Physics 121.
Lecture 06.

Carry-on Luggage.

Physics 121.
Lecture 06.

- Topics:
  - Course announcements
  - Quiz
  - Newton's Law of Motion:
    - Review of Newton's First, Second, and Third Law of Motion
    - Problem Solving Strategies
  - Friction:
    - Static and Kinetic Friction
    - Rounding a Curve
    - Terminal Velocity

Physics 121.
Course announcements.

- Homework set # 2 due on Saturday morning, February 7, at 8.30 am.

- Homework set # 3 will be due next week on Saturday morning, February 14, at 8.30 am.

- As part of homework set # 3 you will be asked to download and install loggerPro from the Physics 121 website and install it on your computer. The software runs on both Windows and Mac OSX. We will be using this tool to start carrying out video analysis on homework set # 4.

Physics 121.
Course announcements.

- In order to access the restricted areas of the Physics 121 website (containing solutions to homework assignments and exams), you will need the use the username and password combinations distributed via email on Saturday.
- This same combination will give you access to the installers of the loggerPro software.

Problem 1
The data shown in Fig. 1 are summarized in Table 1.

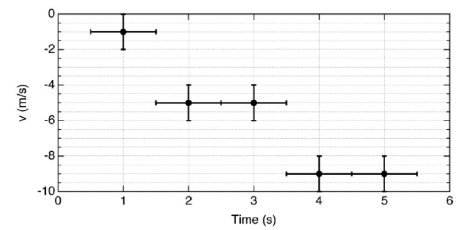


Figure 1: Measured velocity as function of the measured time.

t (s)	v (m/s)	a (m/s^2)	σ_a (m/s^2)	Weight (s^4/m^2)
1	-1	-1.00	1.11	0.8
2	-5	-2.50	0.80	1.6
3	-5	-1.67	0.43	5.3
4	-9	-2.25	0.38	7.1
5	-9	-1.80	0.26	13.8

Table 1: Data obtained from Fig. 1

The calculated acceleration a is equal to

$$a = \frac{v}{t} \tag{1}$$

The error in the acceleration a is equal to

$$\sigma_a = \sqrt{\left(\frac{\partial a}{\partial t}\right)^2 \sigma_t^2 + \left(\frac{\partial a}{\partial v}\right)^2 \sigma_v^2} = \sqrt{\left(-\frac{v}{t^2}\right)^2 \sigma_t^2 + \left(\frac{1}{t}\right)^2 \sigma_v^2} = a\sqrt{\left(\frac{\sigma_t}{t}\right)^2 + \left(\frac{\sigma_v}{v}\right)^2} \tag{2}$$

Looking at Fig. 1, you see that the error in t is 0.5 s and the error in v is 1 m/s and these errors have been used to determine the errors in a shown in Table 1. The table shows that the error in a is different for each data point.
In order to estimate the acceleration, we must take the weighted average of the 5 values of a shown in Table 1 (note: you need to use the weighted average since the error in each data point, and thus its weight, differs):

$$a = \frac{\sum_{i=1}^{5} w_i a_i}{\sum_{i=1}^{5} w_i} \tag{3}$$

Quiz.

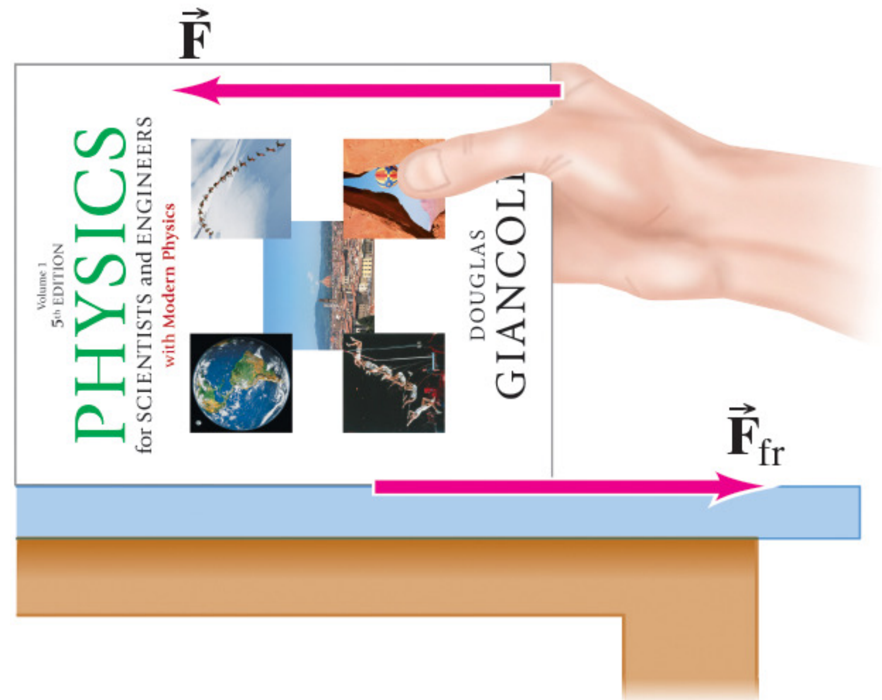
- Let's practice what we learned (and read).

