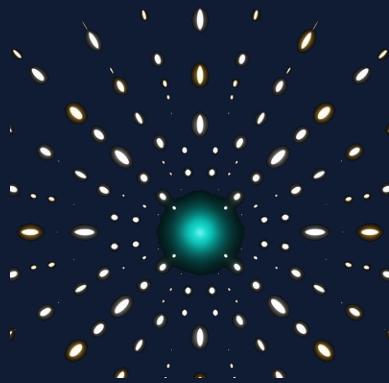




LAUE LABS



Curriculum B

Applied Engineering Laboratory — 1.0 Credit

A 15-week high-school semester: build, instrument, and quantitatively test real machines.

OCTOBER 2026

Curriculum B

Document: LAUE-CURR-B · Version 1.1 · October 2026 **Publisher:** Laue Labs (lauelabs.com)

© 2026 Laue Labs. All rights reserved.

This document — sequence, pacing, objectives, and assessment — may be shared freely with educators evaluating the program. The build instructions, cut files, code, and lessons of the Laue Labs project packs are proprietary to their licensed packs and are not reproduced here.

Hardware cost estimates are approximate and based on typical U.S. retail component pricing at the time of publication; actual costs vary by supplier.

Contents

Curriculum B	2
About Laue Labs	4
How to use this document	4
CURRICULUM B — 1-Credit High-School Semester (120 Hours)	5
Course: Applied Engineering Laboratory — 1.0 Credit	5
Grading	6
15-week schedule	6
Weekly rhythm	7
Transcript line	8
Capstone Worksheet (Week 15 pre-lab)	8
Appendix A — Glossary	9
Appendix B — Master Hardware Index	10
Appendix C — Standards Alignment (Curriculum B)	11
Document History	12

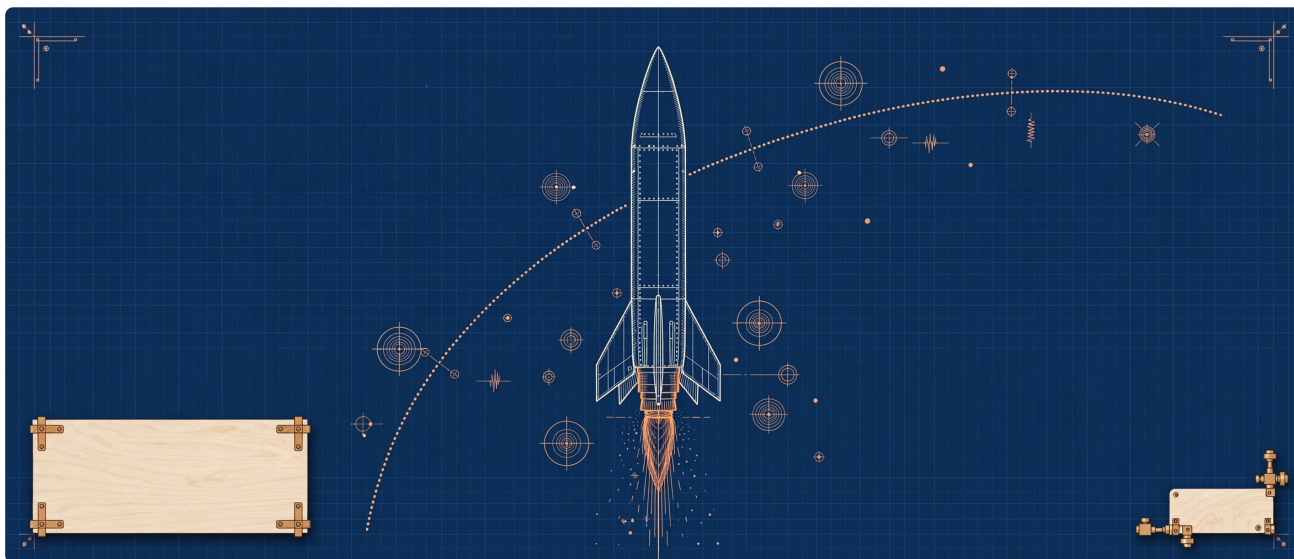
About Laue Labs

Laue Labs (lauelabs.com) designs hands-on engineering project packs — digital build guides, laser-cut files, code, lessons, and bills of materials — for high-school students in grades 9–12 (Algebra I required, concurrent Geometry or higher), families, makers, and

classrooms. Each pack is a complete guided apprenticeship in real engineering: build it, test it, measure it, explain it. The company is named for Max von Laue, whose X-ray diffraction work revealed the structure of crystals — the same spirit of learning by probing the physical world drives every kit.

