ST. LAWRENCE HIGH SCHOOL

A JESUIT CHRISTIAN MINORITY INSTITUTION

- **Subject- Physics** **Study Material -3** **Class IX**
- **Date : 7.05.2020**
- **Chapter: Motion**

Velocity-time graphs

The most important thing to remember about velocity-time graphs is that they are velocity-time graphs, not displacement-time graphs. There is something about a line graph that makes people think they're looking at the path of an object. A common beginner's mistake is to look at the graph to the right and think that the the v = 9.0 m/s line corresponds to an object that is "higher" than the other objects. Don't think like this. It's wrong.

Don't look at these graphs and think of them as a picture of a moving object. Instead, think of them as the record of an object's velocity. In these graphs, higher means *faster* not farther. The v = 9.0 m/s line is higher because that object is moving faster than the others.

These particular graphs are all horizontal. The initial velocity of each object is the same as the final velocity is the same as every velocity in between. The velocity of each of these objects is constant during this ten second interval.

In comparison, when the curve on a velocity-time graph is straight but not horizontal, the velocity is changing. The three curves to the right each have a different slope. The graph with the steepest slope experiences the fastest change in velocity. That object has the greatest acceleration. Compare the velocity-time equation for constant acceleration with the classic slope-intercept equation taught in introductory algebra.

$$v = v_0 + a\Delta t$$

$$y = a + bx$$

You should see that acceleration corresponds to slope and initial velocity to the intercept on the vertical axis. Since each of these graphs has its intercept at the origin, each of these objects was initially at rest. The initial velocity being zero does not mean that the initial position must also be zero, however. This graph tells us nothing about the initial position of these objects. For all we know they could be on different planets.

- On a *velocity-time* graph…
  - slope equals *acceleration*.
  - the "y" intercept equals the *initial velocity*.
  - when two curves coincide, the two objects have the *same velocity* at that time.

The curves on the previous graph were all straight lines. A straight line is a curve with constant slope. Since slope is acceleration on a velocity-time graph, each of the objects represented on this graph is moving with a constant acceleration. Were the graphs curved, the acceleration would not have been constant.

- On a *velocity-time* graph…
  - straight lines imply *uniform acceleration*.
  - curved lines imply *non-uniform acceleration*.
  - an object undergoing *constant acceleration* traces a straight line.

Since a curved line has no single slope we must decide what we mean when asked for *the* acceleration of an object. These descriptions follow directly from the definitions of average and instantaneous acceleration. If the average acceleration is desired, draw a line connecting the endpoints of the curve and calculate its slope. If the instantaneous acceleration is desired, take the limit of this slope as the time interval shrinks to zero, that is, take the slope of a tangent.

- On a *velocity-time* graph…
  - *average acceleration* is the slope of the straight line connecting the endpoints of a curve.

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

- On a *velocity-time* graph…
  - *instantaneous acceleration*is the slope of the line tangent to a curve at any point.

On a *velocity-time* graph…

- positive slope implies an *increase in velocity in the positive direction*.
- negative slope implies an *increase in velocity in the negative direction*.
- zero slope implies motion with *constant velocity*.

acceleration-time

If you trip and fall on your way to school, your acceleration towards the ground is greater than you'd experience in all but a few high performance cars with the "pedal to the metal". Acceleration and velocity are different quantities. Going fast does not imply accelerating quickly. The two quantities are independent of one another. A large acceleration corresponds to a rapid *change* in velocity, but it tells you nothing about the values of the velocity itself.

When acceleration is constant, the acceleration-time curve is a horizontal line. The rate of change of acceleration with time is a meaningless quantity so the slope of the curve on this graph is also meaningless. Acceleration need not be constant, but the time rate of change of this number has no name. On the surface, the only information one can glean from an acceleration-time graph is the acceleration at any given time.

- On an *acceleration-time* graph…
  - slope is meaningless.
  - the "y" intercept equals the *initial acceleration*.
  - when two curves coincide, the two objects have the *same acceleration* at that time.
  - an object undergoing *constant acceleration* traces a horizontal line.
  - zero slope implies motion with *constant acceleration*.

Acceleration is the rate of change of velocity with time. Transforming a velocity-time graph to an acceleration-time graph means calculating the slope of a line tangent to the curve at any point. (In calculus, this is called finding the derivative.) The reverse process entails calculating the cumulative area under the curve. (In calculus, this is called finding the integral.) This number is then the change of value on a velocity-time graph.

Given an initial velocity of zero (and assuming that down is positive), the final velocity of the person falling in the graph to the right is…

$\Delta v = a\Delta t$

$\Delta v = (9.8 \text{ m/s}^2)(1.0 \text{ s})$

$\Delta v = 9.8 \text{ m/s} \approx 20 \text{ mph}$

and the final velocity of the accelerating car is…

$\Delta v = a\Delta t$

$\Delta v = (5.0 \text{ m/s}^2)(6.0 \text{ s})$

$\Delta v = 30 \text{ m/s} \approx 60 \text{ mph}$

- On an *acceleration-time* graph…
  - the area under the curve equals the *change in velocity*.

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