Projectile Motion

Name:

PES 1150 Prelab Questions

Lab Station: 003

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- What are the kinematic equations in two dimensions on the surface of the earth with the starting coordinates of (x_o and y_o) and initial velocities of v_{ox} and v_{oy}? List expressions for:

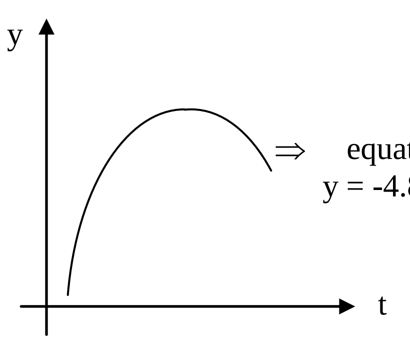
  x, v_x, a_x, y, v_y and a_y. *(Hint: They might be listed in your textbook.)*

$x(t) = x_o + v_{o,x}\, t + (1/2)a_x\, t^2$ $\qquad$ $y(t) = y_o + v_{o,y}\, t + (1/2)a_y\, t^2$

$v_x(t) = v_{o,x} + a_x\, t$ $\qquad$ $v_y(t) = v_{o,y} + a_y\, t$

$a_x(t) = a_x$ $\qquad$ $a_y(t) = a_y$

- From this graph find g, v_{oy} and y_o.



$\Rightarrow$ equation of the line
$y = -4.87\, t^2 + 2.8\, t + 9.9$

Notice that the equation given above is identical to the kinematic equation in two dimensions for "y" displacement. If we compare this given equation of the line to the "y" displacement kinematic equation, we can see the similarities:

$$y = y_o + v_{o,y} t + \frac{1}{2} a_y t^2 \qquad y = (9.9\ m) + \left(2.8 \frac{m}{s}\right) t + \left(-4.87 \frac{m}{s^2}\right) t^2$$

Writing the Equation of the Line in the above form, with the parenthesis, we can clearly see the following relationships:

$y_o = 9.9\ m$
$v_{o,y} = 2.8 \frac{m}{s}$
$\frac{1}{2} a_y = -4.87 \frac{m}{s^2}$

Thus, performing the algebra to calculate the acceleration in the y direction, we get the following value:

$$a_y = -9.74 \frac{m}{s^2}$$

Notice from the first question in the pre-lab, we showed that $a_y = -g$. This means:

$$a_y = -g = -9.74 \frac{m}{s^2}$$

$$g = 9.74 \frac{m}{s^2}$$

Thus, from the graph we can find the following values:

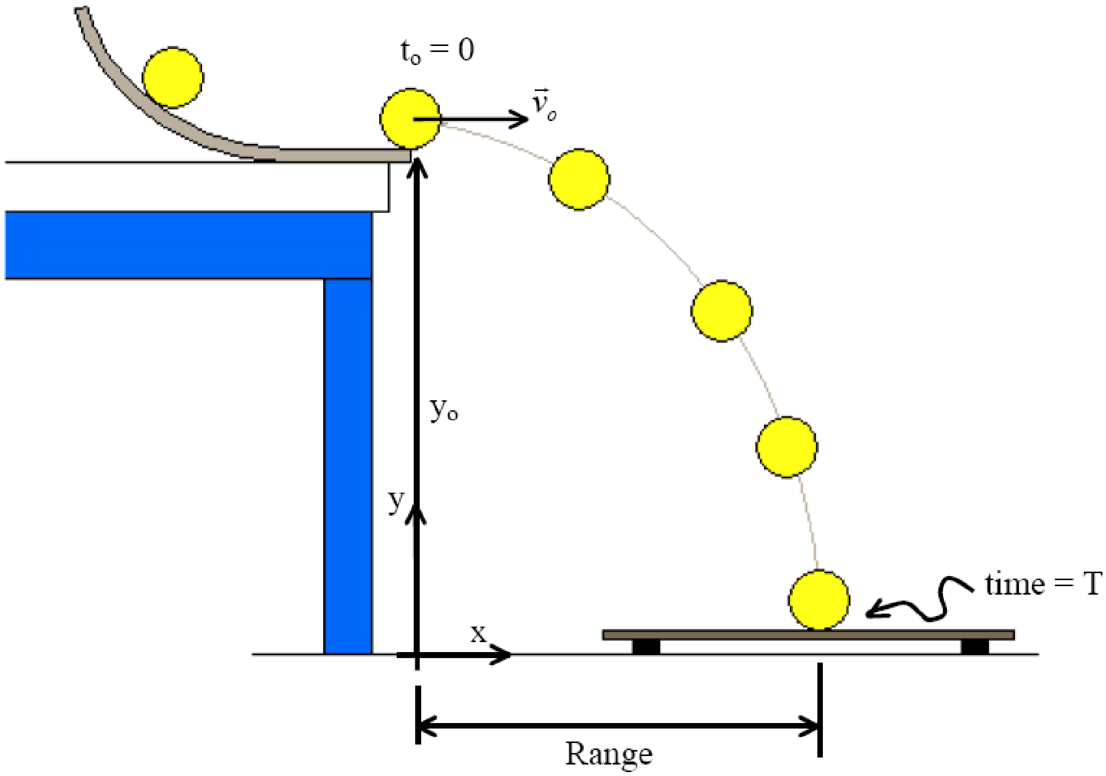
$$\boxed{y_o = 9.9\ m} \quad \boxed{v_{o,y} = 2.8 \frac{m}{s}} \quad \boxed{g = 9.74 \frac{m}{s^2}}$$

