PHYS 1441 – Section 002
Lecture #9

Wednesday, Feb. 13, 2008
Dr. Jaehoon Yu

- Motion in Two Dimensions
  - Projectile Motion
  - Maximum ranges and heights
- Newton's Laws of Motion
  - Force
  - Newton's first law: Inertia & Mass
  - Newton's second law

Announcements

- 1st term exam next Wednesday, Feb. 20
  - Time: 1 – 2:20pm
  - Place: SH103
  - Covers: Appendices, CH 1 – CH4.4
  - Style: mixture of multiple choices and essay problems
  - Class on Monday, Feb. 18: Jason will be here to go over the any problems you would like to review
- Colloquium today
  - UTA Physics faculty research topics
  - Good opportunity to learn what UTA Physics does
  - Possibly working with them if you are interested in…

Reminder: Special Project

- Show that a projectile motion's trajectory is a parabola!!
  - 20 points
  - Due: Wednesday, Feb. 27
  - You MUST show full details of computations to obtain any credit

Physics Department
The University of Texas at Arlington

COLLOQUIUM

Physics Faculty Research Presentations

Wednesday, February 13, 2008
4:00 p.m. Rm. 101SH

SPEAKERS:

Dr. Suresh Sharma

Dr. Manfred Cuntz "Research Developments for the Sun and Extra-Solar Planets"

Dr. Ramon Lopez "Space Science and Visualization"

Dr. John Fry "Search for New Fundamental Laws of Physics"

Dr. Zdzislaw Musielak "My Research Projects"

Dr. Yi-Jiun Su "Magnetosphere-Ionosphere Coupling at Earth and Jupiter: The Most Recent Research Results"

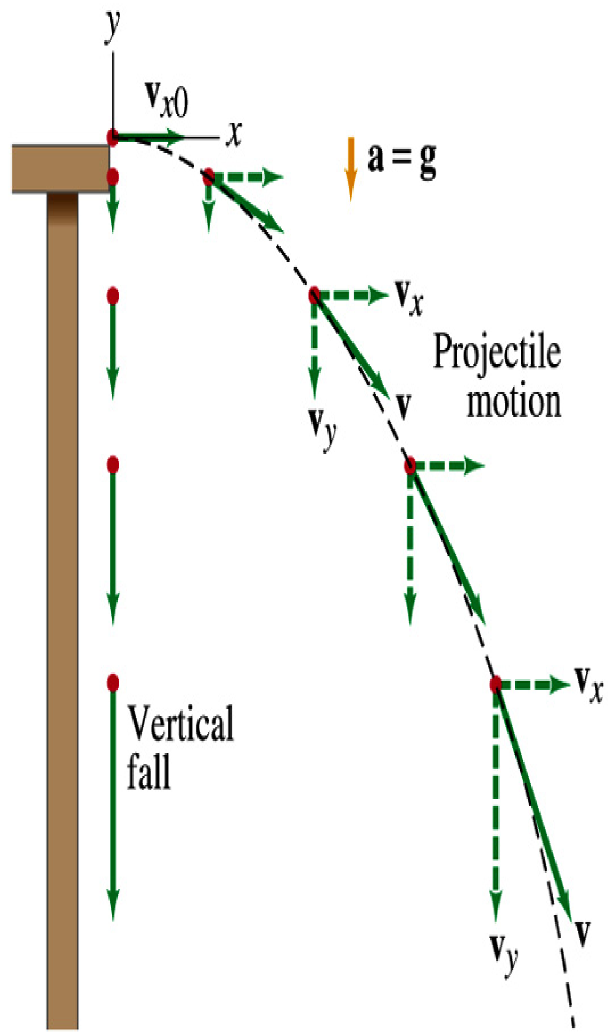
Dr. Jim Horwitz "Dynamic Fluid-Kinetic Simulations of High-Latitude Ionospheric Outflow"

Dr. Amir Farbin "Searching for New Laws of Physics with the World's Largest Particle Accelerator"

Refreshments will be served at 3:30 p.m. in the Physics Library

Projectile Motion

- A 2-dim motion of an object under the gravitational acceleration with the following assumptions
  - Free fall acceleration, g, is constant over the range of the motion
    - $\vec{g} = -9.8\vec{j}\left(m/s^2\right)$
    - $a_x = 0\,m/s^2$ and $a_y = -9.8\,m/s^2$
  - Air resistance and other effects are negligible
- A motion under constant acceleration!!!! ➔ Superposition of two motions
  - Horizontal motion with constant velocity (no acceleration) $v_{xf} = v_{x0}$
  - Vertical motion under constant acceleration (g) $v_{yf} = v_{y0} + a_y t = v_{y0} + (-9.8)t$



