Unit 5 Notes – Physics I – Textbook Chapter 4

Force & Newton's Laws of motion

Galileo mathematically described "how" things move with his "kinematics formulas" which we studied in Units 2, 3, and 4. But "Galileo's kinematics" could not explain **WHY** things move and behave the way they do.

Newton's Laws of Motion make up what is called "Newtonian Mechanics" or "Newtonian Dynamics" and they describe **"why"** things move the way they do. This is what you learn in Unit 5 (Textbook ch 4.)

I. *All changes in motion are caused by an unbalanced or "net" force*

A. There are only three fundamental forces currently identified in nature. They are the:

1. **Electro-weak force** – includes all of the following interactions or forces:
   - the electromagnetic force between electrically charged (positive or negative) objects
   - the force between magnetic objects (with North and South Poles), and
   - the force present in the nucleus of atoms that controls radioactive decay.
2. **Nuclear Strong force** – the force that binds the parts of the atomic nucleus together
3. **Gravitational force** - the force present between all material objects (objects that have mass)

When you look at that list you might wonder why there are no everyday Newtonian "pushes or pulls" listed. The word fundamental is important and means "primary" or "most basic" in this case. An ordinary push or mechanical force is not a fundamental force. The reason for this is because a mechanical push or pull is **actually an electromagnetic force.**

B. We can still define a force in physics **very simplistically** as: a push or a pull on an object. Here are some other quick facts:

NOTE — ***forces do not always make things move - it takes a NET force to*** **CHANGE** ***an object's state of motion (it could make it start moving or stop moving or change direction.***

- **The SI Unit** of force is a **Newton (N) 1 Newton is** ***almost*** **the same weight as ¼ lb.**
- Many forces can easily be measured with a **spring scale** or other type of force sensor
- **Contact forces –** forces that are the result of physical contact between two objects
- **Field forces –** does not involve contact between objects; e.g., gravity, electrostatic, magnetic
- **Free-Body diagram or "force diagram" –** diagram depicting all the **forces** acting on a single object

II. Newton's Laws of Motion

You will need to know all of Newton's Laws by their number, name, and description and will need to recognize and describe examples of each law.

A. Newton's First Law – "Law of Inertia" **Net Force = zero!**

Object can remain still OR object could remain in CONSTANT velocity!

An object in motion will stay in constant motion and an object at rest will stay at rest unless acted upon by an **unbalanced** (or **net**) force. ***"Constant" motion is motion in a straight line at constant speed = constant velocity.*** The law of inertia says that objects with mass also have inertia and this property makes them tend to **maintain their current state of motion.**

"Inertia is a property of matter!!" quoted from Bill Nye the science guy!

Mass is a way of measuring inertia and measures the amount of matter in the object in grams or kilograms. Mass and inertia are fundamental properties of matter and do not change with a change in location.

Questions:

1. Which has greater mass - a kg of feathers or a kg of lead?
   Which of those two would weigh more on Earth?
   Which of those would have a greater volume?
   Which has more inertia?

2. What force keeps a cannonball moving once it has been shot from the cannon?

B. Newton's Second Law - "Law of Force and Acceleration"

When a net force is exerted on an object, the object will accelerate in the same direction as the net force. The amount of the acceleration will be directly proportional to the amount of the net force and will be inversely proportional to the amount of the objects mass.

The equation (in words) is: **Net Force = mass times acceleration**

The NET Force (in N) is equal to the object's mass (in kg) times the resulting acceleration in m/s^2

In symbols it is:

$$\Sigma \mathbf{F} = m\mathbf{a}$$

Weight is a measure of the force of **gravity** on an object. Weight, unlike mass, is not an inherent property of matter. Weight (N) is dependent on the force of gravity which varies with location. Mass (kg) is a property describing the amount of matter in an object which does not change with location.

$$g_e = G\frac{M_e}{R_e^2}$$

$$g_e = 9.8 \text{ m/s}^2$$

$$\mathbf{W} = mg$$

****Remember that - **<u>Weight</u> is a <u>force</u>** and that **<u>"g" is an Acceleration</u>**

Weight DOES change with location…smaller planets make the same amount of mass weigh less than it does here on Earth!

