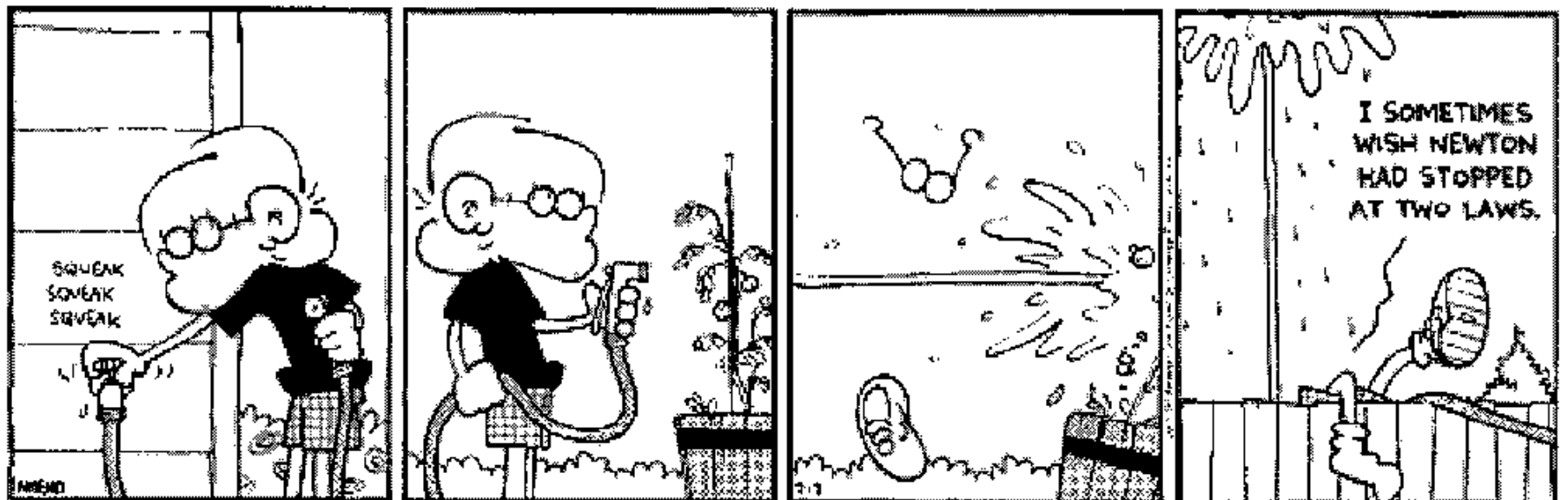■ **Theme Music:** Movin' Out
Billy Joel

■ **Cartoon:** Bill Amend
FoxTrot

Next Week

- Quiz Monday on acceleration.

- Lab 3: The second week of the pendulum lab. You will analyze your data and defend your results to the rest of your class.

- Tutorial 3: Newton's third law. You will try to make sense of N3 and see how it can be true – and test it experimentally as well!

- For HW this week you will need to use Logger Pro to analyze a video. Download it at *http://www.vernier.com/downloads/lp3demo.html*

Summary of Newton's Laws

- ## Newton 0:
  - Objects only feel forces when something touches them.
    An object responds to the forces it feels when it feels them.

- ## Newton 1:
  - An object that feels a net force 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

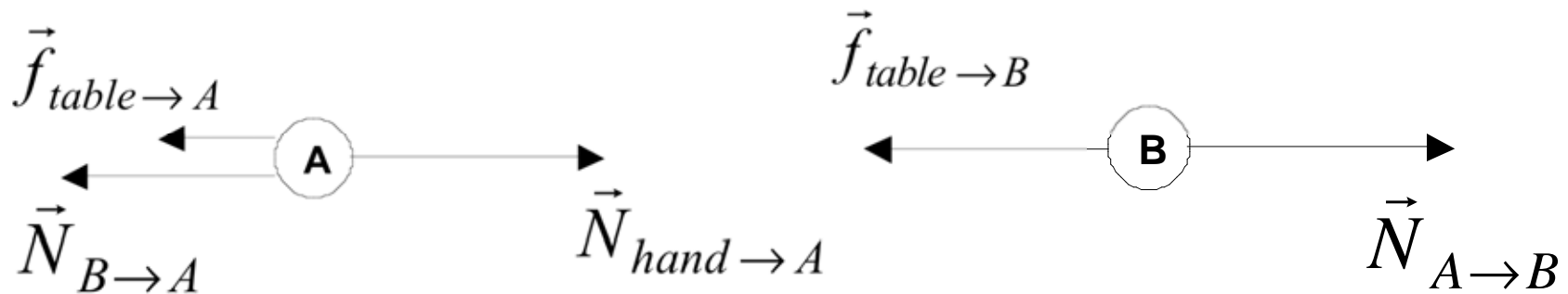$$\vec{a} = \vec{F}^{net}\big/m$$
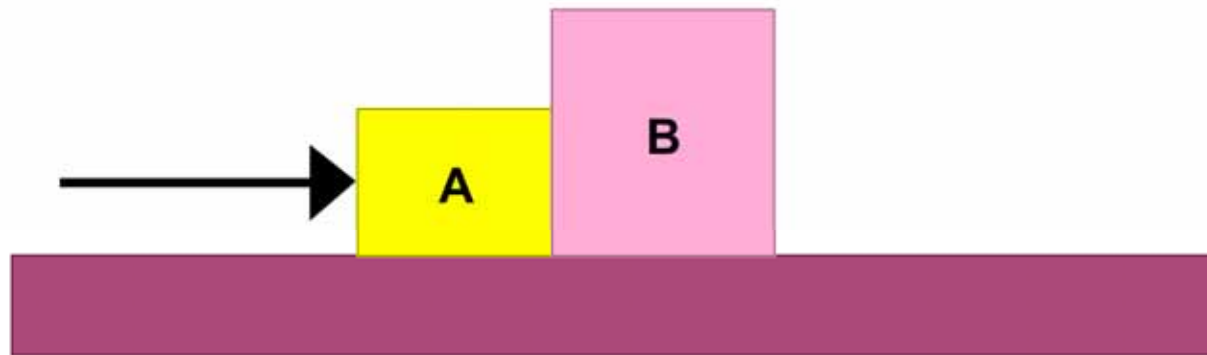
Free-Body Diagrams: Motivation

