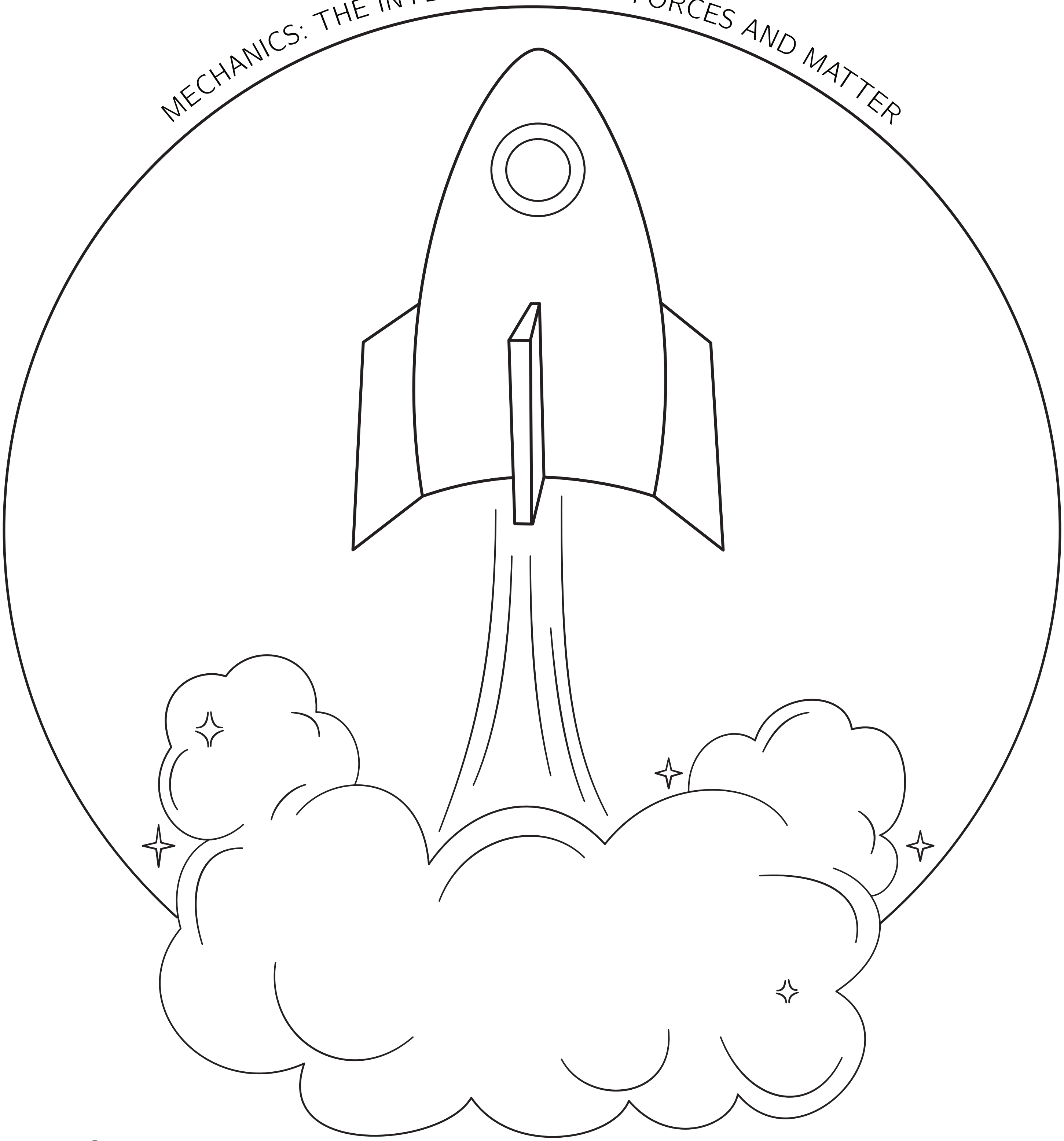
Physics 1

MECHANICS: THE INTERACTIONS OF FORCES AND MATTER



Physics 1

KINEMATICS, NEWTON'S LAWS, FORCES, MACHINES, AND ROTATIONAL MOTION

Lesson	Date	Topic	Pages
Intro	Wednesday Sep 6	Introduction & Quiz Show Practice	-
1	Monday, Sep 11	What is Physics?	4-7
2	Wednesday, Sep 13	Mighty Measures	8-14
3	self-paced	Fun Physics Tricks	15-17
4	Monday, Sep 18	Tracking Motion	18-22
5	Wednesday, Sep 20	Graphing Motion	23-27
6	self-paced	Physics Memory Game	28
7	Monday, Sep 25	Velocity	29-33
8	Wednesday, Sep 27	Acceleration	34-36
9	self-paced	Function Carnival and Degree Golf	37-39
10	Monday, Oct 2	Relative Motion and Combining Vectors	40-43
11	Wednesday, Oct 4	LINEAR MOTION QUIZ SHOW	-
12	self-paced	Assessment	44-47
13	Monday, Oct 9	Forces	48-53
14	Wednesday, Oct 11	Free Body Diagrams	54-58
15	self-paced	Cup Stack Challenge	59
16	Monday, Oct 16	The Law of Inertia	60-63
17	Wednesday, Oct 18	Mass vs Weight	64-66
18	self-paced	Inertia Experiments	67-70
19	Monday, Oct 23	Newton's Second Law	71-75
20	Wednesday, Oct 25	Actions and Reactions	76-79
21	self-paced	Balloon Races	80-81
22	Monday, Oct 30	Gravity and Free Fall	82-86
23	Wednesday, Nov 1	Space Station Physics	87-89
24	self-paced	Lab Reports and Gravity Project	90-95
25	Monday, Nov 6	NEWTON'S LAWS QUIZ SHOW	-
26	Wednesday, Nov 8	Kinetic vs Potential Energy	98-102
27	self-paced	Assessment	96-97
28	Monday, Nov 13	Work	103-105
29	Wednesday, Nov 15	Power	106-109
30	self-paced	Double Bounce	110-111
31	Monday,Nov 27	Momentum and Collisions	112-115
32	Wednesday,Nov 29	Center of Mass	116-118
33	self-paced	Racing Wheels and Center of Mass	119-121

Lesson	Date	Topic	Pages
34	Monday, Dec 4	Rotational Motion	122-123
35	Wednesday, Dec 6	Simple Machines	124-126
36	self-paced	Tensegrity Table	127
37	Monday, Dec 11	Mechanical Advantage	128-129
38	Wednesday, Dec 13	Relativity	130-132
39	self-paced	Rube Goldberg Machine	133
40	Monday, Dec 18	FINAL QUIZ SHOW	-
41	self-paced	Assessment	134-136

SUPPLY LIST:

Lesson 3 - Fun Physics Tricks
- 1 bottle with a narrow neck
- Piece of paper or a dollar bill
- 5 quarters
- 3 matches or flat-tipped toothpicks
- 1 shoelace
- 2 books of approximately the same size

Lesson 15 - Cup Stack Challenge
- 5 stackable paper cups
- 4 index cards or squares of paper
- 15 coins (any type)
- 4-6 short lengths of string or ribbon
- Tape

Lesson 18 - Inertia Experiments
Egg Splash
- Toilet paper tube
- 1 “light” egg
- 1 “heavy” egg
- Aluminum pie pan or piece of cardboard
- A large cup
- Rag or towel (for cleanup)

Tablecloth Pull
- Smooth cloth or scarf
- Bath towel
- Flat table surface
- Unbreakable dishes or water bottles

Inertia Hat
- Wire cutters (optional)
- Wire hanger
- 2 balls (tennis, wiffle) or other objects

Lesson 21 - Racing Balloons
- 2 Balloons
- 2 straws
- 30+ feet of thread or fishing line
- 30+ feet of twine
- Tape
- Clip or clothespin (optional)

Lesson 24 - Gravity Project
Water Rocket Lab*
- Empty plastic 2 liter or 1 liter bottles
- A rubber cork and tubing to fit to a bike pump
- Fins to stabilize the bottle
- Bike pump

Hang Time Lab
- A tennis ball to throw
- Camera or stopwatch for timing
- Ball launcher

Horizontal Motion and Gravity Lab
- 2 identical coins
- Camera for timing
- Ruler
- Measuring tape

Lesson 30 - Double Bounce
- A larger ball that bounces such as a basketball or soccer ball
- A smaller ball that bounces such as a tennis ball or racquet ball
- Camera (for timing)
- Glue gun (optional)

Lesson 33 - Wheels and Rotation
Racing Wheels
- 12 Small paper plates
- 3 Pencils
- Pennies or other small weights such as nuts or bolts
- Tape or glue
- Sloped table or ramp
- Nail or drill to make a hole in a paper plate

Center of Mass
- Paperclip
- Pencil or pen
- Push pin
- Cardboard cereal box
- Straight edge
- String or yarn

Lesson 36 - Tensegrity Table
- At least 12 popsicle sticks
- 60 cm (2ft) of string
- A drill
- Hot glue, super glue, or duct tape

Lesson 39 - Rube Goldberg Machine
- Use any supplies you have on hand!

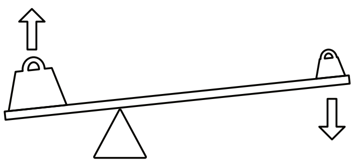
**A water rocket kit is recommended for this activity*

PHYSICS – THE FUNDAMENTAL SCIENCE

Physics is a broad field of science dedicated to understanding matter, space, energy, and time. It has dozens of different areas of specialization!

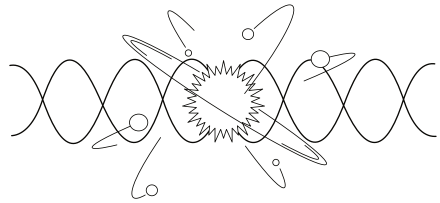
If you could spend a day working with a physicist, which of these areas would you like to explore? Put a star or checkmark by your top three choices.

CLASSICAL MECHANICS



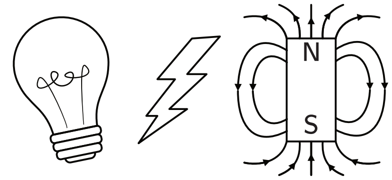
☐ The study of how everyday objects move and behave

QUANTUM MECHANICS



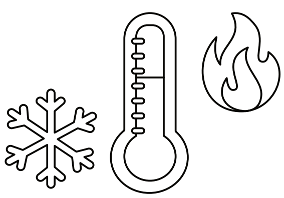
☐ The study of how very small particles behave

ELECTROMAGNETISM



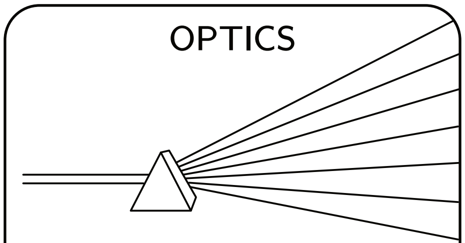
☐ The study of electric and magnetic fields

THERMODYNAMICS



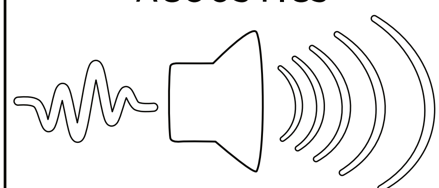
☐ The study of heat, energy, and entropy

OPTICS



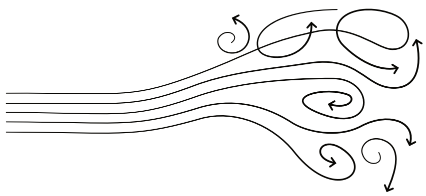
☐ The study of the behavior and properties of light

ACOUSTICS



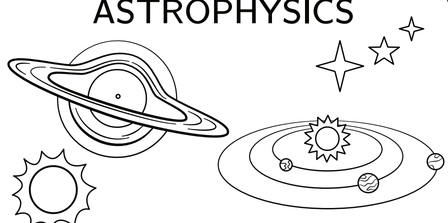
☐ The study of mechanical waves such as sound

FLUID DYNAMICS



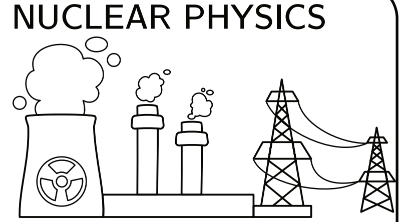
☐ The study of the flow of liquids and gases

ASTROPHYSICS



☐ Physics in outer space! How stars, black holes, and solar systems work

NUCLEAR PHYSICS



☐ The study of atomic nuclei and the generation of nuclear energy

PICK ONE OF THE TOPICS YOU SELECTED ABOVE. WHAT DO YOU ALREADY KNOW ABOUT IT? WHAT ARE YOU CURIOUS ABOUT?

