Motion (Chapter 2)

Speed - a very familiar quantity!

- Our modern world is built on the ability and requirement to be able to transport raw materials and food products over vast distances to satisfy our evolving economies.
- Various forms of transport are used: aircraft, ships, trucks…all of which are subject to the laws of motion.
- Speed is a scalar quantity: units m/s

We are infatuated with speed!

Motion

Typical speeds:

– walking	few km/hr
– ship	30 km/hr
– car	100 km/hr
– jet aircraft	800 km/hr
– fastest car	1,200 km/hr (speed of sound)
– research aircraft	4,800 km/hr
– orbiting space craft	25,000 km/hr (7 km/ sec)
– speed of light (c)	300,000 km/sec (3 x 10^8 m/s)

– c is over 40,000 times faster than current space craft speeds.

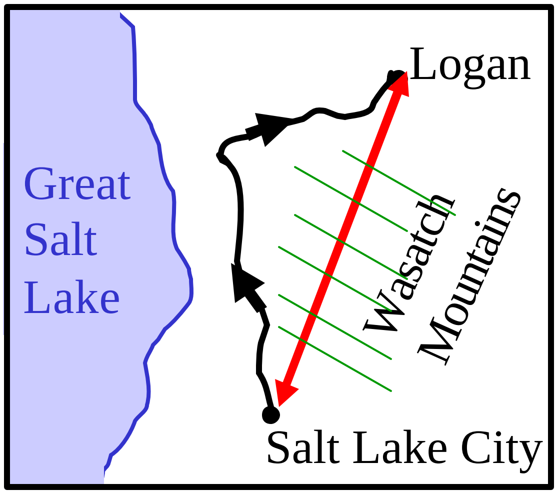
Average Speed

$$\text{Average Speed} = \frac{\text{Distance Traveled}}{\text{Time of Travel}}$$

or $$S = \frac{D}{t}$$

where S = av. speed
D = distance
t = time

Map



Distance traveled can be a lot longer than the direct (line-of-sight) path.

Speed is a scalar quantity, and is usually measured in units of m/s or km/hr.

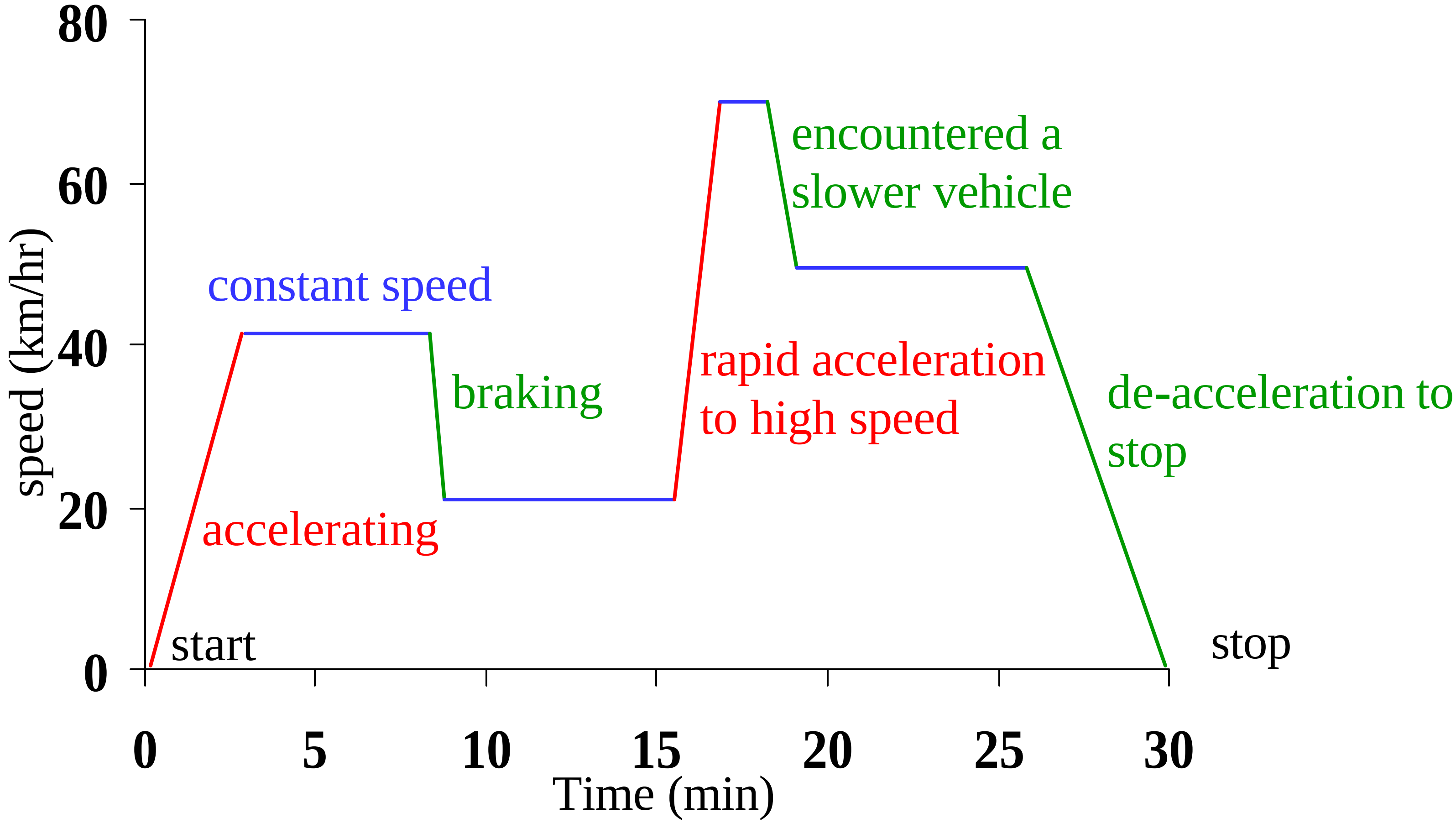
Typical values:

