Projectile Launcher
(Order Code VPL)

The Vernier Projectile Launcher allows students to investigate important concepts in two-dimensional kinematics.

Sample experiments include:
- Investigate projectile range as a function of launch angle
- Measure the launch speed of the Projectile Launcher
- Predict the ball landing point from the initial speed of a horizontally launched ball
- Predict the ball landing point from the initial launch speed and angle
- Attempt to hit a target

What is Included with the Projectile Launcher?
- Launcher
- (6) Steel balls
- Hand pump
- (2) Pairs of safety goggles
- Level
- Roll of waxed marking paper
- Photogate cable

Vernier Projectile Launcher

A Closer Look at the Components

Launcher

Launcher

The Projectile Launcher is used to investigate important concepts in two-dimensional kinematics. A steel ball placed in the launch barrel can be projected for different launch velocities and launch angles.

An easy-to-use dial allows you to set the desired launch angle. A turn knob allows you to control the desired range.

Dial   *Knob*

A unique pneumatic launching system provides excellent repeatability at angles between 0 and 70 degrees and up to a distance of 2.5 m. The launch point is 0.030 m from the back plane of the launcher, 0.146 m above the base, and 0.082 m from the side. The launch point is independent of angle setting.

Upon setting the desired angle and range, the hand pump is then used to pressurize the system.

To initiate the launch, the launching system requires simultaneous engagement of the "Arm" and "Launch" buttons. This allows the ball to be launched quickly and easily, while still ensuring students' safety. For more details on the launch procedure, please see page six.


Two photogates positioned within the launch chamber allow for precise determination of the ball's launch speed using Vernier's various software applications. To do this, the software records when the ball passes through the first gate and the second gate then calculates the difference, known as the *pulse time*. The average speed of the ball is then determined from the ratio of the separation distance of the photogates and the pulse time.

There are four I/O ports located on the base of the launcher, as shown on the following page:

- Interface – For connection to a Vernier interface via the photogate cable. This connection also provides power to the VPL.
- Ext. Switch – For connection to accessory devices, such as the Time of Flight Pad (TOF-VPL).
- Aux Input – Receives input from future optional auxiliary devices

- Power – Allows you to connect an optional 5 V DC power supply for using the launcher when not using an interface. For more details on powering the launcher, please see page six.
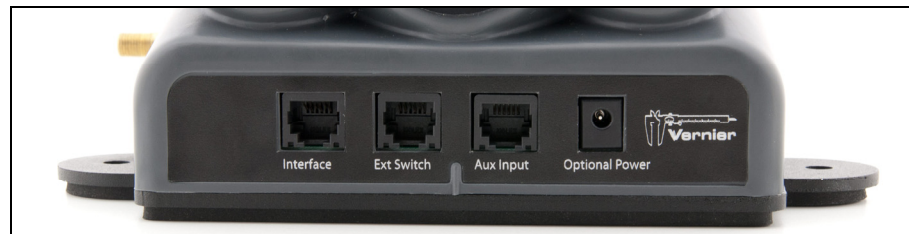
Ports on the front of the base

Steel Balls, Hand Pump, and Safety Goggles

Six steel balls are included for projectiles. Note that the tolerance of the launch barrel for receiving the ball is small. We recommend cleaning the balls with isopropyl alcohol periodically to avoid introducing debris or build-up into the barrel and to ensure proper engaging of the pneumatic launching system.

The included hand pump is designed for generating the necessary pressure for the pneumatic launching system. The pump is easy to use, and features a pressure gauge so that students can collect pressure data to correlate with their range data. A button below the gauge releases residual pressure.

Hand pump

Safety goggles

Two pairs of safety goggles are included to ensure students' safety. We recommend wearing the goggles at all times during data collection.

Roll of waxed marking paper

A roll of waxed marking paper is included for recording the position of the ball landing. When the ball strikes the paper, a dark mark is created on the paper, which can be utilized when measuring the range with a meter stick.

Photogate cable

A photogate cable is included for connecting the launcher to your Vernier interface. The clear telephone-style end connects to the "Interface" port on the Projectile Launcher, and the white rectangular British Telecom end connects to a digital port (e.g., DIG1) on a Vernier interface.

Preparing the Projectile Launcher for Use

Leveling the Launcher

Follow these steps to level the launcher:

1. Position[1] the launcher on a flat surface, with the launch chamber positioned horizontally.
2. Place the level on top of the launch chamber, as shown in the image to the right.
3. Using the lower knob on the back of the unit, adjust the orientation of the launch chamber until level and secure the knob, as shown in the below-right image.
4. Next, using the upper knob on the back of the unit, adjust the position of the angle markings until the zero marking is aligned with the center of the launch chamber and secure the knob.
5. Now that you've aligned the zero marking with true horizontal, you can loosen the lower knob and move the launch chamber to the desired launch angle, and secure the knob.

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[1] Some experiments (e.g., determining the repeatability of the apparatus) benefit from having the apparatus clamped to the tabletop. Tabs at the base of the launcher facilitate this step.

Powering the Projectile Launcher

If you are using the launcher with an interface, the connection via the photogate cable powers the launcher. Therefore, there is no need to connect the launcher to an external power source.

