

Science Simulations User Manual

How to use every lab — from Vectors to Physical Optics — in class, and how students can practise with them at home.

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Manual for site build 8 (4 October 2026): HSC Chemistry (10 chapters), SSC Physics chapters 1–13 and the HSC Physics labs, with Subject and Class menus and one English / বাংলা switch on the home page.

Getting started

Open the site's home page, pick your class (**HSC** or **SSC**) and the language (**English** or বাংলা) at the top right, and choose a lab. Each lab is a single web page: nothing to install and no account. It works in any up-to-date browser (Chrome, Edge, Firefox, Safari) on a phone, tablet, laptop or classroom projector.

- **Home page** lists every lab by paper and chapter.
- Inside a lab, **All simulations** (top right) takes you back to the home page.
- **Help** (top right) opens a short guide for that lab without leaving the page.

Tip. Bookmark a lab or share its link. The address remembers the topic, e.g. `.../hsc/vector/index.html#river` opens straight on the River & boat topic.

The screen at a glance

AREA	WHAT IT DOES
Topic tabs	The row of names under the title. Each tab is one topic of the chapter.
Stage	The big animated picture. On some topics you can click or drag on it (arrow tips, probes, flashes).
Buttons under the stage	Screen choices for that topic (for example Galilean / Lorentz / Adding velocities), plus Pause , Restart or Start , and Clean view .
Control panel (right)	Sliders and chips to change the physics: speeds, angles, wavelengths and so on. The value is shown next to each slider.
Readings box	Live numbers from the simulation: γ , current, wavelength, distances and more.
English / বাংলা (home page, top right)	One switch for the whole site. Choose it once on the home page and every lab opens in that language — tabs, controls, readings, equations, notes, problems and quizzes. The choice is remembered on that device.
Cards below	In Teach mode: equations with the current numbers and "What to notice". In Practice mode: a problem to solve and a short quiz.

Clean view

Press **Clean view** to hide everything except the stage. Use it on a projector or when recording your screen. Press **Esc** or the faint **Exit clean view** button at the bottom right to return.

Light and dark

The labs follow the device's light or dark setting automatically. For a projector in a bright room, the light setting is usually clearer.

Teach and Practice

The **Teach** / **Practice** switch is at the top right of every lab.

Teach mode

- **Equations, with your numbers** shows each formula, then the same formula with the current slider values substituted, then the answer. It updates as you move a slider.
- **What to notice** lists the key ideas to point out for that screen.

Practice mode

1. Read the problem. It uses textbook-style numbers and changes each time.
2. Type the answer as a number, e.g. , or for 3.2×10^{-10} . Press **Check** or .
3. You get the correct answer and the working. **Show it on the stage** sets the simulation to the same numbers so students can see the result.
4. **New problem** gives another one. The score next to the title counts correct answers.

Some topics have their own challenge instead (land the boat on the jetty, hit the projectile target, keep the car glass dry, read the sign of divergence or curl). Every topic also has a **Quick check** multiple-choice quiz with explanations.

Note. Scores are not saved. They reset when the page is reloaded, and nothing a student types leaves their device.

Measurement Lab

SSC Physics · Chapter 1

Physical quantities and how they are measured, with Teach and Practice modes.

Choose **SSC** in the Class menu on the home page to see the SSC labs.

- **The scale of things:** a logarithmic ruler from 10^{-15} m to 10^{25} m. Slide the exponent to see the prefix (nano, micro, milli, kilo, mega...) and an everyday object of that size.
- **SI base units:** the seven base quantities with their units, symbols and dimension letters, and a derived unit built from each.
- **Converting units:** a length, mass or time shown in all its common units at once, with the conversion factor.
- **Metre rule, Vernier calipers and Screw gauge:** realistic scales to read. The vernier highlights the coinciding division; the screw gauge shows the sleeve and thimble readings. Each has a button for a new object, so students can practise reading again and again.
- **Dimensions:** pick force, energy, pressure and so on and see its [M L T] dimensions as blocks. **Errors & precision:** the same length read with a metre rule, vernier and screw gauge, with the absolute and percentage error for each.

Motion Lab

SSC Physics · Chapter 2

Describing motion, graphs and the equations of motion, with Teach and Practice modes.

- **Distance vs displacement:** a boy walking round a block from home; drag along the path and compare the distance walked with the straight displacement arrow.
- **Kinds of motion:** linear, rotational, circular, vibratory and periodic motion animated, each with an everyday example.
- **Speed vs velocity:** a round trip where the average speed stays positive but the average velocity returns to zero.
- **Distance-time** and **velocity-time** graphs for rest, uniform velocity, speeding up and slowing down, with the slope and the area under the graph explained; and a car that draws both graphs live.
- **Equations of motion:** set u , a and t and check $v = u + at$, $s = ut + \frac{1}{2}at^2$ and $v^2 = u^2 + 2as$ on a moving car; **braking distance** shows why doubling the speed quadruples the stopping distance.
- **Falling bodies:** free fall with Galileo's 1 : 3 : 5 spacing and the v - t graph of slope g ; a ball thrown straight up; and a feather and a coin in air and in a vacuum.

Force Lab

SSC Physics · Chapter 3

Newton's three laws, momentum and friction, each shown with moving bodies and force arrows. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Newton's laws:** First law: inertia, Second law: $F = ma$, Third law: action & reaction.
- **Momentum:** Collision, Gun and bullet, Catching a ball.
- **Friction:** Static & kinetic friction, Surfaces & wheels.

Work, Power & Energy Lab

SSC Physics · Chapter 4

Work done by a force, kinetic and potential energy, conservation of energy, power, efficiency and the electricity bill. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Work:** Force and displacement, Lifting against gravity.
- **Energy:** Kinetic ↔ potential, A falling ball, Forms of energy.
- **Power & efficiency:** Power: running upstairs, Efficiency of a machine, Electric energy & bill.

State of Matter & Pressure Lab SSC Physics · Chapter 5

Particle model of the states of matter, density, Hooke's law, pressure in solids, liquids and air, Pascal's law and buoyancy. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Matter & density:** Solid, liquid & gas, Density = m / V , Elasticity: Hooke's law.
- **Pressure:** Solids: $P = F / A$, Liquids: $P = h\rho g$, Air pressure & barometer.
- **Pascal & buoyancy:** Pascal's law, Archimedes' principle, Floating & sinking.

Effect of Heat on Matter Lab SSC Physics · Chapter 6

Temperature scales, heat flow, thermal expansion, the anomalous expansion of water, specific heat and change of state. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Temperature:** Thermometer scales, Heat vs temperature.
- **Expansion:** Linear expansion, Bimetallic strip, Anomalous expansion of water.
- **Heat capacity & change of state:** Specific heat, Heating curve of ice, Evaporation & boiling.

Waves & Sound Lab

SSC Physics · Chapter 7

Transverse and longitudinal waves, $v = f\lambda$, wave graphs, echo, the speed of sound in different media and the audible range. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Waves:** Transverse wave, Longitudinal wave.
- **Wave equation:** $v = f\lambda$, Period and frequency, Wave graphs.
- **Sound:** Echo, Speed in different media, Audible range & sonar.

Reflection of Light Lab SSC Physics · Chapter 8

Laws of reflection, regular and diffuse reflection, images in plane mirrors, two mirrors at an angle, and concave and convex mirror ray diagrams. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Laws of reflection:** A ray on a plane mirror, Regular and diffuse reflection.
- **Plane mirror:** Image in a plane mirror, Two mirrors at an angle.
- **Spherical mirrors:** P, F and C, Concave mirror, Convex mirror.

Refraction of Light Lab

SSC Physics · Chapter 9

Snell's law, apparent depth, total internal reflection, convex and concave lenses, the power of a lens, the eye and dispersion by a prism. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Refraction:** Snell's law, Apparent depth, Total internal reflection.
- **Lenses:** Convex lens, Concave lens, Power of a lens.
- **The eye:** Eye & accommodation, Defects of vision, Prism & dispersion.

Static Electricity Lab

SSC Physics · Chapter 10

Charging by rubbing and by induction, the gold-leaf electroscope, Coulomb's law, electric field lines, field intensity and the lightning conductor. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Charging:** Charging by rubbing, Charging by induction, Gold-leaf electroscope.
- **Coulomb's law:** Force between two charges, Inverse-square law.
- **Electric field:** Field lines, Field intensity & potential, Lightning & conductor.

Current Electricity Lab

SSC Physics · Chapter 11

Current and Ohm's law, resistance of a wire, series and parallel circuits, electric power and heat, the electricity bill and safe house wiring. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Series & parallel:** Series, Parallel, Same bulbs, two ways.
- **Current & Ohm's law:** A simple circuit, V-I graph, Resistance of a wire.
- **Power & safety:** Electric power & heat, Energy bill (kWh), House wiring & fuse.