A quick review:
Newton's first law of motion.

- First Law:

  Consider a body on which no net force acts. If the body is at rest, it will remain at rest. If the body is moving with constant velocity, it will continue to do so.

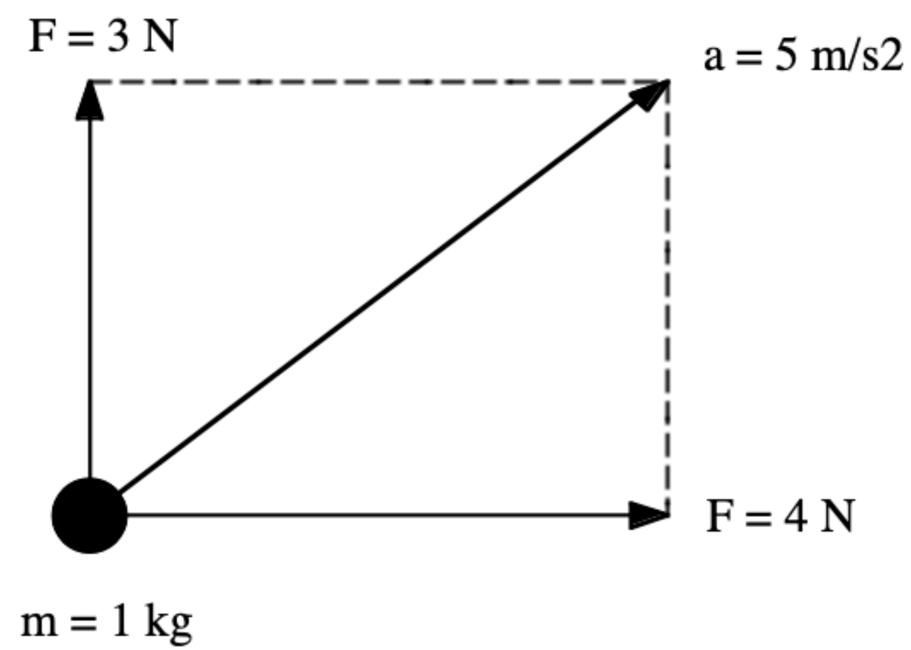
- Notes:
  - **Net force:** sum of ALL forces acting on the body.
  - An object at rest and an object moving with constant velocity both have **no acceleration**.



A quick review:
Newton's second law of motion.

Second Law:

The acceleration of an object is directly proportional to the net force acting on it and it inversely proportional to its mass. The direction of the acceleration is in the direction of the net force acting on the object:



