Conceptual Physics I
Classical Mechanics

Lesson 1A – Motion

(speed, velocity, acceleration)

Lesson 1A - Motion

- Motion is always defined *relative to something.*

Two people walking side-by-side

Two people riding up in a glass elevator while someone in the lobby watches

Passenger in a moving vehicle throws an object in the air and catches it while someone on the sidewalk watches

Another example?

Someone fixed in space watching another person on the earth jump in place

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What are some definitions of *speed*?

- How fast something is going
- Rate of change of distance travelled
- Rate at which distance is covered

What are some units for speed?

- Miles per hour
- Distance unit divided by time unit

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What is a *rate*?

A rate is a *quantity* divided by *time*.

Examples: miles/hr
words/minute
cookies/minute
books/month

Quiz 1

Which of these are possible units for speed?

Miles/hour

Meters/second

Inch/year

Kilometer/millisecond

Miles/second

Parsec/millennium

All!

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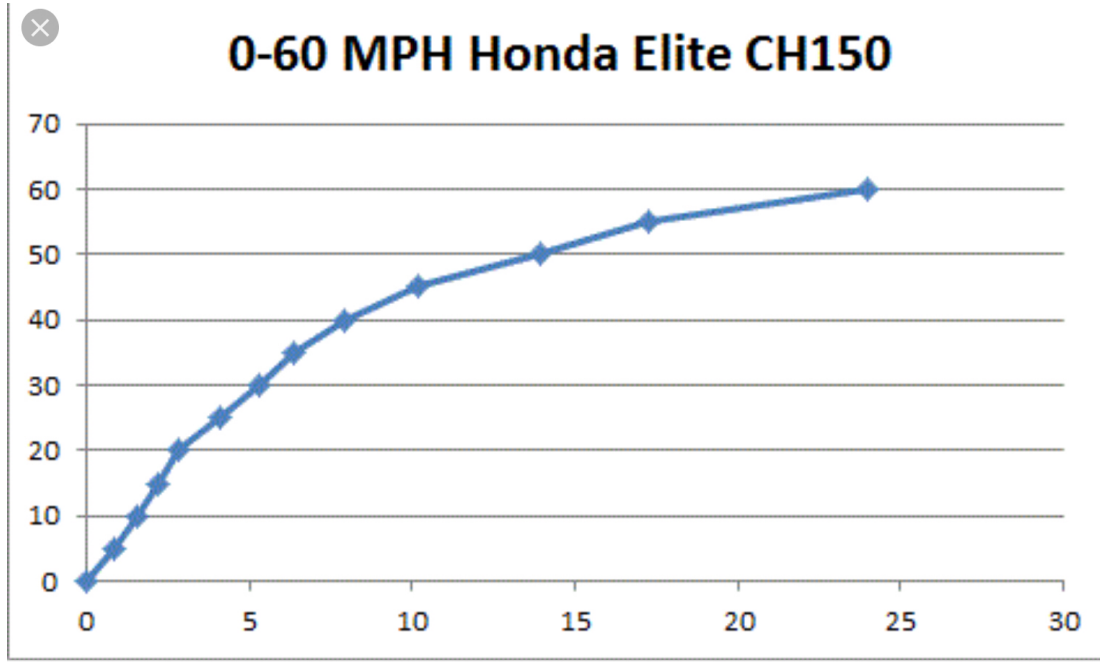
Instantaneous Speed versus Average Speed

- Instantaneous Speed is the speed defined at any instant

  Car starting from rest and speeding up to 60 mph

Time (s)	Speed (mph)
0	0
1	6
2	13
3	22
4	25
5	30
10	45
24	60



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Instantaneous Speed versus Average Speed

- Average Speed is a relationship of the total distance covered to the time it takes to cover it.

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

Instantaneous Speed versus Average Speed

- Average Speed is a relationship of the total distance covered to the time it takes to cover it.

Time (s)	Distance (m)
0	0
1	2
2	5
3	6
4	8
5	11
6	13
7	15

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

$$avg\ speed\ from\ 0\ to\ 2\ sec = \frac{5\ meters}{2\ seconds} = 2.5\ meters/second$$

$$avg\ speed\ from\ 0\ to\ 5\ sec = \frac{11\ meters}{5\ seconds} = 2.2\ meters/second$$

$$avg\ speed\ from\ 2\ to\ 5\ sec = \frac{6\ meters}{3\ seconds} = 2\ meters/second$$

It takes 2 points to determine an average speed!

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Questions:

1) If the odometer reads zero at the beginning of a trip and 35 miles a half hour later, what is the average speed in mph?

35 miles/0.5 hour = 70 miles per hour

2) Would it be possible to attain this average speed and never exceed a reading of 70 miles per hour on the speedometer?

No, because you have to accelerate to 70 mph; therefore there must be some time you exceeded 70 mph to make up for it.

