PHYS151 Lecture 06

Ch 06 Force and Motion - II

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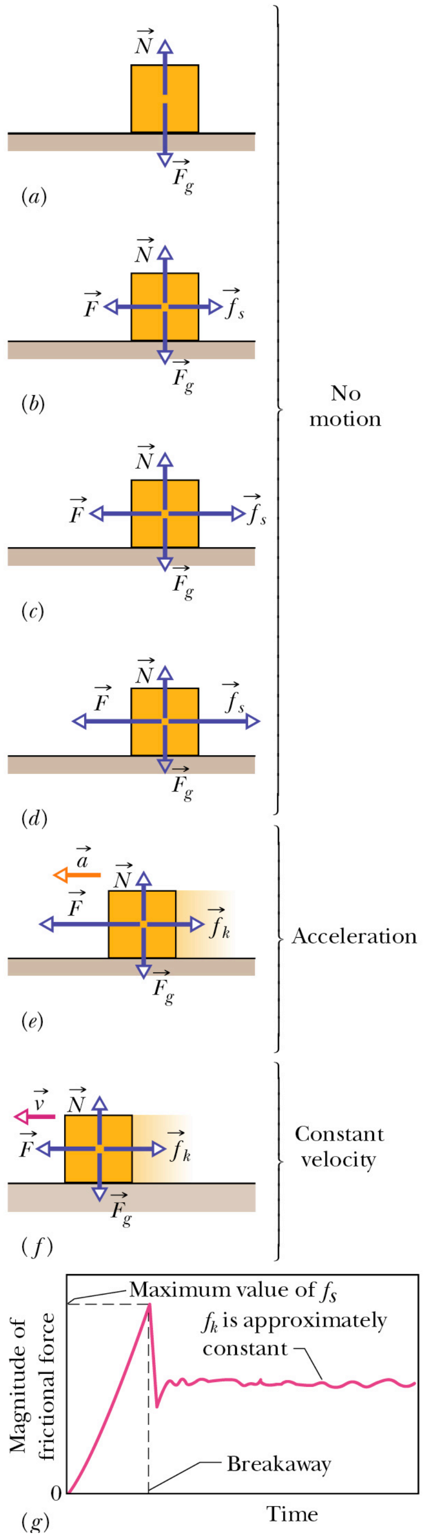


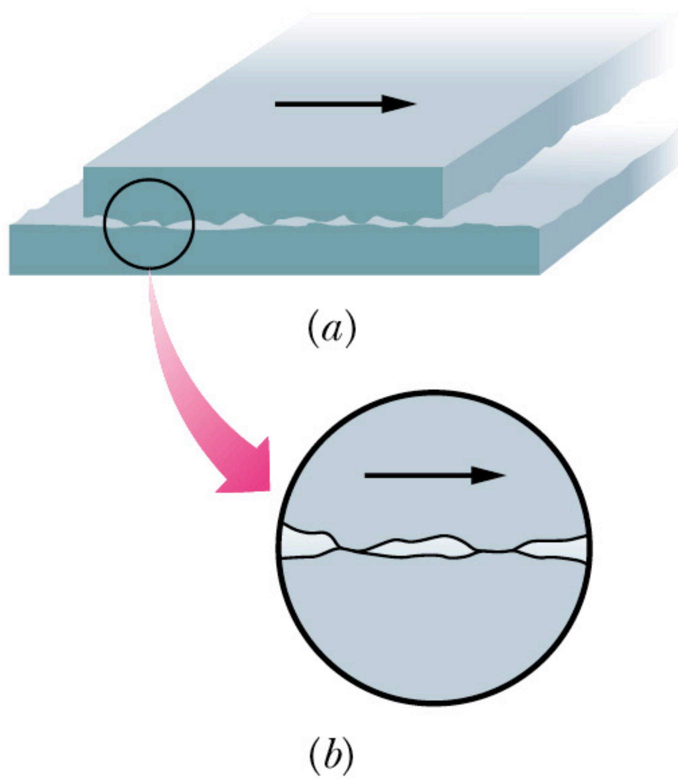
Friction

Frictional forces are unavoidable in our daily lives

ex) 20% of gasoline is used to counteract friction in the engine

$\vec{f}_s$ Static frictional force:
frictional force on a static body

$\vec{f}_k$ Kinetic frictional force:
frictional force on a moving body



Usually, for the maximum value,

$$f_k < f_s$$

Friction

Frictional forces are everywhere in our daily lives

It enables us to climb mountains

In 1982, an Air Florida 737 crashed into the 14th Street Bridge after departing Washington national Airport, killing 78 people on board.

