IT'S DYNAMIC !

The relation between motion and force

STUDENT NOTEBOOKS

YOUR NAME: . . . .

1 Teacher Supplement
INTRODUCTION TO DYNAMICS

Objectives and Resources

Lesson Objectives: Learners should be able to:

5.0 Broad domain appreciation
5.1 State that dynamics is an explanation of how motion and forces relate.

Lesson Resources:

Notebooks/pencils/colored pencils

Assorted demo supplies:
Basketball
Blue Carts (1 per teacher)
Whiteboards (as ramp, one per teacher)
Bricks (4 per teacher)
Bowling Ball
Fancart

Color Coding:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students **may** fill in as they go)
RED: outline topic and approximate timing

Lesson # 1 – *[~20 min]*

Let's stand up, and move a little… take a stretch after all that writing… Students stretch etc.

WELCOME to "Way To Go" Summer Science. Our first unit is on **Dynamics**, which is about **how an object's motion is related to the forces acting upon it.**

Motion is everywhere around us and it's very **important** in our lives. It **can be very simple** or very **complex.** On page 1 you have a colorful picture to remind us of how many different ways things can move. Let's look at **various types of motion …** and describe and classify them.

We can distinguish between objects **at rest** and objects in **motion**. The object may be moving at a constant speed, in a **steady motion** (whether **slow** or **fast**), or it may have a **changing motion** if the object is **speeding up** or **slowing down**. Let's look at the picture. What objects appear to be at rest? What objects appear to be moving fast? or slow? How about changing their motion? (Teachers may write these types of motion on a transparency, and students may copy during discussion)

I have a basketball here **at rest** in my hand. I can demonstrate motion by rolling this across the floor, (roll it) and I can roll it slow or fast. We know it will not roll forever, it will **slow down** and stop… its motion **changes**. Let's show this motion with our hands tracing the horizontal path (do this). I can also drop the ball and here is another example of a **straight line motion**… trace this motion too (do this).

But there is another possibility for what I can do with this ball… it might move in a **curved motion** instead of a straight line, or it might move in some combination of complicated lines and curves. (throw the ball to someone … who is ready to catch it ☺ … you can also bounce it gently across the floor). Let's use our hands to trace the **curved** path (do this).

On your picture, find examples of motion in **straight lines** and also **curved** motions. Over the next several days we will be looking at the motion of some interesting objects and equipment … TEACHER DEMOs… fan carts, bluecarts… if time allows

And of course, we will all get to look at and experience the motion of the HOVERCRAFT that the famous scientist **Isaac Newton** is "riding" on our cover.

1 - INTRODUCTION TO DYNAMICS

WELCOME!

"**Dynamics**" is about how an object's **motion** is related to the **forces** acting upon it.

MOTION IS EVERYWHERE!

Types of motion:

***at rest**

***steady motion (slow/fast/?)**

***changing motion** (speeding up, slowing down)

***straight line motion**

***curved motion**

It is important to understand WHY and how everyday objects like **basketball**s and cars move as they do. Dynamics tells us the REASON for the different types of motion that we've just discussed.

The motion of an object is related to the **FORCES** acting upon it. If we know the forces acting, and know how force and motion are related, we should be able to predict and explain motions. That is the main goal of this **dynamics** unit!

Scientists (like Isaac Newton) have been studying how and why objects move for centuries. We'll just spend the next two weeks doing so. The complicated principles of **dynamics** are now so well understood that we have launched spacecraft from earth and made them travel through a complex motion path through space, and land gently at a chosen spot on the moon … so that human beings have been able to explore the moon in person! We have sent out **space probes** to investigate Mars and the other planets as well.

In science we don't start by studying the most complicated motions we see around us. We'll start with the simplest cases, like an object **at rest** or **moving in a straight line** … and we'll consider how these simple kinds of motion relate to the forces acting on the object.

After that, we can begin to understand the more complicated situations. You might be able to accomplish even more amazing new feats in science and engineering someday, if you learn a lot about Dynamics!

FROM THE EVERYDAY…
TO THE AMAZING

From a basketball …

… to a space probe

Motion can become complex …

… but we'll start simple.

THE GOAL IS TO ENJOY LEARNING…

1) …that "dynamics" is an explanation of how motion and forces relate

2) …Newton's 1st and 2nd laws of motion

3) …how to apply basic laws of "Dynamics" to answer questions, explain new situations, and solve problems

Have Fun!

 # 2 Teacher Supplement
Force and Net Force

Objectives and Resources

Lesson Objectives: Learners should be able to:

1.0 Forces

1.1 State that a force is a push or pull by one object on another at that moment.

1.2 State that some forces act by contact, others at a distance, and give examples.

1.3 Measure forces in units of Newtons, using spring scales.

1.4 Add forces in the same direction and subtract forces in opposite directions, to get the net force, including a net force of zero in the case of balanced forces.

1.5 Represent forces on an object in force diagrams.

6.0 Scientific inquiry objectives

6.1 State that scientific investigations begin with a question.

6.2 State in own words that evidence is required for accepting a scientific claim

Lesson Resources:

Notebooks/pencils/colored pencils/pencil pack
Basketball
Blue Carts (1 per group)
Sandpaper (1 notebook size paper per group)
Masking tape (1 per group)
Whiteboards (1 large per group)
Balloon pucks (1 per group, couple spares) Straws (1 per person, hand out at appropriate time)
Magnets (plastic encased wands) (4 per group?)
Magnets (teacher demonstration, push without touching)
Weights (2 N) - (4 per teacher)
Lab scales – 2 x "20 Newton" scales per teacher, Welch Scientific, Skokie
Wood ½" dowel rods (1 per group, plus 2)
Spring scales, 20 Newtons (2 per student group, plus 2)
Meter sticks (1 per group) Cord/string
NOTE: WORD WALL pieces may be displayed as needed

COLOR CODING:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students may fill in as they go)
RED: outline topic and approximate timing

Lesson # 2 - *[~ 70-75 min]*

(Force ~10 min)

This lesson is about understanding the concept of **force** and combinations of forces, **NET FORCE**. This word NET is a familiar word, we know about basketball nets and hairnets and fishing nets… so when we say NET FORCE, we are "netting" a bunch of forces into a collection or combination of forces.

Okay here we go … FORCE … is simply **a push or a pull by one object on another object.** (teacher states/writes on transparency, use Word Wall, students **COPY** in their notebooks)

We can easily demonstrate this… **Teacher demonstrates applied forces and asks for more examples of forces from students.**

Push cart, pull cart, push wall, pull wall, kick ball, pull drawer open, push drawer shut, etc…

Let's **clarify** an important point... FORCE may or may not be acting **at a given moment.**

Teacher demonstrates

__**Push** a blue cart (and **pull** a blue cart) along continuously … (keep touching) **VERSUS**

__**Push** a blue cart and watch it move on its own,…

Notice carefully that in **one** case the force continues to act (**while TOUCHING**) … in the **other** case the force/push is no longer acting (no longer **TOUCHING**) even though the cart is still rolling away.

My hand was touching the bluecart, there was contact while the force was being applied. ---- No more contact? No more contact force!

[More examples may be used: ball rolled on floor, styrofoam ball thrown, etc.)… **Tap** a basketball on the floor with your foot, it rolls away]

Again, **while** there is a contact force, there is a force acting… no more contact, no more contact force!!

*(Forces can act **by contact** ~ 10-15 min)* So we see that one way that forces act is **by**

2 - FORCE AND NET FORCE

DEFINITION OF "FORCE"

FORCE IS…__a push or a pull on one object by another object________

____

Can you think of some examples of forces?

Clarification …
the presence or absence of force :

FORCE MAY OR MAY NOT BE ACTING … ___at a given moment______

contact. Let's look at a variety of examples of contact forces, like kicking, pushing, pulling a string, lifting, throwing, etc. **[Teacher demonstrates and students may list examples]** Before we talk about another way that forces can act (at a distance), we need to talk about another contact force that happens all the time, but that we don't often see or think about … and that is the **force of FRICTION**. Friction forces act against the motion of an object. For instance, here's a **thought experiment**, like scientists sometimes do in their heads. Close your eyes and *imagine*… even if I were to roll this ball in a room so large and empty that it would never bump into anything, it would still **slow down and stop because of the friction** between the ball and the floor.

Friction forces depend on the nature of the objects in contact with each other. Some things in contact have little frictional forces and some have large frictional forces. Rough surfaces can create more friction force than smooth surfaces.

Students test

On your tables you have a piece of sandpaper and whiteboard and a balloon puck. We are going to **verify that friction forces change** depending on the objects. Test a similar little push on the balloon puck with the same flick of your finger when it is resting on the sandpaper, and then on the whiteboard, and compare how far they move. (Discuss the "control of variables" factor in pushing/flicking with the same amount of force. **Pass out straws** only at this point). Now that you have a straw, you have another option, a cushion of air between the puck and the whiteboard!!

For these **three cases**, tell which case has the **most friction** force against the motion of the puck, which case has **some friction** force, and which case has **very little friction** force between the balloon puck and the surface. Friction is a force that is always around us, and it affects motion; we'll keep this in mind as we study force & motion.

*(Forces can act **at a distance** ~ 5 min)* We've been talking about contact forces, but besides contact forces there are also forces that act **at a distance**, even when the objects are NOT touching.

[Teacher demonstrates on board, magnets pushing magnets with no contact.]

In your supply box, you have some magnets… get them out. We want you all to **verify that you can feel the magnetic forces** between them without them even touching each other.

The other very important example of a force that acts at a distance is the **force of gravity.** [Bring out the basketball again.] We all know what will happen when I take my hand away from underneath the ball. It falls. Gravity pulled it down, even when there was nothing in contact with the ball, nothing touching it.

If you are holding something in your hand, you can feel the downward weight of it… and you can tell whether it is lighter or heavier than another object.

(Describing forces ~ 5 min)

TWO WAYS THAT FORCES ACT

FORCES CAN ACT:

1)____by contact__________________________

Examples:

like kicking, pushing, pulling a string, lifting, throwing, etc…

FRICTION is another important contact force
(and it affects movement)

Friction test (with same amount of applied force):

Rank the amount of friction on each surface:

1) *very little* resistance/friction
2) some resistance/friction
3) most resistance/friction

puck on whiteboard__________2) SOME FRICTION_________________

puck on sandpaper___________3) MOST FRICTION________________

puck on air cushion__________1) *VERY LITTLE* FRICTION___________

FORCES CAN ALSO ACT:

2)_____at a distance_______________________

Examples:

magnetic forces

gravity

As we do science and engineering, it isn't enough just to see or feel differences in forces, we need to be able to **describe forces and work with them scientifically.**

Scientists and engineers work with three concepts when they work with forces… **magnitude, units, and direction. [fill in blanks]**

The magnitude of a force is its size… amount, quantity, how big.
We measure **magnitude** or amount of force with instruments (**scales)** in **UNITS of Newtons,** and we also note the **direction** in which a force is applied.

You students are familiar with force from gravity (weight) being measured in pounds, but we'll use **Newtons** here, because it is a standard unit used around the world, for the benefit of **scientific communication.** In case you were wondering… yes, Newtons are named after Isaac Newton…

Teacher demonstrates using a 2 Newton weight and 20 N dial scale… then adds a second 2 N weight (to make 4 N force down).

Draw attention to the two different readings of force, and the fact that the direction is down (a force is pulling the scale hook down).

(Drawing force diagrams ~ 10 min)
We can show or represent forces by **FORCE DIAGRAMS** which describe **magnitude, units, & direction**.

When we draw these force diagrams we will use the following **convention** … we'll REPRESENT objects as simplified shapes, like a **box**… and the forces acting as **arrows** of varying lengths, pointing in a certain direction, labeling magnitude/units.

Teacher draws the force diagrams on overhead or board, as shown in student section… Instruct students to copy…

Now, instead of a mass pulling down on the scale, I will pull sideways on the scale

DESCRIBING FORCE

Force has…

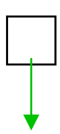
…_______________**Magnitude___________**

…______**Units_(like Newtons or pounds)__**

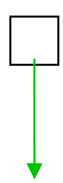
…______________**Direction______________**

"DRAWING" : FORCE DIAGRAMS…

Represent force showing magnitude, units, and direction



2 N (Newtons)



4 N

(to the left)…

Teacher note: Draw simple force diagram for certain amount of Newtons…

3 N

Now I'm going to pull in the opposite direction … and the force diagram looks like this… (draw)

3 N

And if I pull harder (more Newtons!), there is a bigger force, we simply draw a longer arrow. (do this)

6 N

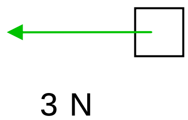
Summary:
So the arrow is drawn in whatever direction the force is acting,
and the bigger the force the longer we draw the arrow.

