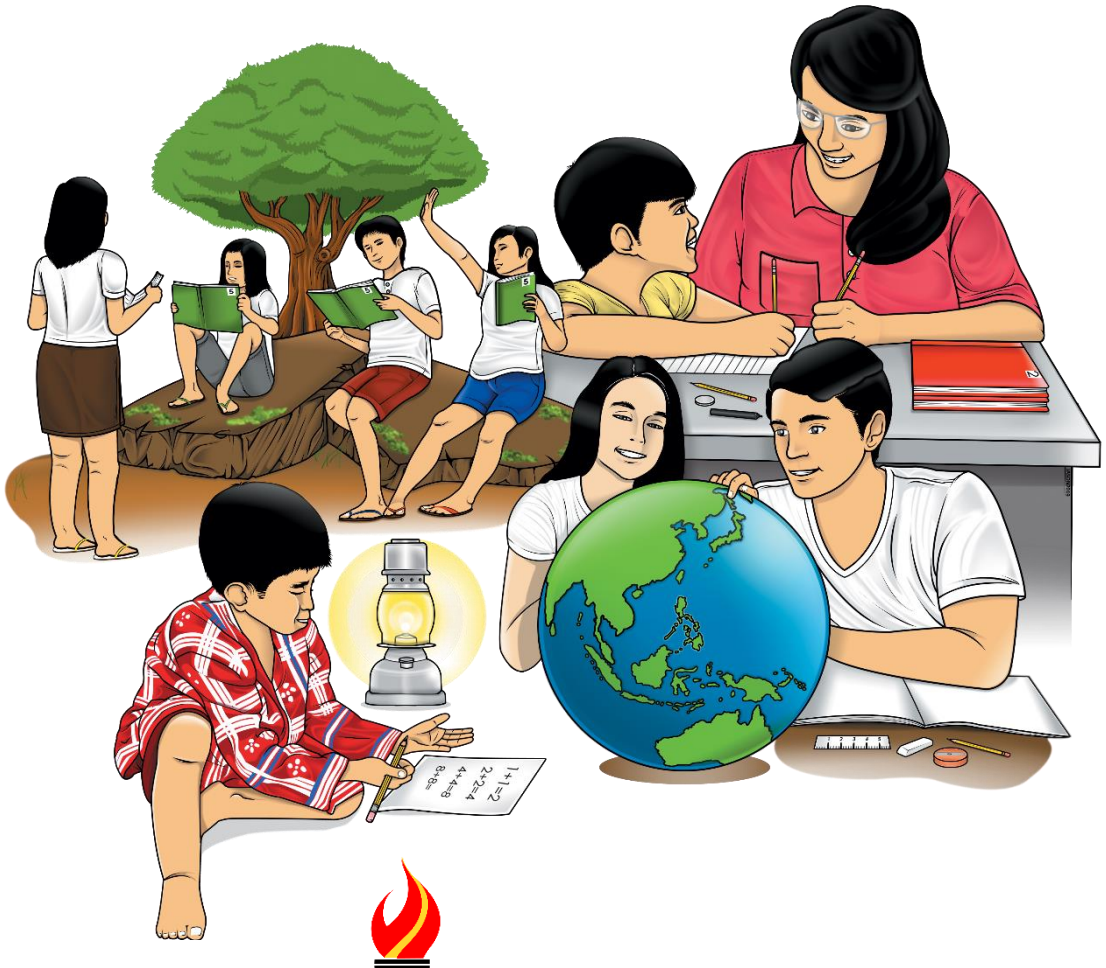
Senior High School

DepED
DEPARTMENT OF EDUCATION

Physical Science

Quarter 2 – Module 7:
Exploring the Consequences of Special Relativity Postulates



ALTERNATIVE DELIVERY MODE
ADM

Physical Science
Alternative Delivery Mode
Quarter 2 – Module 7: Exploring the Consequences of Special Relativity Postulates
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Introductory Message

For the facilitator:

Welcome to the Physical Science Grade 11/12 Alternative Delivery Mode (ADM) Module with the topic Consequences of the Postulates of Special Relativity!

