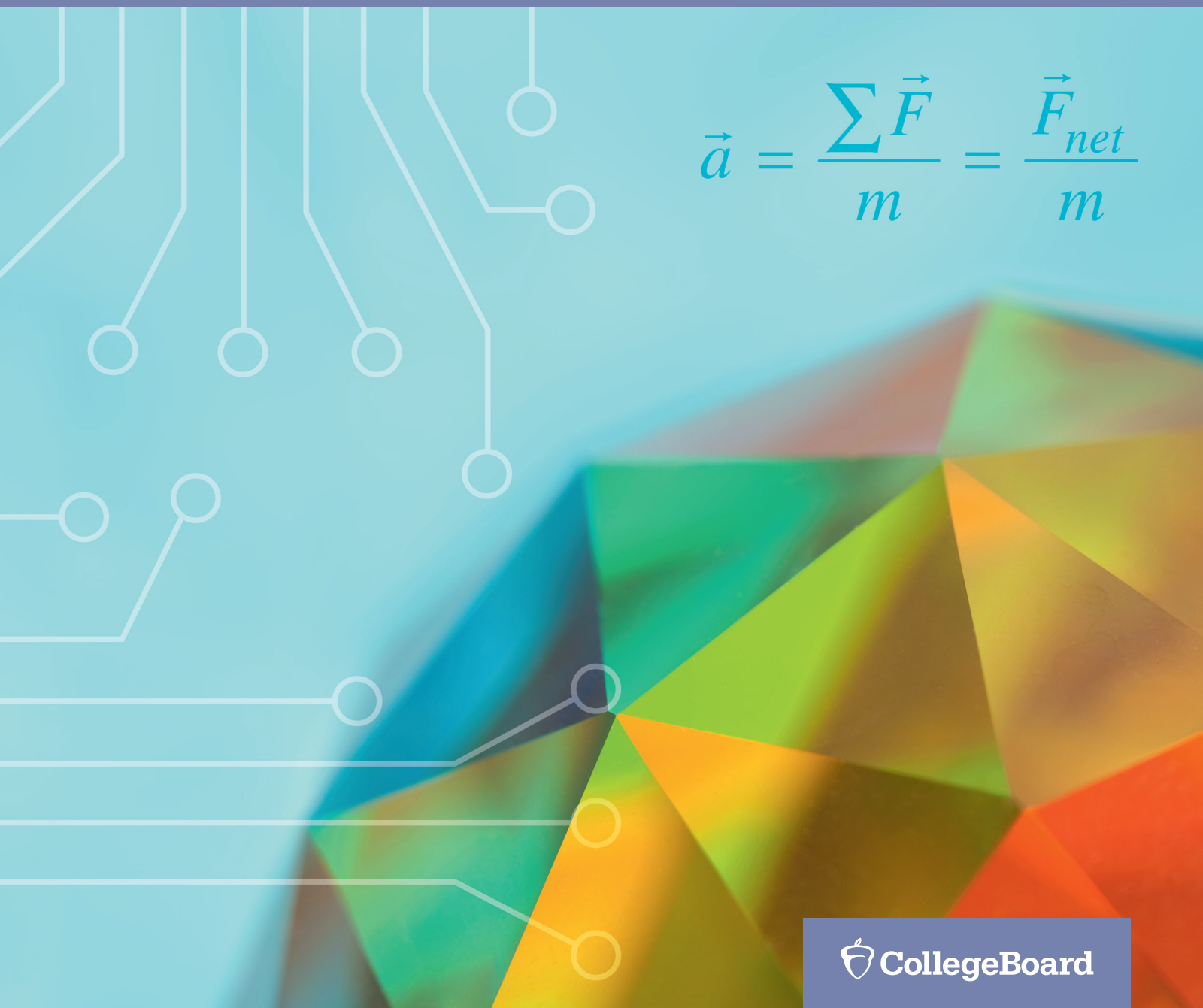
AP® Physics 1 and 2 Inquiry-Based Lab Investigations

Teacher's Manual

Effective Fall 2021



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Appendix B:
Rubrics for Science Practices in AP Physics 1 and 2 Investigations

Science Practice 1.1. The student can *create representations and models* of natural or man-made phenomena and systems in the domain.

