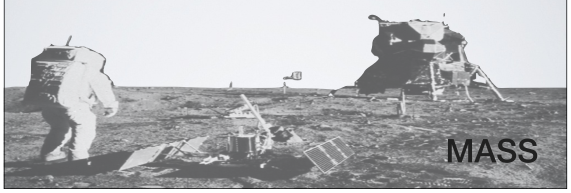
NEWTON'S LAWS

and force diagram solutions

- 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.



MASS

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:

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

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

KNOW 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)

LAB: NEWTON'S 2ND LAW

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

ACCEPTED MASS VALUES

Hanger	Cart	Squares	Washers
85g	340 g	200 g	40 g
0.085 kg	0.34 kg	0.2 kg	0.04 kg

TRIALS 1-6

Acceleration: Slope of a Velocity:Time Graph

Do not change the hanging mass

	Hanging Mass (kg)	Car Mass (kg)	Total Mass (kg)	Pulling Force (N)	Acceleration m/s²
1					
2					
3					
4	—			—	
5					
6					

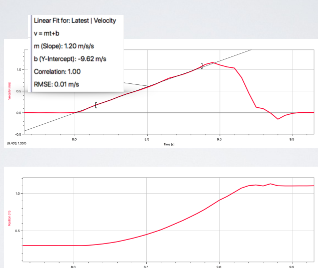
TRIALS 7 - 12

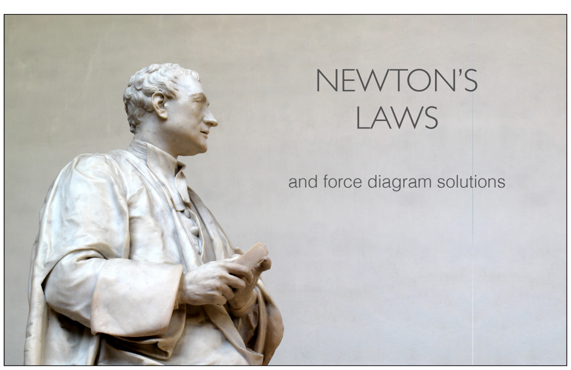
Acceleration: Slope of a Velocity:Time Graph

Do not change the **TOTAL** mass

	Hanging Mass (kg)	Car Mass (kg)	Total Mass (kg)	Pulling Force (N)	Acceleration m/s²
7					
8					
9					
10			—		
11					
12					

FIND ACCELERATION





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.

NEWTON'S THIRD LAW

NEWTON'S THIRD LAW OF MOTION

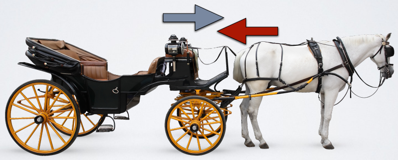
- Another update to 7th grade: "for every action there is an equal and opposite reaction"
- Newton's third law: *For every force there exists an equal and opposite reactive force*

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 between two different objects.
- Discuss: internal or external forces



NEWTON'S 3RD LAW

Who kissed who?

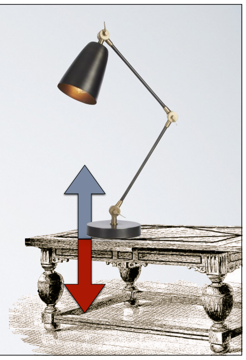
NEWTON'S THIRD LAW OF MOTION

- 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!)

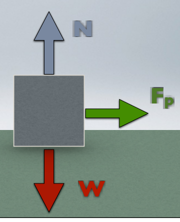


SOLVING PROBLEMS
FREE-BODY DIAGRAMS

- 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.

FREE BODY DIAGRAMS

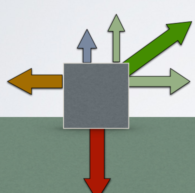
Pull	F_p or F
Weight	F_g or w
Normal	F_n or N



SIMPLE FREE BODY DIAGRAMS

- What Force is required to provide an acceleration of 2.4 m/s² to a 6 kg mass?

