2: Newton’s Second Law of Motion

Force, mass, acceleration, gravity, energy (potential & kinetic)
Day 1: Newton’s Second Law of Motion

Warm Up: What is Newton’s First Law of Motion?

LT: I can explain the difference between distance and displacement.
REVIEW: Newton’s First Law

Revise bobsled model #1

https://www.youtube.com/watch?v=MmkXfRCmRM4
Newton’s Second Law of Motion

The acceleration of an object as produced by a net force is directly proportional to the magnitude of the net force, in the same direction as the net force, and inversely proportional to the mass of the object.

\[ F = ma \]

(Force = mass \times accelerate)
NEWTON'S SECOND LAW

The acceleration of an object is determined by its mass and the force acting on it.
Baseball example

- Normally, baseball is at rest.
- Needs external force to move: gets thrown or is hit
- The distance the ball travels depends on the amount of force that acts on it
- Tball:

  https://www.youtube.com/watch?v=YTdIA2YSRDc

-
- Baseball: attached videos in drive
In order to understand Newton’s Second Law we need to look at many different aspects of the equation.

First Focus: acceleration

What is acceleration??
How do we determine if an object has changed position if we don’t see them move?

https://www.youtube.com/watch?v=aDEaAOcDKnA

Ex: saw skier start at top and now see him at the bottom. If we didn’t actually observe the motion, but inferred he moved because of the CHANGE IN POSITION

Compare STARTING and ENDING positions to see exact DISTANCE of movement. Need to look at FRAME OF REFERENCE (position)
Frame of Reference: Position

- **Position**: An object’s location
- Position symbol: $X$
- Think about a pirate’s treasure map!...x marks the spot
Distance

- Magnitude of change of position is **DISTANCE**
- Is how far an object travels
Distance: Magnitude is always positive

- Magnitude values are written as absolute values
- Add up total distance, not direction
Example of distance:

Ex: skier traveled 2 miles

Does this tell us everything we need to know about the skier’s motion?

No! Don’t know which WAY he traveled...could be up or down the mountain...
Displacement

Change in the position of an object

Need to know:
- Magnitude of change of position
- Direction

Ex: Skier traveled 2 miles DOWNHILL
Who ran the farthest distance?

200m sprint

Mile race
Who had the largest displacement?

200m sprint

Mile race
Who traveled the farthest distance?

- Astronaut on the moon
- Astronaut who traveled to the moon and then back home safely
Who had the largest displacement?

Astronaut on the moon

Astronaut who traveled to the moon and then back home safely
Day 2: Air Trolleys & Calculating Distance & Speed

**Warm up:** What is the difference between distance and displacement?

**LT:** I can calculate distance and displacement.
What is the distance traveled from A to C?
8 m
What is distance traveled from A to D?
Either 11m or 5m
What is displacement from A to D?
5m
What is the displacement from A all the way around and back to A?
0m
Air Trolleys

In order to better understand something moving

- Make air trolley
- Test
- Record results
Discussion:

1. What is the relationship between the number of winds on the rubber band and the distance the trolley travels?
2. How far do you think the trolley will travel with 50 winds? 33 winds?
3. How would you describe the trolley’s movement to someone who wasn’t here to see it?
4. How could we tell how fast the air trolley was traveling?
Day 3: Speed

Warm Up: How can we tell how fast the air trolleys from yesterday were traveling?

LT: I can define speed and calculate an object’s speed
Distance Equation

\( X \) represents position

Initial position: an object’s starting point \( X_i \)

Final position: an object’s ending position \( X_f \)
Distance Equation

Distance traveled: Final Position - Initial Position

\[ d = X_f - X_i \]

Also could be written with \[ \Delta X = \text{change in position} \]

\[ \Delta X = X_f - X_i \]
Practice Question 1

An object moves from point A to point B to point C, then back to point B and then to point C along the line shown in the figure below.

a) Find the distance covered by the moving object.

b) Find the magnitude and direction of the displacement of the object.
Solution Practice Question 1

a) distance = AB + BC + CB + BC = 5 + 4 + 4 + 4 = 17 km

b) The magnitude of the displacement is equal to the distance between the final point C and the initial point A = AC = 9 km
Practice Question 2