- We will be considering many cases that include many objects.

- In order not to get confused about which pForces go where we introduce a *free-body diagram*.

- This allows us to keep careful track of both N0 and N2.
  - each object only feels forces acting on itself (N0)
  - each object satisfies its own N2 response equation, $a = F^{net}/m$

Free-Body Diagrams: Procedure

- For each object in the system being considered, we
  - draw a dot representing the object
  - find all the objects touching it
  - draw arrows starting at the dot in the direction of the forces, with lengths indicating the approximate relative size of the forces
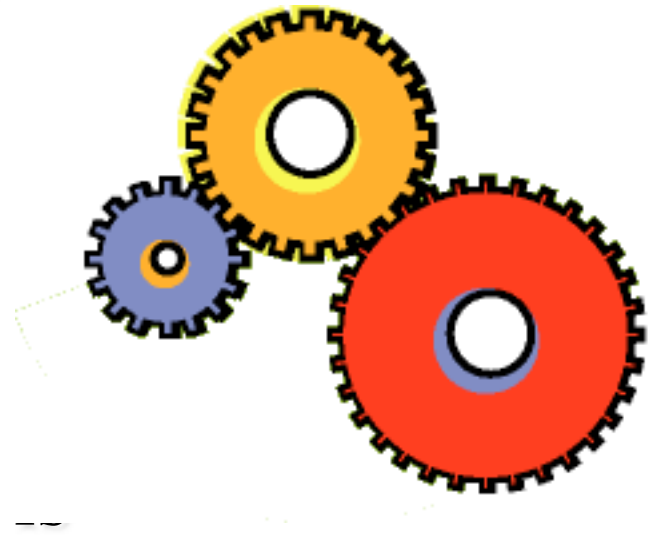 - label each force according to our convention

Example

$\vec{f}_{table \to A}$

$\vec{N}_{B \to A}$

A

$\vec{N}_{hand \to A}$

$\vec{f}_{table \to B}$

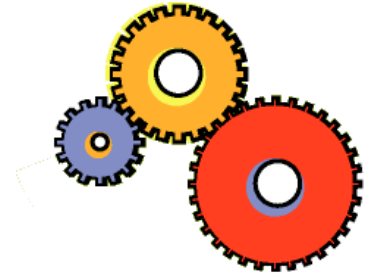B

$\vec{N}_{A \to B}$

Physics 121

One more icon:
The Implications Game

- Once we have established foothold ideas, we work with them to see what they imply for a variety of situations.

- This "implications game" -- the core of scientific reasoning.

See what it implies!
# Working out the implications

- Consider the example above.
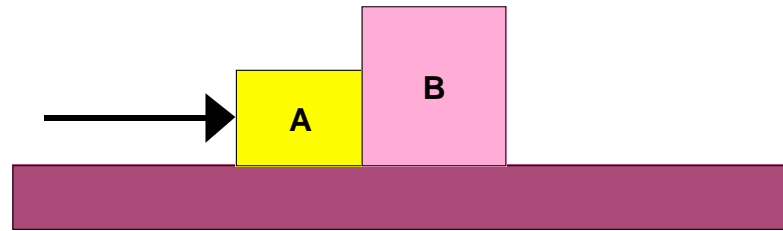 If we assume no friction,
  how does the pair of blocks speed up?
- Consider them first as a single system.
  The problem is much simpler then.
- Afterwards, lets consider it as two separate blocks. What does the result of treating it as a single system tell us?