(How forces combine ~ 25 min)

One Applied Force

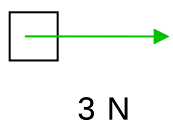
Force to the left

Diagram:



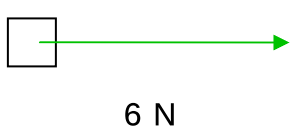
Force to the right

Diagram:



Bigger force to the right:

Diagram:



So far we have been looking at **one force** acting on an object, but often there is **more than one force** acting. In that case, forces combine into a resultant force that we call the **NET FORCE**. (Students write this on page 5).

When we say NET FORCE, we are *"netting"* a bunch of forces into a collection or combination of forces… sort of like a hairnet or a fishing net *collects* things. In other words, the net force is a single force that could replace the combined forces and have the same effect.

Questions like "exactly how do we find the NET FORCE?" can be posed and answered scientifically. Science has informed us of many answers... but we'll search for evidence to verify the claims.

Let's go on to page 6 next…

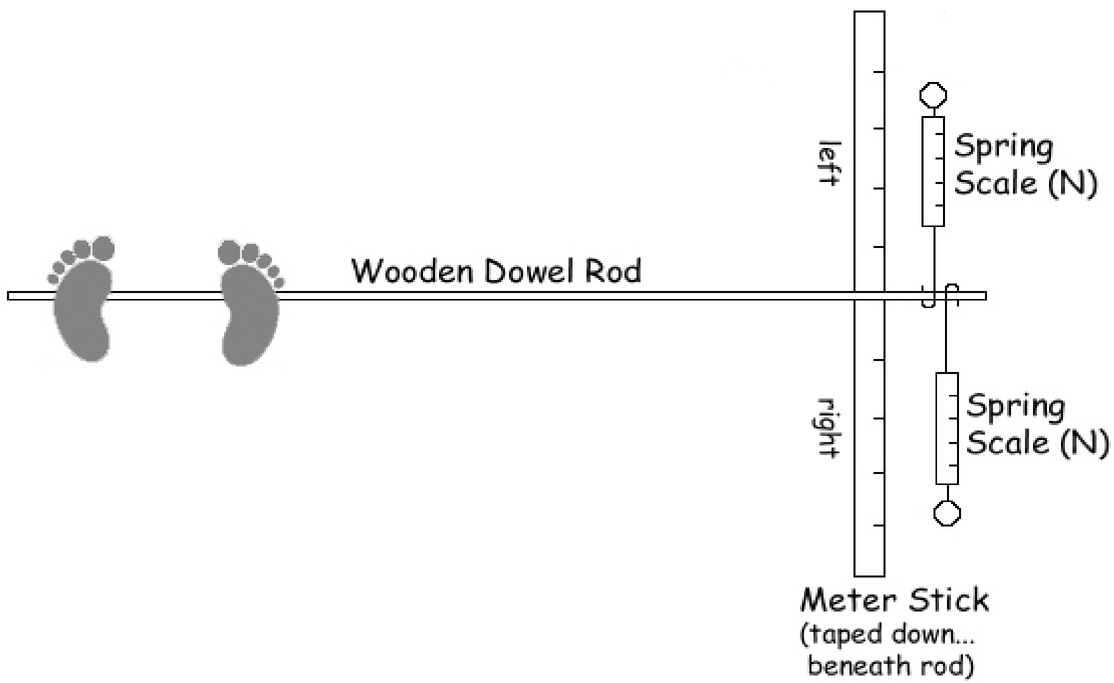
HOW FORCES COMBINE

When more than one force is acting on an object…_**forces COMBINE**…___________

__________________and the result is called the **NET FORCE**________________

Instructions for Deflection Rod Activity

1) Set up your equipment on the floor as shown in the diagram below:



2) Tape the dowel rod to the floor at the two foot locations, and have one person anchor the rod by standing upon it firmly over the two pieces of tape.

3) Tape the meter stick to the floor also, and be sure that the rod is at the middle position of the meter stick (undeflected) before each case of applying forces.

4) Forces are applied by attaching one or two scales to the free end of the rod.

5) When pulling spring scales, pull them slowly and smoothly (… at the same time).
(Be careful not to pull the scales too hard; they may break.)

Let's look at how we find NET FORCES in specific situations… we'll start with the first CASE in the left column in the Table on Page 6. (students then complete each CASE RULE as the teacher writes it on transparency).

__When **two forces act in the same direction**, they **add together** for a NET FORCE.
__When **two different forces act in opposite directions**, they **subtract from one another** for a NET FORCE.
__When **two *equal* forces act in opposite directions**, they are **balanced,** and make a **ZERO** NET FORCE.

Now, we **apply these rules** to draw diagrams of the NET FORCE in the middle column. (As shown in green) (assist students in adding and subtracting forces, labeling them, and diagramming net force)

Next we have an activity to **find evidence to confirm these rules or claims**. **Scientists rely upon evidence to support their claims.** On page 5 in your notebooks there is a **picture** of how to set up the equipment that you will find at your desk, including a wooden dowel rod, a meter stick, spring scales, and tape. Get this equipment out, read and follow the directions, and set it up on the floor according to the picture. NOTE: Teacher, as needed, can explain and clarify the instructions on the paper… Walk around checking and assisting student set-ups.
For each CASE…
Apply **two forces** as shown…
Measure deflection on meter scale, in cm. …
Record deflection effect in table
Apply the corresponding **NET FORCE**, measure and record the effect.
(Students should get qualitatively consistent results within cases… i.e. we get the same effect from the two forces as from the "net force" that replaces them.)
We have found **evidence** to confirm our claims regarding **how forces combine into a NET FORCE**. (time to clean up and get ready for a review of the day)
(Summary ~ 5 min)
Summary statement: Today we have learned that a force is a push or pull acting on an object at a given moment (now). Scientists and engineers work with forces in terms of magnitude, units (called Newtons), and direction. We also learned how to represent forces in simple force diagrams. A collection of two or more forces acting together we refer to as the NET FORCE. To find the net force, we add forces acting in the same direction and subtract forces acting in opposite directions.

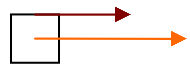
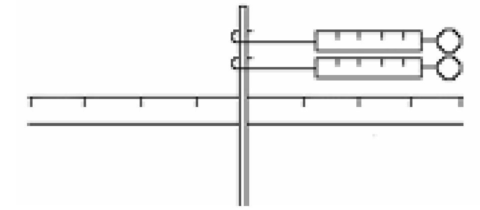
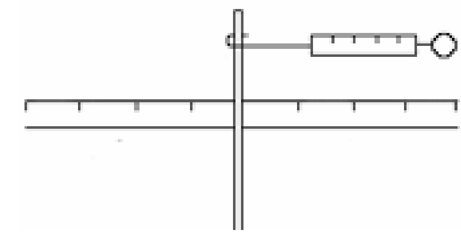
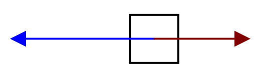
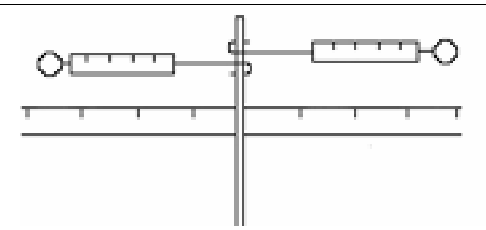
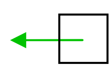
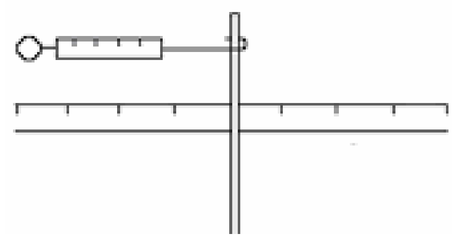
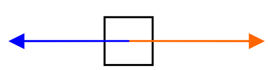
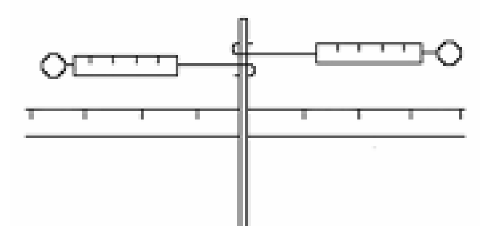
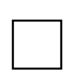
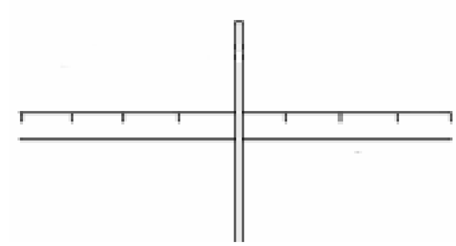
CASE RULE	CASE DIAGRAM	EFFECT MEASUREMENT SIZE (cm.) & DIRECTION (L/R)
Two forces applied in the **same** direction__add together for a NET FORCE________	4 N  7 N	 __________**cm.** to the left/right
	 11 N NET FORCE	 __________**cm.** to the left/right
Two different forces applied in opposite directions subtract from one another for a NET FORCE	 7 N 4 N	 __________**cm.** to the left/right
	 3 N NET FORCE	 __________**cm.** to the left/right
Two **equal** forces applied in **opposite** **directions** _____are BALANCED and make ZERO NET FORCE	 7 N 7 N	 __________**cm.** to the left/right
	 0 Newtons NET FORCE	 __________**cm.** to the left/right

TABLE FOR DEFLECTION ROD ACTIVITY

3 Teacher Supplement
Newton's First Law: Part I

Objectives and Resources

Lesson Objectives: Learners should be able to:

2.0 Motion where there is no net force ('unforced' motion)

2.1 Given a situation where no force (or no net force) acts on an object, state or predict that it will continue its motion in a straight line or remain at rest.

2.2 Vice versa, given a situation of an object at rest or moving steadily in a straight line, infer that there is either no force or no net force on the object (i.e. any forces balance).

6.0 Scientific inquiry objectives

6.2 State in own words that evidence is required for accepting a scientific claim.

Lesson Resources:

Notebooks/pencils/colored pencils/pencil pack
Apple 1 per group
Bowling ball 1
Basketball 1
Hover puck 1 per group (charge in advance)
Tablecloth & crockery (3juice cans per group, 1 for teacher)
Pile of about 6 – 8 books
Sturdy plastic cups (1 per group)
Card to go on cup (1 per group)
Coins (nickels) (1 per group)
Hoop 1 per class
Bottle 1 per class
Wood plug and/or chalk pieces (several per class)

COLOR CODING:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students may fill in as they go)
RED: outline topic and approximate timing

Lesson # 3 - [~ 70-75 min]

(Review ~10-15 min)

We have been learning about force and motion. Force is **a push or a pull** on an object. Forces can act by **touching/contact** an object or **at a distance**.

Force has **magnitude** or size which scientists and engineers measure in **units** of Newtons, and force has **direction**. We learned to use **Force Diagrams** to represent forces, and that the **Net Force** represents **combinations** of forces.

Let's remind ourselves how to calculate and represent the **Net Force** in different situations. [Create some **scenarios** to fit at least the 3 (shown) diagrams of forces acting on an object… assign magnitudes in Newtons, and have student draw and calculate the Net Force. Refer to the Table from Lesson # 2 if needed]

So we have seen that we find the **Net Force** by **adding forces that act in the same direction**, and **subtract forces that act in opposite directions**. We saw a specific case in which even though there were forces acting on an object, the result was a **ZERO NET FORCE** (when **two forces of the same magnitude acted in opposite directions)**. We might also have a ZERO NET FORCE when there are **no forces** acting in *either* direction.

So, there might be a **NET FORCE**, or there might be **ZERO NET FORCE** on an object. Our next goal is to learn about both situations, and how they relate to the motion of an object.

