FREEHOLD REGIONAL HIGH SCHOOL DISTRICT

OFFICE OF CURRICULUM AND INSTRUCTION

INTERNATIONAL BACCALAUREATE PROGRAM

PHYSICS SL, YEAR 2

Grade Level: 12

Credits: 5

BOARD OF EDUCATION ADOPTION DATE:

AUGUST 28, 2017

FREEHOLD REGIONAL HIGH SCHOOL DISTRICT

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IB PHYSICS SL YEAR 2

COURSE PHILOSOPHY

The International Baccalaureate Organization provides the following philosophy for the teaching of Physics SL: *"Physics is the most fundamental of the experimental sciences, as it seeks to explain the universe itself from the very smallest particles—currently accepted as quarks, which may be truly fundamental—to the vast distances between galaxies. . .*

Despite the exciting and extraordinary development of ideas throughout the history of physics, certain aspects have remained unchanged. Observations remain essential to the very core of physics, sometimes requiring a leap of imagination to decide what to look for. Models are developed to try to understand observations, and these themselves can become theories that attempt to explain the observations. Theories are not always directly derived from observations but often need to be created. These acts of creation can be compared to those in great art, literature and music, but differ in one aspect that is unique to science: the predictions of these theories or ideas must be tested by careful experimentation. Without these tests, a theory cannot be quantified. A general or concise statement about how nature behaves, if found to be experimentally valid over a wide range of observed phenomena, is called a law or a principle. . .

At the school level both theory and experiments should be undertaken by all students. They should complement one another naturally, as they do in the wider scientific community. The Diploma Programme physics course allows students to develop traditional practical skills and techniques and increase their abilities in the use of mathematics, which is the language of physics. It also allows students to develop interpersonal and digital communication skills which are essential in modern scientific endeavour and are important life-enhancing, transferable skills in their own right."

COURSE DESCRIPTION

The International Baccalaureate Organization provides the following description for Physics SL: *"IB Physics SL covers the core topics of measurements and uncertainties, mechanics, thermal physics, waves, electricity and magnetism, circular motion and gravitation, atomic, nuclear and particle physics, and energy production. Optional topics such as relativity, engineering physics, imaging, and astrophysics will also be covered. Through studying physics, students should become aware of how scientists work and communicate with each other. While the scientific method may take on a wide variety of forms, it is the emphasis on a practical approach through experimental work."*

COURSE SUMMARY	
COURSE GOALS	
CG1: Within a global context, students will craft experiments and execute inquiry-based labs by problem-solving, gathering existing research, analyzing data, and utilizing laboratory skills. CG2: Students will communicate and justify everyday phenomena using their understanding of content, scientific techniques, methods, and experimentation. CG3: Students will effectively collaborate during scientific activities and communicate their findings through multiple representations.	
COURSE ENDURING UNDERSTANDINGS	**COURSE ESSENTIAL QUESTIONS**
CEU1: Scientists perform investigative experiments in order to develop new theories and conclusions that lead to real-world global innovation.	CEQ1: Why do we still experiment?
CEU2: Physics concepts, techniques, and methods are used to explain and describe experiences in the world around us.	CEQ2: To what extent can we predict the physical world around us or are the events that we experience completely random?
CEU3: Scientific ideas must be effectively communicated across various cultures and various disciplines in order to advance scientific understanding, technology, and innovation.	CEQ3: To what extent does communication impact scientific advancements across the globe?

UNIT GOALS AND PACING		
UNIT TITLE	**UNIT GOALS**	**DURATION**
Unit 1: Circular Motion and Gravitation	Students will describe and predict motion in circular paths, transferring their understandings of Newton's law of gravitation and circular motion to make predictions about orbital phenomena.	5 weeks
Unit 2: Atomic, Nuclear and Particle Physics	Students will use their understanding of the composition of particles at the atomic and nuclear levels to explain and predict atomic and nuclear energy transfers.	10 weeks
Unit 3: Energy Production	Students will use their understanding of energy sources and energy transfer to describe, analyze, and predict global energy consumption patterns and environmental impacts.	8 weeks
Unit 4: Internal Assessment	Students will demonstrate the application of their skills and knowledge through completion of an independent research experiment on a topic of personal interest.	3 weeks
Unit 5: Option A - Engineering Physics	Students will use their understanding of rotational dynamics and thermodynamic energy to analyze mechanically engineered devices.	8 weeks
Unit 5: Option B - Imaging	Students will investigate the behavior of light in order to problem solve with telescopes, microscopes, and optical fibers.	8 weeks

