Free Particle Model

Inertia ,Interactions

1-D & 2-D

Units IV & VI

Models to Date

- Constant Velocity Model
- Uniform Acceleration Model
  - Representations
    - Graphs (xt,vt,at)
    - Motion Diagrams
    - Narrative
    - Mathematical

Free Particle Model

- Essential Questions
  - What type of motion is observed?
    - Constant Velocity (CV) or Uniform Acceleration (UA)?
  - What is causing the type of motion observed?
    - CV – Balanced Forces
    - UA – Unbalanced Forces

Free Particle Model

- Defining system and surroundings
  - Sketch
  - Identify relevant objects in system
  - Reduce system to be considered to a particle
- What forces can be identified?
  - Long Range Force (force fields)
    - Force of earth → object (F_g)
  - Contact (applied) Force (contact between system and surroundings
    - Force of table → object (F_N) “normal force”

Free Particle Model

What type of motion is observed?

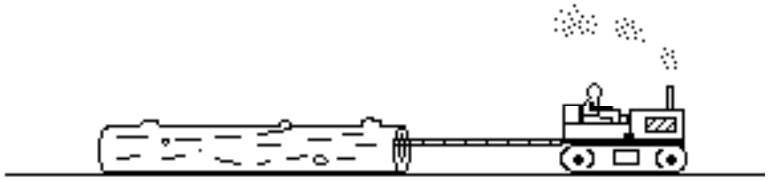
What is causing the type of motion observed?

Consider the analysis of forces acting on a log as a tractor pulls it at a constant speed. The analysis proceeds as follows:

-
- 1. Sketch the system and its surroundings.
- 2. Enclose the system within a system boundary.
- 3. Shrink the system to a point at the center of coordinate axes with one axis parallel to the direction of motion.
- 4. Represent all relevant forces (across the system boundary) by a vector labeled with an appropriate symbol.

Free Particle Model

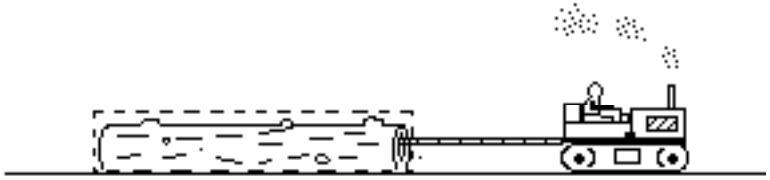
As an illustration of this process, consider the forces acting on a log being pulled by a tractor follows:



- **Step 1**
  - Sketch a diagram of the system and its surroundings as illustrated above.

Free Particle Model

Step 2
In order to assist in the identification of the relevant forces acting on the system, enclose the system (log) within a closed boundary line.



Step 4 Step 3

Free Particle Model

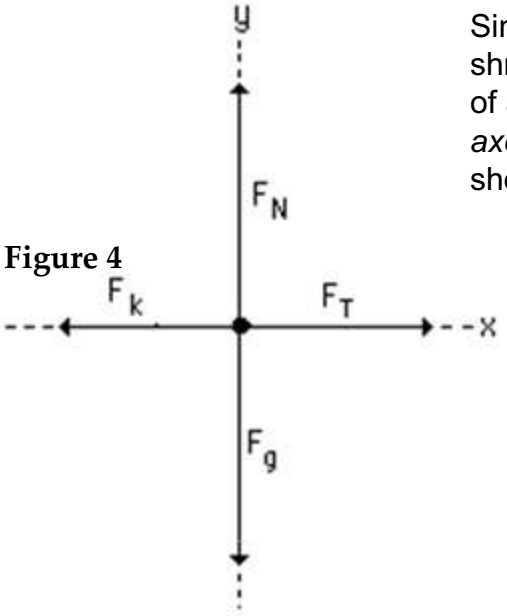
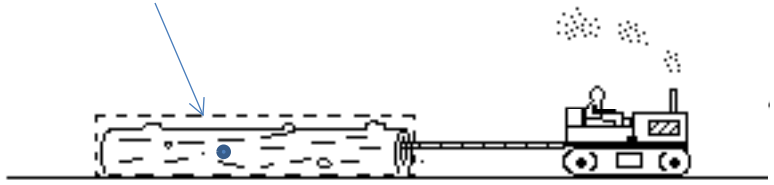


Figure 4

Since the shape of the object is unimportant, shrink it to a point. Place it at the intersection of a set of coordinate axes with one of the *axes parallel to the direction of motion* as shown.