Kinematic Equations in 2-Dim

x-component

y-component

$$v_x = v_{xo} + a_x t$$

$$v_y = v_{yo} + a_y t$$

$$x = \tfrac{1}{2}\left(v_{xo} + v_x\right)t$$

$$y = \tfrac{1}{2}\left(v_{yo} + v_y\right)t$$

$$v_x^2 = v_{xo}^2 + 2a_x x$$

$$v_y^2 = v_{yo}^2 + 2a_y y$$

$$x = v_{xo}t + \tfrac{1}{2}a_x t^2$$

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

Show that a projectile motion is a parabola!!!

x-component $v_{xi} = v_i \cos\theta_i$

y-component $v_{yi} = v_i \sin\theta_i$

$$\vec{a} = a_x\vec{i} + a_y\vec{j} = -g\vec{j}$$

In a projectile motion, the only acceleration is gravitational one whose direction is always toward the center of the earth (downward).

$a_x=0$

$$x_f = v_{xi}t = v_i\cos\theta_i t$$

$$t = \frac{x_f}{v_i\cos\theta_i}$$

$$y_f = v_{yi}t + \frac{1}{2}(-g)\,t^2 = v_i\sin\theta_i t - \frac{1}{2}gt^2$$

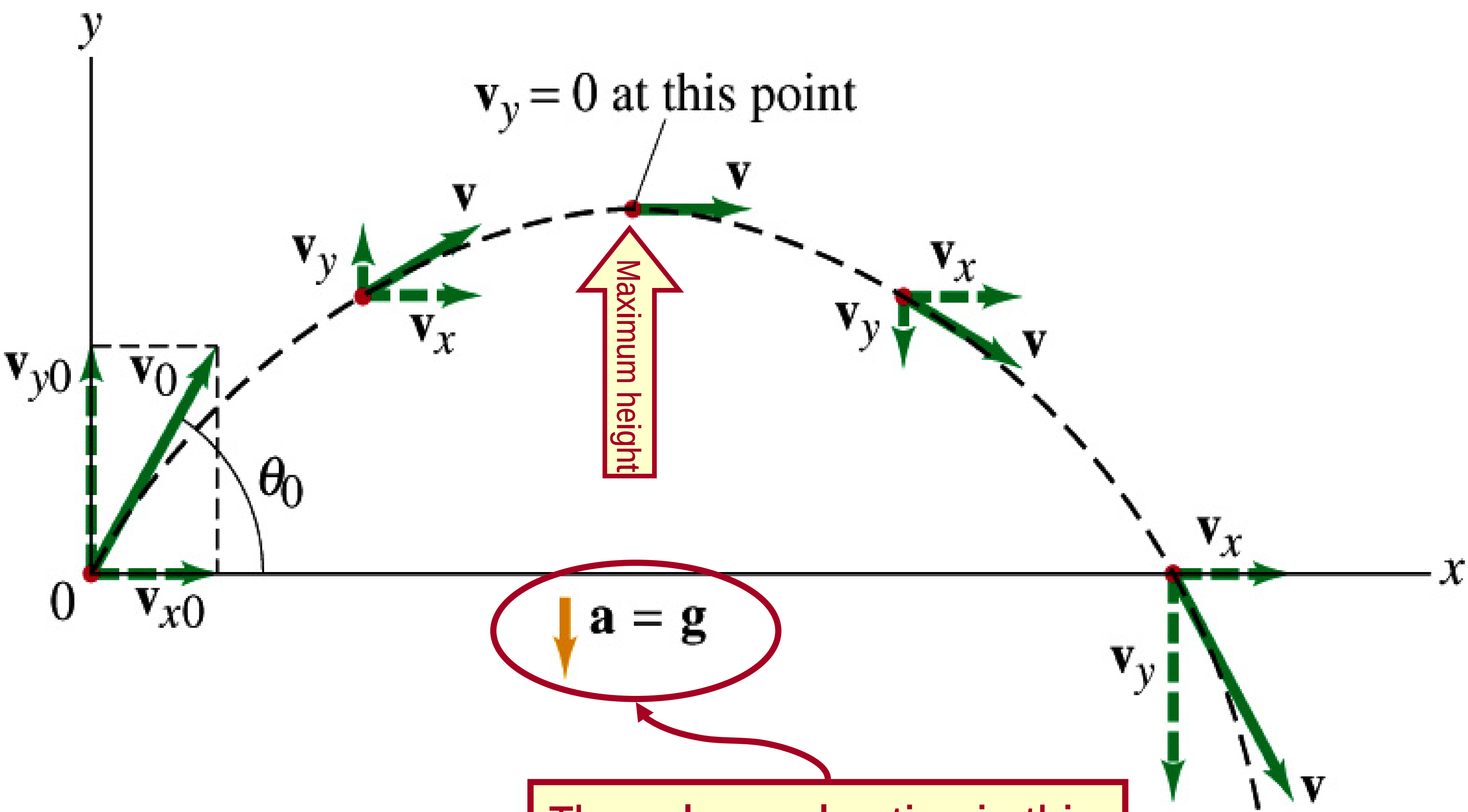
Plug t into the above

$$y_f = v_i\sin\theta_i\left(\frac{x_f}{v_i\cos\theta_i}\right) - \frac{1}{2}g\left(\frac{x_f}{v_i\cos\theta_i}\right)^2$$

$$y_f = x_f\tan\theta_i - \left(\frac{g}{2v_i^2\cos^2\theta_i}\right)x_f^2$$

What kind of parabola is this?

