Black Holes

Curriculum Connections

ALBERTA, NORTHWEST TERRITORIES, NUNAVUT—Physics 20 and Physics 30

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics Curriculum Connections (Physics 20 and Physics 30)
(2007, updated 2014)

Activity 1: Escape Speed and Black Holes

PHYSICS 20 UNIT B—DYNAMICS

Specific Learning Outcomes

20-B2.1k identify the gravitational forces as one of the fundamental forces in nature

20-B2.2k describe, qualitatively and quantitatively, Newton's law of universal gravitation

PHYSICS 20 UNIT C—CIRCULAR MOTION, WORK AND ENERGY

Specific Learning Outcomes

20-C2.1k define mechanical energy as the sum of kinetic and potential energy

20-C2.2k determine, quantitatively, the relationships among kinetic, gravitational potential and total mechanical energies of a mass at any point between maximum potential energy and maximum kinetic energy

20-C2.3k analyze, quantitatively, kinematics and dynamics problems that relate to the conservation of mechanical energy in an isolated system

Specific Outcomes for Skills (Nature of Science Emphasis)

Performing and Recording

20-B2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- explore the relationship between the local value of the acceleration due to gravity and the gravitational field strength

20-C2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*

- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *explore where further science- and technology-related studies and careers can be pursued*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the research contributions of both men and women*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.*,

- *provide the same attention and energy to the group's product as they would to a personal assignment*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*

Activity 2: General Relativity and Black Holes

Specific Outcomes for Skills (Nature of Science Emphasis)

Analyzing and Interpreting

20-A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- construct graphs to demonstrate the relationships among displacement, velocity, acceleration and time for uniform and uniformly accelerated motion

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *be interested in science and technology topics not directly related to their formal studies*
- *explore where further science- and technology-related studies and careers can be pursued*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the research contributions of both men and women*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*
- *seek new models, explanations and theories when confronted with discrepant events*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*

Activity 3: How Do You Make a Black Hole?

PHYSICS 20 UNIT B—DYNAMICS

Specific Learning Outcomes

20-B1.2k apply Newton's second law of motion to explain, qualitatively, the relationships among met force, mass and acceleration

20-B1.6k calculate the resultant force, or its constituents, acting on an object by adding vector components graphically and algebraically

20-B2.1k identify the gravitational forces as one of the fundamental forces in nature

20-B2.2k describe, qualitatively and quantitatively, Newton's law of universal gravitation

Specific Outcomes for Skills (Science and Technology Emphasis)

Analyzing and Interpreting

20-B1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- use free-body diagrams to describe the forces acting on an object

PHYSICS 30 UNIT B—FORCES AND FIELDS

Specific Learning Outcomes

30-B1.2k explain electrical interactions in terms of the repulsion and attraction of charges

30-B1.6k apply Coulomb's law, quantitatively, to analyze the interaction of two point charges

30-B1.8k compare, qualitatively and quantitatively, the inverse square relationship as it is expressed by Coulomb's law and by Newton's universal law of gravitation

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *be interested in science and technology topics not directly related to their formal studies*
- *explore where further science- and technology-related studies and careers can be pursued*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; e.g.,

- *recognize the research contributions of both men and women*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*

Activity 4: What's Making the X-rays in Cygnus?

PHYSICS 20 UNIT B—DYNAMICS

Specific Learning Outcomes

20-B2.2k describe, qualitatively and quantitatively, Newton's law of universal gravitation

PHYSICS 20 UNIT C—CIRCULAR MOTION, WORK AND ENERGY

Specific Learning Outcome

20-C1.4k explain, qualitatively, uniform circular motion in terms of Newton's laws of motion

20-C1.5k explain, quantitatively, planetary and natural and artificial satellite motion, using circular motion to approximate elliptical orbits

20-C1.6k predict the mass of a celestial body from the orbital data of a satellite in uniform circular motion around the celestial body

PHYSICS 20 UNIT D—OSCILLATORY MOTION AND MECHANICAL WAVES

Specific Learning Outcome

20-D2.9k explain, qualitatively and quantitatively, the Doppler effect on a stationary observer of a moving source

Specific Outcomes for Skills (Nature of Science Emphasis)

Analyzing and Interpreting

20-C2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

20-D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *explore where further science- and technology-related studies and careers can be pursued*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; e.g.,

- *recognize the research contributions of both men and women*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*

Activity 5: What Is at the Heart of the Milky Way Galaxy?

PHYSICS 20 UNIT C—CIRCULAR MOTION, WORK AND ENERGY

Specific Learning Outcome

20-C1.4k explain, qualitatively, uniform circular motion in terms of Newton's laws of motion

20-C1.5k explain, quantitatively, planetary and natural and artificial satellite motion, using circular motion to approximate elliptical orbits

20-C1.6k predict the mass of a celestial body from the orbital data of a satellite in uniform circular motion around the celestial body

20-C1.7k explain, qualitatively, how Kepler's laws were used in the development of Newton's law of universal gravitation

Specific Outcomes for Skills (Nature of Science Emphasis)

Analyzing and Interpreting

C1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- organize and interpret experimental data, using prepared graphs or charts

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *explore where further science- and technology-related studies and careers can be pursued*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the research contributions of both men and women*
- *research carefully and discuss openly ethical dilemmas associated with the applications of science and technology*
- *explore personal perspectives, attitudes and beliefs toward scientific and technological advancements*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *question arguments in which evidence, explanations or positions do not reflect the diversity of existing perspectives*
- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*

Activity 6: The Making of the Image of M87*

PHYSICS 20 UNIT D—OSCILLATORY MOTION AND MECHANICAL WAVES

Specific Learning Outcome

20-D2.9k explain, qualitatively and quantitatively, the Doppler effect on a stationary observer of a moving source

PHYSICS 30 UNIT A—MOMENTUM AND IMPULSE

Specific Learning Outcome

30-A1.4k explain, quantitatively, that momentum is conserved in one- and two-dimensional interactions in an isolated system

PHYSICS 30 UNIT C—ELECTROMAGNETIC RADIATION

Specific Learning Outcome

30-C2.6k explain, qualitatively and quantitatively, the Compton effect as another example of wave-particle duality, applying the laws of mechanics and of conservation of momentum and energy to photons

Specific Outcomes for Skills (Nature of Science Emphasis, Science and Technology Emphasis)

Performing and Recording

20-D2.2s conduct investigations into relationships among observable variables and use a broad range of tools and techniques to gather and record data and information

- draw wave-front and ray diagrams

Analyzing and Interpreting

30-A1.3s analyze data and apply mathematical and conceptual models to develop and assess possible solutions

- analyze, quantitatively, one- and two-dimensional interactions, using given data or by manipulating objects or computer simulations

Attitude Outcomes

Interest in Science

show interest in science-related questions and issues and confidently pursue personal interests and career possibilities within science-related fields; *e.g.,*

- *research the answers to questions they generate*
- *explore and use a variety of methods and resources to increase their knowledge and skills*
- *be critical and constructive when considering new theories and techniques*
- *recognize the usefulness of being skilled in mathematics and problem solving*
- *be interested in science and technology topics not directly related to their formal studies*
- *explore where further science- and technology-related studies and careers can be pursued*

