Good morning!

This week, Friday is on Monday schedule!

Please, sign in, login into webassing, locate LectureMCQ_L5 (PY105) and answer question 1 (but ONLY Q1 !)

NOTE: Exam 1 is on Monday, June 4, 8:30 – 10:30 am, in LSE B01

Hint: arrive ~ 8-15

Lab3 is in SCI 134

Slides
Enabled: Statistics Tracking

Textbook

some old exams
Enabled: Adaptive Release

Equation sheets
Enabled: Statistics Tracking

IL (labs)
Enabled: Adaptive Release, Statistic

Old Slides (2017)
Enabled: Adaptive Release, Statistic

EchoCenter

PRACTICING the use of the list of actions

TRYING TO ENACTING THE ACTIONS

THE MEANING SENTENCES = LIST OF ACTIONS

SENTENCES

WORDS

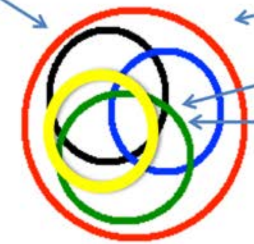
??????

LECTURE

Evolution of understanding

Exam problems → *similar* → **Problems:**
1. HW
2. Lectures
3. Units (IL)

Train yourself in recognition!



Practice HW
Practice exams

Some helpful questions for solving physics problems (page # 12)

1. What objects are involved? What processes are happening to them? (use your imagination - make a picture showing the objects and the processes they are involved into)
2. What properties of the objects and the processes might be important?
3. What physical quantities should be used for describing those properties, what connections might be important?
5. What laws or definitions should be used to describe important connections mathematically?
6. How can I solve my equations mathematically?
8. Does it make a sense?
9. Could I solve a similar problem again? How much time would it take? Who could help me (if I need it)?

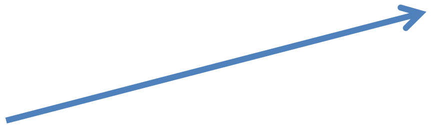
http://teachology.xyz/general_algorithm.htm

Practice makes results

Practice problems

Practice exams

Vectors



A vector is an arrow!

It has a length and a direction.

To describe a vector we can:

1. Set its magnitude and the angle measured from a given direction

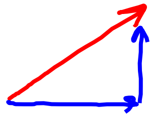
OR

2. Set its components (e.g. numerical)

Vector and its components

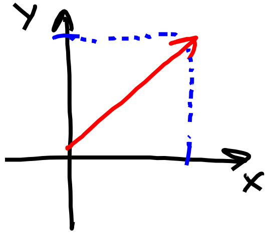
Components of vector $\vec{A}$, are such ***vectors*** $\vec{A}_x$ and $\vec{A}_y$, which are (a) **parallel to *x* and *y* axes**, (b) **the *sum* of which is equal to vector $\vec{A}$.**

A "component" = A "coordinate"



The *x*-component (*x*-coordinate) of a vector *A* is the number which is:

a) equal to the magnitude of its *x*-vector component, if it points *parallel* to the *x*-axis



b) equal to (-1) x the magnitude of its *x*-vector component, if it points *opposite* to the *x*-axis.

$X < 0$ $\qquad$ 0 $\qquad$ $X > 0$ $\qquad$ x

$v_x > 0$ $\qquad$ $v_x < 0$ $\qquad$ $a_x > 0$ $\qquad$ $a_x < 0$

$v_x > 0$ AND $a_x > 0$ OR $v_x < 0$ AND $a_x < 0$ ⇒ **Speeding up**

$v_x > 0$ AND $a_x < 0$ OR $v_x < 0$ AND $a_x > 0$ ⇒ **Slowing down**

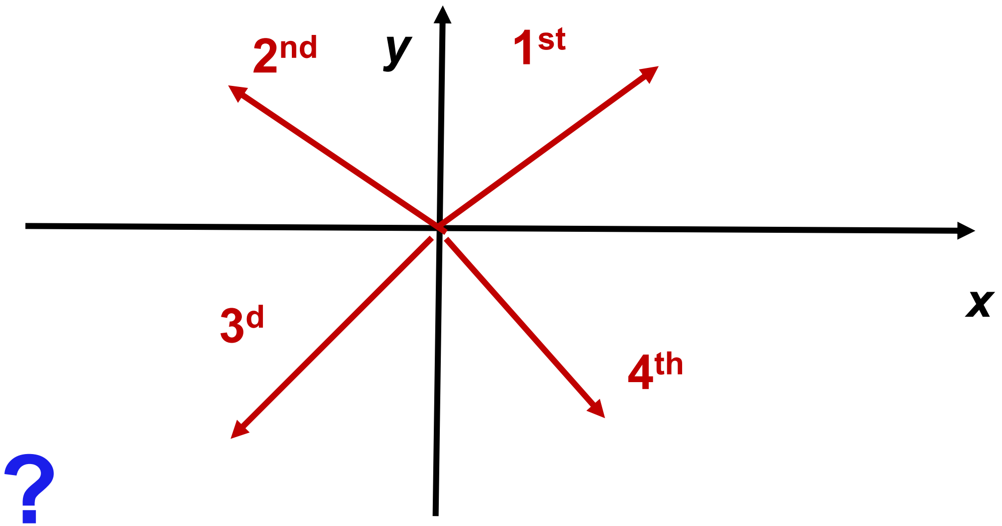
From a "sloppy" language to The accurate description.

"velocity" => "x-component of velocity"

Components of a vector are a_x = -12, and a_y = -16. **Draw the vector from the origin.**

The head of the vector is in … quadrant.

1. 1^{st}
2. 2^{nd}
3. 3^{d}
4. 4^{th}
5. What is a "quadrant"?
6. What is a "vector"?
7. What is a "head"?



Components of a vector are $a_x = -12$, and $a_y = -16$. Draw the vector from the origin.

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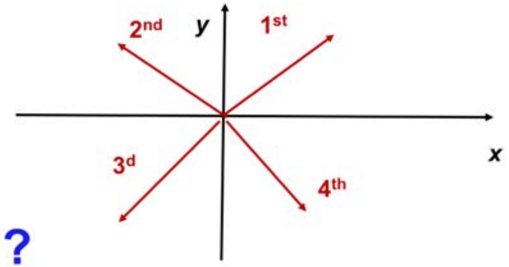

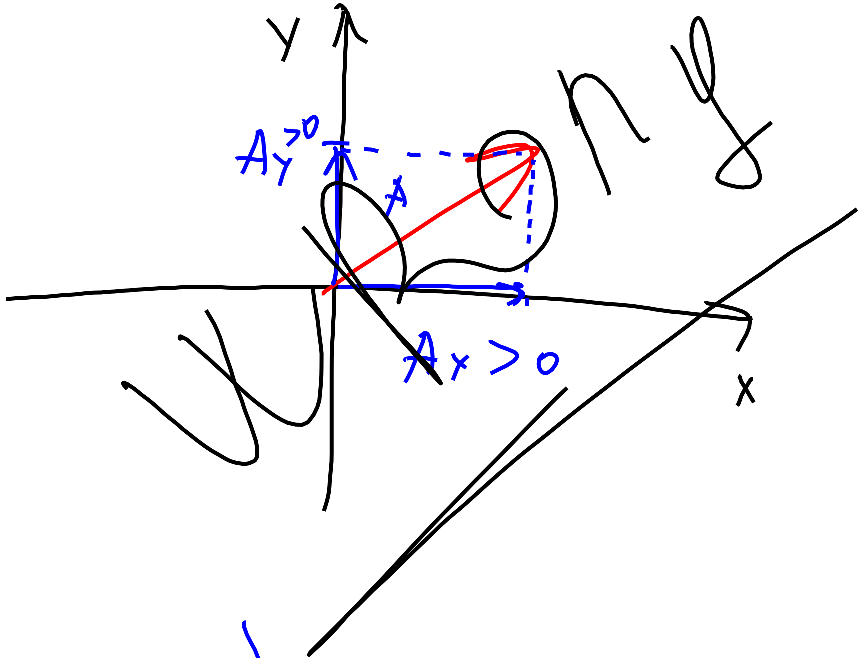

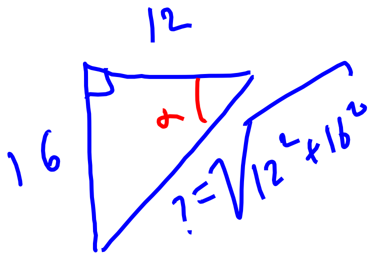

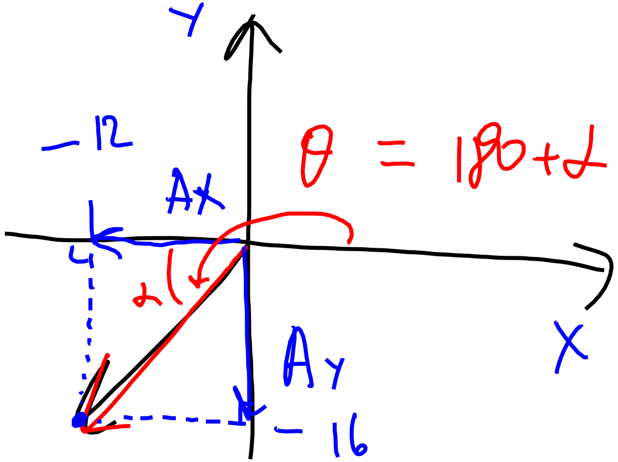

$\theta = 180 + \alpha$

$\tan\alpha = \frac{12}{16}$ or $\frac{16}{12}$

$\alpha = \tan^{-1}\left(\frac{16}{12}\right)$

Components of a vector are $a_x = -12$, and $a_y = -16$. Draw the vector from the origin. The head of the vector is in … quadrant.

1. 1st
2. 2nd
3. 3d
4. 4th

5. What is a “quadrant”?
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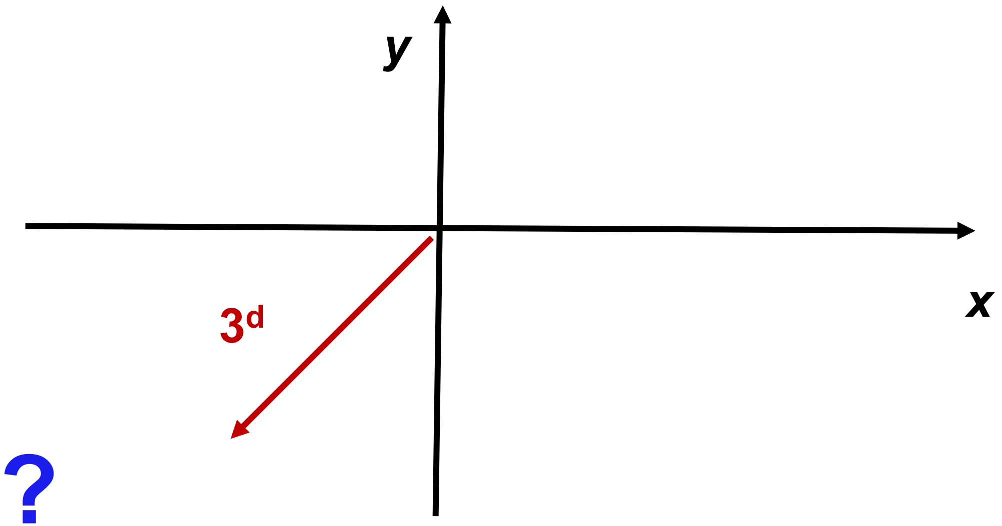
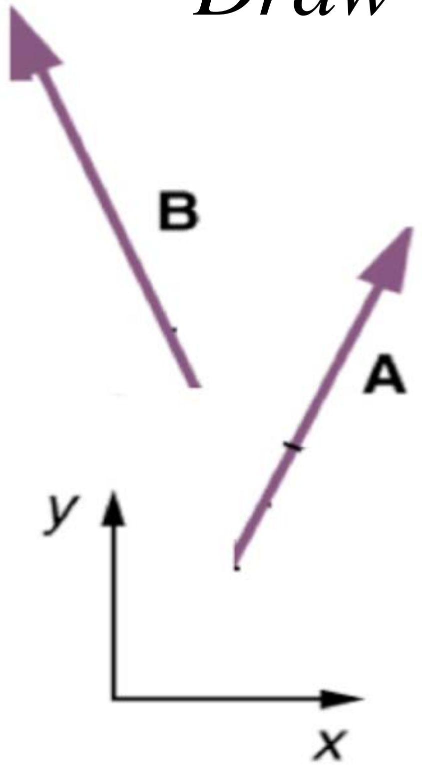


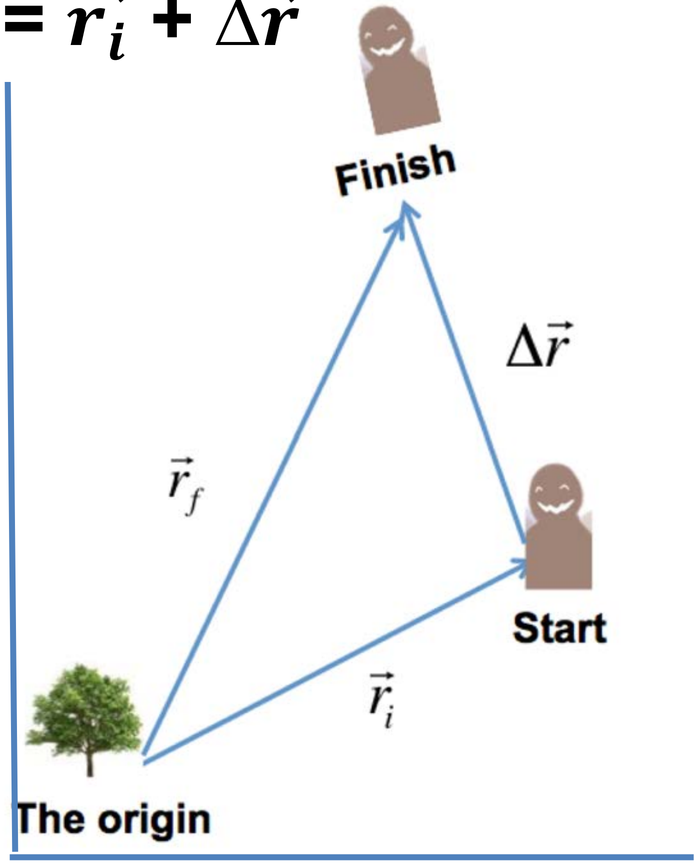
VECTOR ADDITION

$$\vec{r_f} = \vec{r_i} + \Delta\vec{r}$$

$$Draw \quad \vec{A} + \vec{B} \quad (= \mathbf{A} + \mathbf{B})$$

(little arrows vs. bold font)





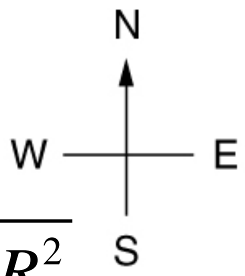
Two-step rule (“*tail-to-head*”): 1. “MOVE”; 2. “CONNECT”

VECTOR ADDITION FOR 2 VECTORS (JUST LEARNED)

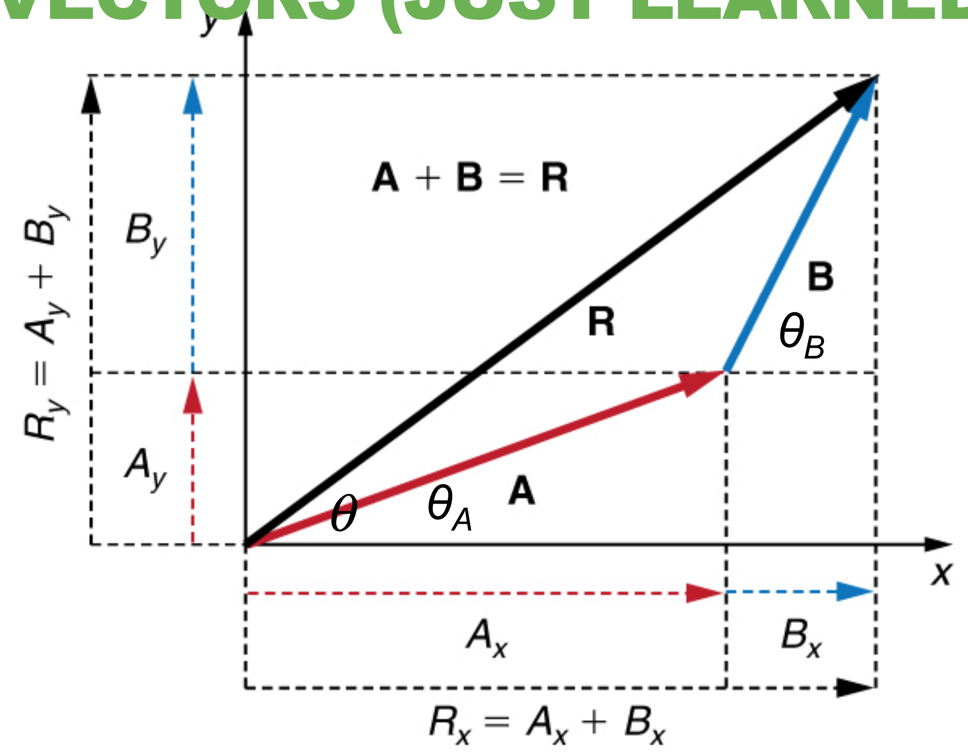
Adding two vectors algebraically

$A_x = A \cos \theta_A \quad A_y = A \sin \theta_A$

$B_x = B \cos \theta_B \quad B_y = B \sin \theta_B$.

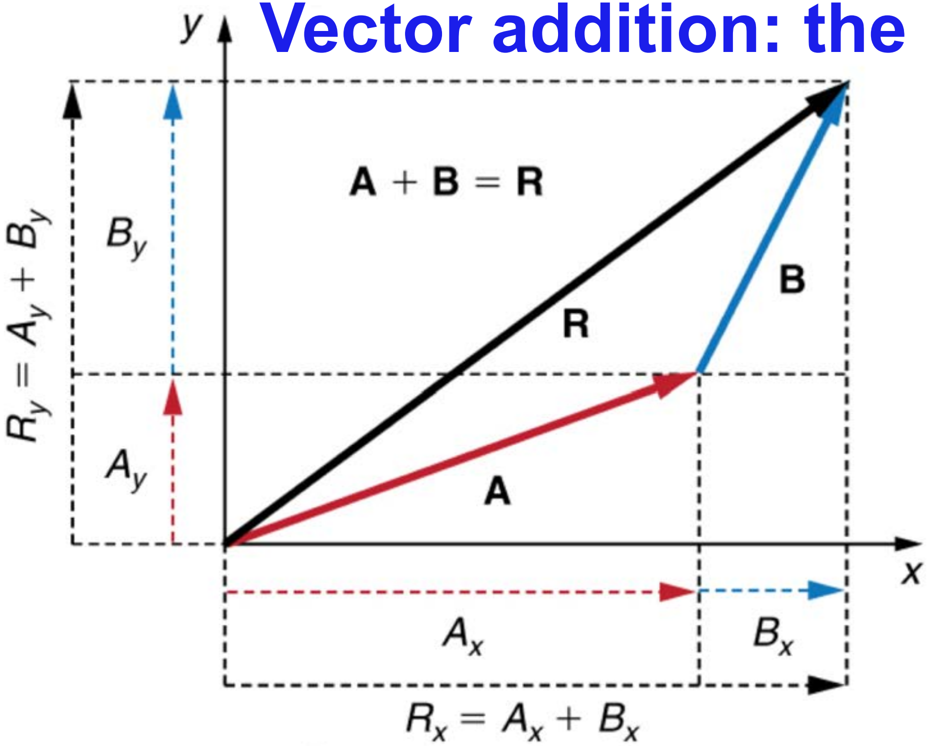


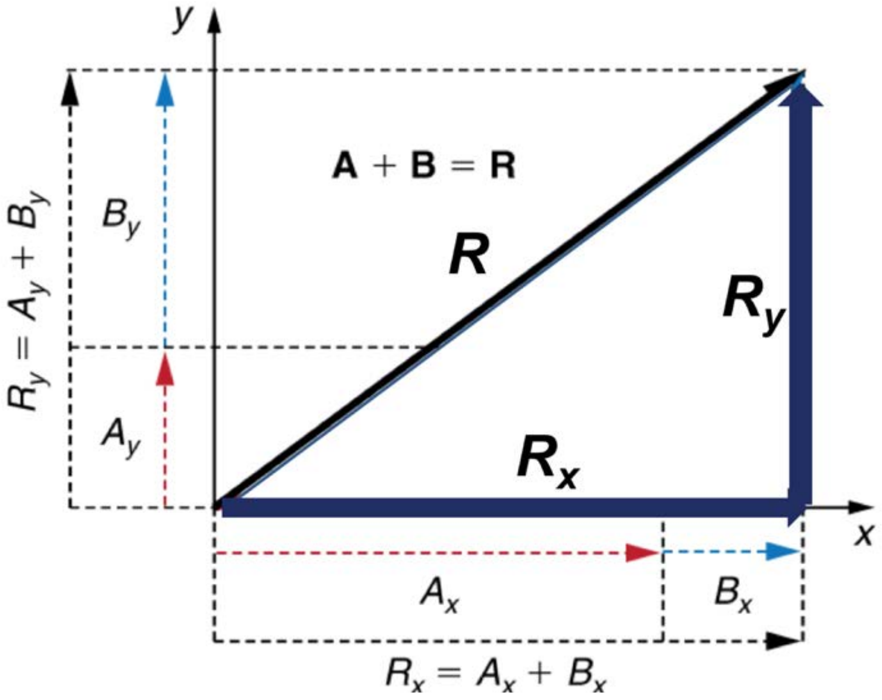
$$\tan \theta = \frac{R_y}{R_x} \qquad R = \sqrt{R_x^2 + R_y^2}$$



To add vectors **A** and **B** , first determine the horizontal and vertical components of each vector. These are the dotted vectors $\mathbf{A}_x$, $\mathbf{A}_y$, $\mathbf{B}_x$ and $\mathbf{B}_y$ shown in the image.