Optionally, you may choose to perform experiments without an interface in which case you will need to supply a LabQuest power supply (order code LQ-PS).

Performing Experiments with the Projectile Launcher

Basic Launching Procedure

Follow these steps to use the Projectile Launcher:

1. Place the launcher on a flat surface and secure. We recommend placing the launcher on a sturdy table and securing the launcher to the table with table clamps.
2. Level the launcher (see page five for detailed instructions) and clamp the base to the table if desired.
3. Connect the hand pump to the launcher.
4. Connect the launcher to a Vernier interface using the photogate cable. If you are not using an interface, you need to connect a LabQuest Power Supply to the power port.
5. Set the desired launch angle.
6. Set the release pressure by adjusting the range knob. Turn clockwise for higher pressure and higher muzzle velocity and counter-clockwise for lower pressure and lower muzzle velocity.
7. Insert one steel ball into the barrel. This is most easily done by inserting the ball into the launch chamber with your index finger and guiding the ball into the barrel.
8. If you are using an interface, verify that the software is set to collect photogate data in the pulse mode and start data collection. For additional details for software setup, see page seven.
9. Pump the hand pump until the pressure stabilizes. You should hear a small release sound when that pressure is reached. We recommend listening for at least three small release sounds and then waiting for five seconds to ensure the pressure has fully stabilized.
10. Press and hold the Arm button, while still pressing the Arm button, press the Launch button to launch the steel ball. If you are using LabQuest App or Logger *Pro*, data collection will stop automatically after the launch. If you are using another data-collection software setup, manually stop data collection.
11. Observe the range of the ball and position the waxed tape along the line of sight for subsequent data collection.

Data-Collection Interface and Software Compatibility

Data collection with the Projectile Launcher is possible with the following combinations of interfaces and software.

- **Logger *Pro* 3** Use version 3.8.5 or newer with LabQuest® 2, original LabQuest®, LabQuest® Mini, and LabPro®.
- **LabQuest App** Use LabQuest 2 or original LabQuest with version 1.6 or newer when LabQuest is used as a standalone device.
- **DataQuest™ Software for TI-Nspire™** Use this application with TI-Nspire™ Technology and the TI-Nspire™ Lab Cradle.
- **EasyData App** Use this app with a TI-83 Plus or TI-84 graphing calculator and LabPro or CBL 2™.
- **LabVIEW™** National Instruments LabVIEW™ software is a graphical programming language sold by National Instruments and used with SensorDAQ. Contact Vernier for more information concerning compatibility.

> **NOTE:** Vernier products are designed for educational use. Our products are not designed nor recommended for any industrial, medical, or commercial process such as life support, patient diagnosis, control of a manufacturing process, or industrial testing of any kind.

Data-Collection Overview and Software Setup

The Projectile Launcher allows students to study the trajectory of a projectile.

In addition to investigating the motion in one or two dimensions, students can use the projectile equations of motion to predict outcomes and test their predictions. Software setup is described in more detail as follows. Be sure to always load the ball into the chamber before starting data collection, as your fingers will pass through the arms of the photogates.

LabQuest with Logger *Pro* or as a Standalone Device

If you are using LabQuest 2 or original LabQuest running LabQuest App 1.6 or later as a standalone device or in combination with Logger *Pro*, the launcher will be identified automatically. If you are using LabQuest Mini and Logger *Pro*, the launcher will be identified automatically.

LabQuest App or Logger *Pro* will be configured to read the pulse time between the photogates and calculate the speed of the ball.

LabPro and Logger *Pro*

If you are using LabPro and Logger *Pro*, the launcher will not be identified automatically. Instead, open the appropriate experiment file within Logger *Pro*. To do this, choose Open from the File menu, then navigate within the Experiments folder and choose the Probes & Sensors folder. Next, choose the Projectile Launcher folder and open the "Projectile Launcher.cmbl" file. Collecting data with this file records the pulse time measured by the photogates and calculates the speed of the ball.

LabPro or CBL 2 and EasyData

If you are using LabPro or CBL 2™ and the EasyData app on TI graphing calculators, the launcher will not be identified automatically. Instead, you will need to manually configure the software. To do this within EasyData, select [File] and choose **New**. Then, select [Setup] and choose **Other Sensors**. Select the channel to which the launcher is connected (e.g., DIG/SONIC1) and select [Next]. This displays a list of digital sensors from which you will select Photogate and then select [Next].

Now that the photogate is set up, modify the settings to collect pulse data. To do this, select [Setup] and choose **Pulse Timing**. Verify that the distance is set to 0.05 m and select [OK]. The launcher is now set up to collect pulse data. After loading the ball, choose [Start], launch the ball, then select **Stop**. Plot 1 displays the pulse time, and Plot 2 displays the speed of the ball.

TI-Nspire™ Lab Cradle and DataQuest

If you are using the TI-Nspire™ Lab Cradle and the DataQuest™ app on a TI-Nspire™, the launcher will not be identified automatically. Instead, you will need to manually configure the software. To do this within DataQuest, open the Menu and then choose Experiment. From the Experiment menu, choose Advanced Setup and then Configure Sensor. Select the channel to which the launcher is connected (e.g., DIG1). This displays a list of digital sensors from which you will select Photogate and then select OK.

