Lecture Notes

(Forces In Two Dimensions)

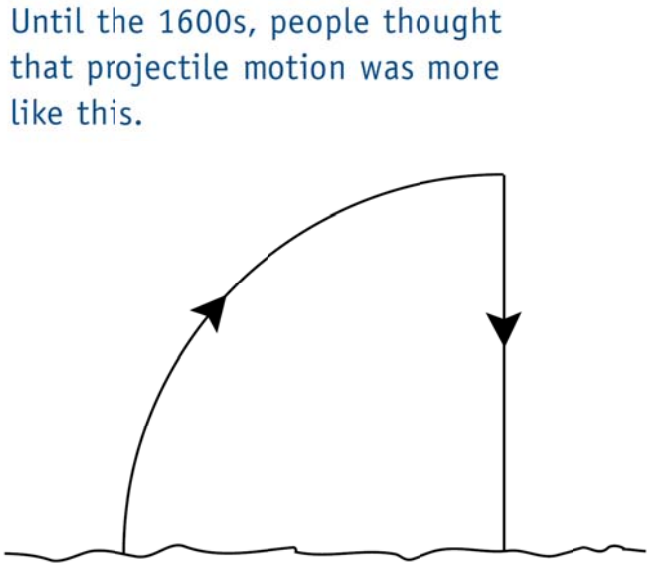
Intro:

- the previous chapters have considered motion mainly in a straight line; this is called rectilinear motion (Latin rectus = 'straight' and linea = 'line')

- this chapter will be looking at motion in two dimensions, that is, curvilinear motion

- projectiles from cannons, a shotput, throwing a baseball, motorcyclists jumping rows of cars; and ballet dancers all involve curvilinear motion

- until the time of Galileo, the motion of a projectile was based on the teachings of Greek philosopher Aristotle

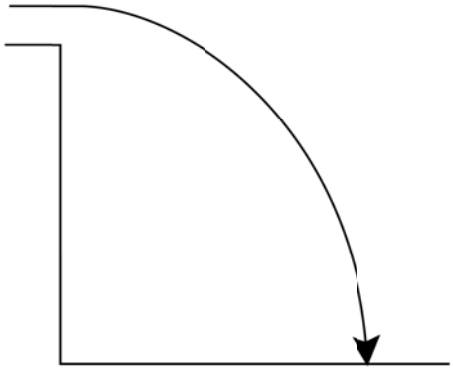


- it wasn't until 1638 that the trajectory of a projectile could be described mathematically

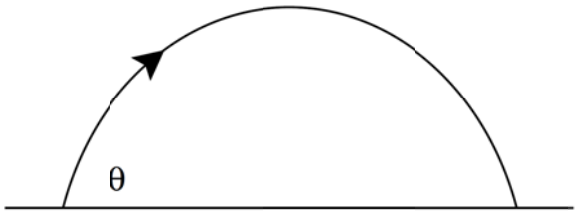
- Galileo's description proved to be correct and has been the basis of mechanics since

<u>Projectile Motion</u>:

- good examples of projectiles are a rock thrown straight out from the top of a cliff and a ball thrown across a field



Horizontal projection — a rock thrown off a cliff



Angled projection — a cricket ball thrown across a field

- the word projectile comes from the Latin jacere meaning 'to throw' and pro meaning 'forward'

- projectile motion can be separated into two components; a vertical (up and down) motion and a horizontal motion

- the vertical motion is the same as discussed earlier, the ball is under the influence of gravity and accelerates at 9.8 m/s^2 directed downward (the negative direction)

- in the horizontal direction, there are no net forces acting on the object so the velocity is constant

- in all cases we are assuming air resistance is negligible

- the path of a moving object is called its <u>trajectory</u> (Latin trajectus means 'crossing' or 'passage'

- a <u>projectile</u> is an object that once given an initial thrust, it moves through the air only under the force of gravity

Independence of Motion in Two Dimensions:

