OVERVIEW OF THE PERFORMANCE STANDARDS
High School

The high school standards are set at a level of performance approximately equivalent to the end of tenth grade. It is expected that some students might achieve this level earlier and others later than this grade. (See "Deciding what constitutes a standard-setting performance," page 10.)

Science

S1 Physical Sciences Concepts

- S1a Demonstrate understanding of structure of atoms.
- S1b Demonstrate understanding of structure and properties of matter.
- S1c Demonstrate understanding of chemical reactions.
- S1d Demonstrate understanding of motions and forces.
- S1e Demonstrate understanding of conservation of energy and increase in disorder.
- S1f Demonstrate understanding of interactions of energy and matter.

S2 Life Sciences Concepts

- S2a Demonstrate understanding of the cell.
- S2b Demonstrate understanding of biological evolution.
- S2c Demonstrate understanding of interdependence of organisms.
- S2d Demonstrate understanding of matter, energy, and organization in living systems.
- S2e Demonstrate understanding of evolution, diversity, and adaptation of organisms.
- S2f Demonstrate understanding of behavior of organisms.

S3 Earth and Space Sciences Concepts

- S3a Demonstrate understanding of energy in the Earth system.
- S3b Demonstrate understanding of geochemical cycles.
- S3c Demonstrate understanding of origin and evolution of the Earth system.
- S3d Demonstrate understanding of origin and evolution of the universe.
- S3e Demonstrate understanding of natural resource management.

S4 Scientific Connections and Applications

- S4a Demonstrate understanding of big ideas and unifying concepts.
- S4b Demonstrate understanding of the designed world.
- S4c Demonstrate understanding of health.
- S4d Demonstrate understanding of impact of technology.
- S4e Demonstrate understanding of impact of science.

S5 Scientific Thinking

S5a Frames questions to distinguish cause and effect; and identifies or controls variables.

S5b Uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena.

S5c Uses evidence from reliable sources to develop descriptions, explanations, and models ; and makes appropriate adjustments and improvements.

S5d Proposes, recognizes, analyzes, considers, and critiques alternative explanations; and distinguishes between fact and opinion.

S5e Identifies problems; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.

S5f Works individually and in teams to collect and share information and ideas.

S6 Scientific Tools and Technologies

S6a Uses technology and tools to observe and measure objects, organisms, and phenomena, directly, indirectly, and remotely, with appropriate consideration of accuracy and precision.

S6b Records and stores data using a variety of formats.

S6c Collects and analyzes data using concepts and techniques in Mathematics Standard 4.

S6d Acquires information from multiple sources.

S6e Recognizes and limits sources of bias in data.

S7 Scientific Communication

S7a Represents data and results in multiple ways.

S7b Argues from evidence.

S7c Critiques published materials.

S7d Explains a scientific concept or procedure to other students.

S7e Communicates in a form suited to the purpose and the audience.

S8 Scientific Investigation

S8a Demonstrates scientific competence by completing a controlled experiment.

S8b Demonstrates scientific competence by completing fieldwork.

S8c Demonstrates scientific competence by completing a design.

S8d Demonstrates scientific competence by completing secondary research.

S1 Physical Sciences Concepts

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S1a The student produces evidence that demonstrates understanding of structure of atoms, such as atomic composition, nuclear forces, and radioactivity.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

* Debate the relative merits of harnessing nuclear fission and fusion as energy sources. 1a, 1b, 1c, E3b
* Predict the age of a hypothetical fossil based on the rate of radioactive decay of several radioactive isotopes. 1a, 2c, 3a, 3b, 3c, 3d
* Research the history of the periodic table; take and defend a position on the configuration that best illustrates properties of elements. 1a, 1b, 1c, 4e
* Explain why a local urban area has smog and what can be done about it. 1a, 1b, 1c, 1e, 4d

New York State Learning Standards for Math, Science, & Technology[140]

Standard 4 Science
Physical Setting

3. Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Students:
explain the uses and hazards of radioactivity. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[141]

Standard B Physical Science

Structure of Atoms

Matter is made of minute particles, called atoms, and atoms are composed of even smaller components.

The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons.

The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart.

Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting particles and/or wavelike radiation. p. 178

Project 2061, AAAS[142]

Benchmarks for Science Literacy

Chapter 4 The Physical Setting

4D Structure of Matter

Atoms are made of a positive nucleus surrounded by negative electrons. An atom's electron configuration, particularly the outermost electrons, determines how the atom can interact with other atoms.

The nucleus, a tiny fraction of the volume of an atom, is composed of protons and neurons, each almost two thousand times heavier than an electron. The number of positive protons in the nucleus determines what an atom's electron configuration can be and so defines the element. In a neutral atom, the number of electrons equals the number of protons. But an atom may acquire an unbalanced charge by gaining or losing electrons.

Although neutrons have little effect on how an atom interacts with others, they do affect the mass and stability of the nucleus.

The nucleus of radioactive isotopes is unstable and spontaneously decays, emitting particles and/or wavelike radiation. It cannot be predicted exactly when, if ever, an unstable nucleus will decay, but a large group of identical nuclei decay at a predictable rate. This predictability of decay rate allows radioactivity to be used for estimating the age of materials that contain radioactive substances. p. 80

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S1 Physical Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S1b The student produces evidence that demonstrates understanding of structure and properties of matter, such as elements and compounds; bonding and molecular interaction; and characteristics of phase changes.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

* Debate the relative merits of harnessing nuclear fission and fusion as energy sources. 1a, 1b, 1c, E3b
* Research the history of the periodic table; take and defend a position on the configuration that best illustrates properties of elements. 1a, 1b, 1c, 4e
* Explain why a local urban area has smog and what can be done about it. 1a, 1b, 1c, 1e, 4d

New York State Learning Standards for Math, Science, & Technology[143]

Standard 4 Science
Physical Setting

3. Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Students:
explain the properties of materials in terms of the arrangement and properties of the atoms that compose them. p. 34

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NRC National Science Education Standards[144]
Standard B Physical Science
Structure and Properties of Matter

Atoms interact with one another by transferring or sharing electrons that are furthest from the nucleus.

An element is composed of a single type of atom.

Bonds between atoms are created when electrons are paired up by being transferred or shared.

The physical properties of compounds reflect the nature of the interactions among its molecules.

Solids, liquids, and gases differ in the distances and angles between molecules or atoms and therefore the energy that binds them together.

Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures. pp. 178-180

Project 2061, AAAS[145]
Benchmarks for Science Literacy
Chapter 4 The Physical Setting
4D Structure of Matter

Atoms often join with one another in various combinations in distinct molecules or in repeating three-dimensional crystal patterns. An enormous variety of biological, chemical, and physical phenomena can be explained by changes in the arrangement and motion of atoms and molecules.

The configuration of atoms in a molecule determines the molecule's properties. Shapes are particularly important in how large molecules interact with others. p. 80

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S1 Physical Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S1c The student produces evidence that demonstrates understanding of chemical reactions, such as everyday examples of chemical reactions; electrons, protons, and energy transfer; and factors that affect reaction rates such as catalysts.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

* Debate the relative merits of harnessing nuclear fission and fusion as energy sources. 1a, 1b, 1c, E3b
* Research the history of the periodic table; take and defend a position on the configuration that best illustrates properties of elements. 1a, 1b, 1c, 4e
* Determine the characteristics for a dinner table candle that will keep the candle burning longer. 1c, 1e
* Explain why a local urban area has smog and what can be done about it. 1a, 1b, 1c, 1e, 4d
* Explain how electric motors and generators illustrate the relationship between electricity and magnetism. 1c, 1d, 1e, 4a, 4b

New York State Learning Standards for Math, Science, & Technology[146]

Standard 4 Science
Physical Setting

3. Matter is made up of particles whose properties determine the observable characteristics of matter and its reactivity.

Students:

use atomic and molecular models to explain common chemical reactions.

apply the principle of conservation of mass to chemical reactions.

use kinetic molecular theory to explain rates of reactions and the relationships among temperature, pressure, and volume of a substance.

5. Energy and matter interact through forces that result in changes in motion.

Students:

explain chemical bonding in terms of the motion of electrons. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[147]

Standard B Physical Science

Chemical Reactions

Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles.

Chemical reactions may release or consume energy.

A large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atpoms.

Chemical reactions can take place in time periods ranging from a few femtoseconds (10-15 seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years.

Catalysts, such as metal surfaces, accelerate chemical reactions. p. 179

Project 2061, AAAS[148]

Benchmarks for Science Literacy

Chapter 4 The Physical Setting

4D Structure of Matter

The rate of reactions among atoms and molecule depends on how often they encounter one another, which is affected by the concentration, pressure, and temperature of the reacting materials. Some atoms and molecules are highly effective in encouraging the interaction. p. 80

4E Energy Transformation

Different energy levels are associated with different configurations of atoms and molecules. Some changes of configuration require an input of energy whereas others release energy. p. 86

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S1 Physical Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S1d The student produces evidence that demonstrates understanding of motions and forces, such as gravitational and electrical; net forces and magnetism.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

* Make an informational videotape describing how an understanding of acceleration and velocity can make one a better driver. 1d, 1e, 7d
* Explain how electric motors and generators illustrate the relationship between electricity and magnetism. 1c, 1d, 1e, 4a, 4b

New York State Learning Standards for Math, Science, & Technology[149]

Standard 4 Science
Physical Setting

5. Energy and matter interact through forces that result in changes in motion.

Students:

explain and predict different patterns of motion of objects (e.g., linear and angular motion, velocity and acceleration, momentum and inertia). p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[150]

Standard B Physical Science

Motions and Forces

Objects change their motion only when a net force is applied.

Gravitation is a universal force that each mass exerts on any other mass.

The electric force is a universal force that exists between any two charged objects.

Between any two charged particles, electric force is vastly greater than the gravitational force.

Electricity and magnetism are two aspects of a single electromagnetic force. pp. 179-180

Project 2061, AAAS[151]

Benchmarks for Science Literacy

Chapter 4 The Physical Setting

4D Structure of Matter

Gravitational force is an attraction between masses. The strength of the force is proportional to the masses and distance between them.

Electromagnetic forces acting within and between atoms are involved in all chemical reactions.

There are two kinds of changes - positive and negative. A small excess or deficit of negative charges in a material produces electric forces.

Different kinds of material respond differently to electric forces.

Moving electric charges produce magnetic forces and moving magnets produce electric forces.

Forces that hold nucleus of an atom together are much stronger than the electromagnetic force. pp. 96-97

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S1 Physical Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S1e The student produces evidence that demonstrates understanding of conservation of energy and increase in disorder, such as kinetic and potential energy; energy conduction, convection, and radiation; random motion; and effects of heat and pressure.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

* Determine the characteristics for a dinner table candle that will keep the candle burning longer. 1c, 1e
* Explain why a local urban area has smog and what can be done about it. 1a, 1b, 1c, 1e, 4d
* Make an informational videotape describing how an understanding of acceleration and velocity can make one a better driver. 1d, 1e, 7d
* Explain how electric motors and generators illustrate the relationship between electricity and magnetism. 1c, 1d, 1e, 4a, 4b
* Explain to a younger student the difference between temperature and heat. 1e, 7d
* Compare the efficiency and energy consumption of several different methods of generating electricity that could be used locally. 1e, 1f, 4b, 4d

New York State Learning Standards for Math, Science, & Technology[152]
Standard 4 Science
Physical Setting

4. Energy exists in many forms and when these forms change energy is conserved.

Students:

observe and describe transmissions of various forms of energy.

explain heat in terms of kinetic molecular theory. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[153]

Standard B Physical Science

Conservation of Energy and the Increase in Disorder

The total energy of the universe is constant.

All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

Heat consists of random motion and the vibration of atoms, molecules, and ions.

Everything tends to become less organized and less orderly over time. p. 180

Project 2061, AAAS[154]

Benchmarks for Science Literacy

Chapter 4 The Physical Setting

4E Energy Transformations

Whenever the amount of energy in one place or form diminishes, the amount in the other places or forms increases by same amount.

Heat energy in a material consists of the disordered motion of its atoms or molecules.

Different energy levels are associated with different configurations of atoms and molecules. Some changes require an input of energy whereas others release energy.

When energy of an isolated atom or molecule changes, it does so in a definite jump from one value to another, with no possible values in between.

Energy is released whenever the nucleus of very heavy atoms split. p. 88

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S1 Physical Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S1f The student produces evidence that demonstrates understanding of interactions of energy and matter, such as waves, absorption and emission of light, and conductivity.

Examples of activities through which students might demonstrate conceptual understanding of physical sciences include:

* Compare the efficiency and energy consumption of several different methods of generating electricity that could be used locally. 1e, 1f, 4b, 4d
* Earn the Energy Merit Badge (Boy Scouts of America) and explain how it helped you to understand the interactions of matter and energy. 1f, 4b, 4d
* Trace the transformations of energy from the electric current that enters a CD player or boombox to a sound that can be heard as music. 1f, 4b

New York State Learning Standards for Math, Science, & Technology[155]
Standard 4 Science
Physical Setting

4. Energy exists in many forms and when these forms change, energy is conserved.

Students:

explain variations in wavelength and frequency in terms of the source of the vibrations that produce them e.g. molecules, electrons, and nuclear particles. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[156]

Standard B Physical Science
Interactions of Energy and Matter

Waves, including sound and seismic waves, waves on water, and light waves, have energy and can transfer energy when they interact with matter.

Electromagnetic waves result when a charged object is accelerated or decelerated.

Each kind of atom or molecule can gain or lose energy only in particular discrete amounts and thus can absorb and emit light only at wavelengths corresponding to these amounts.

In some materials, such as metals, electrons flow easily, whereas in insulating materials such as glass they can hardly flow at all. pp. 180-181

Project 2061, AAAS[157]
Benchmarks for Science Literacy

Chapter 4 The Physical Setting
4E Energy Transformations

The change in energy of an atom occurs when radiation is absorbed or emitted, so the radiation also has distinct energy values. p. 86

4F Motion

The observed wave length of a wave depends upon the relative motion of the source and the observer.

Waves can superpose on one another, bend around corners, reflect off surfaces, but absorbed by materials they enter and change direction when entering a new material. p. 92

4G Forces of Nature

Different kinds of materials respond differently to electric forces. p. 97

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S2 Life Sciences Concepts

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S2a The student produces evidence that demonstrates understanding of the cell, such as cell structure and function relationships; regulation and biochemistry; and energy and photosynthesis.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

* Create a picture book to explain how a producer converts solar energy to chemical energy through an ecosystem. 2a, 1c, 3a
* Explain how cell functions are regulated to allow organisms to respond to the environment and to control and coordinate growth and differentiation. 2a, 2b, 2c, 2f, 1c
* Predict how long a plant will live planted in a closed glass jar located by a window; and explain what additional information regarding the plant and the surrounding environment would be needed to improve the prediction. 2a, 1a, 3a, 3b

New York State Learning Standards for Math, Science, & Technology[158]

Standard 4 Science
The Living Environment

1. Living things are both similar to and different from each other and non-living things.

Students:

describe and explain the structures and functions of the human body at different organizational levels (e.g., systems, tissues, cells, organelles).

explain how a one-celled organism is able to function despite lacking the levels of organization present in more complex organisms. p. 35

National Documents which guided New York State and New York City

NRC National Science Education Standards[159]

Standard C Life Science
The Cell

Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane....

Most cell functions involve chemical reactions.

Cells store and use information to guide their functions. The genetic information stored in DNA....

Cell functions are regulated. Regulation occurs....

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Plant cells contain chloroplasts, the site of photosynthesis. Plants and many microorganisms.... p. 184

Matter, Energy, and Organization in Living Systems

All matter tends toward more disorganized states. Living systems require a continuous input of energy....

The energy for life primarily derives from the sun. Plants capture energy by....

The chemical bonds of food molecules contain energy. Energy is released when....

The complexity and organization of organisms accommodates the need of obtaining, transforming,.... p. 186

Project 2061, AAAS[160]
Benchmarks for Science Literacy
Chapter 5 The Living Environment
5C Cells

Every cell is covered by a membrane that controls what can enter and leave the cell.

Within the cell are specialized parts for the transport of materials, energy capture and release, protein building, waste disposal, information feedback, and even movement.

The work of the cell is carried out by the many different types of molecules it assembles, mostly proteins.

Most cells function best within a narrow range of temperature and acidity.

A living cell is composed of a small number of chemical elements mainly carbon, hydrogen, nitrogen, oxygen, phosphorous, and sulfur. pp. 113-114

5F Evolution of Life

Life on earth is thought to have begun as simple, one-celled organisms about 4 billion years ago. p. 123

Chapter 6 The Human Organism
6C Basic Functions

The immune system is designed to protect against microscopic organisms and foreign substances that enter from outside the body and against some cancer cells that arise within....

The nervous system works by electrochemical signals in the nerves and from one nerve to the next.

Communication between cells is required to coordinate their diverse activities. p. 138

6E Physical Health

Some allergic reactions are caused by the body's immune responses to usually harmless environmental substances.

Some viral diseases, such as AIDS, destroy critical cells of the immune system, leaving the body unable to deal with multiple infection agents and cancerous cells. p. 146

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S2 Life Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S2b The student produces evidence that demonstrates understanding of molecular basis of heredity, such as DNA, genes, chromosomes, and mutations.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

* Explain how cell functions are regulated to allow organisms to respond to the environment and to control and coordinate growth and differentiation. 2a, 2b, 2c, 2f, 1c
* Create a working model to show how the instructions for specifying an organism's characteristics are carried in DNA and its subunits. 2b, 2c, 5c
* Make a storyboard and give a presentation to younger students explaining the increasing prevalence of dark forms of moths 150 years ago and the more recent return to light forms. 2b, 2c, 2d, 7d, E3c

New York State Learning Standards for Math, Science, & Technology[161]

Standard 4 Science
The Living Environment

2. Organisms inherit genetic information in a variety of ways that result in continuity of structure and function between parents and offspring.

Students:

explain how the structure and replication of genetic material result in offspring that resemble their parents.

explain how the technology of genetic engineering allows humans to alter the genetic makeup of organisms.

4. The continuity of life is sustained through reproduction and development.

Students:

explain how organisms, including humans reproduce their own kind. p. 35

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National Documents which guided New York State and New York City

NRC National Science Education Standards[162]

Standard C Life Science

The Molecular Basis of Heredity

In all organisms, the instructions for specifying the characteristics of the organisms are carried in DNA, a large....

Most of the cells in human contain two copies of each of 22 different chromosomes. In addition, there is....

Changes in DNA (mutations) occur spontaneously at low rates. Some of these changes.... p. 185

Project 2061, AAAS[163]

Benchmarks for Science Literacy

Chapter 5 The Living Environment

5A Diversity of Life

The degree of kinship between organisms or species can be estimated from the similarity of their DNA. p. 105

5B Heredity

The sorting and-recombination of genes in sexual reproduction results in a great variety of possible gene combinations.

The information passed from parents to offspring is coded in DNA molecules.

Genes are segments of DNA molecules.

The many body cells in an individual can be very different from one another, even though they are all descended. p. 109

5C Cells

The genetic information in DNA molecules provides instructions for assembling protein molecules.