How to use this document

Front matter orients you: what the program is, how it's organized, and what's in each section. **The body** is the curriculum itself — units, weeks, objectives, and assessment. **The back matter** holds the reference appendices: glossary, master hardware index, standards alignment, and document history. A companion **Teacher's Guide** provides the week-by-week execution plans — timed agendas, launch scripts, checkpoints, and failure rescues — for running every session.



CURRICULUM B — 1-Credit High-School Semester (120 Hours)

Course: Applied Engineering Laboratory — 1.0 Credit

Course description: A 15-week high-school laboratory course in applied physics and engineering design. Students build, instrument, and quantitatively test real machines from the Laue Labs catalog — from measurement foundations through circuits, sensing, robotics, and feedback control — culminating in a model-rocket flight-computer capstone with pre-flight prediction and post-flight data analysis. Emphasis on honest measurement, uncertainty, and first-principles reasoning.

Credit justification: 1.0 credit is awarded on a total-engaged-work basis: 120 documented hours (45 supervised lab + 75 structured independent pre-lab, analysis, and reporting), consistent with common homeschool/independent-school transcript practice (120–150 hours per credit). This exceeds the traditional Carnegie contact-hour definition only when independent work counts; schools that require 120 contact hours should award 0.5 credit or add supervised time. For reference, 45 supervised lab hours is equivalent to the contact time of a 1-credit-hour college laboratory course.

Hour breakdown: - Pre-lab preparation (readings, prediction worksheets, planning): $2.0 \text{ hrs} \times 15 = 30 \text{ hrs}$
- Weekly build & test session (supervised): $3.0 \text{ hrs} \times 15 = 45 \text{ hrs}$ - Post-lab analysis and formal lab reports: $2.5 \text{ hrs} \times 15 = 37.5 \text{ hrs}$ - Reflection and extension investigations: $0.5 \text{ hr} \times 15 = 7.5 \text{ hrs}$ - **Total:**

120 hours → 1.0 credit. 15 instructional weeks fit inside a standard 18-week semester, leaving 3 weeks for breaks, review, and launch-day weather slips.

Prerequisites: Algebra I (required) and concurrent Geometry or higher. Comfort with scientific notation, sin/cos, and spreadsheets is needed; the Week 12 and Week 15 integrals are done numerically as spreadsheet sums ($\Sigma P \cdot \Delta t$), so no calculus is required. No prior building experience required.

Materials: Laue Labs digital packs; hardware per BOM, one shared electronics core per 2 students plus per-week consumables; Z87+ (ANSI/ISEA Z87.1) impact-rated safety glasses (e.g., 3M SecureFit SF201AF) for everyone in the room.

Grading

Component	Weight
Formal lab reports (15)	40%
Build demonstrations (3 unit demos)	25%
Midterm: design review, Weeks 1–7	10%
Capstone: prediction, flight, analysis, presentation	25%

Lab report standard (every week): Question restated · labeled diagram/photo · data in tables and plots with uncertainties · conclusion answering the question with evidence · one paragraph on what you'd change. Failed trials are data — fabricated data fails the report.

15-week schedule

Course units: B1 (Weeks 1–4) · Waves & EM (Weeks 5–6) · Midterm (Week 7) · B2 (8–11) · B3 (12–15). Unit demonstrations at the end of Weeks 4, 11, and 14.

Week	Kit	Lab focus & deliverable
1	Ballista Physics Lab	Projectile motion with error analysis. Deliverable: range-vs-angle plot with uncertainty bars; air-resistance discussion.
2	Bridge Load Lab	Structures; strength-to-weight optimization. Deliverable: failure analysis + redesign proposal.
3	Gear Ratio Lab	Mechanical advantage; efficiency losses. Deliverable: measured efficiency per stage.
4	Strain-Gauge Beam Lab	Materials science. Deliverable: Young's modulus extracted from best-fit slope, with error bounds.

