

Modeling Motion

The nature of motion appears to be the question with which we begin.


-- Socrates

Our universe is in a constant state of motion.





Motion is the most common "physical" event around us.

Motion has been studied by mankind for millennia.




Our modern understanding of motion did not begin until Galileo (1564-1642) first formulated the concepts of motion in mathematical terms (via experiments).





Our understanding climaxed for several centuries after Isaac Newton (1642-1727) & his newly developed Calculus put the concepts of motion on a firm and rigorous footing.



As we begin, we must clearly define what we mean by the term **motion**.

Motion – the change in an object's position with respect to time

NOTE: Position must always be stated with respect to some stationary object or reference point in order to be meaningful!

(Else, measurements of the same event would yield different results)

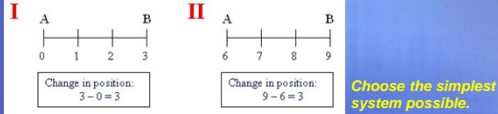
What would be some examples of a stationary reference point for a car traveling down the highway?

Consistent and accurate measurements require a "coordinate system".

Coordinate System – a artificial reference grid imposed on a system in order to make measurements

- Our Choice
- No Right or Wrong Way

Ex. An object changing position from A to B



Every measurement of motion requires a reference point **AND** a suitable coordinate system.

Reference Frame – a coordinate system that is considered stationary with respect to the object that is in motion.

Motion can be classified into 3 main categories.

1. Translational Motion
2. Rotational Motion
3. Periodic Motion

Translational Motion

- **Linear** (*straight-line or 1 dimensional motion*)



- **Projectile** (*arc'ed motion*)




NOTE: When discussing translational motion, scientists often use the term **TRAJECTORY** to represent the path an object moves along.

Rotational Motion

- Circular




- Non-Circular




Periodic Motion

- Oscillations




- Vibrations

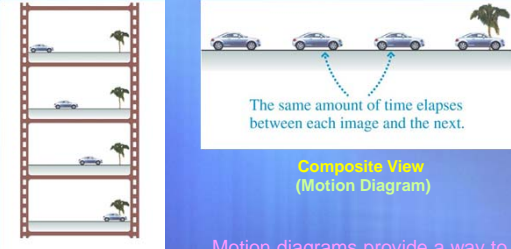


Complex motion is a combination of 2 or more of the basic motion types.

Ex.



Motion Diagrams



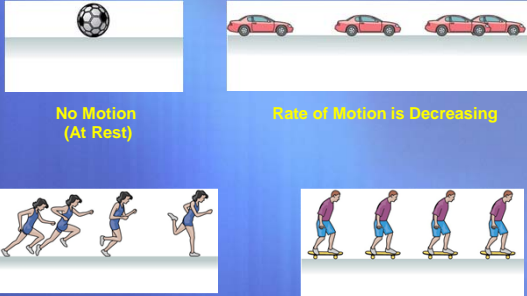
The same amount of time elapses between each image and the next.

Composite View (Motion Diagram)

Motion diagrams provide a way to visually interpret the change in an objects motion with respect to time.

Film Strip View

Motion Diagram Examples



No Motion (At Rest)

Rate of Motion is Decreasing

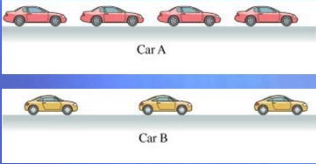
Rate of Motion is Increasing

Constant Rate of Motion

Knowledge Inventory

Cars A and B are traveling at different constant rates of motion.

Which car is going "faster" (has a higher rate of motion), A or B?
(Justify your reasoning - Assume the time interval is the same for both cars)



ANSWER: B

Scalars and Vectors

Scalar – a quantity with magnitude only
(just a number with units)

Vector – a quantity with magnitude and direction

What can we use to indicate direction?
 NSEW, left/right, up/down, +/-

Ex.
 We are driving at 55 mph.
 We are driving West at 55 mph.

Vectors are important because they can make good visual tools to simplify information when used in graphs.

Vector Properties:

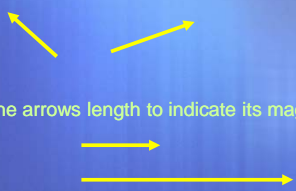
- Represented by bold faced letters or letters with arrows (carrots) over them
- Have magnitude and direction relative to a fixed origin
- Are additive (*can be combined into 1 single vector*)
resultant vector – sum of all the individual vectors
- Can only add magnitudes that are in the same or opposite direction

Ex.
 You start out driving E for 10 miles, then turn W for 7 miles. Where is your location relative to your original starting point?

Vectors can also be represented and added graphically without using **ANY** numbers at all!!!

A vector can be represented graphically by:

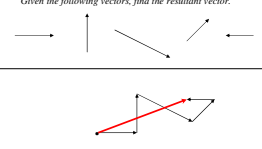
- Drawing an arrow to indicate its direction
- Altering the arrows length to indicate its magnitude



Vector Addition - Tail to Tip Method:

- 1.) Start by placing any vector with its tail at the origin (*starting point*)
- 2.) Place the tail of an unused vector to the tip of the previous vector
- 3.) After placing all the vectors in this fashion, the **resultant vector** is found by drawing a straight line from the **tail of the first vector** to the tip of the last vector.