IB PHYSICS SL YEAR 2	DURATION:
UNIT 1: CIRCULAR MOTION AND GRAVITATION	5 WEEKS

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will describe and predict motion in circular paths, transferring their understandings of Newton's law of gravitation and circular motion to make predictions about orbital phenomena.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can create, defend, and peer-teach real-world applications to complex problems in physics.
3	The student can: ● calculate the centripetal force, centripetal acceleration, period, frequency, angular displacement, linear speed and angular velocity; ● describe scenarios in which tension, friction, gravitational, electrical, and magnetic force provide the centripetal force on an object; ● qualitatively and quantitatively describe cases of circular motion in which an object moves in a horizontal path and vertical path; ● describe the relationship between gravitational force and centripetal force; ● apply an understanding of Newton's law of gravitation to an object in circular motion around a point mass; ● solve complex problems involving gravitational field strength, gravitational force, orbital period and orbital speed; ● apply an understanding of gravitational field strength to determine the resultant from two bodies.
2	The student can identify and define: ● period, frequency, angular displacement and angular velocity; ● centripetal force; ● centripetal acceleration; ● Newton's law of gravitation; ● gravitational field strength.
1	The student needs assistance to avoid major errors in attempting to reach score 3 performances.
0	Even with assistance, the student does not exhibit understanding of the performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: A perpendicular force, instead of parallel force, causes motion that allows us to describe objects in circular paths.	EQ1: To what extent is circular motion similar to linear motion?
EU2: Newton's law of gravitational force and an understanding of circular motion can be used to create a model of the motion of planets and satellites.	EQ2a: How accurate and dependable are predictions of model-based planetary and satellite orbits? EQ2b: How do we have knowledge and proof of unobservable or unmeasurable phenomena (for instance, mass of planets, rotation of planets, etc.)?

COMMON ASSESSMENT	
ALIGNMENT	**DESCRIPTION**
LG 1 EU1,2 EQ1,2a-b HS-PS2-1, 4 RST.11-12.8 WHST.11-12.2 DOK 4	Each student will be given a set of requirements for a satellite that will be need to orbit one of the planets. The mass of satellites, time of orbit, and planet will vary for each student. They will need to develop a plan for launching the satellite and getting it into orbit around their given planet. Students will have to provide calculations and written explanations as evidence that their plan will be successful.

TARGETED UNIT STANDARDS		
DECLARATIVE KNOWLEDGE	**PROCEDURAL KNOWLEDGE**	**NEW STANDARDS TO INTRODUCE**
gravitational field strength Newton's law of gravitation $F = G\frac{Mm}{r^2}$ $g = \frac{F}{m}$ $g = G\frac{M}{r^2}$	Construct a relationship between gravitational force and centripetal force (DOK 2) Apply Newton's law of gravitation to the motion of an object in circular orbit around a point mass (DOK 2) Solve complex problems involving gravitational force, gravitational field strength, orbital speed and orbital period (DOK 2) Determine the resultant gravitational field strength due to two bodies (DOK 2) Use astronomical data to verify the gravitational field and orbital period of planets and satellites (DOK 3)	HS-PS2-4 Use mathematical representations of Newton's Law of Gravitation and Coulomb's Law to describe and predict the gravitational and electrostatic forces between objects. RST.11-12.8 Evaluate the hypotheses, data, analysis, and conclusions in a science or technical text, verifying the data when possible and corroborating or challenging conclusions with other sources of information.
DECLARATIVE KNOWLEDGE	**PROCEDURAL KNOWLEDGE**	**PREVIOUSLY COVERED STANDARDS TO DEVELOP FURTHER**
angular displacement angular velocity centripetal force centripetal acceleration frequency period $v = \omega r$ $a = \frac{v^2}{r} = \frac{4\pi^2 r}{T^2}$ $F = \frac{mv^2}{r} = m\,\omega^2 r$	Compare the different types of forces providing the centripetal forces such as tension, friction, gravitational, electrical, or magnetic (DOK 2) Solve complex problems involving centripetal force, centripetal acceleration, period, frequency, angular displacement, linear speed and angular velocity (DOK 2) Qualitatively and quantitatively construct examples of circular motion including cases of vertical and horizontal circular motion (DOK 3) Create and communicate a scientific procedure for determining the velocity of an object travelling in a circular path when hanging from the ceiling (DOK 4)	HS-PS2-1 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. WHST.11-12.2 Write informative/explanatory texts, including the narration of historical events, scientific procedures/ experiments, or technical processes.

