Version 1.1 | Edited 5.7.2025

PHYSICS IN THE TRADES

A CONCEPTUAL, PROJECT-BASED EXPLORATION

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For use in High School Physical Science and Physics Classrooms

Curriculum Introduction

This conceptual physics course bridges essential physics topics with real-world trade careers.

Across six units, students develop deep understanding of kinematics, forces, fluids, thermodynamics, electricity, and modern physics through hands-on inquiry labs (using Vernier probes and video analysis), tool-based workshops, and culminating design projects that mirror the work of carpenters, concrete technicians, plumbers, HVAC specialists, electricians, and solar/nuclear technicians.

Emphasis is on three-dimensional NGSS learning—science & engineering practices, disciplinary core ideas, and crosscutting concepts—while building career and technical skills.

Version 1 of this curriculum is being developed to be project-based, and taught in Modeling and/or Thinking Classrooms.

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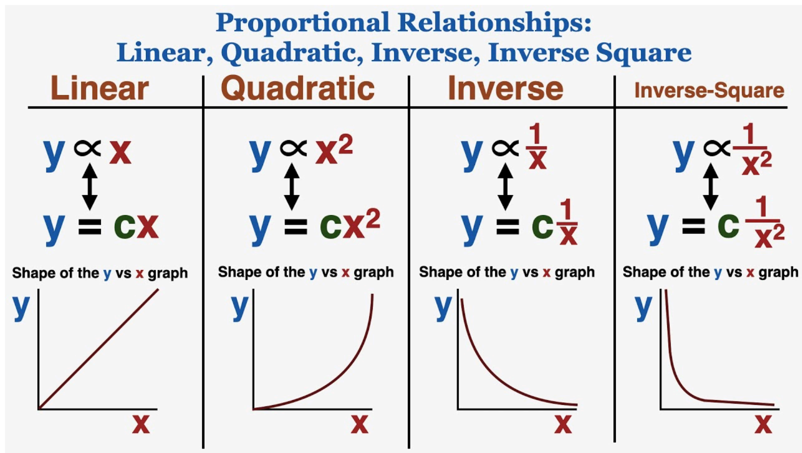
Unit 1: Kinematics & Tools of the Trade

NGSS Standards:

- HS-PS2-1, HS-PS2-2 (Newton's 2nd Law & mathematical representations)
- HS-ETS1-2 (Engineering design decomposition)

Learning Targets



- Apply kinematic equations to predict motion.
- Interpret x–t and v–t graphs; distinguish linear, quadratic, inverse models.
- Safely use hand/power tools to build experimental apparatus.
- Capture and analyze motion via Vernier motion sensors and video analysis.

Key Vocabulary

Displacement, Velocity, Acceleration, Kinematic Equations, Linear/Quadratic/Inverse Models, Calibration, Frame Rate

Common Misconceptions

- Confusing speed vs. velocity; misreading graph slopes; assuming constant acceleration; mixing axes.

Suggested Career Speakers

- Department of Transportation Workers, Radar Technicians

Lesson Sequence		
Lesson	Topic & Activities	Objectives
1	Intro to Motion & Models Demonstrations; sketch x–t & v–t graphs	Qualitatively describe motion; match scenarios to graph shapes.
2	Constant Velocity Flat-track motion sensor data; linear fit	Calculate velocity from slope; assess linear model fit.
3	Accelerated Motion Ramp & cart; quadratic fit of x(t)	Extract acceleration from quadratic fits; predict motion via equations.
4	Inverse Relationships Drop tests; Vernier video analysis of v(t)	Identify deviations due to air resistance; recognize inverse trends.
5	Tools Workshop Tape measure, hammer, drill use; build ramps	Safely construct and document apparatus using proper tool techniques.
6	Video Analysis Deep-Dive Film motion; Logger Pro tracking	Calibrate video; extract position-time data; compare to sensors.

Inquiry Labs

- Lab A: Ramp Acceleration Probe
  - Probe: Vernier Motion Sensor
  - Design: Vary ramp angle; measure a; test $a = g \sin \theta$,.
- Lab B: Free-Fall & Air Resistance
  - Tool: Vernier Video Analysis
  - Design: Drop objects of varying size; analyze v(t); compare to ideal.

Culminating Project

Tool-Powered Marble Run

Design and build a marble run incorporating hand- or battery-powered mechanisms; integrate sensors/video data to predict and verify speeds and accelerations.