Gene mutation in a cell can result in uncontrolled cell division, called cancer. p. 114

5F Evolution of Life

Heritable characteristics can be observed at molecular and whole-organism levels-in structure, chemistry, or behavior. p. 125

Chapter 6 The Human Organism

6A Human Identity

The similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a single species.

New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells of an organism cannot be passed on to the next generation. p. 130

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S2 Life Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S2c The student produces evidence that demonstrates understanding of biological evolution, such as speciation, biodiversity, natural selection, and biological classification.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

* Explain how cell functions are regulated to allow organisms to respond to the environment and to control and coordinate growth and differentiation. 2a, 2b, 2c, 2f, 1c
* Create a working model to show how the instructions for specifying an organism's characteristics are carried in DNA and its subunits. 2b, 2c, 5c
* Make a videotape debating the possible explanations for the extinction of dinosaurs. 2c, 2d, 7d
* Make a storyboard and give a presentation to younger students explaining the increasing prevalence of dark forms of moths 150 years ago and the more recent return to light forms. 2b, 2c, 2d, 7d, E3c
* Develop a recycling outreach program as part of a community service project to illustrate the limited availability of matter and energy in the ecosystem. 2c, 2d, 1c, 4b
* Research the development of, and recent advances in the theory of, evolutionary psychology. 2c, 2f, 4e

New York State Learning Standards for Math, Science, & Technology[164]

Standard 4 Science
The Living Environment

3. Individual organisms and species change over time.

Students:

explain the mechanisms and patterns for evolution. p. 35

explain how individual choices and societal actions can contribute to improving the environment. p. 35

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National Documents which guided New York State and New York City

NRC National Science Education Standards[165]

Standard C Life Science
Biological Evolution

Species evolve over time. Evolution is the consequence....

The great diversity of organisms is the result of more than 3.5 million years of evolution that has filled every available niche with life forms.

Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms.

The millions of different species of plants, animals, and microorganisms that live on earth are today related by descent from common ancestors.

Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of....p. 185

The Behavior of Organisms

Like other aspects of an organism's biology, behaviors have evolved through natural selection. Behaviors often have an adaptive logic when viewed in terms of evolutionary principles.

Behavioral biology has implications for humans, as it provides links to psychology, sociology and anthropology. p. 187

Project 2061, AAAS[166]
Benchmarks for Science Literacy

Chapter 5 The Living Environment
5F Evolution of Life

The basic idea of biological evolution is that the earth's present-day species developed from earlier, distinctly different species.

Molecular evidence substantiates the anatomical evidence for evolution and provides additional detail about the sequence in which various lines of descent branched off from one another.

Natural selection provides the following mechanism for evolution: Some variation in heritable characteristics exists within....

Heritable characteristics can be observed at molecular and whole-organism levels-in structure, chemistry, or behavior. These....

New heritable characteristics can result from new combinations of existing genes or from mutations of genes in reproductive cells. Changes in other cells cannot be passed on to the next generation.

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Natural selection leads to organism that are well suited for survival in particular environments. Chance alone can result in....

The theory of natural selection provides a scientific explanation for the history of life on earth as depicted in the fossil record and in the similarities evident within it diversity existing of existing organisms.

Life on earth is thought to have begun as a simple, one-celled organisms about 4 billion years ago, increasingly complex multicellular organisms evolved.

Evolution builds on what already exists, so the more variety there is, the more there can be in the future, But evolution does not.... p. 125

Chapter 6 The Human Organism
6A Human Identity

The similarity of human DNA sequences and the resulting similarity in cell chemistry and anatomy identify human beings as a single species.

Written records and photographic and electronic devices enable human beings to share, compile, use, and misuse great amounts of.... p. 130

S2 Life Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S2d The student produces evidence that demonstrates understanding of interdependence of organisms, such as conservation of matter; cooperation and competition among organisms in ecosystems; and human effects on the environment.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

* Make a videotape debating the possible explanations for the extinction of dinosaurs. 2c, 2d, 7d
* Make a storyboard and give a presentation to younger students explaining the increasing prevalence of dark forms of moths 150 years ago and the more recent return to light forms. 2b, 2c, 2d, 7d, E3c
* Earn the Ecology Merit Badge (Girl Scouts of the U.S.A.) or the Environmental Science Merit Badge (Boy Scouts of America) and explain how it helped you to understand the interdependence of organisms. 2d, 2e
* Develop a recycling outreach program as part of a community service project to illustrate the limited availability of matter and energy in the ecosystem. 2c, 2d, 1c, 4b

New York State Learning Standards for Math, Science, & Technology[167]

Standard 4 Science
The Living Environment

6. Plants and animals depend on each other and their physical environment.

Students:

explain the importance of preserving diversity of species and habitats.

explain how the living and nonliving environments change over time and respond to disturbances.

7. Human decisions and activities have had a profound impact on the physical and living environment.

Students:

describe the range of interrelationships of humans with the living and nonliving environment.

explain the impact of technological development and growth in the human population on the living and nonliving environment.

explain how individual choices and societal actions can contribute to improving the environment. p. 35

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National Documents which guided New York State and New York City

NRC National Science Education Standards[168]

Standard C Life Science

The Interdependence of Organisms

The atom and molecules on the earth cycle among the living and nonliving components of the biosphere.

Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers.

Human beings live within the world's ecosystems. p. 186

Population Growth

Populations grow or decline through combined effects.

Various factors influence birth rates and fertility rates.

Population can reach limits to growth. p. 198

Natural Resources

Human populations use resources in the environment.

The earth does not have the infinite resources.

Humans use many natural systems as resources. p. 198

Environmental Quality

Materials from human societies affect both physical and chemical cycles of the Earth.

Many factors influence environmental quality. p. 198

Science and Technology in Local, National, and Global Changes

Progress in science and technology can be affected by social issues and challenges. Funding priorities for specific health problems serve as examples of ways that social issues influence science and technology.

Individuals and society must decide on proposals involving new research and the introduction of new technologies into society.

Humans have a major effect on other species. p. 199

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Project 2061, AAAS[169]
Benchmarks for Science Literacy
Chapter 5 The Living Environment
5A Diversity of Life

The variation of organisms within a species increases the likelihood that at least some members of the species will survive under changed environmental conditions, and a great variety of species increases the chance that at least some living things will survive in the face of large changes in the environment. p. 105

5D Interdependence of Life

Ecosystems can be reasonably stable over hundreds or thousands of years. As any population of organisms grows, it is held in check by one or more environmental factors: depletion of food or nesting sites, increased loss to increased numbers of predators, or parasites. If a disaster such as a flood or fire occurs, the damaged ecosystem is likely to recover in stages that eventually result in a system similar to the original one.

Like many complex systems, ecosystems tend to have cyclic fluctuations around a state of rough equilibrium. In the long run, however, ecosystems always change when climate changes or when one or more new species appear as a result of migration or local evolution.

Human beings are part of the earth's ecosystems. Human activities can, deliberately or inadvertently, alter the equilibrium in ecosystems. p. 117

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S2 Life Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S2e The student produces evidence that demonstrates understanding of matter, energy, and organization in living systems, such as matter and energy flow through different levels of organization; and environmental constraints.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

* Make a humorous travel brochure describing the pathway of a carbon dioxide molecule and an oxygen molecule through the living and non-living components of the biosphere. 2e, 1b
* Earn the Ecology Merit Badge (Girl Scouts of the U.S.A.) or the Environmental Science Merit Badge (Boy Scouts of America) and explain how it helped you to understand the interdependence of organisms. 2d, 2e
* Trace a candy bar from the time it is purchased to the time it is completely expended. 2e

New York State Learning Standards for Math, Science, & Technology[170]

Standard 4 Science
The Living Environment

6. Plants and animals depend on each other and their physical environment.

Students:
explain factors that limit growth of individuals and populations. p. 35

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National Documents which guided New York State and New York City

NRC National Science Education Standards[171]

Standard C Life Science

Matter, Energy, and Organization in Living Systems

As matter and energy flows through different levels of organization of living systems-cells, organs. organisms. communities-and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials. p. 186

Project 2061, AAAS[172]

Benchmarks for Science Literacy

Chapter 5 The Living Environment

5E Flow of Matter and Energy

At times, environmental conditions are such that plants and marine organisms grow faster that decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. By burning these fossil fuels' people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide.

The amount of life any environment can support is limited by the available energy, water, oxygen, and minerals, and by the ability of ecosystems to recycle the residue of dead organic materials. Human activities and technology can change the flow and reduce the fertility of the land.

The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. p. 121

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S2 Life Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S2f The student produces evidence that demonstrates understanding of behavior of organisms, such as nervous system regulation; behavioral responses; and connections with anthropology, sociology, and psychology.

Examples of activities through which students might demonstrate conceptual understanding of life sciences include:

* Explain how cell functions are regulated to allow organisms to respond to the environment and to control and coordinate growth and differentiation. 2a, 2b, 2c, 2f, 1c
* Conduct an investigation to determine how different kinds of plants respond to various environmental stimuli. 2f
* Research the development of, and recent advances in the theory of, evolutionary psychology. 2c, 2f, 4e

New York State Learning Standards for Math, Science, & Technology[173]

Standard 4 Science
The Living Environment

5. Organisms maintain a dynamic equilibrium that sustains life.

Students:

explain the basic biochemical processes in living organisms and their importance in maintaining a dynamic equilibrium.

explain disease as a failure of homeostasis.

relate processes at the system level to the cellular level in order to explain dynamic equilibrium in multicelled organisms. p. 35

National Documents which guided New York State and New York City

NRC National Science Education Standards[174]

Standard C Life Science
The Behavior of Organisms

Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells....

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Organisms have behavioral responses to internal changes....

Behavioral biology has implications for humans, as it provides links to psychology, sociology and psychology. p. 187

Project 2061, AAAS[175]
Benchmarks for Science Literacy

Chapter 6 The Human Organism
6D Learning

Differences in the behavior of individuals arise from the interaction of heredity and experience.

The expectations, moods, and prior experiences of human beings can effect how they interpret new perceptions or ideas.

Human thinking involves the interaction of ideas, and ideas about ideas. People can produce many associations internally. p. 142

6E Physical Health

Some allergic reactions are caused by the body's immune response to usually harmless environmental substances.

Faulty genes can cause body parts or systems to work poorly. Some genetic diseases appear only when an individual has inherited a certain gene.

New medical techniques, efficient health care delivery systems, improved sanitation, and a fuller understanding of the nature....

Some viral diseases/ such as AIDS, destroy critical cells of the immune system, leaving the body unable to deal with multiple infection agents and cancerous cells. p. 146

6F Mental Health

Stresses are especially difficult for children to deal with and may have long lasting effects.

Biological abnormalities, such as brain injuries or chemical imbalances/ can cause or increase susceptibility to psychological....

Reactions of other people to an individual/s emotional disturbance may increase its effects.

Human beings differ greatly in how they cope with emotions and may therefore puzzle one another.

Ideas about what constitutes good mental health and proper treatment of abnormal mental states vary from one culture to another.... p. 149

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S3 Earth and Space Sciences Concepts

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S3a The student produces evidence that demonstrates understanding of energy in the Earth system, such as radioactive decay, gravity, the Sun's energy, convection, and changes in global climate.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:

* Make a brochure providing an orientation to the climate of the local region to a newcomer; and explain the likely weather in that context. 3a
* Explain the relationship between gravity and energy. 3a, 1d
* Analyze the risk of natural disasters in the local region and make recommendations for actions that can be taken to mitigate the damage. 3a, 3b, 4b
* Germinate seeds on a rotating platform and explain the observed growth pattern. 3a, 1d, 2e

New York State Learning Standards for Math, Science, & Technology[176]

Standard 4 Science
Physical Setting

1. The Earth and celestial phenomena can be described by principles of relative motion and perspective.

Students:
explain complex phenomena, such as tides, variations in day length, solar insolation, apparent motion of the planets, and annual traverse of the planets.

2. Many of the phenomena that we observe on Earth involve interactions among components of air, water, and land.

Students:
use the concepts of density and heat energy to explain observations of weather patterns, seasonal changes, and the movements of the Earth's plates.

explain how incoming solar radiation, ocean currents, and land masses affect weather and climate. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[177]

Standard D Earth and Space Science
Energy in the Earth System

Earth systems have internal and external sources of energy, both of which create heat.

The outward transfer of earth's internal heat drive convection circulation in the mantle that propels the plates comprising earth's surface across the face of the globe.

Heating of earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

Global climate is determined by energy transfer from the sun at and near the earth's surface. p. 189

Project 2061, AAAS[178]
Benchmarks for Science Literacy

Chapter 4 The Physical Setting
4B The Earth

Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. p. 70

4C Processes that Shape the Earth

The slow movement of material within the earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density.

Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. p. 74

Chapter 8 The Designed World
8C Energy Sources and Use

Energy from the sun (and the wind and water energy derived from it) is available indefinitely. p. 194

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S3 Earth and Space Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S3b The student produces evidence that demonstrates understanding of geochemical cycles, such as conservation of matter; chemical resources and movement of matter between chemical reservoirs.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:

* Analyze the risk of natural disasters in the local region and make recommendations for actions that can be taken to mitigate the damage. 3a, 3b, 4b
* Conduct a study of the geology of an area near the school; and describe the likely history of the region, using observations and reference materials. 3b, 3c

New York State Learning Standards for Math, Science, & Technology[179]

No comparable standard.

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National Documents which guided New York State and New York City

NRC National Science Education Standards[180]

Standard D Earth and Space Science
Geochemical Cycles

The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on earth moves among reservoirs in the solid earth, oceans, atmosphere, and organisms as part of geochemical cycles.

Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. p. 189

Project 2061, AAAS[181]
Benchmarks for Science Literacy

Chapter 5 The Living Environment
5E Flow of Matter and Energy

At times, environmental conditions are such that plants and marine organisms grow faster than decomposers can recycle them back to the environment. Layers of energy-rich organic material have been gradually turned into great coal beds and oil pools by the pressure of the overlying earth. By burning these fossil fuels, people are passing most of the stored energy back into the environment as heat and releasing large amounts of carbon dioxide.

The chemical elements that make up the molecules of living things pass through food webs and are combined and recombined in different ways. At each link in a food web, some energy is stored in newly made structures but much is dissipated into the environment as heat. Continual input of energy from sunlight keeps the process going. p. 121

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S3 Earth and Space Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S3c The student produces evidence that demonstrates understanding of origin and evolution of the Earth system, such as geologic time and the age of life forms; origin of life; and evolution of the Solar System.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:

* Conduct a study of the geology of an area near the school; and describe the likely history of the region, using observations and reference materials. 3b, 3c
* Diagram the birth, development, and death of a human; contrast with the geologic time frame of the origin and evolution of the Earth system or the universe. 3c, 3d, 2c
* Work with other students to become an "expert panel" to describe the historical events leading to the development of the "big bang" theory. 3c, 3d, 5f

New York State Learning Standards for Math, Science, & Technology[182]

Standard 4 Science
Physical Setting

1. The Earth and celestial phenomena can be described by principles of relative motion and perspective.

Students:
Describe current theories about the origin of the universe and solar systems. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[183]

Chapter 10 Historical Perspectives
10D Extending Time

Scientific evidence implies that some rock near the earth's surface is several billion years old.

The idea that the earth might be vastly older than most people believed made little headway in science until the publication of Principles of Geology by an English scientist, Charles Lyell, early in the 19th century.

In formulating and presenting his theory of biological evolution, Charles Darwin adopted Lyell's belief about the age of the earth and his style of buttressing his argument with vast amounts of evidence. p. 246

10H Explaining the Diversity of Life

The scientific problem that led to the theory of natural selection was how to explain similarities within the great diversity of existing and fossil organisms.

Darwin argued that only biologically inherited characteristics could be passed on to offspring.

After the publication of Origin of Species, biological evolution was supported by the rediscovery of the genetics experiments of an Austrian monk, Gregor Mendel, by the identification of genes and how they are sorted in reproduction, and by the discovery that the genetic code found in DNA is the same for almost all organisms. pp. 254-255

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S3 Earth and Space Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S3d The student produces evidence that demonstrates understanding of origin and evolution of the universe, such as the "big bang" theory; formation of stars and elements; and nuclear reactions.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:

* Diagram the birth, development, and death of a human; contrast with the geologic time frame of the origin and evolution of the Earth system or the universe. 3c, 3d, 2c
* Work with other students to become an "expert panel" to describe the historical events leading to the development of the "big bang" theory. 3c, 3d, 5f
* Write a research paper to explain how stars produce energy from nuclear reactions and how these processes led to the formation of other elements. 3d, 1a, 1b, 1c, 1f, E2a

New York State Learning Standards for Math, Science, & Technology[184]
Standard 4 Science
The Living Environment

1. The Earth and celestial phenomena can be described by principles of relative motion and perspective.

Students:
Describe current theories about the origin of the universe and solar systems. p. 34

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National Documents which guided New York State and New York City

NRC National Science Education Standards[185]

Standard D Earth and Space Sciences
The Origin and Evolution of the Universe

The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state; according to this theory, the universe has been expanding ever since.

Early in the history of the universe, matter, primarily the light atoms hydrogen and helium, clumped together by gravitation attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.

Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements. p. 190

Project 2061, AAAS[186]
Benchmarks for Science Literacy

Chapter 4 The Physical Setting
4A The Universe

On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues.

Increasing sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote part of the solar system; and accelerators give subatomic particles energies that stimulate conditions in the stars and in the early history of the universe before stars formed. p. 65

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S3 Earth and Space Sciences Concepts (cont.)

The student demonstrates conceptual understanding by using a concept accurately to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

S3e The student produces evidence that demonstrates understanding of natural resource management.

Examples of activities through which students might demonstrate conceptual understanding of Earth and space sciences include:

* Identify a place that is subject to periodic flooding, evaluate its positive and negative effects, and study different ways of maintaining, reducing, or eliminating the likelihood of flooding. 3e

New York State Learning Standards for Math, Science, & Technology[187]
Standard 4 Science
The Living Environment

No comparable standard.

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National Documents which guided New York State and New York City

NRC National Science Education Standards[188]

Standard F Science in Personal and Social Perspectives
Natural Resources

Human populations use resources in the environment in order to maintain and improve their existence.

The earth does not have infinite resources; increasing human consumption places severe stress on the natural processes that renew some resources, and it depletes those resources that cannot be renewed.

Humans use many natural systems as resources.

Environmental Quality

Natural ecosystems provide an array of basic processes that affect humans

Material from human societies affect both physical and chemical cycles of the earth.

Many factors influence environmental quality. Factors that students might investigate include population growth, resource use, population distribution, overconsumption, the capacity of technology to solve problems, poverty, the role of economic, political, and religious views, and different ways humans view the earth. p. 198

Project 2061, AAAS[189]
Benchmarks for Science Literacy

Chapter 7 Human Society
7E Political and Economic Systems

In the free-market model, the control of production and consumption is mainly in private hands.

In the central-planning model, production and consumption are controlled by the government.

