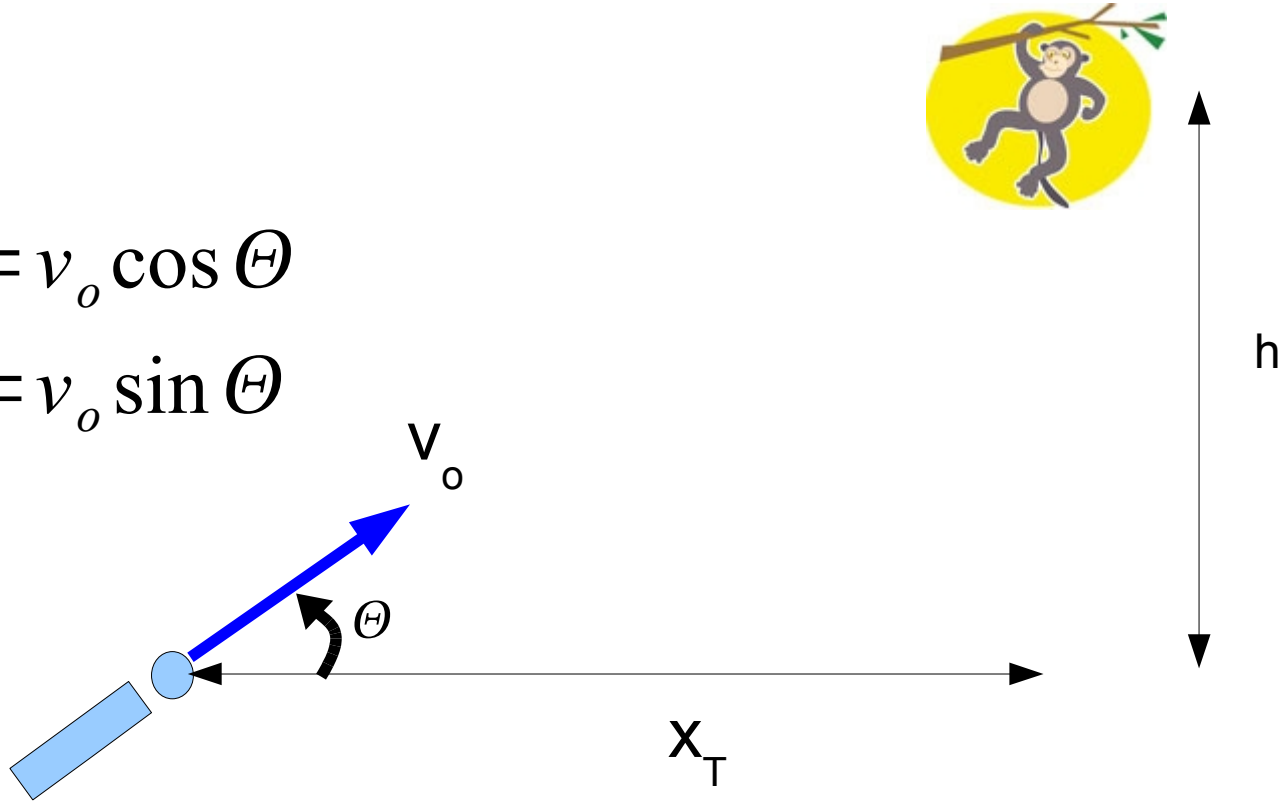
$$v_{o_x} = v_o \cos\Theta$$

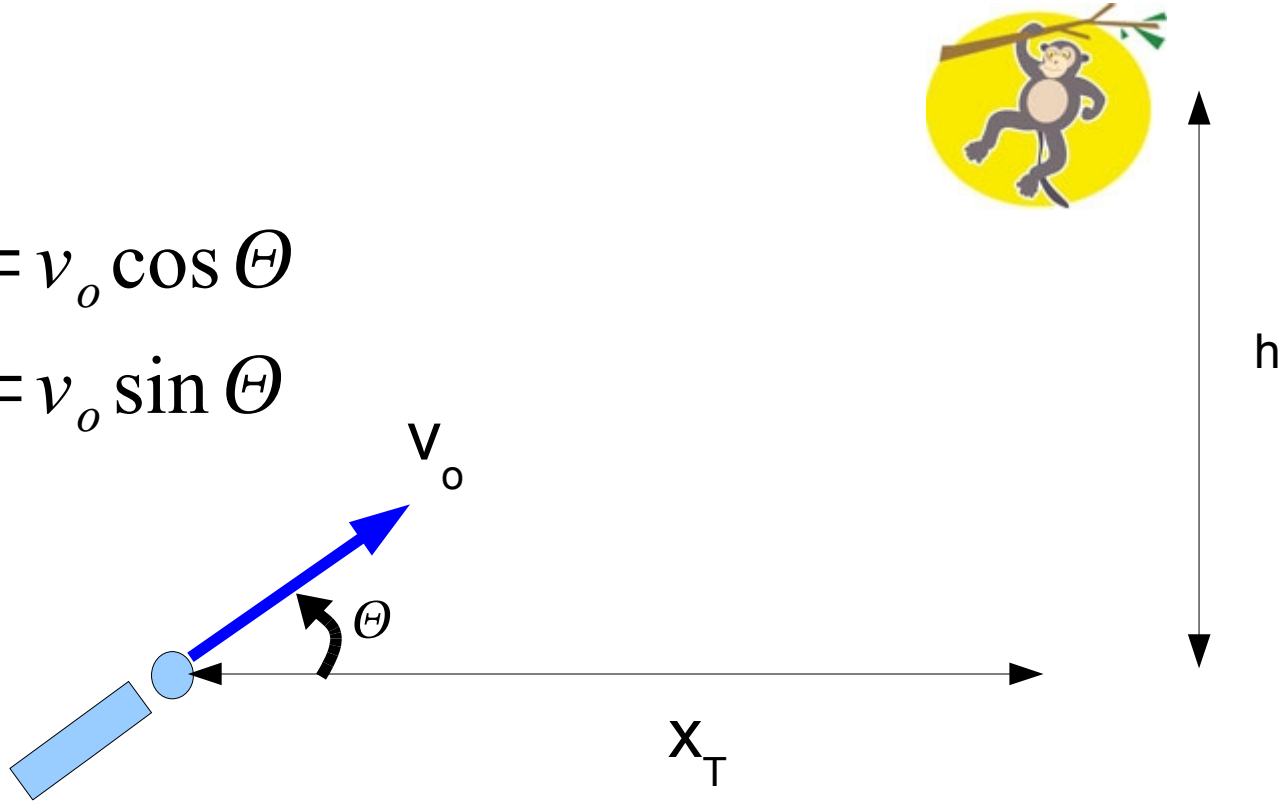
$$v_{o_y} = v_o \sin\Theta$$



A monkey hangs from a tree. I plan to shoot him with a rifle. I know that the very instant I pull the trigger, the monkey will get scared and let go of the branch. The monkey will be in free fall, while the bullet will exhibit projectile motion. Ignore all forces, such as air resistance (drag) and buoyancy. Consider only the force of gravity to be relevant to this experiment

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



At what angle should I point the gun?