(Newton's First Law – Objects at Rest ~10 min)

Back in the 1600s, one of the greatest of scientists, Sir Isaac Newton, formulated three laws of motion. We are starting with **Newton's first law** which refers to situations where **no net force is acting on an object. [Put the poster of the Law up on the wall]**

The Law states that **If no net force acts on an object, an object at rest will stay at rest, and a moving object will continue to move at a constant speed in a straight line.**

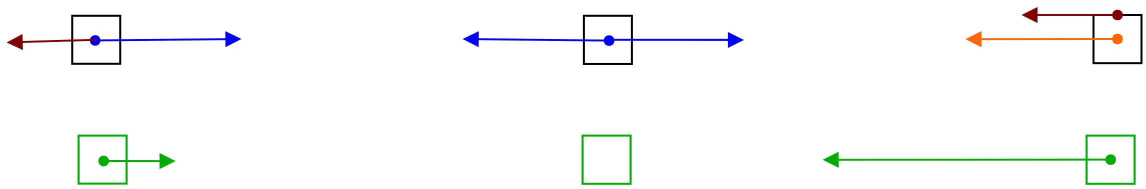
Note that Newton's 1st Law mentions **2 cases, OBJECTS AT REST** & **MOVING OBJECTS**.
Now we'll look at the **first case** of an **object at rest**, and **no net force** acting on it.
We can draw a simple diagram to show this case. We don't draw a force arrow, simply because there is no net force acting on it **[Draw** the simple box, students also]…
Now some examples…. consider this apple. It is at rest. There are no horizontal (sideways) forces acting on it. And it will stay at rest. However, if I apply equal forces with my hands on either side of the apple… as long as they add up to a ZERO NET FORCE, it will still remain at rest. **The point is,** whenever there is **no NET force**, an object at rest will stay at rest.

The same thing is true with this basketball. It too is remaining at rest. The law applies, no matter what the object is.

(Interesting Evidence 20-25 min)

3 - NEWTON'S FIRST LAW – Part I

REVIEW OF FORCE & NET FORCE –



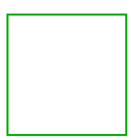
<u>NEWTON'S FIRST LAW</u> –

If no net force acts on an object,
an object at rest will stay at rest,
and a moving object will continue to move
at a constant speed in a straight line.

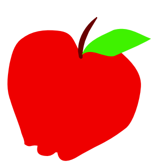
<u>CASE 1</u> -

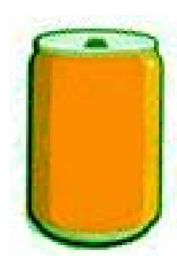
If **no net force** acts on an object
. . . an object **at rest** will stay at rest.

DIAGRAM -



EXAMPLES -





We will look for some rather more interesting evidence that when there is no net force acting [in some direction] objects at rest will tend to stay at rest.

At your tables we have materials for doing three activities.

1) cloth with lemonade cans **[no carbonation!]**
2) stack of books
3) cup, card and nickel

[Briefly explain how to do each one (as needed) then let students do the activity.]

[Afterward… **Call on** different groups to **report** on what happened in each particular case, and whether it provides **additional evidence for our claim**]

We did find more **evidence** for Newton's First Law regarding objects at rest…
In each of these cases, we have an **object or objects at rest that tends to stay at rest when no net force acts on it**.

[Note: Students may notice that these "tricks" only work well with a ***quick* pull**. If asked, you can simply explain that, the quicker the horizontal pull, the shorter the amount of time any [horizontal] contact/friction force is acting… *between* the tablecloth and the cans. So, the cans hardly move at all.]

If you think those are neat tricks, watch this…

[Teacher does the bottle activity - this takes **practice**! Students may try later: Balance hoop vertically atop bottle mouth… and balance chalk/plug standing upright atop hoop… knock hoop out from under chalk/plug so that it drops directly down into bottle.

Wrap up "objects at rest" by discussing how this evidence supports a claim of Newton's First Law.]

(Objects in Motion ~ 15 min)

Newton's First Law states that **If no net force acts on an object, an object at rest will stay**

SOME INTERESTING SITUATIONS –

Newton's First Law says that an object at rest tends to stay at rest.

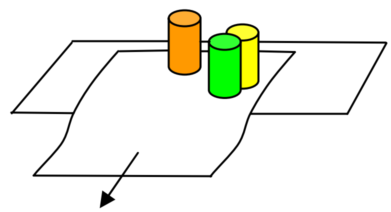
TEST THE LAW -

Three Challenge Activities

1. Tablecloth and objects

Set the juice cans on the cloth. Pull the cloth "straight" out from the table *very quickly*.
Did the cans tend to stay at rest?

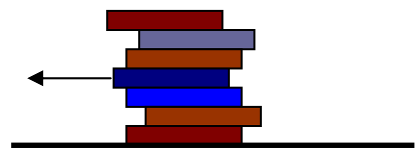
____



2. Book Pile Activity

Stack up the books on your table, and then *quickly* pull out one of the middle books from the stack.
Did the top of the stack tend to stay at rest?

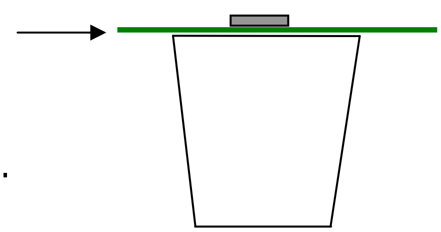
____



3. Cup and Nickel Activity

Place the card on the cup and then place the nickel on top of the card.
Give the card a quick flick with your finger.
Did the nickel tend to stay at rest?

____



Does this **evidence support the claim** of Newton's First Law?_YES_

at rest, *but it also says that* a moving object will continue to move at a constant speed in a straight line with no net force acting on it.

Now let's look at the **second case…** of an **object in motion**, and **no net force** acting on it. Let's represent this case in a simplified **diagram.** [draw a box as shown in **green**] We do *not* draw a force arrow… but our diagram needs to somehow indicate that the object is moving in a certain direction. So we will show that using a dashed arrow above the object. [**Draw** the simple box with dashed arrow above… students copy]

In order to **test the claim of Newton's First Law for a moving object**, we need to find a situation where an object is moving but has no net force acting on it.

If I send this **basketball** rolling across the floor, [do this, students can return it or try it] even after I am no longer applying any contact force to it (no hand! no foot!), it still has the tendency to keep moving in a straight line… until it bumps into something, right? ***But*** recall the thought experiment from yesterday… even if the basketball was in a room so large that it would never bump into anything, **it would still slow down eventually from the force of FRICTION.** Remember that friction is related to roughness, and we can feel the roughness of a basketball's *surface*.

Newton's First Law specifies that there is NO net force on an object, not even 'only friction'! So we can try to minimize the friction by using something with a smoother surface… like this bowling ball. [show how well it tends to continue to roll in a straight line across the floor… students can send it back to you]

So, the bowling ball obeys the First Law pretty well. But remember that yesterday we got an idea of how to **minimize friction force** even more, by creating a **cushion of air** between the **contact surfaces** of the objects. We used those little balloon pucks … but we have something even better.

With this **hoverpuck**, we can **minimize friction** very well [hoverpuck turned **ON**… and give it a push, in as long and flat an area as you can find] "*the object will continue to move at a constant speed in a straight line*" in good accord with Newton's First Law.
[If you find it veering away from straight, you can discuss the need for a perfectly level surface, but you don't need to discuss gravity as the cause]

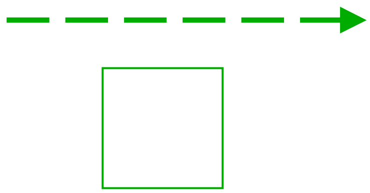
(Summary & Application ~10 min) Today, we've learned about **Newton's First Law** regarding situations where there is **NO NET FORCE** (at least in an ideal example!). Tomorrow we will do some more **testing of Newton's First Law.** [**APPLICATION**, then students can do demos (hoop drop…), build bottle rockets, etc.]

[Note: The term 'inertia' is often used to describe the tendency of an object to keep doing exactly what it was doing – to either keep moving or remain at rest. In everyday language we often say an object has a property of 'inertia', indicating that it doesn't naturally change what it was doing before – either its state of motion or its state of rest. Indeed, the first law is sometimes called the 'law of inertia.'
But, "inertia" does not need mentioning unless someone asks.]

CASE 2 -

If **no net force** acts on a **moving** object
. . . the object will continue to move
at a constant speed in a straight line.

DIAGRAM –



dashed arrow shows the motion

EXAMPLES -

A basketball is rolling to the right…

A bowling ball is rolling to the right…

A hoverpuck is moving to the right…

(to be continued…)

APPLICATIONS –

Bowling ball rolling down the alley

1) In a bowling alley you start the ball rolling and then it keeps going steadily toward the pins. Which is the best statement about the ball while it is moving steadily?

A. All objects naturally keep going, unless there is an opposing force to stop them.
B. The floor of the bowling alley must slope slightly downward for the ball to keep going.
C. The force you applied to start the ball moving continues to act on it while it is moving.
D. There is still a forward force on the ball while it is moving, acting at a distance now instead of by contact.
E. The ball is attracted to the pins at the end and repelled from your hand.

Explain your answer.

2) At an instant while the ball is rolling, and there is no friction, what is true of the horizontal forces on it, if any?

A. There are no horizontal forces on the ball.
B. There is a forward force on the ball.
C. There are forward and backward forces, which are equal and opposite (balance).
D. There are forward and backward forces on the ball, the forward being greater.

Explain your answer.

Boy and dog tugging a shoe

In the bowling alley a boy and a dog are both tugging on a bowling shoe. A girl says that the shoe is not moving one way or the other. Which one of the following is true in this situation?

A. The shoe could never remain at rest with both of them tugging on it.
B. There are no forces acting on the shoe.
C. The only force on the shoe is due to gravity.
D. The forces due to the boy and dog are equal and opposite.
E. The dog applies a bigger force than the boy.

Explain your answer.

4 Teacher Supplement
Newton's First Law: Part II

Objectives and Resources

Lesson Objectives: Learners should be able to:

2.0 Motion where there is no net force ('unforced' motion)

2.1 Given a situation where no force (or no net force) acts on an object, be able to state or predict that it will continue its motion in a straight line or remain at rest.

2.2 Vice versa, given a situation of an object moving steadily in a straight line, infer that there is no net force on the object (i.e. any forces balance).

2.3 For a moving object, given distance traveled and time taken, be able to calculate speed, including units.

6.0 Scientific inquiry objectives

6.1 State that scientific investigations begin with a question.

6.2 State in own words that evidence is required for accepting a scientific claim.

Lesson Resources:

Notebooks/pencils/colored pencils/pencil pack
Newton's poster
Apple (1 for teacher)
Blue cart 1 per group
Juice can 1 per group
Bowling ball 1
Stopwatches (optional)
Hover puck 1 per group
Hovercraft & blower & battery charger 1 per class (charge in advance)
Masking tape to mark floor 1
Meter stick 1
Tape measure
Push scale (with handle) 1 per class
Calculators (1 per group)
Bright index cards or bean bags (to place on floor as markers, 2 colors - 5 of each)

COLOR CODING:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students may fill in as they go)
RED: outline topic and approximate timing

Lesson # 4 - *[~ 70-75 min]*
(Review ~10 min)
We have been learning about situations where there is no net force acting on an object, whether the object is at rest or moving (and we studied these two cases).
When the object is **at rest**, **Newton's 1st Law** states that the **natural tendency** of an object at rest will be to **stay at rest**, if no net force acts upon it.

[Note: you might ask what we did that showed this "at rest" part of Newton's 1st Law. Remind them that we can show this situation and case in a simple diagram as shown]

Newton's 1st Law also tells us that when there is no net force acting on a **moving object**, its **natural tendency** will be to **continue to move** in a straight line at a constant speed.

[Note: you might ask what we did that showed this "*moving*" part of Newton's 1st Law. Remind them that we can show this situation and case in a simple diagram as shown, still no force arrow but has a dashed motion arrow]

Interestingly, **Newton's First Law** works both ways; it can be turned around.
In other words, whenever you observe that something is at rest and remaining at rest, like this apple, you can infer that the NET FORCE is ZERO.

Whenever you notice that something is moving with a constant speed in a straight line, you can infer that the NET FORCE is ZERO.

Recall that there are **two ways** that the **net force can be zero**, either there is **no force acting** on it, or all the **forces are balanced**.

There are plenty of examples of Case 1 … if we look around us, lots of things are at rest and remaining at rest. But let's try to think of some **examples** of **CASE 2.**
[gather some ideas from the kids, additional suggestions are shown in **green**]

(CASE 2 - Objects in motion)
Notice that in our examples from yesterday and today, we have been talking about Newton's First Law only qualitatively, what it "looked like" to us, without measuring anything. Scientists and engineers need **quantitative evidence** as well, to support their claims. Similarly, we will try to confirm Newton's first law by doing a quantitative test for the case of an object in motion with no net force acting upon it.

