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Quiz 2 Kinematics II: Projectile and Uniform Circular Motions

1. Water comes out of the head of a hose (positioned on a flat horizontal ground) at the speed of 6 m/s. At what angle(s) should we point the hose so that the water stream strikes the ground 2.5 m away?

Solution: The initial velocity and maximum horizontal distance are given and wants the angle θ. The water is hit the ground at the same elevation as the nozzle locates, so its vertical displacement is zero, $\Delta y = 0$. Substitute this into the kinematic equation below and get the first required equation

$$\Delta y = -\frac{1}{2}gt^2 + (v_0 \sin\theta)t$$

$$0 = -\frac{1}{2}(10)t^2 + (6\sin\theta)t$$

$$= -5t^2 + 6t\sin\theta$$

$$= t(-5t + 6\sin\theta)$$

The above relation gives us the first equation

$$\boxed{6\sin\theta = 5t}$$

Now, we use the horizontal displacement formula for projectile and set $x = 2.5\,\text{m}$. Thus,

$$x = (v_0\cos\theta)t$$

$$2.5 = (6\cos\theta)t$$

$$\Rightarrow \boxed{6t\cos\theta = 2.5}$$

Dividing these two boxed equations, we have

$$\frac{6\sin\theta}{6t\cos\theta} = \frac{5t}{2.5}$$

$$\boxed{\tan\theta = 2t^2\,, \quad (I)}$$

This is the only equation that we can find with the given information. Note that t in the all above equations is the total time the water is in the air.

There are two unknowns, so we have to find another equation to be able to solve this. With this little information that the problem has given us, we can only use the equation for the velocity's vertical component of the projectile, $v_y = v_0\sin\theta - gt$.

Recall that at the highest point of the projectile trajectory, this component is always zero, $v_y = 0$. By doing this, we have

$$v_y = v_0\sin\theta - gt'$$

$$0 = 6\sin\theta - 10t'$$

$$t' = 0.6\sin\theta$$

2. An object that moves in uniform circular motion has a centripetal acceleration of 13 m/s^2. If the radius of the motion is 0.02 m, what is the period of the motion?

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$a = v^2/r$

$13 = v^2/0.02$

$v = 0.51$ m/s

$v = 2\pi r/T$

$0.51 = 6.28(0.02)/T$

$T = 0.25$ s

$f = 1/T$

$f = 1/(0.25) = 4$ Hz