PHY 107
Force and Motion *returns*

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OUTLINE

- Friction
- Properties of friction
- Drag force and Terminal Speed
- Uniform Circular Motion
- Application/Examples

Motivation

A lot of funds given to do research on the design of car:
Friction: Tyres
Drag force: Passing air
Centripetal force: Turns

Racing car

Friction

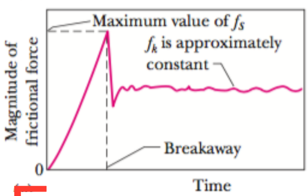
1. $F > f_{s,max}$: Motion; f_k

2. $F < f_{s,max}$: No motion; $f_s = F$

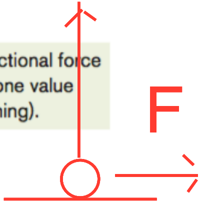
Static frictional force: one that is seen before the object starts moving

Kinetic frictional force: resistive force that is active when motion starts

Static frictional force can only match growing applied force.



Kinetic frictional force has only one value (no matching).



$$f_{s,max} = \mu_s F_N$$
$$f_k = \mu_k F_N$$

F	motion	f
2N	no	2N
4N	no	4N
6N	yes	f_k

Friction

EXAMPLE Friction, applied force at an angle

A block of mass $m = 3.0kg$ slides along a floor while a force $\overrightarrow{F}$ of magnitude 12.0 N is applied to it at an upward angle θ. The coefficient of kinetic friction between the block and the floor is $\mu_k = 0.40$.We can vary θ from 0 to 90° (the block remains on the floor). What θ gives the maximum value of the block's acceleration magnitude a?

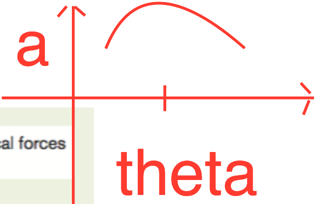
a=f(theta)

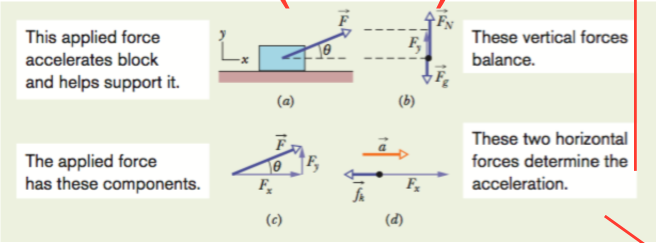
da/d(theta)= ...... = 0

Friction

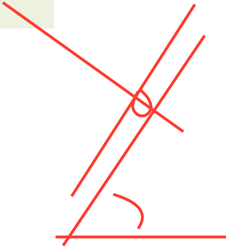
$F_{(g)}=mg$

$a=f(\theta)$





$$F_N - F_g + Fsin(\theta) = m(0)$$
$$Fcos(\theta) - \mu_k F_N = ma$$
$$a = \frac{F}{m}cos(\theta) - \mu_k(g - \frac{F}{m}sin(\theta))$$
$$\frac{da}{d\theta} = -\frac{F}{m}sin(\theta) + \mu_k \frac{F}{m}cos(\theta) = 0$$
$$tan(\theta) = \mu_k$$
$$\theta = 22^\circ$$



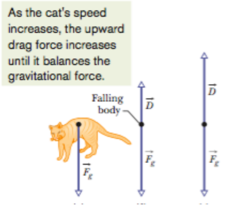
$F_{(N)}=mg-Fsin(\theta)$

Drag and Terminal Speed

The body experiences a drag force that opposes the relative motion and points in the direction in which the fluid flows relative to the body. We examine only cases in which air is the fluid, the body is blunt.

$D = 0.5 C\rho A v^2$

The drag coefficient C (typical values range from 0.4 to 1.0) is not truly a constant for a given body because if v varies significantly, the value of C can vary as well.



