**External Ballistics: Vacuum Trajectories and Measurements**

1. **Range:**

The distance travelled by a projectile is called range. Range is designated by R.

The determination of the range of vacuum trajectory is based up on the fact that in the absence of air resistance, the horizontal component of the projectile velocity does not change and the force of gravity is constant.

Consequently the distance travelled by the projectile in time t is given by using given formula:

**R = t \* V cos E**

Where, E = angle of elevation

V = initial (muzzle) velocity

t = time of flight of a projectile

**Uses of range determination**

By determining the range we get an idea that how far the projectile can reach.

We can also determine that at particular distance what is the velocity of the projectile depending up on the angle of elevation.

We can also find the force of impact depending on the range.

1. **Drop:**

It is the distance through which the projectile falls from the line of fire at a certain range. It is represented by D.

It is given by the formula:

**D= gt2 /2**

Where, g = gravitational force

t = time

The estimation of the drop is also helpful in finding the height of the trajectory at any moment.

1. **Height:**

 As we know the velocity which is taking the projectile upward is V sin E. If it acts for t sec and there is no gravitational pull, the projectile will be located at time t at height H is given by

Height without gravity after t sec = t\*V sin E.

 But the gravity pulls it down to the certain extent at ratio of gt2 /2.

Hence the height H of the projectile after the time interval t sec is given by,

 **H= t\*V sin E - gt2 /2**

1. **Angle of fall:**

The striking angle which the tangent to the curve makes with horizontal at striking point is designated as F.

 The angle of fall can be calculated from the formula:

 **tan F = tan E – ( gt/ V cos E)**

1. **Remaining velocity:**

 The value of remaining velocity (Vr ) can be calculated from the formula,

 **Vr = (V2 – (2gt\*VsinE) + g2 t2 )1/2**

1. **Maximum Range:**

 Maximum range is determined from the equation which is used to find

 the height (H) of the trajectory.

 **H = tVsinE – gt2/2**

 At the maximum range H=0

 Therefore tVsinE = gt2/2

 gt = 2VsinE

 **t = 2VsinE/g**

Substituting the value of t in the formula:

 R = t\*VcosE

 R = 2VsinE\*VcosE/g

 R = V2 2sinEcosE/g

 R = V2 sin2E/g

 **R = V2/g**

when sin2E has maximum value is 1.

since has a maximum value of 1 when the angle 2E=90o

In the vacuum trajectory the maximum range is obtained when the angle of elevation is 45o.

At vertex, the angle of fall is 0.

Consequently, if this value is substituted in angle of fall;

 tan F = tanE – gt/VcosE

 0 = tanE – gt/VcosE

 tanE = gt/VcosE

 t = tanE\*VcosE/g

 t = VsinE/g

 Substituting the value of t in the equation of range,

 **R = Rmax = VsinE\*VcosE/g = V2 sin2E/2g**

Also,

Range for shotgun pallets can be identified by the formula:

 **Rmax = 2200\* pellet diameter in inches**

1. **Vertex Height:**

The height of the vertex can also be determined from the formula for height of the trajectory;

H=t\*VsinE – gt2/2

 on substituting the value of t;

 H =VsinE\*VsinE/g - V2 sin2 E/2g

 H = V2 sin2 E/g - V2 sin2 E/2g

 **H = V2 sin2 E/2g**

1. **Sectional density:**

 The efficiency of the projectile greatly depends upon its sectional density.

 **SD = W / d2**

 where, W = weight of the projectile and d = cross-sectional diameter.

1. **Ballistic co-efficient**:

 The ballistic co-efficient is denoted by ‘C’. It is the index of the ability of the projectile to overcome air resistance.

 C = ( sectional density ) / ( co-efficient of reduction)

 **C = W / nd2**

 Greater the sectional density, more will be the ballistics coefficient leading to flatter shooting with more efficiency. It will also retain a greater measure of its original velocity and energy.