$$\sum \vec{F} = m\vec{a}$$

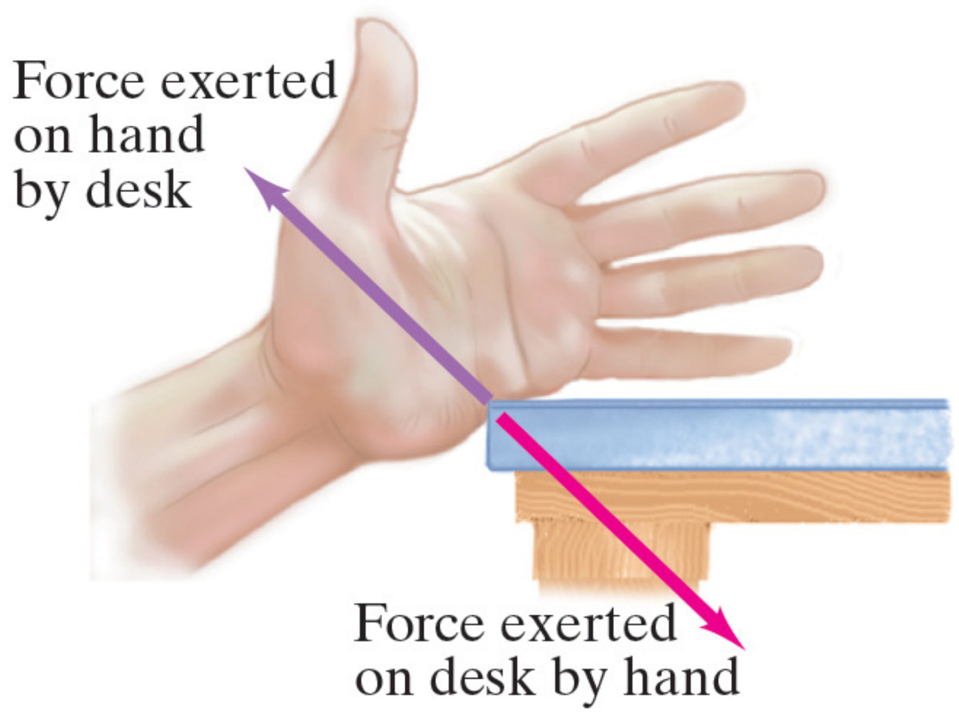
A quick review: Newton's third law of motion.

Third law:

Suppose a body A exerts a force $\vec{F}_{BA}$ on body B. Experiments show that in that case body B exerts a force $\vec{F}_{AB}$ on body A. These two forces are equal in magnitude and oppositely directed:

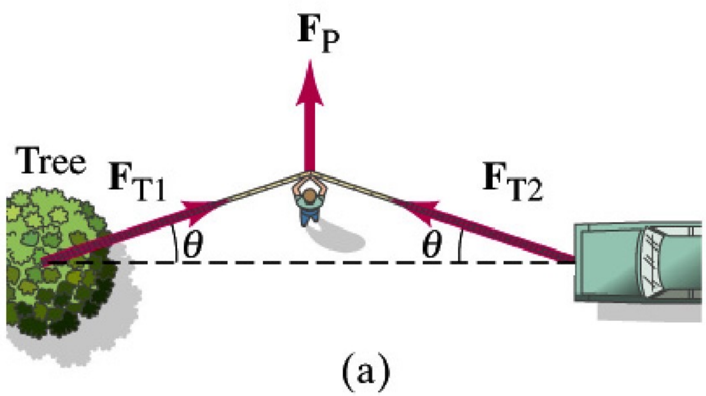
$$\vec{F}_{BA} = -\vec{F}_{AB}$$

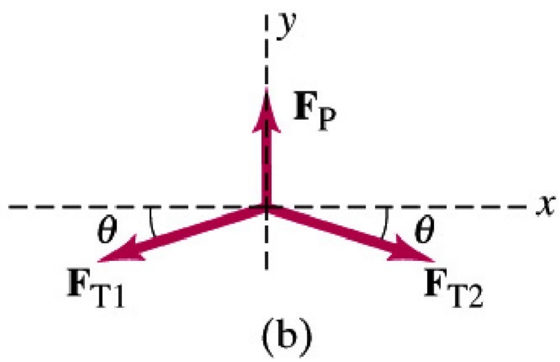
Note: these forces act on different objects, and they do not cancel each other.



A quick review: Problem solving strategies.

