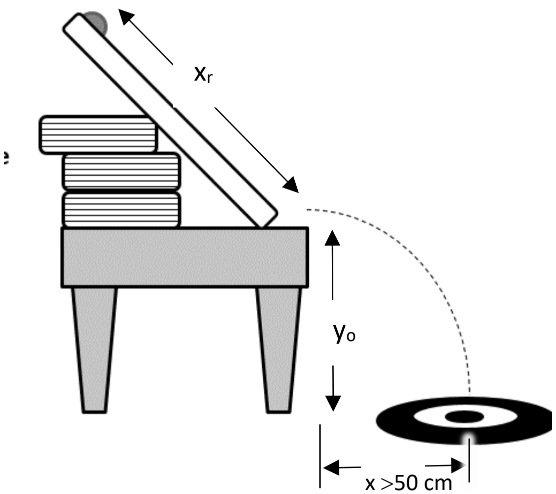
BULLSEYE Lab	Name: ________**ANSWER KEY**______________ Date: ______________________________
Pre-AP Physics ♦ Lab	**Projectile Motion ♦ Weight = 1**

DIRECTIONS: Follow the instructions below, build the ramp, take your measurements, and use your measurements to make the calculations following.



1. **(10 points) Using the materials in the back (insulation foam, siding, cardboard, pvc pipe, tape, books, marbles, bullseye sign), build a ramp like the one shown at right. The most important building aspect is that the ball roll off the table _horizontally_ after coming down an incline of some sort (it shouldn't arc upwards into the air or face downwards as it rolls off).**
2. **Select a distance away from the table & tape down your bullseye target. The center of the bullseye must be at least 50 cm away from the place where the ball rolls off the table.**
3. **Adjust the height of your ramp (or the location of the bullseye) until you are able to roll the steel ball down and make a bullseye (the small center circle not just any part of the target) at least twice in a row. Call the teacher, show him/her that your set up can hit the bullseye twice in a row, and have him/her initial here when you do it.**
   ____________________ INITIALS (five points)
4. **(one point) Measure the distance x_r the ball rolls down the ramp (see Figure at right). Put your measurement in the table below in the correct blank (answer in meters).** **EX: 0.45 m**
5. **(one point) Measure the time t to roll down the ramp (through the distance x). Put your measurement for time in the table below (answer in seconds).** **EX: t = 0.25 sec**
6. **Calculate the acceleration a of the ball as it goes down the ramp by doing the following steps.**
   a. **(one point) Determine which of the following motion formulas from Unit 2 will allow us to find the acceleration of the marble down the ramp if we know the distance travelled x_r by the marble, and the time elapsed t. Put an ☒ in the right box.**

☐ $v = \frac{d}{t}$ velocity = distance ÷ time	☐ $d = ½(v_o + v_f)\cdot t$ distance = ½ · (initial velocity + final velocity)·time	☐ $a = \frac{v}{t}$ acceleration = velocity ÷ time
☐ $v_f = v_o + a\cdot t$ final velocity = initial velocity + acceleration·time	☐ $v_f^2 = v_o^2 + 2\cdot a\cdot d$ (final velocity)² = (initial velocity)² + 2·acceleration·distance	☒ $d = v_o\cdot t + ½\cdot a\cdot t^2$ distance = initial velocity·time+ ½·acceleration·time² This is the only formula that has distance, time, t, and acceleration, a

   b. __**zero**__ **(one point) What is the initial velocity v_o of the marble as it just begins its trip down the ramp a distance x?** **The ball is not moving at all at the beginning.**

c. Based on your answer to Step b., how does the motion formula you picked in Step a. simplify? The formula $d = v_o \cdot t + \frac{1}{2} \cdot a \cdot t^2$ becomes $d = \frac{1}{2} \cdot a \cdot t^2$ because the $v_o \cdot t$ term drops out since v_o is zero and anything times zero is zero.