Proficient	Creates accurate and appropriate representations/models to represent novel phenomena. The models account for the most important features of the phenomena and are experimentally testable, and limitations of the models (or inherent assumptions) are clearly explained.
Nearly Proficient	Creates accurate and appropriate representations/models to represent familiar phenomena. The models account for the most important features of the phenomena and are experimentally testable, but the limitations and assumptions are not explained.
On the Path to Proficiency	Creates representations/models that generally represent familiar phenomena. The models may not fully reflect all aspects of phenomena. The models are not experimentally testable (either involve some artificial explanations or the experiments are difficult to perform).
An Attempt	Creates flawed or incomplete representations/models to represent familiar phenomena.

Science Practice 1.2. The student can *describe representations and models* of natural or man-made phenomena and systems in the domain.

Proficient	Accurately articulates most links among representations/models and the natural phenomena or mechanisms they represent. Uses accurate language and definitions in descriptions associated with elements of the models/representations. Addresses relevancy of the description to the goal of the representation/model. Extracts all relevant information from the representations/models.
Nearly Proficient	Accurately articulates some links among representations/models and the natural phenomena or mechanisms they represent. Uses accurate language and/or definitions in descriptions associated with elements of the representations/models. Extracts relevant information from the representations/models.
On the Path to Proficiency	Accurately articulates a few links among representations/models and the natural phenomena or mechanisms they represent. Includes some inaccuracies in language and definitions within descriptions associated with elements of the representations/models.
An Attempt	Includes errors when articulating links among representations/models and the natural phenomena or mechanisms they represent. Uses generally inaccurate language and definitions within descriptions associated with elements of the representations/models.

Science Practice 1.3. The student can *refine representations and models* of natural or man-made phenomena and systems in the domain.

Proficient	Effectively refines representations/models of phenomena, using accurate and precise definitions and language. Comprehensively identifies deficiencies of given representations/models and explains how the revised representations/models address these deficiencies.
Nearly Proficient	Correctly refines, with occasional or minor errors on complex problems, representations/models of phenomena, using accurate definitions and language. Accurately identifies nearly all deficiencies of given representations/models and explains how the revised representations/models address these deficiencies.
On the Path to Proficiency	Refines representations/models of phenomena with some errors and inaccuracies in definitions and language.
An Attempt	Makes significant errors in refining representations/models of phenomena. Uses incomplete definitions and/or language.

Science Practice 1.4. The student can *use representations and models* to analyze situations or solve problems qualitatively and quantitatively.

Proficient	Accurately uses representations and models to analyze situations or solve complex problems qualitatively and quantitatively without any errors. May manipulate a representation/model as an alternative to manipulation of equations and/or numerical data.
Nearly Proficient	Accurately uses representations and models to analyze situations or solve complex problems qualitatively and quantitatively with occasional or minor errors in analysis or problem solving.
On the Path to Proficiency	Uses representations and models to analyze situations or solve problems qualitatively and quantitatively, but with some significant errors and inaccuracies, either in analysis or problem solving.
An Attempt	Uses representations and models to analyze situations or solve problems qualitatively and quantitatively, but analysis and/or problem solving strategies contain multiple inaccuracies and errors.

Science Practice 1.5. The student can *re-express key elements of natural phenomena across multiple representations* in the domain.

Proficient	Re-expresses key elements of natural phenomena across multiple representations in the domain, and appropriately links elements of one representation with another familiar representation without any errors. The representations address different (but important) aspects of the phenomenon.
Nearly Proficient	Re-expresses key elements of natural phenomena across multiple representations in the domain, and links elements of one representation with another familiar representation with occasional or minor errors.
On the Path to Proficiency	Re-expresses key elements of natural phenomena across multiple representations in the domain, and links elements of one representation with another familiar representation with some significant errors and inaccuracies.
An Attempt	Re-expresses a very limited number of elements of natural phenomena across multiple representations in the domain with many errors and inaccuracies.