IB PHYSICS SL YEAR 2 UNIT 2: ATOMIC, NUCLEAR, AND PARTICLE PHYSICS	DURATION: 10 WEEKS

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will use their understanding of particle composition at the atomic, nuclear, and subatomic levels to explain and predict atomic and nuclear energy transfers.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can create, defend, and peer-teach real-world applications to complex problems in physics.
3	The student can: ● describe the emission and absorption spectra of some common gases; ● solve complex problems involving atomic spectra which include calculations of wavelength emitted during atomic transitions; ● predict the outcome for alpha and beta decay equations; ● use a decay curve to determine the half-life of a nuclide; ● experimentally (or by simulation) explore half-life; ● solve complex problems involving mass defect and nuclear binding energy; ● perform calculations to determine the energy released in radioactive decay, nuclear fission and nuclear fusion; ● sketch and interpret the general shape of the curve for average binding energy per nucleon against nucleon number; ● detail the Rutherford-Geiger-Marsden experiment that led to the discovery of the nucleus; ● apply the various conservation laws to particle reactions; ● distinguish between the interaction strengths of the four fundamental forces; ● use exchange particles to describe the mediation of the fundamental forces.

UNIT LEARNING SCALE (continued)	
2	The student can identify and define: ● discrete energy and discrete energy levels; ● transition between energy levels; ● radioactive decay; ● fundamental forces and their properties; ● alpha particles, beta particles, and gamma rays; ● half-life; ● absorption characteristics of decay particles; ● isotopes; ● background radiation; ● unified atomic mass unit; ● nuclear binding energy and mass defect; ● nuclear fission and nuclear fusion; ● quarks, leptons, and their antiparticles; ● hadrons, baryons, mesons; ● conservation laws of charge, baryon number, lepton number and strangeness; ● strong nuclear force, weak nuclear force, electromagnetic force; ● exchange particles; ● Feynman diagrams; ● confinement; ● the Higgs boson.
1	The student needs assistance to avoid major errors in attempting to reach score 3 performances.
0	Even with assistance, the student does not exhibit understanding of the performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: In the microscopic world, energy is discrete.	EQ1: If particles in the microscopic world are so small, how do we even known they exist?
EU2: A relationship exists between mass and energy, as demonstrated by the energy released during nuclear reactions and nuclear decay.	EQ2: To what extent are mass and energy the same thing?
EU3: As new technologies in particle physics arise, the Standard Model of fundamental particles continues to evolve.	EQ3: What is the purpose of searching for the fundamental particles of matter and will we ever discover particles that are truly fundamental?

COMMON ASSESSMENT	
ALIGNMENT	**DESCRIPTION**
LG 1 EU1,2,3 EQ1,2,3 HS-PS1-4, 7, 8 HS-PS4-4 RST.11-12.2, 5 WHST.11-12.1.B DOK 4	Students will use available databases to gather research data related to a particle and nuclear physics experiment. If necessary, teacher can provide teacher-modified data for students to analyze. Students should analyze the data and information, critiquing the validity of the statements and supposed research findings of the author. They will be required to use an understanding of mass defect and binding energies, as well as their understanding of the Standard Model and quark composition of particles to assess the claims in the text. Students will present their findings and claims to the class.

TARGETED UNIT STANDARDS		
DECLARATIVE KNOWLEDGE	**PROCEDURAL KNOWLEDGE**	**NEW STANDARDS TO INTRODUCE**
absorption characteristics alpha particle background radiation beta particle discrete energy discrete energy levels energy level transition fundamental forces gamma ray half-life isotopes radioactive decay $E = hf$ $\lambda = \frac{hc}{E}$	Make observations of the emission and absorption spectrum of common gases (DOK 2) Use mathematical representations to solve problems involving atomic spectra, including calculating the wavelength of photons emitted during atomic transitions (DOK 2) Construct and present an accurate summary of decay equations for alpha and beta decay from a scientific text (DOK 2) Analyze a decay curve to predict the half-life of a nuclide (DOK 3) Experimentally investigate half-life in order to construct a model that represents the decay of nuclides (DOK 3)	HS-PS4-4 Evaluate the validity and reliability of claims in published materials of the effects that different frequencies of electromagnetic radiation have when absorbed by matter. HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. RST.11-12.2 Determine the central ideas, themes, or conclusions of a text; summarize complex concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms.
binding energy mass defect nuclear fission nuclear fusion unified atomic mass unit $\Delta E = mc^2$	Solve problems involving mass defect and binding energy (DOK 2) Sketch and interpret the general shape of the curve of average binding energy per nucleon against nucleon number (DOK 2) Develop models to predict the energy released in radioactive decay, nuclear fission and nuclear fusion (DOK 3) Analyze the direct relationship between energy and mass at the atomic level during chemical reactions (DOK 3)	HS-PS1-4 Develop a model to illustrate that the release or absorption of energy from a chemical reaction system depends upon the changes in total bond energy. HS-PS1-7 Use mathematical representations to support the claim that atoms, and therefore mass, are conserved during a chemical reaction. HS-PS1-8 Develop models to illustrate the changes in the composition of the nucleus of the atom and the energy released during the processes of fission, fusion, and radioactive decay.

DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE	NEW STANDARDS TO INTRODUCE
antiparticles baryons confinement conservation laws exchange particles electromagnetic force Feynman diagrams gravitational force hadrons Higgs boson leptons mesons quarks strong nuclear force weak nuclear force	Summarize the Rutherford-Geiger-Marsden experiment that led to the discovery of the nucleus (DOK 1) Analyze the structure and hierarchy of the standard model in terms of leptons, hadrons, baryons, and mesons (DOK 2) Show the quark content of protons and neutrons (DOK 2) Compare the interaction strengths of the fundamental forces, including gravity (DOK 2) Sketch and interpret simple Feynman diagrams to predict the exchange particle of a reaction (DOK 2) Describe and/or support the claim that free quarks are not observed (DOK 2) Construct and analyze particle reactions to demonstrate conservation laws (DOK 3) Create a visual model to explain the mediation of the fundamental forces through exchange particles (DOK 3)	RST.11-12.5 Analyze how the text structures information or ideas into categories or hierarchies, demonstrating understanding of the information or ideas. WHST.11-12.1.B Develop claim(s) and counterclaims using sound reasoning and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline appropriate form that anticipates the audience’s knowledge level, concerns, values, and possible biases.

IB PHYSICS SL YEAR 2 UNIT 3: ENERGY PRODUCTION	DURATION: 8 WEEKS

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will use their understanding of energy sources and energy transfer to describe, analyze, and predict global energy consumption patterns and environmental impacts.	
4	In addition to score 3 performances, the student can create, defend, and peer-teach real-world applications to complex problems in physics.
3	The student can: ● compute specific energy and energy density for natural resources; ● sketch and interpret Sankey diagrams; ● describe the main components of fossil fuel stations, nuclear power plants, pumped storage systems, and solar power cells; ● solve problems relevant to energy transformations related to the power generation systems; ● investigate the safety issues and risks associated with nuclear power plants; ● distinguish between photovoltaic cells and solar heating panels; ● sketch and interpret graphs showing the intensity of a radiating body against the wavelength; ● perform calculations using Stefan-Boltzmann law and Wien's displacement law; ● calculate and describe the effects of earth's atmosphere, emissivity, albedo, and solar constant on earth's mean surface temperature; ● describe how and why the greenhouse gases affect earth's surface temperature.
2	The student can identify and define: ● specific energy and energy density; ● Sankey diagrams; ● primary energy sources; ● renewable and nonrenewable energy sources; ● conduction, convection, thermal radiation; ● black body radiation; ● albedo and emissivity; ● solar constant; ● greenhouse effect.

UNIT LEARNING SCALE	
1	The student needs assistance to avoid major errors in attempting to reach score 3 performances.
0	Even with assistance, the student does not exhibit understanding of the performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: With limited amounts of fossil fuels and their impact on global warming, it is becoming essential for humans to develop alternative energy sources.	EQ1a: Are any energy sources completely renewable? EQ1b: What does the future bring for Earth's natural resources if humans do not develop alternative energy sources?
EU2: The Earth can be treated as a black-body radiator in order to create models that can help to predict climate change.	EQ2a: How accurate can climate change models be? EQ2b: How important is it to create accurate models that represent and predict climate change?

COMMON ASSESSMENT	
ALIGNMENT	**DESCRIPTION**
LG1 EU1,2 EQ1a-b, 2a-b HS-PS3-3 HS-ESS3-3, 6 HS-ESS2-4 RST.11-12.1,4 WHST.11-12.1.B DOK 3	Each student will design an energy generation plan to fulfill energy requirements based on available resources, location, and energy needs of their population. They will be provided with a specification sheet for each energy source including efficiencies, energy conversion rates, and other properties to determine the potential energy output. Students will use detailed calculations as evidence to support their claim that their energy generation plan fulfills their given requirements. Students must also take into consideration and explain how the by-product of their energy generation would impact the greenhouse gasses in the earth's atmosphere and the overall climate of earth.