Write the simplified formula here: ____ $d = \frac{1}{2} \cdot a \cdot t^2$ _______(one point).

d. Now solve the motion formula from Step c. for the acceleration, *a*. In other words, leave *a* by itself and get everything else on the other side of the equal sign. $d = \frac{1}{2} \cdot a \cdot t^2 \rightarrow 2 \cdot d = \frac{1}{2} \cdot a \cdot t^2 \cdot 2 \rightarrow 2 \cdot d = a \cdot t^2 \rightarrow \frac{2 \cdot d}{t^2} = \frac{a \cdot t^2}{t^2} \rightarrow \frac{2 \cdot d}{t^2} = a$

Write your formula for *a* here. ______$a = \frac{2 \cdot d}{t^2}$____ (one point)

e. (one point) Find the acceleration *a* of the marble as it moves down the ramp using the data you obtained for distance, x_r, and time, *t*, in Steps 4 and 5 above. Record your value for acceleration in the table below. Show your work here. Acceleration is measured in m/s^2.

$a = \frac{2 \cdot d}{t^2} = \frac{2 \cdot (0.45\ \text{m})}{(0.25)^2} = 14.4\ \text{m/s}^2$

7. (one point) Now look at the motion formula table below. Determine which of the following motion formulas from Unit 2 will allow us to find the final velocity of the marble as it comes down the ramp and onto the table if we know the initial velocity of the marble v_o, the acceleration of the marble *a*, and the time elapsed *t*. Put an ☒ in the right box.

☐ $v = \frac{d}{t}$ velocity = distance ÷ time	☐ $d = \frac{1}{2}(v_o + v_f) \cdot t$ distance = ½ · (initial velocity + final velocity)·time	☐ $a = \frac{v}{t}$ acceleration = velocity ÷ time
☒ $v_f = v_o + a \cdot t$ final velocity = initial velocity + acceleration·time The only formula that has v_o, the initial velocity, a, the acceleration, and t, the time	☐ $v_f^2 = v_o^2 + 2 \cdot a \cdot d$ (final velocity)^2 = (initial velocity)^2 + 2·acceleration·distance	☐ $d = v_o \cdot t + \frac{1}{2} \cdot a \cdot t^2$ distance = initial velocity·time+ ½·acceleration·time^2

8. (one point) Using the motion formula you selected in Step 7, find the final velocity v_{xf} of the marble as it leaves the ramp and makes its way across the horizontal table surface. Show your work here and record your answer in the correct blank in the answer table below.

$v_f = v_o + a \cdot t = 0 + 14.4\ \text{m/s}^2 \cdot (0.25\ \text{s}) = 3.6\ \text{m/s}$

DIRECTIONS: Fill in the missing blanks here:

a. (one point) Notice we are calling the final velocity v_{xf} and not just v_f because we are indicating the marble's velocity when it leaves the ramp is horizontal and not _vertical___.

b. (two points) Also, since the table is horizontal, the velocity at which the marble leaves the ramp is the same as the velocity the marble moves at when it falls of the __table___. The marble has a constant_ velocity on the table, meaning it does not accelerate.

9. (one point) Now in the table below record (in meters) in the correct blank how far the bullseye is horizontally from the base of your table, *x* (see Figure at right on p. 1). Remember that the horizontal distance had to be at least 0.50 m away from the table. EX: 1.5 m

DIRECTIONS: Fill in the missing blanks here:

a. (four points) After the marble flies off the __table__ horizontally, it will experience two kinds of motion. It will continue to move __horizontally__ as it was before but it will now also start to _move/fall_ vertically due to the pull of the force of __gravity__ on it.

b. (three points) But as we saw in the Falling Monkey Firestarter/video and the Firestarter/Mythbusters video about shooting a _bullet__ out of a gun at the same time as you dropped the bullet next to the gun, horizontal movement is independent of __vertical__ movement. Gravity doesn't _affect/impact__ horizontal movement.

10. (one point) Now look at the motion formula table below. Determine which of the following motion formulas from Unit 2 will allow us to find the time *t* it takes the marble to fly horizontally from the table through a horizontal distance *x* to hit the bullseye if it is moving at a horizontal velocity of v_{xf}. Remember: the acceleration due to gravity does NOT affect horizontal motion. Put an ☒ in the right box.