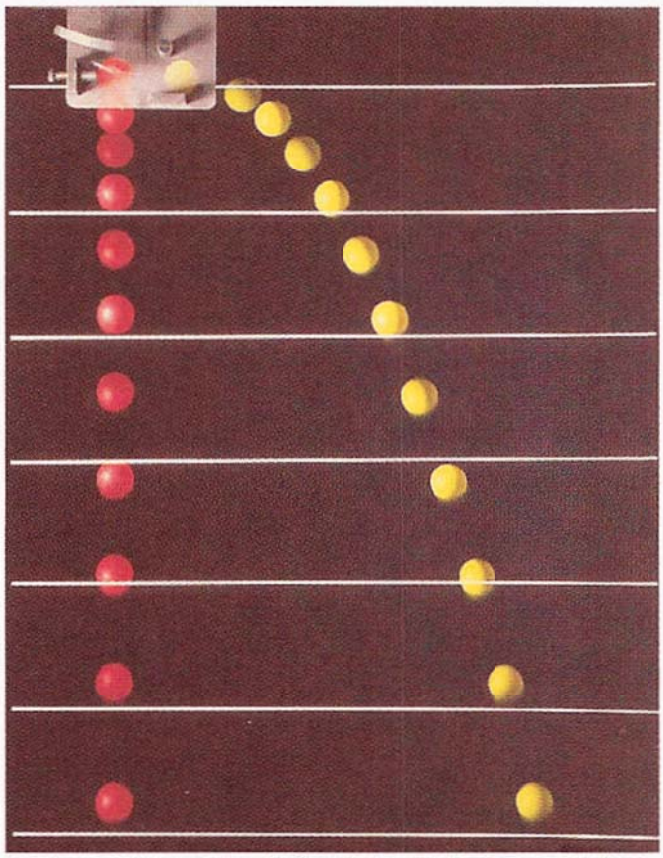


FIGURE 3–15
Two balls released simultaneously have two different trajectories, but in a given time each moves the same vertical distance. The difference in their motions is the magnitude of their (constant) *x*-components of velocity.

- take a look at the example above; we have two golf balls photographed with a strobe light that flashed 30 times per second

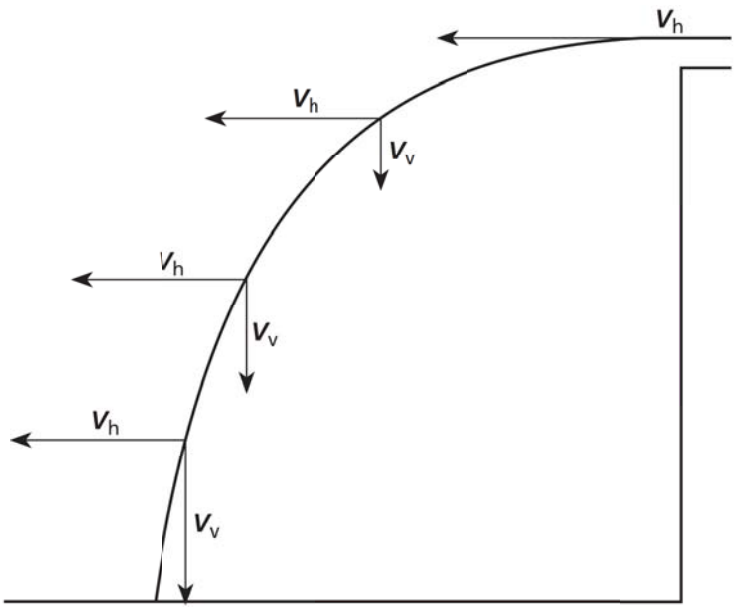
- the ball on the right was given a horizontal velocity; the ball on the left was dropped; you can see that the balls are accelerated downward by the force of gravity

- note that the vertical positions of the two balls are the same at each flash of the strobe light; the horizontal positions differ over time

- the constant horizontal velocity and vertical acceleration produces a trajectory that has the shape of a curve called a parabola

Projectiles Launched Horizontally:

