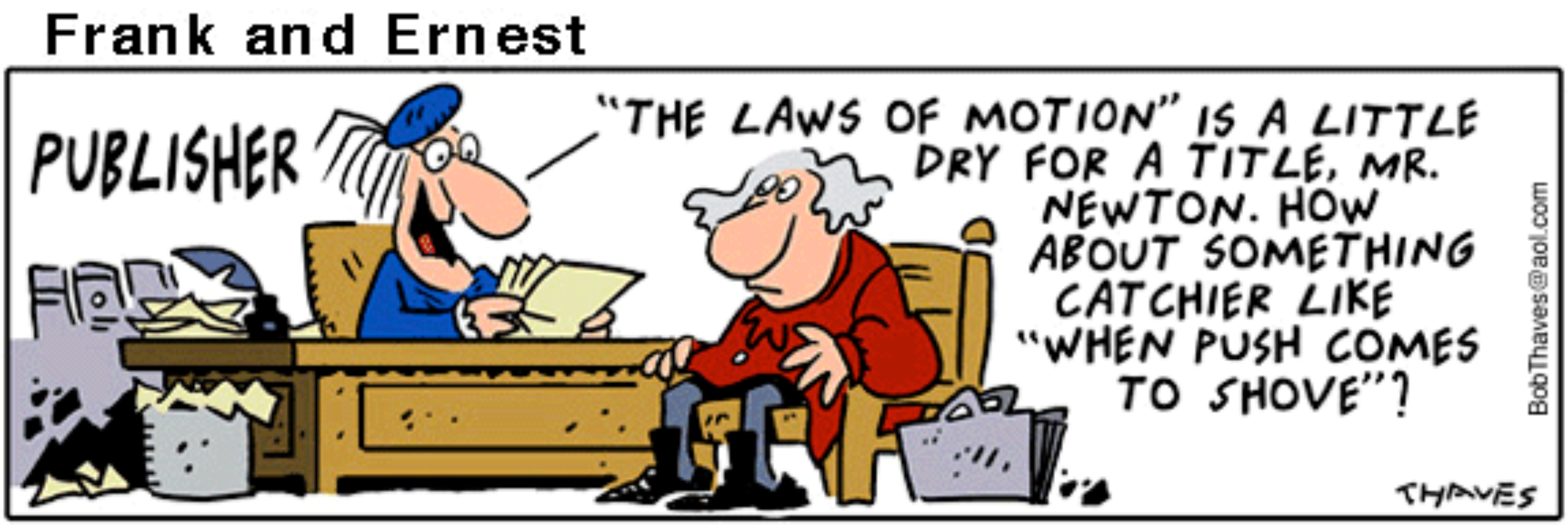
- **Theme Music: Universal Law**

  Java Jazz

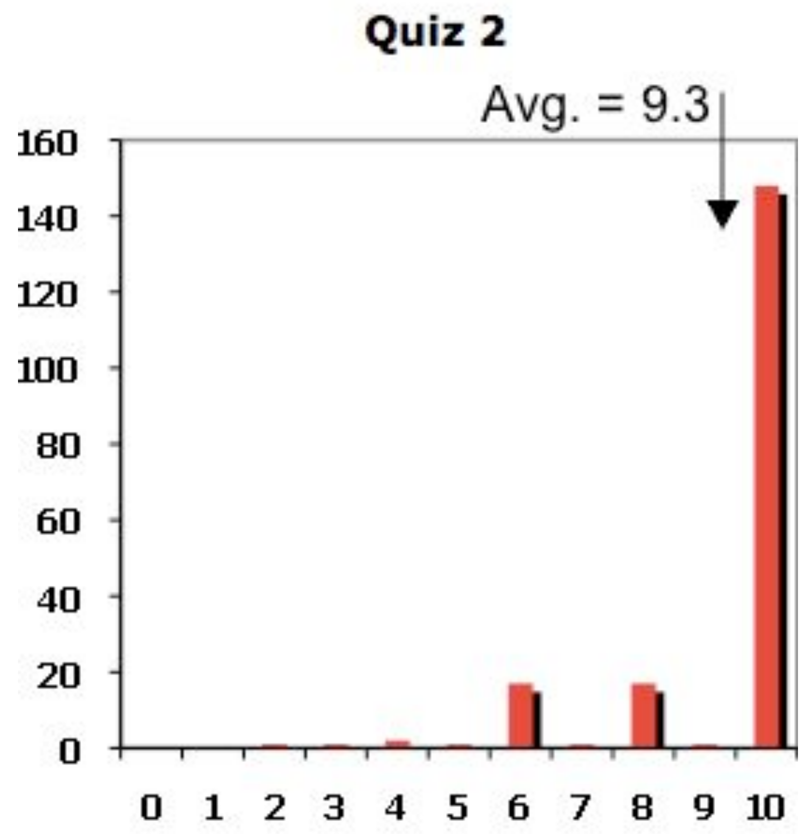
- **Cartoon: Bob Thaves**

  Frank & Ernest



Quiz 2

	2.1	2.A1	2.A2	2.B1	2.B2
a	2%	**95%**	1%	0%	1%
b	3%	0%	1%	0%	2%
c	0%	0%	0%	1%	2%
d	**96%**	1%	**96%**	0%	1%
e	0%	0%	1%	0%	0%
f	0%	0%	0%	11%	**84%**
g	0%	0%	0%	**87%**	5%
n	0%	1%	0%	2%	5%



Newton's law of motion

- As a result of taps

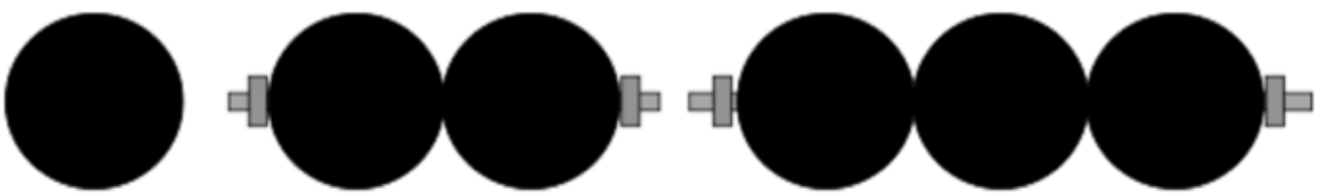
$$T \quad = \Delta v$$

- Between taps

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

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.



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.

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

I ⟵ delivered by hammer to object

m ⟵ number of bowling balls

Newton's 2nd Law

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

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

- Where
  - $\mathcal{I}$ 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 doesn't "tap" it but touches it continually, it's more convenient to extract a time by writing

$$I = F\Delta t$$

- then we get

$$\Delta v = \left(\frac{F}{m}\right)\Delta t$$

$$a = F/m$$

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

Technical term alert: What's a pForce?

- 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 (so far) via contact.
- Until we are accustomed to this new term we will refer to "physical-force" (pForce).

Two Foothold Ideas

- Newton 1:
  – If all the influences (pForces) acting on an object are balanced (or zero) the object keeps whatever velocity it has.
