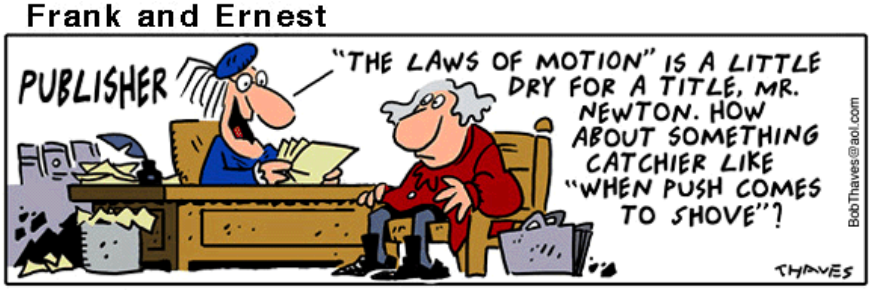
- **Theme Music:** Universal Law
  Java Jazz
- **Cartoon:** Bob Thaves
  Frank & Ernest



Copyright (c) by Thaves. Distributed from www.thecomics.com.

Outline

- Quiz 2
- Building Newton's Laws
- What's a force?
- The conceptual ideas behind Newton's Laws

Why bother to build?

- Why do I bother to build Newton's Laws from experience rather than just give them to you?

Causing Motion

- How do we get something to move?

Block on a table

- Crucial question: What happens to a moving object if nothing acts on it? (or if everything acting on it cancels?)

One more icon: Shopping for Ideas

- What we need to do here is consider some different possibilities and evaluate them to see how well they work for us.

Alternative Laws of Motion

- Redish's Law (from block on table)

$$\mathscr{T} = \Delta x$$

- Newton's Law (from ball on hard floor)

$$\mathscr{T} = \Delta v$$

Newton's law of motion

- As a result of taps

$$\mathscr{T} = \Delta v$$

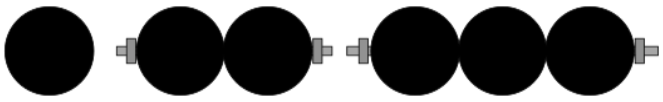
- Between taps

$$\Delta x = v\ \Delta t$$

9/14/11 Physics 131 7

Is "tap" the right concept?

- Is a "tap" ($\mathscr{T}$) the right concept?
- Is it really something the hammer gives to the ball?
  Or does the "tap" also depend on the ball?
- Consider multiple bowling balls ganged together with long bolts.



9/14/11 Physics 131 8

Impulse

- We expect (and would find if we actually did the experiment) that the effect of a given "hit" with a hammer produces a smaller effect (less Δv) for more bowling balls.
- We therefore replace the "tap" by an "impulse" — something delivered by the hammer to the object.

$$\mathscr{T} = \frac{\mathscr{I}}{m}$$

$\mathscr{I}$ ⟵ delivered by hammer to object

m ⟵ number of bowling balls

Newton's 2nd Law

$$\Delta v = \mathscr{I} / m$$

$$\Delta x = v\Delta t$$

- Where
  - $\mathscr{I}$ is the "impulse" (something delivered to the object by another object touching it)
  - m is the "mass" (a property of the object that says how many bowling balls it is equivalent to)

A More Familiar Form

- If the object that is causing the change of velocity by touching our object doesnt "tap" it but touches it continually, it's more convenient to extract a time by writing

$$\mathcal{J} = F\Delta t$$

- then we get

$$\Delta v = \left(\frac{F}{m}\right)\Delta t \quad \Delta x = v\,\Delta t \quad \rightarrow \quad \frac{dv}{dt} = \frac{F}{m} \quad \frac{dx}{dt} = v \quad \rightarrow \quad a = F/m$$

9/14/11 Physics 131 11

Technical term alert: What's a Force?

- The "*F*" in the last slide is an expression of the idea:
  - When two objects touch they do something to each other that tends to change the other's velocity.
- Although the technical term for this is "force" it is different from the common speech idea of force.
  - It is an interaction between two objects.
  - It only occurs via contact or by the non-touching examples of gravity, electricity, and magnetism.
- Until we are accustomed to this new term we will refer to "physical-force" (pForce).

9/16/11 12 Physics 131

Measuring pForces

- We need some way of quantifying pForces.
- To do that, we need to find a physical system that changes when it exerts a pForce in a way we already know how to measure.
- Springs change their length when they exert a pForce and we know how to measure length.

