Chapter 1

- How science is done.
- Experience and reason
- Theory should describe the physical world.
- Often required to accept unusual ideas in order to explain experiments.
- Examples of geocentric theories replaced by heliocentric based on
  - Fit to more accurate experimental data.
  - Unwieldy nature of heliocentric theories.

Chapter 3: Post-Aristotle

- Inertia:
  A body subject to no external forces will
  - Stay at rest if it began at rest
  - Will continue motion in straight line at unchanging speed if it began in motion.
- Can explain how moon keeps orbiting around earth, etc.
- But need details to quantify this

Chapter 3: more definitions

Average speed = \frac{\text{distance traveled}}{\text{traveling time}}

As an equation:
\begin{align*}
\text{Distance traveled} &= d \\
\text{Traveling time} &= t \\
\text{Average speed} &= s
\end{align*}

\[ \mathbf{s} = \frac{\mathbf{d}}{\mathbf{t}} \]

Acceleration is the rate at which velocity changes:
\[ \mathbf{\text{Acceleration}} = \frac{\text{change in velocity}}{\text{time to make the change}} \]

Instantaneous speed and accel = average values over short time interval.

Example of falling ball

\begin{align*}
\text{speed} &= \frac{2.6m - 2.0m}{0.73s - 0.68s} = 6.5m/s \\
\text{speed} &= \frac{1.2m - 0.8m}{0.488s - 0.40s} = 4.5m/s \\
\text{speed} &= \frac{0.6m - 0.2m}{0.275s - 0.18s} = 2.1m/s
\end{align*}

Falling ball: constant accel.

- Instantaneous speed increases proportionally to time for falling ball
- \( s = at \)
- \( a = 9.81 \text{ m/s}^2 \) = acceleration of gravity

For constant accel:
\[ \mathbf{d} = \frac{1}{2} \mathbf{at}^2 \]

On-line review questions for chapters 3-6 at uw.physics.wisc.edu/~rzchowski/phy107
Question

A car has a constant acceleration of 10 km/hr/s. How long will it take to accelerate to 100 km/hr?

- A. 5 seconds
- B. 10 seconds
- C. 12 seconds

Each second, the velocity increases by 10 km/hr. Starting from zero, it would take 10 seconds to reach 100 km/hr.

Chapter 4

- Principle of inertia:
  - object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.
- Defined mass m:
  - amount of inertia of a body
  - Measured in kg
- Define force F:
  - Something that changes a body’s acceleration
- Related force, mass, and acceleration:
  - \( F = ma \), or \( a = \frac{F}{m} \)
  - Subject to the same force, more massive objects accelerate more slowly.
- Weight:
  - Force of gravity on a body = \( mg \)
  - Measured in newtons (N). \( 1 \text{ N} = 1 \text{ kg-m/s}^2 \)

Question

A 1 kg object, weighing 10 N on Earth, is moved to outer space.

- A. It’s mass is zero and it’s weight is zero.
- B. It’s mass is 1 kg and it’s weight is zero.
- C. It’s mass is zero and it’s weight is 10 N.

Mass is an intrinsic characteristic of a body. The force of gravity on the body (weight) will depend on the other bodies around it.

Chapter 4: Newton

- Net Force = Mass \( \times \) Acceleration

\[
\text{Acceleration} = \frac{\text{Net Force}}{\text{Mass}} = \frac{F}{m}
\]

- Constant force gives constant accel:
  - Velocity increases with time.

Chap. 4: Law of force pairs

- Every force is an interaction between two objects
- Each of the bodies exerts a force on the other.
- The forces are equal and opposite
  - An action-reaction pair.

Question

Two people are on roller chairs, and quickly push off each other as hard as they can. They have masses of 100 kg and 50 kg. After the push, the 100 kg person is moving

- A. Twice as fast as the 50 kg person
- B. The same speed as the 50 kg person
- C. Half as fast as the 50 kg person

Equal and opposite forces, but \( a = \frac{F}{m} \), so the accel of 100 kg person is half that of 50 kg person. Accel is applied for same time, and \( v = at \)
Newton’s laws of motion

1) Every object continues in its state of rest, or uniform motion in a straight line, unless acted upon by a force.

2) The acceleration of a body along a direction is proportional to the total force along that direction, and inversely proportional to the mass of the body. 

\[ F = ma \] or, 
\[ a = \frac{F}{m} \]

3) The forces exerted between two interacting objects are equal in magnitude and opposite in direction.

Some equations

- Constant speed (no forces)
  \[ d = \text{velocity} \times \text{time}, \quad d = vt \]
  \[ v = \text{constant} \]

- Constant accel (constant force)
  \[ d = \frac{1}{2} \times (\text{accel}) \times (\text{time})^2, \quad d = \frac{1}{2} at^2 \]
  \[ v = at, \]
  \[ a = \text{constant} \]

Question

You measure the depth of a well by dropping a rock, and measuring the time until the splash. You measure 2 seconds. The well is...

A. 10 m
B. 20 m
C. 40 m

\[ d = \frac{1}{2} at^2 = \frac{1}{2} (10 \text{ m/s}^2) \times (2 \text{ s})^2 = 20 \text{ m} \]

Chapter 5

- Centripetal acceleration: body in circular orbit at constant speed has an acceleration directly inward.
  \[ \text{magnitude is } \frac{v^2}{r}, \quad r = \text{orbital radius} \]

- Gravitational force:
  \[ F = \frac{GM_1 M_2}{r^2} \]
  \[ r = \text{separation between centers} \]

- Free-fall
  \[ \text{Accelerating at acceleration of gravity} \]

Properties of gravity

- Gravitational force between two objects proportional to product of masses
- Gravitational force drops with the square of the distance between centers of objects.
Equation for force of gravity

\[ F_{\text{gravity}} \propto \frac{(\text{Mass of object 1}) \times (\text{Mass of object 2})}{\text{square of distance between them}} \]

For masses in kilograms, and distance in meters,

\[ F = 6.7 \times 10^{-11} \frac{m_1 \times m_2}{d^2} \]

Chaotic motion

- Chaotic systems:
  - Exactly follow Newton’s laws of motion (deterministic)
  - Sensitive dependence on initial conditions
  - Details of this dependence can show fractal (self-similar) behavior.
  - Can have periodic behavior when driven periodically (e.g. driven pendulum)
  - Driven systems go in and out of chaotic behavior depending on details of the drive.
  - Often show period doubling when approaching chaos

Sensitive to initial conditions

Periodically driven system

- Driven pendulum

Chap 6: Work, Energy, and Power

- Work = Force \times Distance
- Energy = an object’s ability to do work
- Kinetic energy of motion: \( E_{\text{kinetic}} = \frac{1}{2}mv^2 \)
- Work - energy relation:
  - Change in kinetic energy of a single object
  - = net work done on it by all forces.
- Potential energy
  - An additional form of energy
  - Can store energy in a system, to be extracted later.
- Conservation of energy:
  - energy is never lost, but just changes form.
- Power: How fast work is done.

Question

While you push on a car with a constant force of 10N it moves 1 m. After you let go, it rolls 9 m more before stopping. How much work did you do on the car?

A. 10 J
B. 50 J
C. 100 J

Work = (Force)\times(\text{Distance}). \text{ The distance is distance move with force applied.}
Question

You lift a 100 N weight over your head two times. The first time in one second, the second time in two seconds? How do the work and power compare?

A. Work same, power same
B. Work different, power same
C. Work same, power different

Work = \text{(Force)}\times\text{(Distance)}

Power = \text{work}/\text{time}