PHYS 1441 – Section 002
Lecture #7

Wednesday, Sept. 29, 2010

Dr. Jaehoon Yu

- Projectile Motion
- Maximum Range and Height
- Force
- Newton's Second Law

Announcements

- First term exam results
  - Class Average: 52/96
    - Equivalent to: 55/100
  - Top score: 94/96
- Evaluation policy
  - Homework: 30%
  - Final comprehensive exam: 25%
  - Better of the two non-comprehensive term exam: 20%
  - Lab: 15%
  - Quizzes: 10%
  - Extra credit: 10%
- Colloquium today at 4pm in SH101

Physics Department
The University of Texas at Arlington
COLLOQUIUM

Adhesion protein dynamics in cells migrating in the 2D and 3D microenviroment

Dr. Michelle Digman, Ph.D.

The University of California, Irvine

4:00 pm Wednesday September 29, 2010 room 101 SH

Abstract:

We have studied protein interaction which are central to adhesion formation, turnover and signaling during cell migration in 2D cell cultures. In 2 D, we used non-linear one and two photon fluorescence excitation microscopy in conjunction with correlation spectroscopy tools to detect proteins interacting during focal adhesion assembly and disassembly. Paxillin, FAK and vinculin binding partners were characterized using cross-raster image correlation spectroscopy (ccRICS) and provided maps of molecular diffusion and binding dynamics from fluorescence fluctuations in time and space. Detecting when and where these complexes form in the cell and quantifying their stoichiometry is an important goal of cell biology. Thus we developed the number and molecular brightness (N&B) method to determine protein aggregate sizes from the fluorescence amplitude fluctuations. Two-color cross-N&B detects the presence of molecular complexes and their stoichiometry. We have demonstrated that focal adhesions form in cell cultures in 2D by adding monomeric proteins at the growing edge and disassemble by the detachment of large protein clusters. Studying these molecular interactions directly in the tissue is technically challenging due to the spatial orientation and mobility of the cell in 3D. We are developing the modulation tracking method (MT) to image cell protrusions in 3D collagen matrices with nanometer and microsecond-millisecond resolution. The MT method uses a variant of circular tracking and high frequency modulation of the laser beam. Using the MT method we can also perform ccRICS and ccN&B with the orbital tracking technique and maintain focus on the cell protrusions while they are moving in 3D. These dynamics methods in conjunction with the MT provide unparalleled tools for image based tracking of compositionally heterogeneous complexes in viable cellular microenvironment and can be applied in live animal models.

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

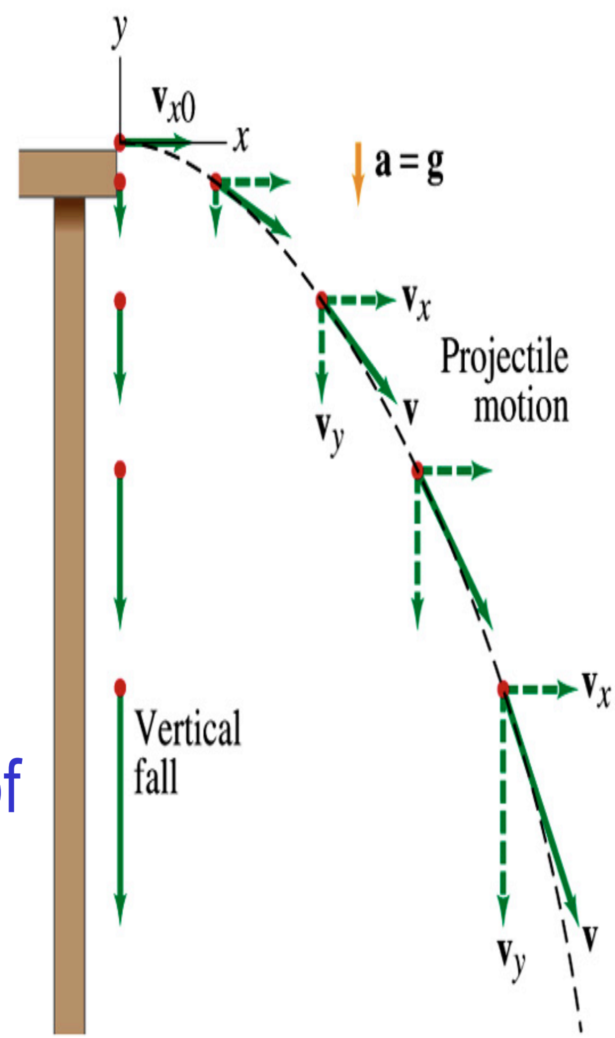
Special Project for Extra Credit

- Show that the trajectory of a projectile motion is a parabola!!
  - 20 points
  - Due: Wednesday, Oct. 6
  - You MUST show full details of your OWN computations to obtain any credit
    - Beyond what was covered in page 8 of this lecture note!!