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$$v_{o_x} = v_o \cos\Theta$$

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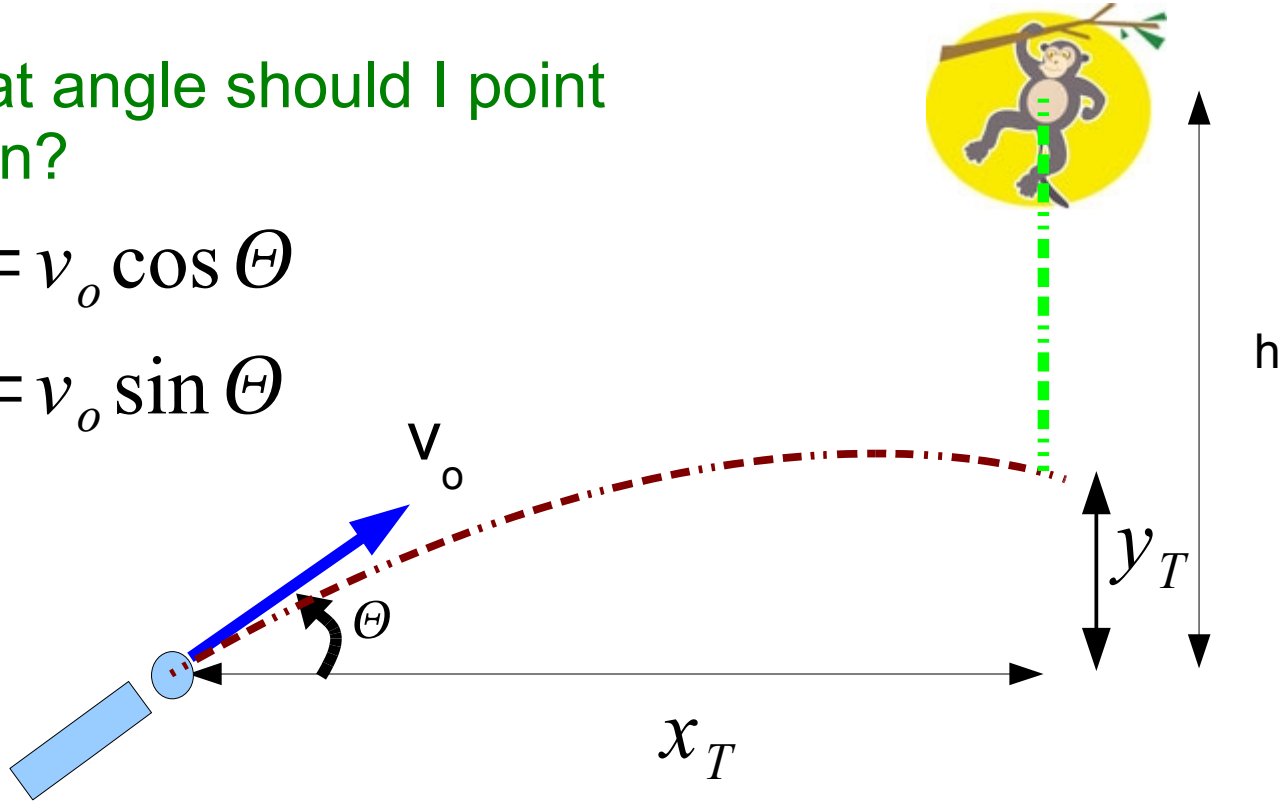


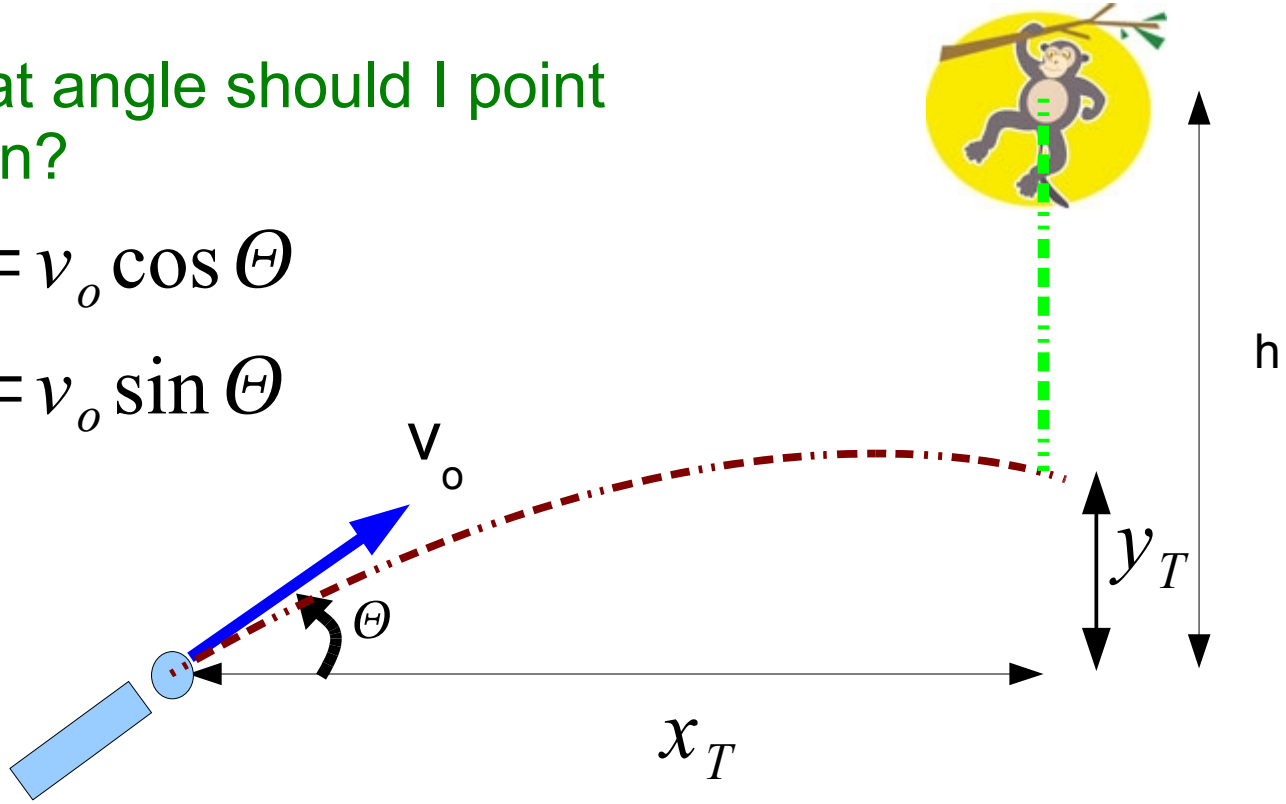
x_T = Horizontal Distance to the Target.

y_T = Vertical position of the Target.