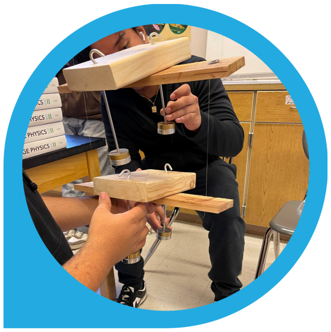
Unit 2: Forces & Construction

NGSS Standards:

- HS-PS2-1, HS-PS2-4 (Newton's laws & computational representations)
- HS-ETS1-2 (Structural design problem decomposition)

Learning Targets

- Apply Newton's laws and torque (\tau=rF\sin\theta).
- Draw free-body diagrams; analyze static and rotational equilibrium.
- Mix, cast, and cure concrete beams; measure compressive strength.
- Use Vernier force/torque sensors to quantify structural performance.

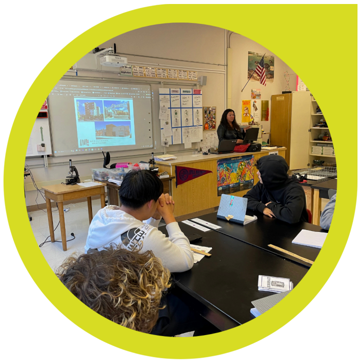


Key Vocabulary

Force, Net Force, Normal Force, Tension, Friction, Torque, Moment Arm, Pivot, Stress, Strain, Compressive Strength, Mix Ratio

Common Misconceptions

- Heavier objects always exert more torque; force "used up"; confusing mass and weight; concrete strength instantaneous.



Suggested Career Speakers

- Civil Engineers, Foremen, Architects

Lesson Sequence		
Lesson	Topic & Activities	Objectives
1	Newton's Laws & FBDs Demos; free-body diagram practice	Draw FBDs; distinguish balanced vs. unbalanced forces.
2	Equilibrium & Net ForceForce sensor in static scenarios	Measure forces; verify $\Sigma F=0$.
3	Torque & Balance Vernier Torque Sensor on lever	Quantify torque; predict rotational equilibrium.
4	Concrete Science Mix ratios; PPE safety	Explain mix ratio effects on strength/workability.
5	Casting Beams Pour beams; record curing times	Follow casting procedures; track strength development.
6	Load Testing Force sensor midspan; deflection vs. load	Plot load-deflection; determine yield points; compare mixes.

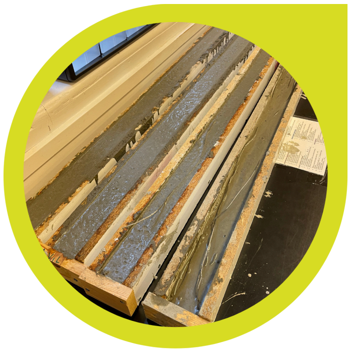
Inquiry Labs

- Lab A: Lever Torque Investigation

- Probe: Vernier Torque Sensor
- Design: Vary lever arm length and force; verify $\tau = Fd$.

- Lab B: Concrete Beam Bending
  - Probe: Vernier Force Sensor
  - Design: Test beams of different mix ratios; record force-deflection curves.

Culminating Project



Mini-Bridge Beam Design

Design, cast, and test a scaled concrete beam for a model bridge; optimize mix and cross-section for maximum load support; deliver CAD sketch, mix rationale, and test report.

Unit 3: Fluids & Plumbing

NGSS Standards:

- HS-PS2-1 (Force, mass, acceleration in fluids as pressure forces)
- HS-ETS1-2 (Design water distribution systems)

Learning Targets

- Apply P=\rho gh, Q=Av, and continuity to plumbing systems.
- Predict pressure and flow in pipes of varying diameter/elevation.
- Use Vernier pressure and flow sensors; video analysis for drag.
- Interpret plumbing blueprints; size pipes for real-world scenarios.

Key Vocabulary

Fluid, Density, Pressure, Pascal's Principle, Hydrostatic Pressure, Flow Rate, Continuity Equation, Bernoulli's Equation, Viscosity, Laminar vs. Turbulent Flow

Common Misconceptions

- Pressure "used up" in flow; smaller pipes always increase pressure; fluids "seek lowest point"; Bernoulli only horizontal; confusing pressure/force.

