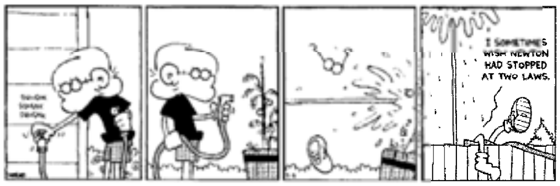
September 24, 2010 Physics 121 Prof. E. F. Redish

- **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

Why footholds?

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

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

Free-Body Diagrams: Motivation

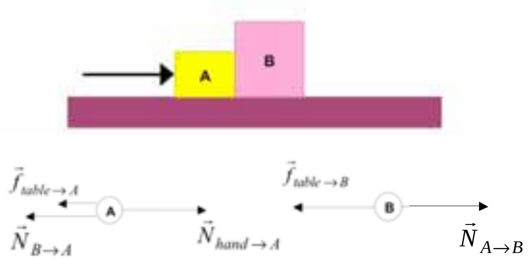
- We will be considering many cases that include many objects.
- In order not to get confused about which pForces go where we introduce a *free-body diagram.*
- This allows us to keep careful track of both N0 and N2.
  - each object only feels forces acting on itself (N0)
  - each object satisfies its 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

We're only considering horizontal motions and pForces!

Example



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.

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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?

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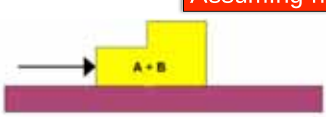
Assuming no friction!



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

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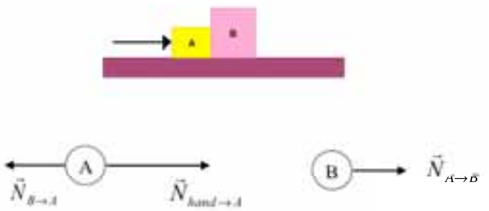
Now consider each box separately



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

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

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"?

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

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

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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:

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

or

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

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Newton's 3rd Law

- When two objects touch each other, each exerts a force on the other.
- pForces are interactions between objects.
- 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!

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

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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.

*It 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.*

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

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