(This picture shows that the Boeing 737 testbed during runway friction tests at Brunswick Naval Air Station, in 1985)

Properties of Friction

Property 1

The magnitude of $\vec{f}_s$ is equal to the component of the external force parallel to the surface

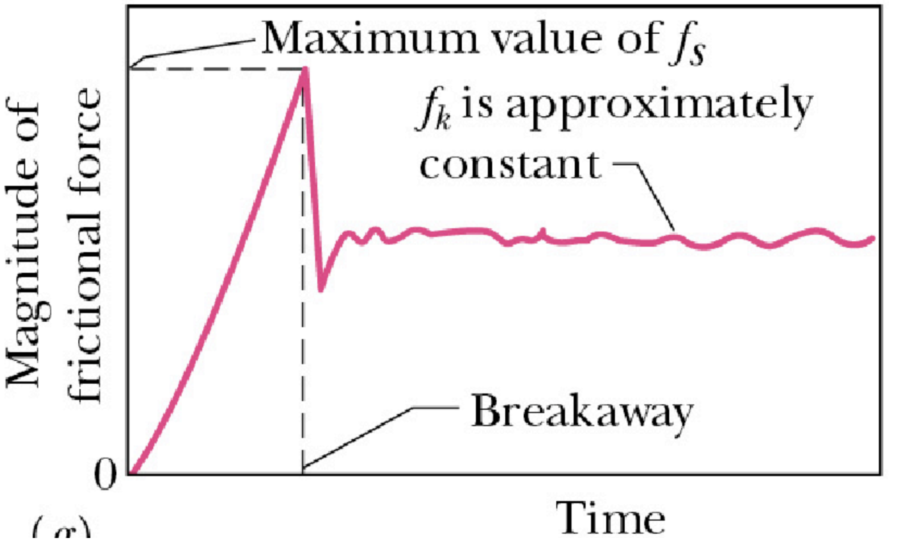
Property 2

The magnitude of $\vec{f}_s$ has a maximum value given by

$$f_{s,max} = \mu_s N$$

μ_s : coefficient of static friction

N : magnitude of the normal force



Property 3

The magnitude of $\vec{f}_k$ is given by

$$f_k = \mu_k N$$

μ_k : coefficient of kinetic friction

μ_s and μ_k are dimensionless

The Drag Force and Terminal Speed

When a body moves in fluid (gas or liquid), it experiences a force that opposes the relative motion. It is called the drag force $\vec{D}$

$$D = \frac{1}{2}C\rho A v^2$$

ρ : density of the fluid
C : drag coefficient
A : effective cross-sectional area

When a body falls off, Newton's 2nd law gives

$$D - F_g = ma$$

and it reaches to a constant speed eventually (terminal speed, v_t)

$$\frac{1}{2}C\rho A v_t^2 - F_g = 0$$

$$v_t = \sqrt{\frac{2F_g}{C\rho A}}$$

Object	Terminal Speed (m/s)
Sky diver	60
Rain drop	7

The Drag Force and Terminal Speed

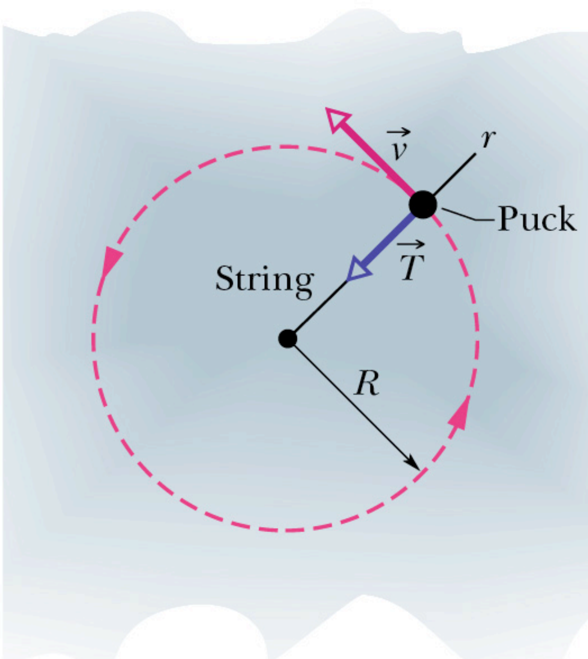
Skiers bend their body to minimize their effective cross-sectional area and thus the air drag acting on them