TARGETED UNIT STANDARDS		
DECLARATIVE KNOWLEDGE	**PROCEDURAL KNOWLEDGE**	**NEW STANDARDS TO INTRODUCE**
energy density of fuel sources non-renewable energy source primary energy sources renewable energy source Sankey diagrams secondary energy forms specific energy $Power = \frac{energy}{time}$ $Power = \frac{1}{2}A\rho v^3$	Use mathematical representations to solve specific energy and energy density problems (DOK 2) Sketch and interpret Sankey diagrams to illustrate or analyze the flow of energy in a device or process (DOK 2) Determine the meaning of the basic features of fossil fuel power stations, nuclear power stations, wind generators, pumped storage hydroelectric systems and solar power cells (DOK 2) Solve problems relevant to energy transformations in the context of these generating systems (DOK 2) Construct an explanation describing the differences between photovoltaic cells and solar heating panels (DOK 2) Design and build a device within the classroom that converts energy from one form to another (DOK 4) Develop an argument using relevant facts and concrete details related to the availability of natural resources, occurrence of natural hazards and climate have influenced human activity (DOK 3) Discuss safety issues and risks associated with the production of nuclear power (DOK 3)	HS-PS3-3 Design, build, and refine a device that works within given constraints to convert one form of energy into another form of energy. HS-ESS3-1 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. RST.11-12.4 Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 11-12 texts and topics*. WHST.11-12.1.B Develop claim(s) and counterclaims using sound reasoning and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline appropriate form that anticipates the audience’s knowledge level, concerns, values, and possible biases.

DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE	NEW STANDARDS TO INTRODUCE
albedo and emissivity black-body radiation conduction convection energy balance greenhouse effect solar constant thermal radiation $P = e\sigma AT^4$ $\lambda_{\max(meters)} = \frac{2.9x10^{-3}}{T(Kelvin)}$ $I = \frac{power}{A}$ $albedo = \frac{total\ scattered\ power}{total\ incident\ power}$	Sketch and interpret graphs showing the variation of intensity with wavelength for bodies emitting thermal radiation at different temperatures (DOK 2) Solve complex problems involving the Stefan–Boltzmann law and Wien's displacement law (DOK 2) Use mathematical representations to solve problems involving albedo, emissivity, solar constant and the Earth's average temperature (DOK 2) Use a computational representation to illustrate the effects of the Earth's atmosphere on the mean surface temperature and provide evidence from sources to assess the impact of human activity (DOK 3)	HS-ESS2-4 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-ESS3-6 Use a computational representation to illustrate the relationships among Earth systems and how those relationships are being modified due to human activity. RST.11-12.1 Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.

IB PHYSICS SL YEAR 2 UNIT 4: INTERNAL ASSESSMENT	DURATION: 3 WEEKS

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will demonstrate the application of research skills and knowledge through completion of an independent research experiment on a topic of personal interest.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can create, defend, and peer-teach real-world applications to complex problems in physics.
3	The student can: ● create a relevant research question that shows personal engagement; ● describe in detail the method used to collect experimental data relevant to their research question; ● collect data which will include uncertainties presented as a range; ● propagate uncertainty through calculations; ● determine the uncertainty in their gradient and intercepts; ● communicate their research findings in a clear and cohesive manner;
2	The student sometimes needs assistance from a teacher, makes minor mistakes, and/or can do the majority of level 3 performances.
1	The student needs assistance to avoid major errors in attempting to reach score 3 performances.
0	Even with assistance, the student does not exhibit understanding of the performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: A relevant and focused research question is essential when communicating scientific findings.	EQ1: What is the importance of conducting scientific research and being able to communicate your findings?
EU2: There should be sufficient qualitative and quantitative data to support a detailed and valid conclusion of a research question.	EQ2: Why are data necessary to a scientific finding?
EU3: A proper analysis of error and uncertainty provides validity to experimental data.	EQ3: Why can you never be 100% certain about a measurement or data collected in an experiment and to what extent does that make data invalid?

COMMON ASSESSMENT	
ALIGNMENT	**DESCRIPTION**
LG1 EU1,2,3 EQ1,2,3 HS-ETS.1-3,4 RST.11-12.9 WHST.11-12.7,8,9 DOK 4	**Internal Assessmen**t: Students will follow IB guidelines to complete the Internal Assessment. In this assessment, students will design, plan, and conduct a laboratory experiment or investigation on a topic of interest with relevance to the IB Physics curriculum. Students must write a formal paper taking into account: ● personal engagement; ● scientific relevance; ● detailing their method or procedure; ● complex analysis of their data; ● drawing formal conclusions using their data and analysis as evidence; ● being critically aware of academic honesty.

