Course Change Request

New Course Proposal

Date Submitted: 04/13/18 11:17 am

Viewing: **PHYS 270 : Introductory and Modern Physics for Scientists and Engineers II**

Last edit: 04/27/18 1:38 pm

Changes proposed by: prubin

Are you completing this form on someone else's behalf?

No

Effective Term: Spring 2019

Subject Code: PHYS - Physics **Course Number:** 270

Bundled Courses:

Equivalent Courses: PHYS 160 - University Physics I
PHYS 260 - University Physics II

Catalog Title: Introductory and Modern Physics for Scientists and Engineers II

Banner Title: Intro Mod Phys Sci Eng II

Will section titles vary by semester? No

Credits: 3

Schedule Type: Lecture

Hours of Lecture or Seminar per week: 3

Repeatable: May only be taken once for credit (NR)

Default Grade Mode: Undergraduate Regular

Recommended Prerequisite(s):

Recommended Corequisite(s):

Required Prerequisite(s) / Corequisite(s) (Updates only): Require co-requisite: MATH 114

Registrar's Office Use Only - Required Prerequisite(s)/Corequisite(s):

And/Or	(	Course/Test Code	Min Grade/Score	Academic Level	)	Concurrency?

Registration Restrictions (Updates only):

Registrar's Office Use Only - Registration Restrictions:

Field(s) of Study:

Class(es):

Level(s):

Degree(s):

School(s):

Catalog Description: The second of a two-course, calculus-based introductory physics sequence. Topics include conservation laws, special relativity, quantum physics, thermal physics, Newtons laws, and electromagnetism.

Justification: The physics pedagogy literature is replete with alternative approaches to introductory physics. Because introductory physics is taught in sequence, it is inconvenient to offer significantly different alternatives

In Workflow

1. **PHYS UG Committee**
2. **PHYS Chair**
3. **SC Curriculum Committee**
4. SC Associate Dean
5. Assoc Provost-Undergraduate
6. Registrar-Courses
7. Banner

Approval Path

1. 05/07/18 10:19 am Philip Rubin (prubin): Approved for PHYS UG Committee
2. 05/07/18 11:47 am Paul So (paso): Approved for PHYS Chair

among existing sections of that sequence. In order to attract and retain students who might prefer a significantly different ordering of the material, a second sequence is necessary. Since multiple sections of the existing introductory sequence are taught, one can be reduced and allocate an alternative sequence with no staffing impact. See attachments for further comments and details.

Does this course cover material which crosses into another department? No

Learning Outcomes:

Attach Syllabus (PDFs only) PHYS270_Syllabus.pdf

Additional Attachments (PDFs only) 170_270LectureOutline.pdf
introsequence_topicscomparison.pdf

Staffing: Anyone in the Department can teach the course. Should require no new staffing.

Relationship to Existing Programs: An alternative required introductory sequence

Relationship to Existing Courses: The PHYS 170-270 sequence is equivalent to the PHYS 160-260 sequence in terms of core introductory material taught with the calculus, but with a greater emphasis on modern physics likely taught in a different order. This course will, like PHYS 260, pair up with PHYS 261 for lab.

Additional Comments:

Reviewer Comments

Key: 15894

Young	Moore
physical units	models
uncertainty	particles and interactions
vectors	**vectors**
velocity	**systems and frames**
acceleration	**conservation of momentum**
projectile motion	**conservation of angular momentum**
circular motion	**conservation of energy**
relative motion	**potential energy**
force	**thermal energy**
Newton's laws	**internal energy**
inertial reference frames	**principle of relativity**
statics	coordinate time
dynamics	spacetime interval
frictional forces	proper time
motion through fluid	coordinate transformations
dynamics of circular motion	Lorentz contraction
work	limiting speed
kinetic energy	four-momentum
potential energy	conservation of four-momentum
power	**waves**
energy conservation	**standing waves**
momentum and its conservation	resonance
center of mass	interference
collisions	diffraction
rigid body rotation	particle nature of light
angular velocity	wave nature of particles
angular acceleration	spin
moment of inertia	rules of quantum mechanics
rotational kinetic energy	wavefunction
torque	simple quantum models
angular momentum	spectra
conservation of angular momentum	schrödinger equation
rotation about moving axis	temperature
work and power in rotational motion	microstates and macrostates
precession	entropy and temperature
periodic motion	Boltzmann factor
harmonic oscillator	ideal gas
pendulum	distributions
damped and forced oscillations	gas processes
gravitation	entropy changes
Kepler's laws	physics of climate change (optional)
weight and apparent weight	**work**
fluid mechanics	**rotational energy**
pressure, buoyancy, viscosity	**collisions**
Bernoulli's equation	**Newton's laws**
elasticity	**forces**
electric charge	**statics**
electric field	**linearly motion**