Vector addition: the component method





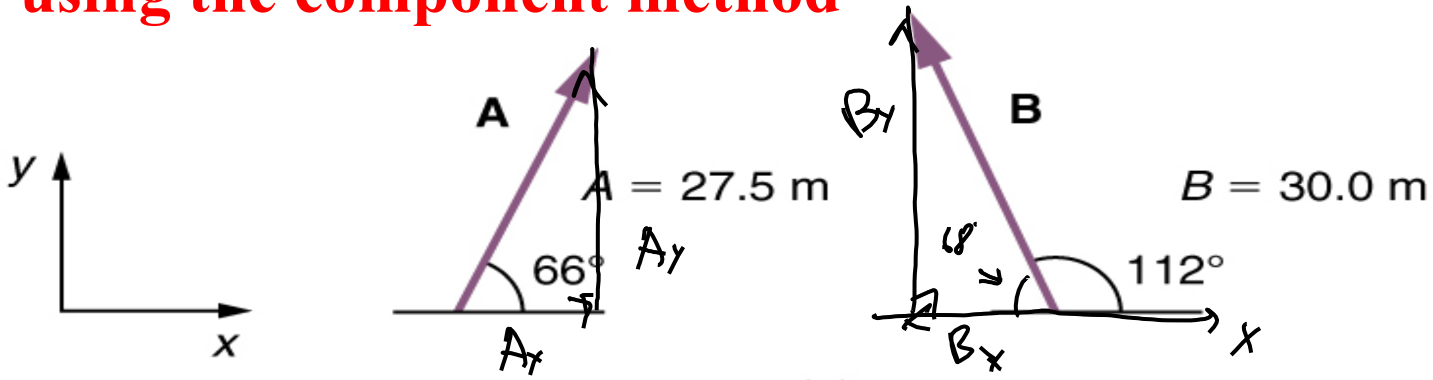
$A_x =$	$A_y =$
$B_x =$	$B_y =$
$R_x = A_x + B_x =$	$R_y = A_y + B_y =$

$$R = \sqrt{R_x^2 + R_y^2}$$

$$\tan\theta = \frac{R_y}{R_x}$$

using the component method

FIND A + B



(a)

$A_x = 27.5 \cdot \cos 66 =$

$A_y = 27.5 \cdot \sin 66$

$B_x = -30 \cdot \cos 68$

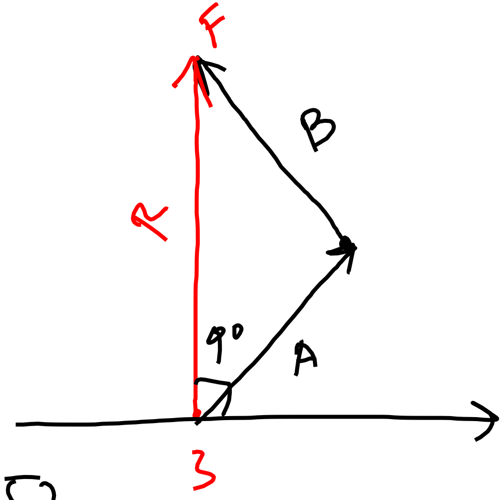
$B_y = 30 \cdot \sin 68$

+

+

$R_x = -0.05 \sim 0$

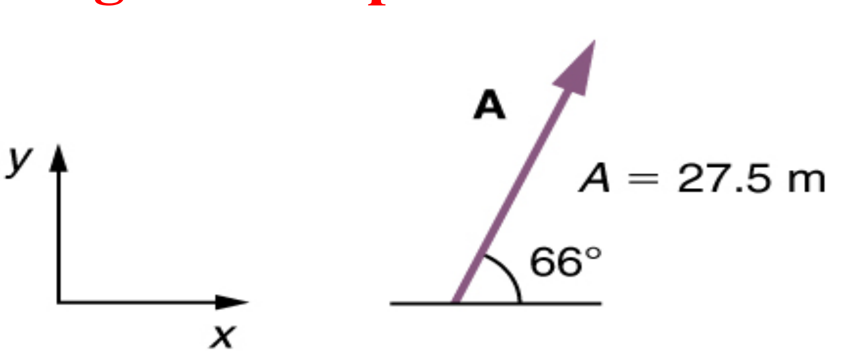
$R_y = 52$



$|R| \approx 52$

using the component method

FIND A + B



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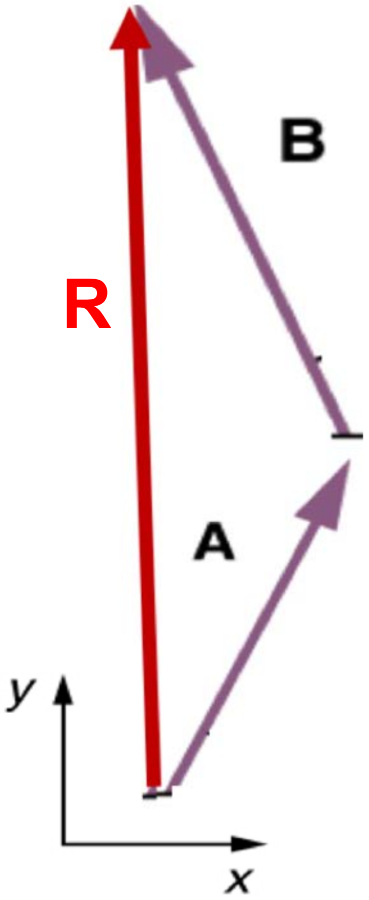


$A_x = 27.5 * \cos 66 = 11.2$

$A_y = 27.5 * \sin 66 = 25.1$

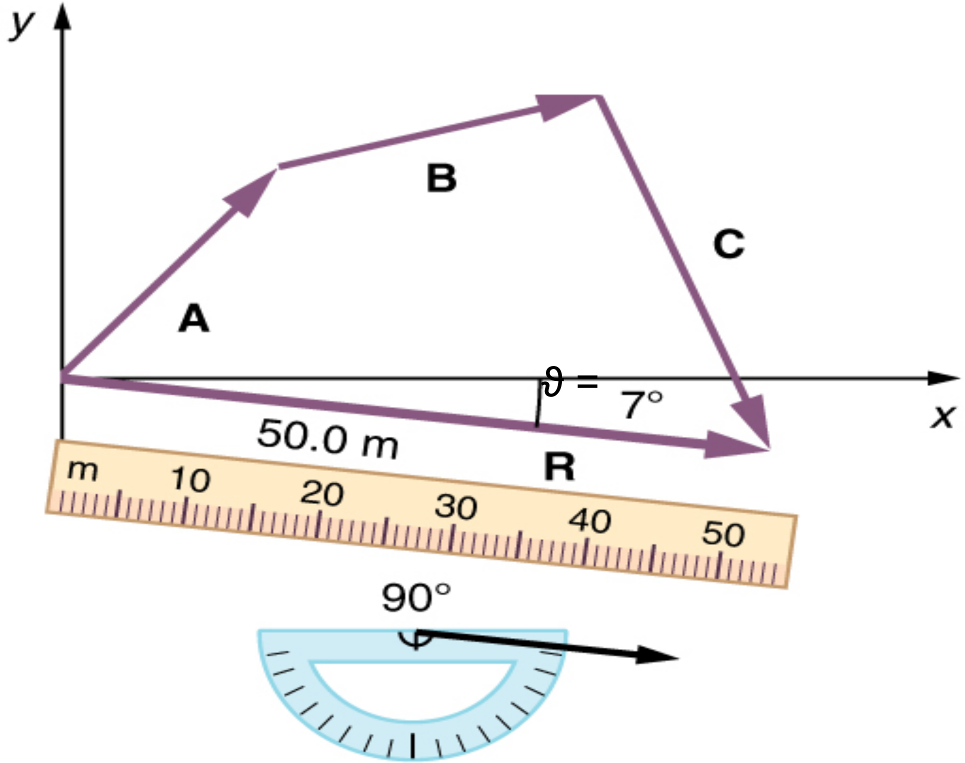
$B_x = -30 * \cos 68 = -11.24$

$B_y = 30 * \sin 68 = 27.8$

$R_x = A_x + B_x = -0.04$

$R_y = A_y + B_y = 52.9$

$$R = \sqrt{R_x^2 + R_y^2} = 53$$



$$\mathbf{R} = \mathbf{A} + \mathbf{B} + \mathbf{C}$$

means

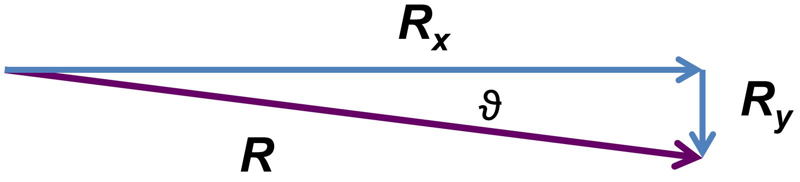
$$R_x = A_x + B_x + C_x$$

AND

$$R_y = A_y + B_y + C_y$$

AND

$$\mathbf{R} = \mathbf{R_x} + \mathbf{R_y}$$

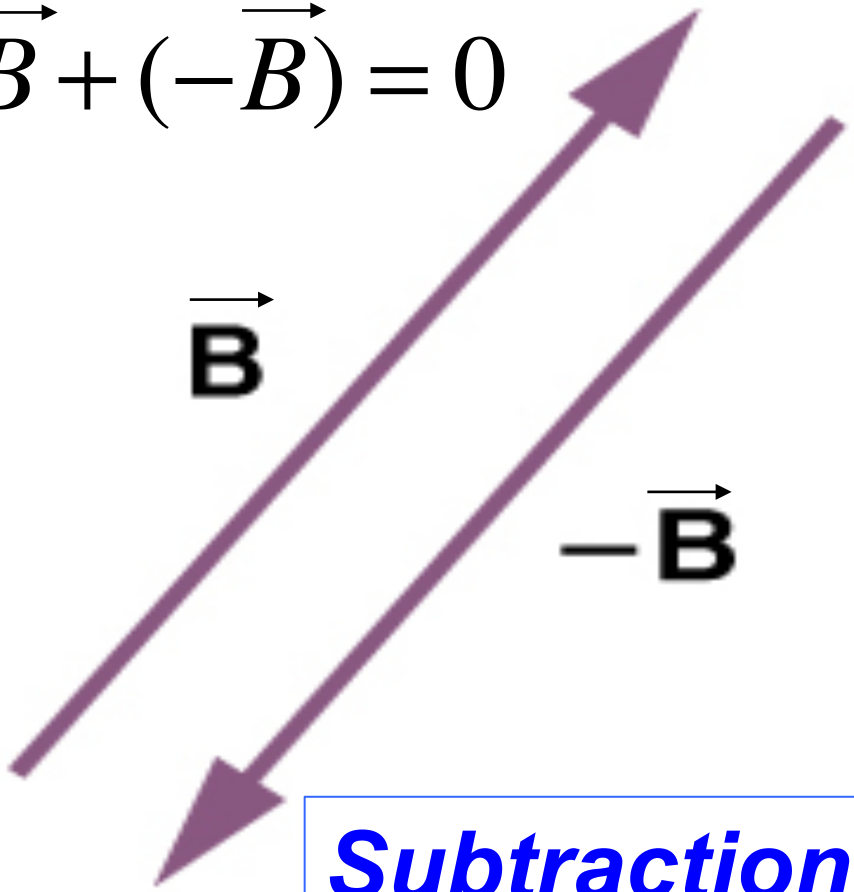


$$|R| = \sqrt{(R_x)^2 + (R_y)^2}$$

$$\tan\vartheta = \frac{|R_y|}{|R_x|}$$

Opposite vector; subtraction.

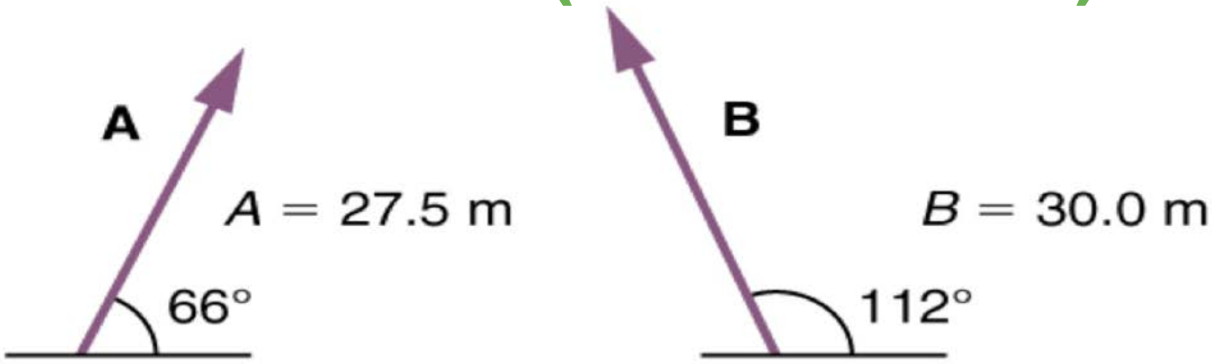
$$\vec{B} + (-\vec{B}) = 0$$



The **negative/opposite of a vector** is just another vector of the same magnitude but pointing in the opposite direction. So -***B*** is the negative of ***B*** ; it has the same length but opposite direction.

Subtraction: $\vec{A} - \vec{B} =: \vec{A} + (-\vec{B})$

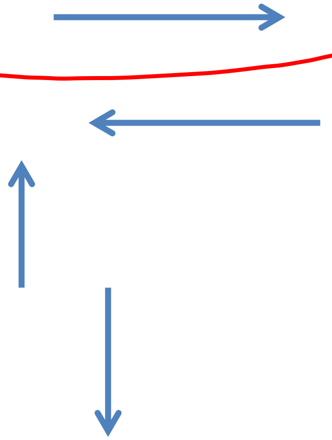
FIND *A* – *B* (BY DRAWING)



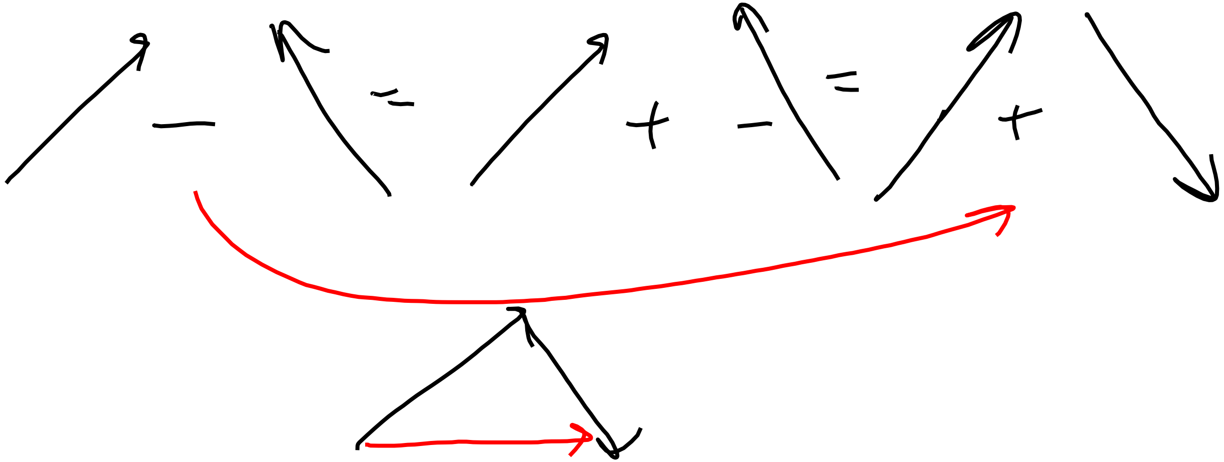
A – B = A + -B (!)

***A* – *B* points mostly …**

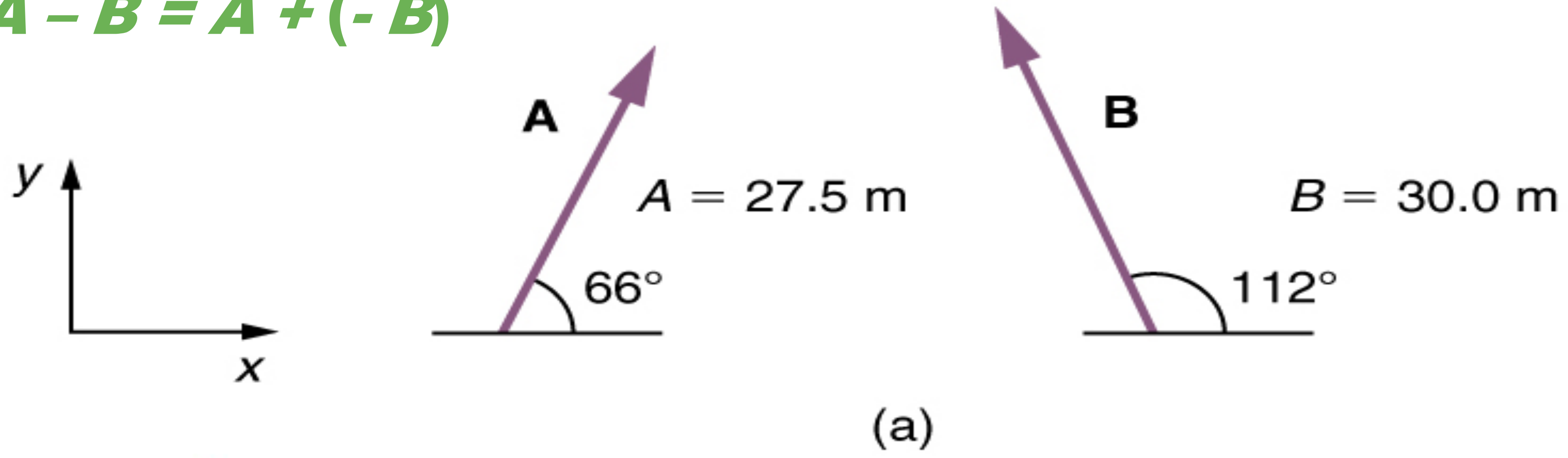
1
2
3
4

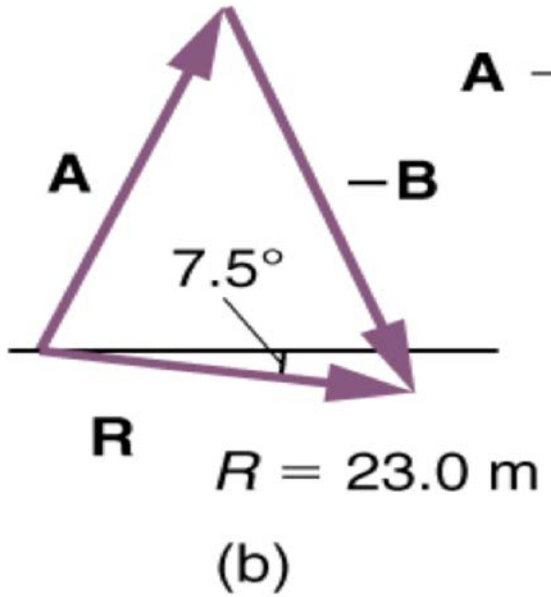


[LectureMCQ_L5_Q3]



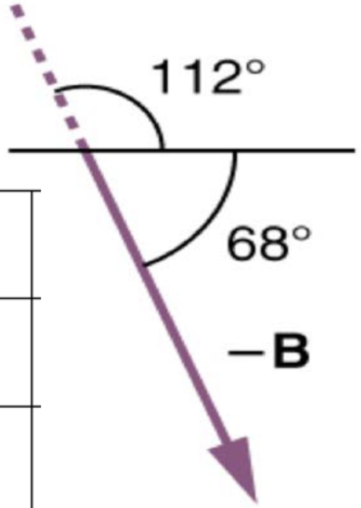
A – B = A + (- B)





