**PHYS:1200 LECTURE 5 – MECHANICS (4)**

Until now, we have been discussing motion in one dimension, i.e., motion in a straight line. Straight line motion is a common type of motion but in general motion is three dimensional. If we restrict the discussion to motion on the earth's surface, then it is two-dimensional.

Projectile Motion

Projectile motion is the general motion of an object in **three dimensions under the influence of gravity**. Air resistance is always present and makes the analysis of motion under gravity a bit more complicated. However, to keep things simple, we will study projectile motion ignoring the effect of air resistance. So what do we mean by projectile motion? *A projectile is an object that is thrown, hit, kicked, shot, etc. initially, and then travels solely under the influence of gravity.* What we are talking about here is not simply throwing an object straight up in the air, so that it returns back to its original position, but an object thrown not directly upward, and lands some distance from where it was thrown. If you are having a catch with someone, the ball is a projectile. This type of motion is really two dimensional, since the path (or trajectory) of the ball always remains in a plane. Examples of what is and isn't a projectile are given on slides 5, 6, and 7.

The **path of a projectile** is shown in the diagram below. The projectile starts at point A, and is given a velocity v_0 in some manner (throw hit, kick, etc.). The velocity is not directed straight up but at some angle with respect to the horizontal which is taken to be the x axis, while the vertical direction is taken to be the y axis of a plane coordinate system. The object then begins rising and moves from A to B, B being the highest point of the objects path. From B to C the object is falling, reaching the ground at point C. The force of gravity on the object is, of course, *always* downward or in the negative y direction.
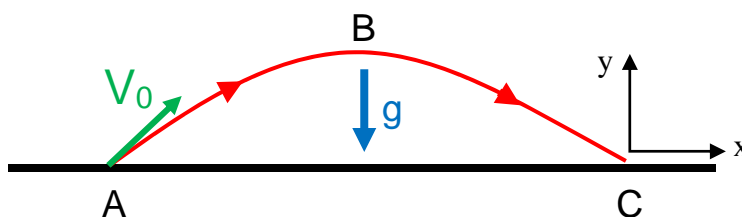
The most important point regarding projectile motion is **that gravity acts in the downward direction (negative y) and only affects the vertical motion of the projectile. Gravity does not affect the horizontal motion of the object.** When we say "affect the motion: we mean change the velocity. Remember **forces change velocities** – the only force on the projectile (once it has been launched) is gravity which is vertically directed and **therefore does not affect the horizontal motion.** The independence of the horizontal and vertical motion of a projectile is illustrated on slide 9.

Since the initial velocity of the projectile which it is given by some external means, is directed at some angle to the horizontal, we can think of the velocity as having both a horizontal (x) and vertical (y) part or component. During the motion of the projectile, the only force acting is gravity (in the – y direction) and it has not effect on the horizontal velocity; therefore throughout the entire path of the projectile, the horizontal component of its velocity is constant, i.e., does not change. **Gravity can only change the y component of velocity**. How does gravity affect the y component of velocity? On the rising part of the path (A to B) gravity acts to change (reduce) the vertical velocity. As it rises, its vertical velocity is decreasing until finally at the very top of its path it is neither rising nor falling – its vertical speed at B is ZERO. However, it still retains all of its horizontal speed, so it continues to move horizontally, however, now gravity causes it to begin falling, so as it moves horizontally to the right it also falls downward, reaching the ground at point C. **Note that there is NO FORCE acting during the rising part of the path that keeps it moving upward.** It moves upward because it was initially given an upward push, hit, kick, etc. The only force on it is gravity which acts to change (reduce) its upward velocity. These points are summarized on slides **18 and 19.**

The maximum horizontal distance that a projectile travels is called its **range**. If you imagine that the projectile is an artillery shell, the range is where it lands. The idea of firing an artillery shell is to have it hit a target, so the range is a critical parameter. The procedure is to set the parameters of the artillery gun so that the shell hits the target. It is interesting to think about how the angle of elevation of the projectile (the angle that the launching device makes with the horizontal) affects the range, and for what angle is the range a maximum. For an artillery shell, if the target is farther than the maximum range there is no point in launching it. For a given initial

velocity of the projectile the maximum range is obtained for an angle of elevation of 45 degrees. The effect of changing the angle of elevation is shown on the diagram on **slide 20.** For angles steeper than 45 degrees, the projectile rises to a higher point but doesn't go as far. In fact, for an artillery shell, the only

At 45 degrees launch angle the projectile achieves maximum range.

Maximum range.
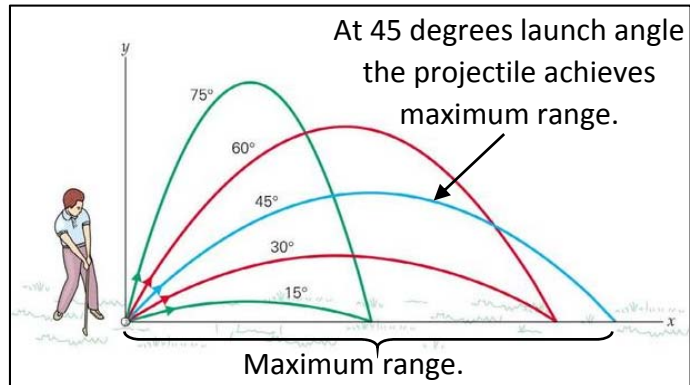
parameter that can be changed is the angle of elevation. The initial speed of the shell out of the cannon is determined by the properties of the ammunition – how much explosive powder is in the shell. This cannot be changed. So to hit a target, the cannon must be set at the proper angle so that the range coincides with the location of the target.

A bullet fired from a pistol or rifle is also a projectile. The explosive powder in the shell casing is detonated by a firing pin, explodes and sends the bullet down the barrel of the gun at very high velocity. Once the bullet leaves the gun barrel, it is a projectile under the influence of gravity and begins to fall. To hit a target the effect of gravity must be compensated for. This is illustrated on **slides 11 and 12**.

An interesting question that Newton first thought about is this: is it possible to throw an object from the earth with a high enough velocity that it never returns to earth? The answer is yes, but the velocity, called **escape velocity**, is huge – 11,000 m/s (25,000 mph). Such velocities are only possible with rocket engines. If an object were given this speed, it would travel so far from the earth, that the earth's gravity would not be able to pull it back. For speeds less than the escape speed, the object will
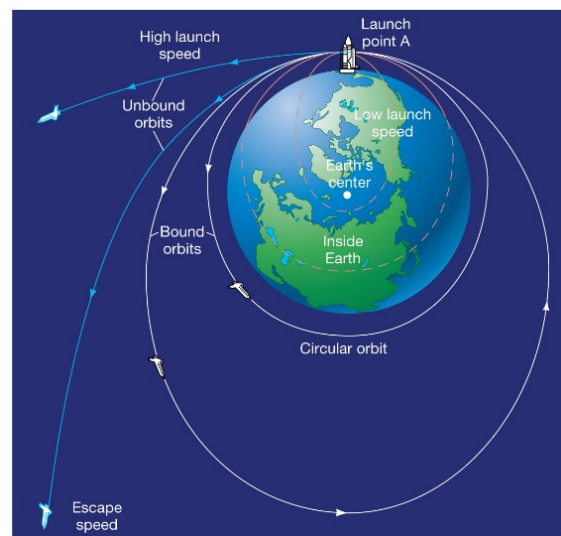
either go into an orbit around the earth or for much lower speeds, it will just fall back to earth. (**see slide 21**).