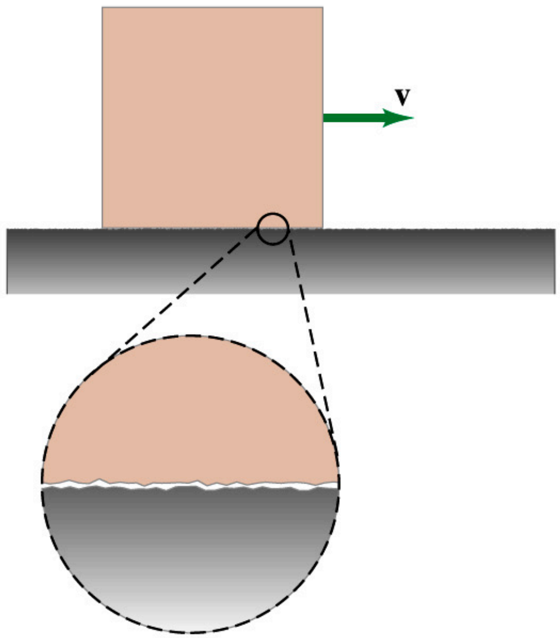
- The first step in solving problems involving forces is to determine all the forces that act on the object(s) involved.
- The forces acting on the object(s) of interest are drawn into a free-body diagram.
- Apply Newton's second law to the sum of to forces acting on each object of interest.





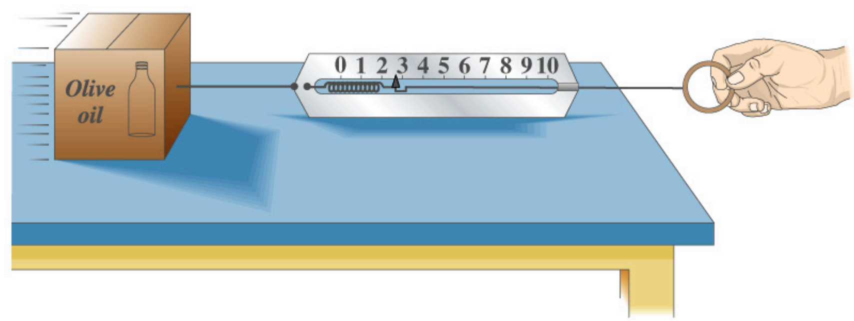
Friction.

- A block on a table may not start to move when we apply a small force on it.
- This means that there is no net force in the horizontal direction, and that the applied force is balanced by another force.
- This other force must change its magnitude and direction based on the direction and magnitude applied force.
- If the applied force is large enough, the block will start to move and accelerate.



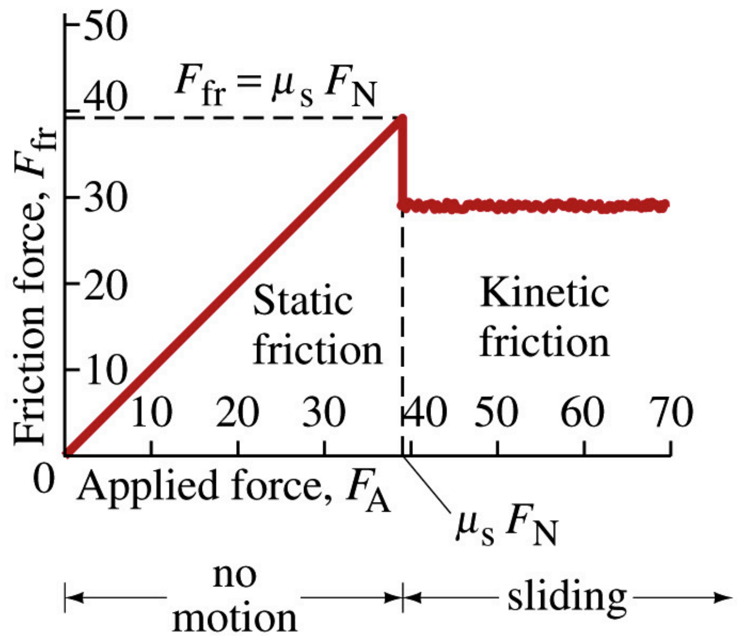
Friction.

- When the applied force exceeds a certain maximum value, the object will start to move.
- Once the object starts to move, the magnitude of the force required to keep the object moving with constant velocity is smaller than the magnitude of the force required to start the motion.
- The forces that try to oppose our motion are the friction forces between the object and surface on which it is resting.



