Recap.

- **Velocity** is a **vector** and represents a body's **speed** and **direction.**
- A **force** must act on a body to **change** its velocity (i.e. its speed, direction, or both).
- The force causes the body to **accelerate,** resulting in a **change** in its velocity.
- Acceleration is a vector and represents the rate of change of velocity with time.

$$\textbf{Average acceleration} = \frac{\textbf{Change in velocity}}{\textbf{Time interval}} = \frac{V_2 - V_1}{t}$$

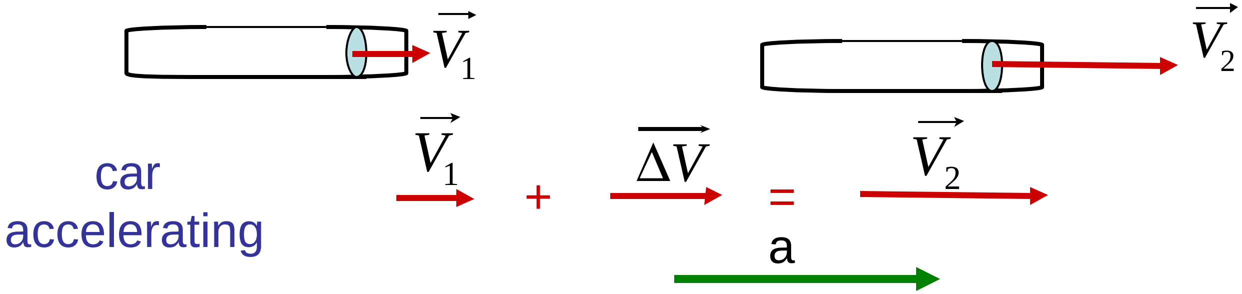
$$\vec{a} = \frac{\Delta \vec{V}}{t} \; m/s^2$$

Instantaneous Acceleration:

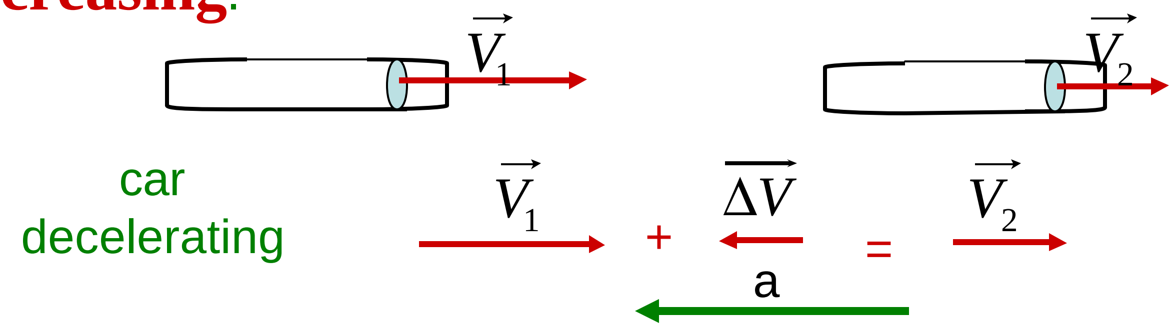
- Rate of **change** of velocity at a given instant.
- ie. The average acceleration measured over a very short time interval.
- If acceleration changing fast we need to sample it very frequently.

Acceleration: Vector Direction

❖ The direction of acceleration vector is given by the direction of the **change** in the **velocity** vector, $\Delta\vec{V}$.



- Acceleration vector in **same direction** as velocity when velocity is **increasing**.



- When the velocity is **decreasing** the change in $\Delta\vec{V}$ is in the opposite direction to motion (ie. to slow car down)

- Acceleration vector is **opposite direction** when velocity is **decreasing**.

- Deceleration is **negative** acceleration.

Example: Negative Acceleration

-Jet preparing to land

Initial velocity V_1=200 km/hr (=55.6 m/s)

Final velocity V_2=120 km/hr (=33.3 m/s)

