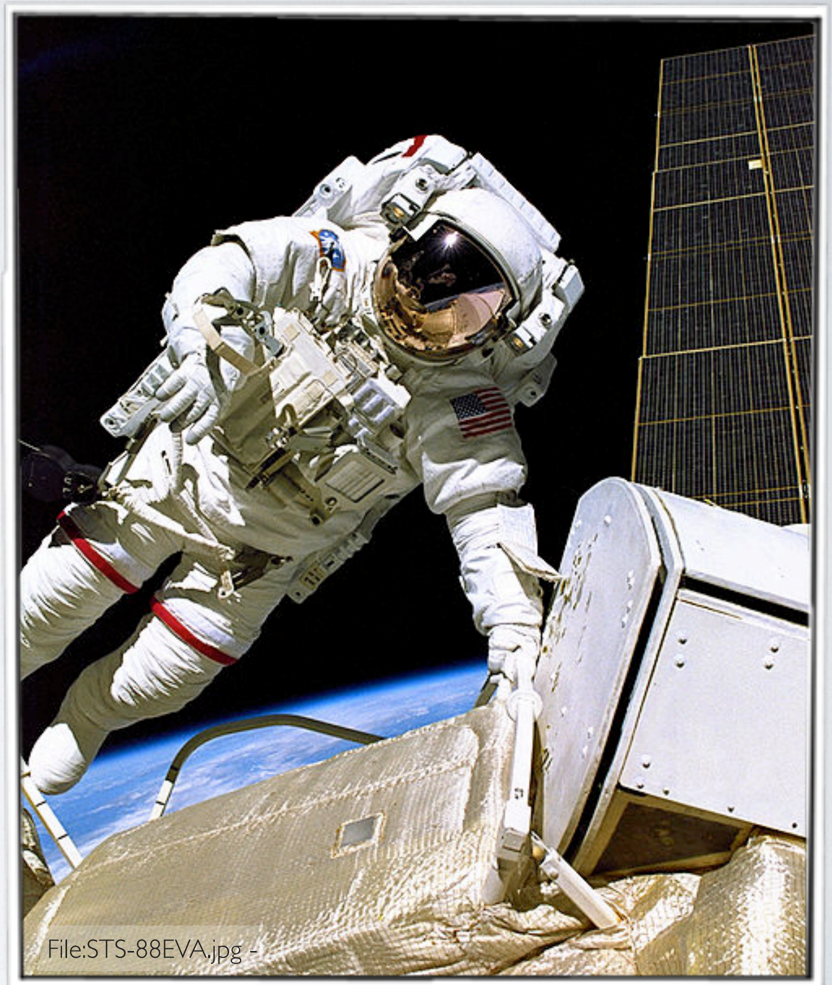
NEWTON'S LAWS

and force diagram solutions

NEWTON'S FIRST LAW

NEWTON'S FIRST LAW

- Newton's first law is often called the law of inertia.
- An object will maintain a constant velocity unless acted upon by a net external force.
    - This improves on the Grade 7 version - "an object at rest will remain at rest, an object in motion will remain in motion"



INERTIAL REFERENCE FRAMES

- An inertial reference frame is one in which Newton's first law is valid.
- This excludes rotating and accelerating frames.

NEWTON'S 2ND LAW

FORCE

- A force is a push or pull.
- An object at rest needs a force to get it moving; a moving object needs a force to change its velocity.
- The magnitude of a force can be measured on a scale.

NEWTON'S SECOND LAW OF MOTION

Newton's second law is the relation between acceleration and force.

Acceleration is proportional to force and inversely proportional to mass.

$$\bar{F} = m\bar{a}$$

NEWTON'S SECOND LAW OF MOTION

- The unit of force in the SI system is the Newton (N).
- Note that the pound is a unit of force, not of mass, and can therefore be equated to Newtons but not to kilograms.
- Force is a vector; F=MA is true along each coordinate axis.

WEIGHT – THE FORCE OF GRAVITY

- Weight is the force exerted on an object by gravity. Close to the surface of the Earth, where the gravitational force is nearly constant, the weight is calculated using:

$$\bar{F} = m\bar{a}$$

$$\bar{w} = m\bar{g}$$

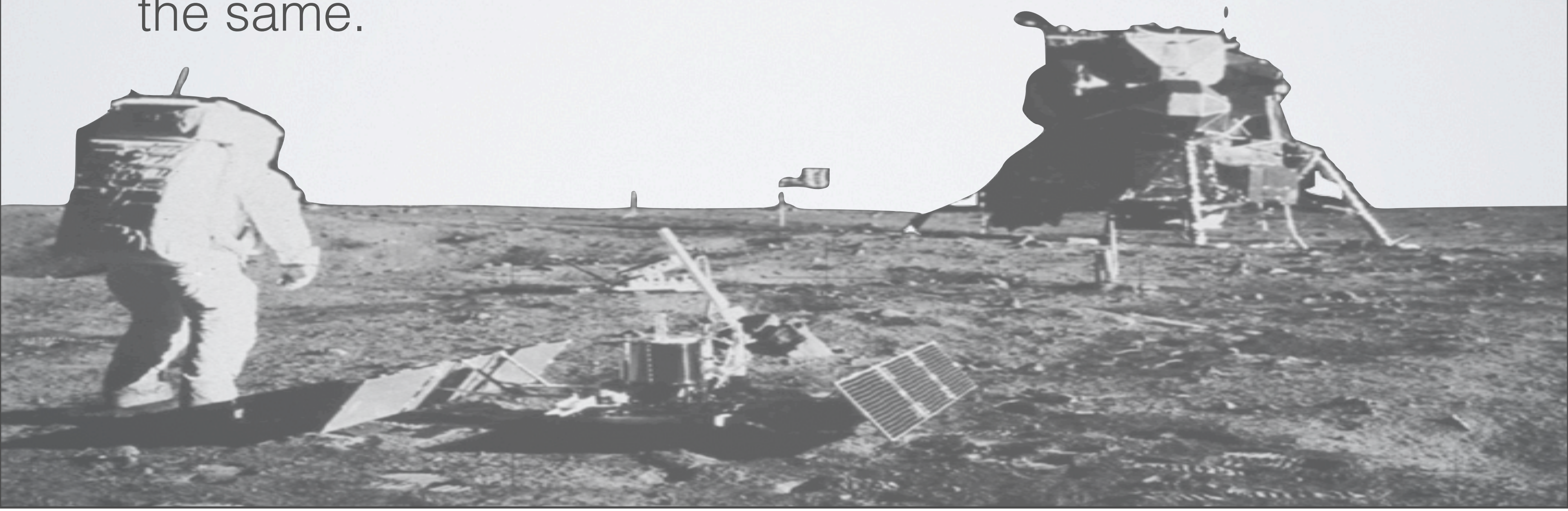
YOUR NUMBERS

- Add to your notes;
  - Your weight in pounds:
  - Your mass in kg:
    - (divide your pound weight by 2.2)
  - Your weight in N:
    - (multiply your mass by 9.8)