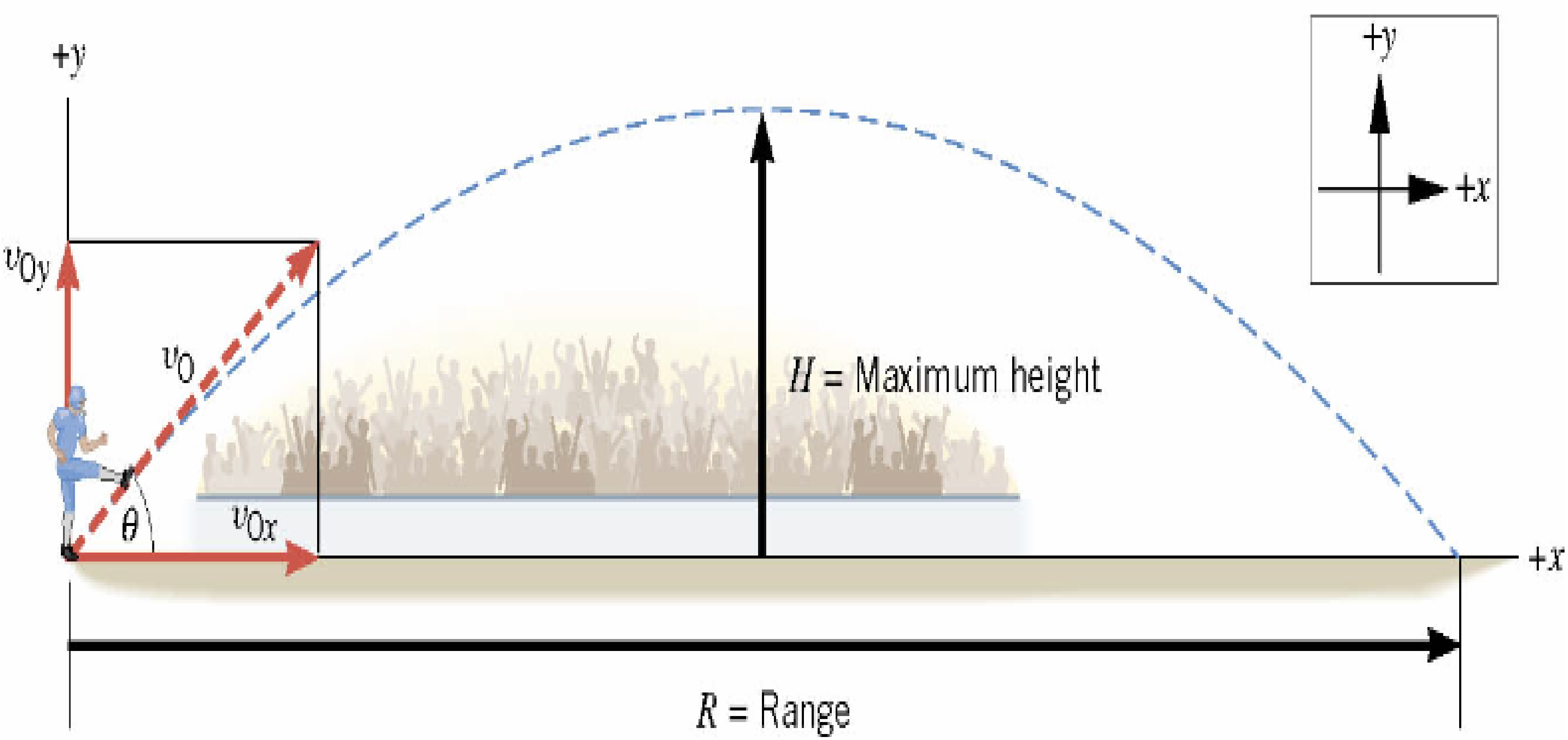
Projectile Motion



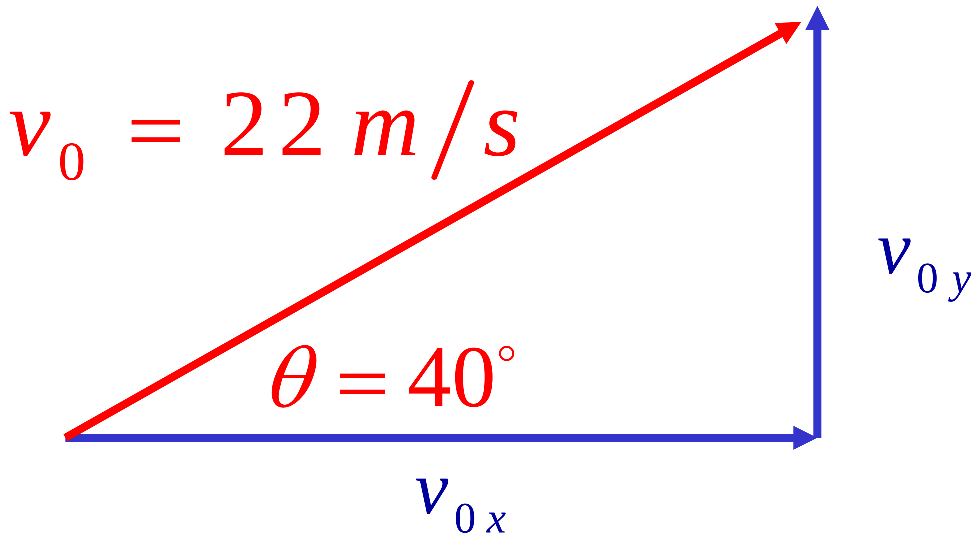
The only acceleration in this motion. It is a constant!!

Example 6 The Height of a Kickoff

A placekicker kicks a football at and angle of 40.0 degrees and the initial speed of the ball is 22 m/s. Ignoring air resistance, determine the maximum height that the ball attains.



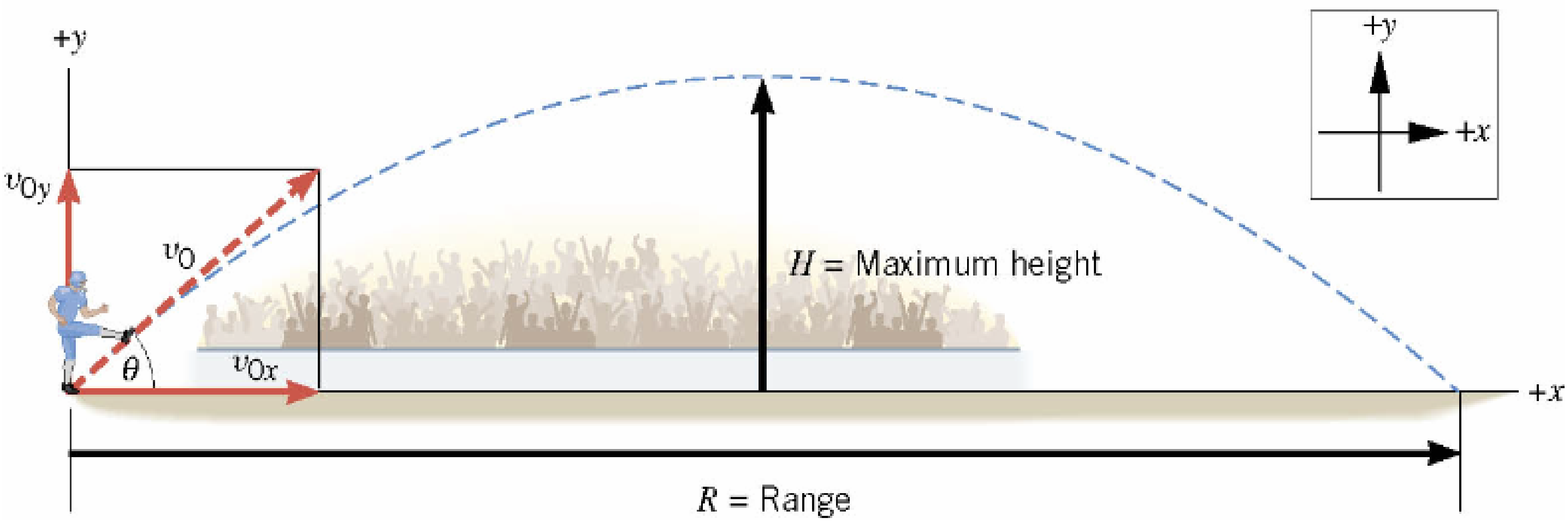
First, the initial velocity components



$$v_{ox} = v_o \cos\theta = (22\,\mathrm{m/s})\cos 40^\circ = 17\,\mathrm{m/s}$$

$$v_{oy} = v_o \sin\theta = (22\,\mathrm{m/s})\sin 40^\circ = 14\,\mathrm{m/s}$$

Motion in y-direction is of the interest..



y	a_y	v_y	v_{oy}	t
?	-9.8 m/s^2	0 m/s	+14 m/s	

Now the nitty, gritty calculations…

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

What happens at the maximum height?

The ball's velocity in y-direction becomes 0!!

And the ball's velocity in x-direction? Stays the same!! Why?

Because there is no acceleration in x-direction!!