Time interval t=5 sec

Acceleration:

$$\vec{a} = \frac{\overrightarrow{\Delta V}}{t} = \frac{\overrightarrow{V_2 - V_1}}{t}$$

$$\vec{a} = \frac{33.3 - 55.6}{5} \; m/s^2$$

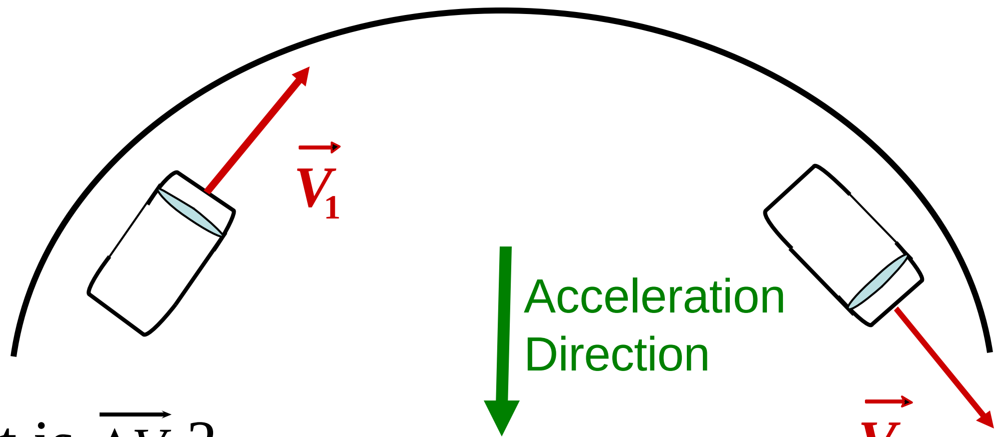
$$\vec{a} = -4.46 \; m/s^2 \quad toward \;\; runway$$

In general:

- Whenever the **velocity is changing** we say the object is **accelerating** (positive or negative).

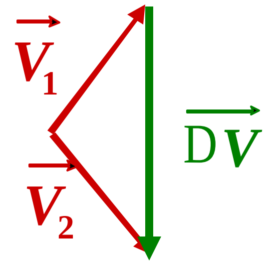
Return to car on a bend

- Car moved at a **constant speed** but its direction continuously changed – thus its **velocity was changing**.
- But we now know that **velocity changes** are produced by an **acceleration**.
- Thus when the car rounds the bend at a **constant speed** it is **accelerating**!!
- **Direction** of acceleration is given by $\overrightarrow{\Delta V}$ **direction.**



Question: what is $\overrightarrow{\Delta V}$?

$$\vec{V}_1 + \overrightarrow{\Delta V} = \vec{V}_2$$



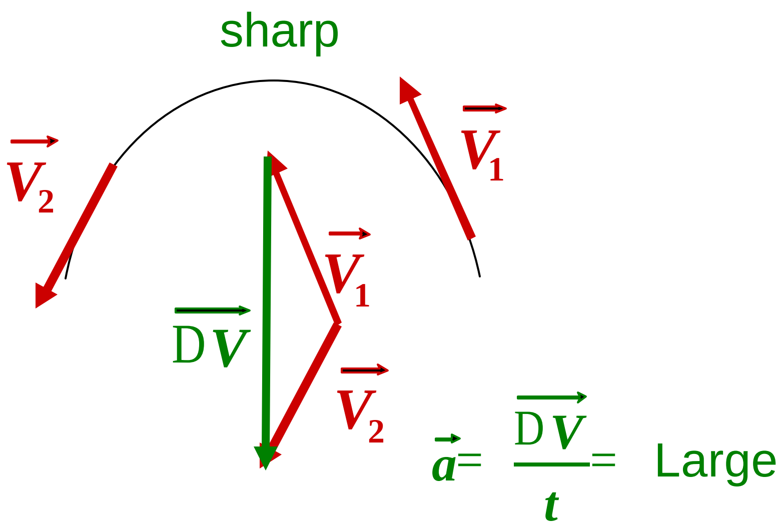
Result: the vector $\overrightarrow{\Delta V}$ acts towards the **center of curvature** of the bend!

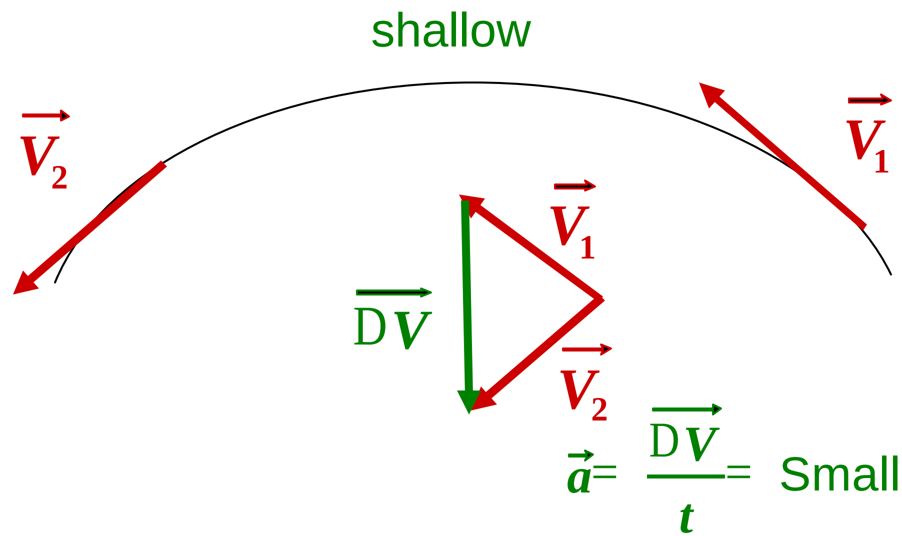
Thus the **acceleration** is also **directed towards** the **center of curvature**.

