FULL-YEAR COURSE

Electricity & Magnetism

From Electric Charge to the Electromagnetic Spectrum

A 36-Week Physics Literacy Course · Physics Literacy for Kids

COURSE INFORMATION	
Duration: 36 Weeks (Full Year)	Level: Introductory / High School+
Class Length: 1 hour per week	Format: Live Zoom + Pre-recorded
Resources: Workbooks, PhET simulations, AI notes	Prerequisites: At least one year of physics
Assessment: Kahoot quizzes, projects, Google Forms	Showcases: Physics Café — end of each semester

Course Description

This course builds a deep conceptual and quantitative understanding of electricity and magnetism. Students will move from the nature of electric charge all the way through electromagnetic induction — connecting abstract ideas to the technology they use every day. The course is hands-on, simulation-rich, and designed for students who have completed at least one year of physics. By the end of the year, students will understand that electricity and magnetism are not two separate subjects, but two faces of the same elegant phenomenon.

Learning Outcomes

By the end of this course, students will be able to:

- Understand the nature of electric charge, electric fields, and electric potential
- Build, analyze, and troubleshoot series, parallel, and mixed circuits
- Explain how magnets work and how magnetic fields interact with moving charges
- Describe the relationship between electricity and magnetism and why it matters
- Apply Faraday's Law to explain generators, transformers, and wireless charging
- Connect electromagnetic induction to the technology that powers modern life
- Understand that visible light is part of a much broader electromagnetic spectrum

Week-by-Week Schedule

Fall Semester — Weeks 1–12

Electric Charge, Fields & Potential

We begin with the invisible world of electric charge — what it is, how it behaves, and how we visualize and measure it. By the end of the fall, students will understand voltage and energy storage in capacitors.

Week 1: What Is Electric Charge?

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Two types of charge: positive and negative Protons, electrons, and the atomic origin of charge Conservation of charge — never created or destroyed Charging by friction, conduction, and induction	Static Electricity Lab: balloon on hair, attract paper and water Build an Electroscope from jar, foil strips, and wire PhET 'Balloons and Static Electricity' — visualize charge transfer	Benjamin Franklin (named + and −) Charles-Augustin de Coulomb J.J. Thomson (discovered the electron, 1897)	$q = ne$ (charge is quantized in units of $e = 1.6 \times 10^{-19}$ C) Conservation: $Q_{initial} = Q_{final}$

Week 2: Conductors, Insulators & Polarization

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Conductors vs. insulators — why materials behave differently Free electrons move in metals Polarization — neutral object attracted to a charged one Everyday examples: lightning rods, grounding, static cling	Material Sorting Activity: test household materials with a charged balloon Polarization Demo: charged rod near paper and water stream Discussion: Why ground electronics? Why metal lightning rods?	Benjamin Franklin (lightning rod) Michael Faraday (field concept) Lord Kelvin (electrostatic induction)	Polarization: no charge transfer Grounding: connect to Earth (V = 0) Conductors: free electrons; Insulators: bound electrons

Week 3: Coulomb's Law — The Force Between Charges

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept

Like charges repel, opposite charges attract Coulomb's Law: force depends on charges and distance Comparing electric force to gravity — similarities and differences Solving quantitative problems with Coulomb's Law	PhET 'Coulomb's Law': test force vs. distance interactively Quantitative Problems: force between known charges at different distances Discussion: Compare to Newton's Law of Gravitation	Charles-Augustin de Coulomb (1784) Henry Cavendish (similar torsion balance method) Joseph Priestley (noticed inverse-square pattern)	$F = kq_1q_2/r^2$ $k = 8.99 \times 10^9\ N \cdot m^2/C^2$ Compare: $F_g = Gm_1m_2/r^2$

Week 4: Electric Fields — Visualizing Invisible Forces

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
What an electric field is and why physicists use it Electric field lines — direction, density, meaning Field around a single charge, two opposite charges, two like charges Uniform electric fields between parallel plates	PhET 'Charges and Fields': place charges, visualize, sketch patterns Parallel Plate Exploration: uniform field between plates Discussion: Why do electric field lines never cross?	Michael Faraday (invented the field concept) James Clerk Maxwell (mathematical formulation) Carl Friedrich Gauss (Gauss's Law)	$E = F/q = kQ/r^2$ (field strength at distance r from charge Q) Field lines: direction = force on +test charge