Motion x:

$$F_{net\text{-}x} = F_T + F_f$$

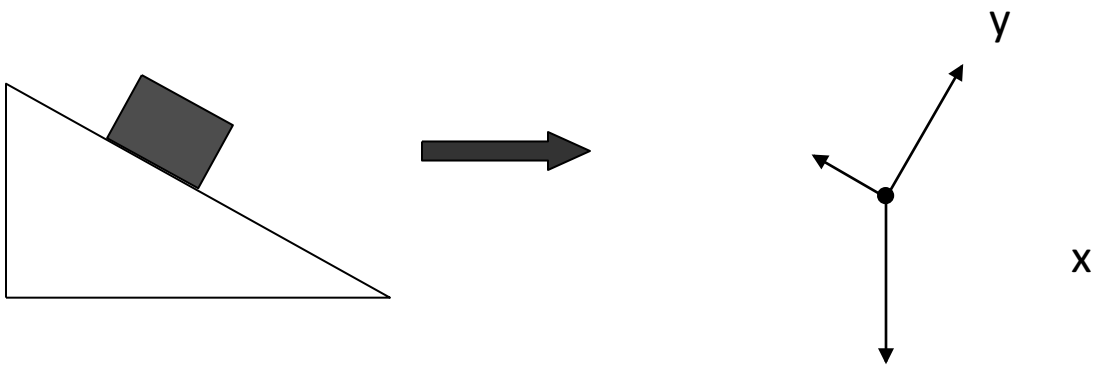
Motion y:

$$F_{net\text{-}y} = Fg + F_N$$

Proceed around the system boundary line and identify all points at which there is contact between the system (log) and its surroundings. Construct qualitative vectors (indicate directions and relative magnitudes) to represent these forces. The contact forces would be kinetic friction, Fk (parallel to the supporting surface), the normal force, FN (the component of force that is perpendicular to the supporting surface), and the tension force of the rope, FT. The long range force(s), in this case would be only the force of gravity, Fg.

Forces with Angles (Honors only)

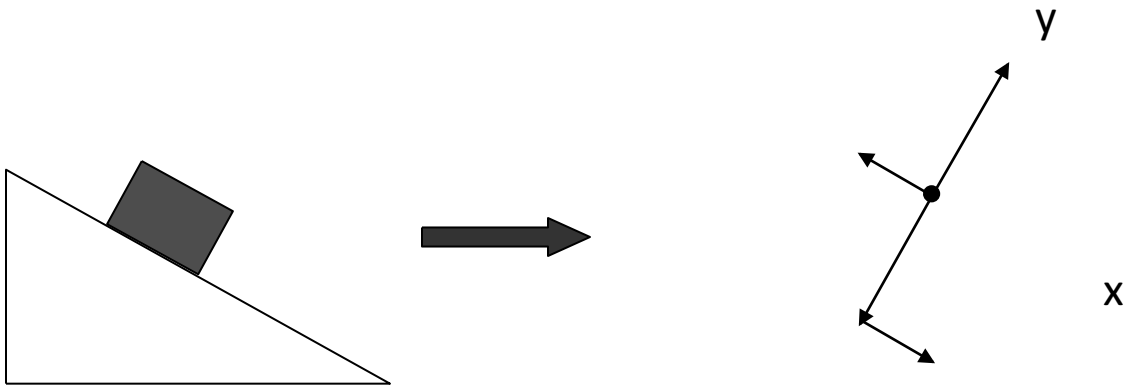
- Repeat steps as before – nothing new just a tilt and some triangle ratios to help quantify.
- Practice putting in the labels for the forces.



As before, we use a **point** to represent the object. Note that we have rotated the coordinate axes as shown above so that the x-axis is *parallel to the surface of the ramp* (the likely direction of motion).

Forces with Angles (Honors only)

- Repeat steps as before – nothing new just a tilt and some triangle ratios to help quantify.
- Practice putting in the labels for the forces.



Next, break any force vector that is not parallel to the coordinate axes (in this case, the force of gravity, Fg) into its **x** and **y** components. See the diagram at right. Note that the **x**-component and **y**-component form the sides of a right triangle with the original force vector, Fg as the hypotenuse.

