

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING

CHAPTER 5/LAB-5: Engineering Lab (3 Hours)



Slide to the Target

Newton-Raphson on a steel beam — where must the load hang so the tip deflects exactly 10 mm?

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Problem

›

Model

›

Compute

›

Analyze

›

Validate

›

Improve

Today a clamped steel bar and a sliding mass perform Newton-Raphson — and the beam judges the model
by Taner & Sebnem Onsay,

Slide to the Target

What is this lab about? Newton-Raphson with a steel beam — validate the deflection model with 1, 2, 3 masses at the free end (Cases 1–3), commit a start, then physically march the load $a_0 \rightarrow a_1 \rightarrow a_2 \rightarrow \dots$ as the tip deflection δ walks to the 10-mm target; then Case 4 asks whether the beam agrees:

Measure $\rightarrow$ Validate $\rightarrow$ Write $\rightarrow$ March $\rightarrow$ Trust $\rightarrow$ Compare $\rightarrow$ Decide (DO $\rightarrow$ OBSERVE $\rightarrow$ RECORD $\rightarrow$ TALK TO AI $\rightarrow$ EVALUATE $\rightarrow$ DECIDE ...)

LEARNING OBJECTIVES By the end of this lab, you will be able to:

Measure a beam and its loads to the resolution the model needs (t^3)

Validate a model before it drives anything — predict, measure, compare

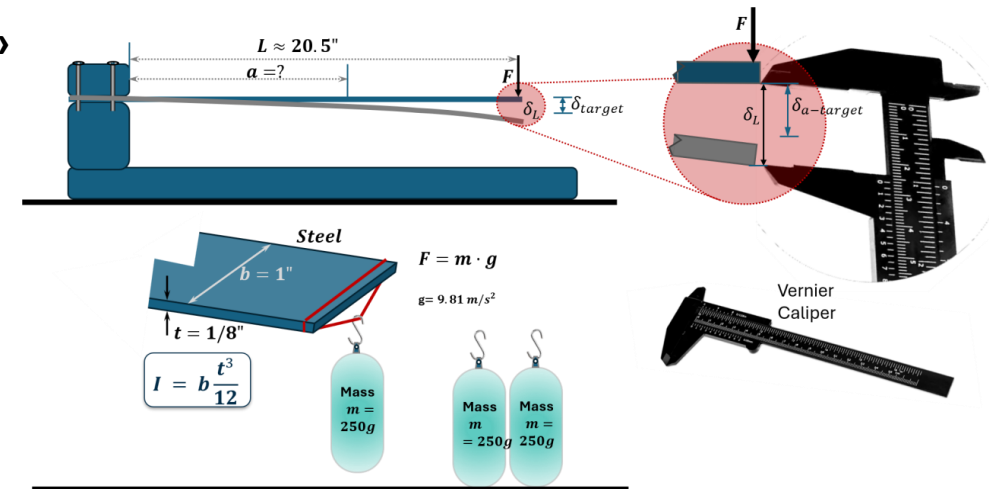
Write a target as $f(a) = 0$ with its derivative — both with physical meaning

Perform Newton-Raphson physically: compute, slide, settle, measure h , record

Stop on a criterion tied to the tolerance and the instrument — never a count

Separate numerical convergence from validation — and compare with bisection

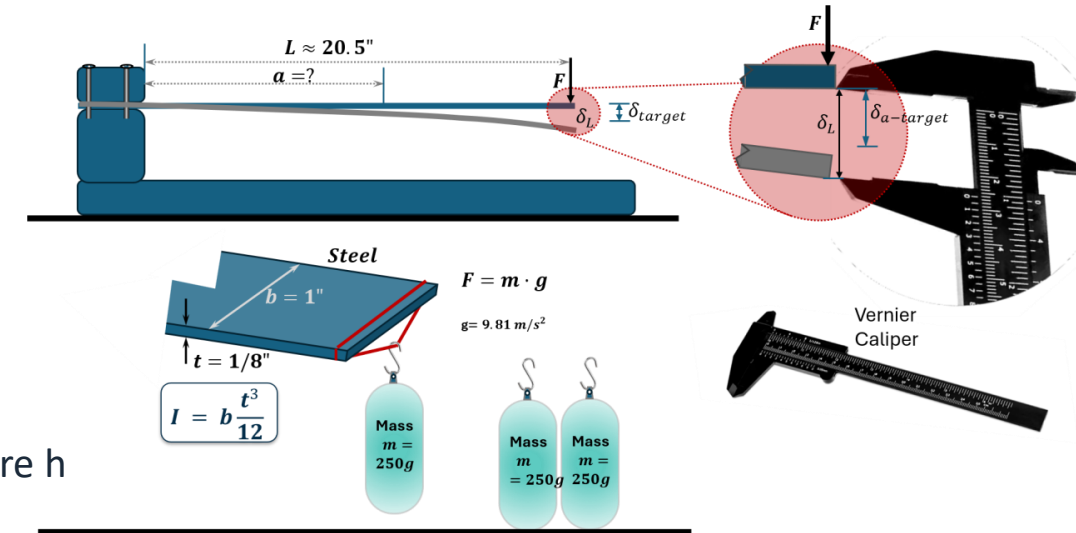
- TOOLS YOU WILL USE
- Clamped steel bar + three 250-g masses on a sliding loop + a fixed datum under the tip
- Vernier caliper + scale — dimensions, masses, tip heights h from the fixed datum ($\delta = h_0 - h$)
- Excel + Python / Jupyter — the model, the Newton loop, bisection
- AI assistant — may propose start, slope, stop; you attack all three
- Your engineering judgment — validate, commit, stop, decide





What you will do (step-by-step):

- 1 Readiness quiz — then verify Excel, Python, AI workspace
- 2 Meet the kit · the rules · safety briefing · roles
- 3 Commit predictions P1–P4 — before any mass is hung
- 4 MEASURE IT — L, b, t · every mass on the scale · Case 0: h_0
- 5 VALIDATE IT — Cases 1–3: 1, 2, 3 masses at $a = L$ · predict δ , measure h
- 6 WRITE IT — $\delta_{\text{model}}(a)$, $f(a) = \delta_{\text{model}}(a) - \delta_{\text{target}}$, $f'(a)$ · sign · domain
- 7 COMMIT a_0 — with a reason · first step by hand · tol_a from 10 ± 1 mm
- 8 MARCH IT — compute · slide · settle · read h · record · until $|\Delta a| \leq \text{tol}_a$
- 9 TRUST IT — Case 4: δ_a in 9–11 mm? · COMPARE IT · BREAK THE AI
- 10 Final certified statement · record → report · human review, then sign



Would you sign a load position because the loop printed “converged”? You will sign one today — after the beam has had its say.

MEASURE › VALIDATE › MARCH › TRUST

THE BEAM JUDGES

In Chapter 5 the AI role advances — the analyst becomes a CRITIC you argue with — while you remain the lead engineer: the measurements, the validated model, the start, the stop, the verdict on the beam, and the decision stay yours.

THE RECURRING LOOP — INSIDE PROBLEM › MODEL › COMPUTE › ANALYZE › VALIDATE › IMPROVE

DO

OBSERVE

RECORD

TALK TO AI

EVALUATE

DECIDE

... and back to DO — the conversation evolves as the experiment evolves.



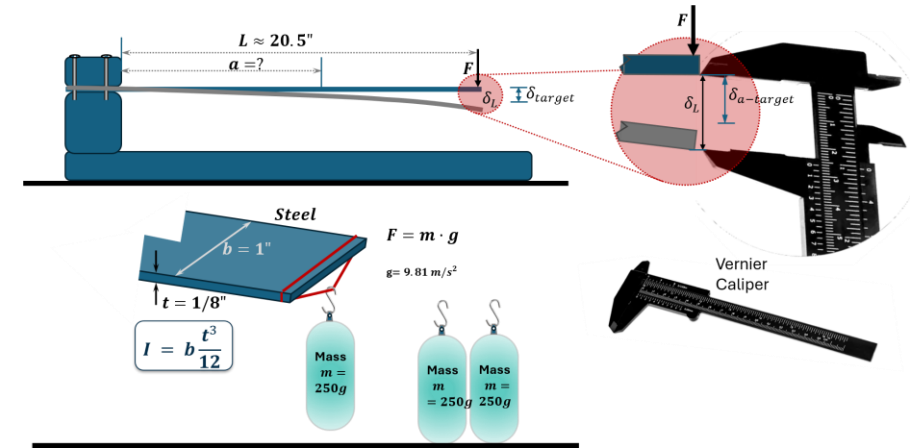
You, not AI: measure and log everything; validate the model first; commit and justify a_0 ; compute each step from the MODEL and slide the load yourself; stop on the criterion; verdict every AI claim — ACCEPT · MODIFY · REJECT — sign.



AI, for you: the derivative checked against yours, the Newton loop you specified, checks of your hand step, a bisection run on the same f , a comparison table — on the evidence you provide.

AI assists. Humans verify. Engineers decide — and the beam judges.

Never feed a measured deflection $\delta = h_0 - h$ into the Newton formula. Newton follows the MODEL; the measurements sit beside it as evidence. Mixing them is a different algorithm.





AI as engineering critic — who does what in Chapter 5



HUMAN TEAM — LEAD ENGINEER

- Own the measurements, the validated model, and the march log
- Perform every measurement, every slide of the load, every tip-height reading — honestly
- Write $f(a) = 0$ and $f'(a)$ — and own what each sign and each unit means
- Commit and justify a_0 from the physics — before the first slide
- Derive the stopping criterion from the 10 ± 1 mm requirement and the caliper
- Keep every iterate inside $0 < a < L$ · compute the step from the MODEL only
- Verdict: did the beam agree? — choose the method, defend it, sign



AI — ENGINEERING ANALYST TURNING CRITIC

- Differentiate $\delta_model(a)$ — and show its derivative for YOUR check
- Implement the Newton loop you specified — Excel or Python, with guards
- Check your hand step and your unit conversions against its own
- Run bisection on the same f and tabulate the comparison
- Propose a starting position — with a reason you can attack
- Construct a failing start for you to diagnose — the critic's job
- Draft report text from your evidence — never the verdict on the beam

A critic you argue with, the same constitution. A proposal arrives with its reasons attached — or it goes back.



Create your AI workspace — the engineering record

ONE WORKSPACE · “LAB-5 — SLIDE TO THE TARGET”

- Lab instructions + report template
- Measurement log · L , b , t , masses · caliper and scale resolution
- Predictions P1–P4 (committed) · validation table (Cases 0–3: $h_0, h_1, h_2, h_3 \rightarrow \delta$)
- Model: I , $\delta_{\text{model}}(a)$, $f(a)$, $f'(a)$ · hand check · committed a_0
- March log · every step: δ_{model} beside the measured $\delta = h_0 - h$
- Stopping criterion · a^* · Case 4: δ_a inside 9–11 mm? · bisection comparison
- BREAK THE AI findings · your verdicts · the decision

The record documents what happened.

The report communicates what matters.

Feed the record as you go — don't reconstruct it at 2:45.

