Polarizer/Analyzer Set for the Optics Expansion Kit
(Order Code PAK-OEK)

The Polarizer/Analyzer Set for the Optics Expansion Kit consists of three linear polarizers. When used with the light source and light sensor holder from the Optics Expansion Kit (order code OEK) and a Vernier Dynamics Track (order code TRACK), basic experiments on plane polarization, such as Malus's Law, may be performed.

The terms polarizer and analyzer are used nearly synonymously here. Often the first filter to intercept a beam of light is known as a polarizer, and the final filter is known as an analyzer. However, both filters function to transmit light polarized parallel to the axis of the filter.

For quantitative experiments, a Vernier Light Sensor (LS-BTA) and an interface, such as the LabQuest or LabPro, are required and are not included with this kit. Angle measurements can be made either manually or by using an optional Vernier Rotary Motion Sensor (RMV-BTD).

Parts included with the Polarizer/Analyzer Set

- Adjustable Analyzer (two; shown above at left and center)
- Adjustable Analyzer for Rotary Motion Sensor (one; shown above at right)
- Mounting Screws for Rotary Motion Sensor (two)
- Belt for Rotary Motion Sensor (one)

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.

Closely Associated Products to the Polarizer/Analyzer Set

- The Polarizer/Analyzer Set is part of a larger set of accessories for the Vernier Dynamics System (order code VDS).
- The Dynamics System includes low-friction carts and a combination track/optics bench. Parts from the Optics Expansion Kit, the Polarizer/Analyzer Set, and the Mirror Set all share a common design and mount on the track.
- The Optics Expansion Kit (OEK) includes lenses, apertures, a screen, a light source, and a light sensor holder. Most experiments with the Polarizer/Analyzer Set require the light source and light sensor holder from the OEK.
- The Mirror Set (M-OEK) includes a concave mirror, a convex mirror, and a half screen. Image formation from mirrors can be quickly studied.

Sensors used with the Polarizer/Analyzer Set

Light Sensor (LS-BTA)

The Light Sensor approximates the human eye in spectral response. It can be used for inverse square law experiments or for studying polarizers, reflectivity, or solar energy.

Vernier Rotary Motion Sensor (RMV-BTD)

The Vernier Rotary Motion Sensor is a bidirectional angle sensor designed to measure rotational or linear position, velocity and acceleration. The Rotary Motion Sensor lets you monitor angular motion precisely and easily. You can use it to collect angular displacement, angular velocity, and angular acceleration data. Typical experiments include measuring moments of inertia, torque, pendula, and Atwood's machine experiments. It can also be used to measure linear position to a fraction of a millimeter.

Common Holder Design

The adjustable analyzers all use similar plastic holders. These holders snap to the track with a slight pull to the side. The base unit has fiducial marks to locate the center line of a screen, sensor, light or lens held by the base. Read the scale on the track through the hole in the base unit. In the case of most polarization experiments, the position of the device is not important.

Polarizing Sheets

The adjustable analyzers have the linear polarizing sheet permanently mounted. Do not remove the sheet.

Adjustable Analyzers

The Adjustable Analyzer has a scale in degrees, with vertical being the zero angle. In this position, the polarizer passes vertically polarized light. The two Adjustable Analyzers are identical. In common use, the upstream unit, closest to the light source, is set to zero to create a beam of vertically polarized light.

The second Adjustable Analyzer unit may be used for manual experiments.

Adjustable Analyzer for Rotary Motion Sensor

The Adjustable Analyzer for Rotary Motion Sensor is similar to the two Adjustable Analyzers, but it includes a bracket for mounting a Vernier Rotary Motion Sensor. When the sensor is not attached, store the included nylon screws in the provided storage threaded holes.

To mount the Vernier Rotary Motion Sensor, attach the sensor to the analyzer base with the provided nylon screws. We recommend first loosely threading the screws into the sensor, then gently sliding the mounted screws through the

channels on the analyzer bracket. Align the mid-sized pulley directly under the analyzer tube and tighten the screws so that the sensor is firmly attached to the bracket. Run the provided belt around the pulley and the analyzer tube groove. Remove any twists from the belt.

The Adjustable Analyzer for Rotary Motion Sensor can also be used without a sensor for manual experiments.

Light Source Assembly (not included with Polarizer/Analyzer Set)

The light source is part of the Optics Expansion Kit, and is not part of the Polarizer/Analyzer Set. However, most experiments require the light source, so it is described here for convenience.

The light source uses a single white LED. A rotating plate lets you choose various types of light for experiments. The open hole exposes the LED to act as a point source. The other openings are covered by white plastic to create luminous sources. The figure "4" is for studying image formation, and is chosen since it is not symmetric left-right or up-down. The "L" shape is 1 by 2 cm in size. The double-slit is used for depth-of-field experiments.

The plane of the luminous sources is located in the plane of the position marked by the pointer on the base. In contrast, the LED point source is located at the back edge of the holder base. This location is important to note for accurate distances in inverse-square experiments.