Science Practice 2.1. The student *can justify the selection of a mathematical routine* to solve problems.

Proficient	Provides relevant and detailed justification for the selection of mathematical routines. Uses accurate and precise language and terminology.
Nearly Proficient	Provides relevant justification for the selection of mathematical routines, but precise detail is lacking. Uses accurate language and terminology.
On the Path to Proficiency	Provides justification for the selection of mathematical routines that lacks some evidence, reasoning, and/or key factors. Uses language and terminology that includes a few errors and inaccuracies.
An Attempt	Provides justification for the selection of mathematical routines that may bear little relevance to the routines. Uses language and terminology with major errors and inaccuracies.

Science Practice 2.2. The student can *apply mathematical routines* to quantities that describe natural phenomena.

Proficient	Appropriately and accurately selects and applies mathematical routines in new contexts and in simple to complex problems.
Nearly Proficient	Selects and applies appropriate mathematical routines in new contexts but with occasional minor errors on complex problems.
On the Path to Proficiency	Selects and applies appropriate mathematical routines in new contexts but with some inconsistency and/or errors.
An Attempt	Selects and applies mathematical routines, but the selections are inappropriate or the applications contain major errors.

Science Practice 2.3. The student can *estimate numerically quantities* that describe natural phenomena.

Proficient	Correctly estimates quantities that describe phenomena through the use of appropriate mathematical routines on complex problems.
Nearly Proficient	Estimates quantities that describe phenomena through the use of appropriate mathematical routines; the estimates contain occasional minor errors on complex problems.
On the Path to Proficiency	Estimates quantities that describe phenomena through the use of appropriate mathematical routines on familiar and/or simple problems.
An Attempt	Estimates quantities that describe phenomena through the use of mathematical routines; the estimates contain some errors or are not always relevant to the description.

Science Practice 3.1. The student can *pose scientific questions.*

Proficient	Poses scientific questions using precise language and terminology. Links the questions to existing knowledge and purpose with clarity and detail. Poses scientific questions which extend thinking about a concept, relationships between concepts, causal mechanism, and/or phenomena.
Nearly Proficient	Poses scientific questions using appropriate language and terminology with occasional minor errors. Links the questions to existing knowledge and purpose.
On the Path to Proficiency	Poses scientific questions using appropriate language and terminology with some inconsistency, errors, and/or inaccuracies. Identifies essential aspects of the phenomenon being queried.
An Attempt	Poses scientific questions using incorrect or imprecise language and terminology, resulting in a lack of clarity in linking a question to its purpose. Incorrectly identifies many of the aspects of the phenomena being queried.

Science Practice 3.2. The student can *refine scientific questions.*

Proficient	Removes ambiguity, fully clarifies, and/or limits focus in refining scientific questions. Provides appropriate justification for refining questions, including appropriate reasoning and evidence.
Nearly Proficient	Removes ambiguity and/or clarifies focus in refining scientific questions. Provides justification for refining the question, and justification includes some reasoning and/or evidence.
On the Path to Proficiency	Reduces ambiguity and/or improves focus in refining scientific questions. Provides simple justification for refining questions; however, justification lacks reasoning and use of complete evidence.
An Attempt	Modifies scientific questions but with little positive effect in removing ambiguity or clarifying focus. Provides some justification for refining questions; however, justification lacks reasoning and/or evidence and includes major inaccuracies.

Science Practice 3.3. The student can *evaluate scientific questions.*

Proficient	Identifies evaluation criteria, explains the relevance of selected evaluation criteria, and evaluates, with convincing justification, scientific questions for inclusion in the scope of an investigation and domain.
Nearly Proficient	Identifies basic evaluation criteria, explains the relevance of the selected criteria with only a few errors, and evaluates and justifies scientific questions for inclusion in the scope of an investigation using some evidence and/or appropriate reasoning.
On the Path to Proficiency	Evaluates scientific questions for inclusion in the scope of either an investigation or domain, but justification is unclear. May use incomplete and/or inaccurate evidence and/or faulty reasoning.
An Attempt	Provides an evaluation of scientific questions that lacks justification for inclusion of the scientific questions in the scope of an investigation or domain, and the evaluation includes inaccuracies.