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

FRICTION

THE COEFFICIENT OF FRICTION

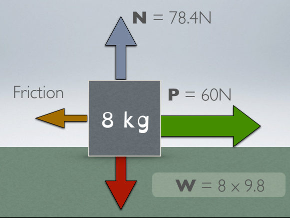
- On a microscopic scale, most surfaces are rough. The force can be modeled in a simple way.
- For kinetic (sliding) friction, we write:

$$F = \mu N$$

- 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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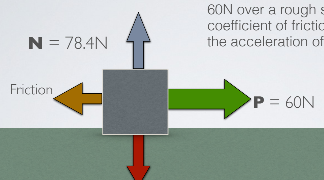


F = μ N

F = 0.35 (78.4)

F= 27.44 N

F = ma

60 -27.44 = 8 **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.

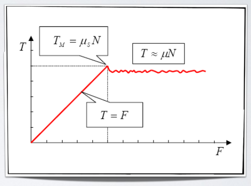
STATIC FRICTION IS A LIMIT

- 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.



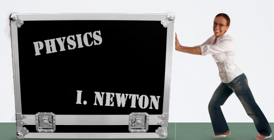
STATIC OR KINETIC FRICTION

- 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?



MORE THAN ONE MASS

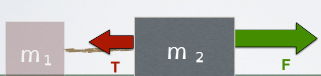
- External Forces - treat the objects as one large group
- $F = (m_1 + m_2)\, a$

MORE THAN ONE MASS

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

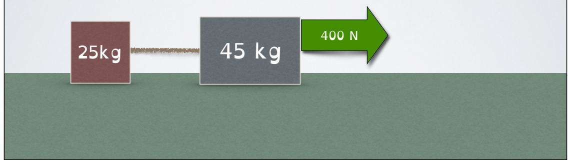
MORE THAN ONE MASS

- Of course, you have a choice.
- $\mathbf{F} - \mathbf{T} = m_2\, a$

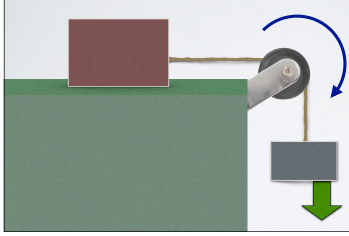


MORE THAN ONE MASS

A force of 400 N pulls two blocks across a frictionless table. Find the acceleration of each block, the tension in the rope between them, and the distance they will move in the first 25 seconds.

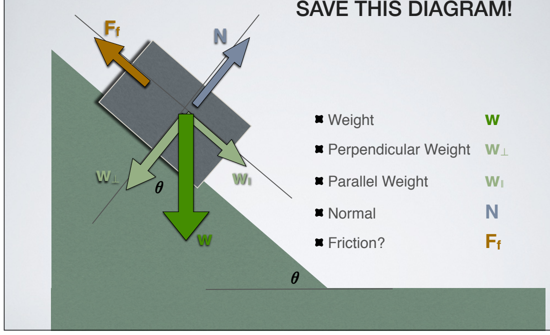


NEW DIRECTIONS



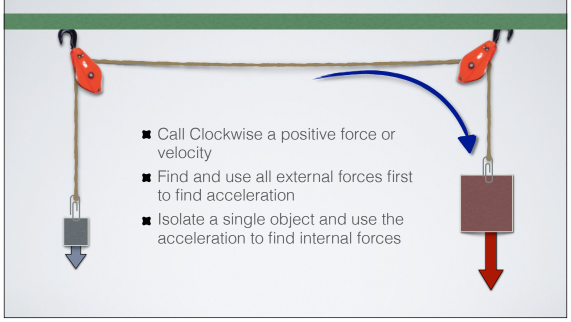
- Clockwise is the new positive direction

SAVE THIS DIAGRAM!