FOR BEST LEARNING

1 DO THE HANDS-ON ACTIVITIES

Gather all of the supplies in advance. Record your results and share them with a friend.

When will you get supplies and where will you store them? Who will you share results with and how? Make a specific plan for doing the activities:

2 USE THE NOTES

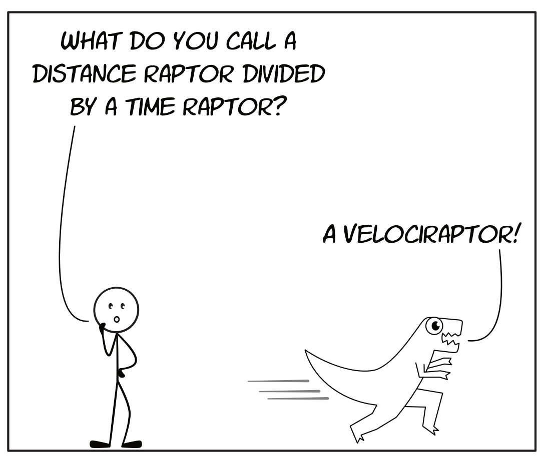
Fill them out! This can be done in advance, during, or after watching the video lesson.

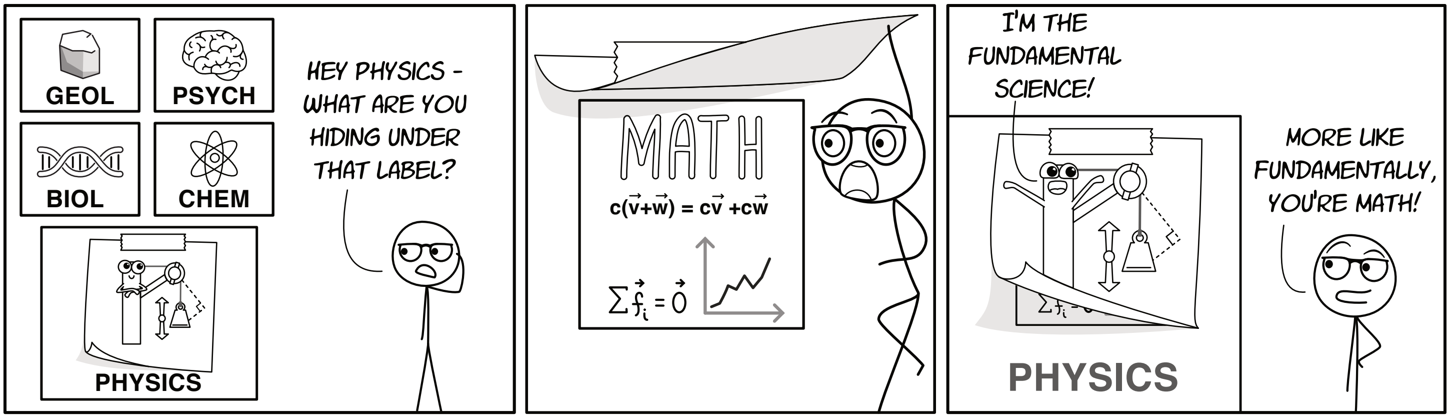
Make a specific plan for using the notes:

3 LEARN THE VOCABULARY

Play the physics vocab memory game, use the vocab list to make flashcards, redefine the terms in your own words, or practice using physics terms in everyday conversations.

Make a specific plan for learning the language of physics:





4 DO ALL OF THE PRACTICE PROBLEMS

Each lesson has a page or two of practice problems that should be completed individually after each lesson. Solve them on your own before looking at the answer key!

The practice problems will:

- Give you a solid foundation for more advanced science courses
- Strengthen your critical thinking and reasoning skills
- Show you how math can be used to solve real-world problems
- Prepare you to defeat Math Dad in our quiz shows

Make a specific plan for conquering the practice problems. When and where will you work on them?

____

____

____

What will you do if there is a problem you don't understand?

____

____

What will you do if there is a lesson or set of practice problems that feel too easy or boring?

____

____

How will you measure your progress or check your work?

____

____

Are you ready for physics?

To build a strong knowledge base in physics you'll need some math skills! How do you feel about each of these areas? If your knowledge is shaky in one of these topics, you should strengthen it before starting this course.

NUMBERS & ARITHMETIC

Strong arithmetic skills with addition, subtraction, multiplication, division, fractions, and decimals.

Can perform calculations using both positive and negative numbers and use a calculator to carry out more complex calculations.

For example: Use a calculator to find the decimal approximation of the number $\sqrt{31}$ accurate to two decimal places.

SLOPE & COORDINATE PLANE

Be able to plot and interpret points in the plane.

Can interpret the meaning of a simple graph.

Know that slope is rise over run.

VARIABLES & EQUATIONS

Know that a variable is a letter or symbol representing an unknown value.

Be able to substitute a value in place of a variable.

Can solve a simple equation involving a variable.

For example: 3 + a = 5. What is a? 4x = 12. What is the value of x?

EXPONENTS

Understand and be able to expand exponents.

For example: 10^3 means $10 \cdot 10 \cdot 10$, which equals 1,000.

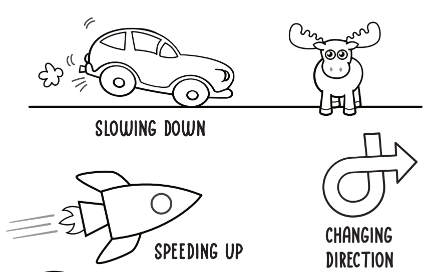
Can recognize and interpret numbers in scientific notation (Optional. We won't use scientific notation often and it could be picked up during class.)

For example: $4.5 \times 10^4 = 45{,}000$

Unit 1: Kinematics

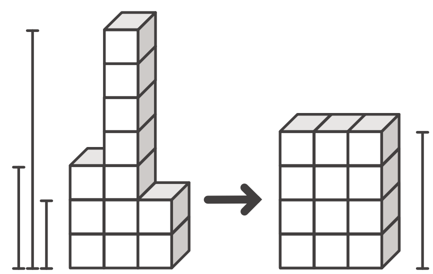
This unit covers how to describe and explain the motion of objects using graphs, diagrams, numbers, and words. Kinematics is all about how measurements are made!

ACCELERATION



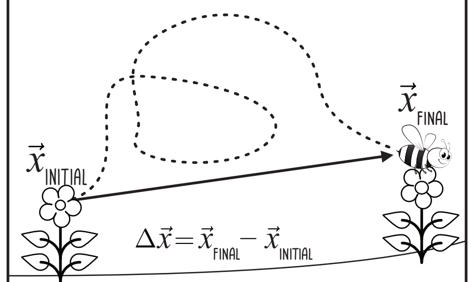
$\vec{a} = \frac{\Delta \vec{v}}{\Delta t}$ The rate of change of velocity

AVERAGE



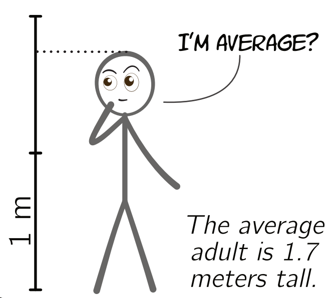
$\frac{x_1 + \cdots + x_n}{n}$ Sum of all values divided by the number of values

DISPLACEMENT



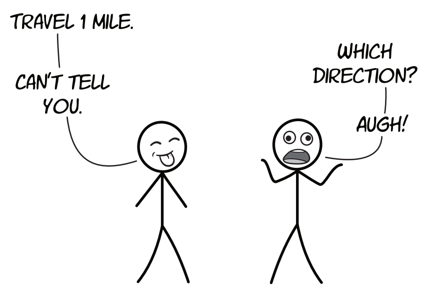
$\Delta \vec{x}$ The straight line distance between initial and final position

METER



m A metric unit of length

SCALAR

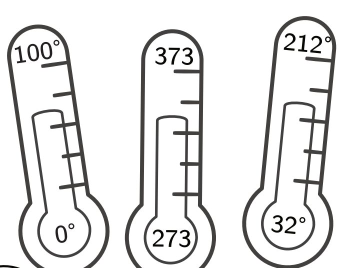


A quantity that has a magnitude (measurement) but no direction

SPEED

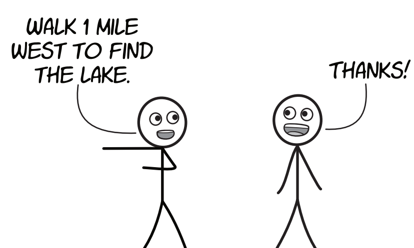
$\frac{d}{t}$ Distance divided by time

TEMPERATURE



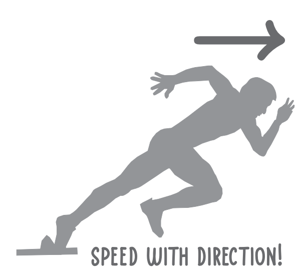
K °C °F Three different systems for measuring temperature

VECTOR



$\vec{v}$ A quantity that has both magnitude and direction

VELOCITY



$\frac{\Delta \vec{x}}{\Delta t}$ Change in position divided by change in time

The science of motion!

FILL IN THE BLANKS:

one	advantage	units	standard	prefixes

The metric system or SI (International System of Units) is the international __standard__ of measurement. The SI has 7 base __units__ that are defined in relation to universal constants. One __advantage__ of SI is that it has only __one__ unit for each quantity or type of measurement. SI systems uses the same __prefixes__ to represent multiples or powers of 10. Kilo means 1,000, so a kilometer will always have 1,000 meters and a kilogram contains 1,000 grams, etc.

CONVERTING UNITS:

Use the steps shown in the two examples below to complete the next conversions:

1. How many feet long is a marathon?

A marathon is 26.2 miles.
There are 5,280 feet in 1 mile.

$$26.2 \text{ mi} = 26.2 \text{ mi} \cdot 1$$

$$= 26.2 \text{ mi} \cdot \frac{5{,}280 \text{ ft}}{1 \text{ mi}}$$

$$= \frac{26.2 \cancel{\text{mi}} \cdot 5{,}280 \text{ ft}}{1 \cancel{\text{mi}}}$$

$$= 138{,}336 \text{ ft}$$

In mathematics, we can always add zero, multiply by one, or substitute something of equal value.