Gauss's Law	**coupled objects**
electric potential	**circular motion**
capacitance	**noninertial frames**
dielectrics	**projectile motion**
current	**oscillatory motion**
resistance	**Kepler's laws**
electromotive force	**orbits**
direct-current circuits	**electric fields**
magnetic field	**charge distributions**
magnetic forces	**electric potential**
electromagnetic induction	**static equilibrium**
inductance	**current**
alternating current	**dynamic equilibrium**
mechanical waves	**circuits**
sound	**magnetic fields**
electromagnetic waves	**currents and magnetic fields**
	electromagnetic field
	Gauss's law
	Ampere's law
	Maxwell's equations
	Faraday's law
	induction
	electromagnetic waves

unique to sequence
covered in both

Physics 270 Newton's Laws to Maxwell's Equations

Instructor:	Phil Rubin
Office:	PH 253
Phone:	703.993.3815
E-mail:	prubin@gmu.edu
Office Hours:	Wednesday 9:00-10:30
Website:	`http://physics.gmu.edu/~rubinp/courses/270/`

Please note:

- All e-mail communication from the instructor concerning this course will be to GMU accounts only.
- If you are a student with a disability and require academic accommodations, please see me and contact the Office of Disability Resources at 703.993.2474. All academic accommodations must be arranged through that office.

Course Goals: This is the second course in a calculus-based, introductory physics sequence. The most important thing you will learn is how to solve word problems: understand what is being asked, estimating an answer, conceptualizing and undertaking a systematic approach toward a solution, checking results and modifying, if necessary, your understanding and/or approach. The physical models you will be exposed to are the fundamental classical theories of Newton (mechanics) and Maxwell (electromagnetism).

General Education: General education natural sciences courses engage students in scientific exploration; foster their curiosity; enhance their enthusiasm for science; and enable them to apply scientific knowledge and reasoning to personal, professional, and public decision-making.

To achieve these goals, students will:

1. understand how scientific inquiry is based on investigation of evidence from the natural world, and that scientific knowledge and understanding:
   (a) evolves based on new evidence
   (b) differs from personal and cultural beliefs
2. Recognize the scope and limits of science.
3. Recognize and articulate the relationship between the natural sciences and society and the application of science to societal challenges (e.g., health, conservation, sustainability, energy, natural disasters, etc.).
4. Evaluate scientific information (e.g., distinguish primary and secondary sources, assess credibility and validity of information).

Tentative Schedule:

Week	**Topics**
1	Introduction, Review of Conservation Laws
2	Review of Energy Concepts
3	Collisions, Newton's Laws
4	Statics, Forces and Motion
5	Linear and Circular Motion
6	Projectile and Oscillatory Motion
7	Kepler's Laws and Orbits
8	Charge Distributions, Electric Fields and Potenials
9	Equilibrium, Circuits
10	Magnetic Fields and Currents
11	The Electromagnetic Field, Gauss's and Ampere's Laws
12	Integral Forms, Maxwell's Equations
13	Faraday's Law, Induction
14	Electromagnetic Waves

Texts Volumes N and E of Six Ideas That Shaped Physics, 3rd Edition, by Thomas Moore, McGraw-Hill

Grading: The point of this course is to develop and employ skills associated with solving physics problems (see Course Goals, above). This requires concerted effort, which will be monitored by frequent graded assignments (50%). There will be two midterm examinations (10% each) and a final examination (30%).