Weeks 5–6: Electric Potential and Voltage

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Electric potential energy — energy stored in a charge arrangement Electric potential (voltage) — potential energy per unit charge Equipotential lines and their relationship to field lines Voltage as the 'push' that drives current in a circuit Quantitative: potential from charge and distance	PhET Equipotential Mapping: trace equipotential lines, compare to field lines Voltage Analogy: water pressure in pipes builds intuition Quantitative practice: calculate V at a point near a known charge Discussion: What does it mean to be at the same potential?	Alessandro Volta (invented the battery, 1800) James Clerk Maxwell Georg Simon Ohm (V-I relationship)	$V = kQ/r$ (electric potential from point charge) $\Delta PE = q\Delta V$ V measured in volts (J/C)

Week 7: Capacitors — Storing Electric Energy

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
What a capacitor is and how it stores charge Capacitance — charge stored per volt Role of the dielectric material between the plates Capacitors in series vs. parallel Energy stored in a capacitor	Build a Simple Capacitor: aluminum foil and plastic wrap layers PhET 'Capacitor Lab': plate size, separation, and dielectric effects Series vs. Parallel Capacitor Problems: equivalent capacitance	Ewald Georg von Kleist (Leyden jar, 1745) Alessandro Volta James Clerk Maxwell	$C = Q/V$ (capacitance in farads) $U = \frac{1}{2}CV^2$ (energy stored) Series: $1/C_T = \Sigma 1/C_i$ | Parallel: $C_T = \Sigma C_i$

Weeks 8–9: Putting It Together — Charge, Fields & Energy Review

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Connecting charge, force, field, potential, and capacitance Real-world applications: touchscreens, defibrillators, camera flashes Introduction to energy density in electric fields	Technology Connections: how does a touchscreen know where your finger is? Mixed problem-solving session: Coulomb's Law, fields, and voltage Fall Semester Mini-Project: choose a real-world device, explain how it works	Nikola Tesla (AC systems and capacitors) Jack Kilby (integrated circuit, 1958) Modern touchscreen engineers	Energy density: $u = \frac{1}{2}\varepsilon_0 E^2$ Full review of: $F = kq_1q_2/r^2$ | $E = kQ/r^2$ $V = kQ/r$ | $C = Q/V$

Weeks 10–12: Fall Review, Demonstrations & Physics Café

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Consolidation of all fall semester concepts Student-led review and Q&A Van de Graaff generator: charge accumulation and sparks Faraday cage: why electric fields don't penetrate a conductor	Van de Graaff generator demo — hair-raising charge accumulation Faraday cage demo — phone signal disappears inside Physics Café: student mini-project presentations (parents welcome!)	Robert J. Van de Graaff (1929) Michael Faraday (Faraday cage, 1836) James Clerk Maxwell	Faraday cage: $E = 0$ inside conductor Full semester key equations reviewed Student-chosen real-world application

	Kahoot review quiz — all fall semester material		

Winter Semester — Weeks 13–24

Electric Circuits & Current

With a solid understanding of voltage and energy, students now explore what happens when charge is set in motion. We build circuits by hand, measure current and resistance, and understand the principles that govern every electronic device.

Weeks 13–14: Electric Current — What Makes Charges Move?

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Electric current — the flow of charge, measured in amperes What drives current: voltage difference and resistance Conventional current vs. electron flow Direct current (DC) vs. alternating current (AC) Real-world context: batteries, wall outlets, and why they differ	Current Analogy: voltage = water pressure, current = flow rate, resistance = pipe narrowness PhET 'Circuit Construction Kit (DC)': build a simple circuit, observe current Discussion: Why does a higher voltage battery make a bulb glow brighter?	André-Marie Ampère (unit of current, 1820) Alessandro Volta (battery) Thomas Edison vs. Nikola Tesla (DC vs. AC)	$I = Q/t$ (current = charge per second) I measured in amperes (A = C/s) DC: constant direction | AC: oscillates (60 Hz in USA)