The countries of the world use elements of both systems and are neither purely free-market nor entirely centrally controlled. p. 170

7G Global Interdependence.

The wealth of a country depends partly on the efforts and skills of its workers, its natural resources, and the capital and technology available to it.

Because of increasing international trade, the domestic products of any country may be made up in part by parts made in other countries.

The growing interdependence of world social, economic, and ecological systems does not always bring greater worldwide stability and often increases the costs of conflicts. p. 178

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S4 Scientific Connections and Applications

The student demonstrates conceptual understanding by using the concept to explain observations and make predictions and by representing the concept in multiple ways (through words, diagrams, graphs, or charts, as appropriate). Both aspects of understanding—explaining and representing—are required to meet this standard.

The student produces evidence that demonstrates understanding of:

S4a Big ideas and unifying concepts, such as order and organization; models, form and function; change and constancy; and cause and effect.

S4b The designed world, such as the reciprocal relationship between science and technology; the development of agricultural techniques; and the reasonableness of technological designs.

S4c Health, such as nutrition and exercise; disease and epidemiology; personal and environmental safety; and resources, environmental stress, and population growth.

S4d Impact of technology, such as constraints and trade-offs; feedback; benefits and risks; and problems and solutions.

S4e Impact of science, such as historical and contemporary contributions; and interactions between science and society.

Examples of activities through which students might demonstrate conceptual understanding of scientific connections and applications include:

* Construct a computer-controlled robot arm that mimics the form and function of a human hand and forearm. 4a, 4b, 4c, 2a
* Work with other students to give a presentation based on scientific principles arguing for a systemic solution to an environmental problem that concerns the school or community. 4a, 4b, 4c, 4d, 1a, 2d, 2e, A1b
* Propose modifications to improve skateboards, in-line skates, bicycles, or similar objects to make them safer, faster, or less expensive. 4b, 4c, 1a, A1b
* Conduct a study of the school cafeteria including: food storage and preparation, nutrition, and student preferences; and make recommendations for improvement. 4c, 4d
* Debate the positive and negative consequences of a recently developed technological innovation. 4b, 4d, 4e, E3b
* Earn the Food, Fibers, and Farming Merit Badge (Girl Scouts of the U.S.A.) and make a poster that shows understanding of agriculture or technology. 4b, 4c, 4d, 4e

New York State Learning Standards for Math, Science, & Technology[190]

Standard 6 Interconnectedness: Common Themes

Students will understand the relationships and common themes that connect mathematics, science, and technology and apply the themes to these and other areas of learning.

Systems Thinking

1. Through systems thinking, people can recognize the commonalities that exist among all systems and how parts of a system interrelate and combine to perform specific functions.

Models

2. Models are simplified representations of objects, structures, or systems used in analysis, explanation, interpretation, or design. p. 56

Magnitude and Scale

3. The grouping of magnitudes of size, time, frequency, and pressures or other units of measurement into a series of relative order provides a useful way to deal with the immense range and the changes in scale that affect the behavior and design of systems.

Equilibrium and Stability

4. Equilibrium is a state of stability due either to a lack of changes (static equilibrium) or a balance between opposing forces (dynamic equilibrium). p. 57

Patterns of Change

5. Identifying patterns of change is necessary for making predictions about future behavior and conditions.

Optimization

6. In order to arrive at the best solution that meets criteria within constraints, it is often necessary to make trade-offs. p.58

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PERFORMANCE DESCRIPTIONS
High School Science

National Documents which guided New York State and New York City

NRC National Science Education Standards[191]

Unifying Concepts and Processes

Systems, order, and organization

Evidence, models, and explanation

Constancy, change, and measurement

Evolution and equilibrium

Form and function pp. 115-119

Standard E Science and Technology pp. 190-193

Standard F Science in Personal and Social Perspectives

Personal Health

Characteristics and Changes in Populations

Types of Resources

Changes in Environments

Science and Technology in Local Challenges pp. 193-199

Standard G History and Nature of Science pp. 200-204

Project 2061, AAAS[192]
Chapter 3 The Nature of Technology pp. 41-57

Chapter 6 The Human Organism pp. 127-149

Chapter 8 The Designed World pp. 181-207

Chapter 10 Historical Perspectives pp. 237-259

Chapter 11 Common Themes
11A Systems
11B Models
11C Constancy and Change
11D Scale pp. 261-279

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S5 Scientific Thinking

The student demonstrates skill in scientific inquiry and problem solving by using thoughtful questioning and reasoning strategies, common sense and diverse conceptual understanding, and appropriate ideas and methods to investigate science; that is, the student:

S5a Frames questions to distinguish cause and effect; and identifies or controls variables in experimental and non-experimental research settings.

S5b Uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena.

S5c Uses evidence from reliable sources to develop descriptions, explanations, and models; and makes appropriate adjustments and improvements based on additional data or logical arguments.

S5d Proposes, recognizes, analyzes, considers, and critiques alternative explanations; and distinguishes between fact and opinion.

S5e Identifies problems; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.

S5f Works individually and in teams to collect and share information and ideas.

Examples of activities through which students might demonstrate skill in scientific thinking include:

* Evaluate the claims and potential benefits and risks of steroid use and apply the scientific evidence to a reported "case study" of an athlete. 5a, 5b, 5c, 5d
* Predict how long a plant will live, planted in moist soil in a closed glass jar located by a window; explain what additional information would be needed to make a better prediction. 5a, 5b, 5c
* Compare and contrast the nutritional value of several common brands of cereals. 5b, 5c, 5d
* Compare and contrast lines of evidence for theories of dinosaur extinction. 5b, 5c, 5d, 2c, 2d
* Explain the chain of inference in DNA testing and debate both positions regarding its inclusion as evidence in a capital trial. 5c, 5d, 1b, 1c, 2a, 2b, 4d

New York State Learning Standards for Math, Science, & Technology[193]

Standard 1 Analysis, Inquiry, and Design
Scientific Inquiry

1. The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.
2. Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. p. 6

[193] Reproduced by permission from *Learning Standards for Mathematics, Science, and Technology*. University of the State of New York and the State Education Department, Albany, NY 12234.

1. The observations made while testing explanations, when analyzed using conventional and invented methods, provide new insights into phenomena. p. 7

National Documents which guided New York State and New York City

NRC National Science Education Standards[194]

Standard A Science As Inquiry

Identify questions and concepts that guide scientific investigations.

Formulate and revise scientific explanations and models using logic and evidence.

Recognize and analyze alternative explanations and models. p. 175

Project 2061, AAAS[195]

Chapter 1 The Nature of Science

1B Scientific Inquiry

Hypotheses are widely used in science for choosing what data to pay attention to and what additional data to seek, and for guiding the interpretation of the data (both new and previously available).

Sometimes, scientists can control conditions in order to obtain evidence. When that is not possible for practical or ethical reasons, they try to observe as wide a range of natural occurrences as possible to be able to discern patterns.

In the short run, new ideas that do not mesh well with mainstream ideas in science often encounter vigorous criticism. In the long run, theories are judged by how they fit with other theories, the range of observations they explain, how well they explain observations, and how effective they are in predicting new findings. p. 13

Chapter 12 Habits of Mind

12D Communication Skills

Participate in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions. p. 297

Suggest alternative ways of explaining data and criticize arguments in which data, explanations, or conclusions are represented as the only ones worth consideration, with no mention of other possibilities. p. 300

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S6 Scientific Tools and Technologies

The student demonstrates competence with the tools and technologies of science by using them to collect data, make observations, analyze results, and accomplish tasks effectively; that is, the student:

S6a Uses technology and tools (such as traditional laboratory equipment, video, and computer aids) to observe and measure objects, organisms, and phenomena, directly, indirectly, and remotely, with appropriate consideration of accuracy and precision.

S6b Records and stores data using a variety of formats, such as data bases, audiotapes, and videotapes.

S6c Collects and analyzes data using concepts and techniques in Mathematics Standard 4, such as mean, median, and mode; outcome probability and reliability; and appropriate data displays.

S6d Acquires information from multiple sources, such as print, the Internet, computer data bases, and experimentation.

S6e Recognizes and limits sources of bias in data, such as observer and sample biases.

Examples of activities through which students might demonstrate competence with the tools and technologies of science include:

* Work with other students to repeat a historical series of experiments, such as those leading to the current understanding of photosynthesis, and write an essay comparing and contrasting the differences in available tools and technologies. 6d, 2a, 4d, 4e, 5c, 7b
* Evaluate the accuracy and timeliness of information reported during the "life" of a hurricane or tropical storm. 6d, 3a, 4a, 5c
* Use the Internet to get current information on a rapidly changing scientific topic. 6d
* Use a computer interface to measure the velocity of objects. 6d, 1d, 5c
* Use telecommunications to compare data on similar investigations with students in another state. 6d
* Earn the Orienteering Merit Badge (Boy Scouts of America) and teach another student what to do if he or she gets lost. 6d, 3a, 5c, 7d

New York State Learning Standards for Math, Science, & Technology[196]

Standard 2 Information Systems

1. Information technology is used to receive, process, and communicate information and as a tool to enhance learning.

Students:

access, select, collate, and analyze information obtained from a wide range of sources such as research databases, foundations, organizations, national libraries, and electronic communication networks, including the Internet. p. 12

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Standard 3 Mathematics
Modeling/Multiple Representation

4. Students use mathematical modeling/multiple representation to provide a means of presenting, interpreting, and communicating, and connecting mathematical information and relationships. p. 23

Measurement

5. Students use measurement in both metric and English measure to provide a major link between the abstractions of mathematics and the real world in order to describe and compare objects and data. p. 24

National Documents which guided New York State and New York City

NRC National Science Education Standards[197]

Standard A Science as Inquiry

Use technology and mathematics to improve investigations and communications. p. 175

Project 2061, AAAS[198]
Chapter 1 The Nature of Science
1B Scientific Inquiry

Scientists in any one research group tend to see things alike, so even groups of scientists may have trouble being entirely objective about their methods and findings. For that reason, scientific teams are expected to seek out he possible sources of bias in the design of their investigations and in their data analysis. Checking each other's results and explanations helps, but that is no guarantee against bias. p 13

Chapter 12 Habits of Mind
12B Computation and Estimation

Use computer spreadsheet, graphing, and database programs to assist in quantitative analysis. p. 291

12C Manipulation and Observation

Use computers for producing tables and graphs and for making spreadsheet calculations. p. 294

12D Communication Skills

Choose appropriate summary statistics to describe group differences, always indicating the spread of the data as well as the data's central tendencies. p. 297

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S7 Scientific Communication

The student demonstrates effective scientific communication by clearly describing aspects of the natural world using accurate data, graphs, or other appropriate media to convey depth of conceptual understanding in science; that is, the student:

S7a Represents data and results in multiple ways, such as numbers, tables, and graphs; drawings, diagrams, and artwork; technical and creative writing; and selects the most effective way to convey the scientific information.

S7b Argues from evidence, such as data produced through his or her own experimentation or data produced by others.

S7c Critiques published materials, such as popular magazines and academic journals.

S7d Explains a scientific concept or procedure to other students.

S7e Communicates in a form suited to the purpose and the audience, such as by writing instructions that others can follow; critiquing written and oral explanations; and using data to resolve disagreements.

Examples of activities through which students might demonstrate competence in scientific communication include:

* Analyze a ballot initiative on a local endangered species. 7a, 7b, 2c, 4d, 5a
* Critique a Time article which reports on something you have studied. 7c
* Make a "claymation" video illustrating in simple terms how a virus attacks the human body. 7c, 2d, 4c, 5c
* Give an oral report describing the change over time in local air quality. 7d, 2d, 3e, 4d, E3c
* Earn the Model Design and Building Merit Badge (Boy Scouts of America) and explain what constitutes an effective model. 7d, 4b, 5c
* Write an advertisement for a cold relief product that explains how it works. 7e, 4c, 5c, 5d, 6d

New York State Learning Standards for Math, Science, & Technology[199]

Standard 1 Analysis, Inquiry, and Design
Scientific Inquiry

3. The observations made while testing explanations, when analyzed using conventional and invented methods, provide new insights into phenomena.

Students:

use various means of representing and organizing observations (e.g., diagrams, tables, charts, graphs, equations, matrices) and insightfully interpret the organized data. p. 7

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National Documents which guided New York State and New York City

NRC National Science Education Standards[200]

Standard A Science as Inquiry

Communicate and defend a scientific argument. p. 176

Project 2061, AAAS[201]

Chapter 1 The Nature of Science
1B Scientific Inquiry

There are different traditions in science about what is investigated and how, but they all have in common certain basic beliefs about the value of evidence, logic, and good arguments. And there is agreement that progress in all fields of science depends on intelligence, hard work, imagination, and even chance. p. 13

Chapter 9 The Mathematical World
9B Symbolic Relationships

Tables, graphs, and symbols are alternative ways of representing data and relationships that can be translated from one to the other. p. 221

9D Uncertainty

The way data are displayed can make a big difference in how they are interpreted. p. 230

Chapter 12 Habits of Mind
12D Communication Skills

Write clear, step-by-step instructions for conducting investigations, operating something, or following a procedure.

Participates in group discussions on scientific topics by restating or summarizing accurately what others have said, asking for clarification or elaboration, and expressing alternative positions. p. 297

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S8 Scientific Investigation

The student demonstrates scientific competence by completing projects drawn from the following kinds of investigation, including at least one full investigation each year and, over the course of high school, investigations that integrate several aspects of Science Standards 1 to 7 and represent all four of the kinds of investigation:

S8a Controlled experiment.

S8b Fieldwork.

S8c Design.

S8d Secondary research.

A single project may draw on more than one kind of investigation.
A full investigation includes:

- **Questions that can be studied using the resources available.**
- **Procedures that are safe, humane, and ethical; and that respect privacy and property rights.**
- **Data that have been collected and recorded (see also Science Standard 6) in ways that others can verify, and analyzed using skills expected at this grade level (see also Mathematics Standard 4).**
- **Data and results that have been represented (see also Science Standard 7) in ways that fit the context.**
- **Recommendations, decisions, and conclusions based on evidence.**
- **Acknowledgment of references and contributions of others.**
- **Results that are communicated appropriately to audiences.**
- **Reflection and defense of conclusions and recommendations from other sources and peer review.**

Examples of projects through which students might demonstrate competence in scientific investigation include:

* Investigate the effectiveness of common household cleaners on bacterial growth. 8a, 1c, 2a, 4c
* Conduct research to determine if the incidence of asthma is related to weather. 8b, 3a, 4c
* Conduct a study of the geology of an area near the school and describe the likely history of the region, using observations and reference materials. 8b, 8d, 3c, 6d
* Compare and contrast the designs of different sports shoes and evaluate the designs considering the varying demands of different sports. 8c
* Conduct an investigation to determine if the shape of a stereo speaker container affects sound quality. 8c, 1f
* Study the distribution of a species in the region or state and discuss the likelihood of it becoming endangered. 8d, 2c, 5c, 6c

PERFORMANCE DESCRIPTIONS
High School Science

New York State Learning Standards for Math, Science, & Technology[202]

Standard 1 Analysis, Inquiry, and Design

Scientific Inquiry

1. The central purpose of scientific inquiry is to develop explanations of natural phenomena in a continuing, creative process.
2. Beyond the use of reasoning and consensus, scientific inquiry involves the testing of proposed explanations involving the use of conventional techniques and procedures and usually requiring considerable ingenuity. p. 6
3. The observations made while testing explanations, when analyzed using conventional and invented methods, provide new insights into phenomena. p. 7

Engineering Design

1. Engineering design is an iterative process involving modeling and optimization finding the best solution within given constraints which is used to develop technological solutions to problems within given constraints. p. 7

National Documents which guided New York State and New York City

NRC National Science Education Standards[203]

Standard A Science as Inquiry

Design and conduct scientific investigations. Designing and conducting a scientific investigation requires introduction to the major concepts in the area being investigated, proper equipment, safety precautions, assistance with methodological problems, recommendations for the use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also require student clarification of the question, method, controls, and variables; student organization and display of data; student revision of methods and explanations; and a public presentation of the results with critical response from peers. Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations. p. 175

Standard E Science and Technology

Identify a problem or design opportunity.

Propose designs and choose between alternate solutions.

Implement a proposed solution.

Evaluate the solution and its consequences.

Communicate the problem, processes, and solution. p. 192

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Project 2061, AAAS[204]
Chapter 1 The Nature of Science
1B Scientific Inquiry

Sometimes, scientists can control conditions in order to obtain evidence. When it is not possible for practical or ethical reasons, they may try to observe as wide a range of natural occurrences as possible to be able to discern patterns.

There are different traditions in science about what is investigated and how, but they all have in common certain basic beliefs about the value of evidence, logic, and good arguments. And there is agreement that progress in all fields of science depends on intelligence, hard work, imagination, and even chance. p. 13

Chapter 3 The Nature of Technology
3B Design and Systems

In designing a device or process, thought should be given to how it will be manufactured, replaced, and disposed of and who will sell, operate, and take care of it. The costs associated with these functions may introduce yet more constraints on the design. p. 52

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Work Sample & Commentary: *Pendulum Experiment*
High School Science

The task[205]

The task was an investigation in which students analyzed an archeological artifact—a pendulum—discovered by the fictional Morgan International Research Institute during an expedition in Mali, West Africa. The students were asked to decide what function the artifact might have served, and to investigate the variables that affect the period of a pendulum's oscillation.

Circumstances of performance

These samples of student work were produced under the following conditions:

√ alone	√ in a group
√ in class	√ as homework
√ with teacher feedback	with peer feedback
timed	opportunity for revision

These work samples illustrate standard-setting performances for the following parts of the standards:[206]

S1d Physical Sciences Concepts: Motions and forces.

S4e Scientific Connections and Applications: Impact of science.

S5a Scientific Thinking: Frame questions to distinguish cause and effect.

S5b Scientific Thinking: Use concepts from Science Standards 1 to 4.

S5e Scientific Thinking: Identify problems.

S5f Scientific Thinking: Work individually and in teams.

S6a Scientific Tools and Technologies: Use technology and tools.

S7a Scientific Communication: Represent data and results in multiple ways.

S7b Scientific Communication: Argue from evidence.

S7e Scientific Communication: Communicate in a form suited to the purpose and the audience.

S8a Scientific Investigation: A controlled experiment.

What the work shows

S1d Physical Sciences Concepts: The student provides evidence that demonstrates understanding of motions and forces, such as gravitational....

(A) (B) The student correctly states that the pendulum's motion is due to the influence of gravity, and notes differences in gravity related to geographical location.

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[205] For related work on Pendula, see "Pendulum", page 65.

[206] The quotations from the Science performance descriptions in this commentary are excerpted. The complete performance descriptions are shown on pages 292-339.

(C) (D) The hypothesis and the narrative comparison of the data tables demonstrate understanding of concepts related to motion and force.

S4e Scientific Connections and Applications: The student produces evidence that demonstrates understanding of the impact of science, such as historical and contemporary contributions….

(E) The student incorporates into the report several references to Galileo's work with pendulums.

S5a Scientific Thinking: The student frames questions to distinguish cause and effect; and identifies or controls variables in experimental and non-experimental research settings.