STARTER PROMPTS

PROMPT-1 “Here are the corresponding lecture notes, lab instructions and the lab report template. Just read them for later reference and wait for my command.”
(drop or attach PDF versions of all 3 documents right into this chat)

PROMPT-2 “You are our AI engineering critic for the LAB-5 Slide to the Target Newton-Raphson laboratory. We are the lead engineers. You may differentiate our model, implement the Newton loop and the bisection we specify, check our arithmetic and units, propose a starting position with reasons, and construct failing cases for us to diagnose — but every proposal must arrive with its reasoning, and every convergence claim must say what it does NOT certify. Never change our measured values, the 10 ± 1 mm target, or our units without flagging the change explicitly. Never invent measurements or material properties, never feed a measured deflection ($\delta = h_0 - h$) into the Newton formula, and never declare that the beam WILL land inside 9–11 mm — the beam decides that, and we record it. This workspace is the engineering record for our final report.”

Any capable AI platform works — a project/workspace feature (e.g., ChatGPT Projects) is convenient, but one persistent conversation is enough.



Validate first — then let the model drive

0:00–0:10		Phase 0 · Readiness quiz + verify Individual quiz — concepts, not calculation · Excel, Python, AI workspace proven working.
0:10–0:20		Phase 1 · Kit · rules · safety · the question Clamped bar, masses, caliper, fixed datum · Cases 0–4 · 10 ± 1 mm target · roles · hands clear.
0:20–0:30		Phase 2 · Commit predictions P1–P4 δ_1 for one mass at the free end · 1 : 2 : 3 scaling · slides to converge · will δ_a land in 9–11 mm — unedited.
0:30–0:45		Phase 3 · MEASURE IT L, b, t (three readings each) · every mass on the scale · Case 0: h_0 from the datum · resolution recorded.
0:45–1:05		Phase 4 · STAGE A — VALIDATE THE MODEL Cases 1–3: 1, 2, 3 masses at $a = L$ · predict $\delta_{\text{model}} \rightarrow$ read $h \rightarrow \delta = h_0 - h \rightarrow$ compare.
1:05–1:30		Phase 5 · STAGE B — WRITE IT + COMMIT a_0 F fixed, a unknown · $f(a) = \delta_{\text{model}}(a) - 10$ mm, $f'(a)$ · sign · domain · a_0 justified · tol_a .
1:30–2:05		Phase 6 · MARCH IT — NEWTON ON THE BEAM Compute from the model · slide · settle · read h · record $\delta = h_0 - h$ — until $ \Delta a \leq \text{tol}_a$.
2:05–2:20		Phase 7 · TRUST IT Case 4: $\delta_a = h_0 - h_a$ inside 9–11 mm? · sort the gap by source · what convergence certifies.
2:20–2:35		Phase 8 · COMPARE IT — BISECTION Bisection on the same f from $[0, L]$ · evaluations · information · containment vs speed.
2:35–2:50		Phase 9 · BREAK THE AI Audit a “converged, therefore the beam will give 10 mm” claim · rewrite it.
2:50–3:00		Phase 10 · Certify · record · sign Final certified statement · evidence complete · human review — then sign.



Stations & logistics — parallel beams, one comparison

EACH STATION'S KIT — NOMINALLY IDENTICAL

**Mild-steel flat bar, 24 in nominal, ≈ 1 in $\times$ 1/8 in**

Clamped over ≈ 3 –4 in, ≈ 20.5 in free. YOU measure L , b and t — nominal is not data.

**Three nominal 250-g masses on a short sliding loop**

The loop is the movable point load. Every mass is weighed; the hook counts in F .

**Vernier caliper · scale · fixed base (datum) under the free end**

The caliper measures b , t — and every tip HEIGHT h from the datum. Target: $\delta = 10 \pm 1$ mm (slide 12); E is posted in Phase 4.

**March log sheet + team laptops**

Printed log, one per team · Excel · Python/Jupyter · AI assistant.

TEAM RULES

- Rotate roles: slider · caliper reader · recorder · computing engineer (announces a_{n+1}).
- Everyone slides at least once; everyone reads the caliper at least once.
- One engineering record per team — team number, members, date, station at the top NOW.
- Masses hang low over the bench; never more than three masses.

EXPERIMENTAL DESIGN: every station marches Newton on the SAME kit toward the same 10 ± 1 mm target — one class comparison.



Safety & conduct — a loaded steel bar stores energy



SAFETY — CLAMP, MASSES, HANDS

- Check the clamp before the first mass — a bar that slips in the clamp is a projectile
- Hang and slide masses GENTLY — no dropping, no bouncing, no plucking the beam
- Hands clear of the free end while a mass is being hung or slid — the tip moves
- Keep masses low over the bench; nothing under the beam but the bench
- Never exceed three masses; never stand the caliper on the beam edge



HONEST DATA

- Start the log row BEFORE the masses move — a_n , $\delta_{\text{model}}(a_n)$, f , f' , a_{n+1} ; then the measurement h
- Every tip height h is recorded as read, to the caliper resolution — never rounded toward the target
- The measured $\delta = h_0 - h$ is NEVER fed into the Newton formula — the model drives, the beam judges
- A slide to a position that is not on the bar is a finding, recorded, never faked
- Rejected AI advice belongs IN the record, with your verdict

Fast is nothing without a validated model, a computed step, an honest reading, and a safe bench. The record is the deliverable.



Readiness check — concepts, not calculation



READINESS QUIZ

- ☐ 5 questions · 5 minutes
- ☐ Individual · closed notes · no AI
- ☐ Collected before any mass is hung



EXCEL + PYTHON

- ☐ Excel opens and computes
- ☐ Notebook runs a test cell
- ☐ You can interrupt the kernel



AI WORKSPACE

- ☐ “LAB-5” workspace created
- ☐ Starter prompts pasted
- ☐ Instructions + template uploaded



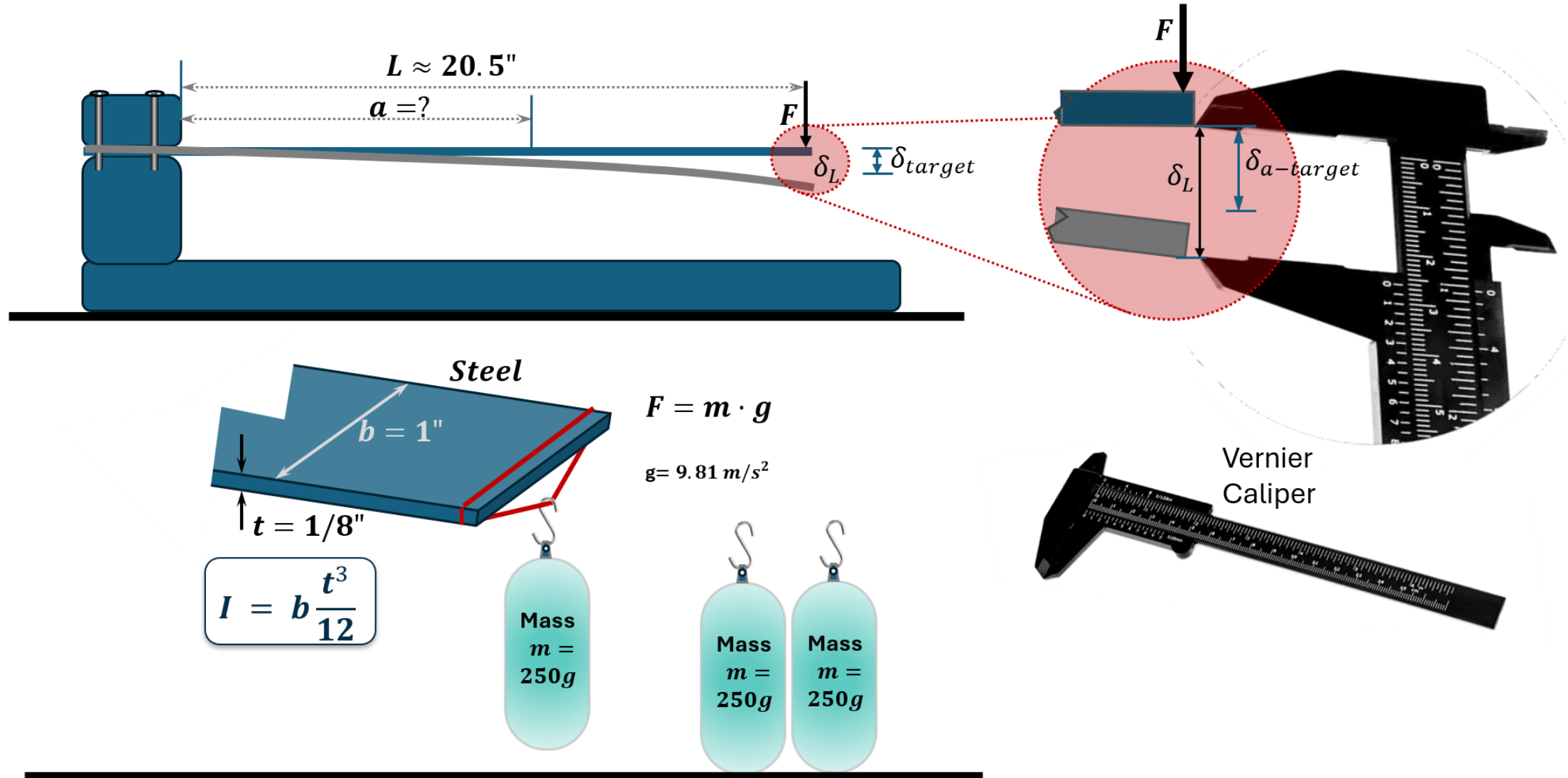
If something is broken

- Ask your instructor/lab facilitator for help — don't burn 40 minutes alone
- Paste the exact error into AI and ask what it means (often faster than you'd think)
- Keep your team moving on one working machine meanwhile

*All nine green? CHECKPOINT ① — the TA reviews quiz answers before the measurements start.
Experienced with another IDE? Fine — as long as you can run and modify a notebook and support yourself.*