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



The monkey is in Freefall. The monkey's initial height is h. The equations to the right show the monkey's position as a function of time. The initial velocity of the monkey is zero since the monkey starts from rest.

Monkey (Freefall)

$$y_T = y_{o_T} + v_{o_y} t - \frac{1}{2} g t^2$$

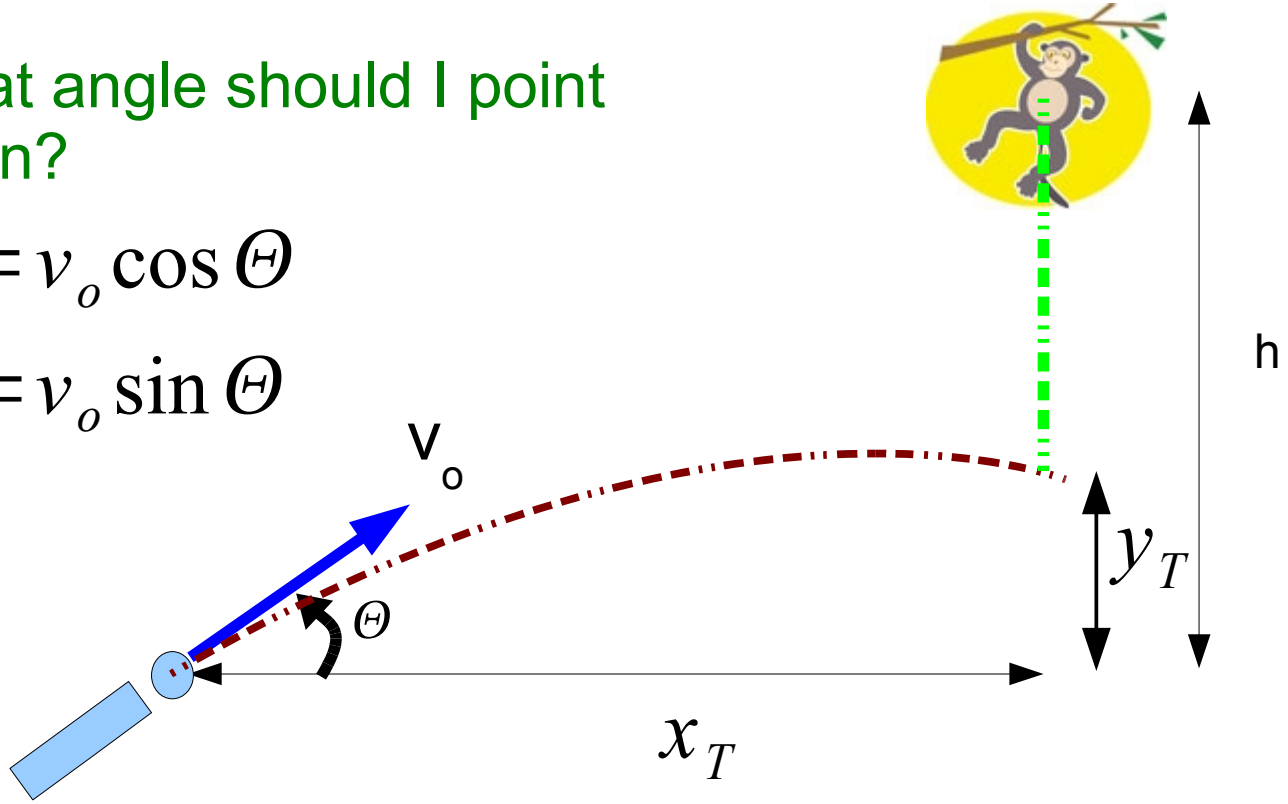
$$y_T = y_{o_T} + \cancel{v_{o_y} t} - \frac{1}{2} g t^2$$

$$y_T = h - \frac{1}{2} g t^2$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



The bullet follows the trajectory of a projectile. The bullet's y position is found by:

$$y_T = y_{o_y} + v_{o_y} t - \frac{1}{2} g t^2$$

$$y_T = v_{o_y} t - \frac{1}{2} g t^2$$

Monkey (Freefall)

$$y_T = y_{o_T} + v_{o_y} t - \frac{1}{2} g t^2$$

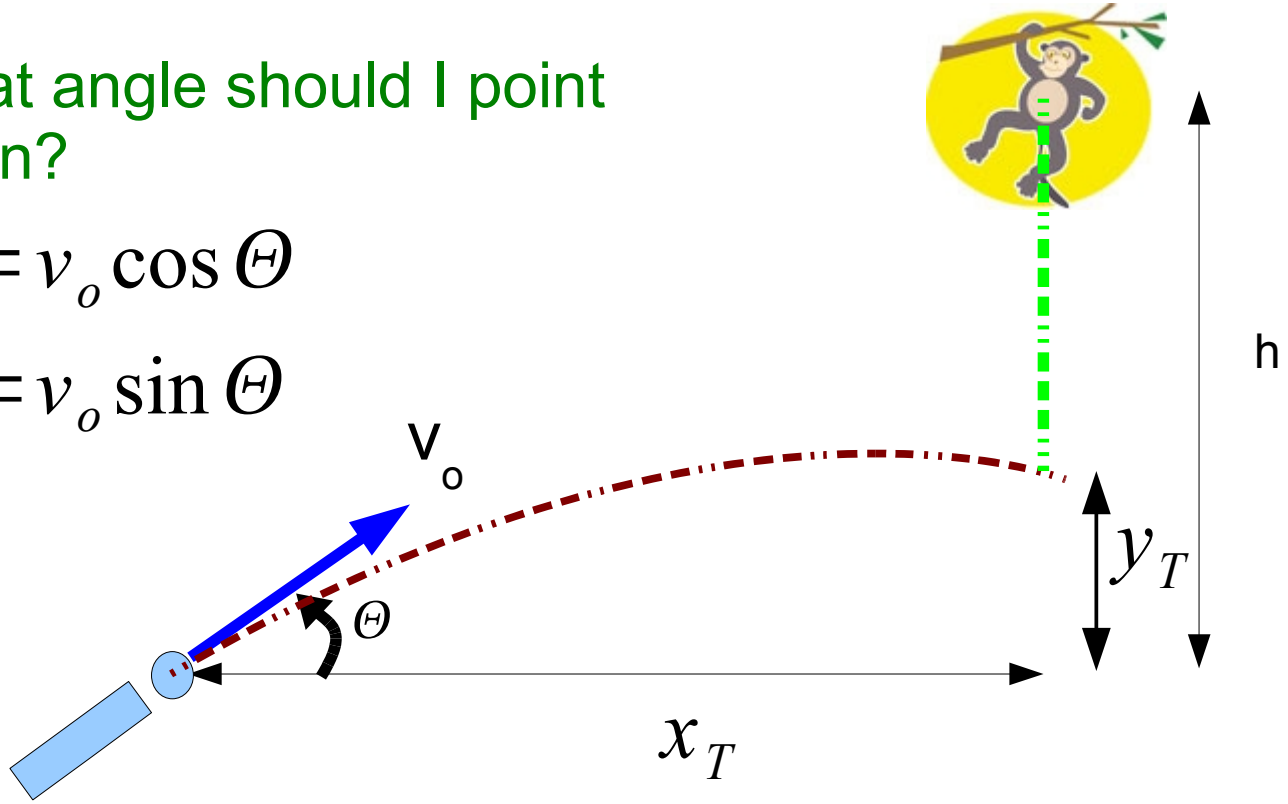
$$y_T = y_{o_T} + \cancel{v_{o_y} t} - \frac{1}{2} g t^2$$

