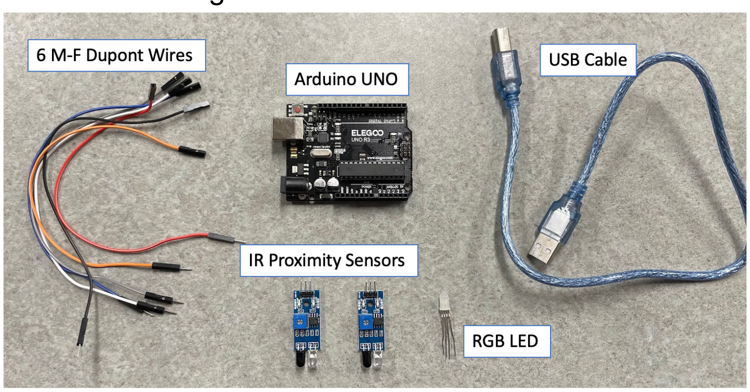
Name: **Date:** **Class:**

Horizontal Projectile Motion With Arduino Handout
Answer Key

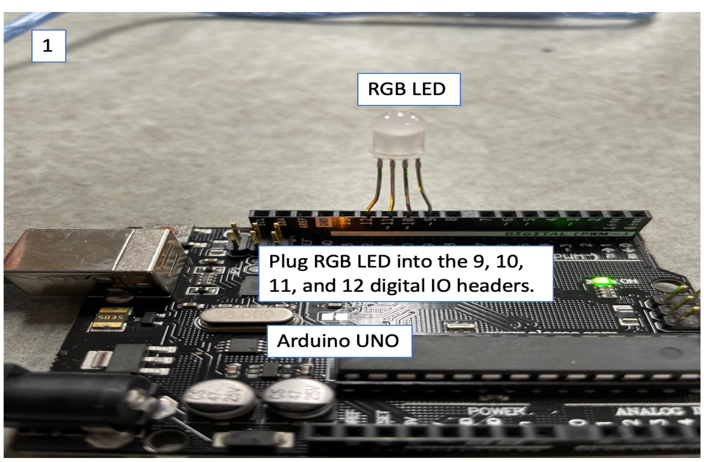
Learning objectives:
By the end of this project, you will be able to:
- Set up an Arduino speed sensor using IR proximity sensors.
- Understand the basics of Arduino programming.
- Determine the distance of a horizontally launched projectile given initial velocity and height.

Materials:
- 1 Arduino UNO w/ USB cable
- 1 computer or laptop with Arduino IDE
- 2 IR proximity sensors
- 1 RGB LED
- 6 female-to-male Dupont wires
- 1 Arduino holder and ramp

Prepare:
1. Gather the following materials:



Assemble
2. Follow the next five diagrams to set up your Arduino IR speed sensor.



