Family edition

Telescope Lab: Too Much Power, Magnification and the Air

Ages 11-14 · about 45 minutes, in one sitting

In Telescope Lab your child points a simulated backyard telescope at Saturn, works out its magnification, and finds out why the biggest view is not the best one.

What you need

- A computer or Chromebook with a current browser.
- The link: mytekdev.com/try/telescopelab?lesson=too-much-power-magnification-and-the-air&ref=fam-telescopelab-1. No account, no email and nothing to install.
- A calculator, if you like.

Before you start: try it once yourself

Open mytekdev.com/try/telescopelab?lesson=too-much-power-magnification-and-the-air&ref=fam-telescopelab-1. A short guide opens over Level 1, See Saturn's rings. The night is 16 February 2027 in a sample backyard on the edge of Denver, not where anyone in your family is. The backyard is in the middle: the deck, the trees, the telescope and Saturn above them. The eyepiece view is on the right: the big circle is what your eye would see, the small one the whole view to scale, with the magnification, the sky across and the air's blur under them. The box at the top left says the level's goal and, after each run, what happened, with the run's own numbers.

1. **The telescope.** An 8 inch (203 mm) mirror with a 1200 mm focal length, and three eyepieces: 25, 10 and 3 mm. The starter blocks are point at Saturn, then use the 25 mm eyepiece.
2. **Level 1.** It passes when Saturn is in view at 100 times or more for 3 seconds. The 25 mm gives 48 times and does not pass; the box says to try a shorter eyepiece. The 10 mm passes at 120 times, about 8 seconds after play. The 3 mm passes too, at 400 times, and the box says the rings are there but blurred.
3. **Level 2.** It wants all three eyepieces for 3 seconds each, finishing on the best. The starter shows only the 3 mm. The for each eyepiece block runs its list in order with use this eyepiece inside it; its own list, 25, 10, 3, ends on the 3 mm and does not pass. 25, 3, 10 with wait 3 passes in 14 seconds. A wait of 2 is too short.
4. **Speed.** The round play button runs the program from the start of the night; Speed up and Slower, at the bottom, change how fast the night goes (up to 10 times in the backyard). A program's seconds are the night's seconds at any speed. Each press of play is a new night's air, so the blur the panel reports changes between 2 and 4 arcseconds from run to run. The magnifications and the times do not change.
5. **Numbers to expect.** Magnification 48, 120 and 400; sky across 1.08, 0.43 and 0.13 degrees. Saturn is 16.5 arcseconds across, its rings 37, and it is 1.51 billion kilometers away. The highest useful power for this mirror is about 400 (2 per millimeter). The air's blur, shown under the view, is 2.1 arcseconds on the first run of a new project and 2 to 4 after that.

> The telescope will not point at the Sun or within 15 degrees of it, and says why: sunlight through a telescope burns the eye in an instant and the damage is permanent. Every view and picture in the app is simulated from real sky data and says so, with its source; none is a real observation.

The ideas, in plain words

A telescope's mirror gathers light and brings it to a focus; the eyepiece is a magnifying glass for that small image. Magnification is the telescope's focal length over the eyepiece's, so a shorter eyepiece magnifies more and shows a smaller piece of sky. On the way, the light is reflected by the mirror, transmitted through the eyepiece's lenses and, before any of that, transmitted through the air, whose moving pockets of warm and cool bend it a little differently each instant. That shimmer is called seeing, and from a backyard it blurs everything by 2 to 4 arcseconds.

Magnifying multiplies every angle in the view by the same number: Saturn's 37 arcsecond rings and the air's blur alike, so both apparent sizes are proportional to the magnification. Past the point where the blur is big enough for the eye to see, more power shows no new detail; the image only gets bigger, dimmer and softer. The rule of thumb of 50 times per inch of mirror (2 per millimeter) is the most any telescope can usefully show; most nights the air stops you sooner. The real big telescopes go to mountaintops, and to space, to get above as much of that air as they can.

Astronomers, telescope operators (the job this app is closest to), engineers who build cameras and adaptive optics, and data scientists who sort survey pictures all work with telescopes like these. Anyone can help with real data through citizen science projects such as Zooniverse and the AAVSO.

Do it together

1. Open mytekdev.com/try/telescopelab?lesson=too-much-power-magnification-and-the-air&ref=fam-telescopelab-1 together. Work out 1200 / 25, then press play.

   > **You'll know it worked when:** 48 times. Saturn is a small dot with bumps on each side.

2. Work out 1200 / 10. Open `Blocks`, choose `10 mm (120x)` in the eyepiece block, go back to `Simulator` and press play.

   > **You'll know it worked when:** 120 times, and the rings stand clear of the ball.

3. Work out 1200 / 3, choose `3 mm (400x)` and press play.

   > **You'll know it worked when:** 400 times. Saturn is big, but soft: the panel under the view says how much the air blurs it tonight, 2 to 4 arcseconds.

4. Open `Missions`, `Choose a level`, and start `Level 2`. Make the program show all three eyepieces for 3 seconds each and finish on the best.

