SLE123 Physics for the Life Sciences

1.5 Problem Solving – Motion with Constant Acceleration

1. Because the skier slows steadily, her deceleration is a constant during the glide and we can use the kinematic equations of motion under constant acceleration. Since we know the skier's initial and final speeds and the width of the patch over which she decelerates, we will use Equation 4 from Module 1.4.

$$v^2{}_f - v^2{}_i = 2a\Delta x$$

Rearrange:

$$a = \frac{v^2{}_f - v^2{}_i}{2\Delta x}$$

Substitute in values:

$$a = \frac{(6.0\,m/s)^2 - (8.0\,m/s)^2}{2(5.0m)} = -2.8\,m/s^2$$

The magnitude of this acceleration is 2.8 m/s^2.

2. We'll do this in parts, first computing the acceleration after the congestion.

$$a = \frac{\Delta v}{\Delta t} = \frac{12.0\,m/s - 5.0\,m/s}{8.0s} = 0.875\,m/s^2$$

Now use the same acceleration to find the new velocity (use Equation 1 from Module 1.4):

$$v_f = v_i + a\Delta t$$

Substitute in values:

$$v_f = 12.0\,m/s + (0.875\,m/s^2)(16s) = 26\,m/s$$

3. Because the car slows steadily, the deceleration is a constant and we can use the kinematic equations of motion under constant acceleration. Since we know the car's initial and final speeds and the width of the patch over which she decelerates, we will use Equation 4 from Module 1.4:

$$v^2{}_f - v^2{}_i = 2\ a\ \Delta x$$

$$2\ a = \frac{(0\,m/s)^2 - (100\,m/s)^2}{150}$$

$$a = -33.33\,m/s^2$$

4. Since we know the eagle's initial speed, its acceleration and the distance over which it accelerates, so we will use Equation 4 from Module 1.4:

$$v_f^2 = v_i^2 + 2\ a\ \Delta x$$

$$v_f^2 = (0\ m/s)^2 + 2\ (5\ m/s^2)(90\ m) = 900\ \mathrm{m}^2/s^2$$

$$v_f = 30\ m/s$$

Which is 108 km/h.

5. Do this question in two parts. Part 1: work out how far from town the train is when the brakes are applied. The train is doing 12 m/s for 30 s, therefore it has travelled:

$$d = v \times t = 12\ m/s \times 30s = 360m$$

So, the brakes are applied 1000 m – 360 m = 640 m from town.
Part 2: work out acceleration knowing initial velocity (12 m/s), final velocity (0 m/s), distance (640 m). We will use Equation 4 from Module 1.4.

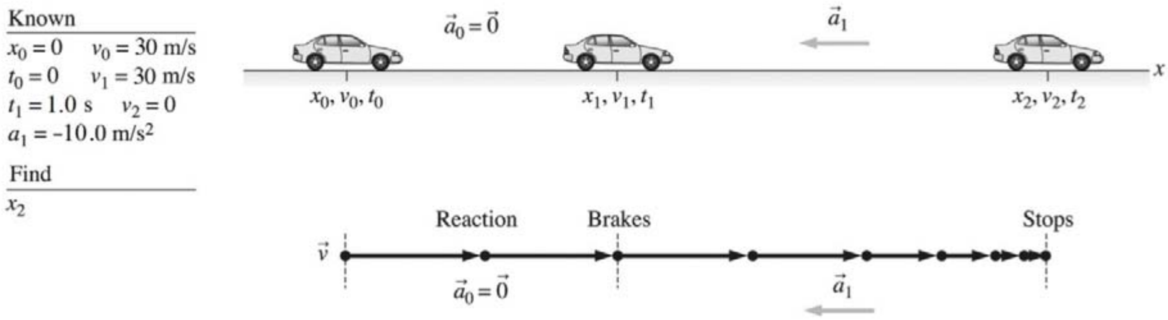
$$v^2{}_f - v^2{}_i = 2a\Delta x$$

Rearrange:

$$a = \frac{v^2{}_f - v^2{}_i}{2\Delta x}$$

$$a = \frac{(0\ m/s)^2 - (12.0\ m/s)^2}{2(640m)} = -0.11\ m/s^2$$

6. A visual overview of the car's motion that includes a pictorial representation, a motion diagram, and a list of values is shown below. We label the car's motion along the x-axis. For the driver's maximum (constant) deceleration, kinematic equations are applicable. This is a two-part problem. We will first find the car's displacement during the driver's reaction time when the car's deceleration is zero. Then we will find the displacement as the car is brought to rest with maximum deceleration.