$$y_T = h - \frac{1}{2} g t^2$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



Bullet (Projectile Motion)

$$y_T = y_{o_y} + v_{o_y} t - \frac{1}{2} g t^2$$

$$y_T = v_{o_y} t - \frac{1}{2} g t^2$$

Monkey (Freefall)

$$y_T = y_{o_T} + v_{o_y} t - \frac{1}{2} g t^2$$

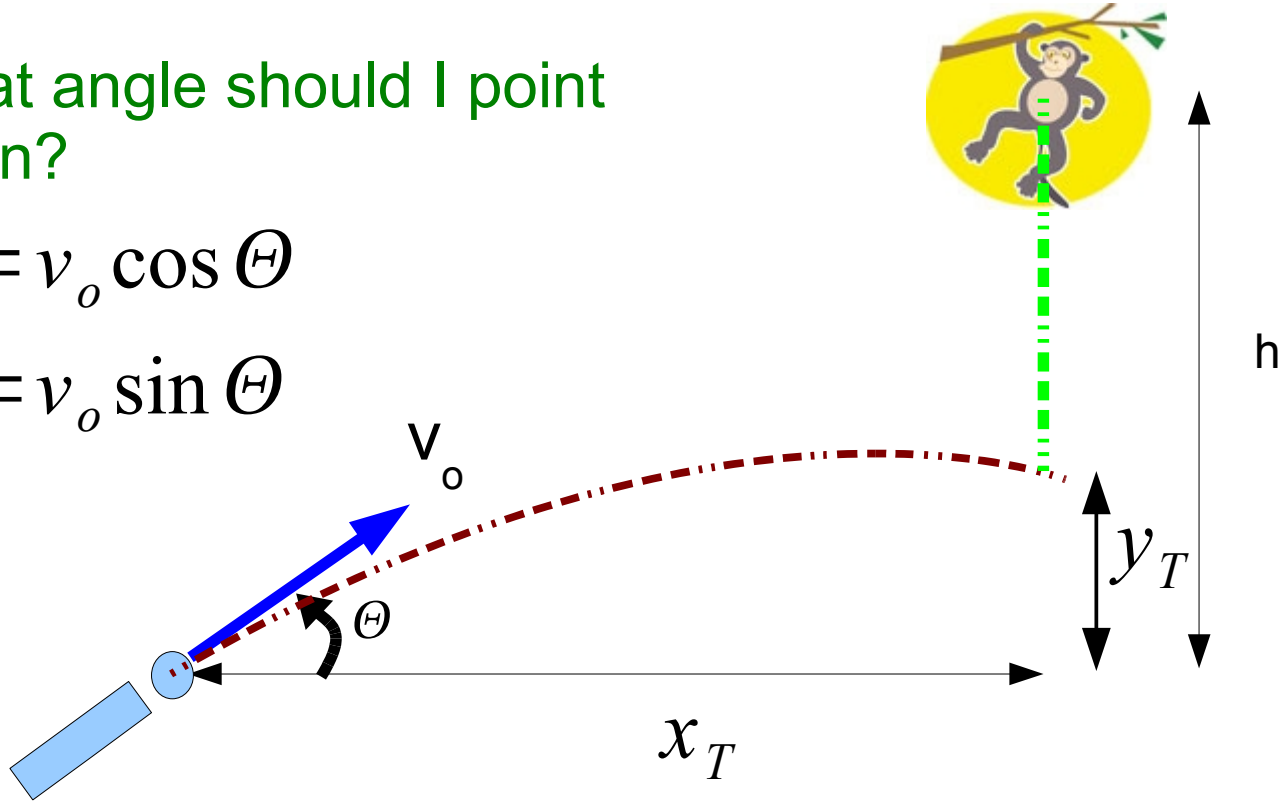
$$y_T = y_{o_T} + \cancel{v_{o_y} t} - \frac{1}{2} g t^2$$

$$y_T = h - \frac{1}{2} g t^2$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



Bullet (Projectile Motion)

$$y_T = v_{o_y} t - \frac{1}{2} g t^2$$

Monkey (Freefall)

$$y_T = h - \frac{1}{2} g t^2$$

These two heights have to be equal if the bullet is to hit the monkey.