A+=100-96.67	A=96.66-93.33	A-=93.32-90
B+=89.99-86.67	B=86.66-83.33	B-=83.32-80
C+=79.99-76.67	C=76.66-73.33	C-=73.32-70
	D=69.99-60	
	F<60	

Honor Code Violations: Science is impossible when dishonesty, in any manifestation, exists. It's the worst possible conduct a scientist can display. Dishonesty of any sort (cheating, plagiarism, lying, stealing), as determined by the instructor, will be reported to the honor council for further disciplinary action. A grade of F will be recorded on your record, pending the outcome of the honor council review.

The GMU Honor Code: `http://www.gmu.edu/catalog/9798/honorcod.html#code`

Why offer an alternative sequence in introductory, calculus-based physics? When a sequence of courses with multiple sections introduces a subject, significantly different approaches to the subject among different sections, especially with regard to the ordering of topics, are impossible. .

No course or sequence of courses can or should cover every topic that might be covered, and this is especially true at the introductory level, where developing ways of thinking about a subject is at least as important as the breadth of topics presented. Few would question that an introduction to physics must offer a foundation in mechanics and electromagnetism, despite the case that has been made that dense and superficially stodgy topics such as these are perhaps not the best settings to begin developing the problem-solving skills expected of physical scientists and engineers. Many alternatives to the pseudo-chronological presentation of topics characterizing the "traditional" introductory physics sequence have been proposed.

This new sequence is being created to offer such alternatives with clear sequential continuity. Presented here is a proposal for one such alternative sequence if I were to teaching it in Spring and Fall 2019. My preferred approach–kinematics, conservation laws, interactions, dynamics–in which topics such as mechanics and electromagnetism, as well as thermal and modern physics, are subsumed by these more general themes, would require writing a textbook from scratch. The introductory physics text **Six Ideas that Shaped Physics**, written by Thomas Moore, professor at Pomona College, on the basis of 8 years of work with the Introductory University Physics Project (IUPP) followed by 17 years of testing and revision, is the closest approximation I've found in terms flexibility of course design and emphasis on the development of "physical thinking." Though not conducive to my preferred sequence of themes, it's six ideas do permit interesting ordering options. In fact, the Pomona College introductory which uses this text inverts the order of topics relative to the "traditional" sequence by beginning with conservatin laws, "modern," and thermal physics before addressing mechanics and electromagnetism in the second semester, and this is the order I would propose to follow.

In this way, topics more interesting to beginning students–and, incidentally, requiring less advanced mathematics–are presented at the outset, forming the environment for developing the problem-solving and model-building skills expected of completers of the sequence. The Pomona experience is that a significantly higher fraction of first semester students return for the second semester than in their parallel, "traditional" sequence.

Further, the lower mathematics requirements of this alternative sequence allows students beginning the calculus sequence to save a semester, relative to the PHYS 160 - 260 sequence, offering a significant option to students who take pre-calculus, rather than CALC 1, in their first semester.

As the class (lecture) order presented below (assuming three 50-minute meetings a week) and the accompanying spread sheet show, nearly all topics covered in the "traditional" sequence, with the exception of fluid dynamics, AC circuits, and optics (which is not covered in PHYS 160 - 260), are covered, just in a different order, albeit perhaps in somewhat less depth. Instead, relativity, quantum/wave mechanics, and thermal physics (none of which are introduced in our present two-semester sequence) are covered.

With regard to labs, this sequence can be paired with our present introductory lab sequence. Most of the topics nominally addressed in the labs are covered. Those that are not may be deemed discovery experiences.

Sequence of Topics Covered

PHYS 170

1. The Art of Model Building
   - The Nature of Science
   - The Development and Structure of Physics
   - Modeling Example
   - Units and Dimensions
     - Units
     - Conversions
     - Dimensional Analysis
2. Particles and Interactions
   - The Principles of Modern Mechanics
   - Describing an Object's Motion
   - Vector Operations
   - Momentum and Impulse
   - Force and Weight
   - Interaction Categories
   - Momentum Transfer
3. Vectors
   - Introduction to Vectors
   - Reference Frames
   - Displacement Vectors
   - Arbitrary Vectors
   - Operations Rules
   - Vectors in Two Dimensions
   - Vectors in One Dimension
4. Systems and Frames
   - Systems of Particles
   - Center of Mass
   - How the Center of Mass Moves
   - Inertial Reference Frames
   - Freely Floating Frames
   - Interactions with the Earth