During the reaction time when $a_0 = 0$, we can use Equation 3 from Module 1.4.

$$\Delta x = v_i \Delta t + \frac{1}{2} a (\Delta t)^2$$

Expand and rearrange:

$$x_1 = x_0 + v_0(t_1 - t_0) + \frac{1}{2} a_0 (t_1 - t_0)^2$$

Substitute values:

$$x_1 = 0m + (30\,m/s)(1s - 0s) + \frac{1}{2}(0\,m/s^2)(1s - 0s)^2 = 30m$$

During deceleration we can use Equation 4:

$$v^2{}_f = v^2{}_i + 2a\Delta x$$

Expand and rearrange:

$$v^2{}_f = v^2{}_i + 2a(x_2 - x_1)$$

Substitute values:

$$0 = (30\,m/s)^2 + 2(-10\,m/s^2)(x_2 - 30m)$$

$$x_2 = 75m$$

She has 60 m to stop, so she can't stop in time.

7. Do this in two parts. First compute the distance travelled during the acceleration phase and what speed it reaches. Then compute the additional distance travelled at that constant speed. During the acceleration phase use Equation 3,

$$\Delta x = v_i \Delta t + \frac{1}{2} a (\Delta t)^2$$

$$x_f = \frac{1}{2}(250\, m/s^2)(20ms)^2 = 0.05m = 5.0cm$$

We also compute the speed it attains using Equation 1.

$$v_f = v_i + a\Delta t$$

$$v_f = 0\, m/s + (250\, m/s^2)(20ms) = 5.0m/s$$

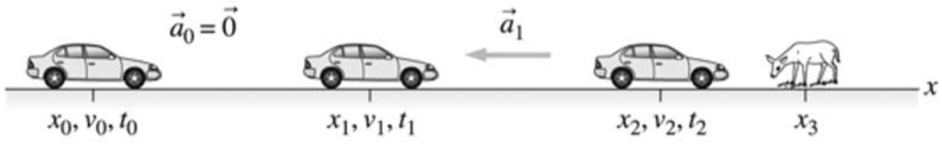
Now the distance travelled at a constant speed of 5.0 m/s.

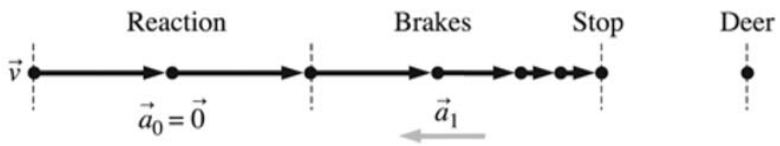
$$\Delta x = v\Delta t = (5.0\, m/s)(30ms) = 0.15m = 15cm$$

Now add the two distances to get the total

$$\Delta x = 15cm + 5.0cm = 20cm$$

8. A visual overview of your car's motion that includes a pictorial representation, a motion diagram, and a list of values is shown below. We label the car's motion along the x-axis. For maximum (constant) deceleration of your car, kinematic equations hold.





To find x_2, we first need to determine x_1.

Using:

$$x_1 = x_0 + v_0(t_1 - t_0)$$

We get:

$$x_1 = 0m + (20\,m/s)(0.50s - 0s) = 10m$$

Now, with $a_1 = 10\ m/s^2$, $v_2 = 0$ and $v_1 = 20\ m/s$, we can use:

$$v^2{}_f = v^2{}_i + 2a(x_2 - x_1)$$

$$0 = (20\,m/s)^2 + 2(-10\,m/s^2)(x_2 - 10m)$$

$$x_2 = 30m$$

The distance between you and the deer is ($x_3 - x_2$) or (35 m – 30 m) = 5 m.

9. Use kinematic equations for constant acceleration. Call the point where the motorcycle started the origin.

a.

$$\Delta t = \frac{\Delta v}{a} = \frac{80\,km/h}{8.0\,m/s^2}\left(\frac{1h}{3600s}\right)\left(\frac{1000m}{1km}\right) = 2.78s$$

b. Compute the distance travelled in 10 s for each vehicle.

For the car:

$$\Delta x = v\Delta t = (80\,km/h)(2.78s)\left(\frac{1h}{3600s}\right)\left(\frac{1000m}{1km}\right) = 61.7\text{m}$$

For the motorcycle:

$$\Delta x = v_i\Delta t + \frac{1}{2}a(\Delta t)^2 = \frac{1}{2}(8.0\,m/s^2)(2.78s)^2 = 30.7m$$

The difference is the distance between the motorcycle and the car at that time. 61.7 m – 30.7 m = 31 m. The motorcycle will never catch up if it never exceeds the speed of the car.

10. We will use the equation for constant acceleration to find out how far the sprinter travels during the acceleration phase:

$$a = \frac{v}{t} = \frac{11.2\,m/s}{2.14s} = 5.23\,m/s^2$$

The distance travelled during the acceleration phase will be

$$\Delta x = v_i \Delta t + \frac{1}{2} a (\Delta t)^2$$

$$\Delta x = 0 + \frac{1}{2}(5.23\,m/s^2)(2.14s)^2 = 12.0m$$

The distance left to go at constant velocity is 100 m – 12.0 m = 88.0 m. The time this takes at the top speed of 11.2 m/s is

$$\Delta t = \frac{\Delta x}{v} = \frac{88.0m}{11.2\,m/s} = 7.86s$$

The total time is 2.14 s + 7.86 s = 10.0 s