2. How many meters tall is Math Dad?

There are 3.28 feet in 1 meter.
Math Dad is 5.5 ft tall.

$$5.5 \text{ feet} = 5.5 \text{ ft} \cdot 1$$

$$= 5.5 \text{ ft} \cdot \frac{1 \text{ m}}{3.28 \text{ ft}}$$

$$= \frac{5.5 \cancel{\text{ft}} \cdot 1 \text{ m}}{3.28 \cancel{\text{ft}}}$$

$$= 1.68 \text{ m}$$

3. How many marathons would it take to equal the circumference of the Earth?

Circumference of the Earth = 24,902 miles.

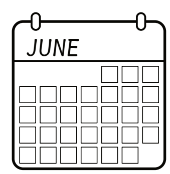
$$1 \text{ circ} = 24{,}902 \text{ mi}$$

$$= 24{,}902 \text{ mi} \cdot \frac{1 \text{ marathon}}{26.2 \text{ mi}}$$

$$= 950.45 \text{ marathon}$$

So it would take about 950.5
marathons to circle the whole Earth.

4. How many minutes are there in June?



$$\text{June} = 30 \text{ days}$$

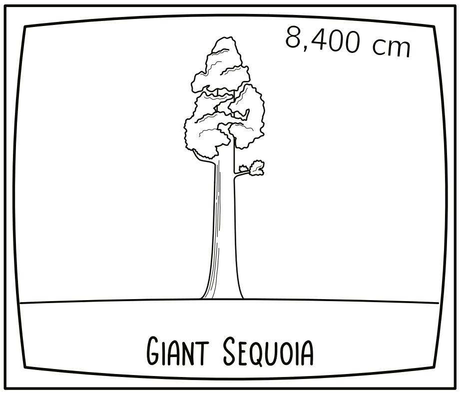
$$= 30 \text{ days} \cdot \frac{24 \text{ h}}{1 \text{ day}} \cdot \frac{60 \text{ min}}{1 \text{ h}}$$

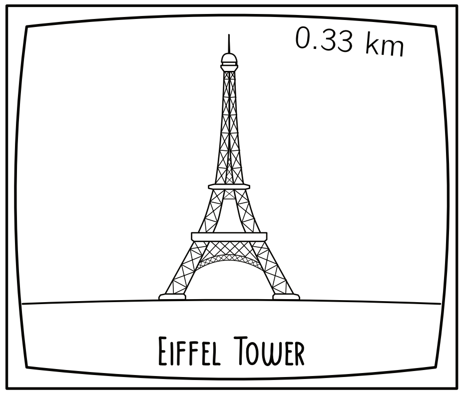
$$= 43{,}200 \text{ min.}$$

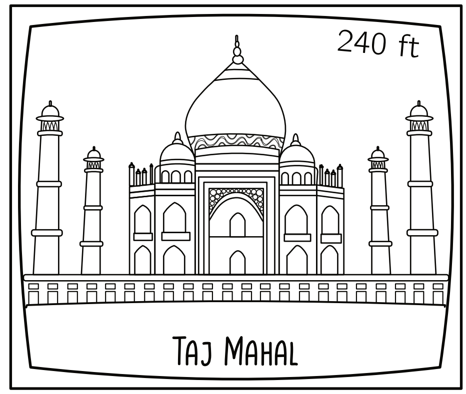
When we multiply a number by a unit conversion fraction, we're really just multiplying by 1!

Mighty Measures

Measuring is an important tool in physics. Can you rank the following from shortest to tallest? Each has been measured accurately, but the measurements are in different units!







Use the table to convert each of the measurements above to meters. Then sketch each object onto the grid below to see how they compare in height to the Great Pyramid of Giza.

$$8,400 \text{ cm} = 8,400 \text{ cm} \cdot \frac{1 \text{ m}}{100 \text{ cm}}$$
$$= 84 \text{ m.}$$

$$0.33 \text{ km} = 0.33 \text{ km} \cdot \frac{1,000 \text{ m}}{1 \text{ km}}$$
$$= 330 \text{ m.}$$

$$240 \text{ ft} = 240 \text{ ft} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} \cdot \frac{1 \text{ m}}{100 \text{ cm}}$$
$$= 73.152 \text{ m.}$$

Imperial system

1 foot	= 12 inches
1 mile	= 5,280 feet

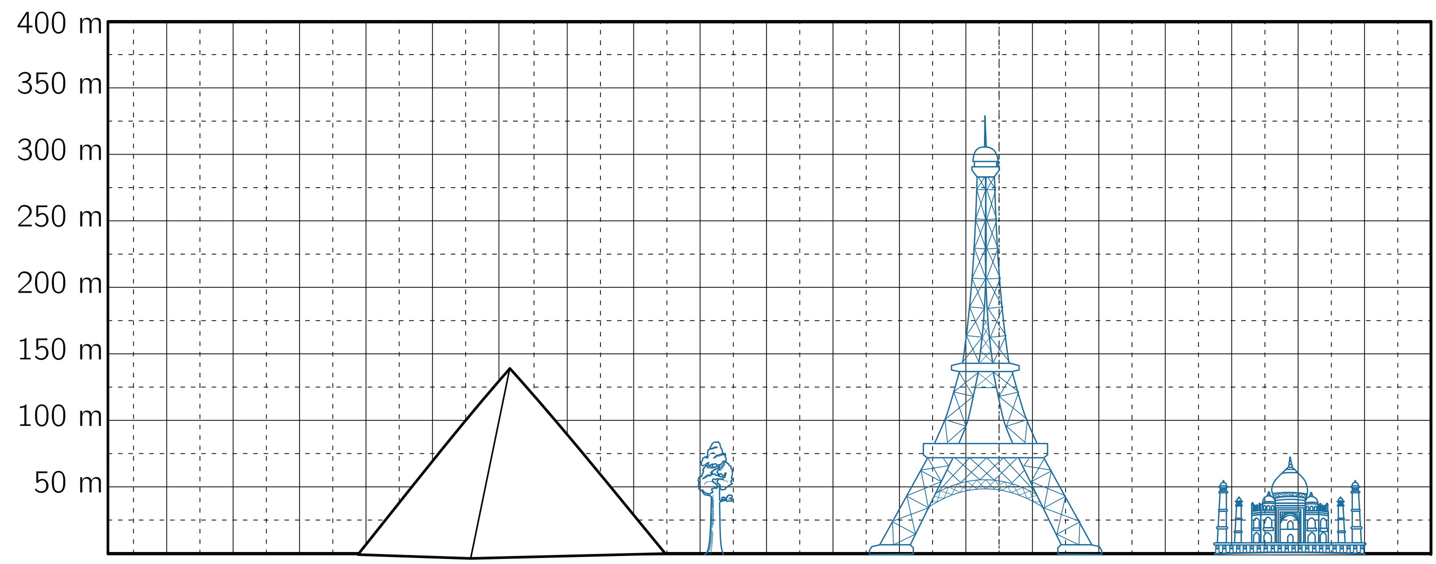
Metric system

1 meter	= 1,000 millimeters
1 meter	= 100 centimeters
1 kilometer	= 1,000 meters

Converting imperial to Metric

1 inch	≈ 2.54 centimeters
1 mile	≈ 1.609 kilometers
1 foot	≈ 0.3 meters

The Taj Mahal is the shortest. Then the giant sequoia. The tallest is the Eiffel Tower.



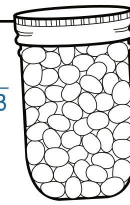
Direct vs Indirect Measurement

Some things, like the volume of a jar, can be measured directly. When candy is in a sealed jar, the number of candies can't be counted directly, but measurements can be used to give a good *estimation*.

How many candies in the jar?

Perhaps you estimate that the candies only fill 64% of the space. You might estimate:

$$1 \text{ jar space} = (0.64) \cdot 473 \text{ cm}^3 \cdot \frac{1 \text{ candy}}{1.65 \text{ cm}^3}$$
$$= 183.67 \text{ candies.}$$



1 pint jar = 473 cm^3
1 candy = 1.65 cm^3
17 candies fit on the bottom row of the jar
The jar is almost 10 candies tall

Perhaps you like the idea of viewing the jar as stacked rows. You might estimate:

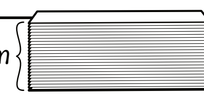
$$1 \text{ jar space} = 10 \text{ rows} \cdot \frac{17 \text{ candy}}{1 \text{ row}}$$
$$= 170 \text{ candies.}$$

A single piece of paper is too thin to be measured with a ruler – or is it?
Use the clues below to measure the thickness of a piece of paper *indirectly!*

How thick is 1 piece of paper?

$$1 \text{ page} = 1 \text{ page} \cdot \frac{1 \text{ stack}}{100 \text{ pages}} \cdot \frac{1.2 \text{ cm}}{1 \text{ stack}}$$
$$= 0.012 \text{ cm.}$$

1.2 cm

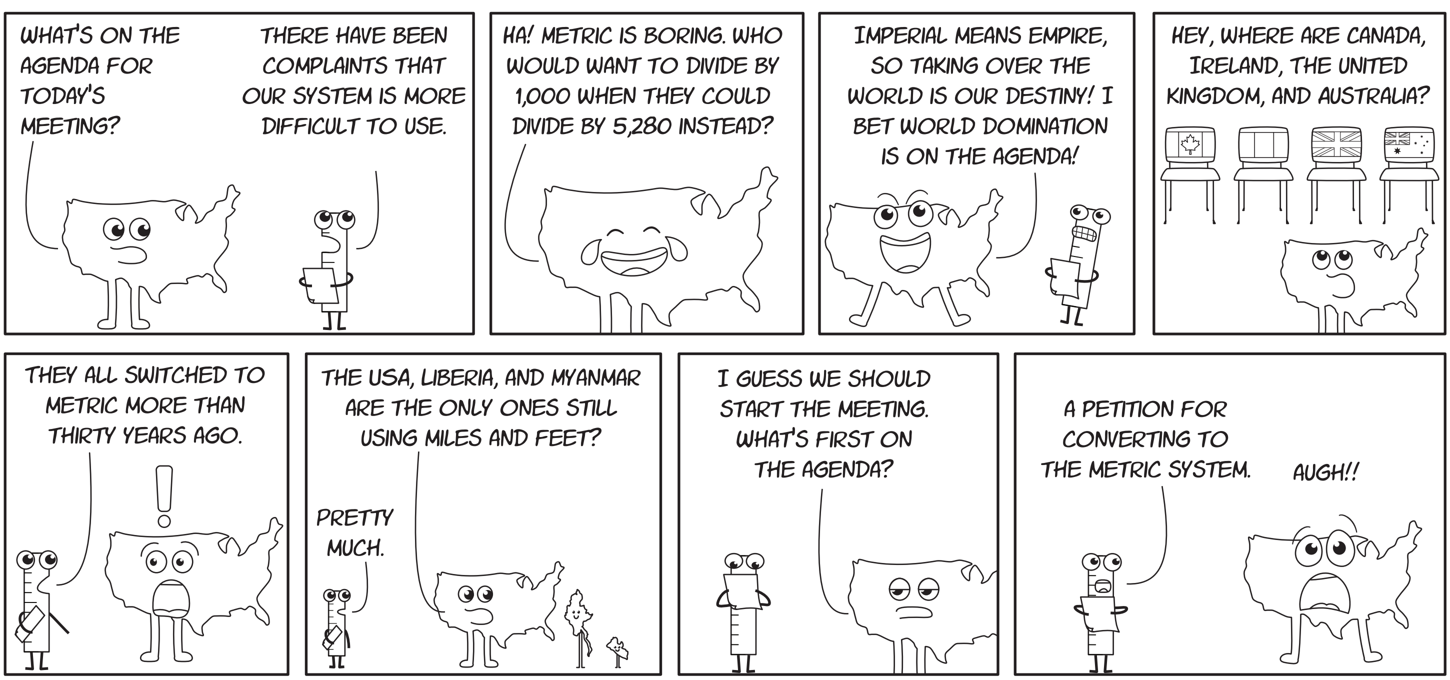


A stack of 100 papers is 1.2 cm tall.