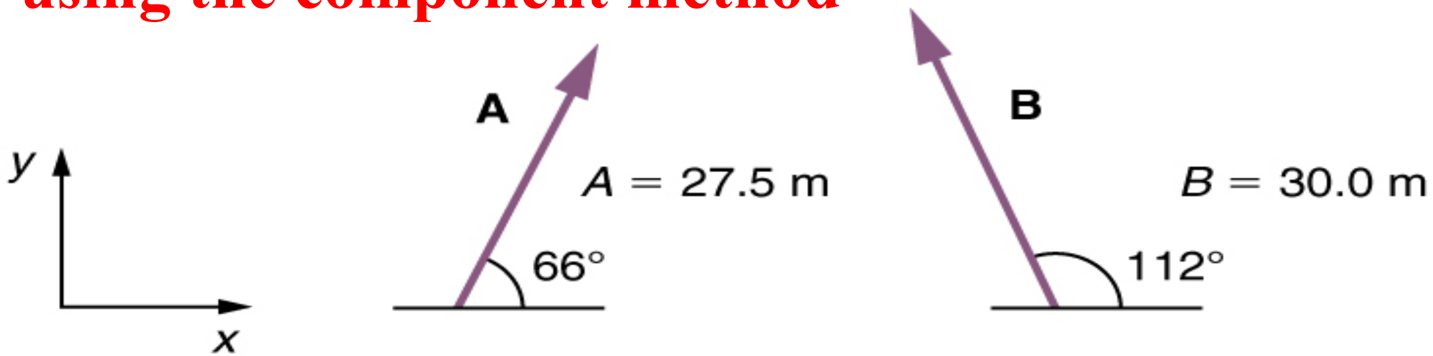
A − B = R

$A_x =$	$A_y =$
$B_x =$	$B_y =$
$R_x = A_x - B_x =$	$R_y = A_y - B_y =$

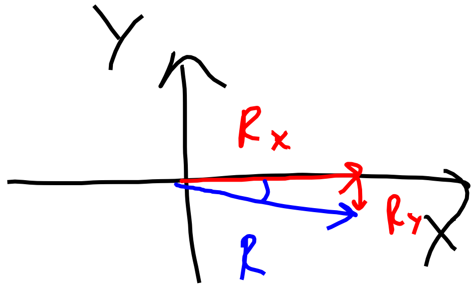


using the component method

FIND A - B



(a)



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$A_y = 27.5 * \sin 66 = 25.1$

$B_x = -30 * \cos 68 = -11.24$

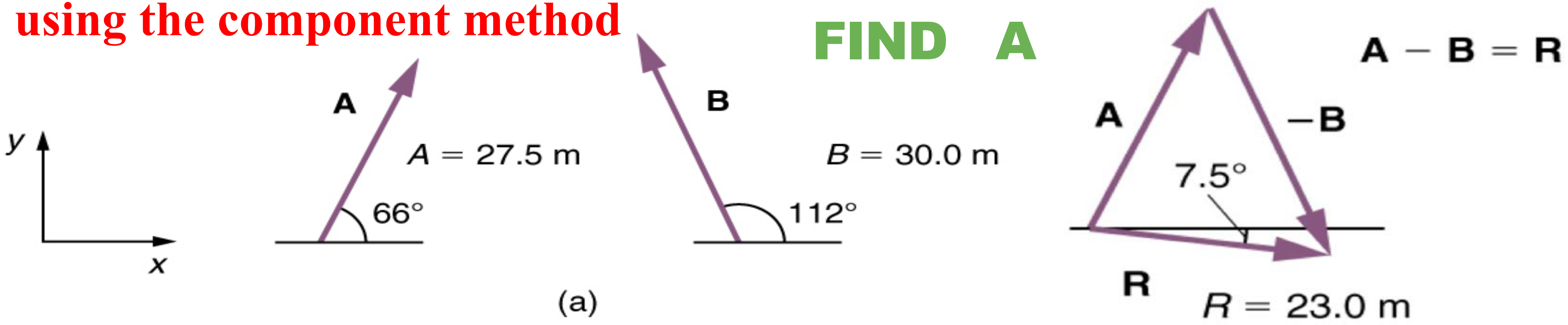
$B_y = 30 * \sin 68 = 27.8$

$R_x = 11.2 - -11.24 = 23$

$R_y = 25.1 - 27.8 = -3.$

using the component method

FIND A



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$B_x = -30 * \cos 68 = -11.24$

$B_y = 30 * \sin 68 = 27.8$

$R_x = A_x - B_x = 22.44$

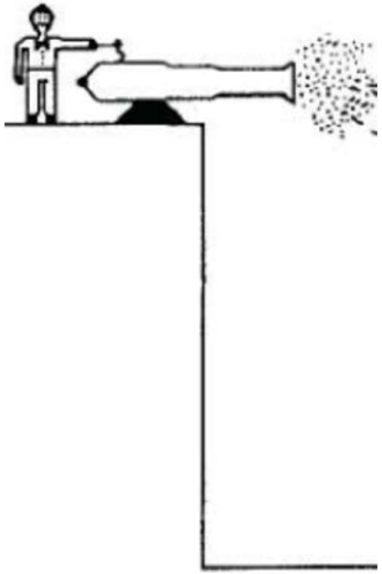
$R_y = A_y - B_y = -2.7$

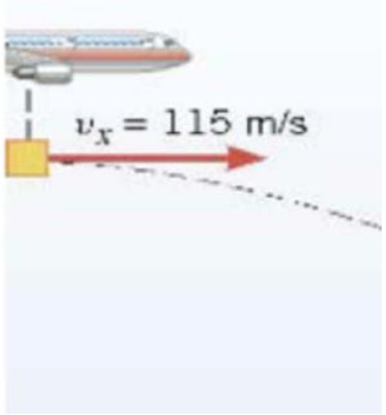
$$R = \sqrt{R_x^2 + R_y^2} = 23$$

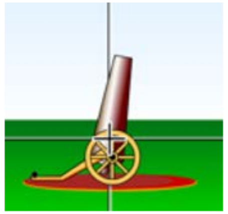
$$\theta = \tan^{-1}(3/22) = 7.6^0$$

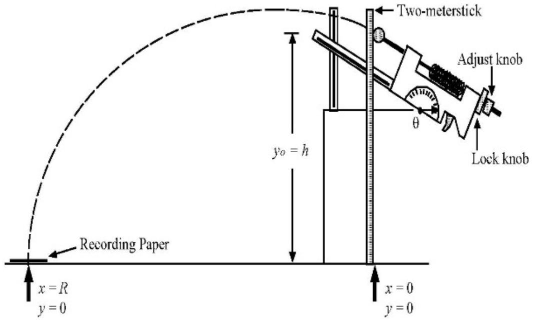
Projectile motion (PM)

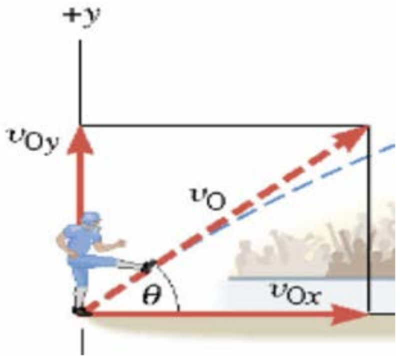
Projectile motion, properties of projectile motion, the range, the maximum height, the time of the fight.





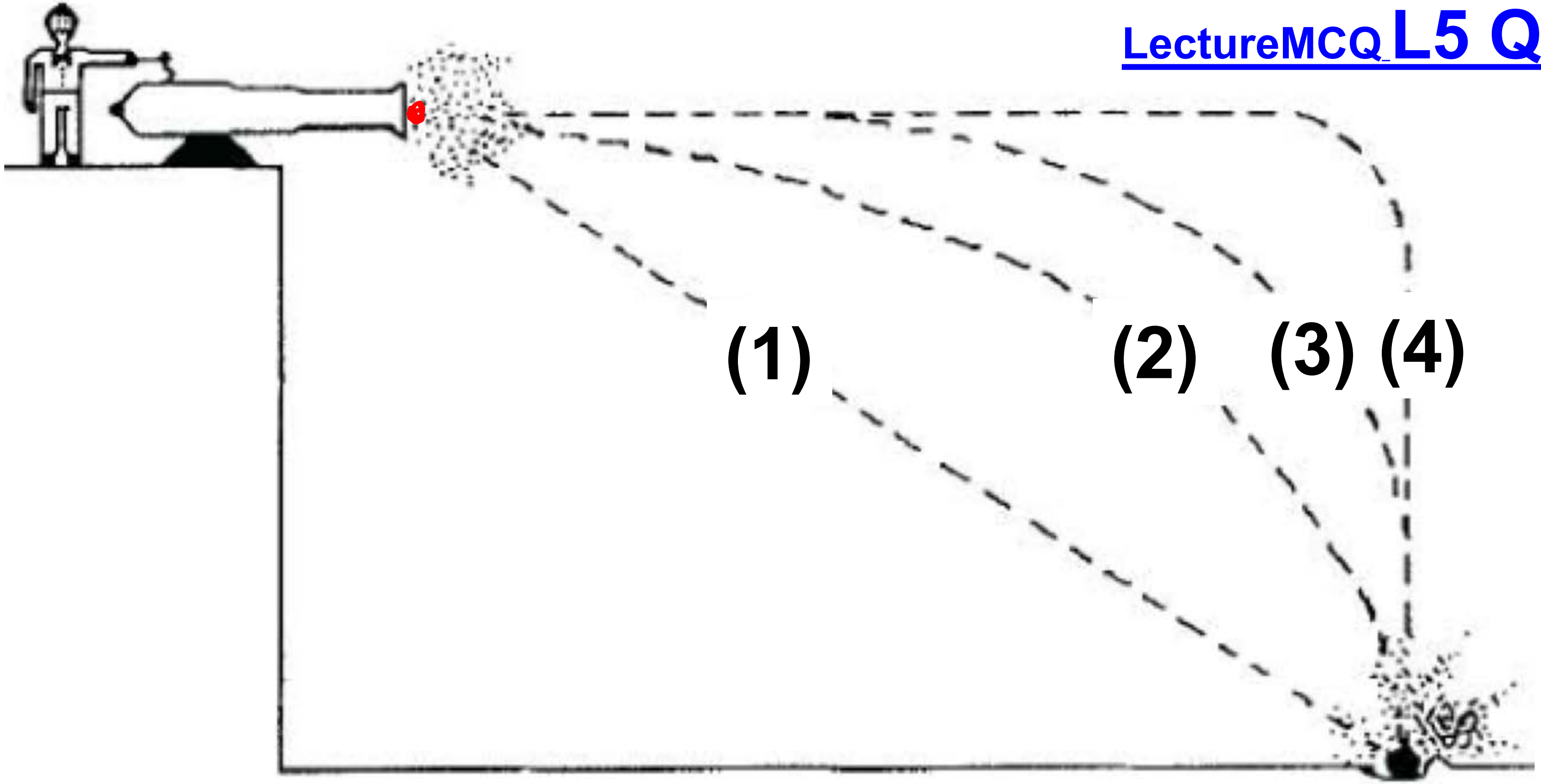






Which of the paths in the picture best represents the path of the cannon ball?

LectureMCQ L5 Q4



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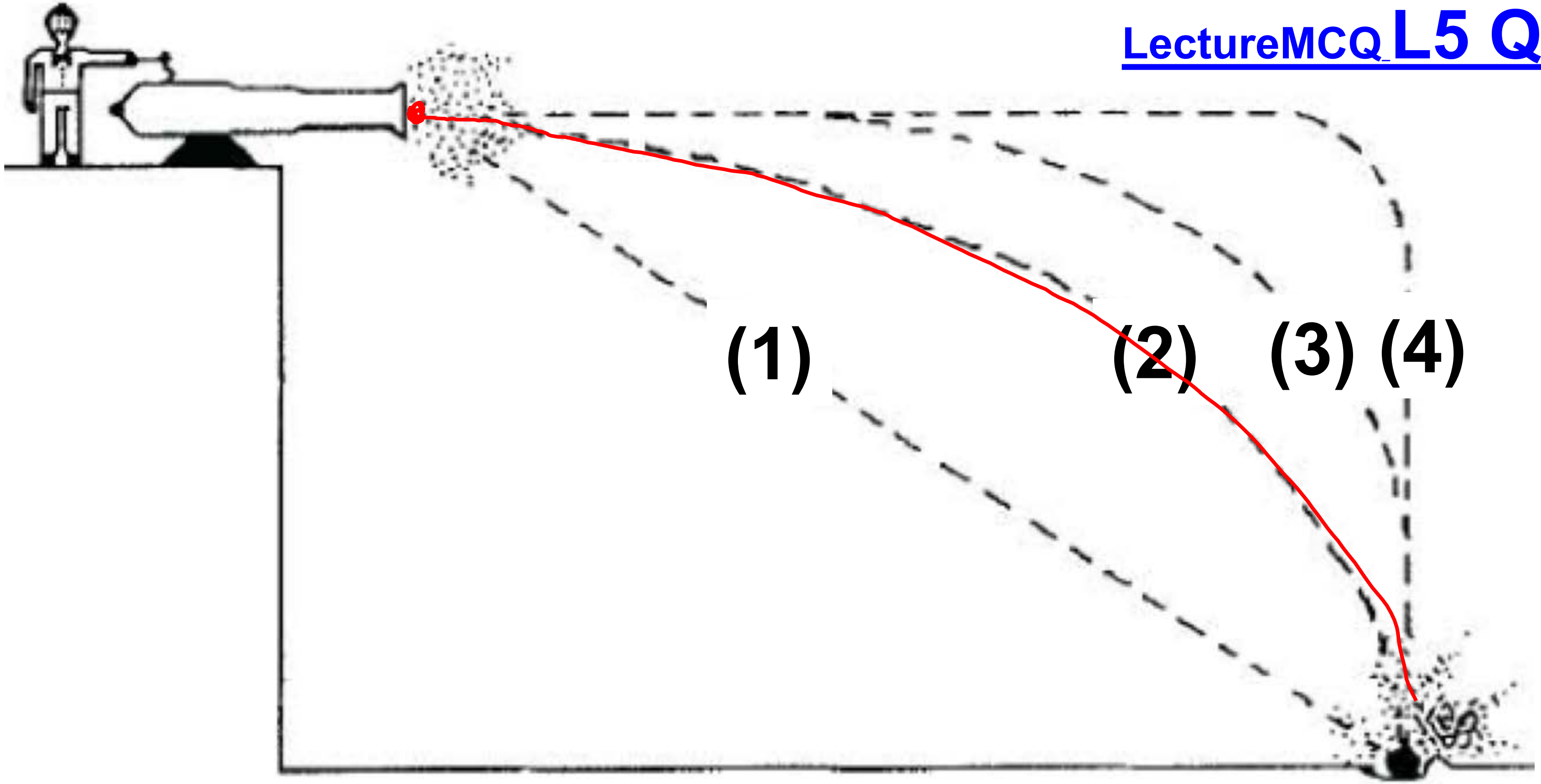
[LectureMCQ L5 Q4]



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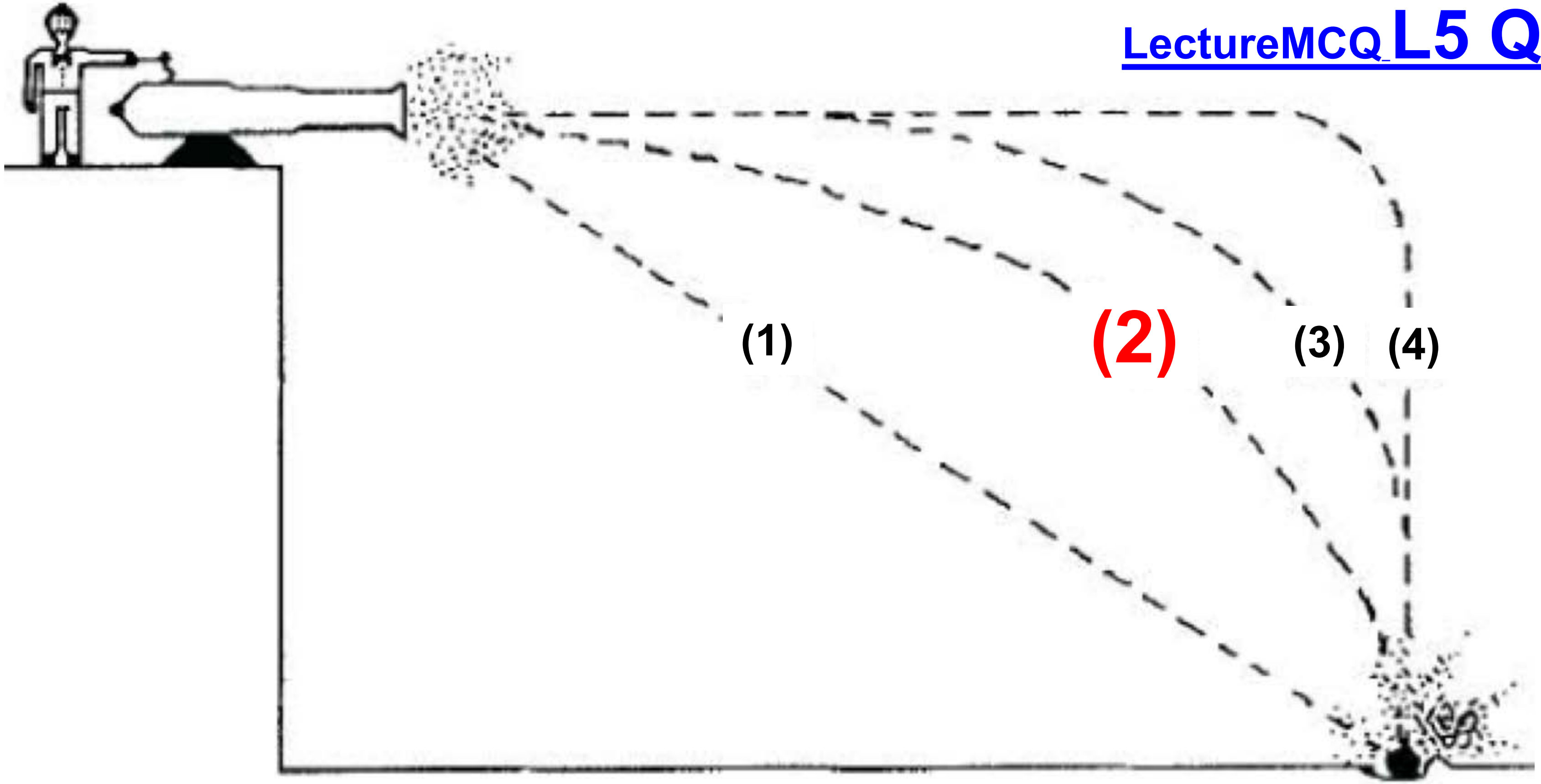
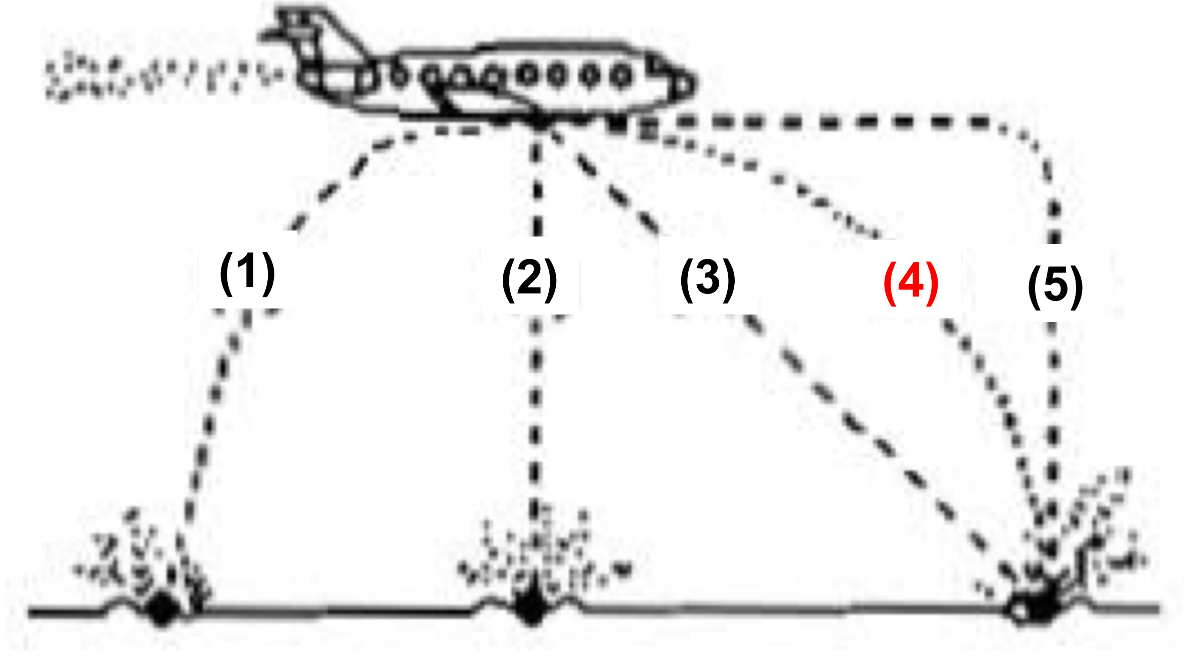
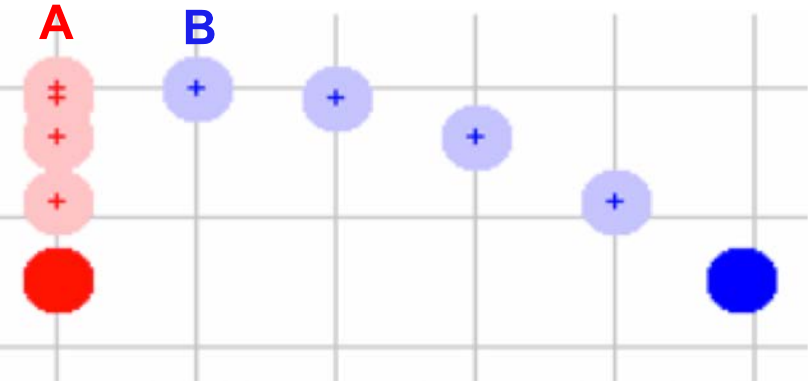
LectureMCQ L5 Q4



A bowling ball accidently falls out of the cargo bay of an airliner as it flies along in a horizontal direction. As seen from the ground, which path would the ball most closely follow after falling the airplane?



