Assignment 9

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1 QUESTION No. 2.21

A fighter plane flying horizontally at an altitude of 1.5 km with speed 720 kmh^{-1} passes directly overhead an anti-aircraft gun. At what angle from the vertical should the gun be fired for the shell with muzzle speed 600 ms^{-1} to hit the plane ? At what minimum altitude should the pilot fly the plane to avoid being hit ? (Take $g = 10\ ms^{-2}$) .

2 SOLUTION

Velocity of plane is given by

$$\mathbf{v_p} = \begin{pmatrix} 200 \\ 0 \end{pmatrix} \quad \left(\because 720kmh^{-1} = 200ms^{-1}\right) \quad (2.0.1)$$

Velocity of bullet is given by

$$\mathbf{v_b} = 600 \begin{pmatrix} \sin\theta \\ \cos\theta \end{pmatrix} \quad (2.0.2)$$

where θ is the angle made by $\mathbf{v_b}$ with the vertical . Let after time t ,bullet hits the fighter plane such that horizontal distance travelled by plane and bullet is equal.
$\therefore$

$$\mathbf{v_p}\begin{pmatrix} t & 0 \end{pmatrix} = \mathbf{v_b}\begin{pmatrix} t & 0 \end{pmatrix} \quad (2.0.3)$$

$$\implies 200t = (600\sin\theta)t \quad (2.0.4)$$

$$\implies \theta = 19.5° \quad (2.0.5)$$

So,gun should be fired at $\boxed{\theta = 19.5°}$ from vertical to hit the plane.

Acceleration of the bullet due to gravity is

$$\mathbf{g} = \begin{pmatrix} 0 \\ -10 \end{pmatrix} \quad (2.0.6)$$

Velocity of the bullet at maximum height is

$$\mathbf{v_m} = \begin{pmatrix} 0 \\ 0 \end{pmatrix} \quad (2.0.7)$$

Now,the maximum height h_{max} achieved by the bullet is given by

$$(\mathbf{v_m}\begin{pmatrix} 0 & 1 \end{pmatrix})^2 - (\mathbf{v_b}\begin{pmatrix} 0 & 1 \end{pmatrix})^2 = 2\mathbf{g}\begin{pmatrix} 0 & 1 \end{pmatrix} h_{max} \quad (2.0.8)$$

$$\implies -(600\cos19.5°)^2 = -20h_{max} \quad (2.0.9)$$

$$\implies h_{max} = 16km \quad (2.0.10)$$

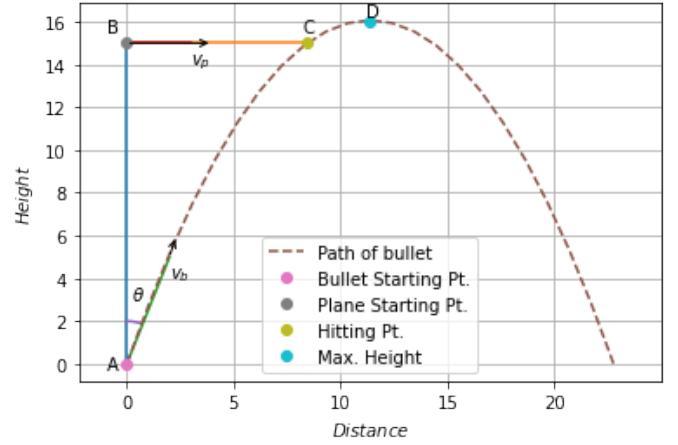So,the pilot must fly above the maximum height of the bullet , $\boxed{h_{max} = 16km}$ to avoid being hit.

Fig. 2.1: Plane and Bullet