## ■Theme Music: Morcheeba

*Friction*

## ■Cartoon: Bob Thaves

*Frank & Ernest*

# The friction relation

- When the surfaces are not sliding on each other (but something is trying to make them slide), the friction force may take any value up to a maximum.

$$f_{A\to B} \le f^{\max}_{A\to B} = \mu^{static}_{AB} N_{A\to B}$$

- When the surfaces are sliding on each other, the friction force is a constant value (usually a bit less than the maximum possible).

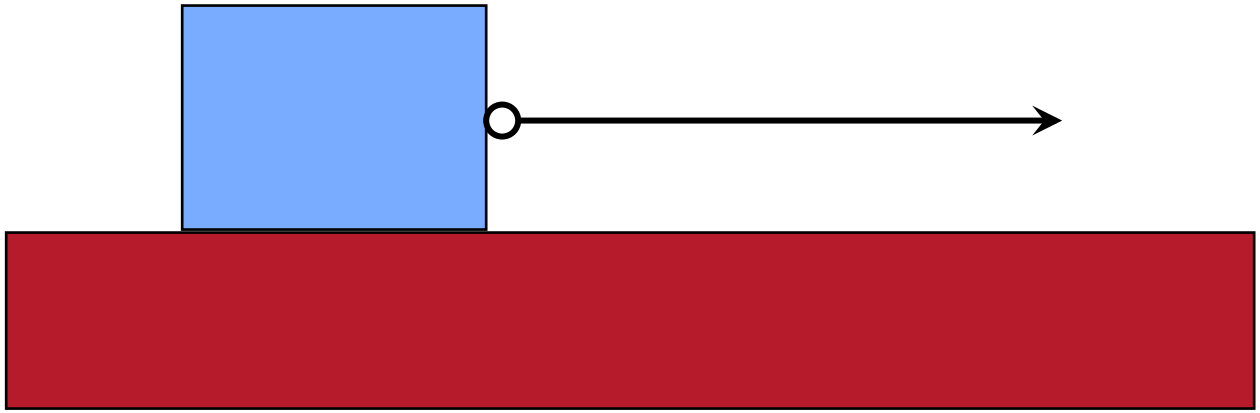
$$f_{A\to B} = \mu^{kinetic}_{AB} N_{A\to B} \qquad \mu^{kinetic}_{AB} \le \mu^{static}_{AB}$$