The power supply provided with the OEK is the same as the power supply for LabQuest® 2, LabQuest, and LabQuest Mini. A rocker switch on the back of the light source turns the light on and off.

Light Sensor Holder (not included with Polarizer/Analyzer Set)

The light sensor holder is part of the Optics Expansion Kit, and is not part of the Polarizer/Analyzer Set. However, most experiments require the use of a light sensor and its holder, so the holder is described here for convenience.

Insert a Vernier Light Sensor (LS-BTA) into the light sensor holder. The holder keeps the light sensor in position to measure the intensity of light transmitted by the polarizers.

Basic Assembly

To quickly see how the Polarizer/Analyzer Set can be used, try the following setup.

1. Attach the light source to the track at the 20 cm mark, directed along the track toward higher values. Set the disk to its open circle, to fully expose the LED. Connect power and turn on the LED. Caution: the LED is bright.
2. Place an Adjustable Analyzer (i.e., the polarizer) immediately adjacent to the light source, oriented so that the scale is visible. Set the pointer to zero degrees.
3. Place the other Adjustable Analyzer (i.e., the analyzer) downstream of the first. Orient it so the scale is visible.

4. Light will pass through the polarizer and analyzer, with the amount of transmitted light depending on the relative angles of the polarizing sheets. Allow the light to fall on your hand or the screen from the Optics Expansion Kit.
5. Rotate the analyzer and observe how the light intensity varies with angle, reaching two maxima per full rotation.

You are seeing a qualitative demonstration of Malus's law, with a cosine-squared dependence on the angle between the polarizer and analyzer.

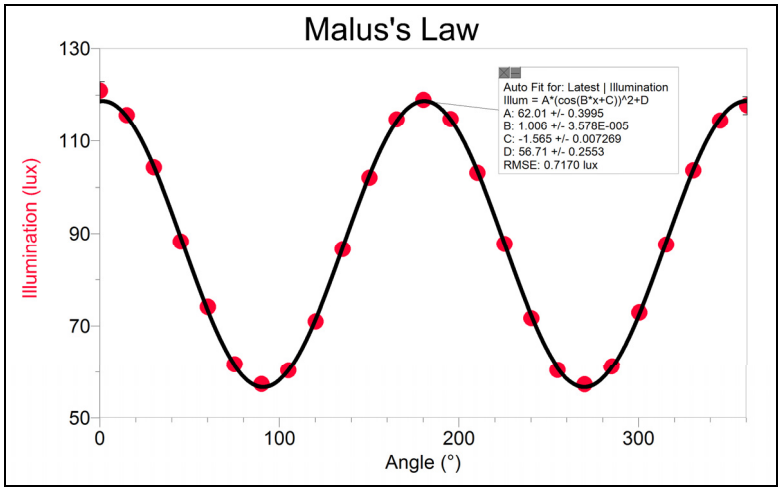
Basic assembly with Light Sensor

Sample Experiment: Malus's law with manual data collection

The basic assembly demonstrates Malus's law, and can be modified for qualitative data collection by adding a Light Sensor, as shown above.

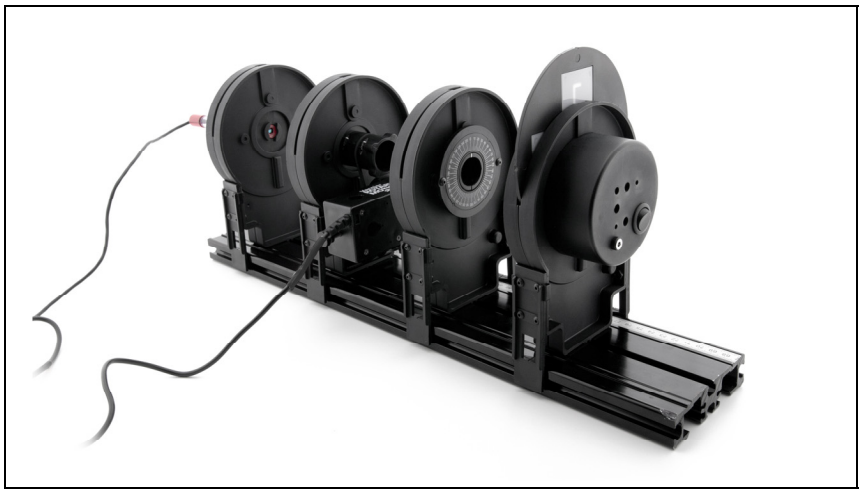
1. Set up basic assembly.
2. Place the Light Sensor Holder downstream of the analyzer, oriented so that the Light Sensor will intercept light passing through the polarizer and analyzer. Insert the Light Sensor into the holder. Set the range to the 600 lux setting.
3. Connect the Light Sensor to a data collection interface and start data collection. Within the Data Collection menu, change the mode to Events With Entry and label the column Angle, with units of degrees.
4. The default graph should display light intensity *vs*. angle. Within Graph Options, uncheck the Connect Points setting. Click Collect, and then Keep. Read the angle from the analyzer, and enter it in your software. Click OK to continue with data collection. Rotate the analyzer about 15 degrees. Repeat until you have gone through a full rotation.