An object moves along the grid through the points A, B, C, D, E, and F as shown below.

a) Find the distance covered by the moving object.

b) How would we find the magnitude of the displacement of the object?
Solution Question 2

a) distance = AB + BC + CD + DE + EF
= 3 + 1 + 1.5 + 0.5 + 0.5 = 6.5 km

b) Initial point is A and the final point is F, hence the magnitude of the displacement is equal to the distance AF which is calculated by applying Pythagora's theorem to the triangle AHF as shown in the figure below.
Road Races WS

Complete in class

Go over answers
Speed

The rate at which something changes position (how fast something is traveling)

- Distance per unit of time
- Speed is ALWAYS positive
- Directly proportional to distance and inversely proportional to time
- As distance increases, the speed increases
- As time increases, speed decreases
Calculating Speed

Speed equation: Speed = distance/time interval

Symbol for speed: $s$

Symbol for time: $t$

Symbol for distance: $d$

Speed equation: $s = \frac{d}{t}$
So we know the speed equation... $s = \frac{d}{t}$

What if we know the speed at which an object moves and how long it moves that speed...can we figure out how far it is?

With a partner, construct an equation that solves for:

1. Distance
2. Time
Time Travel WS

Work on in class

Homework if you do not finish
Day 4: Speed Practice

Warm Up: What is the equation for calculating speed?

LT: I can calculate the speed, distance, and time an object travels.
Calculating Speed

Speed equation: Speed = distance/time interval

Symbol for speed: s
Symbol for time: t
Symbol for distance: d

Speed equation: \( s = \frac{d}{t} \)
Review Time Travel WS
SPEED TRIANGLE

\[
\begin{align*}
&d \\
&s \qquad \times \qquad t
\end{align*}
\]
Practice speed questions

1. If a car travels 400m in 20 seconds, how fast is it going?
2. A plane travels 395,000 meters in 9000 seconds, what is its speed?
3. You arrive to my class 45 seconds after leaving math which is 90 meters away. How fast did you travel?
4. It takes Serina 0.25 hours to drive to school. Her route is 16 km long. What is her average speed on the drive to school?
Practice speed questions

1. If a car travels 400m in 20 seconds, how fast is it going? 20 m/s
2. A plane travels 395,000 meters in 9000 seconds, what is it’s speed? 43.89 m/s
3. You arrive to my class 45 seconds after leaving math which is 90 meters away. How fast did you travel? 2 m/s
4. It takes Serina 0.25 hours to drive to school. Her route is 16 km long. What is her average speed on the drive to school? 64 km/hr
Practice Time Questions

1. How much time will it take a bug to travel 5 meters across the floor if it is traveling 1 m/s?
2. You need to get to class, 200 meters away, and you can only walk in the hallways at 1.5 m/s...how much time will it take you to get to class?
Practice Time Questions

1. How much time will it take a bug to travel 5 meters across the floor if it is traveling 1 m/s? 5 sec
2. You need to get to class, 200 meters away, and you can only walk in the hallways at 1.5 m/s...how much time will it take you to get to class? 133 sec
Practice Distance Questions

1. How far can you get away from your little brother who has a squirt gun filled with paint if you can travel 3 m/s and you have 15 sec before he sees you?

2. How far can your little brother get if he can travel 2.5 m/s and in 5 seconds you will discover that his squirt gun has run out of paint?
Practice Distance Questions

1. How far can you get away from your little brother who has a squirt gun filled with paint if you can travel 3 m/s and you have 15 sec before he sees you? 45 m

2. How far can your little brother get if he can travel 2.5 m/s and in 5 seconds you will discover that his squirt gun has run out of paint? 12.5 m
Speed and Distance Practice Questions

You MAY work with a partner

SHOW YOUR WORK

Be prepared to EXPLAIN your answers

FALSE

PRACTICE MAKES PERMANENT
Day 5: Average speed

**Warm up:** A cyclist travels 100 miles at 30 mph, how long does his ride take him?

**LT:** I can define and calculate average speed.
SPEED TRIANGLE
3 conceptions of speed:

**Constant speed:** steady rate of speed (cruise control)
- Constant speed is rare, most moving objects exhibit some variation in speed