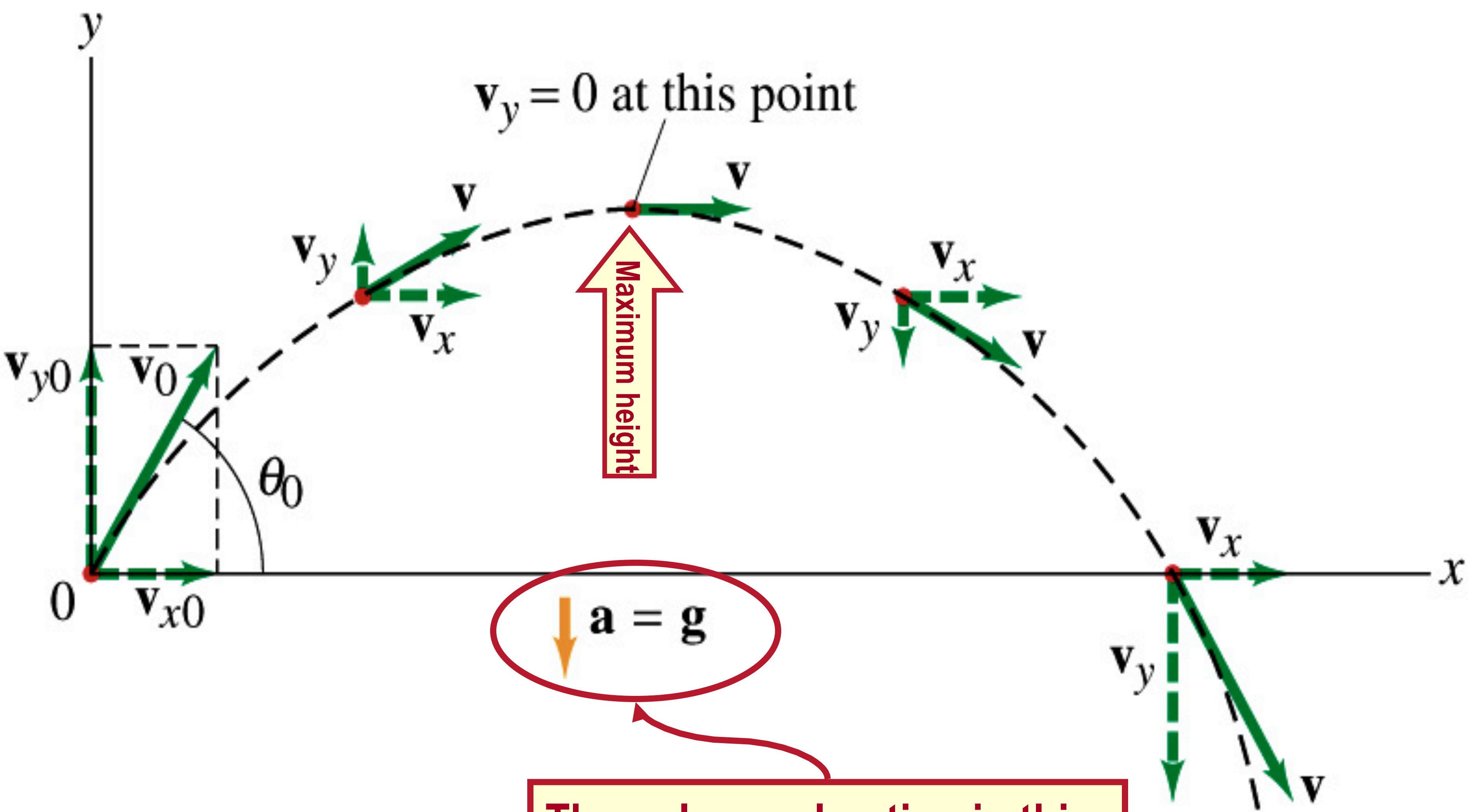
What is the Projectile Motion?

