I. While approaching a school zone you steadily reduce your speed from 45 mph to 25 mph in 5s. It takes you 10 seconds to drive through the school zone at 25 mph, then 3 more seconds to speed up steadily to 45 mph again. (1 m/s = 2.2 mph)

\[
(45 \text{ mph}) \left( \frac{1 \text{ m/s}}{2.2 \text{ mph}} \right) = 20.5 \text{ m/s}
\]

\[
(25 \text{ mph}) \left( \frac{1 \text{ m/s}}{2.2 \text{ mph}} \right) = 11.4 \text{ m/s}
\]

a) Plot \( v_x \) vs \( t \) graph the diagram below (be sure to label the vertical axes).

b) Plot \( a_x \) vs \( t \) graph the diagram below (be sure to label the vertical axes).

\[
\alpha_{I} = \frac{(20.5 - 11.4)}{5} = -1.8 \text{ m/s}^2
\]

\[
\alpha_{II} = 0
\]

\[
\alpha_{III} = \frac{20.5 - 11.4}{3} = 3.1 \text{ m/s}^2
\]

c) How far do you drive in the 18 seconds of your motion described above?

\[
\Delta x_I = v_0t + \frac{1}{2}a t^2 = (20.5)(5) + \frac{1}{2}(-1.8)(25) = 80 \text{ m}
\]

\[
\Delta x_{II} = \left( \frac{11.4}{3} \right)(10) \text{ m} = 114 \text{ m}
\]

\[
\Delta x_{III} = \left( 11.4 \right)(3) + \left( \frac{1}{2} \right)(3)(9) = 47.7 \text{ m}
\]

\[
\Delta x_{TOTAL} = 242 \text{ m}
\]

\[
\text{TO TWO DIGITS} \Rightarrow 240 \text{ m}
\]
II. Your little sister is running at 2 m/s toward a mud puddle that is 6.0 m in front of her. You are 10 m behind her running at 5.0 m/s to catch her before she enters the mud.

a) Make an \( x(t) \) vs \( t \) graph of your motion and of your sister’s motion on the axes below. Use the same axes for both graphs, but label them.

b) Write an equation below that describes your motion, \( x(t) \), and do the same for your sister assuming the same coordinate system. Replace symbols with any numeric values that you know.

YOU:

\[ x_y(t) = \left( \frac{5 \text{ m}}{\text{s}} \right) t \]

YOUR SISTER:

\[ x_{\text{sister}}(t) = 10 \text{ m} + \left( \frac{2 \text{ m}}{\text{s}} \right) t \]

c) Determine whether or not you will catch your sister before she reaches the mud puddle. Show your work and explain your reasoning.

**Graphically:** The graphs intersect when you catch your sister.

Since that happens at a position that is \( > 16 \text{ m} \), then you do not catch your sister before she reaches the puddle.

**Based on equations:** When you catch her, \( x_y(t_{\text{catch}}) = x_{\text{sister}}(t_{\text{catch}}) \)

\[ (5t_c) = 10 \text{ m} + (2t_c) \Rightarrow t_c = \frac{10}{3} \text{ s} = 3.33 \text{ s} \]

\[ x_y(t_c) = (5 \times 3.33) = 16.7 \text{ m} \]

Since \( 16.7 \text{ m} > 16 \text{ m} \), you don’t catch her before she reaches the puddle.
3. An airplane is heading due east and is moving at a speed of 370 km/h relative to the air. The wind is blowing northeast (45 degrees north of east) at a speed of 92.5 km/h. What is the speed of the airplane relative to the ground?

a) 463 km/h  
\[ v_{\text{plane}} = (370 \text{ km/h}) \hat{i} \]

b) 381 km/h  
\[ v_{\text{wind}} = (92.5 \text{ km/h}) \cos 45^\circ \hat{i} + (92.5 \text{ km/h}) \sin 45^\circ \hat{j} \]

c) 417 km/h  
\[ v_{\text{total}} = \left[ (370 + 65.4) \hat{i} + 65.4 \hat{j} \right] \text{km/h} \]
\[ v_{\text{total}} = \left[ 435.4 \hat{i} + 65.4 \hat{j} \right] \text{km/h} \]
\[ v_{\text{total}} = 440 \text{ km/h} \]

d) 370 km/h

e) 440 km/h

4. Traffic moves steadily through the Holland Tunnel traveling \( n \) miles in 3.5 minutes. A transportation engineer characterizes the traffic with a traffic index \( \text{traffic}_H = 3.5/n \). The traffic index for the Lincoln Tunnel, \( \text{traffic}_L \), is larger than \( \text{traffic}_H \). Select the best answer from the answers below.

a) The traffic is moving faster in the Lincoln Tunnel.

b) The traffic is moving faster in the Holland Tunnel.

c) The traffic is moving at the same rate in both tunnels.

d) \( \text{traffic}_L = n \) times \( \text{traffic}_H \).