As usual, there are many ways to get the same answer.

$$\frac{1.2 \text{ cm}}{100 \text{ pages}} = 0.012 \text{ cm/page.}$$

A MEETING OF IMPERIAL MEASURES



THE BASE UNITS	WHERE THEY CAME FROM
Length **meter (m)**	The distance from the North Pole to the equator divided by ten million
Time **Second (s)**	1/86,400 of a day
Quantity **Mole (mol)**	The number of atoms in 12 grams of carbon
Electric current **Ampere (A)**	1/10 the electric current that produces a certain amount of force
Temperature **Kelvin (K)**	Kelvin = Celsius + 273 degrees (the C° temperature scale comes from the freezing/boiling points of water)
Luminous intensity **Candela (cd)**	The brightness of a standard candle flame
Mass **Kilogram (kg)**	The weight of one liter of water

BASE UNITS CAN BE COMBINED TO MAKE MANY MORE UNITS!

Circle the units you've seen before. Put a box around ones that are new or unfamiliar.

hertz
pascal
newton
volt
watt
ohm
joule
lumen
farad
sievert
coulomb

SI PREFIXES

Fill in the missing prefixes, symbols, and multipliers below:

Symbol
Prefix

SMALLER | BIGGER

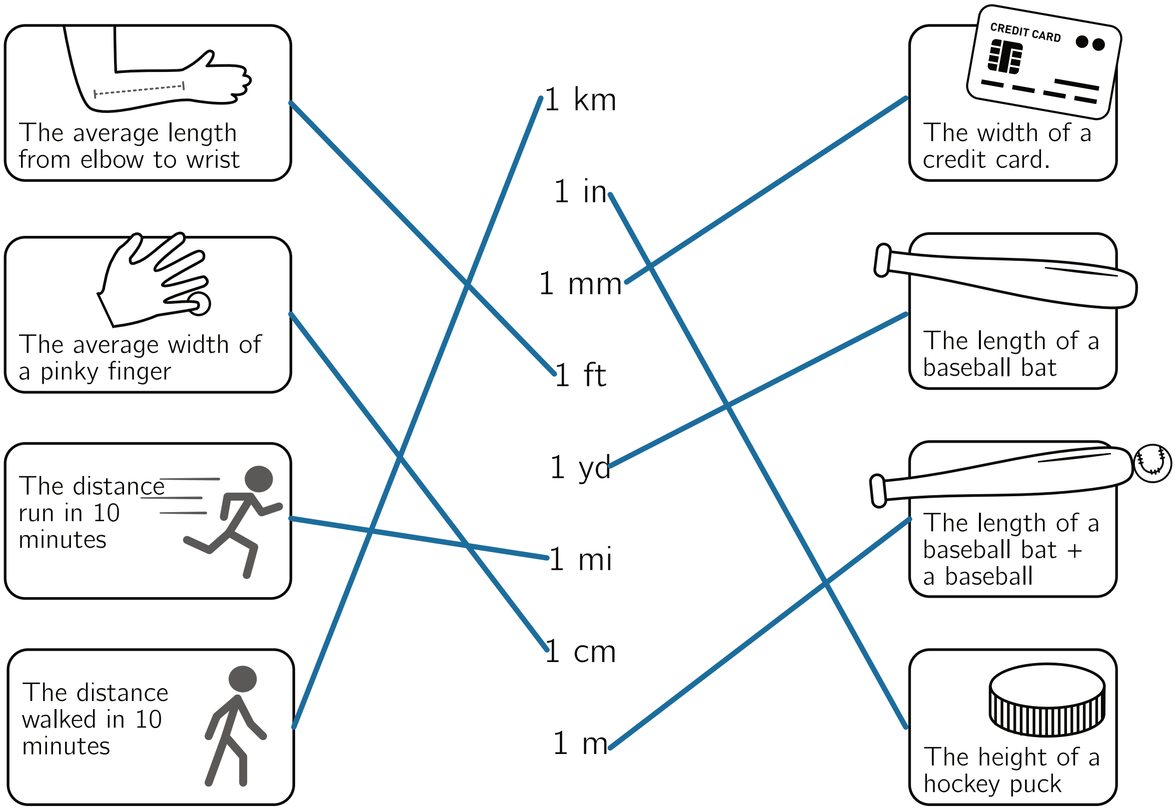
Prefix	pico	nano	micro	milli	centi	base unit	kilo	mega	giga	tera	peta
Symbol	p	n	μ	m	c		k	M	G	T	P
	1 trillion times smaller	*1 billion times smaller*	*1 million times smaller*	*1,000 times smaller*	*100 times smaller*	1	*1,000 times bigger*	*1 million times bigger*	*1 billion times bigger*	*1 trillion times bigger*	***Quadrillion times bigger!***
Exponential Multiplier	10^{-12}	10^{-9}	10^{-6}	10^{-3}	10^{-2}		10^{3}	10^{6}	10^{9}	10^{12}	10^{15}

For more about metric prefixes and notation, check out the table in the appendix!

Practice Problems – Mighty Measures

MATCHING LENGTHS:

Draw a line to match each distance with its best measurement.



A TABLE ON COMPUTER DATA:

Use your knowledge of the metric system to complete the table below and fill in the blanks below:

Unit:	***Number of bytes:***
byte	1
Kilobyte (KB)	1,000
Megabyte (MB)	$1{,}000{,}000 = 10^6$
Gigabyte (GB)	$1{,}000{,}000{,}000 = 10^9$
Terabyte (TB)	$1{,}000{,}000{,}000{,}000 = 10^{12}$
Petabyte (PB)	$1{,}000{,}000{,}000{,}000{,}000 = 10^{15}$

1,000 KB = 1 MB.

1,000 megabytes = 1 gigabyte.

1 terabyte = 1,000,000 megabytes.

1,000,000 GB = 1 PB

How many kilobytes are in a petabyte?

1,000,000,000,000

Practice Problems – Mighty Measures

Convert units to answer each question. Practice doing neat work!

1. Jerry says he'll trade Jill 41 dimes for 16 quarters. Jill agrees. Who has more money after the trade and why?

$$41 \text{ dimes} = 41 \text{ dimes} \cdot \frac{\$1}{10 \text{ dimes}} = \$4.10.$$

$$16 \text{ quarters} = 16 \text{ quarters} \cdot \frac{\$1}{4 \text{ quarters}} = \$4.$$

Jill has more money after the trade.

2. How many dollars are the same value as 61 quarters?

$$61 \text{ quarters} = 61 \text{ quarters} \cdot \frac{\$1}{4 \text{ quarters}} = \$15.25.$$

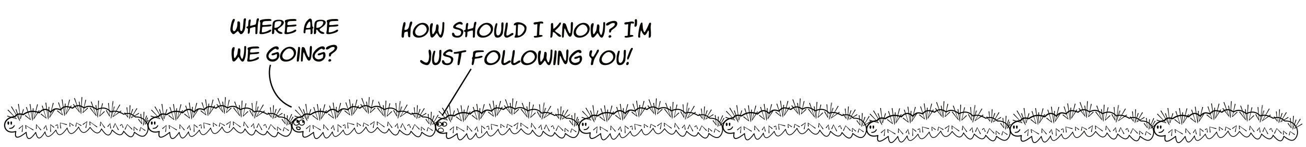
3. How many Abs are in 10 Gabs?

1 Ab = 4 Babs
3 Babs = 7 Cabs
2 Cabs = 3 Dabs
7 Dabs = 1 Fab
6 Fabs = 1 Gab

$$10 \text{ Gab} = 10 \text{ Gab} \cdot \frac{6 \text{ Fab}}{1 \text{ Gab}} \cdot \frac{7 \text{ Dab}}{1 \text{ Fab}} \cdot \frac{2 \text{ Cab}}{3 \text{ Dab}} \cdot \frac{3 \text{ Bab}}{7 \text{ Cab}} \cdot \frac{1 \text{ Ab}}{4 \text{ Bab}} = 30 \text{ Ab}.$$

Challenge Question How many Fabs are in 8 Babs?

$$8 \text{ Bab} = 8 \text{ Bab} \cdot \frac{7 \text{ Cab}}{3 \text{ Bab}} \cdot \frac{3 \text{ Dab}}{2 \text{ Cab}} \cdot \frac{1 \text{ Fab}}{7 \text{ Dab}} = 4 \text{ Fab}.$$



Challenge Question

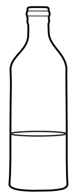
The pine processionary caterpillar (*Thaumetopoea pityocampa*) is 4 cm long. When migrating, the caterpillars march in a single-file line. If a line of caterpillars is just under 1 mile long, then how many caterpillars are marching in the line?

$$1 \text{ mi} = 1 \text{ mi} \cdot \frac{5{,}280 \text{ ft}}{1 \text{ mi}} \cdot \frac{12 \text{ in}}{1 \text{ ft}} \cdot \frac{2.54 \text{ cm}}{1 \text{ in}} \cdot \frac{1 \text{ caterpillars}}{4 \text{ cm}} = 40{,}233.6$$

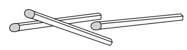
*Since there won't be a fraction of a caterpillar walking in line, the answer is 40,233 caterpillars.

FUN PHYSICS TRICKS

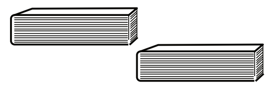
MATERIALS



1 water bottle with a narrow neck and lid that can be partially filled with water



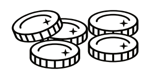
3 matches or flat-tipped toothpicks



2 books that are approximately the same size

1 shoelace or 60 cm (2 ft) of yarn

A dollar bill or similarly-sized piece of paper



5 quarters

GOALS

- Experience curiosity and wonder about physics!
- Get hands-on experience with physics principles that we will learn about later in this course.
- Bonus: Learn 3 tricks that can stump your friends and family members!

1 MIGHTY MATCH CHALLENGE

Can you hang a water bottle from the edge of a table using only 3 matches and yarn?

1. Tie the yarn to a water bottle that is ¼ full of water. For best results, the bottle should not weigh more than 0.4 kg (1 pound or 16 ounces). The yarn should extend from the bottle in one long loop. Make sure the yarn is secure and supports the weight of the bottle.

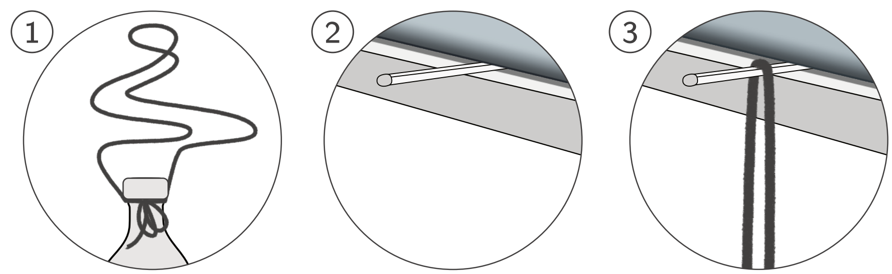
2. Place a match on the edge of a table so that it dangles a bit more than half-way over the edge. Place a counterweight (such as the two books) on the end of the match to hold it in place.