5. Conservation of Momentum
    - Degrees of Isolation
    - How to Solve Physics Problems
    - Conservation of Momentum Problems
    - Airplanes and Rockets (optional)
6. Conservation of Angular Momentum
    - Introduction to Angular Momentum
    - Quantifying Orientation
    - Angular Velocity
    - Angular Momentum of a Rigid Object
    - Twirl and Torque
    - Gyroscopic Precession
    - Conservation of Angular Momentum
7. Conservation of Energy
    - Introduction to Energy
    - Kinetic Energy
    - Potential Energy
    - Fundamental Potential Energy Formulas
    - Internal Energy and Power
    - Isolation
    - Solving Conservation-of-Energy Problems
8. Potential Energy
    - Interactions Between Macroscopic Objects
    - Interactions Between Two Atoms
    - One-Dimensional Potential Energy Diagrams
    - Relaxing the Mass Limitation
    - The Spring Approximation
    - The Potential Energy "of an Object"
9. The Principle of Relativity
    - Introduction to the Principle
    - Events, Coordinates, and Reference Frames
    - Inertial Reference Frames
    - Newtonian Relativity

- Timelike, Lightlike, and Spacelike Intervals
- The Causal Structure of Spacetime
- The Einstein Velocity Transformation

16. Four-Momentum
    - Newtonian Momentum Isn't Conserved
    - The Four-Momentum Vector
    - Properties of Four-Momentum
    - Four-Momentum and Relativity
    - Relativistic Energy

17. Conservation of Four-Momentum
    - Energy-Momentum Diagrams
    - Solving Conservation Problems
    - The Mass of a System of Particles
    - The Four-Momentum of Light
    - Applications to Particle Physics (optional)

18. Wave Models
    - What Is a Wave?
    - A Sinusoidal Wave Model
    - The Phase Speed of a Sinusoidal Wave
    - Sound
    - Energy in Waves
    - The Doppler Effect

19. Standing Waves and Resonance
    - The Superposition Principle
    - Reflection
    - Standing Waves
    - Resonance

20. Interference and Diffraction
    - Two-Dimensional Waves
    - Simple Diffraction
    - Two-Slit Interference
    - Two-Slit Interference of Light

- Optical Resolution (optional)

21. The Particle Nature of Light
    - A Short History of Light
    - The Photoelectric Effect
    - Predictions of the Wave Model
    - The Photon Model of Light
    - Detecting Individual Photons

22. The Wave Nature of Particles
    - Subatomic Particles as Particles
    - The de Broglie Hypothesis
    - Preparing an Electron Beam
    - The Davisson-Germer Experiment
    - Modern Interference Experiments
    - Interference a Quanton at a Time
    - Implications

23. Spin
    - Introduction to Spin
    - Introduction to the Stern-Gerlach Experiment
    - Gyroscopic Precession
    - Spin Experiments
    - Spin and Angular Momentum

24. The Rules of Quantum Mechanics
    - The Mathematics of Quantum Mechanics
    - The Rules

25. Quantum Weirdness (optional)
    - The EPR Argument
    - Bells Theorem
    - Superposition and Schrödinger's Cat
    - Wave Function Collapse

26. The Wave Function
    - Vectors to Wave Functions
    - Wave Functions and Position Probability

- The Collapse of the Wave Function
- The Heisenberg Uncertainty Principle
- Two-Slit Interference

27. Simple Quantum Models

    - Bound Systems
    - Energy Eigenfunctions
    - A Quanton in a Box
    - Bohr Model of the Hydrogen Atom
    - Simple Harmonic Oscillator

28. Spectra

    - Energy-Level Diagrams
    - Spontaneous Emission of Photons
    - Spectral Lines
    - Absorption lines
    - The Pauli Exclusion Principle
    - Conductors and Semiconductors

29. The Schrödinger Equation (optional)

    - Generalizing the de Broglie Relation
    - Local Wavelength
    - Finding the Schrdinger Equation
    - Solving the Equation Numerically
    - Sketching Energy Eigenfunctions
    - Tunneling