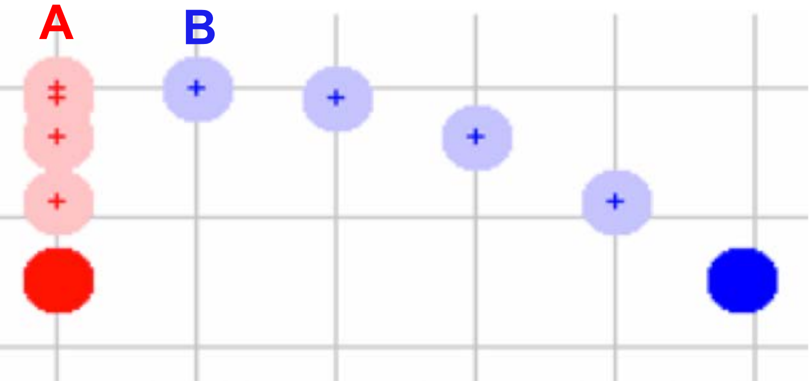


A race

Two balls are launched simultaneously from the same height. Ball A is released from rest, and drops straight down. Ball B is given an initial *horizontal* velocity.

Which ball hits the ground first?

1. This is too early for the morning class.
2. Ball A
3. Ball B
4. Both balls hit the ground at the same time
5. It depends on the mass of the balls.



Hard to see?? Listen!

A race LectureMCQ L5 Q5

Two balls are launched simultaneously from the same height. Ball A is released from rest, and drops straight down. Ball B is given an initial *horizontal* velocity.

Which ball hits the ground first?

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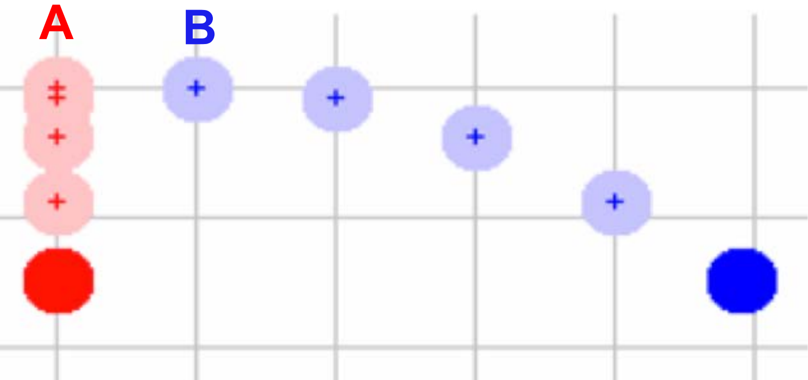
5. **It depends on the mass of the balls**

Follow your Intuition!



Hard to see?? Listen!

A race

LectureMCQ L5 Q5

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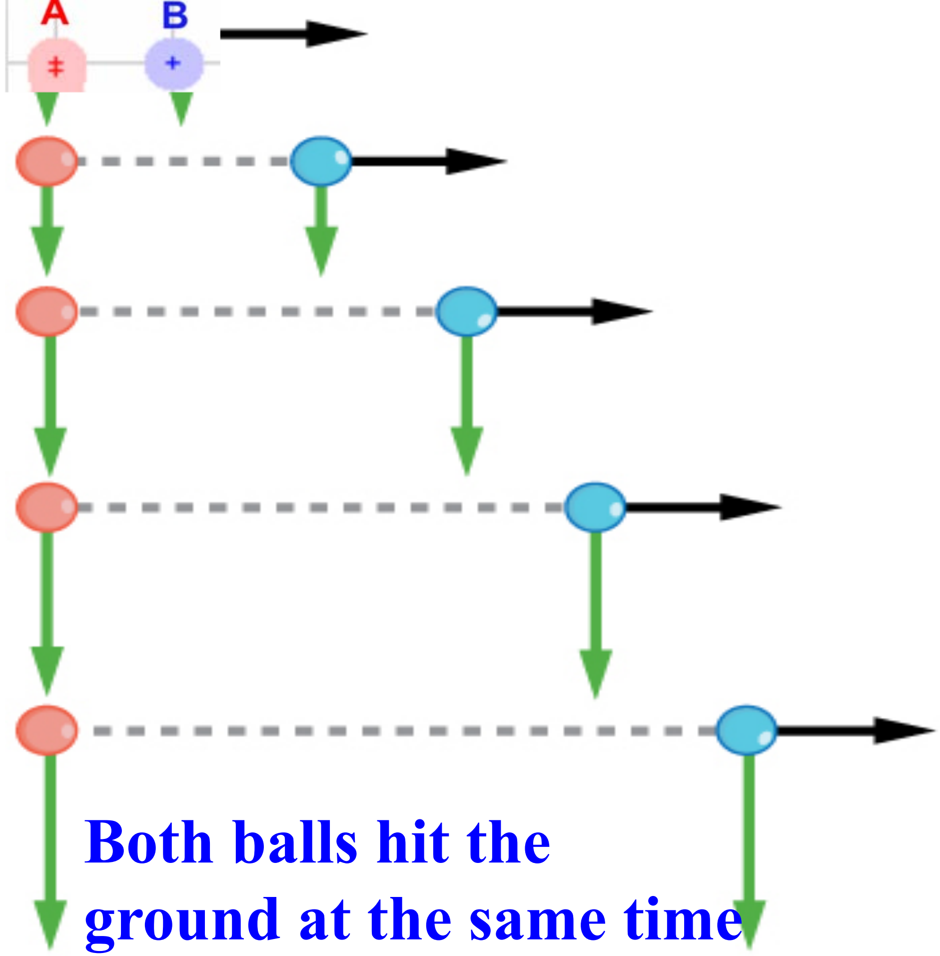
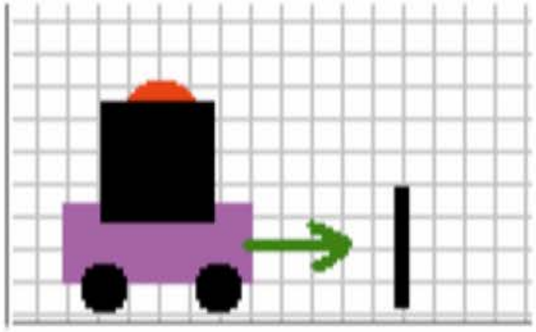


The horizontal component of velocity does *not* affect its vertical component!

This shows the motions of two identical balls—one falls from rest, the other has an initial horizontal velocity. Each subsequent position is an equal time interval. Arrows represent horizontal and vertical velocities at each position. The ball on the right has an initial horizontal velocity, while the ball on the left has no horizontal velocity. Despite the difference in horizontal velocities, the vertical velocities and positions are identical for both balls. **This shows that the vertical and horizontal motions are independent.**

You Shot a Bullet into the Air...

Suppose you are driving a convertible with the top down. The car is moving to the right at constant velocity. You point a rifle straight up into the air and fire it. In the absence of air resistance, where would the bullet land ?



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Ballistic cart

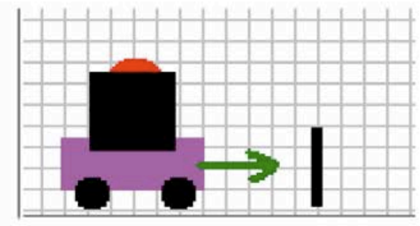
A ballistic cart is a cart that shoots a ball vertically upward.

With the cart rolling at constant speed when it shoots the ball, where will the ball land?

LectureMCQ_L5 Q6

1. It depends on the speed of the cart.
2. In the cart
3. Behind the cart
4. Ahead of the cart
5. Impossible to tell

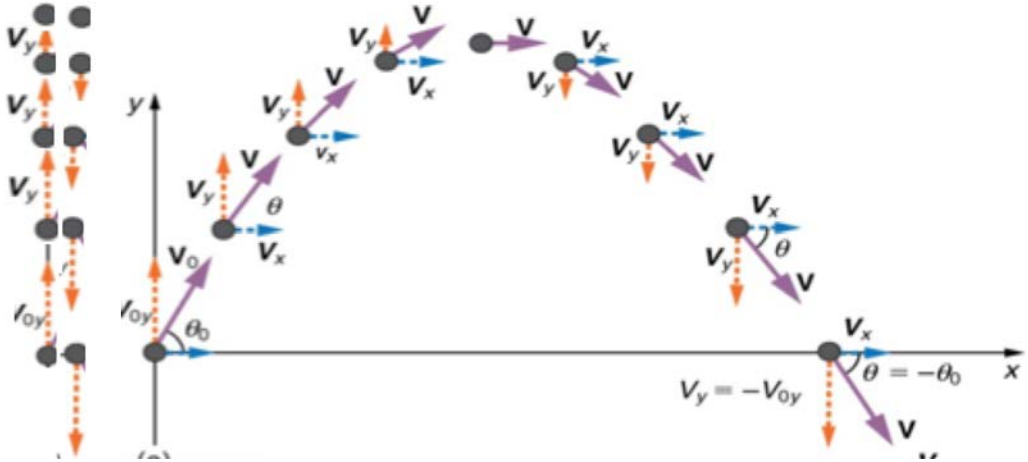
Ballistic cart



A ballistic cart is a cart that shoots a ball vertically upward.

With the cart rolling at constant speed when it shoots the ball, where will the ball land?

1. It depends on the speed of the cart.
2. In the cart.
3. Behind the cart.
4. Ahead of the cart.
5. Impossible to tell.

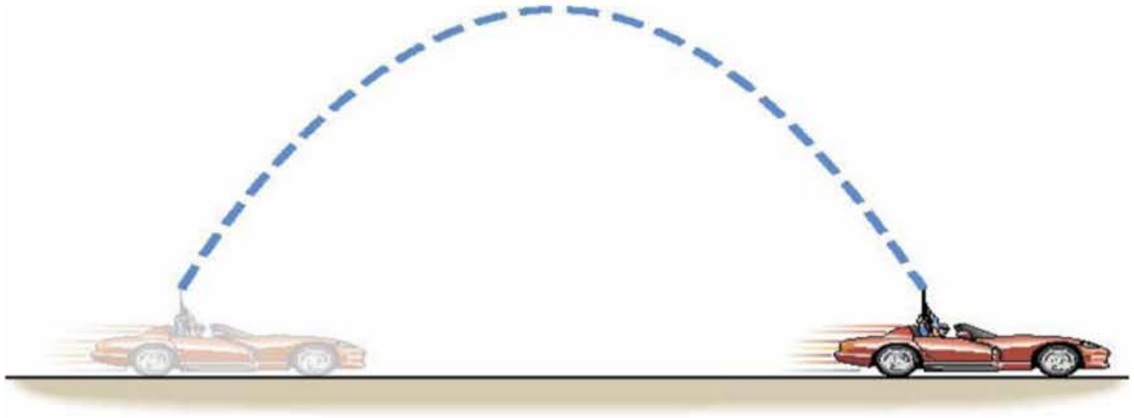


The horizontal component of velocity does *not* affect its vertical component!

You Shot a Bullet into the Air...

Suppose you are driving a convertible with the top down. The car is moving to the right at constant velocity. You point a rifle straight up into the air and fire it. In the absence of air resistance, where would the bullet land –

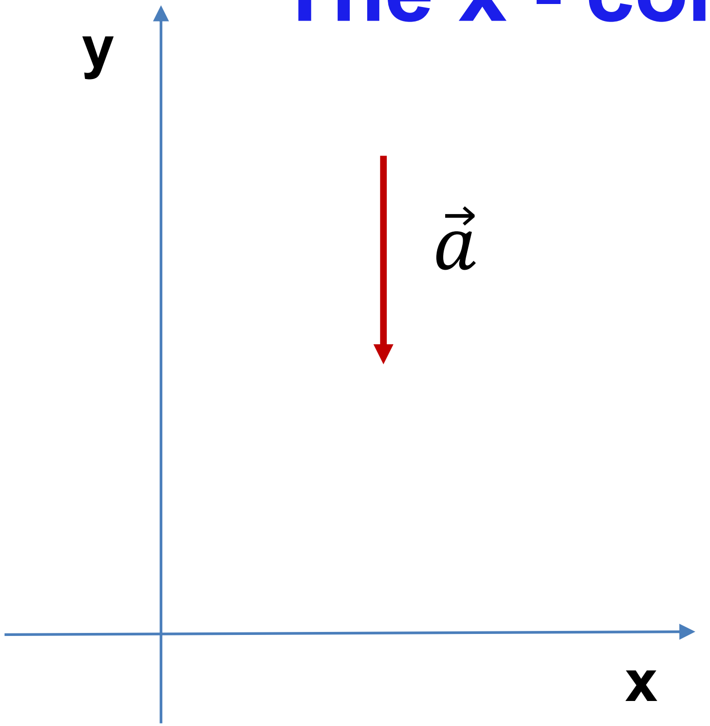
(1) behind you, (2) ahead of you, or (3) in the barrel of the rifle



Experiments show that the vertical and horizontal motions are independent. But – WHY?

We know that $a_y = -g$

"The x - component of vector *a*" is …



LectureMCQ L5 Q7

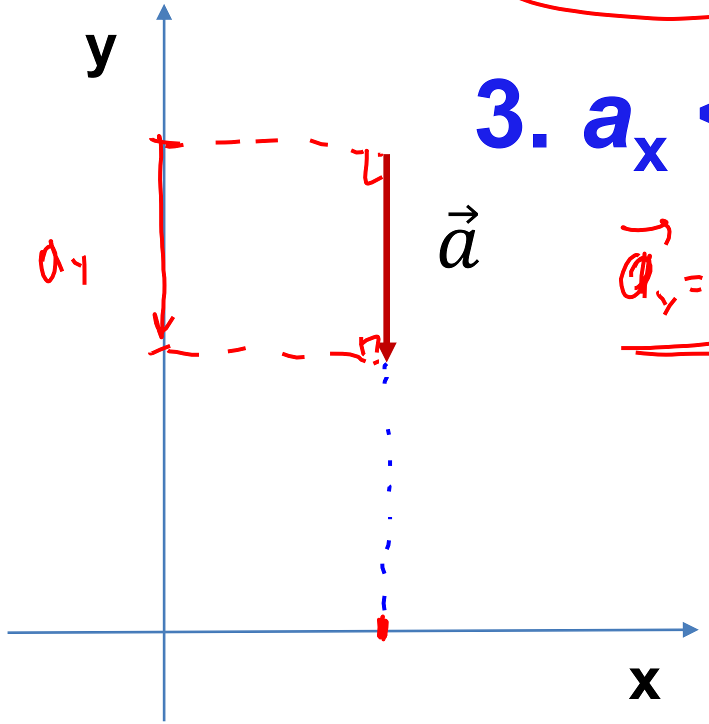
1. $a_x > 0$
2. $a_x = 0$
3. $a_x < 0$

"The x - component of vector *a*" is …

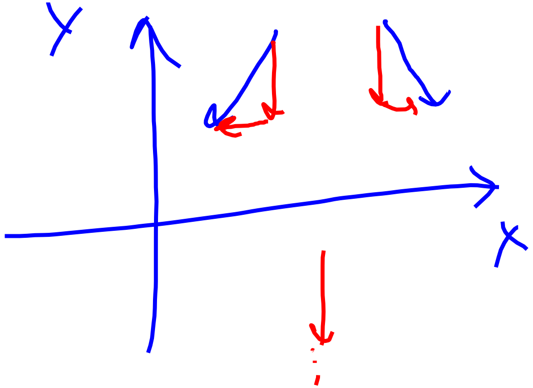
1. $a_x > 0$

2. $a_x = 0$

3. $a_x < 0$



$\vec{a}_y = \vec{a}$



$\vec{a} = \vec{a}_x + \vec{a}_y$

$\vec{a} = \vec{a}_x + \vec{a}$

$\vec{a} - \vec{a} = \vec{a}_x$

$0 = a_x$

We know that $a_y = -g$

"The x - component of vector *a*" is …

1. $a_x > 0$
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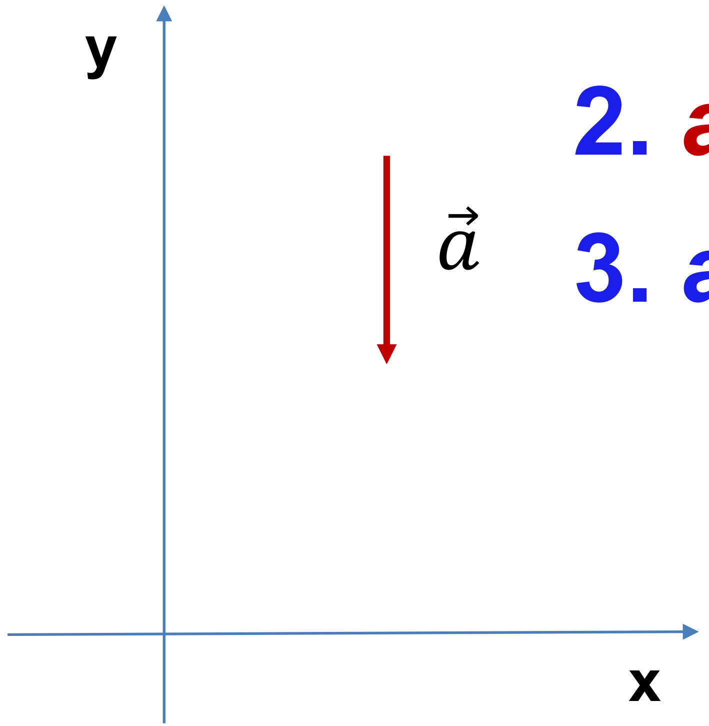
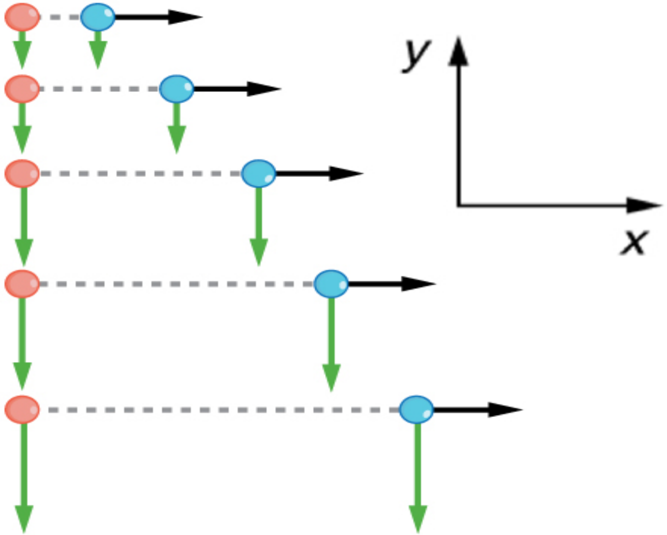
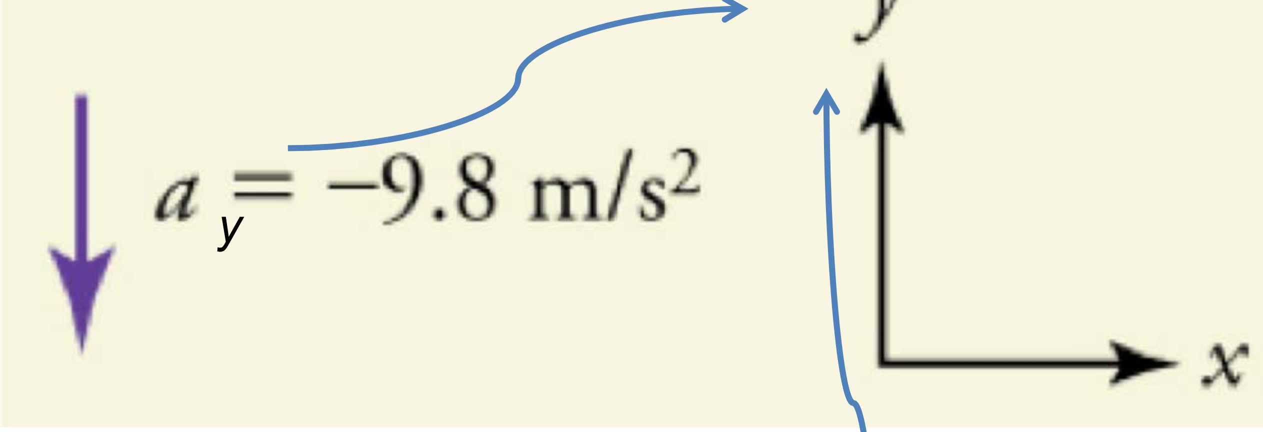