This module was collaboratively designed, developed, and reviewed by educators to assist you, the teacher or facilitator in helping the learners meet the standards set by the K to 12 Curriculum while overcoming their personal, social, and economic constraints in schooling.

This learning resource hopes to engage the learners in guided and independent learning activities at their own pace and time. Furthermore, this also aims to help learners acquire the needed 21st century skills while taking into consideration their needs and circumstances.

In addition to the material in the main text, you will also see this box in the body of the module:

Notes to the Teacher

This contains helpful tips or strategies that will help you in guiding the learners.

As a facilitator, you are expected to orient the learners on how to use this module. You also need to keep track of the learners' progress while allowing them to manage their own learning. Furthermore, you are expected to encourage and assist the learners as they do the tasks included in the module.

For the learner:

Welcome to the Physical Science 11/12 Alternative Delivery Mode (ADM) Module with the topic Consequences of the Postulates of Special Relativity!

Our hands are one of the most symbolized part of the human body. It is often used to depict skill, action and purpose. Through our hands we may learn, create and accomplish. Hence, the hand in this learning resource signifies that you as a learner is capable and empowered to successfully achieve the relevant competencies and skills at your own pace and time. Your academic success lies in your own hands!

This module was designed to provide you with fun and meaningful opportunities for guided and independent learning at your own pace and time. You will be able to process the contents of the learning resource while being an active learner.

This module has the following parts and corresponding icons:

 ***What I Need to Know***	This will give you an idea of the skills or competencies you are expected to learn in the module.
 ***What I Know***	This part includes an activity that aims to check what you already know about the lessons. If you get all the answers correct (100%), you may decide to skip this module.
 ***What's In***	This is a brief drill or review to help you link the current lesson with the previous one.
 ***What's New***	In this portion, the new lesson will be introduced to you in various ways such as a story, a song, a poem, a problem opener, an activity, or a situation.
 ***What is It***	This section provides a brief discussion of the lesson. This aims to help you discover and understand new concepts and skills.
 ***What's More***	This comprises activities for independent practice to solidify your understanding and skills of the topic. You may check the answers to the exercises using the Answer Key at the end of the module.
 ***What I Have Learned***	This includes questions or blank sentences/paragraphs to be filled in to process what you learned from the lesson.
 ***What I Can Do***	This section provides an activity that will help you transfer your new knowledge or skill I into real-life situations or concerns.

 ***Assessment***	This is a task which aims to evaluate your level of mastery in achieving the learning competency.
 ***Additional Activities***	In this portion, another activity will be given to you to enrich your knowledge or skill of the lesson learned. This also tends retention of learned concepts.
 ***Answer Key***	This contains answers to all activities in the module.

At the end of this module you will also find:

References	This is a list of all sources used in developing this module.

The following are some reminders in using this module:

1. Use the module with care. Do not put unnecessary mark/s on any part of the module. Use a separate sheet of paper in answering the exercises.
2. Don't forget to answer *What I Know* before moving on to the other activities included in the module.
3. Read the instruction carefully before doing each task.
4. Observe honesty and integrity in doing the tasks and checking your answers.
5. Finish the task at hand before proceeding to the next.
6. Return this module to your teacher/facilitator once you are through with it.

If you encounter any difficulty in answering the tasks in this module, do not hesitate to consult your teacher or facilitator. Always bear in mind that you are not alone.

We hope that through this material, you will experience meaningful learning and gain a deep understanding of the relevant competencies. You can do it!

What I Need to Know

This module was designed and written with you in mind. It is to help you master the Consequences of the Postulates of Special Relativity. The scope of this module permits it to be used in many different learning situations. The language used recognizes the diverse vocabulary level of students. The lessons are arranged to follow the standard sequence of the course.

The module consists of one lesson only:

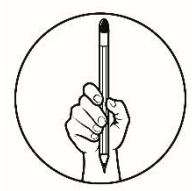
- Lesson 1 – Consequences of Special Relativity Postulates

After going through this module, you are expected to:

1. Explain the consequences of Einstein's Theory of Special Relativity postulates;
2. Analyze situations and calculate problems involving the consequences of the postulates of Einstein's Theory of Special Relativity; and
3. Cite practical applications of Einstein's Theory of Special Relativity and its postulate in our day to day living.