- 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*)

$$v_{yf} = v_{y0} + a_y t = v_{y0} + (-9.8)t$$



Projectile Motion



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

Kinematic Equations for a projectile motion

x-component

$$a_x = 0$$

$$v_x = v_{xo}$$

$$\Delta x = v_{xo} t$$

$$v_{x0}^2 = v_{xo}^2$$

$$\Delta x = v_{xo} t$$

y-component

$$a_y = -\left|\vec{g}\right| = -9.8\, m/s^2$$

$$v_y = v_{yo} - gt$$

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

$$v_y^2 = v_{yo}^2 - 2gy$$

$$\Delta y = v_{yo} t - \tfrac{1}{2} g t^2$$

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

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

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

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

Plug t into the above

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

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

What kind of parabola is this?

Example for a Projectile Motion

A ball is thrown with an initial velocity **v**=(20**i**+40**j**)m/s. Estimate the time of flight and the distance from the original position when the ball lands.

Which component determines the flight time and the distance?

Flight time is determined by the y component, because the ball stops moving when it is on the ground after the flight.

$$y_f = 40t + \frac{1}{2}(-g)t^2 = 0m$$

$$t(80 - gt) = 0$$

So the possible solutions are…

$$\therefore t = 0 \text{ or } t = \frac{80}{g} \approx 8\sec$$

$$\therefore\ t \approx 8\sec$$

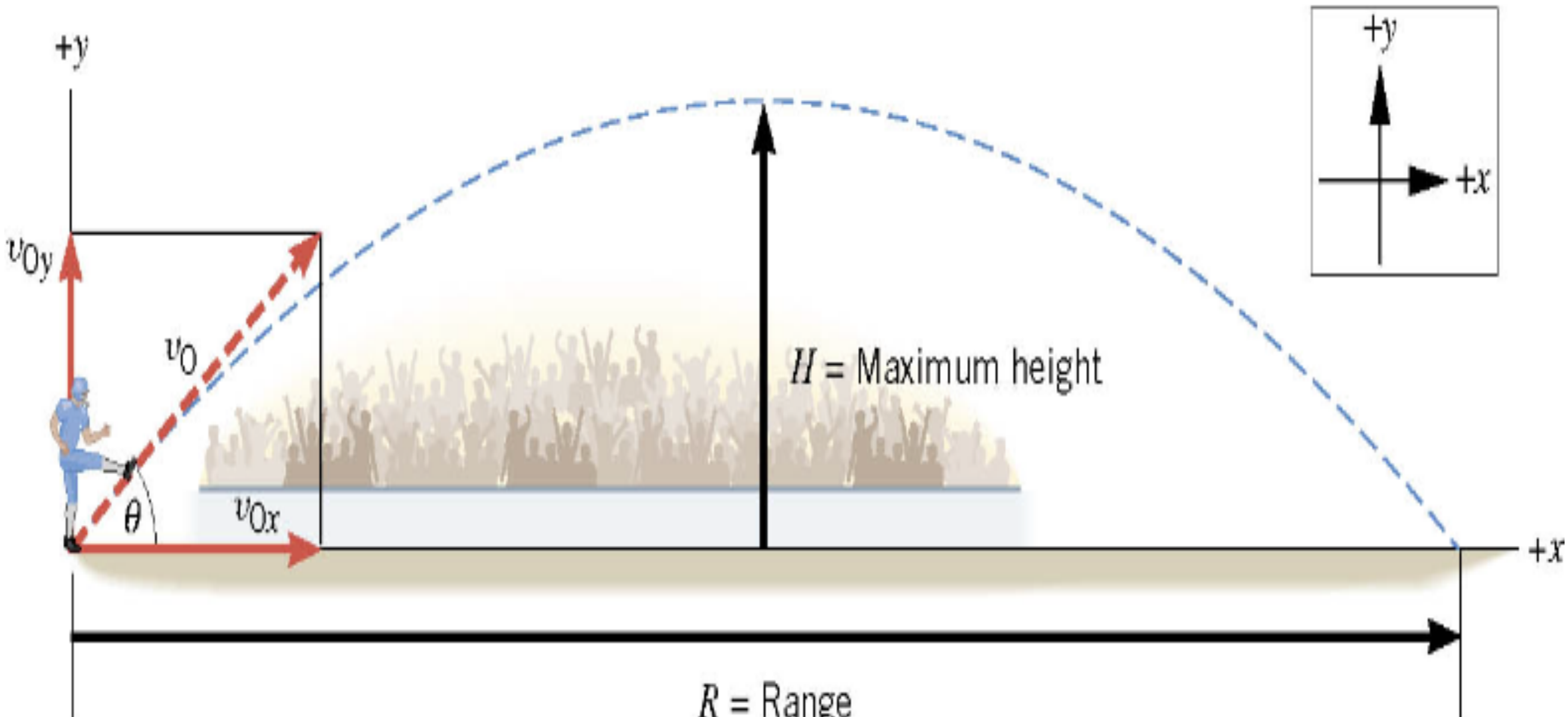
Why isn't 0 the solution?