A vertical vector has **NO** horizontal component

2-D motion





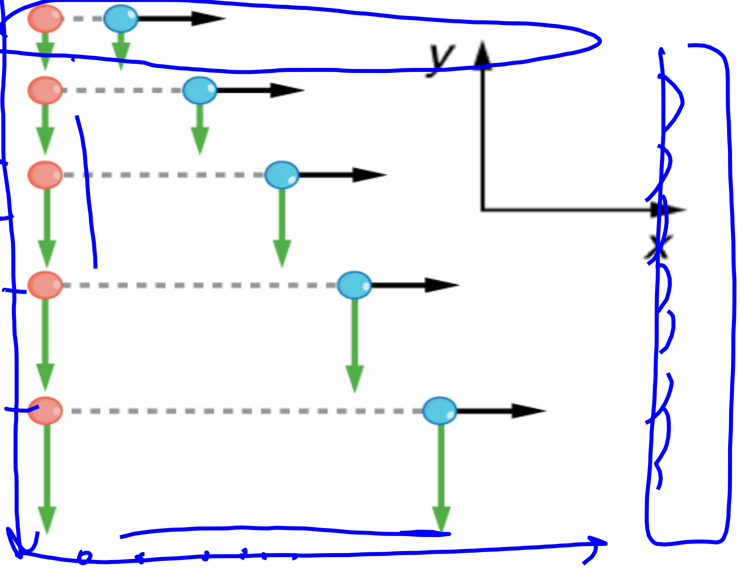
At the Earth's surface, $\vec{g}$, the acceleration due to gravity, equals 9.8 m/s² and is directed down.

$$g = |a_y| = 9.8\ \text{m/s}^2 \sim 10\ \text{m/s}^2 \Rightarrow \quad a_y = -g$$

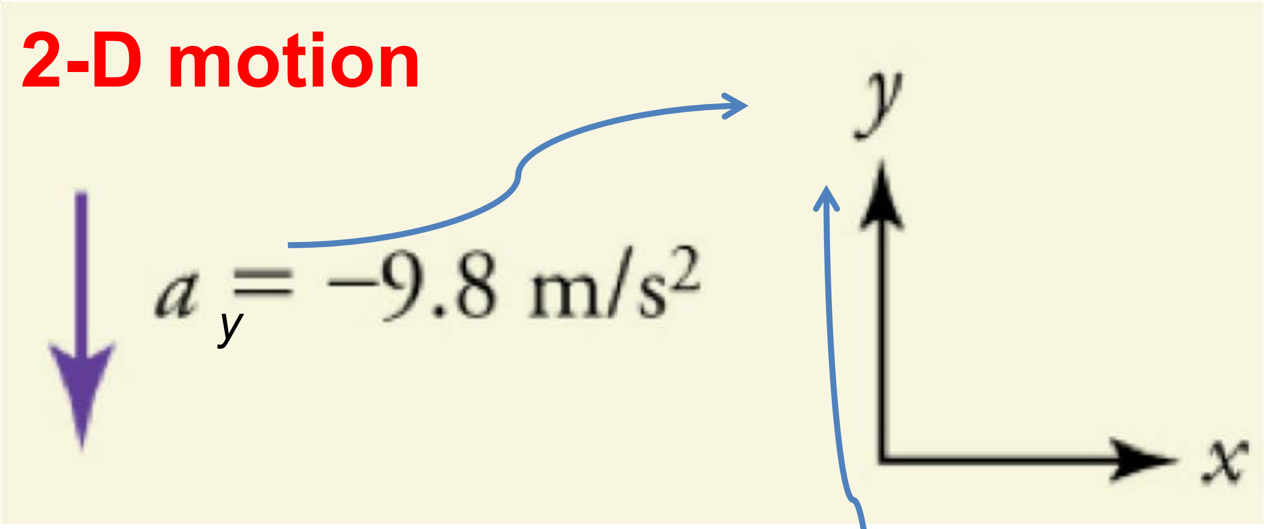
$$v_y = v_{0y} - gt$$

y–axis points UP !

$$a_x = 0 \longrightarrow \boxed{v_x = v_{ox} = \text{constant}}$$



2-D motion



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y–axis points UP !

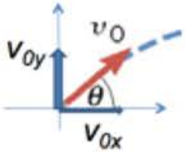
$$a_x = 0 \longrightarrow \boxed{v_x = v_{ox} = \text{constant}}$$

Add an x or y subscript to our usual equations of 1-D motion (appropriate for constant acceleration…).

MCV

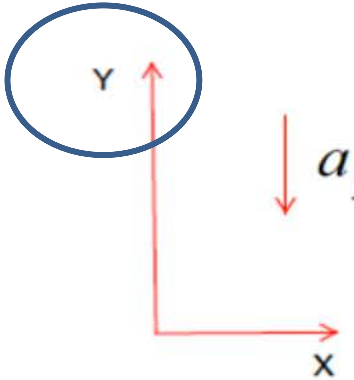
$v_{ox} = v_o \cos\theta$

$V_{oy} = v_y \sin\theta$



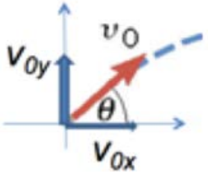
$$v_x = v_{0x} + a_x t \quad = \text{const}$$

$$x = x_0 + v_{0x} t + \frac{1}{2} a_x t^2$$



$$a_y = -9.80\,\text{m/s}^2$$

$$a_x = 0$$

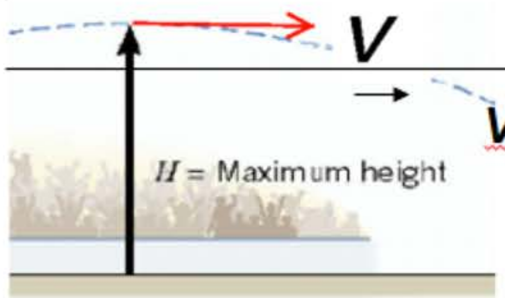


MCA

$$v_y = v_{0y} + a_y t$$

$$y = y_0 + v_{0y} t + \frac{1}{2} a_y t^2$$

$$v_y^{\,2} = v_{0y}^{\,2} + 2a_y (y - y_0)$$



$V_y = 0$ $\quad V_x = V_0 = const$

IMPORTANT: When solving problems always keep the x-component data separate from the y-component data. **The only thing that can be used in both sets of equations is time.**

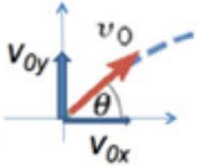
When solving problems on projectile motion; for the natural choice of the x – and y (up) – coordinates we have this:

The x-component equations	The x-component equations
$v_x = v_{ox}$	$v_y = v_{oy} - g\,t$
$x = v_{ox}\,t$	$y = h + v_{oy}\,t - \frac{1}{2}\,g\,t^2$

$x_0 = 0$

$V_{ox} = v_o \cos\theta$

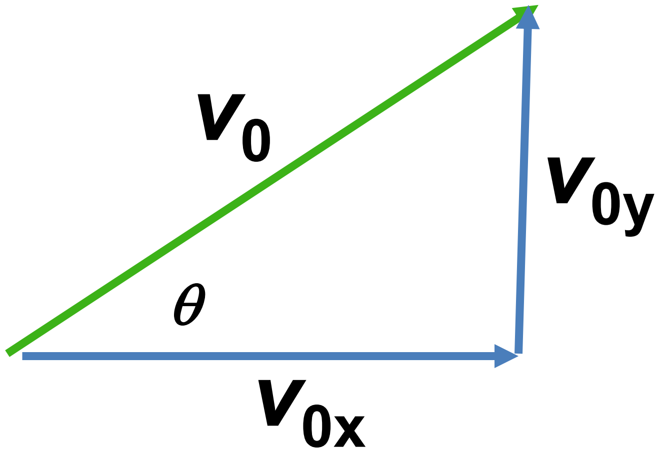
$V_{oy} = v_y \sin\theta$



In general, $h \neq 0$!

θ = **launch angle**

v_0 = **the initial speed**



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$$V_{ox} = V_o \cos\theta$$

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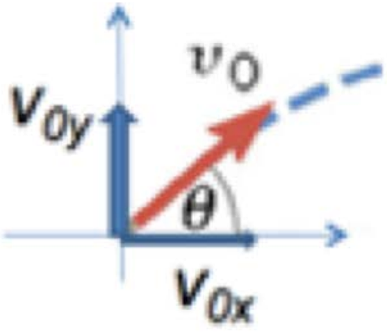
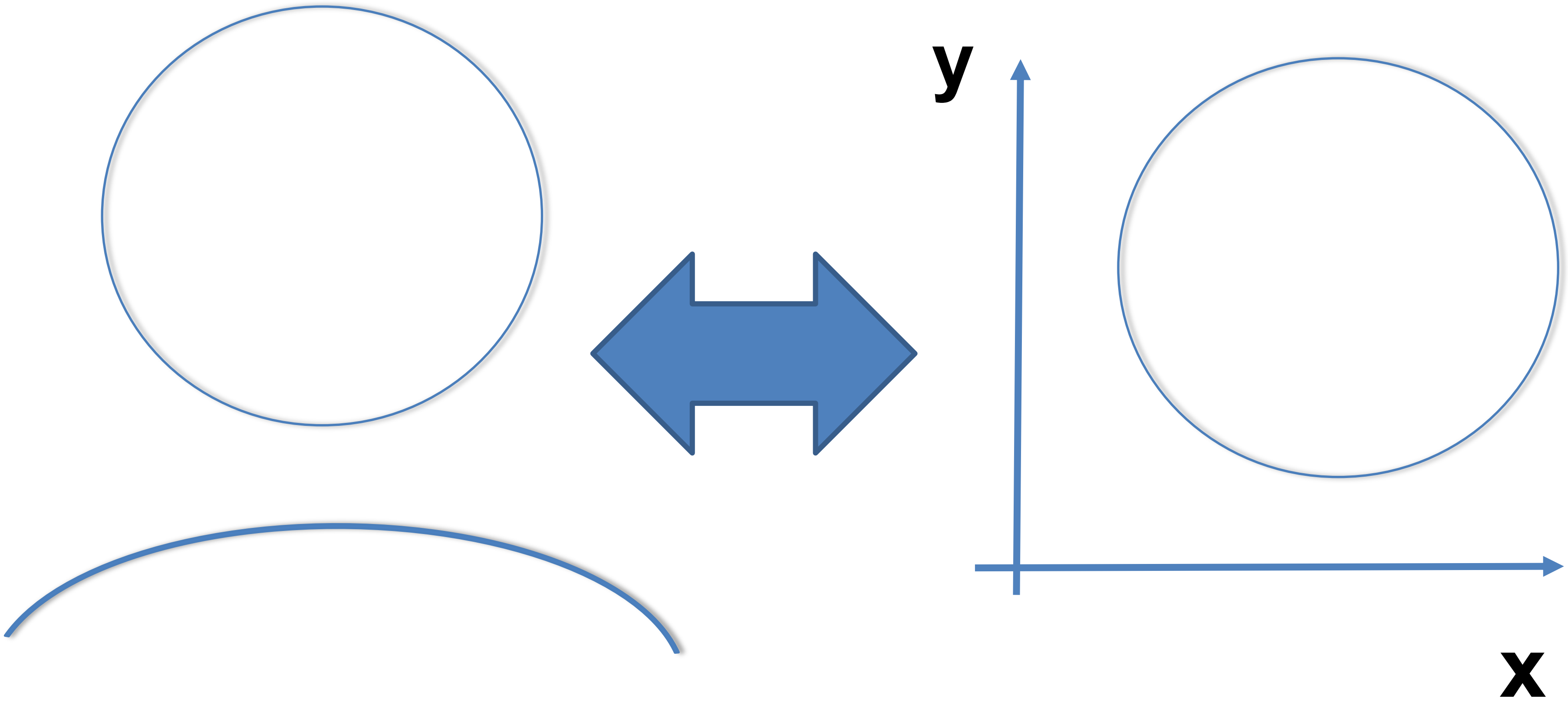
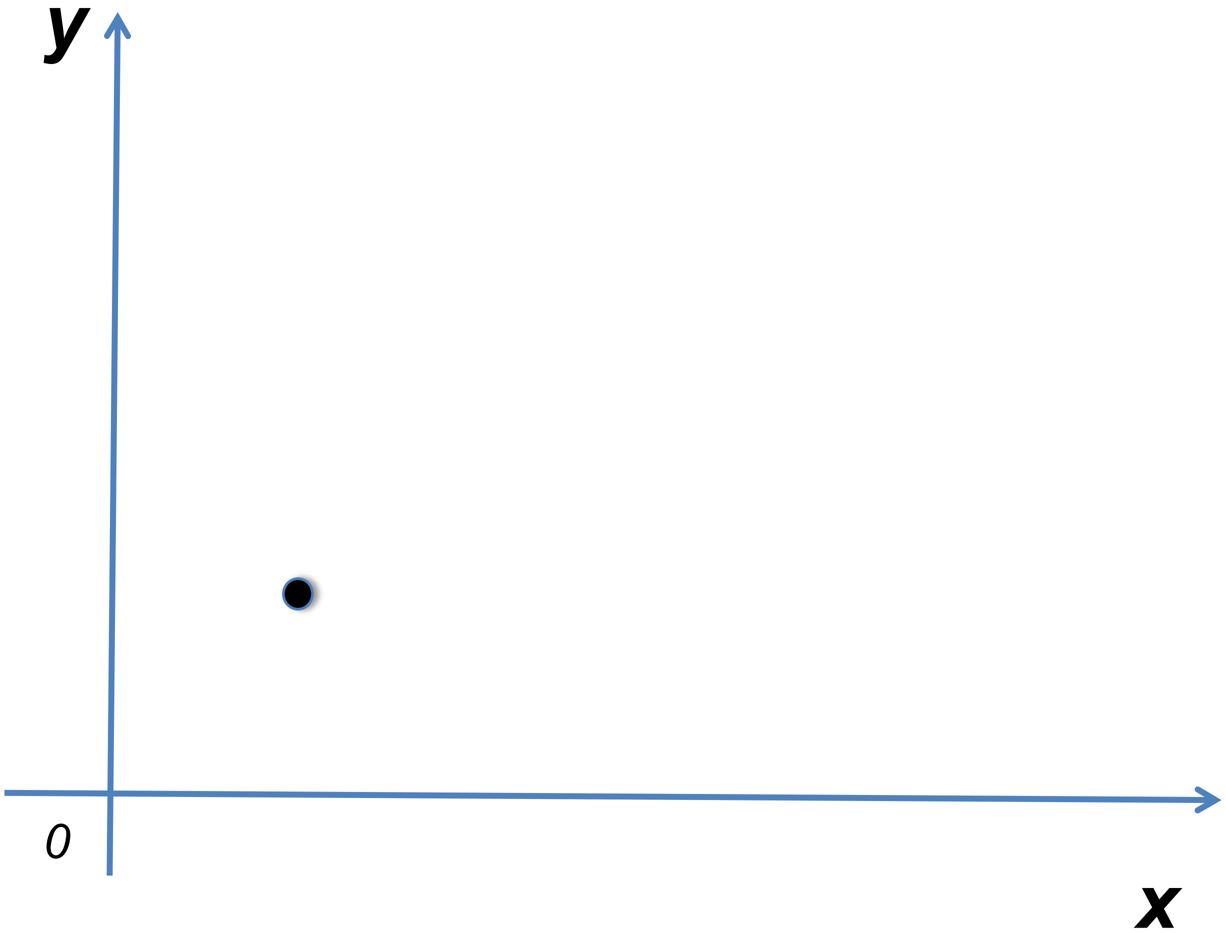