<u>So, the formula to calculate weight is just a special case of using F=ma because Wt=mg</u>

Example 1 -

What is the weight of a 2.50 kg mass on Earth?

Example 2 -

What net force is required to bring a 1500.0 kg truck to rest from a speed of 100.0 km/h (27.8 m/s) within a distance of 55.0 m?

Question: Why is the acceleration due to gravity the same for a heavy and a light ball?

C. Newton's Third Law – the law of action and reaction.

[$F_{1,2} = - F_{2,1}$] This is read as ….. Force on object 1 due to object 2 is equal and opposite to the Force on object 2 due to object 1. Often stated, "For every action there is an equal and opposite reaction."

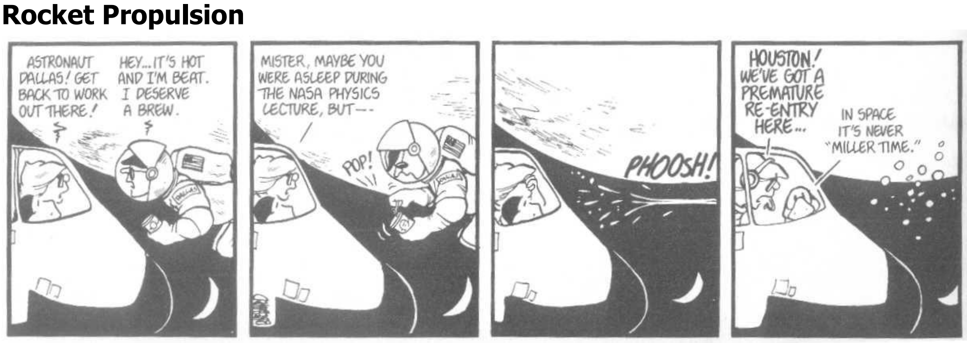
- Whenever an object exerts a force on a second object, the second object exerts an equal and opposite force on the first object. This interaction is simultaneous.

  For every action or force there is an equal and opposite reaction force. Another way to state Newton's third law is **"Forces always occur as pairs".**

  These "force pairs" **always act on different objects** and are always simultaneous! **- NO time delay!** If object "a" acts on object "b", then the reverse is also true…that object "b" also acts on object "a" with an equal force. If "A" forces "B", then "B" forces "A" equally. The forces are opposite and equal – **BUT *the resulting accelerations will depend on the masses of the objects involved as stated in Newton's Second Law.***

  A third way of saying the law of action and reaction is to say - "You can't touch without being touched".

Rocket Propulsion



Questions:

1. A rock falls to Earth. If the pull of the Earth on the rock is the action force, identify the reaction to this force. Is it:

   a. the force of air resistance acting on the rock, **b**. the pull of the rock on the earth?,
   c. the rock accelerating to earth?, or **d.** the force on the rock when it hits the earth?

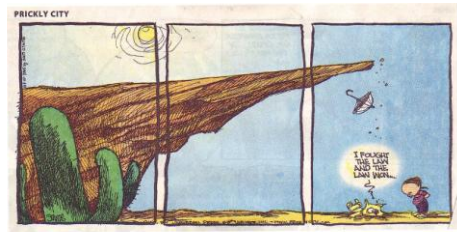
Which of the forces is greater?

2. Why does a gun recoil?

3. How can a rocket accelerate in outer space when the exhaust gases have no air to push against?

4. A bug is hit and splatters on a windshield. Which encounters the greater force the car or the bug?

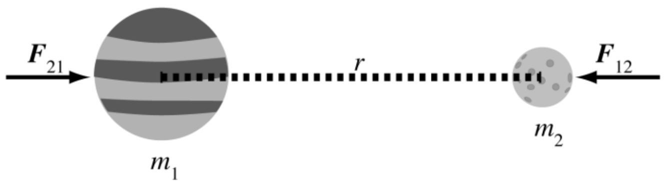
The greater acceleration?