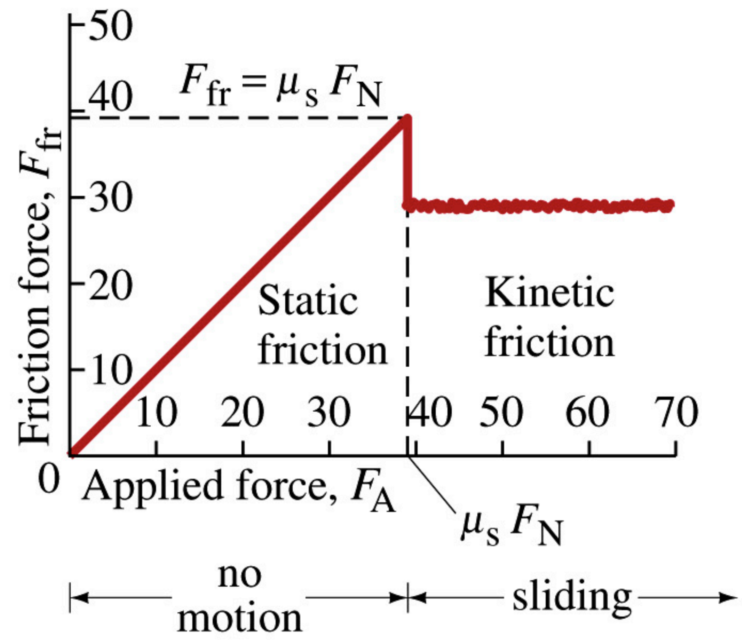
Friction.

- Based on these observations we can conclude :
  - There are two different friction forces: the **static friction** force (no motion) and the **kinetic friction** force (motion).
  - The static friction force increases with the applied force but has a maximum value.
  - The kinetic friction force is independent of the applied force, and has a magnitude that is less than the maximum static friction force.



Friction and braking.

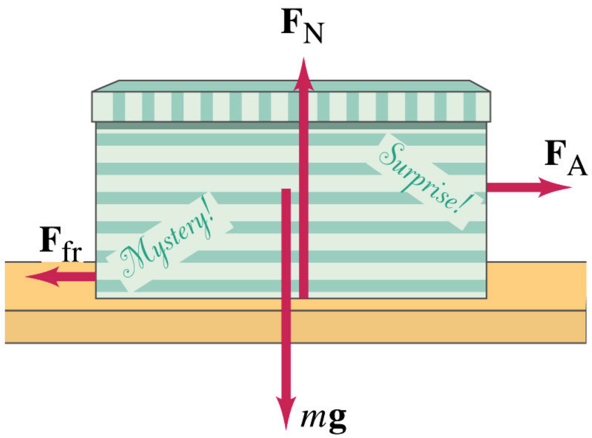
- Consider how you stop in your car:
  - The contact force between the tires and the road is the static friction force (for most normal drivers). It is this force that provides the acceleration required to reduce the speed of your car.
  - The maximum static friction force is larger than the kinetic friction force. As a result, you are **much** more effective stopping your car when you can use static friction instead of kinetic friction (e.g. when your wheels lock up).

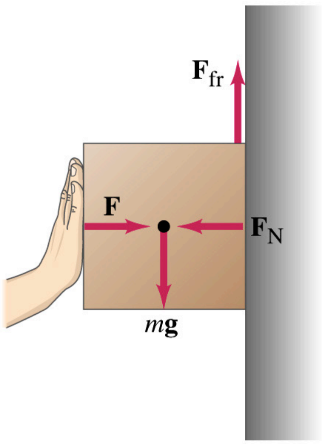


Friction and normal forces.

- The maximum static friction force and the kinetic friction force are proportional to the normal force.
- Changes in the normal force will thus result in changes in the friction forces.

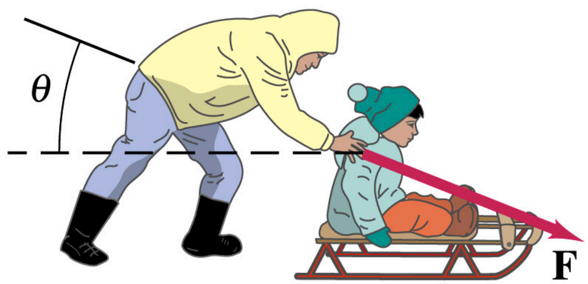
- **NOTE:**
  - The normal force will be always perpendicular to the surface.
  - The friction force will be always opposite to the direction of (potential) motion.