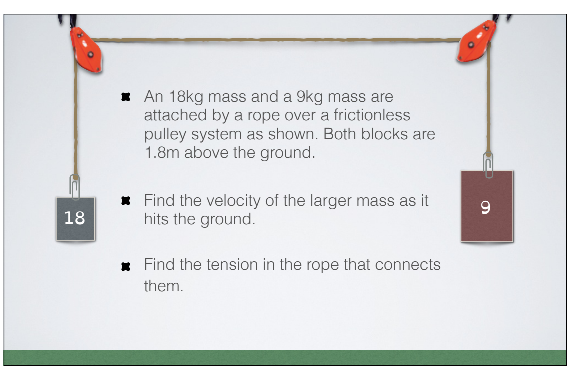


- Weight — W
- Perpendicular Weight — $W_{\perp}$
- Parallel Weight — $W_{\parallel}$
- Normal — N
- Friction? — F_f

THE ATWOOD MACHINE



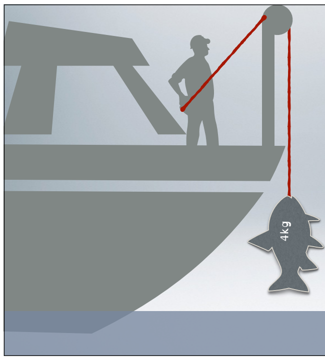
- Call Clockwise a positive force or velocity
- Find and use all external forces first to find acceleration
- Isolate a single object and use the acceleration to find internal forces



- An 18kg mass and a 9kg mass are attached by a rope over a frictionless pulley system as shown. Both blocks are 1.8m above the ground.
- Find the velocity of the larger mass as it hits the ground.
- Find the tension in the rope that connects them.

MORE APPLICATIONS

FISHING



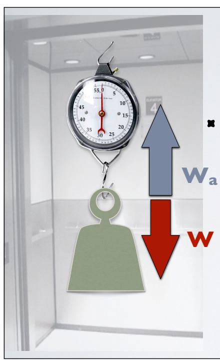
The fishing line you are using has been tested to hold up to 50 N of tension. What is the minimum time you can take to raise the 4kg fish up 2.8 m from the water?

ON AN ELEVATOR

- Gravitational **Weight W**
  W = mg
- Apparent Weight W_a
  Upward Force from the scale.
  - or the floor (Normal)
  - or a rope (Tension)..

  Is only sometimes equal to the weight.

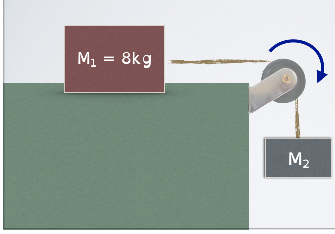
ON AN ELEVATOR



- A 65kg student stands in an elevator. What does the scale read;
  - A) before the elevator starts to move?
  - B) when it accelerates upward at 2.6 m/s².
  - C) when it has a constant speed of 4.2 m/s.
  - D) when it slows down at 1.8 m/s².
  - E) when the lifting wires break and the elevator falls?

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?