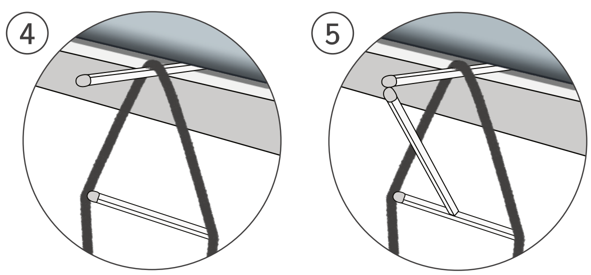
3. Hang the bottle from the match so that the string is up against the side of the table.

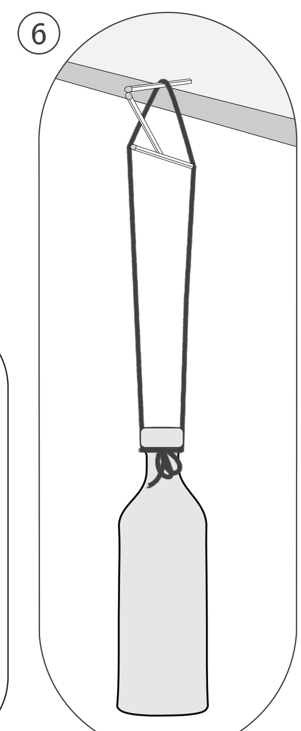
4. Place a second match about one match length below the match that is placed on the table and orient it so that it is wedged between the two strands of string.

5. Wedge a third match between the two matches so that the heads are touching. Adjust as needed.

6. Once the matches are steady, remove the counterweight.







WHAT IS HAPPENING?

Why do you think this trick works? Don't try to look up the answer yet - explore and come up with your own ideas first!

2 DOLLAR BILL CHALLENGE

Can you pull the dollar from beneath the coins without them falling off?

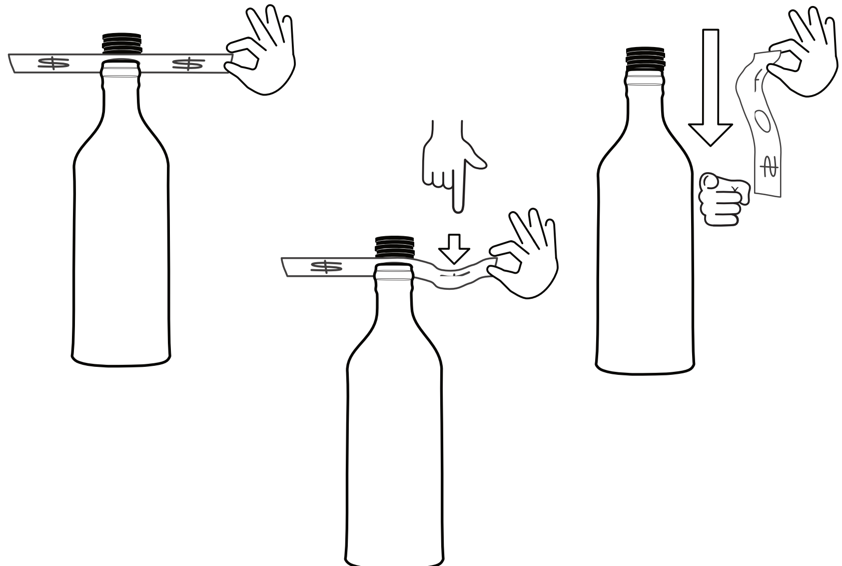
1. Place a dollar bill on a bottle and then place 5 large coins such as quarters on top. Challenge a friend to remove the bill without touching the bottle or knocking off the coins.

2. To remove the bill, pinch one end of the bill with one hand. Don't pull. This hand need to remain stationary.

3. Push down with your other index finger to form a bit of a valley.

4. Slap down quickly with the flat index finger, pushing on the area where the dip in the dollar bill was. The other hand that is pinching the dollar bill should remain stationary.

With a bit of practice, you'll be able to push fast enough on the bill that it will slide out but the the coins will stay in place!



WHAT IS HAPPENING? *Why do you think this trick works? Don't try to look up the answer yet. First explore and come up with your own idea!*

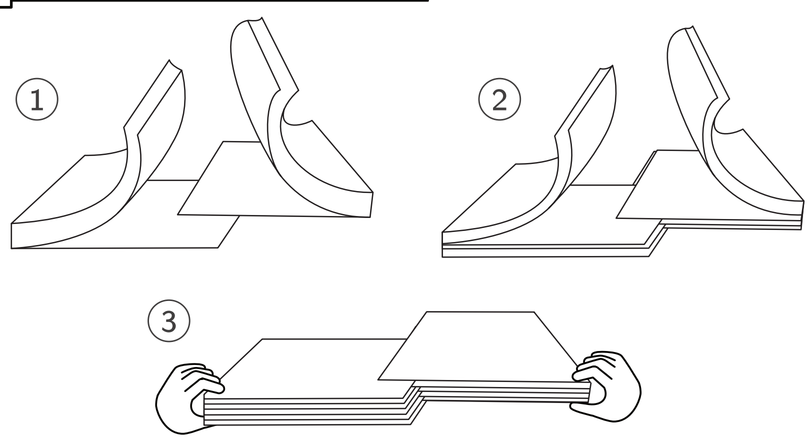
3 BOOK PULL CHALLENGE

Can you pull two books apart when the pages are overlapped?

1.Take two books or two packs of post-it notes and place them on a table or other flat surface. Hold up all but the back cover and overlap the back covers so that ¼ to ½ of one of the pages is covered by the other book.

2. Let the pages flip down so that they alternate.

3. Once the pages have been interwoven and the books are closed, challenge someone to hold on the spine of each book and pull them apart.



WHAT IS HAPPENING? *Why do you think this trick works? Don't try to look up the answer yet. Explore and come up with your own ideas first!*

1 MIGHTY MATCH CHALLENGE

Did the demonstration work? What tips would you give someone else trying this for the first time? Did the activity spark any questions or discoveries?

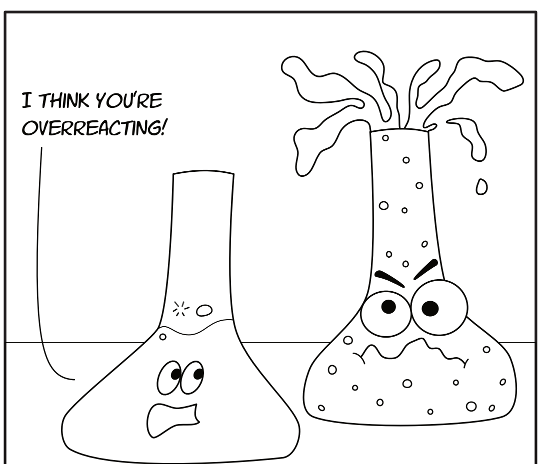
2 DOLLAR BILL CHALLENGE

Did the demonstration work? What tips would you give someone else trying this for the first time? Did the activity spark any questions or discoveries?

3 BOOK PULL CHALLENGE

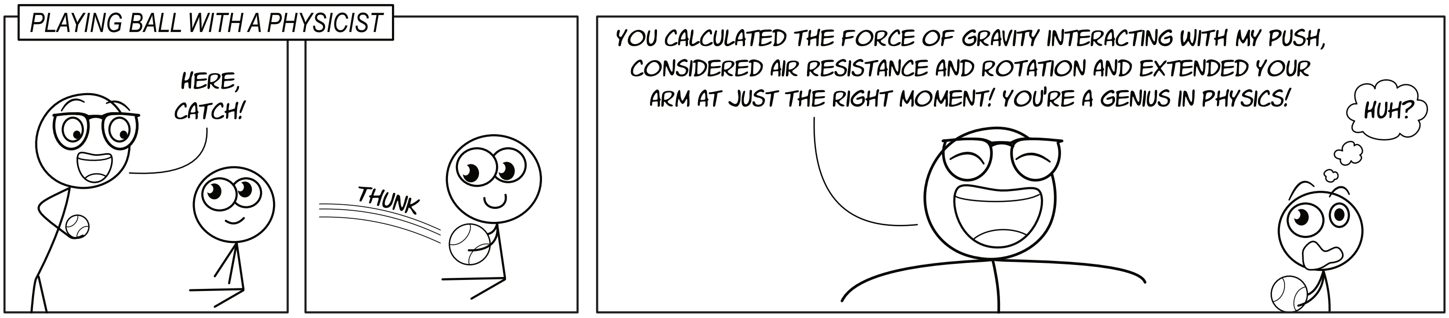
Did the demonstration work? What tips would you give someone else trying this for the first time? Did the activity spark any questions or discoveries?

EXPERT:
A PERSON WHO HAS MADE ALL THE **MISTAKES** THAT CAN BE MADE IN A VERY NARROW FIELD.
-NIELS BOHR



If at first you don't succeed, analyze, revise, and then try again.

Measuring Motion



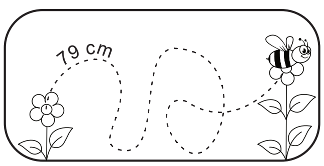
You already have a lot of experience with **mechanics**, the branch of physics that studies the motion of objects. Understanding vectors will help give you tools to make models and speak the language of physics!

The terms illustrated below are: acceleration, displacement, distance, mass, speed, temperature, temperature gradient, time, velocity, and weight. Write each term next to the matching illustration.

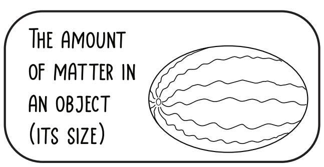
SCALARS VS VECTORS

SCALARS

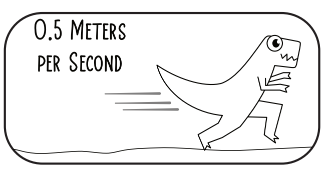
DEFINITION:
Any quantity that doesn't depend on direction.



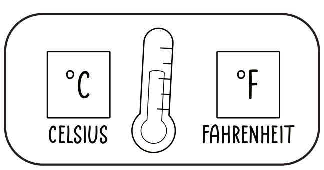
Distance



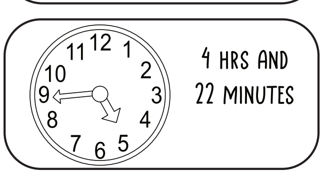
Mass



Speed



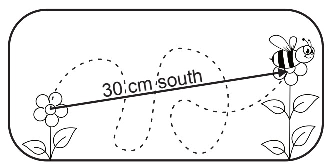
Temperature



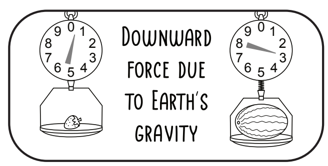
Time

VECTORS

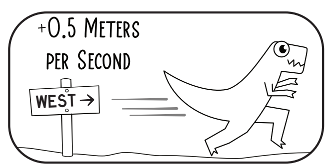
DEFINITION:
Any quantity that has both a magnitude and a direction



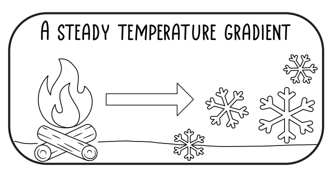
Displacement (total change in position - includes direction)



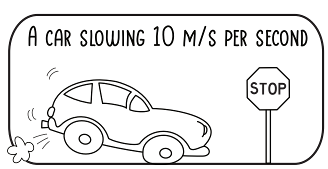
Weight



Velocity



Temperature gradient



Acceleration

FILL IN THE BLANKS:

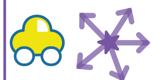
vector magnitude direction scalar

In physics, the size or measurement of something is called its magnitude. A quantity that tells us the magnitude but NOT the direction is called a scalar quantity. Often, we need to know both measurement AND direction. The direction can be described in relation to an object using terms like up, down, north, south, east, west, left, or right. A quantity that has both a magnitude and a direction is called a vector quantity.

