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Tunnel Boring Lab: Stay on the Line, Steering by Thrust

Grades 6-8 · 45 minutes

Engineering · Physical science



Slides, rubric and answer key **Print and go** **No student accounts**

Chromebook friendly

What's included

- A one-page overview: objectives, essential question, vocabulary, standards and assessment
- A 45-minute lesson sequence: warm-up, direct instruction, guided practice, independent practice, closure
- Slides for the board: a PowerPoint file that also opens in Google Slides
- A student worksheet with a QR code and a table for five pushes
- A 3-question exit ticket, two to a page, with an answer key
- A rubric: 3 criteria, 4 levels, scored out of 12
- Differentiation for English learners, students with IEPs or 504 plans, and students who need more support or more challenge
- Cross-curricular extensions, and notes for teaching it in grades 4 and 5 and in high school
- Standards: NGSS

Tunnel Boring Lab: Stay on the Line, Steering by Thrust

Grades 6-8 · 45 minutes · Engineering, Physical science

Level 2 of Tunnel Boring Lab is a tunnel boring machine under a city street, and a line that curves gently left. The machine has no wheels and nothing at the front that turns: it moves by pushing off the rings of the tunnel behind it with four groups of cylinders. The starter pushes the same on every side, so the machine goes straight and ends ring 20 about 340 mm right of the line, far outside the 50 mm limit. Students make the right push bigger than the left, run it again, and measure where ring 20 ends for each push from 60 to 100. The results fall in a pattern: each 10 points more on the right moves the end about 114 mm left, and the difference between the sides is what turns it.

At a glance

ESSENTIAL QUESTION

How do you steer a machine that has nothing at the front to turn?

OBJECTIVES

Students will be able to:

- explain how a machine with no steering is steered by pushing harder on one side
- predict which way an unbalanced push turns the machine
- change one variable at a time and record the result
- find a pattern in the results and use it to choose a push
- explain how the machine knows where it is underground

VOCABULARY

Tunnel boring machine, Thrust cylinders, Unbalanced push, Line, Guidance screen, Tolerance

STANDARDS

MS-PS2-2, MS-ETS1-4

TIME AND MATERIALS

45 minutes, grades 6-8.

- One computer or Chromebook per student
- A projector
- The worksheet and exit ticket, one copy each per student
- The rubric, one copy per student if you grade the work

PREP

Make copies of the worksheet and exit ticket. Before class, open mytekdev.com/try/tunnelboringlab?lesson=stay-on-the-line-steering-by-thrust&ref=tpt-tunnelboringlab-1 once on a student computer, which checks that your school's filter allows the app, and follow the short guide yourself: about ten minutes.

ASSESSMENT

- Formative: the questions under What to look for, asked while students work, and the exit ticket (answer key included).
- Summative: the worksheet, scored with the rubric.

TECHNOLOGY AND PRIVACY

Runs in any browser, Chromebooks included, with nothing to install. Students need no account and no email: the link works signed out, and nothing they do is stored on our server unless they choose to save.

Lesson sequence

MINUTES	STAGE	WHAT YOU DO	WHAT STUDENTS DO
0 to 5	**Warm-up** Hook	Show the title, essential question and Today I can slides (about 1 minute). Then the warm-up: how could a machine with no wheels go round a curve? Leave the answers on the board.	Answer the warm-up on the worksheet.
5 to 13	**Direct instruction (I do)** Model it	Project Level 2 and press play, then Speed up twice. The street is drawn cut open along the tunnel's line like a diagram: the buildings and the road on top, then topsoil, sand, clay and granite. The machine is under the street, boring from the launch shaft on the left. The box at the top says what the level wants and what is happening; the guidance screen is the round dial. Point at the four push numbers in the readings: the machine moves by pushing off the ring behind it. Watch the dot on the guidance screen drift right as the line curves away. Read the result: about 342 mm off, and 50 is allowed. **It's working when:** Ask which way the dot moved before anyone touches the program. The machine went straight; the line went left; so the machine is right of the line.	Watch, and fill in the vocabulary on the worksheet.
13 to 22	**Guided practice (We do)** Push harder on one side	Students open the link or scan the QR code. A short guide walks them through running the starter, then making the right push bigger in Blocks. Walk the room until every student has a green result. Some will need two or three tries; the result line says which way to go. **Watch for:** Students who make the left bigger. The machine turns right and ends about 680 mm right. Ask: which side did you push harder, and which way did it go?	Follow the guide. Write the starter's result and their first passing push.
22 to 37	**Independent practice (You do)** Find the pattern	Students leave the left at 50 and try the right at 60, 70, 80, 90 and 100, one change at a time, and record where ring 20 ended and which side. A drive is many hours of the machine's own time. Speed up, twice, runs it at 6 times faster, 22 minutes of the drive a second, so most runs take under a minute. Play always puts the machine back in the shaft and runs the program as it is now. Walk the room with the What to look for questions. **If they ask:** "How far did each 10 more on the right move the end of ring 20?" The pattern **Watch for:** Students who think more is always better. 100 ends 228 mm left of the line: too far the other way.	Fill in the table with five pushes, and answer the questions.

