

SI Physics - Full Discipline Demo

Hypotheses, Laws, and Theories

Final Report - Answer Guide

Institution	Science Interactive University
Session	SI Physics - Full Discipline Demo
Course	SI Physics - Full Discipline Demo
Instructor	Sales SI Demo

Test Your Knowledge

Order the steps of the scientific method.

≡ Analyze data and draw conclusions.

1 **Correct answer:** Make an observation.

≡ Ask a question and conduct background research on what is already known.

2 **Correct answer:** Ask a question and conduct background research on what is already known.

≡ Communicate the results.

3 **Correct answer:** Formulate a hypothesis.

≡ Formulate a hypothesis.

4 **Correct answer:** Test the hypothesis through experimentation.

≡ Make an observation.

5 **Correct answer:** Analyze data and draw conclusions.

≡ Test the hypothesis through experimentation.

6 **Correct answer:** Verify the conclusions through peer review.

≡ Verify the conclusions through peer review.

7 **Correct answer:** Communicate the results.

Select the appropriate definition and example for each term.

Definition

⌘

A group that does not undergo manipulated conditions.

⌘

A proposed explanation for a phenomenon.

⌘

Conditions that are manipulated by the scientist through the course of the investigation.

⌘

Outcomes or observed factors that are likely to change.

Example

⌘

A new weight loss drug will produce an average of 20% weight loss in test subjects.

⌘ Amount of weight lost.

⌘

Different test subjects and/or different drug doses.

⌘

Providing a placebo (sugar pill) instead of the drug.

Term	Definition	Example
Hypothesis	1	2
Independent variable	3	4
Dependent variable	5	6
Control Group	7	8

Correct answers:

- 1 A proposed explanation for a phenomenon.
 - 2
A new weight loss drug will produce an average of 20% weight loss in test subjects.
 - 3
Conditions that are manipulated by the scientist through the course of the investigation.
 - 4 Different test subjects and/or different drug doses.
 - 5 Outcomes or observed factors that are likely to change.
 - 6 Amount of weight lost.
 - 7 A group that does not undergo manipulated conditions.
 - 8 Providing a placebo (sugar pill) instead of the drug.
-

Categorize each statement as applying to a law or a theory.

Law	Theory
1	2

⚡ A description about how an observed phenomenon occurs under specific conditions.

⚡ A well-substantiated explanation acquired through the scientific method.

⚡ $F_g = G(m_1m_2/r^2)$

⚡ One example is the extensive work clarifying gravity's role in the universe.

Correct answers:

1

A description about how an observed phenomenon occurs under specific conditions.

$$F_g = G(m_1m_2/r^2)$$

2

A well-substantiated explanation acquired through the scientific method.

One example is the extensive work clarifying gravity's role in the universe.

Exploration

Science shapes ____.

- ☐ conservation of our planet
- ☐ new inventions and technologies
- ☐ our personal decisions
- ☐ policies and regulations
- ☐ All of the above



The scientific method is a process for explaining natural phenomena in a way that ____.

- ☐ follows a rigid set of steps
 - ☒ controls for bias and opinion ✓
 - ☐ makes future research unnecessary
 - ☐ All of the above
-

The process for publication, called peer review, is rigorous and the study is reviewed by multiple experts in the field.

- ☒ True ✓
 - ☐ False
-

A(n) ____ is a proposed explanation for a phenomenon.

- ☐ observation
 - ☐ question
 - ☒ hypothesis ✓
 - ☐ experiment
-

A hypothesis, a proposed explanation of a phenomenon, can often be tested with experiments.

- ☒ True ✓
 - ☐ False
-

Scientists use data to draw conclusions about whether a hypothesis is ____ or ____.

- ☒ supported; rejected ✓
- ☐ proven true; proven untrue
- ☐ refutable; discredited
- ☐ All of the above

A scientific law is an explanation of why phenomena occur in nature, while a scientific theory is more of a description.

☐ True

☒ False



___ are expressed in mathematical terms and can be used to predict events and advance technology.

☒ Laws

☐ Theories

☐ Both laws and theories



Exercise 1

What step(s) of the scientific method is/are missing from Data Table 1? Describe each and propose a way that they might be fulfilled in the scenario.

Peer review verification: John might have invited other scientists to review his work or collaborate with their own experiments.
Communicate results: John might communicate with the community and the local authorities about his findings.

What were the independent and dependent variables in the narrative? Explain your answer.

Students should identify removing the pump as the experiment in Data Table 1. The availability of water (presence of the pump) is the independent variable; it is manipulated by the scientist. Contraction of the disease is the dependent variable because it is the outcome based on the manipulation.

Was John's hypothesis supported or rejected? Explain why.

John's hypothesis that the illness was waterborne was supported. When the source of water was removed, disease incidence reduced.