$$D = \frac{1}{2} C \rho A v^2$$

Uniform Circular Motion

Centripetal acceleration: $$a = \frac{v^2}{R}$$

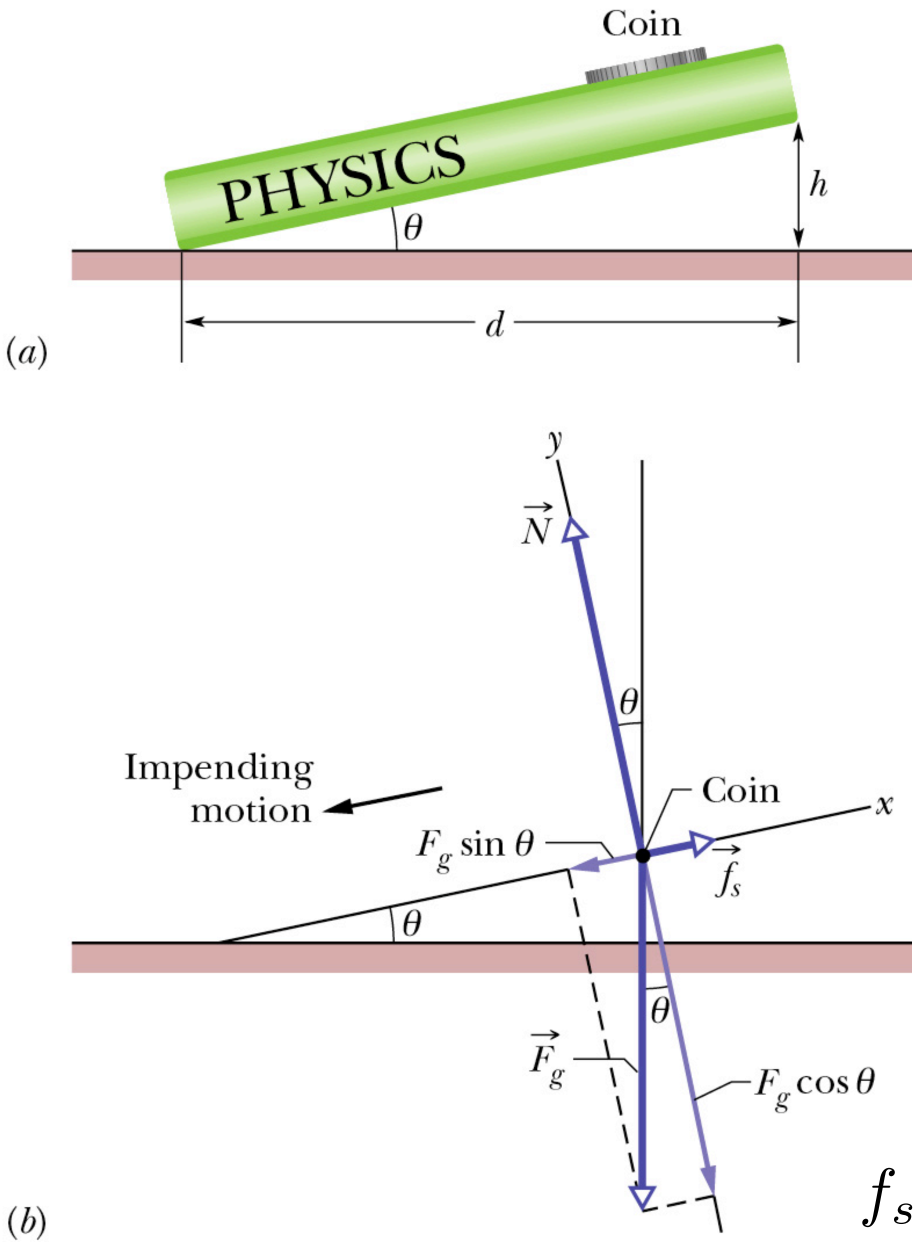
A centripetal force accelerates a body by changing the direction of the body's velocity



$$= m\frac{v^2}{R}$$ (magnitude of centripetal force)

The centripetal force is $\vec{T}$ in this figure

Friction



You find that when θ is increased to 13°, the coin is on the verge of sliding down the book (a slight increase beyond 13° produces sliding). What is the coefficient of static friction μ_s between the coin and the book?