**Average speed:** measures the distance traveled and the time it took to travel that distance. (This is mainly what we will be using)

**Instantaneous speed:** rate of speed at a given time
- Uses the same speed equation, but measures speed just at one specific moment in time
Average Speed

Measures TOTAL distance and TOTAL time

(Use the speed equation to find this)
Practice Problem

A small robot can travel a distance of 32.5 meters in 13 seconds. What is the average speed of the small robot?

a. 2.5 mph
b. 0.4 mph
c. 2.5 m/s
d. 0.4 m/s

Answer: C - 2.5 m/s
Average speed practice WS
LAW 2 Week 2
Day 6: Speed

Warm Up: The pitcher’s mound in baseball is 85 m from the plate. It takes 4 seconds for a pitch to reach the plate. How fast is the pitch?

LT: I can write and solve problems about speed, distance, and time.
SPEED TRIANGLE
Stamp and Go Over HW
Task: Question writing

- Groups of 2-3
- Work together to:
  - Write 1 question solving for time
  - Write 1 question solving for speed
  - Write 1 question solving for distance
- Write questions NEATLY on your whiteboard
- Write QUESTIONS AND ANSWERS on piece of paper and turn in
- Question rotation
Day 7: Speed Lab

Warm Up: A car travels for 10 m and it takes 15 sec. What is its speed?

LT: I can calculate a car’s speed
Instructions:

- Read background information

- Make prediction

- READ ALL INSTRUCTIONS ON LAB

- Run trials
Day 8: Comparing speeds

Warm Up: The distance between Leo’s home and the zoo was 100 meters. He walked 1 m/s for 1 minute. How many meters were left for him to reach the zoo?

LT: I can use the speed equation to compare speeds of moving objects.
Lab Write Up Instructions

- Complete ALL lab questions in complete sentences and RSQ format

- Write a FULL conclusion in RAPPS format on a separate piece of paper and attach to your lab sheet

  R - Restate the Question

  A - Address hypothesis (supported or not supported)

  P - Provide high and low data values

  P - Answer research question

  S - Statement of conclusion
Average speed

Total distance traveled divided by the total time

- TOTAL DISTANCE/TOTAL TIME

How do you find an average:

- Single event: ex - car trip, average time to cover whole distance
- Two or more speeds: average of several speeds added up and divided by total distance, ex: speed of a four man bike team
Graphing Speed

- What is speed?
- Distance/time
- TIME = X AXIS
- DISTANCE = Y AXIS
Comparing speeds:

- Look at graphs
- Slope: rise/run
- Steep vs. gradual slope

![Distance-time graphs]

- A steep line indicates a fast speed
- A shallow graph indicates a slow speed
- A flat line indicates zero speed, the object is stationary
The diagram illustrates the relationship between distance and time with three distinct stages:

1. **Fast, Steady Speed**: The line shows a steep incline, indicating rapid advancement.
2. **Stationary**: The line becomes flat, indicating no change in distance over time, suggesting the object is stationary.
3. **Getting Faster**: The line inclines steeply again, indicating acceleration.

Additionally, there is a label indicating the process of returning to start.
Which line is showing a faster speed?
Work with a partner to create a “story” about this speed graph:
Work with a partner to create a “story” about this speed graph:
Day 9: Calculating your own speed lab

**Warm Up:** Walking at the rate of 4 km/hr a man cover certain distance in 2 hr. Running at a speed of 16.5 km/hr the man will cover the same distance in: ____________

**LT:** I can calculate and compare speeds of moving objects.
Which line shows the fastest speed? Which line shows the slowest speed?
Roadtrip WS

- Complete WS
- Go over in class
Speed Lab 2
Day 10: Speed vs. Velocity

**Warm up:** A biker rode up a 10 mile hill in 2 hours and down the hill in 0.5 hours without stopping. What was his average speed:

A. Going up the hill?___________
B. Going down the hill? ___________
C. For the whole trip? ___________

**LT:** I can explain the difference between speed and velocity
Clancey’s Afternoon WS

Do questions

Go over in class
Scalars

- 11
- 6.32
- 0.1
- 5 1/2

Vectors

- 10 mph NE
- 5 m NE
- 5 cm SSE
- 4 km NNE
Is speed a vector or a scalar?