Ex. Given the following vectors, find the resultant vector.



Method II (Graphically)

Ex. 1: → (3 miles) E

Models

What is a Model?

a simplified version of a real life physical system or event that would otherwise be too complicated to analyze in full detail

(approximation of reality)

Why use models?

Reality is extremely complicated and complex.

Example: Model Trains



Models cont.

• What are the attributes of a GOOD Model?

- Logically self-consistent
- Accurately predicts phenomena over a broad range of cases
- Simple and elegant in design

• What can be included in a model?

- Equations/symbols
- Words
- Definitions
- Analogies
- Diagrams
- Units
- Numbers

Anything that accurately describes the phenomena & correctly represents or explains the underlying physics principle(s) involved.

Models cont.

- **How do you use/apply a model?**
a model can be applied to ANY system that meets the basic requirements of the model

Ex. A model describing motion

Good : Describing the motion of a car

Bad: Describing how a burning candle releases heat
(you might could use it to model heat transfer)

- **All models have limitations!**

What if there are several models proposed to describe the same event?

Occam's Razor (1300's)
All things being equal, the simplest explanation tends to be the correct one.

This principle implies that one should not make more assumptions than necessary.

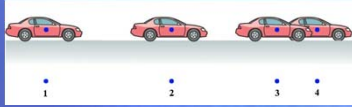
Ex. Analyzing the motion of a baseball

<ul style="list-style-type: none"> • Reality • Mass of the ball • Motion of the earth • Rotation of the ball • Atomic structure of the ball • Effects of gravity • Biochemistry of the body • Muscle behavior • Effects of the air • Initial speed of the ball • Launch angle • Shape of the ball • ... 	<ul style="list-style-type: none"> • Model ▪ Mass of the ball ▪ Initial velocity ▪ Gravity ▪ Air resistance * ▪ Rotation * <p>* Required for a more detailed look at the motion of a baseball (i.e. curveball, slider...)</p>
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Modeling Translational Motion

To describe the motion of a 'solid or rigid' object, all that is necessary is to track a single, fixed point on the object.

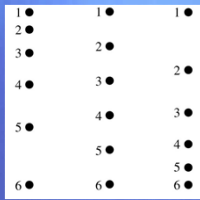
Ex. Modeling the Motion of a Car that is Slowing Down



Knowledge Inventory

Match the motion diagram with its possible description.

- A: A dust particle settling to the ground at a constant speed
- B: A ball dropped from the roof of a building
- C: A rocket descending slowly in order to make a soft landing



B A C

When modeling a rigid object as a single point, we also treat the object as if all of its mass were concentrated at that point. This modeling trick is called the particle model.

Particle Model

A simplification in which the mass of an object is treated as if all of it were concentrated at a single point.

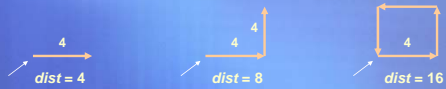
Limitations of the Particle Model

Most effective when describing the translational motion of 'rigid' objects.

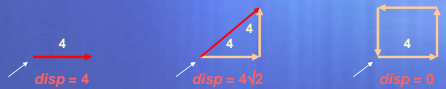
Possible ways to measure a change in position.

Distance vs. Displacement

- **Distance** (scalar)
the total path length traveled

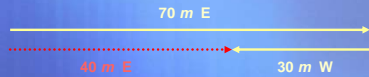


- **Displacement** (vector)
the net change in position



Ex. There and Back Again

A person walks 70 m East and then walks back along the same path 30 m West. What is the total distance traveled and the net displacement relative to the starting point?



Distance = 100 m

Displacement = 40 m E

Ex. Road Trip (Part I)

A college students road trip through several states. What is the students total distance and displacement relative to OBU?

OBU – LR = 60 mi
 LR – OKC = 350 mi
 OKC – Big D = 200 mi
 Big D – OBU = 240 mi

Distance = 850 mi
 Displacement = 0 mi

Ex. Road Trip (Part II)

What is the students total distance and displacement relative to OBU if they stop in Dallas?

OBU – LR = 60 mi
 LR – OKC = 350 mi
 OKC – Big D = 200 mi
 Big D – OBU = 240 mi

Distance = 610 mi
 Displacement = 240 mi

Ex. The Lake

How many minimum distances are there around a lake between two points? **2**

How many displacements are there between two points? **1**

There are an **infinite** number of trajectories (distances) between two points, each with a potentially unique distance. But, there can only ever be **ONE** displacement!

Summary

- Observations and attempts to describe motion have been around for millennia.
- To measure motion quantitatively, suitable **reference frames** are necessary.
- The simplest way to model the motion of objects is to treat them as **point particles** in conjunction with visual aids called **motion diagrams**.
- **Distance** and **Displacement** are two distinct ways of measuring changes in position.
- **Models** are simplified versions of reality used to predict or describe the behavior of an object or event.

*My dear brothers, take note of this:
Everyone should be quick to listen, slow to speak and slow to become angry, for man's anger does not bring about the righteous life that God desires.*

James 1:19-20