File:HK TST Canton Road 新太陽廣場 Sun Arcade Weighting machine with tickets.JPG

MASS

- Mass is the measure of inertia of an object. In the SI system, mass is measured in kilograms.
- Mass is a property of an object. Weight is the force exerted on that object by gravity.
- If you go to the moon, whose gravitational acceleration is about 1/6 g, you will weigh much less. Your mass will be the same.



NEWTON'S THIRD LAW

NEWTON'S THIRD LAW OF MOTION

- Another update to 7th grade: "for every action there is an equal and opposite reaction"
- Newton's third law: *For every force there exists an equal and opposite reactive force*

NEWTON'S 3RD LAW

- Who kissed who?

FORCE PAIRS

- The earth pulls down on the globe held by the teacher.
- What other force MUST exist according to Newton's 3rd?

NEWTON'S THIRD LAW OF MOTION

- A key to the the third law is that the forces are exerted on different objects. Make sure you don't use them as if they were acting on the same object.

File:Horse-drawn carriage, early 19th century.jpg - Wikimedia Foundation

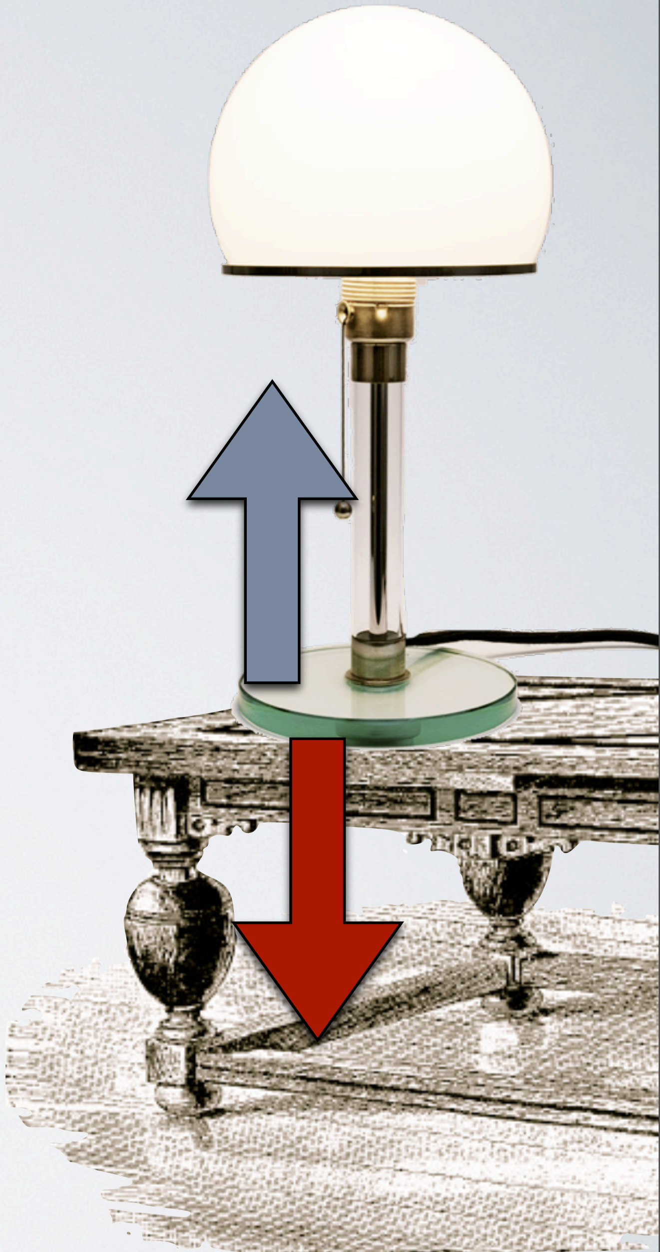
NEWTON'S THIRD LAW OF MOTION

- Rocket propulsion can be explained using Newton's third law

FREE BODY DIAGRAMS AND APPLIED FORCES

THE NORMAL FORCE

- An object at rest has a net force of zero acting on it. If it is sitting on a table, the force of gravity is still there; what other force is also on it?
- The force exerted perpendicular to a surface is called the normal force. It is exactly as large as needed to balance the force from the object (if the required force gets too big, something breaks!)

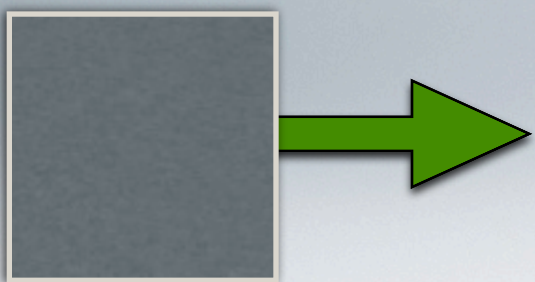


SOLVING PROBLEMS FREE-BODY DIAGRAMS

- Draw a sketch.
- For one object, draw a free-body diagram, showing all the forces acting on the object. Make the magnitudes and directions as accurate as you can. Label each force. If there are multiple objects, draw a separate diagram for each one.
- Resolve vectors into components.
- Apply Newton's second law to each component.
- Solve.

