Written Homework

- Available today*, due Sunday*
- Get an email from GradeScope
- Upload PDF (please use template PDF)
- Traditional problem: 2 balls collide vertically
- Modelling problem: steel ball and ping pong ball dropped off a tall tower
  - Do not need to know much about air resistance except that objects have a terminal speed

An Olympic sprinter can run 100 m in 10 s, starting from rest. Estimate their top speed assuming exponential decay of acceleration.

assume

$$a(t) = a_0 e^{-t/T}$$

assume $T = 4s$

$$v(t) = \int a(t)\,dt + C = a_0 \int e^{-t/T}\,dt + C$$

$$= a_0(-T)e^{-t/T} + C$$

$$t=0 \rightarrow v = -a_0 T + C = 0 \rightarrow C = a_0 T$$

$$v(t) = a_0 T\left(1 - e^{-t/T}\right) \qquad V_{max} = v\left(t = 10s\right)$$

Chapter 4 – Kinematics in 2D

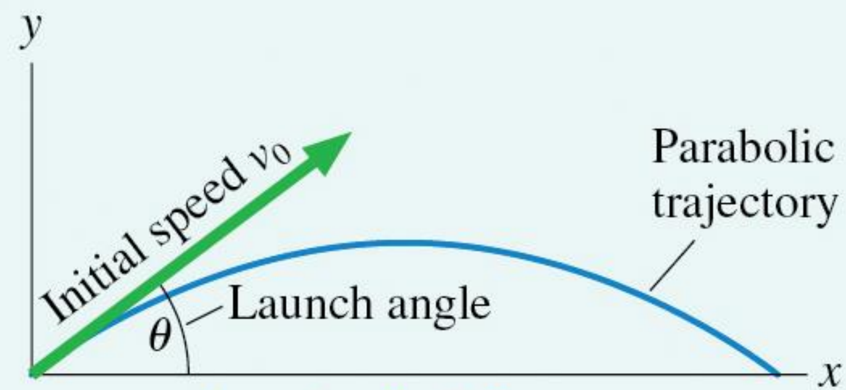
- Mathematics
- Projectile motion
- Relative motion
- Circular motion (next class)

MODEL 4.1

Projectile motion

For motion under the influence of only gravity.

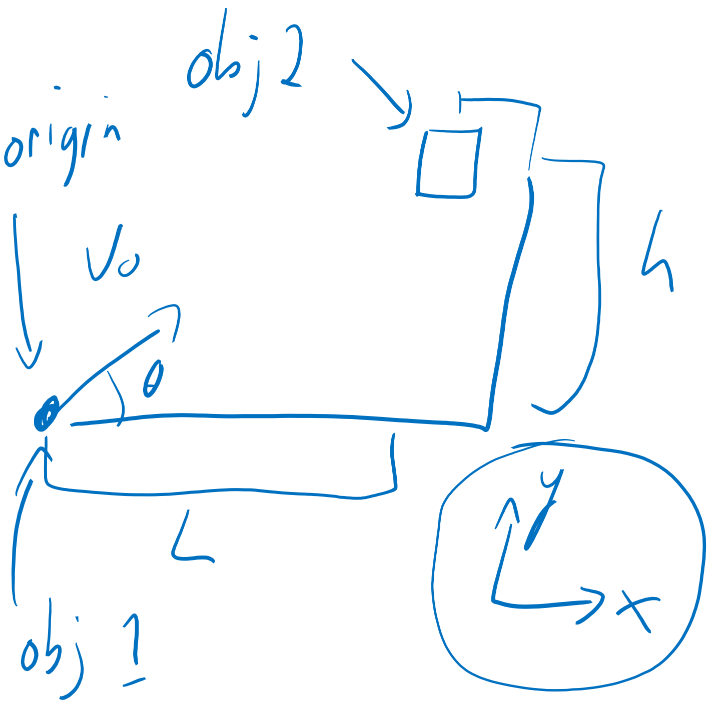
- Model the object as a particle launched with speed v_0 at angle θ:
- Mathematically:
  - **Uniform motion** in the horizontal direction with $v_x = v_0 \cos\theta$.
  - **Constant acceleration** in the vertical direction with $a_y = -g$.
  - Same Δt for both motions.
- Limitations: Model fails if air resistance is significant.



A projectile follows a parabolic trajectory.

Exercise 9

Demo: will the projectile hit the falling figure, go too high, or go too low?



assume v is big enough so we don't hit the floor

$$x_2(t) = L$$
$$y_2(t) = h - \frac{1}{2} g t^2$$

$$x_1(t) = (v_0 \cos\theta) t$$
$$y_1(t) = (v_0 \sin\theta) t - \frac{1}{2} g t^2$$

$$\Delta x = (x_2 - x_1)(t) = L - (v_0 \cos\theta) t = 0 \longrightarrow t = \frac{L}{v_0 \cos\theta}$$