MINUTES	STAGE	WHAT YOU DO	WHAT STUDENTS DO
37 to 45	**Closure** How hard, or the difference? And exit ticket	Show the closure slide. Take predictions, then run both pushes on the board. 30 left with 80 right ends where 50 and 100 did. Back to the warm-up answers: which of them was right? Hand out the exit ticket.	Predict, watch, then answer the exit ticket.

Before you teach: a ten-minute walkthrough

Open mytekdev.com/try/tunnelboringlab?lesson=stay-on-the-line-steering-by-thrust&ref=tpt-tunnelboringlab-1. A short guide opens over Level 2, Stay on the line. The street is drawn cut open along the tunnel's line like a diagram: the buildings and the road on top, then topsoil, sand, clay and granite. The machine is under the street, boring from the launch shaft on the left. The box at the top says what the level wants and what is happening; the guidance screen is the round dial.

1. **The push.** The starter pushes 50 on every side (top, bottom, left, right), out of 100, turns the cutterhead at 3 turns a minute, and bores a stroke and builds a ring 20 times. A stroke is 1.6 m, one ring's width.
2. **The guidance screen.** The filled dot is the machine's head and the small ring its tail; the middle is the line; the orange circle is the 50 mm limit. Past 100 mm the dot waits at the edge, and the box gives the distance. A laser in the tunnel behind the machine measures it. The machine never sees the line.
3. **Speed.** A drive is many hours of the machine's own time. Speed up, twice, runs it at 6 times faster, 22 minutes of the drive a second, so most runs take under a minute. Play always puts the machine back in the shaft and runs the program as it is now.
4. **Numbers to expect.** Left at 50, the right at: 50, ring 20 ends 341 mm right (342 off, with 15 mm low); 60, 228 right; 70, 114 right; 80, on the line sideways and 15 mm low, and it passes; 90, 114 left; 100, 228 left. 80 on the left with 50 on the right: 683 right. 30 on the left with 80 on the right: 228 left.

> Every push in this level ends 15 mm low: the machine is heavy and dips a little each ring. It is inside the limit, so the lesson is the side to side, but a student who asks has seen something real. Pushing harder on the bottom lifts it.

Background for the teacher

A tunnel boring machine moves by pushing off the tunnel it has just built. Hydraulic cylinders round the inside of its shield press against the last ring of the concrete lining, and push the machine forward one ring's width, a stroke. Then the machine stands still while a new ring is built inside its tail, and pushes off that one.

Nothing at the front turns. To go round a curve, the crew pushes harder on the outside of the curve: the cylinders on that side extend a little further each stroke, so the machine swings toward the inside. It is an unbalanced force making a change in motion, a little every millimeter bored. Real machines add a hinge in the shield for tight curves; the app leaves it out.

Underground there is nothing to see by. A laser fixed in the finished tunnel shines on a target on the machine, and a computer works out where its head and tail are against the line. Real drives are built to about the same limit as here: Crossrail's tunnels under London were held to about 50 mm.

What to look for

Ask these while students work. A student who has understood the lesson can answer them without help:

- Which side do you push harder to turn left, and why?
- How does the machine know where it is underground?
- Why is it fair to compare your push with your partner's?
- How far did each 10 more on the right move the end of ring 20?
- 100 on the right is the biggest push. Why does it fail?

> The fourth question is the one that matters. A student who says "about 114 mm each time" has found a pattern and can use it. A student who found 80 by guessing has the result but not the reason.

Cross-curricular extensions

- Math: plot where ring 20 ended against the right push, and find the slope. Is it a straight line?
- Science: why does a rowboat turn when one oar pulls harder? Compare it with the machine.
- Careers: look up what a tunnel engineer or a surveyor does on a tunnel project.
- Geography: find a tunnel under your nearest city, and find out what it carries.

Vocabulary

Tunnel boring machine	A machine that cuts a round tunnel with a turning cutterhead and lines it with concrete rings as it goes.
Thrust cylinders	The pistons that push the machine forward off the last ring built, in four groups: top, bottom, left and right.
Unbalanced push	More push on one side than the other. It turns the machine away from the side pushed harder.
Line	Where the tunnel is meant to go, drawn by its designers before it is dug.
Guidance screen	The dial that shows how far the machine is off the line. A laser in the tunnel behind measures it.
Tolerance	How far off the line is allowed: here 50 mm, about the width of a hand.

Differentiation

ENGLISH LEARNERS

- Keep the vocabulary slide up, and point at the machine, the guidance screen or the readings as you say each word: the picture carries the meaning.

STUDENTS WITH IEPS OR 504 PLANS

- Pair students, one at the keyboard and one recording numbers.
- Give the five pushes on a card: 60, 70, 80, 90, 100.

- Give a sentence frame on a card: When the push on the ____ is bigger, the machine turns ____.
- Act it out: two students push a desk from behind, one harder than the other, and the class says which way it turns.

STUDENTS WHO NEED MORE SUPPORT

- Make the first change together on the board, one number at a time.
- Fill in the starter row of the table together.
- The result line after every run says which way to change the push.

- Where the IEP allows a modified assignment, score the first two rubric rows only.