The goal is to verify that the object will continue to move at a constant speed. To do this we'll need to figure out its average speed in successive time intervals, and see if they are the about the same. To determine speed, we'll take measurements of distance traveled over each time interval [… similar to miles per hour or meters per second]

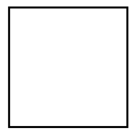
4 - NEWTON'S FIRST LAW – Part II

REVIEW –

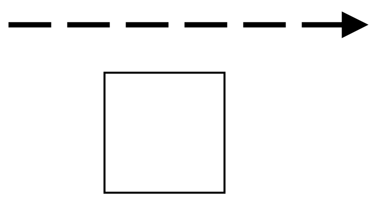
NEWTON'S FIRST LAW

If **no net force** acts on an object . . .

CASE 1 **an object at rest will stay at rest,**



CASE 2 **and a moving object will continue to move at a constant speed in a straight line.**



...more on CASE 2:

Try to suggest some examples of ***moving objects with "no net force"*** *from your experience in everyday life:*

coasting on a road bike (but has some friction in real life)
ice skating
car sliding on icy road
rollerblading
air hockey (very low friction!)
seeing astronauts floating in space
etc.

(Bowling ball activity ~20)
Let's try the test… the instructions are on today's Page 2.
[Practice a few times first…. ☺]
[Do the Bowling Ball Activity as a group with all kids recording the data. Refer to the diagram as needed. Runners (bean bag droppers) may be selected by namesticks.]

Remind the students how to take an **AVERAGE**… we have two runners/markers so that we can eliminate some amount of experimental error.

Help students complete their tables and answer the questions. Hold short discussions on what happened and how the results relate to Newton's 1st Law.

Be prepared to discuss why the distance measurements are not exactly the same for the 2 runners…experimental error in measuring process (reaction time, judgment, etc)

Also be prepared to discuss why the calculated average speeds might vary over the 3 intervals. If it decreases, maybe there is some friction in this system…?]

Were we able to confirm the claim of Newton's First Law regarding objects in motion?

Yes, we were… the speeds are about the same at each distance.

But the bowling ball does/would actually slow down a bit eventually, doesn't it? In day two, we talked about that contact force of Friction that is with is us all the time.

Let's continue our familiar "thought experiment." Close your eyes. Imagine that we are in the longest bowling alley in the world. The lanes are so long that we can't even see the pins at the end. Now imagine that the surface is super-slick ice. We start the ball rolling along the lane toward the pins — which we can't see because they are so far away! Is there anything to stop the ball? No! With the ice there is almost no friction so the ball will keep moving until it is out of our sight. Can you imagine the ball disappearing into the distance? It will roll forever or until SOME FORCE stops it.

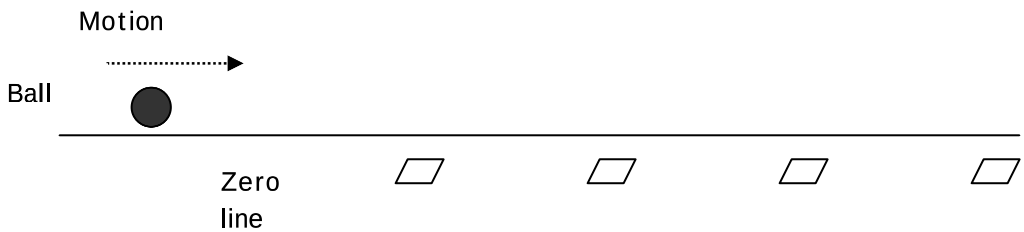
Open your eyes! Back to the real world! We can't get rid of friction completely… but we saw yesterday that we can **reduce friction** quite a bit with a **hoverpuck** that rides on a cushion of air.

MEASURING THE SPEED AT DIFFERENT STAGES

Even if it looked like the speed was constant during the motion, we should measure it to check.

We will roll a bowling ball along a smooth track/surface, and measure the distance it travels in the first 3 "seconds," the next 3 seconds, and the next 3 seconds, to confirm that speed stays constant.

Method



Count: "One Two Three One Two Three One..."

1. Gather around the track.
2. A student rolls the ball. At the moment the ball passes the starting line, the teacher calls out 'one, and counts off "seconds," i.e. "one, two, three, one, two three, etc. Students should count with the teacher, helping keep the beat.
3. At each third count, students on both sides drop markers exactly where the ball is at that moment.
4. Measure distances traveled (distance between markers) and calculate the speed for the three stages.

DATA TABLE for BOWLING BALL			
	Distance traveled in first 3 "seconds"	Distance traveled in next 3 seconds	Distance traveled in last 3 seconds
Measure 1			
Measure 2			
Average* of distance measurements			
Speed = $\frac{\text{Distance}}{\text{Time interval}}$			

Are the speeds the same in the different stages? Are they close?

Is Newton's First Law verified?

Why, or why not?

*HINT: Add and divide by 2

(Hoverpuck activity ~10 min.)
So now we'll repeat our **quantitative test**, but with the **hoverpuck** … with the goal of **reducing friction** to the point where the **actual NET FORCE is even closer to ZERO.**

[class effort, unless there is a way to have each group of students run one good trial with the hoverpuck moving rather slowly on a smooth, even surface. Same manner as with bowling ball]
[**COMMENT**: if teacher chooses, there's no real need for speed **calculations** again, because we saw that the distance traveled per equal time interval is proportional to speed – may just compare distance traveled]

Let's discuss results of this experiment with the hoverpuck… [so the closer we get to the condition of Zero Net Force, the better our results verify Newton's First Law]

(LARGE SCALE DEMO, in suitable location ~20-25 min.)
You have used the "hover pucks" . . . but we've got a bigger version that you can actually ride on! So… it's time for **a ride *with the physics in mind*.**

If Newton's first law is valid then what do we predict?.... **that the hovercraft should keep going on its own.** So here is what we are going to do.

We'll have one person (at a time) sit on the hovercraft. They can control the on/off switch, and once they turn it on and get balanced (it'll be loud), we'll give them a push or a pull just to get them moving. After that, there should be virtually no net force acting on the "moving object" (remember that air cushion minimize friction!). Let's **look carefully** at what happens…

[Note: Do demo with teacher giving the push or pull. Do several times with different kids. **Pointedly discuss the fact that the object tends to keep moving** at a constant speed in a straight line. Also, have fun ☺]

(BACK TO ROOM… Summary & Application ~10 minutes)
Today we found **quantitative evidence** to support Newton's First Law… as well as some more interesting qualitative evidence.

As **Newton said**, and as we have seen today, **no NET FORCE is needed to keep an object moving once it is going…** it has a **natural tendency** to **keep moving**.

… when friction interferes or when the moving object bumps into something, there is then an opposing force that slows and stops the moving object — but if there is no opposing force, the object keeps moving.

[We have a summing-up **Application** to do on Newton's First Law… but if you are short of time the Application can hold till Day 5—the discussion is planned for Day 5 anyway.]

SMALL SCALE – *Hoverpuck experiment*

MEASURING THE SPEED AT DIFFERENT STAGES … with even *less* friction

DATA TABLE for HOVERPUCK			
	Distance traveled in first time interval	Distance traveled in next time interval	Distance traveled in last time interval
Measure 1			
Measure 2			
Average of distance measurements			
Speed = Distance / time interval			

Are the speeds the same in the different stages? Are they close?

Is Newton's First Law verified?

Why, or why not?

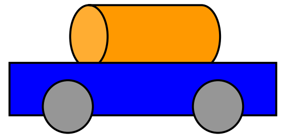
LARGE SCALE – *Hovercraft Demonstration!*

Testing Newton's First Law

Does the low-friction hovercraft move in accord with Newton's 1st Law?? ___YES__

APPLICATION -

CART 'N CAN
Blue cart & juice can



TEST 1 -

If the cart is stationary and we suddenly give it a hard push forward, what will happen?

Why is this? Explain your reasoning.

Now try it. What happens? To the cart and to the can?
Cart moves forward suddenly, can stays at rest, and so falls off the cart.

Was your prediction right?
Was your reasoning good?

TEST 2 -

Get the cart moving at a steady speed with the can on it, then suddenly **stop** the cart. What will happen?

Why is this? Explain your reasoning.

Now try it. What happens? To the cart and to the can?
Cart stops suddenly, but can keeps moving, and so falls off the cart.

Was your prediction right?
Was your reasoning good?

So, using the cart 'n can, we can see both aspects of Newton's first law at work! The 'at rest' aspect and the 'moving' aspect.

5 Teacher Supplement
Newton's Second Law: Part I

Objectives and Resources

Lesson Objectives: Learners should be able to:

3.0 Motion where a net force acts ('forced' motion)

3.1 Describe the effect of a net force on motion, i.e. that the object will speed up or slow down, depending on the force direction. Vice versa, given situations where an object is speeding up or slowing down, be able to infer that there is a net force and identify its direction.

6.0 Scientific inquiry objectives

6.1 State that scientific investigation begins with a question.

6.2 State in own words that evidence is required for accepting a scientific claim

Lesson Resources:

Notebooks/pencils/colored pencils/pencil pack
Hovercraft (1 per teacher) & helmet (charge leaf blower in advance)
Bathroom push scale (1 per teacher)
Skateboard, with little friction (1 per teacher)
Blue sail-carts (1 per student group)
Black fan carts, battery powered (4 per teacher)
Hoverpucks (1 per group, plus 2 per teacher)
Spare batteries (AA)
Hair-blowers (1 per group)
Extension cords (1 per group)
Spring tube scales, 20 Newtons (4 per teacher)
Masking tape
Tape measure, 25 ft. (1 per teacher)
Cheap calculators (1 (1 group)
Bright index cards or bean bags (to place on floor as markers, 2 colors - 5 of each)

COLOR CODING:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students may fill in as they go)
RED: outline topic and approximate timing

Lesson # 5 - *[~ 70-75 min]*

(Review ~5 min)

Welcome to the second week of "Way 2 Go" Summer Science. Let's remember that the goal of this unit is to understand **how force and motion are related.**

What have we done so far? We started with the **concept of force**, and defined it simply as a **push or a pull** on an object. We described forces in terms of **magnitude, units, and direction**. And we represented forces in **force diagrams**.

When more than one force acts on an object, we learned how to **combine forces** into a **NET FORCE** by adding forces if they act in the same direction, or subtracting them if they act in opposite directions.

To study how force and motion are related we started with **NEWTON'S FIRST LAW**, which refers to the situations in which there is **NO NET FORCE** acting on an object (in a particular direction, either there are no forces at all, or the forces are "balanced").

NEWTON'S FIRST LAW states that "With zero net force, objects in motion stay in that motion, and objects at rest stay at rest… in other words, there is **NO CHANGE** in the speed of the object.

Can you recall some of the evidence we found that verified Newton's First Law?
[briefly discuss a few prior activities… you can illustrate showing hoverpuck – at rest, and in motion. You might ask why the hoverpuck was a particularly good object to be used…elicit the need to simplify, and satisfy as well as possible the condition of zero net force.]

Today's lesson is about **NEWTON'S SECOND LAW**, which refers to situations **where there IS A NET FORCE** on an object.

NEWTON'S SECOND LAW states that "**A NET FORCE causes a CHANGE** in the speed of an object in the direction of the force… so that the object will **speed up** if the force acts in the **same direction** as its motion, and **slow down** if the force acts in the **opposite direction** of its motion."

5 - NEWTON'S SECOND LAW – Part I

REVIEW:

NET FORCE is the sum of the forces acting upon an object.

NEWTON'S FIRST LAW: With ZERO NET FORCE,
objects in motion **stay in that motion**
and objects at rest **stay at rest**.

NO CHANGE !!

EFFECT OF A NET FORCE ON MOTION

NEWTON'S SECOND LAW: A NET FORCE causes a CHANGE
in the motion of an object
in the direction of the force.

So, the object will speed up if the force acts in the direction of its motion,

and the object will slow down if the force acts in the opposite direction

from its motion.

(Demonstration ~ 15min) Let's look at various situations in which a **net force acts** on an object, and search for confirming evidence to support NEWTON'S 2nd LAW. Remember that evidence is an essential aspect of science. A difference between everyday thinking and scientific thinking is that in science our statements must be supported by evidence. We ask questions and seek evidence to support our answers and claims.