   The graph will show two peaks, and follow a cosine-squared relationship. If desired, fit a Cosine Squared function to your data, as shown in the graph on the following page. Make sure the file settings are set to use degrees for trigonometric calculations.



Sample Experiment: Malus's law with a Rotary Motion Sensor

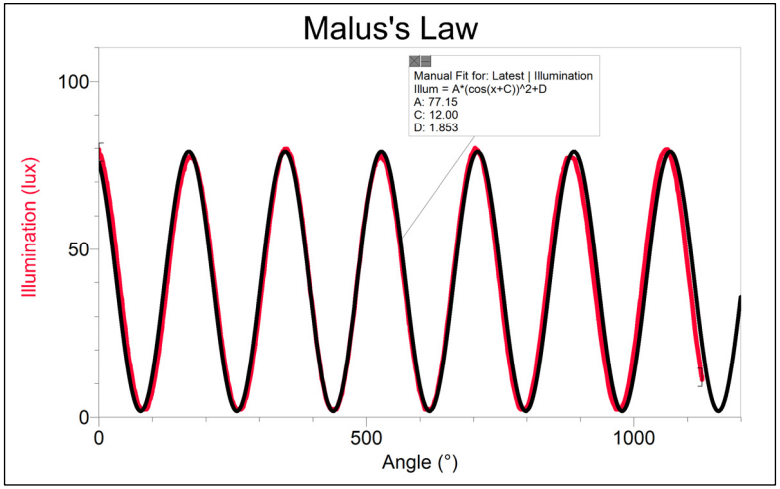
Malus's law can also be demonstrated using the Rotary Motion Sensor to read the angle data. Follow the same setup described above for manual data collection except replace the analyzer with the Adjustable Analyzer for Rotary Motion Sensor, as shown below.



Modified assembly with the Adjustable Analyzer for Rotary Motion Sensor and a Light Sensor

Connect both the Light Sensor and Rotary Motion Sensor to a data-collection interface.

Use the default time-based data-collection mode. Change the angle units for the Rotary Motion Sensor to degrees, if desired. Change the graph to display Illumination *vs*. Angle. Collect data as you rotate the analyzer through at least three full rotations. Analyze the peaks as described above by fitting a Cosine Squared function to your data.



Sample Experiment: Three Analyzers

Start with the same setup as for Malus's Law with a Rotary Motion Sensor and Light Sensor. Set the polarizer to 0 degrees and the analyzer to 90 degrees and observe the transmission of light. You will find that no light is transmitted through the crossed analyzer and polarizer (i.e., none of the vertically polarized light is transmitted through the horizontal analyzer). Next, add another analyzer in between the existing polarizer and analyzer and set the middle analyzer to 45 degrees. You will find that a fraction of the light is now transmitted. This is because the light incident on the final analyzer is no longer vertical. Rather, the middle analyzer will let through half of the vertically polarized light and transmit the now-diagonally polarized light to the final analyzer. The final analyzer will let through half of the diagonally polarized light and transmit the now-horizontally polarized light toward the detector.

Physics with Vernier book

Another resource for experiments in mechanics, sound, light, electricity, and magnetism is our *Physics with Vernier* lab book. In particular, the "Polarization of Light" experiment demonstrates the change in light intensity of light passing through crossed polarizing filters, and examines the transmission of light through two polarizing filters as a function of the angle between their axes for comparison to Malus's law.

Other Products for Use with the Polarizer/Analyzer Set

Vernier Dynamics System (VDS)

The Vernier Dynamics System consists of a track, two low-friction dynamics carts, and associated accessories for dynamics experiments.

Combination Dynamics Track/Optics Bench (TRACK)

The track is a low-friction black anodized track and optics bench combination designed for kinematics, dynamics, and optics experiments.

Light Sensor (LS-BTA)

The Light Sensor approximates the human eye in spectral response. Use it for inverse square law experiments or for studying polarizers, reflectivity, or solar energy.

Vernier Rotary Motion Sensor (RMV-BTD)

The Vernier Rotary Motion Sensor is a bidirectional angle sensor designed to measure rotational or linear position, velocity and acceleration.

Mirror Set (M-OEK)

The Mirror Set (M-OEK) includes a concave mirror, a convex mirror, and a half screen. Image formation from mirrors can be quickly studied.

Optics Expansion Kit (OEK)

Add the Vernier Optics Expansion Kit to your Vernier Dynamics System to conduct optics experiments, such as image formation with lenses and light intensity *vs.* distance. You can even use the kit to build a basic telescope. The OEK includes two convex and one concave lenses, a screen, a light source, light sensor holder, and an aperture plate.

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.

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