

Today: Section 3.5

L10



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L10

Relative
motion

Today: Section 3.5

L10

Wednesday: HW#4 Due

Today: Section 3.5

Wednesday: HW#4 Due

Exam #1

110

Today: Section 3.5

L10

Wednesday: HW#4 Due & Exam #1

Friday: Start of Chapter 4

Today: Section 3.5

L10

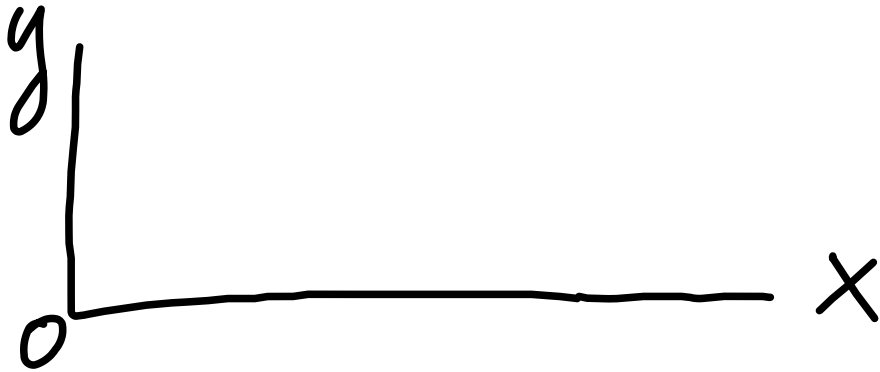
Wednesday: HW#4 Due & Exam #1

Friday: Start of Chapter 4

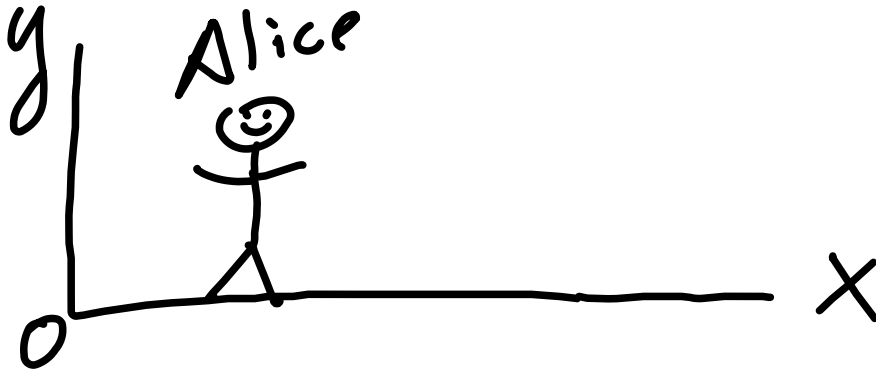
Newton's Laws of
Motion

Relative motion 12

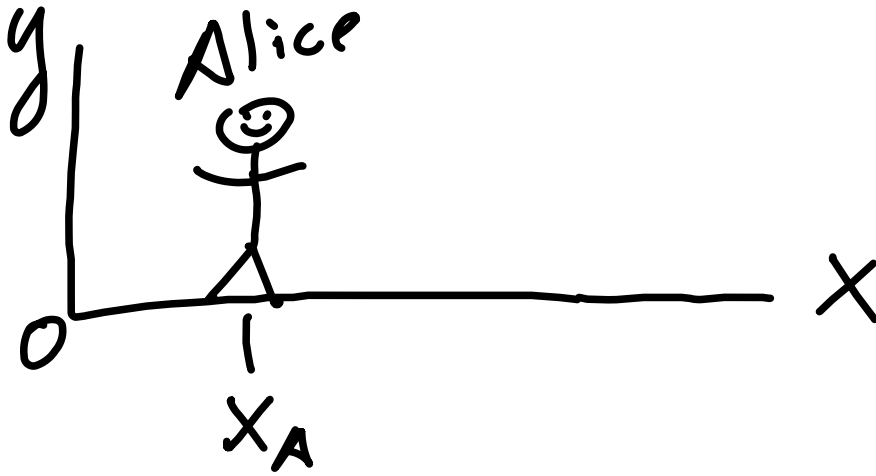
Relative motion 12



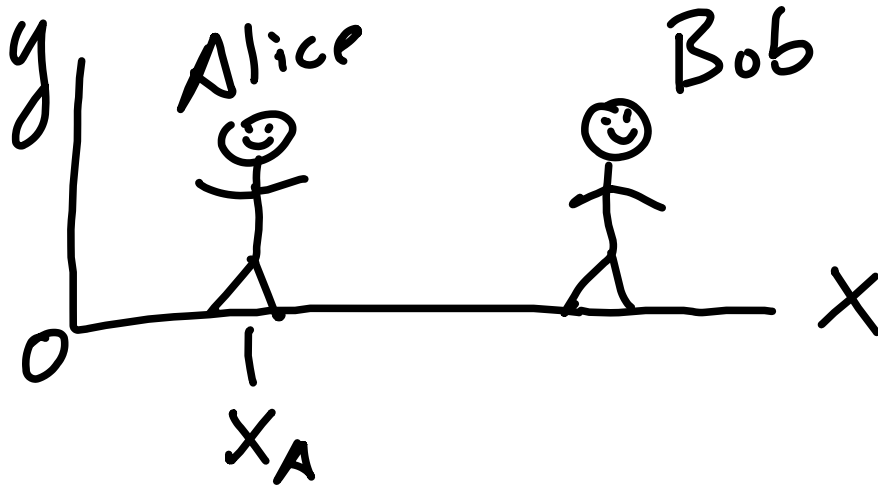
Relative motion 12



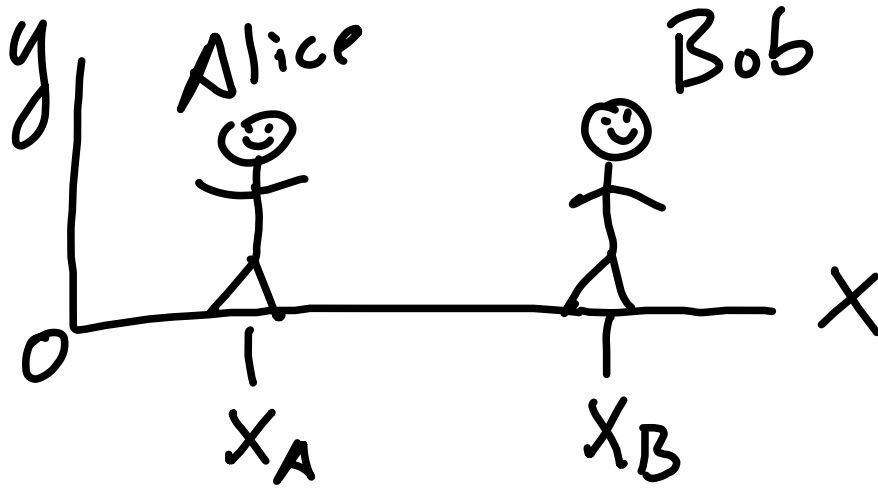
Relative motion 12



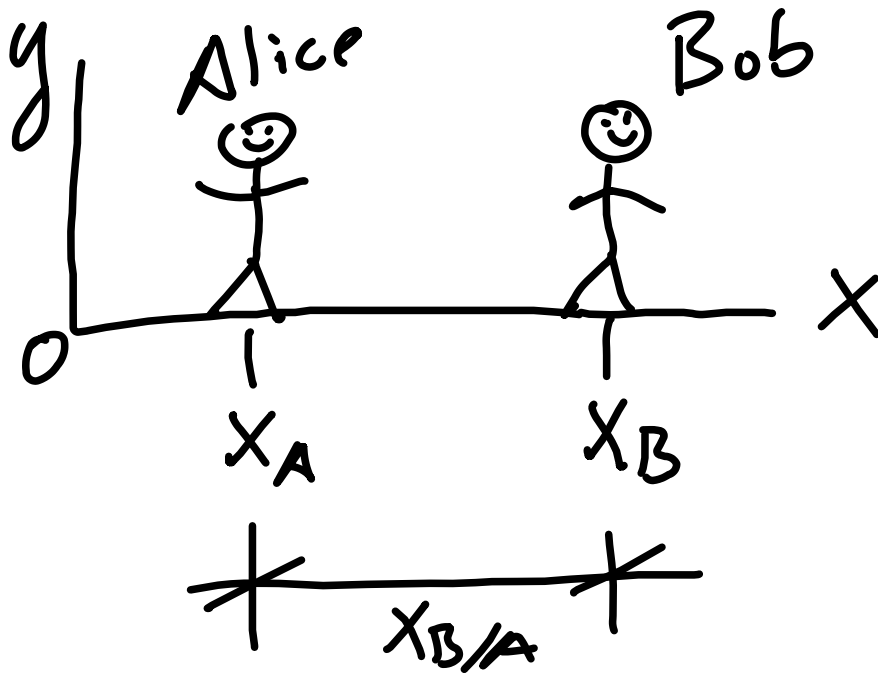
Relative motion 12



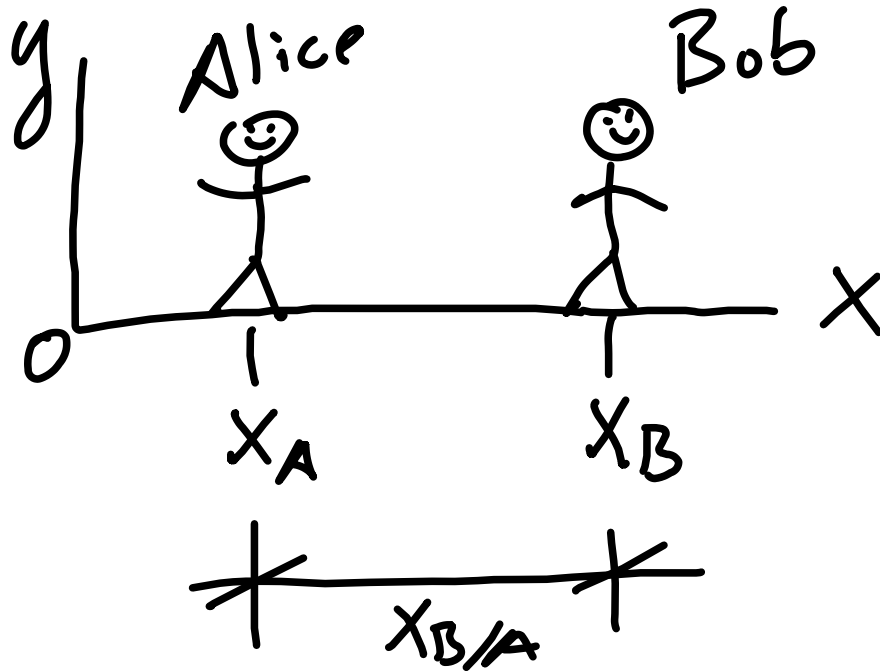
Relative motion 12



Relative motion 12



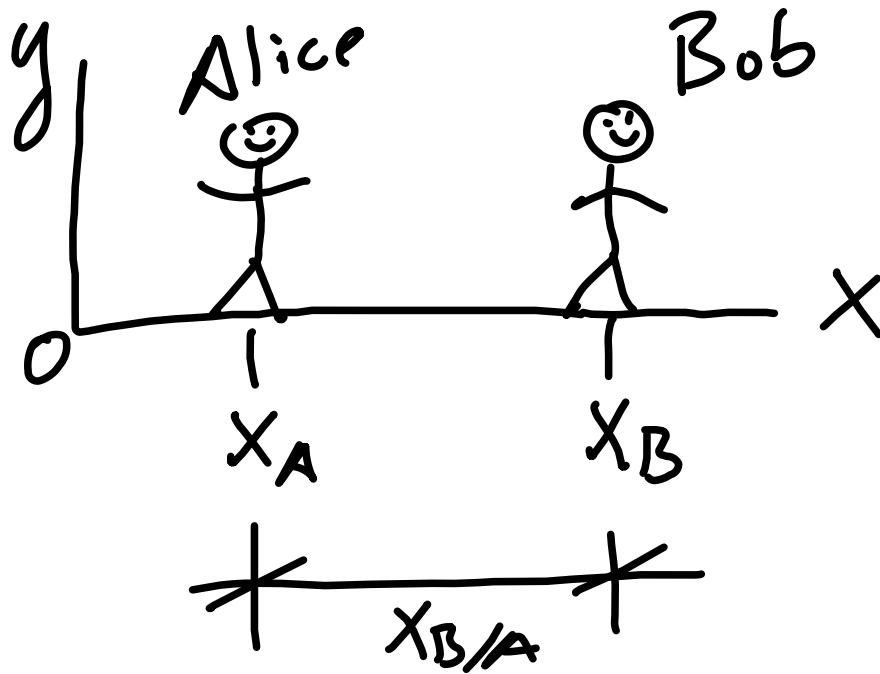
Relative motion 1D



position:

$x_{B/A} \equiv x$ of B
relative to A

Relative motion 1D



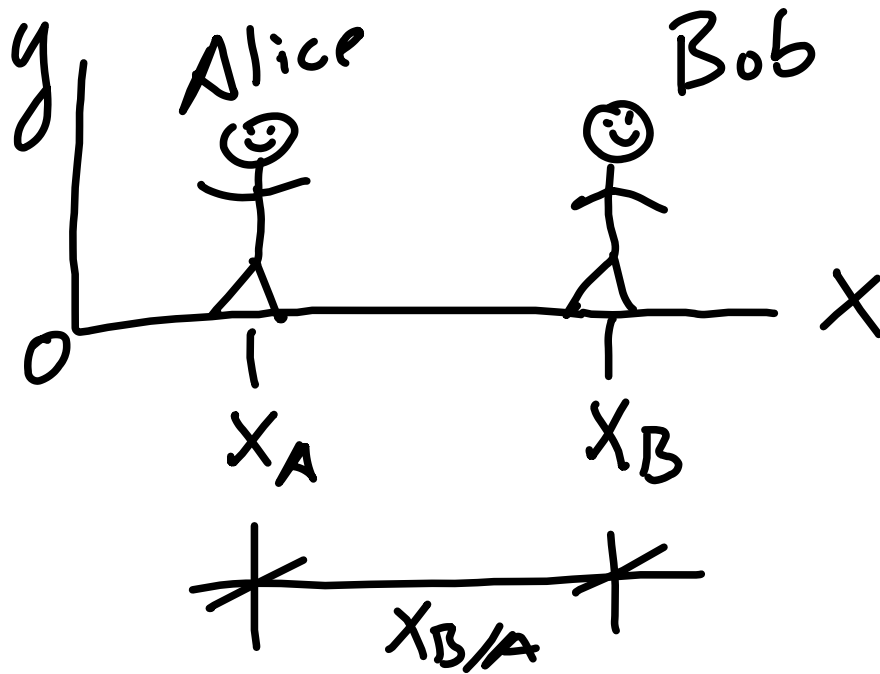
position :

$$x_{B/A} \equiv x \text{ of } B$$

relative to A

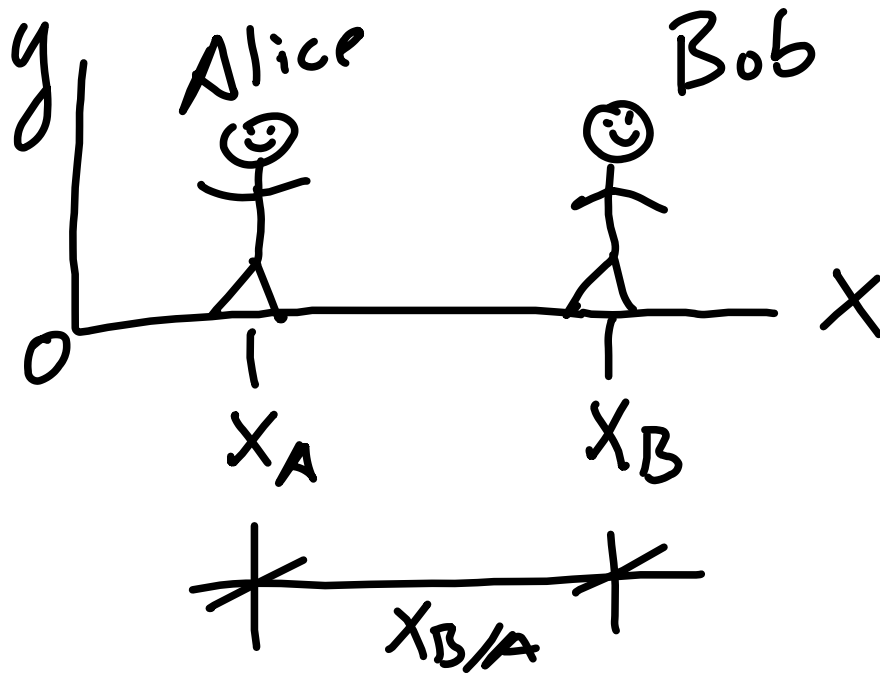
$$\& \ x_{B/A} \equiv x_B - x_A$$

Relative motion 1D



$$\text{Velocity: } \frac{d}{dt} x_{B/A} = \frac{d}{dt} x_B - \frac{d}{dt} x_A$$

Relative motion 1D



position :

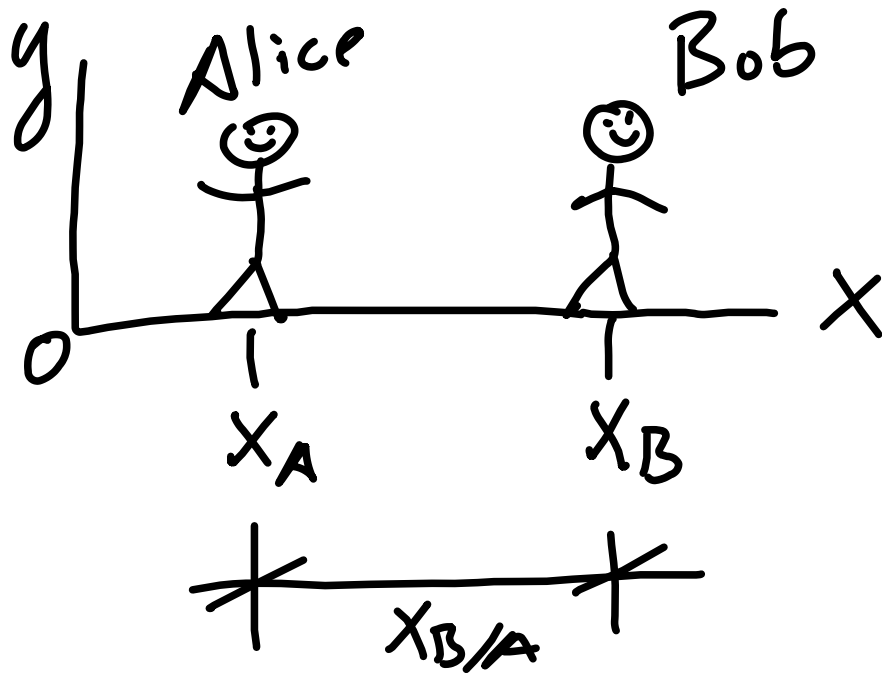
$$x_{B/A} \equiv x \text{ of } B$$

relative to A

$$\& \ x_{B/A} \equiv x_B - x_A$$

$$\text{Velocity : } v_{B/A} = v_B - v_A$$

Relative motion 1D



position:

$$x_{B/A} \equiv x \text{ of } B$$

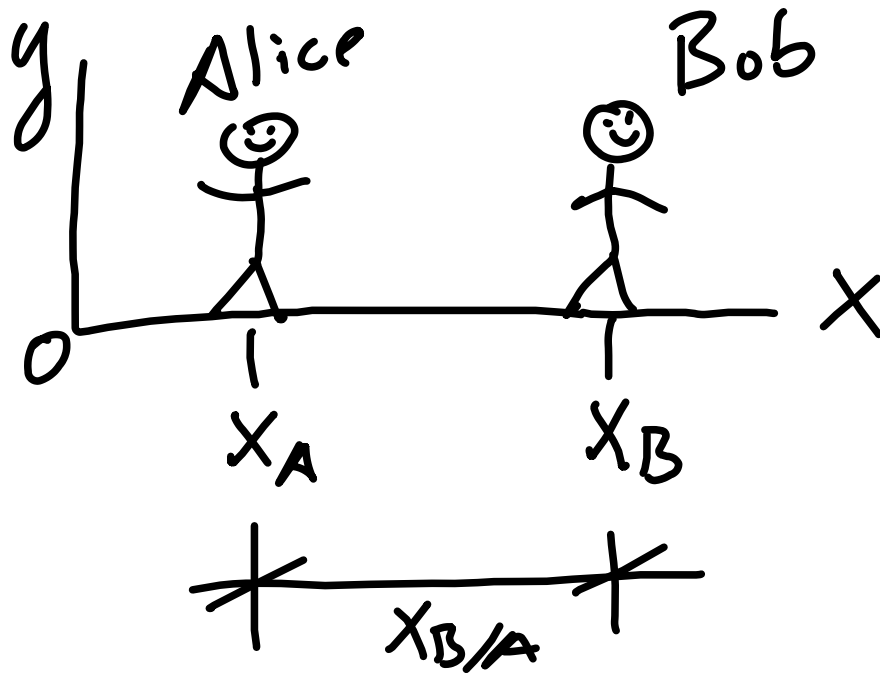
relative to A

$$\neq x_{B/A} \equiv x_B - x_A$$

$$\text{Velocity: } v_{B/A} = v_B - v_A$$

$$\text{acceleration: } \frac{d}{dt} v_{B/A} = \frac{d}{dt} v_B - \frac{d}{dt} v_A$$

Relative motion 1D



position:

$$x_{B/A} \equiv x \text{ of } B$$

relative to A

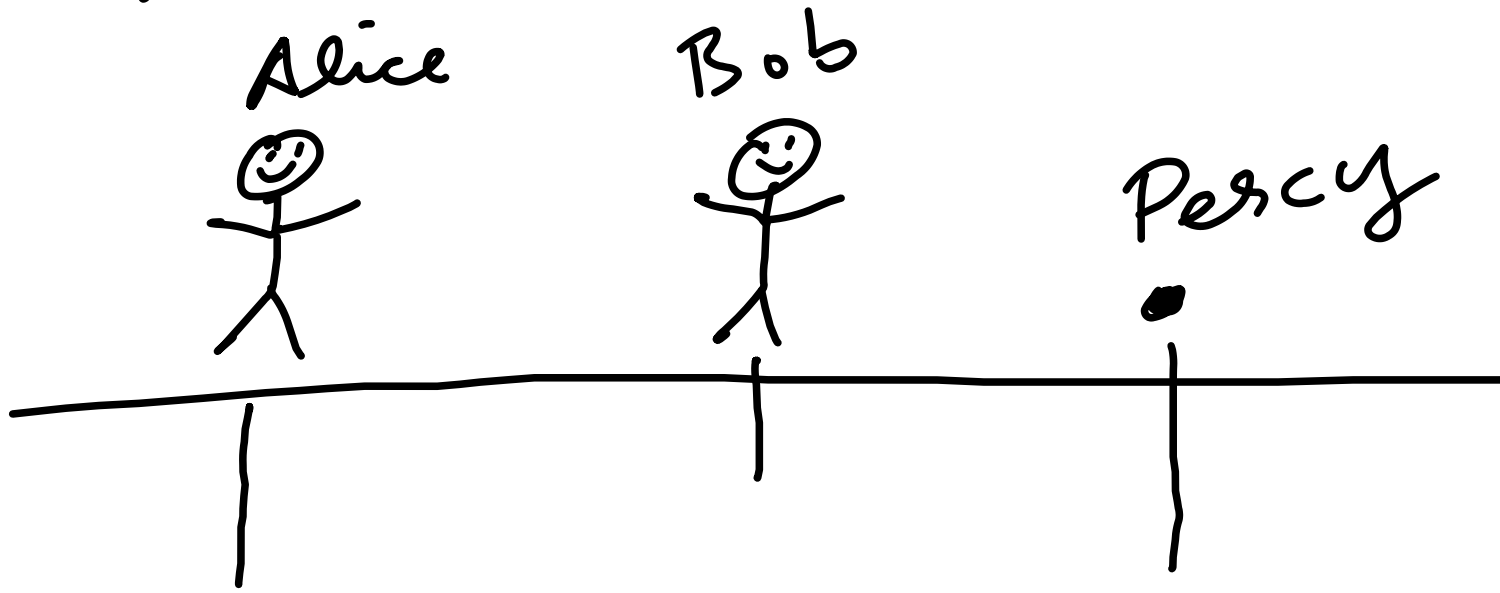
$$\neq x_{B/A} \equiv x_B - x_A$$

$$\text{Velocity: } v_{B/A} = v_B - v_A$$

$$\text{acceleration: } a_{B/A} = a_A - a_B$$

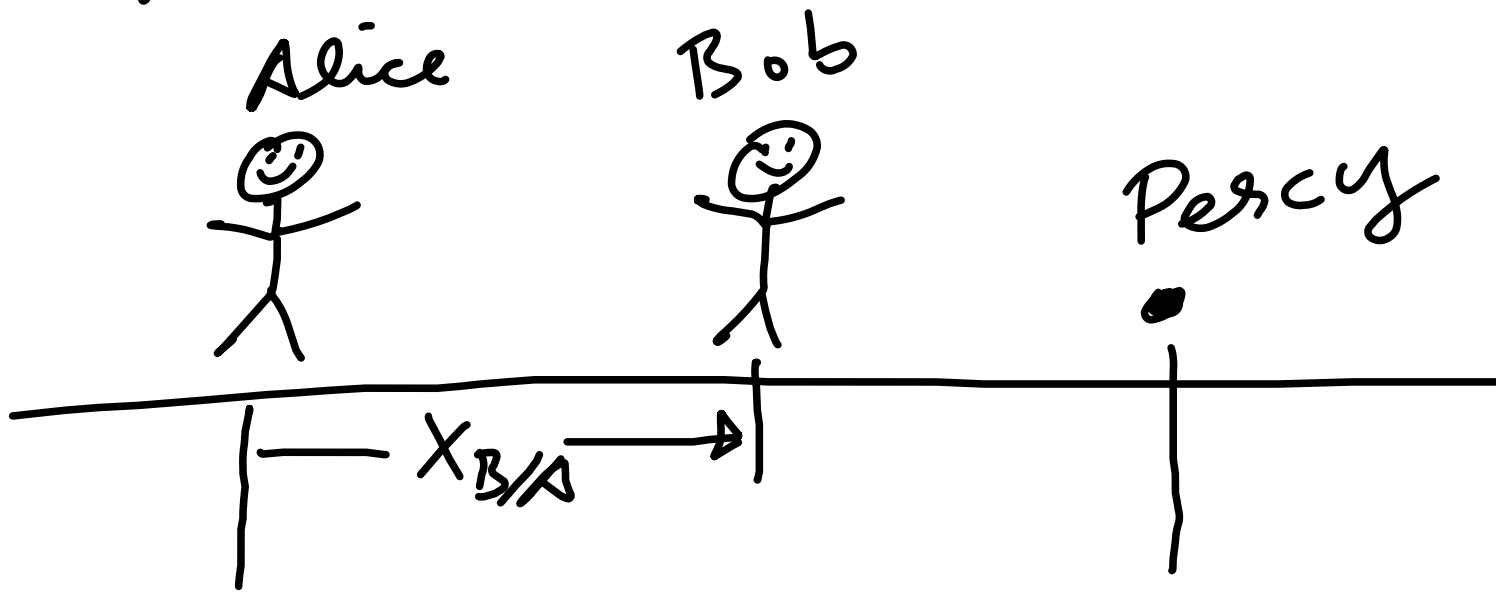
Relative motion 1d

Lets now add in Percy
the point particle



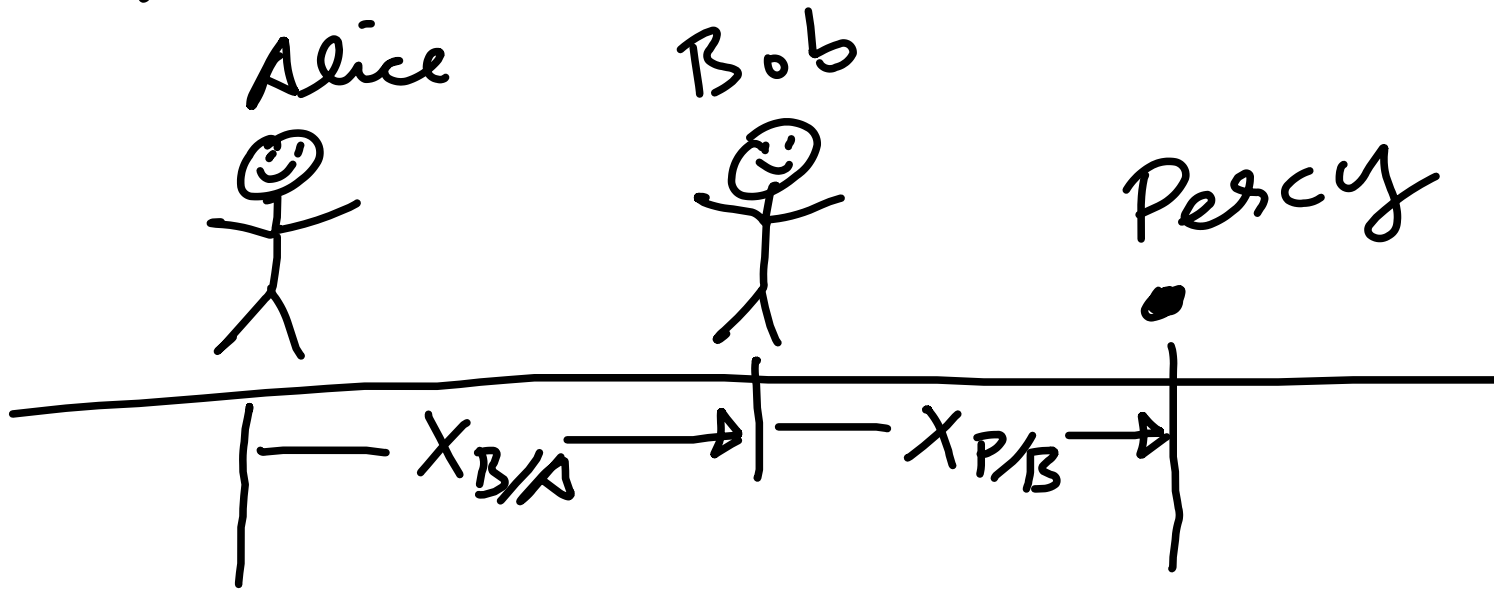
Relative motion 1d

Lets now add in Percy
the point particle



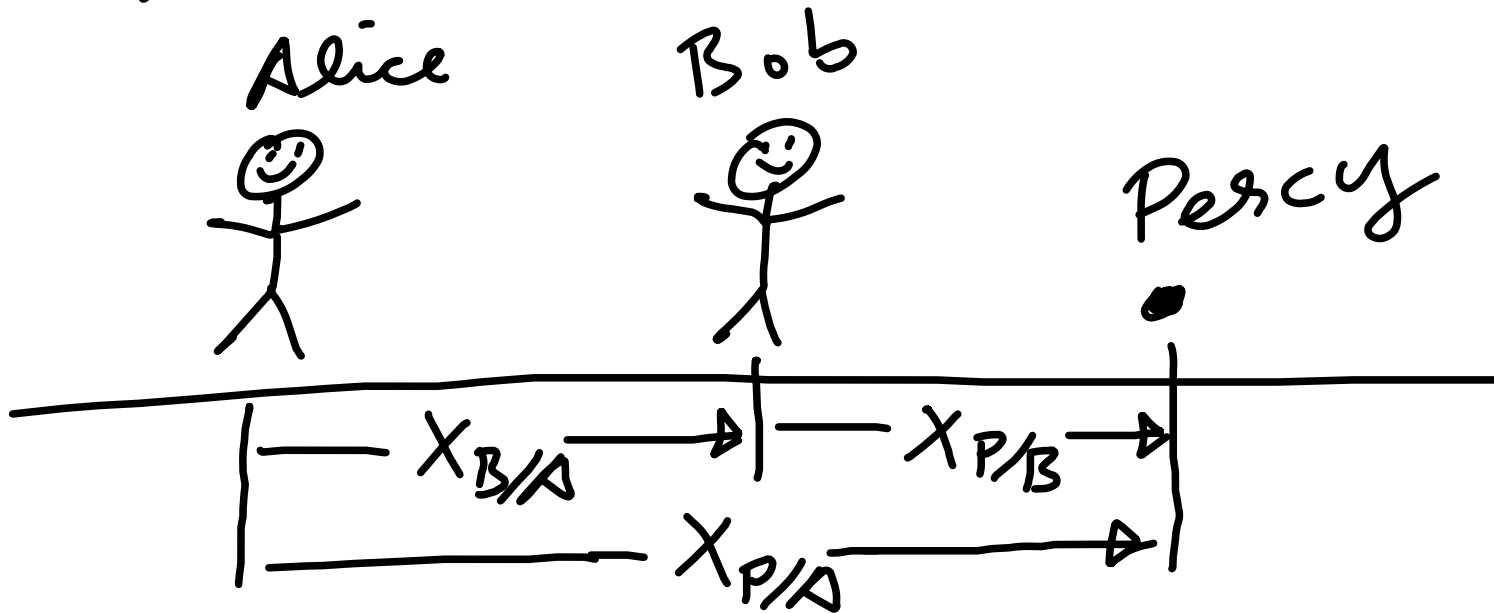
Relative motion 1d

Lets now add in Percy
the point particle



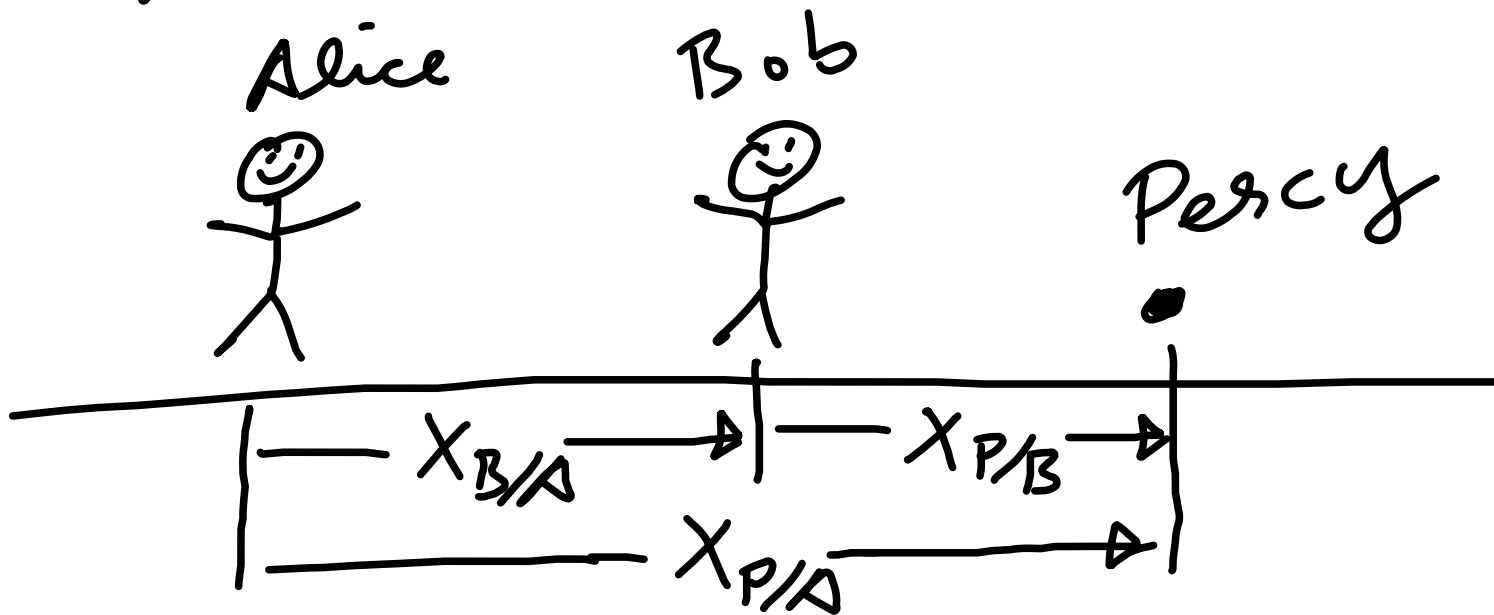
Relative motion 1d

Lets now add in Percy
the point particle



Relative motion 1d

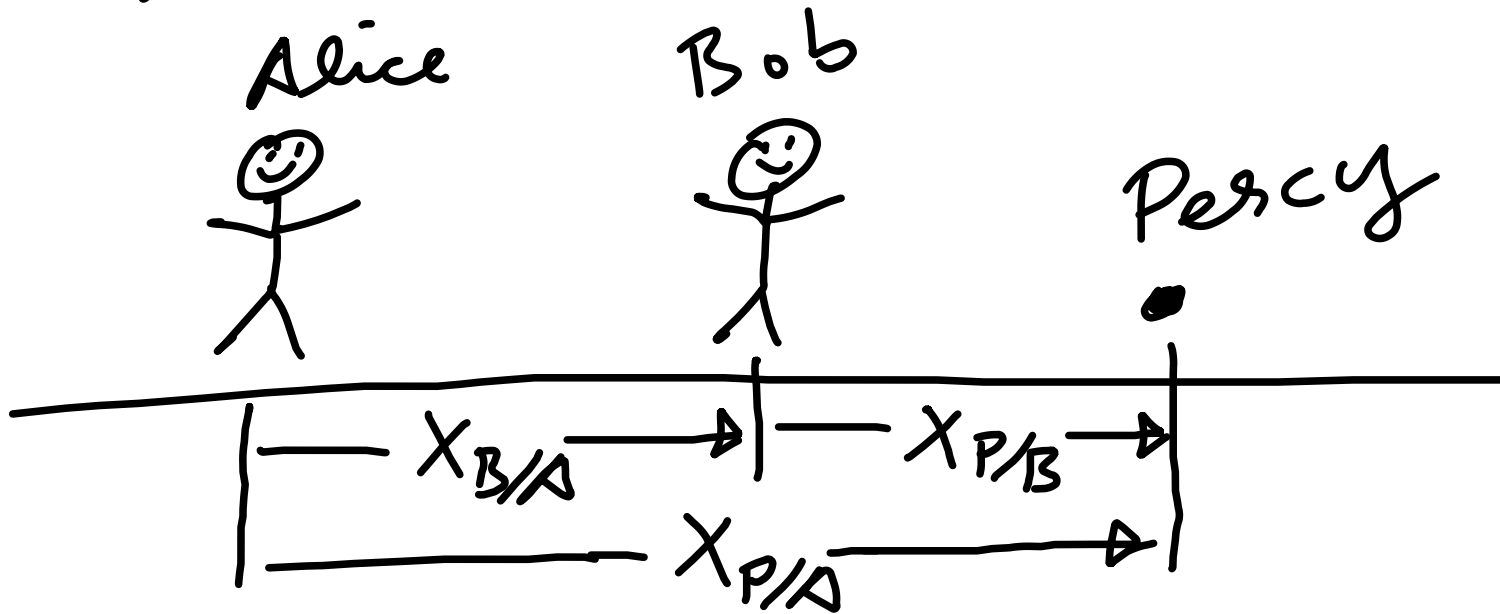
Lets now add in Percy
the point particle



So $X_{P/A} = X_{B/A} + X_{P/B}$

Relative motion 1d

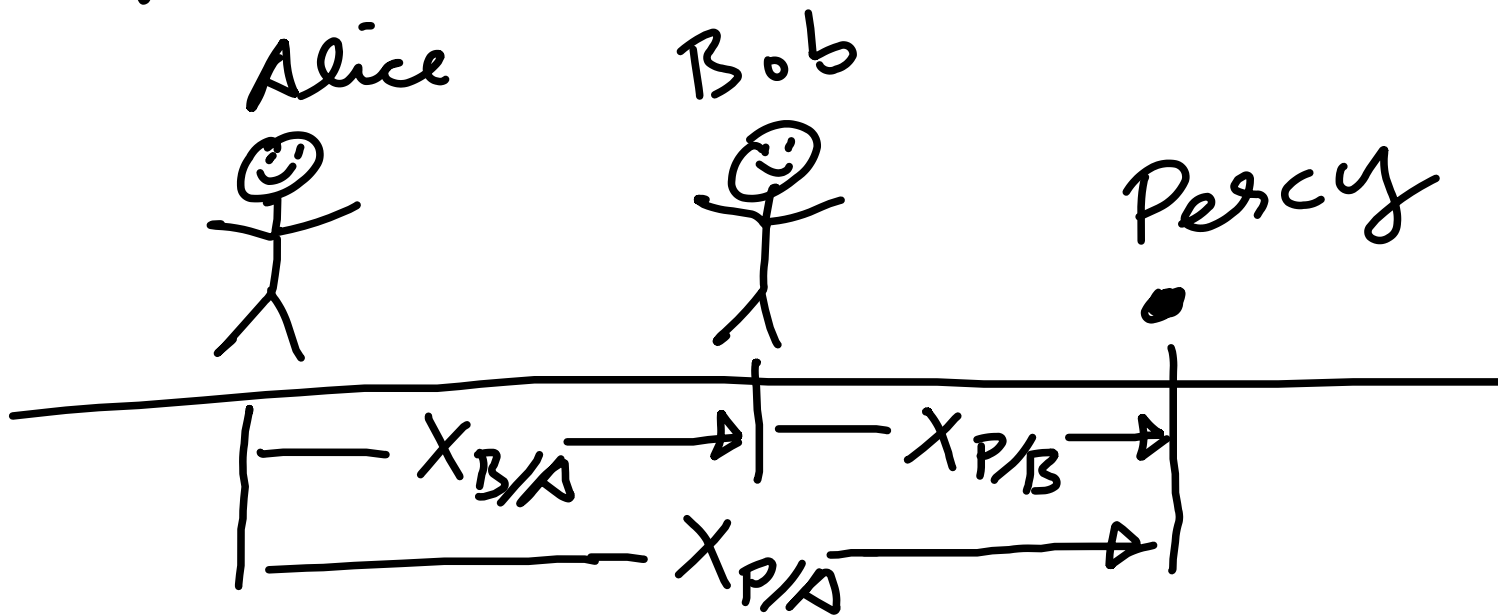
Lets now add in Percy
the point particle



So $X_{P/A}$ = $X_{B/A}$ + $X_{P/B}$ note:

Relative motion 1d

Lets now add in Percy
the point particle

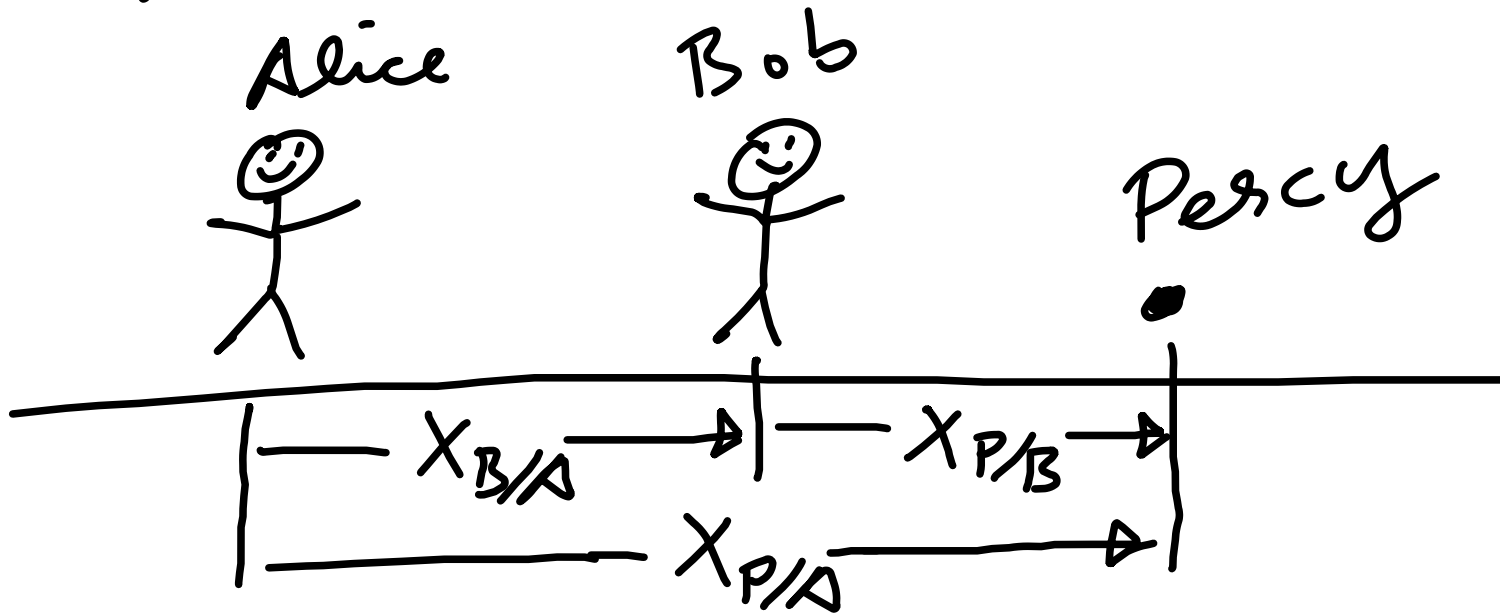


So $X_{P/A} = \underline{X_{B/A}} + X_{P/B}$ note:


 $X_P - X_A = \underline{(X_B - X_A)}$

Relative motion 1d

Lets now add in Percy
the point particle

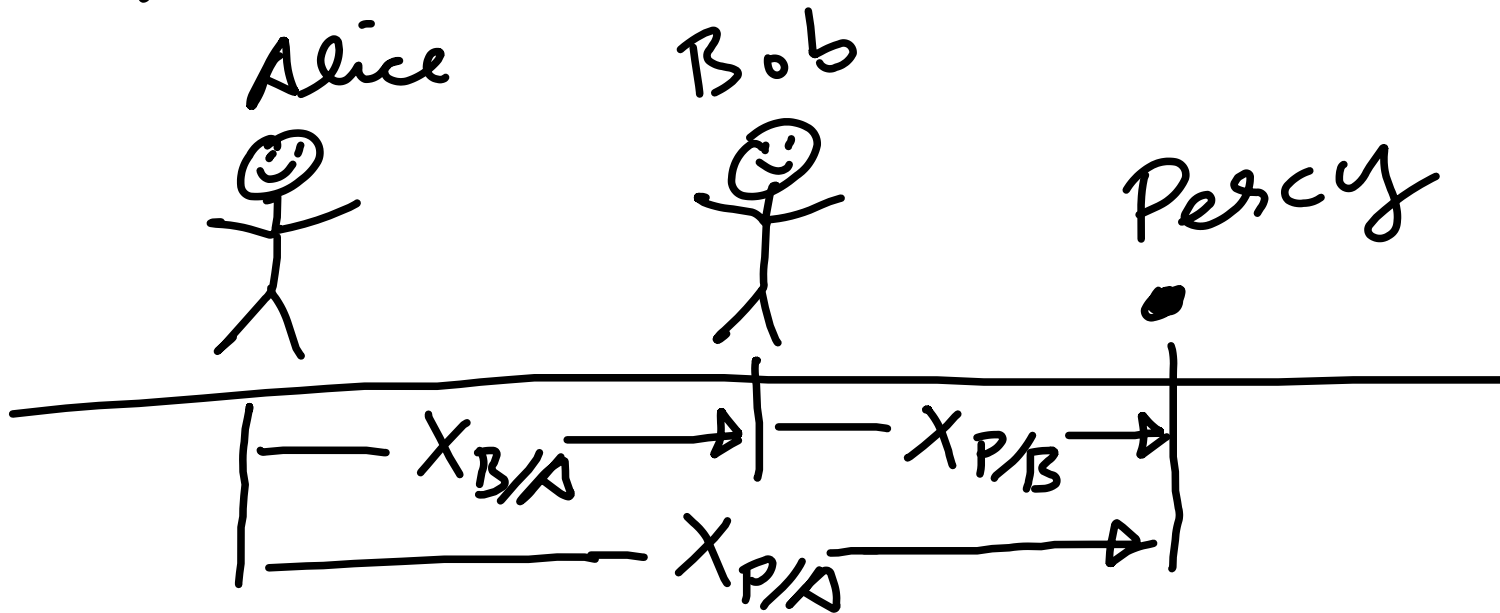


So $X_{P/A} = X_{B/A} + \underline{X_{P/B}}$ note:

 $X_P - X_A = (X_B - X_A) + \underline{(X_P - X_B)}$

Relative motion 1d

Lets now add in Percy
the point particle

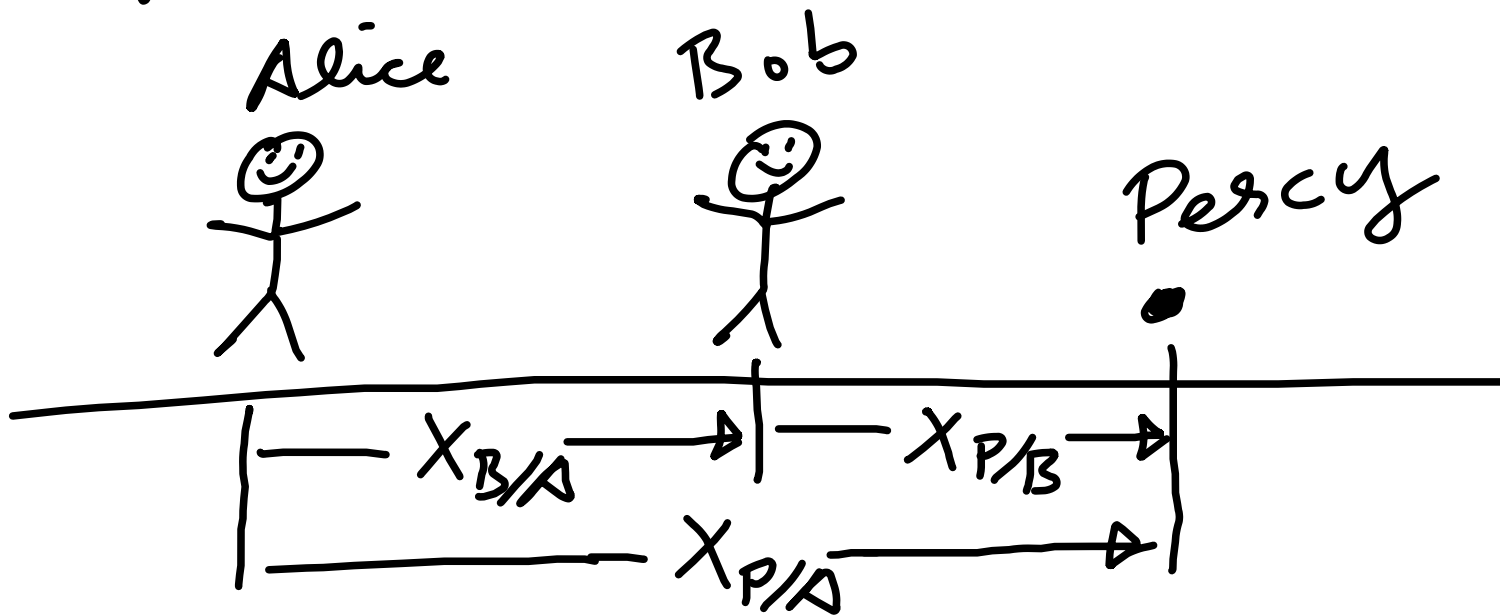


So $X_{P/A} = X_{B/A} + X_{P/B}$ note:

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Relative motion 1d

Lets now add in Percy
the point particle

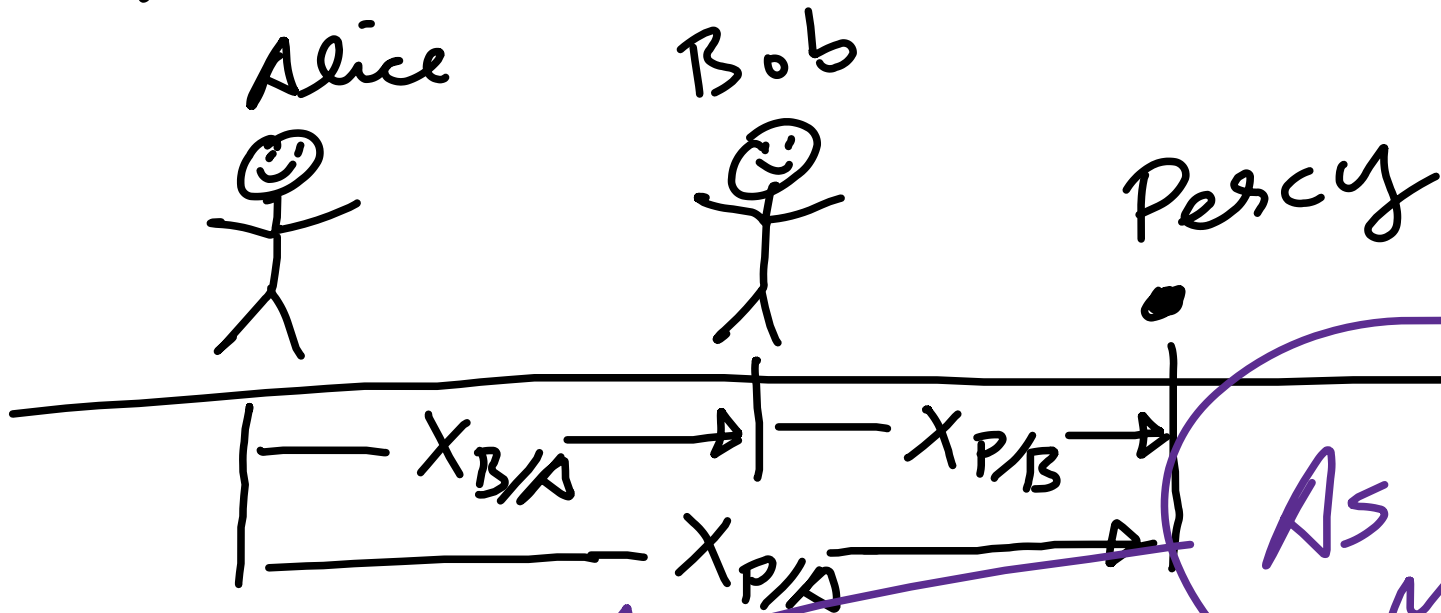


So $X_{P/A} = X_{B/A} + X_{P/B}$ note:

$$X_P - X_A = (X_B - X_A) + (X_P - X_B) = X_P - X_A$$

Relative motion 1d

Lets now add in Percy
the point particle



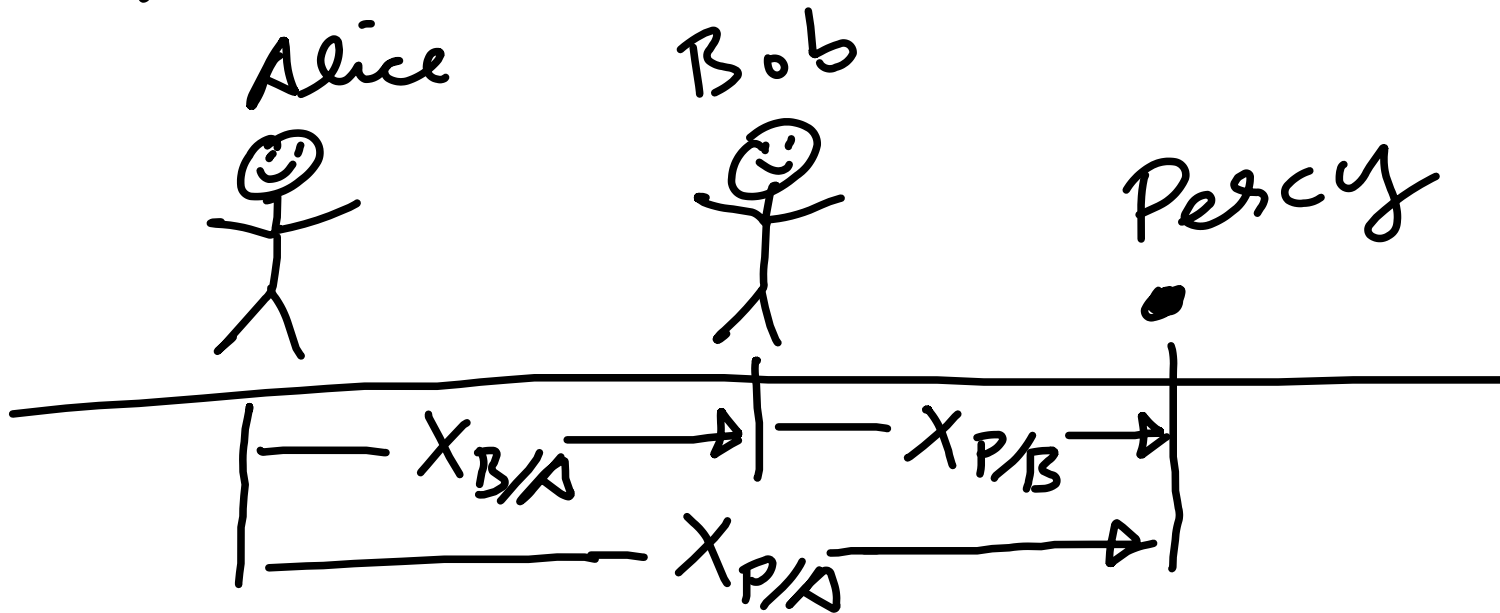
So $X_{P/A} = X_{B/A} + X_{P/B}$

Note:

$$X_P - X_A = (X_B - X_A) + (X_P - X_B) = X_P - X_A$$

Relative motion 1d

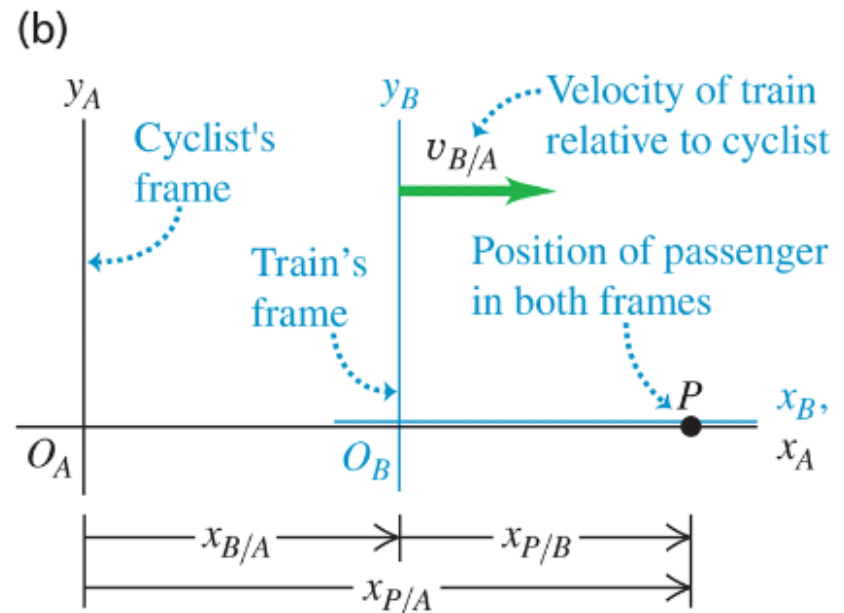
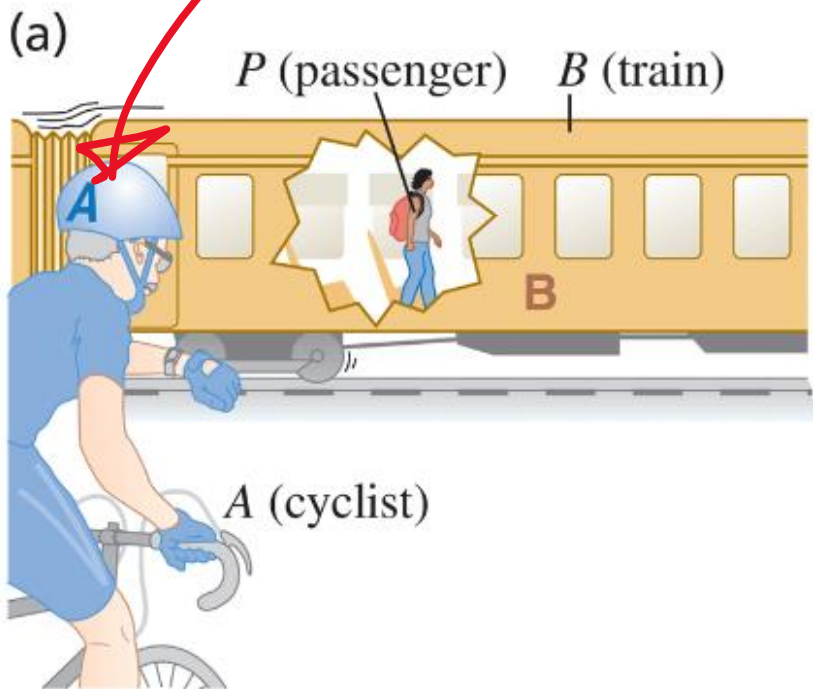
Lets now add in Percy
the point particle



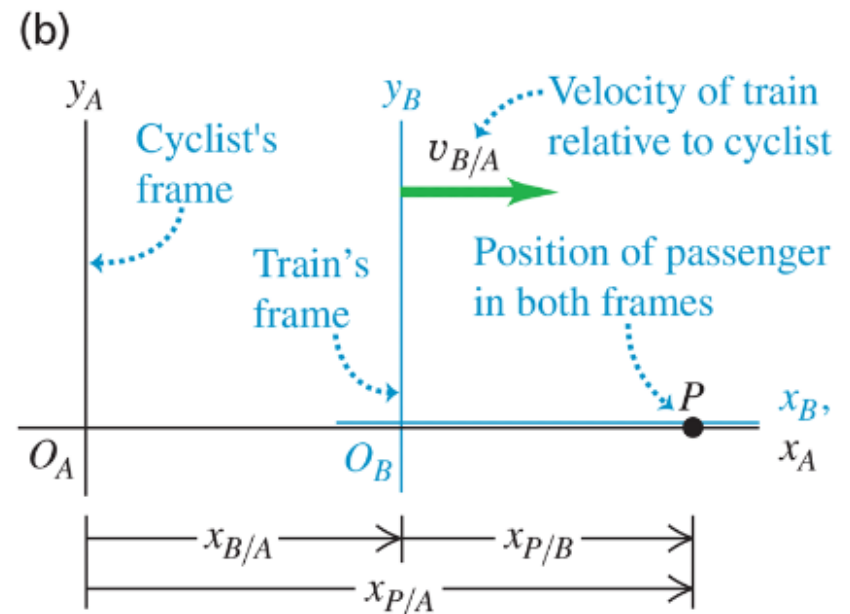
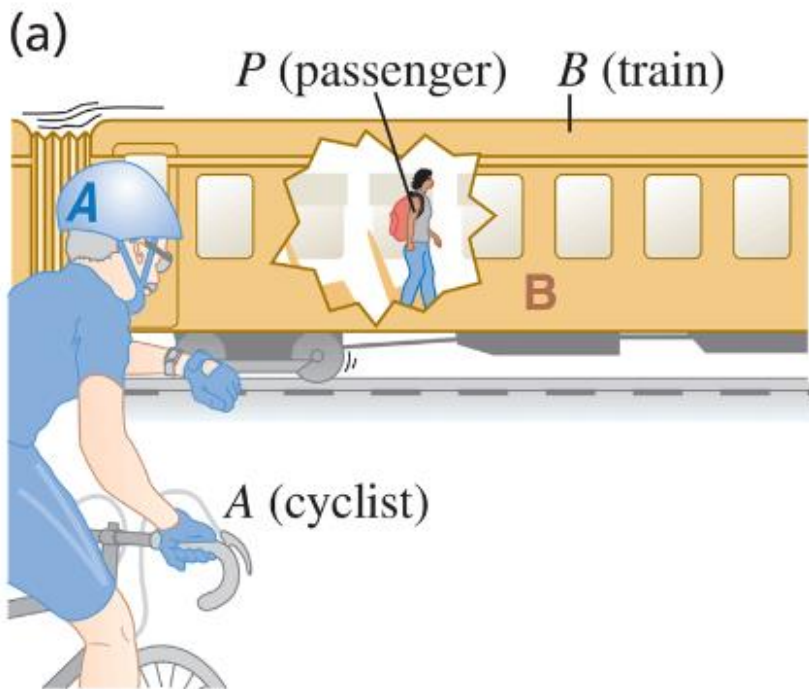
We can now describe the position
of point P as described by Alice's
coordinate system or Bob's

A passenger walks with a velocity of $+1.0 \text{ m/s}$ along the aisle of a train that is moving with a velocity of $+3.0 \text{ m/s}$

Stationary cyclist

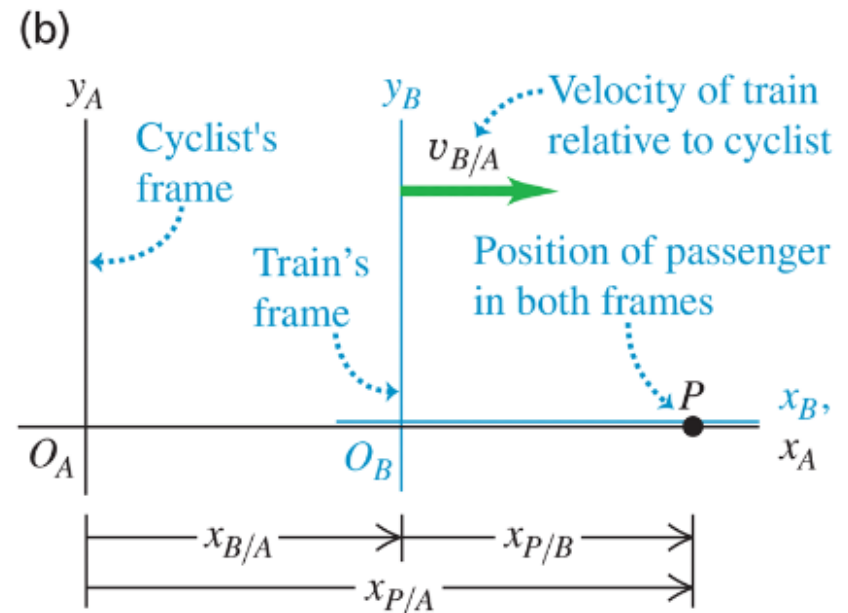
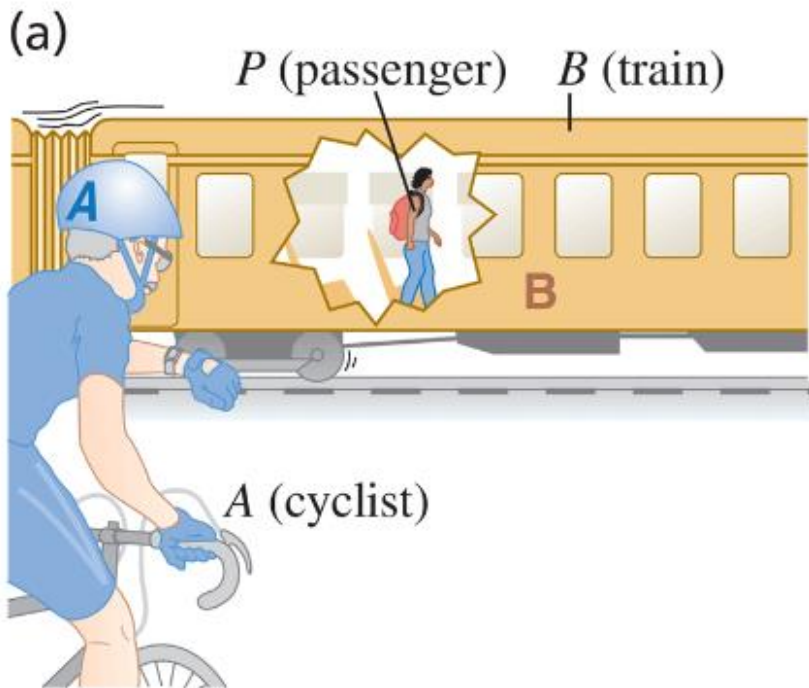


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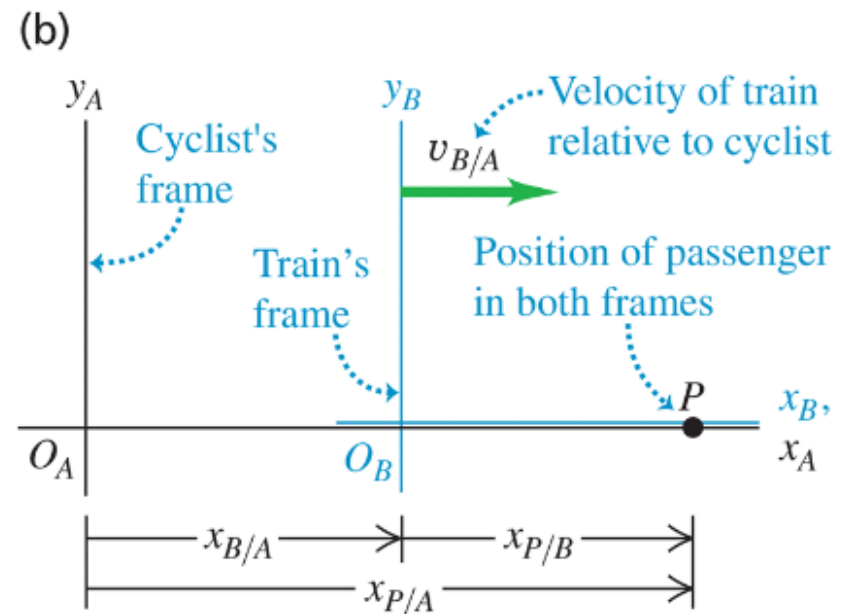
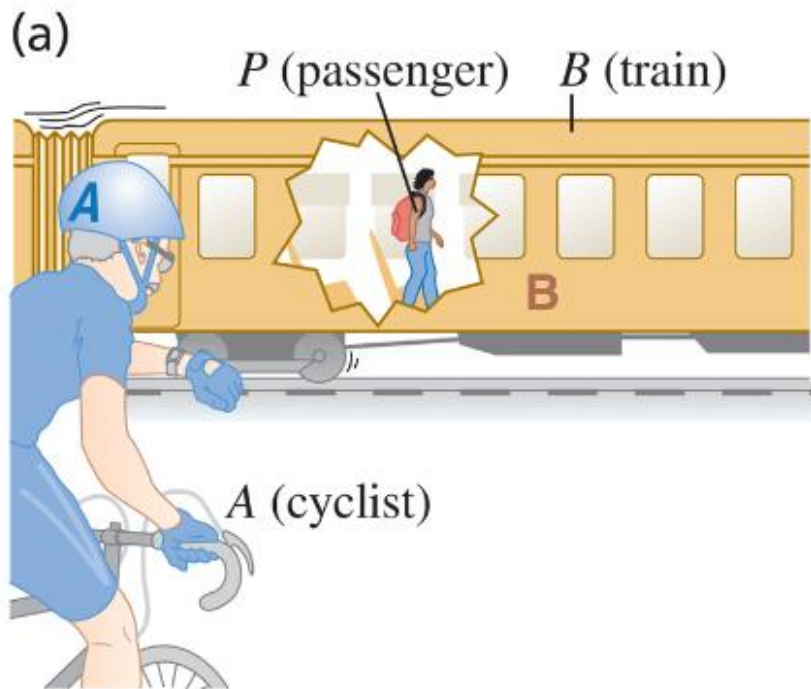
A passenger walks with a velocity of $+1.0 \text{ m/s}$ along the aisle of a train that is moving with a velocity of $+3.0 \text{ m/s}$

$$V_{P/B} = 1 \text{ m/s}$$



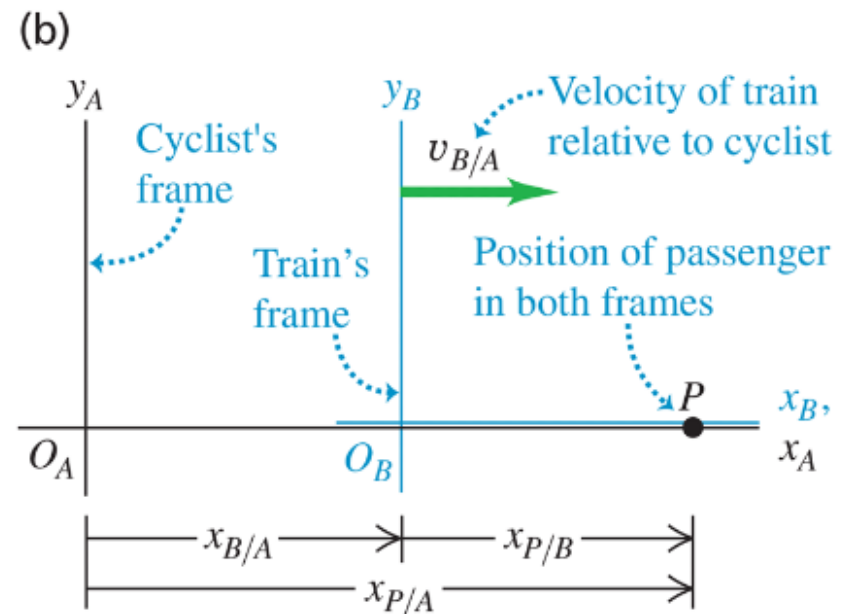
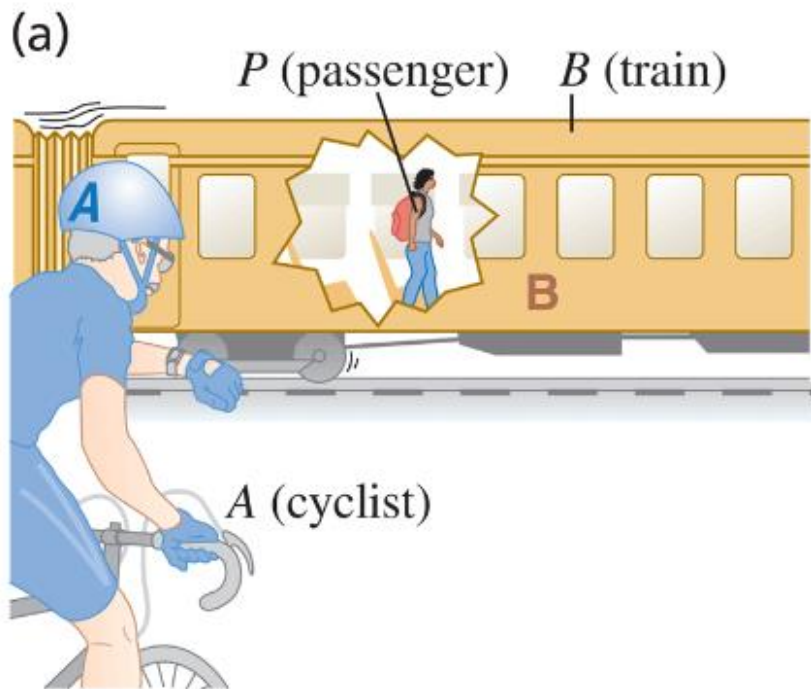
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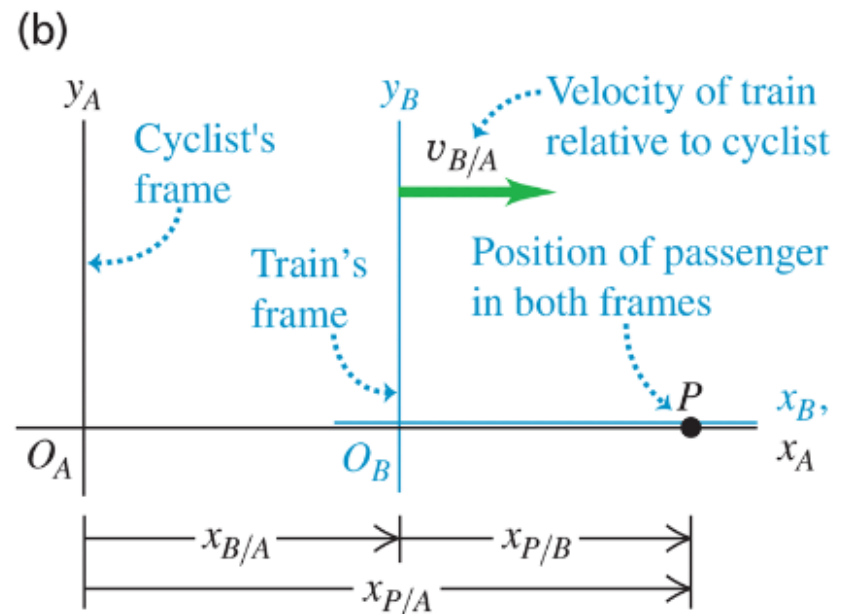
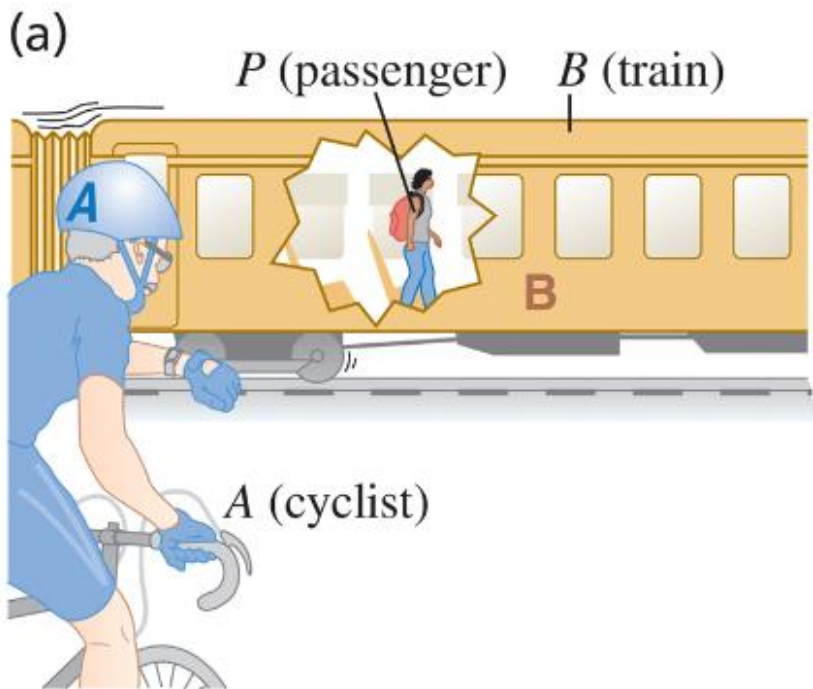
$$V_{P/B} = 1 \text{ m/s}, \quad V_{B/A} = 3 \text{ m/s}$$