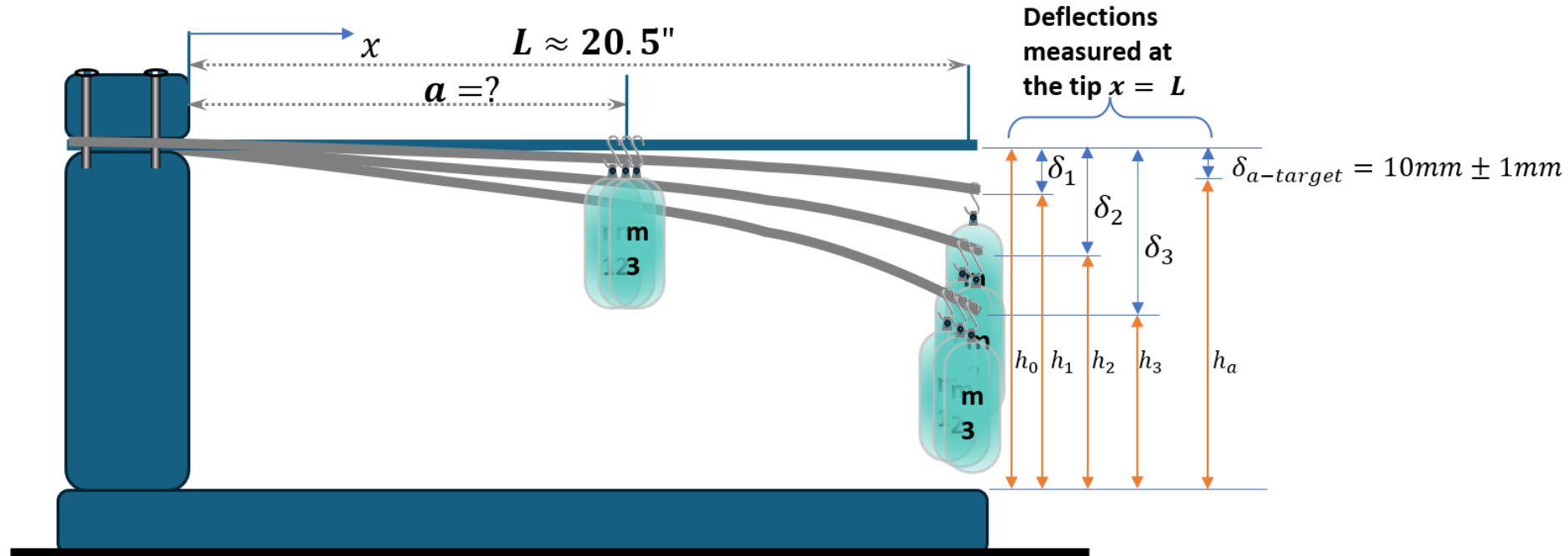


The experimental setup — L , a , F and the tip measurement





The Experimental Setup and summary of test cases:



CASE 0 — BASELINE

No mass attached. Measure and record the unloaded tip position, y_0 . This is the reference position for all deflection measurements.

CASE 1 — ONE MASS $\delta_1 = h_0 - h_1$ (single mass @ the tip)

Place one mass, m_1 , at the free end. Allow the beam to settle. Measure and record the tip deflection, y_1 .

CASE 2 — TWO MASSES $\delta_2 = h_0 - h_2$ (two masses @ the tip)

Place two masses, $m_1 + m_2$, at the free end. Allow the beam to settle. Measure and record the tip deflection, y_2 .

CASE 3 — THREE MASSES $\delta_3 = h_0 - h_3$ (three masses @ the tip)

Place all three masses, $m_1 + m_2 + m_3$, at the free end. Allow the beam to settle. Measure and record the tip deflection, y_3 .

CASE 4 — HIT THE TARGET $\delta_{a-target} = h_0 - h_a$ (find $x=a$, to park the three masses while still measuring the tip deflection h_a)

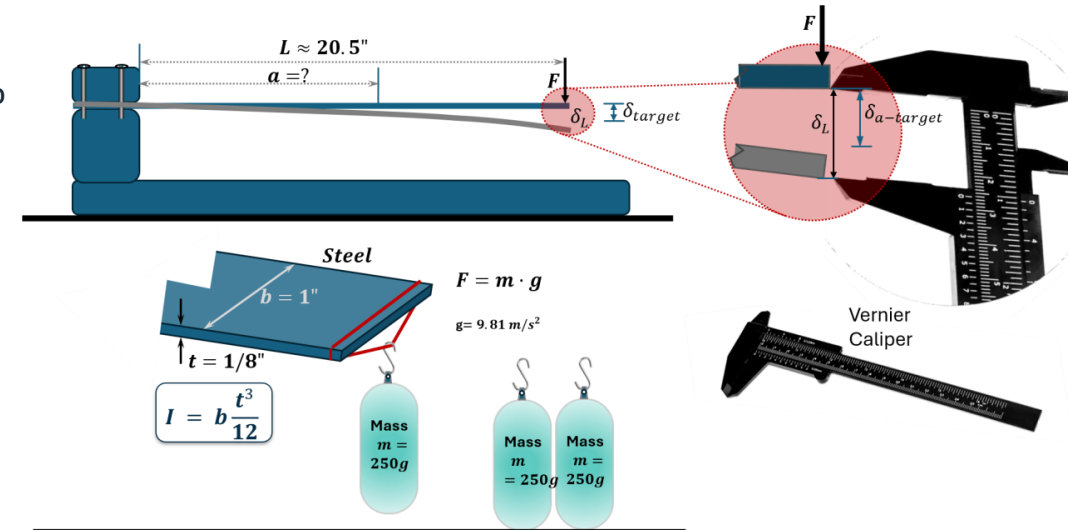
Keep all three masses attached. Use Newton-Raphson to determine the load position a^* . Move the three-mass load to a^* , allow the beam to settle, and measure the actual tip deflection.

TARGET: Success zone: $9.0 \leq \delta_{a-target} \leq 11.0\text{mm}$. Or stated based on h_0 : $(h_0 - 11.0) \leq h_a \leq (h_0 - 9.0)$



The rules of the march — identical at every station

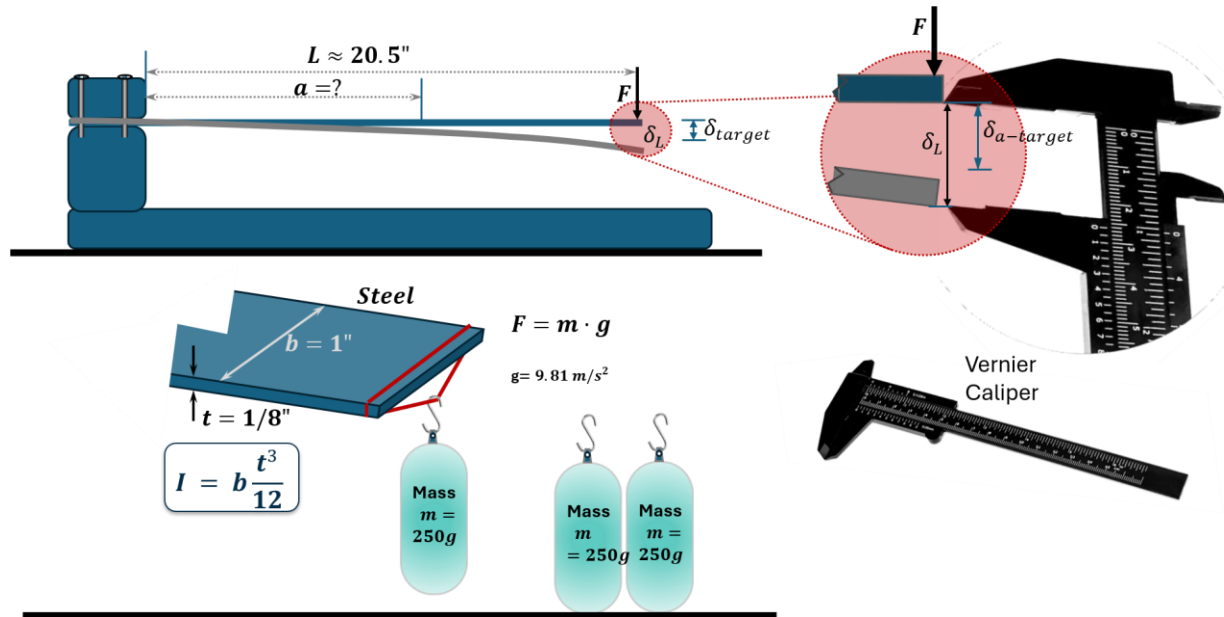
- 1 Free length L : clamp face to tip — YOUR measurement, not the label
- 2 Positions a : clamp face to the centre of the sliding loop
- 3 MEASURE IT first: b, t, L ($\times 3$ readings) · every mass weighed · Case 0: h_0
- 4 VALIDATE IT: Cases 1–3 — 1, 2, 3 masses at $a = L$ · predict δ , read h
- 5 TARGET: $\delta = 10$ mm, zone 9–11 mm (slide 12) · E posted in Phase 4
- 6 COMMIT a_0 in writing, with a reason, before the first slide
- 7 Each step: a_{n+1} from the MODEL · slide · settle · read the tip height h
- 8 δ_{model} beside $\delta = h_0 - h$ — the measurement never enters the formula
- 9 STOP when $|a_{n+1} - a_n| \leq \text{tol}_a$ — never on a count; off the bar = a finding
- 10 Success = validated model + computed steps + honest readings + a stop



Why so strict? The rules ARE the algorithm: validated model, justified start, step from the model, physical move, observation beside it, a stopping decision. Feed the measurement into the formula and you are no longer marching Newton.



A steel bar, a sliding load — and a deflection the tip must reach



FIND: the load position a where the tip deflection $\delta_a = h_0 - h_a$ is ~ 10 mm — inside 9–11 mm, with a valid Newton march log

...model, then slide, then read h . Target 10 mm; acceptance 9–11 mm.

The parallel: compute $\rightarrow$ slide $\rightarrow$ settle $\rightarrow$ measure $\rightarrow$ repeat
Chapter 4 halved a bracket. Chapter 5: the slope says where to go next — the beam says whether the model was right.

Assumptions go in the record — including these:

TALK TO YOUR AI TEAMMATE “Log our setup: clamped flat bar, free length L measured by us, three masses on a sliding loop, tip heights h from a fixed datum ($\delta = h_0 - h$); a from the clamp face; target 10 ± 1 mm.”

ENGINEER DECIDES a POINT load and a RIGID clamp are MODELING choices — state them; the beam will test them.



Predict — in writing, right now

1

P1 — δ_1 for ONE mass at the free end (Case 1)

In millimetres, from the nominal bar and one 250-g mass at $a = L$ — before any measurement. Wrong is fine; uncommitted is not.

2

P2 — Linear scaling with load

With two and three masses (Cases 2, 3), will δ_2 and δ_3 be $2\times$ and $3\times \delta_1$ — exactly, roughly, or not? Commit a ratio and a reason.

3

P3 — Slides to the target

Once a_0 is committed: how many physical slides until the correction is below tol_a ? Commit a number.

4

P4 — Will the beam land inside 9–11 mm at a^* ?

When Newton stops and the three masses sit at a^* , will $\delta_a = h_0 - h_a$ be inside $9 \leq \delta_a \leq 11$ mm? YES / NO — if NO, less or more than 10 mm, and why.



TALK TO YOUR AI TEAMMATE “Here are our committed predictions P1–P4 — log them. Do not evaluate them yet.”

WHY PREDICT FIRST?

A prediction made after the measurement isn’t a prediction — it’s a story. Committing first is what makes the Phase 4 and Phase 7 comparisons honest — and it is how real validation works.

Predictions go in the record BEFORE the first mass is hung — and are never edited afterward.



ENGINEER DECIDES the numbers you commit are yours — AI logs them, you own them.

Problem



Model



Compute



Analyze



Validate



Improve



Before You Measure It — Trust the Label Once

THE SUPPLIER SAYS

Steel flat bar:

1 in × 1/8 in

For your **NOMINAL** prediction only, accept the supplier dimensions as stated:

$b_{\text{nom}} = 25.4 \text{ mm}$

$t_{\text{nom}} = 3.175 \text{ mm}$

Calculate the nominal prediction.
FREEZE IT. Do not revise it.