- This is why the car does **NOT** change speed but you still feel a force on your body as you round the bend… (**change in direction**).
- **Force** is due to **friction** of tires on road enabling the car to change direction.

Example:

For a given speed the acceleration experienced (force) depends on the curvature of the bend.





Skiing - sudden turns create large accelerations & large associated forces!

Summary: Acceleration involves changes!

- **Acceleration** is the rate of **change of velocity** with time.

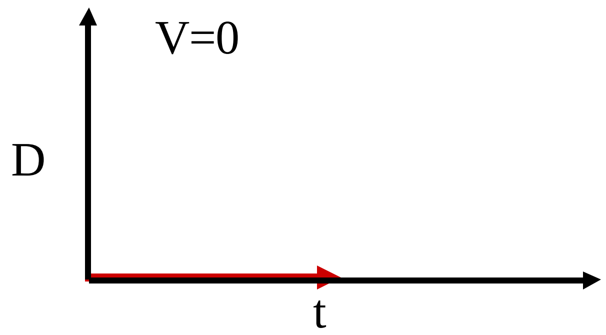
- Acceleration occurs whenever there is a **velocity changes** (ie. a change in its **magnitude or direction**).

- **Acceleration vector** has a **direction** corresponding to the **change in the velocity vector** (i.e., not necessarily in the direction of the instantaneous velocity vector).

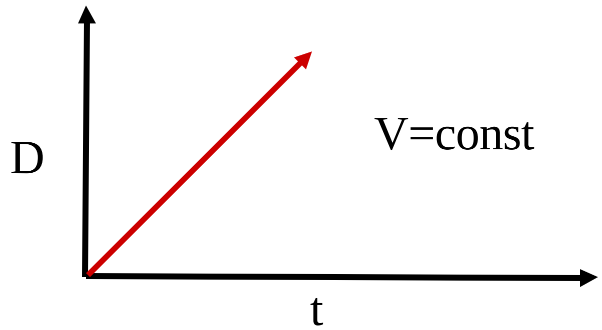
- For **circular motion** the acceleration is always directed **towards the center of curvature** (i.e. perpendicular to velocity vector). (Chapter 5)

Graphs can help understand motion:

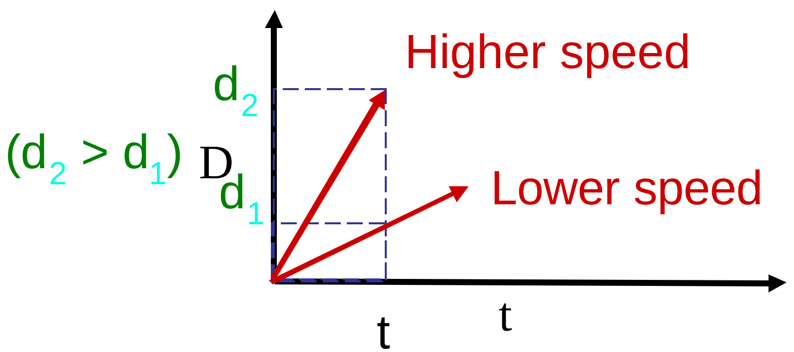
Distance vs. Time

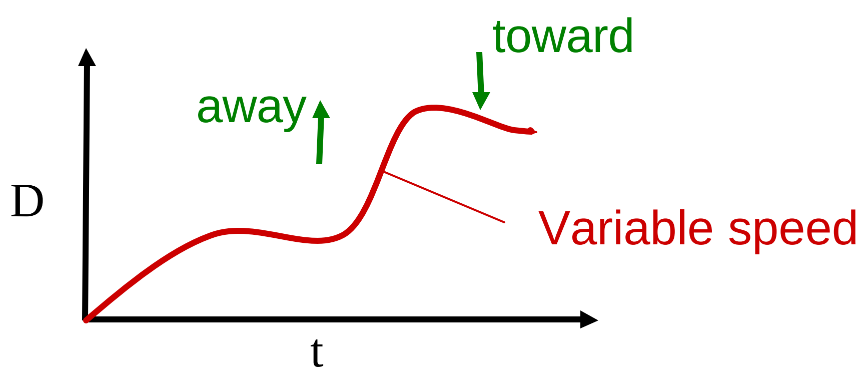


- Stationary object



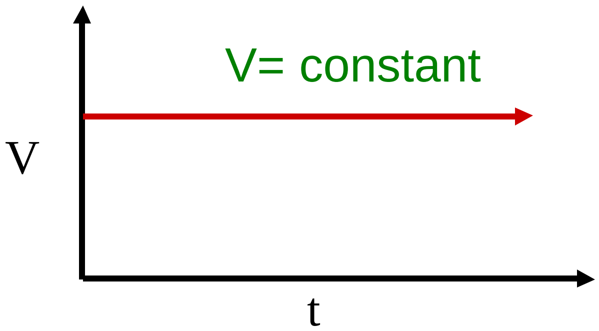
-Constant velocity:
Slope gives value of speed



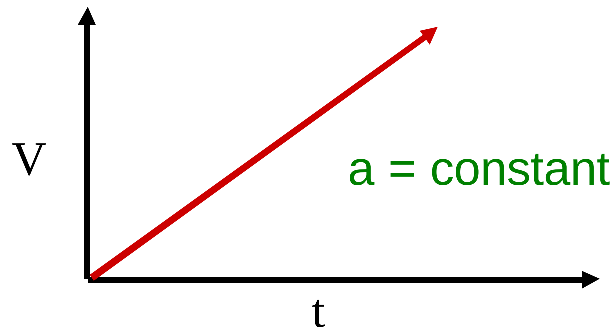


Key: **slope** tells you about the **instantaneous speed**.

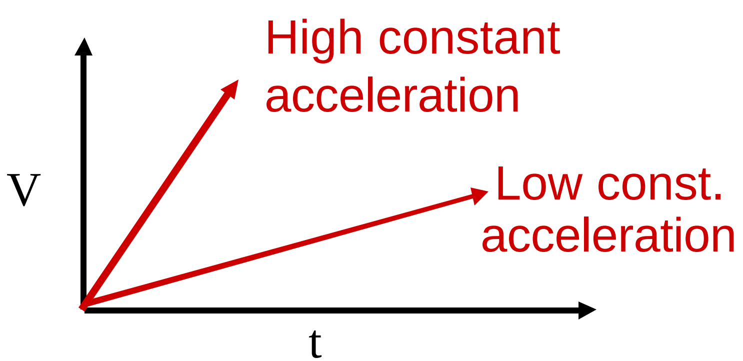
Velocity vs. Time Plots

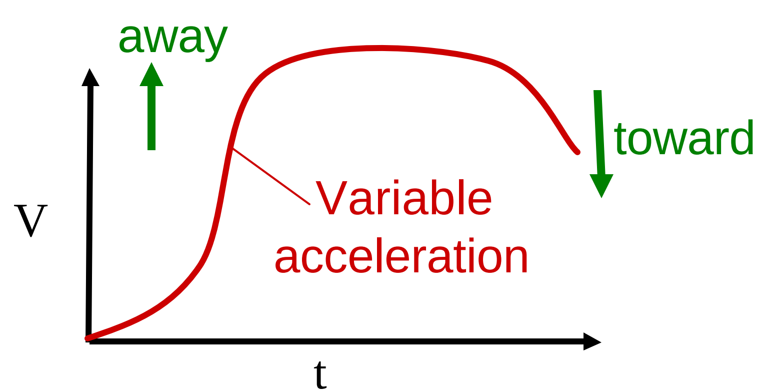


Constant velocity
(no change with time)



Constant acceleration
($\vec{V}$ increases uniformly with time)
Slope gives value of acceleration.