Now that the photogate is set up, modify the settings to collect pulse data. To do this, open the Menu, select Experiment, and then select Collection Mode. Select Photogate Timing and change the collection mode to Pulse Timing. Change the distance to 0.05 m and choose to end data collection after 4 events, then select OK. The launcher is now set up to collect pulse data. After loading the ball, start data collection and launch the ball. The top graph displays the pulse time, and bottom graph displays the speed of the ball.

Other Combinations of Equipment

If you are using any other combination of probeware, the launcher will not be identified automatically, and you will need to manually configure the software. To do this, set up the sensor as a Photogate in Pulse Timing mode. Double-check that the distance is set to 0.05 m. This will record the pulse time measured by the photogates and calculate the speed of the ball. Contact Vernier if you have questions.

Sample Experiments

Although the speeds commonly encountered in the projectile equations of motion are the horizontal and vertical components of the projectile's speed, the measurement performed by the photogates yields the total speed. Knowing the launch angle, students can analyze the speed data in Logger *Pro* or LabQuest App to determine the horizontal and vertical components of the speed of the ball.

Upon determining the vertical component of the ball's speed and knowing the initial height of the ball, students can solve the vertical equation of motion to determine the total time that the ball is in the air. Students can then calculate the expected range from this total time and the horizontal component of the ball's speed.

There are a variety of experiments that can be performed with this Projectile Launcher. Below you will find several detailed examples. You might want to try them out to learn more about the equipment.

Investigate Projectile Range as a Function of Launch Angle

As a preliminary inquiry activity prior to the study of two-dimensional kinematics, have the students measure the launch range as a function of launch angle.

1. Follow the basic launch procedure for a launch angle of 5°.
2. Launch the ball such that it strikes the tape.
3. Increase the angle 5° for the second trial.
4. Repeat Step 3 up to a launch angle of 70°.
5. Examine the relationship between launch angle and range. You will find that a launch angle of 45° produces the maximum range. You will also find that launch angles less than 45° can produce the same range as angles greater than 45°.

Optional: If using Logger *Pro*, begin by opening the experiment file "Angle Range.cmbl" from the Probes & Sensors folder. Students can manually record their range and angle data in the table for each trial.

Measure the Launch Speed

Most of the experiments involving the projectile launcher require measurement of the initial launch speed. This would be an excellent place to start with your students.

1. Follow the basic launch procedure for a horizontal launch angle (e.g., 0°) and using a Vernier interface, but do not perform the test launch.
2. Position an empty box standing vertically about 50 cm in front of the launcher to catch the ball.
3. Launch the ball into the box.
4. Record the launch speed.
5. Collect nine more readings.
6. Determine the average speed and its standard deviation.

Predict the Landing Point from the Launch Speed

Once the launch speed of the projectile is known, students can use their knowledge of two-dimensional kinematics to predict where the projectile will land. This activity can be especially challenging if the students use the technique described above (i.e., catching the ball in a box shortly after it leaves the launcher). This approach prevents the students from visually estimating where the ball will land.

1. Determine the launch speed as described in the section above.
2. Move the setup such that the ball will be launched from the end of a table.
3. Use kinematics to calculate the landing spot.
4. Place one or two pieces of the waxed marking paper at that location.
5. Test your predictions.
6. Extension 1 – Change the launch speed and repeat Steps 1–7 above.

7. Extension 2 – Collect nine more readings. Calculate the range spread and the lateral spread from your prediction.

Predict the Landing Point from the Launch Speed and Angle

Perform the same steps as in the previous experiment, but this time launch the ball at various angles.

Attempt to Hit a Target

Challenge your students to launch a ball at a particular target and hit the target on their first trial. For example, challenge them to launch the ball horizontally from a table top into an empty soup can. Prior to their only trial, allow them to make as many measurements as needed to best determine the launch speed. In measuring the launch speed, do not allow them to actually project it off the table. Rather, specify that the ball be "caught" by an object such as an open box.

Other Products for Use with the Projectile Launcher

Projectile Stop (PS-VPL)

Keep the projectiles from landing out of sight with the Projectile Stop. Place the Projectile Stop in the launch line, beyond the landing site, and the projectile will be caught.

Time of Flight Pad (TOF-VPL)
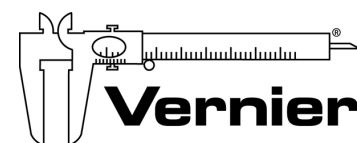
Use the Time of Flight Pad to precisely measure how long a projectile has been in motion.

Independence of Motion Accessory (IOM-VPL)

The Independence of Motion Accessory enables the Projectile Launcher to perform the classic experiment where one ball is dropped as another is projected horizontally. The balls strike the floor simultaneously.

Warranty

Vernier warrants this product to be free from defects in materials and workmanship for a period of five years from the date of shipment to the customer. This warranty does not cover damage to the product caused by abuse or improper use.