Mutual Respect

appreciate that scientific understanding evolves from the interaction of ideas involving people with different views and backgrounds; *e.g.,*

- *recognize the research contributions of both men and women*

Scientific Inquiry

seek and apply evidence when evaluating alternative approaches to investigations, problems and issues; *e.g.,*

- *insist that the critical assumptions behind any line of reasoning be made explicit so that the validity of the position taken can be judged*
- *evaluate inferences and conclusions, being cognizant of the many variables involved in experimentation*
- *ask questions and conduct research to ensure understanding*
- *expend the effort and time needed to make valid inferences*
- *seek new models, explanations and theories when confronted with discrepant events*

Collaboration

work collaboratively in planning and carrying out investigations and in generating and evaluating ideas; *e.g.,*

- *provide the same attention and energy to the group's product as they would to a personal assignment*

Safety

show concern for safety in planning, carrying out and reviewing activities, referring to the Workplace Hazardous Materials Information System (WHMIS) and consumer product labelling information*; e.g.,*

- *manipulate materials carefully, being cognizant of the risks and consequences of their actions*
- *assume responsibility for the safety of all those who share a common working environment, by cleaning up after an activity and disposing of materials according to safety guidelines*

Black Holes

Curriculum Connections

BRITISH COLUMBIA AND YUKON—Physics 11 and 12

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

*Elaborations are not included in this chart.

Physics 11 and 12 Curriculum Connections
(2018)

Activity 1: Escape Speed and Black Holes

Curriculum Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Use appropriate SI units and appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Consider the changes in knowledge over time as tools and technologies have developed
- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Co-operatively design projects with local and/or global connections and applications
- Contribute to finding solutions to problems at a local and/or global level through inquiry
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon

PHYSICS 11—CONTENT

- **projectile motion**
- mass, force of gravity, and apparent weight
- conservation of energy; principle of work and energy

PHYSICS 12—CONTENT

- **gravitational field** and Newton's law of universal gravitation
- gravitational potential energy
- **gravitational dynamics and energy relationships**

Activity 2: General Relativity and Black Holes

Curriculum Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Collaboratively and individually plan, select, and use appropriate investigation methods, including field work and lab experiments, to collect reliable data (qualitative and quantitative)

Processing and analyzing data and information

- Experience and interpret the local environment
- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions
- Describe specific ways to improve their investigation methods and the quality of their data
- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Consider the changes in knowledge over time as tools and technologies have developed
- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

PHYSICS 11—CONTENT

- **projectile motion**
- **graphical methods** in physics

PHYSICS 12—CONTENT

- **relativistic effects** within a moving reference frame
- **graphical methods** in physics

Activity 3: How Do You Make a Black Hole?

Curriculum Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world

Processing and analyzing data and information

- Construct, analyze, and interpret graphs, models, and/or diagrams
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science
- Critically analyze the validity of information in primary and secondary sources and evaluate the approaches used to solve problems
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Contribute to care for self, others, community, and world through individual or collaborative approaches
- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

PHYSICS 11—CONTENT

- mass, force of gravity, and apparent weight

PHYSICS 12—CONTENT

- **gravitational field** and Newton's law of universal gravitation
- **gravitational dynamics and energy relationships**
- **electric field** and Coulomb's law

Activity 4: What's Making the X-rays in Cygnus?

Curriculum Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Use appropriate SI units and appropriate equipment, including digital technologies, to systematically and accurately collect and record data
- Apply the concepts of accuracy and precision to experimental procedures and data:
  - significant figures
  - scientific notation

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate their methods and experimental conditions, including identifying sources of error or uncertainty, confounding variables, and possible alternative explanations and conclusions
- Describe specific ways to improve their investigation methods and the quality of their data
- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Consider the changes in knowledge over time as tools and technologies have developed
- Connect scientific explorations to careers in science
- Assess risks in the context of personal safety and social responsibility

Applying and innovating

- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

PHYSICS 11—CONTENT

- mass, force of gravity, and apparent weight
- **properties and behaviours** of waves
- **characteristics** of sound
- **graphical methods** in physics

PHYSICS 12—CONTENT

- **gravitational field** and Newton's law of universal gravitation
- **graphical methods** in physics

Activity 5: What Is at the Heart of the Milky Way Galaxy?

Curriculum Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world

Processing and analyzing data and information

- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Connect scientific explorations to careers in science
- Consider social, ethical, and environmental implications of the findings from their own and others' investigations

Applying and innovating

- Contribute to finding solutions to problems at a local and/or global level through inquiry
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations
- Express and reflect on a variety of experiences, perspectives, and worldviews through **place**

PHYSICS 12—CONTENT

- **gravitational field** and Newton's law of universal gravitation
- **graphical methods** in physics

Activity 6: The Making of the Image of M87*

Curriculum Competencies

Questioning and predicting

- Demonstrate a sustained intellectual curiosity about a scientific topic or problem of personal, local, or global interest
- Make observations aimed at identifying their own questions, including increasingly abstract ones, about the natural world
- Formulate multiple hypotheses and predict multiple outcomes

Planning and conducting

- Use appropriate SI units and appropriate equipment, including digital technologies, to systematically and accurately collect and record data

Processing and analyzing data and information

- Seek and analyze patterns, trends, and connections in data, including describing relationships between variables, performing calculations, and identifying inconsistencies
- Construct, analyze, and interpret graphs, models, and/or diagrams
- Use knowledge of scientific concepts to draw conclusions that are consistent with evidence
- Analyze cause-and-effect relationships

Evaluating

- Evaluate the validity and limitations of a model or analogy in relation to the phenomenon modelled
- Demonstrate an awareness of assumptions, question information given, and identify bias in their own work and in primary and secondary sources
- Consider the changes in knowledge over time as tools and technologies have developed
- Connect scientific explorations to careers in science

Applying and innovating

- Implement multiple strategies to solve problems in real-life, applied, and conceptual situations
- Consider the role of scientists in innovation

Communicating

- Formulate physical or mental theoretical models to describe a phenomenon
- Communicate scientific ideas and information, and perhaps a suggested course of action, for a specific purpose and audience, constructing evidence-based arguments and using appropriate scientific language, conventions, and representations

PHYSICS 11—CONTENT

- **vector and scalar quantities**
- generation and **propagation of waves**

PHYSICS 12—CONTENT

- **impulse** and momentum
- conservation of momentum and energy in **collisions**

Black Holes

Curriculum Connections

MANITOBA—Senior 3 Physics (30S) and Senior 4 Physics (40S)

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Senior 3 and 4 Physics Curriculum Connections
(2005)

Activity 1: Escape Speed and Black Holes

PHYSICS 3

Skills and Attitudes Outcomes

S3P-0-2d Estimate and measure accurately, using Système International (SI) units.

S3P-0-2g Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

S3P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 2.1: Models, Laws, and Theories

Specific Learning Outcomes

S3P-2-02 Plan and perform an experiment to identify a linear pattern between two variables and state the pattern as a mathematical relationship (law).

S3P-2-04 Outline the tentative nature of scientific theories.

S3P2-05 Describe the characteristics of a good theory.