Newton's Law of Universal Gravitation

- Every particle in the universe exerts an attractive force on every other particle. The magnitude of the force is proportional to the product of the two masses and inversely to the square of the distance between the two objects (inverse square law).

$$F = G\frac{m_1 m_2}{r^2}$$



<u>**Do worksheet on gravitation.**</u>

<u>III. Problem Solving and Working with Forces:</u>

There are a few important facts about forces to remember. **ALWAYS DRAW A "Force or Free Body" DIAGRAM**

1. They are vector quantities – THEY ALWAYS have a direction.

2. Forces always occur in pairs – **action/reaction pairs and act on different objects, but when drawing a free-body diagram we are only interested in the forces acting on the ONE object.**

3. All real-life objects on Earth have forces acting on them. The only time when an object can exist with virtually no forces acting on it – is when the object is FAR out in space away from any stars or planets. The object would be truly weightless - but still have the same mass as always.

4. The net force (sometimes called the resultant force) is found by adding together all of the forces acting on an object as vectors! Keep in mind the direction of the force may be negative or positive.

5. If the net force is zero, the object ***CAN <u>NOT</u>*** *be accelerating* … **BUT the object CAN** be moving with a <u>constant</u> velocity or remaining still.

6. If there is a net force of some amount, then there <u>**must**</u> be acceleration involved and that acceleration will be in the same direction as the net force. If there is acceleration, you must look for an unbalanced or net force!!

7. When analyzing a force problem, the first step is to identify all of the forces acting on an object and to draw a "free-body" or "force" diagram and label all the forces on the object.

Some common forces you will analyze on free-body diagrams:

1. **Weight (F_g or W) —** measure of force of gravity **(W=mg)**
   Weight, unlike mass, is not an inherent property of matter; weight is dependent on the force of gravity, which varies from location to location; mass is a measure of the quantity of matter

2. **Normal force (F_N) —** the one component of the force that a surface exerts on an object with which it is in contact; "normal" means perpendicular (usually thought of as perpendicular to the motion)

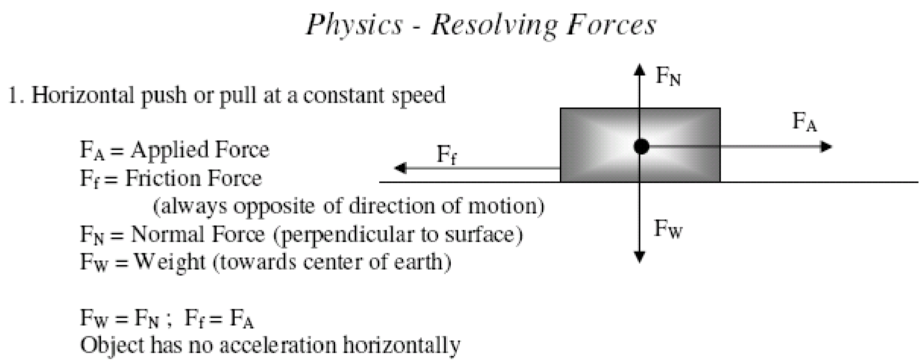
3. **Friction (F_f) – a** force that opposes the motion
   Static friction (F_s) — friction force that opposes the start of motion
   Kinetic friction (F_k) — friction force between surfaces in relative motion; less than static friction

4. **Tension – (T)** a force applied by a rope, cable, string, or chain.

Coefficient of friction (μ)—ratio of the frictional force to the normal force; μ is a constant that depends upon the nature of the surfaces in contact; the larger the value of **μ,** the "stickier" the two surfaces are to each other:

$$F_f = \mu F_N$$

Be sure you are able to and draw and label these forces on a free-body diagram.



Steps for solving challenging force problems

1. Draw a free-body diagram analyzing all forces on the object under analysis,
2. Determine whether or not the object is at equilibrium [$F_{net} = 0$ for equilibrium or $F_{net} = ma$ for accelerations]

Set up as many equations as necessary to solve for all unknown variables

Example 3 –

A 24.0 kg crate is moving at a constant velocity along a horizontal floor because of a 75.0 N horizontal force pushing it along.

a. How much is the force of friction acting on the crate as it moves?

b. Find the coefficient of kinetic or sliding friction between the crate and the floor.