Springs

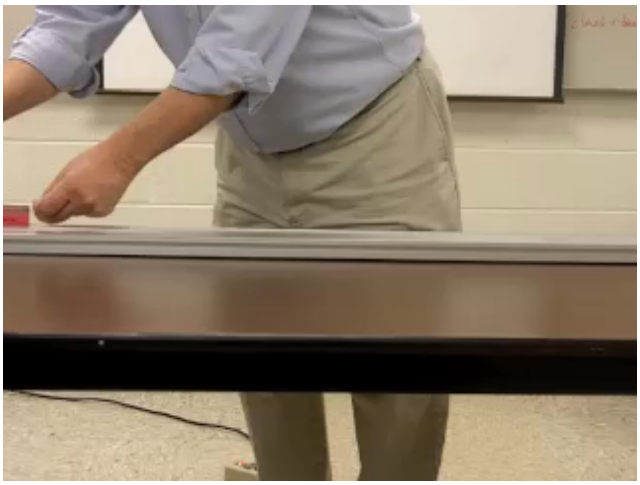
- If you pull on a spring from both sides it changes its length.

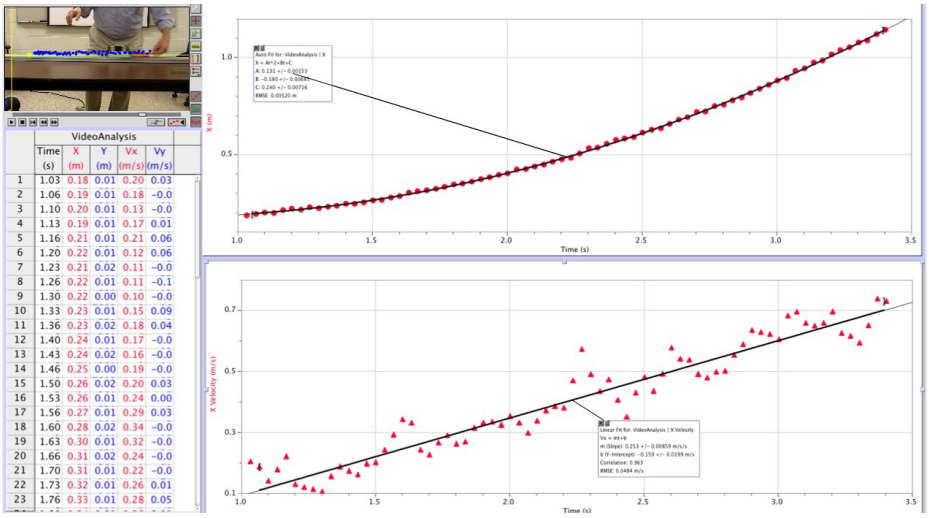
$$T = ks$$

("s" = stretch or squeeze)

- Let's create a "standard" spring that when it stretches a certain length it produces a given acceleration on a particular mass.

Why F rather than $\mathscr{I}$?





VideoAnalysis

	Time (s)	X (m)	Y (m)	Vx (m/s)	Vy (m/s)
1	1.03	0.18	0.01	0.20	0.03
2	1.06	0.19	0.01	0.18	−0.0
3	1.10	0.20	0.01	0.13	−0.0
4	1.13	0.19	0.01	0.17	0.01
5	1.16	0.21	0.01	0.21	0.06
6	1.20	0.22	0.01	0.12	0.06
7	1.23	0.21	0.02	0.11	−0.0
8	1.26	0.22	0.01	0.11	−0.1
9	1.30	0.22	0.00	0.10	−0.0
10	1.33	0.23	0.01	0.15	0.09
11	1.36	0.23	0.02	0.18	0.04
12	1.40	0.24	0.01	0.17	−0.0
13	1.43	0.24	0.02	0.16	−0.0
14	1.46	0.25	0.00	0.19	−0.0
15	1.50	0.26	0.02	0.20	0.03
16	1.53	0.26	0.01	0.24	0.00
17	1.56	0.27	0.01	0.29	0.03
18	1.60	0.28	0.02	0.34	−0.0
19	1.63	0.30	0.01	0.32	−0.0
20	1.66	0.31	0.02	0.24	−0.0
21	1.70	0.31	0.01	0.22	−0.0
22	1.73	0.32	0.01	0.26	0.01
23	1.76	0.33	0.01	0.28	0.05

Conceptual ideas underlying Newton's Laws 1-3

1. Objects respond only to influences acting upon them at the instant that those influences act. (Object egotism)
2. All outside effects on an object being equal, the object maintains its velocity (including direction). The velocity could be zero, which would mean the object is at rest. (Inertia)
3. Every change in velocity an object experiences is caused by the object interacting with some other object – **forces**. (Interactions)

Conceptual ideas underlying Newton's Laws 4-6

4. If there are a lot of different objects that are interacting with the object we are considering, the overall result is the same as if we add up all the forces as vectors and produce a single effective force -- the **net force**. (Superposition)
5. When one object exerts a force on another, that force is shared over all parts of the structure of the object. (Mass)
6. Whenever two objects interact, they exert forces on each other. (Reciprocity)