Notes to the Teacher

This module provides learning activities which encourages self-directed learning. Moreover, your role is to facilitate the learning process by providing a clear understanding on how to maximize the use of this module, monitor the development of our learners, scaffold the acquisition of learning to achieve target mastery level and provide positive feedbacks regarding their progress.



What I Know

DIRECTIONS: Read each question carefully. Choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. Which of the following is a postulate of Einstein's theory of special relativity?
   a. The laws of Physics are the same in all frames of reference.
   b. The laws of Physics are relative in all frames of reference.
   c. The speed of light in a vacuum is relative to the observer.
   d. The speed of light in a vacuum is relative to the source.

2. Which of the following **BEST** describes relativity of simultaneity?
   a. Two events occurring simultaneously in one reference frame are simultaneous in another frame.
   b. Two events occurring simultaneously in one reference frame may not necessarily be simultaneous in another frame.
   c. Two events occurring simultaneously in one reference frame is always simultaneous in another frame.
   d. Two events occurring simultaneously in different reference frame are always simultaneous to the observer's reference frame.

3. Which of the following **BEST** describes time dilation?
   a. The difference in the speed interval between two events as perceived by an observer under a stationary frame.
   b. The difference in the distance interval between two events as perceived by an observer under a stationary frame.
   c. The difference in the time interval between two events as perceived by an observer under a stationary frame.
   d. The difference in the acceleration of two events as perceived by an observer under a stationary frame.

4. Which of the following **BEST** describes length contraction?
   a. Length is absolute regardless of reference frame.
   b. Length may change under one reference frame.
   c. Length may change depending on the environment.
   d. Length varies from one reference frame to another.

5. Which of the following **BEST** describes cosmic speed limit?
   a. Infinite amount of work is needed for an object to reach speed of light.
   b. Infinite amount of force is needed for an object to reach speed of light.
   c. Infinite amount of mass is needed for an object to reach speed of light.
   d. Infinite amount of speed is needed for an object to reach speed of light.

Lesson 1 Consequences of Special Relativity Postulates

"Albert Einstein in his Special Theory of Relativity, proved that different observers in different states of motion, see different realities."

-Leonard Susskind

What's In

In the previous module, you have learned how special relativity resolved the conflict between Isaac Newton's assertion regarding principles of mechanics and James Clark Maxwell's electromagnetic theory using the postulates governing Special Relativity. In this module, you will investigate the consequences of the special relativity postulates and identify its practical applications in our day to day living.

What's New

A Glimpse of Time & Space

Throughout the ages, man has been fascinated to understand, explain, explore, and investigate the world and its natural phenomena using scientific processes. This nature of man striving towards grasps of knowledge and glimpse of enlightenment led to modern day understanding of the natural world through theories and principles governing our very existence.

The vastness of information and immensity of knowledge we unfold throughout our lifetime seems boundless and infinite as to how dedicated and passionate we are in achieving enlightenment. One notable individual who stood out among the rest in terms of investigating natural world was Albert Einstein.

The idea that we are moving everyday governed by the principle of time and the rate of our movement through space varies from turtle pace to supersonic rocket ship velocity may be insignificant and somehow negligible as to importance. However, these often-neglected principles inspired Albert Einstein who was fascinated in explaining and exploring things around him, which paved way to the discovery of one of the most influential theory and principle governing modern day understanding of Physical Science - Einstein's Theory of Special Relativity.

Gearing up for My Relativity Journey

Directions: Read and analyze the given situations/questions below. Complete the table by writing your prediction on the given situation.

1. Will it be possible for a moving person to observe two events happening simultaneously with respect to inertial frame given that another person simultaneously observes the two events in one inertial frame?

2. Does the distance covered by light under a stationary frame similar to the distance it will cover under a moving frame considering a stationary observer?

3. How do time and space influence aging on Earth and on the outer space?

4. Predict what will happen to the length of an object as it reaches the speed of light?
5. How much work is needed for an object to reach the speed of light in a vacuum?