(F) The student frames the question appropriately.

(G) (H) (I) The student identified and controlled each variable in designing her experiment, and in recording data in the tables and graphs.

(J) The "Explanation," clearly demonstrates the student's understanding of variables. This section of the report describes the efforts made to control variables and the limitations of those efforts.

S5b Scientific Thinking: The student uses concepts from Science Standards 1 to 4 to explain a variety of observations and phenomena.

(K) (L) (M) (N) Throughout the "Interpretations" section and in the conclusion, the student applies concepts related to Science Standard S1d.

S5e Scientific Thinking: The student identifies problems; proposes and implements solutions; and evaluates the accuracy, design, and outcomes of investigations.

(J) In the "Explanation" the student identifies limitations of the procedure and comments on the resulting level of accuracy of the data collected.

S5f Scientific Thinking: The student works individually and in teams to collect and share information and ideas.

(G) (J) (O) Both students mention working with team members. (The reports, however, are individual efforts.)

S6a Scientific Tools and Technologies: The student uses technology and tools (such as traditional laboratory equipment, video, and computer aids) to observe and measure objects, organisms, and phenomena, directly, indirectly, and remotely, with appropriate consideration of accuracy and precision.

(P) (Q) (R) (S) (G) The materials lists, responses to the investigation questions, and procedure section make it clear that scientific tools were used during the investigation.

(H) (I) (T) The data in the tables and graphs demonstrate that the student repeated experiments to achieve an appropriate degree of precision.

(J) The student comments on the accuracy and precision of the procedure and data.

S7a Scientific Communication: The student represents data and results in multiple ways, such as numbers, tables, and graphs;…diagrams…; technical and creative writing; and selects the most effective way to convey the scientific information.

(D) (J) The student's narrative writing is clear and concise.

(E) (Q) (R) Throughout the report, the narrative text adds to the flow of information. This is especially true at points such as (Q) and (R), where the narrative is entirely original. The student also successfully incorporates book research into the report, as at (E).

(H) (I) The student uses tables and graphs to collect and represent the data. Each data table and graph deals with changes in one variable.

(T) The student presents data from experiment 1 in three tables. However, data for only one manipulated variable should be presented in each table. It should also be pointed out that the student's use of the term 'fixed' when referring to variables being 'manipulated' is incorrect.

(U) The student uses a diagram to clarify his written description.

(V) The student represents data and results in graphs. Again, the student attempts to incorporate too much information in one graph. (The original graphs were in color; this distinction is lost in reproduction.)

S7b Scientific Communication: The student argues from evidence, such as data produced through his or her own experimentation or data produced by others.

(W) In the "Conclusions" section, the student argues from the experimental data that "…the most influential variable is the string length."

(D) The student uses graphic representations of the data to argue that the largest changes in the pendulum's period of time occurred when the string length was changed.

(X) Based on the graphed data, the student concludes that the largest change in the pendulum's period of time occurred when the length of the pendulum changed.

S7e Scientific Communication: The student communicates in a form suited to the purpose and the audience, such as by writing instructions that others can follow [and] critiquing written and oral explanations….

(D) (X) The student determines which variable contributed most in determining a pendulum's period, and clearly communicates the results in written form.

(G) (J) The student provides a clearly written procedure for others to follow in repeating the experiment, and notes limitations of the procedure.

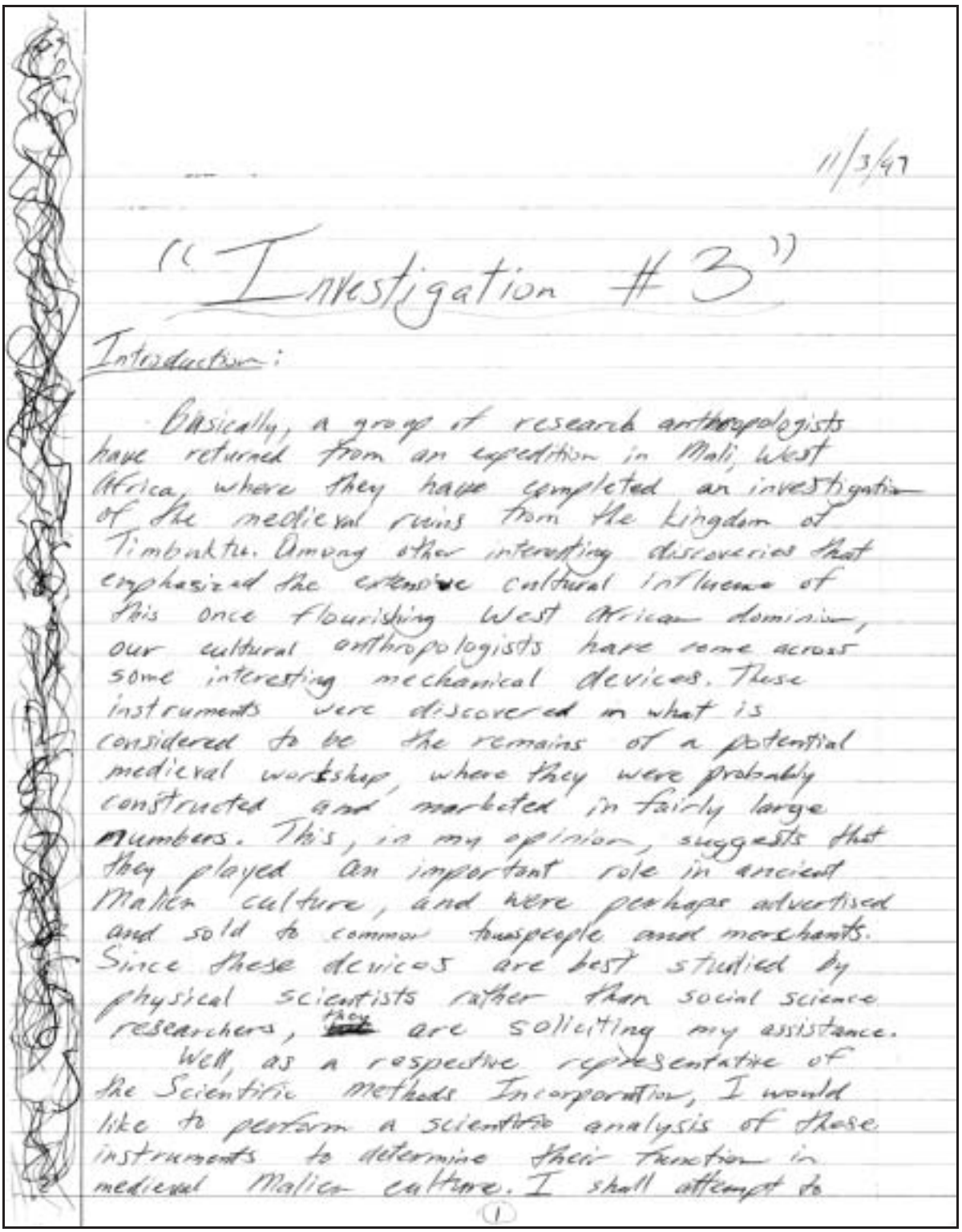
S8a Scientific Investigation: The student demonstrates scientific competence by completing a controlled experiment.

(T) (V) The tables and graphs showed that the student performed a series of steps that tested for specific variables. However, data for only one variable should be presented in each table and graph.

(W) The student uses data from the investigation to reach a correct conclusion.

(G) The student clearly outlines the experiment and states how each variable can be evaluated in a controlled way.

Student 1



11/3/97

"Investigation #3"

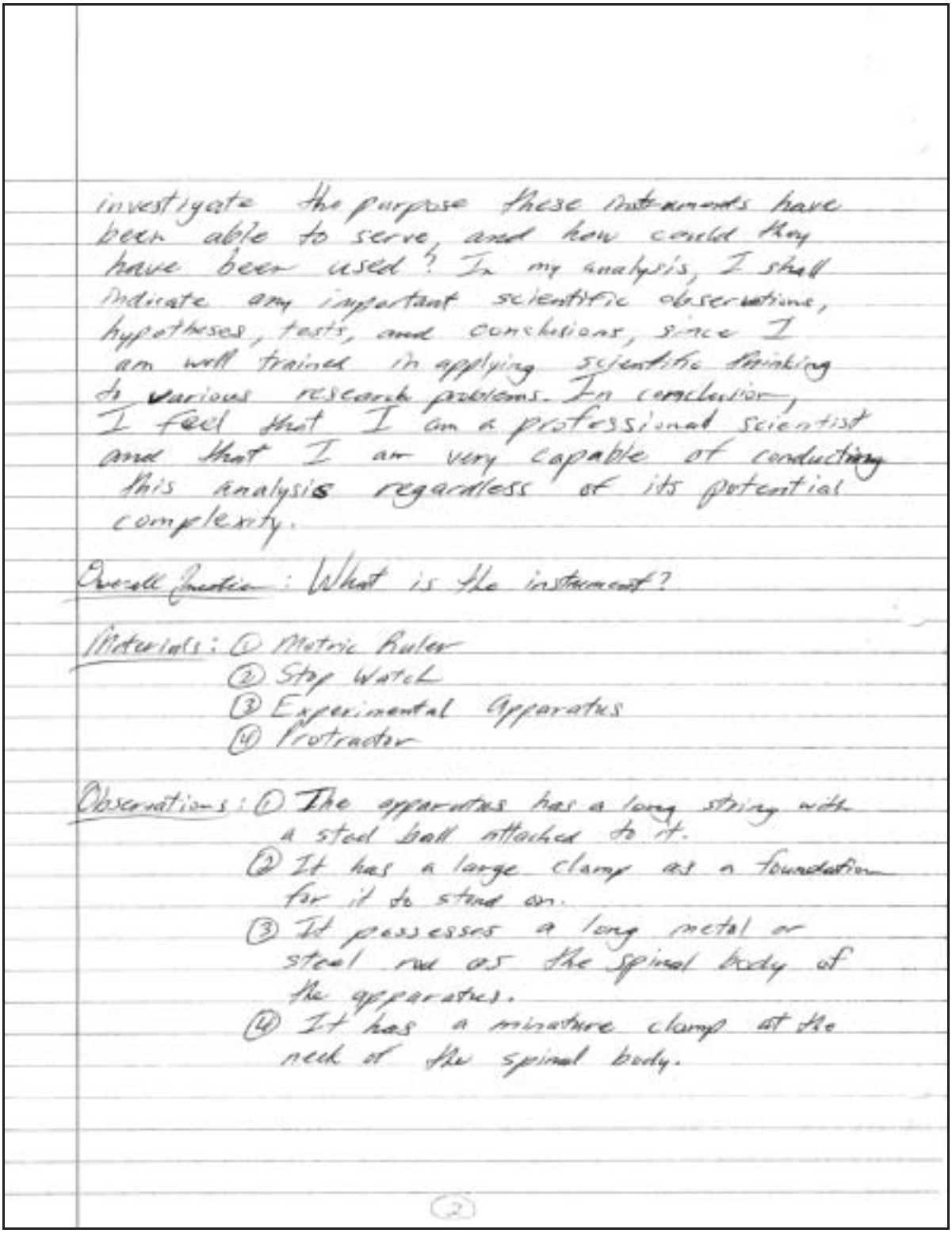
Introduction:

Basically, a group of research anthropologists have returned from an expedition in Mali, West Africa, where they have completed an investigation of the medieval ruins from the Kingdom of Timbuktu. Among other interesting discoveries that emphasized the extensive cultural influence of this once flourishing West African dominion, our cultural anthropologists have come across some interesting mechanical devices. These instruments were discovered in what is considered to be the remains of a potential medieval workshop, where they were probably constructed and marketed in fairly large numbers. This, in my opinion, suggests that they played an important role in ancient Malian culture, and were perhaps advertised and sold to common townspeople and merchants. Since these devices are best studied by physical scientists rather than social science researchers, they are soliciting my assistance.

Well, as a respective representative of the Scientific Methods Incorporation, I would like to perform a scientific analysis of these instruments to determine their function in medieval Malian culture. I shall attempt to

1

Student 1



investigate the purpose these instruments have been able to serve, and how could they have been used? In my analysis, I shall indicate any important scientific observations, hypotheses, tests, and conclusions, since I am well trained in applying scientific thinking to various research problems. In conclusion, I feel that I am a professional scientist and that I am very capable of conducting this analysis regardless of its potential complexity.

Overall Question: What is the instrument?

Materials: ① Metric Ruler
② Stop Watch
③ Experimental Apparatus
④ Protractor

Observations: ① The apparatus has a long string with a steel ball attached to it.
② It has a large clamp as a foundation for it to stand on.
③ It possesses a long metal or steel rod as the spinal body of the apparatus.
④ It has a miniature clamp at the neck of the spinal body.

(2)

Student 1

Hypothesis: Based on the lateral structure of the apparatus, I thought of many possible examples of what the object could possibly be. My associates and I brainstormed some possibilities of what this apparatus could be:

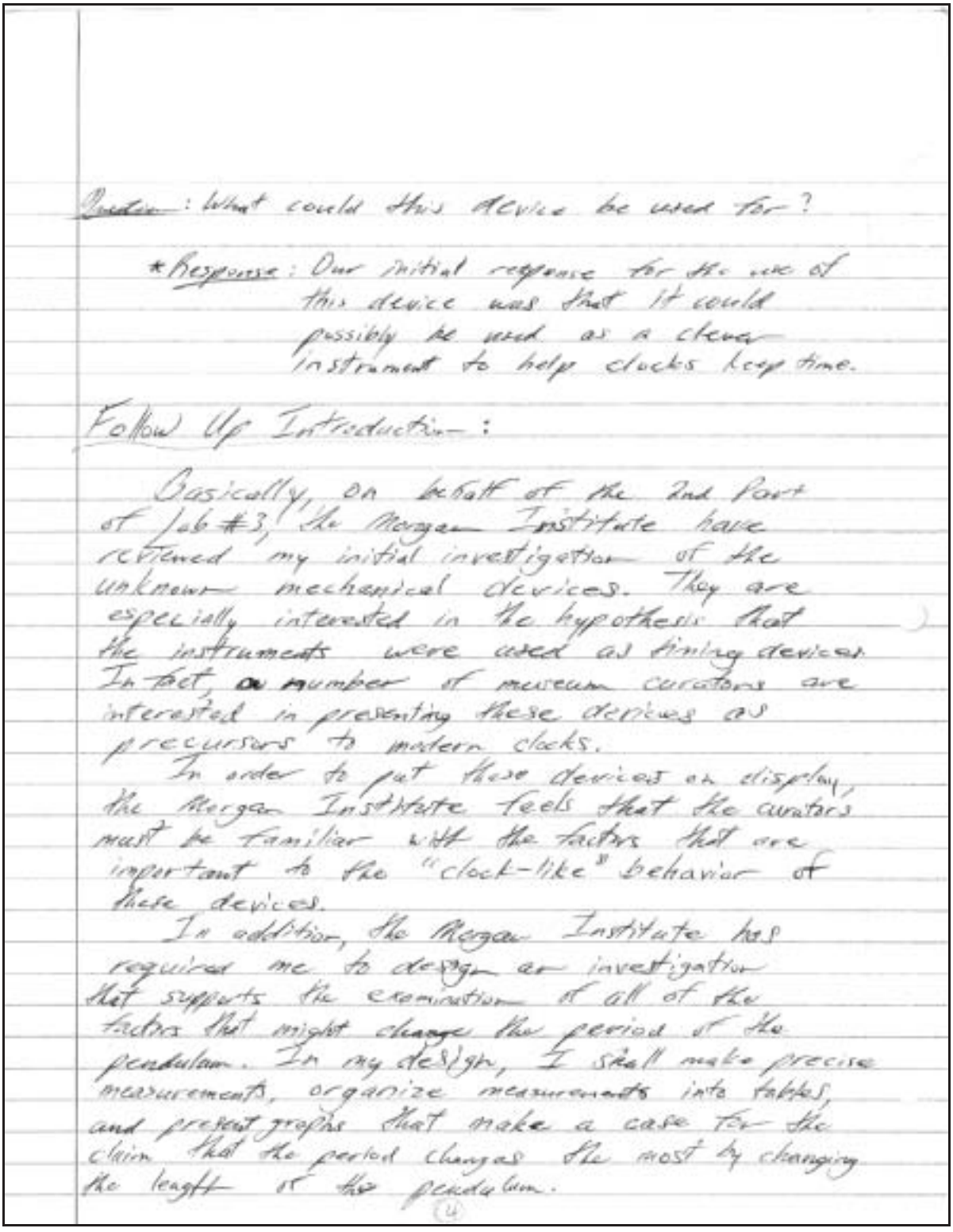
(a) a weighing device
(b) a timer
(c) a hypnotizer
(d) a pendulum ✓
(e) a wind machine

* Well, the first thing that came mind when my associates and I were examing the apparatus was none other than a grandfather clock. So therefore, we instantly concluded that it could be some type of timing device. However, we did some further analysis and concluded that the object is a pendulum based on our general scientific knowledge.

Justin: What purpose could this pendulum serve?

*Response: Well, we could generalize the purpose of the pendulum as a potential timing device to possibly balance time differential or time correspondence.

Student 1



Question: What could this device be used for?

*Response: Our initial response for the use of this device was that it could possibly be used as a clever instrument to help clocks keep time.