STUDENTS READY FOR MORE

- Open Level 3: steer the same curve with the push the same all round, using rings turned left. How many in five?
- Find a push that ends ring 20 within 10 mm of the line sideways.
- Open the Python tab and find tbm.push. Which of the four numbers is the right side?

Adapting for other grades

Younger students: In grades 4 and 5, run the starter and one passing push together on the board, then let pairs try 60 and 100. Score the first two rubric rows, total 8, and 6 meets the objectives.

Older students: In high school, plot where ring 20 ends against the right push from 50 to 100 and fit a line: about 11 mm for each point of push. Then explain why a set push would fail if the curve changed halfway, and open Level 13, where the program has to read the guidance every ring.

Student worksheet

Name: _____ Date: _____

Open the app: scan the QR code, or go to mytekdev.com/try/tunnelboringlab?lesson=stay-on-the-line-steering-by-thrust

Essential question: How do you steer a machine that has nothing at the front to turn?

Warm-up: How could a machine with no wheels go round a curve? _____

1. **Vocabulary.** Tunnel boring machine, thrust cylinders, unbalanced push, line, guidance screen, tolerance: write each in your own words.

2. **The starter.** Push 50 on every side. Ring 20 ended ____ mm off the line, on the ____ side. The limit is ____ mm.
3. **My table.** Left at 50. Right push / mm off at ring 20 / which side. 60: ____ / ____. 70: ____ / ____. 80: ____ / ____. 90: ____ / ____. 100: ____ / ____.

4. **The pattern.** Each 10 more on the right moved the end about ____ mm to the ____ .

1. Why does pushing harder on the right turn the machine left?

2. What do you predict for 30 on the left and 80 on the right? Why?

Exit ticket

Name: _____

1. To turn the machine left, push harder on the: (A) left (B) right (C) top

2. The machine knows where it is underground from: (A) a camera at the front (B) a laser in the tunnel behind it (C) the driver looking out

3. A friend pushes 90 on the right and ends 114 mm left of the line. Use what you learned today to say what to change, and why.

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Exit ticket

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Answer key: exit ticket

QUESTION	ANSWER	WHY
1	B	The right side moves forward more each stroke, so the front swings left.
2	B	A laser fixed in the finished tunnel measures where the head and tail are against the line.
3	Open answer	Make the right push smaller, about 80: each 10 points moved the end about 114 mm, so 10 less brings it back.

Worksheet: what students should find

BLANK	WHAT THE APP SHOWS
The starter	342 mm off (341 right, 15 low), the right side. The limit is 50.
My table	60: 228 right. 70: 114 right. 80: on the line sideways, 15 low, passes. 90: 114 left. 100: 228 left.
The pattern	About 114 mm, to the left.
Question 1	The right side extends further each stroke, so the machine swings left.
Question 2	30 and 80 is a difference of 50, like 50 and 100, so about 228 mm left.

> Every run of Level 2 is the same ground and the same machine, so a push gives the same numbers on any computer. A student whose numbers differ changed something else too.

Rubric

Score each row from 1 to 4.

Name: _____

CRITERIA	4 EXCEEDS	3 MEETS	2 APPROACHING	1 BEGINNING
Steering the machine	Passes the level and explains why pushing harder on the right turns it left.	Passes the level by making the right push bigger.	Changes the push but does not pass, or cannot say which side to change.	Does not change the push.
Testing one variable	Tests five or more pushes, changing only the right, and records the distance and the side each time.	Tests four pushes and records the distance each time.	Tests one or two, or changes more than one number at once.	Does not test.
Finding the pattern	States the pattern with numbers (about 114 mm for each 10) and uses it to predict a push before running it.	States that a bigger right push moves the end further left.	Says some pushes work and some do not, without the pattern.	No pattern.

Total: ____ / 12. A score of 9 or more meets the objectives.

Standards

The lesson is built for MS-PS2-2: an unbalanced push changes the machine's motion, investigated one variable at a time. The simulation is the model of MS-ETS1-4. Steering from a reading every ring, a program with a loop and a condition, is in the high school notes.

FRAMEWORK	CODE	GRADES	STANDARD	HOW THE LESSON MEETS IT
NGSS	**MS-PS2-2**	6-8	Plan an investigation to provide evidence that the change in an object's motion depends on the sum of the forces on the object and the mass of the object.	Students change only the push on one side and record how the machine's path changes, then find that the difference between the sides sets the turn.
NGSS	**MS-ETS1-4**	6-8	Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	The machine is the model; each run generates the data for the next change of the push.

Checked November 2026 against: NGSS MS-PS2-2, Motion and Stability, NGSS: MS-ETS1 Engineering Design.

Optional: save student work in a free class

The whole lesson runs at the link on the worksheet, with no accounts and no sign-up.

To keep students' work, and see it all in one place, make a free class. It takes about ten minutes, once, and covers every lesson in this series: mytekdev.com/tools/class-setup

Students in a class open mytekdev.com/tools/tunnel-boring-lab/lessons/stay-on-the-line-steering-by-thrust/start instead of the worksheet link. Each one gets their own copy of the starter, and the same link reopens it next time.

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