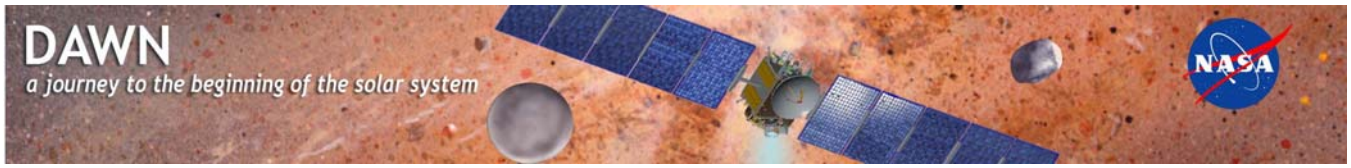

Ion Propulsion

Where Are We?

TEACHER GUIDE – DEVELOPMENT

BACKGROUND

In this section of the module, students will explore the concept that motion is relative by reading the text "Frames of Reference." As a follow-up to the reading, engage students in a writing-to-learn strategy called RAFT (Santa, 1988), which facilitates creative thinking as students reflect on and process concepts presented in informational text. The ensuing writing activity can help students understand how motion depends on specific frames of reference, as they are asked to assume a specific frame of reference and describe motion in relation to multiple perspectives.

The **TEACHER GUIDE SUPPLEMENT** **CONTAINS:**

Specific NSES Science Education Standards for this guide;
Rubric for Relative Motion RAFT Writing Activity"

MATERIALS

Student Reading
- "Frames of Reference"

Student Activity, Relative Motion RAFT Writing Activity"

ESTIMATED TIME:

Part 1: 20 Minutes
Part 2: 25 Minutes (or as homework)

PROCEDURE

Part 1: Relative Motion

1. Make copies of the student reading "Frames of Reference" and accompanying writing activity, Relative Motion RAFT Writing Activity." Distribute copies of the text to each student.
2. Depending on the class, assign the first two paragraphs from the reading to be completed individually, in pairs, or aloud as a class.
3. Distribute a copy of the Relative Motion RAFT Writing Activity" to each student. Explain to students that the purpose of the writing assignment is for them to explore the concept that motion is relative by describing how the perception of motion changes according to a specific frame of reference— for instance a first-person point of view versus an outside observer's perspective. Go over the directions to the assignment and discuss what the RAFT acronym stands for:

Role – What is the writer's role? In this assignment, the role is the first-person perspective (e.g., the baseball, the skateboarder, the person inside a flight simulator, a frog) Students will get to select or create their own role.

Audience – Who will be reading this writing? The audience in this writing activity represents an outside frame of reference (e.g., the batter, a crowd of onlookers, a person outside the flight simulator, a lily pad). The audience for the writing will depend on the role selected.
Format – What is the best way to present this writing? Consider the format or genre of the piece of writing (e.g., a sports commentary, a travel guide, advice column, a letter of complaint). Students can have some flexibility in selecting the format for this assignment.
Topic – Who or what is the subject of this writing? In this assignment, all students must focus on the topic of relative motion or how motion can be described from different frames of reference.[1]

4. Discuss the accompanying rubric to ensure students understand the expectations. Emphasize to students that they will need to describe motion from different perspectives. To do this, they should first describe motion as perceived by the role they assume (e.g., A frog leaping onto a lily pad may describe its forward motion onto a stationary lily pad). Next they should assume the audience's perspective to describe motion (e.g., The lily pad may perceive its own motion as moving down in response to the frog's landing or sideways in response to ripples in the water). Challenge students to take it a step further by considering a third frame of reference (e.g., The pond may perceive itself as stationary while the frog and lily pad are in motion.) However, from the perspective of a single water molecule in a wave, the pond itself is in motion as it responds to the motion of the lily pad!
5. Students may select one of the listed roles (initial, first-person frame of reference) or come up with ideas of their own. It may be helpful to engage the class in a brainstorm of other possible roles, audiences, and formats for the topic of relative motion. Then, students can add these to the blank lines in the RAFT chart. Note: If students choose the role of the xenon ion, it may be necessary for them to first read the text "A Trip through the Ion Engine."
6. Once students have completed their RAFT writing activity, extend the learning by having students review a peer's writing and provide feedback using the assignment rubric. If time permits, allow students to revise their writing according to the peer feedback they received.

Part 2: Frames of Reference

Have students read the entire "Frames of Reference" text. Present the following situations to the class. Once complete, have the students answer the following questions in small groups. Students should write complete sentences to explain their answer.