Which kinematic formula would you like to use?

$$v_y^2 = v_{oy}^2 + 2a_y y$$

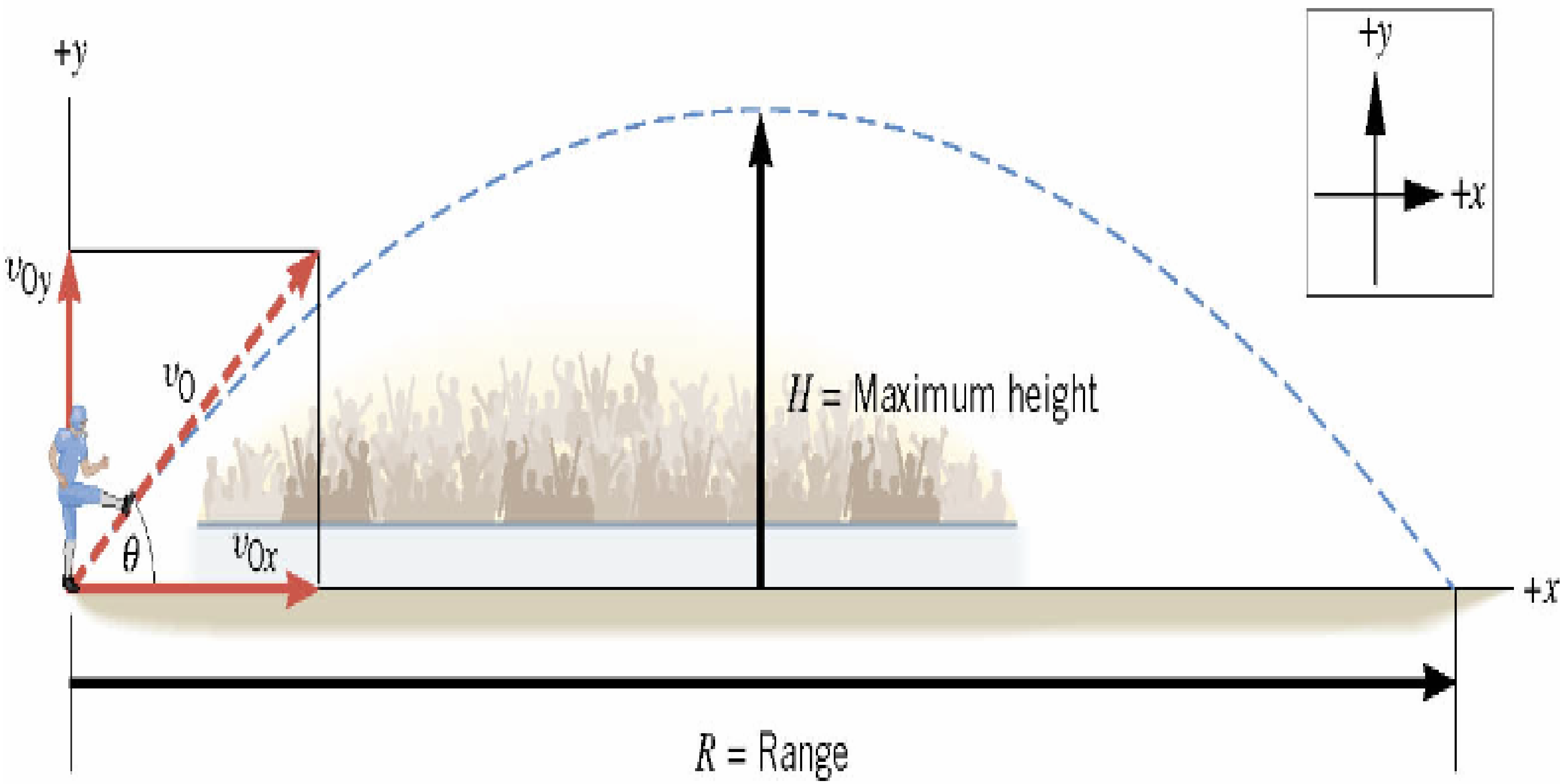
Solve for y

$$y = \frac{v_y^2 - v_{oy}^2}{2a_y}$$

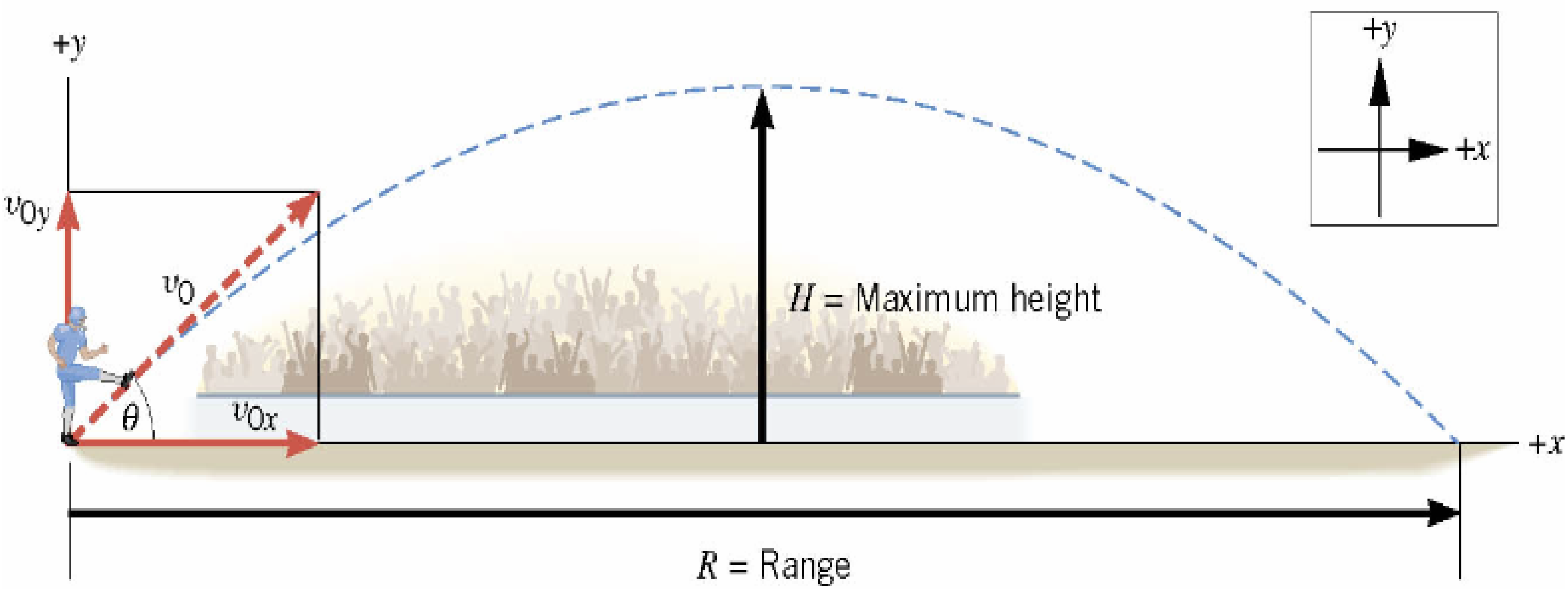
$$y = \frac{0 - (14\,\mathrm{m/s})^2}{2(-9.8\,\mathrm{m/s^2})} = +10\ \mathrm{m}$$

Example 7 The Time of Flight of a Kickoff

What is the time of flight between kickoff and landing?