PHYSICS 4

Skills and Attitudes Outcomes

S4P-0-2d Estimate and measure accurately, using Système International (SI) units.

S4P-0-2g Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

S4P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S4P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 1.6: Work and Energy

Specific Learning Outcomes

S4P-1-33 Solve problems related to the conservation of energy.

Topic 2.1: Exploration of Space

S4P-2-4 State the gravitational potential energy as the area under the force-separation curve and solve problems using $E_{\mathrm{g}} = \frac{-Gm_1m_2}{r}$.

S4P-2-5 Solve problems for the escape velocity of a spacecraft.

Activity 2: General Relativity and Black Holes

PHYSICS 3

Skills and Attitudes Outcomes

S3P-0-1d Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

S3P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 2.1: Models, Laws, and Theories

Specific Learning Outcomes

S3P-2-04 Outline the tentative nature of scientific theories.

S3P-2-05 Describe the characteristics of a good theory.

Topic 3.1 Kinematics

Specific Learning Outcomes

S3P-3-04 Analyze the relationships among position, velocity, acceleration, and time for an object that is accelerating at a constant rate. Include: transformation of position-time, velocity-time, and acceleration-time graphs using slopes and areas

Activity 3: How Do You Make a Black Hole?

PHYSICS 4

Skills and Attitudes Outcomes

S4P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S4P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 1.2 Dynamics

Specific Learning Outcomes

S4P-1-4 Solve vector problems for objects in equilibrium.

Topic 2.1: Exploration of Space

Specific Learning Outcomes

S4P-2-3 Outline Newton's Law of Universal Gravitation and solve problems using $F_g = \frac{Gm_1m_2}{r^2}$.

Topic 2.3: Electric and Magnetic Fields

Specific Learning Outcomes

S4P-2-14 State Coulomb's Law and solve problems for more than one electric force acting on a charge.

Activity 4: What's Making the X-rays in Cygnus?

PHYSICS 3

Skills and Attitudes Outcomes

S3P-0-1d Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

S3P-0-3a Analyze, from a variety of perspectives, the risks and benefits to society and the environment when applying scientific knowledge or introducing technology.

S3P-0-3b Describe examples of how technology has evolved in response to scientific advances, and how scientific knowledge has evolved as a result of new innovations in technology.

S3P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S3P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 1.3: Sound

Specific Learning Outcomes

S3P-1-17 Investigate to analyze and explain how sounds are produced, transmitted, and detected, using examples from nature and technology.

S3P-1-24 Explain the Doppler effect, and predict in qualitative terms the frequency change that will occur for a stationary and a moving observer.

PHYSICS 4

Skills and Attitudes Outcomes

S4P-0-1d Describe how scientific knowledge changes as new evidence emerges and/or new ideas and interpretations are advanced.

S4P-0-3a Analyze, from a variety of perspectives, the risks and benefits to society and the environment when applying scientific knowledge or introducing technology.

S4P-0-3b Describe examples of how technology has evolved in response to scientific advances, and how scientific knowledge has evolved as a result of new innovations in technology.

S4P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S4P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 1.5: Circular Motion

Specific Learning Outcomes

S4P-1-19 Explain qualitatively why an object moving at constant speed in a circle is accelerating toward the centre of the circle.

S4P-1-23 Derive an equation for the constant speed and acceleration of an object moving in a circle ($\vec{v} = \frac{2\pi r}{T}, a = \frac{v^2}{R}$).

S4P-1-24 Solve problems for an object moving with a constant speed in a circle using $a = \frac{v^2}{R}, \vec{v} = \frac{2\pi r}{T}$, and $\vec{F}_{\text{net}} = m\vec{a}$.

Topic 2.1: Exploration of Space

Specific Learning Outcomes

S4P-2-3 Outline Newton's Law of Universal Gravitation and solve problems using $F_{\text{g}} = \frac{Gm_1m_2}{r^2}$.

Activity 5: What's at the Heart of the Milky Way Galaxy?

PHYSICS 4

Skills and Attitudes Outcomes

S4P-0-2g Interpret patterns and trends in data, and infer or calculate linear relationships among variables.

S4P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 1.5: Circular Motion

Specific Learning Outcomes

S4P-1-19 Explain qualitatively why an object moving at constant speed in a circle is accelerating toward the centre of the circle.

S4P-1-23 Derive an equation for the constant speed and acceleration of an object moving in a circle ($\vec{v} = \frac{2\pi r}{T}, a = \frac{v^2}{R}$).

S4P-1-24 Solve problems for an object moving with a constant speed in a circle using $a = \frac{v^2}{R}, \vec{v} = \frac{2\pi r}{T}$, and $\vec{F}_{\text{net}} = m\vec{a}$.

Topic 2.1: Exploration of Space

Specific Learning Outcomes

S4P2-2 Describe planetary motion using Kepler's three laws.

S4P-2-3 Outline Newton's Law of Universal Gravitation and solve problems using $F_{\text{g}} = \frac{Gm_1m_2}{r^2}$.

Activity 6: The Making of the Image of M87*

PHYSICS 4

Skills and Attitudes Outcomes

S4P-0-2h Analyze problems, using vectors. Include: adding and subtracting vectors in straight lines and at right angles, vector components.

S4P-0-3b Describe examples of how technology has evolved in response to scientific advances, and how scientific knowledge has evolved as a result of new innovations in technology.

S4P-0-4a Demonstrate work habits that ensure personal safety, the safety of others, and consideration of the environment.

S4P-0-4b Work cooperatively with a group to identify prior knowledge, initiate and exchange ideas, propose problems and their solutions, and carry out investigations.

Topic 1.3: Momentum

Specific Learning Outcomes

S4P-1-13 Solve problems using the impulse-momentum equation and the law of Conservation of Momentum.

Black Holes

Curriculum Connections

NEW BRUNSWICK—Physics 11 and Physics 12

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 11 and 12 Curriculum Connections
(2003)

Activity 1: Escape Speed and Black Holes

PHYSICS 11—WORK AND ENERGY

Skills

Initiating and Planning

212-8 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making

Performing and Recording

213-2 carry out procedures controlling the major variables and adapting or extending procedures where required

Analysing and Interpreting

214-5 interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables

Knowledge

326-1 analyse quantitatively the relationships among mass, height, speed, and heat energy using the law of conservation of energy

326-5 describe quantitatively mechanical energy as the sum of kinetic and potential energies

PHYSICS 12—PROJECTILES, CIRCULAR MOTION AND UNIVERSAL GRAVITATION

Knowledge

325-6 analyse quantitatively the horizontal and vertical motion of a projectile

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Activity 2: General Relativity and Black Holes

PHYSICS 11—KINEMATICS

Knowledge

325-2 analyse graphically and mathematically the relationship among displacement, velocity, and time

Activity 3: How Do You Make a Black Hole?

PHYSICS 11—DYNAMICS

STSE

Nature of Science and Technology

115-3 explain how a major scientific milestone revolutionized thinking in the scientific communities

Skills

Analysing and Interpreting

214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables

Knowledge

325-8 apply Newton's laws of motion to explain inertia, the relationship among force, mass, and acceleration and the interaction of forces between two objects

PHYSICS 12—PROJECTILES, CIRCULAR MOTION AND UNIVERSAL GRAVITATION

Knowledge

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

PHYSICS 12—FIELDS

Knowledge

328-4 compare Newton's universal law of gravitation and Coulomb's law, and apply both laws quantitatively

Activity 4: What's Making the X-rays in Cygnus?

