<u>CHAPTER 2: NEWTON'S 1ST LAW OF MOTION-INERTIA 01/03/19</u>

HISTORY OF IDEAS ABOUT MOTION

- **Aristotle (384-322 BC)**
  - Natural Motion
    - An object will strive to get to its proper place determined by its "nature" or essence (earth, water, air, fire).
      - Clay naturally falls to earth, smoke naturally rises in air
        - DEMO: drop ball, light a match
      - Heavier objects fall faster (proportional to how much essence they have)
        - DEMO: drop ball, sheet of paper
    - Object rests when it is in its proper place
  - Violent Motion
    - Motion caused by pushing or pulling on an object (forces)
      - Pushing a cart, lifting a weight, wind in a sail, bow & arrow
        - DEMO: push book across table
  - Natural tendency of an object is to be at rest
    - An object in its proper place will not move unless acted on by a force.
    - Since Earth is in its proper place and a force to move it is inconceivable, the Earth is at rest.
- **Copernicus (1473-1543)**
  - Earth circling the sun is the simplest way to account for observations of the motion of sun, moon, and planets.
    - Doubted this idea because it did not make sense according to the accepted laws of motion.
- **Galileo (1564-1642)**
  - A force is required to change the motion of an object moving in a straight line.
    - Heavier objects do not fall faster.
      - DEMO: drop ball and crumpled sheet of paper
    - Friction causes things to slow down and stop.
      - DEMO: drop ball and paper in vacuum tube
      - Ball rolling on inclined and horizontal planes
        - DEMO: balls rolling down binder on carpet
  - Natural tendency of an object is to resist a change in motion. This property is called ***inertia***.
    - In the absence of any force, something moving keeps moving in a straight line.
    - DEMO: balls rolling down binder on tile
    - No force is needed to keep the Earth moving forward – full credence is given to Copernican motion.
    - DEMO: ball whirled on a string
- **Isaac Newton (1642-1727)**
  - Developed his famous laws of motion at age 23.

- **Newton's First Law of Motion**: *every object continues in its state of rest, or of uniform motion in a straight line, unless it is compelled to change that state by forces impressed upon it.*
    - DEMO: tablecloth and dishes
    - Known as the Law of Inertia, it is a refinement of Galileo's concept of inertia.
    - An object continues doing whatever it is doing unless a force acts on it.
        - DEMO: coins, markers, hoop, bottle

CHAPTER 2: NEWTON'S 1ST LAW OF MOTION-INERTIA 01/03/19

NET FORCE

- If more than one force is acting on an object, then we consider the combination of forces, known as the ***net force***.
    - How are multiple forces combined?
        - A force has magnitude and direction; any quantity that has magnitude and direction is called a ***vector***.
        - A vector sum takes the magnitude and direction of the forces into account when the forces are added together.
            - Vector sum: ΣF
            - DRAW: Fig 2.6 (applied and net forces on a block)

EQUILIBRIUM RULE

- If the net force on an object is zero, then it is in ***mechanical equilibrium*** (the net torque, or rotational component of force, must also be zero, but torque will wait until Chapter 8).
    - **Equilibrium Rule**: $\Sigma F = 0$
        - DEMO: weight on a spring
        - FIG: 2.14
        - DRAW: Practice Box, p. 31
- Other ways of stating Newton's 1st Law:
    - If the net force on an object is zero, then its velocity (speed and direction) doesn't change.
    - If an object is in mechanical equilibrium, then its velocity doesn't change.

SUPPORT FORCE

- What forces act on a book lying at rest (in equilibrium) on a table?
    - Weight, or force due to gravity
    - Upward support force exerted by the table
        - Equal in magnitude and opposite in direction to the weight because the net force must be zero.
- Compare to your hand compressing a spring; you exert a pushing force on the spring, and the compressed spring pushes back on your hand.
    - The weight of the book pushes down on the atoms in the table, and the compressed atoms push back up on the book.
        - The atoms' pushing is due to electric forces between atoms.
- Bathroom scale shows the support force necessary to balance your weight.
    - What happens when you stand on two scales, one foot on each?

EQUILIBRIUM OF MOVING THINGS

- An object moving at constant speed in a straight line is in equilibrium. Its motion is not *changing*, so the net force is zero.
- Friction force: Pushing an object across the floor
    - If we push it across the floor at constant speed, what is the balancing force to make the net force zero? Friction.

- If we push on the object and it doesn’t move, what is the balancing force? Friction.

MOVING EARTH

- When I jump in the air, why doesn’t the wall slam into me?
- DEMO: ball dropped as I walk – where will it hit?

CHAPTER 3: LINEAR MOTION 01/04/19

If I drive the 60 miles from Batesville, MS to Memphis, TN in 1hour, what is my velocity? What is my speed? What if I drive from Memphis to Batesville?