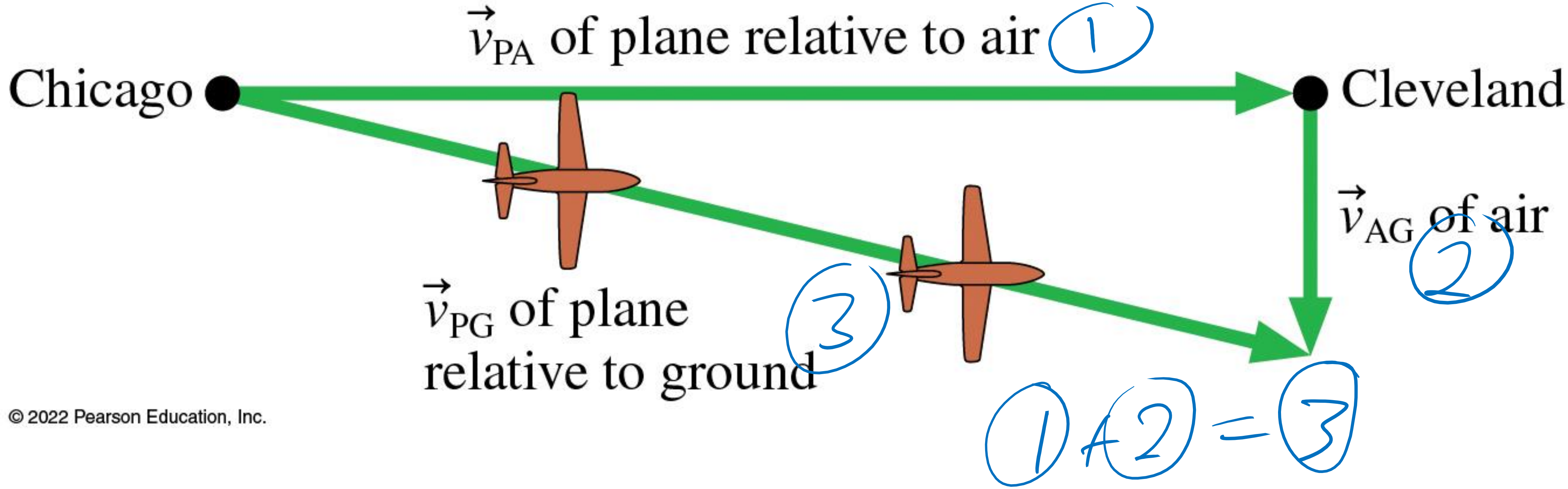
$$\Delta y\ (y_2 - y_1)(t) = h - \cancel{\tfrac{1}{2} g t^2} - \left(v_0 \sin\theta\, t - \cancel{\tfrac{1}{2} g t^2}\right) = h - (v_0 \sin\theta) t = 0$$

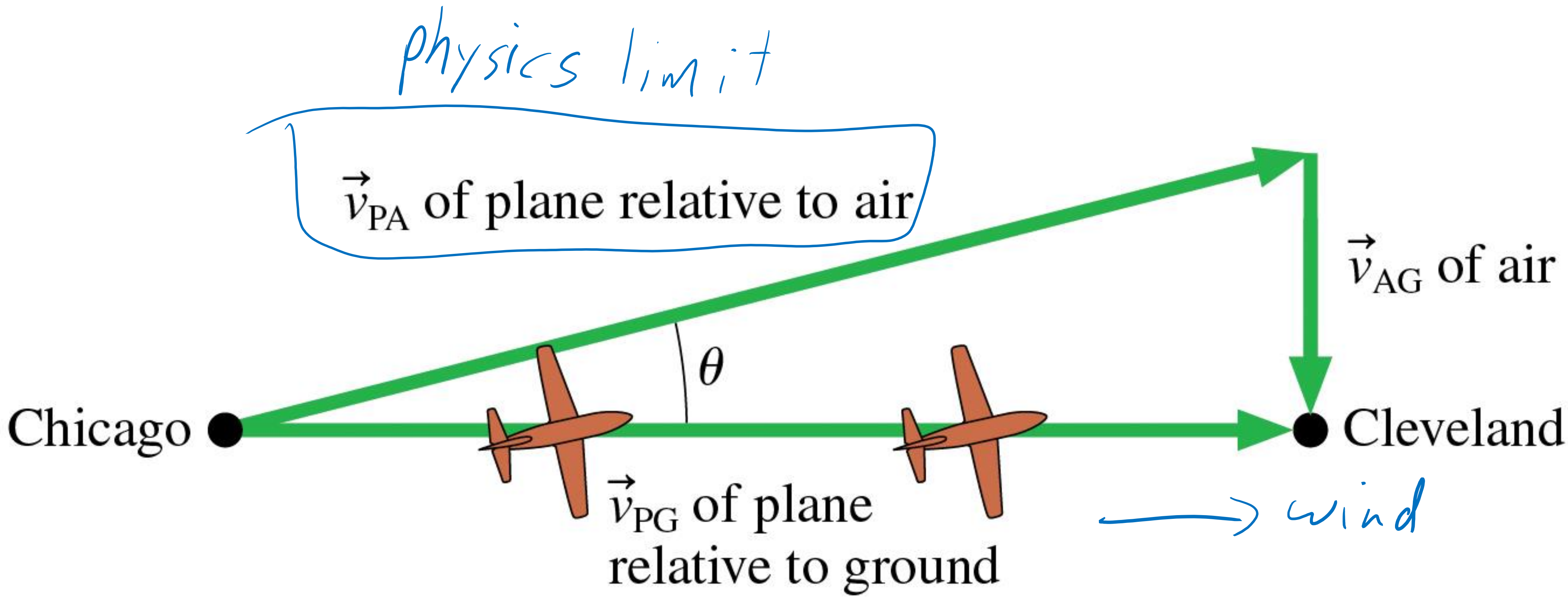
set θ s.t. at $t = \bar{t}$ → time they collide

$\Delta x = 0$ + $\Delta y = 0$

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

Team Up Questions


$\vec{v}_{PA}$ of plane relative to air 1
Chicago
Cleveland
$\vec{v}_{AG}$ of air 2
$\vec{v}_{PG}$ of plane relative to ground 3
1 + 2 = 3


physics limit
$\vec{v}_{PA}$ of plane relative to air
$\vec{v}_{AG}$ of air
θ
Chicago
Cleveland
$\vec{v}_{PG}$ of plane relative to ground
wind

Does the round trip from Chicago to Cleveland and back take more time, less time, or the same time if there is a cross-wind versus if there is no wind?

any wind direction is slower