Science Practice 4.1. The student can *justify the selection of the kind of data* needed to answer a particular scientific question.

Proficient	Provides accurate and detailed justification for data selection, explaining relevance of the selected variables and the data.
Nearly Proficient	Provides accurate justification for data selection with only an occasional or minor error.
On the Path to Proficiency	Provides justification for data selection with occasional and/or minor errors; justification may be correct but lacks completeness and/or reference to relevance.
An Attempt	Provides generally weak justification for data selection; justification includes minimal reasoning and evidence.

Science Practice 4.2. The student can *design a plan* for collecting data to answer a particular scientific question.

Proficient	Designs an effective data collection plan to answer a particular scientific question via well-selected qualitative and quantitative measures, providing rationale for all choices. Accurately evaluates and explains sources of error. Effectively explains tool selection for acquiring data and conditions for their use. Accurately identifies and explains independent, dependent, and controlling variables, and justifies choices.
Nearly Proficient	Designs an appropriate data collection plan to answer a particular scientific question via qualitative and/or quantitative measures; measures may lack complete details. Identifies the selected observation schedule, units of measurement, and tools. Identifies appropriate data sources and sources of error. Accurately identifies and describes independent, dependent, and controlling variables.
On the Path to Proficiency	Designs a data collection plan to answer a particular scientific question via qualitative or quantitative measures; measures may not be clearly defined or articulated. Acknowledges need to consider sources of error. Accurately identifies independent, dependent, and controlling variables with few errors and/or misuse of language or scientific terminology.
An Attempt	Presents an incomplete data collection plan to answer a particular scientific question; includes appropriate data sources but makes insufficient distinction between qualitative and quantitative measures. Makes errors in identifying the variables (independent, dependent, and controlling), and/or misuses language or scientific terminology.

Science Practice 4.3. The student can *collect data* to answer a particular scientific question.

Proficient	Collects appropriate data to fully answer a particular scientific question with precision of observations, accuracy of records, and accurate use of scientific tools and conditions. Accurately applies mathematical routines, and appropriately uses measurement strategies for the question and data sources.
Nearly Proficient	Collects appropriate and adequate data to answer some aspects of a particular scientific question with only minor errors in the precision of observation, record keeping, and use of tools and conditions. Selects appropriate mathematical routines, and provides measurements with only a few minor errors.
On the Path to Proficiency	Collects appropriate data to answer a particular scientific question. Provides observation logs and record keeping that contain several errors; however, the use of tools and conditions is adequate and appropriate for the most part. Selects appropriate mathematical routines and provides measurements with a few errors or a significant error.
An Attempt	Collects relevant but significantly inadequate data to answer a particular scientific question. Provides observations and/or record keeping that are incomplete and/or inadequate for answering a particular question. Selects inappropriate mathematical routines; measurements contain many errors.

Science Practice 4.4. The student can *evaluate sources of data* to answer a particular scientific question.

Proficient	Identifies fully legitimate sources of data to answer a particular scientific question, and justifies the completeness of the data set. Selects, justifies, and/or applies appropriate mathematical routines. Evaluates, explains, and estimates the percent uncertainty based on the largest source of uncertainty (instrumental or random).
Nearly Proficient	Identifies fully legitimate data sources to answer a particular scientific question, and appropriately identifies the data set as complete. Selects and applies appropriate mathematical routines. Estimates the percent uncertainty based on the largest source of uncertainty (instrumental or random), and articulates efforts to minimize uncertainty.
On the Path to Proficiency	Makes only minor errors in identifying legitimate data sources to answer a particular scientific question, and/or fails to recognize that some selected data sets are incomplete or inappropriate. Selects and justifies appropriate mathematical routines for answering the question. Evaluates uncertainty in the data.
An Attempt	Inconsistently identifies legitimate data sources to answer a particular scientific question, frequently failing to recognize the incomplete or inappropriate nature of the data. Identifies and selects appropriate mathematical routines for answering the question but selections lack justification.