A passenger walks with a velocity of $+1.0 \text{ m/s}$ along the aisle of a train that is moving with a velocity of $+3.0 \text{ m/s}$

$$v_{P/B} = 1 \text{ m/s}, \quad v_{B/A} = 3 \text{ m/s}$$

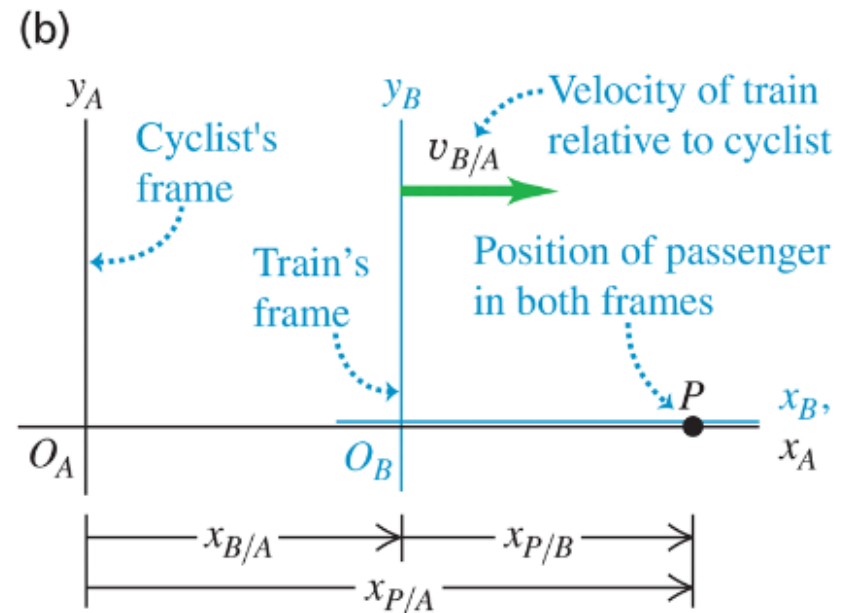
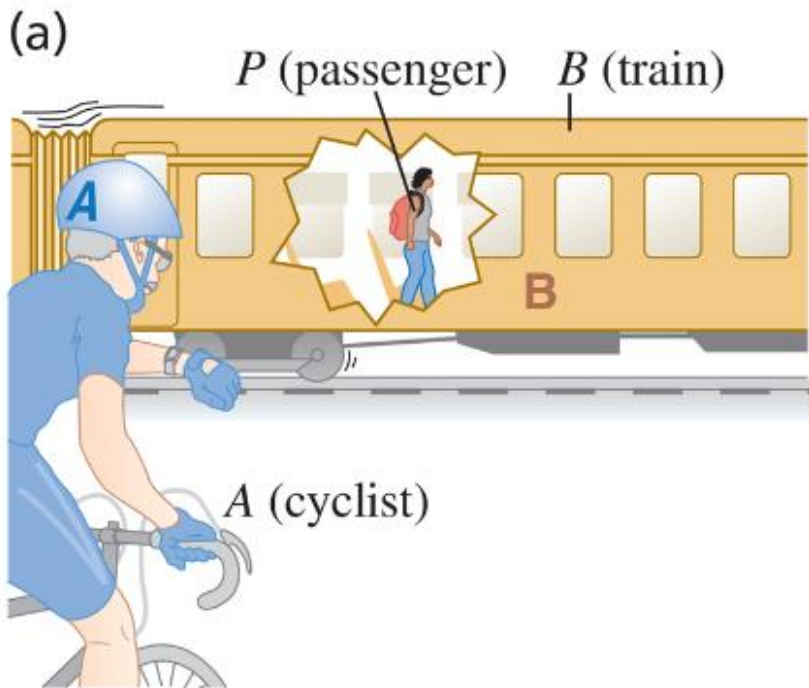
Find $v_{P/A}$:



A passenger walks with a velocity of $+1.0 \text{ m/s}$ along the aisle of a train that is moving with a velocity of $+3.0 \text{ m/s}$

$$v_{P/B} = 1 \text{ m/s}, \quad v_{B/A} = 3 \text{ m/s}$$

Find $v_{P/A}$: $v_{P/A} = v_{P/B} + v_{B/A}$

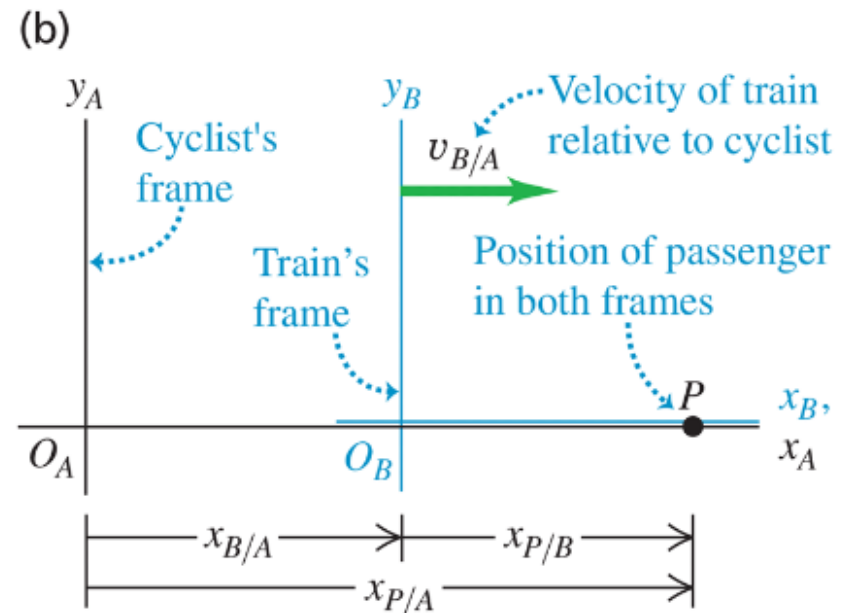
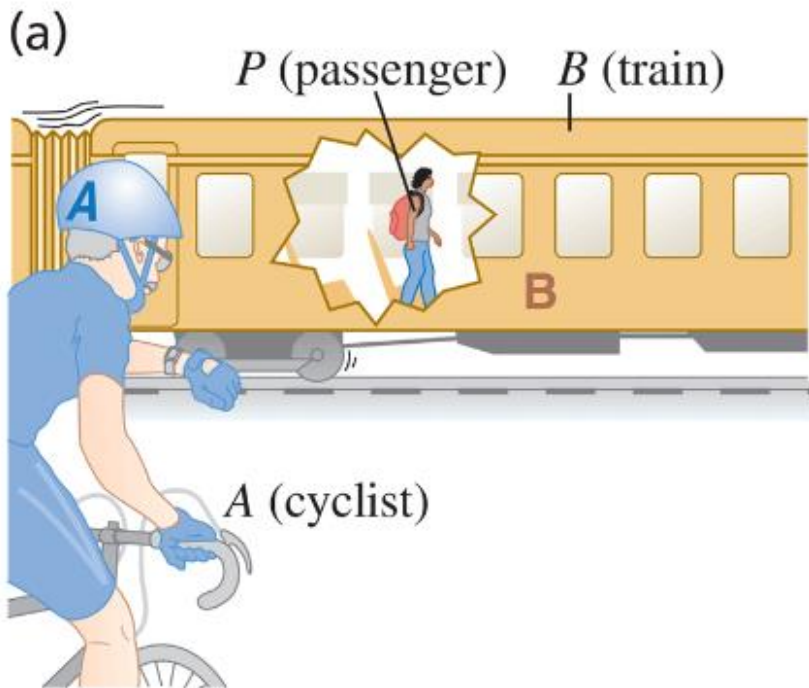


A passenger walks with a velocity of $+1.0 \text{ m/s}$ along the aisle of a train that is moving with a velocity of $+3.0 \text{ m/s}$

$$v_{P/B} = 1 \text{ m/s}, \quad v_{B/A} = 3 \text{ m/s}$$

Find $v_{P/A}$: $v_{P/A} = v_{P/B} + v_{B/A}$

$$\Rightarrow v_{P/A} = 1 \text{ m/s} + 3 \text{ m/s}$$

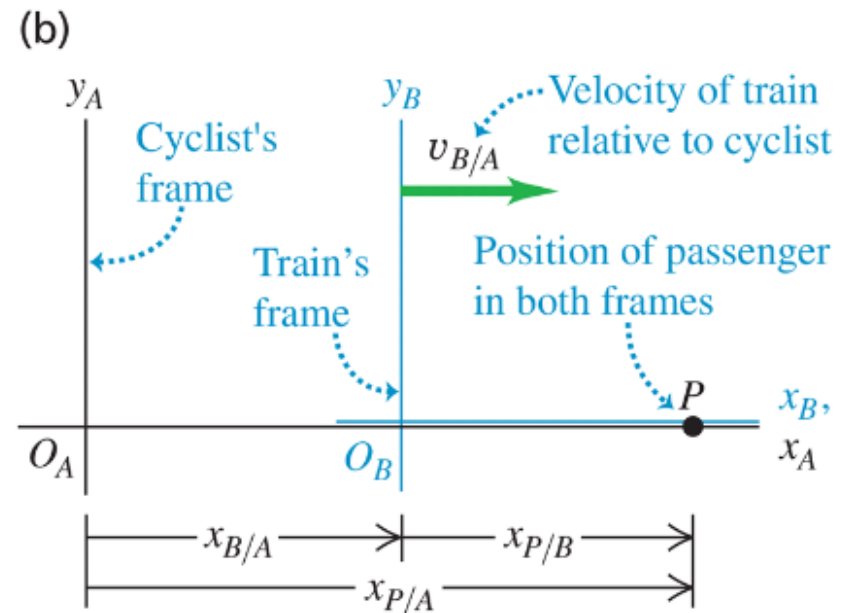
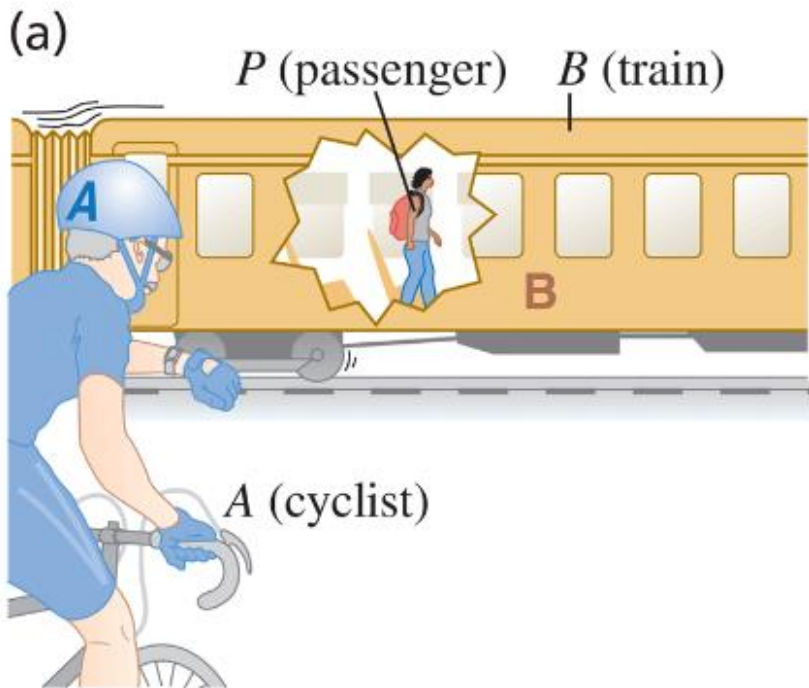


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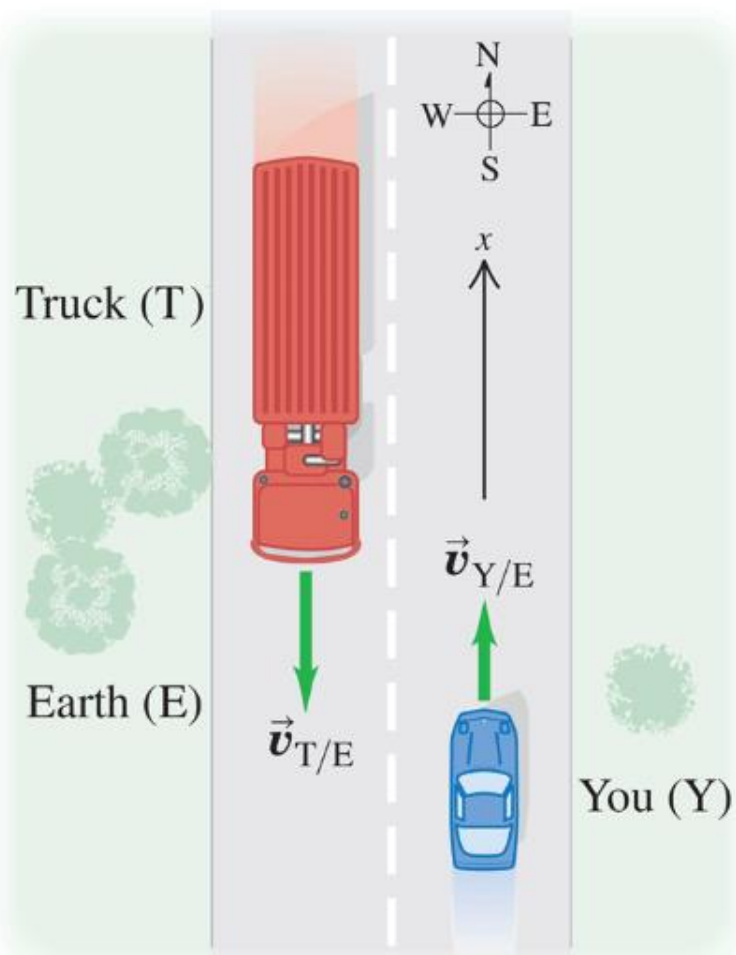
$$v_{P/B} = 1 \text{ m/s}, \quad v_{B/A} = 3 \text{ m/s}$$

Find $v_{P/A}$: $v_{P/A} = v_{P/B} + v_{B/A}$

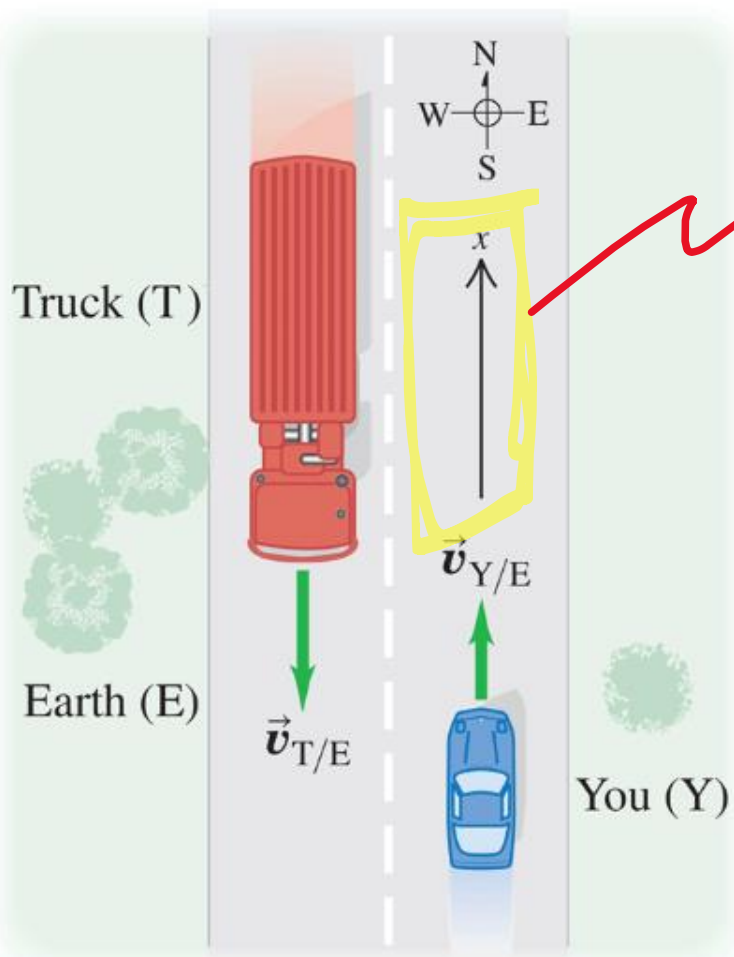
$$\Rightarrow v_{P/A} = 1 \text{ m/s} + 3 \text{ m/s} = 4 \text{ m/s}$$



You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.

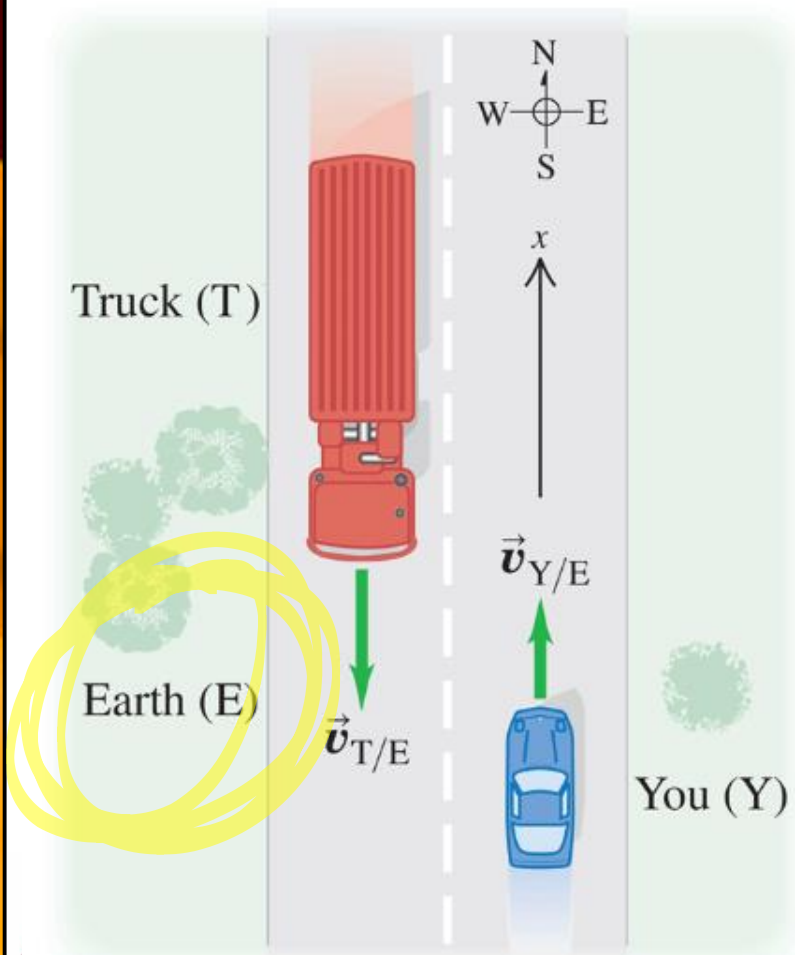


You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.

