Chapter 4

Motion, Force, Energy, Gravity (physics-stuff)
Greek Ideas

• Deductive Reasoning
• Start with the obvious
• What happens if I drop a bowling ball and a basketball
Aristotle:

- Obviously the bowling ball will fall faster and hit the ground first.
- Aristotle’s Laws of motion:
  - Natural Motions
  - Objects seek their place (fire, rock)
  - Violent Motions
  - Heavenly motions were different
Example

- What happens when you stop pushing a cart?
- It stops

Aristotle: No force means no motion
According to Aristotle, why would a ball stop after you kick it?

1. There is a force slowing it down
2. That is what balls do
3. There is no force to keep it going
Apply a constant force to an object, what happens?

1. It continually speeds up
2. It moves at a constant speed
3. It depends on which is greater, the force or the mass
Enter Galileo

- Perhaps the first to challenge Aristotle’s assumption
- Does a heavier ball fall faster?
- What about a rock and a feather?
- What about a pebble and a pillow?
Galileo’s Experiments

- Changed: angle, mass, length
- Idealized - what happens as the track gets lower?
- track slows things down
Galileo’s Results

• Things speed up as they fall (roll)
• Distance goes as time squared
• Does not depend on mass
• No force means it keeps going
Why was Aristotle Wrong?

- Ideas made sense (2000 years)
- No experiments
- Difficult to imagine no air resistance and no friction
Now, for something completely different
(but not really)

• Position (think $x = \ldots$)
• Speed
  \[ \text{speed} = \frac{\text{distance}}{\text{time}} \]
• Velocity
  \[ \text{velocity} = \frac{\Delta \text{position}}{\text{time}} \]
• Acceleration
  \[ \text{acceleration} = \frac{\Delta \text{velocity}}{\text{time}} \]
Change in position (has direction)

Position 1  Position 2

Velocity
Acceleration (change in velocity)

- Also has direction
- Velocity can change in magnitude
- or direction
- NOT velocity
\[ \Delta t = 1 \text{second} \quad \text{acceleration} = \frac{\Delta v}{\Delta t} \]

\[ a = \frac{0 \text{ m/s} - 10 \text{ m/s}}{1 \text{ sec}} = -10 \frac{\text{m}}{\text{sec}^2} \]

\[ a = \frac{-10 \text{ m/s} - 0 \text{ m/s}}{1 \text{ sec}} = -10 \frac{\text{m}}{\text{sec}^2} \]

\[ a = \frac{10 \text{ m/s} - 20 \text{ m/s}}{1 \text{ sec}} = -10 \frac{\text{m}}{\text{sec}^2} \]

\[ a = \frac{-20 \text{ m/s} - (-10) \text{ m/s}}{1 \text{ sec}} = -10 \frac{\text{m}}{\text{sec}^2} \]
Momentum

- Momentum = mass*velocity
- Has direction
Changing momentum

- Change speed
- Change direction of momentum
Enter the Newton

• Force is an interaction BETWEEN two objects
• Forces change momentum
• Change is the key word
• Net Force

\[ \vec{F} = \frac{\Delta \vec{p}}{\Delta t} \]
Forces (Newton’s 3rd)

- “For every FORCE there is an equal and opposite FORCE”
- Forces come in pairs
- Forces are an interaction between TWO objects
What do you have to do to make an object move at a constant velocity

1. Apply a constant force
2. Apply a force equal to its mass
3. Apply no force
Kinds of Forces

- Gravity
- Electromagnetic
- Weak Nuclear
- Strong Nuclear
Common Wrong Ideas about Force

• Force is a property of an object (moves with a lot of force)
• No force means no motion
• No motion means no force
• Basically the idea that force is like motion (NOT TRUE)
Could you make this move?
can you shake it back and forth?
A bug collides with a bus, which exerts a greater force?

1. The bus
2. The bug
3. They exert the same forces
4. No force is exerted, the bug just gets squashed
Circular Motion

Momentum

Force
Gravity

- Newton’s Universal Gravity
- $G = \text{constant}$
- $r$ is the distance between centers

$$F_{\text{gravity}} = G \frac{m_1 m_2}{r^2}$$
Cavendish

- Determined $G$

\[ G = 6.67 \times 10^{-11} \text{ N m}^2 \text{ kg}^{-2} \]
Weightlessness and Apparent Weight
Quick Calculation

- Astronaut mass = 70 kg
- Orbit distance = 360 km above surface

\[ F_{\text{gravity}} = G \frac{m_{\text{person}} M_{\text{Earth}}}{r^2} \]

\[ F_{\text{surface}} = (6.67 \times 10^{-11}) \frac{(70 \text{ kg})(6 \times 10^{24} \text{ kg})}{(6.3 \times 10^6 \text{ m})^2} = 706 \text{ N} = 160 \text{ lbs} \]

\[ F_{\text{orbit}} = (6.67 \times 10^{-11}) \frac{(70 \text{ kg})(6 \times 10^{24} \text{ kg})}{(6.3 \times 10^6 \text{ m} + 0.36 \times 10^6 \text{ m})^2} = 632 \text{ N} = 142 \text{ lbs} \]
A human model

- Standing stationary in elevator

“I feel fine”
Elevator accelerating up

"I feel heavy"
Accelerating Down

“I feel light”
Accelerating Down
In space, far far away from other masses

- no gravitational force
- Floor accelerating
Vomit Comet
You are standing on the Earth. Which is a greater force, the Earth pulling on you or you pulling on the Earth?

1. The Earth
2. You
3. They are the same
4. There is no force, you are just standing on the Earth
For the following, is there a net force on the object?

A car coming to a stop?

1. Yes
2. No
A bus speeding up?

1. Yes
2. No
An elevator moving up at a constant speed.

1. Yes
2. No
A bicycle going around a curve?

1. Yes
2. No
A moon orbiting Jupiter

1. Yes
2. No
On the moon,

1. Your weight is the same, your mass is less
2. Your weight is less, your mass is the same
3. Your weight is more, your mass is the same
4. Your weight is more, your mass is less
Which is true?

1. You can have acceleration not equal to zero, but velocity equal to zero
2. You can have acceleration equal to zero, but velocity not equal to zero
3. You can accelerate without changing your speed
4. 1 and 2
5. 1, 2, 3