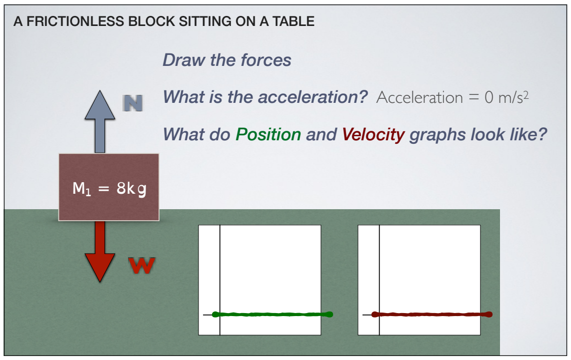


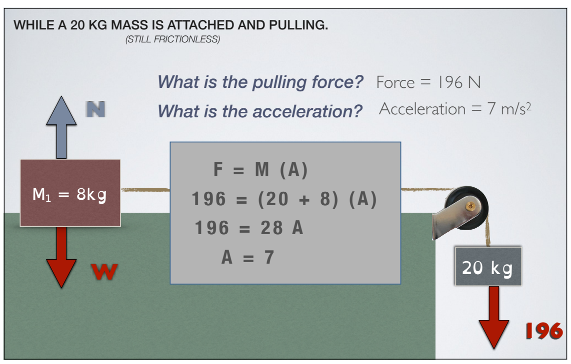
a) if $M_2 = 1$kg

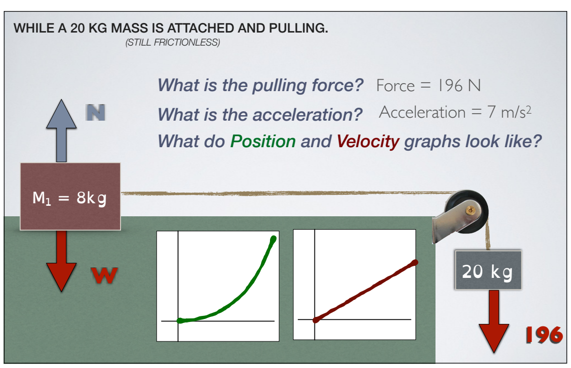
b) if $M_2 = 3$kg

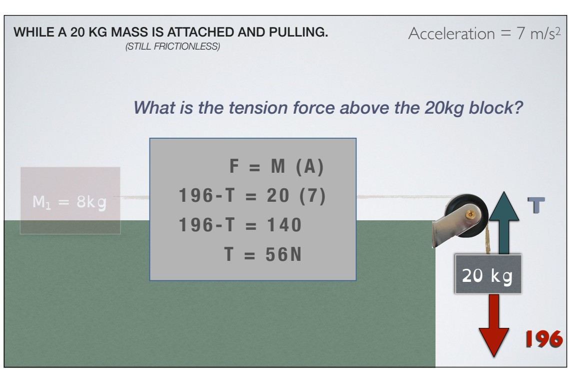
c) if $M_2 = 6$kg

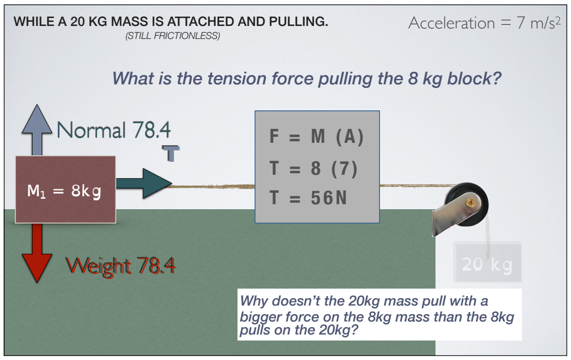
CONCEPT REVIEWS

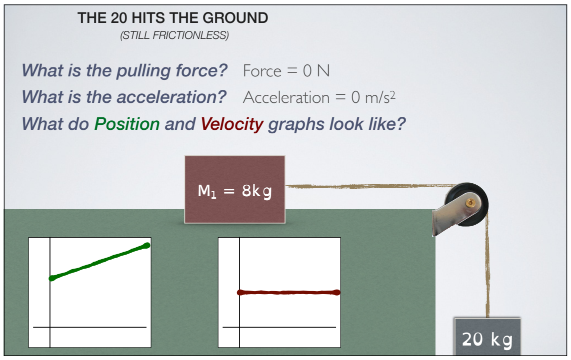


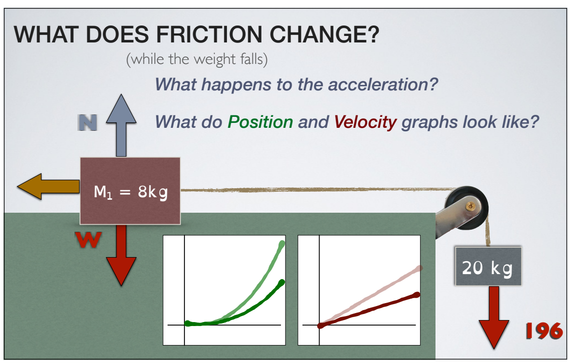


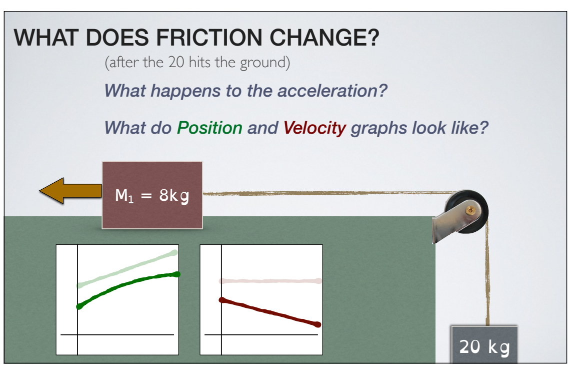


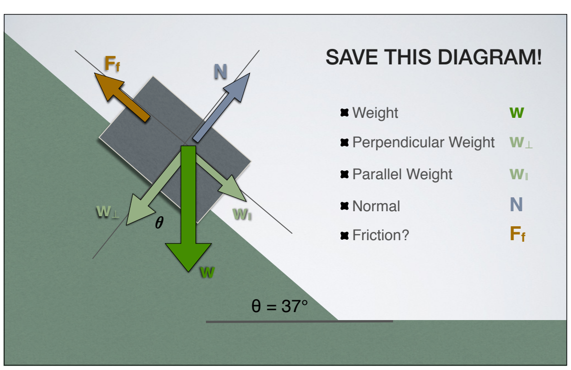


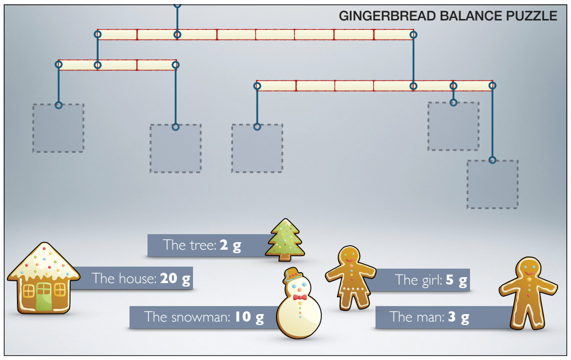

WHILE A 20 KG MASS IS ATTACHED AND PULLING.
(STILL FRICTIONLESS)
Acceleration = 7 m/s^2
What is the tension force pulling the 8 kg block?
Normal 78.4
T
M_1 = 8kg
F = M (A)
T = 8 (7)
T = 56N
Weight 78.4
20 kg
Why doesn't the 20kg mass pull with a bigger force on the 8kg mass than the 8kg pulls on the 20kg?

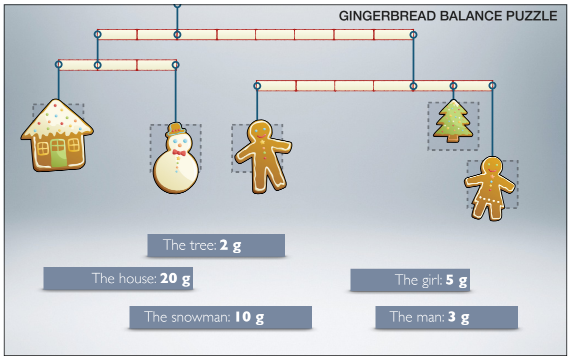

THE 20 HITS THE GROUND
(STILL FRICTIONLESS)
What is the pulling force? Force = 0 N
What is the acceleration? Acceleration = 0 m/s^2
What do Position and Velocity graphs look like?
M_1 = 8kg
20 kg


WHAT DOES FRICTION CHANGE?
(while the weight falls)
What happens to the acceleration?
What do Position and Velocity graphs look like?
N
M_1 = 8kg
W
20 kg
196


WHAT DOES FRICTION CHANGE?
(after the 20 hits the ground)
What happens to the acceleration?
What do Position and Velocity graphs look like?
M_1 = 8kg
20 kg


SAVE THIS DIAGRAM!
Weight W
Perpendicular Weight $W_\perp$
Parallel Weight $W_\parallel$
Normal N
Friction? F_f
F_f
N
$W_\perp$
θ
$W_\parallel$
W
θ = 37°


GINGERBREAD BALANCE PUZZLE
The tree: 2 g
The house: 20 g
The girl: 5 g
The snowman: 10 g
The man: 3 g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