☒ $v = \frac{d}{t}$ velocity = distance ÷ time This is the formula for constant velocity problems where there is no acceleration.	☐ $d = ½(v_o + v_f)\cdot t$ distance = ½ · (initial velocity + final velocity)·time	☐ $a = \frac{v}{t}$ acceleration = velocity ÷ time
☐ $v_f = v_o + a\cdot t$ final velocity = initial velocity + acceleration·time	☐ $v_f^2 = v_o^2 + 2\cdot a\cdot d$ (final velocity)² = (initial velocity)² + 2·acceleration·distance	☐ $d = v_o\cdot t + ½\cdot a\cdot t^2$ distance = initial velocity·time+ ½·acceleration·time²

11. (one point) Solve for time *t* in the formula you selected in Step 10. and find the time it took the marble to hit the bullseye. Record your answer in the correct blank in the table below. Show your work here.

$v = \frac{d}{t} \rightarrow t = \frac{d}{v} = \frac{1.5\text{ m}}{3.6\text{ m/s}} = 0.42\text{ s}$ → 1.50 m was the horizontal distance from the table to the bullseye and 3.6 m/s was v_{xf}, the horizontal velocity of the marble.

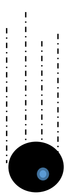
12. Now let's verify if our time *t* that we found in Step 11. is reasonable by doing the following steps.

a. (one point) Measure the height y_o of the table off the ground (See Figure at right on p. 1) in meters. Record your answer in the correct blank in the table below. EX: 0.9 m

DIRECTIONS: Fill in the missing blanks here:

a. (one point) The time for the marble to move horizontally from the table to the target is the same time for the marble to _fall__ down to the ground as gravity pulls it down.

b. (three points) Gravity pulls things down to the ground at a rate of negative _10__ meters per second per second. Gravity is very predictable. So if we did our math right, we should be able to find out how _far_ (in m) the marble fell in the time



we found in Step. 11 when pulled down by gravity. This distance fallen by the marble should match up pretty closely with the _height_ of the table that we measured in Step. 12.a.

c. (one point) Look again at the motion formula table below. Determine which of the following motion formulas from Unit 2 will allow us to find the distance *d* the marble falls from the table after *t* seconds have passed if the marble has an initial velocity of v_o and is being accelerated due to gravity. Put an ☒ in the right box.

☐ $v = \frac{d}{t}$ velocity = distance ÷ time	☐ $d = ½(v_o + v_f) \cdot t$ distance = ½ · (initial velocity + final velocity)·time	☐ $a = \frac{v}{t}$ acceleration = velocity ÷ time
☐ $v_f = v_o + a \cdot t$ final velocity = initial velocity + acceleration·time	☐ $v_f^2 = v_o^2 + 2 \cdot a \cdot d$ (final velocity)^2 = (initial velocity)^2 + 2·acceleration·distance	☒ $d = v_o \cdot t + ½ \cdot a \cdot t^2$ distance = initial velocity·time+ ½·acceleration·time^2 This is the only formula with distance d, time t, and acceleration, a.

d. Wait a second! Let's think about the vertical velocity of the marble as it leaves the table. DIRECTIONS: Fill in the missing blanks here: (one point) Since the marble flew off the table horizontally, it's initial vertical velocity is _zero__. Gravity still hasn't had time to act upon it.

e. (one point) So our formula from Step. c. simplifies. Write down your simplified formula here: $d = ½ \cdot a \cdot t^2$___
NOTE: this formula is a LOT like the formula in Step 6.c. above.

f. (one point) The vertical acceleration is due to gravity which has a value of _-10___ meters per second per second.

g. (one point) Plug in your value for *a* from Step f. above and the time *t* you found in Step 11 into your formula and solve for the distance fallen, y_o. Put your answer here: $d = ½ \cdot (10\ m/s^2) \cdot (0.42)^2$_=_0.87 m___________.

