Are You Ready? Scholars Middle School Physics 1

This diagnostic test helps determine if a student is ready for the Art of Problem Solving Online Class **Scholars Middle School Physics 1**.

If your student can solve 10 or more of the 14 problems after a second try, they are ready for the class. If your student does not solve that many problems, they should consider our **Math 6: Prealgebra (Part 1)** and **Math 6: Prealgebra (Part 2)** series of courses. These courses will both teach the skills used on this test and help students develop their problem-solving skills.

Students will need a calculator, a ruler, a protractor, a writing implement, and paper to take the test.

Many of the questions on this test involve making a measurement or an estimate. For these questions, your answer doesn't need to be exact. Instead, the answer key gives a range for correct answers.

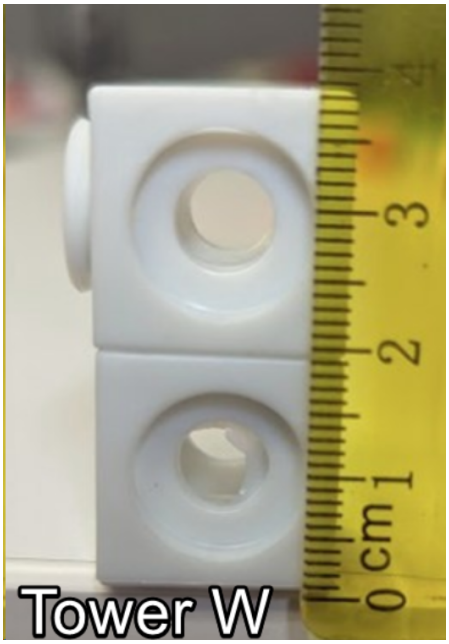
The numbers on this test are not selected to simplify the problem and are not whole numbers. This reflects how, in physics, we often work with numbers derived from experiments.

We recommend using the following process in administering this diagnostic:

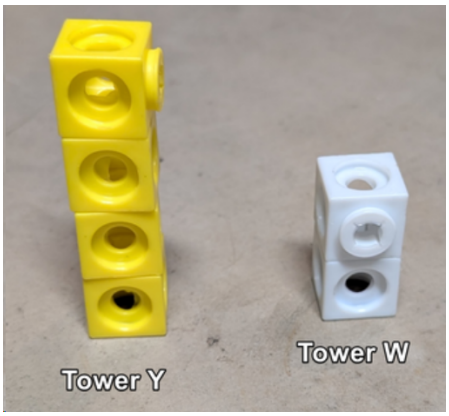
Step 1: The student should attempt all of the questions below without any help. **A calculator is allowed.** There is no time limit.
Step 2: Check the student's responses using the answer key at the end of this document.
Step 3: The student should be given a second chance on the problems that they answered incorrectly.

Towers

1. How tall is Tower W?



2. How tall is Tower Y?

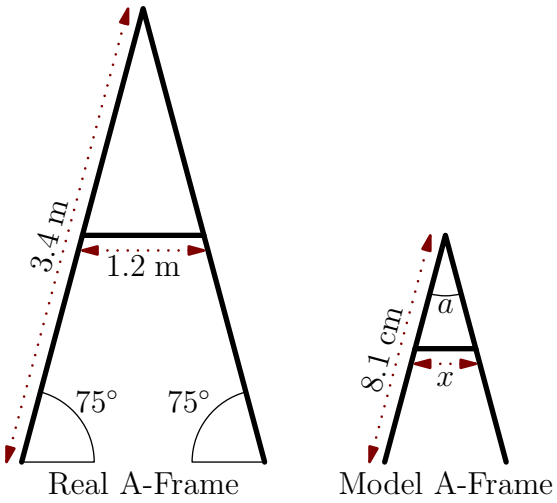


3. What is an important assumption you made about the blocks to answer the previous question?
4. Tower O is made from the same type of blocks as Towers W and Y, stacked in the same way. Seeing Tower O, a student predicted it to be $13.3\ \text{cm}$ tall. Then they measured and found Tower O is $13.6\ \text{cm}$ tall. In centimeters, what was the difference between the student's measurement and their prediction?
5. Assume the student's measurement was accurate. What percentage of Tower O's height is equal to the difference you calculated in the previous problem? This is called the *percent error* of their prediction. Give your answer to the nearest 0.1%.
6. How many blocks tall is Tower O?