# Example

Start from rest

Increase force until box starts moving

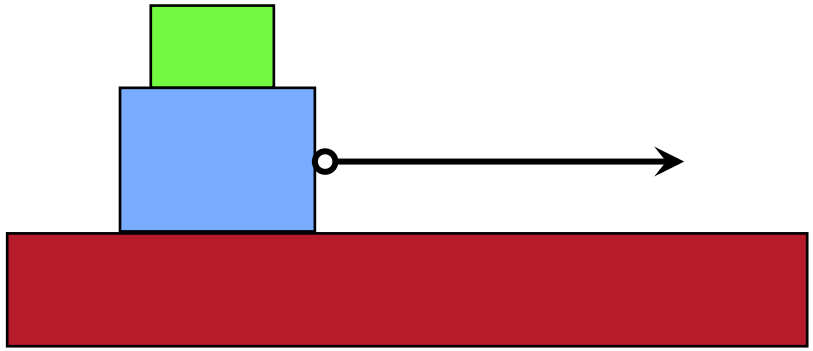
Pull so it goes at a constant speed



Graph: position velocity acceleration

net force applied force friction force

# What does friction do?

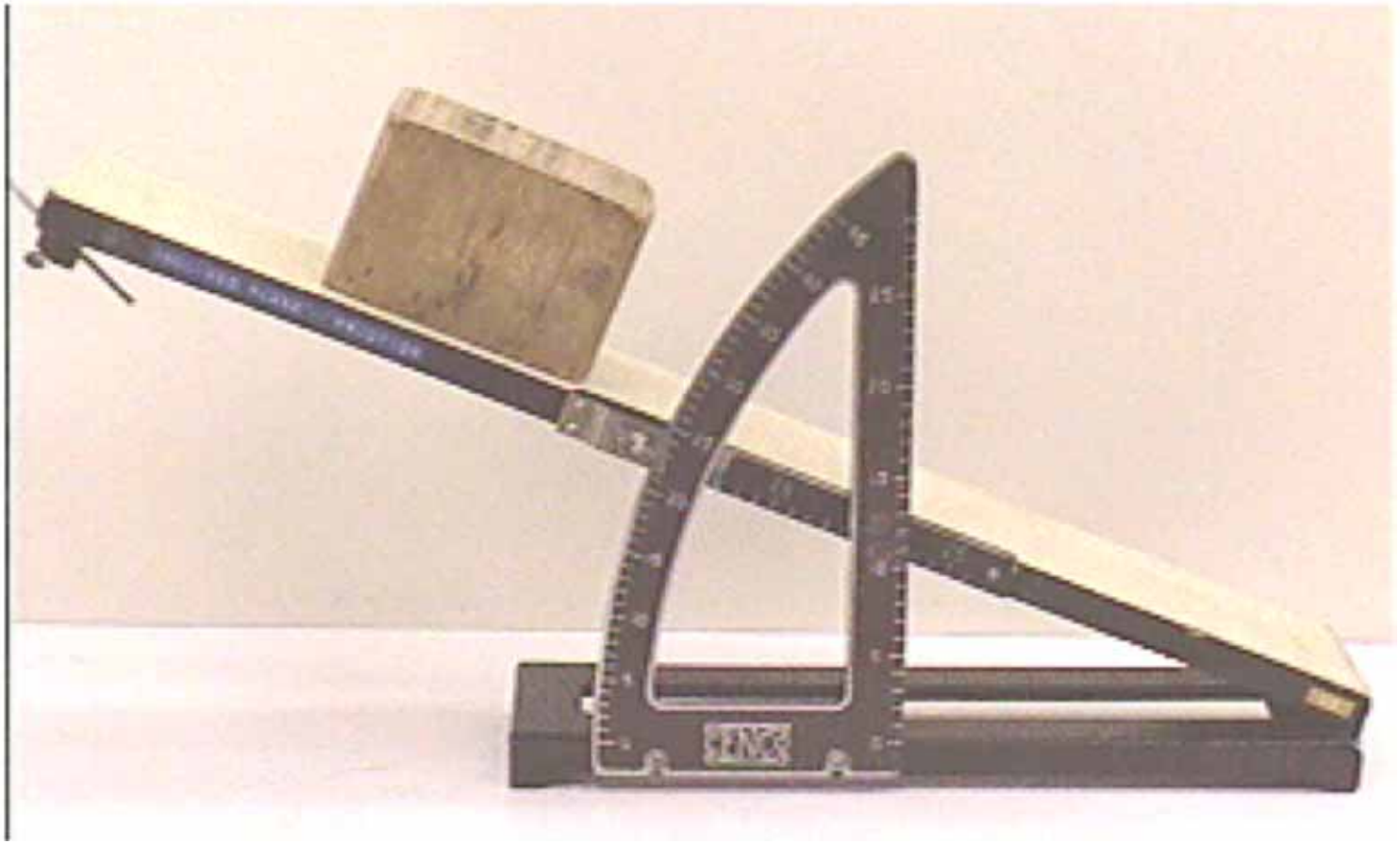



1. Slows things down
2. Speeds things up
3. It can do both

# When you start your car, what pForce causes it to speed up?

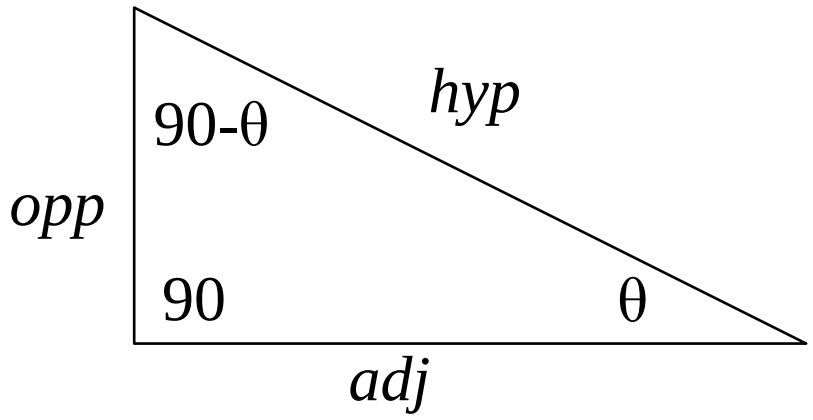

1. The pForce of your foot on the gas pedal.
2. The pForce of the engine turning.
3. The normal pForce the car's wheels exert on the ground.
4. The friction pForce of the ground on the car's wheels.