3) If a cheetah can maintain a constant speed of 25 m/s, it will cover 25 meters every second. At this rate, how far will it travel in 10 seconds? 250 meters

How far in 1 minute? 25x60=1500 meters

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Questions:

4) Speed is the rate at which what happens? Distance is covered.
5) What is the difference between instantaneous speed and average speed? Instantaneous speed is speed at any instant; average speed is the total distance covered divided by the time interval
6) Does the speedometer of a car read instantaneous speed or average speed? Instantaneous speed
7) What is the average speed in m/s of a cheetah that runs 140 meters in 5 seconds? 140 meters divided by 5 seconds = 28 m/s
8) What is the average speed in km/h of Charlie, who runs to the store 4 kilometers away in 30 minutes? 4 km/0.5 hr = 8 km/hr

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Questions:

9) How far in km can Charlie go if he maintains this average speed for 1 hour? 8 km

10) How could you determine your average speed of walking?

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Velocity

- Velocity is speed in a given direction

- A car traveling at 40 mi/h (speed)
- A car traveling at 40 mi/h, North (velocity)

- An airplane flying at 500 knots (speed)
- An airplane flying at 500 knots, 32^{o} East of North (velocity)

Speed is a description of how fast something moves; velocity is how fast and in what direction it moves.

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Constant Velocity

- For an object to have constant velocity, it would have to have both constant speed and a constant direction

Changing Velocity

- If either the speed or the direction (or both) is changing, then the velocity is changing.

Important Example! A car going around in a circle at a constant speed on the speedometer.

- The speed is constant, but the velocity is not because the direction of the car is continually changing.
- Three controls in a car that can change the velocity: the gas pedal, the brake, and the steering wheel.

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Questions:

1) The speedometer of a car moving northward reads 60 km/h. It passes another car that travels southward at 60 km/h. Do both cars have the same speed? Yes. Do they have the same velocity? No, because they are moving in opposite directions.
2) If the speedometer of a car reads a constant speed of 40 km/h, can you say that the car has a constant velocity? No, because you don't know if the car is going in a straight line or turning.
3) What two controls on a car cause a change in speed? Gas pedal and brake. What control causes only a change in velocity? Steering wheel.

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Acceleration

- In order to change the velocity of an object, an acceleration must happen. Acceleration can change the speed, direction or both.
- Acceleration is the rate at which the velocity is changing

$$acceleration = \frac{change\ in\ velocity}{time\ interval}$$

- The key idea that defines acceleration is “change.” When a state of motion is changed, acceleration has occurred.
- Something speeding up, slowing down, or changing direction is experiencing acceleration.

Acceleration along a straight line can be calculated using speed

$$acceleration = \frac{change\ in\ speed}{time\ interval}$$

For example, if our car goes from 0 to 5 mi/h in 1 second, and we didn't change directions, we can say the acceleration is

$$acceleration = \frac{(5-0)mi/h}{1\ sec} = \frac{5\ mi/h}{1\ sec} = 5 \text{ mi/h-sec}$$

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Questions:

1) Suppose a car moving in a straight line steadily increases its speed each second, first from 35 to 40 mph, then from 40 to 45 mph, then from 45 to 50 mph. What is its acceleration?

Acceleration = 5 mph/sec

2) In 5 seconds a car moving in a straight line increases its speed from 50 mph to 65 mph, while a truck goes from rest to 15 mph in a straight line. Which undergoes greater acceleration?

Acceleration of car = 15 mph/5 sec = 3 mph/sec

Acceleration of truck = 15 mph/5 sec = 3 mph/sec

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Questions:

3) What is the acceleration of a car that travels in a straight line at a constant speed of 60 mph? Zero.

4) What is the acceleration of a car moving along a straight-line path that increases its speed from zero to 60 mph in 10 seconds?

   60 mph/10 sec = 6 mph/sec

5) By how much does the speed of a vehicle moving in a straight line change each second when it is accelerating at 2 km/h-s? 2 km/h

   At 4 km/h-s? 4 km/h At 10 km/h-s? 10 km/h

6) Why does the unit of time enter twice in the unit of acceleration? It is the rate of change of a rate. Each rate has time in it.

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Questions:

7) What is the acceleration of a car (in km/h-s) that can go from rest to 100 km/h in 10 s? 100 km/h divided by 10 s = 100 km/h-s

8) Calculate the instantaneous speed (in m/s) at the 10-second mark for a car that accelerates at 2 m/s^2 (2 m/s per second) from rest.

$2\ m/s^2 \times 10\ s = 20\ m/s$

9) Calculate the speed in m/s of a skateboarder who accelerates from rest for 3 seconds down a ramp at an acceleration of 5 m/s^2.

$5\ m/s^2 \times 3\ s = 15\ m/s$

10) Light travels in a straight line at a constant speed of 300,000 km/s. What is the light's acceleration? Zero

Lesson 1A - Motion

Questions:

11) Which has more acceleration when moving in a straight line – a car increasing its speed from 50 to 60 km/h, or a bicycle that goes from 0 to 10 km/h in the same time? Same acceleration

12) A car going at 30 m/s undergoes an acceleration of 2 m/s^2 for 4 seconds. What is its final speed?

30 m/s plus 2 m/s^2 x 4 s = 38 m/s