PHYSICS 11—WAVES

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Skills

Analysing and Interpreting

214-8 evaluate the relevance, reliability, and adequacy of data and data collection methods

Knowledge

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

PHYSICS 12—PROJECTILES, CIRCULAR MOTION AND UNIVERSAL GRAVITATION

STSE

Relationship between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Skills

Analysing and Interpreting

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

214-14 construct and test a prototype of a device or system and troubleshoot problems as they arise

Communication and Teamwork

215-2 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

Knowledge

325-13 explain quantitatively circular motion, using Newton's laws

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Activity 5: What's at the Heart of the Milky Way Galaxy?

PHYSICS 12—PROJECTILES, CIRCULAR MOTION AND UNIVERSAL GRAVITATION

STSE

Relationship between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Nature of Science and Technology

115-5 distinguish between scientific questions and technological problems

Skills

Analysing and Interpreting

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

Communication and Teamwork

213-5 compile and organize data, using data tables and graphs, to facilitate interpretation of the data

Knowledge

325-13 explain quantitatively circular motion, using Newton's laws

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Activity 6: The Making of the Image of M87*

PHYSICS 11—WAVES

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Skills

Initiating and Planning

212-7 formulate operational definitions of major variables

Knowledge

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler effect

PHYSICS 12—DYNAMICS EXTENSION

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Skills

Communication and Teamwork

215-6 work cooperatively with team members to develop and carryout a plan, and troubleshoot problems as they arise

Knowledge

326-3 apply quantitatively the laws of conservation of momentum to one- and two-dimensional collisions and explosions

PHYSICS 12—PROJECTILES, CIRCULAR MOTION AND UNIVERSAL GRAVITATION

Knowledge

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Black Holes

Curriculum Connections

NEWFOUNDLAND AND LABRADOR—Physics 2204 and Physics 3204

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics Curriculum Connections (2204 and 3204)
(2018)

Activity 1: Escape Speed and Black Holes

PHYSICS 2204—WORK AND ENERGY

Skills

5.0 implement appropriate sampling procedures

12.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

Knowledge

45.0 analyze quantitatively the relationships among gravitational potential energy, kinetic energy and heat energy using the law of conservation of energy

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

PHYSICS 3204—MOTION

Skills

7.0 estimate quantities

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

Knowledge

24.0 analyze quantitatively the horizontal and vertical motion of a projectile

Attitudes

- show a continuing and more informed curiosity and interest in science and science-related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

PHYSICS 3204—FIELDS

Skills

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

Knowledge

33.0 apply Newton's universal law of gravitation quantitatively

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 2: General Relativity and Black Holes

PHYSICS 2204—KINEMATICS

Skills

7.0 use instruments effectively and accurately for collecting data

12.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

25.0 work cooperatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

Knowledge

28.0 analyze quantitatively the horizontal or vertical motion of an object

Attitudes

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 3: How Do You Make a Black Hole?

PHYSICS 2204—DYNAMICS

Skills

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

Knowledge

33.0 apply Newton's laws of motion to explain inertia, the relationship between force, mass, and acceleration, and the interaction of forces between two objects

Attitudes

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

PHYSICS 3204—FIELDS

Skills

15.0 explain how data support or refute the hypothesis or prediction

Knowledge

39.0 apply Coulomb's law quantitatively

Attitudes

- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 4: What's Making the X-rays in Cygnus?

PHYSICS 2204—WAVES

Skills

6.0 carry out procedures controlling the major variables and adapting or extending procedures where required

7.0 use instruments effectively and accurately for collecting data

8.0 compile and organize data, using appropriate formats and data treatments to facilitate interpretation of the data

12.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

Knowledge

63.0 describe the characteristics of longitudinal and transverse waves

65.0 describe how sound, as a form of energy, is produced and transmitted

69.0 compare and describe the properties of electromagnetic radiation and sound

70.0 explain qualitatively and quantitatively the Doppler-Fizeau effect

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

PHYSICS 3204—FORCES

Skills

5.0 evaluate and select appropriate instruments for collecting evidence and appropriate processes for problem solving, inquiring, and decision making

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

Knowledge

28.0 describe uniform circular motion, using algebraic and vector analysis

29.0 explain quantitatively circular motion using Newton's laws

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

PHYSICS 3204—FIELDS

Skills

6.0 develop appropriate sampling procedures

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

16.0 identify and correct practical problems in the way a technological device or system Functions

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

Knowledge

33.0 apply Newton's universal law of gravitation quantitatively

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Activity 5: What's at the Heart of the Milky Way Galaxy?

PHYSICS 3204—FORCES

Skills

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

Knowledge

28.0 describe uniform circular motion, using algebraic and vector analysis

29.0 explain quantitatively circular motion using Newton's laws

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science related issues

PHYSICS 3204—FIELDS

Skills

10.0 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

11.0 interpret patterns and trends in data, and infer or calculate linear and nonlinear relationships among variables

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

Knowledge

33.0 apply Newton's universal law of gravitation quantitatively

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- appreciate that the applications of science and technology can raise ethical dilemmas
- show a continuing and more informed curiosity and interest in science and science related issues

Activity 6: The Making of the Image of M87*

PHYSICS 2204—DYNAMICS

Knowledge

36.0 analyze and describe examples where technologies were developed based n scientific understanding

Attitudes

- value the process for drawing conclusions
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

PHYSICS 3204—MOTION

Knowledge

25.0 apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions

Attitudes

- show a continuing and more informed curiosity and interest in science and science-related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

PHYSICS 3204—FORCES

Skills

19.0 select and use appropriate numeric, symbolic, graphical, and linguistic modes of representation to communicate ideas, plans, and results

Knowledge

28.0 describe uniform circular motion, using algebraic and vector analysis

29.0 explain quantitatively circular motion using Newton's laws

Attitudes

- value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not
- show a continuing and more informed curiosity and interest in science and science related issues
- work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Black Holes

Curriculum Connections

NOVA SCOTIA—Physics 11 and 12

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Physics 11 and 12 Curriculum Connections
(2002)

Activity 1: Escape Speed and Black Holes

Physics 11—Kinematics

116-2 analyse and describe vertical motion using the principles of kinematics

Physics 11—Momentum and Energy

326-6 analyse quantitatively problems related to kinematics and dynamics using the mechanical energy concept

Physics 12—Force, Motion, Work, and Energy

325-6 analyse quantitatively the horizontal and vertical motion of a projectile

Physics 12—Fields

328-1 describe magnetic, electric, and gravitational fields as regions of space that affect mass and charge

328-2 describe magnetic, electric, and gravitational fields by illustrating the source and direction of the lines of force

Attitudes

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 2: General Relativity and Black Holes

Physics 11—Kinematics

325-5 use vectors to represent position, displacement, velocity, and acceleration

Physics 12—Fields

328-1 describe magnetic, electric, and gravitational fields as regions of space that affect mass and charge

328-2 describe magnetic, electric, and gravitational fields by illustrating the source and direction of the lines of force

Attitudes

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 3: How Do You Make a Black Hole?