Suggested Career Speakers

- Plumbers, City Water Utility Employee, Car Designer, Aeronautic Engineer, Pilot

Lesson Sequence		
Lesson	Topic & Activities	Objectives
1	Fluid Properties & Hydrostatics Pressure sensor in vertical tube	Verify $P = \rho gh + P_{atm}$; relate density to pressure depth.
2	Continuity & Flow Rate Flow sensor in various tubes	Confirm Q=A\,v; predict velocity changes with pipe diameter.
3	Bernoulli's Principle Constriction demo; pressure vs. velocity	Explain energy conservation in flowing fluids.
4	Fixtures & Traps Clear-tube faucet & P-trap models	Analyze pressure/flow to prevent backflow and sewer gas.
5	Drag & Flow Regimes Video analysis of dye/turbulence; terminal velocity	Distinguish laminar/turbulent flow; discuss drag qualitatively.
6	Blueprint Reading & Design Plumbing schematics; pipe sizing calculations	Draft apartment plumbing layout; calculate diameters and pressure drops.

Inquiry Labs

- Lab A: Hydrostatic Pressure Profile
    - Probe: Vernier Pressure Sensor
    - Design: Measure pressure vs. depth; verify linear relationship.
- Lab B: Flow Rate vs. Diameter
    - Probe: Vernier Flow Sensor
    - Design: Under constant head, test flow in ½″, ¾″, 1″ tubing; verify Q proportional to A.
- Lab C: Drag & Video Analysis
    - Tool: Vernier Video Analysis
    - Design: Drop plates/disks; measure terminal velocity vs. area.

Culminating Project

Apartment Plumbing Demo Board

Create a scaled plumbing schematic for a two-bathroom unit; build a clear-tube demo board showing water delivery and trap action, complete with sensor data to illustrate pressure and flow.

Unit 4: Thermodynamics & HVAC

NGSS Standards:

- HS-PS3-1, HS-PS3-4 (Energy changes & 2nd law evidence)
- HS-ETS1-2 (Break down HVAC system design)

Learning Targets

- Describe conduction, convection, radiation; differentiate heat vs. temperature.
- Apply 1st and 2nd laws of thermodynamics; compute COP.
- Use Vernier temperature probes to test insulation and heat-exchange.
- Evaluate real HVAC systems via SEER ratings and energy audits.

Key Vocabulary

Heat, Temperature, Thermal Equilibrium, Conduction, Convection, Radiation, Specific Heat, Thermal Conductivity, Heat Pump, Refrigeration Cycle, COP, SEER

Common Misconceptions

- Heat = temperature; insulation "creates" heat; all heat engines same efficiency; entropy as "disorder"; SEER vs. operating cost.

Suggested Career Speakers

- HVAC Technician, Civil Engineer

Lesson Sequence		
Lesson	Topic & Activities	Objectives
1	Temperature Scales & Equilibrium Vernier probe in mixed baths	Convert among °C/°F/K; predict equilibrium temps.
2	Conduction & Insulation Cooling curves of insulated bottles	Calculate relative thermal conductivities; rank materials.
3	Convection & Forced Air Probe in airflow; vary fan speed	Relate airflow rate to convective heat transfer rate.
4	Radiation & Heat Loss IR lamp; surface temp vs. time	Model radiative exchange qualitatively.
5	Refrigeration Cycle 4-station temps; compute COP	Diagram cycle; compute COP = Q_{cold}/W_{in}}.
6	Energy Efficiency & SEER Compare unit data; seasonal performance	Evaluate system trade-offs; recommend upgrades based on climate.

Inquiry Labs

- Lab A: Insulation Effectiveness
  - Probe: Vernier Temperature Probe
  - Design: Measure cooling of water bottles with foam, fiberglass, none; fit exponential decay.
- Lab B: Heat-Pump Performance
  - Probe: Vernier Dual Temperature Probe
  - Design: Measure inlet/outlet temps at evaporator/condenser under varied heat input; compute COP.

Culminating Project

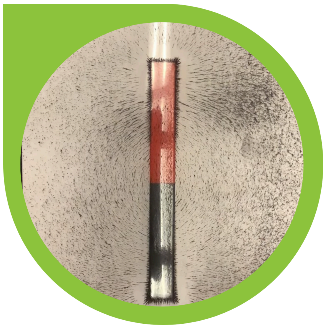
Mini-HVAC System Design

Select insulation, duct layout, and heat-pump configuration for a model home; justify choices with data, estimate heating/cooling loads, COP, and cost-benefit.

Unit 5: Electricity & Magnetism

NGSS Standards:

- HS-PS2-5 (Investigate current↔magnetic field interactions)
- HS-PS3-5 (Model interactions via fields)
- HS-ETS1-2 (Engineer circuits/motors)



Learning Targets

- Build/analyze series & parallel circuits; apply V=IR, P=IV.
- Map magnetic fields of currents; quantify force on wires (F=ILB).
- Assemble simple DC motors; explain commutation.
- Use Vernier voltage/current, magnetic field, and force sensors.