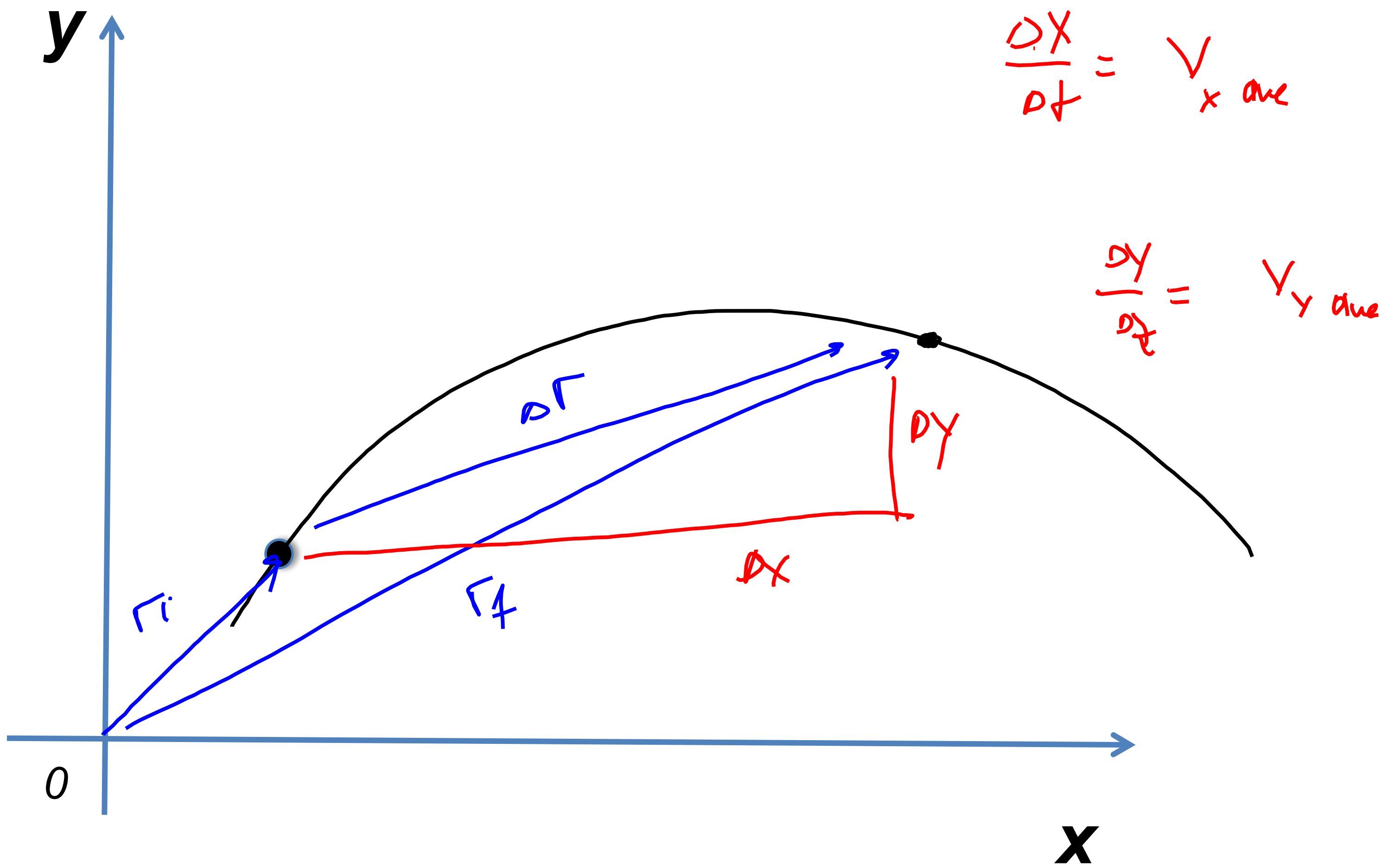
2–D motion = “ [1–D motion] * 2 “



2D: Motion: projectile motion



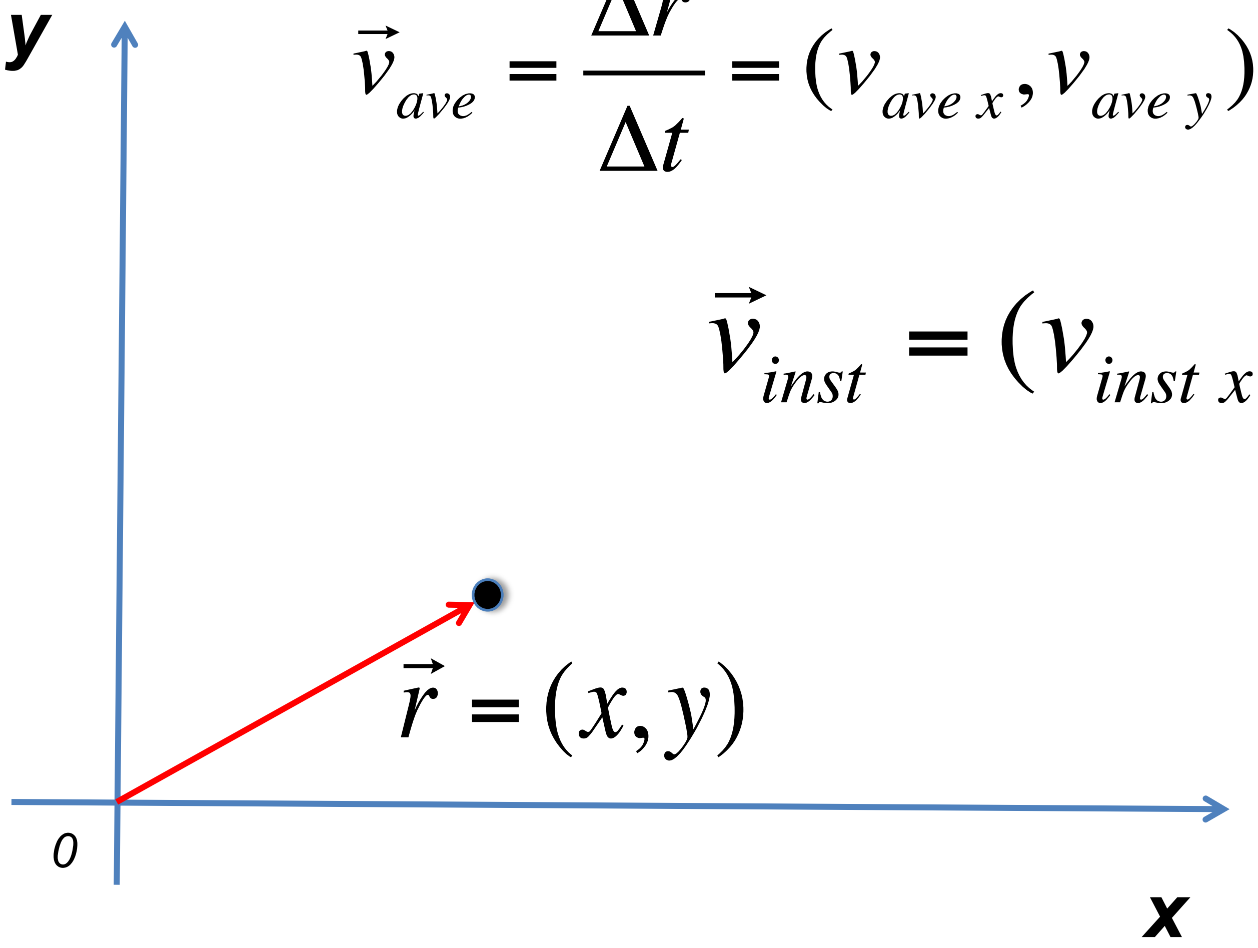
2D: Motion: projectile motion



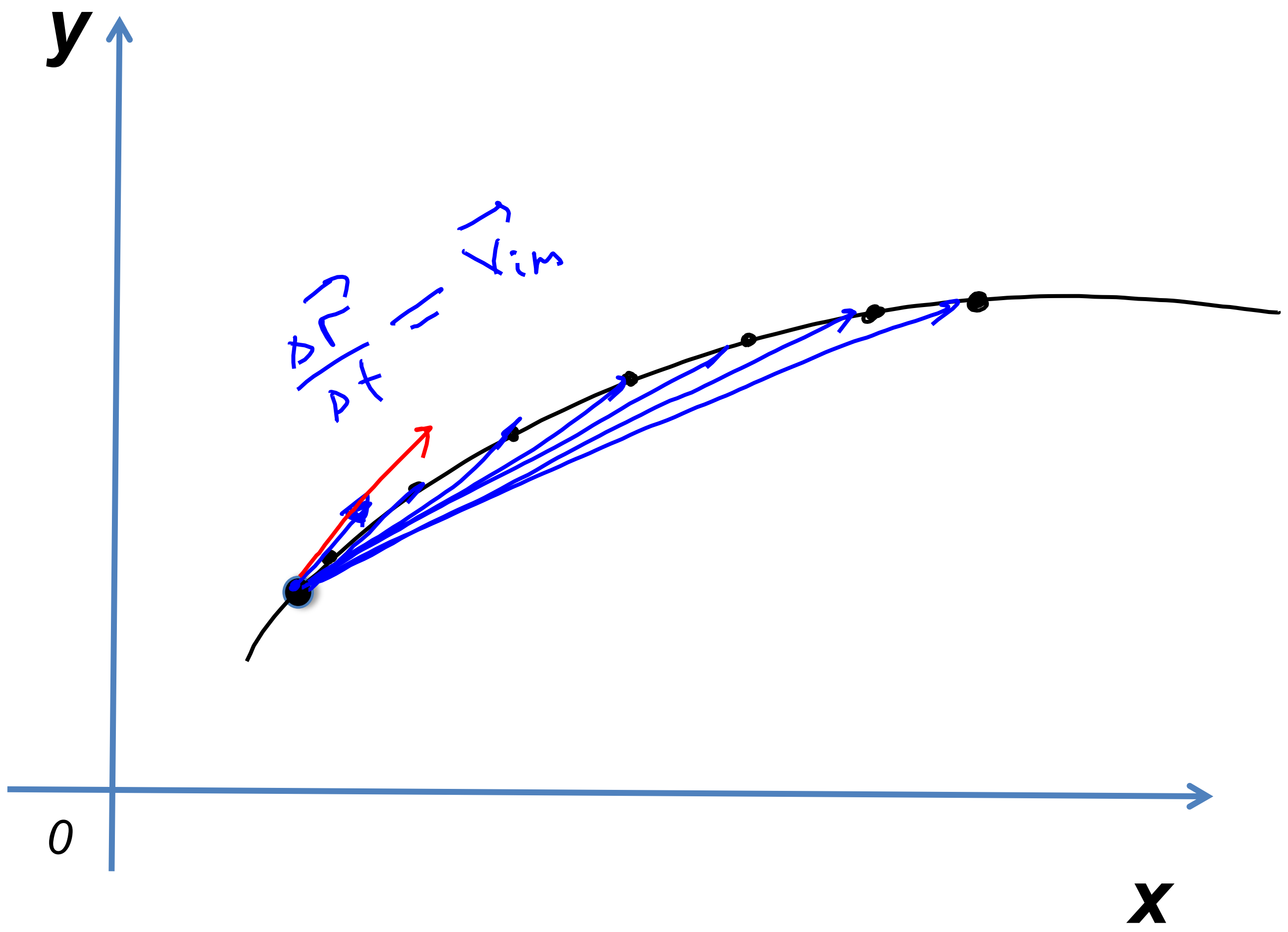
2D Motion: Math description

$$\vec{v}_{ave} = \frac{\Delta \vec{r}}{\Delta t} = (v_{ave\,x}, v_{ave\,y}) = (\frac{\Delta x}{\Delta t}, \frac{\Delta y}{\Delta t})$$

$$\vec{v}_{inst} = (v_{inst\,x}, v_{inst\,y})$$

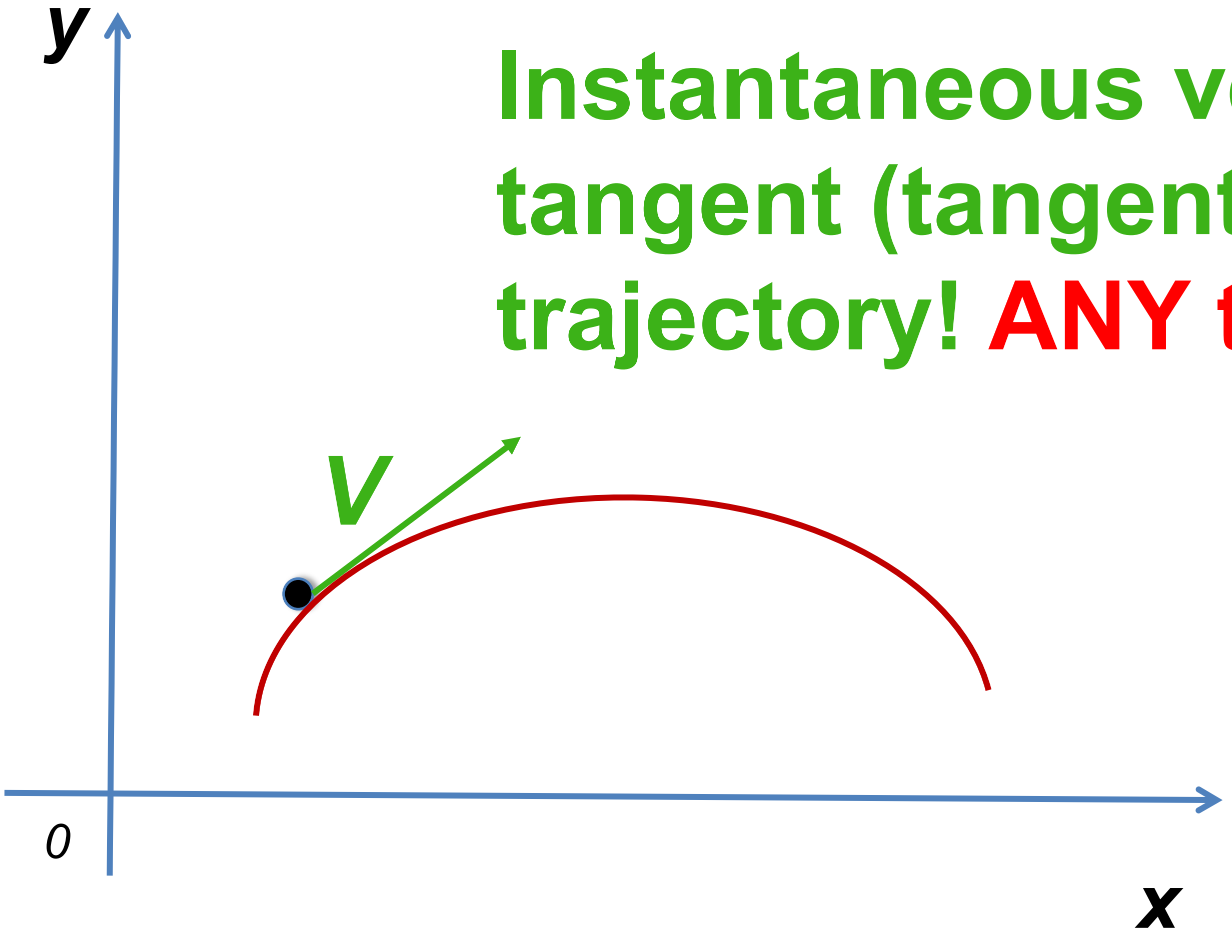


2D Motion: property of $\vec{V}_{inst}$

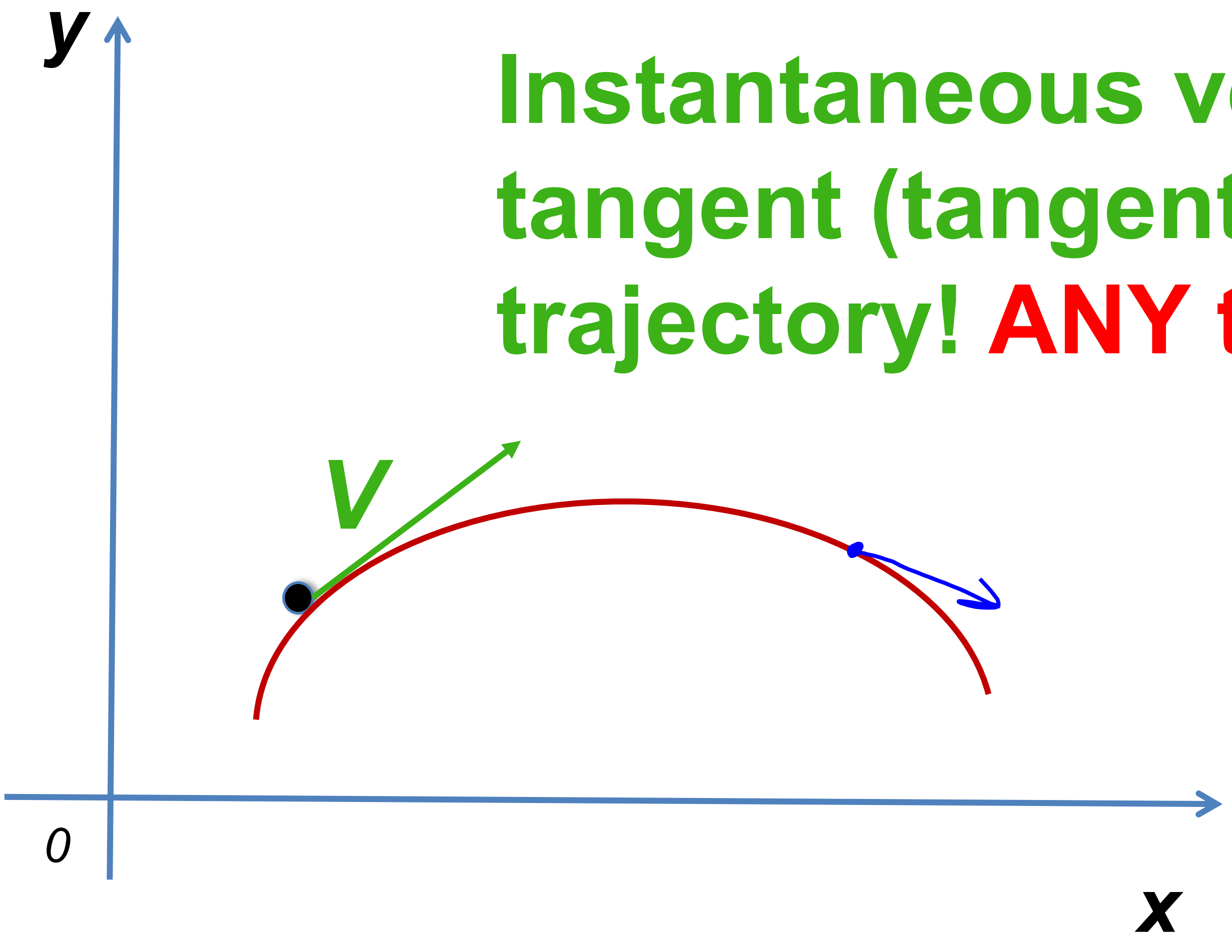


2D Motion: property of $\vec{V}_{inst}$

Instantaneous velocity is tangent (tangential) to the trajectory! ANY trajectory!



2D Motion: property of $\vec{V}_{inst}$



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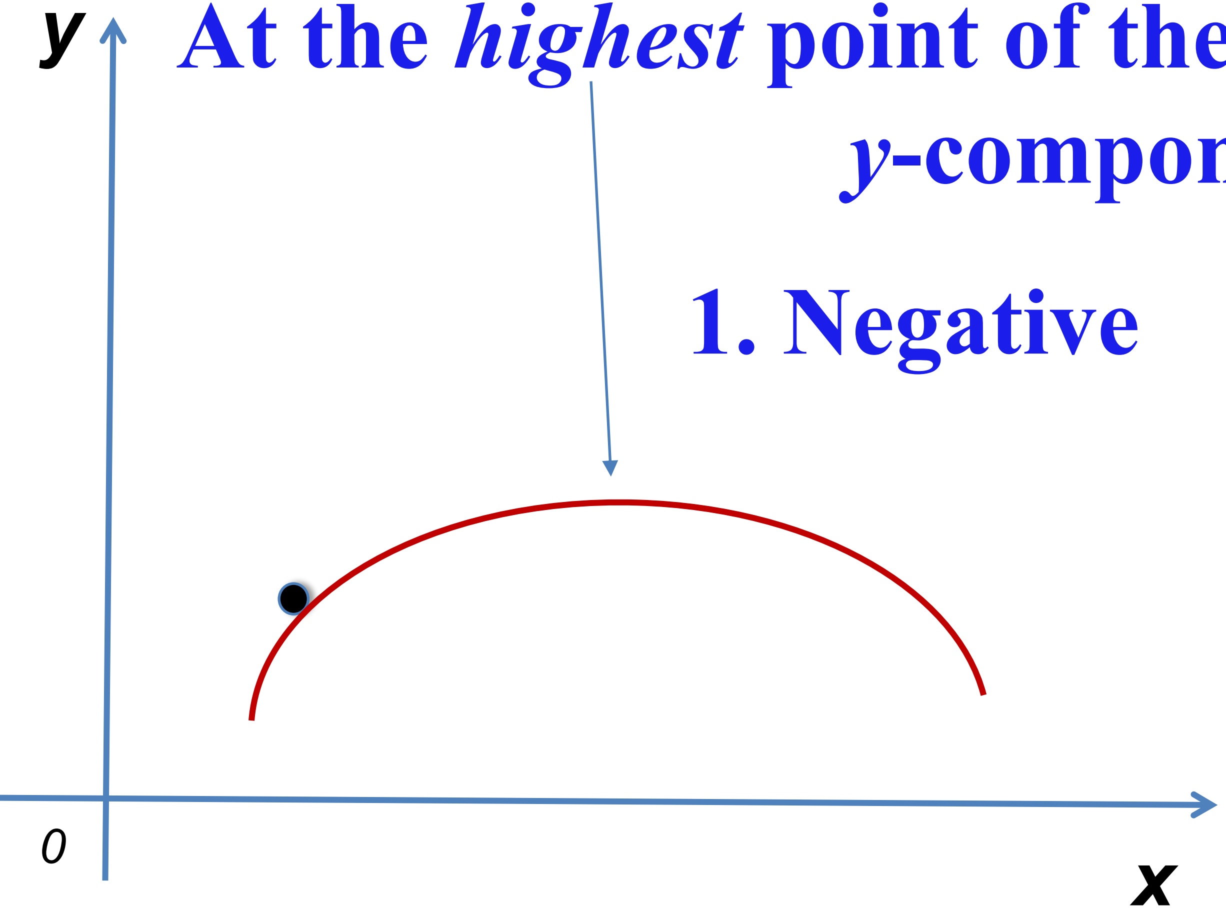
Instantaneous velocity is tangent (tangential) to the trajectory! **ANY trajectory!**

At the *highest* point of the trajectory, the *y*-component of velocity, v_y, …

1. Negative   2. 0   3. Positive



LectureMCQ_L5 Q8

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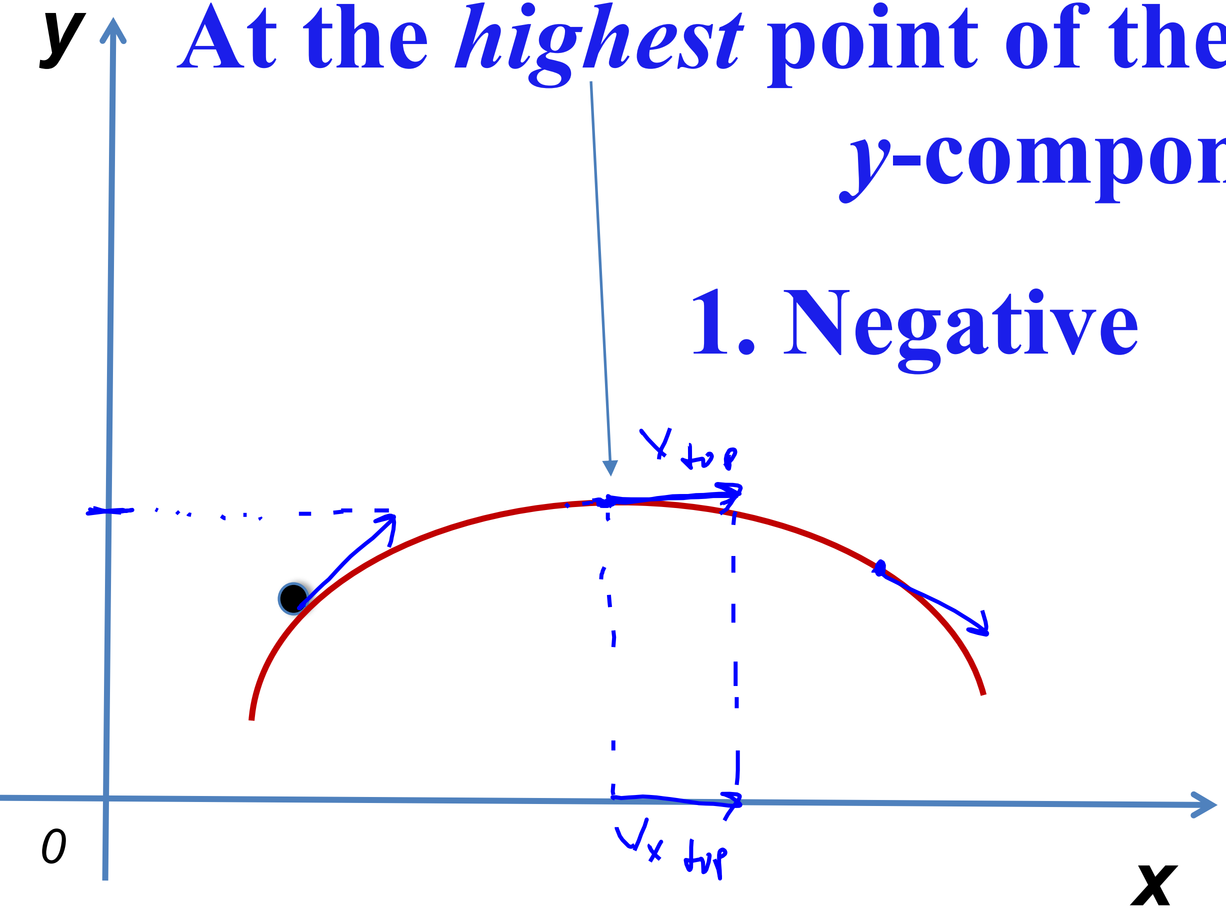