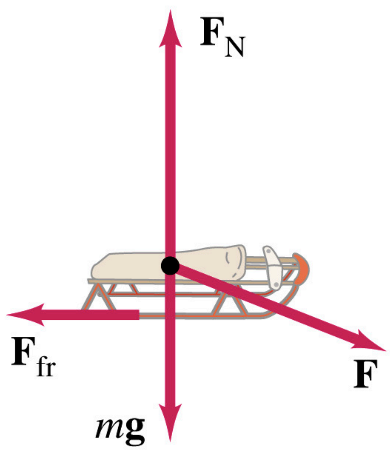




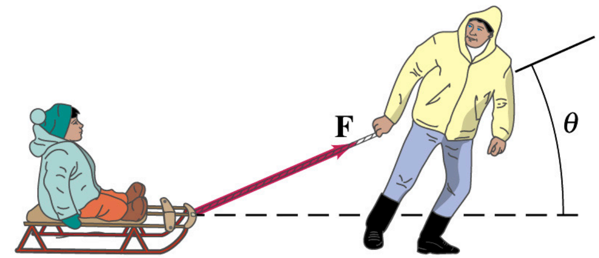
Pushing or pulling: a big difference.

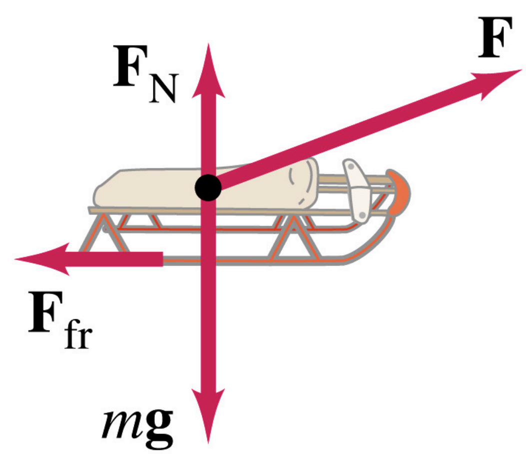
More Friction





Less Friction





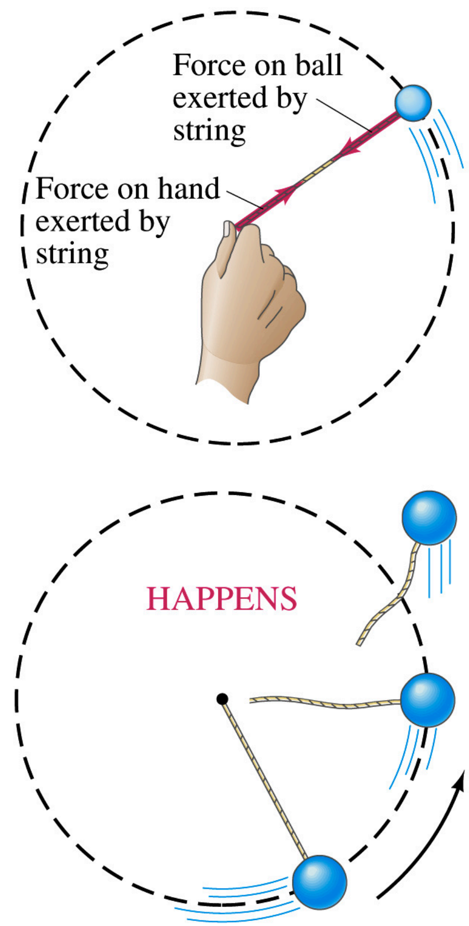
4 Minute 1 Second Intermission

- Since paying attention for 1 hour and 15 minutes is hard when the topic is physics, let's take a 4 minute 1 second intermission.

- You can:
  - Stretch out.
  - Talk to your neighbors.
  - Ask me a quick question.
  - Enjoy the fantastic music.
  - Solve a WeBWork problem.
  - Go asleep, as long as you wake up in 4 minutes and 1 second.

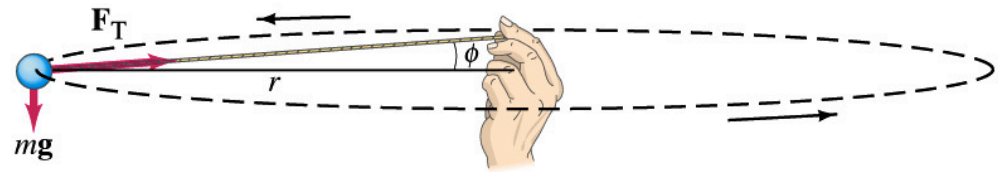
Circular motion.