THE MODEL CARES ABOUT

$$\delta_{L,(a)} = F \cdot a^2 \cdot \frac{3L - a}{6EI}$$

Area moment of Inertia

$$I = b \frac{t^3}{12}$$

$$\delta \propto \frac{1}{I} \rightarrow \delta \propto \frac{1}{t^3}$$



Small change in $t \rightarrow$ large change in I

THEN MEASURE THE REAL BAR

- 1 Measure b and t with the caliper.
- 2 Calculate I from YOUR measured dimensions.
- 3 Make a second prediction.
- 4 Keep BOTH predictions.

How much are you willing to trust
“1/8 inch”?

ENGINEER DECIDES A supplier specification is information. A measurement is evidence.

Problem



Model



Compute



Analyze



Validate



Improve



Measure the beam and the loads — nominal is not data

1

THE BAR — L , b , t with the caliper

L from the clamp face to the tip (mm). b and t with the caliper at THREE places — all readings and the resolution recorded. t enters as t^3 : a **2 % error in t is a 6 % error in the prediction.**

2

THE LOADS — every mass on the scale

Weigh each mass AND the hook/loop; $F = m \cdot g$ uses the total that actually hangs. Record the scale resolution. “250 g” is a label, not a measurement.

3

THE MODEL’S APPETITE — resolution before computing

One unit system: mm, N, N/mm². Compute $I = b \cdot t^3/12$ with YOUR values (mm⁴). Note which measurement the prediction is most sensitive to — Phase 7 needs it.

THE MEASUREMENT LOG

Quantity · instrument · three readings · mean · resolution — $L, b, t, m_1, m_2, m_3, m_{\text{hook}}$ — and CASE 0: the unloaded tip height h_0 from the fixed datum, the reference for every deflection ($\delta = h_0 - h$). Then I , with units. A model driven by nominal numbers predicts a nominal beam; you have a real one.

Chapter 1 returns: scatter is evidence about instrument and object — record it, don’t average it away.



TALK TO YOUR AI TEAMMATE “Here is our measurement log with resolutions. Compute $I = b \cdot t^3/12$ from our means and check our units; do not change any reading.”



ENGINEER DECIDES which quantity dominates the uncertainty of δ_{model} ? Say it now — t^3 makes it non-obvious.

Problem



Model



Compute



Analyze



Validate



Improve



Every quantity is a row — three readings, a mean, a resolution

Quantity	Symbol	Instrument	Reading 1	Reading 2	Reading 3	Mean · units	Resolution
free length (from clamp face → to tip)	L	tape / rule				____ mm	____ mm
width	b	caliper				____ mm	____ mm
thickness	t	caliper				____ mm	____ mm
masses $m_1 \cdot m_2 \cdot m_3 \cdot \text{hook}$	m	scale				____ kg total	____ g
<i>unloaded tip height — CASE 0 (datum → tip)</i>	h_0	<i>caliper</i>				____ mm	____ mm

One row per quantity — readings BEFORE the mean; the instrument resolution beside it. Then: $F = m_{\text{total}} \cdot g$ [N] · $I = b \cdot t^3 / 12$ [mm⁴] · EI [N·mm²] with the POSTED E .
Units are the classic slip: b, t in mm → I in mm⁴; E in N/mm² → EI in N·mm²; a, L in mm → δ in mm. Heights h are read from the datum; every deflection is a difference, $\delta = h_0 - h$.

Record EVERY reading — including the one that disagrees with the others. Scatter is information about the bar and the instrument.

 **TALK TO YOUR AI TEAMMATE** “Here is our measurement log. Check F, I and EI from our means and units — flag slips; do not replace any reading.”

 **ENGINEER DECIDES** the recorder writes what the caliper shows, to its resolution — nobody rounds toward a nice number.

CHECKPOINT ② — measurement log complete with resolutions, h_0 recorded · F, I, EI computed with units · roles rotating.

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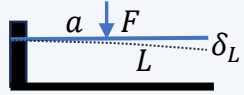
Improve



Cases 1–3: (1,2,3) masses at the free end — predict, measure, compare

THE MODEL YOU ARE TESTING — read it first

1



$$\delta_{L,model(a)} = F \cdot a^2 \cdot \frac{3L - a}{6EI}$$

$$F = mg$$

E: Young's Modulus
I = Area Moment of Inertia
$$I = b \frac{t^3}{12}$$

the static tip deflection for a load F at a from the clamp.

F placed At the free end ($a = L$) it reduces to $\delta_{L,model(L)} = F \cdot \frac{L^3}{3EI}$
Before this model may drive Newton-Raphson, we test whether it predicts OUR beam.

PREDICT, THEN MEASURE — Cases 1, 2, 3 at $a = L$

2

Predict $\delta_{model} = F \cdot L^3 / (3EI)$ for 1, 2, 3 masses with YOUR L, b, t, masses and posted E — units first. Then one mass at the free end, settle, read h_1 ; second, h_2 ; third, h_3 — heights from the datum, to the caliper resolution.

COMPARE — is the model allowed to drive?

3

$\delta_{measured} = h_0 - h$ for each case; difference and % difference against δ_{model} . Do $\delta_1 : \delta_2 : \delta_3$ scale $\approx 1 : 2 : 3$ as the model says? If the model misses by more than the 1 mm you must hit, it is not ready — find out why first.

THE VALIDATION TABLE

case · masses · F (N) · δ_{model} · h (mm) · $\delta_{measured} = h_0 - h$ · difference · % — three rows, plus the ratios δ_2/δ_1 and δ_3/δ_1 . A model earns the right to drive Newton here, or it does not. (Nominal bar, $a = L$: 7.9 · 15.8 · 23.7 mm — ILLUSTRATIVE, NOT LAB DATA.)

Chapter 1: model, experiment and AI may disagree. The engineer decides — with the numbers in hand.

TALK TO YOUR AI TEAMMATE “Here are our heights h_0 – h_3 for Cases 0–3 at the free end and our predictions. Compute $\delta = h_0 - h$, the differences and load ratios; list plausible sources of a systematic gap — do not adjust our model.”

ENGINEER DECIDES a systematic gap (all three the same sign) is a bias — name its likely source before you march.

Problem



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Improve



$\delta_{target} = 10$ mm, zone 9–11 mm — may the model drive?

1

The specification — and the posted value

$\delta_{target} = 10$ mm · zone $9 \leq \delta_a \leq 11$ mm — the same at every station (slide 12). $E = \underline{\hspace{2cm}}$ N/mm² — INSTRUCTOR/PROTOTYPE VALUE posted for your station. Copy them into the record, with units.

2

Fill the validation table

case | masses | F | δ_{model} | h | $\delta_{measured} = h_o - h$ | difference | % — one row per case; ratios δ_2/δ_1 , δ_3/δ_1 . Within 1 mm at every load? Any systematic bias?

3

Revisit P1 and P2 — honestly

δ_1 for one mass: what did the evidence say about P1? Linear scaling: about P2? Answer in the record; never edit the originals.

REACHABILITY CHECK

Is $\delta_{target} = 10$ mm reachable? The most three masses can bend the tip is $\delta_{model}(L)$ — your Case 3 prediction, checked by your measured δ_3 . If 10 mm $> \delta_3$, no position on the bar solves $f(a) = 0$ — say so now. Chapter 4's cage question, again.

A posted E is a REFERENCE, not the truth — Chapter 3's naming. Your validation table says how good it is.



TALK TO YOUR AI TEAMMATE

"Here are the posted E, the 10 ± 1 mm target and our validation table. Check the % differences and whether 10 mm $<$ our δ_3 ."



ENGINEER DECIDES 10 mm and the 9–11 mm zone are the specification — they own the stop in Phase 6 and the verdict in Phase 7.

Problem



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Stage B — the same model, a new unknown

The tip deflection model:



$$\delta_L(a) = F \cdot a^2 \cdot \frac{(3L - a)}{(6 \cdot E \cdot I)}, \quad I = b \cdot t^3 / 12$$

Three masses stay on $\rightarrow F = mg$ is **fixed**, Load position $\rightarrow a$ is **the unknown**,
Turn the target into $f(a) = 0$:

$$f(a) = \delta_L(a) - \delta_{L-target}, \quad f(a^*) = 0$$

Task: Find $x = a^*$ which will locate the force to yield target tip deflection



The slope:

$$f'(a) = F \cdot a \cdot \frac{(2L - a)}{(2 \cdot E \cdot I)}$$

—millimetres of tip deflection per millimetre of load position



Hand-check **ONE** point — $\delta_L(L)$ with three masses, on paper: it must reproduce your Case 3 prediction



Then write it: $f(a) = \delta_L(a) - \delta_{target} \rightarrow$ the load position where the model gives 10 mm is the **ROOT**

$\delta_{L-target} = 10 \text{ mm}$ · the sign of f carries the meaning · domain $0 < a$

WHAT THE MODEL LEAVES OUT

- A perfectly rigid clamp · a true point load · a straight, uniform bar.
- Your caliper: $\pm 0.02 \text{ mm}$ on t , and δ goes like $1/t^3$.
- E as posted — one number for a whole bar of “mild steel”.
- Small-deflection theory — adequate at these deflections; not a law.

A model this simple can still be **USEFUL** — Phase 4 said how useful. Phase 7 tests it again, at the root.

ILLUSTRATIVE — DO NOT USE AS YOUR LAB DATA: $b = 25.4$, $t = 3.175$, $L = 508 \text{ mm}$, $E = 200 \text{ GPa}$, $F = 7.36 \text{ N} \rightarrow I = 67.7 \text{ mm}^4$, $\delta_{\text{model}}(L) = 23.7 \text{ mm}$

Problem



Model



Compute



Analyze



Validate



Improve



Python — the model gets a name, then f and f'

WORKING METHOD — YOUR MEASUREMENTS DRIVE THE CODE

- AI may coach the code; the MEASUREMENTS and the posted E stay yours
- `delta_model(L)` must reproduce your hand check and your Case 3 prediction
- Units: mm, N, N/mm² — one system, no conversions inside the loop
- `f(a) = delta_model(a) - delta_target` — `delta_target = 10.0` mm is the specification
- `fprime(a)` checked at one point against your hand value
- Same signatures everywhere — the Phase 6 loop calls f and fprime

Three small functions is right-sized.

A model, the question, and its slope — all testable.

If the hand check and `delta_model()` disagree, the code is wrong or the arithmetic is — find out which before anything is built on it.

THE CODE

```
import math
# YOUR measurements go here (illustrative values shown - DO NOT
USE AS LAB DATA):
b, t, L = 25.4, 3.175, 508.0      # mm (caliper / tape)
m = 0.750                        # kg (three masses, scale)
E = 200e3                        # N/mm^2 - INSTRUCTOR VALUE
g = 9.81
F = m * g                        # N - fixed: three masses
stay on
I = b * t**3 / 12                # mm^4 - t enters as t^3
delta_target = 10.0             # mm - the specification
def delta_model(a):              # tip deflection (mm), load at
    a (mm)
    return F * a*a * (3*L - a) / (6 * E * I)
def f(a):                        # f(a) = 0 where the model
    gives 10 mm
    return delta_model(a) - delta_target
def fprime(a):                   # slope: mm of deflection per
    mm of position
    return F * a * (2*L - a) / (2 * E * I)
print(I, delta_model(L), delta_model(L)/3) # check: I, Case 3,
Case 1
67.74600026041666 23.729385826771654 7.909795275590551
```

The printed values are the real output of this program for the ILLUSTRATIVE values — yours will differ. Same signatures in the Phase 6 loop.