Key Vocabulary

Charge, Current, Voltage, Resistance, Ohm's Law, Electric Power, Magnetic Field, Flux, Right-Hand Rule, Electromagnet, Relay, Commutator, Lorentz Force, Generator

Common Misconceptions

- Current "used up"; electron flow direction; single-pole magnets; induction always opposes; motors vs. generators distinctions.

Suggested Career Speakers

- Electrician, Electrical Engineer

Lesson Sequence		
Lesson	Topic & Activities	Objectives
1	Circuit Basics & Ohm's Law Build circuits; measure V,I	Verify V=IR; calculate unknowns.
2	Series vs. Parallel & Safety Node mapping; GFCI demo	Apply series/parallel rules; explain electrical safety.
3	Magnetic Fields of Currents Vernier Magnetic Field Sensor mapping	Map B(r); compare to $B = (\frac{\mu_0}{2\pi})\frac{I}{r}$.
4	Electromagnets & Relays Build coil; test lift force	Relate turns/current to field strength.
5	Motor Effect & DC Motor Vernier Force Sensor; assemble motor	Measure F=ILB; build motor; explain commutation.
6	Generation & Distribution Hand-crank generator; measure V vs. RPM	Link mechanical to electrical; calculate efficiency.

Inquiry Labs

- Lab A: Magnetic Field Mapping
    - Probe: Vernier Magnetic Field Sensor
    - Design: At set radii/angles, record B around wire; test inverse relationship.
- Lab B: Motor Force Investigation
    - Probe: Vernier Force Sensor
    - Design: Vary I,L,B; test F=ILB; compare to spec.

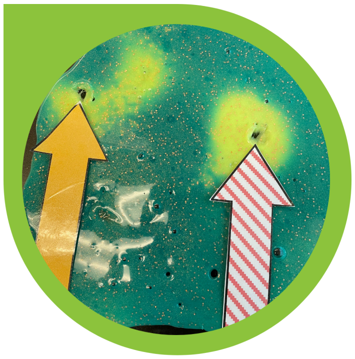
Culminating Project

Home-Scale Motor & Circuit Showcase

Wire a battery-powered circuit driving a DC motor (e.g., small fan); integrate switch and sensor feedback; present wiring diagram, energy flow, and efficiency calculation.

Unit 6: Modern Physics & Solar Panels

NGSS Standards:



- HS-PS4-3 (EM radiation models)
- HS-PS1-8 (Nuclear reactions & energy release)
- HS-ESS3-2 (Evaluate energy resource designs)
- HS-ETS1-3 (Evaluate competing designs)

Learning Targets

- Explain wave–particle duality; calculate photon energy E=hf.
- Plot solar cell I–V curves; compute efficiency and fill factor.
- Model nuclear decay; determine half-life and mass–energy equivalence.
- Compare energy systems (solar, nuclear, fossil) in cost, safety, and sustainability.

Key Vocabulary

Photon, Planck's Constant, Frequency, Photoelectric Effect, Work Function, Semiconductor, I–V Curve, Fill Factor, Fission, Fusion, Half-Life, Decay Constant, Mass–Energy Equivalence, Efficiency

Common Misconceptions

- Light only wave or particle; intensity vs. photon energy; solar panels store energy; nuclear only bombs; half-life misunderstandings.

Suggested Career Speakers

- Solar Panel Tech, Nuclear Submarine Crew, Radon Tech

Lesson Sequence		
Lesson	Topic & Activities	Objectives
1	EM Spectrum & Duality Wave vs. photon simulations	Argue duality with evidence.
2	Photoelectric Effect Vernier Light Sensor + LEDs; threshold freq	Verify E=hf; identify cutoff frequencies.
3	Solar Cell Operation I–V curves; power point	Plot I–V; compute P_{\rm max} and efficiency.
4	Nuclear Decay Intro Radiation detector/data; fit decay	Determine λ, half-life; estimate $E = \Delta mc^2$.
5	Energy System Comparison Analyze cost/output data	Weigh trade-offs; recommend systems for context.
6	Careers & Future Tech Guest speaker or case study	Map skills/certifications for solar & nuclear careers.

Inquiry Labs

- Lab A: Photovoltaic Performance
    - Probes: Vernier Light Sensor, Voltage & Current Probes
    - Design: Vary LED wavelength/intensity; record I–V; calculate efficiency.
- Lab B: Radioactive Decay Modeling
    - Probe: Vernier Radiation Detector or dataset
    - Design: Measure count rate vs. time; fit $N(t) = N_0e^{-\lambda t}$.