Magnetic Effect of Current Lab SSC Physics · Chapter 12

Magnetic field of a wire and a solenoid, the electromagnet, force on a current, the DC motor, electromagnetic induction, the AC generator and the transformer. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Magnetic field of a current:** Straight wire, Solenoid, Electromagnet.
- **Force & motor:** Force on a wire, DC motor.
- **Electromagnetic induction:** Magnet and coil, AC generator, Transformer.

Modern Physics & Electronics Lab

SSC Physics · Chapter

13

Radioactivity and half-life, analog and digital signals, the p-n diode and rectifier, the transistor, logic gates and modern communication. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Radioactivity:** α , β and γ rays, Deflection in a field, Half-life.
- **Electronics:** Analog and digital, p-n junction diode, Half-wave rectifier.
- **Transistor & logic gates:** Transistor as a switch, Logic gates.
- **Communication:** Radio waves & modulation, Optical fibre, Satellite & internet.

Laboratory Safety Lab

HSC Chemistry 1st Paper · Chapter 1

Hazard pictograms, the fire triangle and extinguishers, protective equipment, diluting acid safely, heating and smelling safely, and reading glassware and balances correctly. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Hazards & fire:** GHS hazard pictograms, Fire triangle & extinguishers, PPE & acid spills.
- **Safe handling:** Diluting concentrated acid, Heating a test tube, Smelling a gas by wafting.
- **Measurement & glassware:** Reading the meniscus, Choosing glassware, Balance & percentage error.

Qualitative Chemistry Lab

HSC Chemistry 1st Paper · Chapter 2

Rutherford and Bohr atomic models and the hydrogen spectrum, quantum numbers, orbital shapes and electron configuration, solubility and K_{sp}, flame tests, spectroscopy and paper chromatography. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Atomic models:** Rutherford: gold foil, Bohr model: electron jumps, Hydrogen spectrum.
- **Quantum numbers & configuration:** Quantum numbers, Orbital shapes, Electron configuration.
- **Solubility & K_{sp}:** Solubility curves, K_{sp} and precipitation, Common ion effect.
- **Flame test & spectroscopy:** Flame test, EM spectrum & spectroscopy, Paper chromatography.

Periodic Properties & Bonding Lab HSC Chemistry 1st

Paper · Chapter 3

Periodic trends in radius, ionisation energy, electronegativity and electron affinity; ionic, covalent and coordinate bonds; VSEPR shapes and hybridisation; bond polarity and hydrogen bonding. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Periodic table & trends:** Periodic trends, Ionisation energy vs Z, Atomic size & shielding.
- **Ionic, covalent & coordinate bonds:** Ionic bond, Covalent bond, Coordinate bond.
- **Shapes & hybridisation:** VSEPR shapes, Hybridisation.
- **Polarity & intermolecular forces:** Bond polarity, Hydrogen bonding.

Chemical Changes Lab

HSC Chemistry 1st Paper · Chapter 4

Collision theory, Maxwell-Boltzmann distribution, Arrhenius equation and energy profiles; dynamic equilibrium, Le Chatelier's principle, K_c and K_p ; pH, indicators, weak acids and buffers; heat of neutralisation and Hess's law. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Reaction rate:** Collision theory, Maxwell-Boltzmann & Arrhenius, Energy profile.
- **Chemical equilibrium:** Dynamic equilibrium, Le Chatelier: Haber process, K_c and K_p .
- **Acids, bases & pH:** pH scale & indicators, Strong and weak acids, Buffer solution.
- **Heat of reaction:** Heat of neutralisation, Hess's law.

Applied Chemistry Lab

HSC Chemistry 1st Paper · Chapter 5

Food spoilage, preservatives and adulterant tests; saponification, how soap removes grease and hard water; fermentation to vinegar, titrating vinegar and bleaching powder; colloids, the Tyndall effect and coagulation. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Food preservation:** Spoilage, Preservatives, Adulterants.
- **Soap & detergent:** Making soap, Removing grease, Hard water.
- **Vinegar & bleach:** Fermentation, Titration, Bleach.
- **Colloids:** Tyndall effect, Coagulation.

Environmental Chemistry Lab

HSC Chemistry 2nd Paper ·

Chapter 1

Boyle's, Charles's, Gay-Lussac's and Avogadro's laws, Dalton's partial pressures and Graham's diffusion; molecular speeds and real gases; the atmosphere, greenhouse effect and ozone layer; acid rain and water-quality testing. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Gas laws:** Boyle, Charles, Gay-Lussac, Avogadro, Dalton: partial pressures, Graham: diffusion.
- **Kinetic theory & real gases:** Molecular speeds, Real gases: Z and van der Waals.
- **Atmosphere & ozone:** Composition & layers, Greenhouse effect, Ozone layer & CFCs.
- **Acid rain & water quality:** Acid rain, Water quality tester.

Organic Chemistry Lab

HSC Chemistry 2nd Paper · Chapter 2

Homologous series and IUPAC naming, functional groups and hybridisation of carbon; structural, geometric and optical isomerism; addition, substitution and elimination reactions; benzene and aromaticity; an identify-the-unknown game with lab tests. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Structure & naming:** Homologous series, Functional groups, Hybridisation of carbon.
- **Isomerism:** Structural isomers, Geometric (cis-trans), Optical isomers.
- **Reaction types:** Addition, Substitution, Elimination.
- **Aromaticity & lab tests:** Benzene & aromaticity, Identify the unknown.

Quantitative Chemistry Lab

HSC Chemistry 2nd Paper ·

Chapter 3

Mass, moles, particles and molar volume; empirical and molecular formulae; limiting reactant and percentage yield; molarity, molality, normality and ppm; preparing a standard solution and dilution; acid-base and redox titrations and balancing redox equations. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Mole concept:** Mass, moles, particles & volume, Empirical & molecular formula, Limiting reactant & yield.
- **Solutions & concentration:** Molarity, molality, normality, ppm, Preparing a standard solution, Dilution $M_1V_1 = M_2V_2$.
- **Titration & redox:** Acid-base titration, Redox titration, Balancing redox equations.

Electrochemistry Lab

HSC Chemistry 2nd Paper · Chapter 4

Metallic and electrolytic conduction, strong and weak electrolytes and molar conductance; products of electrolysis and Faraday's laws; the Daniell cell, electrode potentials, the Nernst equation, and corrosion and its prevention. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Conductance:** Metallic vs electrolytic, Strong & weak electrolytes, Molar conductance.
- **Electrolysis:** Products at the electrodes, Faraday's first law, Faraday's second law.
- **Galvanic cells:** Daniell cell, Electrode potentials, Nernst equation, Corrosion & protection.

Economic Chemistry Lab

HSC Chemistry 2nd Paper · Chapter 5

The Haber-Bosch process, urea fertilizer and the Contact process; cement, glass and ceramics; the reactivity series, metal extraction and the blast furnace; sugar and ethanol production, addition polymers and atom economy. Every view animates, and has sliders, live readings, the equations worked with your numbers, notes, a Practice problem and a quiz.

- **Chemical industry:** Haber-Bosch ammonia, Urea fertilizer, Contact process (H_2SO_4).
- **Materials & metals:** Cement (rotary kiln), Glass & ceramics, Reactivity & extraction, Blast furnace (iron).
- **Everyday & green chemistry:** Sugar & ethanol, Addition polymers, Atom economy.

Vector Lab

HSC 1st Paper · Chapter 2

Add & multiply

- Choose **Triangle law**, **Parallelogram law**, **Components**, **Dot product** or **Cross product** under the stage.
- Drag the circled tips of A and B on the stage, or use the sliders for size and direction.
- Readings: θ between the vectors, $|R|$, α , $A \cdot B$, $|A \times B|$ and whether $A \times B$ points into or out of the page.
- Show that the triangle and parallelogram laws give the same R, and that $A \times B$ flips when the order is swapped.

River & boat

- Set river width d , current u , boat speed v (in still water) and heading θ from the current. Press **Start**.
- The boat points along v but moves along the resultant R . Its path is traced; earlier paths stay grey until **Clear paths**.
- **Shortest time** heads straight across ($\theta = 90^\circ$). **Reach opposite point** heads upstream at $\cos \theta = -u/v$. If $v \leq u$ it says the opposite point cannot be reached.
- Practice: river values are fixed; students choose θ to land on the red jetty and enter their crossing time.

Rain: umbrella & car

- At the top of the panel choose **Walker with umbrella** or **Car windows**.
- **Ground view** shows the rain as seen from the road. **Walker's view** / **Driver's view** shows the same rain from the moving person: it slants towards them.
- Walker: rain speed, wind (+ blows forward) and walking speed. **Auto tilt** sets the umbrella to the correct angle; **Hold it myself** lets you choose it and see whether he gets wet. Scenario chips set up common cases.
- Car: speed from reverse (negative) to forward, rear glass angle β and front glass angle γ . Each glass shows **wet** or **dry**. Driving forward fast keeps the rear glass dry ($v \geq v_r \cot \beta$); only reversing fast keeps the front glass dry.
- Practice: find the umbrella tilt, or the least speed that keeps a glass dry, then watch the result.

