Today:

Chapter 2: Laws Governing Motion
Why do things move the way they do?
- Newton’s laws of motion
  - One of the greatest intellectual achievements in history.
  - It may sound simple but it really isn’t.
  - Many great minds couldn’t get it right.

The material in the Supplement by Harrison contains material (beyond that in the book) which you are expected to know. (graphs and vectors)

Changing position x

Direction of change important
- Moving an eraser 1 meter is not enough information (demo)
- Need to also know the direction
- Moving a distance of 45 miles may or may not get you to Salt Lake
- Amount (size) of position change and its direction is a vector.
- Can represent a vector with an arrow.

Description of straight line Motion – Changing Position

- Pick the direction to your right as +, direction to left as -, and pick an origin.
- What is the resulting change in position (x) of the eraser? (vector, arrow) (demo)
- **P1:** Draw a graph, x vs t, of this eraser motion (1 meter) (transparency)
- **P2:** From origin (zero) go – then go back to zero. What is change of position for (a) half of the trip, (b) for all of the trip? Draw a graph, x vs t.

Description of Motion - Velocity

- Speed = (change in position)/time = (rate of change in position)
- Speed and direction is a vector, called velocity
- **P3:** Which has greater velocity? a vs b

What is direction of the velocity vector?

Common units are meters/sec or miles/hour

Combining Vectors

Example: Walking on moving sidewalk

- Person (1 mile/hour)
- Sidewalk (2 miles/hour)
- Combined motion (3 miles/hour)

Vector Procedure

Vectors can be drawn as arrows
- Size = length of arrow
- Direction = direction of arrow

Put the tail of one arrow on the head of the other.
The combined vector goes from tail of the first to the head of the second.
Combining Vectors

What if we walked in opposite direction on moving sidewalk?

Person (1 mile/hour)

Sidewalk (2 miles/hour)

Combined motion (1 mile/hour)

Description of Motion - acceleration

- Velocity can also change
  
  \[
  \text{Acceleration} = \frac{\text{Change in Velocity}}{\text{Change in Time}} = \frac{V_f - V_i}{\Delta t}
  \]

  = rate of change of velocity

- Common units are meters/sec/sec or miles/hour/sec.

- Acceleration is speeding up or slowing down and it is a vector

Vectors (cont.)

Acceleration changes velocity

1. Car speeds up
   
   \[
   \text{initial velocity} + \text{change of velocity} = \text{final velocity}
   \]

2. Car slows down
   
   \[
   \text{initial velocity} + \text{change of velocity} = \text{final velocity}
   \]

3. Car turns
   
   \[
   \text{initial velocity} + \text{change of velocity} = \text{final velocity}
   \]

Adding Vectors

\[
A + B
\]

Understanding Newton: some words to keep straight

- position

- velocity: change in position / change in time (e.g., miles/hour, m/s, ft/s) and direction

- acceleration: change in velocity / change in time

  (e.g. a car that can go from 0 to 60 mi/hr in 10 sec has acceleration of 6 mi/hr/sec)

Speed vs. Acceleration

Suppose a car is moving in a straight line to the right starting from rest. If it goes from zero to 60 mi/hr in 15 s, what is its acceleration? The table shows its speed and what the acceleration is:

<table>
<thead>
<tr>
<th>time</th>
<th>speed</th>
<th>acceleration</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 sec</td>
<td>0 mi/hr</td>
<td>4 mi/hr/sec</td>
</tr>
<tr>
<td>1 sec</td>
<td>4 mi/hr</td>
<td>4 mi/hr/sec</td>
</tr>
<tr>
<td>2 sec</td>
<td>8 mi/hr</td>
<td>4 mi/hr/sec</td>
</tr>
<tr>
<td>10 sec</td>
<td>40 mi/hr</td>
<td>4 mi/hr/sec</td>
</tr>
<tr>
<td>15 sec</td>
<td>60 mi/hr</td>
<td>4 mi/hr/sec</td>
</tr>
</tbody>
</table>
Acceleration

P4: Then going from zero to sixty in + direction, what direction is the acceleration?

(\(v vs t\))

Going 60 mph in the + direction and you put on the brakes.

What happens? (Hint: force=acceler.)

P5: What direction is the acceleration?

(\(v vs t\))

Going 60 mph in the + direction and you put on the brakes.

What happens? (Hint: force=accel.)

P6: What direction is the acceleration?

(\(v vs t\))

General rule:

if a is in same direction as v then speeds up

if a is in opposite direction to v then slows down

One can be zero while the other is not. (acceleration zero while velocity is not, velocity is zero while acceleration is not)

Acceleration (cont)

V>0, a<0   What is the object doing?

V<0, a<0   What is the object doing?

General rule:

if a is in same direction as v then speeds up

if a is in opposite direction to v then slows down

One can be zero while the other is not. (acceleration zero while velocity is not, velocity is zero while acceleration is not)

Example 1

P7: Example 1:

A car is traveling with a velocity of +25 m/s at \(t=0\). Two seconds later it has a velocity of +15 m/s. The average acceleration is:

- a) 5 m/s\(^2\)
- b) -5 m/s\(^2\)
- c) 20 m/s\(^2\)
- d) 0 m/s\(^2\)

Example 2

P8: Example 2:

A car is traveling with a velocity of -15 m/s at \(t=0\). Two seconds later it has a velocity of -25 m/s. The average acceleration is:

- a) 5 m/s\(^2\)
- b) -5 m/s\(^2\)
- c) 20 m/s\(^2\)
- d) 0 m/s\(^2\)

Plot \(v vs t\)?