e) there is not enough information to compare

\[ \text{traffic}_H = \frac{3.5}{n} \text{ min/mile} \]
\[ \text{traffic}_L > \text{traffic}_H \]

\[ \therefore \text{ LINCOLN TUNNEL IS SLOWER } \]

5. If you drove night and day without stopping for one year without exceeding the speed limit of 60 miles/hour, the maximum number of miles you could drive would be closest to:

a) \( 5 \times 10^5 \)

\[ \left( 60 \frac{\text{miles}}{\text{hour}} \right) \left( \frac{24 \text{ hours}}{1 \text{ day}} \right) \left( \frac{365 \text{ days}}{1 \text{ year}} \right) \left( 1 \text{ year} \right) = 5.3 \times 10^5 \text{ miles} \]

b) \( 9 \times 10^3 \)

c) \( 1 \times 10^6 \)

d) \( 3 \times 10^5 \)

e) \( 3 \times 10^7 \)
6. A toy car starts from rest, speeds up gradually to a constant speed, and slows down until it comes to
rest. It speeds up gradually in the opposite direction, slows down, and comes to rest at its starting
point. Which of the following graphs of $x(t)$ represents this motion?

![Graphs of x(t)]

7. In normal traffic driving at an average speed of 60 km/hr, it takes one hour to go from New
Brunswick, NJ to Brooklyn, NY. In heavy traffic cars make the same trip at an average speed of
45 km/hr. How much longer does this trip take in heavy traffic?

a) 90 mins
b) 80 mins
c) 30 mins
d) 20 mins
e) 15 mins

\[
\Delta x = \left(\frac{60 \text{ km/hr}}{\text{hr}}\right)(1 \text{ hr}) = 60 \text{ km} \quad t_1 = 1 \text{ hour}
\]

\[
t_2 V_2 = \Delta x \implies t_2 = \frac{\Delta x}{V_2} = \frac{60 \text{ km}}{45 \text{ km/hr}} = 1 \frac{2}{3} \text{ hr}
\]

\[
t_2 - t_1 = 0.33 \text{ hr} = \left(\frac{1}{3}\right)(60 \text{ min}) = 20 \text{ min}
\]

8. You are standing at the edge of a cliff and throw a rock straight down with an initial speed of
2.0 m/s. The rock hits the ground 3.0 s later. You take a second rock and drop it from the same
cliff. How long will it take to hit the ground?

a) 1.8 s
b) 2.2 s
c) 2.8 s
d) 3.5 s
e) 3.2 s

\[
V_{01} = 2 \frac{\text{m}}{\text{s}} \quad t_1 = 3 \text{ s} \quad a = +9.8 \frac{\text{m}}{\text{s}^2}
\]

\[
\Delta y = V_{01} t_1 + \frac{1}{2} a t_1^2 = 2 \cdot 3 + \frac{1}{2} \cdot 9.8 \cdot 9
\]

\[
\Delta y = 50.1 \text{ m}
\]

\[
V_{02} = 0 \quad \Delta y = \frac{1}{2} a t_2^2 \implies t_2 = \sqrt{\frac{2 \Delta y}{a}}
\]

\[
t_2 = \sqrt{\frac{\Delta y}{a}} = 3.2 \text{ s}
\]
I. While approaching a school zone you steadily reduce your speed from 55 mph to 23 mph in 5s. It takes you 10 seconds to drive through the school zone at 23 mph, then 3 more seconds to speed up steadily to 55 mph again. (1 m/s = 2.2 mph)

a) Plot \( v_x \) vs \( t \) graph the diagram below (be sure to label the vertical axes).

\[
\begin{align*}
\text{a}_1 &= -\frac{14.6 \text{ m/s}^2}{5 \text{ s}} = -2.9 \text{ m/s}^2 \\
\text{a}_2 &= 0 \\
\text{a}_3 &= +\frac{14.6 \text{ m/s}^2}{3 \text{ s}} = +4.9 \text{ m/s}^2
\end{align*}
\]

b) Plot \( a_x \) vs \( t \) graph the diagram below (be sure to label the vertical axes).

c) How far do you drive in the 18 seconds of your motion described above?

\[
\begin{align*}
\Delta x_1 &= v_0 t + \frac{1}{2} a t^2 = (23)(5) + \left(\frac{1}{2}\right)(-2.9)(25) = 88.75 \text{ m} \\
\Delta x_2 &= v_0 t = (10.4 \text{ m/s})(10 \text{ s}) = 104 \text{ m} \\
\Delta x_3 &= (10.4)(3) + \left(\frac{1}{2}\right)(4.9)(9) = 53.25 \text{ m} \\
\Delta x_{\text{TOTAL}} &= 246 \text{ m} \quad \text{To two digits} \Rightarrow 250 \text{ m}
\end{align*}
\]
II. Your little sister is running at 2 m/s toward a mud puddle that is 6.0 m in front of her. You are 10 m behind her running at 6.0 m/s to catch her before she enters the mud.

a) Make an $x(t)$ vs $t$ graph of your motion and of your sister's motion on the axes below. Use the same axes for both graphs, but label them.

b) Write an equation below that describes your motion, $x(t)$, and do the same for your sister assuming the same coordinate system. Replace symbols with any numeric values that you know.