Follow Up Introduction:

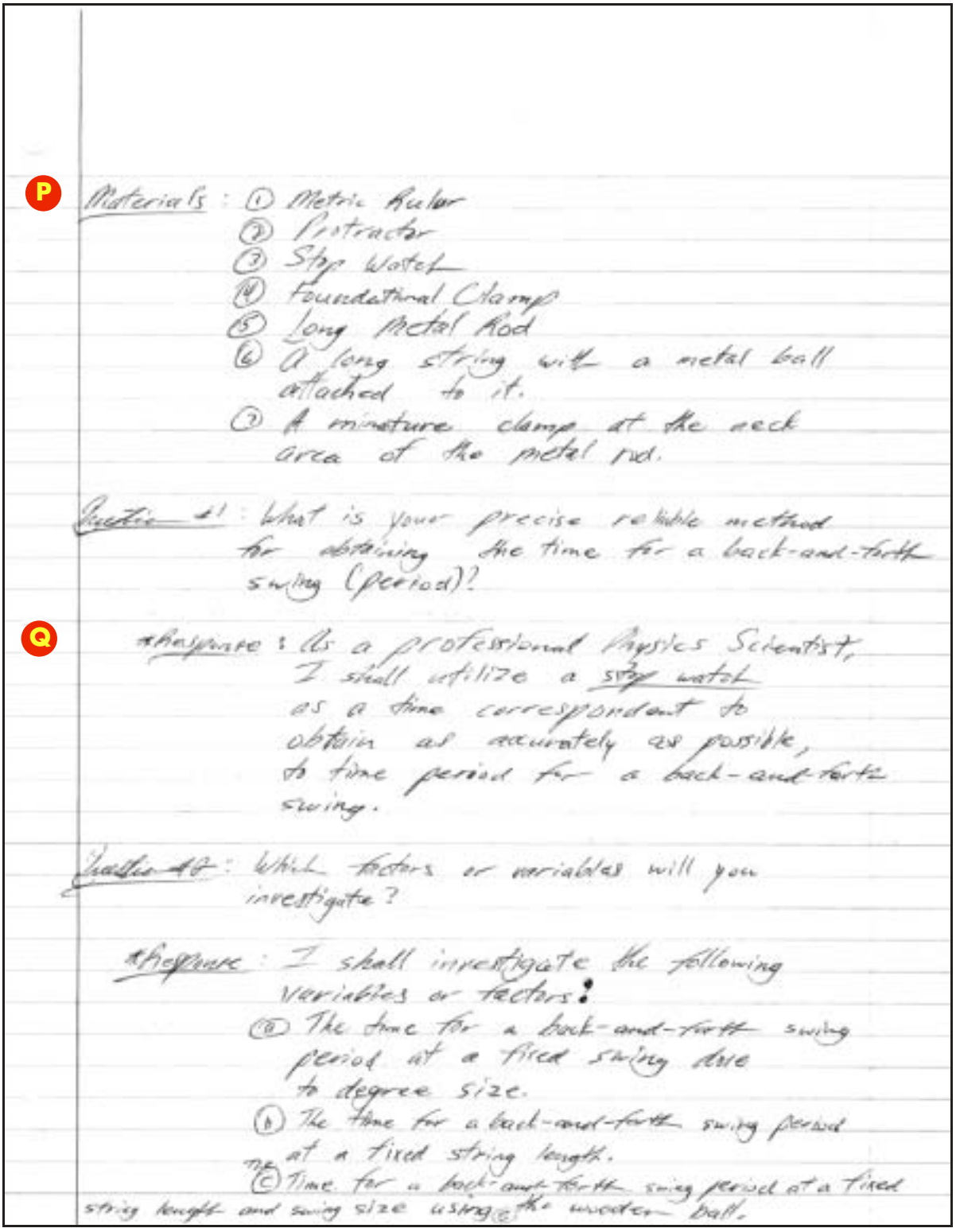
Basically, on behalf of the 2nd Part of Job #3, the Morgan Institute have reviewed my initial investigation of the unknown mechanical devices. They are especially interested in the hypothesis that the instruments were used as timing devices. In fact, a number of museum curators are interested in presenting these devices as precursors to modern clocks.

In order to put these devices on display, the Morgan Institute feels that the curators must be familiar with the factors that are important to the "clock-like" behavior of these devices.

In addition, the Morgan Institute has required me to design an investigation that supports the examination of all of the factors that might change the period of the pendulum. In my design, I shall make precise measurements, organize measurements into tables, and present graphs that make a case for the claim that the period changes the most by changing the length of the pendulum.

(4)

Student 1



P

Materials: ① Metric Ruler
② Protractor
③ Stop Watch
④ foundational Clamp
⑤ Long Metal Rod
⑥ A long string with a metal ball attached to it.
⑦ A miniature clamp at the neck area of the metal rod.

Question #1: What is your precise reliable method for obtaining the time for a back-and-forth swing (period)?

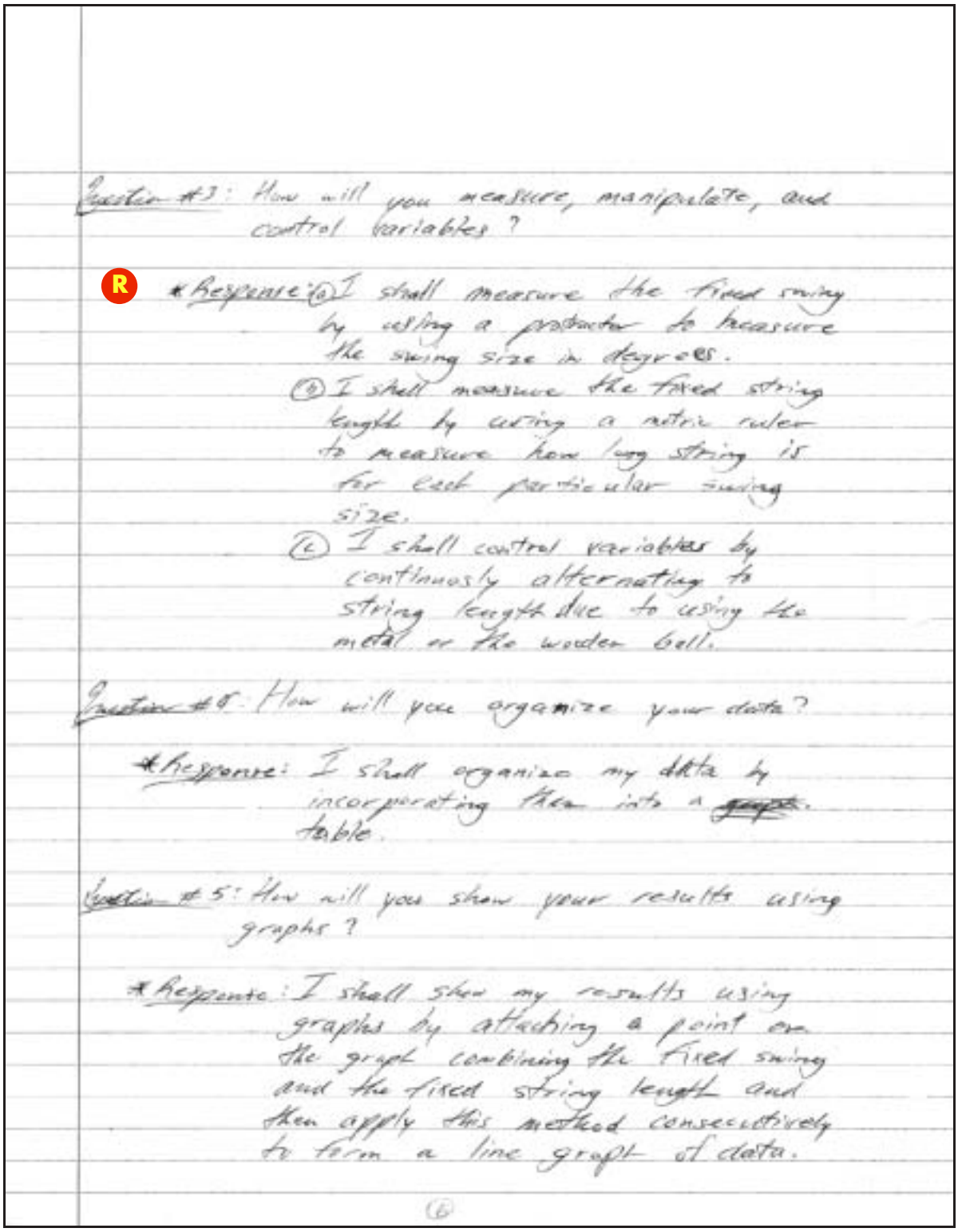
Q

*Response: As a professional Physics Scientist, I shall utilize a stop watch as a time correspondent to obtain as accurately as possible, the time period for a back-and-forth swing.

Question #2: Which factors or variables will you investigate?

*Response: I shall investigate the following variables or factors:
(a) The time for a back-and-forth swing period at a fixed swing degree to degree size.
(b) The time for a back-and-forth swing period at a fixed string length.
(c) Time for a back-and-forth swing period at a fixed string length and swing size using the wooden ball.

Student 1



Question #3: How will you measure, manipulate, and control variables?

R *Response: (a) I shall measure the fixed swing by using a protractor to measure the swing size in degrees.
(b) I shall measure the fixed string length by using a metric ruler to measure how long string is for each particular swing size.
(c) I shall control variables by continuosly alternating to string length due to using the metal or the wooden ball.

Question #4: How will you organize your data?

*Response: I shall organize my data by incorporating them into a ~~graph~~ table.

Question #5: How will you show your results using graphs?

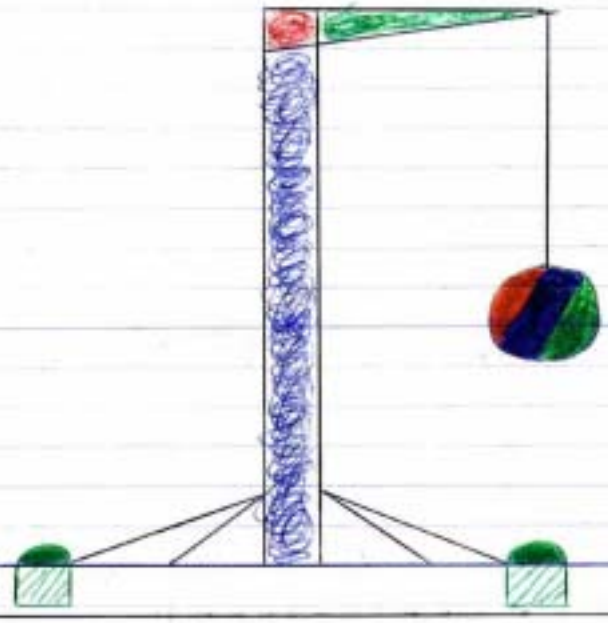
*Response: I shall show my results using graphs by attaching a point on the graph combining the fixed swing and the fixed string length and then apply this method consecutively to form a line graph of data.

(6)

Student 1

U

Diagram:



Experiment #1: Design an experiment to analyze the time it takes for a ball-and-~~for~~ swing period at a swing size of 20°, 40°, and 60° due to a string length of short and long.

T

Table for a Fixed Swing:

Ball Type	Swing Size	String Length	T 1st	2nd	3rd	Average
Metal	20°	Short	.36s	.39s	.39s	.38s
Metal	40°	Short	.52s	.45s	.46.	.48s
Metal	60°	Short	.52s	.55s	.62s	.56s
Metal	20°	Long	.87s	.73s	.81s	.80s
Metal	40°	Long	.98s	.91s	.97	.95s
Metal	60°	Long	.94s	.91s	1.10s	.98s
Wood	60°	Short	.64s	.67s	.57s	.61s
Wood	60°	Long	1.02s	1.13s	1.13s	1.09s

(1)

Student 1

Experiment #2: Design an experiment to analyze the time it takes for a back-and-forth swing period at a string length of 20 cm, 40 cm, 60 cm due to swing size of Big or Small

Table for a fixed String Length:

Ball Type	String Length	Swing Size	1st	2nd	3rd	Average
Metal	20 cm	small	.75s	.62s	8/s	.64s
Metal	40 cm	small	.86s	.92s	.91s	.90s
Metal	60 cm	small	.94s	.96s	.88s	.94s
Metal	20 cm	Big	.72s	.73s	.68s	.71s
Metal	40 cm	Big	1.10s	1.15s	1.20s	1.15s
Metal	60 cm	Big	1.24s	1.29s	1.31s	1.28s
Wood	60 cm	small	1.10s	1.10s	1.16s	1.12s
Wood	60 cm	Big	1.49s	1.52s	1.50s	1.50s

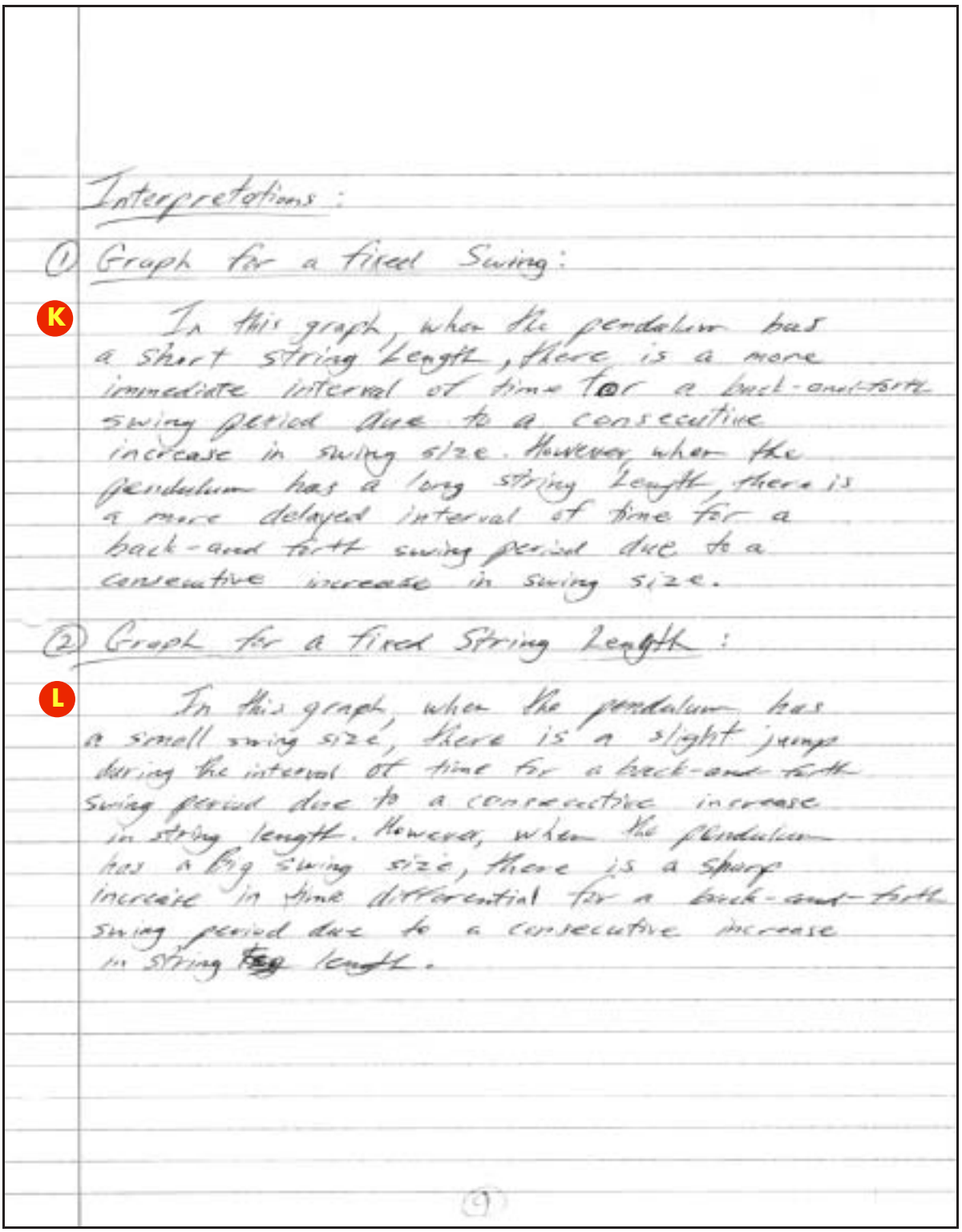
Experiment #3 - Design an experiment to analyze the time it takes for a back-and-forth swing period at a fixed string length and swing size.

Table for a Fixed String Length combined with a fixed Swing Size:

Ball Type	String Length	Swing Size	1st	2nd	3rd	Average
Metal	20 cm	20°	.63s	.71s	.68s	.67
Metal	20 cm	40°	.63s	.73s	.67s	.68s
Metal	20 cm	60°	.63s	.72.	.64s	.66s
Metal	40 cm	20°	.84s	.80s	.82s	.84s
Metal	40 cm	40°	.90s	1.15s	.95s	1.00s
Metal	40 cm	60°	.89s	1.16s	.98s	1.01s
Metal	60 cm	20°	.96s	1.28s	.80s	1.01s
Metal	60 cm	40°	.96s	.95s	.96s	.96s
Metal	60 cm	60°	.96s	.98s	.97s	.97s
Wood	60 cm	60°	1.12s	1.50s	1.09s	1.24s

(5)

Student 1



Interpretations:

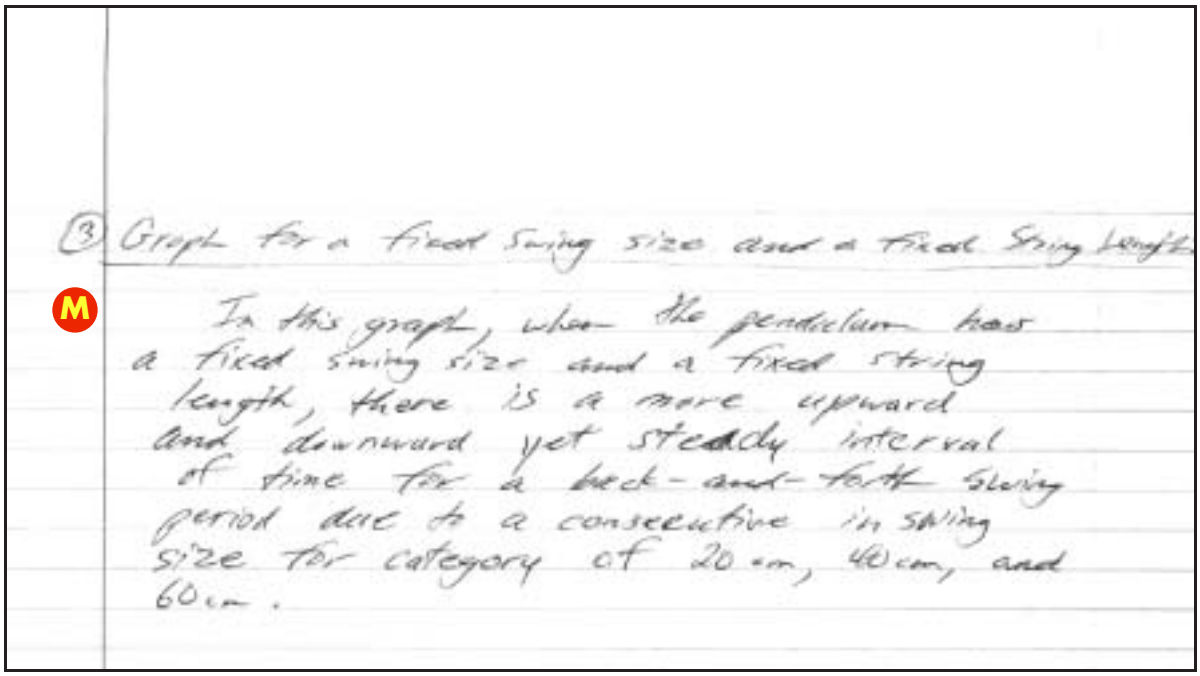
(1) Graph for a fixed Swing:

K In this graph, when the pendulum has a short string length, there is a more immediate interval of time for a back-and-forth swing period due to a consecutive increase in swing size. However when the pendulum has a long string length, there is a more delayed interval of time for a back-and-forth swing period due to a consecutive increase in swing size.