30. Temperature

    - Irreversible Processes
    - Heat, Work, and Internal Energy
    - Thermal Processes
    - Temperature and Equilibrium
    - Thermometers
    - Temperature and Thermal Energy

31. Macrostates and Microstates (optional)

    - The Einstein Model of a Solid

- Distinguishing Macrostates and Microstates
- Counting Microstates
- Two Einstein Solids in Thermal Contact
- The Fundamental Assumption
- The Emergence of Irreversibility

32. Entropy and Temperature
    - The Definition of Entropy
    - The Second Law of Thermodynamics
    - Entropy and Disorder
    - The Definition of Temperature
33. The Boltzmann Factor (optional)
    - The Boltzmann Factor
    - Some Simple Applications
    - The Average Energy of a Quantum System
    - Application to the Einstein Solid
34. The Ideal Gas
    - Quantum Particles in a One-Dimensional Box
    - A Three-Dimensional Monatomic Gas
    - Diatomic Gases
    - The Equipartition Theorem and Its Limits
    - The Ideal Gas Law
35. Distributions (optional)
    - Counting Quantum States
    - The Maxwell-Boltzmann Distribution
    - The Photon Gas
    - Blackbody Emission
36. Gas Processes
    - Work during Expansion or Compression
    - The State of a Gas
    - PV Diagrams and Constrained Processes
    - Work
    - Adiabatic Processes

- Ideal Gas Heat Capacities

37. Calculating Entropy Changes
    - Entropy of an Ideal Gas
    - Work and Entropy
    - Constant-Temperature Processes
    - Changing Temperatures
    - Replacement Processes
38. Heat Engines
    - Perfect Engines Are Impossible
    - Real Heat Engines
    - Efficiency of a Heat Engine
    - Consequences
    - Refrigerators
    - The Carnot Cycle
39. The Physics of Climate Change (optional)
    - Radiative Equilibrium
    - The Atmospheric Blanket
    - The Ocean Effect
    - Consequences

PHYS 270

1. Particles and Interactions
    - The Principles of Modern Mechanics
    - Describing an Object's Motion
    - Vector Operations
    - Momentum and Impulse
    - Force and Weight
    - Interaction Categories
    - Momentum Transfer
2. Conservation of Angular Momentum
    - Introduction to Angular Momentum
    - Quantifying Orientation
    - Angular Velocity
    - Angular Momentum of a Rigid Object
    - Twirl and Torque
    - Gyroscopic Precession
    - Conservation of Angular Momentum
3. More About Angular Momentum
    - The Cross Product
    - Angular Momentum of a Moving Particle
    - Rotating Objects
    - Rotating and Moving Objects
    - Torque and Force
    - Why Angular Momentum Is Conserved
4. Conservation of Energy
    - Introduction to Energy
    - Kinetic Energy
    - Potential Energy
    - Fundamental Potential Energy Formulas
    - Internal Energy and Power
    - Isolation
    - Solving Conservation-of-Energy Problems
5. Work

- Asteroid Impacts (optional)

10. Newton's Laws
    - The Newtonian Synthesis
    - Newton's Laws of Motion
    - Vector Calculus
    - Velocity
    - Acceleration
    - Uniform Circular Motion
11. Forces and Motion
    - Kinematics Review
    - Classification of Forces
    - Force Laws
    - Free-Body Diagrams
    - Motion Diagrams
    - Graphs of One-Dimensional Motion
12. Motion and Forces
    - Graphical Antiderivatives
    - Integrals for One-Dimensional Motion
    - Free-fall in One Dimension
    - Integrals in Three Dimensions
    - Constructing Trajectory Diagrams
13. Statics
    - Introduction to Statics
    - Statics Problems (Involving Torque)
14. Linearly Constrained Motion
    - Motion at a Constant Velocity
    - Static and Kinetic Friction Forces
    - Drag Forces
    - Linearly Accelerated Motion
15. Coupled Objects
    - Notation
    - Pushing Blocks