LectureMCQ_L5 Q8

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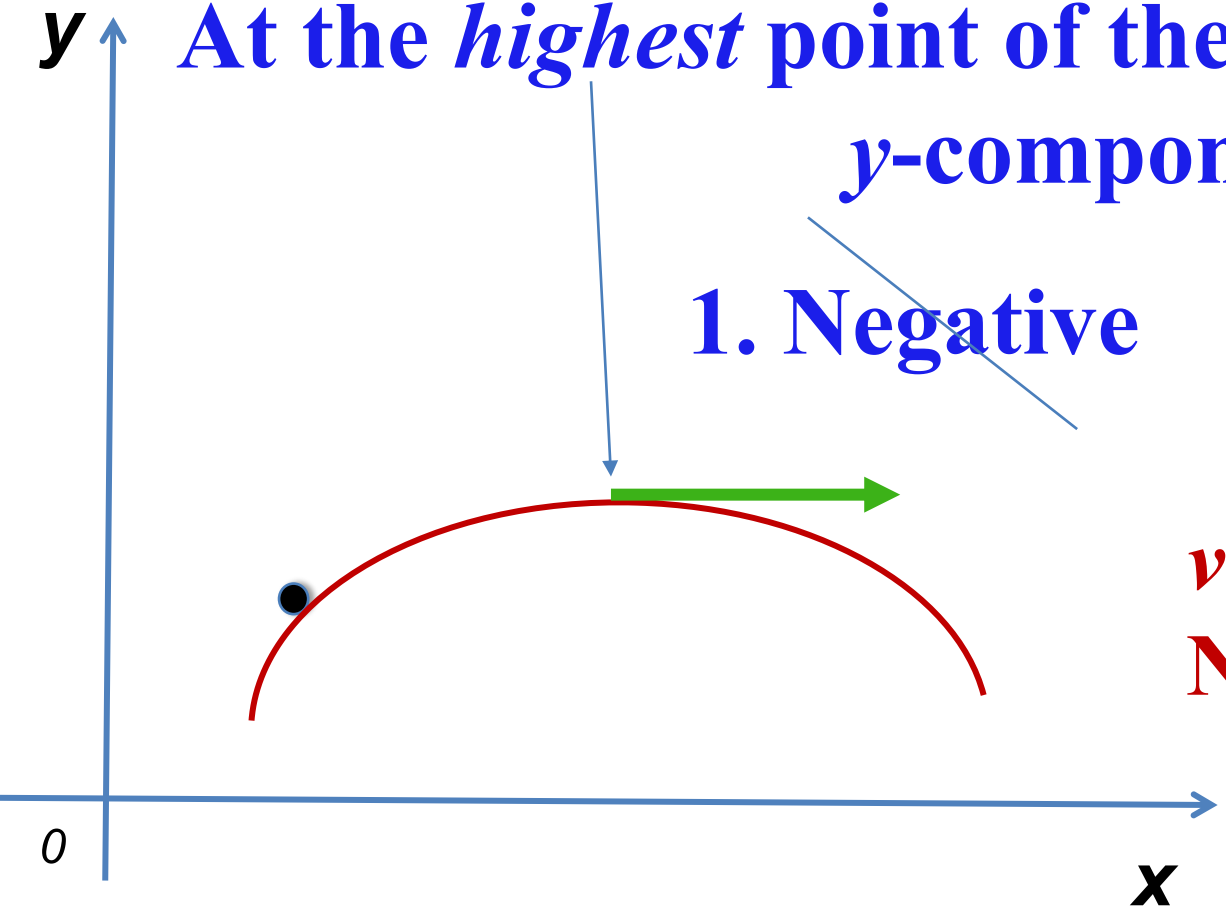


v_{top} is *horizontal* and has NO vertical component,

$$v_{y\_top} = 0$$

Learned!

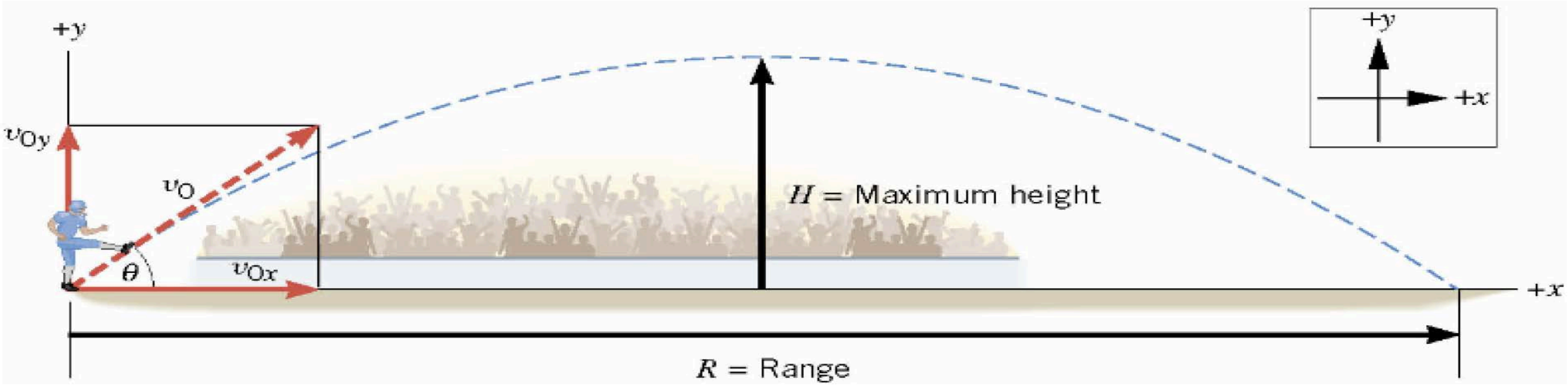
Projectile motion

=> Practice

The Height of a Kickoff

A special case: h = 0

A placekicker kicks a football at an angle of 40.0 degrees and the initial speed of the ball is 22 m/s. Ignoring air resistance, analyze various points in the motion.



The Height of a Kickoff

A special case: h = 0

A placekicker kicks a football at an angle of 40.0 degrees and the initial speed of the ball is 22 m/s. Ignoring air resistance, analyze various points in the motion.

$V_x = 22 \cdot \cos 40$

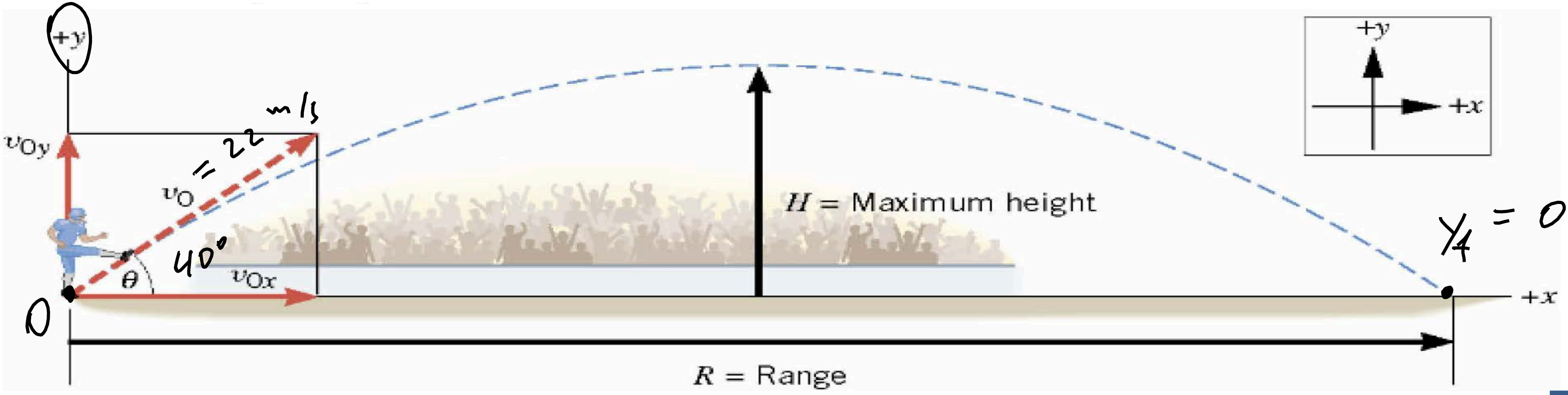
$V_{y0} = 22 \cdot \sin 40$

x: $x = x_0 + v_x \cdot t$ ($x_0 \to 0$)

$a_y = -g$

y: $v_y = v_{y0} - g \cdot t$

$y = y_0 + v_{y0} \cdot t + \frac{1}{2}(-g)t^2$ ($y_0 \to 0$)



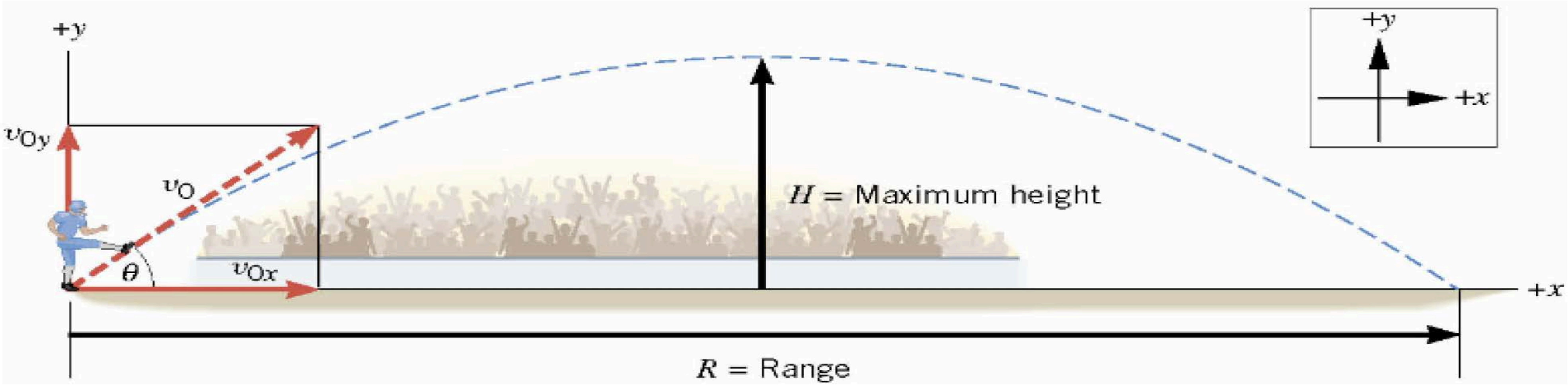
A special case: h = 0

The Height of a Kickoff

A placekicker kicks a football at an angle of 40.0 degrees and the initial speed of the ball is 22 m/s. Ignoring air resistance, analyze various points in the motion.

$v_{ox} = v_o \cos\theta = (22\text{ m/s}) \cos(40°) = 16.85\text{ m/s}$

$V_{oy} = v_y \sin\theta = (22\text{ m/s}) \sin(40°) = 14.14\text{ m/s}$



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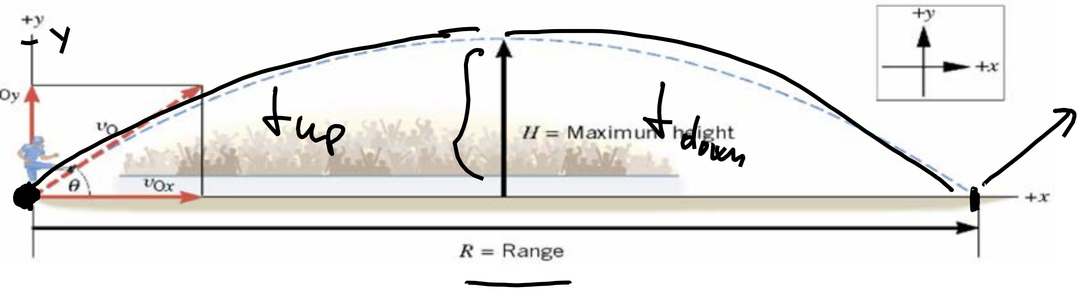


$Y_f = 0$; $Y = Y_0 + V_{y0} \cdot t - \frac{1}{2} g t^2$

$0 = 0 + 14 \cdot t_{tot} - \frac{1}{2} \cdot 10 \cdot t_{tot}^2$

$X = X_0 + V_x \cdot t = 0 + 17 \cdot t_{tot}$

$t_{up} = t_{down}$; $t_{tot} = 2 t_{up} = 2 t_{down}$

$0 = 14 \cdot t_{tot} - 5 \cdot t_{tot}^2 \quad | \div t_{tot}$

$t_{up} = t_{down} = \frac{1}{2} t_{tot} = 1.4\ s$

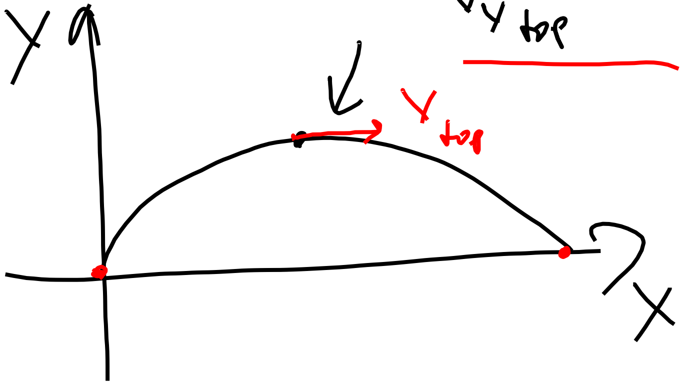
$R = 17 \cdot 2.8 =$

$0 = 14 - 5 \cdot t_{tot}$

$t_{tot} = \frac{14}{5} = 2.8\ s$

$Y = 14 \cdot t - 5 \cdot t^2 \Rightarrow H_{max} = 14 \cdot 1.4 - 5 \cdot 1.4^2 = \ldots$

$Y \to H_{max}$, $t \to t_{up}$, $t \to t_{up}$



$V_{y\,top} = 0$

$V_y = V_{y_0} - g \cdot t$

$0 = 14 - 10\, t_{up}$

$t_{up} = 1.4\ s \Rightarrow t_{down} = t_{up} = 1.4\ s$

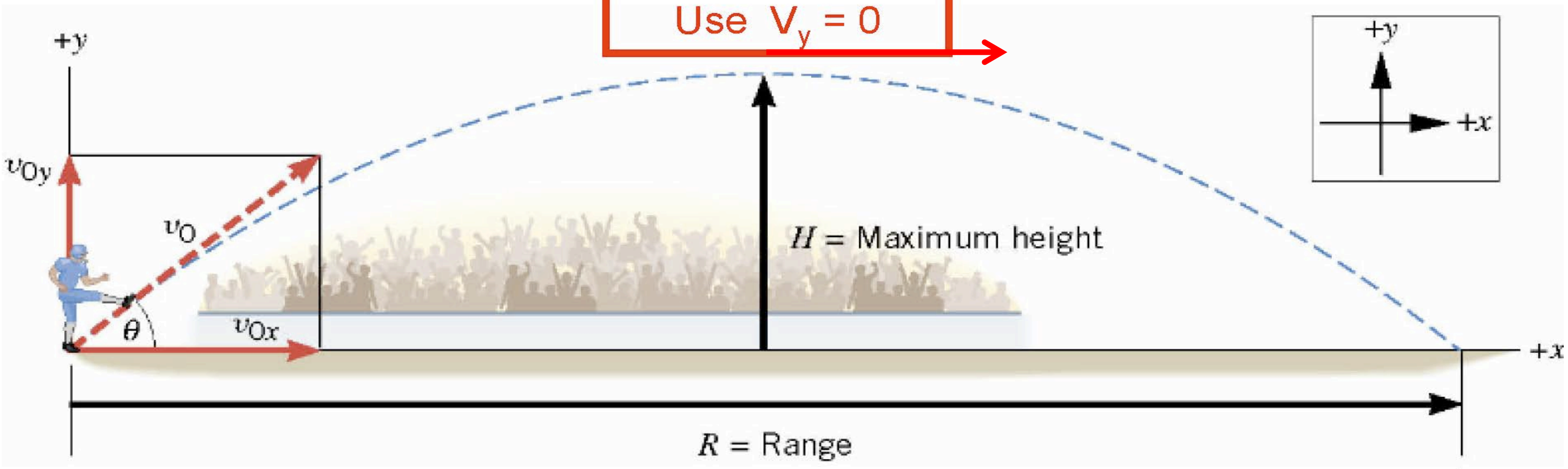
$t_{tot} = 2 \cdot t_{up} = 2.8\ s$

Projectile Motion

Find time to top.

Use $V_y = 0$

$\vec{v}_{top} = \vec{v}_{0x}$



y	a_y	v_y	v_{oy}	t
?	-9.80 m/s²	0	14 m/s	?

$0 = v_y = v_{oy} + a_y t = (14\ m/s) + (-9.8\ m/s^2)\ t$

$(9.8\ m/s^2)\ t = (14\ m/s)$

$t = (14\ m/s) / (9.8\ m/s^2) = 1.428\ s =$ 1.43 s time to top

$$H = y_{max} = v_{0y} t_{up} + \frac{-9.8 t_{up}^2}{2} = 10\ m$$

Projectile Motion

(total time)

Find time to hit ground (hang time).
Use y = 0

y	a_y	v_y	v_{oy}	t
0	$-9.80\ m/s^2$		14 m/s	?

$$y = v_{oy}t + \tfrac{1}{2}a_y t^2$$

$$0 = (14\,\mathrm{m/s})t + \tfrac{1}{2}(-9.80\,\mathrm{m/s^2})t^2$$

"Cancel" t

$$0 = 2(14\,\mathrm{m/s}) + (-9.80\,\mathrm{m/s^2})t$$

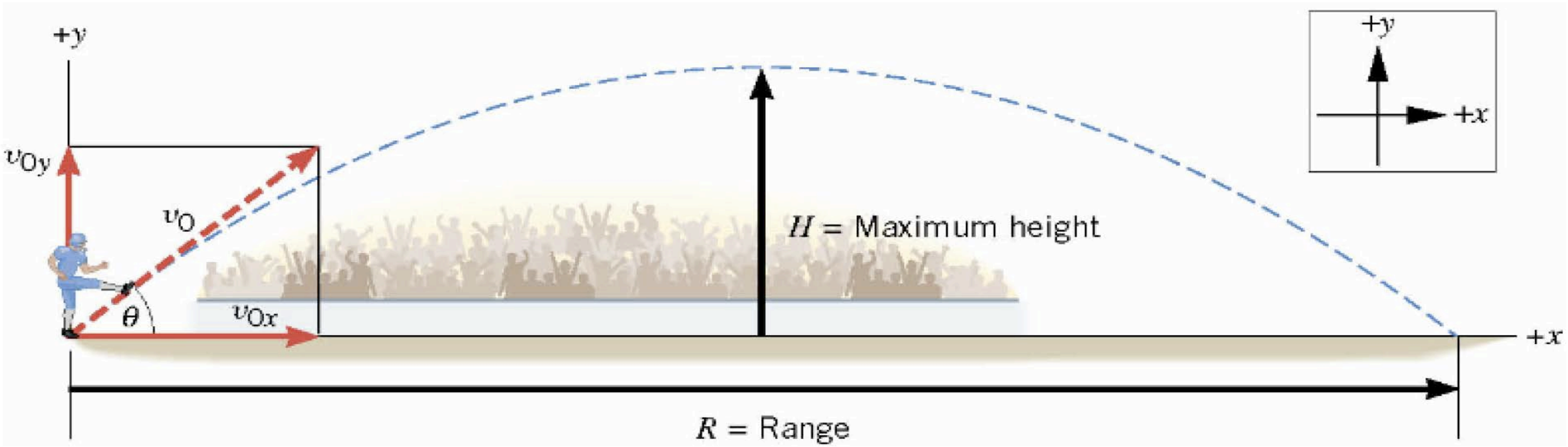
t = 0 is also correct mathematically, but doesn't answer the physical question.

$$t = 2.9\,\mathrm{s}$$

= twice the time to top!

Example The Range of a Kickoff

Calculate the range R of the projectile.



$$R = x = v_{ox}t + \frac{1}{2}a_x t^2 = v_{ox}t$$

$$= (17\,\text{m/s})(2.9\,\text{s}) = +49\,\text{m}$$

a guy throwing a ball on the roof of a 6 m high barn. The ball is 2 m above the ground when leaving the guy's hands, and its horizontal velocity (the x- component of the initial velocity) is 10 m/s.

The ball travels 20 m in horizontal direction before it hits the roof.

Try to find the following (in any order):

$t = ?$ the time the ball was in the air

$v_{iy} = ?$ the vertical component on the initial velocity of the ball

$v_f = ?$ the final speed of the ball (the speed of the ball when it just start touching the roof)

how much higher was the ball at the highest point of its parabolic trajectory relative to the roof?

a guy throwing a ball on the roof of a 6 m high barn. The ball is 2 m above the ground when leaving the guy's hands, and its horizontal velocity (the x- component of the initial velocity) is 10 m/s.

The ball travels 20 m in horizontal direction before it hits the roof.