Gradient, div & curl

- Choose a screen under the stage: **Gradient**, **Divergence**, **Curl** or **All together (advanced)**. Start with the first three: each shows one idea.
- **Gradient:** a coloured height map ϕ with contour lines. Drag the dot: $\nabla\phi$ points uphill, across the contours.
- **Divergence:** drag the circle. Green edge arrows mean flow leaving, red mean flow entering.
- **Curl:** drag the paddle wheel. It spins anticlockwise for positive curl, clockwise for negative.
- **All together:** everything at once, colour maps for div or curl, and a box to type your own field using x , y , numbers, $+$ $-$ $*$ $/$ $^$ and $\sin$, $\cos$, $\tan$, $\exp$, sqrt , abs , $\log$, π .

Projectile Lab

HSC 1st Paper · Chapter 3

- Set launch speed u , angle θ , launch height h and gravity (Earth, Moon, Mars, Jupiter). Press **Launch**.
- **Pause**, **Step** > (a small time step) and **Slow motion** help you stop at the top of the path.
- Show chips: velocity vectors (v , v_x , v_y), predicted path, equal-time dots, keep old paths.
- Class demos: **Angle family $15^\circ \rightarrow 75^\circ$** and **Complementary pair θ & $90^\circ - \theta$** .
- Practice: hit the red target. Students write their predicted range first and see their error.

Newtonian Mechanics Lab

HSC 1st Paper · Chapter 4

Collisions & momentum

- **Collision:** set m_1 , m_2 , u_1 , u_2 and the coefficient of restitution e (or tap **Elastic**, **Partly elastic**, **Stick together**). Two carts collide on a smooth track.
- The bar charts compare momentum (each cart and total) and kinetic energy before and after. The total momentum bars always match; KE matches only when $e = 1$.
- **Explosion & recoil:** a spring pushes two carts apart from rest. Their momenta are equal and opposite, like a gun and bullet.

Force & friction

- **F = ma:** set the push F , mass and μ . The free-body arrows show F , friction, N and mg ; the v - t graph's slope is the acceleration.
- **Static & kinetic friction:** the pull rises by itself. Static friction matches it until $\mu_s N$, then the block breaks free and friction drops to $\mu_k N$. The graph traces friction against the pull.

Inclined plane

- Set θ , mass, μ_s and μ_k . The weight is split into $mg \sin \theta$ and $mg \cos \theta$. The block slides only when $\tan \theta > \mu_s$; the graph of a against θ marks the angle of repose.

Pulleys

- **Two hanging masses** (Atwood machine) and **Block on a table** with a hanging mass and friction. The right-hand panel writes the equation of motion for each body and the results for a and T .

Circular motion

- **Centripetal force:** a ball on a string, seen from above. Change r , v and m ; press **Cut the string** and the ball leaves along the tangent, not outward.
- **No centrifugal force:** a smooth ball on a turning car's dashboard, shown side by side from the road (it goes straight) and from the driver's seat (it seems thrown outward).

Banking of roads

- Three screens: **Banked, no friction**; **Banked with friction**; **Flat road**. Set the radius, banking angle, speed and μ for a 1000 kg car.

- The cross-section shows N , mg and friction; the speed gauge shows the safe band ($v_{\min}$ to $v_{\max}$) and the ideal speed. Outside the band the car skids up or slides down the bank.

Angular momentum

- **Spinning skater:** tap **Arms in / Arms out** or use the slider. I falls, ω rises, and $L = I\omega$ stays constant; KE rises because the arms do work.
- **Ball on a shortening string:** pull the string through the hole; mvr stays constant, so the ball speeds up.

Gravitation Lab

HSC 1st Paper · Chapter 6

Five topics, from Newton's law to Kepler's laws, with Teach and Practice modes and the English / বাংলা switch.

Newton's law

- **Two masses:** pick a pair — two people, an apple and the Earth, the Earth and the Moon, the Earth and the Sun — and change the separation. The force on each body is drawn equal and opposite, and the inverse-square graph shows why doubling r quarters F .
- **Field round a planet:** field lines and rings at $2R$, $3R$...; the field strength at any distance from Earth, Moon, Mars or Jupiter, with g at the surface of each on a bar chart.

Variation of g

- **With height:** the exact $gR^2/(R + h)^2$ and the approximation $g(1 - 2h/R)$ on the same graph, so students can see where the approximation stops working. The readout names what is at that height (aircraft, the ISS, GPS, geostationary).
- **With depth:** the Earth in cross-section with only the inner sphere shaded — the shell outside cancels — and the classic graph, $g \propto r$ inside, $g \propto 1/r^2$ outside.
- **With latitude:** the spinning Earth, the circle of radius $R \cos \lambda$, the centripetal term $\omega^2 R \cos^2 \lambda$, and the measured g from 9.78 at the equator to 9.83 at the poles.

Potential & escape

- **Potential well:** $V = -GM/r$ drawn as the well it is, with the energy of a chosen mass and the work to climb from R to r or out completely.
- **Escape velocity:** throw a body straight up from the Earth, Moon, Mars or Jupiter at any speed. It either rises, stops and falls back (the highest point is marked) or escapes for good. The KE, PE and total-energy bars beside it make the condition $E \geq 0$ visible.

Satellites

- **Circular orbit:** set the height and read $v = \sqrt{GM/r}$, $T = 2\pi\sqrt{r^3/GM}$, the kinetic and total energy. Graphs of v and T against height, with the 24-hour line marked at 35 786 km.
- **Geostationary:** a clock runs, the Earth turns with Dhaka marked, the geostationary satellite stays above it, and a 400 km satellite laps them both 16 times a day.

- **Weightlessness:** a person on a scale in a lift. Move the acceleration slider from $+g$ to $-g$: the scale reading $N = m(g + a)$ goes from twice the weight to zero, and the free-fall case is exactly what a satellite is.

Kepler's laws

- **1st law:** an ellipse with the Sun at one focus; change the eccentricity from 0 to 0.85. The planet moves with the correct varying speed (Kepler's equation is solved each frame).
- **2nd law:** two slices swept in equal times, one near perihelion and one near aphelion, with their areas computed to show they are equal.
- **3rd law:** the eight planets on a log-log plot of T against a with slope $3/2$, T^2/a^3 for each, and a slider to place a new planet.

Matter & Fluids Lab HSC 1st Paper · Chapter 7

Structural properties of matter: three topics on elasticity and three on fluids. Like the other 2nd-paper labs it has Teach and Practice modes, and an **English** / বাংলা switch at the top right that translates everything on the page.

Stress & strain

- **Load a wire:** choose steel, copper, aluminium, brass or rubber, then the load, length and diameter. The panel gives $\sigma = F/A$, $\epsilon = \Delta L/L$, the extension and Y , and says in words whether the wire is still in the Hooke's-law region, has yielded, or has snapped. The stretch on the stage is exaggerated so it can be seen.
- **Stress-strain curve:** the graph students must draw in the exam. Drag the slider and a point walks along it past P (proportional limit), E (elastic limit), Y (yield point), U (breaking stress) and B (fracture); the specimen beside the graph stretches, necks and breaks. Past E a dashed red line shows the permanent set left on unloading — the difference between elastic and plastic deformation.
- **Young's modulus compared:** four wires, same length, same thickness, same load. The stretch is inversely proportional to Y , and the picture makes the point without any numbers.
- **Elastic energy:** the triangle under the F - ΔL graph, $W = \frac{1}{2}F\Delta L$, with the energy density $\frac{1}{2}\sigma\epsilon = \sigma^2/2Y$.

Bulk, shear & Poisson

- **Bulk modulus:** a cube squeezed from all sides; $\Delta V/V = \Delta P/B$ for water, mercury, glass, copper and steel, and the compressibility $1/B$.
- **Rigidity (shear):** a block with its base clamped leaning by $\theta = (F/A)/\eta$. Switch to rubber to see why it leans so easily.
- **Poisson's ratio:** the rod gets longer and thinner together; σ between 0 (cork) and 0.5 (rubber), and the relation $Y = 3B(1 - 2\sigma) = 2\eta(1 + \sigma)$.

Surface tension

- **Film on a frame:** the classic U-frame with a sliding wire. $F = 2Tl$ because a film has two surfaces; the work done pulling the wire out is $T \times$ the new area, which is why T is also the surface energy per unit area.
- **Excess pressure:** $2T/r$ for a drop or an air bubble, $4T/r$ for a soap bubble, with the hyperbola of p against r .
- **Angle of contact:** water on clean glass, water on wax, mercury on glass, or any angle you set; the drop shape, the meniscus and whether the liquid wets follow.