Example 4–

A force of 200.0 N is required to slide a 325.0 N trunk on a level surface with a constant velocity. Calculate the coefficient of friction between the trunk and plane.

Example 5 – A 825 N cart is held on a horizontal frictionless track and is attached to a cord that goes over a frictionless pulley and to a 2.68 kg hanging mass (including hanger).

a. Draw a force diagram for the cart and the hanging mass individually while the cart is being held stationary.

b. Calculate the net force acting on the system of connected masses once they are released and allowed to move.

c. Calculate the acceleration of the system when released.

d. If you were to remove 1.50 kg from the hanging mass and place it on the cart, what would happen to the acceleration of the system? (increase? , decrease?, or remain the same?)

e. Would the mass of the system be changed? _______________

f. Would the net force acting on the system be changed? ______________

g. Calculate the value of the system's acceleration in this new situation.

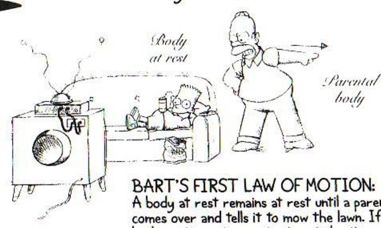
h. Identify the action reaction pairs acting on each object in this system.

i. If Newton was correct with his third law, and all of the forces acting on the system have equal and opposite forces identified…how can it accelerate at all?

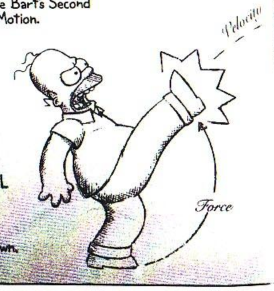
Ch. 4 HW problems Physics: Part 1: 7, 8, 9, 10 and 12. Part 2-3: 19, 20, 21, & 25. Part 4: 27, 33, 36, 37, 48, 50, & 52.

BART'S LAWS

We hold these truths to be self-evident.
Do not try to avoid these laws,
for they refuse to be avoided.



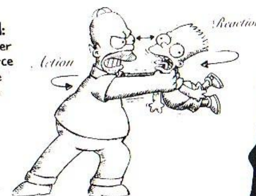
BART'S FIRST LAW OF MOTION:
A body at rest remains at rest until a parental body comes over and tells it to mow the lawn. If that body continues to remain at rest despite the urgings of the parental body, see Bart's Second Law of Motion.

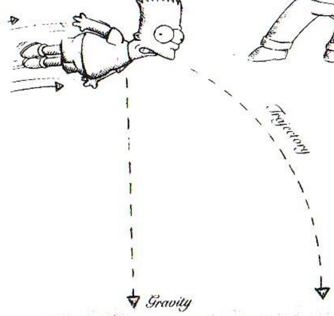


BART'S UNIVERSAL LAW OF MOTION:
What goes up must come down, man.

BART'S SECOND LAW OF MOTION:
The acceleration produced by an unbalanced force acting on a body is directly proportional to the mass of the force plus whether or not the force is carrying a weapon plus how loud the force is screaming.

BART'S THIRD LAW OF MOTION:
When one body exerts a force upon another body, the second body exerts an equal force upon the first body, and these forces are opposite in direction (i.e., for every action there is an equal and opposite reaction).





THE AGE OF BUFFOONERY

1471 Count Dracula born.

1492 Columbus gets lost and discovers America.

1559 Ice cream invented. Montezuma's Revenge — WHO'S LAUGHING NOW?

1586 Francis Bacon invents the salty breakfast treat named for him.

1630 The Three Musketeers invent the swashbuckle to hold up their pants.

AHRR!

1650 Pirates rule the seven seas.

1687 Newton invents gravity, so people don't have to tie themselves to their beds when they go to sleep at night.