John Snow (1813-1858) is considered a father of modern epidemiology, the study of disease. Snow's conclusion that the disease cholera was transmitted via sewage-polluted sections of the River Thames was considered a radical discovery in the 1850s. Snow used collected data, statistical analyses, and other methods such as mapping to convince the local population that contracting cholera was related to the location of a water pump.

a) What is the miasma theory and during what years was it accepted? How did Snow's work refute the miasma theory? Use a textbook or reliable Internet sources as needed.

b) What is the germ theory and during what years was it accepted? How did Snow's work support what would later become the germ theory? Use a textbook or reliable Internet sources as needed.

a) The miasma theory was accepted from ancient times to the mid to late 1800s; it postulated that diseases such as cholera and the bubonic plague resulted from "bad air," the source of which was rotting/ decaying matter. Snow's hypothesis differed from the theory of the time because he postulated that diseases could be carried by water.

b) The germ theory was proposed in the 1550s but did not receive recognition until the mid to late 1800s; it is still the prevailing theory on disease transmission. The germ theory states that microorganisms are pathogens that cause disease. Although technology of the time did not allow Snow to see microorganisms in the water, we now know that cholera is caused by *Vibrio cholera*, a bacteria common in waters near areas with poor sanitation standards.

Data Table 1: The Scientific Method: Steps and Examples
(SAMPLE ANSWER BELOW)

Step of the Scientific Method	Example(s) from the Narrative
Observation	People are becoming ill within a geographic area.
Question	Why are people becoming ill? Are people becoming ill because of the local water?
Hypotheses	The illness is waterborne and people are contracting the disease from the local water source.

Experiment	Remove the water source and determine if disease incidence is reduced.
Analysis and Conclusion	The water was making individuals ill. The hypothesis is supported.

Exercise 2

The term “theory” is often used in the English language to describe an explanation or a guessed reasoning. How does the use of the term “theory” in conversational English differ from use in science vocabulary?

In conversational English, the word “theory” might mean a guessed reasoning, but in science a “theory” is a well-substantiated explanation that is accepted by most scientists within a discipline as being true.

Which has the greatest impact on our understanding of science: laws, theories, or both laws and theories equally? Explain your answer.

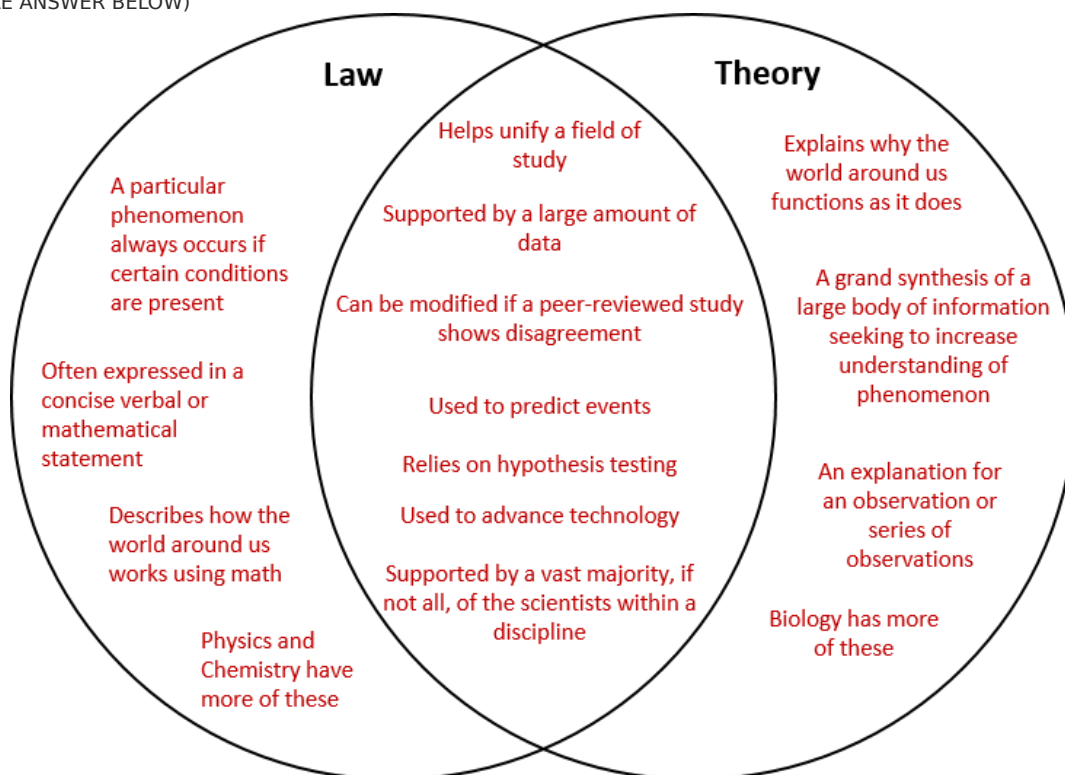
Laws and theories are equally valuable in science. They are both used to predict events, improve human understanding, and advance technology. Both are valid since they are supported by large bodies of empirical data derived from hypothesis testing.