Three signs, three physical situations — and a slope with units

THE SHAPE OF THE QUESTION

$$f(a) = \delta_{\text{model}}(a) - \delta_{\text{target}}$$

[mm]

$f(a) < 0 \rightarrow$ the tip deflects LESS than 10 mm: the load is too close to the clamp

$f(a) = 0 \rightarrow$ THE TARGET, $\delta_{\text{model}} = 10$ mm: the root the decision cares about

$f(a) > 0 \rightarrow$ the tip deflects MORE than 10 mm: the load is too far out

The classic gap: reporting $\delta_{\text{model}}(a)$ instead of $f(a)$ — and losing the sign that decides which way to slide.

Zero is not algebraic decoration; it is the 10-mm deflection the tip must reach — LESS / MORE, now in millimetres of a model.

YOUR f STATEMENT MUST CONTAIN:

- ☐ The function AND its derivative, with units on both sides
- ☐ What each sign means for THIS beam
- ☐ Where δ_{target} (the 10-mm specification) and E (posted) came from — given, not chosen
- ☐ Two evaluated values of f — positions and signs
- ☐ The physical domain $0 < a < L$ — and why $a_0 = 0$ fails
- ☐ One sentence: what f' means physically, and its units
- ☐ ...all written BEFORE a_0 is committed

WRITE IT before you COMMIT a_0 — a thousand engineering questions, one mathematical shape: $f(x) = 0$.



Commit the start — then derive the stop

1

Choose a_0 from the physics — and write the reason

Not 0 (no slope), not past L (not on the bar). Defensible: mid-bar, or where your validation data point. Illustrative: $a_0 = L/2$ (NOT LAB DATA).

2

Derive the stop — from 1 mm, through the slope

The requirement is on the DEFLECTION: $\delta_{\text{target}} \pm \text{tol}_\delta = 10 \pm 1$ mm. Through the slope it becomes a position tolerance: $\text{tol}_a \approx \text{tol}_\delta / f'(a)$. A stop below the caliper's resolution buys nothing.

3

Read the fine print

Newton has no bracket. Check every a_{n+1} against $0 < a < L$ BEFORE anyone slides a mass. A stop is “ $|\Delta a| \leq \text{tol}_a$ ” — never “three iterations”.



TALK TO YOUR AI TEAMMATE “Here is our committed a_0 with its reason, the 1-mm tolerance and our f' near the root. Check our tol_a ; do not choose a_0 for us.”

THE CRITERION

$\text{tol}_a = \text{tol}_\delta / f'(a)$. Illustrative: $\text{tol}_\delta = 1$ mm, $f' \approx 0.058$ mm/mm near the root $\rightarrow \text{tol}_a \approx 17$ mm (NOT LAB DATA). Want margin for model bias? Choose a tighter tol_δ — and say so in the record.

Stop because the requirement is satisfied — not because a count was reached. Then validate.



ENGINEER DECIDES a teammate proposes $a_0 = 0$ “because it is simple”? Ask what $f'(0)$ is.

Problem



Model



Compute



Analyze



Validate



Improve

No AI, no Python, no Excel — the exam rep

n	a_n (mm)	$\delta_L(a_n)$ (mm)	$f(a_n)$ (mm)	$f'(a_n)$	correction (mm)	a_{n+1} (mm)
0	your a_0	fill in	fill in	fill in	fill in	fill in
1	fill in	fill in	fill in	fill in	fill in	fill in
...	...	...	...	...	...	...

Row 0: $\delta_model(a_0) \rightarrow f(a_0)$ and its sign $\rightarrow f'(a_0) \rightarrow \text{correction} = -f/f' \rightarrow a_1 = a_0 + \text{correction} \rightarrow$ on the bar? Row 1 the same at a_1 — as many rows as the criterion demands. The only judgment per row: is the correction still larger than tol_a ?

PREDICT first: is the first correction toward the tip or the clamp — and how large? (Illustrative, $a_0 = 254$ mm: $\delta_model = 7.42$, $f = -2.58$, $f' = 0.0526 \rightarrow +49$ mm $\rightarrow a_1 = 303$ mm — NOT LAB DATA.)

The arithmetic is Phase 5. The judgment — stop, or step again? — is Chapter 5. That judgment is the exam question.



TALK TO YOUR AI TEAMMATE “Here is our hand row 0 (and row 1). Check δ_model , f , f' and the correction against your own arithmetic — flag disagreements only.”



ENGINEER DECIDES if AI and your row disagree, one of you evaluated the model wrong — find out which before anyone slides a mass.

Continue in Phase 6 — as many rows as the criterion demands, never a fixed count. Same logic as your Chapter 5 hand steps; a different f , and a beam waiting to judge each one.





Newton on the beam — compute, slide, settle, measure, record

1 COMPUTE — the model at a_n

1

$\delta_{\text{model}}(a_n)$, $f(a_n)$, $f'(a_n)$, $\text{correction} = -f/f'$, $a_{n+1} = a_n + \text{correction}$; check $0 < a_{n+1} < L$. The row is written BEFORE the loop moves; the computing engineer announces a_{n+1} .

2 SLIDE — SETTLE — MEASURE

2

Slide the loop from a_n to a_{n+1} (clamp face to loop centre). Let the beam settle — no bouncing. Read the tip height h from the fixed datum to the caliper resolution; write $\delta_{\text{measured}} = h_0 - h$ beside $\delta_{\text{model}}(a_{n+1})$.

3 DECIDE — stop, or step again?

3

If $|\text{correction}| \leq \text{tol}_a$: STOP — $a^* = a_{n+1}$. Otherwise the next row from the MODEL at a_{n+1} — never from the measured δ . Watch $a_0 \rightarrow a_1 \rightarrow a_2 \rightarrow \dots$ walk the bar while δ walks to 10 mm.

THE WINNING CONDITION

VALIDATED MODEL + STEPS FROM THE MODEL + EVERY ITERATE ON THE BAR + HONEST READINGS + A DEFENDED STOP. Fewest slides wins nothing; a replayable log wins everything.

Two columns, never mixed: the model's prediction and the beam's answer. It is Newton only if the model drives.



TALK TO YOUR AI TEAMMATE “Here is our march log. Verify each row's f , f' and correction from OUR model, and every a_{n+1} on the bar. Never use the measured δ .”



ENGINEER DECIDES the computing engineer computes, the slider slides, the reader reads, the recorder writes — nobody moves the loop before the row is started.

Problem



Model



Compute



Analyze



Validate



Improve



Every slide is a row — the model beside the beam

n	a_n (mm)	$\delta_L(a)$ (mm)	f (mm)	f'	correction (mm)	a_{n+1} · on bar?	$h \rightarrow \delta_{\text{meas}} = h_0 - h$ (mm)	gap (mm)
0	a_0							
1								
2								
...								

One row per slide — model columns BEFORE the loop moves; the height h , $\delta_{\text{measured}} = h_0 - h$ and the gap AFTER the beam settles. The log must show a_0 (committed) $\rightarrow a_1 \rightarrow a_2 \rightarrow \dots \rightarrow \text{STOP}$ with $|\text{correction}| \leq \text{tol}_a$, every a_n on the bar.

The gap column is evidence, never an input: a_{n+1} comes from $\delta_{\text{model}}(a_n)$, not $\delta_{\text{measured}}(a_n)$ · an unresolved reading is “—”, never an invention · an iterate off the bar ends the march as a FINDING.

Record EVERY slide — including one that overshoots 10 mm. Overshoot is what a tangent step does when the curve bends; the next row corrects it.



TALK TO YOUR AI TEAMMATE “Here is our march log. Check every correction is $-f/f'$ from our model and the gap column never computed a position — flag slips; do not choose our next move.”



ENGINEER DECIDES the stopping row names the criterion it met: $|\text{correction}| \leq \text{tol}_a$ — with tol_a 's derivation beside it.

CHECKPOINT ③ — a_0 committed with reason · at least two rows computed and executed · δ_{measured} beside every δ_{model} · roles rotating.

Problem



Model



Compute



Analyze



Validate



Improve



The Newton loop — your f and f' , one WHILE, one guard

THE MARCH — COMPUTED

```

a = 254.0           # YOUR committed a0 (mm) - illustrative: L/2
tol_a = 17.0        # mm of position: 1 mm of deflection / f'(a)
near the root
n = 0
while True:
    corr = -f(a) / fprime(a)
    a_next = a + corr
    n = n + 1
    print(n, round(a,2), round(delta_model(a),3), round(f(a),3),
          round(fprime(a),5), round(corr,2), round(a_next,2))
    assert 0 < a_next < L, 'left the beam - stop and think'
    a = a_next
    if abs(corr) <= tol_a: break
print('a* =', round(a, 1), 'mm model delta =', round(delta_model(a),
2), 'mm')
1 254.0 7.415 -2.585 0.05255 49.18 303.18
2 303.18 10.156 0.156 0.05868 -2.66 300.52
a* = 300.5 mm model delta = 10.0 mm

```

If the assert fails: your start sent the iterate off the bar — the model has no idea where the bar ends; you do.

Re-read a_0 and $f'(a_0)$ before touching the loop; a start near the clamp has almost no slope.

BEFORE YOU RUN IT — WRITE DOWN:

- ☐ Your committed a_0 and the reason
- ☐ Your tol_a — derived from the 1-mm deflection tolerance, with the slope
- ☐ The first row — your hand row 0 — and its sign
- ☐ What stops the loop: the correction, never a count
- ☐ What the assert does if an iterate leaves the bar
- ☐ Then run — compare the printed rows with your hand row(s)
- ☐ Excel first, if you prefer: same rows, the stop test exposed

Many printed digits against a 17-mm position tolerance and a 0.02-mm caliper? You know better: report a^* to the millimetre. (Output shown is ILLUSTRATIVE — NOT LAB DATA.)



Inspect the march — don't just fill it

n	a_n (mm)	$f(a_n)$ (mm)	correction (mm)	$ corr \leq tol_a?$	$\delta_measured = h_o - h$ (mm)	gap (mm)
0	a_o	fill in	fill in	NO	fill in	fill in
1	fill in	fill in	fill in	fill in	fill in	fill in
2	fill in	fill in	fill in	fill in	fill in	fill in
...	...	...	...	...	...	...
n_final	a^*	fill in	fill in	YES — STOP	fill in	fill in

Excel: a_n carried from the previous row, δ_model , f , f' , the correction, the stop test as an IF; copy the row down. Python prints the same rows. Same algorithm, two platforms — one beam.

Report: $a^* =$ _____ mm (to the millimetre) · $\delta_model(a^*) =$ _____ mm · Case 4: $h_a =$ _____ mm $\rightarrow \delta_a = h_o - h_a =$ _____ mm · corrections _____ $\rightarrow$ _____ $\rightarrow$ _____ — do they collapse?