Before we start, let's remember that as we study forces and motion, we try to simplify the situation. One way that we do this is by minimizing friction forces. We will continue to work with objects that have very little friction so that our force system is as simple as possible.

Now we'll run several tests. The first **case** we will test will be of an **object at rest**; this hoverpuck is at rest, and then I **apply a force**. [**DO THIS** and point out that the hoverpuck simply **changes its speed from zero to "some speed" in the direction of the force**].
Let's draw a **diagram** to represent this situation. We will draw the initial situation, which is just an object at rest, and then add a force arrow. Remember that we are looking at "what happens" to **the object at rest**… after it is moving it is no longer at rest; then it becomes a moving object which is our *NEXT CASE!*

For the next **case** of **objects in motion,** the first object we'll look at is this battery powered fancart, that is propelled by a constant force and has minimal friction from its wheels.
[Describe and demonstrate **Test 1,** of **force in direction of motion** … turn on a black fancart, set it down, and let it go.]
Notice what's going on: The fancart starts at rest, with zero speed, and from the force that keeps pushing it in the direction of its motion, it speeds up steadily, going faster and faster.

Let's draw a **diagram** to represent this situation. We will use our regular convention of a box and an arrow to show the force acting on the object. But we must also show the direction of motion, and for that we will use a dashed arrow. *Have students copy diagram **(in green)***
Newton's 2nd Law says that an object will **speed up** from a **force in the direction of its motion.** Is the second law confirmed by our experiment? ***YES***

Many people incorrectly believe that a constant force will cause a constant speed;
but as we saw, and as Newton's 2nd Law states, a constant force in the direction of motion causes an increasing speed.
[Describe and demonstrate **Test 2**, of force **in opposite direction of motion**. Turn it on, and set it down so that it would come toward you… then push on it so it rolls away from you]

Notice that it slows down as it rolls away from me. The force on the fancart is against the motion, and pushes it back toward me so it **slows down** (just as it would from friction that acts against the motion!). Let's **draw the diagram for this case.**

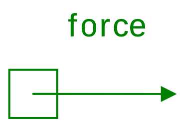
Newton's 2nd Law says that an object will slow down from a force opposite its motion. Is the second law confirmed by our experiment? ***YES.***
To summarize: a net force causes a **change in motion**, in the **direction of the force**.

<u>Qualitative Demonstration of Newton's 2nd Law</u>

CASE 1: OBJECT AT REST

Test: Force applied to hoverpuck in some direction… the hoverpuck **SPEEDS UP**
(a change in motion)

Diagram:



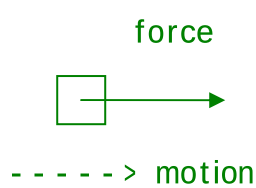
Are our observations consistent with the 2nd Law? **YES, speed increases from zero in the direction of the force**

CASE 2: OBJECT IN MOTION

Observe the battery-powered fancarts that are propelled by constant force… and have very little friction.

Test 1: A constant force in the direction of motion… the fancart **SPEEDS UP**
(a change in motion)

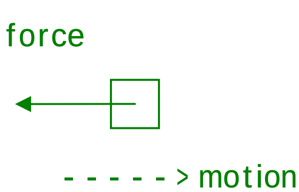
Diagram:



Are our observations consistent with the 2nd Law? **YES**

Test 2: A force **against** the direction of motion… the fancart **SLOWS DOWN**
(a change in motion)

Diagram:



Are our observations consistent with the 2nd Law? **YES**

(Student sailcart activity ~ 15min)

To **check this out for yourselves (i.e.,** *a net force causes a change in motion, in the direction of the force)*, we will do an **activity in your groups**. We will do two tests as shown in the **diagrams** on your paper. One test is for a **force in the direction of motion** and the other is for a **force that acts against the motion**.

In your bin you have a **blue sailcart** and a **hair-blower** that can blow with a constant force. Please get them out. Carefully **plug the hair-blower** into the electrical cord that you have near your table, and **set up the blue sailcart** on the corrugated plastic tracks. **Clear a path** ahead of your sailcart.

Test 1:
Switch on the hair-blower to the high speed, and blow directly into the sail from a few inches away. Then **keep blowing on the sail** from the same distance as it starts to move. Carefully watch the motion of the blue sailcart (like a scientist!), and have someone ready to catch it. Record your observation in your notebook.

Test 2:
Now have a member of your group on the opposite end of the "track" push the cart back to you by hand, without turning the sailcart around, so that it looks like it is rolling backwards. As the sailcart approaches halfway, turn the hair-blower and observe what happens. Record your observation in your notebook.

Call for observations and discussion.

Emphasize that in Test 1, the blue sailcart starts at rest with zero speed. From the force that keeps pushing the sailcart in the direction of its motion, it speeds up steadily, going faster and faster.

In Test 2, the blue sailcart is already moving in a certain direction, and the force that blows against that motion causes the cart to slow down (just as it would from friction that acts against the motion!).

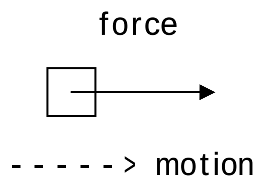
Do our results verify Newton's Second Law? ***YES.***

Sailcart Activity: Verifying 2nd Law

Use a hair-blower to apply a constant force to blue sailcarts. The sailcarts have very little friction. Move with the carts, trying to keep a constant distance from the hair-blower to the sail.

Test 1: Force in same direction as motion

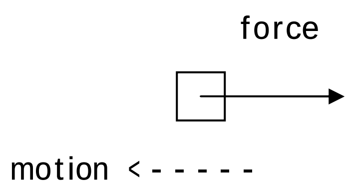
Diagram:



Observation: ___force in same direction, speeds up *(a change in motion)*___________

Test 2: Force in opposite direction to motion

Diagram:



Observation: ______force opposite direction, slows down *(a change in motion)*______

Is Newton's Second Law confirmed by all tests?: _____YES ______________

(Skateboard activity ~ 20-25 min)

So far, we have studied **Newton's Second Law** and verified it without measuring anything (qualitatively). Scientists and engineers use **specific measurements** to support their ideas. We want to do the same.

Remember that when we studied Newton's First Law, we used measurements of **distance and time**, and we were able to describe more accurately what happened with the motion of a bowling ball along its track.

So far today we have tried to verify Newton's 2nd law by observation alone. Our fancart/sailcart *seemed to be* speeding up or slowing down. A more accurate approach requires measurements to quantify our observations. I'll show you how to do this for the case of a rider sitting on a skateboard, being pushed with a constant force in one direction.

[Note: Pick a student volunteer to be the rider and one to be the pusher. You may either have the rider drop/place markers on the "beats" if they are able… or else have student "runners" who run alongside "marking" positions on the "beats."]

The rest of you are needed to help us keep the beat for the rider to place MARKERS (bean bags), every 3 seconds while the skateboard is moving. We will clap "one, two, three, one, two, three" and so forth to keep the time. The "pusher" will take the bathroom scale, place it on the rider's back and push with a constant force of about 10 pounds on the bathroom scale. We will make several practice runs before we collect our data.

Method

We will push a skateboard & rider along a smooth floor with a constant force, and measure the distance traveled in each of three equal time intervals. Then we'll calculate the speed for each interval, and verify whether or not the speed keeps increasing (obeying Newton's Second Law).

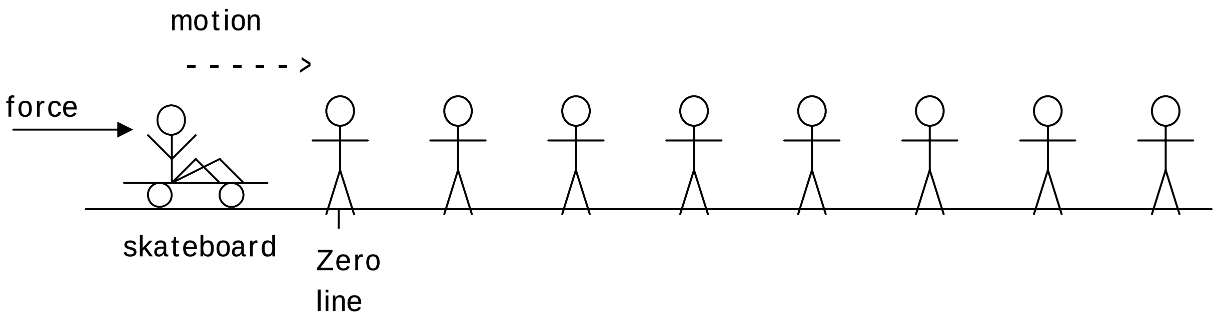
[Describe steps 1-6 as outlined on student page. Run 1 trial after some good practice runs. Help students to record the data and make calculations. Hold brief discussion on results. May include some discussion of "error" elements, even while making main point.]

Summary Points: Our results agree with Newton's 2nd Law which states that a constant force will cause an object to keep *speeding* up.

We can conclude that a constant net force causes a change in an object's motion, in this case the skateboard sped up.

Quantitative Demonstration of Law: Skateboard Activity

Apply a constant force to a skateboard & rider to demonstrate Newton's Second Law



Method – 1 trial after practice runs

We will push a skateboard & rider along a smooth floor with a constant force, and measure the distance traveled in each of three equal time intervals.

1. Choose a Start/Zero line on the floor. Teacher leads the clapping & counting: "**one**, two, three, **one**, two, three… Students clap/count with the teacher.

2. A student will sit comfortably on the skateboard, holding a stack of cards or bean-bag MARKERS. The "pusher" pushes so that the scale reads about 10 pounds. The rider resists moving by *holding on to the floor to keep from rolling while* . . .

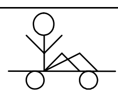
3. Rider will resist moving until he or she chooses a starting BEAT to "let go" on, placing the first MARKER.

4. The rider places a marker every time that beat/number is counted. The pusher must try to keep the scale reading 10 pounds.

5. Measure and record distances over each of 3 time intervals

6. Calculate average speed for each of 3 intervals (average distance divided by time)…record in **TABLE**

DATA TABLE

	Interval 1	Interval 2	Interval 3
Distance Traveled (cm.)			
Time Interval ("seconds")	3	3	3
Speed = Distance / Time Interval (cm./"second")			

COMPARE SPEEDS OVER THREE INTERVALS:.
What happened? Try to explain what the data mean.

SPEED INCREASES… from the constant applied force

(Hovercraft ~ 15min) We have used fancarts, and blue sailcarts, and a skateboard to study Newton's 2nd Law, if the law is true then it should apply to motion for any kind of situation when a net force is acting, even with a hovercraft. So we'll check this out with the hovercraft as our final demonstration. [if time permits]…

We predict from Newton's Second Law that if we keep applying a constant force to the hovercraft, it will keep speeding up in the direction of the force.

So now we need a VOLUNTEER to ride on the hovercraft, wearing a helmet.
(Pick a student… others can ride afterward.]
We need someone to push gently with the scale, probably on the back of the rider, [test/practice beforehand] so that they have their hands free to hold and operate the ON/OFF switch. Who'd like to try to push with a constant force?

(Select someone to push gently. This person must understand that they will push in a forward direction with a small constant force, and that it is likely to involve the ability to walk faster and faster and faster, while reading a scale, and trying not to trip on a hovercraft. We also need to have a group of students "**spotting**" at the final destination of the hovercraft, in case the rider forgets to turn the switch off.)

Let's get set up… for this to work well, let's get our group to spread out along the path, with some of you down where we will end up so that you can help stop the hovercraft if needed. We also need someone to hold onto the hovercraft to resist the force of the pusher until we want to let it go (ASSIGN someone as the "holder")
OKAY… turn on the hovercraft's blower and start pulling with 5 N force.

Does it obey Newton's 2^{nd} Law and keep speeding up? Definitely yes!!

(You might find an opportune moment to make a connection here to Newton's first law… What will happen to the rider if the hovercraft stops very suddenly?)

(Summary) To sum up today's lessons, we have studied and exemplified Newton's Second Law in various situations, which states that a Net Force causes a CHANGE in the speed of an object in the direction of the force.

Notice that a constant net force on an object does not result in a constant speed as people often believe, but a constantly CHANGING speed!

LARGE SCALE DEMO
of
NEWTON'S SECOND LAW

Hovercraft ride (force in direction of motion)

Observation: ___*keeps speeding up!*___

SUMMING UP:

A NET FORCE causes a ___CHANGE___ in the motion (speed) of an object.