$D - F_g = ma$

After a very long time, the speed no longer increases (terminal speed) $\rightarrow 0.5 C\rho A v_t^2 - F_g = 0$

Terminal Speed

A=pi*R^2

EXAMPLE Terminal Speed of falling raindrop
A raindrop with radius $R = 1.5mm$ falls from a cloud that is at height $h = 1200m$ above the ground. The drag coefficient C for the drop is 0.60. Assume that the drop is spherical throughout its fall. The density of water ρ_w is $1000kg/m^3$, and the density of air ρ_a is $1.2kg/m^3$

Solution:

$F_g = V\rho_w g = (4/3)\pi R^3 \rho_w g$

$v_t = \sqrt{(\frac{2F_g}{C\rho_a A})}$

$v_t = 7.4m/s$

F_(g)=mg
=(den*vol) g
=(rho_(w)*vol) g
=rho_(w)*(4/3)*pi*R^3 * g

Uniform Circular motion

A body moves in a circle (or a circular arc) at constant speed v, it is said to be in uniform circular motion. Also recall that the body has a centripetal acceleration (directed toward the center of the circle) of constant magnitude given by $a = \frac{v^2}{R}$

Rounding a curve in a car: While the car moves in the circular arc, it is in uniform circular motion; that is, it has an acceleration that is directed toward the center of the circle.

By Newton's second law, a force must cause this acceleration.

The force must also be directed toward the center of the circle.

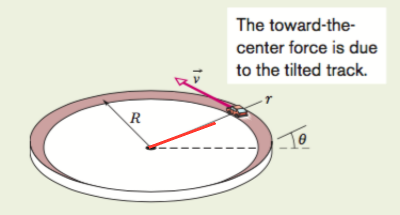
Thus, it is a centripetal force, where the adjective indicates the direction. In this example, the centripetal force is a frictional force on the tires from the road; it makes the turn possible.

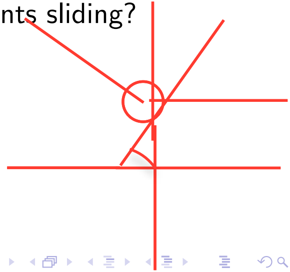
F_(c)=m(v^2 /R)

Uniform Circular motion

EXAMPLE Car in banked circular turn

Curved portions of highways are always banked (tilted) to prevent cars from sliding off the highway. When a highway is dry, the frictional force between the tires and the road surface may be enough to prevent sliding. When the highway is wet, however, the frictional force may be negligible, and banking is then essential. Figure represents a car of mass m as it moves at a constant speed v of $20m/s$ around a banked circular track of radius $R = 190m$. (It is a normal car, rather than a race car, which means any vertical force from the passing air is negligible.) If the frictional force from the track is negligible, what bank angle θ prevents sliding?

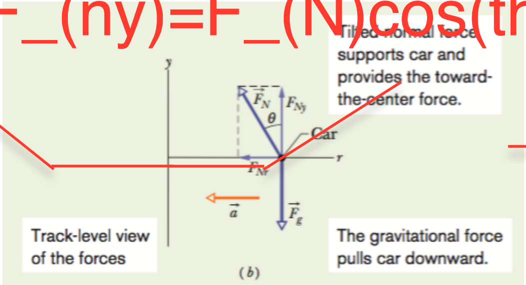


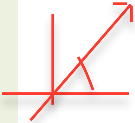


Uniform Circular Motion

F_(nr)=F_(N)sin(theta)

F_(ny)=F_(N)cos(theta)





Radial: $-F_N sin(\theta) = m(-\frac{v^2}{r})$

Vertical: $F_N cos(\theta) - mg = 0$

$tan(\theta) = \frac{v^2}{gr}$

$\theta = 12°$

F_(c)=mv^2/R

-F_(N)sin(theta)

=m(-v^2/R)

Some important problems

Fundamentals of Physics by Halliday/Resnik (Edition: Extended 9th)
Properties of friction: 5,9,11,17
Uniform Circular Motion: 51, 57

Reference

Fundamentals of Physics by Halliday and Resnik