- What should a_x and a_y be on earth for all projectile motion (no external forces)?

On Earth, for all projectile motion with no external forces, the acceleration for the x-direction and acceleration for the y-direction are given constants. (This can be seen explicitly in the previous question.) These were given in the kinematic equations for the first question above. Specifically, these are:

$$\boxed{a_x = 0.0 \frac{m}{s^2}} \quad \boxed{a_y = -g = -9.81 \frac{m}{s^2}\ (at\ sea\ level)}$$

- Find the expressions for the Range (R) and Time of Flight (T) for the following situation. In terms of $|\vec{v}_o|$, θ, x_o, y_o and g.



Notice that the location of the coordinate system is on the table surface. By placing our coordinate system at the location show above, we can get the following initial conditions:

$x_o = 0$ m	$y_o = y_o$
$v_{o,x} = v_o$	$v_{o,y} = 0$ m/s
$a_x = 0$ m/s^2	$a_y = -g = -9.81$ m/s^2
$x_f = R$	$y_f = 0$ m

We can use the Equations of Motion and the given initial conditions to plug-in to effectively "re-write" the Equations of Motion.

X direction	Y Direction
$x = (0) + (v_o)t + \frac{1}{2}(0)t^2$	$y = (y_o) + (0)t + \frac{1}{2}(-g)t^2$
$v_x = (v_o) + (0)t$	$v_y = (0) + (-g)t$
$a_x = 0$	$a_y = -g = -9.81\frac{m}{s^2}$

Calculated X direction (with Givens)	Calculated Y Direction (with Givens)
$x = v_o t$ (** Eq. 1 **)	$y = y_o - \frac{1}{2}gt^2$ (** Eq. 2 **)
$v_x = v_o$	$v_y = -gt$
$a_x = 0$	$a_y = -9.81\frac{m}{s^2}$

If we use Eq. 1 from the previous problem, we can solve for t, and then plug it into Eq. 2. This will give us an equation of the form above.

Solving Eq. 1 for t:

$$t = \frac{x}{v_o}$$

Plugging t into Eq. 2:

$$y = y_o - \frac{1}{2}g\left(\frac{x}{v_o}\right)^2 = y_o - \frac{gx^2}{2v_o^2}$$

$$y_f = y_o - \frac{gx_f^2}{2v_o^2}$$

If we solve the equation above for x_f, we can determine the range the ball will travel during the fall.

$$x_f = R = \sqrt{(y_f - y_o)\left(-\frac{2v_o^2}{g}\right)}$$

$$R = \sqrt{(0 - y_o)\left(-\frac{2v_o^2}{g}\right)} = \sqrt{\frac{2y_o v_o^2}{g}}$$

$$\boxed{R = \sqrt{\frac{2y_o v_o^2}{g}}}$$

Remember that a few pages back we solved equation 1 for time, and we found:

$$t = \frac{x}{v_o}$$

This is precisely the equation for the Time of Flight:

$$T = \frac{R}{v_o}$$

$$T = \left(\frac{1}{v_o}\right)\left(\sqrt{\frac{2y_o v_o^2}{g}}\right) = \sqrt{\frac{2y_o}{g}}$$

$$\boxed{T = \sqrt{\frac{2y_o}{g}}}$$

Notice that since the acceleration due to gravity and the initial height are all constant – the Time of Flight will always be a constant, regardless of the initial velocity.