NOTE: A constant NET FORCE does *not* cause a constant speed, but a constant ***change*** in speed (speeding up or slowing down).

6 Teacher Supplement

Newton's Second Law: Part II FORCE, MASS, and MOTION

- how motion depends on force and mass

Objectives and Resources

Lesson Objectives: Learners should be able to:

3.0 Motion where a net force acts ('forced' motion)

3.2 State that a larger force causes speed to change more rapidly, and apply to particular cases.

3.3 State that a larger mass changes its motion less (rapidly) in response to a force, and apply in particular cases

6.0 Scientific inquiry objectives

6.1 State that scientific investigations begin with a question.

6.2 State in own words that evidence is required for accepting a scientific claim

6.3 Develop and defend a scientific claim based on evidence.

Lesson Resources:

Fan carts (3 per teacher, 2 with full battery set, and 1 with 2 blanks)
Batteries (AA's and blanks)
Blue sailcarts (1 per small student group... size of group?)
Weights (8 x 2N weights)
Hair-blowers (1 per small group)
Extension cords (care must be taken with these)
Long whiteboards (1 per student group)
Bathroom push scale with handle (1 reliable one per teacher)
Skateboard (1 per teacher)
Bright index cards or bean bags (to place on floor as markers, 2 colors - 5 of each)
Stopwatch (optional)
Tape measure
Cheap calculators (1 per group)

COLOR CODING:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students may fill in as they go)
RED: outline topic and approximate timing

Lesson # 6 - ***[~ 75 min]***

(Review Newton's Second Law ~5 min)

Greetings! Yesterday we started to look at **Newton's 2nd Law**, which refers to situations where a **NET FORCE** is acting upon an object. We used fan carts, blue sailcarts, and a skateboard & rider to verify the law that says that a **Net Force causes a change in the speed of an object**, in other words, it causes the object to **speed up or slow down.**

… but there is more to the story of Newton's 2nd Law, because we can consider factors/variables that are important to how force affects motion. These factors (or **variables**) are the **size of the force**, and the **mass of the object** on which a force is acting.

(Dependencies: mass & force ~5min)

I can push this **blue** sailcart with a small force or a **bigger force** (**do this**)… or I can push it empty, or I can add a **heavy item on top** of it (*that will **increase the "mass" of the object(s)!***) (**do this**).

Keeping in mind these two factors, **magnitude of force**, and **mass of the object**, Newton's Second Law becomes more complete… it tells us that:

A net force causes a **change** in the speed of an object, **directly related** to the magnitude of the force, that is, more force, more change in speed;

but for mass the relationship is opposite, that is, more mass, less change in speed. This is called an inverse relationship. We can **test these two claims.**

We begin with a **FAIR** test about the effects of force magnitude and mass of object.

To do a careful, **scientific investigation** of the effect on motion of these two variables, force size and object mass, we look at them "**one at a time**." To do this we'll keep everything else the same, and change/vary only one thing, and we'll **see what difference that one change makes**. This is called the method of "**Control of Variables.**"

We will do two experiments: first to vary **only the force** … and then second to vary **only the mass**.

In the process, we will make measurements, record, analyze, and interpret them.

6 - NEWTON'S SECOND LAW – Part II

How motion depends on force and mass

NEWTON'S SECOND LAW: *Force, Mass, and Motion*

A **NET FORCE** causes a change in the speed of an object that is:

Directly related to the **magnitude of the force**, and

Inversely *related* to the **mass of the object**.

DOING A FAIR TEST:

To look scientifically at the particular causes of particular effects,
we use a method called: ____*CONTROL OF VARIABLES*______

We change only one thing at a time and then look
to see what difference that ONE change makes.

(Demonstrations Qualitative ~10 min)

Before making measurements, we will **demonstrate and verify qualitatively** (without numbers), how each factor affects the motion. First we will look at the factor of **Force Size** or magnitude.

For this we will try out **two tests** with these battery powered **fancarts**. One has a full power supply of batteries, and one has half, so one fancart has a greater force applied to it than the other. We can represent these situations with the aid of force diagrams. (Teacher draws the diagrams and asks the students to copy them).

Ok, let's have a race! We'll lay down two whiteboards end to end on the floor to make our track (may tape underneath if needed). Then I'll turn on both fancarts and set them down at the "start position" and let them go at the same time … on your mark, get set, GO. (do this)

Here they go! Notice that the one with a **larger applied force** is the Winner. Since it traveled the same distance in less time, we know that its speed was greater, and that it had a **bigger change in speed**, starting from zero. So it got to the end of the "**track**" *sooner,* crossing the "finish line" at the end of the whiteboards.

Were our **observations** consistent with Newton's 2nd Law? **YES**

Next we show a test of two fancarts which have the same number of batteries, the same applied force, but which **vary in how much mass** they carry. I'll put **a couple of weights** on one of them, increasing the mass of one "object" … and we'll let them race again.

(same procedure for the race)

Notice that the fancart with the **larger mass** crosses the "finish line" last… so it must have had a **smaller change in speed**, starting from zero . . . so it gets to the end of the track *later.*

Are these results in accord with Newton's Second Law? **YES**

<u>**Qualitative Demonstrations**</u>

<u>TEST 1 - EFFECT ON MOTION FROM VARYING THE FORCE</u>

Observe a race between fancarts with different numbers of batteries.
Larger force should cause a bigger change in speed.

Fancart 1 – Large Force

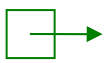
Diagram: force

- - - - - > motion

-

Fancart 2 – Smaller Force

Diagram: force



- - - - - - > motion

Are our observations consistent with the 2nd Law? ____<u>YES</u>_______

<u>TEST 2 - EFFECT ON MOTION FROM VARYING THE MASS</u>

Observe a race between fancarts with different mass.
Larger mass should cause a smaller change in speed.

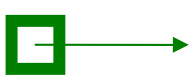
Fancart 1 -

Diagram: force

- - - - - > motion

Fancart 3 - With Extra Mass

Diagram: force



- - - - - > motion

Are our observations consistent with the 2nd Law? ______<u>YES</u> _______

(Student verification - ~15 min)
To **check out Newton's Second Law for yourselves**, we will verify it with 2 tests using blue sailcarts.

One test is to **see the effect on motion from varying the force,** and the other is for seeing the **effect on motion from varying the mass.**

Ok, let's set up for the races. Each group needs to lay down a corrugated whiteboards on the floor to make their track. Get out your **blue sailcarts**, **hair-blowers,** and **a couple of weights.**

Carefully **plug the hair-blower** into the electrical cord that you have near your table, and **set up two blue sailcarts** on each track.

For Test 1: Two students will operate the blowers, one at high speed and one at low speed to provide two different forces to the sailcarts.

For Test 2: We need two other students to operate the blowers, this time using the same HIGH speed, but on one of the carts we must add extra MASS.

Start your blowers first and then drop them down to the sails at the same time to start the motion... and **REMEMBER to blow** into the sail from the **same close distance on both** sailcarts!!

So let's **record what we observed**. . .
Again . . . "The **bigger the force**, the **bigger the change** in speed."
And again . . . "The **bigger the mass**, the **smaller the change** in speed in response to a force."

Are these results in accord with Newton's Second Law? **YES**

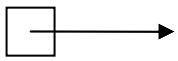
For the rest of our lesson we will do some quantitative testing . . . so grab your notebooks and pencils. **Skateboard time again**!

Student Verifications of Law:

TEST 1 - EFFECT ON MOTION FROM VARYING THE FORCE

Sailcart 1 – Large Force

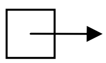
Diagram: force



- - - - - > motion

Sailcart 2 – Smaller Force

Diagram: force



- - - - - > motion

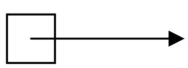
Observation: the bigger the force, the bigger the change in speed________________

____

TEST 2 - EFFECT ON MOTION FROM VARYING THE MASS

Sailcart 1 -

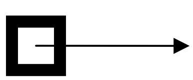
Diagram: force



- - - - -> motion

Sailcart 2 - With Extra Mass

Diagram: force



- - - - - > motion

Observation:_the bigger the mass, the smaller the change in speed in response to a force____

CONCLUSION: is 2nd Law confirmed for both factors? _____yes______

(Student verification - ~30 min)
We need another skateboard rider today, CAN I HAVE A VOLUNTEER? Pick a student volunteer to be the rider …

Like yesterday, the rest of you are needed to help us keep us **keep the beat** for the rider to place **MARKERS**, every 3 seconds while the skateboard is moving. We'll have a 3 second TIMER clapping away, and the rider will mark on 3 second beat (we'll practice first so we can make sure we've got good rhythm!).

We will run two separate tests to verify Newton's 2nd Law with a skateboard & rider.
Test 1 will look at the effect on motion from varying the FORCE and
Test 2 will look at the effect on motion from varying the MASS.

Test 1 – Vary the Force
We will perform the following process twice,
1st for CASE 1 with a small constant force of about 10 pounds, and
2nd for CASE 2 with a larger constant force of about 15 pounds. . .
pushing a skateboard & rider along a smooth floor. For each Case we will use brightly colored markers, leaving the markers on the floor for later measuring.

May describe steps 1-8 as outlined on student page

Let's do the skateboard activity now…
[Teacher and students complete the activity,]

As we look at the MARKERS on the floor, we can see again the evidence of speeding up from a constant applied force in both cases . . . but also we can notice a difference in the pattern (it gets stretched to longer distances when the force is bigger!). Let's measure the distances, record them in our Data Table, use them to calculate speeds, and then analyze the results.

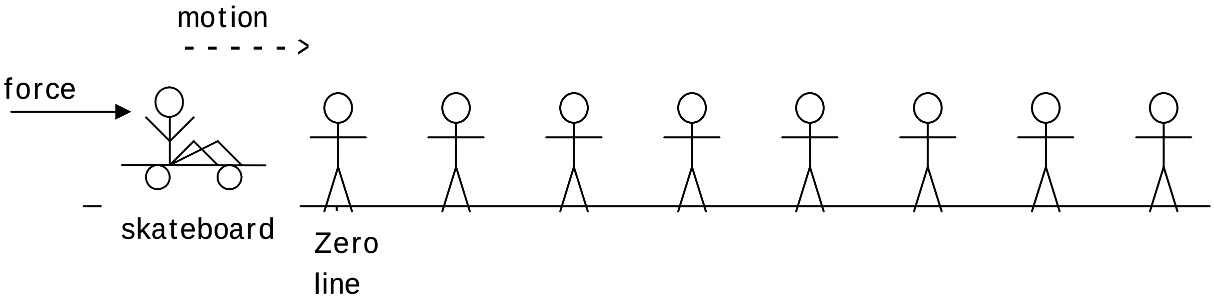
[Measure… and fill in data table which includes average speeds during 3 intervals for each case]

Do our results **agree with Newton's Second Law, which** states that a bigger force will cause a bigger change in the speed? **YES!**

<u>Quantitative Demonstration of Law</u>: Force, Mass, and Motion

<u>Skateboard Activity</u>

With a skateboard & rider, test the effect on motion from varying the FORCE,
and the effect on motion from varying the MASS, to verify Newton's Second Law.



Test 1 – Vary the Force

We will perform the following process twice, **1st for CASE 1** with a small constant force of about 10 pounds, and **2nd for CASE 2** with a larger constant force of about 15 pounds, pushing a skateboard & rider along a smooth floor. For each Case we will use a different color of **MARKER/CARDS**.

<u>1.</u> Choose a Start/Zero line on the floor. Students line up along either side of the skateboard's path, to observe and to help keep the beat by clapping every 3 seconds (practice first)

<u>2.</u> A student will sit comfortably on the skateboard, holding several beanbags, and will need to start out by *holding on to the floor to keep from rolling. . .* while . . .

<u>3.</u> Another student will be gently applying a *constant* force to rider's back.

<u>4.</u> Rider will resist moving until he or she chooses a starting BEAT to "let go" on, dropping the first MARKER.

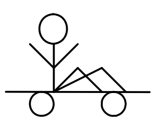
<u>5.</u> Rider will slap down a MARKER/Card on the floor next to the skateboard for this first and then for each successive 3 second BEAT.

<u>6.</u> Measure the distance traveled in each of three equal successive time intervals, for CASE 1 and CASE 2.

<u>7.</u> Record all three distance measurements for both cases in the DATA TABLE.

