PowerPoint Lectures
to accompany
Physical Science, 8e

Chapter 2
Motion

Core Concept

A net force is required for any change in a state of motion.

New Symbols for this Chapter

- d-*distance*
- t-*time*
- Δ-*Greek letter delta Means change in*
- v-*Speed or Velocity*
- a-*Acceleration*
- F-*force*
- m-*mass*
- p-*momentum*

What is Motion?

Its description and explanation
with applications

Describing Motion

Three basic concepts

1. Position
2. Speed and velocity
3. Acceleration

Applications

- Horizontal motion on land
- Falling objects
- Compound (2-D) motion

Explaining Motion

Basic ideas

- Forces
- Inertia and mass
- Newton's laws

Applications

- Momentum and impulse
- Circular motion
- Newton's law of gravitation
- Earth satellites

Measuring Motion

Two fundamental components:

- Change in position
- Change in time

Three important combinations of length and time:

1. Speed
2. Velocity
3. Acceleration

Speed

- Change in position with respect to time
- Average speed - most common measurement
- Instantaneous speed - time interval approaches zero

$$speed = \frac{distance}{time}$$

$$\bar{v} = \frac{d}{t}$$

Example 1 (Parallel Exercise Group B #2)

1) What was the average speed in km/hr of a boat that moves 15.0 km across a lake in 45 min?

Velocity

- Describes speed (How fast is it going?) *and* direction (Where is it going?)
- Graphical representation of vectors: length = magnitude; arrowheads = direction

Acceleration

- Rate at which motion changes over time
- Speed can change
- Direction can change
- Both speed and direction can change
- Can be negative

$$a = \frac{v_f - v_i}{t}$$

Uniform Acceleration

- Constant, straight-line acceleration
- Average velocity simply related to initial and final velocities in this case

$$a = \frac{v_f - v_i}{t} \qquad \overline{v} = \frac{v_f + v_i}{2}$$

Example 2 (Parallel Exercise Group B #10)

2) What is the acceleration of a car that moves from a speed of 5.0 m/s to a speed 0f 15 m/s during a time of 6.0 s?

Forces - Historical Background

Aristotle

- Heavier objects fall faster
- Objects moving horizontally require continuously applied force
- Relied on thinking alone

Galileo and Newton

- All objects fall at the same rate
- No force required for uniform horizontal motion
- Reasoning based upon measurements

Aristotle on Motion

According to Aristotle every object in the world has an appointed place in nature.
The natural place for an object depended on which of the four elements (**Earth**, **Water**, **Air**, and **Fire**) the object was composed of.

Galileo on Motion

Galileo is the father of the scientific method and based all of his results on observation and experiment.

All Objects Accelerate at The Same Rate

Galileo found by repeated experiments that all objects accelerate at the same rate due to gravity

Being at Rest is Not the Only Natural State

Galileo also found that if there is no outside interactions acting on an object then the object will continue as it is either moving ant a constant speed or remaining at rest.

Force

- A push or pull capable of changing an object's state of motion
- Overall effect determined by the (vector) sum of all forces - the "net force" on the object

Fundamental Forces

Most basic of all interactions

1. Gravitational
   - Mass interactions
   - Motions of planets, stars, galaxies...
2. Electromagnetic
   - Charge interactions
   - Electricity and magnetism
   - Atoms and molecules, chemistry
3. Weak force
   - Involved in certain nuclear reactions
4. Strong force
   - Holds nuclei together

Horizontal Motion on Land

"Natural motion" question: Is a continuous force needed to keep an object moving?

- No, in the absence of unbalanced retarding forces.
- Inertia - measure of an object's tendency to resist changes in its motion (including rest).