$$\vec{F}_{net} = m\vec{a} \qquad \vec{f}_s + \vec{N} + \vec{F}_g = 0$$

For the x axis:

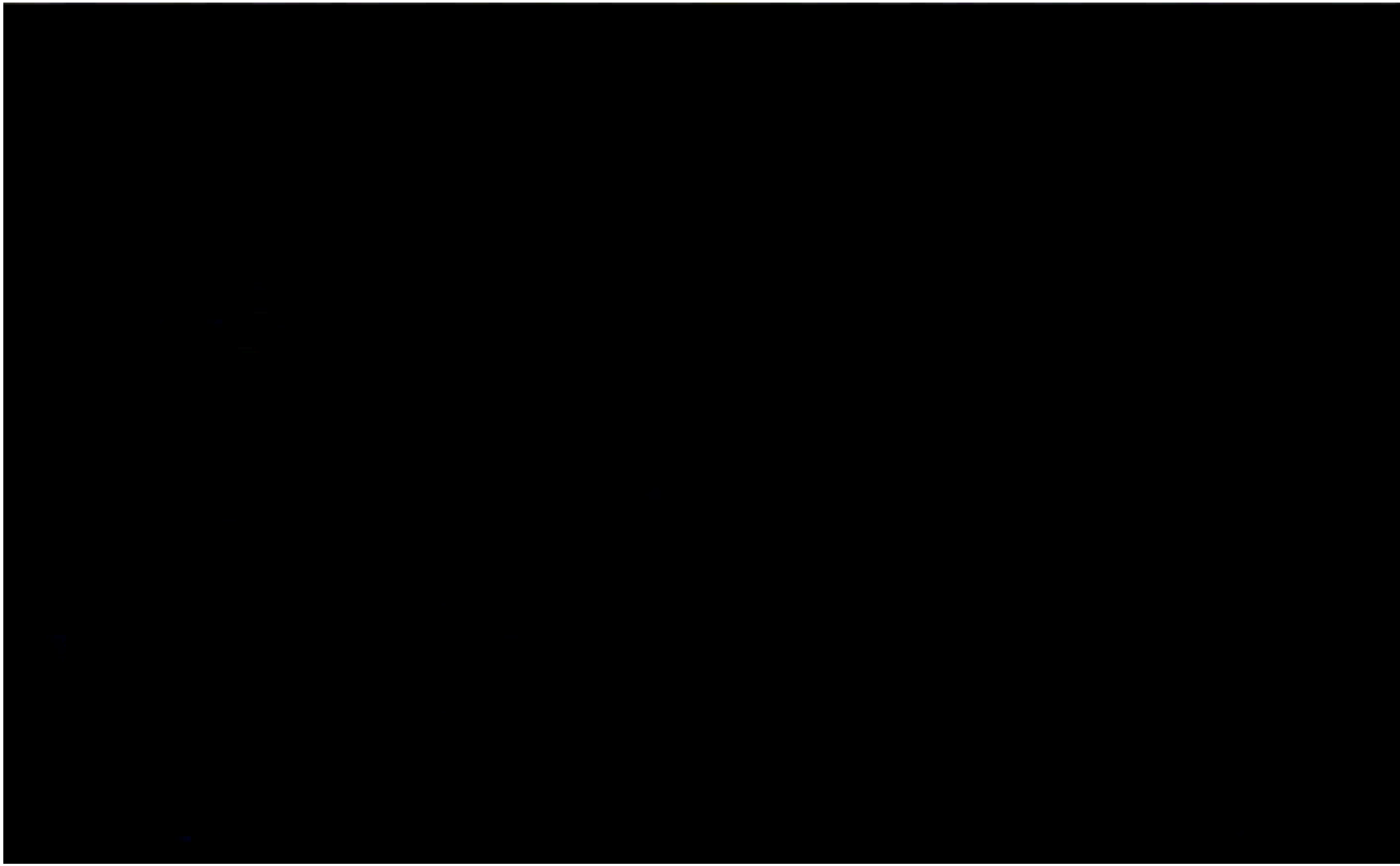
$$\begin{aligned} f_s + 0 - mg\sin\theta &= 0 \\ f_s &= mg\sin\theta \end{aligned}$$

For the y axis:

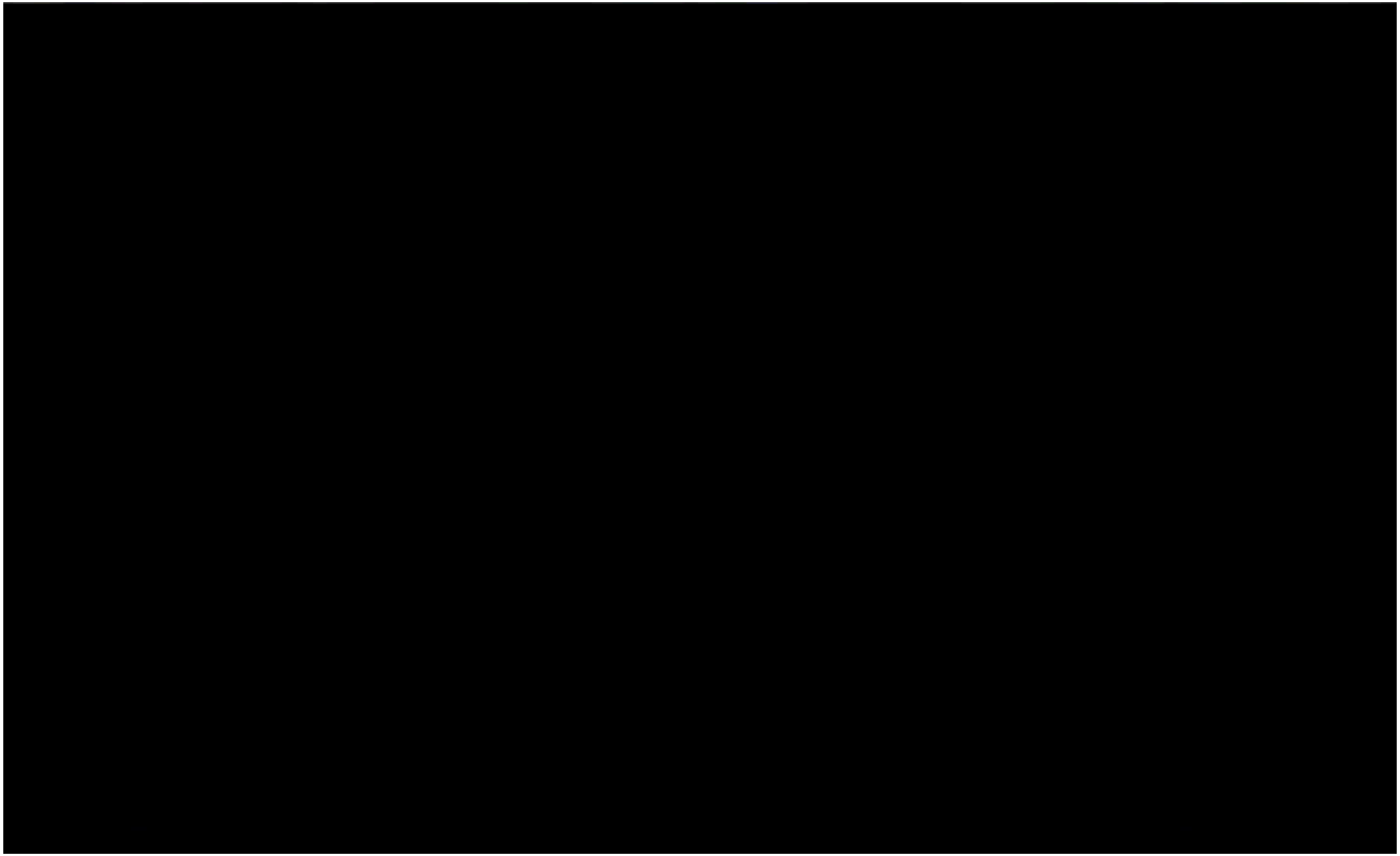
$$\begin{aligned} 0 + N - mg\cos\theta &= 0 \\ N &= mg\cos\theta \end{aligned}$$

$$f_s = \mu_s N \qquad \begin{aligned} \mu_s &= \frac{f_s}{N} = \frac{mg\sin\theta}{mg\cos\theta} = \tan\theta \\ &= \tan 13^0 = 0.23 \end{aligned}$$

Air Track Friction



Stability of Rolling Car



Summary

Static frictional force: $$f_{s,max} = \mu_s N$$

Kinetic frictional force: $$f_k = \mu_k N$$

Terminal velocity: $$v_t = \sqrt{\frac{2F_g}{C\rho A}}$$

Centripetal force: $$F = m\frac{v^2}{R}$$