What is y when it reached the max range?



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

Now solve the kinematic equations in y direction!!

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

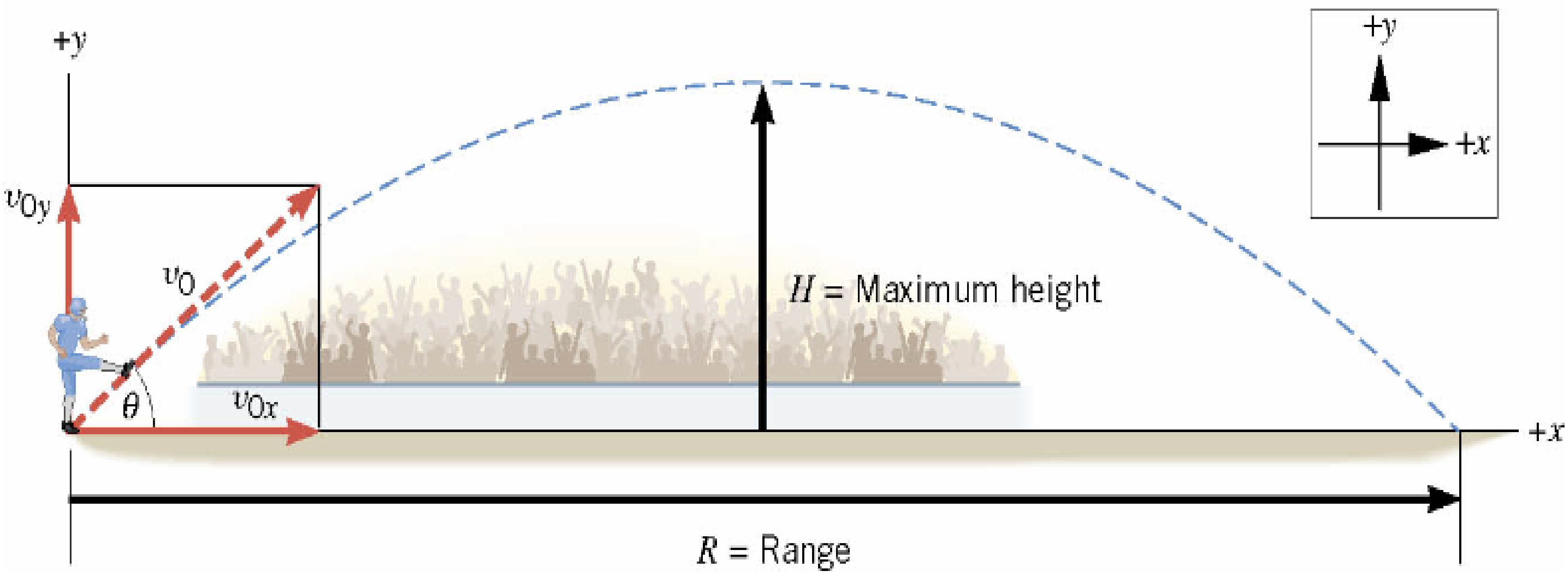
$$y = v_{oy}t + \tfrac{1}{2}a_y t^2 \quad \xrightarrow{\text{Since } y=0} \quad 0 = v_{oy}t + \tfrac{1}{2}a_y t^2 = t\left(v_{oy} + \tfrac{1}{2}a_y t\right)$$