Week	Kit	Lab focus & deliverable
5	Diffraction Spectroscope	Waves & calibration. Deliverable: calibration curve; unknown source identified by wavelength.
6	Electromagnet Lab	Electromagnetism; driver design. Deliverable: force-vs-turns data + MOSFET driver schematic.
7	Midterm	Design review: revisit any Weeks 1–6 build, identify one flaw with data, rebuild, present before/after.
8	Binary Logic Gates Board	Digital logic through compound gates. Deliverable: truth tables + a 2-bit adder sketch.
9	Capacitive Touch Synth	Capacitance & oscillators. Deliverable: frequency measurements vs. theory.
10	Ultrasonic Rangefinder Lab	Sensor characterization. Deliverable: accuracy map (distance × target material).
11	Desk Load-Cell Scale	Metrology. Deliverable: calibration with residuals; unknown mass with stated uncertainty.
12	Solar Tracker + Weather Station	Energy & long-term data. Deliverable: fixed-vs-tracking output; one finding from logged data.
13	3-DOF Plywood Arm	Kinematics & servo control. Deliverable: pick-and-place demo + workspace sketch.
14	Gyro Leveling Platform	Feedback control. Deliverable: disturbance/response analysis; oscillation-vs-sluggishness trade.
15	Capstone: Rocket Flight Computer & Telemetry Lab	Prediction worksheet (thrust/drag → apogee), build, launch day, post-flight comparison, error analysis, final presentation. High-school level; run it as a joint engineering investigation.

Weekly rhythm

- **Pre-lab, 2 hrs (at home):** read the pack lesson, complete the prediction worksheet, plan the test matrix.
- **Build & test, 3 hrs (meetup):** build, run trials, iterate, capture data.
- **Post-lab, 2.5 hrs (at home):** analyze data, write the formal report.
- **Reflection, 0.5 hr:** extension question or redesign sketch.

Transcript line

Applied Engineering Laboratory — 1.0 credit — [Semester, Year] — Grade: [A–F] Lab science elective; 15 build-test-analyze modules; NGSS HS-PS2/PS3/PS4/ETS1 aligned.

Capstone Worksheet (Week 15 pre-lab)

Goal: predict the rocket's apogee before launch, then compare against the flight computer's barometric altitude log. All worksheet math is Algebra I; the post-flight accelerometer check uses a spreadsheet running sum.

Measure or look up: - m — liftoff mass in kg, motor installed (weigh it on your Week 11 scale) - F — motor average thrust in N, t_b — burn time in s (manufacturer thrust curve) - d — body diameter in m → frontal area $A = \pi \cdot (d/2)^2$ - $C_d \approx 0.6\text{--}0.75$ (model rocket estimate) · $\rho = 1.225 \text{ kg/m}^3$ (air density) · $g = 9.81 \text{ m/s}^2$

Phase 1 — powered flight. Net acceleration $a = F/m - g$. Burnout velocity $v_b = a \cdot t_b$. Burnout altitude $h_b = \frac{1}{2} \cdot a \cdot t_b^2$. (Drag during the ~1 s burn is small; it enters in Phase 2.)

Phase 2 — coasting flight. No-drag coasting height $h_c = v_b^2/(2g)$. Average drag on the way up: $F_d = \frac{1}{2} \cdot \rho \cdot (v_b/2)^2 \cdot C_d \cdot A$ (using $v_b/2$ as the average speed). Corrected coasting height $h_c' = h_c \cdot (1 - F_d/(m \cdot g))$.

Predicted apogee = $h_b + h_c'$.