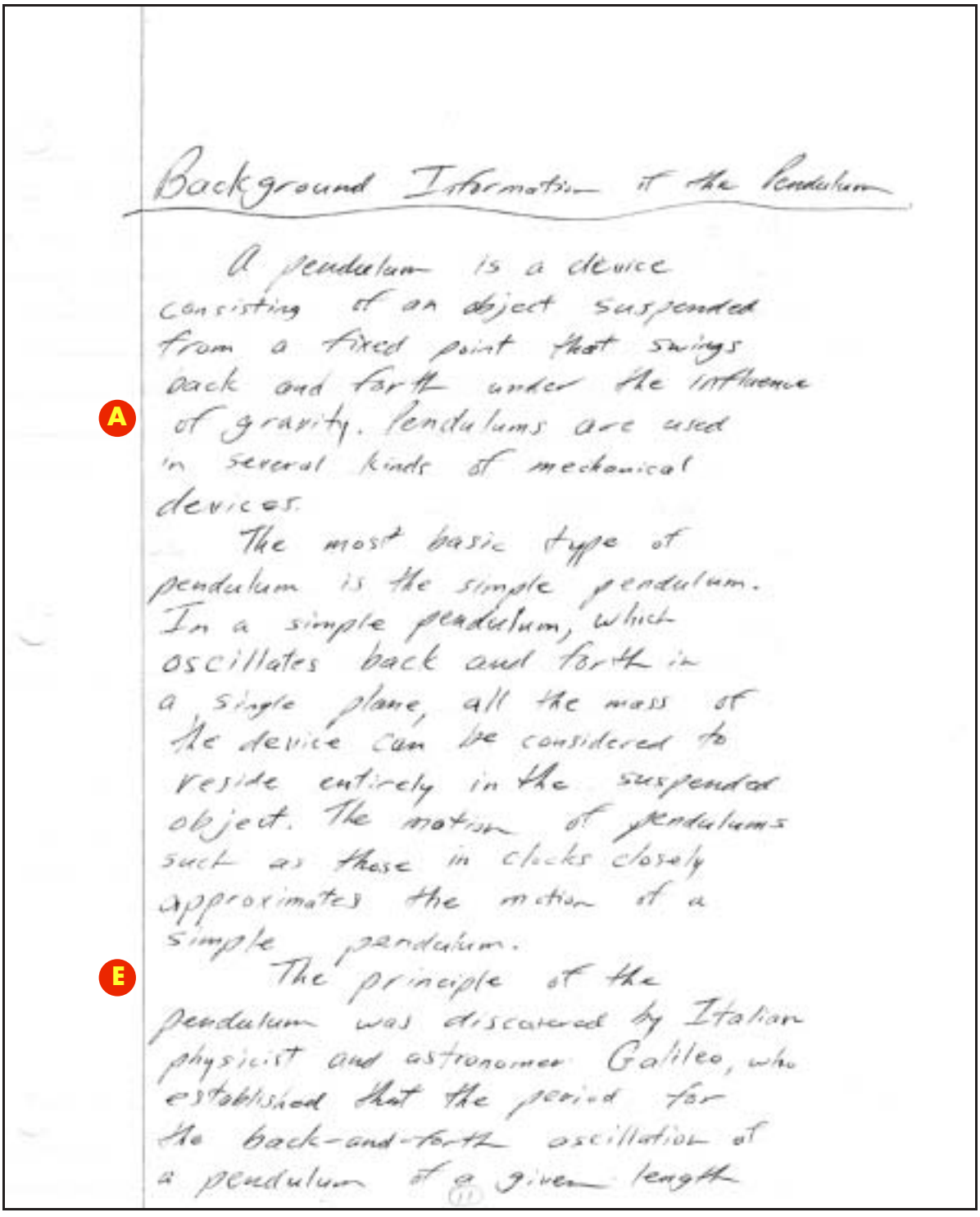
(2) Graph for a fixed String length:

L In this graph, when the pendulum has a small swing size, there is a slight jump during the interval of time for a back-and-forth swing period due to a consecutive increase in string length. However, when the pendulum has a big swing size, there is a sharp increase in time differential for a back-and-forth swing period due to a consecutive increase in string ~~leg~~ length.

Student 1


(3) Graph for a fixed swing size and a fixed string length
M
In this graph, when the pendulum has a fixed swing size and a fixed string length, there is a more upward and downward yet steaddy interval of time for a back-and-forth swing period due to a consecutive in swing size for category of 20 cm, 40 cm, and 60 cm.

Student 1



Background Information of the Pendulum

A pendulum is a device consisting of an object suspended from a fixed point that swings back and forth under the influence of gravity. Pendulums are used in several kinds of mechanical devices.

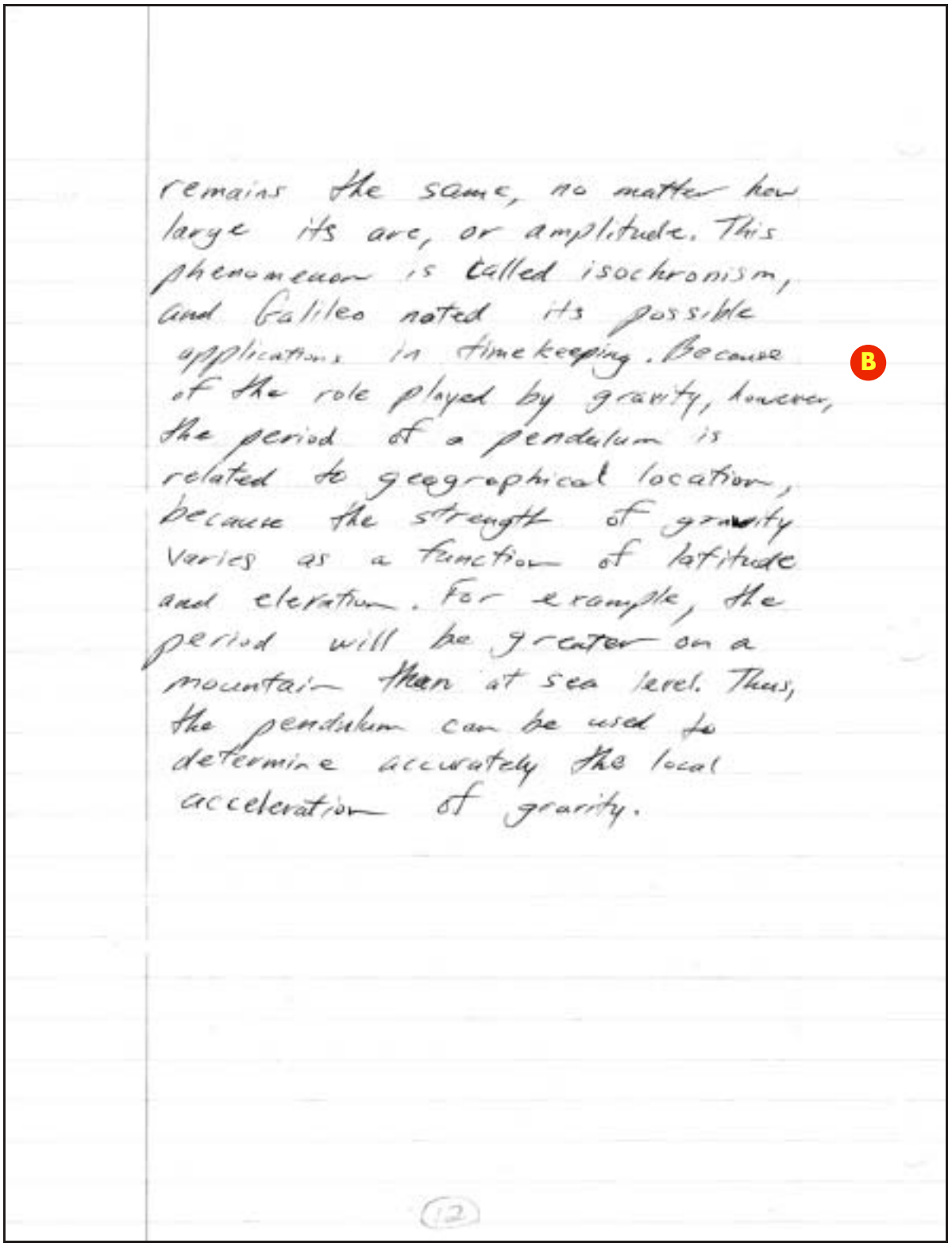
A

The most basic type of pendulum is the simple pendulum. In a simple pendulum, which oscillates back and forth in a single plane, all the mass of the device can be considered to reside entirely in the suspended object. The motion of pendulums such as those in clocks closely approximates the motion of a simple pendulum.

E

The principle of the pendulum was discovered by Italian physicist and astronomer Galileo, who established that the period for the back-and-forth oscillation of a pendulum of a given length

Student 1

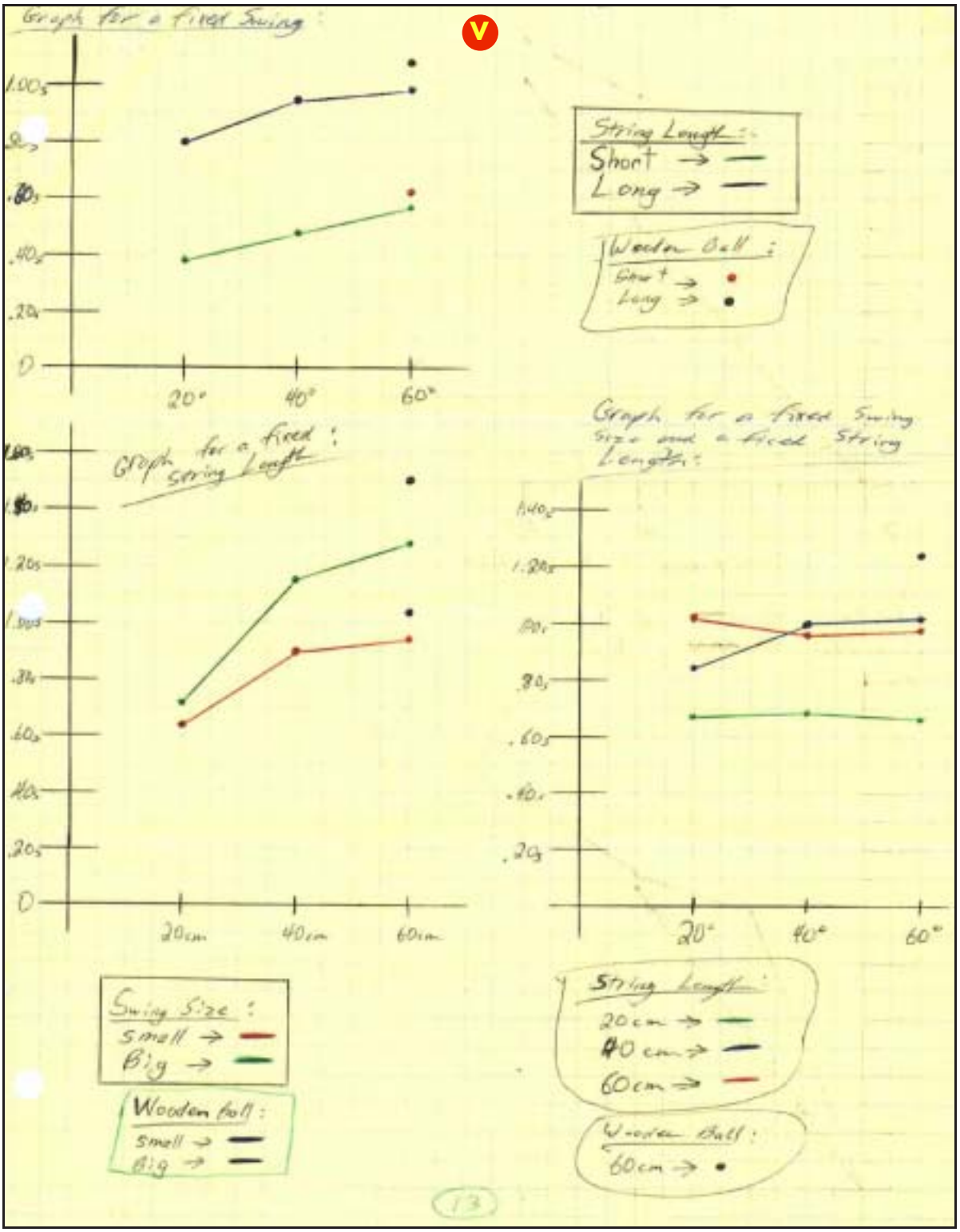


remains the same, no matter how large its arc, or amplitude. This phenomenon is called isochronism, and Galileo noted its possible applications in timekeeping. Because of the role played by gravity, however, the period of a pendulum is related to geographical location, because the strength of gravity varies as a function of latitude and elevation. For example, the period will be greater on a mountain than at sea level. Thus, the pendulum can be used to determine accurately the local acceleration of gravity.

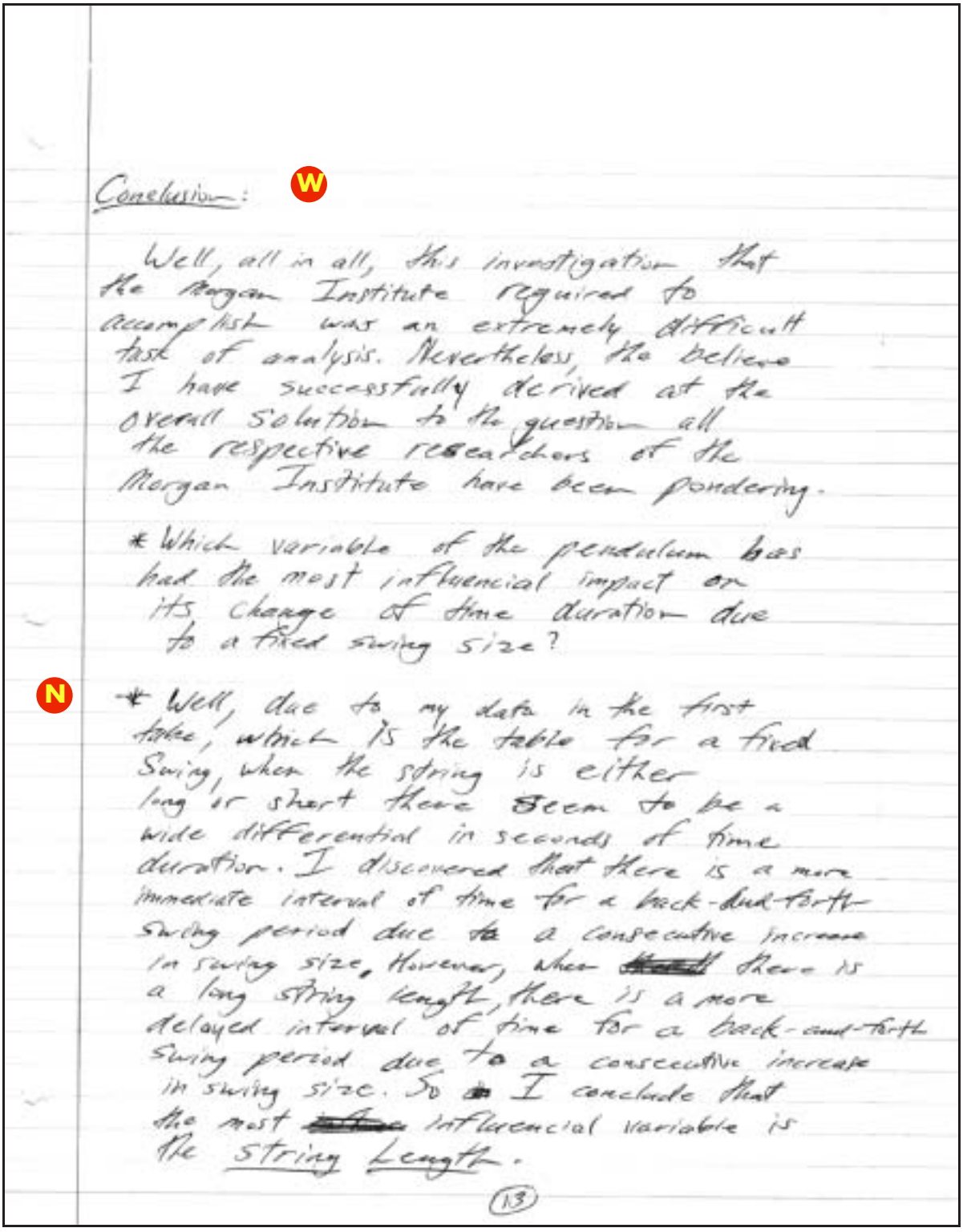
B

(12)

Student 1


Graph for a fixed Swing:
String Length:
Short →
Long →
Wooden Ball:
Short →
Long →
20°
40°
60°
Graph for a fixed String Length:
20cm
40cm
60cm
Graph for a fixed Swing size and a fixed String Length:
20°
40°
60°
Swing Size:
Small →
Big →
Wooden Ball:
Small →
Big →
String Length:
20cm →
40cm →
60cm →
Wooden Ball:
60cm →
13

Student 1



Conclusion: W

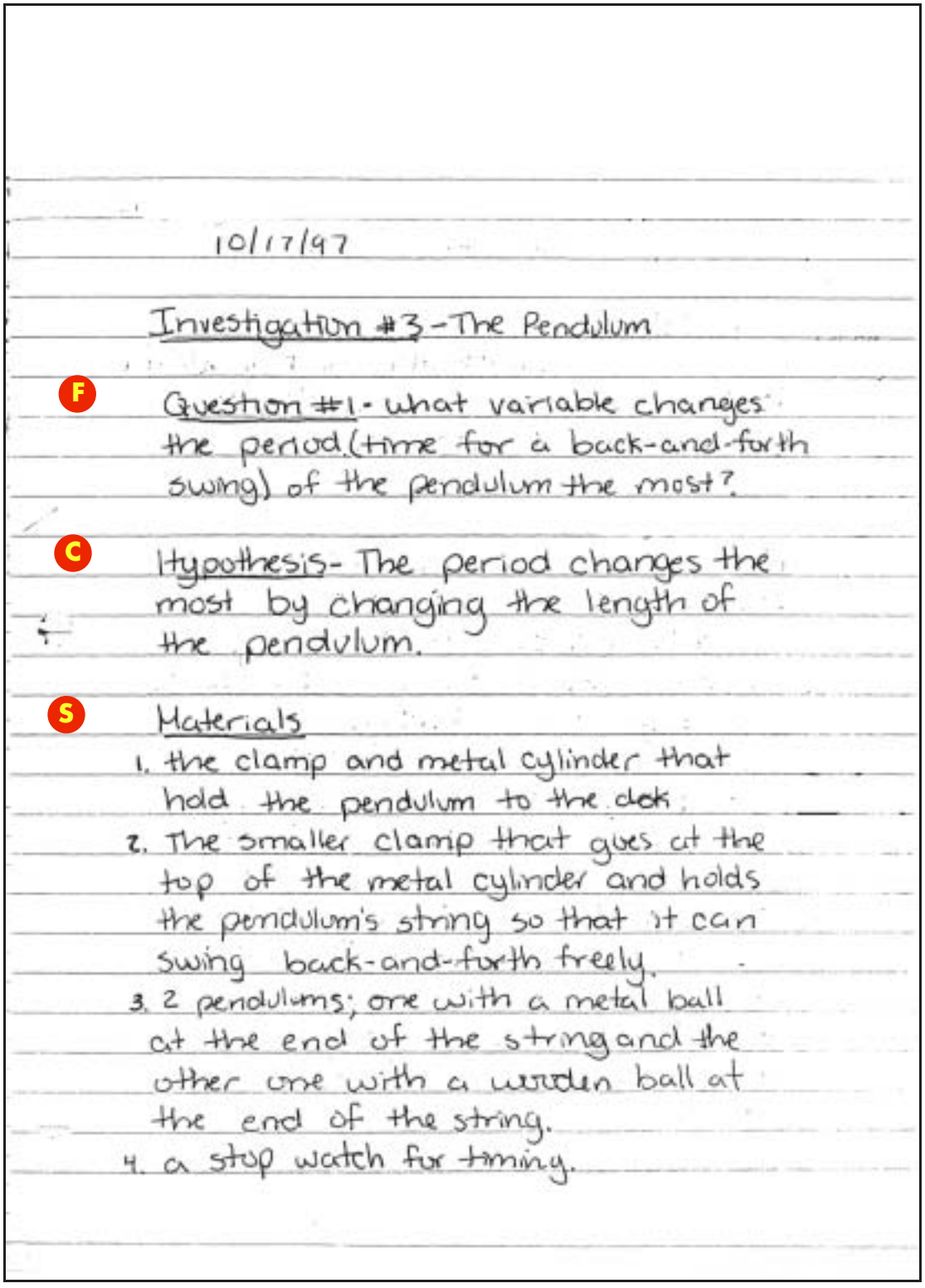
Well, all in all, this investigation that the Morgan Institute required to accomplish was an extremely difficult task of analysis. Nevertheless, I believe I have successfully derived at the overall solution to the question all the respective researchers of the Morgan Institute have been pondering.