Example 1:

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Plot \(v vs t\)?

Graph 3

Push an object across the table and back.

Graph \(v vs t\)?

Vectors

Vectors have

- Size
- Direction

Examples

- Velocity
- Acceleration
- Forces (pushes or pulls)

Expect a graph question on the exam!
The First Law of Motion

Q: How do objects move if they are left alone? What is the "natural" motion of free objects?

(Note: left alone and free means no interactions with any other objects, i.e. no forces)

Newton (1687): A body at rest tends to remain at rest; a body in motion tends to continue moving in a straight line – An object subject to no net force will either remain at rest or move with its original straight-line motion. (thrown rock is easy to explain)

Demo: air track with and without friction; whiplash, Goliath ball

Vocabulary of motion

UNIFORM MOTION - motion in which neither the speed nor the direction of the object changes

ACCELERATED MOTION - motion in which either the speed or the direction changes (or both)

Newton’s first law: uniform motion

unless acted on by a net force, an object will continue in uniform (natural) motion

<table>
<thead>
<tr>
<th>uniform motion</th>
<th>accelerated motion</th>
</tr>
</thead>
<tbody>
<tr>
<td>sliding ice skater</td>
<td>moon revolving</td>
</tr>
<tr>
<td>ball rolling on level</td>
<td>baseball player</td>
</tr>
<tr>
<td>surface</td>
<td>sliding to a stop at third base</td>
</tr>
<tr>
<td>rock sitting on the</td>
<td>falling apple</td>
</tr>
<tr>
<td>ground</td>
<td></td>
</tr>
</tbody>
</table>

Newton’s first law: uniform motion

Some more Demos-

Encyclopedia Physics #2

- Chapter 12 – car on track
- Chapter 15 – table cloth
- Chapter 16 – egg drop

Newton’s second law

net force causes an acceleration
acceleration is in the direction of the force
stronger forces cause more acceleration (for same mass)
larger mass results in less acceleration (for same mass)

Summary of Newton’s 2nd Law

acceleration = \( \frac{\text{net force}}{\text{mass}} \)

net force

the sum of all the forces acting on an object

- when several forces act on an object, each would produce its own acceleration independent of the others
- the resulting acceleration of the object is due to the net force, i.e. the vector sum of the independent forces
- Note: forces must be added as vectors
- If an object experiences no acceleration, no net forces are acting on it.

Net force is also called the “resultant force”
Newton’s Second Law: force causes acceleration

- A net (unbalanced) force can cause:
  - change of speed
  - change of direction
- Demo:
  - Small magnets
  - Car on airtrack with friction
  - Fan driven car on airtrack (2 speeds)
  - Ball moving in a circle, earth in its orbit
  - Balloon
  - VE disk 2, #24 – Extinguisher Wagon

True or False

P9: It is possible for an object to be moving in the absence, at that time, of any net force.

mass

- the amount of matter contained in an object (not its volume)
- a property of objects that determines how they respond to a force
- Combine two identical erasers, mass is now twice the mass
- different from weight
  - weight is a force that depends on gravity
  - objects in space still have mass
  - Toblerone bar weighing 2 lbs, here or on the moon
- measured in grams, kilograms, slugs

force

- a push or pull on one object by another
- anything that causes acceleration
- measured in newtons (pounds)
- examples
  - weight
  - friction
  - car crash

friction

- contact force
- retards motion of two surfaces relative to one another when they are in contact
- examples
  - tires on a road
  - boots on the ground
  - hands on a rope (grease it?)

a “normal” force

- the force on an object due to its contact force and
  - the force is perpendicular to the surface of contact (this is not the frictional force)
- caused by atomic electrical forces
Net force (on a windy day)

- Are there forces acting on the rock?
- Is there a net force on the rock?

Can have normal force, frictional force, and weight acting all at once.

skier example

What are the forces on the skier? (no friction)

Gravitational Force

Normal Force

Net Force

Some Key Ideas

- If you observe an object at rest or in uniform motion then:
  - The acceleration is 0.
  - There are no unbalanced forces.
- If you observe an acceleration then:
  - There is an unbalanced force.

NO EXCEPTIONS!!!!

Newton’s third law

- Forces come from interacting objects (objects cannot act on themselves)
- There are forces on both interacting objects

Third Law

The forces between interacting objects are equal in strength and opposite in direction

Demo:
  - push game with student
  - standing or walking on floor

Newton’s third law examples

- firing a gun on air track
- glider collision
- walking on ice
- bouncing a basketball
- Video Encyclopedia #2
  - Chapter 18 - gliders push against one another
  - Chapter 20 - car on rolling board
- making a car go

Moving Automobile

The action force of tires on road can be seen.
STOP!

Remember to read Chapter 3 before next class!