...a **SCALAR**!

Speed is just a NUMBER, it does not have a direction

Ex: The car is going 60mph

The **VECTOR** version of speed is VELOCITY

Ex: The car is going 60 mph, West
Scalars and Vectors

A scalar quantity has only magnitude.
A vector quantity has both magnitude and direction.

Scalar Quantities
- length, area, volume
- speed
- mass, density
- pressure
- temperature
- energy, entropy
- work, power

Vector Quantities
- displacement
- velocity
- acceleration
- momentum
- force
- lift, drag, thrust
- weight

[Diagram showing volume and velocity]
Check your understanding! Decide if each one is a scalar or vector...

1. 5m
   a. SCALAR...no direction

2. 30 m/sec, East
   a. VECTOR...has direction

3. 5 mi., North
   a. VECTOR

4. 20 degrees Celsius
   a. SCALAR

5. 256 bytes
   a. SCALAR

6. 4000 Calories
   a. SCALAR
Day 11: Acceleration

Warm Up: What is the difference between speed and velocity? What is a vector? What is a scalar?

LT: I can calculate velocity.
Scalars and Vectors

**Scalar:** only have magnitude (a NUMBER)

- Ex: Distance...only a number! Total amount of distance traveled

**Vectors:** magnitude (a number) AND a direction

- Ex: Displacement...distance and direction, overall comparison of initial and final position
Velocity

Rate of change of displacement

Speed with a DIRECTION

Ex: 5 mph North, 15 m/s to the left
Equations for Speed & Velocity

Speed = distance/time

Velocity: displacement/time

\[ V = \frac{\Delta x}{\Delta t} \]
Speed vs. Velocity

Speed is simply how fast you are travelling...

This car is travelling at a speed of 20m/s.

Velocity is “speed in a given direction”...

This car is travelling at a velocity of 20m/s east.
Tutorial: https://www.youtube.com/watch?v=O22zcaELpaA

Usain Bolt: https://www.youtube.com/watch?v=-6lrr6-ADY0
Velocity vs. Speed Practice Questions
Friday: Acceleration

Warm Up: A train travels 100 miles in 2 hours east. Then it travels 50 miles in 2 hours west. What is the train’s velocity for the entire trip?

LT: I can define acceleration
Hand back quizzes

Go over homework
Brainstorm: What is acceleration?
Acceleration

A net force is applied on an object, resulting in a change in motion

\[ F = ma \]

Changing velocity

- A VECTOR (has magnitude and direction)
- Deceleration - decreasing velocity
- Acceleration - Increasing velocity
- Graph using Time vs. Velocity Graph
I'm accelerating because I'm **speeding up**.

I'm accelerating because I'm **slowing down**.

I'm accelerating because I'm **changing directions**.
Work with a partner to explain how these are examples of acceleration:
Calculating Acceleration:

**Acceleration = a**

\[ a = \frac{\Delta V}{\Delta t} \]

\( \Delta V = \) change in velocity \( = V_f - V_i \)

\( \Delta t = \) change in time \( = t_f - t_i \)
\[ a = \frac{\Delta v}{\Delta t} \]

\[ \Delta v = v_f - v_i \]

\[ \Delta t = t_f - t_i \]

- \( v_f \rightarrow \) final velocity
- \( v_i \rightarrow \) initial velocity
- \( t_f \rightarrow \) ending time
- \( t_i \rightarrow \) starting time
Ex. 1

$v_f = 46.1 \text{ m/s}$
$v_i = 18.5 \text{ m/s}$
$t_f = 2.47 \text{ s}$
$t_i = 0 \text{ s}$
Ex. 2

\( v_f = 0 \text{ m/s} \)
\( v_i = 22.4 \text{ m/s} \)
\( t_f = 2.55 \text{ s} \)
\( t_i = 0 \text{ s} \)
Acceleration Worksheet
Monday: Acceleration

Warm Up: What is the equation for acceleration?