- projectiles launched horizontally have no initial vertical velocity



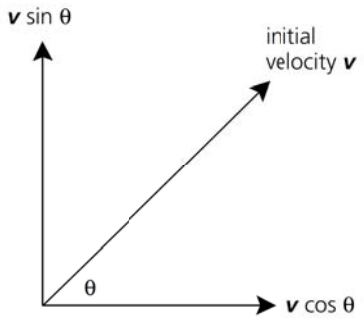
- as a result, the vertical motion is identical to that of a dropped object

- the downward velocity increases due to the acceleration due to gravity

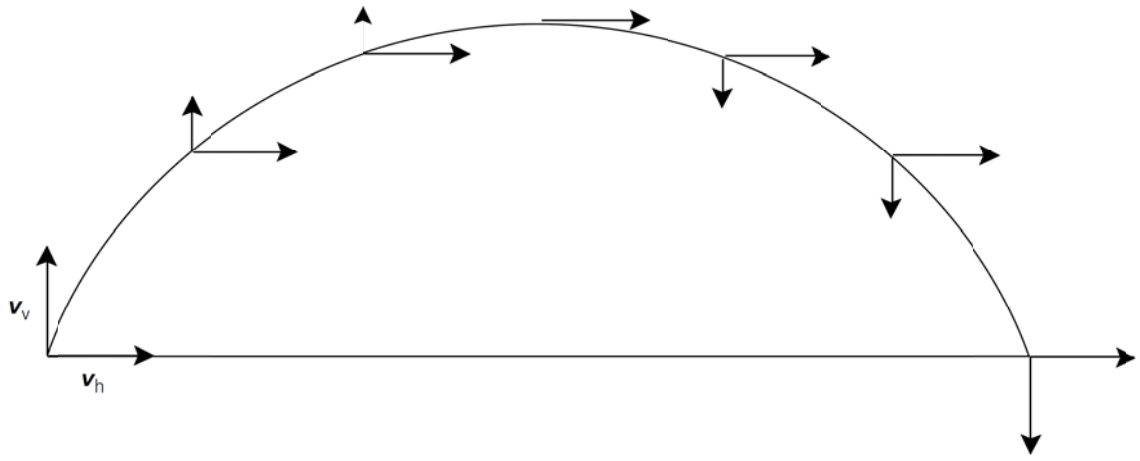
Projectiles Launched Vertically:

- not all objects are thrown in a horizontal direction; cannonballs, footballs for example, are often projected upward at an angle

- to study projectile motion, we let θ be the angle at which the object is thrown relative to the horizontal; this is called the elevation angle



- when a projectile is launched at an angle, the initial velocity has a vertical component as well as a horizontal component



- if an object is launched upward, it rises with slowing speed, reaches the top of its path (zero vertical velocity), and descends with increasing speed

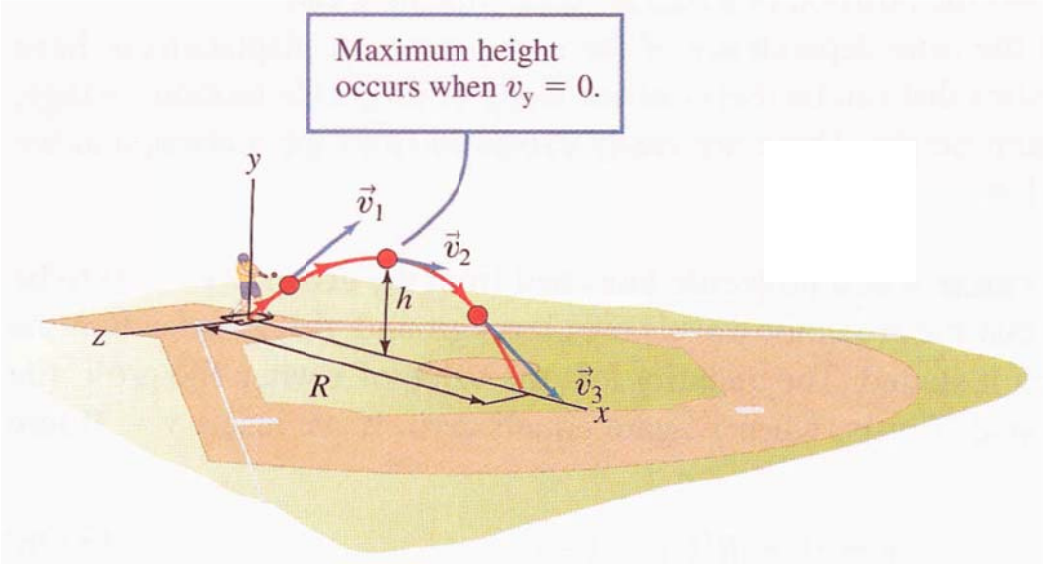
- at each point in the vertical direction, the velocity of the object, as it is moving up, has the same magnitude as when it is moving down; their directions, however, are opposite