Physics 11—Dynamics

325-8 apply Newton's laws of motion to explain inertia and the relationships among force, mass, and acceleration

214-8 interpret patterns and trends in data and infer or calculate linear and non-linear relationships among variables

116-2 analyse and describe examples where knowledge of the dynamics of bodies was enhanced or revised as a result of the invention of a technology

Physics 12—Force, Motion, Work, and Energy

ACP-1 use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques

213-5 compile and organize data, using data tables and graphs, to facilitate interpretation of the data

Physics 12—Fields

328-4 compare Newton's universal law of gravitation and Coulomb's law, and apply both laws quantitatively

Attitudes

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 4: What's Making the X-rays in Cygnus?

Physics 11—Waves

327-1 describe the production, characteristics, and behaviours of longitudinal and transverse mechanical waves

115-5 analyse why and how a particular technology was developed and improved over time

213-1, 214-8 implement appropriate sampling procedures and evaluate the relevance, reliability, and adequacy of data and data collection methods in wave experiments

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler-Fizeau effect

327-6 describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted

116-2 analyse and describe examples where scientific understanding was enhanced as a result of the invention of a technological device

Physics 12—Force, Motion, Work and Energy

327-2 explain qualitatively the relationship between displacement, velocity, time, and acceleration for simple harmonic motion

213-5 compile and organize data, using data tables and graphs, to facilitate interpretation of the data

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

215-2 explain and apply the law of universal gravitation to orbital notations by using appropriate numeric and graphic analysis

115-1 distinguish between scientific questions and technological problems as applied to orbital situations

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Activity 5: What's at the Heart of the Milky Way Galaxy?

Physics 12—Force, Motion, Work and Energy

213-5 compile and organize data, using data tables and graphs, to facilitate interpretation of the data

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

215-2 explain and apply the law of universal gravitation to orbital notations by using appropriate numeric and graphic analysis

115-1 distinguish between scientific questions and technological problems as applied to orbital situations

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Scientific Inquiry

443 use factual information and rational explanations when analysing and evaluating

Activity 6: The Making of the Image of M87*

Physics 11—Momentum and Energy

326-3 apply quantitatively the law of conservation of momentum to one-dimensional collisions and explosions

Physics 11—Waves

115-5 analyse why and how a particular technology was developed and improved over time

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection and refraction, and the Doppler-Fizeau effect

327-5 compare and describe the properties of electromagnetic radiation and sound

327-6 describe how sound and electromagnetic radiation, as forms of energy transfer, are produced and transmitted

116-2 analyse and describe examples where scientific understanding was enhanced as a result of the invention of a technological device

Physics 12—Force, Motion, Work, and Energy

326-3 apply quantitatively the laws of conservation of momentum to two-dimensional collisions and explosions

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

215-2 explain and apply the law of universal gravitation to orbital notations by using appropriate numeric and graphic analysis

115-1 distinguish between scientific questions and technological problems as applied to orbital situations

Physics 12— Waves and Modern Physics

115-3 explain how a photon momentum revolutionized thinking in the scientific community

327-11 summarize the evidence for the wave and particle models of light

Attitudes

Appreciation of Science

436 value the role and contribution of science and technology in our understanding of phenomena that are directly observable and those that are not

Scientific Inquiry

442 confidently evaluate evidence and consider alternative perspectives, ideas, and explanations

443 use factual information and rational explanations when analysing and evaluating

Collaboration

445 work collaboratively in planning and carrying out investigations, as well as in generating and evaluating ideas

Safety in Science

449 show concern for safety and accept the need for rules and regulations

450 be aware of the direct and indirect consequences of their actions

Black Holes

Curriculum Connections

ONTARIO—Grade 11 Physics, Grade 12 Physics, Grade 12 Science

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Grade 11 and 12 Curriculum Connections for Physics and Science (SPH3U, SPH4U, SNC4M)

(2008)

Activity 1: Escape Speed and Black Holes

PHYSICS GRADE 11 (SPH3U)

Scientific Investigation Skills and Career Exploration

A1.5 conduct inquires, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data.

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 11 (SPH3U)

Forces

C2.1 use appropriate terminology related to forces, including, but not limited to: *mass, time, speed, velocity, acceleration, friction, gravity, normal force,* and *free-body diagrams* [C]

C2.2 conduct an inquiry that applies Newton's laws to analyse, in qualitative and quantitative terms, the forces acting on an object, and use free-body diagrams to determine the net force and the acceleration of the object [PR, AI, C]

C3.4 describe, in qualitative and quantitative terms, the relationships between mass, gravitational field strength, and force of gravity

PHYSICS GRADE 12 (SPH4U)

Scientific Investigation Skills and Career Exploration

A1.5 conduct inquires, controlling relevant variables, adapting or extending procedures as required, and using appropriate materials and equipment safely, accurately, and effectively, to collect observations and data.

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 12 (SPH4U)

Energy and Momentum

C2.1 use appropriate terminology related to energy and momentum, including, but not limited to: *work, work-energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum-impulse theorem, elastic collision, and inelastic collision [C]*

C2.3 use an inquiry process to analyse, in qualitative and quantitative terms, situations involving work, gravitational potential energy, kinetic energy, thermal energy, and elastic potential energy, in one and two dimensions (e.g., a block sliding along an inclined plane with friction; a cart rising and falling on a roller coaster track; an object, such as a mass attached to a spring pendulum, that undergoes simple harmonic motion), and use the law of conservations of energy to solve related problems [PR, AI]

PHYSICS GRADE 12 (SPH4U)

Gravitational, Electric, and Magnetic Fields

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic field (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including but not limited to, differences between near-Earth and distance fields, parallel plates and point charges, straight line conductors and solenoids

Activity 2: General Relativity and Black Holes

PHYSICS GRADE 11 (SPH3U)

Scientific Investigation Skills and Career Exploration

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 11 (SPH3U)

Kinematics

B2.2 analyse and interpret position-time, velocity-time, and acceleration-time graphs of motion in one dimension (e.g., use tangent slopes to create velocity-time graphs from position-time graphs and acceleration-time graphs from velocity-time graphs; use the area under the curve to create position-time graphs from velocity-time graphs and velocity-time graphs from acceleration-time graphs) [AI, C]

PHYSICS GRADE 12 (SPH4U)

Scientific Investigation Skills and Career Exploration

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 12 (SPH4U)

Gravitational, Electric, and Magnetic Fields

D3.1 identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics)

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic field (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including but not limited to, differences between near-Earth and distance fields, parallel plates and point charges, straight line conductors and solenoids

Activity 3: How Do You Make a Black Hole?