5. None of the above.
6. All of the above.

# At what angle will the block begin to slide?



# Review of Trig: 1

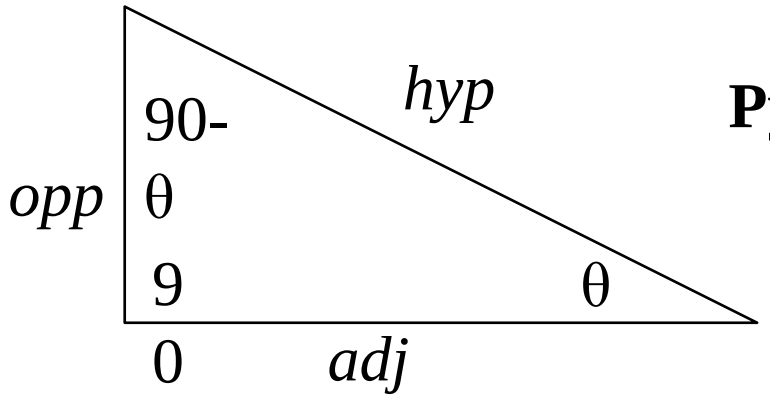
- Trig is based on a small number of principles:
  - The sum of the angles of a triangle is $180^o$.
  - The Pythagorian theorem
  - Every right triangle with the same angles is similar (has the same ratio of its sides).




Although *opp*, *adj*, and *hyp* all depend on the size of the triangle, the ratios *opp/adj*, *opp/hyp*, and *adj/hyp* only depend on itsshape (that it, on θ) .

# Review of Trig: 2

$$\sin\theta = \frac{opp}{hyp} \qquad \cos\theta = \frac{adj}{hyp} \qquad \tan\theta = \frac{opp}{adj}$$