Capillarity

- Three tubes of radius $r/2$, r and $2r$ in water, alcohol, olive oil or mercury. The liquid climbs (or is pushed down, for mercury) to $h = 2T \cos \theta / (r\rho g)$, and the force balance — $2\pi rT \cos \theta$ up, $\pi r^2 h \rho g$ down — is shown beside it.

Viscosity

- **Layers & velocity gradient:** a plate dragged over a liquid; the layers, the velocity gradient and $F = \eta A \, dv/dx$, for liquids from honey to air.
- **Falling sphere:** weight, upthrust and Stokes' drag $6\pi\eta r v$ on a ball, and the v - t curve rising to the terminal velocity $v_t = 2r^2(\rho - \sigma)g/9\eta$. Because τ is only milliseconds the animation runs in slow motion; the Reynolds number warns when Stokes' law no longer applies.
- **Flow through a tube:** Poiseuille's $Q = \pi P r^4 / 8 \eta L$, the parabolic profile, and the bar chart that shows halving r cuts the flow to a sixteenth.

Fluids in motion

- **Equation of continuity:** $A_1 v_1 = A_2 v_2$ with dots that speed up in the narrow part of the pipe.
- **Bernoulli's theorem:** manometer tubes on the wide and narrow parts; the liquid in the narrow part rises less. $P_1 - P_2 = \frac{1}{2}\rho(v_2^2 - v_1^2)$ — the venturi meter.
- **Torricelli's theorem:** a jet from a hole at depth h with $v = \sqrt{2gh}$, its parabola and range $R = 2\sqrt{h(H - h)}$; move the hole to find the longest jet.

Periodic Motion Lab

HSC 1st Paper · Chapter 8

Five topics on oscillations, with Teach and Practice modes and the English / বাংলা switch.

Simple harmonic motion

- **Reference circle:** the standard picture — a particle in uniform circular motion and its shadow on a line. Set the amplitude, period and initial phase ϕ ; the phase angle $\omega t + \phi$ is drawn on the circle, the velocity on the shadow, and x against t traces beside it.
- **x , v and a against t :** the three curves stacked with a moving time marker, so the phase relationships (v a quarter period ahead, a half a period ahead) are obvious.
- **v and a against x :** $v^2 = \omega^2(A^2 - x^2)$ as an ellipse and $a = -\omega^2 x$ as a straight line — the definition of SHM in graph form.

Energy in SHM

- **Energy bars:** a mass on a spring oscillates while PE, KE and total bars trade height; the energy-time strip below shows each oscillating twice per cycle.
- **Energy against x :** the PE parabola $\frac{1}{2}kx^2$, the inverted KE parabola and the flat total, with the crossing at $A/\sqrt{2}$.

Spring & mass

- **Mass on a spring:** the natural length, the static stretch mg/k , the oscillation about the new equilibrium with kx and mg drawn, and $T = 2\pi\sqrt{m/k}$ — with the point that g does not appear.
- **Springs in series & parallel:** the two arrangements drawn, with $1/k = 1/k_1 + 1/k_2$ or $k = k_1 + k_2$ and the resulting period.
- **T^2 against m :** the straight line of slope $4\pi^2/k$, with other k values shown faintly.

Simple pendulum

- **The swing:** the bob with mg , $mg \sin \theta$ and the tension; choose L , the planet (g) and the amplitude. θ against t beside it, with a warning when the amplitude is too large for the small-angle formula.
- **T^2 against L :** one line per planet; the slope $4\pi^2/g$ gives g .
- **Seconds pendulum & g :** the length needed for $T = 2$ s on Earth, the Moon and Jupiter, and a pendulum in a lift with $g_{\text{eff}} = g + a$ — down to free fall, where it stops swinging.

Damped & forced oscillations

- **Damped oscillation:** x against t inside the envelope $A e^{(-bt/2m)}$; raise b through light, critical and heavy damping, with the critical value $2\sqrt{km}$ given.
- **Forced oscillation & resonance:** the amplitude–frequency curve for the chosen damping (others faint), the driven mass with its phase lag, and the peak at the natural frequency.

Waves Lab HSC 1st Paper · Chapter 9

Five topics on waves and sound, with Teach and Practice modes and the English / বাংলা switch.

Progressive waves

- **Transverse wave:** the wave travels to the right while a red particle bobs up and down on the spot — the distinction students most often miss. λ , f and A are sliders; $v = f\lambda$ is shown on the stage and the particle's own displacement is traced against time.
- **Longitudinal wave:** rows of air particles shuttling back and forth, compressions and rarefactions labelled as they move, and the displacement-position graph underneath to explain why the textbook draws a longitudinal wave as a sine curve.
- **Wave equation & phase:** $y = A \sin(\omega t - kx)$ with two movable points; their path difference, the phase difference $2\pi\Delta x/\lambda$, and both motions against time so "in phase" and "in antiphase" can be seen.

Superposition & stationary waves

- **Superposition:** two waves and their sum. Change the phase difference from 0 to 360° and the second wave's amplitude; the resultant amplitude $\sqrt{(A_1^2 + A_2^2 + 2A_1A_2\cos \phi)}$ is given.
- **String fixed at both ends:** the fundamental and harmonics up to the sixth, nodes and antinodes marked, the envelope drawn, and $f = nv/2L$ worked out for the chosen length and wave speed.
- **Pipes:** closed at one end or open at both, any allowed harmonic, the displacement envelope with the air particles moving, and the list of harmonics with frequencies — showing that a closed pipe has odd harmonics only.

Beats

- Two waves of close frequency, their sum inside the beat envelope, and the beat frequency $|f_1 - f_2|$; set $f_1 = f_2$ and the beats vanish.

Doppler effect

- **Moving source & observer:** wavefronts spread from the source; give the source or the observer a velocity (towards is positive) and watch the wavefronts bunch or stretch while the heard frequency is calculated from $f' = f(v + v_o)/(v - v_s)$.

- **The four cases:** source or observer, approaching or receding, all four formulas evaluated for the same numbers, so the asymmetry between a moving source and a moving observer is plain.

Speed & intensity of sound

- **Speed of sound:** $v = \sqrt{\gamma RT/M}$ against temperature for air, helium, CO₂ and hydrogen; Newton's isothermal value beside Laplace's correction.
- **Intensity & decibels:** a source of chosen power, the $1/r^2$ spreading, $I = P/4\pi r^2$, $L = 10 \log_{10}(I/I_0)$, and a decibel ruler from the threshold of hearing to a jet engine.

Ideal Gas Lab HSC 1st Paper · Chapter 10

Gas laws, the ideal gas equation, kinetic theory and humidity, with Teach and Practice modes and the English / বাংলা switch. Every view has molecules moving in a box whose speed follows $\sqrt{T}$.

Gas laws

- **Boyle's law:** push the piston in at constant temperature; the pressure readout and the P-V hyperbola follow, and the molecules visibly hit the walls more often.
- **Charles's law:** heat at constant pressure (the piston is free); the box grows and the V-t line is extrapolated to $-273\text{ }^{\circ}\text{C}$ to show where absolute zero comes from.
- **Pressure law:** a rigid box with a gauge; P-t is again a straight line through absolute zero.

Ideal gas equation

- **PV = nRT:** sliders for n, T and V give P in kPa and atmospheres, the number of molecules, and PV against nRT.
- **Two states:** $P_1V_1/T_1 = P_2V_2/T_2$ with both states drawn; set the first state and two of the second and the lab finds V_2 .
- **Density & moles:** $\rho = PM/RT$ compared for hydrogen, helium, air, oxygen and CO_2 — why balloons float.

Kinetic theory

- **Where pressure comes from:** the model's assumptions, a highlighted molecule reversing its momentum at the wall, and $P = \frac{1}{3}\rho\bar{c}^2$ evaluated to show it gives 1 atm.
- **Molecular speeds:** Maxwell's distribution for the chosen gas and temperature with the most probable, mean and rms speeds marked, other temperatures shown faintly.
- **Temperature & energy:** $\text{KE} = 3kT/2$ against T, and the rms speeds of five gases at the same temperature to make the point that the energy is the same but the speeds are not; degrees of freedom and equipartition in the notes.

Humidity

- **Relative humidity & dew point:** set the air temperature and the dew point; a "capacity" beaker shows RH, the thermometer shows how far the air must cool for dew, and absolute humidity is given in g/m^3 .
- **Saturation curve:** the steeply rising e_s -T curve with the air's state and the horizontal path down to the dew point.

Thermodynamics Lab

HSC 2nd Paper · Chapter 1

Five topics on heat, work and entropy, with Teach and Practice modes. Pressures are in kPa and volumes in litres, so $P \times V$ is in joules directly, and W always means the work done *by* the gas — the sign convention the textbook uses.