PHYSICS GRADE 11 (SPH3U)

Scientific Investigation Skills and Career Exploration

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 11 (SPH3U)

Forces

C2.1 use appropriate terminology related to forces, including, but not limited to: *mass, time, speed, velocity, acceleration, friction, gravity, normal force,* and *free-body diagrams* [C]

C2.2 conduct an inquiry that applies Newton's laws to analyse, in qualitative and quantitative terms, the forces acting on an object, and use free-body diagrams to determine the net force and the acceleration of the object [PR, AI, C]

C2.4 analyse the relationships between acceleration and applied forces such as the force of gravity, normal force, force of friction, coefficient of static friction, and coefficient of kinetic friction and solve related problems involving forces in one dimension, using free-body diagrams and algebraic equations (e.g., use a drag sled to find the coefficient of friction between two surfaces) [AI,C]

C3.3 state Newton's laws, and apply them, in qualitative terms, to explain the effect of forces acting on objects

C3.4 describe, in qualitative and quantitative terms, the relationships between mass, gravitational field strength, and force of gravity

PHYSICS GRADE 12 (SPH4U)

Scientific Investigation Skills and Career Exploration

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 12 (SPH4U)

Dynamics

B2.4 predict, in qualitative and quantitative terms, the forces acting on systems of objects (e.g., masses in a vertical pulley system [a "dumb waiter"], a block sliding off an accelerating vehicle, masses in an inclined-plane pulley system), and plan and conduct an inquiry to test their predictions [IP, PR, AI]

PHYSICS GRADE 12 (SPH4U)

Gravitational, Electric, and Magnetic Fields

D2.2 analyse, and solve problems relating to Newton's law of universal gravitation and circular motion (e.g., with respect to satellite orbits, black holes, dark matter) [AI]

D3.1 identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics)

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic field (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including but not limited to, differences between near-Earth and distance fields, parallel plates and point charges, straight line conductors and solenoids

Activity 4: What's Making the X-rays in Cygnus?

PHYSICS GRADE 11 (SPH3U)

Scientific Investigation Skills and Career Exploration

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 11 (SPH3U)

Waves and Sound

E3.1 distinguish between longitudinal and transvers waves in different media, and provide examples of both types of waves

PHYSICS GRADE 12 (SPH4U)

Scientific Investigation Skills and Career Exploration

A1.6 compile accurate data from laboratory and other sources, and organize and record the data, using appropriate formats, including tables, flow charts, graphs, and/or diagrams

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 12 (SPH4U)

Energy and Momentum

C3.2 describe and explain the simple harmonic motion (SHM) of an object, and explain the relationship between SHM, Hooke's Law and uniform circular motion

PHYSICS GRADE 12 (SPH4U)

Gravitational, Electric, and Magnetic Fields

D3.1 identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics)

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic field (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including but not limited to, differences between near-Earth and distance fields, parallel plates and point charges, straight line conductors and solenoids

SCIENCE GRADE 12 (SNC4M)

Astronomy (Science of the Universe)

B3.1 use appropriate terminology related to astronomy, including, but not limited to: *Doppler effect, electromagnetic radiation, protostar, celestial equator, ecliptic, altitude and azimuth, and right ascension and declination [C]*

B2.3 analyse spectroscopic data mathematically or graphically to determine various properties of stars (e.g., determine surface temperature from peak wavelength using Wein's law; predict chemical composition from spectral absorption lines; determine motion using the Doppler effect) [AI, C]

B3.3 describe the characteristics of electromagnetic radiation (e.g., the relationship between wavelength, frequency, and energy) and the ways in which each region of the electromagnetic spectrum is used in making astronomical observations (e.g., X-rays in the search for black holes; infrared radiation to see through interstellar dust)

Activity 5: What's at the Heart of the Milky Way Galaxy?

PHYSICS GRADE 12 (SPH4U)

Scientific Investigation Skills and Career Exploration

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.11 communicate ideas, plans, procedures, results, and conclusions orally, in writing and/or in electronic presentations, using appropriate language and a variety of formats (e.g., data tables, laboratory reports, presentations, debates, simulations, models)

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 12 (SPH4U)

Dynamics

B2.1 use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction and kinetic friction [C]*

B3.3 explain the derivation of equations for uniform circular motion that involve the variables frequency, period, radius, speed, and mass

PHYSICS GRADE 12 (SPH4U)

Gravitational, Electric, and Magnetic Fields

D2.2 analyse, and solve problems relating to Newton's law of universal gravitation and circular motion (e.g., with respect to satellite orbits, black holes, dark matter) [AI]

D3.1 identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics)

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic field (e.g., the strength of each field; t-he relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including but not limited to, differences between near-Earth and distance fields, parallel plates and point charges, straight line conductors and solenoids

Activity 6: The Making of the Image of M87*

PHYSICS GRADE 12 (SPH4U)

Scientific Investigation Skills and Career Exploration

A1.8 synthesize, analyse, interpret, and evaluate qualitative and/or quantitative data; solve problems involving quantitative data; determine whether the evidence supports or refutes the initial prediction or hypothesis and whether it is consistent with scientific theory; identify sources of bias and/or error; and suggest improvements to the inquiry to reduce the likelihood of error

A1.13 express the results of any calculations involving data accurately and precisely, to the appropriate number of decimal places or significant figures

A2.2 describe the contributions of scientists, including Canadians to the fields under study

PHYSICS GRADE 12 (SPH4U)

Dynamics

B2.1 use appropriate terminology related to dynamics, including, but not limited to: *inertial and non-inertial frames of reference, components, centripetal, period, frequency, static friction and kinetic friction* [C]

B2.2 solve problems related to motion, including projectile and relative motion, by adding and subtracting two-dimensional vector quantities, using vector diagrams, vector components, and algebraic methods [PR, AI, C]

B3.3 explain the derivation of equations for uniform circular motion that involve the variables frequency, period, radius, speed, and mass

PHYSICS GRADE 12 (SPH4U)

Energy and Momentum

C2.1 use appropriate terminology related to energy and momentum, including, but not limited to: *work, work-energy theorem, kinetic energy, gravitational potential energy, elastic potential energy, thermal energy, impulse, change in momentum-impulse theorem, elastic collision, and inelastic collision* [C]

C2.5 analyse, in qualitative and quantitative terms, the relationships between mass, velocity, kinetic energy, momentum, and impulse for a system of objects moving in one and two dimensions (e.g., an off-centre collision of two masses on an air table, two cars recoiling from opposite ends of a released spring), and solve problems involving these concepts [PR, AI]

PHYSICS GRADE 12 (SPH4U)

Gravitational, Electric, and Magnetic Fields

D3.1 identify, and compare the properties of, fundamental forces that are associated with different theories and models of physics (e.g., the theory of general relativity and the standard model of particle physics)

D3.2 compare and contrast the corresponding properties of gravitational, electric, and magnetic field (e.g., the strength of each field; the relationship between charge in electric fields and mass in gravitational fields)

D3.3 use field diagrams to explain differences in the sources and directions of fields, including but not limited to, differences between near-Earth and distance fields, parallel plates and point charges, straight line conductors and solenoids

PHYSICS GRADE 12 (SPH4U)

The Wave Nature of Light

E3.2 describe and explain the diffraction, refraction, polarization, and interference of light waves (e.g., reduced resolution caused by diffraction, mirages caused by refraction, polarization caused by reflection and filters, thein-film interference in soap films and air wedges ,interference of light on CDs)

