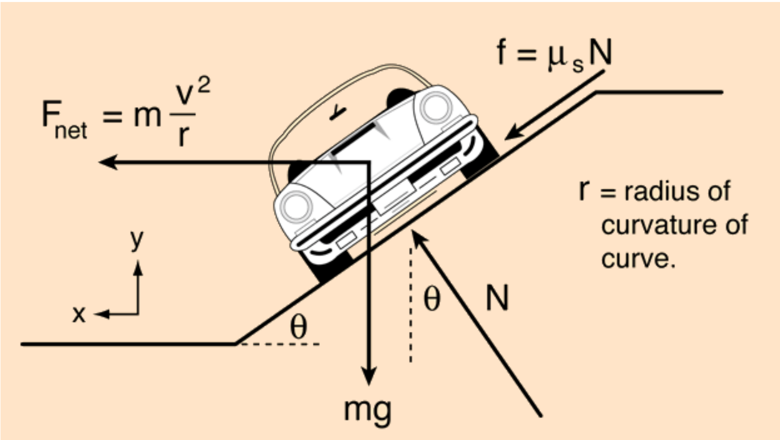
$r = 20\ m,$

$\mu_s = 0.4$

The road is banked with an angle,

$$\theta = \tan^{-1}\left(\frac{v^2}{rg}\right) = \tan^{-1}\left(\frac{10^2}{20 * 10}\right) = 26.57°$$

When the car travels at max speed it slips upward



Force equations at maximum speed v, at threshold of sliding up incline

$$\sum F_x = \frac{mv^2}{r} = N\sin\theta + \mu_s N\cos\theta$$

$$\sum F_y = 0 = N\cos\theta - \mu_s N\sin\theta - mg$$

Solving the pair of equations for the maximum speed v gives:

$$v_{max} = \sqrt{\frac{rg(\sin\theta + \mu_s\cos\theta)}{\cos\theta - \mu_s\sin\theta}}$$

$$v_{max} = \sqrt{\frac{20\cdot 10\cdot(\sin 26.57° + 0.4\cdot\cos 26.57°)}{\cos 26.57° - 0.4\cdot\sin 26.57°}} = 15\frac{m}{s} = 15\cdot 3.6\frac{km}{hr} = 54\frac{km}{hr}$$

For the case of sliding down

$$\sum F_x = \frac{mv^2}{r} = N\sin\theta - \mu_s N\cos\theta$$
$$\sum F_y = 0 = N\cos\theta + \mu_s N\sin\theta - mg$$

Solving the pair of equations for the minimum speed v gives:

$$v_{min} = \sqrt{\frac{rg(\sin\theta - \mu_s\cos\theta)}{\cos\theta + \mu_s\sin\theta}}$$

$$v_{min} = \sqrt{\frac{20\cdot 10\cdot(\sin 26.57° - 0.4\cdot\cos 26.57°)}{\cos 26.57° + 0.4\cdot\sin 26.57°}} = 4.085\frac{m}{s} = 4.085\cdot 3.6\frac{km}{hr} = 14.7\ \frac{km}{hr}$$

Answer: $v_{min} = 14.7\ \frac{km}{hr}$, $v_{max} = 54\frac{km}{hr}$.

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