Distance is determined by the x component in 2-dim, because the ball is at $y=0$ position when it completed it's flight.

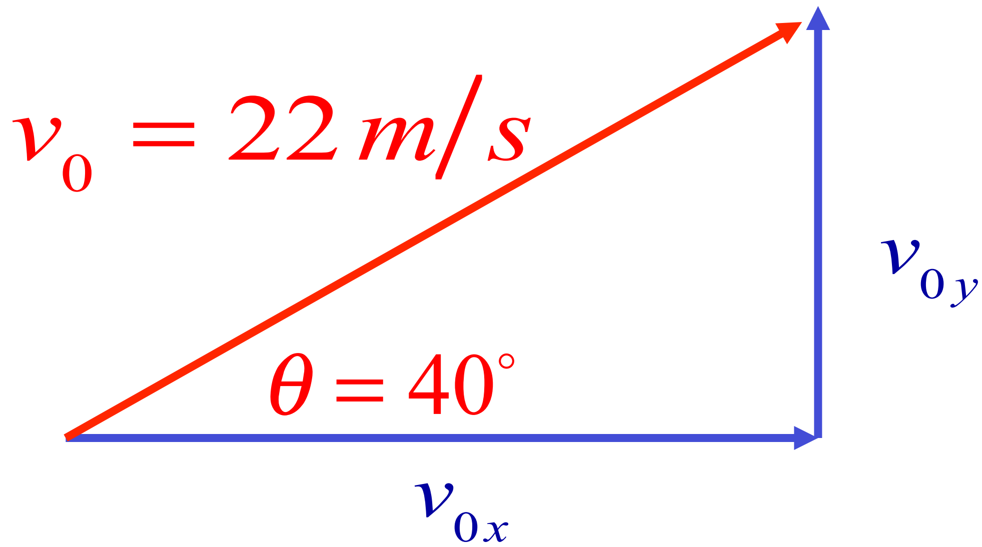
$$x_f = v_{xi}t = 20 \times 8 = 160(m)$$

Ex.3.9 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, determine the maximum height that the ball attains.



