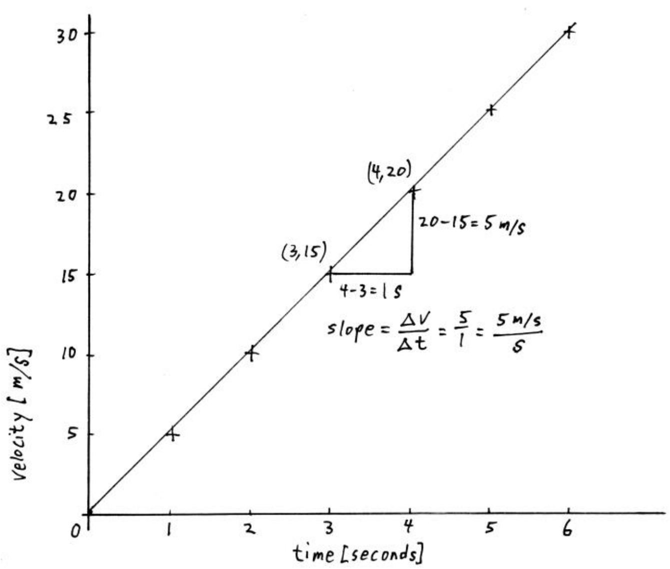
**Physics Lecture #3: Velocity-Time Graphs and Acceleration**

**Suppose you are sitting in a car at rest with a camera. When the car starts to move in a straight line, you take a picture of the speedometer at 1 second intervals. At the end of 6 seconds, you have the following data:**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Time (seconds)** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Velocity (m/s)** | **0** | **5** | **10** | **15** | **20** | **25** | **30** |

**If we plot time on the horizontal axis and velocity on the vertical axis, we get the graph below:**




**It looks like the car is going faster as time passes. Notice that the line slants upward. We can make the following conclusion:**

***In a velocity – time graph, a line slanting upward from left to right indicates that the speed is increasing.***

**What is the rate at which speed is increasing? If we pick two points, (3,15) and (4,20), we can calculate the change in velocity (Δv) that occurs over a change in time (Δt).**

$$\frac{\Delta v}{\Delta t} = \frac{20\text{ m/s} - 15\text{ m/s}}{4\text{ s} - 3\text{ s}} = \frac{5\text{ m/s}}{1\text{ s}}$$

**Each second, the velocity increases by 5 m/s. Thus, the rate at which speed is increasing is 5 (m/s)/s, or 5 m/s$^2$. This is also known as the *acceleration* of the object.**

**Change in velocity divided by change in time also gives the slope of the line. Thus,**

***In a velocity – time graph, the slope of the line gives the acceleration of the object.***

**The acceleration (a) of an object can be calculated using**

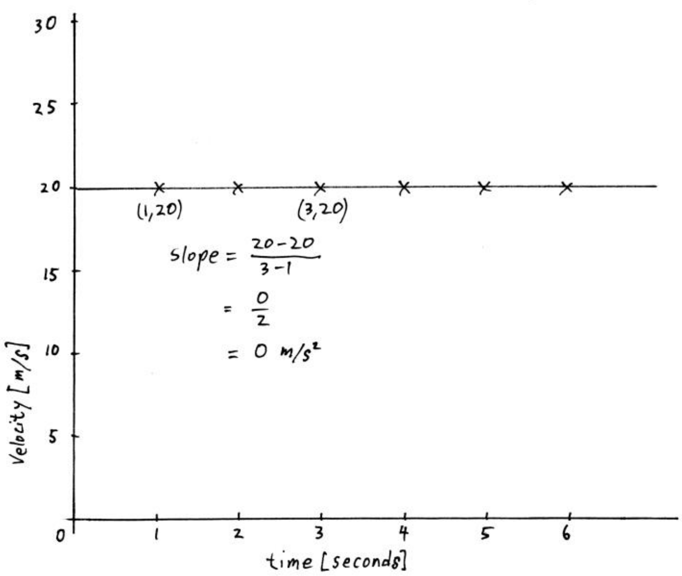
$$\mathbf{a = \frac{\Delta v}{\Delta t} = \frac{v_f - v_i}{t_f - t_i}}$$

**where $v_f$ = final velocity** **$t_f$ = final time**
**$v_i$ = initial velocity** **$t_i$ = initial time**

**Suppose we have another car where we photograph the speedometer at 1 second intervals, and we get the data below:**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Time (seconds)** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
| **Velocity (m/s)** | **20** | **20** | **20** | **20** | **20** | **20** | **20** |