Science Practice 5.1. The student can *analyze data* to identify patterns or relationships.

Proficient	Comprehensively describes the patterns and relationships within data, relative to a scientific question being asked. Accurately applies appropriate mathematical routines.
Nearly Proficient	Identifies most patterns within data, relative to a scientific question being asked, with only an occasional, minor error. Selects appropriate mathematical routines and applies them with only minor errors.
On the Path to Proficiency	Identifies the most obvious patterns within data, relative to a scientific question being asked, with some errors and inaccuracies. Selects appropriate mathematical routines but makes some application errors.
An Attempt	Identifies one or more legitimate patterns in data, though these may be irrelevant to a scientific question being asked. Identifies some mathematical routines that are appropriate.

Science Practice 5.2. The student can *refine observations and measurements* based on data analysis.

Proficient	Accurately identifies relevant data, and makes appropriate and comprehensive refinements to the observations and/or measurements. Appropriately selects and accurately applies mathematical routines.
Nearly Proficient	Accurately identifies relevant data, and makes appropriate refinements to the observations and/or measurements. Appropriately selects mathematical routines; application includes only minor errors.
On the Path to Proficiency	Accurately identifies relevant data, but selects incomplete and/or inappropriate refinements to observations and/or measurements. Selects and applies mathematical routines with at least one significant error.
An Attempt	Identifies relevant data, but applies mathematical routines that fail to improve the data collection plan.

Science Practice 5.3. The student can *evaluate the evidence provided by data sets* in relation to a particular scientific question.

Proficient	Evaluates evidence provided by data sets by effectively justifying the appropriateness of the data as they relate to a particular scientific question and the data collection methods used. Appropriately selects and accurately applies mathematical routines.
Nearly Proficient	Evaluates evidence provided by data sets by justifying the appropriateness of the data, but provides only basic insight into how data relate to a particular scientific question and the data collection methods used. Appropriately selects mathematical routines; application includes only minor errors.
On the Path to Proficiency	Relates evidence provided by data sets to a particular scientific question, but fails to fully align the evidence to a question or to the data collection methods used. Selects and applies mathematical routines with at least one significant error.
An Attempt	Makes some judgment errors about how data are used as evidence in relation to a particular scientific question and about appropriate data collection methods. Selects and applies mathematical routines with some significant errors.

Science Practice 6.1. The student can *justify claims with evidence.*

Proficient	Accurately identifies and aligns a comprehensive array of evidence with claims the evidence supports. Provides a substantive justification for the selection and/or exclusion of evidence. Considers data from multiple sources, and provides appropriate rationales for the selection and exclusion of evidence.
Nearly Proficient	Accurately identifies and aligns most but not all available and relevant evidence with claims it supports. Provides a clear justification for the selection and/or exclusion of evidence. Considers data from multiple sources.
On the Path to Proficiency	Identifies and aligns evidence with claims; but some evidence is inappropriate or fails to support the claims. Accurately differentiates between a claim and the evidence that supports it.
An Attempt	Identifies some appropriate evidence in support of claims, but connections drawn between evidence and claims are generally weak.

Science Practice 6.2. The student can *construct explanations of phenomena based on evidence* produced through scientific practices.

Proficient	Provides comprehensive explanations of phenomena based on evidence produced through scientific practices, presents a logical argument that links evidence and claims, and uses scientific language precisely and accurately.
Nearly Proficient	Provides explanations of phenomena based on evidence produced through scientific practices, links evidence and claims, and uses precise and accurate scientific language with only minor or occasional errors.
On the Path to Proficiency	Provides explanations of phenomena based on some evidence produced through science practices using basic logic. Identifies some links between evidence and claims, and uses scientific language with few significant errors.
An Attempt	Describes phenomena with limited reference to evidence produced through scientific practice. Uses flawed language and terminology.