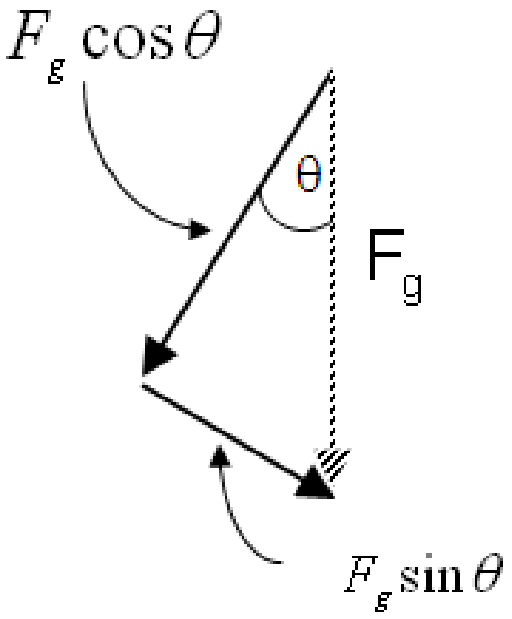
The Triangle Ratios

- In this case, the **y**-component cancels out the normal force, so the object does not accelerate up or down. The **x**-component of Fg is opposed by the force of static friction. If these forces have the same magnitude, the object will stay put.

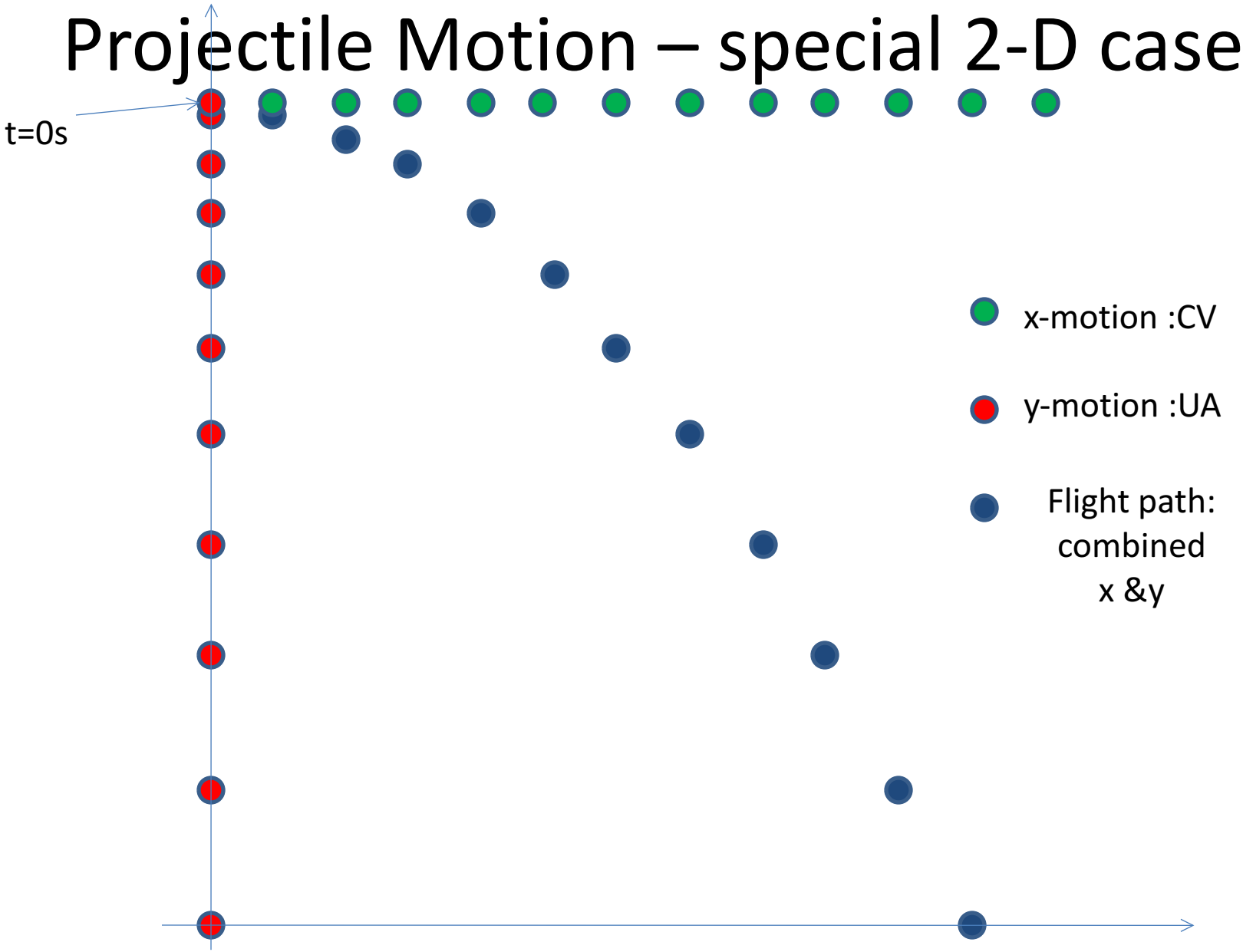
- To determine the **magnitudes** of Fx and Fy, you need to use some simple trigonometry. There are just a few points to keep in mind.