Every row preserves the evidence: the correction column shows Newton's speed as it happens; the gap column shows whether the beam agrees — two different stories, side by side.

TALK TO YOUR AI TEAMMATE “Here is our completed march log. Verify the corrections shrink and the stop met our criterion. Then say, separately, what the gap column shows.”

ENGINEER DECIDES *did the corrections collapse the way Chapter 5 promised near a root? Look at your correction column before answering.*

PREDICT $\rightarrow$ RUN $\rightarrow$ INSPECT — the printed rows must match your hand rows. If they don't, the code or the arithmetic is wrong.

Problem



Model



Compute



Analyze



Validate



Improve



Newton converged. Did the beam? — sort the gap by source

✓ Numerical — the Newton stop	NUMERICAL	The corrections collapsed below tol_a: the MODEL's root is found. If the deflection gap is larger than the model's own residual, the numerics are NOT the culprit.
✓ E and t^3 — the stiffness EI	PARAMETER	E is a posted reference; t enters cubed. A 2 % thickness error moves every prediction 6 %. Your Phase 4 bias already told you the direction.
✓ The clamp — assumed rigid	MODEL	A compliant clamp adds tip deflection the model does not have; the effective L is longer than the measured one.
✓ The load — assumed a point	MODEL	The loop has width and hangs off-centre; friction where it sits on the bar. Which way does each push the tip?
🔗 The caliper and the settle	MEASUREMENT	Resolution ± 0.02 mm; a beam that has not settled; parallax at the caliper jaw. Small — quantify it.
⚠ Small-deflection theory	MODEL	Adequate at these deflections; if you doubt it, the validation ratios at 1, 2, 3 masses are your evidence.

CASE 4 — the three masses at a^* , settled: read h_a from the SAME fixed datum, then $\delta_a = h_o - h_a = \underline{\hspace{1cm}} \text{ mm}$. Inside $9 \leq \delta_a \leq 11$ mm? Newton certified only that the MODEL's δ is 10 mm at a^* — the gap belongs to the other five rows.



What convergence certifies — and what only the beam can



① THE MODEL'S ROOT

Corrections collapsed below tol_a and $f(a^*) \approx 0$ mm: the MODEL says $\delta = 10$ mm at a^* . Show the corrections and the residual.

Converged: YES / NO — with the last two corrections.



② THE RIGHT ROOT, ON THE BAR

$f' > 0$ on $0 < a < L$: one crossing. Every iterate stayed on the bar — say it from the log. The cubic has other roots; none is a place on this beam.

Which root — and why it is the only one on the bar.



③ THE BEAM'S VERDICT

Case 4: $\delta_a = h_o - h_a$ inside 9–11 mm? The ONLY line convergence never wrote. Yes: model, parameters and march all held. No: name the source (previous slide).

Validated: YES / NO — with h_a , δ_a and the gap.

WHAT CONVERGENCE NEVER COVERS: E , t^3 , the clamp, the loop, the caliper, the theory. A Newton run on a wrong EI converges — in three steps — to the wrong beam's answer.

RUNS $\neq$ CORRECT · CONVERGED $\neq$ CORRECT · a guarantee holds only where its conditions hold · and now: CONVERGED FAST $\neq$ CONVERGED RIGHT.



Chapter 4 on the beam — which information did each use?

	BISECTION (Chapter 4) — computational	NEWTON (today) — physical march	Who owns it
① information required	cage $[0, L]$ with $f(0) = -\delta_{\text{target}} < 0$, $f(L) > 0$; continuity	a justified a_0 ; f AND f' at every step; the domain check	the engineer
② tolerance	tol_a on the position — the same one	tol_a on the position — derived from the 1-mm deflection tolerance	the specification
③ evaluations to stop	n halvings + 2 endpoint checks: ____	n steps, each $f + f'$: ____ (and ____ physical slides)	the price list
④ what it guarantees	containment: $a^* \pm$ final half-width	nothing — a collapsing correction is evidence	the contract
⑤ agreement	$a^*_{\text{bisection}} = \text{____} \pm \text{____}$ mm	$a^*_{\text{Newton}} = \text{____}$ mm — inside the bisection bracket? YES / NO	your validation

Run Chapter 4’s bisection on YOUR $f(a)$ from $[0, L]$ to the same tol_a (stop on the half-width). Illustrative bar, $\delta_{\text{target}} = 10$ mm, $\text{tol}_a = 17$ mm: 4 halvings (6 evaluations) $\rightarrow 301.6 \pm 15.9$ mm; Newton from $L/2$: 2 steps ($2f + 2f'$) $\rightarrow 300.5$ mm. ILLUSTRATIVE — DO NOT USE AS YOUR LAB DATA

Record: “Bisection needed ____ evaluations for a bound of $\pm$ ____ mm; Newton needed ____ steps for a correction of ____ mm and no bound. Newton used the slope; bisection used the cage. Bracket first, move intelligently second: our Newton a^* lies / does not lie inside the bisection bracket.”

No universal winner. Bisection could have marched the beam too — halving the interval physically — but every halving is a slide; the slope bought Newton its speed. Neither method validated the beam. The beam did.

TALK TO YOUR AI TEAMMATE “Run bisection on our $f(a)$ from $[0, L]$ to our tol_a and tabulate evaluations and the final bracket beside our Newton log. Do not declare a winner.”

ENGINEER DECIDES is the Newton a^* inside the bisection bracket? If yes, two independent methods agree on the MODEL’s root — the beam is still a separate question.

For the first time you can promise accuracy in advance — and price it in evaluations. Accuracy becomes a schedule, not an experiment.





Phase 9 · 2:35–2:50 · Audit the convergence — not the syntax



Interrogate the claim — pick at least three

From which start, on whose measurements? · residual 10^{-9} mm — of the MODEL or the beam? · four decimals vs a 0.02-mm caliper? · “exactly” — which log line says so? · E, t^3 , the clamp: covered? · known case: your Phase 4 gap



Re-read the AI conversation

Did AI assume a start, a stop, an E, or a beam you never measured — and promise a physical outcome from a numerical one? Verdict what you find ›



Document every attack

What you asked, what it claimed, what you concluded — “the numerical part survived” is a finding too, if you show HOW you verified it and where the claim stopped being mathematics.

VERDICT WHAT YOU FIND:



ACCEPT — with your reason



MODIFY — then retest



REJECT — with evidence



VERIFIED — also a result

BREAK THE AI: “Newton from $a_0 = 254$ mm converged in 3 iterations to $a^* = 300.5165$ mm (residual 3×10^{-9} mm). Since it has converged, placing the three masses at 300.52 mm will put the tip deflection exactly on the 10-mm target.” Separate the mathematically supported from the experimentally unsupported — then rewrite the claim into one you would sign.



Rebuild the claim — from the evidence, not the convergence



1 · EVIDENCE

A defensible result needs: a validated model, a justified a_0 , corrections vs tol_a , every iterate on the bar — AND the measured $\delta_a = h_0 - h_a$ at a^* . Present? Missing?

“Converged, therefore the beam will...” — which evidence connects the two halves?



2 · INTERROGATE

Your evidence against the claim: Phase 4 bias, caliper resolution, f' near a^* , the measured δ_a at a^* . Where does “exactly” stop being mathematics?

4 decimals of a^* against 0.02 mm on the tip and 0.058 mm/mm? Compute $0.02 / 0.058$.



3 · REWRITE → DEFEND

“On our validated model (bias __ %), Newton from $a_0 =$ __ mm converged in __ steps (last correction __) to $a^* =$ __ mm; $\delta_a = h_0 - h_a =$ __ mm vs 10 ± 1 mm — gap: __.”

AI may draft it — it becomes YOURS when every clause points at a row of your record.

Never grade tone — grade the EVIDENCE. A converged root with no measured δ_a beside it is not a physical claim; it is a model talking to itself.

A convergence claim that survives your audit is one you may use — and you state exactly what it does and does not certify. That, too, is engineering.



Make — and defend — the validated root

“For our bar ($L = \underline{\hspace{1cm}}$, $b = \underline{\hspace{1cm}}$, $t = \underline{\hspace{1cm}}$ mm; $m_{\text{total}} = \underline{\hspace{1cm}}$ kg; posted $E = \underline{\hspace{1cm}}$ N/mm²; $h_o = \underline{\hspace{1cm}}$ mm) the model predicted $\delta = \underline{\hspace{1cm}} / \underline{\hspace{1cm}} / \underline{\hspace{1cm}}$ mm for 1 / 2 / 3 masses at $a = L$ and we measured $\delta = h_o - h = \underline{\hspace{1cm}} / \underline{\hspace{1cm}} / \underline{\hspace{1cm}}$ mm (bias $\underline{\hspace{1cm}}$ %). For $\delta_{\text{target}} = 10$ mm (zone 9–11 mm) we wrote $f(a) = \delta_{\text{model}}(a) - \delta_{\text{target}}$, $f'(a)$, committed $a_o = \underline{\hspace{1cm}}$ mm because $\underline{\hspace{1cm}}$, derived $\text{tol}_a = \underline{\hspace{1cm}}$ mm. Newton converged in $\underline{\hspace{1cm}}$ steps (corrections $\underline{\hspace{1cm}} \rightarrow \underline{\hspace{1cm}} \rightarrow \underline{\hspace{1cm}}$) to $a^* = \underline{\hspace{1cm}}$ mm; every iterate on the bar. Case 4: $h_a = \underline{\hspace{1cm}}$ mm, $\delta_a = h_o - h_a = \underline{\hspace{1cm}}$ mm — INSIDE / OUTSIDE 9–11 mm; gap attributed to $\underline{\hspace{1cm}}$. Bisection needed $\underline{\hspace{1cm}}$ evaluations for $\pm \underline{\hspace{1cm}}$ mm and agrees / disagrees. Decision: the model IS / IS NOT adequate for placing the load on bars of this type.”

YOUR DEFENSE — one line of evidence on each rule:

The four lines: ① measurements with resolution + validated model ② a_o justified + tol_a derived ③ every step from the model, every iterate on the bar, corrections collapsed ④ Case 4: h_a read, $\delta_a = h_o - h_a$ vs 9–11 mm + gap attributed + bisection comparison + stated limitations.

An engineering answer is a ROOT + ITS CONVERGENCE EVIDENCE + ITS PHYSICAL VALIDATION + A DECISION. A bare converged root is a model talking to itself.

Problem



Model



Compute



Analyze



Validate



Improve



Leave with the record complete — the report follows



EVIDENCE OF DOING

Measurement log —
readings, resolutions, h_0

Predictions P1–P4 —
unedited

Posted E · target 10 ± 1 mm
— with units

Validation table — Cases 1–
3 ($\delta = h_0 - h$)

March log — model beside
beam, every slide



EVIDENCE OF THINKING

Model, f , f' + hand check
 a_0 justified · tol_a derived

First step by hand · Excel /
Python log

Bisection comparison ·
BREAK THE AI



DECISIONS RECORDED

a^* to the millimetre,
corrections shown

Converged: YES / NO —
Validated: YES / NO (δ_a in 9–
11 mm?)