A + B
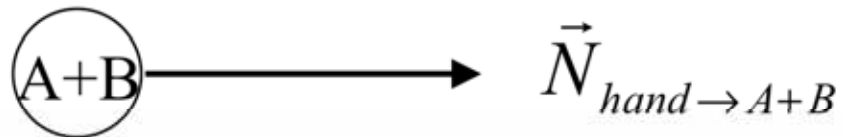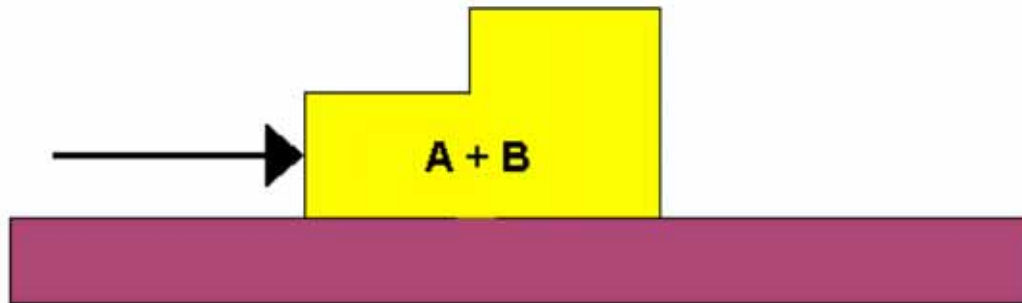
$\left(A+B\right)$ ⟶ $\vec{N}_{hand \rightarrow A+B}$

$$\vec{a}_{A+B} = \frac{1}{m_{A+B}} \vec{N}_{hand \rightarrow A+B}$$

Now consider each box separately
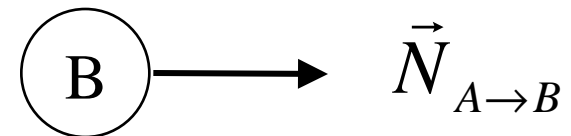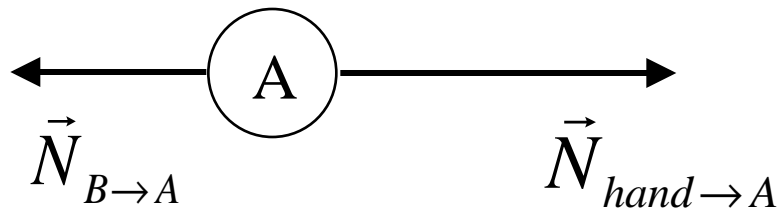
$$\vec{a}_A = \frac{1}{m_A}\left(\vec{N}_{hand \to A} + \vec{N}_{B \to A}\right)$$

$$\vec{a}_B = \frac{1}{m_B}\vec{N}_{A \to B}$$

Compare the equations!

■ All the accelerations must be the same.

$$(m_A + m_B)\vec{a} = \vec{N}_{hand \to A}$$

Why is this *N* "on A" and not "on A+B"?

$$m_A\vec{a} = \vec{N}_{hand \to A} + \vec{N}_{B \to A}$$

$$m_B\vec{a} = \vec{N}_{A \to B}$$

$$(m_A + m_B)\vec{a} = \vec{N}_{hand \to A} + \vec{N}_{B \to A} + \vec{N}_{A \to B}$$

A serious implication

- In order for our treatment of the two objects as a system and as separate parts to be the same we must conclude:

$$\vec{N}_{B \to A} + \vec{N}_{A \to B} = 0$$

$$\text{or}$$

$$\vec{N}_{B \to A} = -\vec{N}_{A \to B}$$

Newton's 3rd Law

- When two objects touch each other, each exerts a force on the other.

- pForces are <u>interactions between objects</u>.

- In order for our analysis to be consistent, when two objects interact, the pForces they exert on each must be equal and opposite.

- This must be tested experimentally.

- Strangely enough, it works!

$$\vec{F}_{A \to B} = -\vec{F}_{B \to A}$$

Does N3 always hold?

- You will be checking N3 for some cases of normal forces in tutorial next week and it will always work.

- For tension and friction forces we could also do the experiment and see that it works.

*I t will work for **every** case until we get into systems where more than two-bodies interact at the same time– for example when radiation (e.g., light) is emitted.*

Footholds 2.0
Revised summary of Newton's Laws

- ## Newton 0:
  - Objects only feel forces when something touches them. An object responds to the forces it feels when it feels them.

- ## Newton 1:
  - An object that feels a <u>net force</u> of 0 keeps moving with the same velocity (which may = 0).

"Net force " = vector sum of all the forces acting on the object.

- ## Newton 2:
  - An object that is acted upon by other objects changes its velocity according to the rule $\vec{a} = \vec{F}^{net}/m$

- ## Newton 3:
  - When two objects interact the forces they exert on each other are equal and opposite.

$$\vec{F}_{A \to B} = -\vec{F}_{B \to A}$$