   > **If you get stuck:** Use the `for each eyepiece` block with `use this eyepiece` and `wait 3` inside, and change its list so it ends on 10.
   >
   > **You'll know it worked when:** The box says the 10 mm shows Saturn best, and why.

5. Multiply: Saturn's rings are 37 arcseconds across. How big do they look at 48, 120 and 400 times? Do the same for the air's blur.

   > **You'll know it worked when:** Both grow by the same factor, so the ratio between them never changes: more power adds no detail.

Talk about it

Ask these while you work together. A child who has understood it can answer them without help:

- Why does the 3 mm eyepiece magnify more than the 25 mm?
- How big do Saturn's rings look at 120 times, in arcseconds?
- Tonight the air blurs by about 2 arcseconds. How big does that blur look at 400 times?
- Why did the 3 mm not show more detail than the 10 mm?
- Which order of eyepieces passes Level 2, and why?

> The fourth question is the one that matters. A child who says "the blur grew 400 times too, so the rings are no sharper compared with it" understands that magnification multiplies everything. A child who says "it was blurry" has the result but not the idea.

For younger and older kids

Younger: For a younger child, stop after the three eyepieces in Level 1, and talk about which view looked best and why.

Older: For an older child, look for Saturn or Jupiter on a clear evening with binoculars or a small telescope, with an adult, and never point either anywhere near the Sun: sunlight through them causes permanent eye damage.

Keep going

- Work out the exit pupil, the beam of light that leaves the eyepiece: 203 mm divided by the magnification. Compare it with a dark-adapted pupil, about 7 mm, and explain why 400 times looks dimmer.
- Each eyepiece shows about 52 degrees to the eye. Work out how much sky each shows: 52 divided by the magnification. Check against the panel.

- Open Telescope, Configurator. Change the mirror and the focal length, and predict the magnification and the highest useful power before reading them.

Bring it into other subjects

- Math: graph apparent ring size against magnification for the three eyepieces. Is the graph a straight line through the origin? What is its slope?
- Science: hold a pencil over a hot road or a candle and look past it. That shimmer is the same thing as seeing.
- History: Galileo's first telescopes magnified about 20 times, and he could not make out Saturn's rings; he drew it as three bodies.
- Careers: look up what a telescope operator does at a big observatory.

For your records

Ready to copy into an hour log, a portfolio or a transcript.

LESSON	Telescope Lab: Too Much Power, Magnification and the Air
SUBJECTS	Science, Math
TIME	45 minutes
WHAT WE DID	Calculated a simulated backyard telescope's magnification from focal lengths, tested three eyepieces on Saturn, and used proportional reasoning to explain why the air's blur limits useful magnification.
SKILLS PRACTICED	Ratios; Proportional relationships; How telescopes work

Activity sheet (optional)

Name: _____ Date: _____

Open the app: scan the QR code, or go to mytekdev.com/try/telescopelab?lesson=too-much-power-magnification-and-the-air

Essential question: Is more magnification always a better view?

Warm-up: Can you zoom a photo of the Moon until it shows more than the photo had in it?

_____

1. **Vocabulary.** Focal length, magnification, eyepiece, arcsecond, seeing, proportional: write each in your own words.

2. **My predictions.** 1200 / 25 = _____ 1200 / 10 = _____ 1200 / 3 = _____
3. **What the app showed.** 25 mm: _____ times. 10 mm: _____ times. 3 mm: _____ times. The air's blur tonight: _____ arcseconds.
4. **Size table.** Apparent size = magnification x true size. Rings (37 arcseconds) at 48: _____ at 120: _____ at 400: _____. My blur at 48: _____ at 120: _____ at 400: _____. Rings divided by blur at each power: _____ _____ _____
5. **Level 2.** The order of eyepieces that passed: _____. The best eyepiece: _____.

1. Why did 400 times not show more detail than 120 times?

2. Write an equation for the rings' apparent size, a, at a magnification m.

Quick check

Name: _____

1. A telescope has a 900 mm focal length. A 9 mm eyepiece magnifies: (A) 9 times (B) 100 times (C) 8100 times

2. You switch from 100 times to 200 times. The air's blur looks: (A) the same size (B) twice as big (C) half as big

3. A friend wants the strongest eyepiece for the sharpest view of Saturn. Use what you learned today to answer.

Answers

QUESTION	ANSWER	WHY
1	B	900 / 9 = 100: the telescope's focal length over the eyepiece's.
2	B	Magnification multiplies every angle in the view, the blur included: it is proportional.
3	Open answer	Past the air's blur, more power makes the blur bigger along with the planet, so the view gets bigger and softer, not sharper. A middle eyepiece (here 120 times) showed Saturn best.

If your state or umbrella school asks, this lesson covers Common Core Math 7.RP.A.2a, Common Core Math 7.RP.A.2c, NGSS MS-PS4-2.

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The app this lesson uses is free and runs in the browser, with nothing to install and no account needed. It is at mytekdev.com.

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