- the impact velocity will have the same magnitude as the launch velocity, but be directed in a general downward direction not upward as at launch

- there are three quantities associated with trajectory; 1) maximum height, 2) range, and 3) flight time

- the range is the horizontal distance the projectile travels to reach the same height from which it started

- maximum height is the height of the projectile when the vertical velocity is zero and the projectile has only its horizontal velocity component



- flight time is another term used with projectile motion; it refers to the amount of time the projectile is in the air

- at exactly halfway through its trajectory the projectile will reach maximum height; the time it takes to reach max height is flight time/2

Maximum Range:

- it was the invention of the cannon in the late 1400s that created a new form of warfare; war at sea using cannons became more common and defense using medieval castles became obsolete

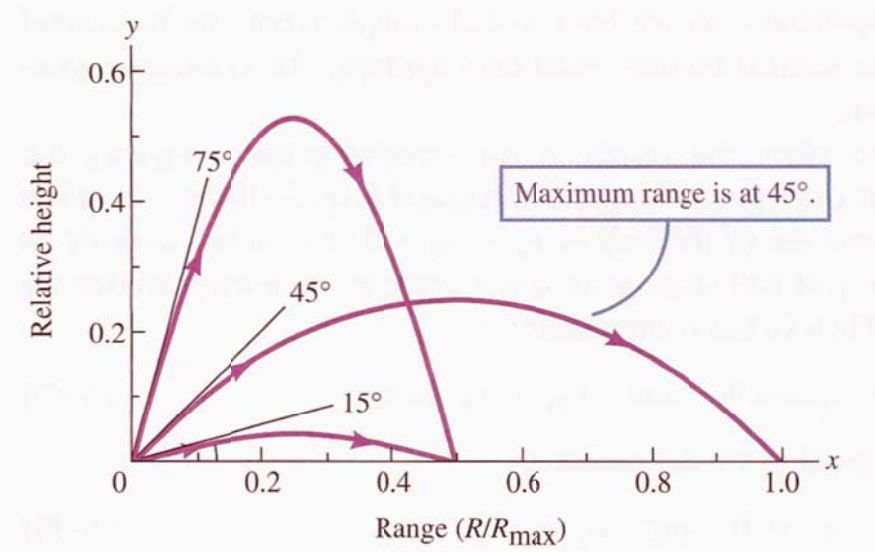
- medieval mechanics also became obsolete. Until then, the motion of a projectile was only of philosophical interest because they all thought they knew how projectiles moved

- after all, Aristotle described the motion over 1000 years earlier and no one was prepared to challenge his theories

- the theories weren't challenged until they had to be tested in warfare and were found wanting

- aiming was very much a hit-or-miss affair; there was no way of determining the trajectory or even the angle of launch in advance

- it wasn't until self-taught engineer Niccolo Fontana published the results of his experiments in 1546 that gunners realized a 45° angle of elevation would give the maximum range



Air Resistance:

- air resistance has been left out of our discussions up to this point, but in the real world it plays a significant role in projectile motion

- for some streamlined, heavy objects, air resistance is minimal; but for other objects, it plays a large factor in the trajectory of a projectile

- the speed of an object also play a role in air resistance; the greater the speed of an object the greater the air resistance