Two Dimensional Kinematics Worksheet

Name: ______________________________ Lab Partner: ______________________________

NOTE: This is **NOT** a substitute for your log book. On this sheet, record only items where there is a blank. Other steps tell you what to do, but don't necessarily cover everything that should be in your log books. Your log book should have everything on here, and much more!
Hand this in along with three graphs AFTER THE **SECOND** LAB SESSION.

1. Measure the length per division on the grid board (both x and y); the distance from the lens to the grid board and the ball to the grid board (both measured perpendicularly from the vertical board), and the x and y position of the lens (in the grid coordinate system).
2. When executing your shot, measure the firing angle θ_f and estimate its uncertainty. Enter this in the lower table on the reverse.
3. Identify and record the first frame with the projectile visible. The time of this frame will be chosen as the "initial" time $t = 0$. For the "final" time, we will choose the "time of flight" $t = T$, which occurred when the projectile returned to the initial height (i.e., the height at $t = 0$). It is extremely unlikely that you have an image of this; identify and record the frames just before and after this. By estimating time between those frames, record your observed time of flight (with uncertainty) in the lower table on the reverse.
4. Using the video, obtain apparent values for the initial position (x_0, y_0), the maximum vertical position y_{max}, and the final horizontal position x_f in grid units (estimation between frames probably needed from those last two). Obtain numerical values for these four quantities, in grid units. Convert to SI units and enter in the lower table on the reverse the range R and the maximum height H, with estimated uncertainties.
5. In Excel, make a table with columns for frame #, t, apparent x, and apparent y (in cm).
6. Make 3 graphs: y vs. x, y vs. t, and x vs. t.
7. Show the instructor your graphs.
8. Based on your y vs. x graph, determine the initial angle θ_0 and enter in the lower table on the reverse with estimated uncertainty. Note that this is a different quantity from the firing angle θ_f. Important consideration: Is your graph a true "picture" of the flight?
9. Use Trendline to determine the "best fit" equation for each of the graphs. Record them here, with appropriate variables and units. Do ***NOT*** assume that horizontal acceleration is zero.

   y as a function of x: ____

   x as a function of t: ____

   y as a function of t: ____

10. Use the equations above and LINEST to determine the following quantities. Record uncertainties to at least 3 significant digits and values to match, for calculation purposes.

    v_{0x} = ____________________ ± ________________ ___________

    v_{0y} = ____________________ ± ________________ ___________

    a_x = ____________________ ± ________________ ___________ (NOTE: **not** zero)

    a_y = ____________________ ± ________________ ___________

11. Using the fundamental equations for constant acceleration, find equations for each of the following quantities in terms of the parameters from step 11: initial firing angle θ_0, magnitude of the initial velocity v_0, range R, height H, and time of flight T.
12. Using the rules for propagation of uncertainties, find equations for the uncertainties in each of those quantities. For these, you may start by making the approximation $a_x \approx 0\,\mathrm{m/s^2}$.

Equations ONLY (no numbers)

(in terms of only the parameters from step 11 and with all derivatives evaluated)

Values	Uncertainties
$\theta_0 =$	$\delta\theta_0 =$
$v_0 =$	$\delta v_0 =$
$T =$	$\delta T =$
$H =$	$\delta H =$
$R =$	$\delta R =$

13. Use the equations in the upper table and the values in part 10 to fill in the table below.

Quantities

(with significant digits appropriate for reporting results)

Quantity	Observed	Calculated From Fit
θ_f	±	(no entry)
θ_0	±	±
v_0	(no entry)	±
R	±	±
H	±	±
T	±	±