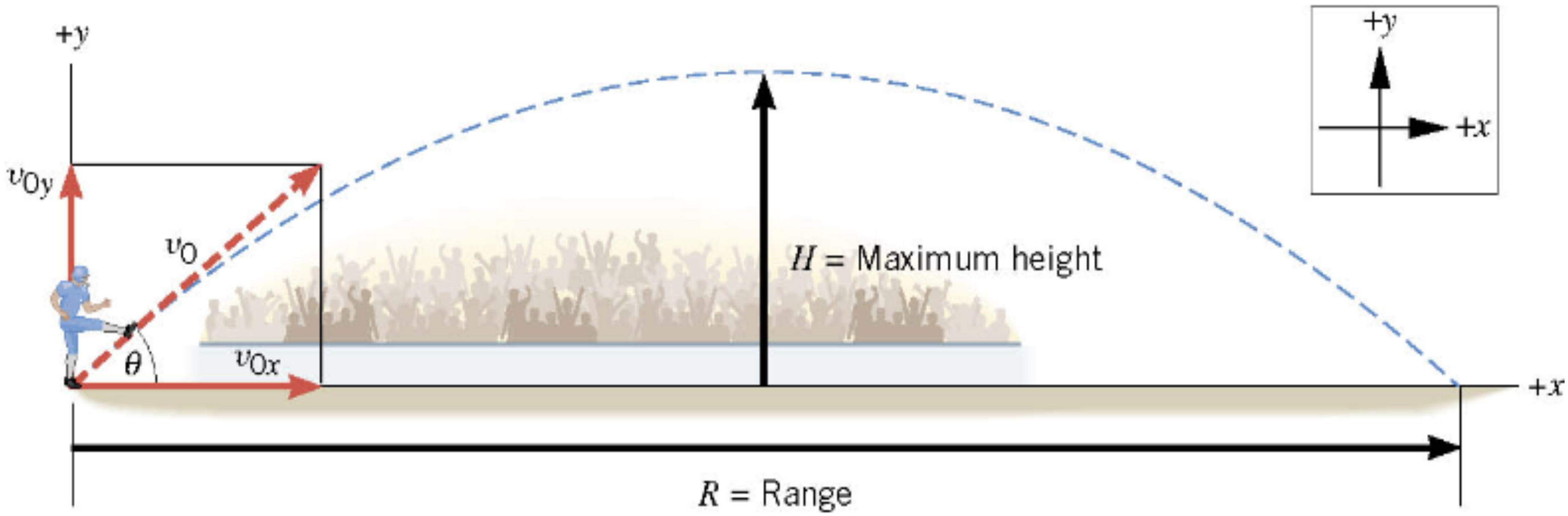
First, the initial velocity components



$$v_{0x} = v_o \cos\theta = (22\,\mathrm{m/s})\cos 40^\circ = 17\,\mathrm{m/s}$$

$$v_{0y} = v_o \sin\theta = (22\,\mathrm{m/s})\sin 40^\circ = 14\,\mathrm{m/s}$$

Motion in y-direction is of the interest..



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

Now the nitty, gritty calculations…

y	a_y	v_y	v_{0y}	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?