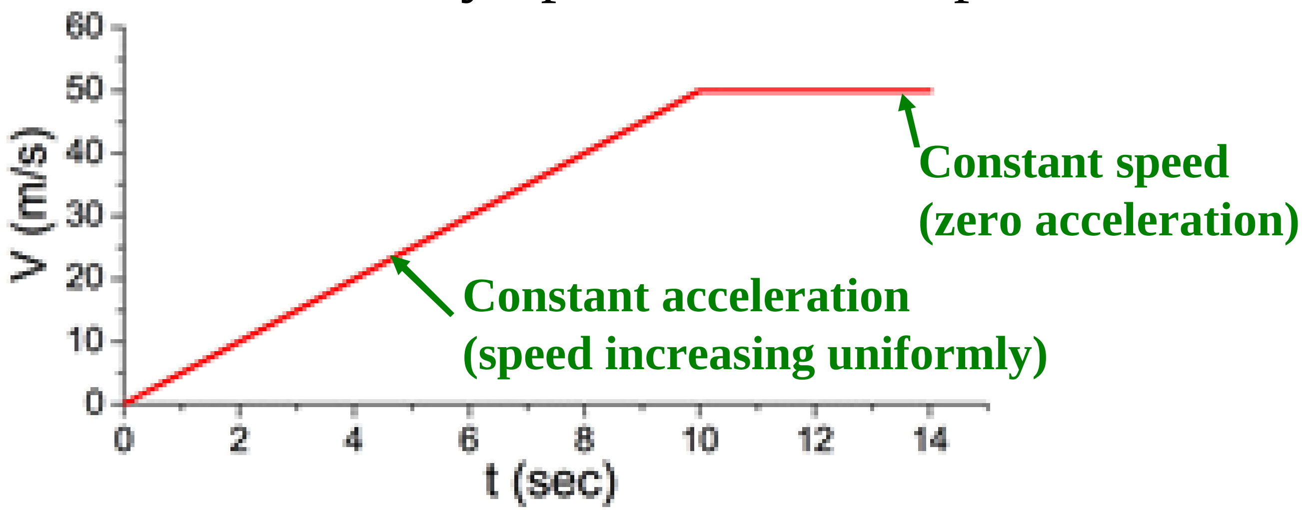


Key: - **Slope** of velocity-time plots gives information on the **instantaneous acceleration**.

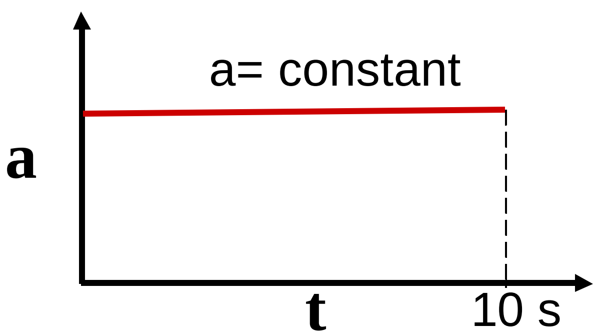
- **Area** under curve gives **distance** traveled.

Example:

Car at rest accelerates uniformly up to a constant speed of 50 m/sec in 10 sec.



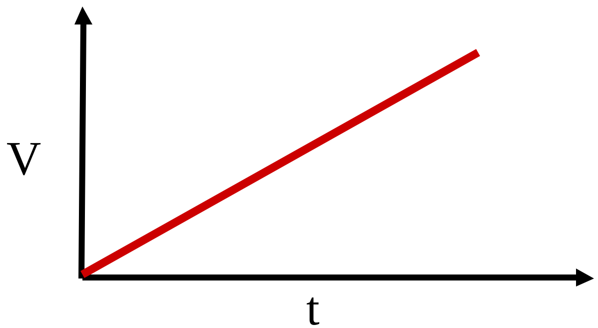
- **Constant acceleration** produces a **linear increase** (**decrease**) in **velocity** with time.



Acceleration does **NOT** change with time.

This is the **simplest form of acceleration** and occurs in nature whenever a **CONSTANT FORCE** is applied e.g. gravity!

Equations of Motion for Uniform (Constant) Acceleration a = constant

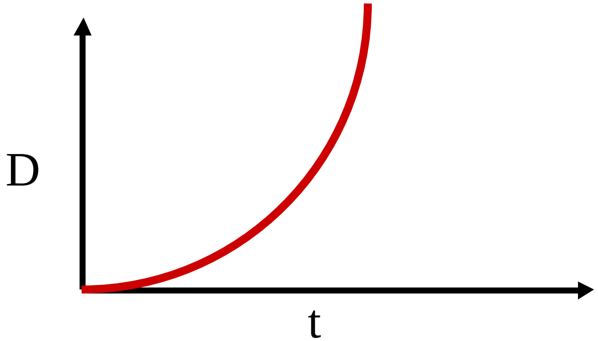


Produces a **linear** increase in velocity with time.