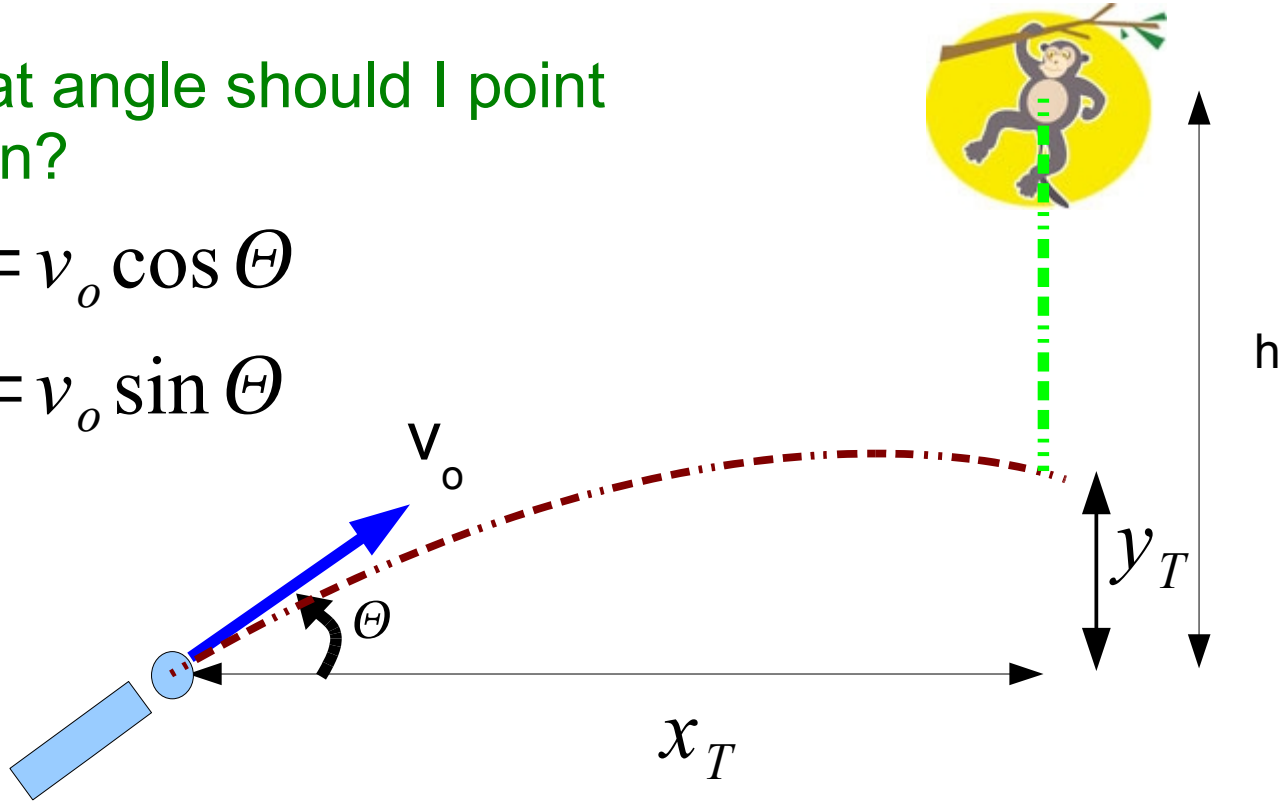
$$y_T = h - \frac{1}{2} g t^2 = v_{o_y} t - \frac{1}{2} g t^2$$

$$h - \frac{1}{2} g t^2 = v_o \sin\theta\, t - \frac{1}{2} g t^2$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



Bullet (Projectile Motion)

$$y_T = v_{o_y} t - \frac{1}{2} g t^2$$

Monkey (Freefall)

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$$h - \frac{1}{2} g t^2 = v_o \sin\theta\, t - \frac{1}{2} g t^2$$

$$h = v_o \sin\theta\, t$$

At what angle should I point the gun?

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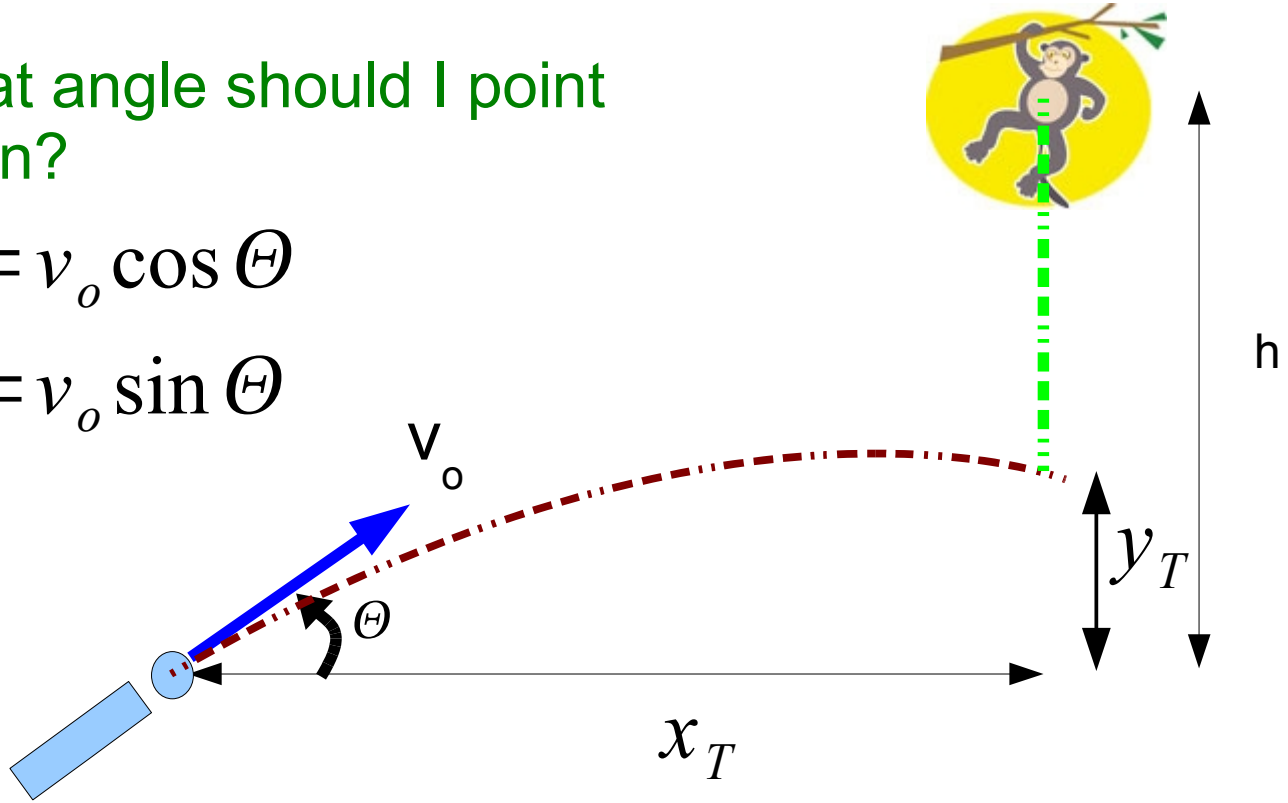
$$v_{o_y} = v_o \sin\Theta$$



Bullet (Projectile Motion)

$$y_T = v_{o_y} t - \frac{1}{2} g t^2$$

Monkey (Freefall)

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$$y_T = h - \frac{1}{2} g t^2 = v_{o_y} t - \frac{1}{2} g t^2$$

$$h - \frac{1}{2} g t^2 = v_o \sin\theta\, t - \frac{1}{2} g t^2$$

$$h = v_o \sin\theta\, t$$

The time can be calculated from the constant x component of the velocity.