CIRCLE ALL OF THE VECTORS:

3 liters	5 ft per second east of the yellow car	100 square kilometers	60 kilometers per hour
20 meters above	24 lbs downward	6 kilometers south	21° North
42	98 grams	20° Celsius	4 gallons per minute

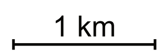
This one could also be interpreted as NOT being a vector.

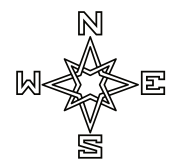


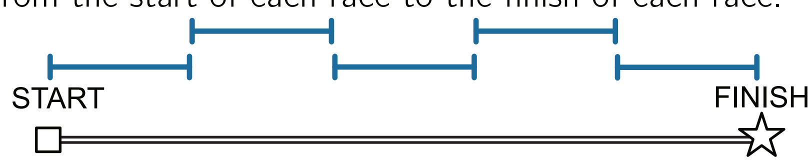
5 ft/s east (tells you position, but speed could be going in any direction from that position)

5 ft/s eastward (speed with direction)

Below are the courses for three different races. Use the scale and compass to estimate both the distance and displacement from the start of each race to the finish of each race.

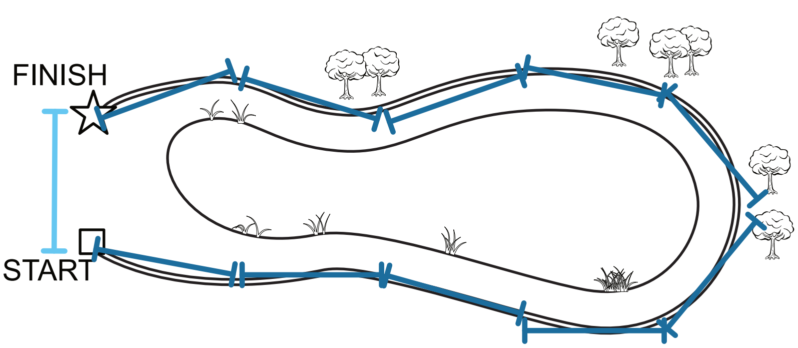






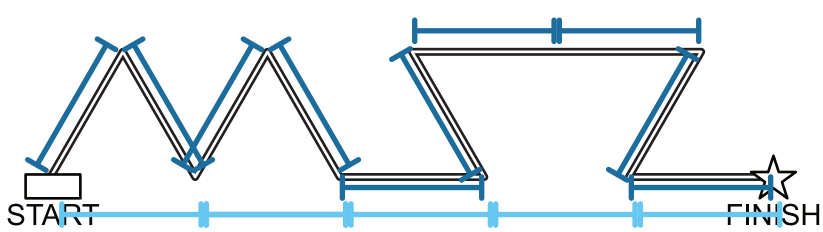
Distance: 5 km

Displacement: 5 km east



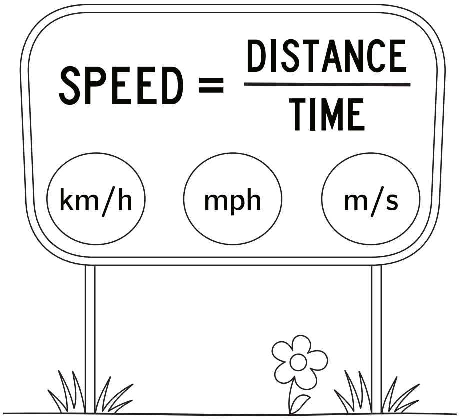
Distance: 10 km

Displacement: 1 km north

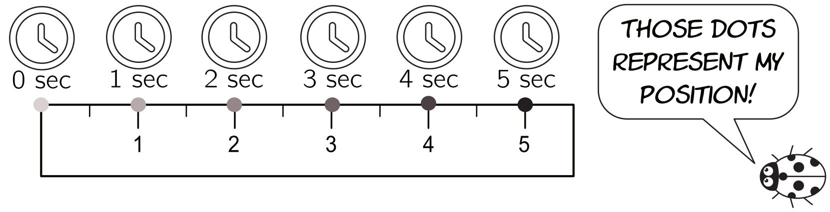


Distance: 10 km

Displacement: 5 km east

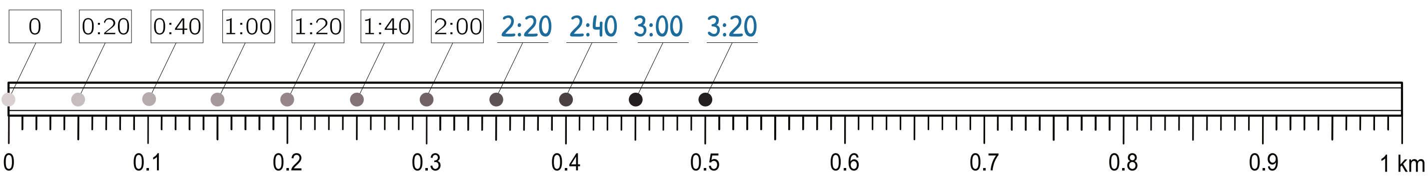


When we know the distance traveled and how much time it took, we can calculate how fast an object was moving, or its **speed**. The ladybug on the ruler moved 5 cm in 5 seconds, so its speed is 5 cm/5 seconds or 1 cm/s.



CALCULATING SPEED

The dots below indicate the position of a runner every 20 seconds as they run along a path.



How far did they run? Be sure to include units in your answer!

They ran 0.5 km.

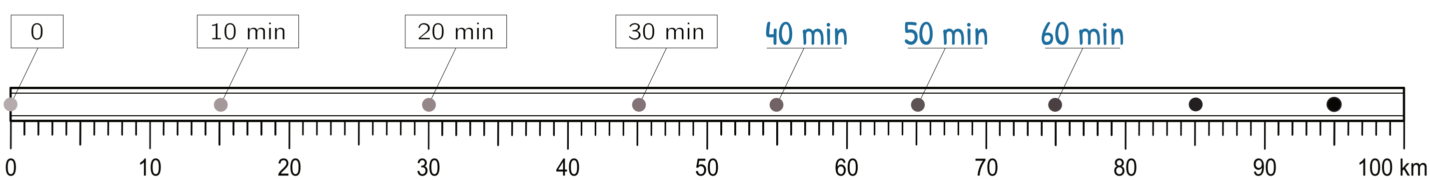
How fast did they run? (Answer in km/hr) Distance divided by time can be calculated a few different ways:

$$\frac{0.15\text{ km}}{1\text{ min}} \cdot \frac{60\text{ min}}{1\text{ h}} = 9\,\frac{\text{km}}{\text{h}} \quad \text{OR} \quad \frac{0.3\text{ km}}{2\text{ min}} \cdot \frac{60\text{ min}}{1\text{ h}} = 9\text{ km/hr}$$

Assuming the runner kept the same pace, how long will it take to run 1 kilometer?

$$1\text{ km} = 1\text{ km} \cdot \frac{1\text{ h}}{9\text{ km}} \cdot \frac{60\text{ min}}{1\text{ h}} = 6\frac{2}{3}\text{ min}$$

The dots below indicate the position of a car every 10 minutes driving south.



How fast did the car travel during the first 45 km?

The car drove 45 km in 30 min, so its speed was $\frac{45\text{ km}}{30\text{ min}} \cdot \frac{60\text{ min}}{1\text{ h}} = 90\,\frac{\text{km}}{\text{h}}$.

When did the car slow down?

The car slowed down at the 30 minute (45 km) mark because all the subsequent dots are closer together.

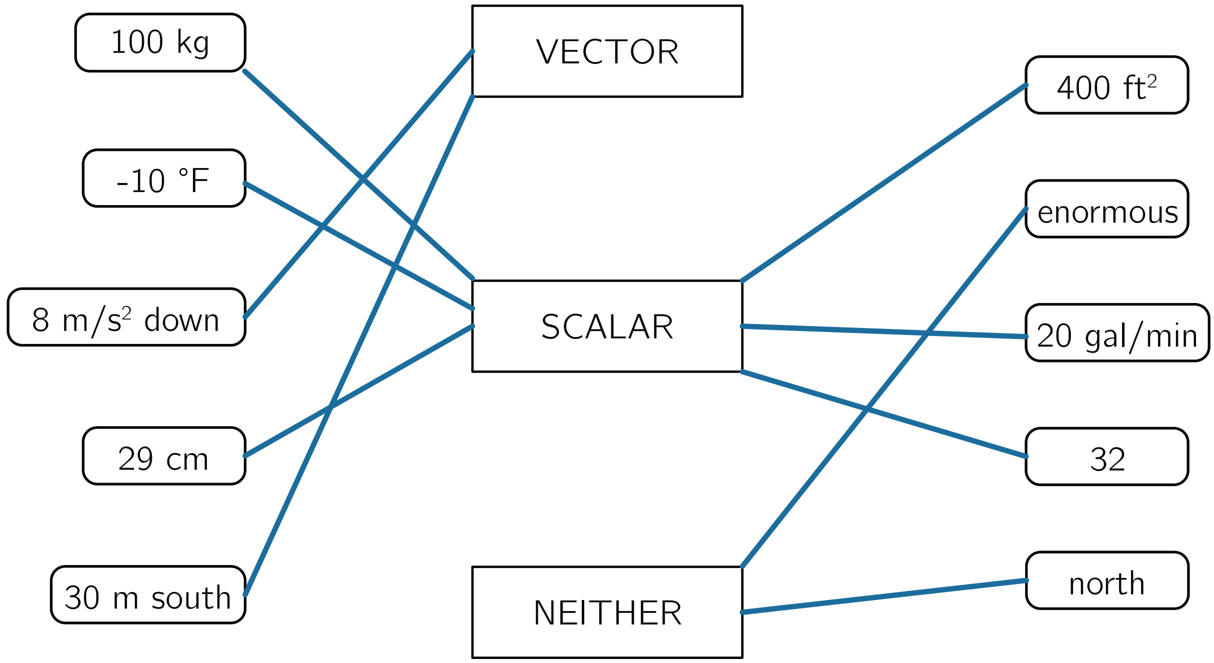
How long did it take the car to reach the 75 km mark?

It took 60 minutes to reach 75 km.

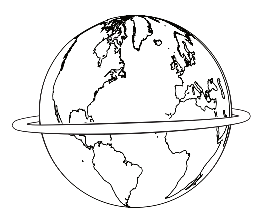
Practice Problems – Tracking Motion

Is it a vector?

Draw lines to classify each measurement below as either a vector, a scalar, or neither a vector or scalar.



Measure this motion:



1. Eli travels around the equator of the world in 70 days, arriving back in the exact same position from which he started his journey. What is his displacement?

   Relative to the Earth, Eli's displacement is 0 m.

   (Relative to the sun, Eli has a much larger displacement.)

2. Aisha and Arjun are training to run a 5K race. They ran for 24 minutes and want to know if they reached their daily running goal of completing 3 kilometers. Which will be most useful in answering their question: distance or displacement?

   Distance is more useful. They don't care about the net distance. They only care about the total distance they have traveled.