PREDICT	ANALYZE	EXPLAIN

What is It

Relativity of Simultaneity

Relativity of simultaneity states that two simultaneously occurring event under one reference frame is not necessarily simultaneous in another frame. In addition, the concept of simultaneity depends on the reference frame of the observer.

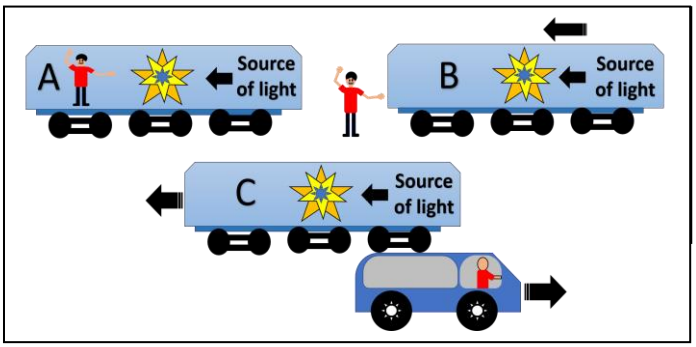


Figure 1. Observer A was able to observe the light reaching both ends, observer B was able to observe the light on the left end , while observer C was able to observe the light on the right end first.

Time Dilation

States that the difference in the time interval between two events as perceived by an observer under a stationary frame varies. Whereas, **t_0** is the proper time, **t** is the dilated time, **v** is the speed of the relative motion and **c** is the speed of light.

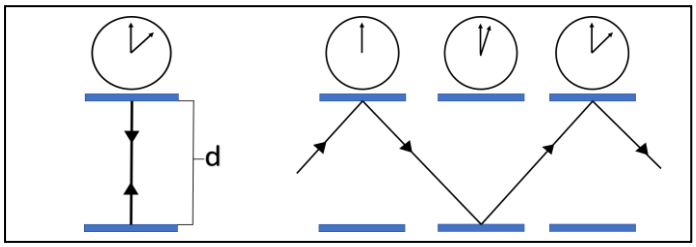


Figure 2. With respect to a stationary observer, the distance covered by light on a stationary frame is shorter as compared to the distance covered by light under a moving reference frame.

Problem 1. A space ship returned to Earth after 10 Earth years of space journey, if the ship's velocity is .75c how many years have elapsed for the astronauts inside their ship?

Answer $t_0 = t\sqrt{1-\frac{v^2}{c^2}}$

$t_0 = 10\sqrt{\left(1-\frac{.75c^2}{c^2}\right)}$ ⟶ **6.61 years**

Length of Contraction

States that the length of an object varies from one reference frame to another. In addition, this principle also emphasized that the length of an object contracts as it reaches the speed of light. Whereas, in the equation below, **Vx**=speed of the object, **c**=speed of light, **lp**=proper length of the object and **l**= observed length of the object.

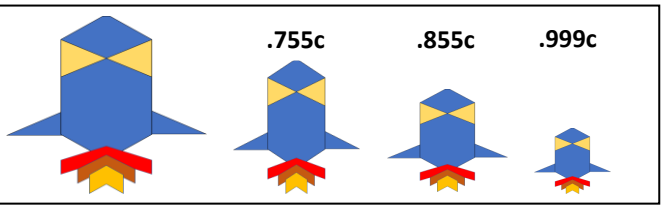


Figure 3. The length of an object contracts as it travels near the speed of light.

Problem 2. You have see spacecraft traveling at .406c. Identify the length of the spacecraft relative to your perspective.

Length of Contraction $= \frac{1}{\sqrt{1-\left(\frac{v_x}{c}\right)}} lp$

$L = \frac{1}{\sqrt{1-\left(\frac{.406c^2}{.9c^2}\right)}} 50m$ ⟶ **6.31 m**

Mass Energy Equivalence & Cosmic Speed Limit

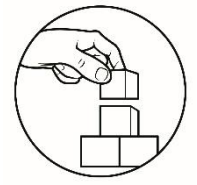
Mass Energy Equivalence is represented by Einstein's $E=mc^2$ whereas, E represents the total energy of a system, m represents the relativistic mass and c

Problem 3. Determine the energy equivalent of an object with a mass of .002 kg.