TARGETED UNIT STANDARDS		
DECLARATIVE KNOWLEDGE	**PROCEDURAL KNOWLEDGE**	**NEW STANDARDS TO INTRODUCE**
absolute uncertainty aim dependent variable error bars fractional uncertainty gradient uncertainty independent variable percentage uncertainty random error systematic error $if\ y = a \pm b$ then $\Delta y = \Delta a + \Delta b$ $if\ y = \frac{ab}{c}\ then\ \frac{\Delta y}{y} = \frac{\Delta a}{a} + \frac{\Delta b}{b} + \frac{\Delta c}{c}$ $if\ y = a^n\ then\ \frac{\Delta y}{y} = \left\|n \frac{\Delta a}{a}\right\|$	Collect data that includes absolute and/or fractional uncertainties and state as an uncertainty range (DOK 2) Propagate uncertainties through calculations involving addition, subtraction, multiplication, division and raising to a power (DOK 2) Construct a self-generated research question appropriate to the level of study and involving personal engagement (DOK 3) Gather and interpret information from a range of sources and texts to provide scientific context for the investigation and provide evidence to support analysis, reflection, and research (DOK 3) Assess the investigation's random and systematic errors, explain how they can be identified and propose steps to reduce them (DOK 3)	HS-ETS1-3 Evaluate a solution to a complex real-world problem based on prioritized criteria and trade-offs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts. HS-ETS1-4 Use a computer simulation to model the impact of proposed solutions to a complex real-world problem with numerous criteria and constraints on interactions within and between systems relevant to the problem. RST.11-12.9 Synthesize information from a range of sources (e.g., texts, experiments, simulations) into a coherent understanding of a process, phenomenon, or concept, resolving conflicting information when possible. WHST.11-12.7 Conduct short as well as more sustained research projects to answer a question (including a self-generated question) or solve a problem; narrow or broaden the inquiry when appropriate; synthesize multiple sources on the subject, demonstrating understanding of the subject under investigation. WHST.11-12.8 Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the strengths and limitations of each source in terms of the specific task, purpose, and audience; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and overreliance on any one source and following a standard format for citation. WHST.11-12.9 Draw evidence from informational texts to support analysis, reflection, and research.

IB PHYSICS SL YEAR 2	DURATION:
UNIT 5: OPTION A - ENGINEERING PHYSICS	**8 WEEKS**

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will use their understanding of rotational dynamics and thermodynamic energy to analyze mechanically engineered devices.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can create, defend, and peer-teach real-world applications to complex problems in physics.
3	The student can: ● perform torque calculations for single forces and couples including when objects are in both rotational and translational equilibrium; ● apply Newton’s second law to calculate the torque, moment of inertia, and angular acceleration of a rotating object; ● construct a relationship between the rotational quantities and their analogous linear quantities; ● sketch and interpret rotational motion graphs; ● calculate and investigate the rotational energy of objects that are rolling without slipping; ● use conservation of energy to describe the first law of thermodynamics; ● apply the first law of thermodynamics to solve complex problems; ● explain the second law of thermodynamics in Clausius form, Kelvin form, and as a result of entropy; ● describe examples and solve problems involving entropy change; ● sketch and interpret cyclic processes; ● solve problems for adiabatic processes for monatomic gases; ● calculate thermal efficiency in thermodynamic problems.

UNIT LEARNING SCALE (continued)	
2	The student can identify and define: ● torque; ● moment of inertia; ● rotational and translational equilibrium; ● angular acceleration; ● equations of rotational motion; ● conservation of angular momentum; ● first law of thermodynamics; ● second law of thermodynamics; ● entropy; ● cyclic processes and pV diagrams; ● isovolumetric, isobaric, isothermal, and adiabatic processes; ● Carnot cycle; ● thermal efficiency.
1	The student needs assistance to avoid major errors in attempting to reach score 3 performances.
0	Even with assistance, the student does not exhibit understanding of the performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: The basic laws of mechanics can be extended and applied to rotational motion.	EQ1: To what extent do you see similarities and differences between linear and rotational motion?
EU2: Engineers utilize the laws of thermodynamics and energy transfer to design heat engines, which play a significant role in our society.	EQ2a: To what extent can heat transfer be utilized to do work? EQ2b: What is the significance of heat engines in modern society?

COMMON ASSESSMENT	
ALIGNMENT	**DESCRIPTION**
LG1 EU1,2 EQ 1,2a-b HS-PS2-2 HS-PS3-1 RST.11-12.1,3 DOK 3	Groups will be given different parameters for a machine that must convert heat energy into rotational energy. Based on the desired outcomes, students must design a device that would accomplish this task. Students will need to provide detailed drawings and calculations as evidence of their device providing the desired outcomes.

