TopEdu

PROJECT 6 INSTRUCTIONS

Why earthquakes pick certain buildings

In 1985 an earthquake spared some Mexico City buildings and destroyed others. Height was part of why.

START HERE

Set up in ten minutes

This project comes with one short Python file, `06_basin_resonance.py`. It solves the project's equation with simple methods you can read line by line, checks itself against an answer that is known exactly, and ends with a list of first experiments. The research is what you do after that.

1. **Install Python 3** from python.org (on a Mac it may already be there: type `python3 --version` in Terminal).
2. **Download the starter** from the project's page, or all ten as a zip from topedu.club/topedu/research/starter-code/.
3. **Install the two libraries** in Terminal (Mac) or PowerShell (Windows):

   ```
   python3 -m pip install numpy matplotlib
   ```

   On Windows, type `py` where this guide says `python3`.
4. **Run it:**

   ```
   python3 06_basin_resonance.py --show
   ```

   The CHECK line must say PASS. `--show` opens the plots; without it they are saved in the `output` folder.

No computer of your own? Google Colab works in a browser for free: open a new notebook, upload the file with the folder icon on the left, and run `!python 06_basin_resonance.py` in a cell.

The rules that make it research

- **Predict before you run.** Write your guess, and why, in your log first. A wrong prediction you can explain is worth more than a right one you cannot.
- **Keep a log.** Date, what you changed, what you expected, what happened. Your paper is written from it.
- **Check the grid.** Run your key result again with twice the points. If the answer moves, report by how much.
- **Never edit the CHECK to make it pass.** A FAIL after your change is information: undo, confirm PASS, then change one thing at a time.
- **Own every line.** Your mentor explains; you write and run. Name everyone and everything that helped, including this starter.

The full guide, with all ten projects and five numerical ideas the starters use, is at topedu.club/topedu/research/starter-code/.

PROJECT 6 · EARTHQUAKE SCIENCE

Why earthquakes pick certain buildings

In 1985 an earthquake spared some Mexico City buildings and destroyed others. Height was part of why.

FILE	MATH	YOU NEED
`06_basin_resonance.py`	Algebra II, trigonometry	A laptop and published seismic data

The question

Soft sediment over rock traps seismic waves at a natural period. How do depth, width and wave speed set that period, and when does the quick estimate T = 4H/c stop being good enough?

Objectives

Weeks 1 to 3	**Learn to trust the model.** Run 06_basin_resonance.py until its CHECK line says PASS, and explain every line of it to your mentor. Then reproduce a known answer: Modes satisfy $\omega^2 = c^2\pi^2(m^2/W^2 + (n - ½)^2/H^2)$. Checkpoint: you reproduce a known answer and report how close you got.
Weeks 4 and 5	**Ask your own question.** Narrow the question above to one sentence that could turn out to be wrong, and write your prediction before you run anything. The first experiments below are a place to start. Checkpoint: a one-page plan with your question and prediction.
Weeks 6 to 9	**Run it, then measure the world.** Model a basin cross-section with rock on three sides and a free surface on top, measure its period over many shapes, then map the error of the quick estimate. Then step away from the screen: compare with the well-documented 1985 Mexico City lakebed, where shaking near a 2-second period damaged mid-height buildings; compare with published data for another basin. Checkpoint: one chart comparing your model with reality.
Weeks 10 to 12	**Explain the gap, and share it.** Work out why your model and your measurements disagree, test at least one explanation, and write it up yourself. Say which numbers came from the starter and which from the lab. Keep the honest limit in view: wave speed is the same everywhere and the basin is a rectangle, so this is a first-order explanation and not a hazard estimate. Do not present it as a prediction for a real place. Checkpoint: a final paper, your code and a ten-minute talk.

The model in the starter

A valley of soft sediment sits in rock. Shear waves bounce between the rock walls and floor and the free ground surface, so the valley rings at a natural period. Buildings whose own sway period is close to it shake hardest.

This model is a rectangle W wide and H deep. Ground motion u obeys the wave equation with u = 0 at the rock (the two sides and the floor) and no stress at the surface. Its slowest ring has period T = 2 pi / omega, omega = c pi sqrt(1/W^2 + 1/(2H)^2). Engineers' quick estimate ignores the width: T = 4H / c.