Black Holes

Curriculum Connections

PRINCE EDWARD ISLAND—Physics 521A and 621A

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 521A and 621A Curriculum Connections
(2009 and 2010)

Activity 1: Escape Speed and Black Holes

PHYSICS 521A—MOMENTUM AND ENERGY

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Skills

Initiating and Planning

212-3 design an experiment, identifying and controlling major variables

Performing and Recording

213-2 carry out procedures, controlling the major variables and adapting or extending procedures where required

Analysing and Interpreting

214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables

Communication and Teamwork

215-6 work co-operatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

Knowledge

326-1 analyse quantitatively the relationships among mass, height, speed, and heat energy using the law of conservation of energy

326-5 describe quantitatively mechanical energy as the sum of kinetic and potential energies

PHYSICS 621A—APPLICATION OF VECTORS

Knowledge

325-6 analyse quantitatively the horizontal and vertical motion of a projectile

Activity 2: General Relativity and Black Holes

PHYSICS 521A—KINEMATICS

Skills

Communication and Teamwork

215-6 work co-operatively with team members to develop and carry out a plan, and troubleshoot problems as they arise

Knowledge

325-2 analyse graphically and mathematically the relationships among displacement, velocity, and time

Activity 3: How Do You Make a Black Hole?

PHYSICS 521A—DYNAMICS

Knowledge

325-8 apply Newton's laws of motion to explain inertia; the relationship among force, mass, and acceleration; and the interaction of forces between two objects

PHYSICS 621A—ELECTRICITY AND MAGNETISM

STSE

Nature of Science and Technology

115-3 explain how a major scientific milestone revolutionized thinking in the scientific communities

Knowledge

308-14 identify properties of static electric charges

328-2 describe gravitational, electric, and magnetic fields by illustrating the source and direction of the lines of force

328-4 compare Newton's universal law of gravitation with Coulomb's law, and apply both laws quantitatively

Activity 4: What's Making the X-rays in Cygnus?

PHYSICS 521A—WAVES

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

Skills

Initiating and Planning

212-4 state a prediction and a hypothesis based on available evidence and background information

Knowledge

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

PHYSICS 621A—CIRCULAR AND PLANETARY MOTION

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Skills

Performing and Recording

213-2 carry out procedures, controlling the major variables and adapting or extending procedures where required

213-3 use instruments effectively and accurately for collecting data

213-5 compile and organize data, using data tables and graphs to facilitate interpretation of the data

Analysing and Interpreting

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables

Knowledge

325-13 explain quantitatively circular motion, using Newton's laws

327-3 explain qualitatively the relationship among displacement, velocity, time, and acceleration for simple harmonic motion

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Activity 5: What's at the Heart of the Milky Way Galaxy?

PHYSICS 621A—CIRCULAR AND PLANETARY MOTION

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Skills

Analysing and Interpreting

214-3 compile and display evidence and information, by hand or computer, in a variety of formats, including diagrams, flow charts, tables, graphs, and scatter plots

214-5 interpret patterns and trends in data, and infer or calculate linear and non-linear relationships among variables

Knowledge

325-13 explain quantitatively circular motion, using Newton's laws

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Activity 6: The Making of the Image of M87*

PHYSICS 521A—WAVES

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-2 analyse and describe examples where scientific understanding was enhanced or revised as a result of the invention of a technology

116-7 analyse natural and technological systems to interpret and explain their structure and dynamics

Skills

Initiating and Planning

212-4 state a prediction and a hypothesis based on available evidence and background information

Knowledge

327-8 explain qualitatively and quantitatively the phenomena of wave interference, diffraction, reflection, and refraction, and the Doppler-Fizeau effect

327-6 describe how sound and electromagnetic radiation, as forms of energy, are produced and transmitted

PHYSICS 621A—APPLICATION OF VECTORS

Knowledge

ACP-1 use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques

PHYSICS 621A—CIRCULAR AND PLANETARY MOTION

STSE

Nature of Science and Technology

115-5 analyse why and how a particular technology was developed and improved over time

Relationships between Science and Technology

116-4 analyse and describe examples where technologies were developed based on scientific understanding

Knowledge

325-13 explain quantitatively circular motion, using Newton's laws

ACP-2 explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law

Black Holes

Curriculum Connections

SASKATCHEWAN—Physics 30

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

Physics 30 Curriculum Connections
(2016)

Activity 1: Escape Speed and Black Holes

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

b. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

Force and Motion

PH30-FM1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motion. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Conservation Laws

PH30-CO1 Investigate the nature of mechanical energy and efficiency in mechanical systems in relation to the law of conservation of energy. [SI]

e. Explain the law of conservation of energy in terms of isolated and non-isolated systems and conservation of mechanical energy. (STSE, K)

f. Solve problems related to kinetic, potential and total mechanical energy using relevant equations (e.g., $W = \vec{F} \cdot \vec{d}\cos\theta$, $W = \Delta E$, $E_{\mathrm{k}} = \frac{m\vec{v}^2}{2}$, $E_{\mathrm{p}} = m\vec{g}\vec{h}$, and $TME = E_{\mathrm{k}} + E_{\mathrm{p}}$). (K, S)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

Foundation 4: Attitudes

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Activity 2: General Relativity and Black Holes

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

b. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

c. Distinguish between the theories of general and special relativity with respect to space and time (e.g., curvature of space-time, time dilation, length contraction and relativistic mass). (K, STSE)

Force and Motion

PH30-FM1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motion. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

c. Explore phenomena such as gravitational lensing, dark matter, universal expansion and contraction and time dilation as they relate to gravitational fields within the universe. (K, STSE)

Foundation 4: Attitudes

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

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Activity 3: How Do You Make a Black Hole?

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

b. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

Force and Motion

PH30-FM1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motion. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

b. Provide examples of how Newton's three laws of motion can describe the movement of objects in the real world. (STSE, K)

e. Solve problems involving force, mass and acceleration, using free-body diagrams and Newton's second law of motion ($\vec{F} = m\vec{a}$). (K, S)

g. Predict and investigate the effect of balanced or unbalanced forces, including the effect of friction, on an object that is at rest, undergoing uniform motion or undergoing uniformly accelerated motion. (K, S)

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

c. Explore phenomena such as gravitational lensing, dark matter, universal expansion and contraction and time dilation as they relate to gravitational fields within the universe. (K, STSE)

PH30-FI2 Investigate electric and magnetic fields and their interactions with matter. [SI, TPS]

d. Solve problems related to Coulomb's law ($F = k\frac{q_1 q_2}{r^2}$), including electrostatic equilibrium in one- and two-dimensions. (K, S)

Foundation 4: Attitudes

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Activity 4: What's Making the X-rays in Cygnus?