<u>8.</u> Calculate speed for each interval for each case (distance divided by time)…record in **TABLE**

Test 1 – Data Table

	CASE 1 – smaller force			CASE 2 – bigger force		
	Interval 1	Interval 2	Interval 3	Interval 1	Interval 2	Interval 3
Distance (cm.)						
Time interval (seconds)	3	3	3	3	3	3
Speed = <u>Distance</u> / Time (cm/sec)						

COMPARE SPEEDS OVER THREE INTERVALS… within each CASE. What happened?
________________________________<u>speeds up</u>____

COMPARE CHANGE IN SPEED (Last SPEED minus ZEROo initial speed)… between CASES.
What happened? ___________<u>bigger mass speeds up less</u>_________________________
Does this result verify the motion/"size of force" dependencies in Newton's Second Law?_<u>YES</u>_

Test 2 – Vary the Mass

We will perform the following process twice,
-1st for CASE 3 with a constant force, and
-2nd for CASE 4 with the same constant force but a bigger mass. . .
both involve pushing a skateboard & rider along a smooth floor. CASE 4 will differ from CASE 3 by having an additional amount of MASS (rider plus bowling ball).

As before, we will use a different beanbag markers, leaving the markers on the floor for later measuring.

May describe steps 1-8 as outlined on student page

Let's DO the skateboard activity now…
Teacher and students complete the activity,

As we look at the MARKERS on the floor, we again see evidence of speeding up from a constant applied force in both cases.

but also we can notice a difference in the pattern (it gets stretched to longer distances when the mass is smaller!). Let's measure the distances, record them in our Data Table, use them to calculate speeds, and then analyze the results.

Measure… and fill in data table which includes speeds during 3 intervals for each case)

Do our results in **agreement with Newton's 2nd Law, which** states that a bigger mass will cause a smaller change in the speed in response to a force? **YES!**

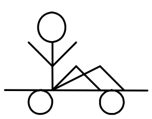
Test 2 – Vary the Mass

Again we will push the skateboard & rider along the floor, and this time we will perform the same process of MARKING positions at equal time intervals for two NEW cases, **CASE 3** and **CASE 4**.

CASE 3 will involve a particular rider, and **CASE 4** will involve the same rider carrying a bowling ball. For each Case we will use a different color of **MARKER/CARDS.**

1. Choose a Start/Zero line on the floor. Students line up along either side of the skateboard's path, to observe and to help keep the beat by clapping every 3 seconds (practice first).
2. A student will sit comfortably on the skateboard, holding the beanbag MARKERS, and will need to start out by *holding on to the floor to keep from rolling . . .* while . . .
3. Teacher or another student will be gently applying a *constant* force with a push scale on the back of the rider.
4. Rider will resist moving until they choose a starting BEAT to "let go" on, placing their first MARKER
5. Rider will slap down a MARKER/Card on the floor next to the skateboard for this first and then for each successive 3 second BEAT.
6. Measure distance traveled in each of three equal successive time intervals for **CASE 3** & **CASE 4**.
7. Record all 3 distance measurements for both cases in the DATA TABLE.
8. Calculate speed for each interval for each case (distance divided by time)…record in **TABLE**

Test 2 – Data Table

	CASE 3 - smaller mass			CASE 4 – bigger mass		
	Interval 1	Interval 2	Interval 3	Interval 1	Interval 2	Interval 3
Distance (cm.)						
Time interval ("seconds")	3	3	3	3	3	3
Speed = Distance / Time (cm/sec)						

COMPARE SPEEDS OVER THREE INTERVALS… within each CASE. What happened?
__________________________speeds up____________________________________

COMPARE CHANGE IN SPEED (Last SPEED minus ZERO initial speed)… between CASES.
What happened? ___________bigger mass speeds up less___________________________
Does this result verify the mass/motion dependencies in Newton's Second Law?_YES___

(Summary & Application ~10 min)

To **sum up** today's lessons, we have explored Newton's Second Law **more completely** in various situations. . . with fancarts, blue sailcarts, and with skateboard riders.

In all these situations we found out that

A NET FORCE causes **a change** in the speed of an object that is:

directly related to
the magnitude of the force, and

inversely related to the mass of the object, that is, as the mass increases
the more difficult it becomes to change the speed.

In other words…

More force --- more change
More mass --- less change

[DO **APPLICATION page]**

SUMMING UP:

NEWTON'S SECOND LAW

A **NET FORCE** causes **a change** in the speed of an object that is

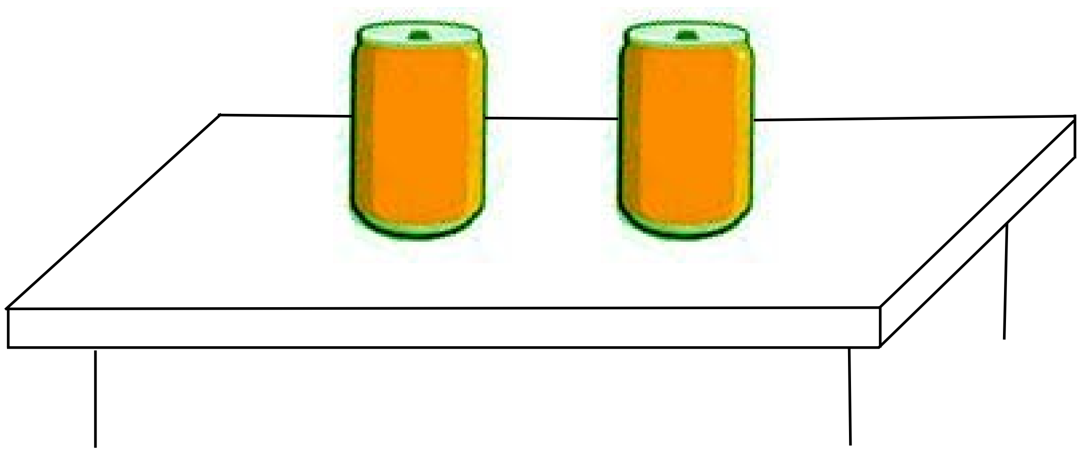
directly related to the **magnitude of the force**,

and

inversely related to the **mass of the object**,
that is, as the mass increases
the more difficult it becomes to change the speed.

APPLICATION -

Apply your knowledge of physics to determine if there is any difference between the two cans on the teacher's desk…***without*** lifting them up off of the desk.



What are you going to do… and why?

Try it out…

 # 7 Teacher Supplement
Reality Check! Putting it all together in real situations

Objectives and Resources

Lesson Objectives: Learners should be able to:

4.0 Real situations, friction, and unit consolidation

4.1 State that friction and air resistance acting on moving objects affect their motion, and apply to examples.

4.2 Explain that if frictional forces are exactly equal to the applied force on an object, it will move at constant speed (and vice versa), and apply to examples.

4.3 Identify the forces acting in various situations which include friction.

4.4 Apply concepts relating force and motion to real world contexts.

Lesson Resources:

Hoverpucks (2 per teacher)
Stomp rocket (1 per teacher)
Matchbox cars (1 per student)
Leaf Blowers (1 per class),
Beach balls (1 per teacher)
White boards
Hair driers, ping pong ball (1 per group, plus teacher's, plus spare balls)

COLOR CODING:

BLACK: general text (**BOLDED** for essential points)
BLUE: action notes for teachers
GREEN: student inputs - spoken, written, drawn (students may fill in as they go)
RED: outline topic and approximate timing

Lesson # 7 - ***[~ 75 min]***
(Review ~10 min)

Today, we will **put everything together** and enrich our understanding of force and motion by addressing **real world situations**.

So far we've covered the concept of **force as a push or a pull** on an object. We've also described force in terms of **magnitude, units, and direction**, and represented it in **force diagrams**.

We learned how to combine forces into a NET **FORCE**, and we have studied how **net force and motion** are related. We are familiar now with **Newton's 1st Law** regarding motion with **no net force**, and **Newton's 2nd Law** regarding motion **with a net force**. Yesterday, using fancarts and skateboards we explored Newton's 2nd Law and found out that

> A NET FORCE causes **a change** in the speed of an object that is **directly related** to the magnitude of the force, that is, as force increases the change in speed increases
>
> and
>
> **inversely related** to the mass of the object, that is, as the mass increases the smaller the change in speed in response to a force.

After the teacher's review, go over each of the five review questions.

Basically,
1st law says that with **no net force** the motion will **not change** and the **2nd law** says that **with a net force** the motion **will** change.

We need to look at the two laws together. For example,
1st law says that if there is **no change in motion,** there is **no net force** acting; and
2nd law says that if there is a **change in motion**, there **is a net force** acting!

So, from knowing the net force that acts upon an object, we can predict its motion, and from knowing the motion of an object we can make inferences about the net force that acts upon it.

7 – REALITY CHECK!

PUTTING IT ALL TOGETHER IN REAL SITUATIONS

REVIEW OF NEWTON'S LAWS

In accord with Newton's 1st & 2nd Laws, complete these sentences…

1) An object at rest with no net force on it will
_____________stay at rest ____

2) An object in motion with no net force on it will
___________stay in that motion____

3) An object at rest with a net force on it will
__________begin to move in the direction of the net force ____________________

4) An object in motion with a net force in the direction of its motion will
_____________________speed up____

5) An object in motion with a net force acting opposite the direction of its motion will
__________slow down____

(Review ~20 min – 2 pages)
While studying Newton's Laws we've tried to **simplify or "IDEALIZE"** situations by reducing friction… (using balls, low friction wheels, skateboard, hoverpucks, hovercraft).

But in the ***"REAL"*** **world**, though sometimes "hidden," **whenever objects are moving,** FRICTION must be considered just like any other force acting on an object. So let's look at the difference that friction makes in a couple of situations of moving objects.

Teacher demonstrates with 2 hoverpucks . . .
I have two hoverpucks and I will give each a brief force by flicking them with my finger. I will do this to get them moving — they are at rest and won't move unless I apply a force.

In CASE 1, the hoverpuck will be turned ON (it will have no friction), &
In CASE 2 the hoverpuck will be OFF (it will have a lot of friction).
(Do it…)

CASE 1

Let's draw the diagram for CASE 1 . . .
. . . record our observations, and relate them to Newton's Laws.

In CASE 1 the hoverpuck is moving with virtually ZERO net force acting on it; it tends to keep moving … obeying Newton's First Law. **NO NET FORCE - NO CHANGE IN MOTION**!

CASE 2

Let's draw the diagram for CASE 2. . .
. . . record our observations, and relate them to Newton's Laws.

In CASE 2, the hoverpuck is moving & it has a friction force acting, so there **IS** a net force acting against the motion, which causes it to slow down and stop… obeying Newton's 2nd Law. **NET FORCE - CHANGE IN MOTION**!

… ah, we've revealed that "hidden" force of friction that acts against motion!!

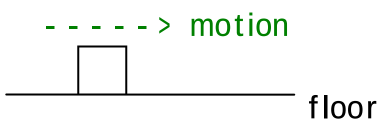
FROM IDEAL TO REAL

CONSIDERING FRICTION

Teacher Demonstrations :

CASE 1 – Hoverpuck **moving** on air cushion above floor
(almost no friction, no applied force)

Diagram:

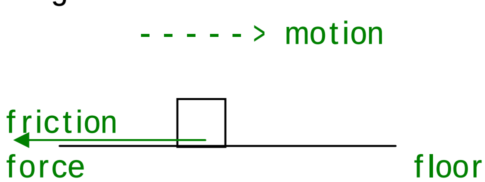


Observation:__continues moving in straight line, at constant speed___

Conclusion:__no net force? no change in motion - Newton's 1st Law

CASE 2 - Hoverpuck **moving** on floor
(no air cushion – plenty of **friction force**, no applied force)

Diagram:



Observation: ____slows down and stops.________________________

Conclusion:__net force! change in motion! Newton's 2nd Law________________

Now, we'll **keep a hoverpuck moving** across the floor/whiteboards with a **constant/ continuous** force, first in **CASE 3 with no friction**, and then in **CASE 4 with friction.**

CASE 3

In CASE 3, the hoverpuck is turned ON (it will move with **little friction**),
and we use a hair-blower to **apply a constant force** to the hoverpuck.
Let's draw a diagram for case 3, record observations & relate them to Newton's Laws.

In this case the hoverpuck has a net force pushing it in the direction of the motion. It speeds up, obeying Newton's 2^{nd} Law. **NET FORCE CHANGE IN MOTION**!