Model Playground

A hobbyist is building a miniature model of their town. The town has a playground with swings. The frame that holds up the swings has the shape of an A, with two angled sides and a horizontal crossbar connecting the center of each side.

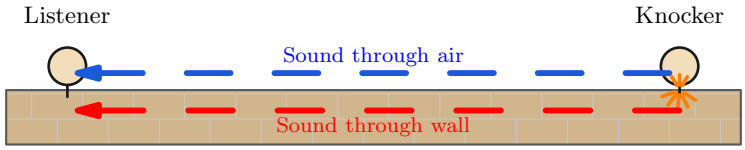
Diagrams of the A-frames for the real and model playgrounds are shown below. They are geometrically similar. The model has been drawn at a larger scale to allow it to be clearly visible on the page.



7. What is the value of x, the length of the crossbar in the model? Give your answer to the nearest 0.1 cm.
8. What is the value of a, the angle where the sides of the model meet at the top?
9. Suppose the angle a is changed to $50°$ and the real A-frame is changed similarly. The crossbar is still attached to the center of each side, and the side lengths are unchanged. What would the new length of the crossbar on the real playground need to be? To answer, you don't need to use formulas or make calculations. Instead, draw the new A-frame shape to scale using a ruler and protractor. Use measurements on your drawing to get an approximate answer.

Speed of Sound

10. If you place your ear on a long brick wall and have a friend knock on the wall far away, the sound of the knock can travel to you through the wall and through the air.



overhead view

You will hear the sound through the wall before you hear it through the air. The paths sound takes through the wall and through air can be assumed to be straight lines of the same length. In which material is the speed of sound is faster?

(a) in brick

(b) in air

(c) It's the same.

(d) We would need to know how far away the knock happened to say.

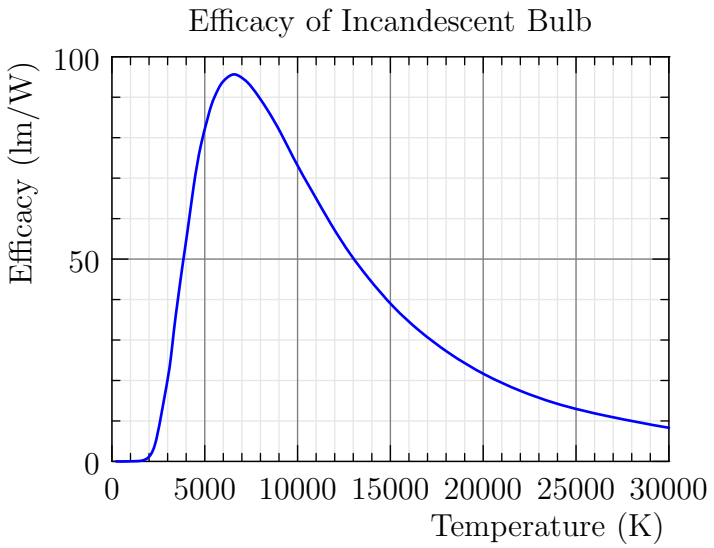
11. If the speed of sound in brick is $3930\ \mathrm{m/s}$ (meters per second) and the knock occurred $52.4\ \mathrm{m}$ away, how long will it take the sound to travel from the knock to your ear? Give your answer to the nearest $0.001\ \mathrm{s}$.

12. If the sound takes $0.157\ \mathrm{s}$ to travel to you through the air, what was the speed of sound through air? Give your answer to the nearest whole number of meters per second.