SPEED

- How fast something moves
  - Speed = distance/time
  - Units: miles/hr, km/hr, m/s, etc.
- Instantaneous speed vs. Average speed
  - Instantaneous speed: speed at a given instant
  - Average speed = total distance covered/total travel time
    - Batesville-Memphis speed?
  - Usain Bolt won the 100 m with a time of 9.58 s.
    - What is his average speed for the race? ~10.4 m/s
    - What is his instantaneous speed at the beginning of the race? 0 m/s
    - Is his top instantaneous speed in the race higher, lower or the same as 10.4 m/s? Higher

VELOCITY

- Velocity is speed plus direction, i.e. speed in a particular direction.
  - DEMO: walking at the same speed in different directions
- Constant speed vs. constant velocity
  - DEMO: release ball twirled on a string at different points in the path
- Batesville-Memphis/Memphis-Batesville velocities?
- Speed is a scalar quantity: magnitude (or amount) only
- Velocity is a vector quantity: magnitude and direction

ACCELERATION

- Acceleration is how quickly velocity changes (how quickly speed **and/or** direction changes!)
  - Acceleration = change of velocity/time interval
  - It is the time rate of change of velocity, not the total change in velocity.
  - Acceleration is a vector quantity.
- What three controls in am auto can cause acceleration?
  - Accelerator (gas pedal), brake, steering wheel
- DEMO: ball on a string
  - Twirled; Is it accelerating?
  - Released: Is it accelerating?
- Porsche Cayenne Turbo S
  - 0-60 mi/hr in 4 s (actually 3.8 but let's not quibble)
    - What is its speed at the end of 4 s? 60 mi/hr
    - What is its velocity at the end of 4 s? Not enough information
      - Pick forward direction on the track as positive: +60 mi/hr or 60 mi/hr in forward direction
    - What is its acceleration? +15 mi/hr·s or 15 mi/hr·s forward

- 60-0 mi/hr in 4 s (I just made this number up)
  - What is its speed at the end of 4 s? 0 mi/hr
  - What is its velocity at the end of 4 s? 0 mi/hr
  - What is its acceleration? -15 mi/hr·s or 15 mi/hr·s backward
- Turn the car around and go 0-60 mi/hr in 4 s
  - What is its acceleration? -15 mi/hr·s or 15 mi/hr·s backward
    - We already picked the first direction as forward, or positive

- Acceleration due to gravity, $g = 9.8\ m/s^2 \approx 10\ m/s^2$ downward
  - DEMO: drop ball
    - When is acc = 0? When is vel = 0?
  - DEMO: throw ball up in the air
    - When is acc = 0? When is vel = 0?
- Free fall: ball dropped off a cliff
  - Velocity after starting from rest with constant acceleration
    - Velocity = acceleration × time $v = at$
  - What is velocity at 1 s, 2 s, 3 s, 4 s, 5 s, 6 s, 7 s?
- Ball thrown in the air at 30 m/s
  - Velocity after starting with some initial velocity with constant acceleration
    - $v = v_0 + at$
  - What is velocity at 1 s, 2 s, 3 s, 4 s, 5 s, 6 s, 7 s (careful!)?
- How far something falls
  - Distance traveled from rest with constant acceleration
    - Distance = ½ acceleration × time × time $d = \frac{1}{2} at^2$
    - Derive this from d = average velocity × time
  - Dropped ball
    - What is distance at 1 s, 2 s, 3 s, 4 s, 5 s?

CHAPTER 4: NEWTON'S 2ND LAW OF MOTION 01/04/19

FORCE CAUSES ACCELERATION

- Acceleration is how fast velocity changes
- Acceleration is caused by a net force on an object
- Acceleration is directly proportional to the net force
  - Acceleration α net force
  - Double the force, double the acceleration; triple the force, triple the acc.
- DEMO: 1 student pushing a student in a chair vs. 2 students pushing the student

MASS AND WEIGHT

- Mass: the quantity of matter in an object
  - Measured in kilograms (kg)
  - The more mass, the more inertia or resistance to a change in motion
    - DEMO: competition to shake big mass and little mass
  - A fundamental quantity – it doesn't change from place to place
- Weight: the force upon an object due to gravity
  - Measure in Newtons (N), the unit of force
    - Define Newton, convert to pounds
  - Weight is directly proportional to mass
  - A non-fundamental quantity – it does change from place to place
    - Weight on the moon is 1/6 the weight on the Earth; weight in deep space is zero.
    - DEMO: lift objects to estimate weight
- DEMO: massive block hanging by a string