Work & P-V diagram

- **Piston & work:** 1 mol of gas in a cylinder with bouncing molecules. Drag the volume and the work $\int P \, dV$ accumulates while the P-V trace is drawn and its area shaded; keep T fixed or P fixed.
- **Area under the curve:** the same two states joined by isobaric-then-isochoric, isochoric-then-isobaric, straight-line and isothermal routes, each with its own work — the demonstration that W is a path function while ΔU is not.
- **Cyclic process:** a rectangle or triangle traced clockwise or anticlockwise, with the enclosed area as the net work and its sign telling engine from refrigerator.

Processes

- **Four processes** from one starting state, monatomic or diatomic: the isobaric, isothermal and adiabatic curves to V_2 and the isochoric line, with W , ΔU and Q tabulated for each.
- **Adiabatic compression:** an insulated cylinder; squeeze it and read T from $TV^{(\gamma-1)} = \text{constant}$, with the isothermal curve dashed for comparison.
- **C_p and C_v :** the same heat given to a rigid box and to a free piston; the box warms more because the piston gas spends $nR\Delta T$ on work. $C_v = fR/2$, $C_p = C_v + R$, γ .

First law

- **Energy balance:** sliders for Q and W with the ΔU bar worked out and the piston and heat arrows drawn to match the signs.
- **Internal energy:** $U = (f/2)nRT$ against temperature, with average molecular KE and rms speeds.
- **Isothermal & adiabatic:** the same expansion in a heat bath ($Q = W$) and insulated ($\Delta U = -W$, the gas cools).

Heat engines

- **Carnot cycle:** the four strokes animated on the P-V diagram and in the cylinder, with Q_1 , Q_2 , W and η for the chosen T_1 and T_2 .

- **Efficiency:** the energy-flow diagram from hot reservoir to engine to cold reservoir; $\eta = 1 - T_2/T_1$ and why 100 % is impossible.
- **Refrigerator & heat pump:** the same diagram reversed, with $\text{COP} = T_2/(T_1 - T_2)$ and the heat dumped into the room.

Second law & entropy

- **Heat flow & entropy:** press **Let heat flow** and watch two bodies equalise while the entropy bars show the hot body's loss, the cold body's larger gain and the positive total.
- **The two statements:** Kelvin-Planck and Clausius drawn as the machines they forbid.
- **Free expansion:** remove the partition and the molecules spread; Q , W , ΔU and ΔT are all zero yet $\Delta S = nR \ln(V_2/V_1)$, and the chance of the gas returning by itself is shown.

Practice problems: $P\Delta V$ and area work, net work per cycle, isothermal work and heat, adiabatic temperature change, C_v from γ , ΔT at constant pressure, $Q = \Delta U + W$, internal energy, Carnot efficiency and rejected heat, COP, and entropy changes.

Static Electricity Lab

HSC 2nd Paper · Chapter 2

Five topics on electrostatics, with Teach and Practice modes and the English / বাংলা switch.

Coulomb's law

- **Two charges:** set q_1 , q_2 and the separation; the two force arrows are always equal and opposite, and switch between attraction and repulsion as the signs change. $F = kq_1q_2/r^2$ is evaluated with $k = 9 \times 10^9$.
- **In a medium:** the same pair in air, paper, glass or water ($\kappa = 80$) to show the force falling by the dielectric constant.
- **Three charges in a line:** the forces on the middle charge from each neighbour and their vector sum — superposition.

Electric field

- **Field lines:** traced live for a single + or – charge, a dipole, two like charges (with the neutral point) and two parallel plates.
- **Field of a point charge:** $E = kq/r^2$ at a movable point, with the $1/r^2$ graph.
- **Uniform field:** an electron or a proton released between two plates; $E = V/d$, the force qE , the acceleration, the crossing time and the energy gained qV (in eV).

Gauss's law

- **Electric flux:** a flat loop in a uniform field, turned through θ ; $\Phi = EA \cos \theta$ and a count of the lines that pass through.
- **Choosing a Gaussian surface:** the method itself. Pick spherical, cylindrical or planar symmetry; the picture marks where E is perpendicular to the surface (flux = EA) and where it is parallel (flux = 0), and a numbered list walks through symmetry → surface → flux → $q_{\text{enclosed}}/\epsilon_0 \rightarrow E$.
- **Point charge: sphere:** a Gaussian sphere of any radius round q ; the flux q/ϵ_0 does not change with r , the area does, and $E \times 4\pi r^2 = q/\epsilon_0$ gives Coulomb's law.
- **Line charge: cylinder:** a long wire with λ per metre inside a coaxial cylinder of radius r and length L ; no flux through the end caps, $E \times 2\pi rL = \lambda L/\epsilon_0$, $E = \lambda/2\pi\epsilon_0 r = 2k\lambda/r$, the $1/r$ graph, and the point that L cancels.
- **Plane sheet: pillbox:** a large sheet with σ per m^2 and a pillbox through it; both end caps give EA , $2EA = \sigma A/\epsilon_0$, $E = \sigma/2\epsilon_0$ — move the caps and nothing changes.
- **Two plates & conductors:** two sheets $\pm\sigma$ superposed — σ/ϵ_0 between, zero outside — or a pillbox on the surface of a metal plate with $E = 0$ inside; $V = Ed$ and $C = \epsilon_0 A/d$

follow.

- **Charged sphere: inside & out:** a conducting sphere ($E = 0$ inside) or a uniformly charged insulating sphere ($E = kQr/R^3$ inside), kQ/r^2 outside, with the Gaussian sphere drawn at r , the charge it encloses and the E - r graph.

Electric potential

- **Potential of a point charge:** $V = kq/r$, the equipotential circles, and the $1/r$ graph (contrast with $E \propto 1/r^2$).
- **Moving a charge:** a test charge carried from r_A to r_B ; V_A , V_B , ΔV and $W = q_0\Delta V$ with its sign explained.
- **Equipotentials:** contour maps computed on the fly for a single charge, a dipole and two plates, with field lines drawn over them to show the right-angle rule.

Capacitors

- **Parallel plates:** $C = \kappa\epsilon_0 A/d$ with area, gap, dielectric and voltage; charge flows from the battery onto the plates, the field lines show $E = V/d$.
- **Dielectric:** an air capacitor and one with a dielectric side by side, the polarised molecules and the induced surface charges drawn; choose battery connected (V fixed) or removed first (Q fixed) and a table shows how C , Q , V , E and U change and where the energy came from.
- **Series & parallel:** charges and voltages on each capacitor.
- **Energy stored:** the Q - V triangle, $U = \frac{1}{2}CV^2$ and the energy density.
- **Charging through R:** an RC circuit charging or discharging with the current dots slowing as the plates fill; V_C and I against t/τ , $\tau = RC$, 63 % after one time constant, 99 % after five.

Current Electricity Lab

HSC 2nd Paper · Chapter 3

Five topics on current electricity, with Teach and Practice modes and the English / বাংলা switch. Every circuit is drawn with animated current dots whose speed follows the current.

Current & Ohm's law

- **Drift of electrons:** electrons jitter at random through a lattice of + ions and drift slowly to the left while conventional current points right. $I = nAve$ is evaluated for the current and wire area you set, with the time to cross 1 m and the contrast with the signal speed.
- **V-I graphs:** a metal resistor (straight line), a filament lamp, a diode and a thermistor, with V/I at the working point and the reason each curve bends.
- **Resistance & resistivity:** a wire whose length and cross-section you set, in copper, aluminium, tungsten, nichrome or carbon; $R = \rho L/A$, the R-T line $R = R_0(1 + \alpha\Delta T)$ (negative α for carbon) and a log-scale bar chart of resistivities.

Series & parallel

- **Series:** three resistors and a battery; one current everywhere, $V_1 + V_2 + V_3 = V$.
- **Parallel:** the full voltage across each branch, the branch currents adding, and the combined resistance smaller than the smallest.
- **A mixed network:** $R_2 \parallel R_3$ in series with R_1 — the pair first, then the total, then the main current and its split.

EMF & Kirchhoff

- **Internal resistance:** a cell drawn with its r inside a dashed box, an ammeter and a voltmeter across the external resistor; $V = E - Ir$, the lost volts, and the V-I line with intercept E and slope $-r$.
- **Power transfer:** the P-R curve $E^2R/(R + r)^2$, its maximum at $R = r$, $P_{\max} = E^2/4r$ and the 50 % efficiency there.
- **Kirchhoff's laws:** two cells with series resistors in parallel across a third resistor; the junction and loop equations are written with your numbers and solved, and a negative current is flagged as the cell being charged.

Bridge & potentiometer

- **Wheatstone bridge:** P, Q, R, S in a diamond with the galvanometer needle driven by a full node analysis; balance when $P/Q = R/S$, the potentials of B and D, and the S

needed for balance.

- **Meter bridge:** known R and unknown X in the gaps of a 100 cm wire; slide the jockey, the galvanometer tells you which way to move, and at balance $X = R(100 - l)/l$.
- **Potentiometer:** a driver cell and rheostat across the wire, E_1 or E_2 through a galvanometer to the jockey, the potential-along-the-wire graph with both balancing lengths, $E = kl$ and $E_1/E_2 = l_1/l_2$ — and the case of a cell above the driver voltage that cannot be balanced.