* Which variable of the pendulum has had the most influencial impact on its change of time duration due to a fixed swing size?

N * Well, due to my data in the first table, which is the table for a fixed swing, when the string is either long or short there seem to be a wide differential in seconds of time duration. I discovered that there is a more immediate interval of time for a back-and-forth swing period due to a consecutive increase in swing size, However, when [redacted] there is a long string length, there is a more delayed interval of time for a back-and-forth swing period due to a consecutive increase in swing size. So I conclude that the most [redacted] influencial variable is the String Length.

(13)

Student 2



10/17/97

Investigation #3 - The Pendulum

F Question #1 - what variable changes the period (time for a back-and-forth swing) of the pendulum the most?

C Hypothesis - The period changes the most by changing the length of the pendulum.

S Materials

1. the clamp and metal cylinder that hold the pendulum to the desk
2. The smaller clamp that goes at the top of the metal cylinder and holds the pendulum's string so that it can swing back-and-forth freely.
3. 2 pendulums; one with a metal ball at the end of the string and the other one with a wooden ball at the end of the string.
4. a stop watch for timing.

Student 2

2

5. a protractor for measuring the swing angle.
6. a ruler for measuring length.

Observations

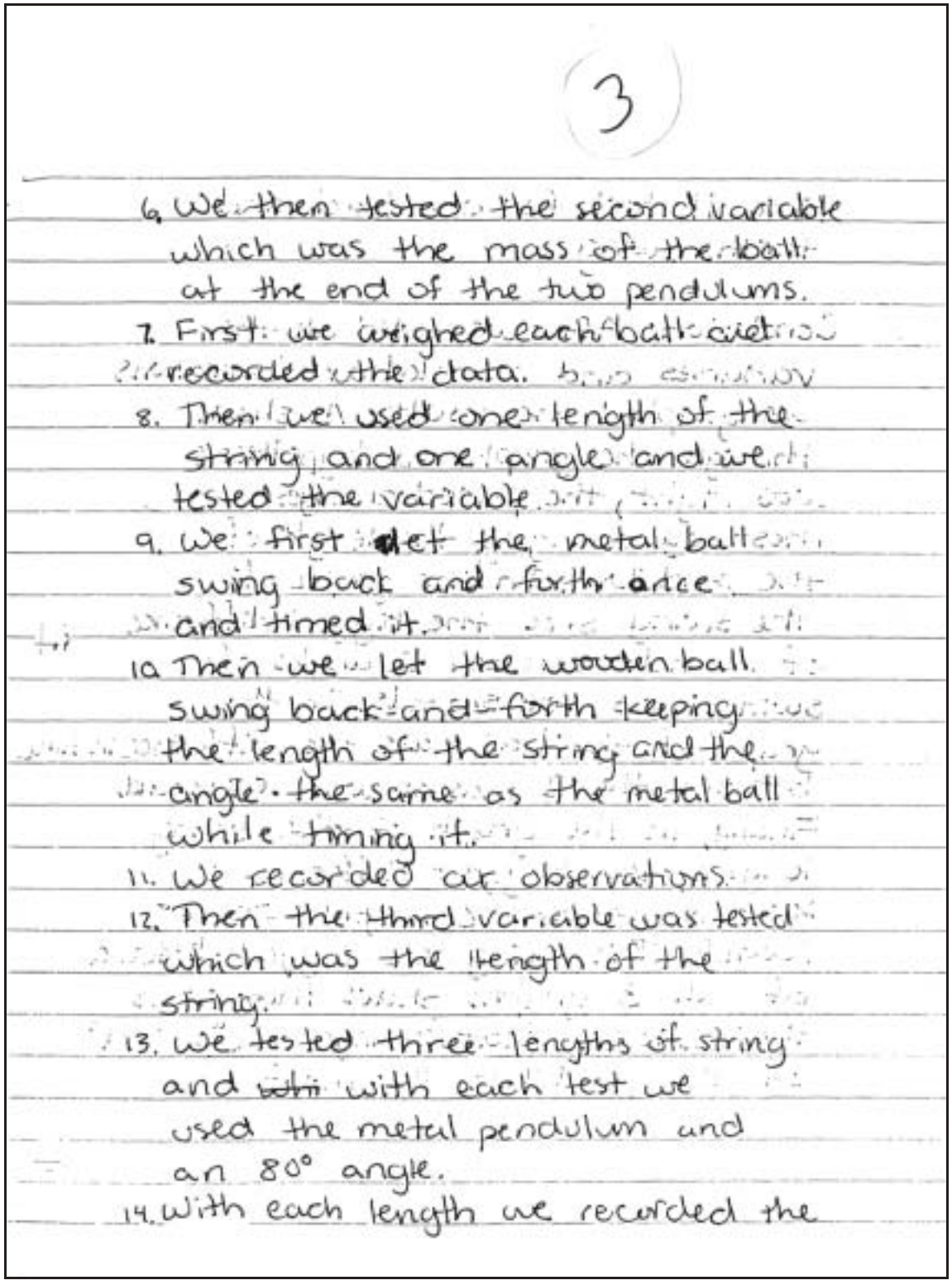
The metal ball of the first pendulum is heavier than the wooden ball of the second pendulum.

G

Procedures

1. First we set up the pendulum stand.
2. Then we tested the first variable which is the size of the swing.
3. We used the protractor to measure the angle of the swing.
4. We held the string at 70° on the protractor, and let it swing back-and-forth once while timing it, and recorded our observations.
5. We did the same thing with the string held at 50° and then let go and with string held at 30° and then let go. For each one we recorded the time it took for one swing.

Student 2



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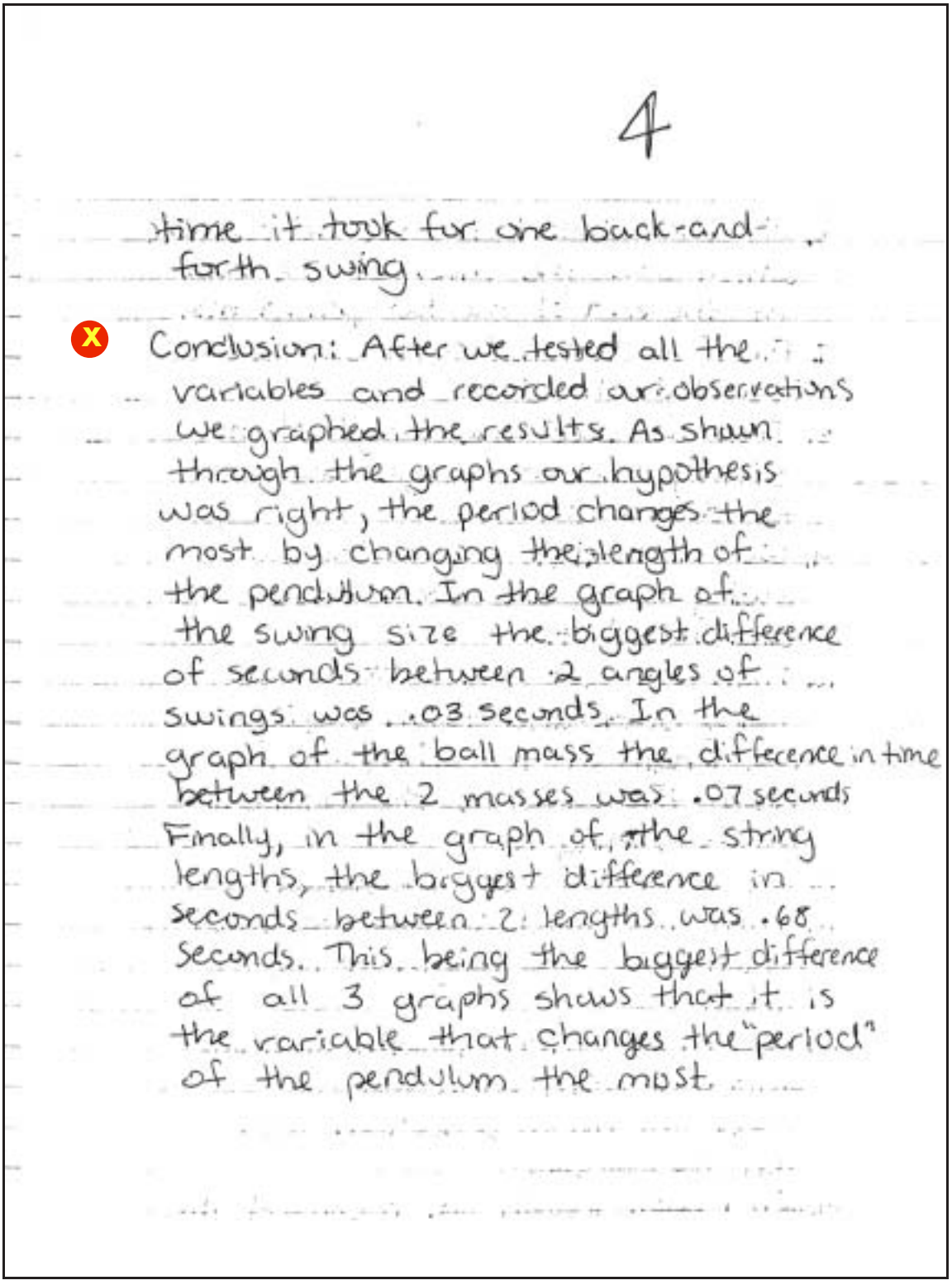
6. We then tested the second variable which was the mass of the ball at the end of the two pendulums.
7. First we weighed each ball and recorded the data.
8. Then we used one length of the string and one angle and we tested the variable.
9. We first let the metal ball swing back and forth once and timed it.
10. Then we let the wooden ball swing back and forth keeping the length of the string and the angle the same as the metal ball while timing it.
11. We recorded our observations.
12. Then the third variable was tested which was the length of the string.
13. We tested three lengths of string and ~~both~~ with each test we used the metal pendulum and an 80° angle.
14. With each length we recorded the

Student 2



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time it took for one back-and-forth swing.

X Conclusion: After we tested all the variables and recorded our observations we graphed the results. As shown through the graphs our hypothesis was right, the period changes the most by changing the length of the pendulum. In the graph of the swing size the biggest difference of seconds between 2 angles of swings was .03 seconds. In the graph of the ball mass the difference in time between the 2 masses was .07 seconds Finally, in the graph of the string lengths, the biggest difference in seconds between 2 lengths was .68 seconds. This being the biggest difference of all 3 graphs shows that it is the variable that changes the "period" of the pendulum the most.

Student 2

H Evidence:

Variable #1: Size of swing

String length - 25 cm, Used-metal ball - 66.2 grams

Size of swing	1st trial	2nd trial	3rd trial	Average
70°	.88s	.84s	.75s	.82s
50°	.81s	.84s	.84s	.83s
30°	.82s	.75s	.82s	.80s

Variable #2: Mass of ball

String length - 15 cm, angle of swing - 60°

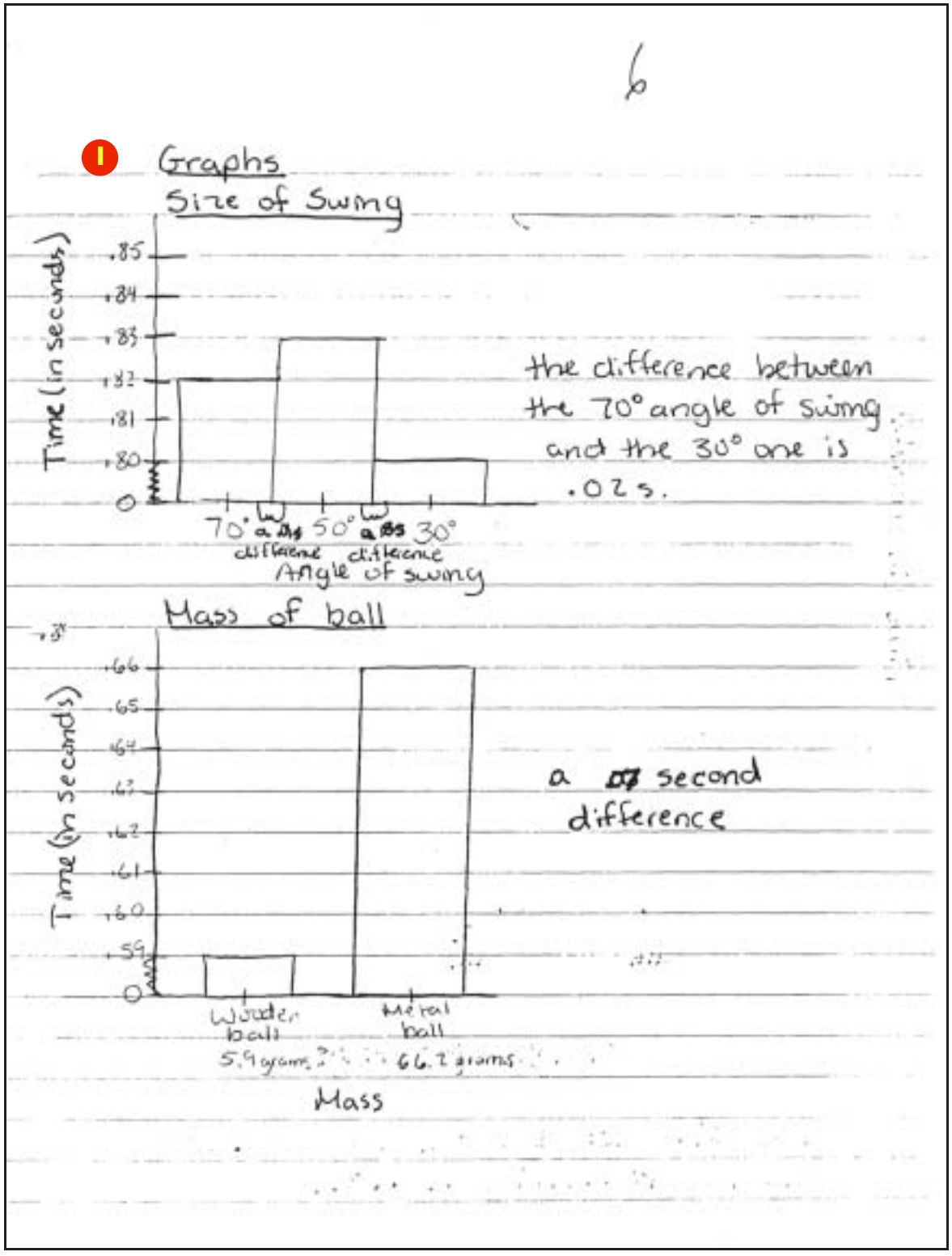
Mass of ball	1st trial	2nd trial	3rd trial	Average
Wood (5.9 grams)	.62s	.56s	.59s	.59s
metal (66.2 grams)	.75s	.63s	.59s	.66s

Variable #3: length of string

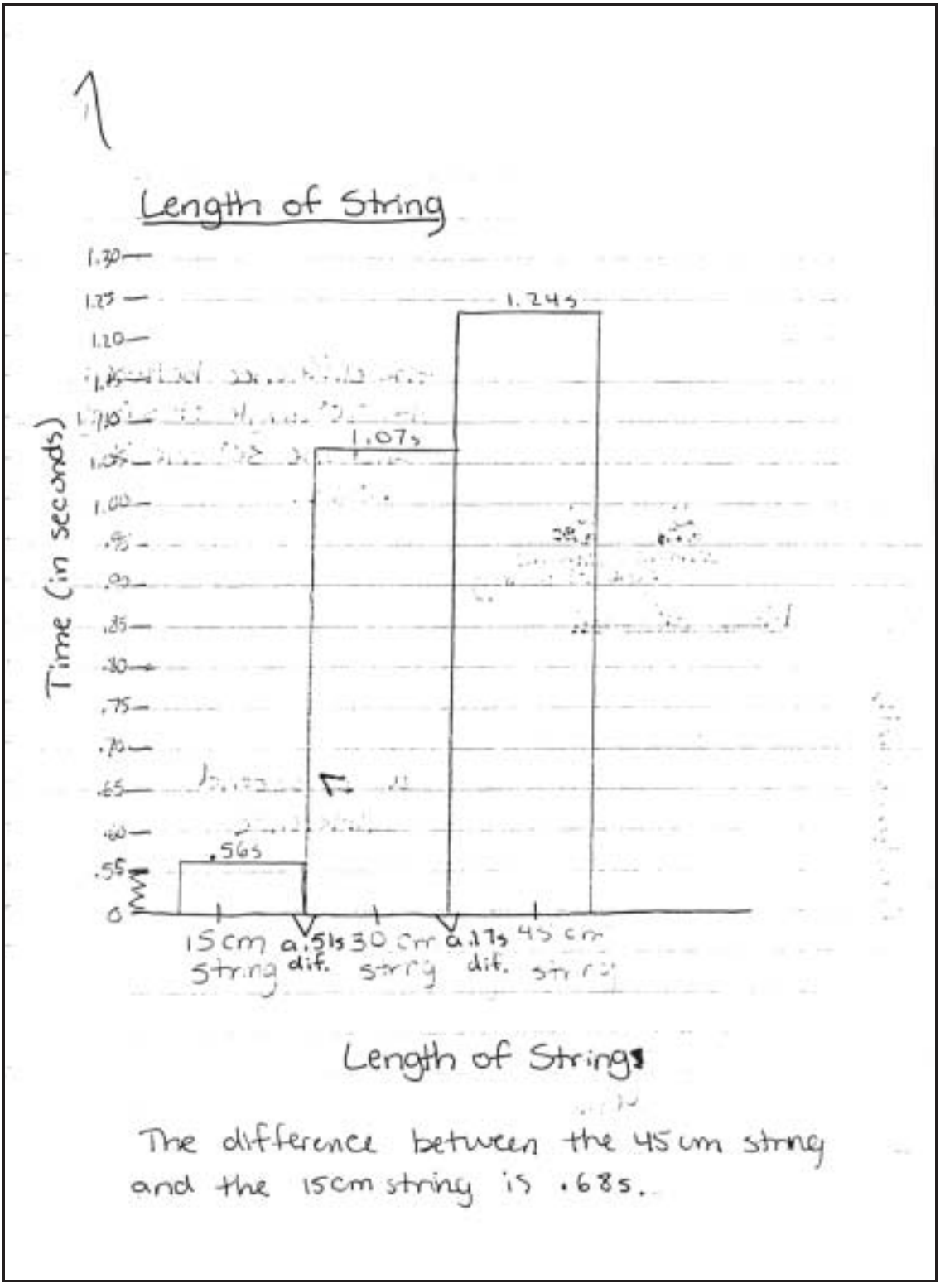
angle of swing - 80°, Used - metal ball - 66.2 grams