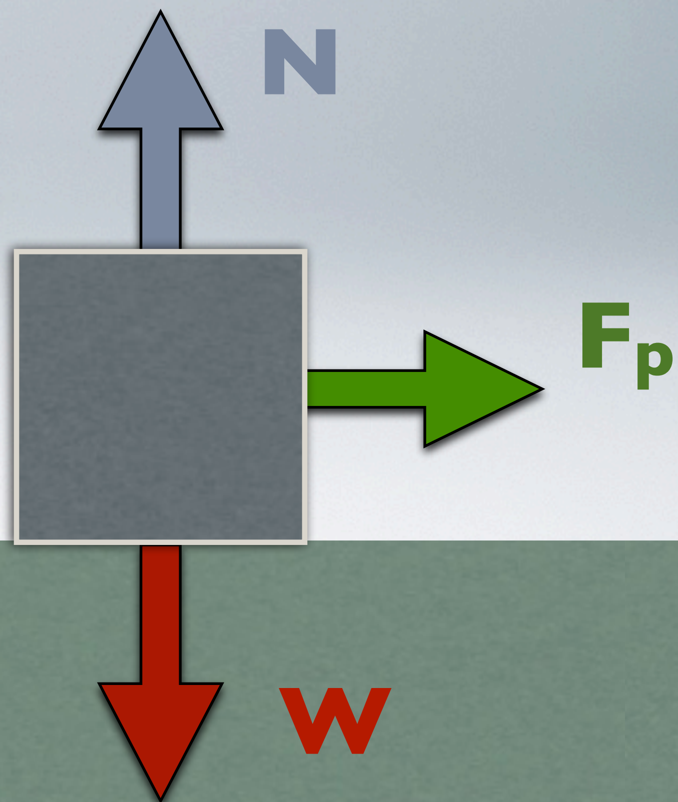
SIMPLE FREE BODY DIAGRAMS

- What Force is required to provide an acceleration of $2.4 m/s^2$ to a 6 kg mass?

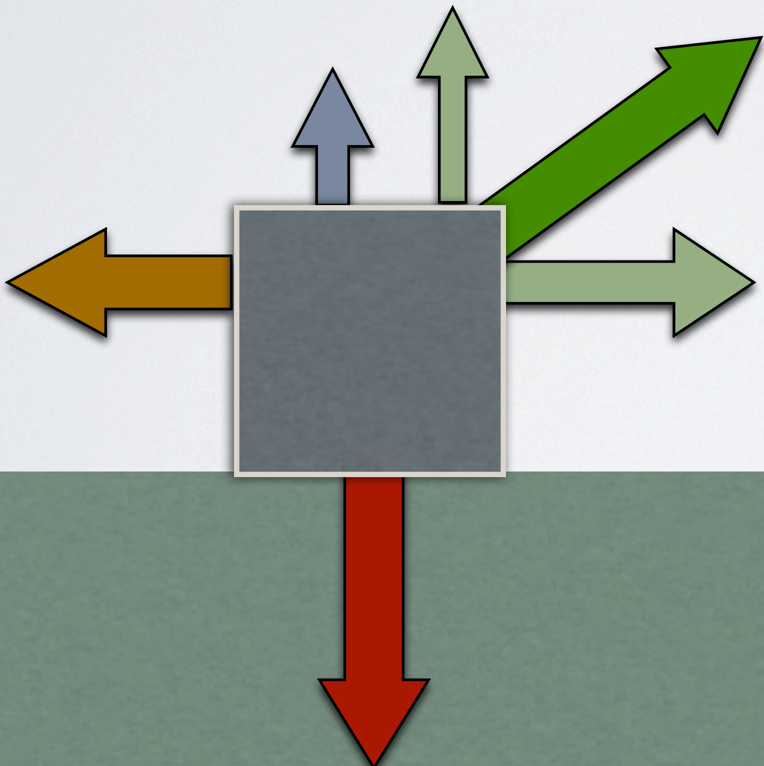


FREE BODY DIAGRAM

- Pull F_p or F
- Weight F_g or w
- Normal F_n or N



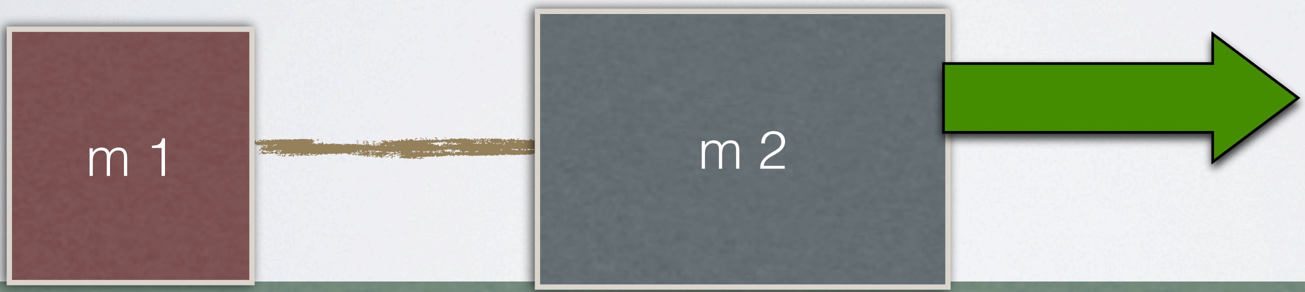
FORCES WITH COMPONENTS



- Pull F_p P or F
- X and Y F_x and F_y
- Weight F_g or w
- Normal F_n or N
- Friction (?) F_f