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

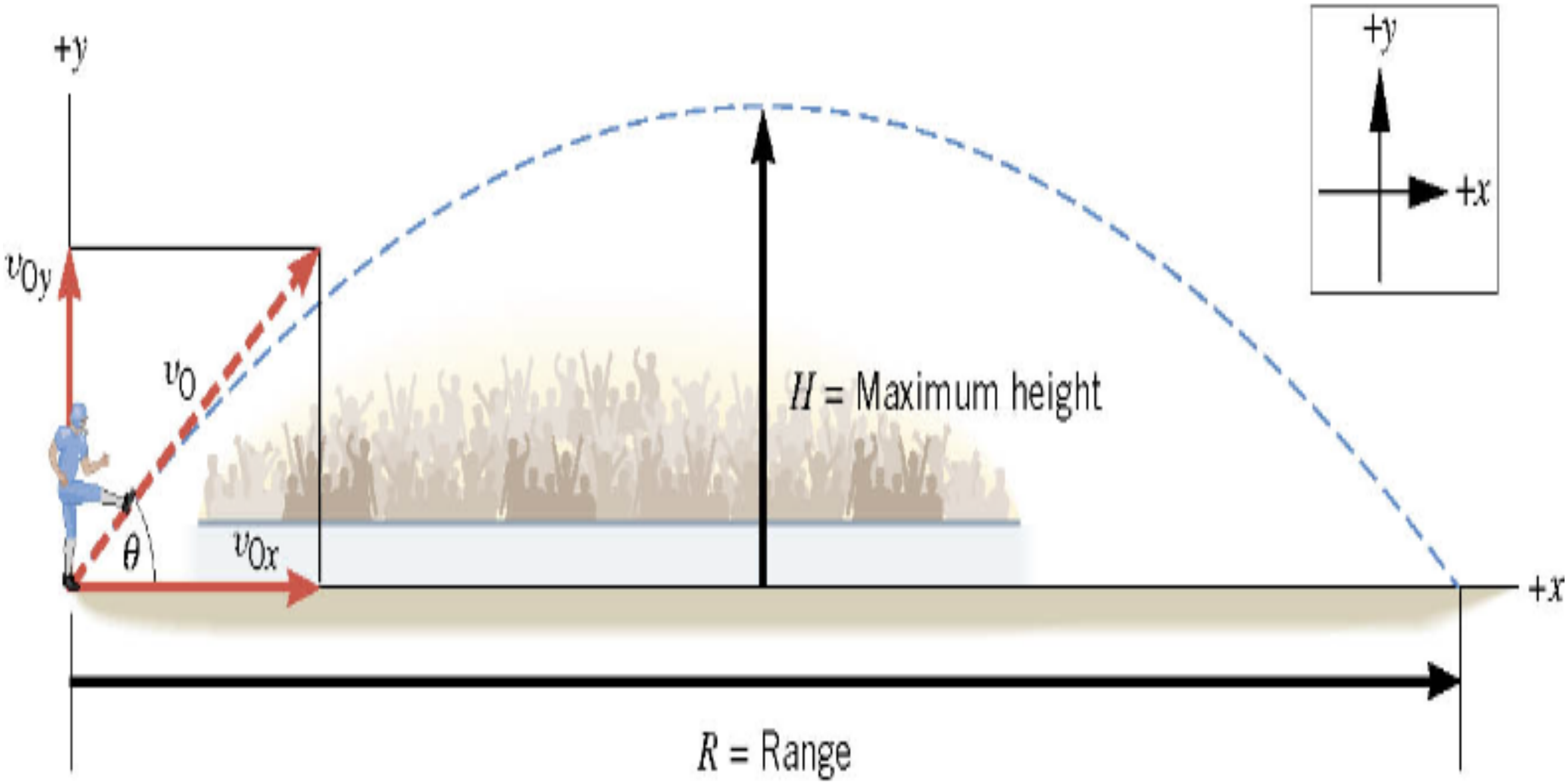
Solve for y

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

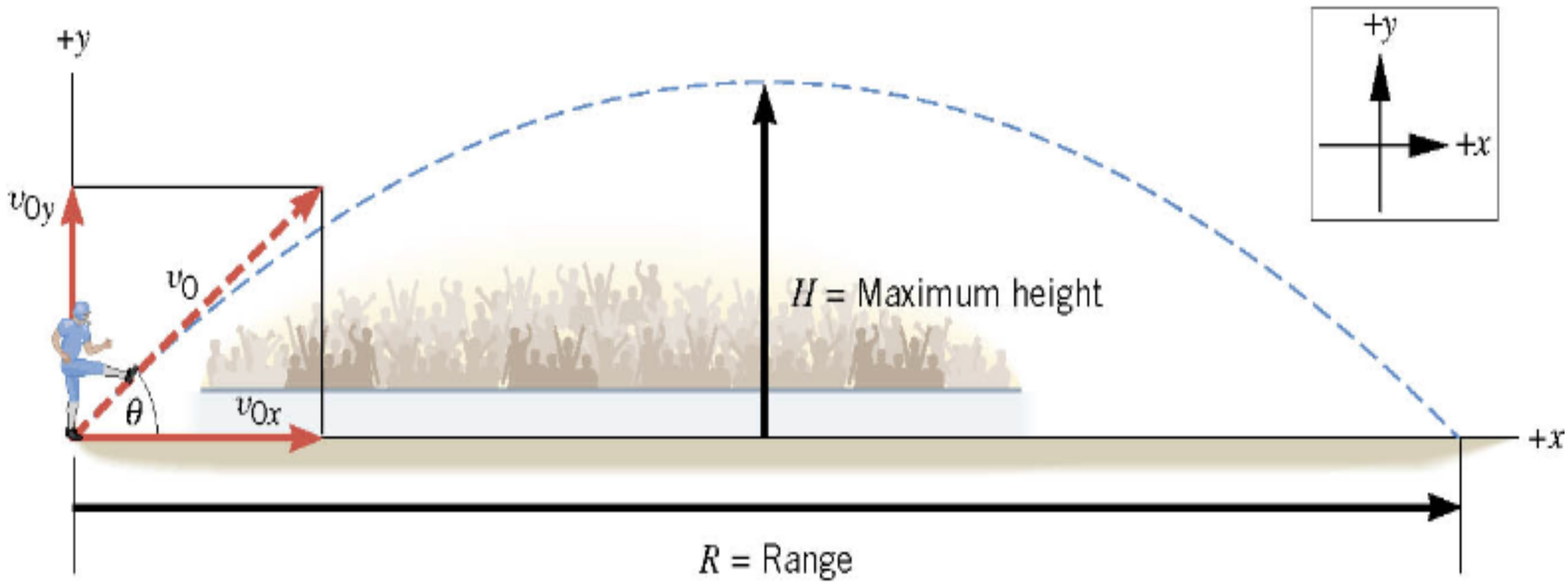
$$y = \frac{0-(14\,\mathrm{m/s})^2}{2(-9.8\,\mathrm{m/s^2})} = +10\ \mathrm{m}$$