Culminating Project

Hybrid Energy System Design

Propose and size a solar array (and optional micro-reactor concept) for the school/community; use local irradiance data; estimate annual output vs. building load; include career pathway analysis.

Course-Wide Resources & Assessment

- Tools: Vernier Probes, motion/force/pressure/flow/temperature/magnetic/radiation probes, Graphical Analysis, Video Analysis, video cameras, hand/power tools.
- Assessment: Ongoing formative checks (exit tickets, lab reports), summative unit projects, presentations, and conceptual quizzes.
- 3D Learning Mapping: Each lab and activity aligns explicitly to one Science & Engineering Practice, one Disciplinary Core Idea, and one Crosscutting Concept.

This rough curriculum guide equips students with conceptual mastery, technical lab skills, data-analysis proficiency, and a clear view of trade career pathways—preparing them for both STEM and CTE futures.

NGSS Performance Expectations

Space Systems

HS-ESS1-1 - Nuclear Fusion and the Sun's Energy

Develop a model based on evidence to illustrate the life span of the sun and the role of nuclear fusion in the sun's core to release energy in the form of radiation.

HS-ESS2-4

Energy Variation and Climate Change

Use a model to describe how variations in the flow of energy into and out of Earth's systems result in changes in climate.

HS-ESS3-5

Climate Change and Future Impacts

Analyze geoscience data and the results from global climate models to make an evidence-based forecast of the current rate of global or regional climate change and associated future impacts to Earth systems.

Human Sustainability

HS-ESS3-1

Global Impacts on Human Activity

Construct an explanation based on evidence for how the availability of natural resources, occurrence of natural hazards, and changes in climate have influenced human activity.

HS-ESS3-2

Cost-Benefit Ratio Design Solutions

Evaluate competing design solutions for developing, managing, and utilizing energy and mineral resources based on cost-benefit ratios.

HS-ESS3-4

Reducing Human Impact Design Solutions

Evaluate or refine a technological solution that reduces impacts of human activities on natural systems.

HS-ESS3-6

Human Impacts on Earth Systems

Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity.

Forces and Interactions

HS-PS2-1

Newton's Second Law of Motion

Analyze data to support the claim that Newton's second law of motion describes the mathematical relationship among the net force on a macroscopic object, its mass, and its acceleration.

HS-PS2-2

Conservation of Momentum

Use mathematical representations to support the claim that the total momentum of a system of objects is conserved when there is no net force on the system.

HS-PS2-3

Reducing Force in Collisions Device

Apply scientific and engineering ideas to design, evaluate, and refine a device that minimizes the force on a macroscopic object during a collision.

HS-PS2-5

Electric Current and Magnetic Fields

Plan and conduct an investigation to provide evidence that an electric current can produce a magnetic field and that a changing magnetic field can produce an electric current.

Energy

HS-PS3-1

Energy Change in Components of a System

Create a computational model to calculate the change in the energy of one component in a system when the change in energy of the other component(s) and energy flows in and out of the system are known.

HS-PS3-2

Macroscopic Energy Due to Particle Position and Motion

Develop and use models to illustrate that energy at the macroscopic scale can be accounted for as a combination of energy associated with the motions of particles (objects) and energy associated with the relative positions of particles (objects).

HS-PS3-3

Energy Conversion Device Design

Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy.

HS-PS3-5

Energy Change Due to Interacting Fields

Develop and use a model of two objects interacting through electric or magnetic fields to illustrate the forces between objects and the changes in energy of the objects due to the interaction.

Waves and Information

HS-PS4-1

Wave Properties in Various Media

Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media.

HS-PS4-2

Digital Transmission and Storage of Information

Evaluate questions about the advantages of using a digital transmission and storage of information.

HS-PS4-4

Absorption of Electromagnetic Radiation

Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter.

Science & Engineering Practices (SEP)	Crosscutting Concepts (CCC)
1. Asking Questions (for science) & Defining Problems (for engineering) 2. Developing & Using Models 3. Planning & Carrying Out Investigations 4. Analyzing & Interpreting Data 5. Mathematics & Computational Thinking 6. Construct Explanations (for science) & Designing Solutions (for engineering) 7. Engaging in Argument from Evidence 8. Obtain, Evaluate, Communicate Information	1. Patterns 2. Cause & Effect: Mechanism & Explanation 3. Scale, Proportion, & Quantity 4. Systems & System Models 5. Energy & Matter: Flow, Cycle, Conservation 6. Structure & Function 7. Stability & Change