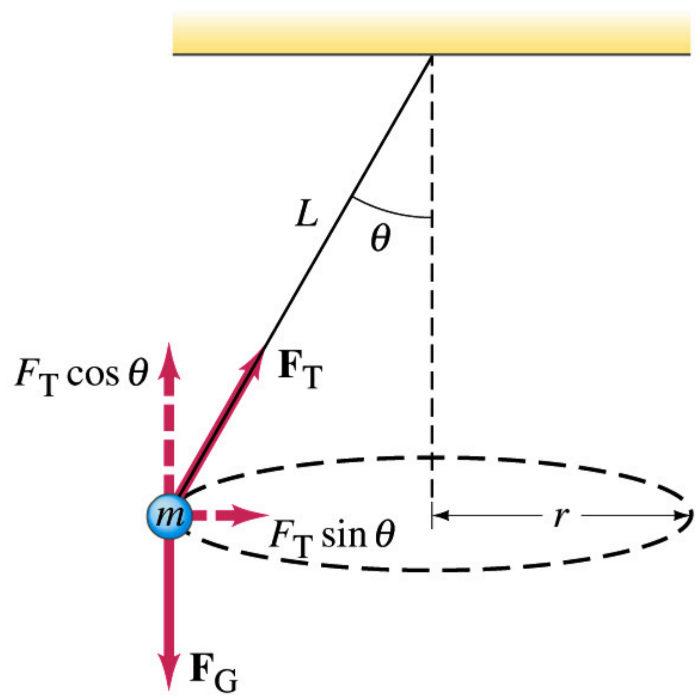
- When we see an object carrying out circular motion, we know that there must be force acting on the object, directed towards the center of the circle.
- When you look at the circular motion of a ball attached to a string, the force is provided by the tension in the string.
- When the force responsible for the circular motion disappears, e.g. by cutting the string, the motion will become linear.



Circular motion.

- In most cases, the string force not only has to provide the force required for circular motion, but also the force required to balance the gravitational force.
- Important consequences:
  - You can never swing an object with the string aligned with the horizontal plane.
  - When the speed increases, the acceleration increases up to the point that the force required for circular motion exceeds the maximum force that can be provided by the string.





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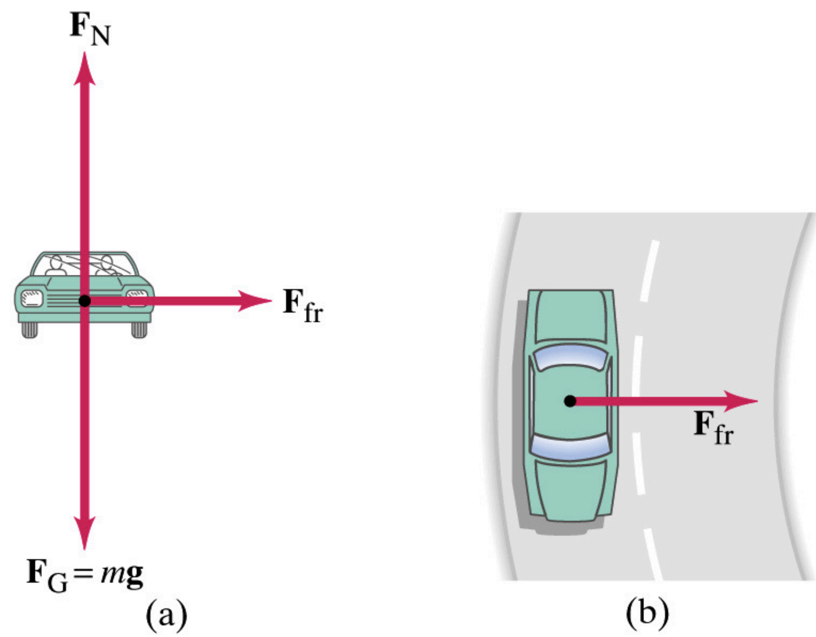
Circular motion and its connection to friction.