Ex.3.9 extended: 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	?

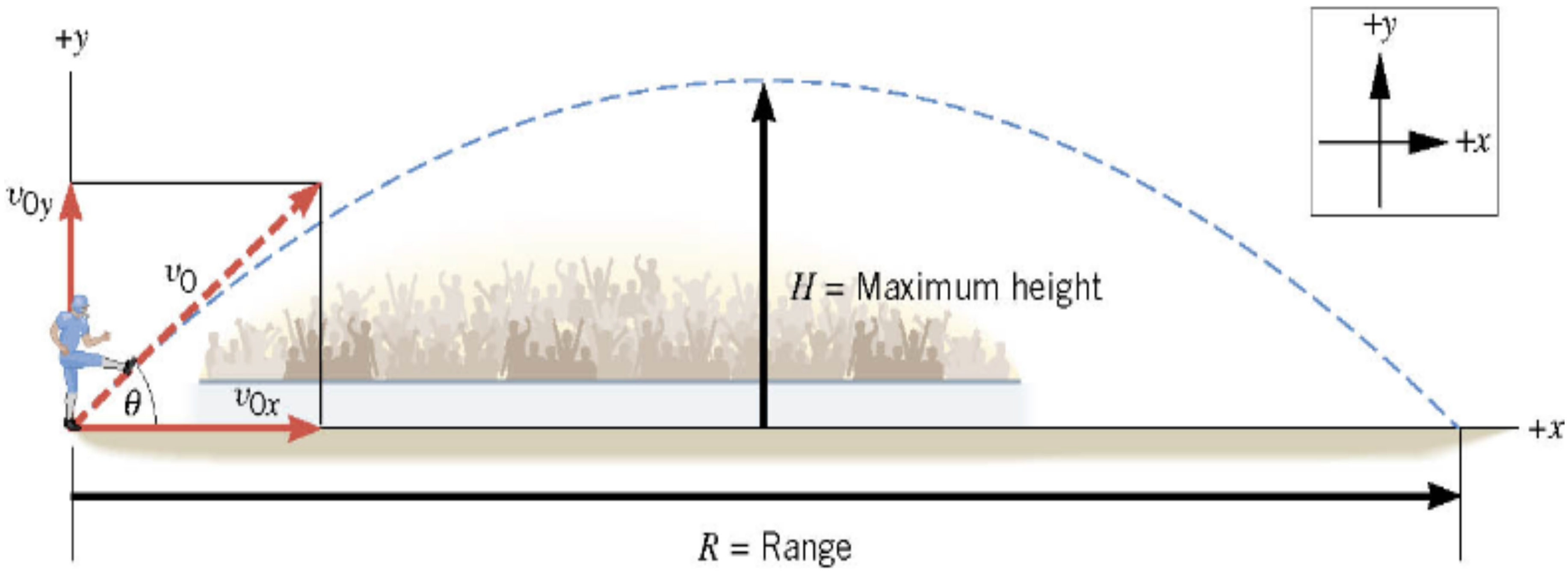
$$y = v_{oy}t + \tfrac{1}{2}a_y t^2 \xrightarrow{\text{Since } y=0} 0 = v_{oy}t + \tfrac{1}{2}a_y t^2 = t\left(v_{oy} + \tfrac{1}{2}a_y t\right)$$

Two soultions $t = 0$ or

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

Ex.3.9 The Range of a Kickoff

Calculate the range R of the projectile.