<table>
<tr><th colspan="3">TARGETED UNIT STANDARDS</th></tr>
<tr><th>DECLARATIVE KNOWLEDGE</th><th>PROCEDURAL KNOWLEDGE</th><th>PREVIOUSLY COVERED STANDARDS TO DEVELOP FURTHER</th></tr>
<tr><td>angular acceleration
conservation of angular momentum
moment of inertia
rotational equilibrium
torque
translational equilibrium

$\Gamma = Fr sin\theta$

$I = \Sigma mr^2$

$\Gamma = I\alpha$

$\omega = 2\pi f$

$\omega_f = \omega_i + \alpha t$

$(\omega_f)^2 = (\omega_i)^2 + 2\alpha\theta$

$\theta = \omega_i t + \frac{1}{2}\alpha t^2$

$L = I\omega$

$E_{K_{rot}} = \frac{1}{2}I\omega^2$</td><td>Calculate the amount of torque for a single force (DOK 2)

Use mathematical representations to solve complex problems involving torque, moment of inertia, and angular acceleration (DOK 2)

Apply an understanding of rotational and translational equilibrium to describe the forces acting on an object (DOK 2)

Sketch and interpret graphs of rotational motion (DOK2)

Solve problems involving rolling without slipping (DOK 2)

Follow a complex procedure in order to demonstrate the change in angular momentum of an object
(DOK 2)

Formulate mathematical representations of rotational quantities that are analogous to linear quantities in order to solve complex problems (DOK 3)</td><td>HS-PS2-2 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.

RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text.</td></tr>
</table>

DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE	PREVIOUSLY COVERED STANDARDS TO DEVELOP FURTHER
adiabatic processes cyclic processes carnot cycle entropy Isobaric Isothermal isovolumetric first law of thermodynamics pV diagrams second law of thermodynamics thermal efficiency $Q = \Delta U + W$ $U = \frac{3}{2}nRT$ $\Delta S = \frac{\Delta Q}{T}$ $pV^{\frac{5}{3}} = constant\ (for\ monatomic\ gases)$ $W = p\Delta V$ $\eta = \frac{useful\ work\ done}{energy\ input}$ $\eta_{Carnot} = 1 - \frac{T_{cold}}{T_{hot}}$	Explain the sign convention used when stating the first law of thermodynamics in equation form (DOK 2) Solve complex problems involving the first law of thermodynamics (DOK 2) Solve complex mathematical problems involving entropy changes (DOK 2) Sketch and interpret cyclic processes (DOK 2) Solve problems for adiabatic processes for monatomic gases using $pV^{5/4}$ = constant (DOK 2) Assess the validity that the first law of thermodynamics is a statement of conservation of energy (DOK3) Differentiate between the second law of thermodynamics in Clausius form, Kelvin form and as a consequence of entropy (DOK 3) Create and describe examples of processes in terms of entropy change (DOK 3) Create a computational model to critique the thermal efficiency of a system (DOK 3)	HS-PS3-1 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. RST.11-12.1 Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.

IB PHYSICS SL YEAR 2	DURATION:
UNIT 5: OPTION B - IMAGING	8 WEEKS

UNIT OVERVIEW	
UNIT LEARNING GOALS	
Students will investigate the behavior of light in order to problem solve with telescopes, microscopes, and optical fibers.	
UNIT LEARNING SCALE	
4	In addition to score 3 performances, the student can create, defend, and peer-teach real-world applications to complex problems in physics.
3	The student can: ● describe how a curved lens modifies the shape of an incident wavefront; ● use a scaled diagram of a converging and diverging lens to determine the focal point and focal length; ● construct scaled ray diagrams in order to solve problems involving no more than two lenses; ● construct scaled ray diagrams in order to solve problems involving no more than curved mirrors; ● solve complex problems involving the thin lens equation, linear magnification, and angular magnification; ● describe spherical and chromatic aberrations including ways to reduce their effects; ● interpret and construct ray diagrams of optical compound microscopes and simple optical astronomical refracting telescopes; ● solve complex problems for the angular magnification and resolution of optical compound microscopes and simple optical astronomical refracting telescopes; ● compare the performance of Earth based telescopes to satellite telescopes; ● within the context of optical fibers, calculate the critical angle for total internal reflection; ● describe and explain how waveguide and material dispersion can lead to attenuation; ● solve complex problems involving attenuation; ● compare the use of fiber optics to twisted pairs and coaxial cables.

UNIT LEARNING SCALE (continued)	
2	The student can identify and define: ● thin lenses; ● converging and diverging lenses; ● converging and diverging mirrors; ● ray diagrams; ● real and virtual images; ● linear and angular magnification; ● spherical and chromatic aberrations; ● optical compound microscope; ● simple optical astronomical refracting telescope; ● simple optical astronomical reflecting telescope; ● single-dish radio telescope; ● radio interferometry telescope; ● satellite-borne telescope; ● optic fibers; ● step index fibers and graded index fibers; ● total internal reflection and critical angle; ● waveguide and material dispersion; ● attenuation and decibel scale.
1	The student needs assistance to avoid major errors in attempting to reach score 3 performances.
0	Even with assistance, the student does not exhibit understanding of the performances listed in score 3.