- 1. The angle **q** should be drawn so that it is included in the triangle formed by the three vectors.

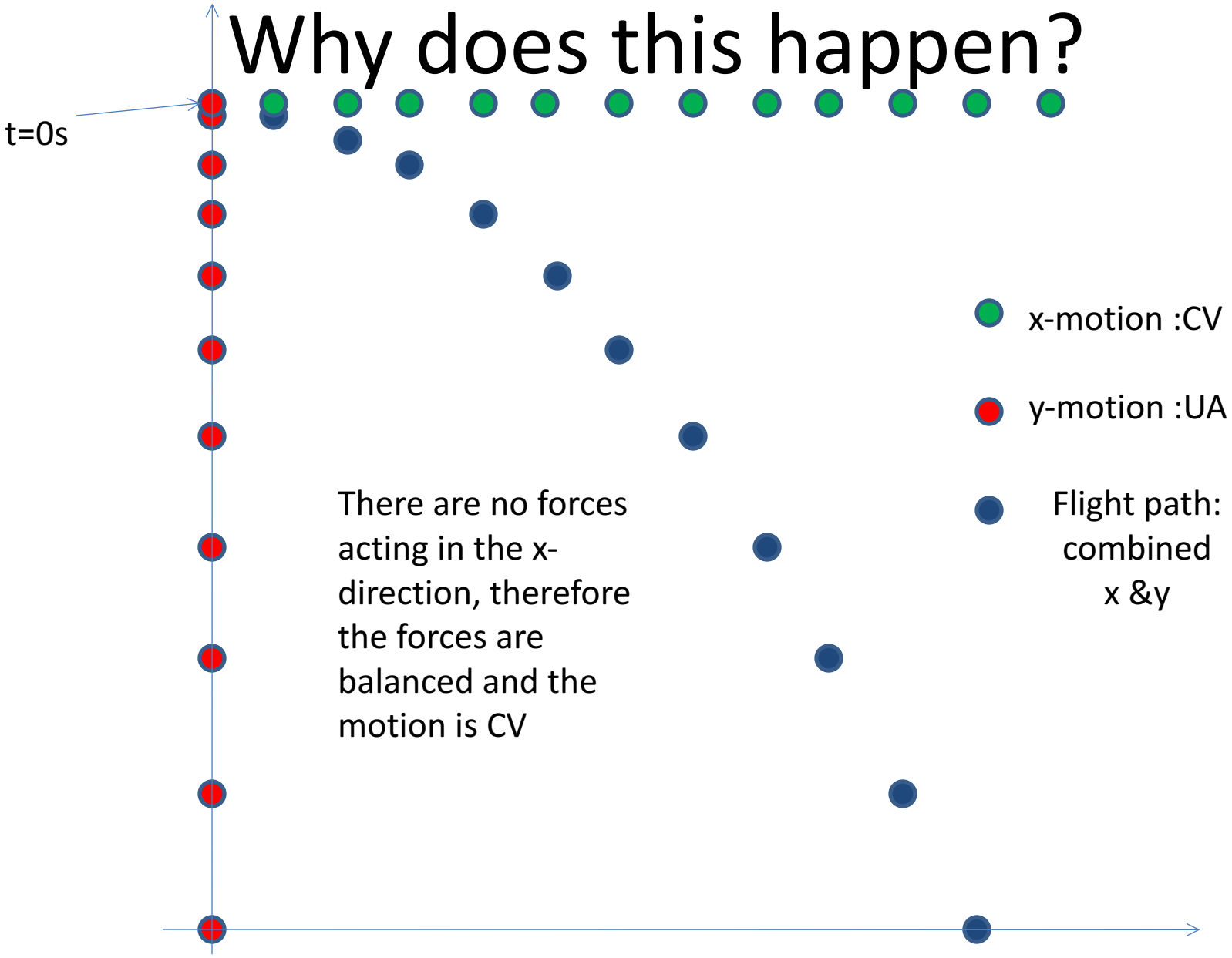
- 2. The side **opposite** the angle has magnitude equal to the original vector times the **sine** of the angle.
- 3. The side **adjacent** to the angle has magnitude equal to the original vector times the **cosine** of the angle.