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

Example for a Projectile Motion

- A stone was thrown upward from the top of a cliff at an angle of 37° to horizontal with initial speed of 65.0m/s. If the height of the cliff is 125.0m, how long is it before the stone hits the ground?

$$v_{xi} = v_i \cos\theta_i = 65.0 \times \cos 37^\circ = 51.9 m/s$$

$$v_{yi} = v_i \sin\theta_i = 65.0 \times \sin 37^\circ = 39.1 m/s$$

$$y_f = -125.0 = v_{yi}t - \frac{1}{2}gt^2$$

Becomes

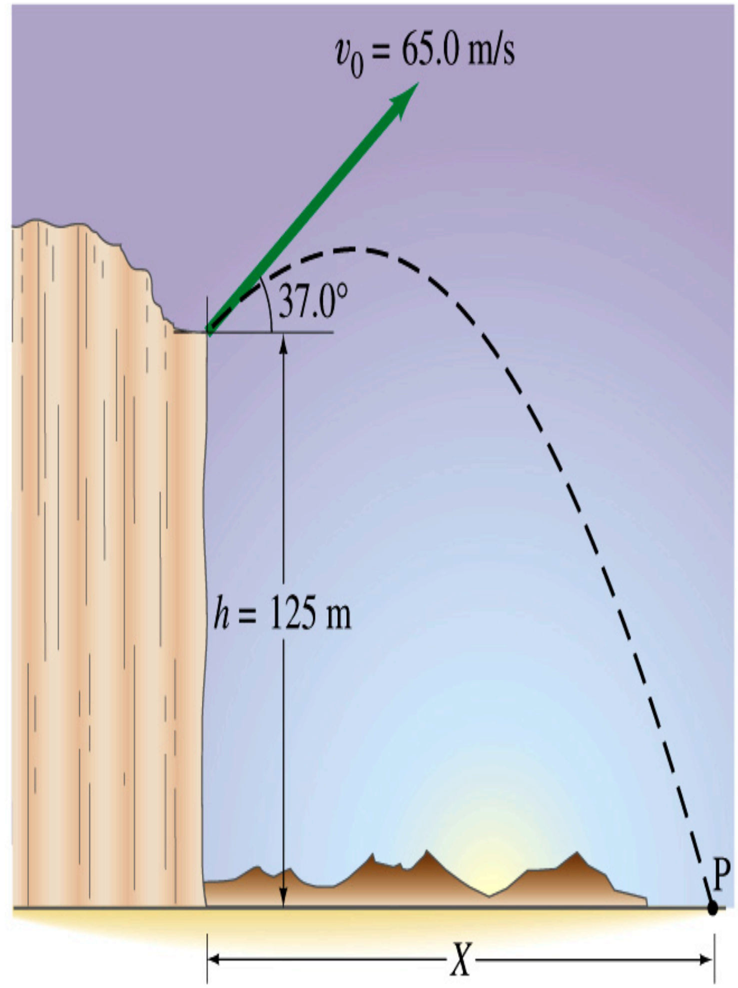
$$gt^2 - 78.2t - 250 = 9.80t^2 - 78.2t - 250 = 0$$

$$t = \frac{78.2 \pm \sqrt{(-78.2)^2 - 4 \times 9.80 \times (-250)}}{2 \times 9.80}$$

$$t = -2.43s \quad \text{or} \quad t = 10.4s$$

$$\boxed{t = 10.4s}$$

Since negative time does not exist.



Example cont'd

- What is the speed of the stone just before it hits the ground?

$$v_{xf} = v_{xi} = v_i \cos\theta_i = 65.0 \times \cos 37^\circ = 51.9 m/s$$

$$v_{yf} = v_{yi} - gt = v_i \sin\theta_i - gt = 39.1 - 9.80 \times 10.4 = -62.8 m/s$$

$$|v| = \sqrt{v_{xf}^2 + v_{yf}^2} = \sqrt{51.9^2 + (-62.8)^2} = 81.5 m/s$$

- What are the maximum height and the maximum range of the stone?

Do these yourselves at home for fun!!!

Horizontal Range and Max Height

- Based on what we have learned in the previous pages, 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

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

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

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

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

Height

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

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 $\theta_0 = 90^o$!!!

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

This formula tells us that the maximum range can be achieved when $2\theta_0 = 90^o$, i.e., $\theta_0 = 45^o$!!!