Two soultions $t = 0$ or

$$v_{oy} + \tfrac{1}{2}a_y t = 0 \quad \xrightarrow{\text{Solve for t}} \quad t = \frac{-v_{oy}}{\frac{1}{2}a_y} = \frac{-2v_{oy}}{a_y} = \frac{-2\cdot 14}{-9.8} = 2.9s$$

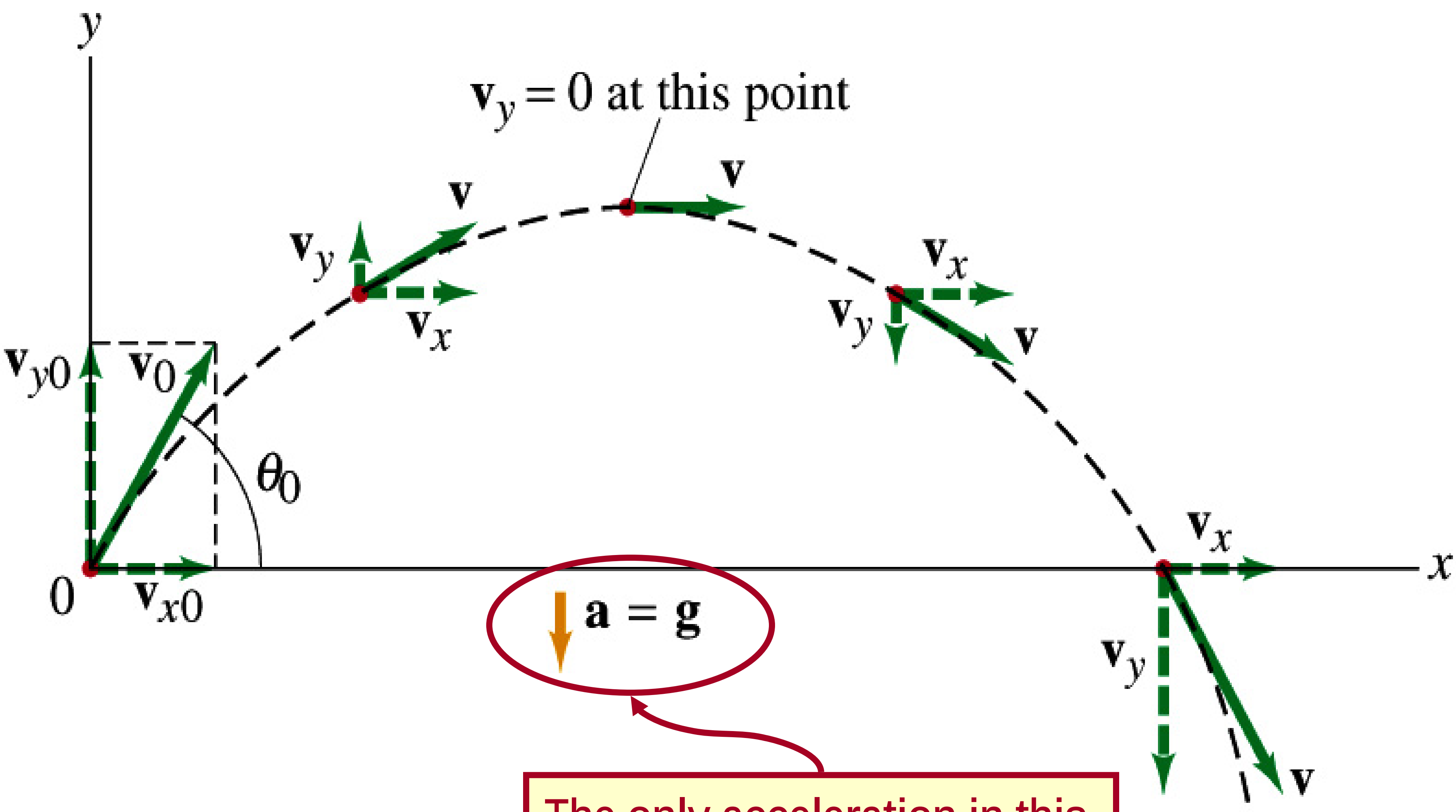
Ex. 8 The Range of a Kickoff

Calculate the range R of the projectile.



$$x = v_{ox}t + \tfrac{1}{2}a_x t^2 = v_{ox}t = (17\ \text{m/s})(2.9\ \text{s}) = +49\ \text{m}$$

Projectile Motion



The only acceleration in this motion. It is a constant!!

