Physics 200 (Stapleton) Name ____________________________

Directions – Trajectory with Drag Spreadsheet

Before you begin, copy the template. Leave the values in the yellow cells. **As you enter new formulas, use the "answer key" on the back of this sheet to check your work.**

1. Initial angle in radians is the inverse tangent of Y velocity / X Velocity. The spreadsheet function will be "=atan(B6/B5)"
2. Initial direction in degrees is achieved by converting the radians angle to degrees. The formula is "=degrees(B3)"
3. Initial Speed – use Pythagorean theorem. Vy^2 + Vx^2 = initial speed^2
4. First row of calculations (row 14). ***Important note: any cell reference to a cell above row 13 can (and usually shoud) include dollar signs to keep the cell reference absolute rather than relative***.
    a. Time = starting time
    b. X velocity = initial x velocity
    c. Y velocity = initial y velocity
    d. Weight = -mg. Use dollar signs so that this formula can be copied downward without the values changing. It should look like "=B$7*B$1" Make sure it's negative, because weight is downward.
    e. Drag – These are the hardest formulas.
    f. X drag -- Use the drag formula. Drag = 0.5*Cd*Air density*Cross-sectional Area*Velocity^2. For X drag, you will just be using the X velocity.
    g. X drag
        i. First, use the drag formula. Drag = 0.5*Cd*Air density*Cross-sectional Area*Velocity^2. For X drag, you will just using the current X velocity.
        ii. HOWEVER, drag can be positive or negative depending on the direction of the object's velocity, so you will need a conditional formula. When Vx is positive, drag should be negative, and when Vx is negative, drag should be positive.
            1. A conditional formula works like this… "=if (condition, value if condition is met, value if condition is not met)"
            2. So, your formula for X drag should be… "=if(B14>0,-0.5*B$10*B$9*B$8*B14^2,0.5*B$10*B$9*B$8*B14^2)"
            3. Your formula for Y drag should be the same, but it should use the current Y velocity (C14)
    h. X net force = the X drag from the current row (row 14). There's no other X force.
    i. Y net force = sum of the weight and the Y drag, both from the current row.
    j. X acceleration – using F_{net}=ma, a=F_{xnet}/m. Use the current (row 14) net force, but use the mass from above. Mass will need a dollar sign so that you can copy the formula downward later without the mass changing.
    k. Y acceleration – same method as X.
    l. X position = initial x position, from above.
    m. Y position = initial y position, from above.
    n. X change in velocity during the time interval. ΔV = at, so you multiply the time increment (B12) by current acceleration (I14). Since B12 comes from the top of the spreadsheet, it needs a dollar sign.
    o. Y change in velocity during the time interval. Same method as X
    p. X change in position during the time interval. ΔX = V_{0x}t + 0.5at^2. V_{ox} is cell B14. t is the time interval, which is B12. B12 should be entered as B$12.
    q. Y change in position is done the same way as X.
5. 2nd row of calculations:
    a. Time = previous time + time increment. Increment will need a dollar sign, but previous time won't. Formula will be "=A14+B$12"
    b. X velocity = previous x velocity plus previous change in X velocity. Formula is "=B14+M14"
    c. Y velocity. Same method as X velocity
    d. X position = previous X position plus previous change in X position. Formula is "=K14+O14"
    e. Y position. Same method as X.
6. Cell Q20. Enter the formula, =if((abs(L20))<0.5,A20,""). This will return values for Time (A20) whenever the Y position is very close to zero. These are times that are very near the time when the rocket lands.
7. Now all of the blue cells can be copied downward. Copy them as far as they will go – probably to row 1,000.
8. Time to do the orange cells…
    a. Max height is an easy one. Enter "=max(L14:L1000)"

b. Time aloft is the average of the values in column Q. Column Q only produces values of time when the rocket's height is close to zero. The formula can be "=average(Q14:1000)"

c. Terminal velocity occurs when drag = weight. Set drag equal to weight and solve for Velocity. To get you started, here's drag = weight… 0.5*air density*drag coefficient*cross-sectional area*v^2 = mg. Again, rearrange this to solve for V.

As you complete each step, use these values to check your work:

g	9.8		Initial X Position (m)	0
Initial Direction (degrees above horizontal)	88.57973		Initial Y Position (m)	3.3
Initial Angle (radians)	1.54601			
Initial Speed (m/s)	60.51859			
Initial X Velocity (m/s)	1.5			
Initial Y Velocity (m/s)	60.5		Time aloft (s)	7.554
Mass (kg)	0.13		Max Height (m)	66.72212054
Air Density (kg/m^3)	1.27			
Cross-sectional area (m^2)	0.01		Terminal Velocity (m/s)	-25.8605182
Drag Coefficient (no units)	0.3			
Starting Time (s)	0.179			
Time Increments (s)	0.01			

Time (s)	X velocity (m/s)	Y Velocity (m/s)	Weight (N)	X Drag (N)	Y Drag (N)	X Net Force (N)	Y Net Force (N)	X Acceleration (N)	Y Acceleration (N)	X Position (m)	Y Position (m)	Change in X Velocity during next time interval (m)	Change in Y Velocity during next time interval (m)	Change in X Position during next time interval (m)	Change in Y Position during next time interval (m)
0.179	1.5	60.5	-1.274	-0.00428625	-6.97277625	-0.00428625	-8.24677625	-0.0329711	-63.436740	0	3.3	-0.000329	-0.634367	0.01499835	0.601828163
0.189	1.49967028	59.8656326	-1.274	-0.00428436	-6.827318005	-0.00428436	-8.1013180	-0.0329566	-62.3178308	0.0149983	3.9018281	-0.000329	-0.623178	0.01499505	0.5955404344
0.199	1.49934072	59.2424542	-1.274	-0.00428248	-6.685918283	-0.00428248	-7.9599182	-0.03294217	-61.230140	0.0299934	4.4973685	-0.000329	-0.612301	0.01499176	0.5893630358