Mechanics is a foundational subject in physics. Building on the scientific reasoning skills taught in our *Scholars High School Physics: Foundations* course, *Scholars High School Physics 1* shows students how to build models to understand and predict motion in the natural world. These models rely on concepts such as energy, momentum, vectors, and Newton's laws. Common models include the ideal spring, Coulomb's model of friction, and Newton's model of gravitational forces. The course emphasizes integrating intuitive understanding of models with quantitative reasoning, for example understanding the origin and impact of each term in an equation and relating them to physical effects. Students will use video tracking, simulations, and hands-on experimentation to test their models.

This course is aimed at students with broad curiosity and a willingness to learn challenging new material, and is more difficult than a typical introductory physics course. Students will examine modern topics such as exoplanet detection, windmill design, and particle physics, often using data published by professional scientists. At the conclusion of the course, students should have sufficient preparation to take the AP Physics 1 exam; however, AP exam preparation is not the main focus of the course.

Textbook(s): Scholars High School Physics 1 does not have a required textbook. A helpful supplemental book is *College physics: Explore and Apply* by Etkina, Eugenia, Gorazd Planinšič, and Alan Van Heuvelen.

Sample Problems:

- On the International Space Station, astronauts cannot use a bathroom scale to weigh themselves because they feel weightless. Instead, NASA uses a "Body Mass Measurement Device" (BMMD) which consists of a massive plate attached to a spring. The astronaut grabs the plate, which then oscillates due to the spring. When no astronaut is using the BMMD, the oscillation frequency is $3.00\ \mathrm{Hz}$. When astronaut A uses the BMMD, the frequency decreases to $1.11\ \mathrm{Hz}$. When astronaut B uses the BMMD, the frequency is $0.98\ \mathrm{Hz}$. Which astronaut is more massive? What is the ratio of their masses?

- A swing ride (as seen at carnivals or amusement parks) has a central tower with a rotating top. We will assume the top does not tilt. Swing chairs hang from the edge of the top. As the top rotates, the swing chairs fly out at an angle from the vertical. How does this angle depend on (a) the distance R that the tops of the chair swings are attached from the center of the tower (b) the length ℓ of the chair swings (c) the angular frequency ω that the top rotates and (d) the effective gravity g_{eff} that a rider feels? For each, first draw a qualitative plot of swing angle angle versus the variable, then find an equation or proportionality for the relationship and test whether its graph is similar to your qualitative plot.

- When a projectile is fired from ground level over flat terrain, we can maximize its range by firing at $45°$ above the horizontal, assuming the firing speed is fixed and complicating effects such as air resistance are negligible. Suppose instead that you are firing a projectile from the top of a cliff. Draw a qualitative plot showing the angle to fire for maximum range as a function of firing speed. Make sure your plot matches your intuition when $v \to \infty$ and when $v \to 0$. Find a speed $v_{\text{transition}}$ so that for firing speed $v_0 \ll v_{\text{transition}}$, the solution is close to the solution when $v \to 0$, and so that when $v_0 \gg v_{\text{transition}}$ the firing speed is close to the solution when $v \to \infty$.

Time Commitment: 24 lessons, 1.5 in-class hours + 4–5 hours of prepwork & homework per lesson.

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	Velocity
2	Acceleration
3	Projectile Motion
4	Energy Conservation
5	Forms of Energy
6	Simple Machines
7	Circular Motion
8	Simple Harmonic Motion
9	Rotational Kinematics
10	Rotational Dynamics
11	Vectors
12	2D and 3D Kinematics
13	Momentum
14	Collisions
15	Forces via Momentum
16	Forces via Energy
17	Statics
18	Newton's Laws of Motion
19	Problem Solving with Forces
20	Newton's Gravitational Law
21	Torque and Angular Momentum
22	Problem Solving with Torque and Angular Momentum
23	Fluid Statics
24	Fluid Dynamics

Materials:

This course involves home experiments. Materials such as those listed below are recommended, but substitutes are usually possible for any specific item. Students don't need a special kit or special materials for this course. Students should bring paper, a writing utensil, and a calculator to each class session. They should also have graph paper available.

- a ruler or tape measure
- coffee filters
- a sturdy, large cardboard box and a stack of books, or other objects to build a simple ramp
- a stopwatch (a cell phone app is fine)
- a toy car, ball, or other object that rolls easily
- coins
- thin string, such as sewing thread or twine
- scissors
- rubber bands (any size)
- tape