13. The "standard" value for the speed of sound in air is $343\ \mathrm{m/s}$. You should have found something different from this in the last problem, though. That's because the speed of sound in air varies depending on the temperature and humidity. If you had predicted that the speed of sound in air would be $343\ \mathrm{m/s}$, but measured it to be the result of your calculation in the previous problem, what would your percent error have been? Give your answer to the nearest 0.1%.

Interpreting Graphs

14. The efficacy of a light bulb is related to its brightness and power use. Imagine a series of light bulbs that heat up wires to various temperatures. A plot of the efficacy of these bulbs versus their temperature would look like this:



Source: Tannous, C. "Light production metrics of radiation sources." European Journal of Physics 35.4 (2104): 045006.

At what temperature is the maximum efficacy?

Don't look at the next page until you've attempted all the problems!

The answers are below.

1. Approximately 3.9 cm. Answers from 3.7 cm to 4.0 cm are correct.
2. Approximately 7.8 cm. Answers from 7.4 cm to 8.0 cm are correct. This answer is also correct if it is double the answer to problem 1, even if problem 1 is incorrect. Students should recognize that Tower Y has 4 blocks while Tower W has 2 blocks, so Tower Y is $\frac{4}{2}=2$ times as tall as Tower W.
3. Some good answers are that the blocks are all the same size, or that the yellow blocks are the same size as the white blocks. Other acceptable answers are that the blocks fit together tightly or that the blocks are not oriented so that a nub sticks out the top of Tower O.
4. 0.3 cm
5. Accept 2.2% or 2.3%. The percent error is $\dfrac{0.3\text{ cm}}{13.6\text{ cm}}\times 100\%\approx 2.2\%$. (While 2.3% is mistake due to rounding, it shows the student understands the concept well enough for this course.)
6. 7 blocks. Using the height of Tower W (about 3.9 cm for 2 blocks), each block is about 1.95 cm tall. Tower O has $\dfrac{13.6}{1.95}\approx 7$ blocks. Do not accept answers, such as 6.97 blocks, that are not whole numbers.
7. $x=2.9\text{ cm}$ In the real A-frame, the crossbar is shorter than a side of the frame by the factor $\dfrac{1.2\text{ m}}{3.4\text{ m}}$. Applying this factor to the side length of the model frame, we have $8.1\text{ cm}\times\dfrac{1.2\text{ m}}{3.4\text{ m}}\approx 2.9\text{ cm}$.
8. $a=30^\circ$. In the A-frame, the two base angles are each 75°, so the top angle is $180^\circ-75^\circ-75^\circ=30^\circ$.
9. Answers from 1.3 m to 1.6 m are correct. When the angle at the top increases to 50°, the crossbar becomes longer. Students should draw the shape and measure. The ratio between the crossbar and a side of the A-frame becomes about 0.42. Multiplying this by the 3.4 m length of a side of the A-frame gives the answer. Students are not expected to solve the problem with trigonometry.
10. (a) in the wall. Since the sound arrives sooner through the wall, and both paths are the same distance, the sound must travel faster through the wall.
11. 0.013 s. Time $=\dfrac{\text{distance}}{\text{speed}}=\dfrac{52.4\text{ m}}{3930\text{ m/s}}\approx 0.0133\text{ s}$, which rounds to 0.013 s.
12. 334 m/s. Speed $=\dfrac{\text{distance}}{\text{time}}=\dfrac{52.4}{0.157}\approx 334\text{ m/s}$.
13. 2.7%. The percent error is $\dfrac{|343\text{ m/s}-334\text{ m/s}|}{334\text{ m/s}}\times 100\%\approx 2.7\%$. If the student gave a different answer to the previous problem, this problem should be counted correct if the student's answer is consistent. For example, if the student gave an answer of 500 m/s for the previous problem, their answer to this problem would be $\dfrac{|343\text{ m/s}-500\text{ m/s}|}{500\text{ m/s}}\approx 31.4\%$.
14. $\approx 6600\text{ K}$. Based on the labels, each tick mark on the graph represents one thousand kelvin. The peak is reached a bit more than halfway between the tick mark for 6000 K and 7000 K. Student answers within a few hundred kelvin would be accepted.