Length of string	1st trial	2nd trial	3rd trial	Average
15 cm	.54s	.59s	.56s	.56s
30 cm	1.06s	1.12s	1.03s	1.07s
45 cm	1.25s	1.18s	1.28s	1.24s

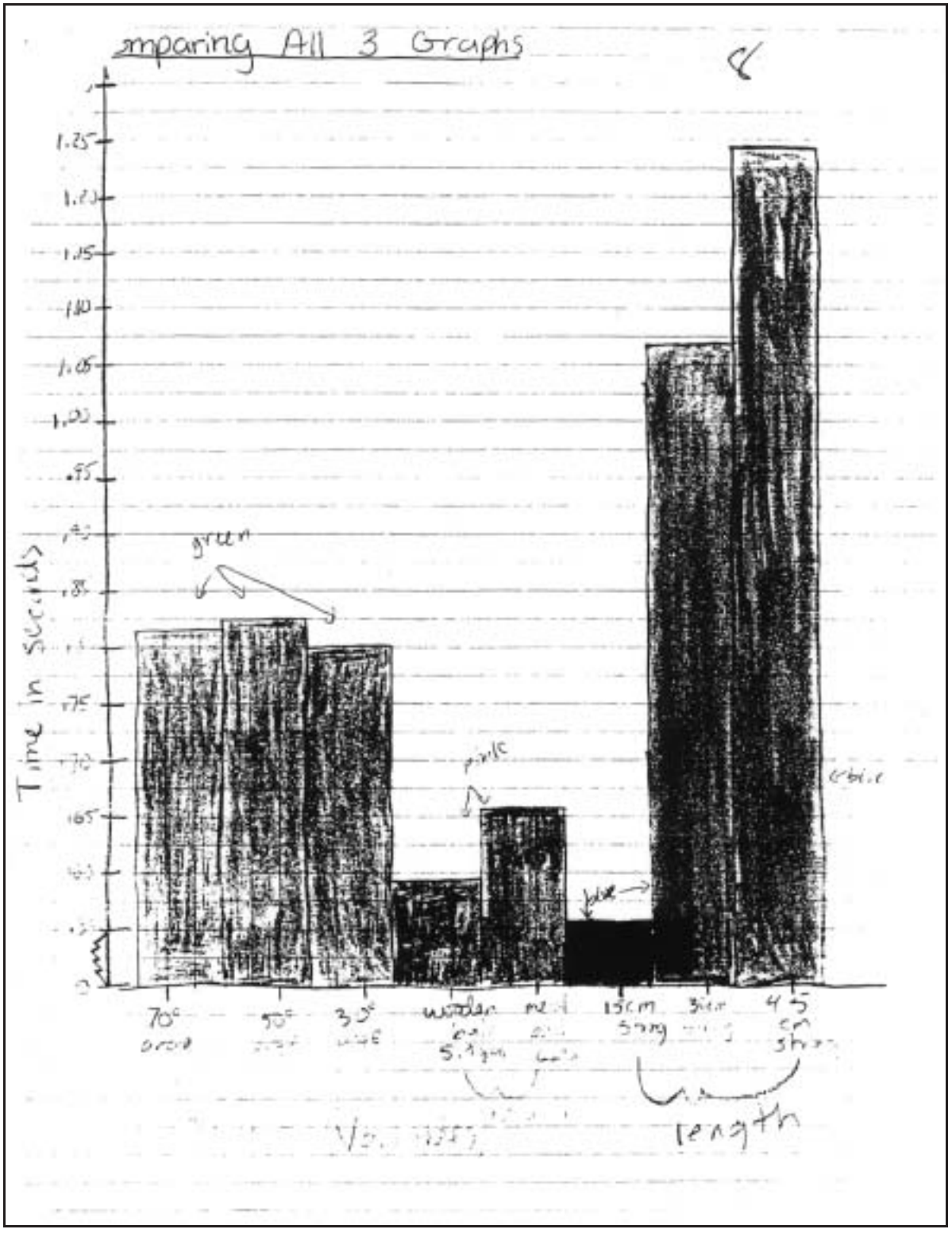
Student 2


6
I
Graphs
Size of Swing
Time (in seconds)
.85
.84
.83
.82
.81
.80
0
70° a
difference
50° a
difference
30°
Angle of swing
the difference between the 70° angle of swing and the 30° one is .02 s.
Mass of ball
Time (in seconds)
.66
.65
.64
.63
.62
.61
.60
.59
0
Wooden ball
5.9 grams
Metal ball
66.2 grams
Mass
a .02 second difference

Student 2


Length of String
Time (in seconds)
1.30
1.25
1.20
1.24s
1.07s
.95
.90
.85
.80
.75
.70
.65
.60
.55
.56s
0
15 cm String
.51s dif.
30 cm string
.17s dif.
45 cm
Length of String
The difference between the 45 cm string and the 15cm string is .68s.

Student 2



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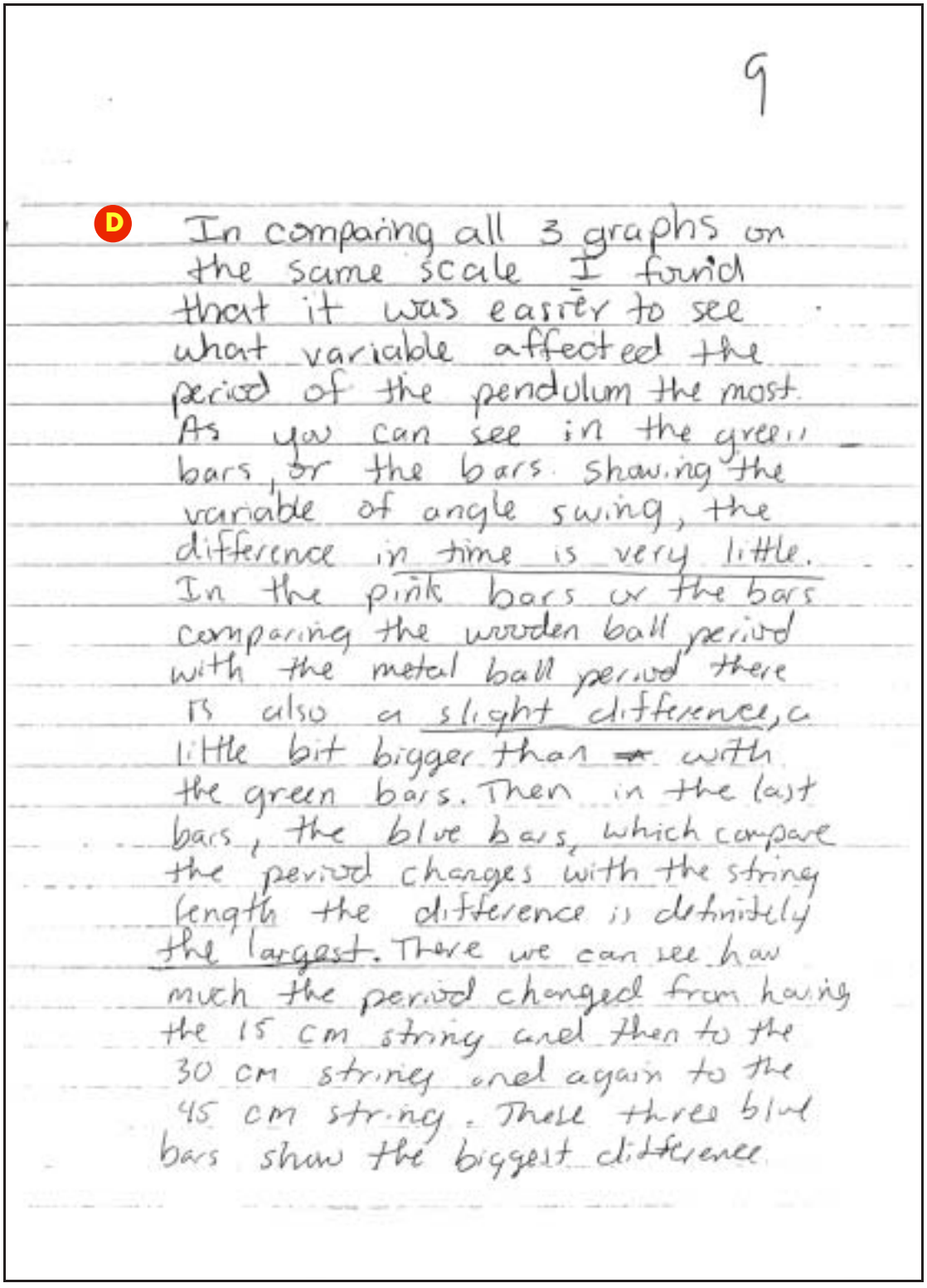

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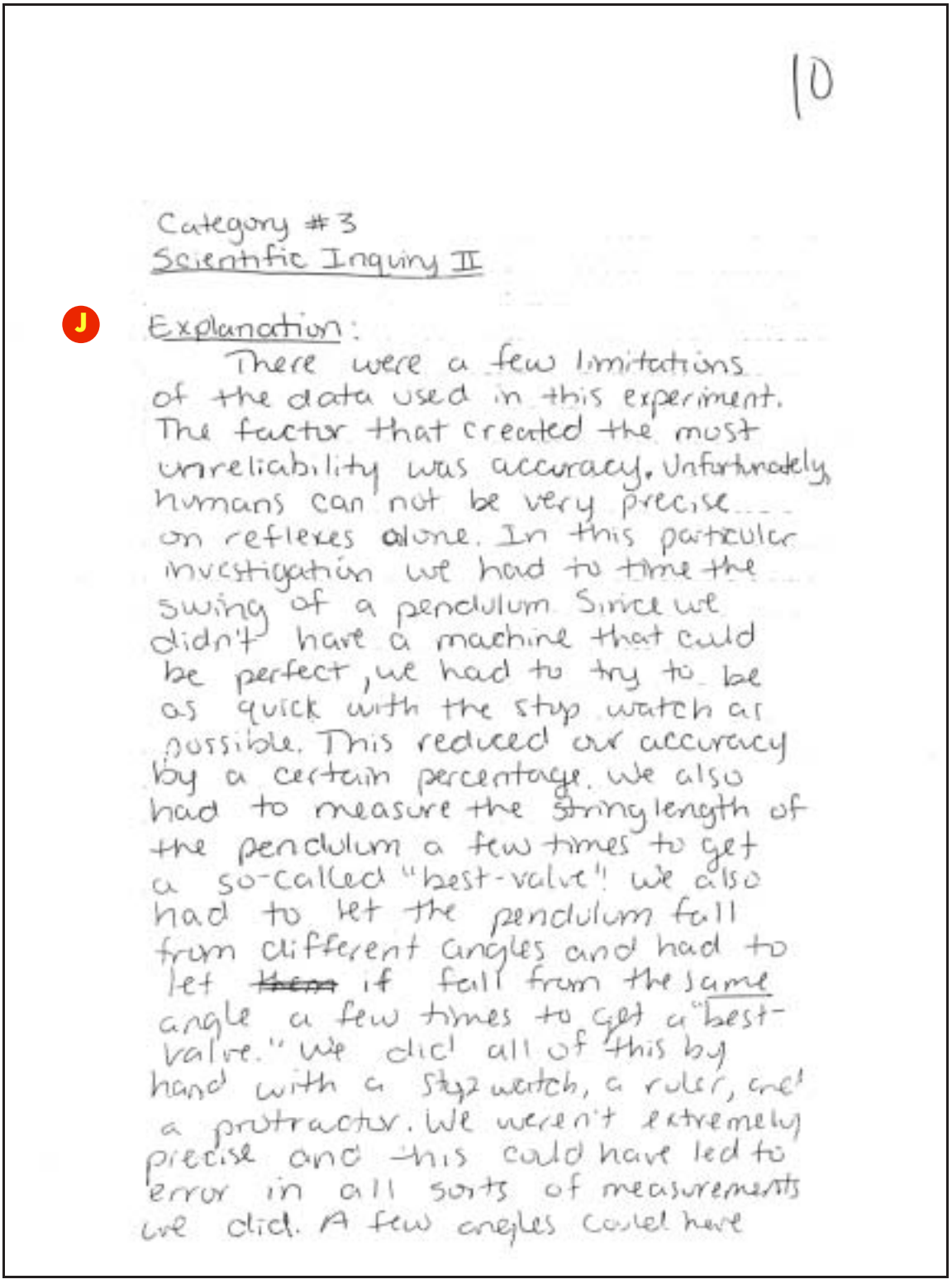
D In comparing all 3 graphs on the same scale I found that it was easier to see what variable affected the period of the pendulum the most. As you can see in the green bars, or the bars showing the variable of angle swing, the difference in time is very little. In the pink bars or the bars comparing the wooden ball period with the metal ball period there is also a slight difference, a little bit bigger than with the green bars. Then in the last bars, the blue bars, which compare the period changes with the string length the difference is definitely the largest. There we can see how much the period changed from having the 15 cm string and then to the 30 cm string and again to the 45 cm string. These three blue bars show the biggest difference

Student 2



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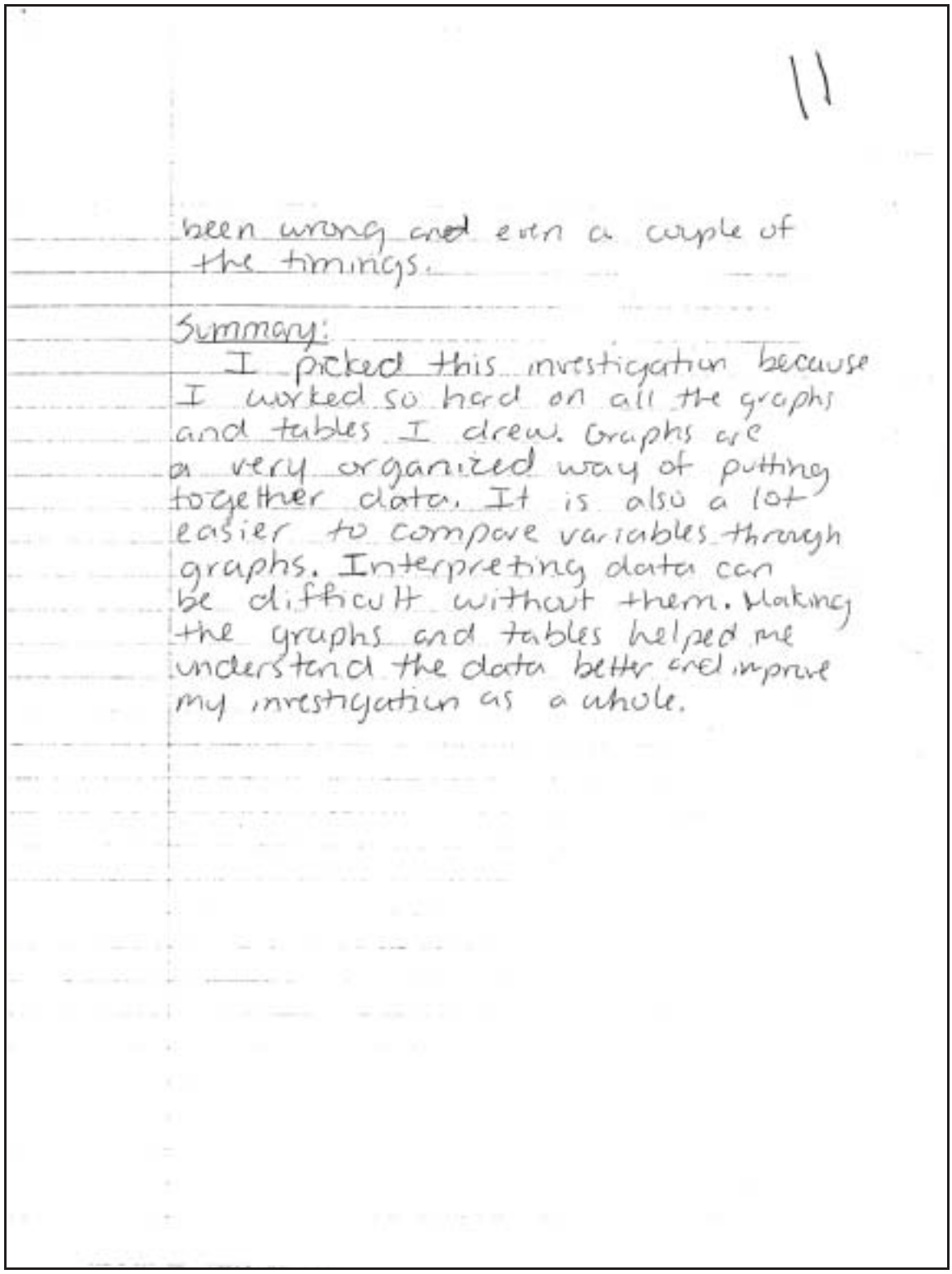
Category #3
Scientific Inquiry II

J

Explanation:

There were a few limitations of the data used in this experiment. The factor that created the most unreliability was accuracy. Unfortunately, humans can not be very precise... on reflexes alone. In this particular investigation we had to time the swing of a pendulum. Since we didn't have a machine that could be perfect, we had to try to be as quick with the stop watch as possible. This reduced our accuracy by a certain percentage. We also had to measure the ~~string~~ length of the pendulum a few times to get a so-called "best-value"! We also had to let the pendulum fall from different angles and had to let ~~them~~ it fall from the same angle a few times to get a "best-value." We did all of this by hand with a stop watch, a ruler, and a protractor. We weren't extremely precise and this could have led to error in all sorts of measurements we did. A few angles could have

Student 2



11

been wrong and even a couple of the timings.

Summary:

I picked this investigation because I worked so hard on all the graphs and tables I drew. Graphs are a very organized way of putting together data. It is also a lot easier to compare variables through graphs. Interpreting data can be difficult without them. Making the graphs and tables helped me understand the data better and improve my investigation as a whole.