MORE THAN ONE MASS

- External Forces - treat the objects as one large group
- $F = (m_1 + m_2)\ a$



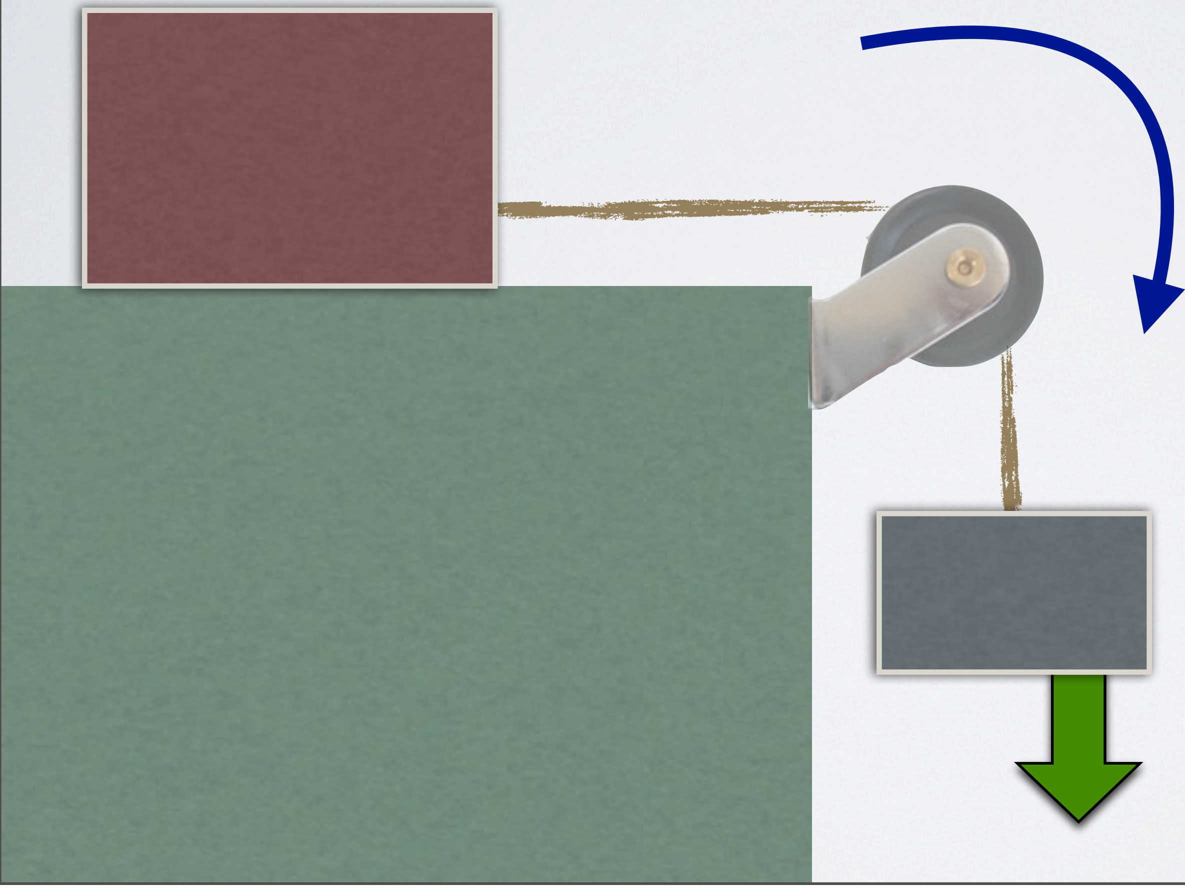
MORE THAN ONE MASS

- Internal Forces - **isolate** a smaller part of the problem
- $T = m_1 a$

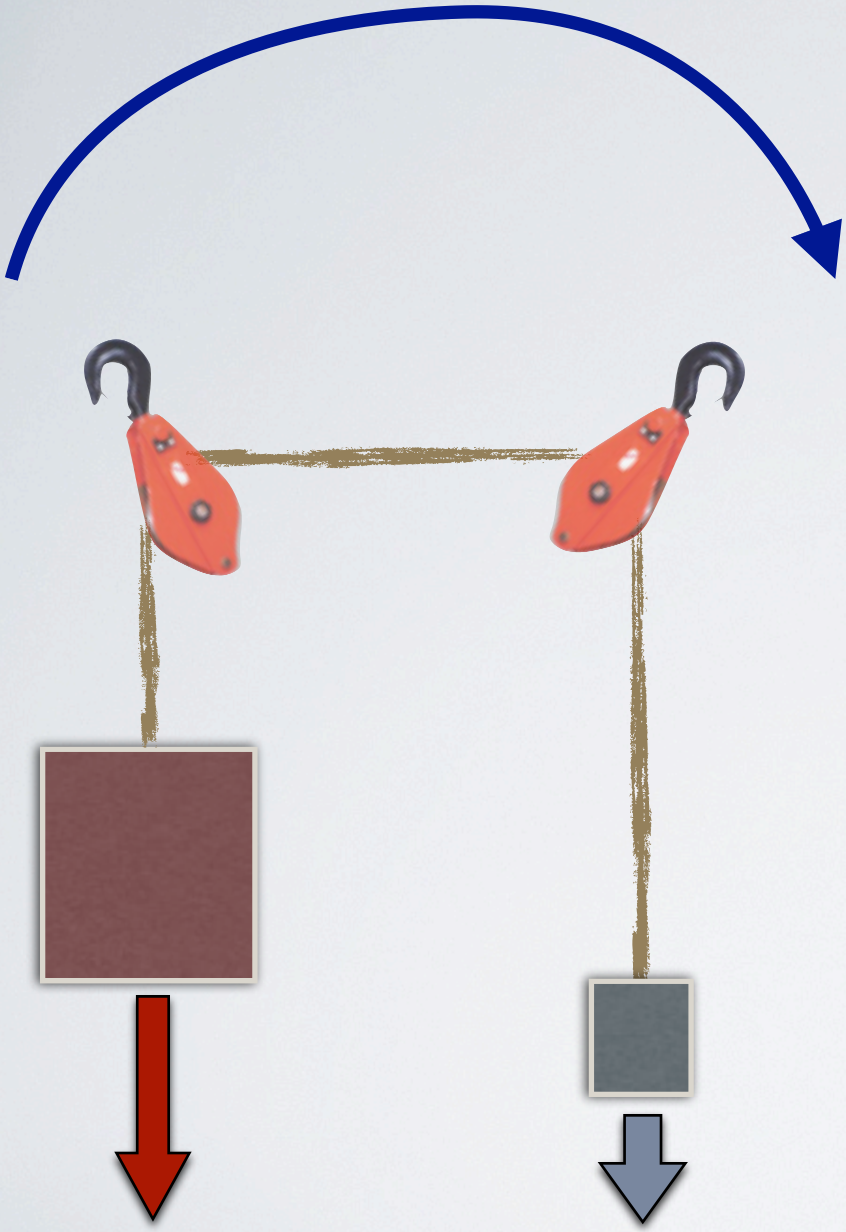
MORE THAN ONE MASS

- Of course, you have a choice.
- **F** - **T** = m_2 a

NEW DIRECTIONS



- Clockwise is the new positive direction



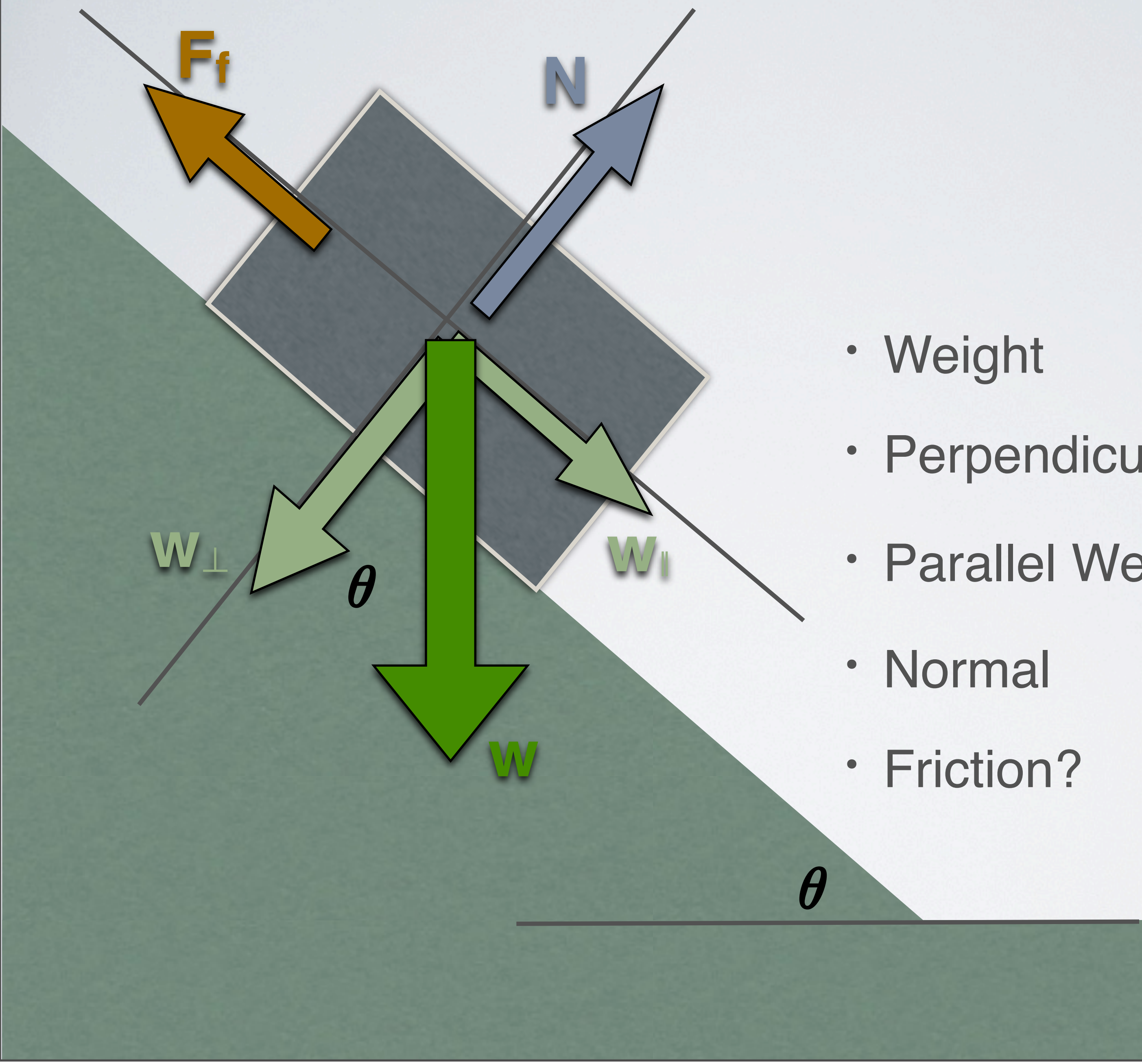
THE ATWOOD MACHINE

- Call Clockwise a positive force or velocity
- Find and use all external forces first to find acceleration
- Use an acceleration to find internal forces