Gap sorted by source

Model adequate: YES / NO +
why



BEFORE YOU LEAVE

Missing report items listed

Assembly assigned — who, by
when

Station reset — masses off,
loop removed, clamp released
only if instructed, caliper
closed and stored

CHECKPOINT ④ — TA sign-off

Final formatting may be finished after lab — a complete, honest record tonight beats a polished report missing evidence.

Problem



Model



Compute



Analyze



Validate



Improve



Final report · human review & approval

“Before submission, we reviewed the completed report against our original engineering record — measurements, calculations, observations, code, plots, tests, validation evidence, and conclusions. We accept responsibility for the submitted engineering work.”

Human reviewed and approved.

EVERY TEAM MEMBER SIGNS — BEFORE
SUBMISSION (digital signature: create
once, copy-paste)

The recurring question, now literal: ***Would you confidently put your name on this result?***

AI assists. Humans observe. Humans verify. Humans decide. Humans approve.

Problem ›

Model ›

Compute ›

Analyze ›

Validate ›

Improve



One concise report — built from your record



FRAME IT

- 1 Problem / objective
- 2 The activity — rules & roles
- 3 Assumptions
- 4 Apparatus · safety · photo
- 5 Predictions P1–P4



GROUND IT

- 6 Measurement log — L , b , t , masses, h_0 (Case 0)
- 7 Validation table — Cases 1–3 at $a = L$
- 8 Target 10 ± 1 mm · posted E · reachability



BUILD IT

- 9 WRITE IT — $\delta_{\text{model}}(a)$, f , f' , hand check
- 10 COMMIT $a_0 + \text{tol}_a$ derived
- 11 First Newton step(s) by hand
- 12 Excel / Python Newton log + screenshot
- 13 The march log — model beside beam
- 14 TRUST IT — δ_a in 9–11 mm?



OWN IT

- 15 COMPARE IT — bisection on the same f
- 16 AI analysis + BREAK THE AI
- 17 Final certified statement
- 18 Method judgment + limitations
- 19 Human review & approval — signed

A few honest sentences per section. The logs, the tables, and the screenshot carry the evidence — prose carries the verdict.

Problem



Model



Compute



Analyze



Validate



Improve

WHAT JUST HAPPENED

You measured a bar and made a model earn its place with
1, 2, 3 masses at the free end,
wrote the target as $f(a) = 0$ with its slope, committed a
start, derived a stop,
marched Newton along the beam as the tip deflection
walked to 10 mm,
**and asked the one question convergence cannot answer:
did the beam agree?**

MEASURE → VALIDATE → MARCH → TRUST. The model drove; the beam judged. Newton needed the slope and a justified start and gave back speed without a bound; bisection needed a cage and gave back containment at a price. Neither validated the beam — the caliper did. Chapter 6 asks the question this laboratory earned: every f you have solved was a formula you could differentiate. What happens when the engineer's f arrives as a table of measurements — and nothing else?

Problem

›

Model

›

Compute

›

Analyze

›

Validate

›

Improve

FUNDAMENTALS OF AI-AUGMENTED ENGINEERING

CHAPTER 5 / LAB-5

Engineering Report Rubric

Slide to the Target — Main LAB-5 Team Report

Suggested Assessment · 40 points

Used by the instructor and, where applicable, by an AI grading agent. Assessment rewards measured (not nominal) inputs, a validated model, a justified start and a derived stop, the honest two-column march log, the separation of numerical convergence from physical validation, the method comparison, and human responsibility.

Criterion	What full credit looks like	Pts
Problem, rules, assumptions & the specification	Clear objective; the physical rules (model drives, beam judges; step computed from the model; slide, settle, read h; stop on the criterion) and roles stated; assumptions listed (point load, rigid clamp, small deflection, posted E); the target $\delta_{\text{target}} = 10$ mm with success zone 9–11 mm and the posted E recorded with units — never invented.	3
Committed predictions	P1–P4 (δ_i for one mass at the free end · 1 : 2 : 3 scaling · slides to converge · will δ_a land inside 9–11 mm) recorded before any mass is hung and left unedited; each revisited against the evidence afterward. Prediction correctness is not graded — commitment and reasoning are.	3
Measurement log — the beam, the loads, the datum	L, b, t with three readings each and the instrument resolution; every mass weighed, hook included; Case 0 unloaded tip height h_0 recorded from the fixed datum; F, I, EI computed with units in one consistent system; the t^3 sensitivity stated. Nominal values are not used as data.	4
Validation table — the model earns the march (Cases 1–3)	$\delta_{\text{model}} = F \cdot L^3 / (3EI)$ predicted for 1, 2, 3 masses at $a = L$ with the team's own values before measurement; settled heights h_1, h_2, h_3 read from the datum and $\delta = h_0 - h$ computed; differences, % differences and the load ratios; a systematic bias recognized and attributed; the reachability check $10 \text{ mm} < \delta_{\text{model}}(L)$ (and $< \delta_3$) done before Newton.	5
WRITE IT — model, f, f' & the hand check	$\delta_{\text{model}}(a)$, $f(a) = \delta_{\text{model}}(a) - \delta_{\text{target}}$ and $f'(a)$ written with units; what changed from Stage A stated (F fixed, a unknown); each sign given its physical meaning; f' interpreted (mm of deflection per mm of position) and $f'(0) = 0$ recognized; one hand-checked point that the code reproduces.	3

Continued

Engineering Report Rubric — continued

Suggested Assessment · 40 points

Criterion	What full credit looks like	Pts
COMMIT a_0 , derive the stop, first step by hand	a_0 justified from the physics (on the bar, away from the clamp); tol_a derived from the 1-mm deflection tolerance through f' with the caliper resolution noted; at least the first Newton step computed by hand and the domain check written.	4
The march log — Newton on the beam	Every slide a row: model quantities written before the move, a_{n+1} checked against $0 < a < L$, the height h read from the datum and $\delta_measured = h_0 - h$ recorded beside each δ_model ; corrections computed from the MODEL only (the gap column never enters the formula); the stop defended by $ \Delta a \leq tol_a$, never a count. The march can be replayed from the log alone.	7
TRUST IT — Newton converged; did the beam? (Case 4)	Two verdicts kept separate: numerical convergence (corrections, residual) and physical validation (h_a read from the same datum, $\delta_a = h_0 - h_a$ vs the 9–11 mm success zone); the gap sorted by named sources (E , t^3 , clamp, loop, caliper, theory) — never called numerical error; what convergence does NOT certify stated explicitly.	5
COMPARE IT — bisection on the same f	Bisection run from $[0, L]$ to the same tol_a with the certified signs; evaluations, information required and guarantee compared with Newton's; agreement of a^* with the bisection bracket checked; no universal winner declared — the judgment argued from information and certificate.	3
BREAK THE AI, final statement & approval	The planted convergence-implies-physics claim attacked with at least three specific, checkable points and rewritten into a statement the team would sign; the final certified statement complete (measurements, validation, a_0 , tol_a , corrections, a^* , h_a and δ_a , gap, comparison, decision); human approval signed.	3
TOTAL		40

CHAPTER - 5

Lab 5 · ≈ 30 MIN

Lab Extension Challenge:

(Individual Assignment)

Students can do it at their convenience (individually) but remind them it is part of the Lab-5 assessment.

Problem



Model



Compute



Analyze



Validate



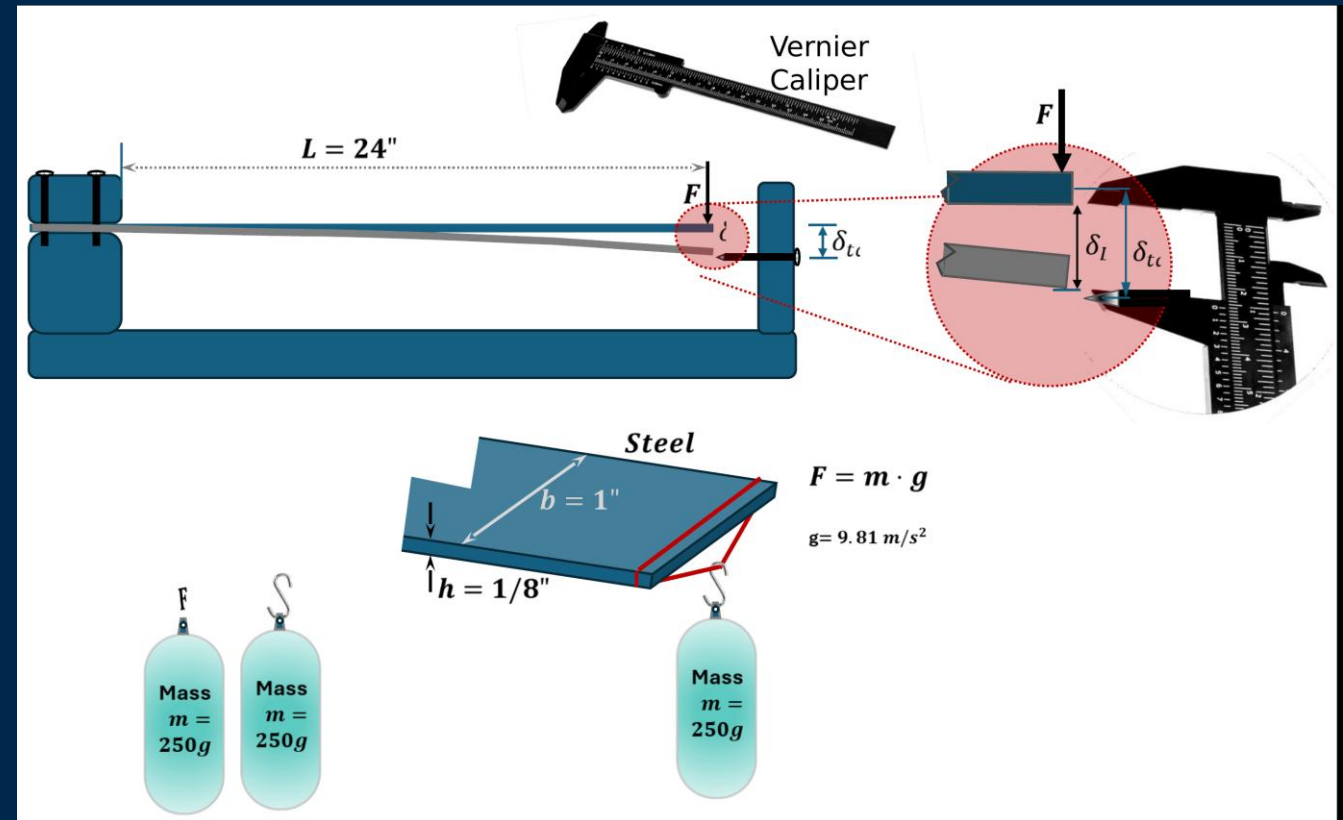
Improve



Same Beam, Six Starts — Where Newton Begins Matters

Newton needed a start you could defend. What happens from starts you cannot — $a_0 = 0$, a_0 near the clamp, a_0 past the end of the bar? Predict first — then compute, on your own beam.