Power & meters

- **Power, heating & bills:** choose an appliance (LED bulb to room heater), its hours per day and the tariff; $I = P/V$ and $R = V^2/P$ at 220 V, a running kWh meter, and the energy and cost per month with $1 \text{ kWh} = 3.6 \times 10^6 \text{ J}$.
- **Galvanometer → ammeter:** G and I_g of the galvanometer and the wanted range; the shunt $S = I_g G / (I - I_g)$, the current split between coil and shunt and the tiny meter resistance.
- **Galvanometer → voltmeter:** the multiplier $R = V/I_g - G$ in series, the large voltmeter resistance and the sensitivity in Ω/V .

Magnetism Lab

HSC 2nd Paper · Chapter 4

Eight topics, from Oersted's experiment to permanent magnets. Fields are shown with the usual $\otimes$ (into the page) and $\odot$ (out of the page) symbols, and every reading is given in μT or mT as well as tesla.

Oersted & moving charge

- **Compass round a wire:** a ring of compass needles round a vertical wire. Switch the current on and reverse it; the needles turn to the tangent, which is the right-hand grip rule. Turn on **Earth's field** and the needle settles along the sum of the two fields — the classic $\tan \theta = B_{\text{wire}}/B_{\text{H}}$ of a tangent galvanometer.
- **Moving charge:** a charge enters a uniform field and moves in a circle, $r = mv/qB$, period $T = 2\pi m/qB$. A launcher fires the charge at right angles to B and its path is drawn. With B into the page ($\otimes$) a positive charge turns anticlockwise and an electron clockwise; reverse the charge or switch B to out of the page ($\odot$) and the turn reverses ($F = qv \times B$). Change the particle, v and B to see r change.

Biot-Savart law

- **Current element:** drag the point P . The panel works out $dB = (\mu_0/4\pi) \cdot I \, dl \sin \theta / r^2$ with your r and θ , and shows dB is zero along the element and largest at right angles to it.
- **Straight wire:** $B = \mu_0 I / 2\pi a$. Drag the distance a and watch the $1/a$ graph.
- **Circular coil:** $B = \mu_0 NI / 2a$ at the centre, and $B = \mu_0 NI a^2 / 2(a^2 + x^2)^{3/2}$ on the axis. Drag the point along the axis to see it fall off.

Ampère's circuital law

- **Wire:** the Amperian circle is drawn round the wire; $\oint B \cdot dl = \mu_0 I$ gives the same answer as Biot-Savart, in one line.
- **Solenoid:** $B = \mu_0 nI$ inside and nearly zero outside. Change the turns, the length and the current.
- **Toroid:** $B = \mu_0 NI / 2\pi r$. Move the point inside, in the core and outside to show the field exists only in the core.

Force on a current & torque

- **Wire in a field:** $F = BIL \sin \theta$. Change the angle to show the force is zero when the wire lies along the field, and use the drawn directions for the left-hand rule.
- **Two parallel wires:** $F/L = \mu_0 I_1 I_2 / 2\pi d$. Same direction $\rightarrow$ attract, opposite $\rightarrow$ repel. Set both currents to 1 A and the distance to 1 m for the definition of the ampere.

- **Current loop:** $\tau = NBI A \sin \theta$. This is the moving-coil galvanometer and the d.c. motor; the same screen gives the orbital magnetic moment of an electron and the spin moment (the Bohr magneton).

Hall effect

- Set B , current, slab thickness and carrier density n . The Hall voltage $V_H = BI/nqt$ builds up across the slab, and the Hall coefficient $R_H = 1/nq$ is shown.
- Switch the carriers between **electrons** and **holes**: the sign of V_H flips, which is how the Hall effect tells n-type from p-type.

Earth's magnetism

- **Globe:** the Earth as a bar magnet with field lines. Drag the latitude; the dip needle follows $\tan \delta = 2 \tan(\text{latitude})$ — flat at the equator, vertical at the poles.
- **Elements:** the three magnetic elements — declination, dip δ and the horizontal component $H = B \cos \delta$ (with $V = B \sin \delta$) — drawn as a 3-D box so the students can see where each angle sits.

Magnetic materials

- **Kinds:** a diamagnetic, a paramagnetic and a ferromagnetic sample in the same field, with their susceptibility χ and how each behaves near a magnet.
- **Domains:** a grid of domains. Raise H and they line up one by one, tracing the M - H curve up to saturation.
- **Hysteresis:** the B - H loop. Compare **soft iron** (thin loop, small coercivity) with **steel** (fat loop). The loop area is the energy lost per cycle — the reason transformer cores are soft iron.

Magnets

- **Bar magnet:** pole strength m and length $2l$ give the moment $M = m \cdot 2l$. Compare the axial (end-on) field $2M/d^3$ with the equatorial (broadside-on) field M/d^3 at the same distance.
- **Electromagnet:** a coil with a switch. $B = \mu_0 \mu_r nI$. Change the core between air, soft iron and steel and switch off — soft iron loses its magnetism, steel keeps it, which is exactly the electromagnet-versus-permanent-magnet distinction.

Induction & AC Lab HSC 2nd Paper · Chapter 5

Seven topics, from the first kick of a galvanometer needle to resonance in an LCR circuit. Voltages are shown in mV or V automatically, and every screen states the formula with the numbers on the sliders.

Faraday's law

- **Magnet & coil:** let the magnet swing to and fro, or tap **I will move it** and drag the position slider yourself. The needle kicks only while the magnet moves — hold it still anywhere and $\varepsilon = 0$.
- The graph beside it plots emf against magnet position. The point worth stopping on: at the centre of the coil the flux is **largest** but the emf is **zero**, because there the flux is not changing.
- **Rod on rails:** $\varepsilon = BLv$. The rod sweeps area Lv each second, the induced current makes a force BIL against the motion, and the panel shows that your power Fv equals the heat I^2R .
- **What changes the flux:** pick **Change B**, **Change the area** or **Turn the coil**. The two curves show that the emf is the slope of the flux — zero at the turning points of Φ , largest where Φ crosses fastest. Turning the coil gives a sine emf, which is the generator.

Lenz's law

- **Push in, pull out:** choose the direction and which pole faces the coil. The coil's near face is labelled with the induced pole, the induced current direction is drawn, and the force on the magnet points the opposite way to the motion.
- **Magnet in a metal tube:** the same magnet dropped down a plastic and a copper tube. Eddy currents in the copper oppose the fall, so it drifts down at a terminal speed while the other is in free fall. The slider changes how good a conductor the tube is.
- **Where the energy comes from:** two bars — the work you do each second and the heat produced each second. They are always equal. Use this to argue why Faraday's law must carry a minus sign.

Self induction

- **Inductance of a coil:** $L = \mu_0\mu_r N^2 A/l$. Change the turns, length, radius and core; the graph shows $L \propto N^2$, and the readings give the back emf for the chosen dI/dt .
- **Growth & decay of current:** an LR circuit with a switch. The current rises as $I = (V/R)(1 - e^{-t/\tau})$ with $\tau = L/R$ marked on the graph — 63% after one τ . Switch off to

watch it decay, and talk about the spark at the switch.

- **Energy stored:** $U = \frac{1}{2}LI^2$ drawn as a parabola, with the electric twin $\frac{1}{2}CV^2$ named alongside.

Mutual induction

- **Mutual inductance:** two coils on one core, $M = \mu_0\mu_r N_1 N_2 A/l$. The primary current is a triangle wave, so dI_1/dt is constant in each half and the secondary emf is a clean square wave — a good way to show $\varepsilon_2 = -M dI_1/dt$.
- **Transformer:** set the turns, the primary voltage, the load current and the efficiency. $V_s/V_p = N_s/N_p$, and the bars compare input power, output power and losses. The label tells you whether it is step-up or step-down.

Generator & dynamo

- A coil turns between the poles; the output is traced beside it with the peak and rms lines marked. $\varepsilon = NBA\omega \sin \omega t$, so $\varepsilon_0 = NBA\omega$ — raise N , B , A or the speed.
- **AC generator** uses two slip rings; **DC dynamo** uses a split-ring commutator and the output never goes negative. The $\otimes$ and $\odot$ on the coil sides show the current reversing every half turn.

Peak, mean & rms

- **On the waveform:** peak I_0 , rms $0.707 I_0$ and the half-cycle mean $0.637 I_0$ marked on one sine wave, with the full-cycle mean of zero pointed out.
- **The effective value:** the i^2 curve with its average $I_0^2/2$, and two lamps — an a.c. of peak I_0 and a d.c. of $I_0/\sqrt{2}$ — glowing equally. This is the meaning of "220 V mains" (peak ≈ 311 V).