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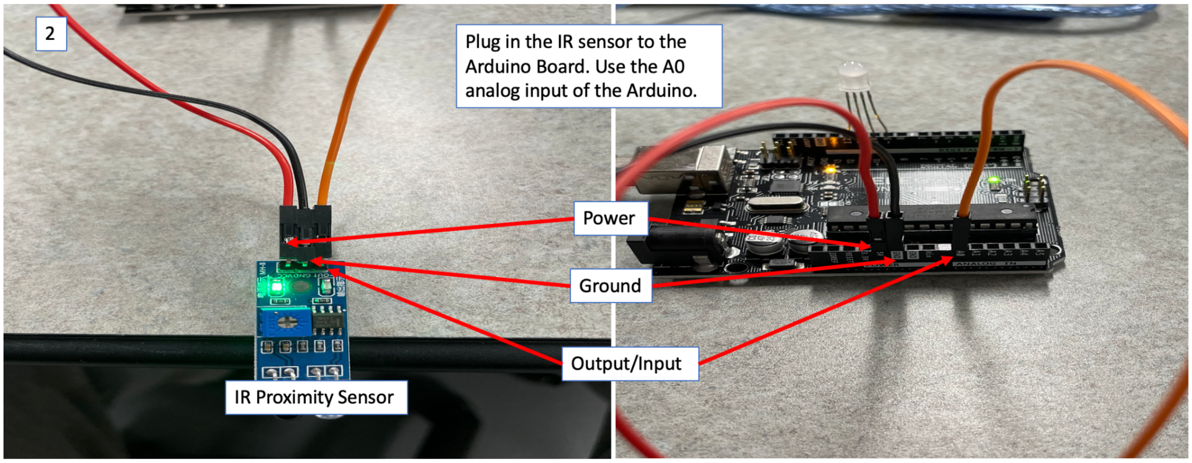
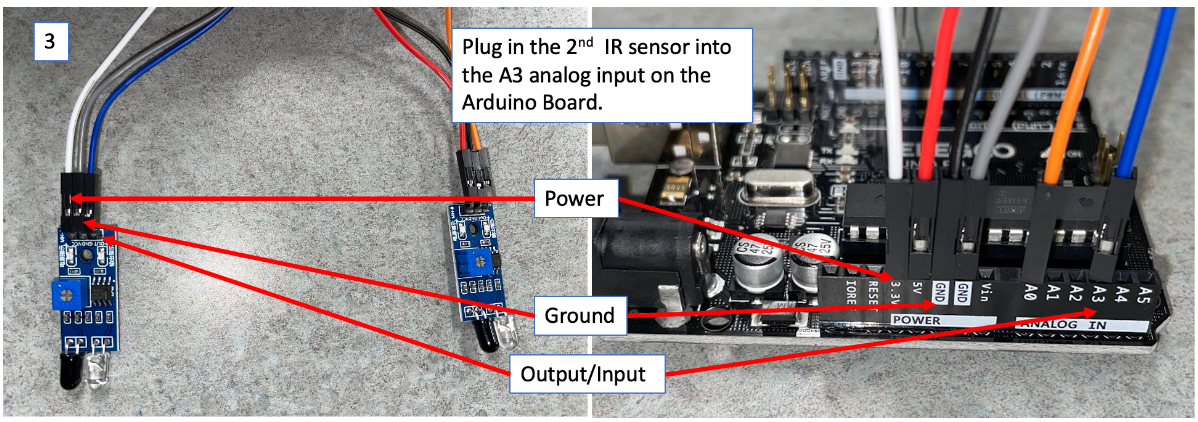
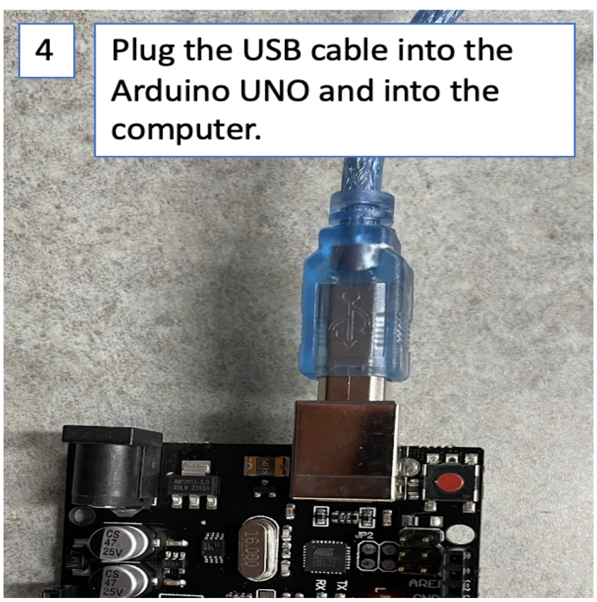
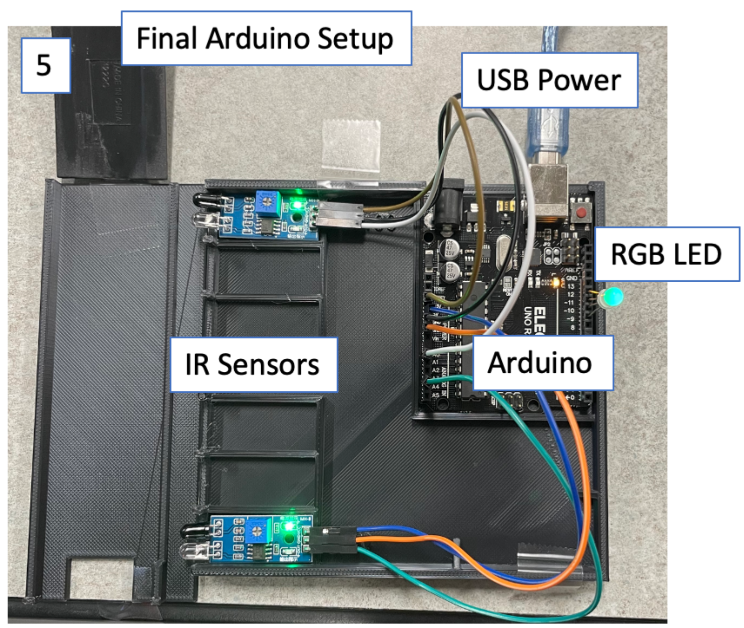








3. Set up the Arduino IDE code.
    a. Open the Arduino IDE software on computer.
    b. Copy and paste the IR Speed Sensor Using Arduino code into the IDE.