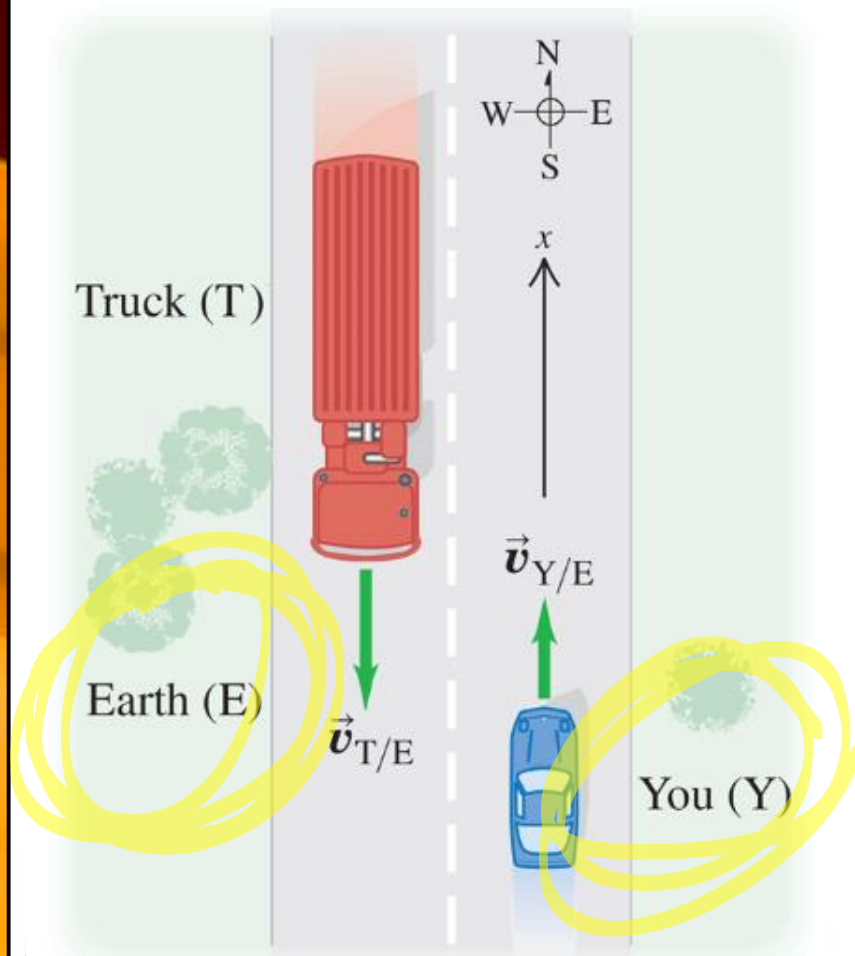


Use coordinate system shown instead of N, S, E, W

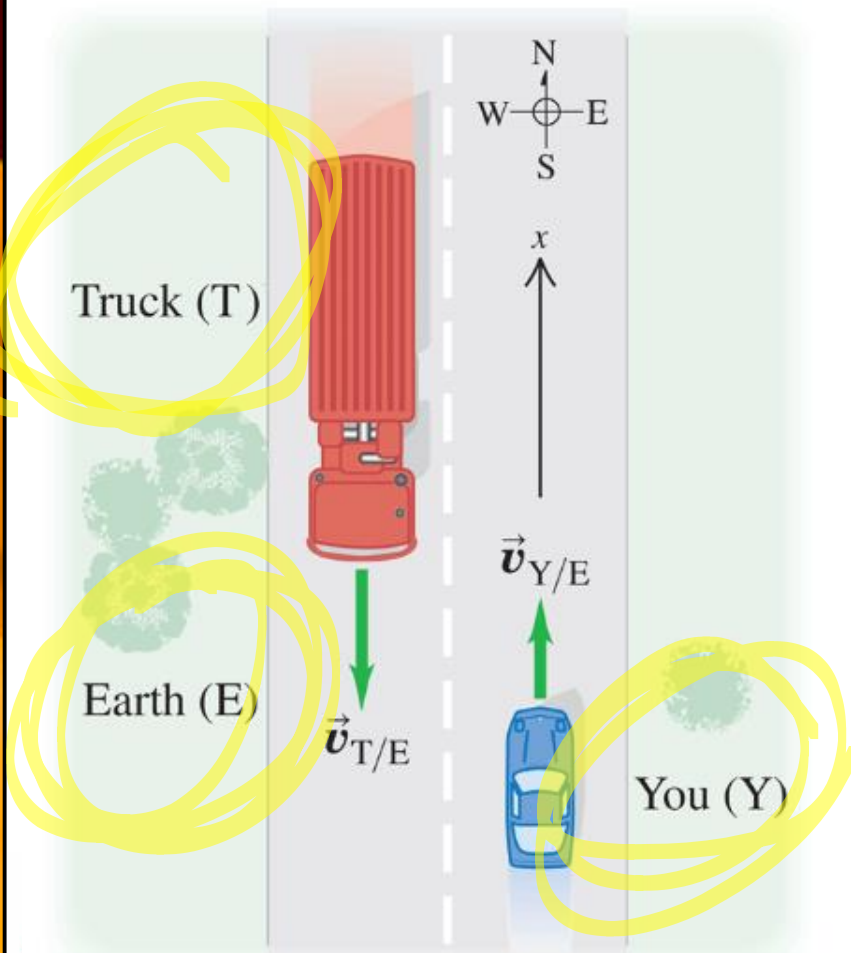
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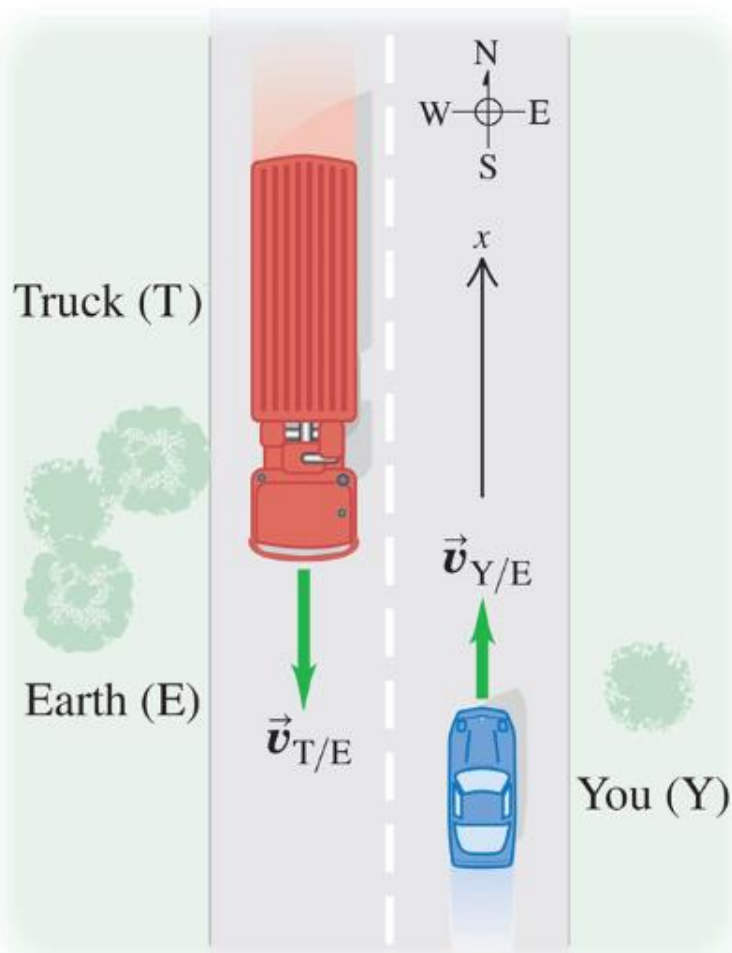
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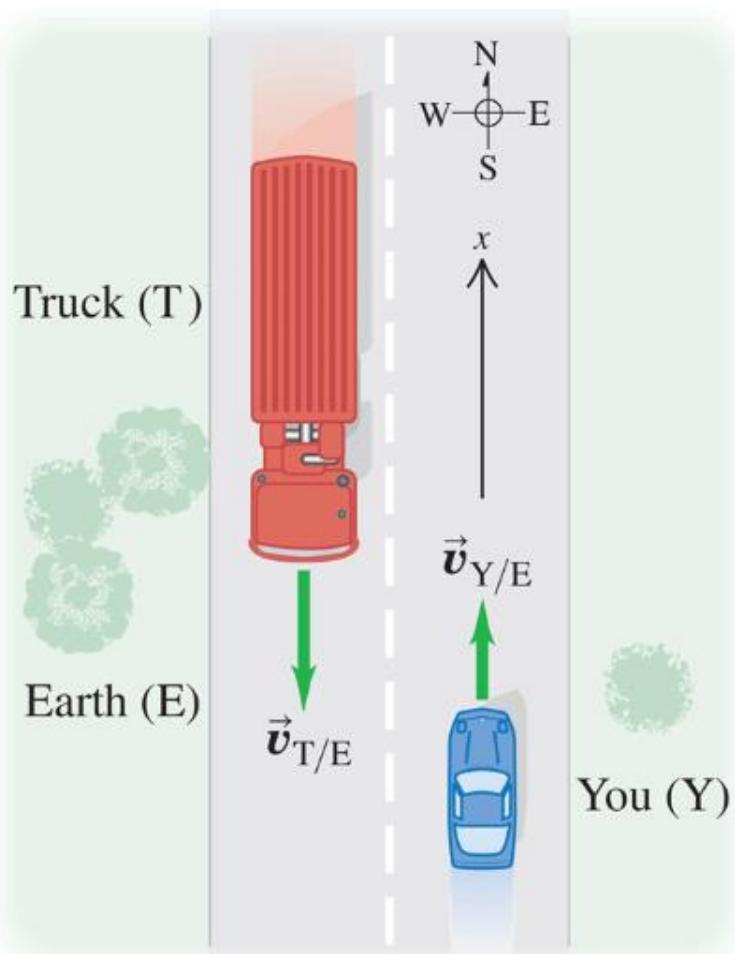


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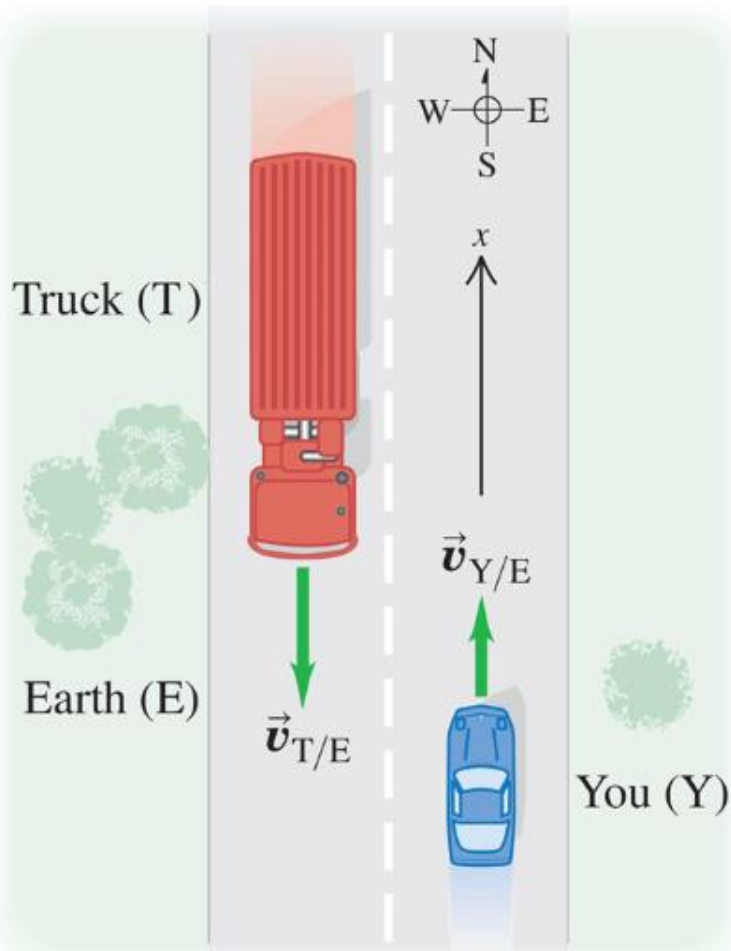
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$$v_{Y/E} = 88 \text{ km/h}$$

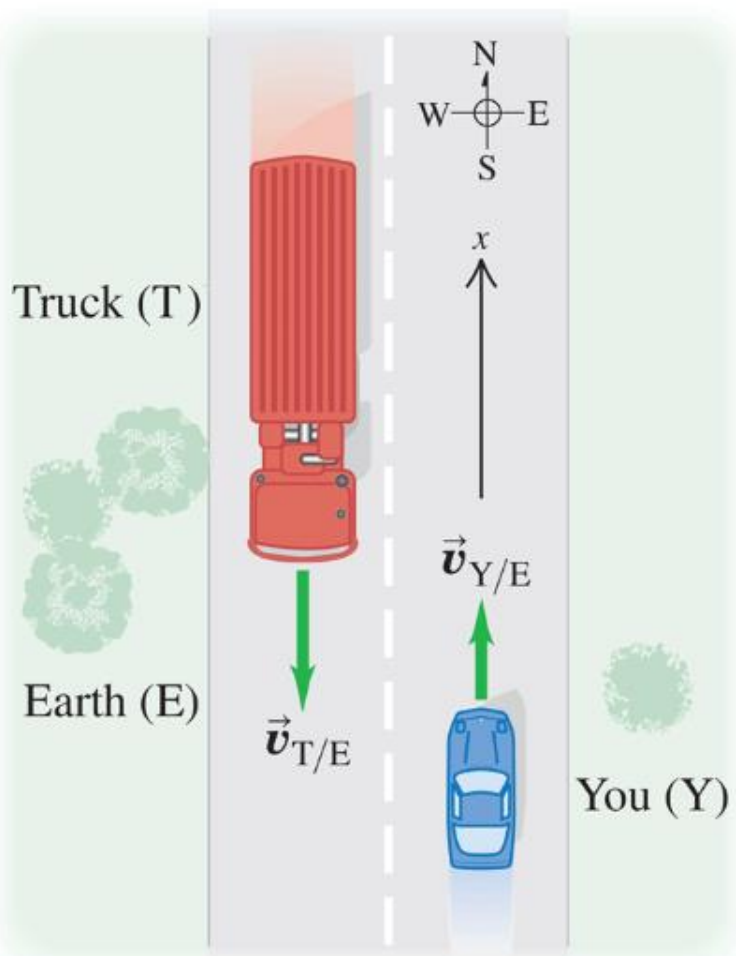


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$$v_{Y/E} = 88 \text{ km/h}$$



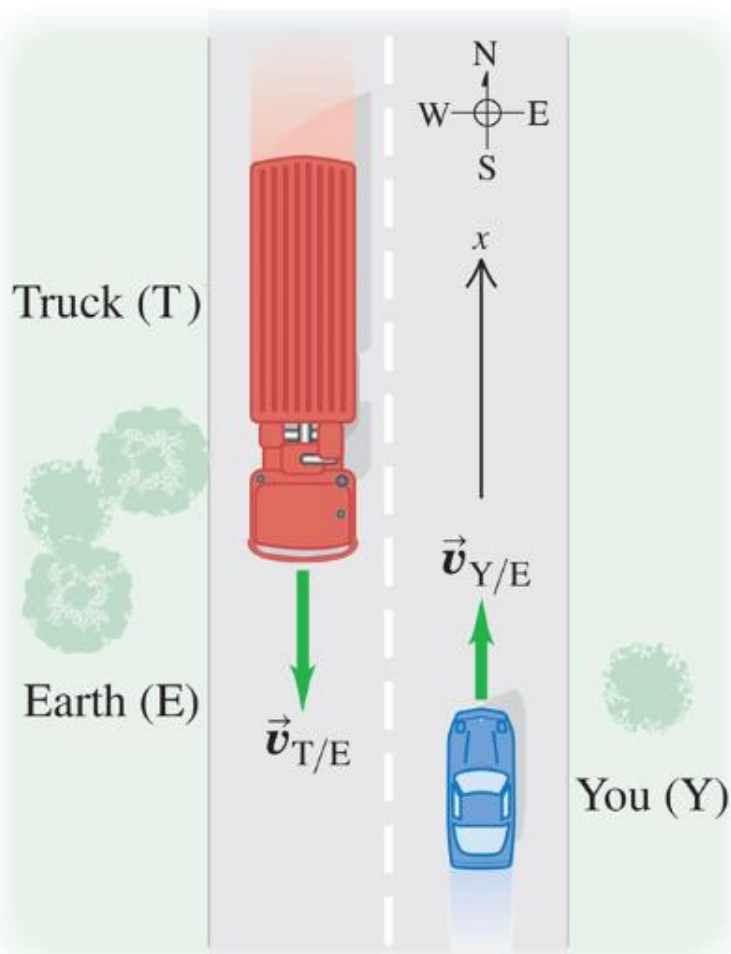
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$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

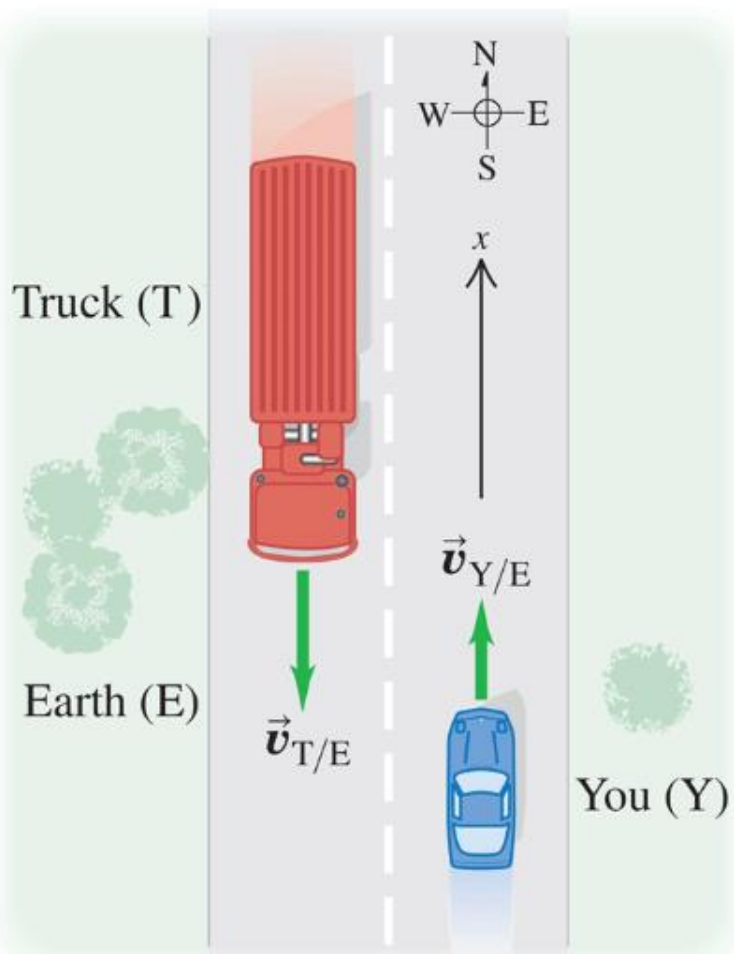
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$$v_{Y/E} = 88 \text{ km/h}$$

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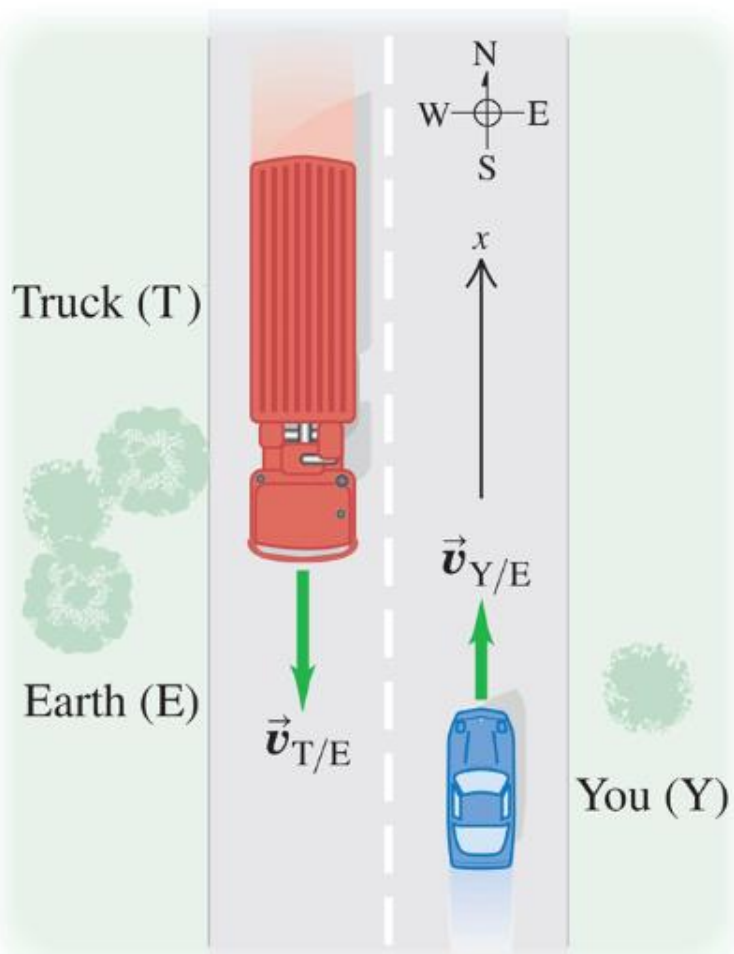


$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/Y}$:

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



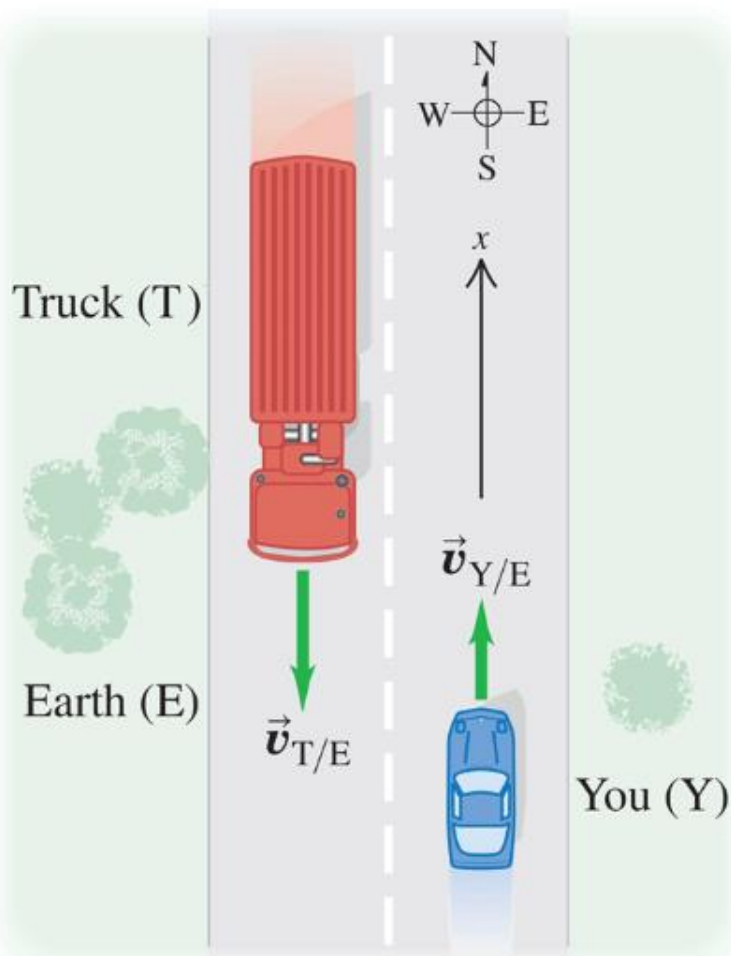
$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/Y}$:

$$v_{T/Y} = v_{T/E} + v_{E/Y}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{y/\epsilon} = 88 \text{ km/h}$$

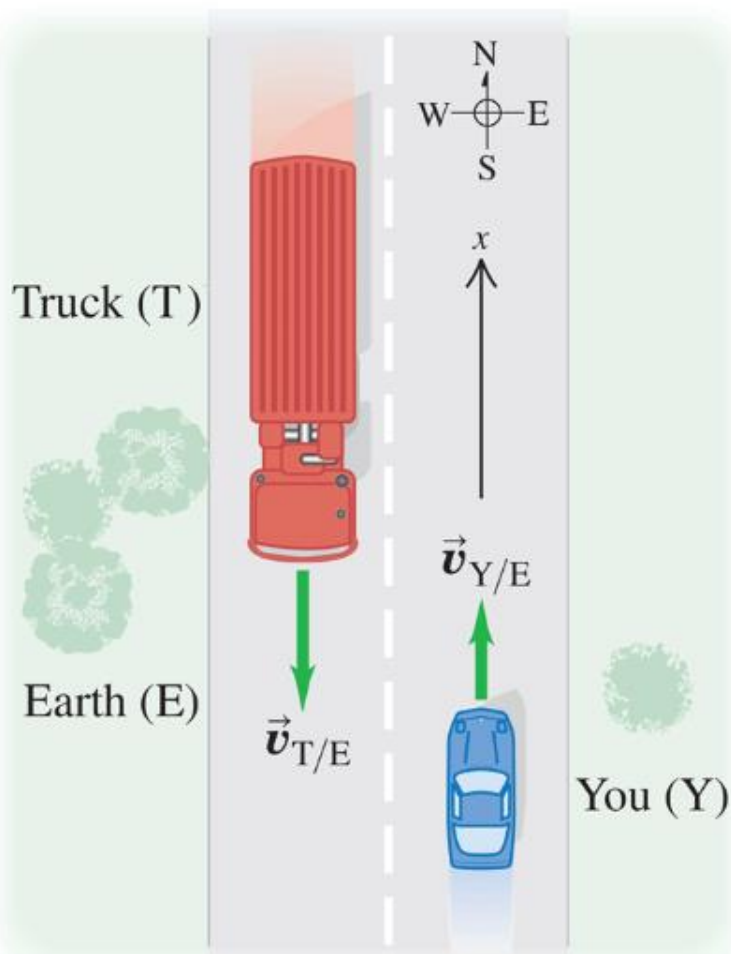
$$v_{T/\epsilon} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/y}$:

$$v_{T/y} = v_{T/\epsilon} + v_{\epsilon/y}$$

Note $v_{\epsilon/y} = v_{\epsilon} - v_y$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{Y/E} = 88 \text{ km/h}$$

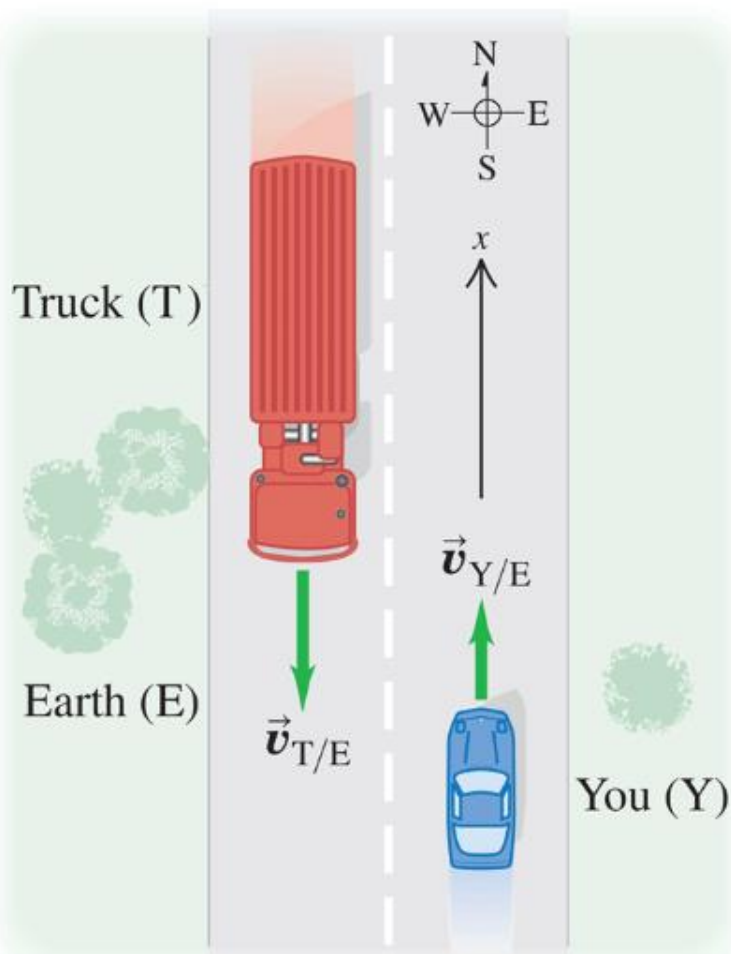
$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/Y}$:

$$v_{T/Y} = v_{T/E} + v_{E/Y}$$

$$\begin{aligned} \text{Note } v_{E/Y} &= v_E - v_Y \\ &= -(v_Y - v_E) \end{aligned}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