ON AN ELEVATOR

- Gravitational Weight **W**
  - $W = mg$
- Apparent Weight **W$_a$**
  - Also called F_s
  - Upward Force from the spring.
  - Is only sometimes equal to the weight.

SAVE THIS DIAGRAM!



- Weight — w
- Perpendicular Weight — $w_\perp$
- Parallel Weight — $w_\parallel$
- Normal — N
- Friction? — F_f

FRICTION

THE COEFFICIENT OF FRICTION

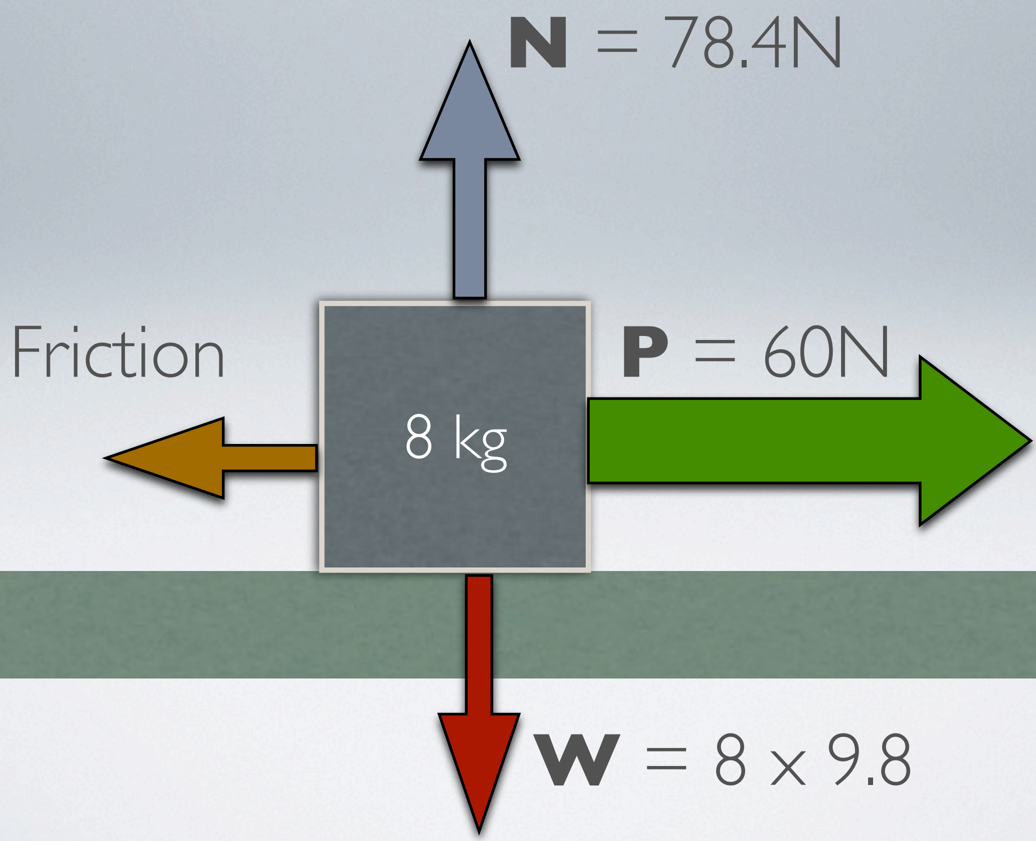
- On a microscopic scale, most surfaces are rough. The force can be modeled in a simple way.
- For kinetic (sliding) friction, we write:

$$F = \mu N$$

- μ is the coefficient of kinetic friction, and is different for every pair of surfaces.