**Pythagorian theorem:**

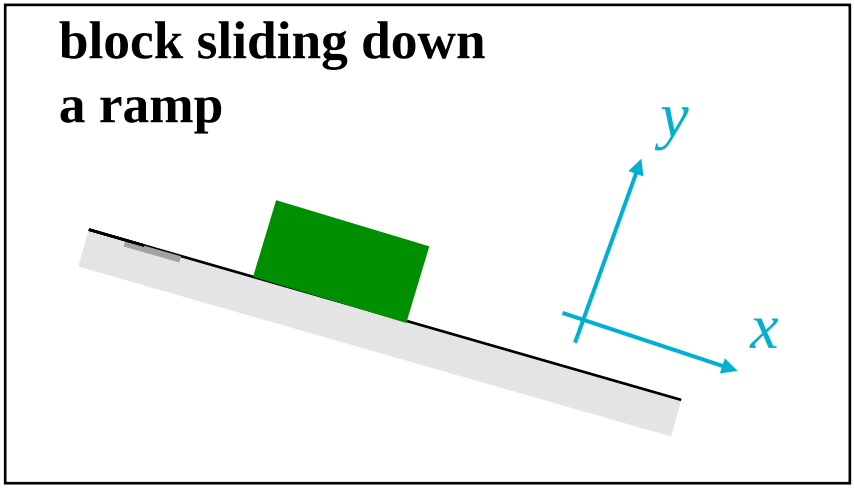
$$(adj)^2 + (opp)^2 = (hyp)^2$$

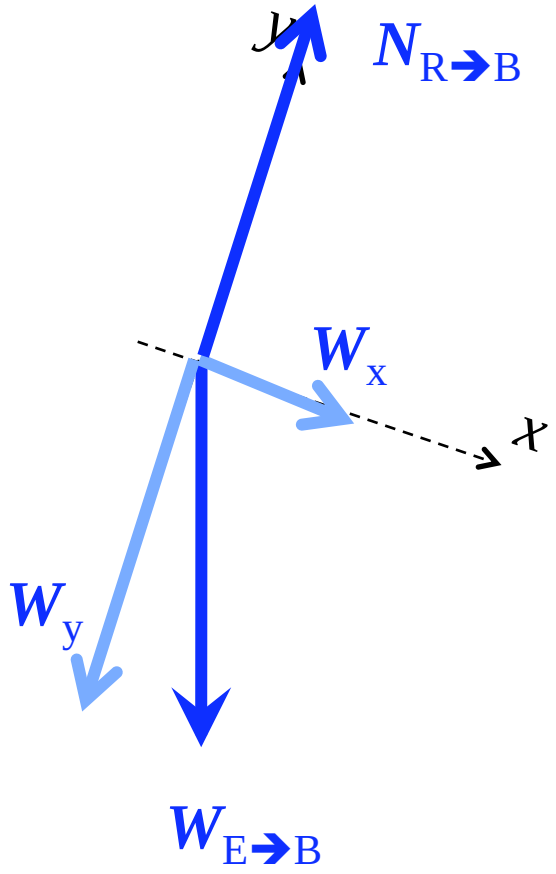
or

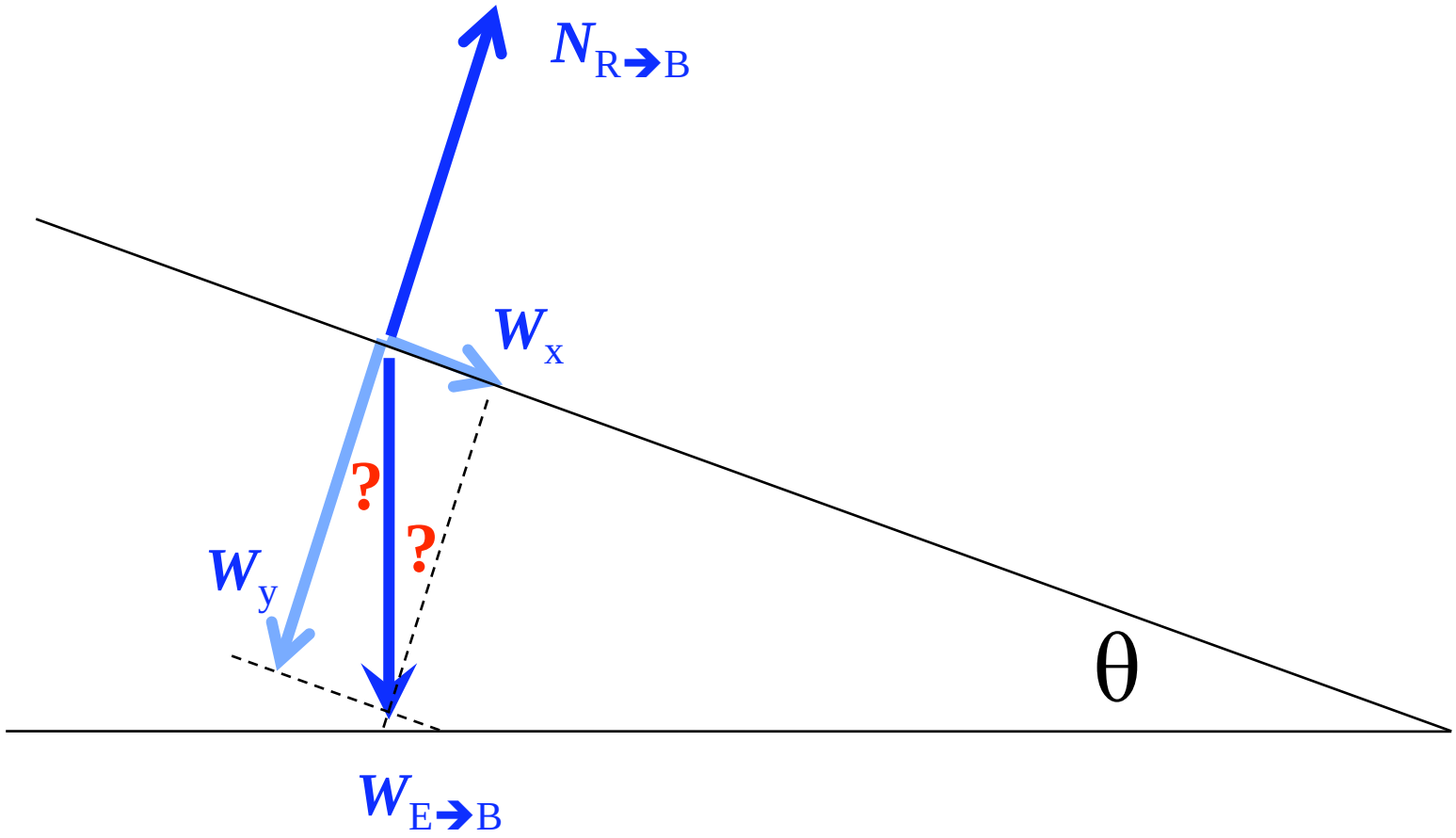
$$\sin^2\theta + \cos^2\theta = 1$$

**Physics geometry heuristic**: If you are drawing a diagram that is controlled by a single angle θ, and the rest of the lines are constructed as perpendiculars to the original or later lines, then the only angles in the diagram are θ, 90-θ, and 90 –- and it's easy to tell which is which.