AC circuits & resonance

- **R, L or C alone:** the voltage and current waveforms with a phasor diagram. In phase for R, current lagging 90° for L, leading 90° for C, with $X_L = 2\pi fL$ and $X_C = 1/2\pi fC$.
- **Series LCR:** the phasor diagram, the impedance triangle, $Z = \sqrt{R^2 + (X_L - X_C)^2}$, the phase angle and the power factor $\cos \phi$. Note that V_L and V_C can each be bigger than the supply voltage.
- **Resonance:** current against frequency with $f_0 = 1/(2\pi\sqrt{LC})$ marked. Change R to show it changes the sharpness but not f_0 .

Geometrical Optics Lab

HSC 2nd Paper · Chapter 6

Eight topics along the top, with Teach and Practice modes and the English / বাংলা switch. The Cartesian sign convention is used throughout — distances measured from the pole or optical centre, positive to the right — and every reading shows the sign, so the numbers on screen match what students write in the exam.

Mirrors

- **Plane mirror:** the image as far behind as the object is in front, drawn with the two rays that reach the eye, and the half-height rule for the shortest mirror that shows the whole body.
- **Concave and convex mirror:** the object arrow, the three standard rays (parallel → F, through C, to the pole) and the image, real or virtual. $1/v + 1/u = 1/f$ with $f = R/2$; readings give v , m , the image height and its nature. Slide the object through C, F and inside F and watch the image jump.

Refraction

- **Plane surface:** $n_1 \sin i = n_2 \sin r$ for any pair of air, water, glass and diamond. The reflected ray brightens as i grows; from a denser medium it becomes total.
- **Glass slab:** the ray inside, the emergent ray parallel to the incident one, and the lateral shift $d = t \sin(i - r)/\cos r$ drawn and worked out.
- **Apparent depth:** a coin under water seen from above (apparent = real / n) and a bird seen by a fish from below (apparent = $n \times$ real), with the rays traced back to the apparent position.

Total internal reflection

- **Critical angle:** sweep i in water, glass or diamond; at C the refracted ray grazes the surface and beyond it everything is reflected.
- **Optical fibre:** core and cladding indices, the entry angle, the angle at the wall compared with C, the acceptance angle and the numerical aperture $\sqrt{(n_1^2 - n_2^2)}$. Rays outside the acceptance cone visibly leak into the cladding.
- **Reflecting prism:** the 45°–90°–45° prism turning light through 90° or 180°, and the erecting pair used in binoculars.

Spherical surface

- $n_2/v - n_1/u = (n_2 - n_1)/R$ with a signed radius and both indices adjustable — the step before the lens-maker's formula.

Thin lenses

- **Ray diagrams** for convex and concave lenses with F , F' , $2F$ marked and the image nature read off; **lens-maker's formula** with two signed radii and n , and what the same lens does in water; **power and combinations** — dioptries, and two lenses in contact.

Prism

- **Deviation**: the ray through both faces with i , r_1 , r_2 , e and δ marked, the i - δ graph with its minimum, a button that sets minimum deviation, and n from δ_m .
- **Dispersion**: white light split by crown or flint glass; the true spread is small, so a chip exaggerates it $\times 5$ for the class while the readings stay true.

Instruments

- **Magnifying glass** with the image at the near point ($M = 1 + D/f$) or at infinity ($M = D/f$); **compound microscope** with the intermediate image, tube length and $M = m_o \times m_e$; **astronomical telescope** in normal adjustment with $M = f_o/f_e$ and $L = f_o + f_e$.

The eye

- A reduced eye (about 50 D, with 4 D of accommodation) and an object at any distance: the image lands on, in front of or behind the retina, and a power bar shows how much accommodation is used.
- **Short sight**: set the far point x , see distant objects focus in front of the retina, switch the correcting lens on and read $P = -1/x$. **Long sight**: set the near point y and correct with $P = 1/0.25 - 1/y$.

Practice problems cover every view: mirror and lens formulas with signs, Snell's law, lateral shift, apparent depth, critical angle, numerical aperture, the spherical-surface equation, lens-maker's formula, powers in contact, δ_m and n , angular dispersion, magnifying powers and spectacle powers.

Physical Optics Lab

HSC 2nd Paper · Chapter 7

Chapter 7 on its own: the wave nature of light. Four topics along the top, each with its own set of views, Teach and Practice cards, and an **English / বাংলা** toggle in the top right — switch it and every label, note, question and readout turns into Bangla.

Light as an electromagnetic wave

- **E and B fields:** the oscillating electric and magnetic fields drawn in perspective, at right angles to each other and to the direction of travel. Change the wavelength and the whole picture, including its colour, follows. The panel gives $f = c/\lambda$, the period, $E_0/B_0 = c$ and the photon energy in eV.
- **The whole spectrum:** a logarithmic ruler from radio waves to gamma rays with the visible band marked, so students can see for themselves how narrow 400–700 nm is. $c = 1/\sqrt{(\mu_0\epsilon_0)}$ is worked out beside it — the calculation that told Maxwell light is an electromagnetic wave.
- **Energy it carries:** a lamp radiating in all directions, with $I = P/4\pi r^2$, the field strength $E_0 = \sqrt{2I/\epsilon_0 c}$, the energy density and the radiation pressure $p = I/c$.

Interference

- **Huygens' wavefronts:** plane and spherical wavefronts built from secondary wavelets, with the envelope drawn in. Also the refraction case, which is Huygens' proof of Snell's law.
- **Young's double slit:** the two slits, the spreading waves, and the fringe pattern on the screen. Moving the **screen distance D** actually moves the screen across the picture and the bright and dark bands visibly crowd together or spread out; λ and d do the same. $\beta = \lambda D/d$ is given in mm, with the order of each fringe labelled.

Diffraction

- **Single slit:** light bending round the edges, the broad central band and the weak side fringes, with a $\sin \theta = n\lambda$ giving the minima. Narrowing the slit widens the pattern — the point students usually get backwards. The width of the central band, $2\lambda D/a$, is worked out.
- **Grating:** thousands of slits, $d = 1/N$, and each order coming out at its own angle from $d \sin \theta = n\lambda$. The panel says how many orders are possible for the chosen wavelength.

Polarisation

- **Malus's law:** unpolarised light through a polariser ($I_0/2$) and then an analyser ($I = I_1 \cos^2 \theta$). Turn the analyser to 90° and the beam goes out completely — the demonstration that light is a transverse wave.
- **Brewster's angle:** reflection off glass or water, with $i_p = \tan^{-1} n$. At that angle the reflected ray is fully plane polarised and sits at exactly 90° to the refracted ray — the physics behind polarised sunglasses.

Chapter 6 — mirrors, refraction, lenses, prisms, instruments and the eye — is in the Geometrical Optics lab above.

Modern Physics Lab

HSC 2nd Paper · Chapter 8

Frames & transformations

- **Galilean** and **Lorentz**: a train (frame S') passes the ground (frame S). Click the ground track to make a flash. The readings show its (x, t) and (x', t') , and the train ruler and clocks at that spot agree with the formulas.
- In Lorentz, distances are in light-seconds ($c = 1 \text{ ls/s}$). The train ruler is shorter and the train clocks run slow and out of step.
- **Adding velocities**: compares $u = u' + v$ with Einstein's formula. Choose **Light** ($u' = c$) to show light stays at c .

Time dilation

- **Light clock**: a resting and a moving clock. The moving clock's light takes the slanted path, so it ticks more slowly; the triangle for $\Delta t = \gamma \Delta t_0$ is drawn on it.
- **Muon decay**: muons fall from 10 km. Compare how many reach the ground with and without time dilation.

Length contraction

- Set speed and rest length L_0 . Compare the ship at rest with the ship in flight; the graph of L/L_0 is a quarter circle.

Mass & energy

- **Relativistic mass**: a constant force pushes; press **Restart** to push again. Newton's speed passes c ; the relativistic speed never reaches it, while $m = \gamma m_0$ grows.
- **$E = mc^2$** : pick a mass (electron, proton, 1 u, He-4 mass defect, 1 mg, 1 g, 1 kg) and read its energy in J, MeV and kWh.
- **Energy-momentum**: $E^2 = (pc)^2 + (m_0c^2)^2$ as a right-angled triangle. Choose electron or photon and drag pc .

Photoelectric effect

- Choose the metal, then set wavelength (100–750 nm, UV included), brightness and collector voltage.
- Switch the graph between **K_{max} vs frequency** and **Current vs voltage**. Make the collector voltage negative to find the stopping potential.
- Work functions are typical textbook values.

Compton effect

- Set the X-ray wavelength (pm) and scattering angle θ . The scattered photon comes out longer; the bars at the bottom compare λ and λ' to scale.

Matter waves & quantum

- **de Broglie**: choose electron, proton, alpha particle or cricket ball, and the voltage (or speed). The wavelength is marked on a size scale from a proton to a hair.
- **Bohr orbit**: set the number of waves n round the orbit. Only whole numbers join up, which gives the allowed energy levels.
- **Uncertainty**: squeeze Δx and watch the momentum spread Δp widen; their product never drops below $\hbar/2$.