Properties of Waves

PS20-PW1 Investigate the properties and characteristics of one-, two- and three-dimensional waves in at least three different media (e.g., springs, ropes, air and water). [SI]

c. Recognize that scientists understand waves as the transmission of energy originating from a vibrating source that determines the frequency and amplitude of the wave. (K)

f. Identify characteristics of transverse and longitudinal waves including crests (positive pulse), troughs (negative pulse), compressions, rarefactions and the relationship between direction of vibration and energy transfer. (K)

l. Provide examples of application of the properties and characteristics of waves or electromagnetic radiation in various technologies (e.g., ultrasound, sonar, Doppler Effect, sonic booms, satellite dishes, microwaves, mobile phones, wireless routers, Bluetooth, radio waves, X-rays, radar and remote controls). (STSE, K)

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

b. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

e. Explore the impact of scientific understanding of relativity on the development of technologies such as the Global Positioning System, atomic clocks and communication systems. (K, S, STSE)

Force and Motion

PH30-FM1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motion. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

i. Describe the orbits (e.g., geosynchronous, elliptical and/or circular) of satellites and celestial bodies using uniform circular motion concepts. (K, STSE)

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

i. Solve problems involving gravitational field strength using $g = \frac{Gm}{r^2}$ and Newton's law of universal gravitation ($F = \frac{Gm_1m_2}{r^2}$). (K, S)

Foundation 4: Attitudes

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Activity 5: What's at the Heart of the Milky Way Galaxy?

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

b. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

e. Explore the impact of scientific understanding of relativity on the development of technologies such as the Global Positioning System, atomic clocks and communication systems. (K, S, STSE)

i. Describe the orbits (e.g., geosynchronous, elliptical and/or circular) of satellites and celestial bodies using uniform circular motion concepts. (K, STSE)

Force and Motion

PH30-FM1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motion. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

i. Solve problems involving gravitational field strength using $g = \frac{Gm}{r^2}$ and Newton's law of universal gravitation ($F = \frac{Gm_1m_2}{r^2}$). (K, S)

Foundation 4: Attitudes

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Activity 6: The Making of the Image of M87*

Modern Physics

PH30-MP1 Analyze the importance of relativistic principles and quantum mechanics in our world. [SI, DM]

b. Differentiate how Newtonian mechanics, quantum mechanics, relativity and emerging theories describe the universe on different scales. (K, STSE)

e. Explore the impact of scientific understanding of relativity on the development of technologies such as the Global Positioning System, atomic clocks and communication systems. (K, S, STSE)

Force and Motion

PH30-FM1 Analyze motion in one- and two-dimensions, including uniform motion, uniformly accelerated motion, circular motion and projectile motion. [SI]

a. Provide examples of situations in which everyday objects undergo uniform motion, uniformly accelerated motion, circular motion and projectile motion. (STSE)

i. Describe the orbits (e.g., geosynchronous, elliptical and/or circular) of satellites and celestial bodies using uniform circular motion concepts. (K, STSE)

PH30-FM2 Analyze the effects of forces on objects undergoing uniform motion, uniformly accelerated motion and circular motion. [SI]

i. Explore the limitations of Newton's laws of motion in relativistic and quantum situations (e.g., objects moving at or near the speed of light and subatomic particles). (K, STSE)

Conservation Laws

PH30-CO2 Analyze the motion of objects and interactions between objects using momentum concepts, including the law of conservation of momentum. [SI]

d. Provide examples that show how momentum is or is not conserved in everyday situations. (K)

f. Solve problems using the law of conservation of momentum in one- and two-dimensional interactions (e.g., head-on collisions, glancing collisions, rocket launches and explosions). (K, S)

Fields

PH30-FI1 Investigate gravitational fields and their interactions with matter. [SI, DM]

b. Describe the characteristics of the gravitational force and its effect on large-scale phenomena throughout the universe. (K, STSE)

i. Solve problems involving gravitational field strength using $g = \frac{Gm}{r^2}$ and Newton's law of universal gravitation ($F = \frac{Gm_1m_2}{r^2}$). (K, S)

Foundation 4: Attitudes

Interest in Science

Students will be encouraged to develop curiosity and continuing interest in the study of science at home, in school and in the community.

Inquiry in Science

Students will be encouraged to develop critical beliefs concerning the need for evidence and reasoned argument in the development of scientific knowledge.

Collaboration

Students will be encouraged to nurture competence in collaborative activity with classmates and others, inside and outside of the school.

Safety

Students engaged in science and technology activities will be expected to demonstrate a concern for safety and doing no harm to themselves or others, including plants and animals.

Black Holes

Curriculum Connections

Next Generation Science Standards (NGSS): Grades 9–12

Note: These curriculum connections are meant to be a quick reference guide only. If you have any suggestions for additional curriculum connections, or if you are aware of changes in your curriculum, please contact outreach@perimeterinstitute.ca.

* The performance expectations marked with an asterisk integrate traditional science content with engineering through a Practice or Disciplinary Core Idea.

Physics Curriculum Connections
(April 2013)

Activity 1: Escape Speed and Black Holes

Forces and Interactions

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. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

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. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

Activity 2: General Relativity and Black Holes

Forces and Interactions

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. [Clarification Statement: Examples of data could include tables or graphs of position or velocity as a function of time for objects subject to a net unbalanced force, such as a falling object, an object sliding down a ramp, or a moving object being pulled by a constant force.] [Assessment Boundary: Assessment is limited to one-dimensional motion and to macroscopic objects moving at non-relativistic speeds.]

Activity 3: How Do You Make a Black Hole?

Forces and Interactions

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. [Clarification Statement: Emphasis is on both quantitative and conceptual descriptions of gravitational and electric fields.] [Assessment Boundary: Assessment is limited to systems with two objects.]

Energy

HS-PS3-5. 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. [Clarification Statement: Examples of models could include drawings, diagrams, and texts, such as drawings of what happens when two charges of opposite polarity are near each other.] [Assessment Boundary: Assessment is limited to investigations based on materials and tools provided to students.]

Activity 4: What's Making the X-rays in Cygnus?

Space Systems

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

Activity 5: What's at the Heart of the Milky Way Galaxy?

Space Systems

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary : Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

Engineering Design

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.

Activity 6: The Making of the Image of M87*

Forces and Interactions

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. [Clarification Statement: Emphasis is on the quantitative conservation of momentum in interactions and the qualitative meaning of this principle.] [Assessment Boundary: Assessment is limited to systems of two macroscopic bodies moving in one dimension.]

Waves and Electromagnetic Radiation

HS-PS4-3. Evaluate the claims, evidence, and reasoning behind the idea that electromagnetic radiation can be described either by a wave model or a particle model, and that for some situations one model is more useful than the other. [Clarification Statement: Emphasis is on how the experimental evidence supports the claim and how a theory is generally modified in light of new evidence. Examples of a phenomenon could include resonance, interference, diffraction, and photoelectric effect.] [Assessment Boundary: Assessment does not include using quantum theory.]

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.*

[Clarification Statement: Examples could include solar cells capturing light and converting it to electricity ; medical imaging; and communications technology .] [Assessment Boundary: Assessments are limited to qualitative information. Assessments do not include band theory.]

Space Systems

HS-ESS1-4. Use mathematical or computational representations to predict the motion of orbiting objects in the solar system. [Clarification Statement: Emphasis is on Newtonian gravitational laws governing orbital motions, which apply to human-made satellites as well as planets and moons.] [Assessment Boundary: Mathematical representations for the gravitational attraction of bodies and Kepler's Laws of orbital motions should not deal with more than two bodies, nor involve calculus.]

Engineering Design

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.