Essential Hands-on Labs for Physics 1 (mechanics units) - Marc Reif – marc.pricereif@gmail.com

Content Area	Title	Essential Qs	Synopsis	Low Tech	Higher Tech	Possibilities
1. Kinematics – 1-d motion [Constant Velocity Model; Constant Acceleration Model]	1-d Kinematics Lab. Describing Motion.	How can we model constant velocity? How can we model changing velocity?	Collect and analyze graphs of constant velocity and constant acceleration motion using constant velocity toy, dynamics cart and ramp, bowling ball.	CV toy, lab cart, ball, Meter sticks, rulers, stopwatches	Computer interface, motion detector; or video camera and software	• Compare and contrast CV and CA • Predict graphs • derive kinematics eq'ns • Derive models for CV, interpret slope, intercept and area • Derive models for CA, interpret slope, intercept, and area (linearization of x vs. t possible but unlikely, requires zero initial velocity and zero initial position)
2. Kinematics – Projectile motion [often placed after forces]	Projectile Motion Lab.	How can we model 2-dimensional projectile motion?	Collect video of projectile motion (tossed ball) for analysis. Or, using a projectile launcher, determine initial velocity of projectile, and then calculate using projectile equations to predict landing point.	Meter sticks, rulers, stopwatches, projectile launcher, carbon paper.	Video camera and software. Projectile launcher with timing apparatus.	• Determine initial velocity of launcher • Predict landing spot of projectile • Apply CV and CA models to real situation
3. Zero Net Force Model	Force Table Lab	How do we sum forces?	Use Force Table to investigate balanced forces. Alternatively, suspend object vertically from angled strings with force measuring devices.	String, objects, spring scales, protractors, meter sticks	n/a	• Show how vector sums add to zero • Determine unknown mass, angle, or tension
4. Zero Net Force Model	Friction Lab	How can we describe friction?	Collect force vs. time graph for sliding wooden blocks. Vary mass (blocks stacked), vary speed, vary surface area (hook blocks together), vary surfaces.	Blocks, cart, spring scale	Blocks, cart, force sensor, motion detector	• Tow block with spring scale or force sensor • Plot F vs. m, F vs. Area, F vs. speed, F vs. surface • Look for peak of static friction • Compare to cart • Derive Frictional force law mu = F_f/F_N
5. Zero Net Force Model [also often performed in Energy unit]	Hooke's Law Lab	What is the relationship b/w spring force and stretch?	Suspend masses from springs, collect data for mass and change of length. Alternatively, mount spring on dynamics cart, connect spring to fixed force sensor, wiggle cart back and forth in front of motion detector.	Meter sticks, linear springs, masses.	Linear springs, force sensors, motion detectors, dynamics carts.	• Convert masses to forces, plot F_{spring} vs. change in length. • Interpret slope, intercept, and area.
6. Constant Net Force Model	NSL Activity	What causes acceleration?	Investigate the relationship between net force and acceleration by pushing and pulling a lab cart.	n/a	Cart, track, motion detector, force sensor, interface	• Wiggle cart back and forth by hand • Plot F vs. t, F vs. v, F vs. a • Derive NSL
7. Constant Net Force Model	Half-Atwood's machine (cart towed by hanging mass), or Atwood's machine	What is the relationship b/w force and acceleration?	Collect data for acceleration of Half-Atwood's (cart on a ramp accelerated by a falling mass) or Atwood's machine. Vary mass of system, or vary force without varying mass (all masses must stay in system).	Atwood's machine is easier low-tech, meter sticks, rulers, stopwatches	Half-Atwood's Machine: Cart, track, motion detector or smart pulley, interface.	• ½ A - Plot a vs. m with constant force (inverse) • ½ A - Plot a vs. F with constant mass (linear) • Atwood's Plot a vs. delta m • Derive NSL
8. Impulse	Impulse Lab	What happens when a varying force is exerted?	Cart collides with a force sensor. Vary mass, vary speed.	n/a	Cart, hoop spring or plunger, force sensor, motion detector	• Compare area of F-t graph to change in momentum of cart, determine Impulse proportional to Δ momentum

