Q- A car travels around a flat curved road with constant speed.
(a) Draw Free body diagram for the car.
(b) What is direction of net force acting on the car?
(c) Is there a maximum speed to negotiate the curve? If so find an expression for it.
(d) If the road is banked, derived an expression for the banking angle so that there will be no friction force between the road and tires.

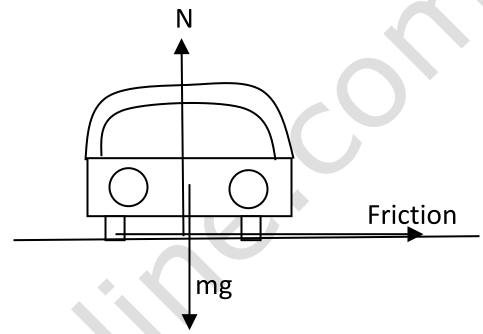
(a) Free body diagram

There are three forces acting on the car

1. The weight of the car, mg, vertically downward, exerted by earth gravity on the car.

2. The normal force of the ground N vertically upward, exerted by earth surface on the car.

3. The friction force between the earth and the tires, to the center of curved path, by earth surface on the car.



(b)
The vertical forces will be balanced but the horizontal friction force will be the net force acting on the car which behaves as the centripetal force required to move the car on the curved path.

(c)
The centripetal force required to move the car on the circular path is given by

$$F = mv^2/R$$

Here m is mass of the car, v is its speed and R is the radius of the circular track.

This centripetal force increases with increase in the speed of the car for a given radius of the curved path.

This centripetal force is provided by the friction between the car and the track. As we know that the friction is having a limiting (maximum) value given by μN where μ is the coefficient of friction, the centripetal force and hence the speed of the car is having a limiting value given by

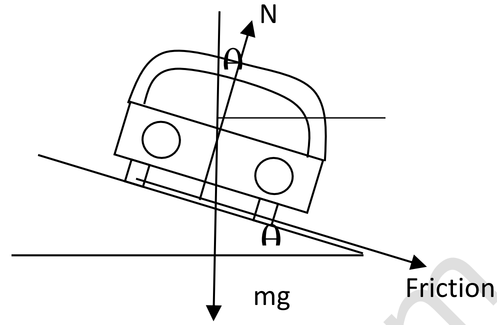
$$\mu N = \mu mg = \frac{mv_{max}^2}{R}$$

Gives, $v_{max}^2 = \mu gR$

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

If the speed of the car is greater than that the friction will not be sufficient to move it in the circular path and the car will skid out of the track.

(d) If there is no friction, there are only two forces acting on the truck



1. The weight of the truck, mg, vertically downward, exerted by earth gravity on it.
2. The normal force of the track N, normal to the track, exerted by the track surface on the car.

Resolving the normal reaction N horizontal and vertically, the vertical component N cos θ will balance the weight of the car and thus

$$N\cos\theta = mg$$

Or $$N = \frac{mg}{\cos\theta}$$

Now the horizontal component N sin θ is the only force providing the necessary centripetal force and thus we get

$$N\sin\theta = \frac{mv^2}{R}$$

Substituting for N from equation above we get

$$\frac{mg}{\cos\theta}\sin\theta = \frac{mv^2}{R}$$

Or $$\tan\theta = \frac{v^2}{gR}$$