- Strings
- Pulleys

16. Circularly Constrained Motion
    - Uniform Circular Motion
    - Unit Vectors
    - Nonuniform Circular Motion
    - Banking
17. Noninertial Frames (optional)
    - Fictitious Forces
    - Galilean Transformation
    - Inertial Reference Frames
    - Linearly Accelerating Frames
    - Circularly Accelerating Frames
    - Using Fictitious Forces
    - Freely Falling Frames and Gravity
18. Projectile Motion
    - Weight and Projectile Motion
    - Simple Projectile Motion
    - Drag and Terminal Speed
19. Oscillatory Motion
    - Mass on a Spring
    - The Oscillator as a Model
    - A Mass Hanging from a Spring
    - The Simple Pendulum
20. Kepler's Laws
    - Kepler's Laws
    - Orbits Around a Massive Primary
    - Kepler's Second Law
    - Circular Orbits and Keplers Third Law
    - Black Holes and Dark Matter (optional)
    - Kepler's First Law and Conic Sections (optional)
21. Orbits and Conservation Laws (optional)

- Conservation Laws and Elliptical Orbits
- Conservation Laws and Hyperbolic Orbits

22. Electric Fields
    - Unit Charge
    - Electric Force
    - The Field Concept
    - Electric Field
    - Field of a Single Particle
    - The Superposition Principle
23. Charge Distributions
    - The Dipole
    - Electrical Polarization
    - Some Other Charge Distributions
    - Field of an Infinite Line
    - The Field of an Infinite Plane
24. Electric Potential
    - Review of Energy Concepts
    - Electrical Potential
    - Field to Potential
    - Potential to Field
25. Static Equilibrium
    - Conductors and Insulators
    - Static Charges on Conductors
    - Capacitance
    - Parallel-Plate Capacitor
    - Electric Field as a Form of Energy
26. Current
    - Current Flow Models
    - Current Density
    - Flux
    - Electrical Current
27. Dynamic Equilibrium

- A Model of a Battery
- Implications of Equilibrium
- Surface Charges Direct the Flow
- Potentials in a Simple Circuit
- Resistance and Power
- Discharging a Capacitor (optional)

28. Analyzing Circuits
    - Circuit Diagrams
    - Kirchhoff's Laws
    - Circuit Elements in Series
    - Circuit Elements in Parallel
    - Analyzing Complex Circuits (optional)
    - Realistic Batteries (optional)

29. Magnetic Fields
    - Magnetism
    - Magnetic Field Direction
    - Magnetic Forces on Moving Charges
    - Cross Product
    - Defining the Fields Magnitude
    - A Free Particle in a Magnetic Field

30. Currents and Magnetic Fields
    - Magnetic Force on a Wire
    - Magnetic Torque on a Loop
    - Current Loops as Bar Magnets
    - Potential Energy of an Oriented Loop
    - Electric Motors
    - Moving Loops

31. Currents and Magnetic Fields, cont.
    - Magnetic Field of a Moving Charge
    - Magnetic Field of a Wire Segment
    - Magnetic Field of an Infinite Wire
    - Magnetic Field of a Circular Loop
    - Magnets as Circulating Currents

32. The Electromagnetic Field
    - Relativity and the Electromagnetic Field
    - How the Fields Transform
    - The Electromagnetic Field of a Moving Particle
33. Gauss's Law
    - Field Equation
    - Divergence
    - Gauss's Law
    - Applications
34. Ampere's Law
    - Curl
    - Ampere's Law
    - Applications
35. Integral Forms
    - Integrating Gauss's Law
    - Integrating Ampere's Law
36. Maxwell's Equations
    - Correcting Ampere's Law
    - Gauss's Law
    - Faraday's Law
    - Maxwell's Equations
37. Faraday's Law
    - Applying Faraday's Law
    - Magnetic Flux and Induced EMF
    - Lenz's Law
    - Applications
    - Superconductivity and Magnetic Flux (optional)
38. Induction
    - Self-Induction
    - "Discharging" an Inductor
    - Energy in a Magnetic Field
    - LC Circuits

- Transformers

39. Electromagnetic Waves
    - Electromagnetic Disturbances
    - Properties of Electromagnetic Waves
    - Intensity of an Electromagnetic Wave
    - Waves from a Charged Particle
    - Maxwell's Rainbow (optional)
    - Why the Sky Is Blue (optional)