Content Area	Title	Essential Qs	Synopsis	Low Tech	Higher Tech	Possibilities
9. Momentum	Collisions Lab	How can we model collisions?	Carts collide elastically and inelastically on a track.	mass of an unknown	Carts, ramp, masses, photogates OR motion sensors OR video analysis	• Vary mass, speed, type of collision, directions • calculate initial and final momenta and kinetic energy
10. Models for Energy	Hooke's Law Lab	What is the relationship b/w spring force and stretch?	Suspend masses from springs, collect data for mass and change of length. Alternatively, mount spring on dynamics cart, connect spring to fixed force sensor, wiggle cart back and forth in front of motion detector.	Meter sticks, linear springs, masses.	Linear springs, force sensors, motion detectors, dynamics carts.	• Convert masses to forces, plot F_{spring} vs. change in length. • Inspect area, compare units to energy units, derive Elastic Potential Energy relationship [$1/2kx^2$]
11. Models for Energy	Energy transfer lab	What is the relationship b/w kinetic energy and potential energy?	Determine spring constant of springs. Launch dynamics carts with springs, record max velocity with motion sensor [if spring is attached to force sensor, computer can show area of F vs x graph] Alternatively, launch dynamics carts with springs on an incline, record max height	Dynamics carts, compression springs (cart launchers work well), dynamics track, meter sticks	Dynamics carts, compression springs (cart launchers work well), dynamics track, motion sensor and force sensor	• If use motion sensors, plot v_{max} vs. Δ x • If use incline method, use distance up ramp and a = g*sin theta to determine initial speed
12. Oscillating Particle Model	Oscillating Mass lab	What factors influence the period/frequency of a simple harmonic oscillator?	Suspend spring-mass system and use stopwatches or suspend spring-mass system from a force sensor OR place motion detector underneath. Alternatively, mount force sensor on stand, attach one end of spring to force sensor and other end to dynamics cart on track. Incline track, monitor motion with force sensor OR place motion detector in position to monitor cart motion. Vary mass, vary spring constant, vary amplitude	Support stands, masses, meter sticks, linear springs with different spring constants, stopwatches.	Masses (and dynamics cart and track if using inclined track), linear springs with different spring constants, force sensor OR motion detector	• Plot T^2 vs. 1/k; T^2 vs. m; T vs. amplitude
13. Oscillating Particle Model	Pendulum Lab	What factors influence the period of a pendulum?	Suspend mass from string, vary length, mass, other factors if you wish (amplitude/angle – to see that the large-angle approximation is necessary for model to work; air resistance – use modeling clay; initial push – students often think this is important)	Support stands, masses, string, meter sticks, stopwatches.	Same as low-tech, add force sensor or motion detector. Alternatively: Rotary motion sensor, pendulum attachment.	• Plot T^2 vs. L; T vs. m; T vs. other quantities.
14. Oscillations and gravitation; Work, Energy, Power	Energy and Oscillation	How can we model the behavior of an oscillator using energy?	Suspend spring-mass system from a force sensor, motion detector underneath. Alternatively, mount force sensor on stand, attach one end of spring to force sensor and other end to dynamics cart on track. Incline track, place motion detector in position to monitor cart motion.	n/a	Masses and vertical springs; or cart, ramp, and spring; or pendulum; motion detector	• plot T vs. m, T vs. k, T vs. A (mass spring) • plot T vs. m, T vs. l, T vs. theta (pendy) • investigate damped oscillation • qual plot energy bar charts •

Essential Labs for Physics I Waves and Sound Units

Content Area	Title	Essential Qs	Synopsis	Low Tech	Higher Tech	Possibilities
15. Mechanical Waves	Wave speed Lab	What factors influence the speed of wave pulses in a string?	String vibrator creates standing waves, vary string tension, vary linear density of string	n/a	String vibrator (and frequency generator/power amplifier, depending on string vibrator), string, pulley, masses	• Plot v^2 vs. Tension; plot v^2 vs. 1/linear density
16. Mechanical Waves	Standing Waves on a string lab	How does wavelength vary with frequency?	String vibrator creates standing waves, vary frequency.	n/a	String vibrator (and frequency generator/power amplifier, depending on string vibrator), string, pulley, masses	• Plot Wavelength vs. 1/frequency
17. Sound	Resonance Tube Lab	How does resonance work?	Change effective length in an open-closed tube while a source plays a constant frequency into the tube. Listen for resonances	Tuning fork, stopper and dowel (or bucket of water)	Frequency generator and speaker, stopper and dowel (or bucket of water)	• Using speed of sound in air, determine wavelengths of sound that may resonate in the tube. Compare to Δ length to $\lambda /2$

Essential Labs for Physics I Electric Force and Circuits

18. Forces, or Gravitation or Electricity	Coulomb Force Lab	What is the relationship between charge, force and distance?	Obtain two Xmas ornaments or similar small spheres. Place one sphere on an insulated plate on a balance, mount other sphere in PVC on support stand. Charge spheres with electrophorus. Quickly move spheres together while collecting balancing readings and separation.	Plastic ornaments with shiny finish (60 mm), balance with milligram readability, styrofoam plate, support stand, short piece of PVC	n/a	• Convert mass readings to force, distances to center-center separation, plot F vs. 1/r^2
19. Electric Circuits	Ohm's Law	What is the relationship between Potential Difference and Current for a resistor and a bulb?	Vary potential difference and monitor current for resistors and bulbs.	Multimeters, DC power supplies or D cells, resistors, flashlight bulbs, connecting wires.	Same as low-tech, substitute differential voltage probe and ammeter.	• Plot I vs. V for resistor, and I^2 vs. V for bulb.