Worked example (C motor, 9.9 N·s): $m = 0.128 \text{ kg}$ (average during burn), $F = 6.0 \text{ N}$, $t_b = 1.65 \text{ s}$, $d = 0.034 \text{ m}$, $C_d = 0.75$. $a = 6.0/0.128 - 9.81 = 37.1 \text{ m/s}^2$ → $v_b = 61.2 \text{ m/s}$ → $h_b = 50 \text{ m}$. $h_c = 61.2^2/(2 \cdot 9.81) = 191 \text{ m}$. $A = \pi \cdot (0.017)^2 = 0.000908 \text{ m}^2$. $F_d = \frac{1}{2} \cdot 1.225 \cdot (30.6)^2 \cdot 0.75 \cdot 0.000908 \approx 0.39 \text{ N}$; weight = 1.26 N. $h_c' = 191 \cdot (1 - 0.39/1.26) = 131 \text{ m}$. (Liftoff mass 0.134 kg minus half the 12 g propellant; liftoff T/W = 4.6.) Predicted apogee $\approx 182 \text{ m}$ ($\approx 595 \text{ ft}$). This simple method usually reads high: the full quadratic-drag model gives $154 \pm 24 \text{ m}$ for this rocket, so expect your flight to come in 10–20% below the worksheet. Note liftoff T/W = $6.0/(0.134 \cdot 9.81) \approx 4.6$ (≈ 4.8 on average burn mass), below the 5:1 minimum recommended for a safe rod-exit speed. Use a longer rod/rail or a higher-initial-thrust C motor (check the thrust curve's peak, not the average).

Post-flight: the flight computer logs pressure; apogee is the altitude of minimum pressure. Compute percent difference vs. prediction and attribute the gap in your report — wind, actual C_d , mass added by paint and glue, and average-thrust vs. real thrust curve are the usual suspects.

Prepared by Laue Labs · lauelabs.com · October 2026 Contact: Lance Haney — Dora, AL

Appendix A — Glossary

Term	Definition
Apogee	The highest point of a rocket's flight; the flight computer finds it as the altitude of minimum barometric pressure.
Ballista	An ancient torsion-powered projectile launcher; here, a tabletop model for studying projectile motion.
Bernoulli's principle	Faster-moving fluid exerts lower pressure; one contributor to wing lift (the other is downward deflection of air).
Braitenberg vehicle	A robot whose sensors wire directly to its motors, producing lifelike behavior with no programmed "brain."
Calibration	Teaching an instrument what its readings mean, using known references.
Cam	A shaped wheel that converts rotation into a patterned push-pull motion in a follower.
Capacitive sensing	Detecting touch by the tiny electric charge the human body carries; no pressure required.
Carnegie unit	The traditional U.S. high-school credit standard, nominally 120 hours of instructional contact time (e.g., 1 h × 5 days × 24 weeks).
Diffraction	The spreading of waves around obstacles or through gratings; Max von Laue used X-ray diffraction to reveal crystal structure (Nobel Prize, 1914).
Drag	Air resistance opposing motion, growing with the square of speed: $F = \frac{1}{2}\rho v^2 C_d A$.
Feedback loop	Sense, compare to a target, correct, repeat; the basis of the self-leveling platform and all control systems.
Grating equation	$d \cdot \sin\theta = m\lambda$; relates a grating's line spacing to the angles at which colors appear.
Gyroscope	A sensor that measures rotation rate; integrating it gives tilt angle but drifts, so the platform fuses it with the accelerometer's gravity reference (complementary filter) to sense tilt.
Load cell	A sensor that converts force into an electrical signal; the heart of a digital scale.
MOSFET	A transistor switch that lets a small signal control a large current, e.g., driving an electromagnet.
Residuals	The leftover differences between measured data and a fitted model; their pattern diagnoses bad calibrations.

Term	Definition
Servo	A small motor that moves to a commanded angle and holds it.
Strain gauge	A sensor whose electrical resistance changes as it stretches; used to measure tiny bends.
Thrust	The force a motor produces; average thrust $\times$ burn time gives the impulse that sets burnout velocity.
Truth table	The complete list of inputs and outputs for a logic gate or circuit.
Ultrasonic ranging	Distance from echo time: $d = v \cdot t/2$, halved because sound travels there and back.
Uncertainty	The honest $\pm$ range on a measurement; every reported result in this program carries one.
Young's modulus	A material's stiffness, extracted here from the slope of beam-deflection vs. load.

