

Middle School Physics is appropriate for middle schoolers, and does not assume any prior physics experience. The course introduces students to two areas of physics: geometric optics and waves. Grounded in real-world phenomena, students develop skills in making observations, building and testing hypotheses, recording and analyzing data, using and converting units, and mathematical problem-solving in physics contexts. Students conduct experiments independently using common household materials. They also conduct virtual experiments through simulations and pre-recorded data.

Students will study phenomena including shadows, color mixing, imaging by mirrors and lenses, beats, the Doppler effect, and diffraction. Real-life applications to be studied include ultrasound imaging, lunar laser ranging, digital screens, measuring cell population growth, and others, often using data published by professional scientists. We will also study historical experiments and debates to learn about the nature of progress in physics.

The course builds on students' background in mathematics, including topics through prealgebra. There is no specific science or physics prerequisite. This course is aimed at students with broad curiosity and a willingness to learn challenging new material and is more difficult than a typical middle school physics course.

Textbook(s): Scholars Middle School Physics does not have a required textbook.

Sample Problems:

- ▶ Susumu is 1.3 m tall. He throws a basketball straight up into the air. His friend measures that the bottom of the basketball's shadow reaches a maximum distance of 6.5 m from Susumu's feet and that Susumu's shadow is 2.1 m long. Did Susumu throw the ball high enough to reach a basket 3.1 m above the ground? Explain how you know with words and a sketch. To simplify, treat the basketball as a point.
- ▶ You have a small flat mirror used to signal airplanes in an emergency. You want to signal an airplane 11 mi to your right and 6 mi above the ground. The Sun is far away, but the light from it comes as if from a point that is 3 mi to your left and 10 mi above the ground. At what angle θ to the horizontal do you need to hold the mirror so that light from the Sun will bounce off it and reach the airplane? Solve this problem by drawing the situation on graph paper and measuring the mirror angle on your drawing. You should be accurate to within 5° .
- ▶ In the 1830s, Félix Savart built a spinning toothed wheel constructed so that each tooth impacted a steel plate as it spun past. In one test, Savart spun a wheel at 40 revolutions per second, generating a pitch at 24,000 Hz, the upper limit of human hearing. How many teeth did this wheel have?
- ▶ In active sonar, a source emits a sound that reflects diffusely off a target. The reflections are then detected at three different locations in a straight line behind the source, each at the same depth as the sound source. In one setup, the first detector is 75 m behind the source, and there are 25 m between detectors. Take the speed of sound in water to be 1500 m/s. If the first and third detectors detect a sound simultaneously, and the time between the source emitting the sound and the sound reaching the second detector is 0.20 s, how deep below the sonar array is the target?

Time Commitment: 16 lessons, 1.5 in-class hours + 4–5 hours of homework each week.

Grading: 64% short answer challenge problems, 32% writing problems that will get detailed feedback from a human grader, and 4% class participation.

Content:

Lesson	Scholars Topic
1	Shadows
2	Light and Matter
3	Sight and Images
4	Color
5	Mirrors
6	Curved Mirrors
7	Speed of Light
8	Refraction and Lenses
9	Sound as Vibration
10	Loudness
11	Musical Instruments
12	Interference
13	Doppler Effect
14	Sound in Different Media
15	Water Waves
16	Light as a Wave

Materials:

This course involves home experiments. Materials such as those listed below are recommended, but substitutes are usually possible for any specific item. A smartphone is fine for items whose function it can fill, such as the stopwatch and flashlight. Instead of using a color printer, students could color images with markers, etc.

- a ruler
- graph paper
- twine or string
- two mirrors
- cardboard tube, e.g., from a used paper towel roll
- cardboard boxes
- construction paper
- a flashlight
- aluminum foil
- a thumbtack
- scissors
- tape
- a stopwatch
- a color printer