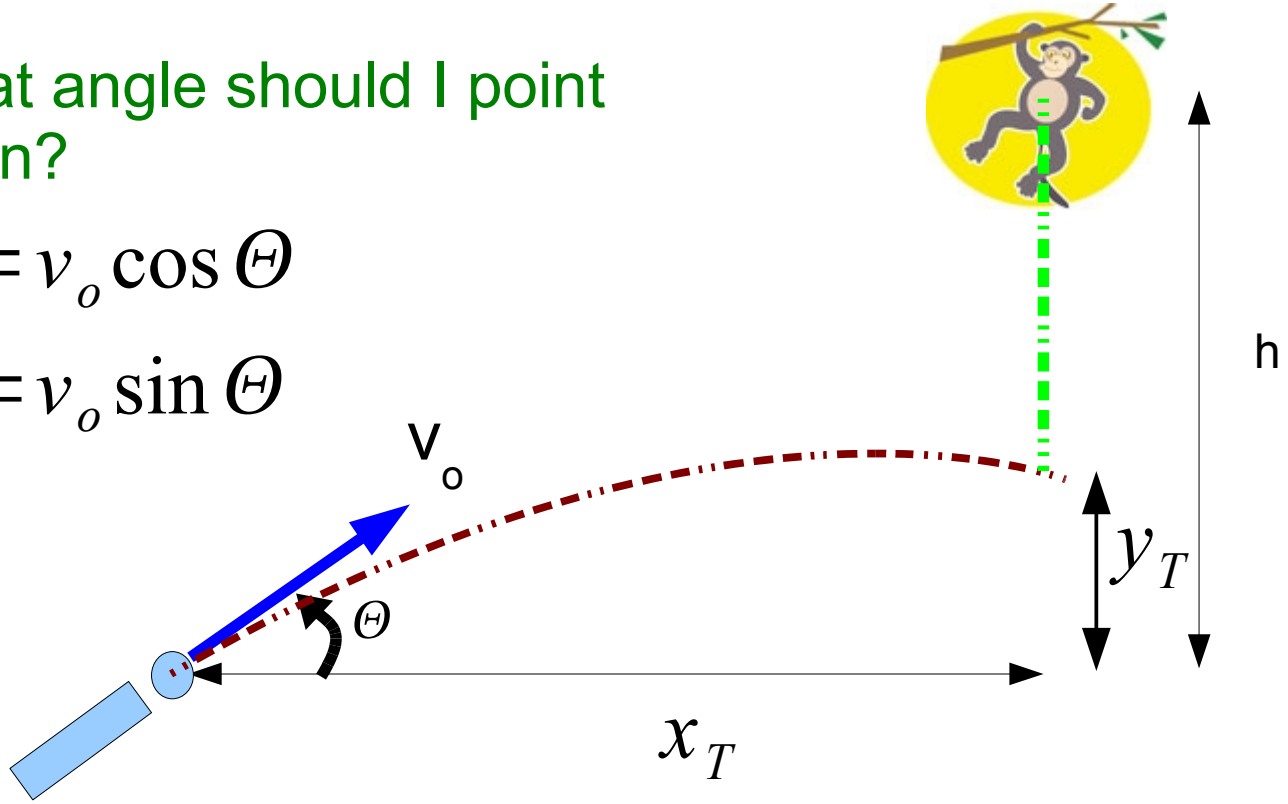
$$x_T = v_{o_x} t$$

$$t = \frac{x_T}{v_{o_x}}$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



$$y_T = h - \frac{1}{2} g t^2 = v_{o_y} t - \frac{1}{2} g t^2$$

$$h - \frac{1}{2} g t^2 = v_o \sin\theta\, t - \frac{1}{2} g t^2$$

$$h = v_o \sin\theta\, t$$

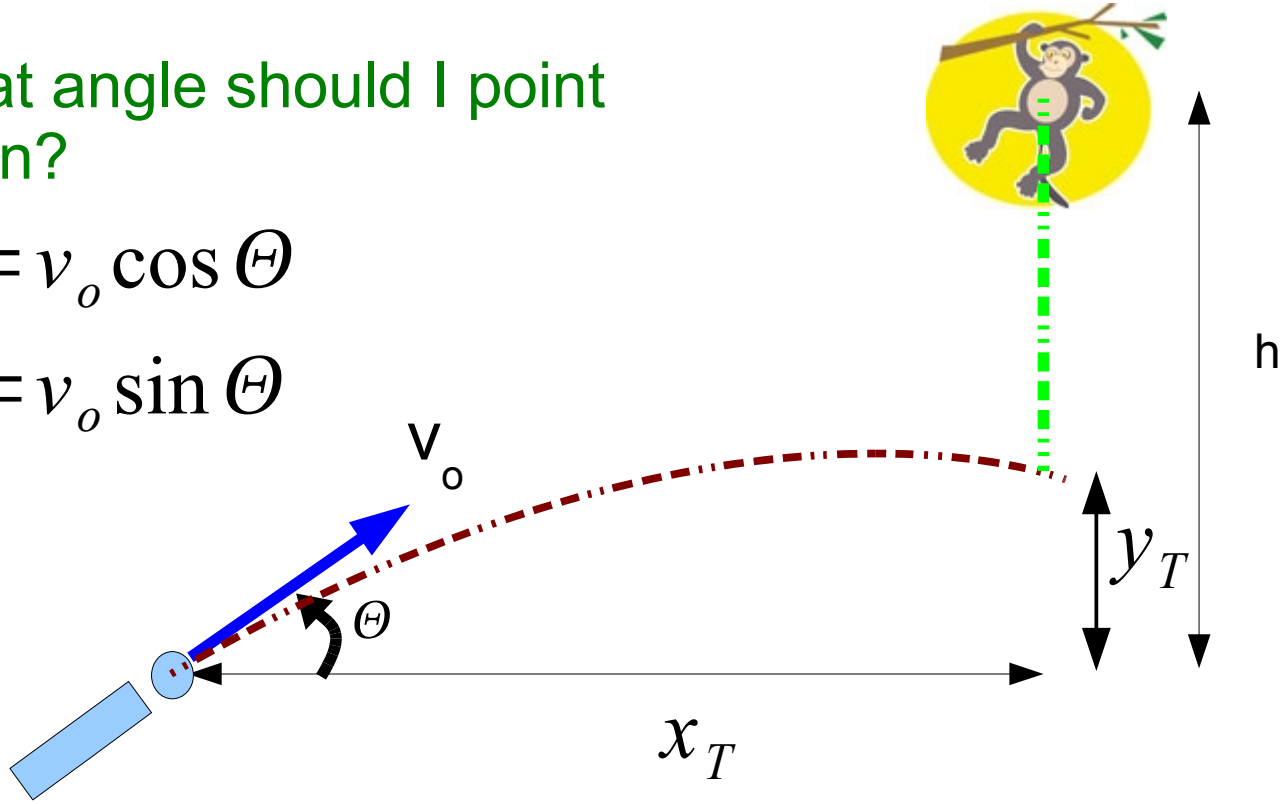
$$x_T = v_{o_x} t$$

$$t = \frac{x_T}{v_{o_x}} = \frac{x_T}{v_o \cos\theta}$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