Projectile Motion – special 2-D case

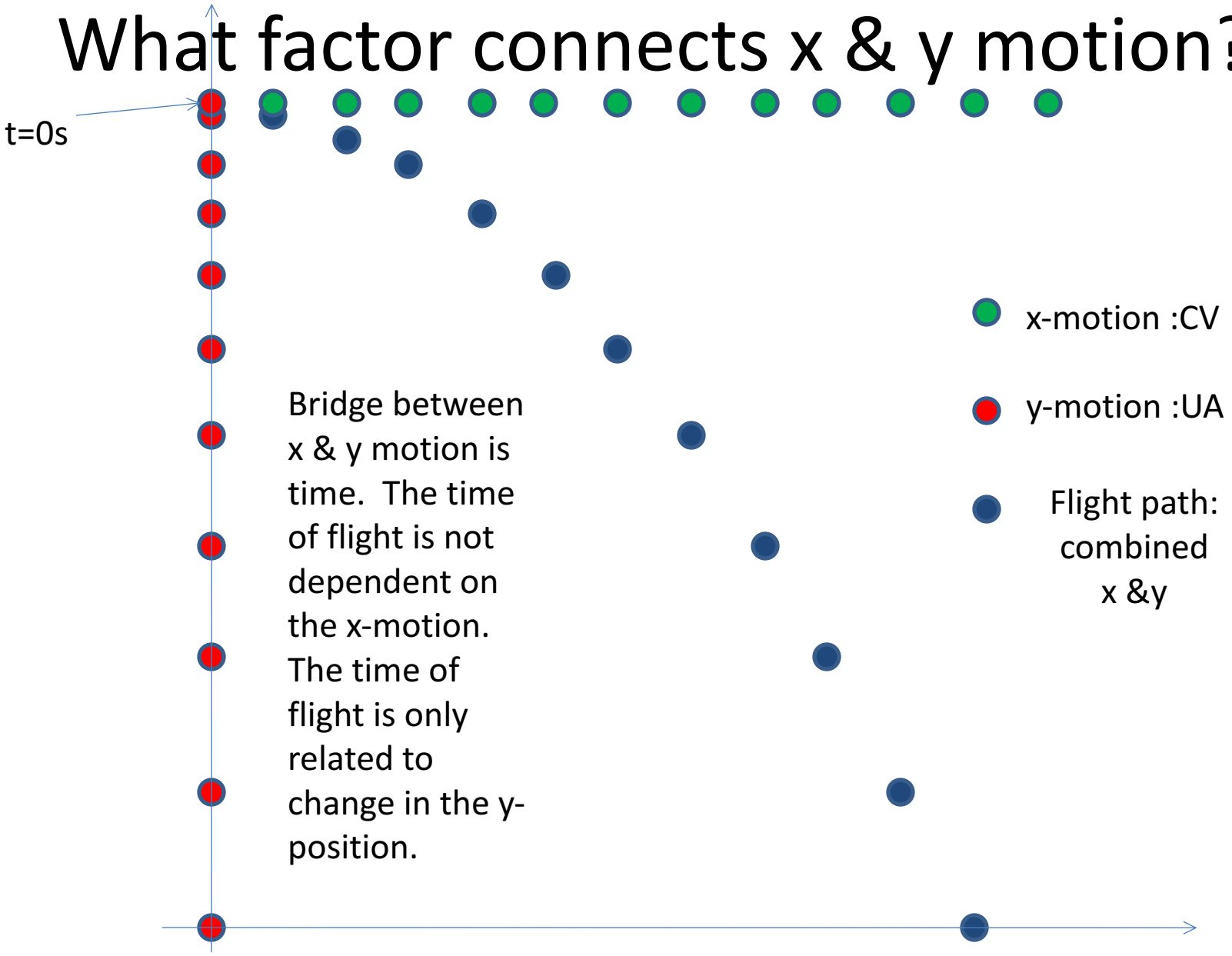


Why does this happen?