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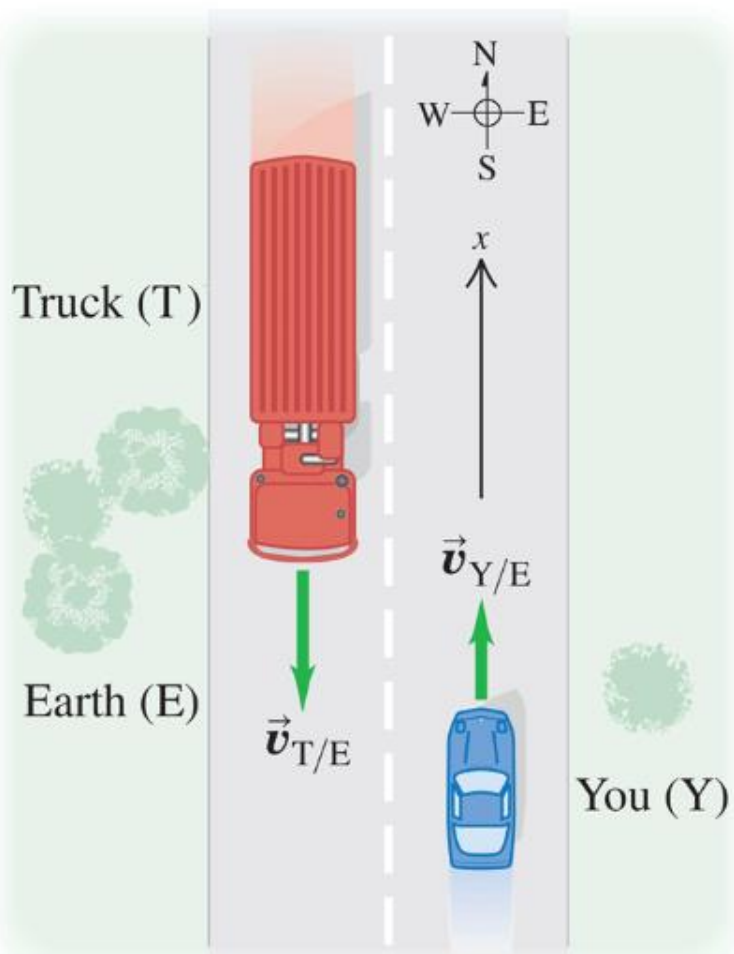
$$v_{T/\epsilon} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/y}$:

$$v_{T/y} = v_{T/\epsilon} + v_{\epsilon/y}$$

$$\begin{aligned} \text{Note } v_{\epsilon/y} &= v_{\epsilon} - v_y \\ &= -(v_y - v_{\epsilon}) \\ &= v_{y/\epsilon} \end{aligned}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{Y/E} = 88 \text{ km/h}$$

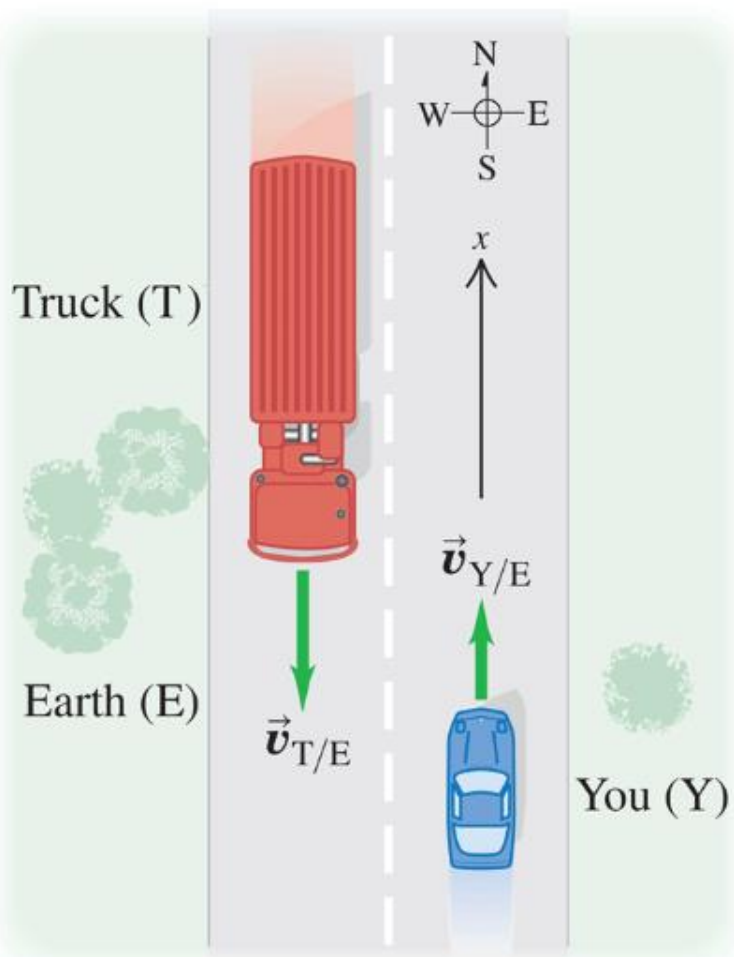
$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/Y}$:

$$v_{T/Y} = v_{T/E} + v_{E/Y} \quad \text{so}$$

$$v_{T/Y} = -104 \frac{\text{km}}{\text{h}} - 88 \frac{\text{km}}{\text{h}}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

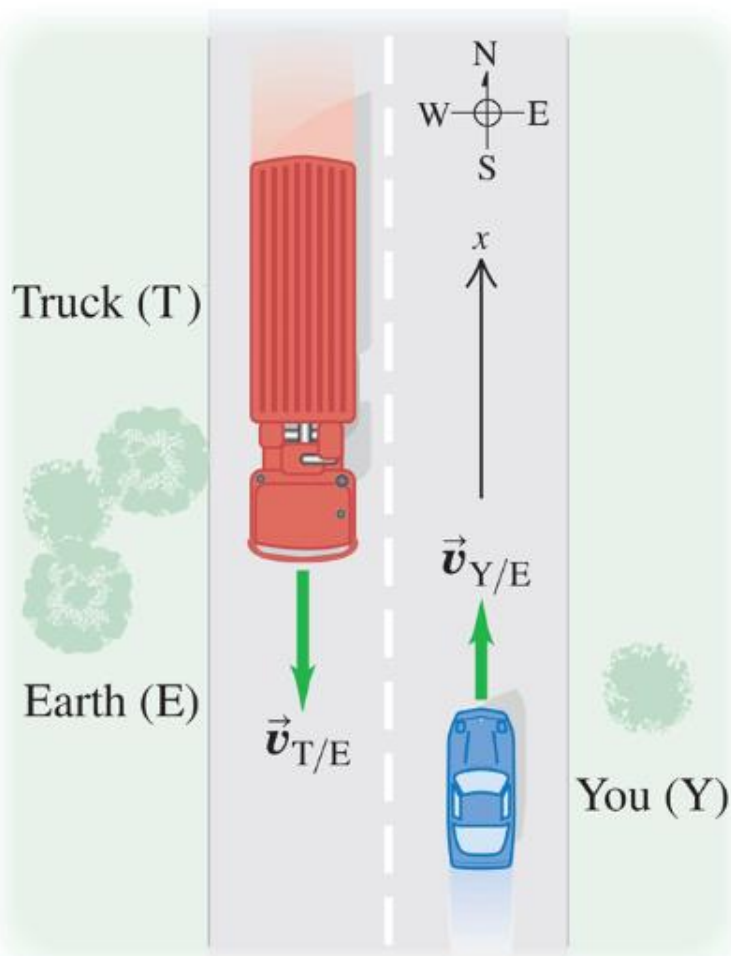
Find $v_{T/Y}$:

$$v_{T/Y} = v_{T/E} + v_{E/Y} \quad \text{so}$$

$$v_{T/Y} = -104 \frac{\text{km}}{\text{hr}} - 88 \frac{\text{km}}{\text{hr}}$$

$$v_{T/Y} = -192 \frac{\text{km}}{\text{hr}}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{y/\epsilon} = 88 \text{ km/h}$$

$$v_{T/\epsilon} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{T/y}$:

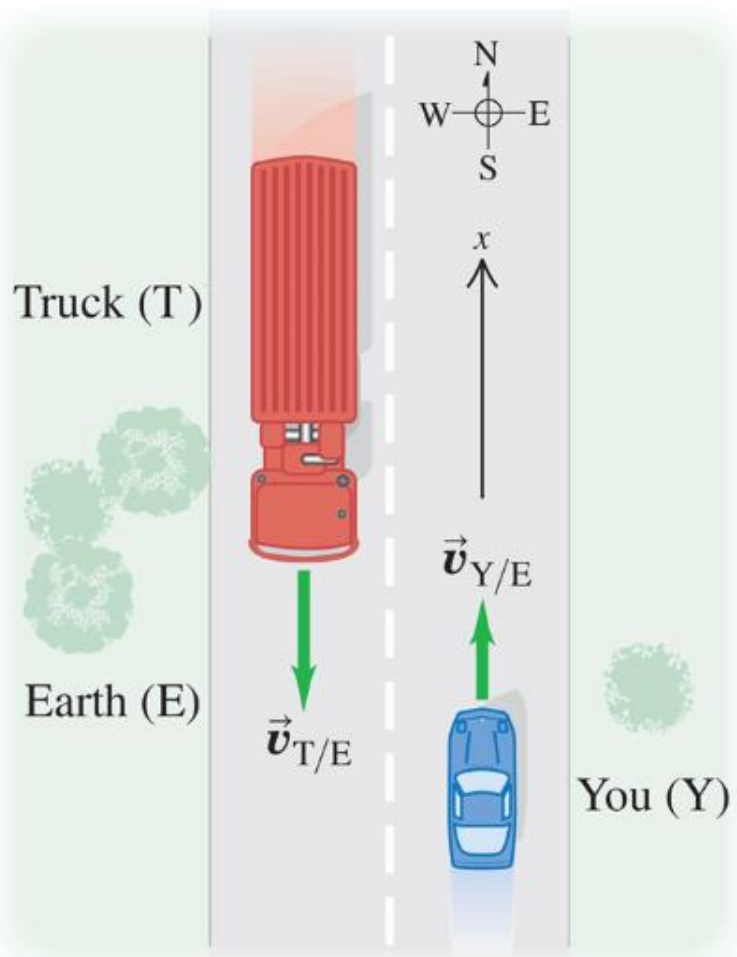
$$v_{T/y} = v_{T/\epsilon} + v_{\epsilon/y} \quad \text{so}$$

$$v_{T/y} = -104 \frac{\text{km}}{\text{hr}} - 88 \frac{\text{km}}{\text{hr}}$$

$$v_{T/y} = -192 \text{ km/hr}$$

$$= 192 \text{ km/hr south}$$

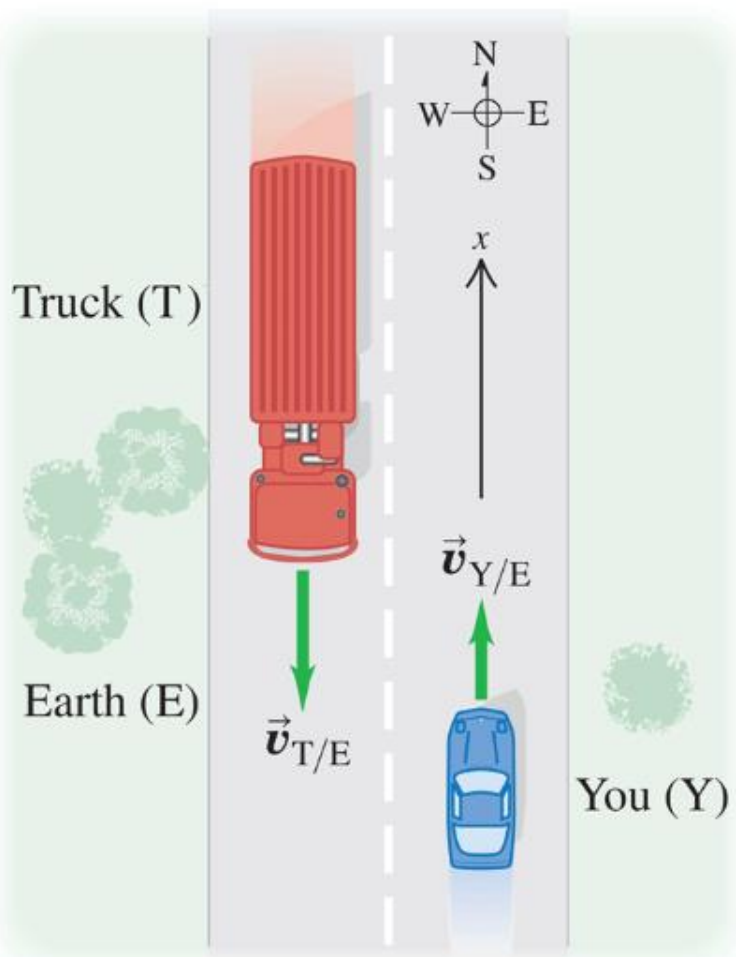
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$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

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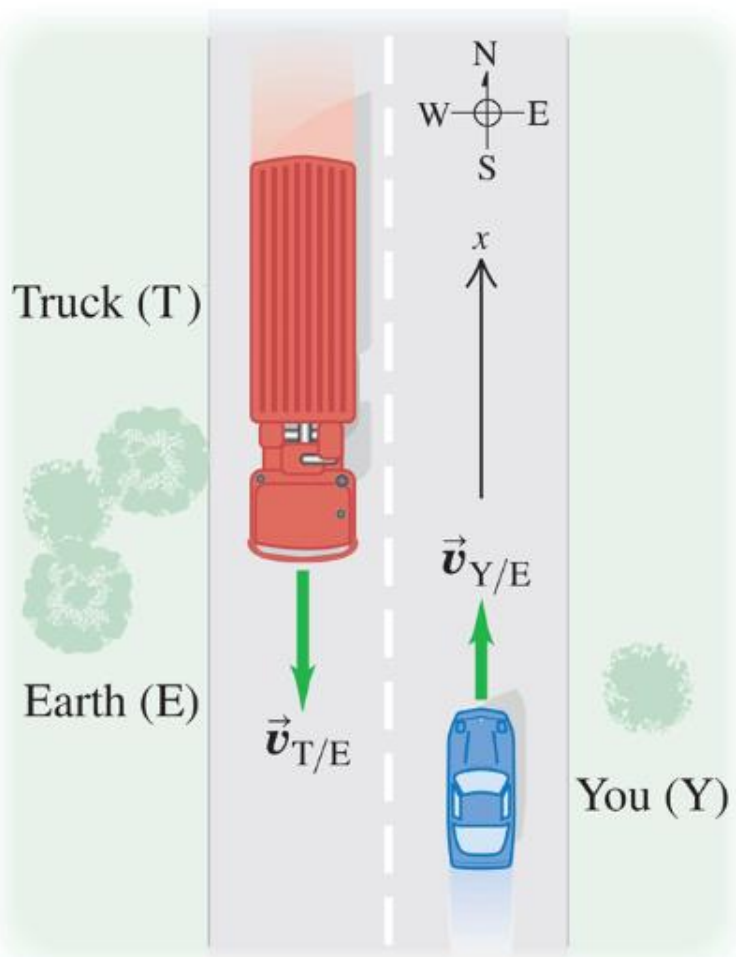


$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{Y/T}$:

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



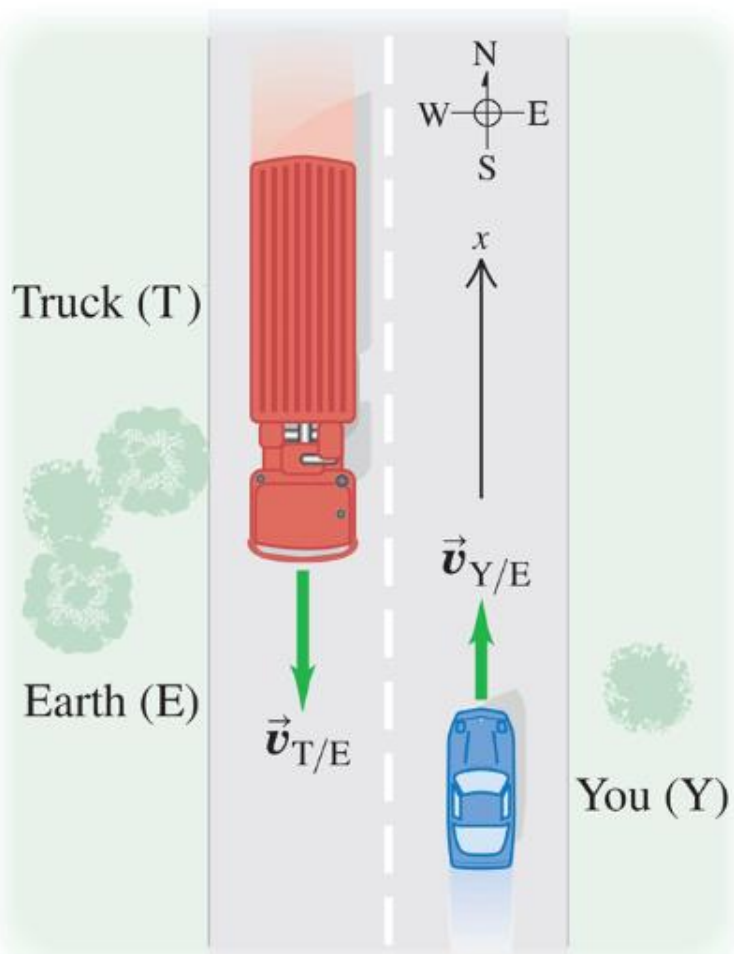
$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{Y/T}$:

$$v_{Y/T} = v_{Y/E} + v_{E/T}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{Y/E} = 88 \text{ km/h}$$

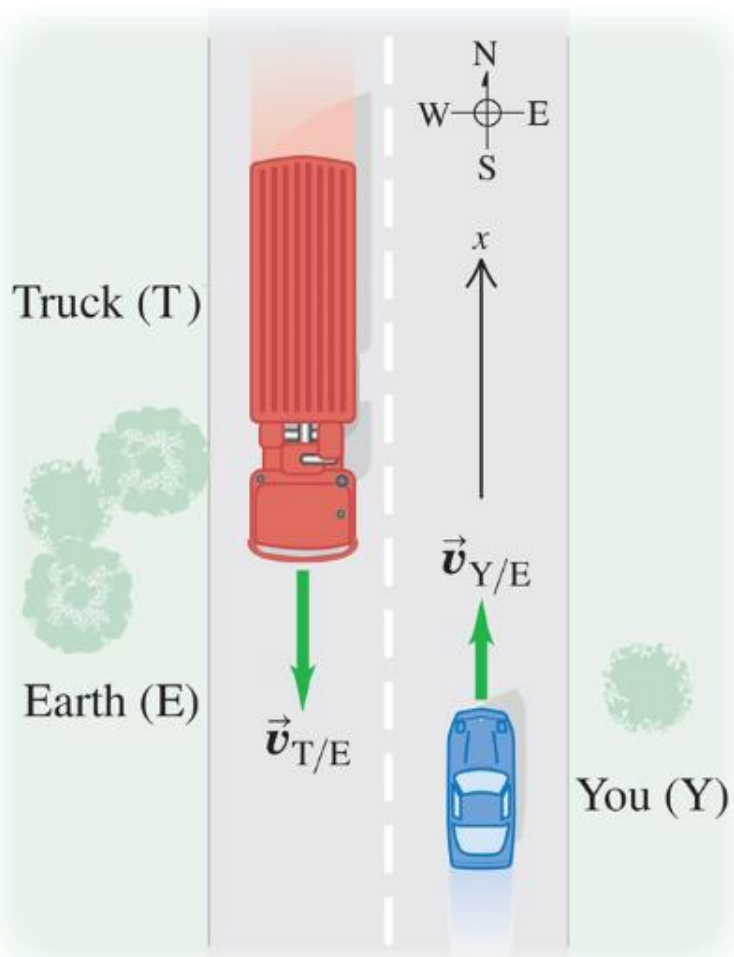
$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{Y/T}$:

$$v_{Y/T} = v_{Y/E} + v_{E/T}$$

Note: $v_{E/T} = -v_{T/E}$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

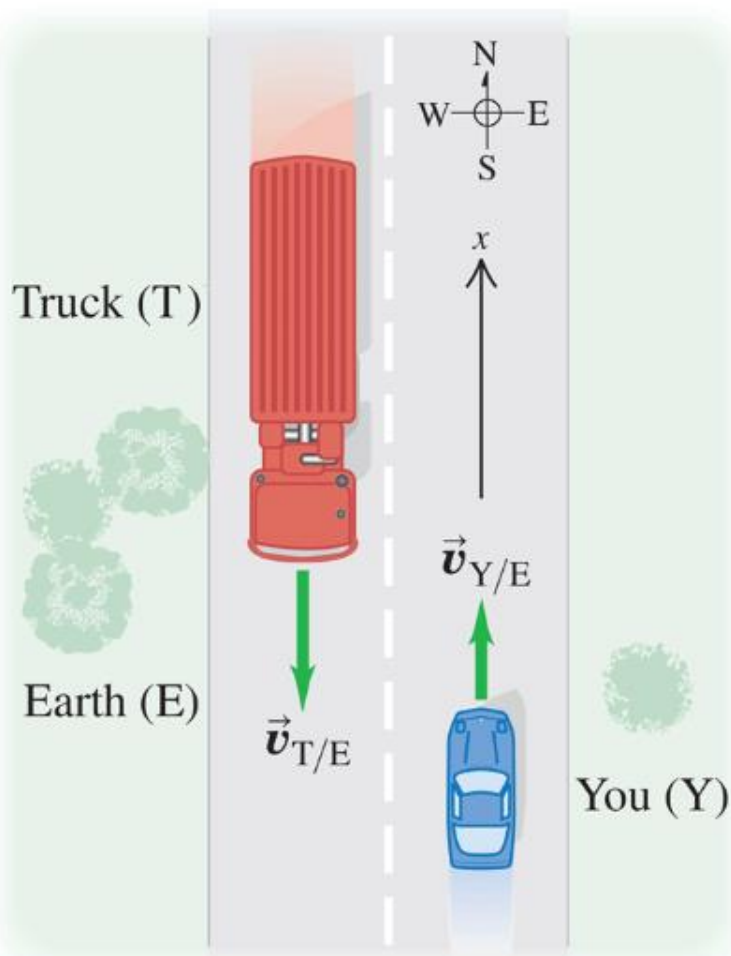
Find $v_{Y/T}$:

$$v_{Y/T} = v_{Y/E} + v_{E/T}$$

Note: $v_{E/T} = -v_{T/E}$

so $v_{Y/T} = v_{Y/E} - v_{T/E}$

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$$v_{y/\epsilon} = 88 \text{ km/h}$$

$$v_{T/\epsilon} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{y/T}$:

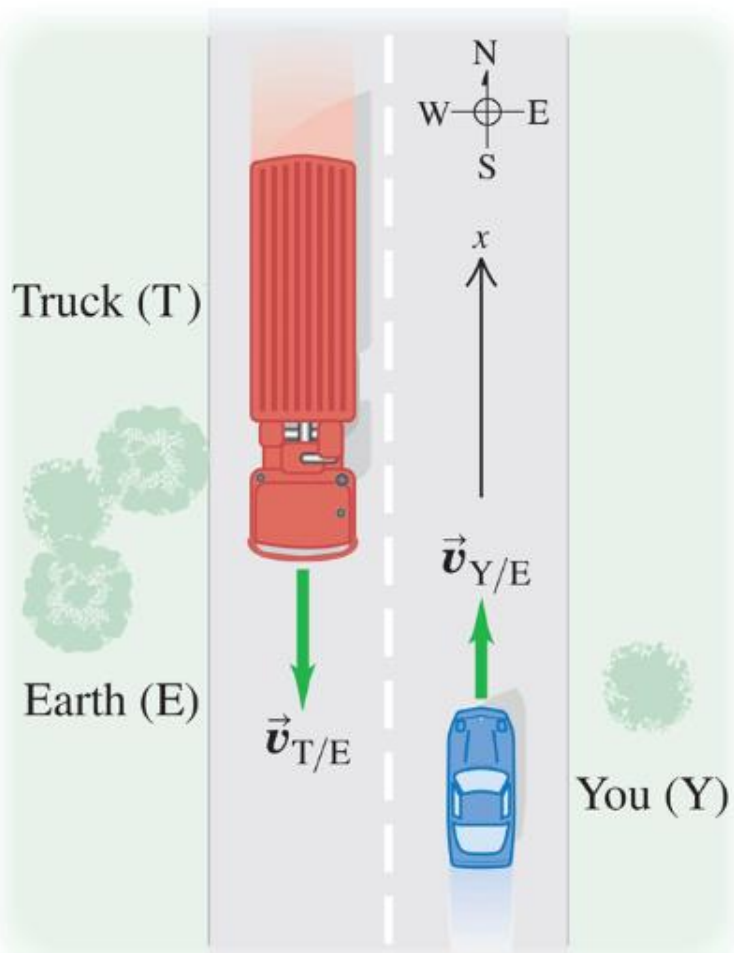
$$v_{y/T} = v_{y/\epsilon} + v_{\epsilon/T}$$

Note: $v_{\epsilon/T} = -v_{T/\epsilon}$

$$\Rightarrow v_{y/T} = v_{y/\epsilon} - v_{T/\epsilon}$$

$$\Rightarrow v_{y/T} = 88 \text{ km/h} + 104 \text{ km/h}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{y/\varepsilon} = 88 \text{ km/h}$$

$$v_{T/\varepsilon} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{y/T}$:

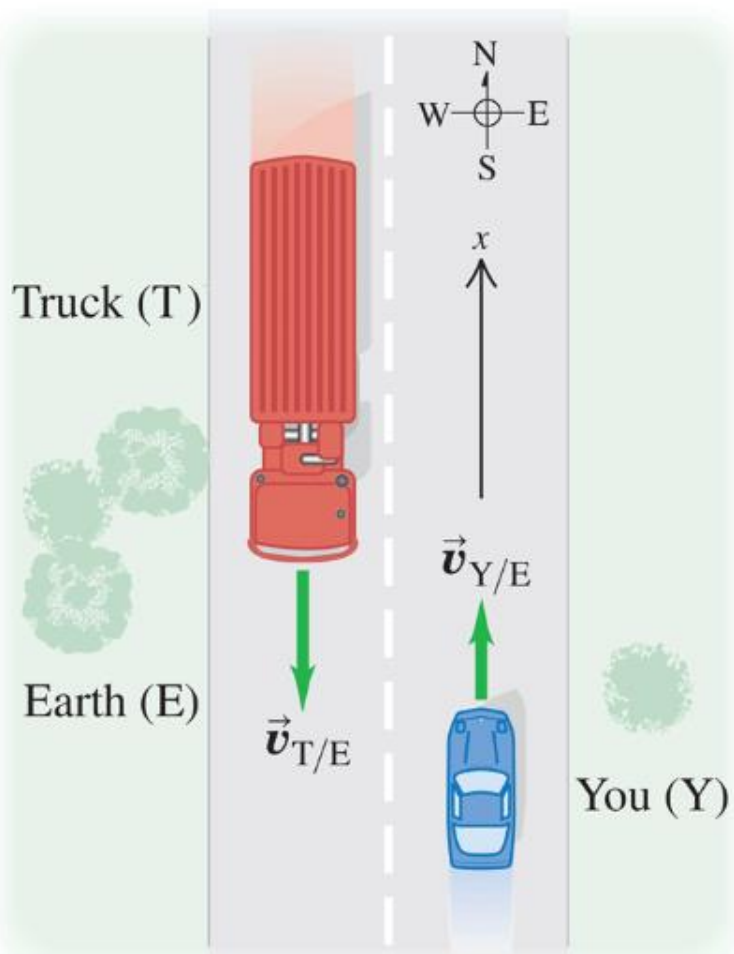
$$v_{y/T} = v_{y/\varepsilon} + v_{\varepsilon/T}$$

Note: $v_{\varepsilon/T} = -v_{T/\varepsilon}$

$$\Rightarrow v_{y/T} = v_{y/\varepsilon} - v_{T/\varepsilon}$$

$$\Rightarrow v_{y/T} = 192 \text{ km/hr}$$

You drive north on a straight two-lane road at a constant 88 km/h. A truck in the other lane approaches you at a constant 104 km/h (Fig. 3.33). Find (a) the truck's velocity relative to you and (b) your velocity relative to the truck. (c) How do the relative velocities change after you and the truck pass each other? Treat this as a one-dimensional problem.



$$v_{y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Find $v_{y/T}$:

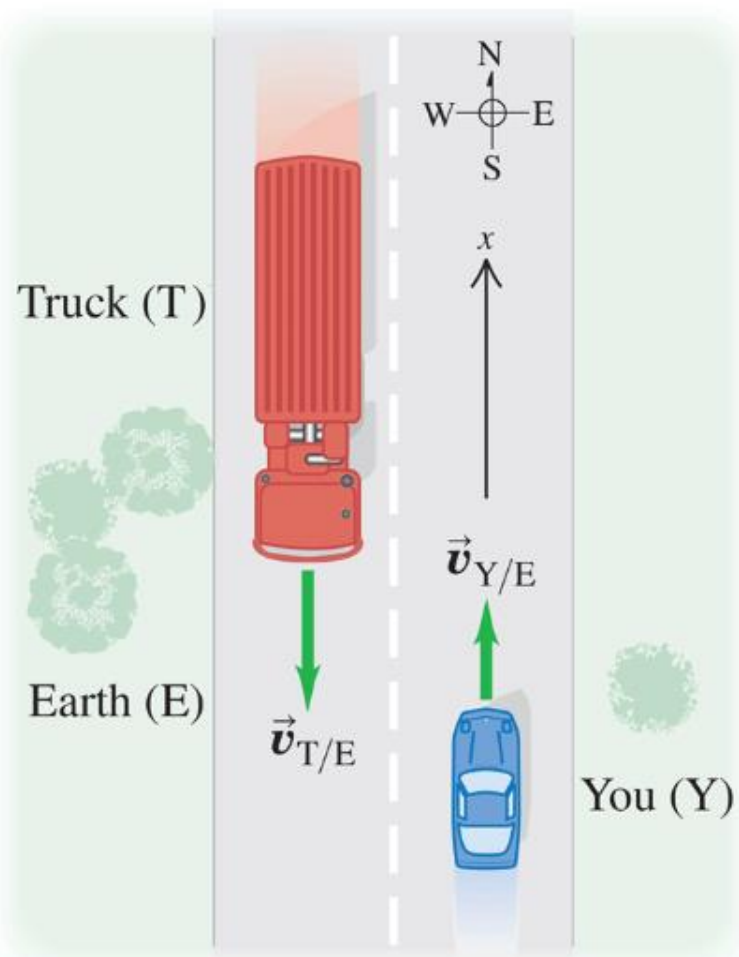
$$v_{y/T} = v_{y/E} + v_{E/T}$$

Note: $v_{E/T} = -v_{T/E}$

$$\text{so } v_{y/T} = v_{y/E} - v_{T/E}$$

$$\Rightarrow v_{y/T} = 192 \text{ km/hr North}$$

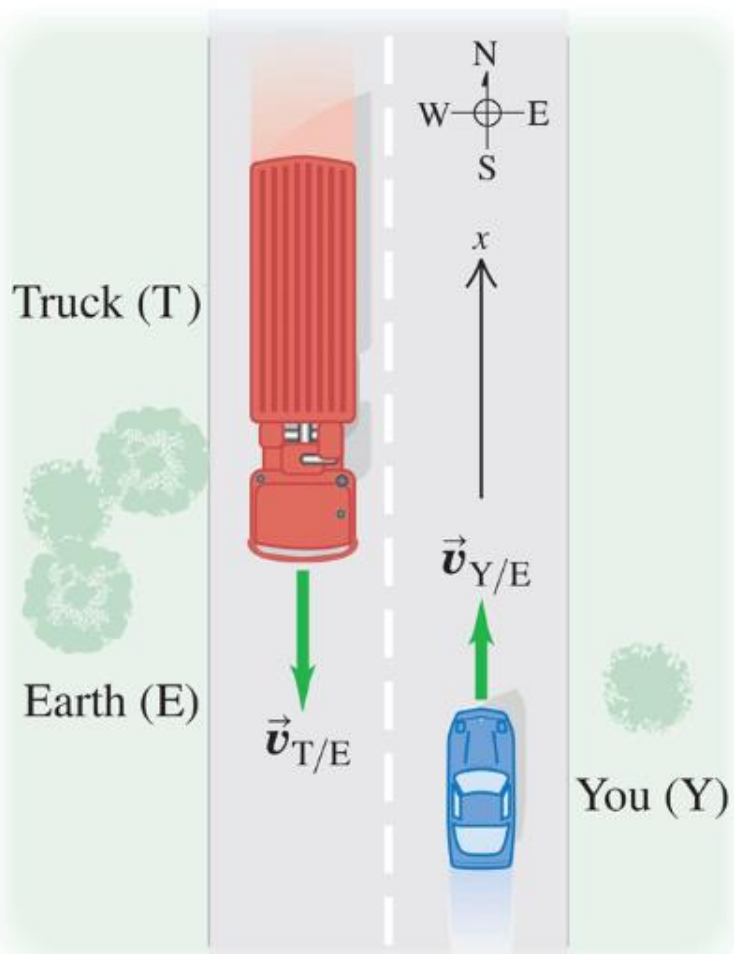
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$$v_{Y/E} = 88 \text{ km/h}$$

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$$v_{Y/E} = 88 \text{ km/h}$$

$$v_{T/E} = -104 \frac{\text{km}}{\text{h}}$$

Relative velocities are not position dependent

Relative motion in 2 & 3 d

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} +$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} + (y_A - y_B)\hat{j} +$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} + (y_A - y_B)\hat{j} + (z_A - z_B)\hat{k}$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} + (y_A - y_B)\hat{j} + (z_A - z_B)\hat{k}$$

$$\frac{d}{dt}\vec{r}_{A/B} = \frac{d}{dt}\vec{r}_A - \frac{d}{dt}\vec{r}_B$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} + (y_A - y_B)\hat{j} + (z_A - z_B)\hat{k}$$

$$\frac{d}{dt} \vec{r}_{A/B} = \frac{d}{dt} \vec{r}_A - \frac{d}{dt} \vec{r}_B \Rightarrow$$
$$\vec{v}_{A/B} = \vec{v}_A - \vec{v}_B$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} + (y_A - y_B)\hat{j} + (z_A - z_B)\hat{k}$$

$$\frac{d}{dt} \vec{r}_{A/B} = \frac{d}{dt} \vec{r}_A - \frac{d}{dt} \vec{r}_B \Rightarrow$$

$$\vec{v}_{A/B} = \vec{v}_A - \vec{v}_B$$

$$\frac{d\vec{v}_{A/B}}{dt} = \frac{d\vec{v}_A}{dt} - \frac{d\vec{v}_B}{dt}$$

Relative motion in 2 & 3 d

$$\vec{r}_{A/B} = \vec{r}_A - \vec{r}_B = (x_A - x_B)\hat{i} + (y_A - y_B)\hat{j} + (z_A - z_B)\hat{k}$$

$$\frac{d}{dt} \vec{r}_{A/B} = \frac{d}{dt} \vec{r}_A - \frac{d}{dt} \vec{r}_B \Rightarrow$$

$$\vec{v}_{A/B} = \vec{v}_A - \vec{v}_B$$

$$\frac{d}{dt} \vec{v}_{A/B} = \frac{d}{dt} \vec{v}_A - \frac{d}{dt} \vec{v}_B \Rightarrow$$

$$\vec{a}_{A/B} = \vec{a}_A - \vec{a}_B$$

Relative motion in 2 & 3 d

Adding in Percy the point particle

Relative motion in 2 & 3 d

Adding in Percy the point particle

$$\vec{v}_{P/A} = \vec{v}_{P/B} + \vec{v}_{B/A}$$

Relative motion in 2 & 3 d

Adding in Percy the point particle

$$\begin{aligned}\vec{V}_{P/A} &= \vec{V}_{P/B} + \vec{V}_{B/A} \\ &= \vec{V}_P - \vec{V}_B + \vec{V}_B - \vec{V}_A\end{aligned}$$

Relative motion in 2 & 3 d

Adding in Percy the point particle

$$\begin{aligned}\vec{V}_{P/A} &= \vec{V}_{P/B} + \vec{V}_{B/A} \\ &= \vec{V}_P - \vec{V}_B + \vec{V}_B - \vec{V}_A\end{aligned}$$

Relative motion in 2 & 3 d

Adding in Percy the point particle

$$\begin{aligned}\vec{V}_{P/A} &= \vec{V}_{P/B} + \vec{V}_{B/A} \\ &= \vec{V}_P - \vec{V}_B + \vec{V}_B - \vec{V}_A = V_P - V_A\end{aligned}$$

Relative motion in 2 & 3 d

Adding in Percy the point particle

As it must

$$\vec{V}_{P/A} = \vec{V}_{P/B} + \vec{V}_{B/A}$$
$$= \vec{V}_P - \vec{V}_B + \vec{V}_B - \vec{V}_A = V_P - V_A$$

Relative motion in 2 & 3 d

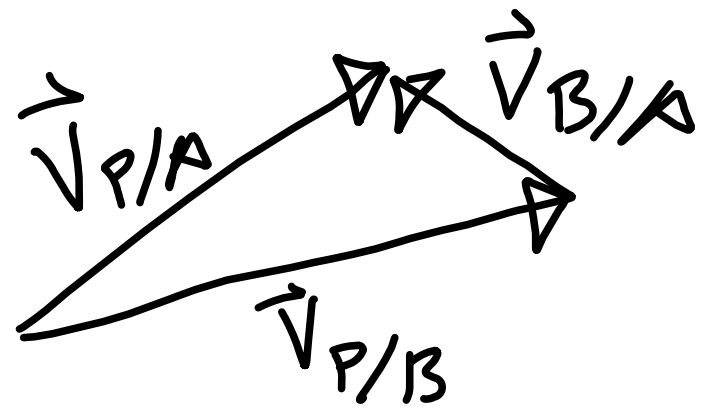
Adding in Percy the point particle

$$\vec{v}_{P/A} = \vec{v}_{P/B} + \vec{v}_{B/A}$$

Relative motion in 2 & 3 d

Adding in Percy the point particle

$$\vec{v}_{P/A} = \vec{v}_{P/B} + \vec{v}_{B/A}$$



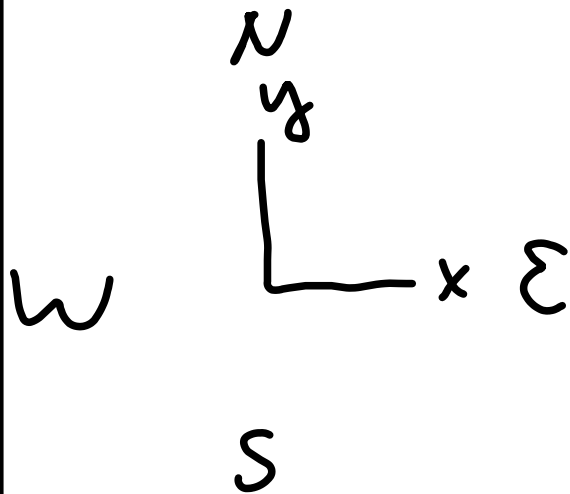
An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h . If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?



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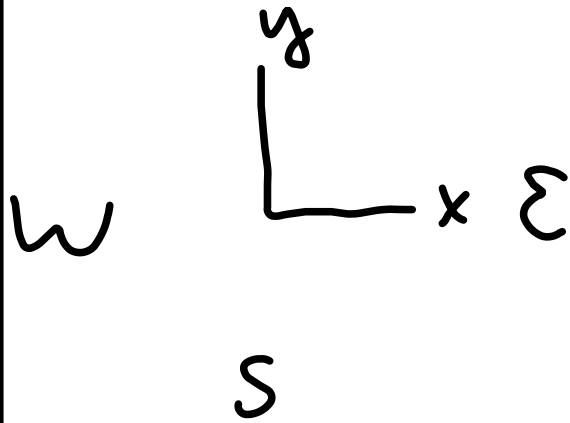
Let coordinate

be as shown



An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

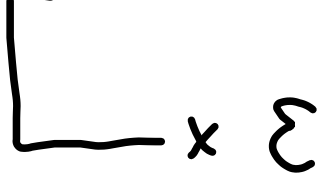
Let coordinate be as shown. Let $A \rightarrow$ airplane



An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

be as shown.

N
y



S

Let

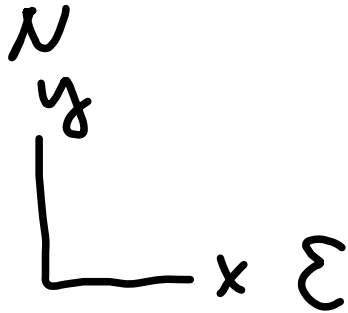
$A \rightarrow$ airplane

$E \rightarrow$ Earth

Let coordinate

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

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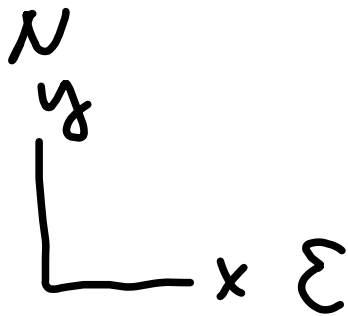


Let

Let coordinate
 $A \rightarrow$ airplane
 $E \rightarrow$ Earth
 $W \rightarrow$ Wind

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

be as shown.

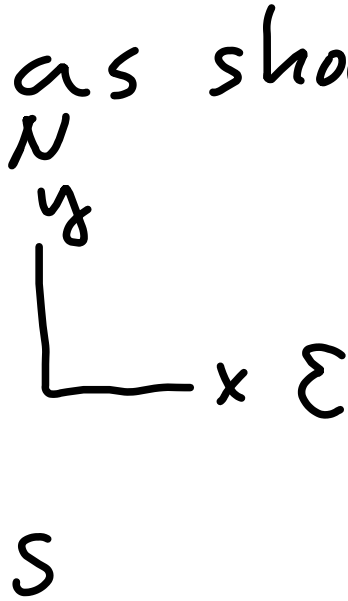


Let

Let coordinate
 $A \rightarrow$ airplane
 $E \rightarrow$ Earth
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An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

be as shown.



Let

Let coordinate
 $A \rightarrow$ airplane
 $E \rightarrow$ Earth
 $W \rightarrow$ Wind

$$\vec{v}_{A/W} =$$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let

$\Lambda \rightarrow$ airplane
 $\Sigma \rightarrow$ Earth
 $W \rightarrow$ Wind

$\vec{v}_{A/W} = \theta \hat{i} + 240 \frac{\text{km}}{\text{h}} \hat{j}$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h . If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let

$\Lambda \rightarrow$ airplane
 $\Sigma \rightarrow$ Earth
 $W \rightarrow$ Wind

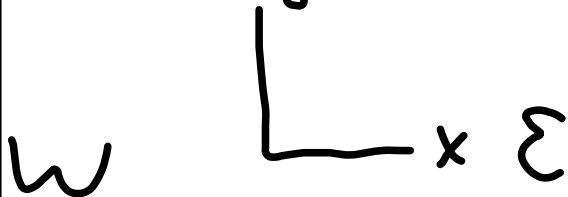
$\vec{v}_{A/W} = 240 \frac{\text{km}}{\text{h}} \hat{y}$
 $\vec{v}_{W/\Sigma} = 100 \frac{\text{km}}{\text{h}} \hat{x}$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let $A \rightarrow$ airplane

$E \rightarrow$ Earth

$W \rightarrow$ Wind



$$\vec{V}_{A/W} = \theta \hat{i} + 240 \frac{\text{km}}{\text{h}} \hat{j}$$

$$\vec{V}_{W/E} = 100 \frac{\text{km}}{\text{h}} \hat{i} + \theta \hat{j}$$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

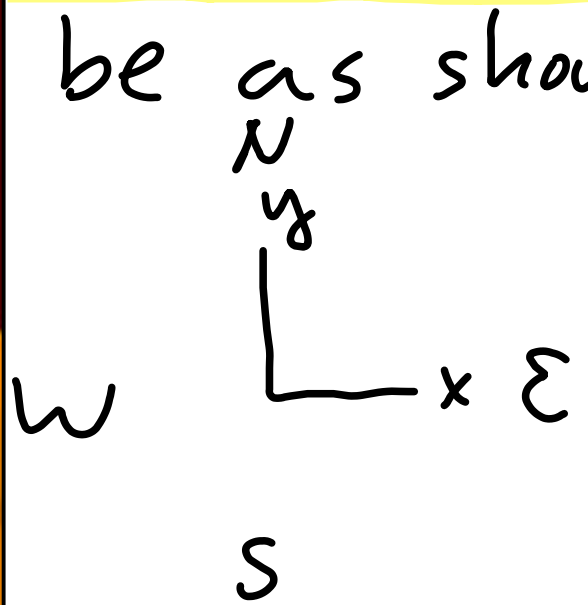
Let coordinate be as shown. Let

$\Lambda \rightarrow$ airplane
 $\Sigma \rightarrow$ Earth
 $W \rightarrow$ Wind

$\vec{v}_{A/W} = \theta \hat{i} + 240 \frac{\text{km}}{\text{h}} \hat{j}$
 $\vec{v}_{W/\Sigma} = 100 \frac{\text{km}}{\text{h}} \hat{i} + \theta \hat{j}$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let
 $\mathcal{A} \rightarrow$ airplane
 $\mathcal{E} \rightarrow$ Earth
 $\mathcal{W} \rightarrow$ Wind



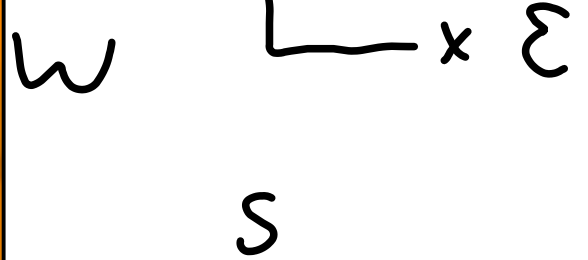
$\vec{v}_{\mathcal{A}/\mathcal{W}} = 240 \frac{\text{km}}{\text{h}} \hat{j}$
 $\vec{v}_{\mathcal{W}/\mathcal{E}} = 100 \frac{\text{km}}{\text{h}} \hat{i}$

Find $\vec{v}_{\mathcal{A}/\mathcal{E}}$:



An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let
 $\Lambda \rightarrow$ airplane
 $\Sigma \rightarrow$ Earth
 $W \rightarrow$ Wind



$$\vec{v}_{A/W} = \theta \hat{i} + 240 \frac{\text{km}}{\text{h}} \hat{j}$$

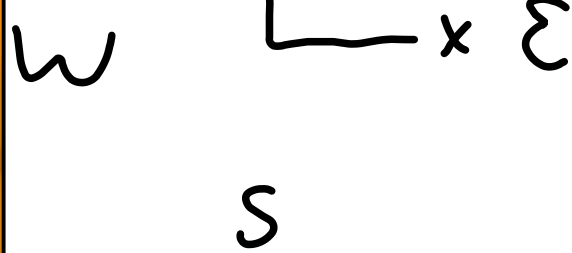
$$\vec{v}_{W/\Sigma} = 100 \frac{\text{km}}{\text{h}} \hat{i} + \theta \hat{j}$$

Find $\vec{v}_{A/\Sigma}$: $\vec{v}_{A/\Sigma} = \vec{v}_{A/W} + \vec{v}_{W/\Sigma}$



An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let
 $\Delta \rightarrow$ airplane
 $\Sigma \rightarrow$ Earth
 $W \rightarrow$ Wind



$$\vec{v}_{A/W} = 0\hat{i} + 240\frac{\text{km}}{\text{h}}\hat{j}$$

$$\vec{v}_{W/\Sigma} = 100\frac{\text{km}}{\text{h}}\hat{i} + 0\hat{j}$$

Find $\vec{v}_{A/\Sigma}$: $\vec{v}_{A/\Sigma} = \vec{v}_{A/W} + \vec{v}_{W/\Sigma}$

$$\Rightarrow \vec{v}_{A/\Sigma} = [(0 + 100)\hat{i} + (240 + 0)\hat{j}]\frac{\text{km}}{\text{h}} = [100\hat{i} + 240\hat{j}]\frac{\text{km}}{\text{h}}$$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

Let coordinate be as shown. Let $A \rightarrow$ airplane

$E \rightarrow$ Earth

$W \rightarrow$ Wind

$$\vec{V}_{A/E} = [100\hat{i} + 240\hat{j}] \frac{\text{km}}{\text{h}}$$

From previous slide

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?

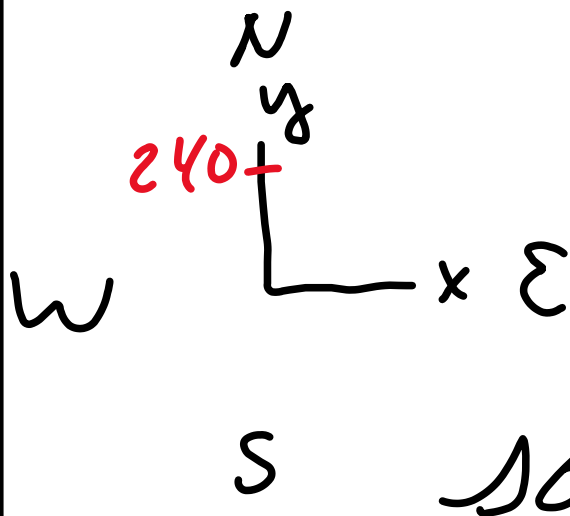
Let coordinate be as shown. Let

\hat{i} → airplane
 \hat{j} → Earth
 \hat{k} → Wind

$\vec{v}_{A/E} = [100\hat{i} + 240\hat{j}] \frac{\text{km}}{\text{h}}$

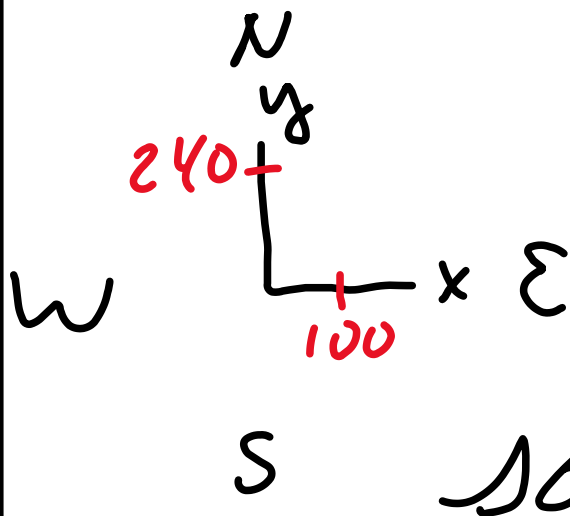
So $v_{A/E} = 260 \frac{\text{km}}{\text{h}}$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?