Data Table 2: Attributes of Laws and Theories
(SAMPLE ANSWER BELOW)

Attribute	Law	Theory
Helps unify a field of study	X	X
A particular phenomenon always occurs if certain conditions are present	X	
Supported by a large amount of data	X	X
Explains why the world around us functions as it does		X
A grand synthesis of a large body of information seeking to increase understanding of phenomenon		X
Can be modified if a peer-reviewed study shows disagreement	X	X
Used to predict events	X	X
Often expressed in a concise verbal or mathematical statement	X	

Relies on hypothesis testing	X	X
An explanation for an observation or series of observations		X
Used to advance technology	X	X
Describes how the world around us works using math	X	
Biology has more of these		X
Physics and chemistry have more of these	X	
Supported by a vast majority, if not all, of the scientists within a discipline	X	X

Photo 1: Venn Diagram of Law and Theory
(SAMPLE ANSWER BELOW)



Exercise 3

Describe the relationship of the scientific method to each of the following elements: hypothesis, theory, law, and opinion.

Formulating a hypothesis is the third step of the scientific method.
Many rounds of the scientific method can lead to the formation of a law or theory.
Opinions are not related to the scientific method.

Select one of the topics classified as a law or theory in Data Table 3. Record the topic number. Then, use a textbook or a reliable Internet source to 1) identify the name of the law/theory that the topic describes, 2) list the primary scientist(s) credited with the work, 3) identify an estimated year that the law/theory was developed, and 4) expand on the general premise of the law/ theory.

Student answers should reflect one of the following descriptions.

Topic 2:

- 1) Cell theory
- 2) Schleiden and Schwann primarily
- 3) 1839
- 4) There are three basic tenets in the original cell theory, although the basic theory has been expanded on as new discoveries developed. 1- All living organisms are composed of one or more cells. 2- The cell is the basic unit of structure and organization in organisms. 3- Cells arise from pre-existing cells. The modern cell theory includes other tenants to address cell activity, energy flow, genetic material, and chemical composition in species. Experiments included observations of the cells of numerous plant and animal tissues.

Topic 4:

- 1) Hubble's law of cosmic expansion
- 2) Edwin Hubble (Contributing elements from Lemaitre, Slipher, Einstein, and others)
- 3) 1929
- 4) Distant galaxies are moving away from Earth as evidenced by their red shifts.

Objects observed in deep space are found to have a Doppler shift interpretable as relative velocity away from Earth; this Doppler-shift-measured velocity of various galaxies receding from the Earth is approximately proportional to their distance from the Earth for galaxies up to a few hundred megaparsecs away. Velocity of galactic movement can be described as $v=H_0D$. These observations and calculations are the basis of modern cosmology.

Topic 6:

- 1) Archimedes' buoyancy principle, also called the physical law of buoyancy
- 2) 250 BC
- 3) Archimedes
- 4) The force acting on, or buoying, a submerged or partially submerged object equals the weight of the liquid that the object displaces; apparent immersed weight equals the weight of object minus the weight of displaced fluid.

Topic 8:

- 1) Newton's second law of motion
- 2) 1687
- 3) Sir Isaac Newton
- 4) Newton's second law states that the rate of change of momentum of a body, is directly proportional to the force applied and this change in momentum takes place in the direction of the applied force. In an inertial reference frame, the sum of forces (F) on an object is equal to the mass (m) of that object multiplied by the acceleration (a) of the object: $F = ma$.

Topic 10:

- 1) Theory of evolution by natural selection
- 2) 1859
- 3) Charles Darwin
- 4) Tenets have been greatly expanded since the original theories were accepted. Basic components include the knowledge that there is variation in traits among natural populations of organisms. Variation is heritable. More offspring are produced than can survive. There will be differential survival and reproduction among individuals in a population. Genetic variation exists in a population, and individuals with more favorable traits survive to reproduce and pass traits on to the next generation.