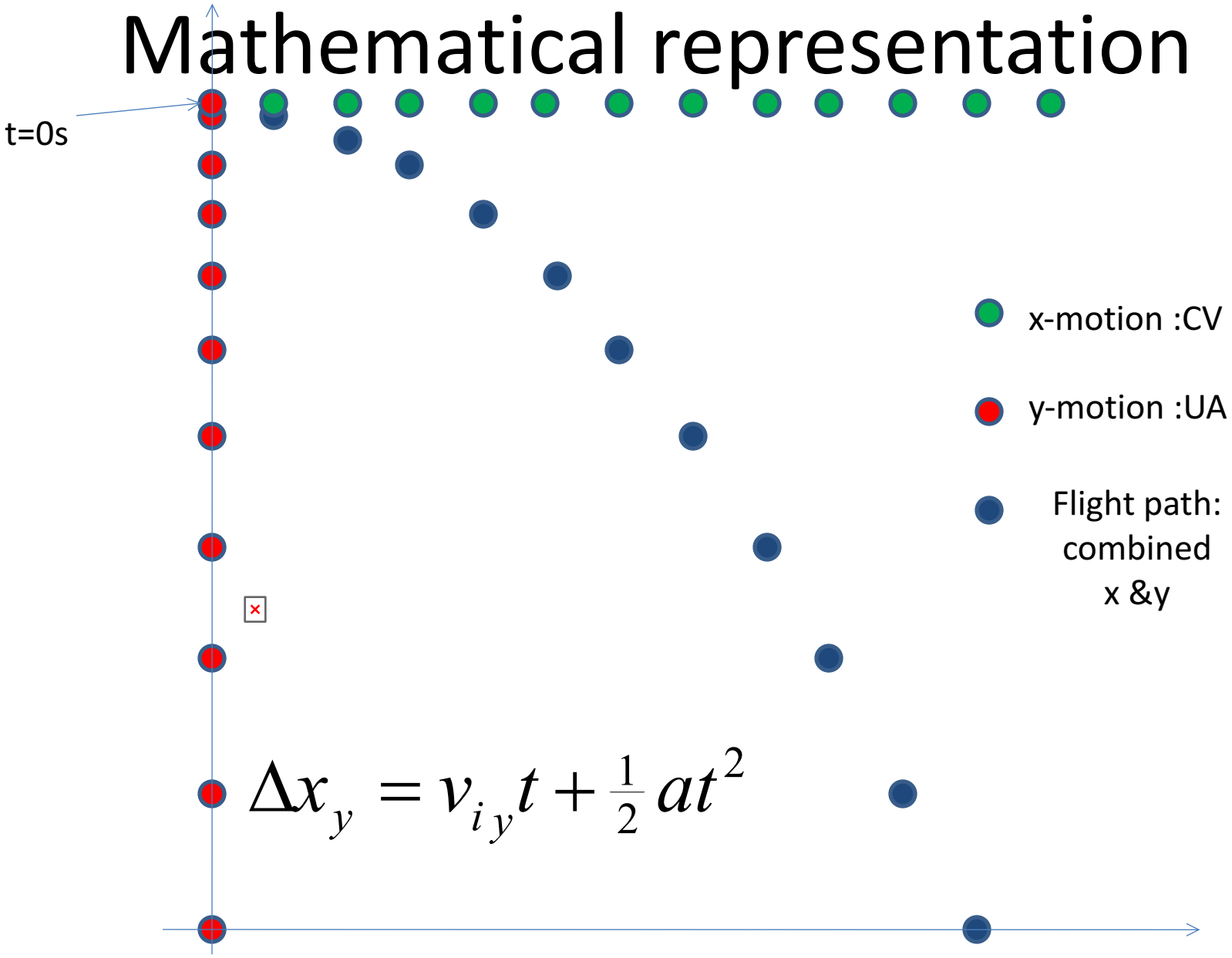
Why does this happen?

What factor connects x & y motion?