Sample Problem 3. **$E=mc^2$**

$E= (.002\ Kg) \times (3 \times 10^8\ m/s)^2$ **1.8×10^{14} J**

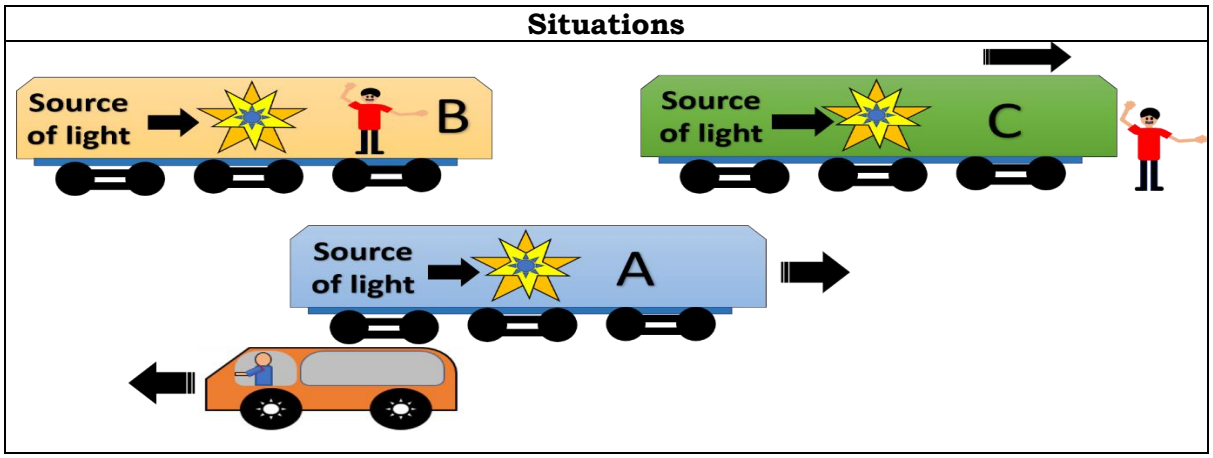
represents the speed of light. In addition, it requires an infinite amount of energy to keep the relativistic mass of an object in motion with the speed of light. On the other hand, the speed of light is regarded as the cosmic speed limit being the fastest speed ever recorded thus, no known object can travel faster than the speed of light.



What's More

Activity 1.1. Simple Activity on Simultaneity

Consider the given illustrations/situations below as reference for this activity. Analyze and explain the perception of the observers below using your understanding of relativity of simultaneity.



Activity 1.2. Resolving Twin Paradox

Deniece is one of the most promising young Physicist in our country. At the age of 20, she participated on a space journey with a speed of .85c leaving her twin brother Liam who facilitated the conduct of the said space exploration. In addition, the space journey took 35 years based on Earth's time. Based on this situation, identify the age of the twins after Deniece successfully returned to Earth. In addition, describe how time dilation affects aging in the outer space.

Activity 1.3. Shrinking Ship

Danny is driving a spaceship with a length of 60 meters at the speed of .32c and is observed by Susan in the direction relative to her. Based on this situation, identify the perceived length of the space shuttle using the principle of length contraction. In addition, describe what happened to the length of the space shuttle. Moreover, describe what will happen to an object as it reaches the speed of light.

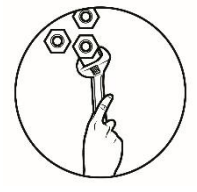
Activity 1.4. Mastering Mass and Energy

Based on your understanding about mass and energy equivalence, calculate the energy equivalence of the following subatomic particles:

Proton: 1.67×10^{-24}Kg Electron: 9.11×10^{-28}Kg

What I Have Learned

1. Two events that are simultaneously observed in one reference frame are not simultaneous under a moving reference frame.
2. Time dilation refers to the difference in the time interval between two events as perceived by an observer under a stationary frame.
3. The length of an object may change based on the reference frame of the observer.
4. The mass and energy equivalence, $E=mc^2$ denotes that the relativistic mass of an object can be converted into energy.