Balanced and Unbalanced Forces

- Motion continues unchanged w/o unbalanced forces
- Retarding force decreases speed
- Boost increases speed
- Sideways force changes direction

Falling Objects

- Free fall - falling under influence of gravity w/o air resistance
- Distance proportional to time squared
- Speed increases linearly with time
- Trajectories exhibit up/down symmetries
- Acceleration same for all objects

$v = at$ $\quad$ $d = \frac{1}{2}at^2$

Example 3 (Parallel Exercise Group B #17)

3) An object is observed to fall from a bridge, striking the water below 2.5 s later.

a) With what velocity did it strike the water

b) What was its average velocity during the fall?

c) How high was the bridge?

Compound Motion

Three types of motion:

A. Vertical motion
B. Horizontal motion
C. Combination of A. and B.

Projectile motion

- An object thrown into the air Basic observations:
  - Gravity acts at all times.
  - Acceleration (g) is independent of the object's motion.

Projectile Motion

Vertical projectile

- Slows going up
- Stops at top
- Accelerates downward
- Force of gravity acts downward throughout

Horizontal projectiles

- Horizontal velocity remains the same (neglecting air resistance)
- Taken with vertical motion = curved path

Fired Horizontally vs. Dropped

- Vertical motions occur in parallel
- Arrow has an additional horizontal motion component
- They strike the ground at the same time!

Example: passing a football

- Only force = gravity (down)
- Vertical velocity decreases, stops and then increases
- Horizontal motion is uniform
- Combination of two motions = parabola

Three Laws of Motion

- First detailed by Newton (1564-1642 AD)
- Concurrently developed calculus and a law of gravitation
- Essential idea - forces

Newton's 1st Law of Motion

- "The law of inertia"
- Every object retains its state of rest or its state of uniform straight-line motion unless acted upon by an unbalanced force.
- Inertia resists any changes in motion.

Newton’s 2nd Law of Motion

- Forces cause accelerations
- Units = Newtons (N)
- Proportionality constant = mass
- More force, more acceleration
- More mass, less acceleration

$$F_{net} = ma$$

Examples - Newton’s 2nd

- More mass, less acceleration, again
- Focus on net force
  - Net force zero here
  - Air resistance + tire friction match applied force
  - Result: no acceleration; constant velocity

Weight and Mass

- Mass = quantitative measure of inertia; the amount of matter
- Weight = force of gravity acting on the mass
- Pounds and newtons measure of force
- Kilogram = measure of mass

Example 4 (Parallel Exercise Group B #24)

4) What is the weight of a 5.00 kg backpack?
b) What is the acceleration of the backpack if a net force of 10.0 N is applied?

Newton's 3rd Law of Motion

- Source of force - other objects
- 3rd law - relates forces between objects
- "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."

Momentum

- Important property closely related to Newton's 2nd law
- Includes effects of both motion (velocity) and inertia (mass)

$$p = mv$$

Conservation of Momentum

- The total momentum of a group of interacting objects remains the same in the absence of external forces.
- Applications: Collisions, analyzing action/reaction interactions

Example 5 (Parallel Exercise Group B #22)

5) A 30.0 kg shell is fried from a 2,000 kg cannon with a velocity of 500 m/s. What is the resulting velocity of the cannon?

Impulse

- A force acting on an object for some time (*t*)
- An impulse produces a change in momentum
- Applications: airbags, padding for elbows and knees, protective plastic barrels on highways

Forces and Circular Motion

- Circular motion = accelerated motion (direction changing)
- Centripetal acceleration present
- Centripetal force must be acting
- Centrifugal force - apparent outward tug as direction changes
- Centripetal force ends: motion = straight line

Newton's Law of Gravitation

- Attractive force between all masses
- Proportional to product of the masses
- Inversely proportional to separation distance squared
- Explains why $g=9.8m/s^2$
- Provides centripetal force for orbital motion

Earth Satellites

- Artificial satellites must travel more than 320 km above Earth
- Must travel at least 8 km/s to maintain orbit
- Example - GPS

Weightlessness

- Astronauts “appear” to be weightless but are still affected by weight; therefore can not be “weightless”
- Astronauts are actually in constant freefall.