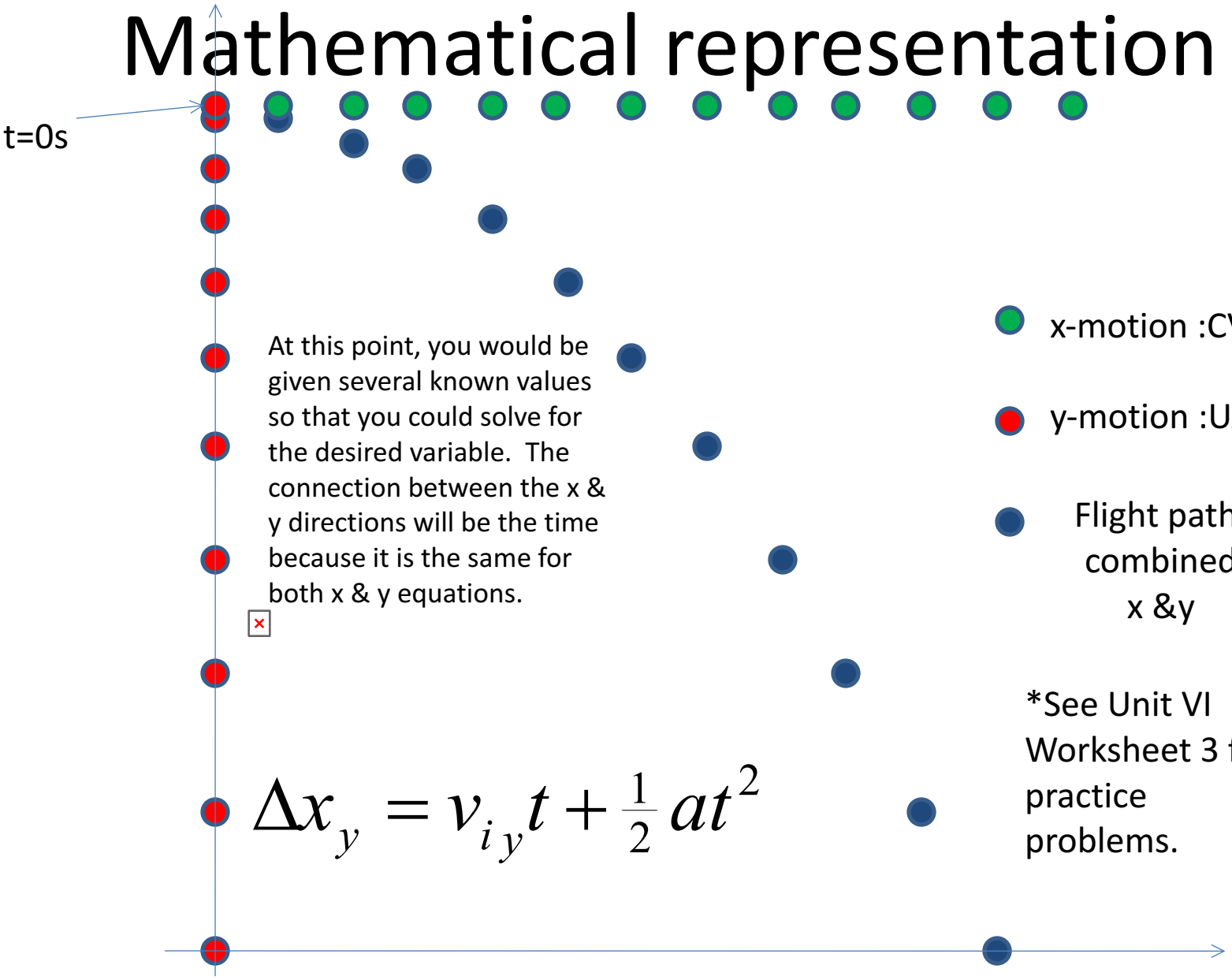
Bridge between x & y motion is time. The time of flight is not dependent on the x-motion. The time of flight is only related to change in the y-position.

Mathematical representation



$$\Delta x_y = v_{iy} t + \frac{1}{2} a t^2$$

Mathematical representation



At this point, you would be given several known values so that you could solve for the desired variable. The connection between the x & y directions will be the time because it is the same for both x & y equations.

x-motion :CV

y-motion :UA

Flight path: combined x &y

$$\Delta x_y = v_{iy} t + \frac{1}{2} a t^2$$

*See Unit VI Worksheet 3 for practice problems.