Weeks 15–16: Resistance and Ohm's Law

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
What resistance is and what causes it in a material Ohm's Law: V = IR — the fundamental circuit relationship Factors affecting resistance: material, length, thickness, temperature Resistivity and why some materials resist more than others	Hands-On Resistance Lab: battery, wires, resistors, pencil graphite of different lengths Ohm's Law Problems: calculate V, I, or R given the other two PhET 'Resistance in a Wire': explore how length and cross-section affect resistance	Georg Simon Ohm (1827) Heinrich Lenz (temperature and resistance) Modern semiconductor engineers	$V = IR$ (Ohm's Law) $R = \rho L/A$ (resistivity formula) Resistivity ρ: property of the material

Solving real-world problems using Ohm's Law			

Weeks 17–18: Series Circuits

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
How current behaves in a series circuit — same everywhere How voltage divides across components in series Total resistance in a series circuit What happens when one component fails (the Christmas lights problem)	Build a Series Circuit: wire two bulbs in series, observe brightness, remove one bulb Voltage Measurement: use virtual voltmeter in PhET to measure voltage drops Practice: total resistance, current, and voltage drops in series circuits	Gustav Kirchhoff (circuit laws, 1845) Georg Simon Ohm Thomas Edison (series circuit limitations in early lighting systems)	Series: I same everywhere $V_T = V_1 + V_2 + V_3 ...$ $R_T = R_1 + R_2 + R_3 ...$ Kirchhoff's Voltage Law (KVL)

Weeks 19–20: Parallel Circuits

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
How voltage behaves in parallel — same across each branch How current divides through parallel branches Total resistance in parallel — why it decreases with more branches Why homes are wired in parallel	Build a Parallel Circuit: two bulbs in parallel, compare brightness to series, remove one PhET 'Circuit Construction Kit': compare series vs. parallel side by side Discussion: Why would a series-wired house be impractical? Practice: equivalent resistance, branch currents, total current	Gustav Kirchhoff (current law) George Westinghouse (parallel AC distribution) Modern home electrical engineers	Parallel: V same across each branch $I_T = I_1 + I_2 + I_3 ...$ $1/R_T = 1/R_1 + 1/R_2 ...$ Kirchhoff's Current Law (KCL)

Weeks 21–22: Mixed Circuits and Real-World Applications

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Circuits with both series and parallel elements How to simplify complex circuits step by step	Mixed Circuit Challenge: calculate all V, I, and R from a complex diagram	Gustav Kirchhoff Nikola Tesla (AC circuit design)	Simplify step by step: 1. Identify series/parallel sections

Real-world mixed circuits: household wiring, battery packs, electronics Fuses and circuit breakers — protection against overload	PhET simulation: build and analyze a mixed circuit Discussion: What causes a circuit breaker to trip? What happens without one?	Modern electrical engineers (circuit board design)	2. Replace with equivalents 3. Work back to find V and I Use KVL and KCL throughout

Weeks 23–24: Electric Power and Energy

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Electric power — the rate of energy use (P = IV) Power in terms of resistance: P = I²R and P = V²/R Reading a utility bill — kilowatt-hours explained Energy efficiency and why it matters Phone charger vs. hair dryer — which uses more power?	Home Energy Audit: look up wattage of 5 appliances, calculate monthly cost Practice problems: calculate power and energy for real devices Winter Mini-Project: design a room's circuit, specify appliances and wattage Kahoot review quiz — all circuit concepts	James Watt (unit of power) James Prescott Joule (energy unit) Modern electrical engineers (grid efficiency)	P = IV = I²R = V²/R (power in watts) Energy = P × t Kilowatt-hour: 1 kWh = 3.6 × 10⁶ J Cost = kWh × rate ($/kWh)

Spring Semester — Weeks 25–36

Magnetism, Electromagnetism & Induction

In the final semester, we discover one of the most elegant ideas in all of physics: electricity and magnetism are two faces of the same phenomenon. From permanent magnets to generators and the electromagnetic spectrum, students see how everything connects.