YOU: $x_y(t) = (6 \text{ m/s}) t$

YOUR SISTER: $x_s(t) = (2 \text{ m/s}) t + 10 \text{ m}$

c) Determine whether or not you will catch your sister before she reaches the mud puddle. Show your work and explain your reasoning.
3. An airplane is heading due east and is moving at a speed of 370 km/h relative to the air. The wind is blowing northeast (45 degrees north of east) at a speed of 92.5 km/h. What is the speed of the airplane relative to the ground?

a) 440 km/h
b) 463 km/h
c) 381 km/h
d) 417 km/h
e) 370 km/h

\[ V_{\text{TOTAL}} = (370 \hat{i} + 92.5 \cos 45^\circ \hat{j} + 92.5 \sin 45^\circ \hat{k}) \text{ km/hr} \]

\[ V_{\text{TOTAL}} = \sqrt{(435.4)^2 + (65.41)^2} \text{ km/hr} = 440 \text{ km/hr} \]

4. Traffic moves steadily through the Lincoln Tunnel traveling \( n \) miles in 3.5 minutes. A transportation engineer characterizes the traffic with a traffic index \( \text{traffic}_L = \frac{3.5}{n} \). The traffic index for the Holland Tunnel, \( \text{traffic}_H \) is larger than \( \text{traffic}_L \). Select the best answer from the answers below.

a) The traffic is moving faster in the Lincoln Tunnel.
b) The traffic is moving faster in the Holland Tunnel.
c) The traffic is moving at the same rate in both tunnels.
d) \( \text{traffic}_H = n \) times \( \text{traffic}_L \).
e) there is not enough information to compare

\[ \text{traffic}_L = \frac{3.5}{n} \text{ min/mile} \]

\[ \text{traffic}_H > \text{traffic}_L \]

more minutes to travel each mile

[Image]: SILVER

5. If you drove night and day without stopping for one year without exceeding the speed limit of 60 miles/hour, the maximum number of miles you could drive would be closest to:

a) \( 9 \times 10^5 \)
b) \( 1 \times 10^6 \)
c) \( 3 \times 10^5 \)
d) \( 3 \times 10^7 \)
e) \( 5 \times 10^5 \)

\[ \left( \frac{24 \text{ hr}}{\text{ day}} \cdot \frac{365 \text{ days}}{1 \text{ year}} \right) \left( \frac{1 \text{ year}}{\text{ yr}} \right) \left( \frac{60 \text{ miles}}{\text{ hour}} \right) = 5.3 \times 10^5 \text{ miles} \]
6. A toy car starts from rest, speeds up gradually to a constant speed, and slows down until it comes to rest. It speeds up gradually in the opposite direction, slows down, and comes to rest at its starting point. Which of the following graphs of x(t) represents this motion?

7. In normal traffic driving at an average speed of 60 km/hr, it takes one hour to go from New Brunswick, NJ to Brooklyn, NY. In heavy traffic cars make the same trip at an average speed of 40 km/hr. How much longer does this trip take in heavy traffic?

   a) 90 mins
   b) 80 mins
   c) 30 mins
   d) 20 mins
   e) 15 mins

\[ \Delta x_1 = \left( \frac{60 \text{ km}}{\text{hr}} \right) \left( 1 \text{ hr} \right) = 60 \text{ km} \quad \Rightarrow \quad t_1 = 1 \text{ hr} \]

\[ \Delta x_2 = \left( \frac{40 \text{ km}}{\text{hr}} \right) t_2 = 60 \text{ km} \quad \Rightarrow \quad t_2 = \left( \frac{60}{40} \right) \text{ hr} \]

\[ t_2 - t_1 = 0.5 \text{ hr} = 30 \text{ min} \]

8. You are standing at the edge of a cliff and throw a rock straight down with an initial speed of 2.0 m/s. The rock hits the ground 2.0 s later. You take a second rock and drop it from the same cliff. How long will it take to hit the ground?

   a) 1.8 s
   b) 2.2 s
   c) 2.8 s
   d) 3.5 s
   e) 3.2 s

\[ V_0 = 2 \text{ m/s} \quad t_1 = 2 \text{ s} \quad \Delta y = V_0 t + \frac{1}{2} a t^2 \]

\[ a = 9.8 \text{ m/s}^2 \quad \Rightarrow \quad \Delta y = (2)(2) + \left( \frac{1}{2} \right)(9.8)(4) = 23.6 \]

\[ V_{02} = 0 \text{ m/s} \quad \Delta y = \frac{1}{2} a t_2^2 \quad \Rightarrow \quad t_2 = \sqrt{\frac{2\Delta y}{a}} = 4.8 \]

\[ t_2 = 2.2 \text{ s} \]