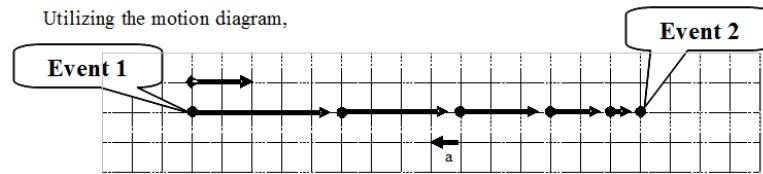


04. Tabulating Motion Information - Motion Graphs

1. Tabulating Motion Information - Motion Graphs
2. Doing the Math (Quantitative)

Tabulating Motion Information - Motion Graphs

After constructing the two qualitative representations of the motion (the motion diagram and the motion graphs), we are ready to tackle the quantitative aspects of the motion.



you can now assign numerical values to several of the kinematic variables. A glance at the situation description should indicate that information is presented about the car at two distinct events. Information is available about the car at the instant the driver applies the brakes (the velocity is given), and the instant the driver stops (the position is given). Other information can also be determined by referencing the motion diagram. To tabulate this information, you should construct a *motion table*.

Event 1: The instant the driver first applies the brakes.	Event 2: The instant the car finally stops.
$t_1 = 0 \text{ s}$	$t_2 = ?$
$r_1 = 0 \text{ m}$	$r_2 = +30 \text{ m}$
$v_1 = +15 \text{ m/s}$	$v_2 = 0 \text{ m/s}$
$a_{12} = ?$	

In addition to the information explicitly given, the velocity at the first event and the position at the second event, other information can be extracted from the problem statement and the motion diagram.

Example

- the position of the car at the first event is zero because the origin of the coordinate system is at this point,
- the time at the first instant can be "set to zero" by imagining a hypothetical stopwatch that is clicked on as the car begins to brake,
- and the velocity at the second event is zero because the car is stopped.

Since you are working under the assumption in this model that the acceleration is constant, the acceleration *between* the two instants in time is some unknown, constant value. To remind you that this assumption is in place, the acceleration is not labeled at the first instant, a_1 , or the second instant, a_2 , but rather as the acceleration *between* the two instants in time, a_{12} .

You now have a complete tabulation of all the information presented, both explicitly and implicitly, in the situation description. Moreover, you now can easily see that the only kinematic information not known about the situation is the assumed constant acceleration of the auto and the time at which it finally stops. Thus, to complete a kinematic description of the situation, these two quantities must be determined. What you may not know is that you have already been presented with the information needed to determine these two unknowns.

Doing the Math (Quantitative)

In the concepts and principles portion of this unit, you were presented with two formal, mathematical relationships, the definitions of velocity and acceleration. In the example that you are working on, there are two unknown kinematic quantities. You should

remember from algebra that two equations are sufficient to calculate two unknowns. Thus, by applying the two definitions, you should be able to determine the acceleration of the car and the time at which it comes to rest.

Although you can simply apply the two definitions directly, normally the two definitions are rewritten, after some algebraic rearranging, into two different relationships. This rearrangement is simply to make the algebra involved in solving for the unknowns easier. It is by no means necessary to solve the problem. In fact, the two definitions can be written in a large number of different ways, although this does not mean that there are a large number of different formulas you must memorize in order to analyze kinematic situations. There are only two independent kinematic relationships. The two kinematic relationships we will use when the acceleration is constant are:

$$v_2 = v_1 + a_{12}(t_2 - t_1)$$

and

$$r_2 = r_1 + v_1(t_2 - t_1) + \frac{1}{2}a_{12}(t_2 - t_1)^2$$

To finish the analysis,

<p>Event 1: The instant the driver first applies the brakes.</p> <p>$t_1 = 0 \text{ s}$</p> <p>$r_1 = 0 \text{ m}$</p> <p>$v_1 = +15 \text{ m/s}$</p> <p>$a_{12} =$</p>	<p>Event 2: The instant the car finally stops.</p> <p>$t_2 =$</p> <p>$r_2 = +30 \text{ m}$</p> <p>$v_2 = 0 \text{ m/s}$</p>
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simply write the two kinematic relationships, input the known kinematic variables from the motion table, and solve the two relations for the two unknowns. (This process is not physics, it's algebra.)

$$\begin{aligned} v_2 &= v_1 + a_{12}(t_2 - t_1) \\ 0 &= 15 + a_{12}(t_2 - 0) \\ a_{12} &= \frac{-15}{t_2} \end{aligned} \quad \begin{aligned} r_2 &= r_1 + v_1(t_2 - t_1) + \frac{1}{2}a_{12}(t_2 - t_1)^2 \\ 30 &= 0 + 15(t_2 - 0) + \frac{1}{2}a_{12}(t_2 - 0)^2 \end{aligned}$$

Now substitute this expression into the other equation:

$$\begin{aligned} 30 &= 15t_2 + \frac{1}{2}a_{12}t_2^2 \\ 30 &= 15t_2 + \frac{1}{2}\left(\frac{-15}{t_2}\right)t_2^2 \\ 30 &= 15t_2 - 7.5t_2 \\ 30 &= 7.5t_2 \\ t_2 &= 4.0 \text{ s} \end{aligned}$$

Substitute this result back into the original equation:

$$\begin{aligned} a_{12} &= \frac{-15}{4} \\ a_{12} &= -3.8 \text{ m/s}^2 \end{aligned}$$

Thus, the car must have accelerated at 3.8 m/s^2 in the negative direction, and stopped after 4.0 seconds. The kinematic description of the situation is complete.

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