Appendix B — Master Hardware Index

Approximate hardware cost per build station (electronics core reused across weeks). Packs are digital (guide, cut files, code, lessons); hardware is sourced per each pack's bill of materials.

Kit	Hardware (approx.)
Animatronic Hand	\$42–148
Animatronic Mascot Head	\$36–109
Ballista Physics Lab	\$19–61
Bernoulli Wind Lab	\$29–79
Binary Logic Gates Board	\$20–67
Birch Differential Rover	\$42–149
Bridge Load Lab	\$14–58
Cam-Follower Engine	\$25–59
Capacitive Touch Synth	\$21–56
Color-Sort Chute	see BOM

Kit	Hardware (approx.)
Desk Load-Cell Scale	\$18–100
Diffraction Spectroscope	\$8–43
Electromagnet Lab	\$15–40
Gear Ratio Lab	\$16–71
Gyro Leveling Platform	\$34–128
IR Tripwire Doorbell	\$16–80
Light-Following Robot	\$31–183
Line-Following Rover	\$50–157
Piano Circuit Machine	\$15–65
Pneumatic Soft Gripper	\$14–48
POV LED Spinner	\$66–101
Rocket Flight Computer & Telemetry Lab	see BOM
Servo Expression Face	\$38–111
Solar Tracker	\$21–102
Stepper Clock Escapement	\$22–77
Strain-Gauge Beam Lab	\$11–82
Tilt Maze Labyrinth	\$35–88
Ultrasonic Rangefinder Lab	\$18–73
Weather Station	\$25–102
3-DOF Plywood Arm	\$32–125

Appendix C — Standards Alignment (Curriculum B)

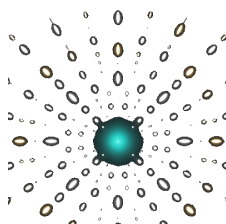
Unit	Weeks	NGSS
B1 · Mechanics & Materials	1–4	HS-PS2 (motion and forces), HS-ETS1 (engineering design)

Unit	Weeks	NGSS
Midterm design review	7	HS-ETS1
B2 · Circuits & Sensing	8–11	HS-PS3-5, HS-PS4-1, HS-ETS1-3
B3 · Energy, Control & Flight	12–15	HS-PS2-1, HS-PS3-3, HS-ETS1-2/-3

Weeks 5–6 · Waves & Electromagnetism: HS-PS4-1, HS-PS2-5, HS-ETS1-2. Full performance-expectation crosswalk available from Laue Labs on request.

Document History

Version	Date	Notes
1.0	2026-10-12	Initial release · v1.1 (2026-10-13): safety & technical corrections



Laue Labs · lauelabs.com
 Lance Haney — Dora, AL
lance.haney@gmail.com

Build instructions and pack contents are proprietary to their licensed Laue Labs packs; this document is the curriculum wrapper and does not reproduce them.

Safety & Corrections (v1.1)

About this page

Version 1.1 (2026-10-13). The items below were corrected after technical review. Where a page in this document says something different, this page governs.

1. Eye protection

ANSI/ISEA Z87.1-marked (Z87+) impact-rated safety glasses, e.g., 3M SecureFit SF201AF, worn by everyone in the room (students, teachers, observers) whenever anything launches, breaks, spins, is cut, is soldered, or is under spring/elastic tension. Ordinary eyeglasses and non-Z87+ 'safety' glasses do not qualify. Do not substitute unmarked glasses.

7. Audience

Curriculum B is for high-school students in grades 9–12 (Algebra I required, concurrent Geometry or higher).

8. Credit justification (Curriculum B)

1.0 credit is awarded on a total-engaged-work basis: 120 documented hours (45 supervised lab + 75 structured independent pre-lab, analysis, and reporting), consistent with common homeschool/independent-school transcript practice (120–150 hours per credit). This exceeds the traditional Carnegie contact-hour definition only when independent work counts; schools that require 120 contact hours should award 0.5 credit or add supervised time. For reference, 45 supervised lab hours is equivalent to the contact time of a 1-credit-hour college laboratory course. Glossary — Carnegie unit: the traditional U.S. high-school credit, nominally 120 hours of instructional contact time (e.g., 1 h × 5 days × 24 weeks).