$$y_T = h - \frac{1}{2} g t^2 = v_{o_y} t - \frac{1}{2} g t^2$$

$$h - \frac{1}{2} g t^2 = v_o \sin\theta\, t - \frac{1}{2} g t^2$$

$$h = v_o \sin\theta \left(\frac{x_T}{v_o \cos\theta} \right)$$

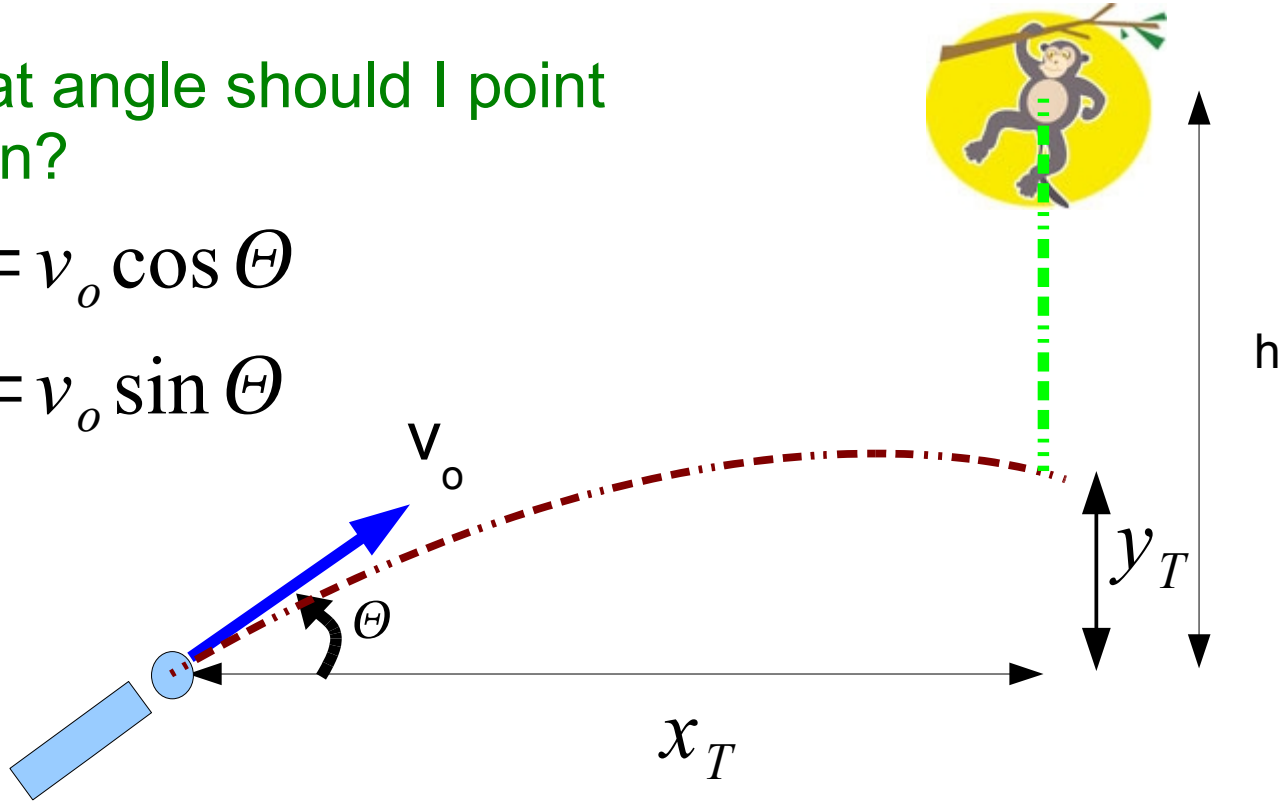
$$x_T = v_{o_x} t$$

$$t = \frac{x_T}{v_{o_x}} = \frac{x_T}{v_o \cos\theta}$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



$$h = v_o \sin\theta \left(\frac{x_T}{v_o \cos\theta} \right)$$

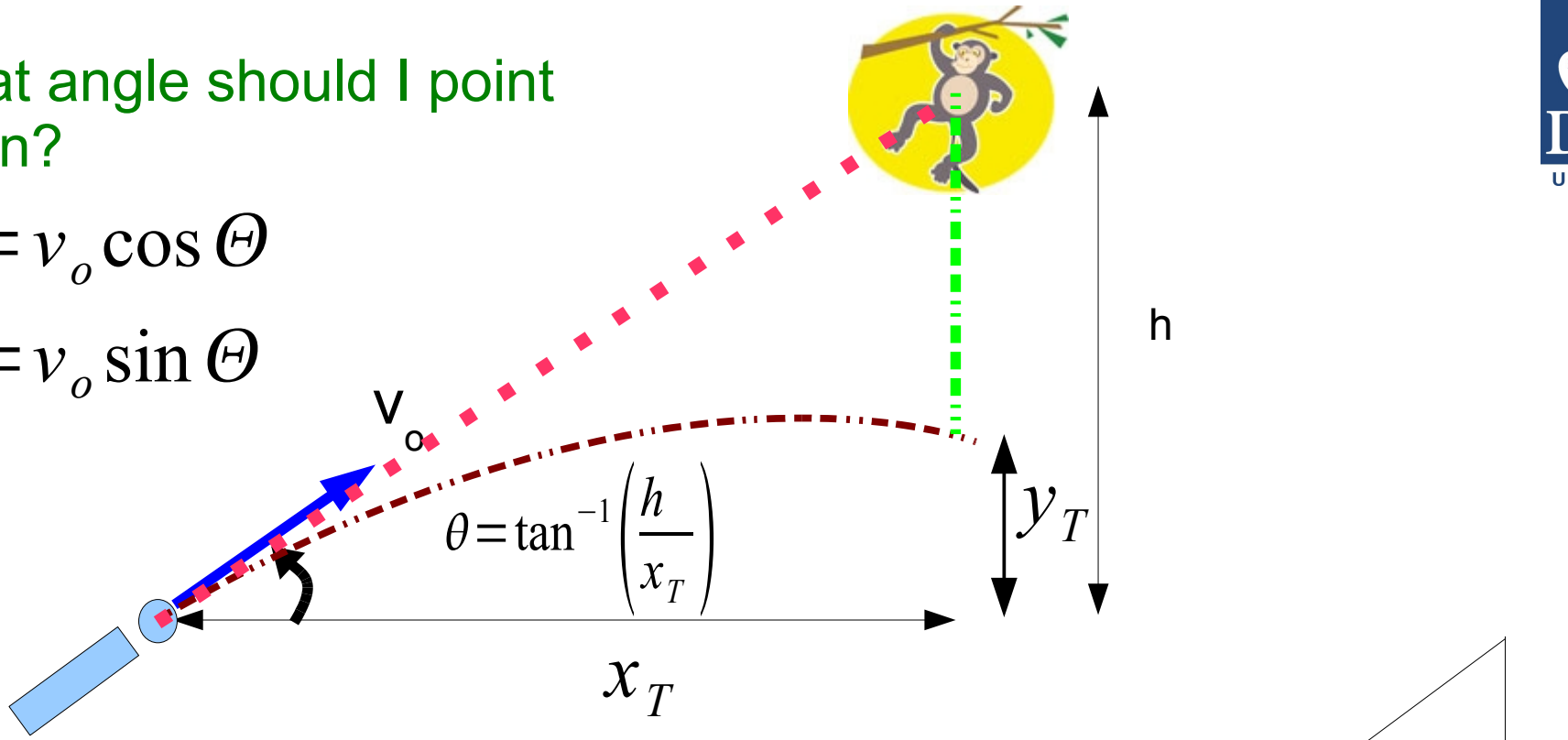
$$h = \sin\theta \left(\frac{x_T}{\cos\theta} \right)$$