Weeks 25–26: Magnets and Magnetic Fields

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Permanent magnets — poles, attraction, and repulsion Magnetic field lines — direction, density, and meaning Earth as a giant magnet — why compasses work	Iron Filings Lab: reveal field lines around bar and horseshoe magnets, sketch results Compass Navigation: map the field around a bar magnet, compare to Earth's field	William Gilbert (Earth as magnet, 1600) Hans Christian Ørsted (electricity-magnetism link)	Magnetic field: B (measured in tesla, T) Field lines: N → S outside magnet No magnetic monopoles: ∇·B = 0 (Gauss's Law for Magnetism)

Magnetic domains — why some materials are magnetic and others aren't	Discussion: Can a magnet have only one pole? What is a magnetic monopole?	Pierre Curie (magnetic domains and temperature)	

Weeks 27–28: Magnetic Forces on Moving Charges and Wires

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
A moving charge in a magnetic field experiences a force (Lorentz force) The right-hand rule — determining the direction of magnetic force Force on a current-carrying wire in a magnetic field Applications: electric motors, speakers, particle accelerators	PhET 'Charges and Fields': observe deflection of a moving charge in B field Right-Hand Rule Practice: work through diagrams for various charge and field orientations Discussion: How does a speaker turn an electrical signal into sound?	Hendrik Lorentz (Lorentz force, 1895) Hans Christian Ørsted (1820) Ernest Lawrence (cyclotron, 1930)	$F = qv \times B$ $F = qvB \sin\theta$ F on wire: $F = IL \times B$ $F = BIL \sin\theta$ Right-hand rule: thumb = v, fingers = B, palm = F

Weeks 29–30: Electromagnetism — Electricity Creates Magnetism

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Ørsted's discovery: current-carrying wire creates a magnetic field The magnetic field around a straight wire and a coil Solenoids — how winding wire into a coil amplifies the field Electromagnets — turning the field on and off	Build an Electromagnet: wire around iron nail, pick up paper clips, test coil number and voltage Solenoid Exploration: PhET 'Faraday's Electromagnetic Lab' — field inside solenoid Discussion: How does an MRI machine use an electromagnet? Why so powerful?	Hans Christian Ørsted (1820) André-Marie Ampère (Ampère's Law) Joseph Henry (electromagnet strength)	B around wire: $B = \mu_0 I/(2\pi r)$ Solenoid: $B = \mu_0 nI$ (n = turns per meter) Ampère's Law: $\oint B \cdot dl = \mu_0 I_{enc}$

Weeks 31–32: Electromagnetic Induction — Magnetism Creates Electricity

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Faraday's discovery: a changing magnetic field creates a current	Magnet-Through-Coil Experiment: push magnet through coil	Michael Faraday (induction, 1831)	Faraday's Law: $EMF = -N \cdot \Delta\Phi/\Delta t$

Factors affecting induced current: speed, field strength, coil number Lenz's Law — induced current opposes the change that caused it Real-world applications: generators, transformers, wireless charging	connected to sensitive meter PhET 'Faraday's Electromagnetic Lab': explore induction interactively Lenz's Law Demo: drop magnet through copper tube — observe slow fall Discussion: How does a wireless phone charger work?	Joseph Henry (independent discovery, USA) Heinrich Lenz (Lenz's Law, 1834)	$\Phi = BA\cos\theta$ (magnetic flux) Lenz's Law: induced current opposes change

Weeks 33–34: Generators, Motors & Transformers

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
How a generator converts mechanical energy to electrical energy How a motor converts electrical energy to mechanical energy Transformers — stepping voltage up or down using induction Why electricity is transmitted at high voltage over long distances AC vs DC revisited — why AC is used for the power grid	Build a Simple Motor: battery, wire coil, magnets, safety pin frame — observe rotation Transformer Exploration: PhET — how coil ratio changes output voltage Discussion: Why transmit at 500,000 V? What if we used 120 V instead?	Michael Faraday (generator principle) Nikola Tesla (AC motor and transformer) George Westinghouse (AC power grid)	Transformer: $V_s/V_p = N_s/N_p$ Generator: EMF = $NBA\omega \sin\omega t$ Power loss: $P = I^2R$ (high V → low I → less heat loss)