NOW, WITH VALUES

An 8 kg block is pulled with a force of 60N over a rough surface where the coefficient of friction is 0.35. What is the acceleration of the block?



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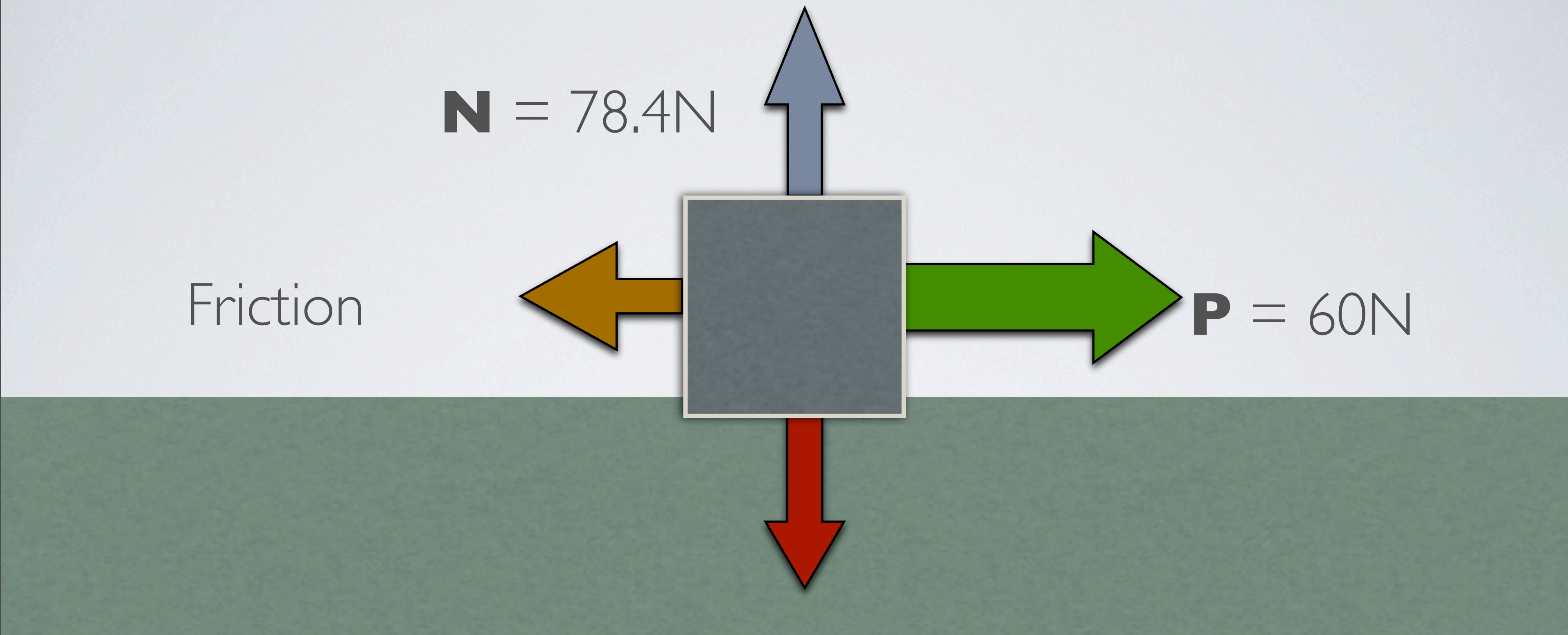


F = μ N

$F = 0.35\ (78.4)$

$F = 27.44\ N$

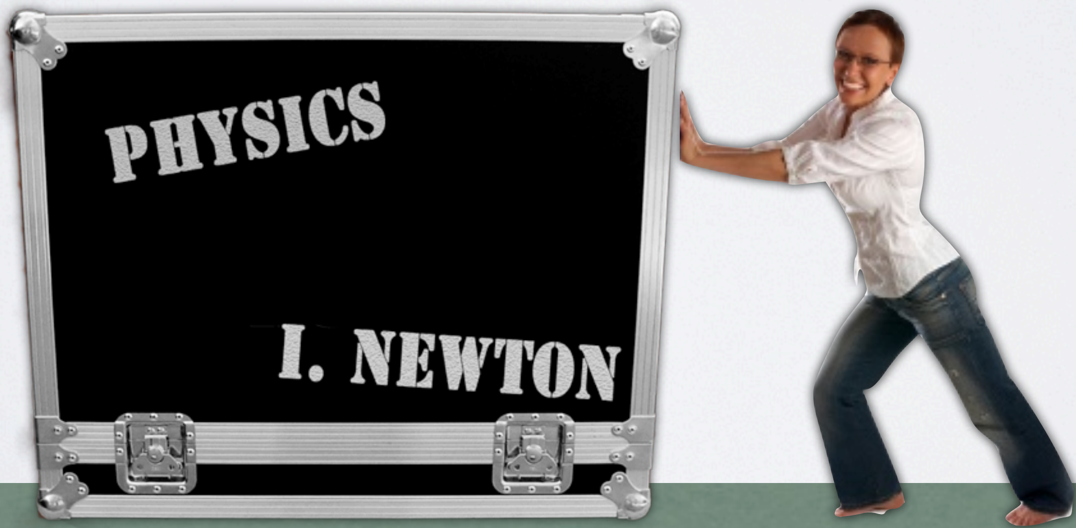
F = ma

$60 - 27.44 = 8\ \mathbf{a}$

$a = 4.07\ m/s^2$

STATIC OR KINETIC FRICTION

- Kinetic Friction is applied when one object slides over a second surface. The blocks have relative velocity.
- Static Friction is applied to hold one object in place on a surface. Their relative velocity is zero.