ENDURING UNDERSTANDINGS	ESSENTIAL QUESTIONS
EU1: A ray or wavefront can be used to model the behavior of light when moving between two different media.	EQ1: Knowing that light rays can be manipulated, how accurate is our perception of objects?
EU2: Light can be manipulated for various applications through the use of lenses and mirrors in optical devices.	EQ2: To what extent have optical devices, which utilize lenses and mirrors to manipulate light, affected society?
EU3: Worldwide communication by voice, video, and data has been transformed through a global network of fiber optic cables.	EQ3: How has society changed due to the application of fiber optic cables?

COMMON ASSESSMENT	
ALIGNMENT	**DESCRIPTION**
LG1 EU1,2,3 EQ1,2,3 HS-PS4-1,5 RST.11-12.1,3 WHST.11-12.1.A DOK 4	Students will be randomly assigned to create either a microscope or telescope with varying magnification and resolution needs. They will use a provided set of optical component specification sheets to design their device for their given parameters. Students will complete complex calculations and draw a scaled ray diagram in order to provide evidence that the device will provide their desired outcome.

TARGETED UNIT STANDARDS		
DECLARATIVE KNOWLEDGE	**PROCEDURAL KNOWLEDGE**	**PREVIOUSLY COVERED STANDARDS TO DEVELOP FURTHER**
angular magnification chromatic aberrations converging lens converging mirror diverging lens diverging mirror linear magnification ray diagram real image spherical aberrations thin lenses virtual image $\frac{1}{f}=\frac{1}{v}+\frac{1}{u}$ $P=\frac{1}{f}$ $m=\frac{h_i}{h_o}=-\frac{v}{u}$ $M=\frac{\theta_i}{\theta_o}$ $M_{near\ point}=\frac{D}{f}+1;\ M_{infinity}=\frac{D}{f}$	Distinguish between the principal axis, focal point and focal length of a simple converging or diverging lens on a scaled diagram (DOK 2) Cite evidence from the text to explain how an incident wavefront can be modified when travelling through a curved surface (DOK 2) Construct and analyze scaled ray diagrams to mathematically solve problems involving lenses, and curved mirrors (DOK 3) Derive and use a mathematical representation of thin lenses, linear magnification, and angular magnification (DOK 3) Draw conclusions about spherical and chromatic aberrations to formulate ways to reduce their effects on images (DOK 3)	HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. RST.11-12.1 Accurately cite strong and thorough evidence from the text to support analysis of science and technical texts, attending to precise details for explanations or descriptions.

DECLARATIVE KNOWLEDGE	PROCEDURAL KNOWLEDGE	PREVIOUSLY COVERED STANDARDS TO DEVELOP FURTHER
optical compound microscope radio interferometry telescope satellite-borne telescope simple optical reflecting telescope simple optical refracting telescope single-dish radio telescope $M = \frac{f_o}{f_e}$	Use mathematical representations to calculate the angular magnification and resolution of optical compound microscopes and simple optical astronomical refracting telescopes (DOK 2) Construct and differentiate between the ray diagrams of optical compound microscopes and simple optical astronomical refracting telescopes with relation to their application (DOK 3) Experimentally investigate the optical compound microscope and the simple astronomical refracting telescope and communicate information about its uses and of wave behavior and wave interactions (DOK 3) Investigate Earth-based telescopes and satellite-borne telescopes in order to develop and defend a claim comparing their performances (DOK 3)	HS-PS4-1 Use mathematical representations to support a claim regarding relationships among the frequency, wavelength, and speed of waves traveling in various media. HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy RST.11-12.3 Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks; analyze the specific results based on explanations in the text. WHST.11-12.1.A Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.
attenuation critical angle decibel (dB) scale graded-index fibers material dispersion in optic fibers step-index fibers structure of optic fibers total internal reflection waveguide $n = \frac{1}{\sin c}$ $attenuation = \frac{10 \log I}{I_o}$	Solve problems involving critical angle and total internal reflection of fiber optics (DOK 2) Explain how waveguides and material dispersion can lead to attenuation (DOK 2) Use mathematical representations of fiber optics to solve problems which involve attenuation (DOK 2) Apply an understanding of wave behavior and wave interactions to develop a logical argument for the advantages of fiber optics over twisted pair and coaxial cables (DOK 3)	HS-PS4-5 Communicate technical information about how some technological devices use the principles of wave behavior and wave interactions with matter to transmit and capture information and energy.