1. Consider the following situation. You are riding on a school bus and are juggling three oranges. Ultimately, you wish to analyze the motion of the oranges by applying Newton's laws.
   a. Give two conditions that must be met for the interior of the bus to be used as an inertial frame of reference. *Answer:* The bus must be moving at a constant velocity and it must be moving in a straight line. An inertial frame of reference can be defined as a coordinate system that is not accelerating.
   b. If the windows of the bus were covered and the road was perfectly smooth, would you be able to determine whether or not the bus was moving? *Answer:* You would not be able to tell the difference between a velocity of zero and a velocity of 60 miles per hour without some outside reference against which you could determine relative motion as long as the bus moved with a constant velocity in a straight line.
   c. If you analyzed the motion of the oranges while the bus is traveling at 60 miles per hour and again while it is standing still, would you arrive at the same answers? *Answer:* Yes. The

motion of the oranges is independent of the motion of the bus as long as the bus meets the criteria necessary for it to serve as an inertial frame of reference.

d. Could you get any clues from the motion of the oranges as to whether or not the bus was moving? *Answer:* No. See #3.
e. If the bus driver suddenly slammed on the brakes, slowing the bus from 60 miles per hour to a stop in a few seconds, would you be able to continue to juggle the oranges during the deceleration of the bus? *Answer:* Probably not. You would be thrown forward along with the oranges and you would most likely lose control of them.
f. During the deceleration of the bus, would it still qualify as an inertial frame of reference? *Answer:* No. The bus would not be traveling at a constant velocity, as required by the concept of an inertial frame of reference. During the deceleration, the bus would be classified as a non-inertial (or accelerated) frame of reference and Newton's First Law would not apply. The analysis of motion in this situation is very complex.

2. Consider juggling a set of three oranges while seated on a merry-go-round. Would it be possible to analyze the motion of the oranges within the context of an inertial frame of reference? *Answer:* No. The merry-go-round moves in a circular path and not only would juggling be more difficult in this situation, but you also could not analyze the motion of the oranges in the context of an inertial frame of reference because the circular motion implies acceleration.
3. Consider standing on the surface of the Earth and juggling three oranges. Since the Earth is rotating and orbiting the Sun, is it possible to analyze the motion of the oranges within the context of an inertial frame of reference? *Answer:* Very <u>strictly</u> speaking, "No." In a sense, this is like the merry-go-round example above. However, for most situations one can make use of Newton's Laws in coordinate systems attached to the Earth because the Earth's angular velocity is very small and the effects of the rotation are quite negligible. However, for certain large-scale effects such as the circulation of air masses on the surface of the Earth or the path of large projectiles, the effect of earthly rotation must be taken into consideration.

Teacher Guide Supplement

A. *National Science Education Standards* addressed in this guide

Science as Inquiry (Grades 9–12)
Abilities Necessary to Do Inquiry

Communicate and defend a scientific argument.

- Students in school science programs should develop the abilities associated with accurate and effective communication...These include writing...expressing concepts...using language appropriately.

Physical Science (Grades 9–12)
Motion and Forces

Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects.

B. Language Arts Standards from *Content Knowledge: A Compendium of Standards and Benchmarks for K-12 Education*, 4th Edition[1]

Uses the general skills and strategies of the writing process

- Uses strategies to address writing to different audiences (e.g., includes explanations and definitions according to the audience's background, age, or knowledge of the topic, adjusts formality of style, considers interests of potential readers)
- Uses strategies to adapt writing for different purposes (e.g., to explain, inform, analyze, entertain, reflect, persuade)
- Writes descriptive compositions (e.g., uses concrete details to provide a perspective on the subject being described; uses supporting detail [concrete images, shifting perspectives and vantage points, sensory detail, and factual descriptions of appearance])

Uses the stylistic and rhetorical aspects of writing

- Uses precise and descriptive language that clarifies and enhances ideas and supports different purposes (e.g., to stimulate the imagination of the reader, to translate concepts into simpler or more easily understood terms, to achieve a specific tone, to explain concepts in literature)

[1]Kendall, J. S., & Marzano, R. J. (2004). *Content knowledge: A compendium of standards and benchmarks for K-12 education*. Aurora, CO: Mid-continent Research for Education and Learning. Online database: https://www2.mcrel.org/compendium/browse.asp

C. Rubric for Frames of Reference RAFT Writing Activity

Criteria	In Progress	Meets Expectations	Exceeds Expectations
Understanding of Content	Describes motion from only one perspective. Missing and/or misinterpreted information.	Describes motion from two different perspectives: the writer's role and the audience's frame of reference. Information presented reveals an understanding that motion is relative.	Describes motion from three or more different perspectives. Information presented reveals a sophisticated understanding that motion is relative.
Organization of Ideas	Ideas are disconnected and lack transitions. Attempts to write using a particular format, but may be missing format features or includes information that detracts from the purpose of the assignment.	Ideas flow; incorporates transitions when presenting different perspectives. Uses format effectively to write for a specific purpose. Uses format and information effectively to write for a specific purpose.	Ideas flow; incorporates transitions when presenting different perspectives. Uses format effectively and creatively to write for a specific purpose.
Communication of Ideas	Ideas are vague because writing lacks descriptive details and precision. Writing does not show an awareness of audience.	Ideas are clear because writing contains precise descriptions and details. Writing shows an awareness of audience.	Ideas are compelling and engaging because writing contains vivid, creative descriptions and sensory details. Writing reflects a keen awareness of audience.

RESOURCES

Barton, M. & Jordan, D. L (2001). *Teaching reading in science: A supplement to Teaching reading in the content areas teacher's manual (2nd edition).* Alexandria, VA: Association for Supervision and Curriculum Development.