3. Kat drove 200 miles in 4 hours. What was her average speed?

   200 mi / 4 h = 50 mi/h.

4. A car is driving on a freeway at a speed of 100 km/h.

A. How far does the car travel in 1 min?

$$1\text{ min} = 1\text{ min} \cdot \frac{1\text{ h}}{60\text{ min}} \cdot \frac{100\text{ km}}{1\text{ h}} = 1.\overline{6}\text{ km}$$

B. A blink lasts for about 0.3 s. How many meters does the car travel while the driver blinks?

$$0.3\text{ s} = 0.3\text{ s} \cdot \frac{1\text{ min}}{60\text{ s}} \cdot \frac{1\text{ h}}{60\text{ min}} \cdot \frac{100\text{ km}}{1\text{ h}} \cdot \frac{1000\text{ m}}{1\text{ km}} = 8.\overline{3}\text{ m}$$

5. The formula showing the relationship between *r* (rate), *d* (distance), and *t* (time) is often written as $d = rt$. Rearrange the variables to solve for *r* and *t*.

The formula $d = rt$ can be rearranged to read: $r = \frac{d}{t}$, and $t = \frac{d}{r}$

6. On her bike, Jade travels *n* miles north and then turns around and travels *s* miles south.

A. Use *s* and *n* to write an expression that shows how far Jade traveled.

The total distance Jade travels can be written as:

$d = n + s$

B. If Jade travels directly north and then turns around and travels directly south, will her **displacement** be the same as the total **distance** traveled?

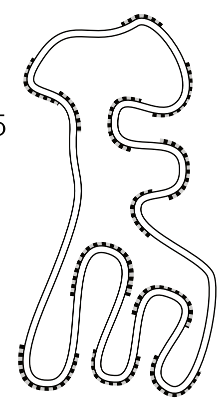
No. The displacement is the difference between starting end ending position. It's a vector so it will be + or – depending on direction. Calculate displacement by $n - s$ or $s - n$.

C. Calculate Jade's displacement when $n = 4$ and $s = 7$. Then write a sentence explaining what the calculation means.

If Jade traveled 4 miles north and then 7 miles south, her distance traveled was 11 miles. Displacement could be calculated either as miles north or miles south.

Jade's displacement is 3 miles south.

7. A go-kart track has a length of 500 m.



A. What is the average speed in m/s of a go-kart that completes 3 laps in 2.5 minutes?

$$\frac{3\text{ laps}}{2.5\text{ min}} \cdot \frac{500\text{ m}}{1\text{ lap}} \cdot \frac{1\text{ min}}{60\text{ s}} = 10\ \frac{\text{m}}{\text{s}}.$$

B. How many laps would be completed in 4 minutes at an average speed of 8 m/s?

$$4\text{ min} \cdot \frac{60\text{ s}}{1\text{ min}} \cdot \frac{8\text{ m}}{1\text{ s}} \cdot \frac{1\text{ lap}}{500\text{ m}} = 3.84\text{ laps.}$$

C. What is the displacement for a go-kart that has completed 7 complete laps?

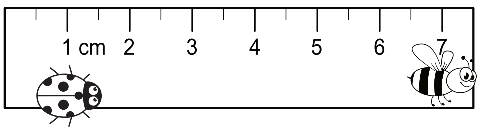
After the go-kart completes each lap, its displacement is 0 m.

Graphing Motion

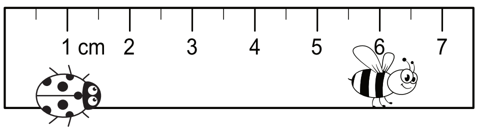
Graphs are useful for sharing information. They let us see a lot of data at the same time and help us understand the relationship between two or more things.

Graph the movement of the bee and ladybug below with **position** on the **vertical axis** and **time** on the **horizontal axis**.

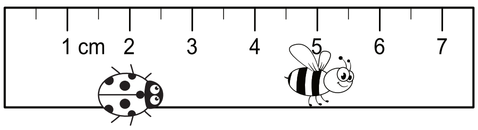
0 sec



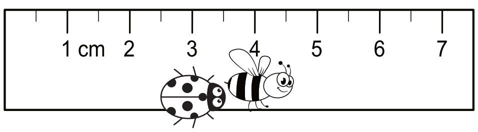
1 sec



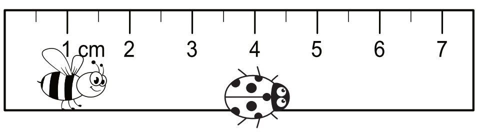
2 sec



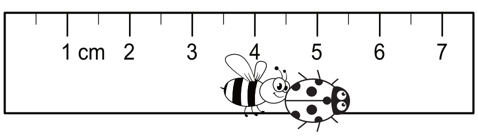
3 sec



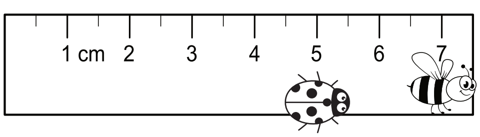
4 sec



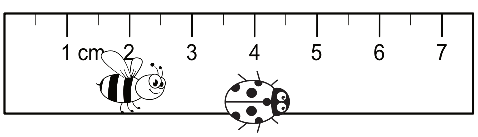
5 sec



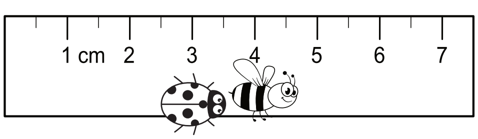
6 sec



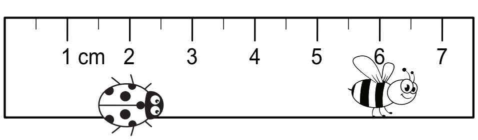
7 sec



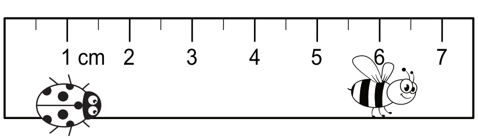
8 sec

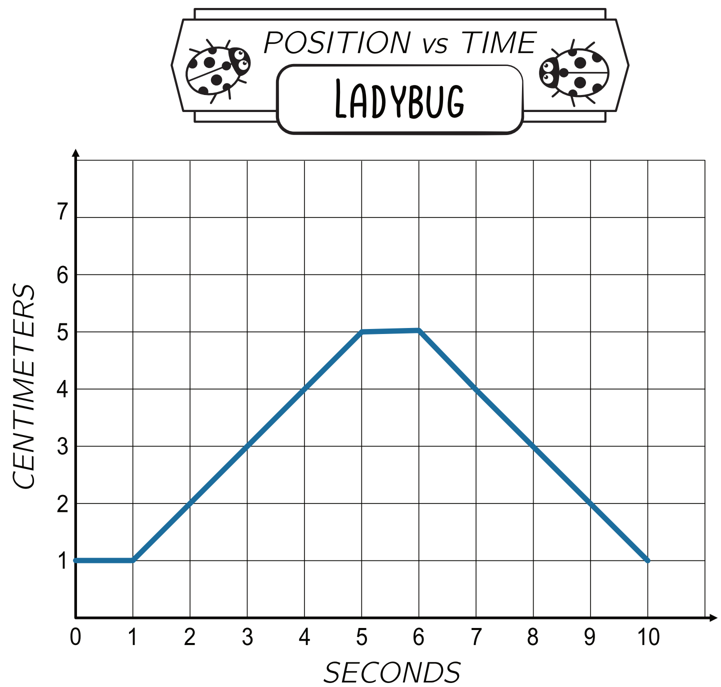


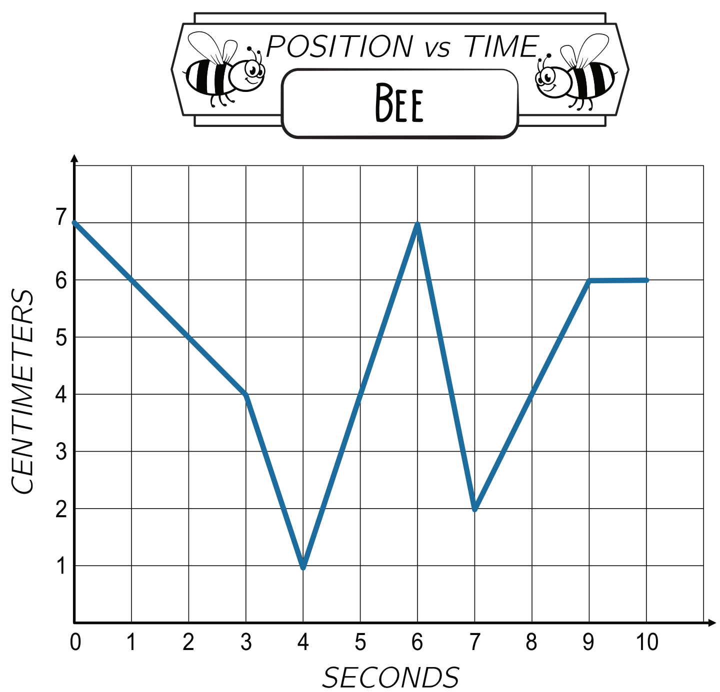
9 sec



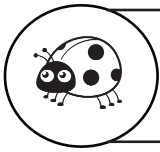
10 sec



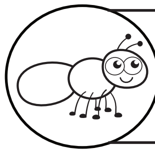




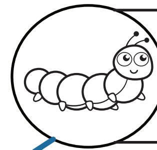
Match the time/position graph with the correct insect:



A ladybug starts at the 7 cm mark and then runs back to the start of the ruler.

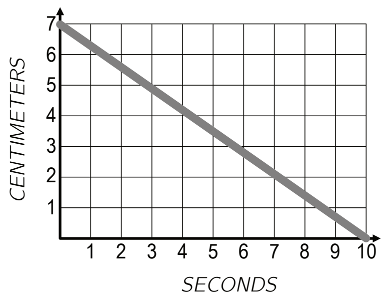


An ant travels to 3 cm and rests for 5 seconds before going forward to the 7 cm mark.

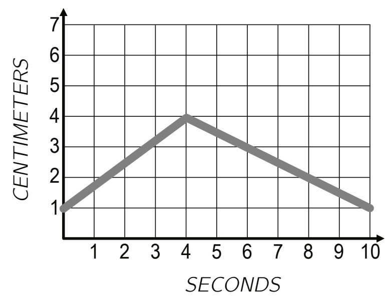


A caterpillar walks from the 1 cm mark to 4 cm and then back to 1 cm.

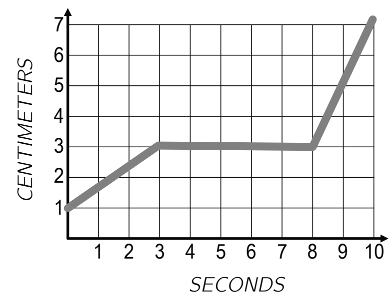
GRAPH 1



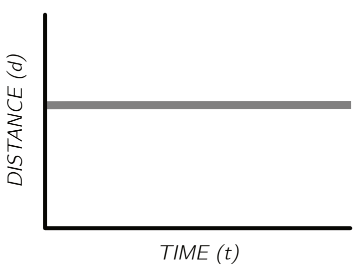
GRAPH 2



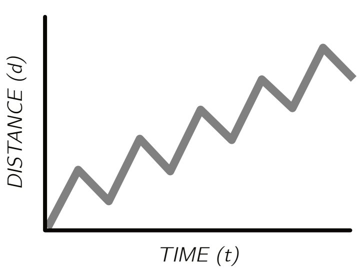
GRAPH 3



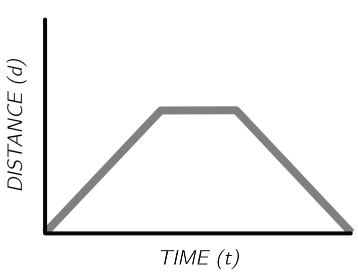
The graphs below represent the position of 3 birds on the ruler. Write a sentence or two describing what each bird is doing.