20 mph	=	32 km/hr	=	9 m/s
40 mph	=	64 km/hr	=	18 m/s
60 mph	=	97 km/hr	=	27 m/s
80 mph	=	130 km/hr	=	36 m/s
100 mph	=	160 km/hr	=	45 m/s

Instantaneous Speed

- At any given time the **instantaneous speed** of a vehicle will be **different** from its **average speed**.
- Instantaneous speed tells you the speed at that **moment** in time.
- A speedometer measures instantaneous speed.
- In contrast, average speed helps tell us the length of a trip but gives **no** information on the variations in speed during the trip.

Graphic example:



$$\text{instantaneous speed} = \frac{\text{distance covered}}{\text{very short time interval}}$$

(or average speed = average of all instantaneous speeds)

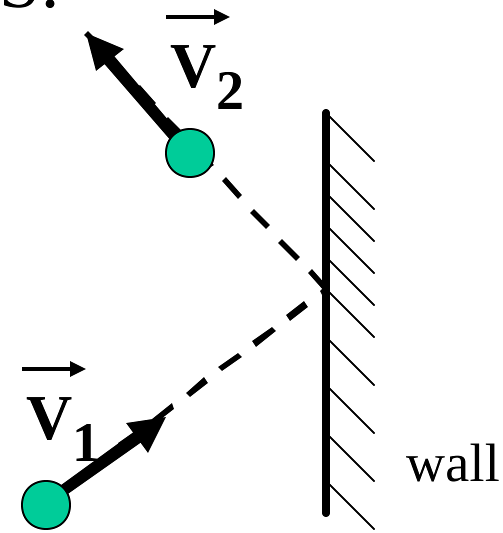
Summary

- **Average speed** = Average rate at which distance is being covered.
- **Instantaneous speed** = Rate distance is covered at a given moment in time.

Velocity

- **Speed** and **velocity** are **NOT** the same!
- **Velocity** is a **vector** and includes **direction** in the description of motion, eg. 10 m/s due S.