$$\frac{h}{x_T} = \tan\theta$$

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$

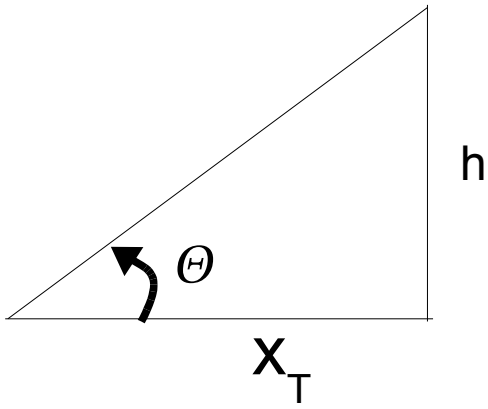


$$h = v_o \sin\theta \left(\frac{x_T}{v_o \cos\theta}\right)$$

$$h = \sin\theta \left(\frac{x_T}{\cos\theta}\right)$$

$$\frac{h}{x_T} = \tan\theta$$

$$\theta = \tan^{-1}\left(\frac{h}{x_T}\right)$$

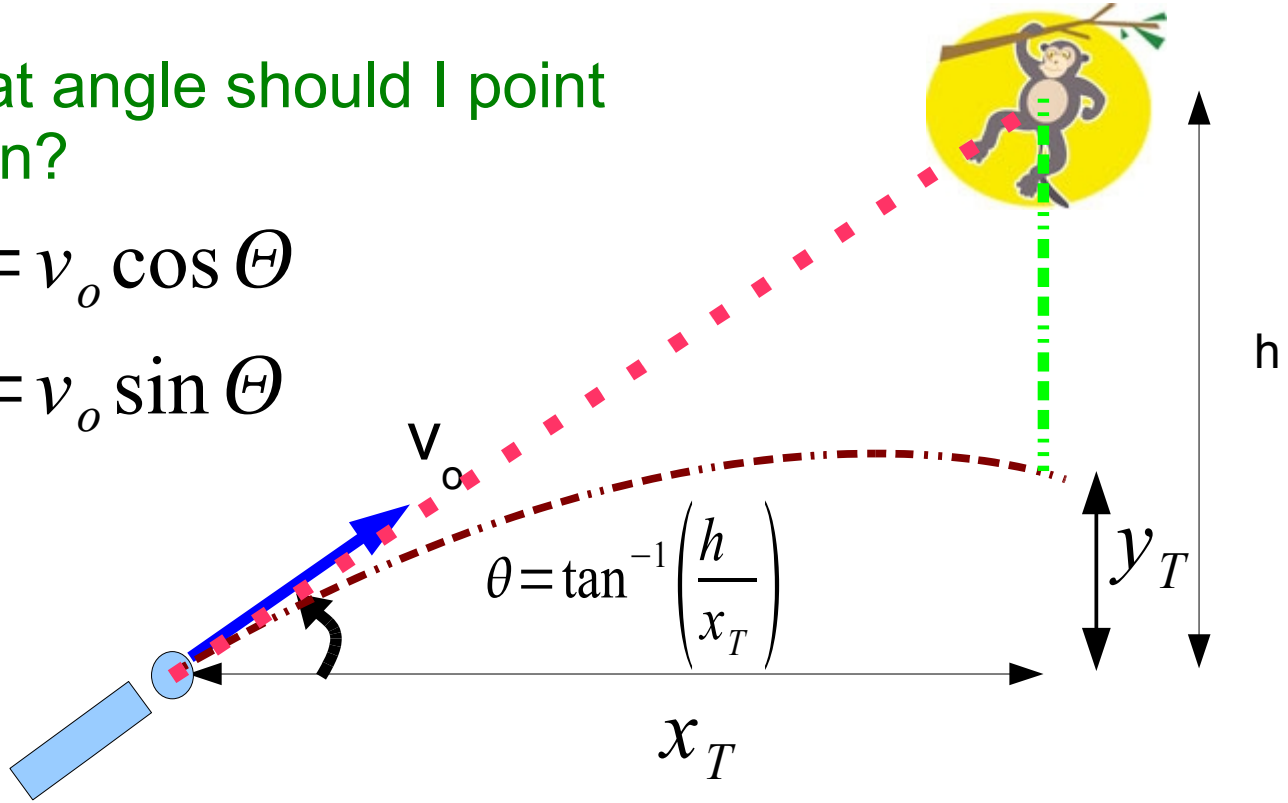


Point the gun at the monkey's initial position.

At what angle should I point the gun?

$$v_{o_x} = v_o \cos\Theta$$

$$v_{o_y} = v_o \sin\Theta$$



$$\theta = \tan^{-1}\left(\frac{h}{x_T}\right)$$

The faster the initial velocity, the higher the y_T will be.

$$y_T = v_{o_y} t - \frac{1}{2} g t^2$$

$$t = \frac{x_T}{v_o \cos\theta}$$

$$y_T = v_o \sin\theta \left(\frac{x_T}{v_o \cos\theta}\right) - \frac{1}{2} g \left(\frac{x_T}{v_o \cos\theta}\right)^2$$

$$y_T = x_T \tan\theta - \frac{1}{2} g \left(\frac{x_T}{v_o \cos\theta}\right)^2$$