Chapter 02: Motion

Information about the mass of an object and the forces acting on it will enable you to predict if it is going to move up, down, or drift horizontally. This chapter is about such relationships among force, mass, and changes in motion.

Section 2.1: Describing Motion

Things Move...How Do You Know?

- It was right there yesterday...today, it's all the way over here
- What are the important parameters? Time and place
- How are they related? Change in place occurs during some interval of time

It's All Relative

- Relative means "with respect to"
- Displacement: change in location compared to something specific
- Point of reference might be at rest or also in motion

Section 2.2: Measuring Motion

Speed

- How fast = distance divided by time: $v = \frac{d}{t}$
- Ratio! $\frac{d}{t}$ compares how far and how long
- Time in denominator means "rate of change"

Average Speed

- An object might travel at a constant speed for the entire time
- $v = \frac{d}{t}$ ignores any speeding up or slowing down (or even stopping)
- When you say "distance = rate x time," you are assuming either constant speed or average speed

Velocity

- This really is different than speed! $v = \frac{\Delta x}{\Delta t}$ (The equation tells you!)
- Vector velocity has two parts: magnitude and direction
- Speed is the magnitude (how fast)
- To be complete you also must specify which direction the motion

Acceleration

- Also a vector, also a rate of change: $a = \frac{\Delta v}{\Delta t}$
- Positive acceleration: speeding up
- Negative acceleration: slowing down

Change In Direction = Acceleration

- Object with constant speed can still be accelerating!
- Constant velocity means both speed and direction remain constant
- Change direction means new velocity vector–which means acceleration

Forces

- Another vector! Yay for vectors!
- Magnitude: How hard are you pushing (or pulling)?
- Direction: Which way are you pushing (or pulling)?

Adding Forces

- Pretty common for an object to experience more than one force at the same time
- Whether you are sitting or standing, right now you are experiencing at least two separate forces
- Vector addition gets math-y, but stay in a straight line: a push right is (+) and a pull left is (–)

Fundamental Forces

- Gravity: Exists because of mass; all masses pull on all other masses
- Electrostatic: Exists because of charge; all charges either push or pull all other charges
- Strong: Exists between particles in atomic nuclei, pulling them together

- Weak: Actually related to electrostatic, responsible for nuclear decay

Section 2.3: Horizontal Motion on Land

Aristotle: So Wrong About So Much

- Frequently called the Father of the Scientific Method because of his insistence on explanations supported by observations
- Unfortunately, living 2300 or so years ago limited his ability to observe many things
- Incorrectly concluded that an object will only remain in motion if constantly subjective to some motive force

Galileo: Not Just All About the Telescopes

- Also made very important contributions to kinematics
- Used experimentation to get --> <-- this close to Newton's laws of motion
- Correctly concluded that force was necessary to *change* motion (subtle, but super-important distinction)

Section 2.4: Falling Objects

There Goes Galileo, Dropping Things Off Towers Again...

- Demonstrated that the speed of a falling object doesn't depend on its weight
- Yes, but...yes, there's a lot more to it, but start with round balls of the same size/different weight
- If you measure your distances and times carefully, you can actually develop a working definition of acceleration
- He was able to measure the acceleration due to the earth's gravity (note that metric system did not exist yet, so no, he did not come up with 9.8 m/s^2)

Section 2.6: Three Laws of Motion

Newton's First Law

- "Every object retains its state of rest or its state of uniform straight-line motion unless acted upon by an unbalanced force."
- Inertia Law: inertia is an object's tendency to keep doing whatever it's doing
- An object's mass is a measure of its inertia: more mass = more resistance to change

Newton's Second Law

- $F = ma$: If you push it, it goes. (push = F, it = m, goes = a)
- Or: the harder you push an object, the more you change the motion (speeding up or slowing down)
- Or: the more massive an object, the more force needed to move it

Weight and Mass

- Not the same thing! $w = mg$
- Mass m = amount of matter, measured in kg
- Weight w = force on object due to gravity, measured in Newtons
- Constant g = Earth's gravity, or acceleration due to Earth's mass

Newton's Third Law

- "Whenever two objects interact, the force exerted on one object is equal in size and opposite in direction to the force exerted on the other object."
- Forces must *always* exist in pairs! This is a very profound idea.
- For every action, equal/opposite reaction

Section 2.7: Momentum

Momentum Is A Vector

- $p = mv$
- Magnitude = mass x speed
- Direction = same direction as velocity vector, direction of motion

Conservation of Momentum

- "The total momentum of a group of interacting objects remains the same in the absence of external forces."
- System momentum is conserved: objects might swap (A gains, B loses), but total will not increase or decrease
- Why is this important? Because it lets us look at collisions! Also, the whole Newton #3 thing.

Impulse-Momentum Theorem

- $F\Delta t = m\Delta v$, or $mv_i + F\Delta t = mv_f$
- mv_i: An object exists, and it has some state of motion
- $F\Delta t$: Something happens the the object; it interacts with ?????
- mv_f: As a result, the object now has a new state of motion

Section 2.9: Newton's Law of Gravitation

The Force of Gravity

- $F = G\frac{(m_1 m_2)}{r^2}$
- Force is always attractive; mass pulls mass, never pushes it away
- Directly proportional to mass: 2x the mass, 2x the force
- Inverse-square of distance: 2x the distance, ¼ the force

Big G, Little g

- $G = 6.67 \times 10^{-11} \frac{\mathrm{N \cdot m^2}}{\mathrm{kg^2}}$ = universal constant
- $g = 9.81 \frac{\mathrm{m}}{\mathrm{s^2}}$ = specific to Earth
- Moon: $g = 1.62 \frac{\mathrm{m}}{\mathrm{s^2}}$
- Mars: $g = 3.71 \frac{\mathrm{m}}{\mathrm{s^2}}$

Earth Satellites

- Newton's thought experiment: shoot a cannon ball horizontally, faster and faster, until...until what?
- Until you reach the point where it doesn't fall back to Earth...wait, what? It's *falling*, but it's *not* getting any closer to the Earth?
- Action-at-a-distance: The cannon ball does not need to be touching the Earth to feel its pull

Weightlessness

- *Apparent* weightlessness: gravity never gets switched off
- Free-fall produces the sensation of weightlessness, but objects are not truly free from the force of gravity