- Newton 0:
  – An object responds to the pForces that act on it at the instant considered.
  (Objects have no long range sensors and no memory for anything except their velocity.)

Newton 0:
Thinking inside the box

- "Physics by empathy"
- "Method acting" – an acting technique in which actors try to replicate real life emotional conditions under which the character operates, in an effort to create a life-like, realistic performance.
  - "What's my motivation?"

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.

Dimensions of pForce

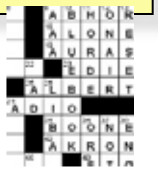
$$[F] = [ma] = M\frac{L}{T^2}$$

- Choose the unit

  1 Newton = 1 kg-m/s^2

- This is the pForce needed to give a 1 kg mass an acceleration of 1 m/s^2

Remember “dynes”



pForce-labeling convention

- According to our foothold idea, pForces are what objects do to each other when they touch.
- If a pForce is a
  - Normal pForce we label it as N
  - Tension pForce we label it as T
  - Friction pForce we label it as f
- We put subscripts on each force telling *who* is acting on *whom*.

$$\vec{F}_{(\text{object causing force})\rightarrow(\text{object feeling force})}$$

Summary of Newton's Laws

- Newton 0:
  - Objects only feel pForces when something touches them
    An object responds to the pForces it feels when it feels them.
- Newton 1:
  - An object that feels a net pForce of 0 keeps moving with the same velocity (which may = 0).
- Newton 2:
  - An object that is acted upon by other objects changes its velocity according to the rule

$$\vec{a} = \vec{F}^{net} / m$$