Data Table 3: Classification of Hypotheses, Laws, Theories, and Opinions
(SAMPLE ANSWER BELOW)

#	Statement	Classification: Hypothesis, Law, Theory, or Opinion	Explanation
1	If two objects that have the same volume but different masses are dropped from some height, the heavier object will land first.	Hypothesis	This statement outlines a testable experiment, in which observed, measurable variables are mass and speed.
2	The explanation of cells: that living organisms are composed of cells, cells are the basic unit of life, and new cells arise from pre-existing cells.	Theory	This is a broad explanation about nature. Students may recognize this as cell theory.
3	Global climate is something to be concerned about.	Opinion	This is a view or judgement formed about something.
4	Velocity of galactic movement can be	Law	This statement uses math to

	described as $v=H_0D$, where v is velocity, H is the Hubble constant, and D is proper distance to the galaxy.		describe how nature behaves. Students may recognize this as Hubble's law of cosmic expansion.
5	The pH of surface ocean water is 30% more acidic due to human-related carbon emissions.	Hypothesis	This statement outlines a testable scientific study, in which the measurable variables are ocean pH and carbon emissions.
6	The force acting on, or buoying, a submerged or partially submerged object equals the weight of the liquid that the object displaces; apparent immersed weight equals the weight of object minus the weight of displaced fluid.	Law	This statement describes how nature behaves under certain conditions. Students may recognize this as Archimedes' buoyancy principle, also called the physical law of buoyancy.
7	Laws are most usefully applied in Physics.	Opinion	This is a view or judgement formed about something.
8	The sum of forces on an object is equal to the object's mass times acceleration.	Law	This statement describes how objects behave under certain conditions. Students may recognize this as Newton's second law of motion.
9	If three different gases are isolated and held at the same volume, pressure, and temperature, then the gases will contain the same number of molecules.	Hypothesis	This statement outlines a testable experiment, in which the measurable variables are volume, pressure, temperature, and number of molecules. Student's may recognize this as being reflective of Avogadro's principle.
10	The complex understanding about why organisms change over time and that changes to physical and behavioral traits allow organisms to better adapt to their environments, resulting in increased survival and reproduction.	Theory	This is a broad explanation about nature. Students may recognize this as the theory of evolution by natural selection.

Competency Review

The creation of nutrition and warning labels on foods and the laws that ban the dumping of hazardous waste are just a few protections developed because of science.

- ☒ True
☐ False



What are most often the final two steps of the scientific method?

- ☐ Testing the hypothesis and analyzing the data
- ☐ Drawing conclusions and communicating the results
- ☐ Conducting final observations and drawing conclusions
- ☒ Verifying the work through peer review and communicating the results

✓

A goal of the scientific method is to generate explanations that are free from opinion.

- ☒ True
- ☐ False

✓

A good scientific hypothesis ____.

- ☐ is an explanation of a phenomenon
- ☐ holds across space and time
- ☐ is simple
- ☐ is testable and potentially falsifiable
- ☒ All of the above

✓

Experiments that test a hypothesis often have two types of variables: ____ variables that are manipulated by the scientist and ____ variables that are observed.

- ☐ control; independent
- ☐ dependent; control
- ☒ independent; dependent
- ☐ dependent; independent

✓

Through application of the scientific method, hypothesis testing can lead to the development of ____.

- ☐ laws
- ☐ theories
- ☒ laws and theories

✓

____ are used to predict events, improve human understanding, and advance technology.

- ☐ Laws
- ☐ Theories
- ☒ Laws and theories

✓

Recently, scientists carefully manipulated grassland and forest ecosystems to investigate variables related to climate change, including precipitation, carbon dioxide, and temperature changes. This is an example of a(n) ____.

- ☐ hypothesis
- ☒ experiment
- ☐ data analysis
- ☐ peer review

✓

A Venn diagram has overlapping circles and facilitates the visualization of shared and unique attributes.

- ☒ True
- ☐ False

✓

The ____ states that a line connecting a planet to the sun covers an equal area over equal periods of time.

- ☐ Copernicus theory
- ☒ law of areas

✓

Einstein's ____ explained how the universe works and helped lay the foundation for quantum physics.

- ☒ theory of relativity
- ☐ law of conservation of mass



This statement is an example of a(n) ____: "If a solar panel is placed facing directly south, the maximum amount of energy will be generated."

- ☐ theory
- ☐ law
- ☒ hypothesis
- ☐ opinion



Extension Questions

There is a common assumption that cold water boils more quickly than hot water. Develop a strategy to investigate this theory.

- a. Construct a well thought out question.**
- b. State a testable hypothesis.**
- c. Design an experiment to test your hypothesis. Include an explanation of how the data you collect will be able to support or refute the hypothesis. Identify independent and dependent variables.**

(SAMPLE ANSWER BELOW)

Question: Does cold water boil more quickly than hot water?

Hypothesis: Students could propose that hot water boils more quickly, cold water boils more quickly, or that temperature does not influence time to boiling.

Experiment: Students should include timed measurements and various initial temperatures of water. The measured time it takes to boil hot and cold water will either support or refute the hypothesis. Initial temperature of water is the independent variable, and time to boil is the dependent variable.