9. Capstone worked example (C motor)

Worked example (C motor, 9.9 N·s): $m = 0.128$ kg (average during burn), $F = 6.0$ N, $t_b = 1.65$ s, $d = 0.034$ m, $C_d = 0.75$. $a = 6.0/0.128 - 9.81 = 37.1$ m/s² → $v_b = 61.2$ m/s → $h_b = 50$ m. $h_c = 61.2^2/(2 \cdot 9.81) = 191$ m. $A = \pi \cdot (0.017)^2 = 0.000908$ m². $F_d = \frac{1}{2} \cdot 1.225 \cdot (30.6)^2 \cdot 0.75 \cdot 0.000908 \approx 0.39$ N; weight = 1.26 N. $h_{c'} = 191 \cdot (1 - 0.39/1.26) = 131$ m. (Liftoff mass 0.134 kg minus half the 12 g propellant; liftoff T/W = 4.6.) Predicted apogee ≈ 182 m (≈ 595 ft). This simple method usually reads high: the full quadratic-drag model gives 154 ± 24 m for this rocket, so expect your flight to come in 10–20% below the worksheet. Note liftoff T/W = $6.0/(0.134 \cdot 9.81) \approx 4.6$ (≈ 4.8 on average burn mass), below the 5:1 minimum recommended for a safe rod-exit speed. Use a longer rod/rail or a higher-initial-thrust C motor (check the thrust curve's peak, not the average). Motor class: C-class, ≤ 10 N·s.

10. Prerequisites (Curriculum B)

Algebra I (required) and concurrent Geometry or higher. Comfort with scientific notation, sin/cos, and spreadsheets is needed; the Week 12 and Week 15 integrals are done numerically as spreadsheet sums ($\Sigma P \cdot \Delta t$), so no calculus is required. All worksheet math is Algebra I; the post-flight accelerometer check uses a spreadsheet running sum.

13. Strain-Gauge Beam Lab: second, independent E

Your strain gauge gives a second, independent E. At distance x from the load, surface strain is $\epsilon = 6 \cdot F \cdot x / (E \cdot b \cdot h^2)$. The gauge reads $\Delta R/R = GF \cdot \epsilon$ ($GF \approx 2.0$ for foil gauges), and a quarter bridge at excitation V_{ex} outputs $V_{out} \approx V_{ex} \cdot GF \cdot \epsilon / 4$ (e.g., 5 V, $GF = 2.0$, $\epsilon = 1.4 \times 10^{-3} \rightarrow 3.5$ mV, which is why the HX711 amplifier is needed). Plot ϵ vs. F ; $E = 6x/(b \cdot h^2 \cdot \text{slope})$. Compare the two values of E. Data table: add a column " ϵ ($\mu\epsilon$) from bridge" for each load (0.98–5.88 N).

Safety & Corrections (v1.1)

15. Curriculum B standards

B1 (Weeks 1–4): HS-PS2, HS-ETS1 · Weeks 5–6 · Waves & Electromagnetism: HS-PS4-1 (wave frequency/wavelength/speed), HS-PS2-5 (electric current produces magnetic field), HS-ETS1-2 · Midterm (Week 7): HS-ETS1 · B2 (Weeks 8–11): HS-PS3-5 (fields/energy in circuits), HS-PS4-1 (ultrasonic ranging), HS-ETS1-3 · B3 (Weeks 12–15): HS-PS2-1 ($F = ma$, rocket flight), HS-PS3-3 (design energy-conversion device: solar tracker), HS-ETS1-2/-3.

17. Appendix naming

The capstone worksheet is titled "Capstone Worksheet (Week 15 pre-lab)"; Appendix B is the Master Hardware Index.

18. Semester fit

15 instructional weeks fit inside a standard 18-week semester, leaving 3 weeks for breaks, review, and launch-day weather slips.

19. Gyroscope (glossary)

A sensor that measures rotation rate; integrating it gives tilt angle but drifts, so the platform fuses it with the accelerometer's gravity reference (complementary filter) to sense tilt.