LT: I can interpret an acceleration graph and calculate acceleration.
Acceleration

A net force is applied on an object, resulting in a change in motion

\[ F = ma \]

Changing velocity

- A VECTOR (has magnitude and direction)
- Deceleration - decreasing velocity
- Acceleration - Increasing velocity
- Graph using Time vs. Velocity Graph
Stamp and Go over Homework
How to graph acceleration?

X-axis: Time

Y-axis: Speed (aka velocity)

So slope...rise/run...v/time = acceleration
What does acceleration look like on a speed graph?

![Graph showing distance (d) over time (t)]
Fig. 9.2 A velocity-time graph.
Graphing Acceleration WS
\[ F_{\text{net}} = \text{total force (N)} \]
\[ m = \text{mass (m)} \]
\[ a = \text{acceleration (\(\frac{\text{m}}{\text{s}^2}\))} \]

\[ F_{\text{net}} = m \times a \]
MAY THE
MASS TIMES
ACCELERATION
BE WITH
YOU

https://www.youtube.com/watch?v=nO7XeYPi2FU
Acceleration Lab

Do cars roll down ramps at a constant velocity or do they accelerate?

Lab Instructions:
- READ lab instructions thoroughly
- Answer pre-lab questions
- Run lab working WITH your group
- Clean up materials
- Answer post-lab questions
- Write RAPPS conclusion and attach
Tuesday: Acceleration Lab

**Warm up:** Draw a distance vs. time graph that shows an object’s motion that is accelerating.

**LT:** I can calculate a car’s acceleration.
Acceleration Lab

Do cars roll down ramps at a constant velocity or do they accelerate?

Lab Instructions:

- READ lab instructions thoroughly
- Answer pre-lab questions
- Run lab working WITH your group
- Clean up materials
- Answer post-lab questions
- Write RAPPS conclusion and attach
Thursday: Force

Warm Up: What is acceleration? List some examples of objects that are accelerating.

LT: I can define force and calculate net force.
Review: Acceleration

A net force is applied on an object, resulting in a change in motion

Changing velocity

- A VECTOR (has magnitude and direction)
- Deceleration - decreasing velocity
- Acceleration - Increasing velocity
- Graph using Time vs. Velocity Graph
Acceleration of an object is dependent on the net force applied to it and its mass.

Mythbusters car vs human: https://www.youtube.com/watch?v=seNRu5JjpDM
FORCE!

A push or pull

- Forces are ALL around us and acting constantly
- Forces may be very large or very small
- Today we are going to learn how to predict movement and calculate force!

https://www.youtube.com/watch?v=GmIMV7bA0TM
Units of Force: Newtons

Unit of force = Newton

Symbol: N

\[ 1 \text{N} = 1 \text{ kg} \cdot \text{m/s}^2 \]
Brainstorm: what forces are acting on you RIGHT NOW?
Net Force

The **sum** of all forces acting on an object

- A net force is capable of accelerating a mass
- To calculate net force: **DRAW** a diagram and then add up all forces
- If an object is **ACCELERATING** there is an **UNBALANCED** net force acting on it
- If an object is at **REST** or moving but **NOT** accelerating (think about inertia!) there is a **BALANCED** net force acting on it
\[ F_{\text{net}} = \text{total force (} N \text{)} \]
\[ m = \text{mass (} m \text{)} \]
\[ a = \text{acceleration (} \frac{m}{s^2} \text{)} \]
\[ F_2 = 20 \text{ Newtons} \]
\[ F_1 = -20 \text{ Newtons} \]

Net Force = 0 Newtons
Net force
25 N + 20 N = 45 N
to the right
Practice 1:

What is the net force acting on the book? (Include magnitude AND direction)
Practice 2:

The red man is pulling with a force of 50N and the blue man is pulling with a force of 35N. What is the net force? Include magnitude and direction!
Practice 3:
Practice 4:
Force on Carts WS
Friday: Quiz + Review

Warm Up:

**LT:** I can calculate the net force acting on an object.
Quiz
Review: Force and Net Force

A push or pull

- Forces are ALL around us and acting constantly
- Forces may be very large or very small
- Today we are going to learn how to predict movement and calculate force!
Net Force

The sum of all forces acting on an object

- A net force is capable of accelerating a mass
- To calculate net force: DRAW a diagram and then add up all forces
- If an object is ACCELERATING there is an UNBALANCED net force acting on it
- If an object is at REST or moving but NOT accelerating (think about inertia!) there is a BALANCED net force acting on it
Go over homework
Calculating Net Force WS
Day 15: Net Force + Gravity + Friction

Warm Up: Write something fun you did over break!

LT: I can calculate net force and explain friction and gravity.
Review: Net Force

The sum of all forces acting on an object

- A net force is capable of accelerating a mass
- To calculate net force: DRAW a diagram and then add up all forces
- If an object is ACCELERATING there is an UNBALANCED net force acting on it
- If an object is at REST or moving but NOT accelerating (think about inertia!) there is a BALANCED net force acting on it
Football Physics

https://www.youtube.com/watch?v=qu_P4lmbV_I
Forces are constantly acting on, even if objects are not in motion or you can’t feel the force!
Gravity
Acceleration due to GRAVITY

- Acceleration due to gravity is always constant
- Pulling objects toward earth’s core

\[ g = 9.81 \text{ m/s}^2 \]

EXAMPLE: dropping different objects, they fall at the same rate
FIRST PHYSICS LAW OF CARTOONS

GRAVITY WILL NOT WORK 'TILL YOU LOOK DOWN...
Bullet vs. Fired Bullet

Which will hit the ground first!??


https://www.youtube.com/watch?v=abUBrQmI33Q
Friction

A FORCE that holds back the movement of a sliding object

Ex: sliding on carpet

Acts opposite to movement

Different surfaces have different amounts of friction

Ex: ice vs. grass
Measuring Friction

Measures of friction are based on the type of materials that are in contact.

Coefficient of Friction: measure how easily one object moves in relationship to another.

High Coefficient of Friction: lots of friction between materials, difficult to move.
  Ex: Concrete

Low Coefficient of Friction: less friction between materials, easier to move.
  Ex: Teflon (pots and pans)
Toy Car Vs. Real Car...who will win??

Discuss

Watch

Friction/Gravity WS
Day 16: Putting it all together: $F = ma$

Warm up: What is friction? What is gravity?

LT: I can explain Newton’s Second Law of Motion
Balloon Astronaut!

https://www.youtube.com/watch?v=CUg8pArZbCs

What did we see here?

How is someone able to go up toward space with JUST balloons?
Brainstorming time!
- Individually think about what is happening that allows Erik to go up into space with just balloons!
- **DRAW** your idea with **LABELS** in your journal
- **WRITE** a description of what is happening next to it
- Work with your **group**...brainstorm ideas about what is going on that allows for Erik to go up into the space...you do NOT have to agree!
- Draw ideas on whiteboard
- Be prepared to share ideas with the class!

Group discussion, Ms. P writes ideas on whiteboard
CER about the balloon astronaut
Revise Bobsled Model
Day 17 +18 : Acceleration Lab Part 2

**Warm Up:** Give an example of Newton’s Second Law from your everyday life.

**LT:** I can work with my group to design and conduct a lab about acceleration.
Acceleration Lab Part 2

Design experiment

Run experiment

Write conclusion and discuss results

Example research questions:

How does the mass of a car affect acceleration?

How does force applied on a car affect acceleration?

How does distance traveled affect a car’s acceleration?
Lab Write Up Instructions:

- Typed, 12 pnt font, double spaced, times new roman
- Heading with name, class period, date
- Parts needed:
  - Research Question
  - Hypothesis
  - Experimental Procedure (written steps and drawing)
  - Materials
  - Results (data table and graph)
  - RAPPS conclusion