What I Can Do

In order to concretize the concepts you learned from this module, relate your understanding of the consequences of the postulates of Einstein's theory of special relativity to the following practical applications such as Satellite-based measurement and Global Positioning System (GPS) and explain how these applications utilized the concepts of consequences of the postulates of Einstein's theory of special relativity.

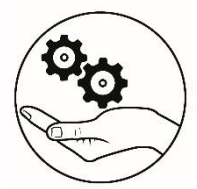
Assessment

DIRECTIONS: Read each question carefully. Choose the letter of the best answer. Write your answer on a separate sheet of paper.

1. At the age of 20, Donna joined a space exploration at the speed of .8c and completed it in 20 years. Identify her age upon his return to Earth.
   a. 32 b. 45 c. 51 d. 56
2. Determine the perceived length of a 5m ship travelling at .637c.
   a. 1.25m b. 2.95m c. 3.55m d. 4.35m
3. Determine the energy equivalent of an object with a mass of 27kg.

a. 2.11 x10^{18}J b. 2.23x10^{16}J c. 2.43x10^{18}J d. 2.53x10^{19}J

4. At the age of 23, Danny joined a space expedition at the speed of .6c and completed it in 25 years. Identify his age upon his return to Earth.
   a. 33 b. 35 c. 40 d. 43
5. Determine the energy equivalent of an object with a mass of 1230 kg.
   a. 1.11x10^{20}J b. 1.36x10^{18}J c. 2.25x10^{25}J d. 2.45x10^{37}J



Additional Activities

Activity 1. Siblings Paradox

At the age of 21 and 24 respectively, Dyllan left Earth with his older brother Alleister to take part on a space voyage at the speed of .9c leaving their younger sister Beatrice who was 12 years old with their parents. The journey took 25 years based on Beatrice's time. Identify the age of the siblings after Dyllan and Alleister successfully returned to Earth.

Activity 2. Space Nap

Calyx, an astronaut is traveling outer space at .9c speed relative to Earth for his space exploration journey. After a long tiring day of working, he decided to rest and take a nap for 2 hours. Based on your understanding of time dilation principle, how long did Calyx napped if measured on Earth?

Activity 3. Size & Speed: A Space Shuttle Mystery

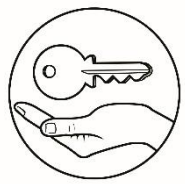
Beatrice is driving a space shuttle with a length of 40 meters at the speed of .637c and is observed by Althea in the direction relative to her. Identify the perceived length of the space shuttle using the principle of length contraction. In addition, describe what happened to the length of the space shuttle.

Activity 4. From Mass to Energy

Based on your understanding about mass and energy equivalence, identify the energy equivalent of the following and relate the mass of an object to its energy equivalence.

- A Tricycle with a mass of 637 kg
- A Book with a mass of 1.3 Kg
- A sack of rice with a mass of 25 kg
- A man whose mass is 65 kg
- A train with a mass of 22, 680 kg
- A car with a mass of 15, 000 kg
- A tennis ball with a mass of .25 kg

- A bowling ball with a mass of 5 kg
- Earth with a mass of 5.972 x 10^{24} kg
- Moon with a mass of 7.35 x 10^{22} kg



Answer Key

What I Know

1. A
2. B
3. C
4. D
5. A

Assessment

1. A
2. B
3. C
4. D
5. A

What's More

1.1. Observer B is able to observe the light reaching both ends, observer C is able to observe the light the right end first while observer A is able to observe the light the left end first.

1.2. Deniece 38, Liam, 55

1.3. 7.24m

1.4. 1.503x10-7J, 8.20

Additional Activities

1.1. 10.90=11 yrs Dyllan32, Alleister35, 37

1.2. .87 hours

1.3. 4.47m, the space shuttle reduced in length.

a. 5.73 x 1019 J
b. 1.17 x 1017 J
c. 2.25 x 1018 J
d. 5.85 x 1018 J
e. 2.04 x 1021 J
f. 1.35 x 1021 J
g. 2.25 x 1016 J
h. 4.5 x 1017 J
i. 5.37 x 1041 J
j. 6.62 x 1039 J

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