Horizontal Range and Max Height

- Based on what we have learned in the previous lecture, one can analyze a projectile motion in more detail
  - Maximum height an object can reach
  - Maximum range

What happens at the maximum height?

At the maximum height the object's vertical motion stops to turn around!!

$$v_{yf} = v_{0y} + a_y t = v_0 \sin\theta_0 - g t_A = 0$$

Solve for t_A

$$\therefore t_A = \frac{v_0 \sin\theta_0}{g}$$

Time to reach to the maximum height!!

Horizontal Range and Max Height

Since no acceleration is in x direction, it still flies even if v_y=0.

$$R = v_{0x}t = v_{0x}\left(2t_A\right) = 2v_0\cos\theta_0\left(\frac{v_0\sin\theta_0}{g}\right)$$

Range

$$R = \left(\frac{v_0^2\sin 2\theta_0}{g}\right)$$

$$y_f = h = v_{0y}t + \frac{1}{2}(-g)t^2 = v_0\sin\theta_0\left(\frac{v_0\sin\theta_0}{g}\right) - \frac{1}{2}g\left(\frac{v_0\sin\theta_0}{g}\right)^2$$

Height

$$y_f = h = \left(\frac{v_0^2\sin^2\theta_0}{2g}\right)$$

Maximum Range and Height

- What are the conditions that give maximum height and range of a projectile motion?

$$h = \left(\frac{v_0^2 \sin^2 \theta_0}{2g} \right)$$

This formula tells us that the maximum height can be achieved when $\theta_i = 90^o$!!!

$$R = \left(\frac{v_0^2 \sin 2\theta_0}{g} \right)$$

This formula tells us that the maximum range can be achieved when $2\theta_i = 90^o$, i.e., $\theta_i = 45^o$!!!

Force

We've been learning kinematics; describing motion without understanding what the cause of the motion is. Now we are going to learn dynamics!!

Can someone tell me what FORCE is?

FORCE is what causes an object to move.

The above statement is not entirely correct. Why?

Because when an object is moving with a constant velocity no force is exerted on the object!!!

FORCEs are what cause any changes to the velocity of an object!!

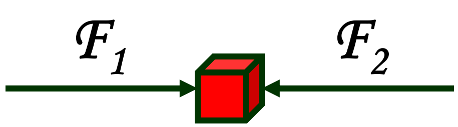
What does this statement mean?

When there is force, there is change of velocity!!

What does force cause? It causes an acceleration.!!

What happens if there are several forces being exerted on an object?

Forces are vector quantities, so vector sum of all forces, the NET FORCE, determines the direction of the acceleration of the object.



NET FORCE, $F = F_1 + F_2$

*When the net force on an object is **0**, it has constant velocity and is at its equilibrium!!*

More Force

There are various classes of forces

Contact Forces: Forces exerted by physical contact of objects

Examples of Contact Forces: Baseball hit by a bat, Car collisions

Field Forces: Forces exerted without physical contact of objects

Examples of Field Forces: Gravitational Force, Electro-magnetic force

What are possible ways to measure strength of the force?

A calibrated spring whose length changes linearly with the force exerted .

Forces are vector quantities, so the addition of multiple forces must be done following the rules of vector additions.

Newton's First Law and Inertial Frames

Aristotle (384-322BC): *A natural state of a body is rest. Thus force is required to move an object. To move faster, ones needs larger forces.*

Galileo's statement on natural states of matter: *Any velocity once imparted to a moving body will be rigidly maintained as long as the external causes of retardation are removed!!*

Galileo's statement is formulated by Newton into the 1st **law of motion (Law of Inertia)**: *In the absence of external forces, an object at rest remains at rest and an object in motion continues in motion with a constant velocity.*

What does this statement tell us?

- When no force is exerted on an object, the acceleration of the object is 0.
- Any isolated object, the object that do not interact with its surroundings, is either at rest or moving at a constant velocity.
- Objects would like to keep its current state of motion, as long as there are no forces that interfere with the motion. This tendency is called the Inertia.

A frame of reference that is moving at a constant velocity is called the ***Inertial Frame***

Is a frame of reference with an acceleration an ***Inertial Frame?***

NO!