Atomic & Nuclear Lab

HSC 2nd Paper · Chapter 9

Five topics from Rutherford's experiment to fusion, with Teach and Practice modes and the English / বাংলা switch.

Rutherford scattering

- **α -particle scattering:** α -particles stream past a single nucleus of the chosen foil; their paths are integrated in the Coulomb field, so most pass nearly straight and the few aimed close swing through large angles. Flashes appear on the zinc-sulphide arc and a histogram counts the deflections. Raise the α energy or change the foil and $r_0 = 2kZe^2/K$ changes with it.
- **Plum pudding vs nucleus:** Thomson's diffuse positive sphere and Rutherford's nuclear atom side by side, with the atom-to-nucleus size ratio.
- **Closest approach:** a head-on α climbs the Coulomb hill, stops at r_0 and returns; KE and PE bars trade places, and r_0 is evaluated for the energy and nucleus you set.

Bohr model

- **Orbits & jumps:** orbits to scale ($r \propto n^2$) for $n = 1-6$; the electron circles at the upper level, drops to the lower one and a photon of the correct colour (or grey for UV/IR) travels out; r_n , v_n and E_n for both levels and $\lambda = hc/\Delta E$.
- **Energy levels:** the ladder of levels $E_n = -13.6/n^2$ eV with the transition arrow, ΔE , frequency, wavelength and the series it belongs to.
- **Hydrogen spectrum:** the Lyman, Balmer, Paschen and Brackett lines on a logarithmic wavelength axis with the visible band coloured, a table of the first five lines and the series limit; $1/\lambda = R(1/n_1^2 - 1/n_2^2)$.

The nucleus

- **Size & density:** fifteen nuclides from ^2H to ^{238}U drawn as nucleon clusters; $R = 1.2 A^{1/3}$ fm, the R against $A^{1/3}$ line and the density that comes out the same for all.
- **Mass defect & binding energy:** Z protons and N neutrons separate versus the bound nucleus, real atomic masses, Δm , $BE = \Delta m \times 931.5$ MeV and BE per nucleon.
- **Binding energy per nucleon:** the curve with every nuclide marked, the iron-56 peak, the fusion arrow on the left and the fission arrow on the right.

Radioactivity

- **Decay law & half-life:** 400 nuclei each decaying at random with probability λ per second beside the smooth $N_0 e^{-\lambda t}$ curve; the half-life markers $T_{1/2}$, $2T_{1/2}$, $3T_{1/2}$ and

the fraction left.

- **α , β and γ :** the three rays from a source in a magnetic field (into the page), an electric field or none — α bends a little, β a lot the other way, γ not at all — and their penetration through paper, 5 mm of aluminium and 5 cm of lead, with the decay equations.
- **Activity & mean life:** eight isotopes from technetium-99m to uranium-238 and a sample mass; $N = (m/M)N_A$, $\lambda = 0.693/T_{1/2}$, $A = \lambda N$ in becquerel and curie, the activity curve and $\tau = 1.44 T_{1/2}$.

Fission & fusion

- **Nuclear fission:** a slow neutron is captured, $^{235}\text{U}^*$ elongates and splits into Ba + Kr (or Xe + Sr) with 2–3 neutrons; the mass-defect account gives the energy released and the comparison with coal.
- **Chain reaction:** the tree of fissions generation by generation for $k = 1, 2$ or 3 — steady for $k = 1$ (reactor, with moderator and control rods) and runaway for $k > 1$.
- **Nuclear fusion:** deuterium and tritium approach at the temperature you set; below $\sim 10^7$ K the Coulomb repulsion turns them back, above it they fuse to $^4\text{He} + n$ with 17.6 MeV; the energy-against-separation picture and the Sun's proton-proton reaction.

Semiconductor & Electronics Lab HSC 2nd Paper ·

Chapter 10

Five topics from energy bands to logic gates, with Teach and Practice modes and the English / বাংলা switch.

Bands & doping

- **Energy bands:** a conductor (overlapping / partly filled band), a semiconductor and an insulator drawn to the same energy scale; pick silicon, germanium, GaAs or diamond, set the temperature, and watch electrons appear in the conduction band with holes left behind; the longest wavelength hc/E_g that can excite them.
- **Doping:** a 5×5 silicon lattice with its covalent bonds; switch to n-type and a phosphorus atom's fifth electron wanders free, or to p-type and a boron atom's missing bond hops around as a hole; the donor and acceptor levels are sketched alongside.
- **Carriers & temperature:** resistance against temperature for a metal (rising) and a semiconductor (falling), and the electron and hole densities for the donor density you set, with $n_p = n_i^2$.

p-n junction

- **Depletion layer:** electrons and holes diffuse across, recombine and leave the fixed ions; the built-in field, the potential step and V_0 for silicon or germanium.
- **Forward & reverse bias:** the junction with its battery; from -6 V to $+1$ V the effective barrier, the depletion width and the current follow the diode equation.
- **I-V characteristic:** the full curve with the knee voltage, the tiny reverse saturation current and breakdown at -5 V; the operating point with its static and dynamic resistance.

Rectifier

- **Half-wave:** the diode lights up on positive half-cycles; input and output waveforms scroll in slow motion; $V_{dc} = V_m/\pi$, $V_{rms} = V_m/2$, $PIV = V_m$.
- **Full-wave:** a centre-tap circuit with two diodes or a bridge with four, showing which diodes conduct on each half-cycle; $V_{dc} = 2V_m/\pi$, ripple at $2f$, PIV and efficiency.
- **Capacitor filter:** a reservoir capacitor across the load; set C and R_L and see the ripple shrink; RC compared with the half-cycle and $V_{pp} \approx V_m/(2fRC)$.

Transistor

- **Structure & action:** emitter, base and collector blocks (n-p-n or p-n-p) with the forward and reverse bias batteries; carriers stream from emitter to collector with a few lost in the thin base; $I_E = I_B + I_C$, α and β for the base current you set.
- **CE characteristics:** the family of I_C - V_{CE} curves for $I_B = 20\text{--}100\ \mu\text{A}$, the Q point you move with two sliders, and the cut-off, saturation and active regions.
- **CE amplifier:** the single-stage circuit, the small input and the large inverted output, gain $\approx R_C/r_e$, and clipping when the signal is too big for the bias point.

Logic gates

- **The basic gates:** AND, OR, NOT, NAND, NOR and XOR with their proper symbols; click A and B, the output lamp and the highlighted truth-table row respond, with the Boolean expression, what the gate is built from and what it is used for.
- **Universal NAND:** NOT from a NAND with tied inputs, AND from two NANDs, OR from three (De Morgan), and a half adder from XOR + AND with SUM and CARRY.
- **Binary numbers:** slide 0–255 and see the 8 bits light up with their place values, the sum, binary, octal and hexadecimal forms and the repeated-division method.

Using them in class

1. **Predict first.** Before moving a slider, ask: "What will happen if...?" Then show it.
2. **One idea per screen.** Use the simple screens first; save "All together" for revision.
3. **Project in Clean view.** Zoom the browser with `Ctrl` + `+` so the back row can read the numbers.
4. **Freeze the moment.** Use Pause and Step to stop at the key instant (top of a projectile path, a boat mid-river).
5. **Homework.** Send the lab link and ask students to reach a score in Practice mode and send you a screenshot.

Putting the site online (Netlify)

1. Unzip **science-platform-physics-simulations.zip**. You get a folder of the same name with `index.html` inside.
2. Sign in at **app.netlify.com**. Add a new site/project and choose to **deploy manually**, then drag the whole folder onto the upload area.
3. When it finishes, open the project settings and change the site name to **science-platform-physics-simulations**. The address becomes `science-platform-physics-simulations.netlify.app` if that name is free.
4. To update later, open the site's **Deploys** page and drag the new folder onto it. The address stays the same.

Tip. Netlify's screens change from time to time; if a button has a slightly different name, look for "Deploy manually" or "drag and drop".

Troubleshooting

PROBLEM	FIX
Stage is blank or frozen	Reload the page. Use an up-to-date browser.
Text looks slightly different	The special fonts load from the internet; without it the page uses the device's own font. Everything still works.
Controls hidden	You are in Clean view. Press <code>Esc</code> .
Answer marked wrong but close	Check units (nm vs m, pm, eV) and use the constants given in the problem. Answers are accepted within a small margin.
Page too small on the projector	Zoom the browser (<code>Ctrl</code> + <code>+</code>) or use Clean view.

Science Platform. Constants used: $h = 6.63 \times 10^{-34} \text{ J s}$, $c = 3 \times 10^8 \text{ m/s}$, $e = 1.6 \times 10^{-19} \text{ C}$, $m_e = 9.11 \times 10^{-31} \text{ kg}$.