An extension of the Lab-5 Newton study. You already own the validated beam model, f and f' , and a working Newton loop — now the START itself goes on trial, including one deliberately problematic start, and one question the loop cannot answer: what does an iterate that is not on the bar mean?





An assessment mini-challenge — not another lab report

1

Designed as part of the Lab-5 assessment

The rubric is on the last slide of this section.

2

Separate from the 3-hour lab

An individual follow-on, completed at your convenience — no bar, no masses: your Lab-5 measurements, posted values, and functions are all you need.

3

Submit a separate short report

Download and use Chp5-Lab5-LabExtension-Challenge-SameBeamSixStarts-Report-Template.docx

THE ENGINEERING QUESTION

Same beam, same 10-mm target, same loop — six starts. Which converge, which fly off the bar, which fail before step 1? What does a position that is not on the bar MEAN?

Same workflow as the whole lab:

Predict → Compute → Compare → Audit
AI → Validate → Decide



ENGINEER DECIDES

the question is not whether Newton converges — it is from where, to what, and whether the answer is a place on this beam. AI assists. Humans verify. Engineers decide.

Problem



Model



Compute



Analyze



Validate



Improve



Commit to a prediction

1

The convenient start

$a_0 = 0$: what is $f'(0)$, and the first correction? Commit: converges / fails before step 1 / flies off.

2

Near the clamp

$a_0 = 5 \text{ mm}$ and $a_0 = L/4$: does the first step land on the bar, or past its end? Commit a rough a_1 for each.

3

Past the end

$a_0 = 1.2 \cdot L$ is not a place on the bar. Does the loop care? Commit: converges to a^* / elsewhere / diverges.

4

The shortcut

An AI will claim “Newton converges from any start on this smooth model.” Can any result you know guarantee that? YES / NO.

THE MODEL

$$f(a) = \delta_{\text{model}}(a) - \delta_{\text{target}}, \quad f'(a) = F \cdot a \cdot (2L - a) / (2EI)$$

same bar · same $\delta_{\text{target}} = 10 \text{ mm}$ · same tol_a — held fixed

Look closely: $f'(0) = 0$, and f' is small near the clamp.

What does a small slope do to $-f/f'$ — and to where a_1 lands?

✓ **ENGINEER DECIDES** *record your predictions NOW — no revising after you compute (correctness is not graded).*

Problem

>

Model

>

Compute

>

Analyze

>

Validate

>

Improve



Six starts — one model, one loop, six stories

a_0 (mm)	$f'(a_0)$	a_1 (mm) · on bar?	steps · a_{final} · verdict	Notes
0	___	___ · —	fails before step 1 / ___	$f'(0) = 0$
5	___	___ · Y/N	$n = __ \cdot __ \cdot __$	
$L/4 = __$	___	___ · Y/N	$n = __ \cdot __ \cdot __$	
$L/2 = __$	___	___ · Y/N	$n = __ \cdot __ \cdot __$	the lab's march
$L = __$	___	___ · Y/N	$n = __ \cdot __ \cdot __$	
$1.2 \cdot L = __$	___	___ · Y/N	$n = __ \cdot __ \cdot __$	not on the bar

HELD FIXED

same bar

same target ·

tol_a

Your Lab-5 L, b, t, F, E ·

$\delta_{\text{target}} = 10 \text{ mm}$

Run WITHOUT the domain

assert first, then WITH it

Verdicts: to a* · elsewhere · left

the bar · failed

THEN — ONE PICTURE

Plot $\delta_{\text{model}}(a)$ for $0 \leq a \leq 1.5 \cdot L$ with the 10-mm target line, the domain $0 < a < L$, and the tangent at $a_0 = 5 \text{ mm}$ — where does it cross the target? Does your committed prediction survive the table?

✓ ENGINEER DECIDES reuse your Lab-5 f , f_{prime} and loop — one extra loop over six starts. If you are rewriting Newton, stop and ask why.





Interrogate the starts — don't just tabulate them

THE ZERO-SLOPE START

$a_0 = 0$: a load at the clamp bends nothing, so $f'(0) = 0$ and $-f/f'$ is undefined. Convenient number, useless start.

*What did your program do — an error, or a silent “inf”?
Which is honest?*

THE FLAT REGION

Near the clamp f' is tiny, so the correction is enormous: the tangent hits the target far beyond the bar. How far, from 5 mm — in bar lengths?

Read it from your table — and from the tangent you drew.

OFF THE BAR — WHAT IT MEANS

An iterate past L is a number the model produced and a place the beam does not have. Unguarded, some starts recover; one finds a root that is not on the bar.

What does an engineer do: continue, refuse, restart from a justified start — or bracket first?

THE START PAST THE END

$a_0 = 1.2 \cdot L$ converged — from a position you could never load. The loop says it was a fine start; the domain says it was never admissible.

Convergence is not a defense of the start. The physics is.

✓ **ENGINEER DECIDES** *use your computed evidence — not what you expected to see. The table and the picture decide.*

Problem

›

Model

›

Compute

›

Analyze

›

Validate

›

Improve



Ask AI for the analysis — then grade it

SUGGESTED PROMPT

“Here is the cantilever model $\delta_{\text{model}}(a) = F \cdot a^2 \cdot (3L - a) / (6EI)$ with my measured $L = \underline{\hspace{1cm}}$, $b = \underline{\hspace{1cm}}$, $t = \underline{\hspace{1cm}}$ mm, $F = \underline{\hspace{1cm}}$ N, posted $E = \underline{\hspace{1cm}}$ N/mm², and target $\delta_{\text{target}} = 10$ mm. I want to solve $f(a) = \delta_{\text{model}}(a) - \delta_{\text{target}} = 0$ with Newton-Raphson. Which starting position do you recommend, and can you guarantee convergence from it? What about starting at $a_0 = 0$?”

Any capable AI assistant (your engineering critic). Record its recommended start, its claimed guarantee, and what it says about $a_0 = 0$. Do NOT copy the full answer.

NOW AUDIT THE AI RESPONSE

- 1 Did it justify the start from the physics — or from “a reasonable guess”?
- 2 Did it claim a guarantee? Which theorem — and does one exist for Newton from an arbitrary start?
- 3 Did it catch $f'(0) = 0$ — or propose $a_0 = 0$ as “simple”?
- 4 Check it: run YOUR loop from its recommended start — steps, a^* , every iterate on the bar?
- 5 Verdict: **ACCEPT · MODIFY · REJECT** — with your six-start table as evidence.



THE KEY DISTINCTION *Newton’s convergence is LOCAL: a good start converges fast; a bad start may fail, fly, or find the wrong root. “Converges from anywhere” is a claim no theorem in this course backs.*



ENGINEER DECIDES *AI proposes; engineers check the start against the physics and the run against the domain before signing.*

Problem



Model



Compute



Analyze

**Validate**

Improve



Validate the roots — then judge the start

1 INDEPENDENT CHECK

Plug every converged a_{final} back into δ_{model} — does it give 10 mm? Including the one OFF the bar? Then say why a root can be a root and still not be an answer.

One line of Python or a calculator. Then compare every on-bar a^* with your Lab-5 a^* and the measured $\delta_a = h_0 - h_a$ at a^* .

2 ENGINEERING JUDGMENT

State a defensible conclusion: which starts are admissible, which is best, and what rule would you give a teammate for choosing a_0 on a NEW beam?

Say what a start needs (on the bar, away from the clamp, near the answer if known). Would one bisection halving of $[0, L]$ have supplied a defensible start? Bracket first, move second.

You are NOT asked to prove convergence theory — the admissible starts and the meaning of an off-bar iterate are the deliverable.

NEWTON CONVERGES TO A ROOT — YOU DECIDE WHETHER IT IS THE ANSWER. And no start validates the beam model. Validation does.

Problem

›

Model

›

Compute

›

Analyze

›

Validate

›

Improve



One compact report — 10 points

LAB EXTENSION CHALLENGE REPORT

separate from your main Lab-5 report · ½–1 page

- 1 **Committed predictions — 0, near the clamp, past the end, the shortcut**
- 2 **Inputs — Lab-5 measurements, $\delta_{\text{target}} = 10$ mm, tol_a ; f and f'**
- 3 **Six-start table — $f'(a_0)$, a_1 on bar?, steps, a_{final} , verdict**
- 4 **$\delta_{\text{model}}(a)$ plot — 10-mm target, domain, tangent at 5 mm**
- 5 **Interrogation — zero slope, flat region, off the bar**
- 6 **AI start recommendation — claimed guarantee, audit + verdict**
- 7 **Plug-back validation — every a_{final} ; the lab's a^* and δ_a**
- 8 **Final judgment — admissible starts; a rule for a_0**

No formal Intro / Methods / Results / Discussion structure required.

Recommended Challenge Rubric	Points
Committed predictions (before computing)	1
Six-start table with verdicts, $f'(a_0)$ and the on-bar check	3
Interrogation — zero slope, flat region, off-bar meaning	2
AI start audit — ACCEPT / MODIFY / REJECT with evidence	2
Plug-back validation	1
Final judgment — admissible starts and a rule for a_0	1
TOTAL :	10

Serious enough to take seriously — small enough that Lab-5 still belongs to the main lab.

Problem

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Model

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Compute

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Analyze

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Validate

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Improve

RUBRIC for the Lab Extension Report

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FUNDAMENTALS OF AI-AUGMENTED ENGINEERING

CHAPTER 5 / LAB-5

Lab Extension Challenge Rubric

Same Beam, Six Starts — Individual Report

Suggested Assessment · 10 points

Used by the instructor and, where applicable, by an AI grading agent. Assessment rewards committed predictions, honest computation on the student's own model, the meaning given to an inadmissible iterate, the audit of an AI convergence claim, and a defensible rule for choosing a start.

Criterion	What full credit looks like	Pts
Committed predictions (before computing)	$a_0 = 0$, near-clamp, past-the-end and the AI shortcut predicted in writing before any run; unedited afterward. Correctness is not graded.	1
Six-start table with verdicts	$f(a_0)$, a_1 with the on-bar check, steps, a_{final} and a verdict (converged to a^* · converged elsewhere · left the bar · failed) for all six starts, computed with the student's own Lab-5 model and $\delta_{\text{target}} = 10$ mm, first unguarded then guarded.	3
Interrogation	The zero-slope start explained ($f'(0) = 0 \rightarrow$ undefined step; honest error vs silent inf); the flat region near the clamp connected to the enormous first correction; the meaning of an off-bar iterate stated and the engineer's options (refuse, restart, bracket first) named.	2
AI start audit	The AI's recommended start and claimed guarantee recorded concisely; the absence of an any-start convergence theorem identified; the recommendation verified by a run; verdict ACCEPT / MODIFY / REJECT graded on justification, never on which box is checked.	2
Plug-back validation	Every converged a_{final} substituted back into δ_{model} ; the off-bar root recognized as a root that is not an answer; on-bar a^* compared with the lab's a^* and the measured $\delta_a = h_0 - h_a$.	1
Final judgment	Admissible starts named with reasons; a defensible rule for choosing a_0 on a new beam (mid-bar, or one halving of $[0, L]$ first); what no start can validate stated.	1
TOTAL		10