MASS RESISTS ACCELERATION

- The property of mass to resist changes in motion, or acceleration, is inertia
  - More mass, more inertia, less acceleration
- DEMO: 1 student pushing a light student in a chair vs. 1 student pushing more massive student
- Acceleration is inversely proportional to mass
  - Acceleration α 1/mass
  - Double the mass, half the acceleration; one third the mass, triple the acc.
- DEMO: sledgehammer steel block stacked on me while lying on a bed of nails
- DEMO: driving a nail on top of a student's head

NEWTON'S 2ND LAW OF MOTION

- Newton's 2nd Law: the acceleration of an object is directly proportional to the net force acting on the object, is in the direction of the net force, and is inversely proportional to the mass of the object.
- Acceleration α net force/mass
  - $a = F_{net}/m$
  - What about acceleration = change in velocity/time interval?
- Acceleration is always in the direction of the net force

CHAPTER 4: NEWTON'S 2ND LAW OF MOTION 01/07/19

FRICTION

- Draw forces on a block on a table. What is ΣF? a? (i.e. PRACTICE BOOK, p. 23)
    - At rest
    - Pulled, but not moving
    - Pulled at constant velocity
    - Pulled, with acceleration
    - DEMO: pull a block with a spring scale in each case above
- Friction acts any time two surfaces slide or tend to slide over one another.
    - Caused by irregularities (can be microscopic) on the surface
    - Direction of friction force is always in the direction opposing motion
- Static friction is a little larger than sliding friction
    - This is why jamming your brakes and locking the tires (so that the tires slide) gives worse braking performance than a steady rolling stop (such that the tires always have static friction with the road).
- The force of friction
    - Depends on the kinds of material in contact and how much they are pressing together (e.g. weight).
    - For solids, does not depend on speed or area of contact.
        - For fluids (water, air), speed and area are important: a big, fast airplane/boat pushes aside more air/water than small, slow ones.
    - DEMO: show with spring scale

FALLING OBJECTS

- **Free fall**: When gravity is the only force acting on an object (no friction or air resistance), the object is in free fall.
    - a = F/m, or g = W/m
        - a = acceleration, F = force, g = acc. Due to gravity, W = weight
    - Double the mass of a falling object and you also double its weight
        - g = W/m → g = 2W/2m = W/m
        - Twice the gravitational force that produces acceleration is exerted on twice the inertia (mass) that resists acceleration.
        - Acceleration due to gravity is independent of mass.
        - DEMO: dropping steel ball and ping pong ball from standing, then from ladder
- **Non-free fall**: If air resistance acts on a falling object, then it is in non-free fall.
    - Must keep in mind the idea of net force
        - Draw the forces on an object falling in air.
            - $a = F_{net}/m = (mg-R)/m$, where R is air resistance
            - R increases with the frontal area and speed of an object.
        - DEMO: dropped paper
            - Sheet vs. a ball
            - Crumpled sheet vs. a ball
            - Sheet beneath book
            - CHECK QUESTION: Sheet on top of book

- When does a falling object stop accelerating?
  - When weight = air resistance, i.e. when the object is falling fast enough that the air resistance is as large as the weight. This is called reaching ***terminal velocity***.
  - PRACTICE BOOK: page 24.

CHAPTER 5: NEWTON'S 3RD LAW OF MOTION 01/07/19

FORCES AND INTERACTIONS

- Change our thinking about forces: instead of thinking of a force as a *push or pull on* another object, think of a force as an *interaction between* objects.
    - You can't touch without being touched.
        - Push on your neighbor's hand
        - Push your fingers together
        - Push your fingers on your desk
    - When there is an interaction between two things, the interaction requires a pair of forces of equal magnitude and opposite direction.
        - Push balloon against table
        - Earth and Moon
            - Rubber band between two fingers
        - NY-LA analogy

NEWTON'S 3RD LAW OF MOTION

- **Whenever one objects exerts a force on another object, the second object exerts an equal and opposite force on the first.**
    - To every action there is an equal and opposite reaction.
- Forces come in pairs: action and reaction, which together make an interaction.
    - CHECK QUESTION: Identify action and reaction forces for:
        - Hammering a nail
        - Hitting a baseball
        - Walking on the ground
        - Dropped ball
        - Rocket (DEMO: released balloon)
    - DEMO: guys vs. girls tug-of-war
        - What are all of the force pairs?

DEFINING YOUR SYSTEM

- Don't action and reaction forces cancel each other out to produce a net force of zero?
    - No, because the action and reaction forces are on different objects, or *systems*.
    - Orange and apple example
        - Orange system
        - Orange and apple system
        - Orange and apple system on the floor
    - Pushing a dead car example: car is the system
        - Inside pushing on the dashboard
        - Outside pushing, on road or ice

ACTION AND REACTION ON DIFFERENT MASSES

- Earth and dropped ball
- Rifle and bullet