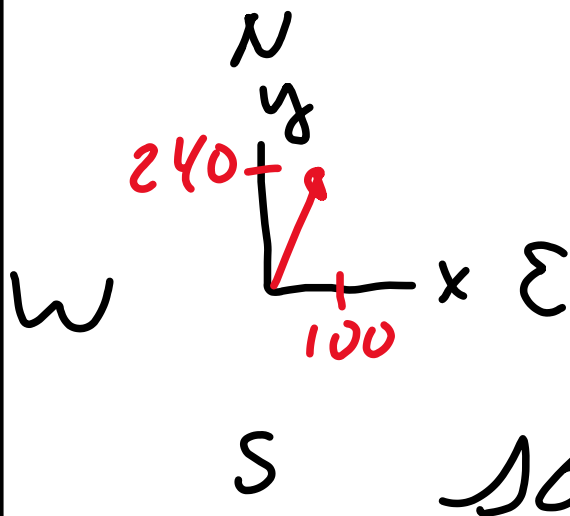
$$\vec{V}_{A/E} = [100\hat{i} + 240\hat{j}] \frac{\text{km}}{\text{h}}$$
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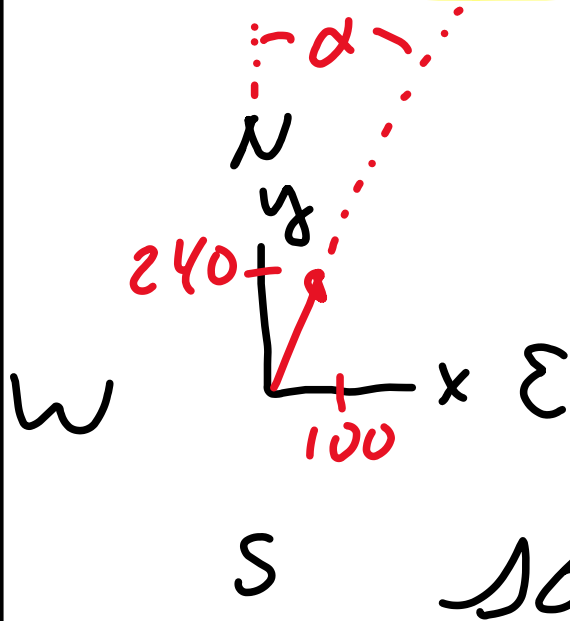
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$$\vec{V}_{A/E} = [100\hat{i} + 240\hat{j}] \frac{\text{km}}{\text{h}}$$
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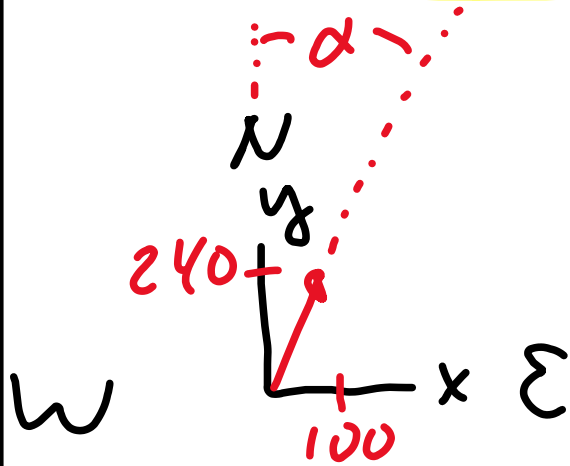
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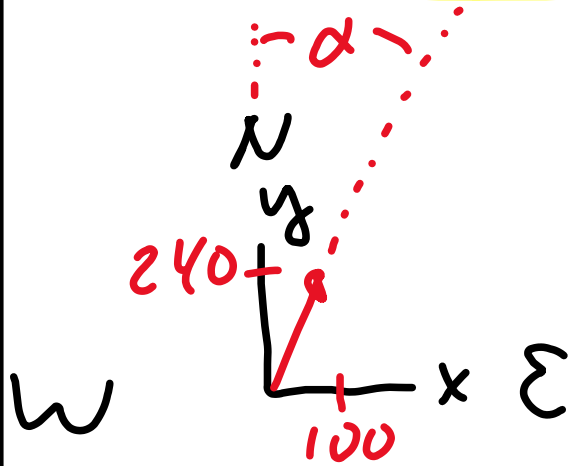
$$\vec{v}_{A/E} = [100\hat{i} + 240\hat{j}] \frac{\text{km}}{\text{h}}$$

$$\text{So } v_{A/E} = 260 \frac{\text{km}}{\text{h}}$$

$$\tan \alpha = \frac{100}{240} \Rightarrow \alpha = \tan^{-1}\left(\frac{100}{240}\right)$$

$$\Rightarrow \alpha = 23^\circ$$

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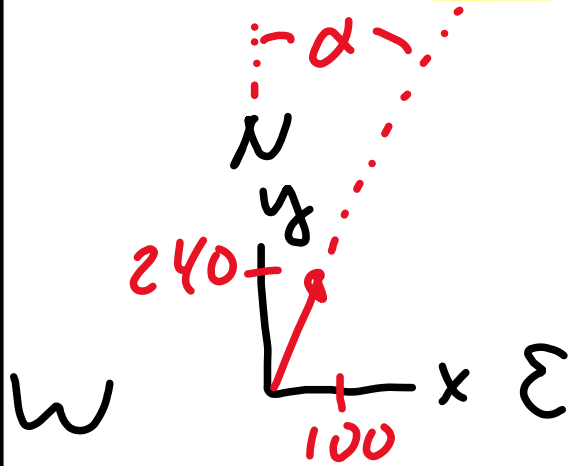
$$\vec{v}_{A/E} = [100\hat{i} + 240\hat{j}] \frac{\text{km}}{\text{h}}$$

$$\text{So } v_{A/E} = 260 \frac{\text{km}}{\text{h}}$$

$$\tan \alpha = \frac{100}{240} \Rightarrow \alpha = \tan^{-1}\left(\frac{100}{240}\right)$$

$$\Rightarrow \alpha = 23^\circ \text{ East of North}$$

An airplane's compass indicates that it is headed due north, and its airspeed indicator shows that it is moving through the air at 240 km/h. If there is a 100 km/h wind from west to east, what is the velocity of the airplane relative to the earth?



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With wind and airspeed as in [Example 3.14](#), in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{W/E} = (600 \text{ km/h}) \hat{i}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

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With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{W/E} = (100 \text{ km/h}) \hat{i}, \quad \vec{v}_{A/E} = v_{A/E} \hat{j},$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{W/E} = (100 \text{ km/h}) \hat{i}, \quad \vec{v}_{A/E} = v_{A/E} \hat{j},$$

$$|\vec{v}_{A/W}| = 240 \frac{\text{km}}{\text{h}}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{W/E} = (100 \text{ km/h}) \hat{i}, \quad \vec{v}_{A/E} = v_{A/E} \hat{j},$$

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$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$

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$$|\vec{v}_{A/W}| = 240 \frac{\text{km}}{\text{h}}$$

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E} \Rightarrow$$

$$v_{A/E} \hat{j} = (v_{A/W})_x \hat{i} + (v_{A/W})_y \hat{j} + (100 \frac{\text{km}}{\text{h}}) \hat{i}$$

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$$|\vec{v}_{A/W}| = 240 \frac{\text{km}}{\text{h}}$$

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E} \Rightarrow$$

$$v_{A/E} \hat{j} = (v_{A/W})_x \hat{i} + (v_{A/W})_y \hat{j} + (100 \frac{\text{km}}{\text{h}}) \hat{i}$$

$$\Rightarrow (v_{A/W})_x \hat{i} = -100 \frac{\text{km}}{\text{h}} \hat{i}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{W/E} = (100 \text{ km/h}) \hat{i} \quad , \quad \vec{v}_{A/E} = v_{A/E} \hat{j} \quad ,$$

$$|\vec{v}_{A/W}| = 240 \frac{\text{km}}{\text{h}}$$

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E} \Rightarrow$$

$$v_{A/E} \hat{j} = (v_{A/W})_x \hat{i} + (v_{A/W})_y \hat{j} + (100 \frac{\text{km}}{\text{h}}) \hat{i}$$

$$\Rightarrow (v_{A/W})_x \hat{i} = -100 \frac{\text{km}}{\text{h}} \hat{i} \Rightarrow (v_{A/W})_x = -100 \frac{\text{km}}{\text{h}}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{w/\epsilon} = (100 \text{ km/h}) \hat{i}, \quad \vec{v}_{A/\epsilon} = v_{A/\epsilon} \hat{j},$$

$$|\vec{v}_{A/w}| = 240 \frac{\text{km}}{\text{h}}$$

$$\vec{v}_{A/\epsilon} = \vec{v}_{A/w} + \vec{v}_{w/\epsilon} \Rightarrow$$

$$v_{A/\epsilon} \hat{j} = (v_{A/w})_x \hat{i} + (v_{A/w})_y \hat{j} + (100 \frac{\text{km}}{\text{h}}) \hat{i}$$

$$\Rightarrow (v_{A/w})_x \hat{i} = -100 \frac{\text{km}}{\text{h}} \hat{i} \Rightarrow (v_{A/w})_x = -100 \frac{\text{km}}{\text{h}}$$

$$\nabla \quad v_{A/w}^2 = (v_{A/w})_x^2 + (v_{A/w})_y^2$$

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$$\Rightarrow (v_{A/W})_x \hat{i} = -100 \frac{\text{km}}{\text{h}} \hat{i} \Rightarrow (v_{A/W})_x = -100 \frac{\text{km}}{\text{h}}$$

$$\nabla \quad v_{A/W}^2 = (v_{A/W})_x^2 + (v_{A/W})_y^2 \Rightarrow$$

$$(v_{A/W})_y = [(v_{A/W})^2 - (v_{A/W})_x^2]^{1/2}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{w/\epsilon} = (100 \text{ km/h}) \hat{i}, \quad \vec{v}_{A/\epsilon} = v_{A/\epsilon} \hat{j},$$

$$|\vec{v}_{A/w}| = 240 \frac{\text{km}}{\text{h}}$$

$$\vec{v}_{A/\epsilon} = \vec{v}_{A/w} + \vec{v}_{w/\epsilon} \Rightarrow$$

$$v_{A/\epsilon} \hat{j} = (v_{A/w})_x \hat{i} + (v_{A/w})_y \hat{j} + (100 \frac{\text{km}}{\text{h}}) \hat{i}$$


$$\Rightarrow (v_{A/w})_x \hat{i} = -100 \frac{\text{km}}{\text{h}} \hat{i} \Rightarrow (v_{A/w})_x = -100 \frac{\text{km}}{\text{h}}$$

$$\nabla v_{A/w}^2 = (v_{A/w})_x^2 + (v_{A/w})_y^2 \Rightarrow$$
$$(v_{A/w})_y = 218 \text{ km/hr} \quad \text{But } (v_{A/w})_y = v_{A/\epsilon}$$

$$\text{So } \vec{v}_{A/\epsilon} = 218 \text{ km/hr } \hat{j}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$


$$\vec{v}_{A/E} = 218 \hat{j}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

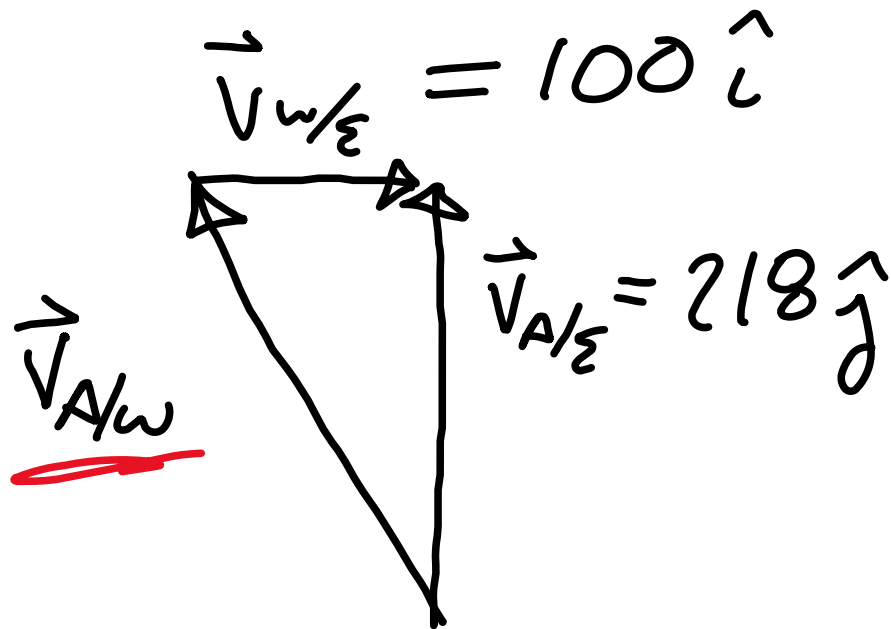
$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$

$$\vec{v}_{W/E} = 100 \hat{i}$$

$$\vec{v}_{A/E} = 218 \hat{j}$$

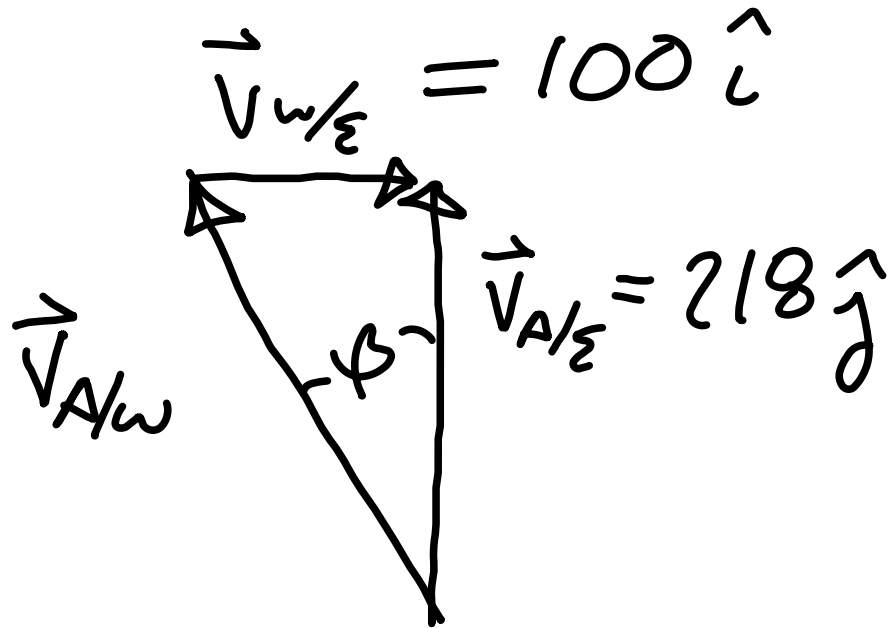
With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$



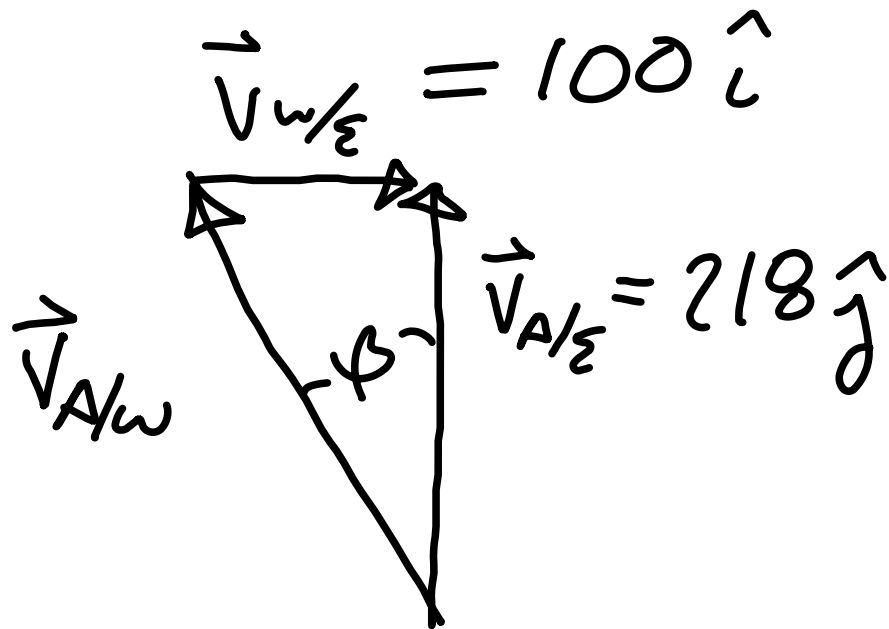
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$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$



With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

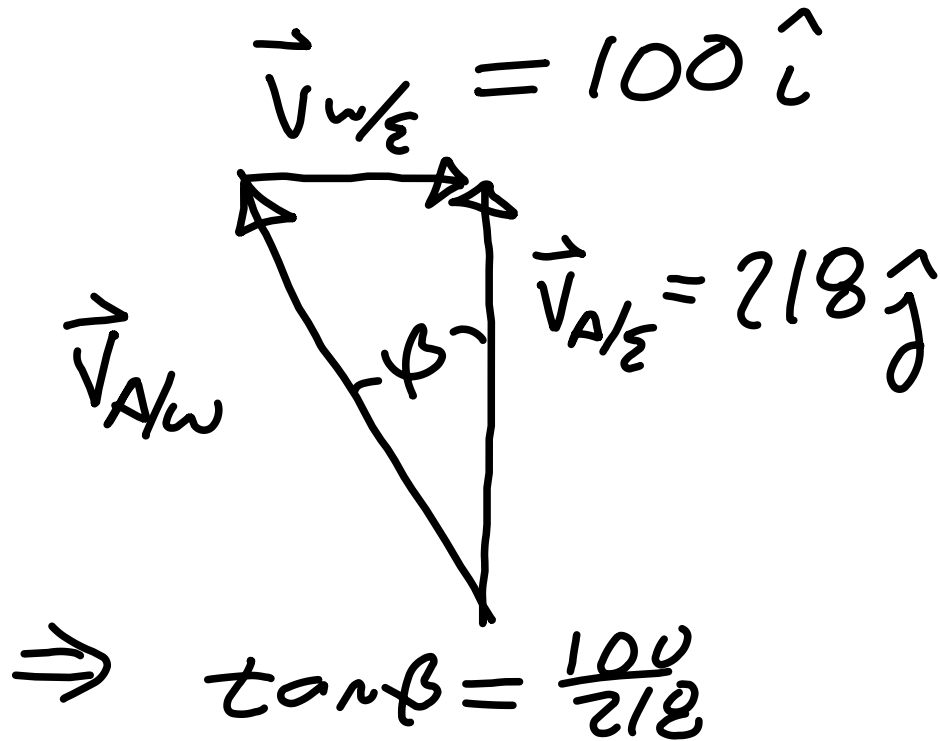
$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$



$$\tan(\beta) = \frac{v_{W/E}}{v_{A/E}}$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

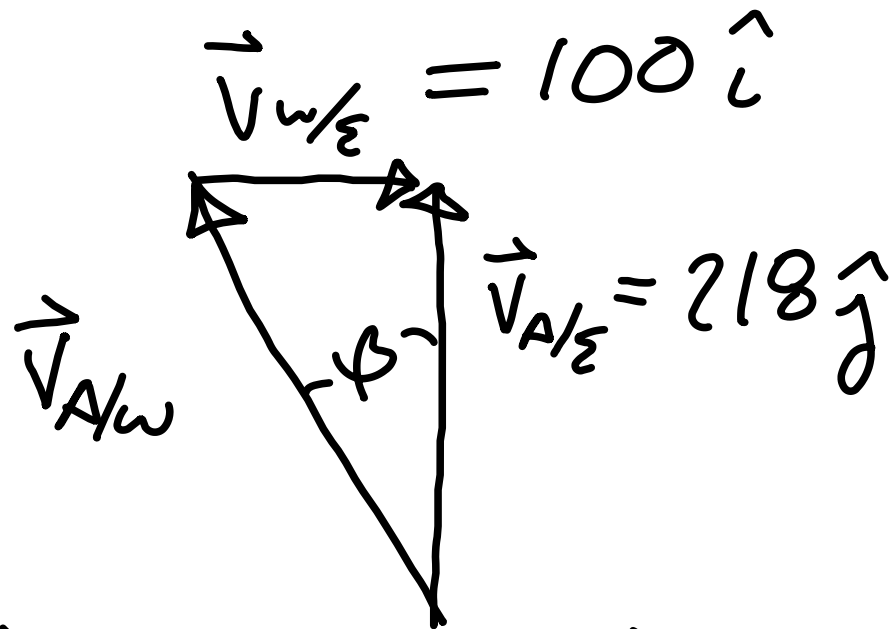
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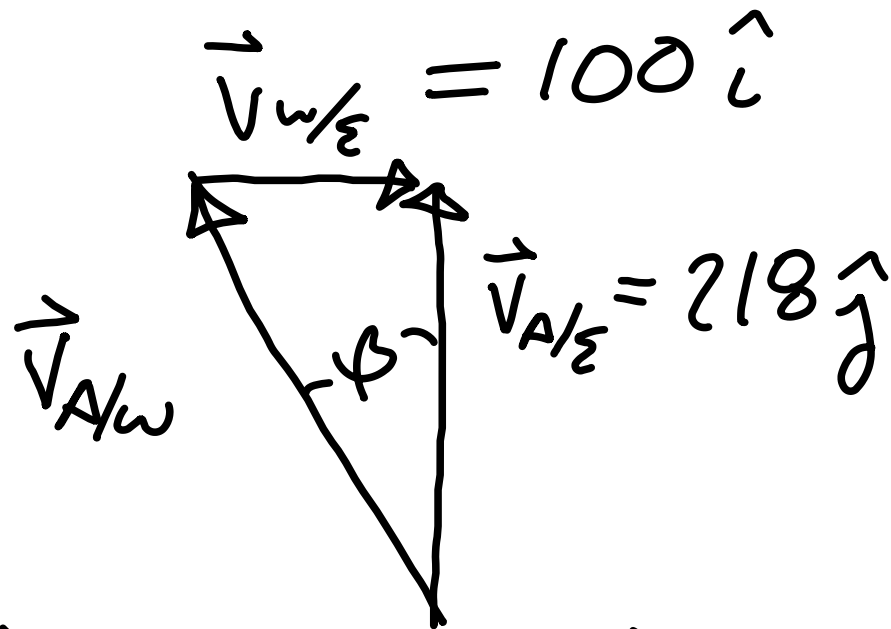
$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$



$$\Rightarrow \tan \beta = \frac{100}{218} \Rightarrow \beta = \tan^{-1} \left[\frac{100}{218} \right]$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$



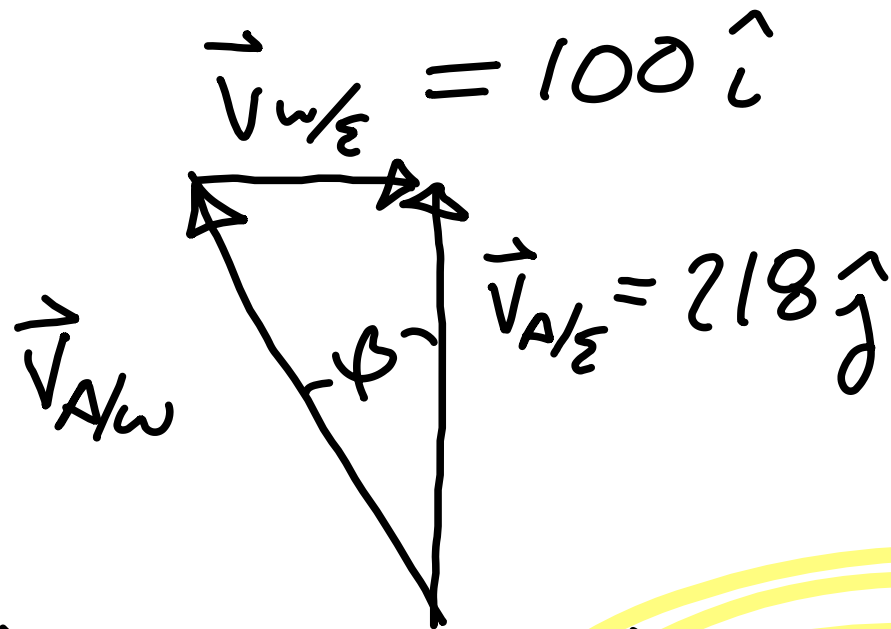
$$\tan(\beta) = \frac{v_{W/E}}{v_{A/E}}$$

$$\Rightarrow \tan \beta = \frac{100}{218} \Rightarrow \beta = \tan^{-1} \left[\frac{100}{218} \right]$$

$$\Rightarrow \beta = 25^\circ$$

With wind and airspeed as in **Example 3.14**, in what direction should the pilot head to travel due north? What will be her velocity relative to the earth?

$$\vec{v}_{A/E} = \vec{v}_{A/W} + \vec{v}_{W/E}$$



$$\tan(\beta) = \frac{v_{W/E}}{v_{A/E}}$$

$$\Rightarrow \tan \beta = \frac{100}{218} \Rightarrow \beta = \tan^{-1} \left[\frac{100}{218} \right]$$

$$\Rightarrow \beta = 25^\circ \text{ west of North}$$