# Draw and Label All Forces on the Block

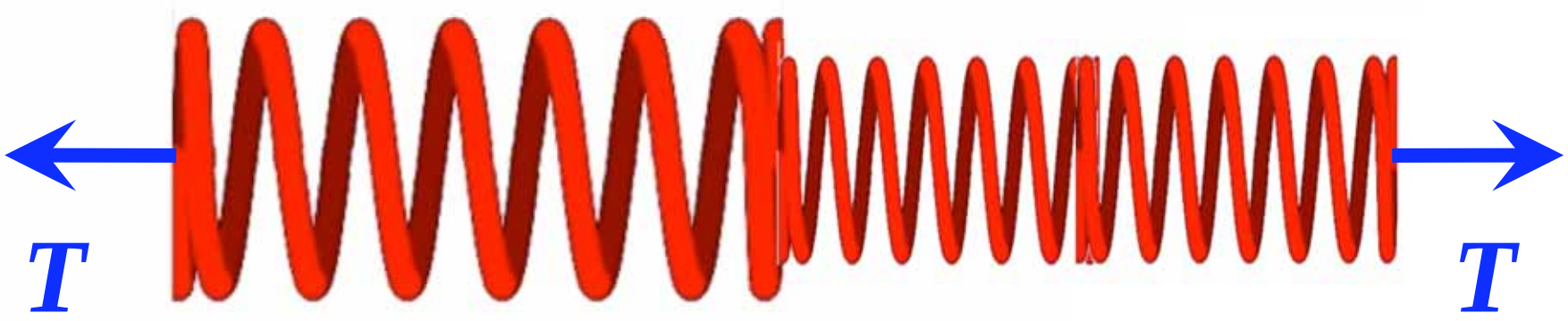



$N_{R\rightarrow B}$
$W_x$
?
?
$W_y$
θ
$W_{E\rightarrow B}$

# Springs

- How much does each spring stretch?
- What are the forces the springs exert on each other?
- How do you know?




$k_1$ (large) $k_2$ (small)

# ILD 3

- Reconciling Intuition by Looking at it Another Way:  The Normal Force