**If we plot the data, we get the graph below:**



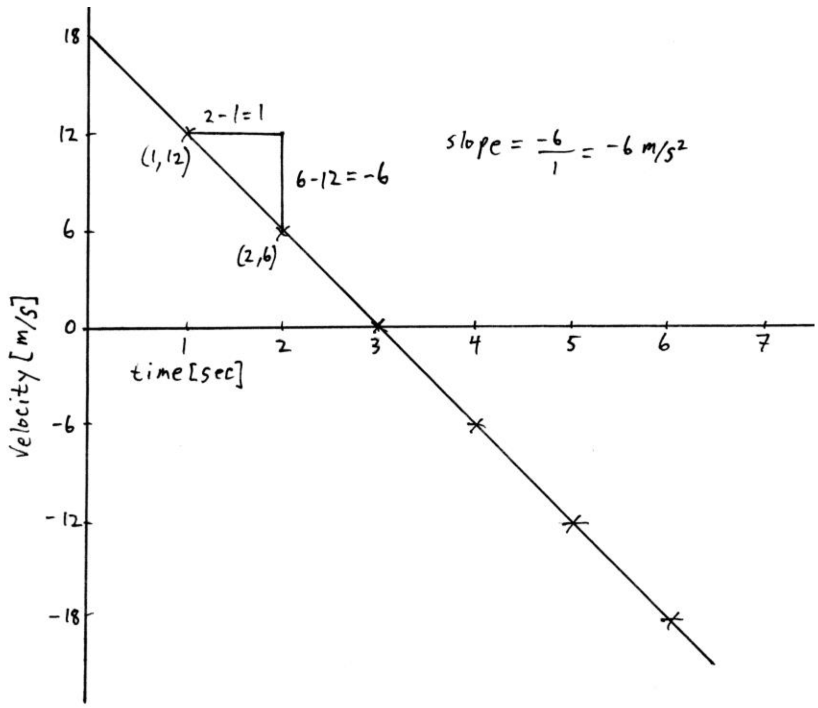

**If we pick points (1,20) and (3,20), we can calculate the slope or acceleration as (20-20)/(3-1) = 0 m/s$^2$. The object is neither speeding up nor slowing down. It is moving at a constant velocity. Notice also that this is a horizontal line.**

***In a velocity – time graph, a horizontal line indicates that the acceleration is zero.***

**Suppose we are sitting in a car that is moving in a straight line, and we have photographed the speedometer at 1 second intervals. The time and velocities are:**

| **Time (seconds)** | **0** | **1** | **2** | **3** | **4** | **5** | **6** |
|---|---|---|---|---|---|---|---|
| **Velocity (m/s)** | **18** | **12** | **6** | **0** | **-6** | **-12** | **-18** |

**If we plot the data, we get the graph below:**




**If we use points (1,12) and (2,6), we compute the slope as (6-12)/(2-1) = - 6 m/s$^2$. Notice that the slope is negative, and the line slants downward. A negative slope means the object is slowing down or speeding up in the opposite direction.**

***In a velocity – time graph, if the line is slanted downward, the object is slowing down or speeding up in the opposite direction.***

**If the object is slowing down, we sometimes say that it is decelerating. From 0 to 3 seconds, the object is indeed slowing down. At exactly 3 seconds, the object has come to a complete halt – its velocity is zero. But immediately after 3 seconds, the object begins to move in the opposite direction. At 4 seconds, the object is moving at 6 m/s in the opposite direction, which we express as -6 m/s. Thus, the object has sped up in a direction opposite from its original motion.**

**A car is moving north in a straight line at 12 m/s. 8.0 seconds later, it is moving at 32 m/s.**

- **a. Find the acceleration of the car.**
- **b. Would a velocity – time graph of the car be a horizontal line, a line slanted up, or a line slanted down?**
- **c. Is the car slowing down, speeding up, or maintaining the same speed?**

***Answer***

$$a = \frac{\Delta v}{\Delta t}$$

$$a = \frac{v_f - v_i}{t_f - t_i}$$

$$a = \frac{32 \text{ m/s} - 12 \text{ m/s}}{8.0 \text{ s} - 0.0 \text{ s}}$$

**If all they give is the elapsed time, we can assume $t_i = 0$.**

$$a = 5.5 \text{ m/s}^2$$

**Since 5.5 is a positive number, the velocity – time graph would have a positive slope and be slanted upward.**

**Since the graph has a positive slope, it means the car is speeding up.**