$V = a\,t$

Or if initial velocity (V_0) **NOT** zero:

$V = V_0 + a\,t$



Distance covered **grows very rapidly** with time. (as velocity is **increasing with time**).

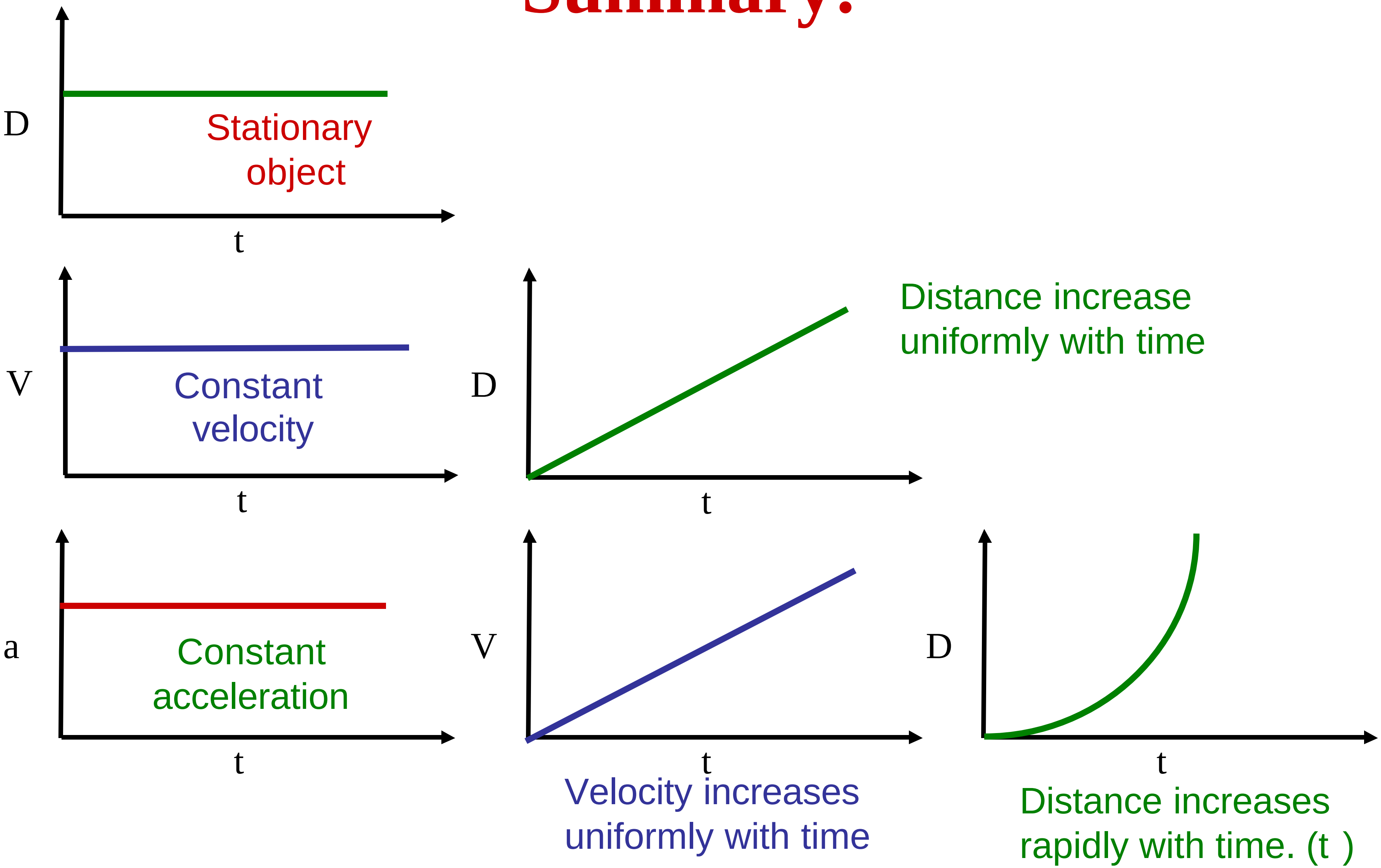
$D = 1/2\; a\, t^2$

Or if initial velocity **NOT** zero:

$D = V_0\, t + 1/2\; a\, t^2$

- **Important formulas** for calculating velocity and distance under **constant (uniform) acceleration** (i.e., constant force)
- Laws developed by Galileo (1638)!

Summary:



Constant acceleration "a" occurs in nature whenever the **force is constant** e.g. gravity.