Ball bounced against a wall

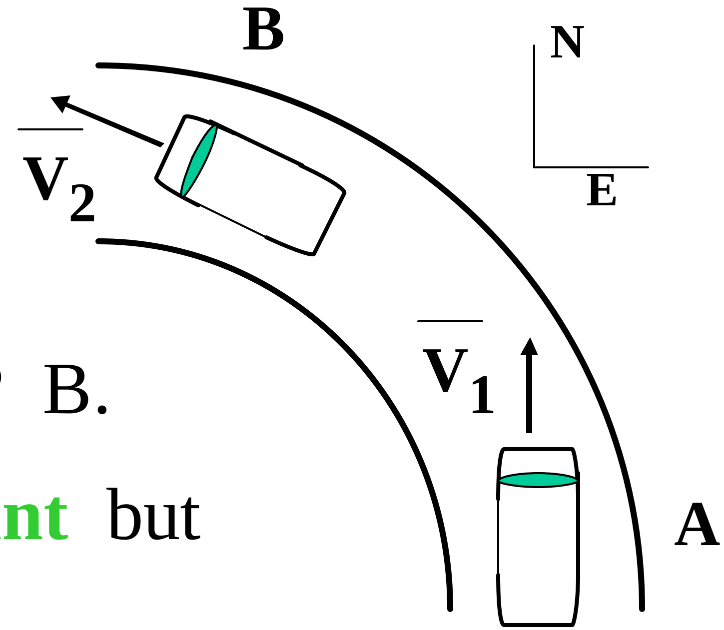


The **magnitude** of the velocity (speed) after impact may be similar to before the impact but the **direction** is quite **different**, therefore the **velocity is different**!

To **change** the velocity a **force** had to be exerted on the ball (by the wall in this case).

Car Turning a Bend:

- Car is traveling at a **constant speed** around the bend.
- But its **direction** of motion is continuously **changing** from A**?** B.
- So the **speed** of the car is **constant** but its **velocity** is **changing**!
- The **change in velocity** implies a **<u>force</u>** acting on the car to change its direction.
- **Frictional force** exerted by road on the car tires allows the car to change direction (if low friction, cannot change direction very easily eg. skidding on ice.)



Instantaneous Velocity:

- Measures the instantaneous **speed** and its **direction** at that **moment** in time.
- Instantaneous velocity provides a more **scientific description** of motion as the **velocity vector** may change in **magnitude** or **direction** with time. (eg. driving your car home!)

Summary:

- Velocity is a **vector** quantity describing the speed and direction of motion.
- A **force** is required to change either the magnitude or the direction of the velocity vector.
- Instantaneous velocity is important for our study of motion.

Acceleration: (vector quantity)

- Like speed (but perhaps **not** velocity), we are very familiar with the term '**acceleration**'.
- When a car, aircraft or elevator accelerates, we feel a **force** on our body.
- The acceleration causes a **change** in the **velocity** of the vehicle (eg. in its magnitude, direction or both).

Acceleration is the **rate of change** of velocity (not speed) with time.

- Acceleration is the key to **Newton's Laws** of motion and is vital to understanding our every day world.

Average acceleration:

$$\bar{a} = \frac{\text{change in velocity}}{\text{time interval}} = \frac{\bar{v}_2 - \bar{v}_1}{t_2 - t_1} \quad \text{or} \quad \bar{a} = \frac{?\,\bar{v}}{?\,t}$$

Example:

- Rocket at lift off accelerates uniformly up to a velocity of 1,000 km/hr in 10 sec. Determine ‘a’.

$$\bar{a} = \frac{\bar{v}_2 - \bar{v}_1}{t_2 - t_1}$$

$$v_1 = 0$$

$$v_2 = 10^3 \text{ km/hr or } 10^3 \times \frac{10^3}{3600} \text{ m/s}$$

$$? \ t = 10 \text{ sec}$$

$$\bar{a} = \frac{10^6}{3600} \times \frac{1}{10} = 27.8 \text{ m/s}^2$$

- Units: m/s^2 = meter per second per second.
- i.e The rocket’s velocity (measured in **m/s**) is increasing at a rate of 27.8 m/s every second.
- Very fast accelerations can be measured in km/s^2.
- **Acceleration** is NOT $\frac{\text{velocity}}{\text{time}}$, it is the **change** in velocity with time.
- So if the velocity is constant there is **no** acceleration.

Questions:

- **Large velocities** are associated with **large accelerations?**

  FALSE!

- A vehicle starting from rest often has its largest acceleration while its velocity is still low? **TRUE!**

Example truths:

- The **velocity** of a vehicle **accumulates** with time as it continues to accelerate. (So **time** is important to achieve large velocities from modest accelerations).
- If the **velocity** is **constant** there is **no acceleration**.
  (ie. a = 0).
- **Key** = **CHANGE**!
- Applied force causes an acceleration which produces a change in velocity!
- Think about this over the long weekend!

No class on Monday (Martin Luther King day)

First Laboratory demo: Tuesday 19 Jan
(ESLC Room 046 at 1:30 pm)

Next lecture: Wednesday 20 Jan (here)

Read: All Chapter 2