- When you drive your car around a corner you carry out circular motion.
- In order to be able to carry out this type of motion, there must be a force present that provides the required acceleration towards the center of the circle.
- This required force is provided by the friction force between the tires and the road.
- But remember ….. The friction force has a maximum value, and there is a maximum speed with which you can make the turn.

Required force = Mv^2/r.
If v increases, the friction force must increase and/or the radius must increase.



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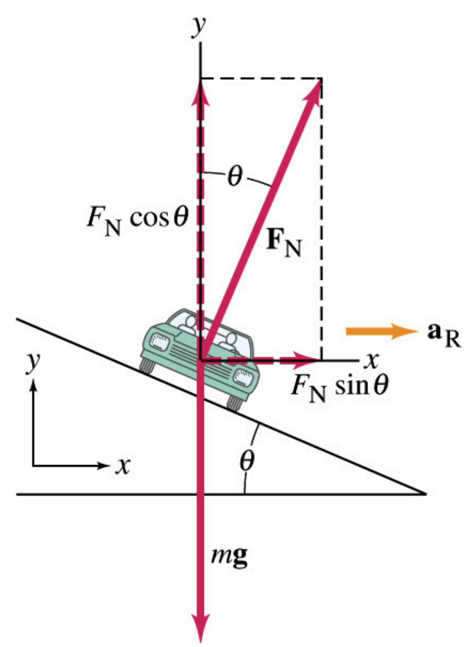
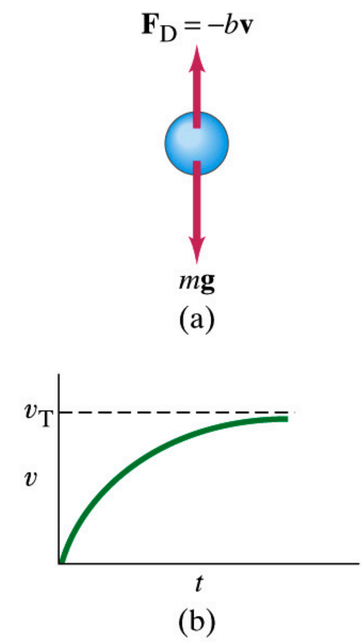
Circular motion and its connection to friction.

- Unless a friction force is present you can not turn a corner …… unless the curve is banked.
- A curve that is banked changes the direction of the normal force.
- The normal force, which is perpendicular to the surface of the road, can provide the force required for circular motion.
- In this way, you can round the curve even when there is no friction ……. but only if you drive with exactly the right speed (the posted speed).



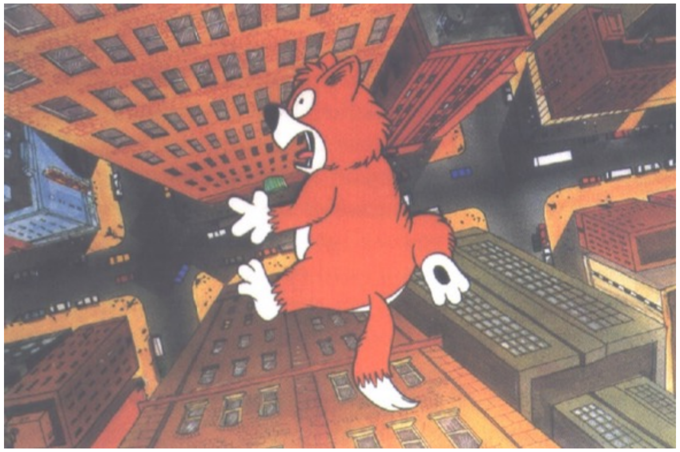
Air "friction" or drag.

- Objects that move through the air also experience a "friction" type force.
- The drag force has the following properties:
  - It is proportional to the cross-sectional area of the object.
  - It is proportional to the velocity of the object.
  - It is directed in a direction opposite to the direction of motion.
- The drag force is responsible for the object reaching a terminal velocity (when the drag force balances the gravitational force).



Terminal air "friction" or drag.

- The science of falling cats is called feline pesematology.
- This area of science uses the data from falling cats in Manhattan to study the correlation between injuries and height.
- The data show that the survival rate is doubling as the height increases (effects of terminal velocity). E.g. only 5% of the cats who fell seven to thirty-two stories died, while 10% of the cats died who fell from two to six stories.



That's all!
Next week: gravity keeps us together!