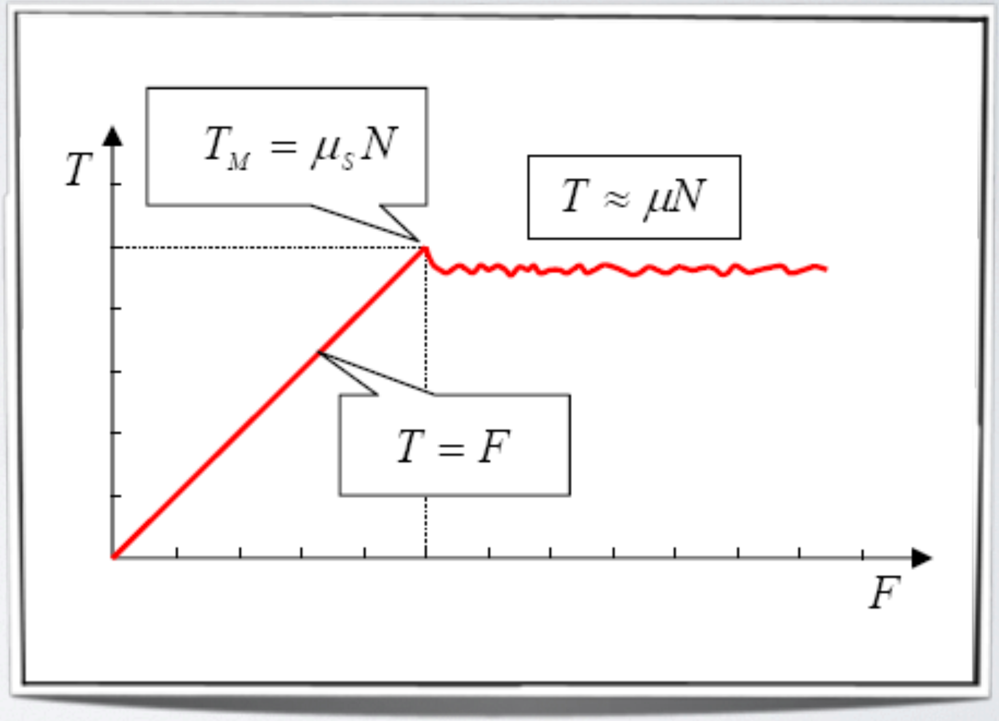
STATIC FRICTION IS A LIMIT

- Static friction is the frictional force between two surfaces that are not moving along each other. Static friction keeps objects on inclines from sliding, and keeps objects from moving when a force is first applied.

$$F \leq \mu_s N$$

STATIC AND KINETIC ON THE SAME GRAPH

- The static frictional force increases as the applied force increases, until it reaches its maximum. Then the object starts to move, and the kinetic frictional force takes over.

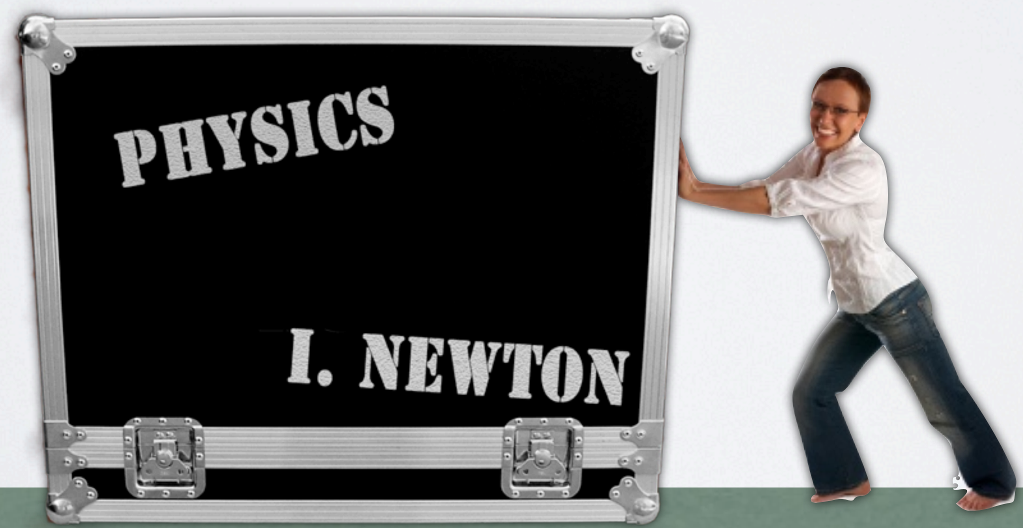


STATIC OR KINETIC FRICTION

- A woman pushes a 500 N box over the floor. The known values for friction are:

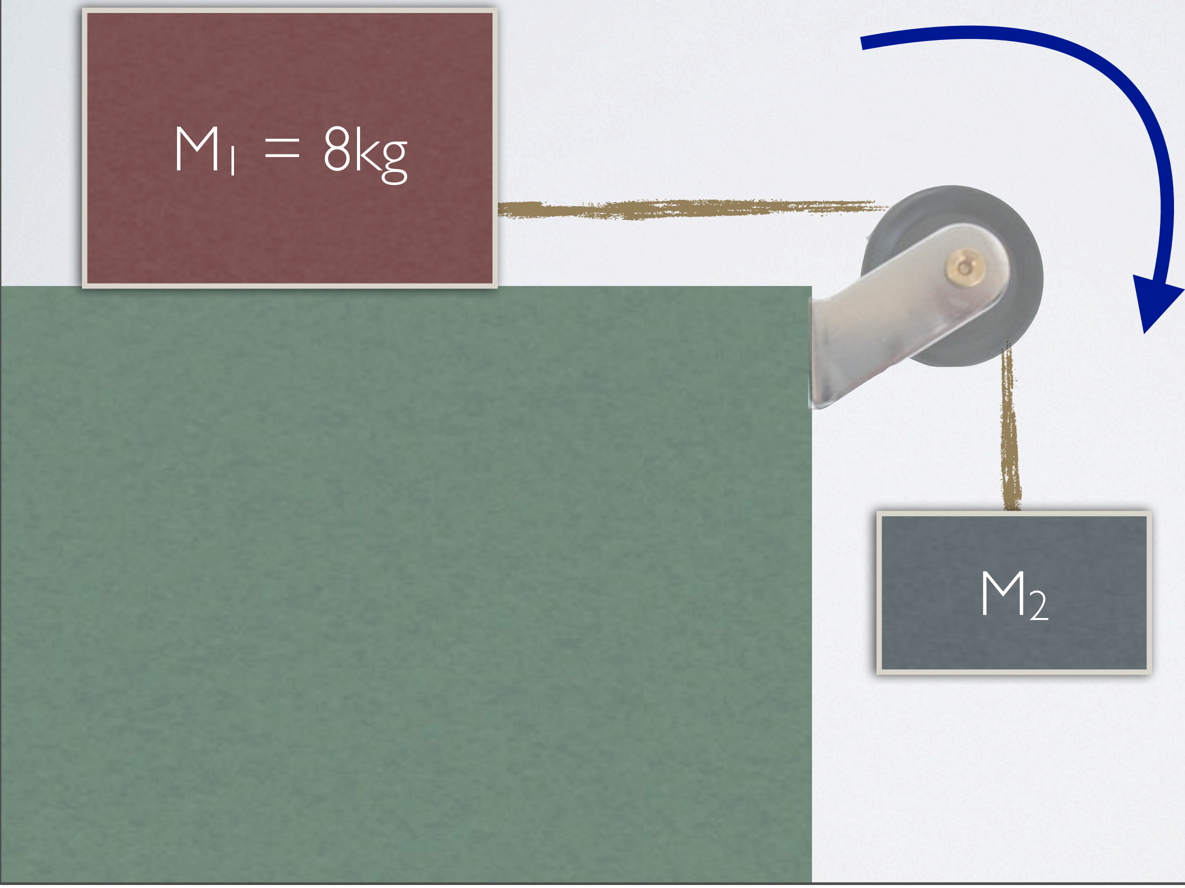
$\mu_s = 0.6$ $\mu_k = 0.2$

  - What is the force required to make the box slide?
  - What is the force required to keep the box sliding?



OLD PICTURE - NEW PROBLEM

- The known values for friction are:
  - $\mu_s = 0.6 \quad \mu_k = 0.2$
- What happens with each of the blue masses?

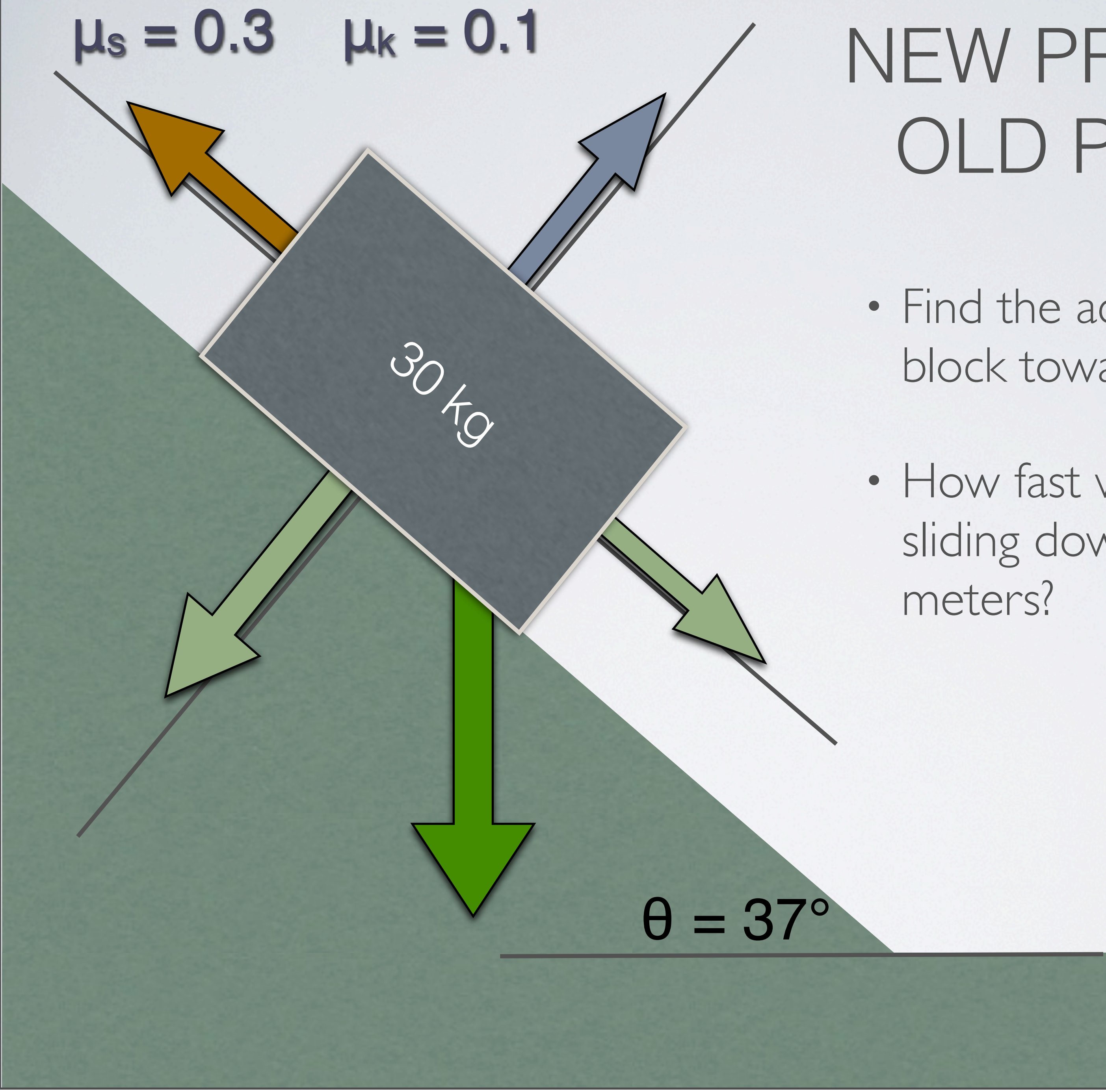


a) $M_2 = 1$kg

b) $M_2 = 3$kg

c) $M_2 = 6$kg

NEW PROBLEM - OLD PICTURE



- Find the acceleration of the block towards the bottom
- How fast will it move after sliding down for 2.1 meters?

ALL TOGETHER, NOW