CASE 4

Our last case, Case 4, is a bit tricky. We are going to consider how **two** forces acting on an object relate to Newton's laws.

In **CASE 4**, the hoverpuck is turned OFF (there will be a **friction force** when moving)
and we push it with our hand (an **applied force**) at a **constant speed**

If there is an **applied force** causing an object to **speed up** in one direction, and at the same time, there is a **friction force** acting **against** the motion of the object, **slowing it down** . . . then, to find out the combined effect of the two forces (the **NET FORCE**!), we **subtract one force from the other**.

Whenever we **subtract two forces of different size,** we will end up with **a NET FORCE** in one direction or the other, acting on an object …. a simple case of Newton's 2^{nd} Law, in which the motion of an object **changes** (as in **CASE 2** and **CASE 3**).

In **CASE 4** we want **constant speed,** so we want NO CHANGE in the motion of our object. From Newton's 1^{st} Law, we know that to get NO CHANGE in motion, there must be ZERO NET FORCE (no net force!).

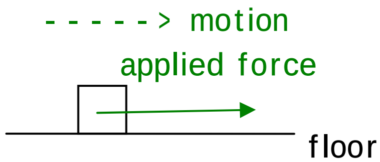
To get to ZERO NET FORCE when two forces are acting, as in CASE 4, the applied force and the friction force must be equal (they must be "balanced").

Let's draw a diagram for this last case, where the **applied force is exactly equal to the friction force**, so that we move the object/hoverpuck along at a constant speed.

Notice that CASE 4 (**balanced forces**) and CASE 1 (**no forces**) are the two possible ways to get **ZERO NET FORCE**, and obey **Newton's First Law**.

CASE 3 – Hoverpuck **moving** on air cushion above floor
(almost no friction, constant **applied force**)

Diagram:



Observation:__speeds up_________

Conclusion:__net force in direction of motion… CHANGE!   N's 2nd Law

Okay, now we'll need our
"HANDS ON"… and our
"MINDS ON" too ☺

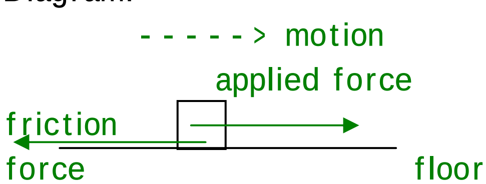
CASE 4 - Hoverpuck **moving** on floor
(no air cushion – plenty of **friction**, **apply force** to keep constant speed)

hmmm… constant speed?
no change in motion?
AHHHH! Newton's First Law!!!

There must be Zero Net Force!
The two forces must be balanced!

In this case, the applied force **must be equal** to the friction force . . . so this is actually a way to measure the force of friction!!!

Diagram:



(Application table ~ 25 min)

OUT FOR A DRIVE (1,2,3,4) create scenario with students

DRAG RACE (4a, 4b, 4c) create scenario with students

Let's now look at a **common real world example**, and discuss it in terms of **Newton's Laws of motion**. We'll use an object we see every single day … the "car". You each have a **model of a car** on your table to help you **simulate car behavior and think** about the relationship between the forces acting and the effects they have on motion.

In spite of the fact that the car is a very common and familiar object, the **system of forces** that act in and on a car is **very complicated**. As we've done before, we'll need to **simplify in order to clarify** our understanding of how force and motion relate.

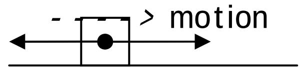
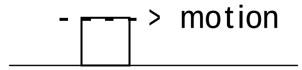
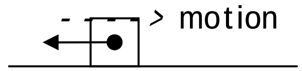
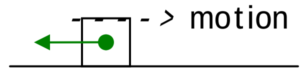
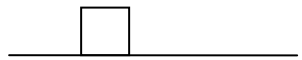
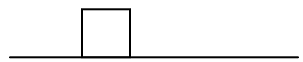
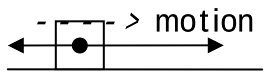
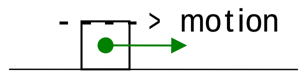
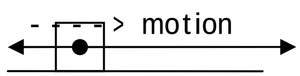
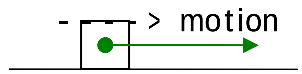
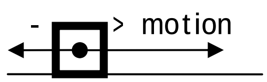
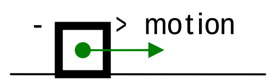
So, we'll consider there to be one **total forward force**, and/or one **total backward force**, and they may vary in magnitude. Another aspect of our cases is that there may or may not be motion.
me cases regarding the forces that may be acting on a car (big cars OR toy cars!). Yo
In your notebook you have **a TABLE** that **describes so**ur table also contains **force diagrams** for each case.

We will work each Case together asking these questions:

Is there a **Net Force** in the Net Force Diagram?
Does Newton's 1st or 2nd Law apply to this case?
What is the car's motion if any?

Teacher works with class to do all four cases.

Here we have seen a variety of aspects of Newton's laws of motion, and how they relate to common real world situations. Actually, Newton's laws relate to all kinds of motion, not just simple horizontal motions like we have been studying ... but to far more amazing ones.

Case	Description of Case	Force Diagram	Net Force Diagram	Newton's Law	Description of motion
1	A forward force and a backward force are equal (balanced)			No net force? Newton's 1st Law No change!	traveling at steady/constant speed
2	Backward force			Net force? Newton's 2nd Law Change!	slowing down (net force, opposite direction of motion!)
3	No horizontal forces acting			No net force? Newton's 1st Law No change!	sitting still
4a	Forward force that is greater than the backward force			Net force? Newton's 2st Law Change!	speeding up (net force, same direction as motion)
4b	Just like Case 4a, except **greater forward FORCE**			Bigger net force? Same mass? Newton's 2nd Law Bigger change!	speeds up more
4c	Forces just like Case 4a, except the object has **greater MASS**			Same net force? Bigger mass? Newton's 2nd Law Smaller change!	speeds up less

NEWTON'S LAWS APPLY IN THE REAL WORLD

A CAR ON A ROAD ... A MODEL ON YOUR TABLE

(Everyday to Amazing ~ 20 min)
With that in mind, let's look at a few situations with vertical motion... as we go **from the everyday to the amazing.**

(Teacher will then demonstrate and explain ... asking that one person in each group mimic the teacher's actions)
Get out a **ping pong ball** and a **hair-blower** from your bin.
I can hold this ping pong ball up in the air between my fingers (so can you!) ... it's **not moving at all, either horizontally or vertically.**

According to Newton's 1st law, because it is **not moving**, there must be a **zero net force** on the ball. There ***are*** forces acting on it, contact forces from my hand, and the force of gravity (at a distance), so those **forces must be balanced** for there to be a zero net force. In your notebook you'll find a picture of a ping pong ball. **Match it up with the force diagram** that corresponds to the situation.

Now we let go of **the ball. It falls**. Of course we're not surprised... but let's discuss this in terms of Newton's Laws. The hand no longer acts on the ball when it is no longer touching the ball, so there is only one force left acting on the ball, the **force of gravity.** This is a situation in which the **net force acts** in the direction of motion, causing the object to **speed up (downward)** (this is depicted in the top diagram).

Take that hair-blower and see if you can use it to **keep that ball up in the air**.

Point out that the **diagram f**or this situation would be just like the one for the hand holding the ball up.

Ok this is just tiny ball... like before when we played with a tiny car... but that tiny car was representing a big car. We can change the **SCALE** of this ping pong experiment too. [take out the beach ball first, and then... whip out the leaf blower !! Demonstrate the big ball floats with a big force]

Now, we've just looked at a couple of cases with a balance of vertical forces ... what if the **upward force was far greater than the force of gravity?** [Elicit the fact that it would speed up and rise into the air. (Get out the stomp rocket!!)]

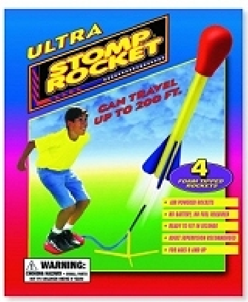
We will demonstrate this case. Here is an object that will shoot upward when we apply the force of a strong blast of air underneath it. [Demonstrate in a very slight way in the classroom and explain that...] This little rocket won't keep going up,

CHALLENGE PAGE

FROM THE EVERYDAY…
TO THE AMAZING

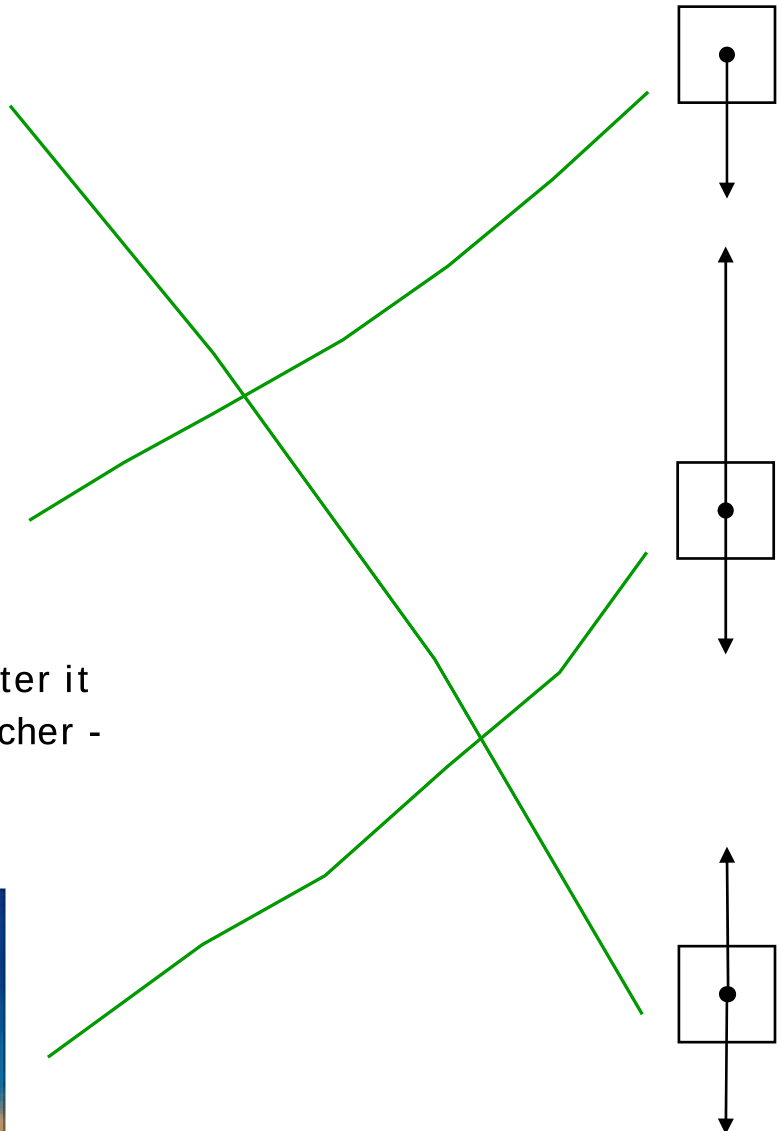
Draw a line to connect the left side to the corresponding vertical force diagram on the right

Ping pong ball holding still -



Stomp rocket after it has left the launcher -

Apollo 11 on its way to the moon -



because the upward force is brief and only acts for a short time at the beginning of the flight.

After leaving the launcher, there remains only the force of gravity, which pulls the stomp rocket downward. On your notebook page, **Match up the stomp rocket with the diagram** that describes the forces acting **after** it has left the launcher.

But still… the stomp rocket will go pretty high if you stomp really hard.

[Go outside to have students try the stomp rockets.]

Now, let's imagine… what if that upward force, greater than gravity, **kept acting** as the rocket rose? According to Newton's 2nd Law, we would have an upward net force, which would cause the object to continue to speed up! How far would it go?

Let's go back to thinking about **SCALE.** What does this "little rocket" bring to mind? How about a "big rocket"? Do you remember what we talked about on the first day of our lessons? That dynamics is the key to explaining and predicting and controlling how objects move, from ping pong balls . . . to objects like 100,000 pound rocket ships on their way to the moon and other planets. I'll bet you can tell which force diagram matches up with the rocket blasting off.

There you have it. **Newton's laws of motion** apply just the same, from the ping pong ball, to the rocket ship on its way to the moon, and even to the moon itself.

Dynamics will take you anywhere you need to go!