Science Practice 6.3. The student can *articulate the reasons that scientific explanations and theories are refined or replaced.*

Proficient	Articulates the reasons why scientific explanations and theories are refined or replaced, and appropriately explains why particular revisions were necessary.
Nearly Proficient	Articulates the appropriate reasons that scientific explanations and theories are refined or replaced, and uses appropriate and accurate scientific language with only minor or occasional errors. Descriptions of why revisions are necessary may be incomplete.
On the Path to Proficiency	Articulates general reasons why scientific explanations and theories are refined or replaced, and uses scientific language and terminology with few errors and inaccuracies. Describes why revisions are necessary but not why they might represent an improvement.
An Attempt	Articulates a limited number of reasons why familiar scientific explanations and theories are refined or replaced, but offers inaccurate or incomplete reasoning or justification for why they were refined or replaced.

Science Practice 6.4. The student can *make claims and predictions about natural phenomena* based on scientific theories and models.

Proficient	Draws convincingly from scientific theories and models in making claims and predictions about phenomena, with appropriate justification and reasoning. Explains the connections between the model and the claim or prediction and the model and the phenomena.
Nearly Proficient	Draws directly and appropriately from scientific theories and models in making claims and predictions about phenomena, with appropriate justification and reasoning. Explains, with few errors, connections between the model and the claim or prediction and the model and the phenomena.
On the Path to Proficiency	Draws directly from scientific theories and models in making claims and predictions about phenomena, with incomplete justification or reasoning. Describes, with some limitations, connections between the model and the claim or prediction and the model and the phenomena. Accurately describes the scope of the claim or prediction.
An Attempt	Describes scientific theories and models in making claims and predictions about phenomena but without appropriate reasoning and/or justification. Some connections are inappropriate or inaccurate. Articulates the scope of claims or predictions with some errors.

Science Practice 6.5. The student can *evaluate alternative scientific explanations.*

Proficient	Evaluates alternative scientific explanations with consideration of both the alternative's strengths and its weaknesses appropriately based on available evidence.
Nearly Proficient	Evaluates alternative scientific explanations with consideration of both the alternative's strengths and its weaknesses, though the evaluation of either the strengths or weaknesses may be flawed.
On the Path to Proficiency	Evaluates alternative scientific explanations with limited consideration of either the alternative's strengths or its weaknesses based on evidence; evaluation of the strengths or weaknesses may be flawed.
An Attempt	Evaluates the appropriateness or accuracy of contradictory evidence or alternative explanations; evaluation contains some errors.

Science Practice 7.1. The student can *connect phenomena and models* across spatial and temporal scales.

Proficient	Connects phenomena and models across both spatial and temporal scales. Fully explains how a change at one scale affects phenomena or models at another scale with an occasional or minor error.
Nearly Proficient	Connects phenomena and models across spatial and/or temporal scales. Describes the impact on phenomena or models caused by a change at one scale with few or occasional errors.
On the Path to Proficiency	Connects phenomena and models across spatial or temporal scales, relating specific variables across finer or greater spatial and/or temporal scales. Cites relationships among variables that are not fully valid.
An Attempt	Articulates a general account of phenomena described at one scale and some relationships at another scale, but makes some errors in attempts to connect phenomena and models.

Science Practice 7.2. The student can *connect concepts* in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas.

Proficient	Connects concepts in and across domain(s) to accurately generalize or extrapolate in and/or across enduring understandings and/or big ideas. Predicts, with appropriate reasoning and detailed justification, how a change in one phenomenon might affect another.
Nearly Proficient	Connects concepts in and across domain(s) to generalize or extrapolate in and/or across enduring understandings and/or big ideas with only occasional or minor errors. Predicts, with reasoning and justification, how a change in one phenomenon might affect another with only occasional or minor errors.
On the Path to Proficiency	Compares features of phenomena that are related, making connections across concepts and among contexts but not necessarily across big ideas and/or enduring understandings. Predicts, with basic reasoning or justification, how a change in one phenomenon might affect another.
An Attempt	Makes statements linking concepts or phenomena but with some errors and inaccuracies. Makes claims about how a change in one phenomenon might affect another but with an incomplete consideration of evidence.