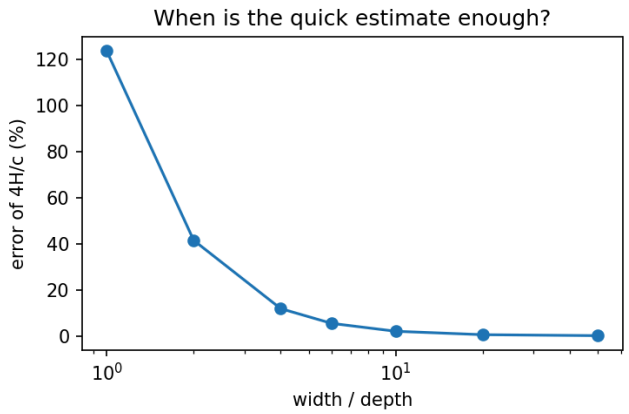
What the starter does

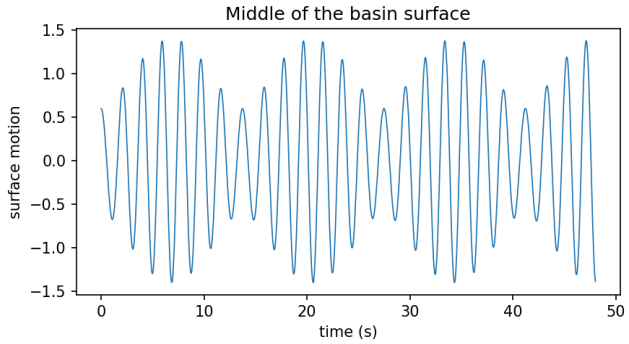
- Stage 1: run this file. It shakes the basin, listens at the middle of the surface, and checks the period it hears against the exact one. The CHECK line should say PASS.
- Stage 2: map where the quick estimate is good enough, and compare with a real, documented basin.

What you should see

Run `python3 06_basin_resonance.py`. This is the output from the run that built this guide. The numbers that depend on your computer's speed may differ; the CHECK line must say PASS.

```
basin 400 m wide, 40 m deep, c = 80 m/s
simulated period 1.961 s, exact 1.961 s, quick estimate 4H/c = 2.000 s
CHECK period against the exact formula: error 0.01% -> PASS (limit 1%)
  width/depth   1: 4H/c is off by 123.6%
  width/depth   2: 4H/c is off by  41.4%
  width/depth   4: 4H/c is off by  11.8%
  width/depth   6: 4H/c is off by   5.4%
  width/depth  10: 4H/c is off by   2.0%
  width/depth  20: 4H/c is off by   0.5%
  width/depth  50: 4H/c is off by   0.1%
```





Your first experiments

From the YOUR TURN list at the bottom of the file. Write your prediction in your log *before* you run each one.

1. Before running: at what width/depth does 4H/c reach 10% error? Read it off the plot and check with simulate().
2. The formula assumes a rectangle. Make the floor slope (set u = 0 below a slanted line each step) and see how the period moves. Explain why.

3. Mexico City, 1985: look up published lakebed depth and shear wave speed. Does the model's period come near the roughly 2 s that damaged mid-height buildings? Say clearly that this explains, and does not predict.
4. Rule of thumb: a building's sway period is about 0.1 s per storey. Which heights match your basin?

The data

Settings in the online lab

Setting	Range	Starts at
Basin width	100 to 2000 m	400
Sediment depth	20 to 100 m	40
Shear wave speed	50 to 400 m/s	80

Checked on the research solver

Solver (Wave, 2D)	fundamental period 1.962 s
Known answer	exact 1.961 s; quick estimate 4H/c = 2.000 s
Error	0.04% (limit 1.00%): passed

The real world

Compare with the well-documented 1985 Mexico City lakebed, where shaking near a 2-second period damaged mid-height buildings; compare with published data for another basin.

The honest limit

Wave speed is the same everywhere and the basin is a rectangle, so this is a first-order explanation and not a hazard estimate. Do not present it as a prediction for a real place.

How the full project checks itself: Modes satisfy $\omega^2 = c^2\pi^2(m^2/W^2 + (n - ½)^2/H^2)$. The online lab runs the same project on the research solver (Wave, 2D).

REFERENCE

When something goes wrong

You see	Try this
`No module named numpy`	Run the install line again with the same Python you use to run the file: `python3 -m pip install -r requirements.txt`
Numbers become nan or huge	A time step is past its speed limit, usually after you made the grid finer. Each solver works out its step from the grid; check you did not fix it by hand.
`did not settle`	An iterative solver needs more sweeps for a finer grid. Raise its limit, or keep the grid smaller while you explore.
A CHECK line says FAIL after your change	Good: your change moved the model away from the case with a known answer. Undo it, confirm PASS, then change one thing at a time.
No window opens	Add `--show`, or open the PNG files in the `output` folder.
A recording gives strange notes	Record in a quiet room, save as .wav (not .m4a), trim silence at the start, and set the note you expect in the file.

How the starters relate to the online lab

The online lab, for members, runs each project on the research solver (AutoSBPSAT): high-order SBP-SAT methods, the full 3D elasticity for project 9, and frames of a time series. The starters use plain second-order methods instead, so every line is short enough to read. Both are checked against the same kind of exact answers. Use the starter to understand and to explore quickly; use the lab for results you will quote, and say in your paper which one produced each number.

How these starters were checked

Every number in "What you should see" came from running the starter while this guide was built, on Python 3.9.23, numpy 1.24.4, matplotlib 3.5.2. `check_all.py` also feeds each optional data reader (the soil-station CSV, the ruler CSV and two .wav recordings) a made-up file with a known answer, and confirms the answer comes back. They have not yet been used by a student. The twelve-week plan and the time estimates in it are a design, to be revised after the first group: tell your mentor what was unclear.