4. Answer the following questions based on the IR Speed Sensor Using Arduino code:
    a. Identify lines where the IR sensors are inputting their data:
    If copied exactly, declared on lines 1 and 2: int sen1 = A0;
    int sen2 = A3;
    Taking signals from those (A0 and A3 on Arduino board) as inputs on lines 13 and 14:
    pinMode(sen1, INPUT);
    pinMode(sen2, INPUT);

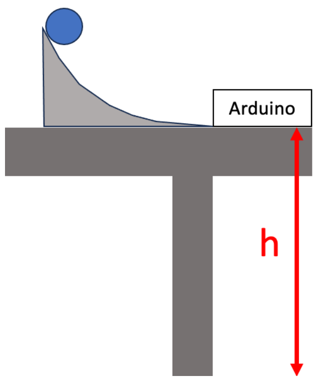
    b. Identify the line where the distance between the sensors is being set:
    Line 9: const float distConst = 7.5; (this needs to be changed depending on your setup)

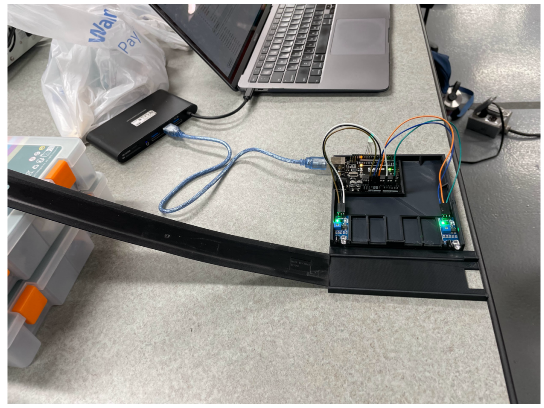
    c. Identify the lines where the velocity is being calculated:
    Lines 29-30: diff = timeScnd - timeFirst;
    velocity = distConst / diff; // velocity in cm/ms

    d. What unit is the velocity in after being calculated?
    Starts in cm/ms on line 30.

    e. Where is the velocity being converted into m/s?
    Line 31: velocity_real = (velocity * 10);
    (Velocity is converted to m/s. You can do dimensional analysis with students so they see how.)

5. Ramp setup:
    a. Place the Arduino speed detector at the edge of the table.
    b. Place the ramp just before the speed detector, as shown in the diagrams below:





What is the height of your launch point?

h = _______________ meters

6. Test ramp and Arduino set up
    a. Initial Velocity
        i. Place the projectile on the ramp and release it from the same spot three times. **DO NOT let the projectile hit the floor; catch it after it passes the speed sensor.**
        ii. Record these values in the table below:

	Trial 1	Trial 2	Trial 3	Avg (m/s)
Velocity				

    b. Calculate Distance
        i. Use the following kinematic equation to determine the distance away the projectile will hit the ground. Use your calculated **Avg Velocity** and the **height** you measured.

$$d = v_i t + \frac{1}{2}at^2$$

y-direction

$$d = v_i t + \frac{1}{2}at^2$$

$$h = 0 + \frac{1}{2}gt^2$$

$$\sqrt{\frac{2h}{g}} = t$$

x-direction

$$d = v_i t + \frac{1}{2}at^2$$

$$d = v_i t + 0$$

$$d = v_i t$$

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c. Test!
   i. Place a cup at the distance you calculated.
   ii. Place the ball on the ramp and release it.
   iii. Did your projectile land in the cup?

Post-Experiment Questions:

1. How did you use the Arduino speed detector to determine the initial velocity of the ball? Describe the process, and any challenges you encountered.
   Students should have some understanding of the IR proximity sensors and Arduino took the time that the projectile took to pass between the sensors, then divide the distance between the sensors by that time to calculate velocity.

2. Without the use of the Arduino, how could you have found the initial velocity?
   Students should know that they could have found the time manually and done the math themselves.

3. Explain how you used the kinematic equations to predict the horizontal distance where the ball would land.
   Students should be able to describe finding the time it takes for the ball to hit the ground (y-direction), then using that time to find the distance (x-direction).

4. Identify and discuss at least three potential sources of error in your experiment. How could these errors have affected your results, and what steps could you take to minimize them in future experiments?
   These can vary but I would encourage students to think more deeply than "human error."
   What are the limitations of the measurement tools? Are there external forces not considered (air resistance, friction)? Is the initial velocity truly instantaneous?

5. Outside of learning how to predict the distance of a horizontally launched projectile, describe something you learned from this experiment.
   The goal is to have students feel more comfortable looking at code, working with a microcontroller (the Arduino), wiring, understanding how sensors work, etc.