The bird didn't move at all. It stayed exactly where it started.



The bird started at the left end of the ruler. Then it kept repeating 2 steps right, 1 step left

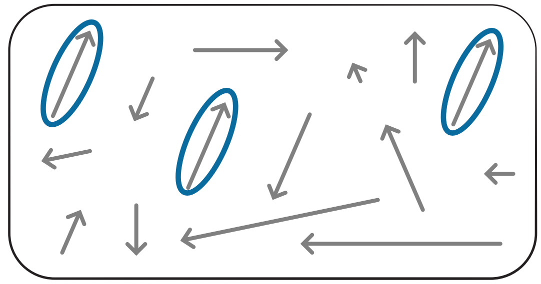


The bird started at the left end of the ruler. It walked at a uniform pace to the a little past the center of the ruler, waited a bit, and then traveled back to the left end at a uniform pace.

PLOTTING VECTORS

VECTORS have both magnitude and direction

Vector quantities are often represented by an arrow. Identify the vectors that are the same.



The Coast Guard boat received a call for help from a small boat. Which vector would result in a rescue?

VECTOR A
d = 10 miles
8 mi E, 6 mi N
(8,6)

VECTOR B
d = 10 miles
8 mi W, 6 mi S
(-8,-6)

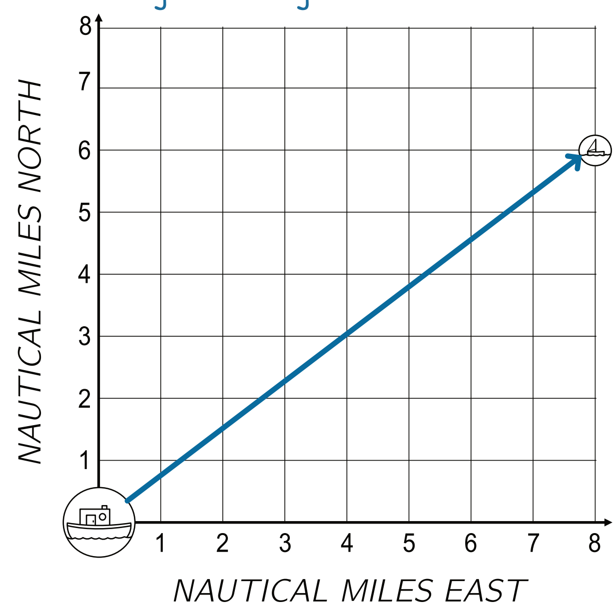
VECTOR C
d = 10 miles
6 mi E, 8 mi N
(6,8)

VECTOR D
d = 5 miles
4 mi E, 3mi N
(4,3)

VECTOR E
d = 10 miles
10 mi N
(0,10)

VECTOR F
d = 17 miles
15 mi E, 8 mi N
(15,8)

Vector A will guide the big boat to the small boat



Which vectors have the correct magnitude but the wrong direction?

Vectors B, C and E

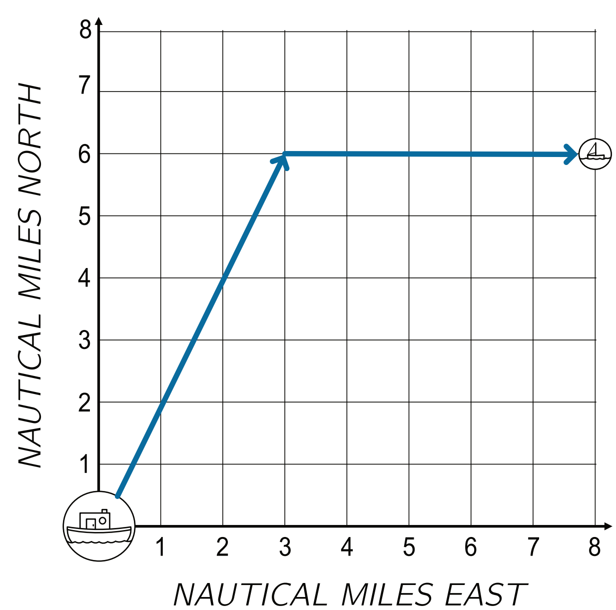
Which vectors have the correct direction but the wrong magnitude?

Vector D

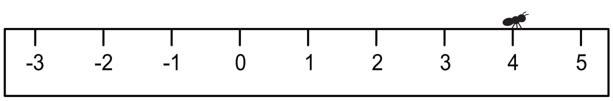
Identify 2 or more vectors that the Coast Guard could combine to reach the boat.

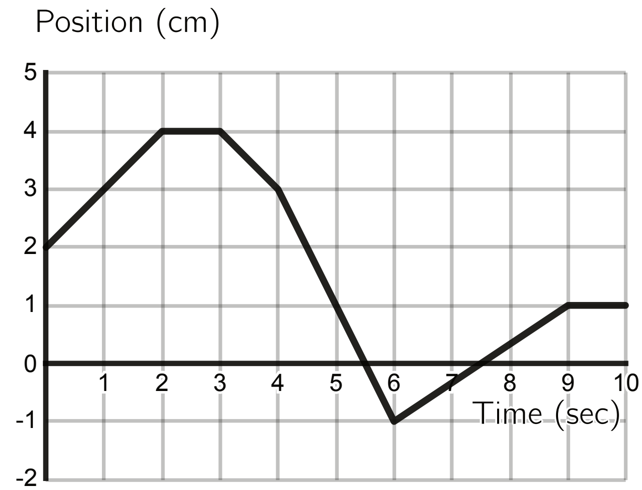
There are many possible correct answers. Any sequence of arrows that starts at (0,0) and ends at (8,6) will work.

One possible answer is to use the vectors ⟨ 3,6 ⟩ and ⟨ 5,0 ⟩.



Practice Problems – Graphing Motion





The graph to the right shows the position of an ant walking back and forth across an unusual ruler that includes negative numbers.

1. Where did the ant start her journey?
   Started at the 2 cm mark

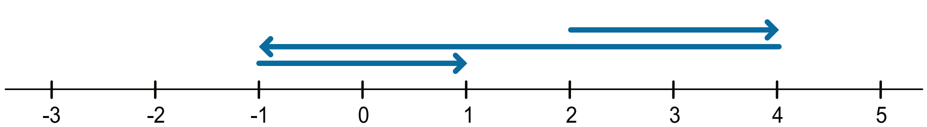
2. When was ant at rest?
   The flat lines are from 2 s to 3 s and from 9 s to 10 s

3. When was the ant crawling to the right?
   Position was increasing from 0 s to 2 s and from 6 s to 9 s.

4. When was the ant at the 1 cm mark?
   -At 5 s and for the interval from 9s to 10 s.

5. When was the ant traveling fastest?
   Slope is steepest from 4 s to 6 s.

6. Use the number line to trace the path of the ant from start (0 seconds) to finish (10s)



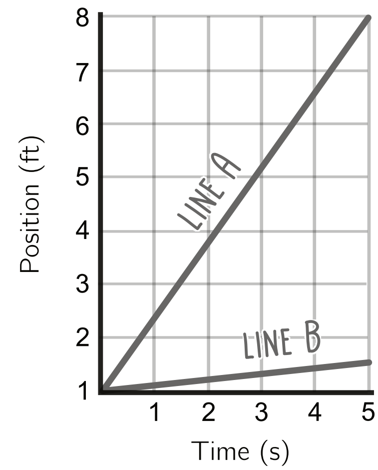
7. Write a short narration explaining the meaning of the graph. How would you explain the ant's motion it to a person who couldn't see the graph?

The ant started at the 2 cm mark. Over the first two seconds it walked to the 4 cm mark where it waited one full second. From 3s to 4 s, it turned back around and walked to the 3 cm mark. Then it sped up from 4 s to 6 s and walked to the -1 cm mark. It abruptly turned around and walked slowly from 6 s to 9 s to the 1 cm mark where it stood still.

Practice Problems – Graphing Motion

8 FAST OR SLOW?

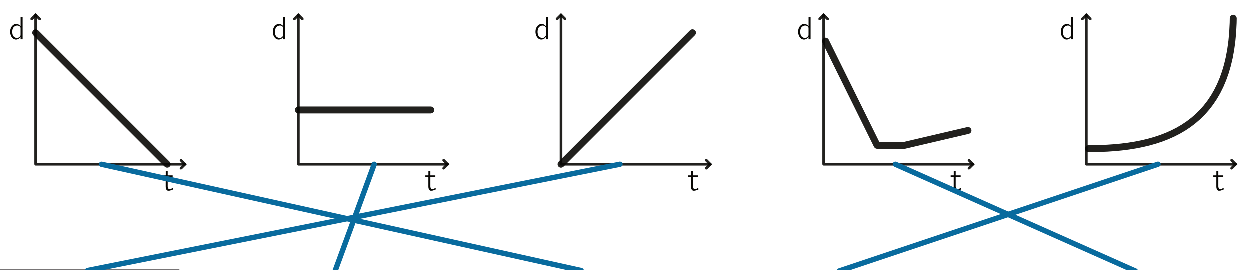
One of these lines represents the motion of a rabbit moving forward very quickly. The other is for a tortoise moving slowly. Which is which and how can you tell?



Line A is the rabbit, and line B is the tortoise. The steeper slope of line A shows that more feet are traveled per second.

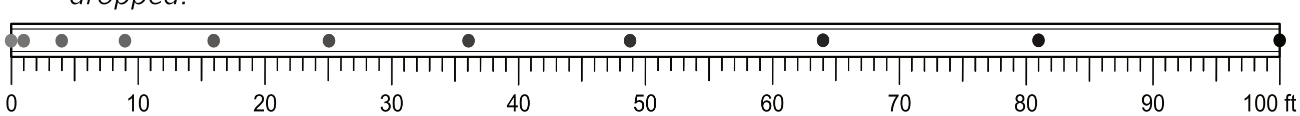
9 MATCHING GRAPHS:

Below are 5 different graphs of distance versus time (which work the same as position vs time graphs). Match each graph with the appropriate description.



THE OBJECT IS MOVING FORWARD AT A STEADY SPEED	THE OBJECT IS NOT MOVING.	THE OBJECT IS MOVING BACKWARD AT A STEADY SPEED	THE OBJECT STARTS MOVING SLOWLY BUT THEN MOVES MUCH FASTER	THE OBJECT MOVES BACKWARDS AND THEN PAUSES BEFORE MOVING FORWARD SLOWLY

10 *The dots below indicate the distance that a rock falls every 0.25 seconds after being dropped.*



How long did it take for the rock to fall 60 feet?

It takes almost 2 seconds for the rock to fall 60 feet (8 quarter seconds).

When was the rock falling slowest?

The rock was falling slowest as it was dropped and then it sped up.

How fast was the rock falling on average from 1 s to 2 s?

It fell from 16 ft to 64 ft. $\text{avg} = \frac{\Delta \text{ft}}{\Delta \text{s}} = \frac{64\text{ ft} - 16\text{ ft}}{2\text{ s} - 1\text{ s}} = 48\ \frac{\text{ft}}{\text{s}}$