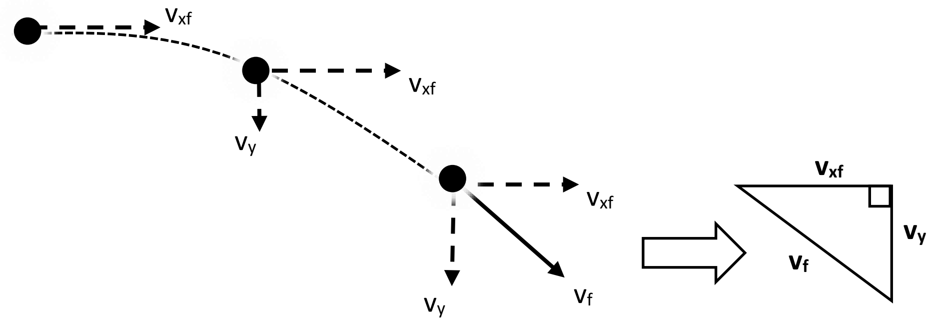
h. (one point) Is the answer for Step g. above reasonably close to the answer you got for y_o from Step 12.a.? ☒ YES ☐ NO
0.9 m (our measured table height) is reasonably close to 0.87 m (our calculated falling distance/table height)

13. Now let's find the final vertical velocity v_y of the marble right before it hits the ground. This is one of your mental math tricks. DIRECTIONS: Fill in the missing blanks here:

(two points) It took the marble __0.42 s_ (Ans. to Step. 11) seconds to fall to the ground. If gravity increases the velocity of a falling object by –10 meters per second per second, then the final vertical velocity v_y of the marble is __4.2__ m/s . Put your answer in the correct blank in the table below. This is the mental math thing we practiced. Gravity (10 m/s/s), g, times the time, t = vertical velocity

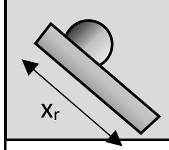
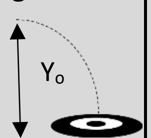
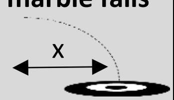
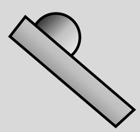
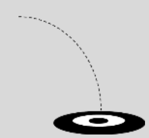
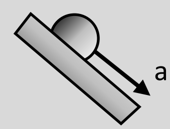
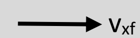
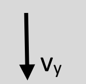
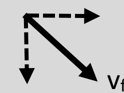
14. Final step. We said earlier that the marble is moving horizontally – – – – ► v_{xf} and falling ¦ at the same time once it leaves the table.
▼vy

15. Right before it lands, it is moving diagonally at a velocity of v_f meters per second as shown in the illustration at right:

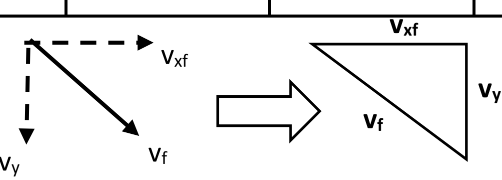


a. (three points) DIRECTIONS: Fill in the missing blanks here. To find the final diagonal velocity v_f of the marble right before it hits the ground we have to recognize the geometric shape of a right __triangle__ above formed by the three velocities put together. This lets us use the _Pythagorean_ Theorem to find the value of v_f, the final diagonal velocity, which is the __hypotenuse__ of the triangle. v_{xf} is the adjacent side of the triangle and v_y is the opposite side.

b. (one point) Find the final velocity v_f, of the marble from Step 15.a. and put the answer in the correct blank in the table below.

Length of ramp, x_r (in m) that the marble rolls down 	Height of table, y_f (in m) above ground 	Horizontal distance, x, from table to target (in m), where the marble falls 	Time, t_r (in s) to roll down the ramp to edge of table 	Time, t_f (in s) marble is in the air after rolling off the table 	Acceleration, a, of marble down the ramp (in m/s/s) 	Horizontal velocity, v_x, of the marble (in m/s) when it flies off the table 	Final vertical velocity, v_y, of the marble (in m/s) when it lands. 	Final diagonal velocity, v_f, of the marble (in m/s) when it lands. 
0.45 m	0.9 m	1.5 m	0.25 sec	0.42 s	14.4 m/s²	3.6 m/s	4.2 m/s	5.5 m/s

Final diagonal velocity from Pythagorean Theorem: $c^2 = a^2 + b^2$



$v_f^2 = v_y^2 + v_{xf}^2 \rightarrow v_f = \sqrt{v_y^2 + v_{xf}^2} = \sqrt{(4.2\ \mathrm{m/s})^2 + (3.6\ \mathrm{m/s})^2}$

$v_f = \sqrt{17.36 + 12.96} = \sqrt{30.32} = 5.5\ \mathrm{m/s}$