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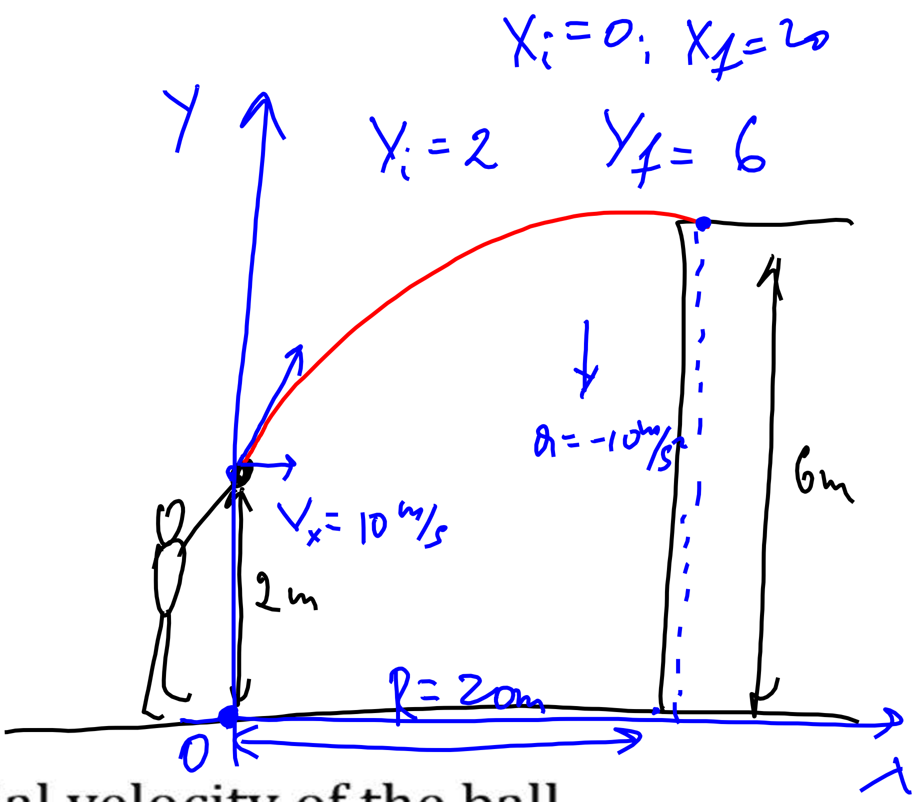


t = ? the time the ball was in the air

v_{iy} = ? the vertical component on the initial velocity of the ball

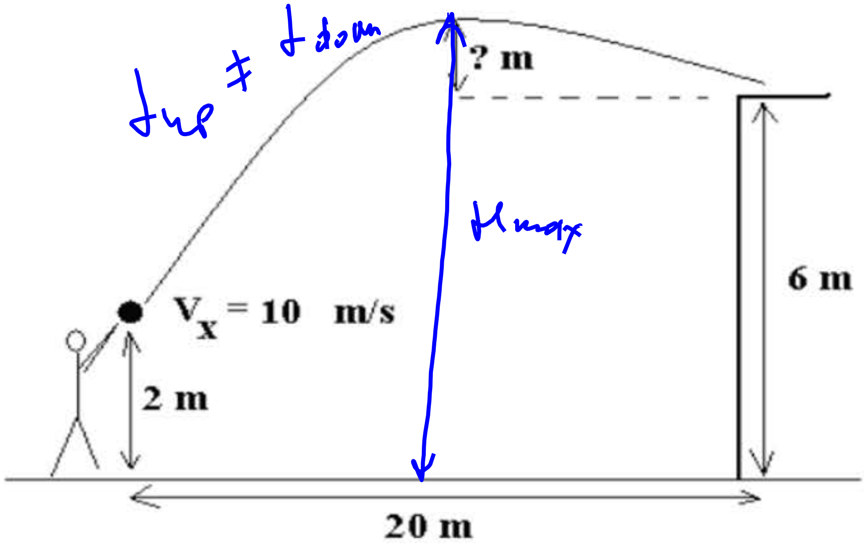
v_f = ? the final speed of the ball (the speed of the ball when it just start touching the roof)

how much higher was the ball at the highest point of its parabolic trajectory relative to the roof?

In the picture to the right you see a guy throwing a ball on the roof of a 6 m high barn. The ball is 2 m above the ground when leaving the guy's hands, and its horizontal velocity (the x- component of the initial velocity) is 10 m/s.

The ball travels 20 m in horizontal direction before it hits the roof.

Try to find the following (in any order):



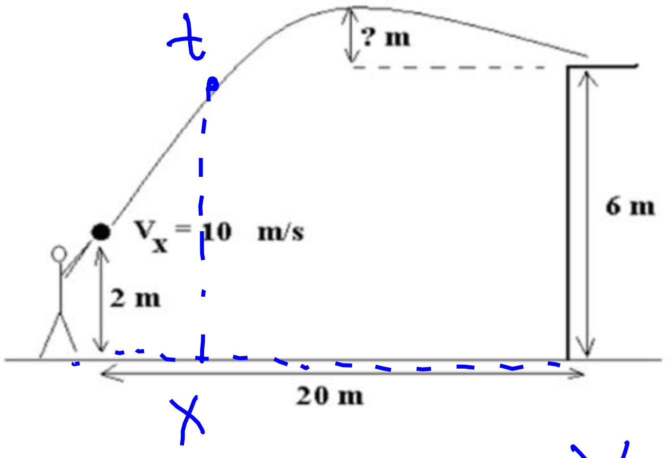
Find everything !

t = ? the time the ball was in the air

v_{iy} = ? the vertical component on the initial velocity of the ball

v_f = ? the final speed of the ball (the speed of the ball when it just start touching the roof)

how much higher was the ball at the highest point of its parabolic trajectory relative to the roof?



$X = V_x \cdot t \Rightarrow$

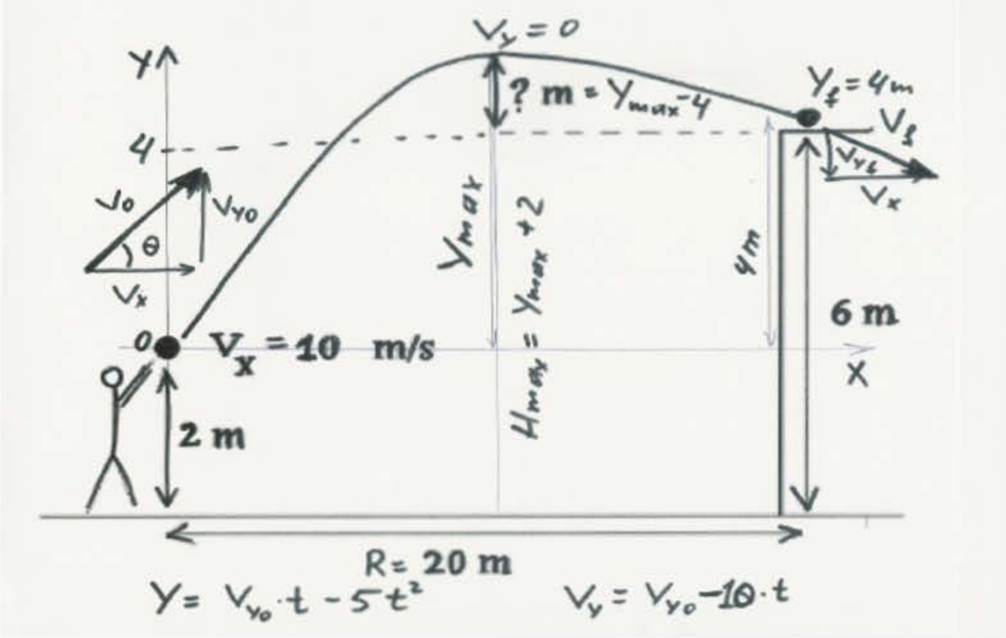
$20 = 10 \cdot t_{total} \Rightarrow t_{total} = \frac{20}{10} = 2s$

$Y = Y_i + V_{y0} \cdot t + \frac{1}{2}(-10) \cdot t^2$

$6 = 2 + V_{y0} \cdot 2 + \frac{1}{2}(-10) 2^2$

$\hookrightarrow V_{y0}$

In the picture to the right you see a guy throwing a ball on the roof of a 6 m high barn.



The ball is 2 m above the ground when leaving the guy's hands, and its horizontal velocity (the x-component of the initial velocity) is 10 m/s.

The ball travels 20 m in horizontal direction before it hits the roof.

Try to find the following (in any order):

t = ? the time the ball was in the air

R = x = 20 = 10*T => T = 2 s

v_{iy} = ? the vertical component of the initial velocity of the ball

$Y_f = Y(2) = 4 = v_{y0}*2 - 5*2^2$ => $v_{y0} = 12$ m/s

v_f = ? the final speed of the ball (the speed of the ball when it just start touching the roof) $v_{yf} = 12 - 10*2 = -8$ m/s

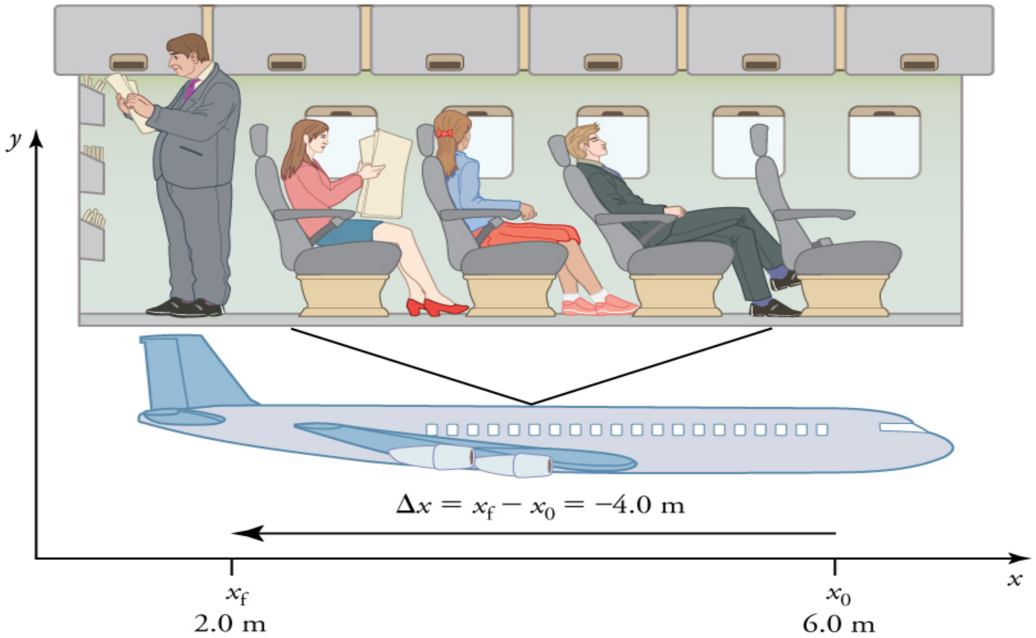
$$v_f = \sqrt{v_x^2 + v_{yf}^2} = \sqrt{10^2 + (-8)^2} = 12.8\ m/s$$

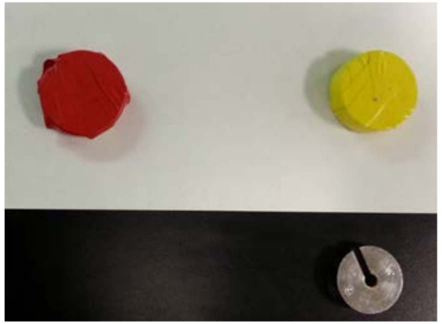
How much higher was the ball at the highest point of its parabolic trajectory relative to the roof?

$Y_{max} = 12*t_\uparrow - 5(t_\uparrow)^2$ $0 = 12 - 10*t_\uparrow$ => $t_\uparrow = 1.2$ s => $Y_{max} = 12*1.2 - 5(1.2)^2 = 7.2$ m

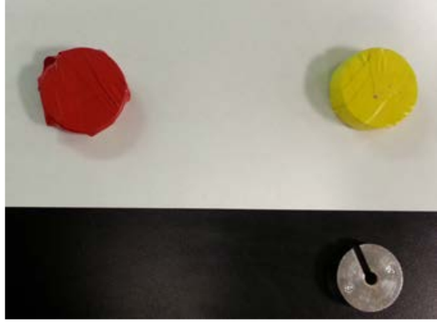
(in general $Y_{max} = \frac{v_{y0}^2}{2g} = \frac{gt_\uparrow^2}{2}$) ? = 7.2 – 4 = 3.2 m

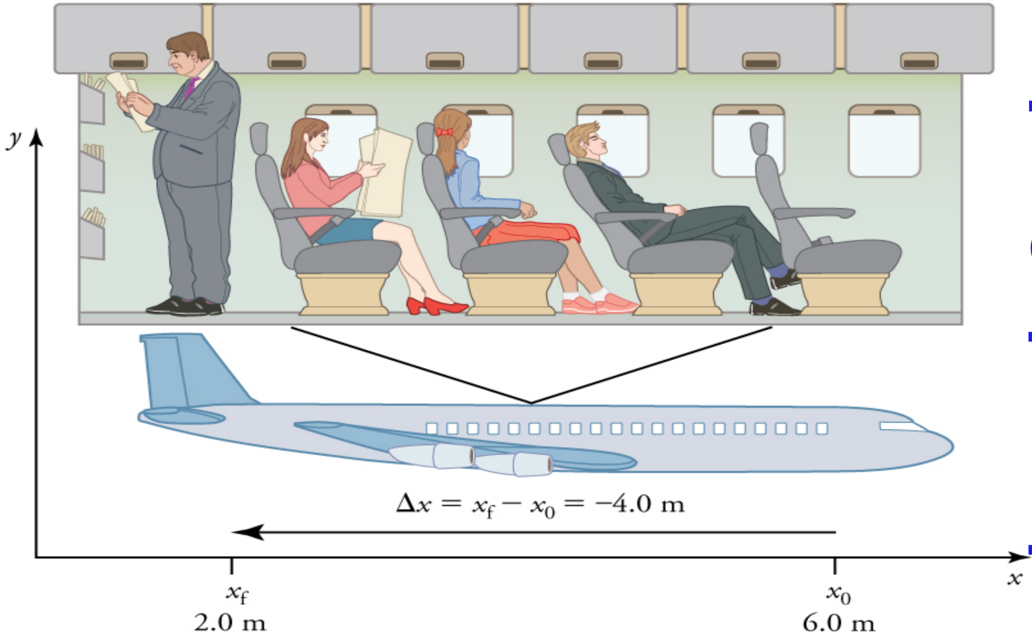
Relative motion, velocity addition, “crossing a river”.



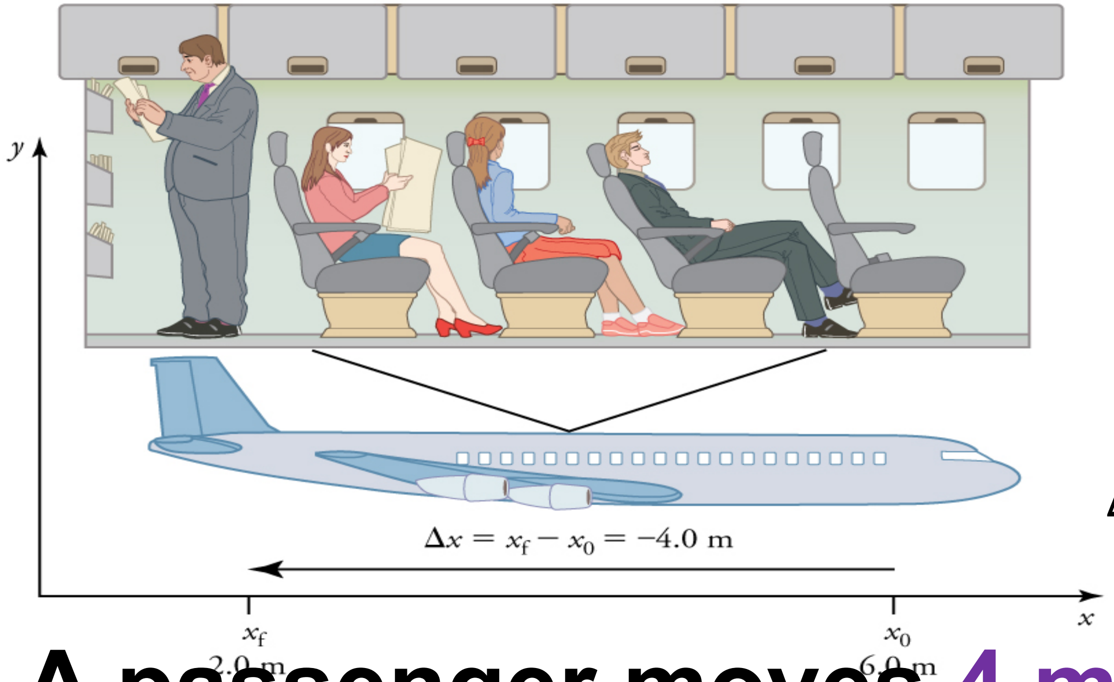


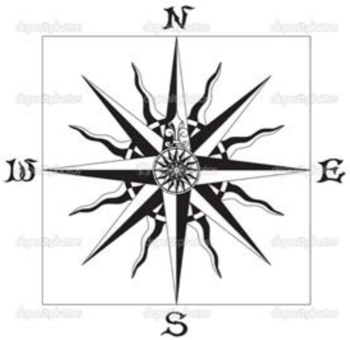
Relative motion, velocity addition, "crossing a river".





A passenger moves relative to an airplane. The −4.0 m displacement of the passenger relative to the plane is represented by an arrow toward the rear of the plane.



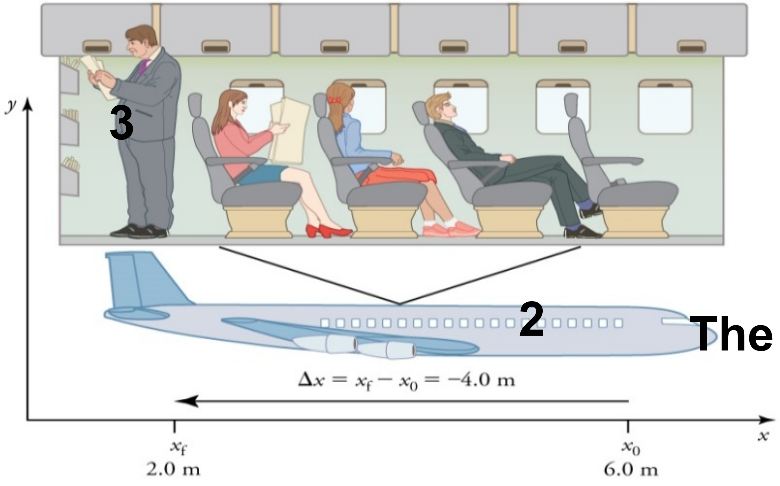


$$\Delta\vec{r}_{31} = \Delta\vec{r}_{32} + \Delta\vec{r}_{21}$$

A passenger moves 4 m west relative to the airplane. If over the same time the plane moved 300 m east relative to the ground, what is the displacement of the passenger relative to the ground?

Relative displacement

The passenger



The airplane

$$\Delta\vec{r}_{pg} = \Delta\vec{r}_{pP} + \Delta\vec{r}_{Pg}$$

Specific equation

1

The ground

$$\Delta\vec{r}_{31} = \Delta\vec{r}_{32} + \Delta\vec{r}_{21}$$

General equation

For ANY 3 objects

Relative velocity

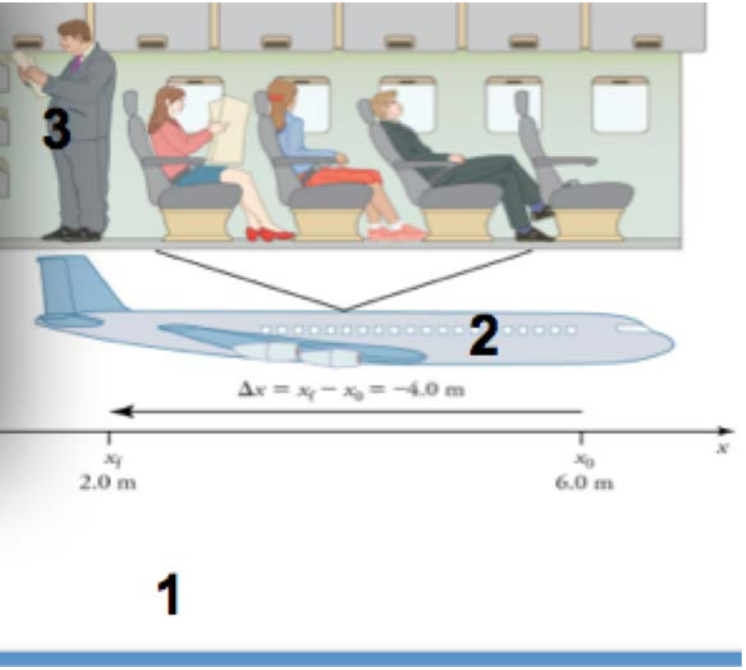
$$\frac{\Delta\overrightarrow{r_{31}}}{\Delta t} = \frac{\Delta\overrightarrow{r_{32}}}{\Delta t} + \frac{\Delta\overrightarrow{r_{21}}}{\Delta t}$$

or

General equation

$$\vec{v}_{31} = \vec{v}_{32} + \vec{v}_{21}$$

For ANY 3 objects



The law of relative velocities (LRV)

Specific equation

$$\vec{v}_{pg} = \vec{v}_{pP} + \vec{v}_{Pg}$$

Relative velocity

The law of relative velocities (LRV)

For ANY three objects

$$\vec{v}_{31} = \vec{v}_{32} + \vec{v}_{21}$$

LEARNED! => Practice!