Weeks 35–36: The Electromagnetic Spectrum & Year-End Showcase

Topics Covered	Lab / Activity	Key Figures	Key Equation / Concept
Maxwell's insight: changing E and B fields create electromagnetic waves The EM spectrum — radio, microwave, infrared, visible, UV, X-ray, gamma Speed of light and why all EM waves travel at c in a vacuum	Spectrum Mapping Activity: annotate EM spectrum with frequency, wavelength, energy, and one application per region Discussion: Why can radio waves pass through walls but visible light cannot? Year-End Physics Café: student presentations	James Clerk Maxwell (EM waves predicted, 1865) Heinrich Hertz (confirmed EM waves, 1887) Wilhelm Röntgen (X-rays, 1895)	$c = \lambda f = 3 \times 10^8$ m/s Maxwell's equations (conceptual): $\nabla \cdot E = \rho/\varepsilon_0$ $\nabla \cdot B = 0$ $\nabla \times E = -\partial B/\partial t$ $\nabla \times B = \mu_0 J + \mu_0\varepsilon_0 \partial E/\partial t$

How different parts of the spectrum are used in everyday technology	— build a circuit, demo induction, explain a device, or run a PhET simulation live (parents welcome!) Final Kahoot review quiz — covering all three semesters	Marie Curie (gamma radiation research)	

Assessment & Grading

Component	Weight	Notes
Semester Kahoot Quizzes (3 total)	20%	End of each semester, ~15 min each
Weekly Lab Reports & Activities	25%	One per week, submitted digitally
Fall Mini-Project (real-world device)	10%	Short written or visual explanation
Winter Mini-Project (room circuit design)	10%	Specify appliances and total power draw
Physics Café Presentations (×2)	20%	End of fall and spring semesters
Google Form Assessments	10%	Periodic checks throughout the year
Participation & Discussion	5%	In-class and Zoom engagement

Recommended Resources

Simulations

- PhET Interactive Simulations — phet.colorado.edu (Balloons & Static Electricity, Charges and Fields, Capacitor Lab, Circuit Construction Kit, Faraday's Electromagnetic Lab)
- Falstad Circuit Simulator — falstad.com/circuit (for more advanced circuit analysis)

Books & Reading

- The Feynman Lectures on Physics, Vol. 2 — Richard Feynman (electromagnetism, free online)
- Electricity and Magnetism — Edward Purcell (rigorous but accessible)
- How Things Work: The Physics of Everyday Life — Louis Bloomfield
- Physics Literacy for Kids workbooks (course series)

Online & Video

- PBS Space Time (YouTube) — electromagnetism and Maxwell's equations episodes

- Veritasium (YouTube) — 'How electricity actually works', 'The big misconception about electricity'
- 3Blue1Brown (YouTube) — visualizations of fields and waves
- Khan Academy — AP Physics 2 electricity and magnetism (free)

Historical Primary Sources

- Michael Faraday, Experimental Researches in Electricity (1839) — selected excerpts
- James Clerk Maxwell, A Dynamical Theory of the Electromagnetic Field (1865)
- Hans Christian Ørsted, Experiments on the Effect of a Current of Electricity (1820)

Instructor Notes

The fall semester is the most conceptually demanding — electric potential (Weeks 5–6) is historically the topic students find hardest. Budget extra discussion time and use the water-pressure analogy repeatedly before introducing the equation. The winter semester tends to flow naturally once students have the voltage intuition from fall. Series and parallel circuits (Weeks 17–20) are best taught with physical wire-and-bulb labs before any simulation work.

The spring semester is the most exciting for most students — the magnet-through-coil experiment (Week 31–32) and the motor build (Week 33–34) are reliable crowd-pleasers. Save the EM spectrum for last as it provides a satisfying synthesis: everything the course covered is encoded in Maxwell's four equations.

Physics Café sessions at the end of each semester are the highlight of the year. Encourage parents to attend — student explanations to non-physicist adults is one of the most powerful learning experiences in the course.

"The special theory of relativity owes its origins to Maxwell's equations of the electromagnetic field." — Albert Einstein