The Rate of Motion

Introduction

Every four years the world becomes transfixed by the athletes participating in the Olympic Games. From their inception in 776 B.C. to the present day, the Games have showcased the human body and its ability to move through space and time in powerful, complex, and beautiful ways.

Modern athletes often apply the laws of physics to improve their performance. For example, long jumpers strive to maximize the force with which their feet push off the track to generate the greatest velocity. By leaping up *and* out, they hope to increase their "hang time" and cover the greatest distance possible before the force of gravity causes them to touch down. Likewise, high divers push down with tremendous force on the board to accelerate quickly upward. The greater the acceleration, the higher the divers fly, and the longer they have in which to perform their amazing spins, tucks, and rotations before they hit the water.

One need not look far to see how the laws of motion and principles of physics apply to the motion of athletes competing not only against one another but also against the forces of mass, inertia, and gravity.

Questions for Investigation

- How can speed, velocity, and acceleration be used to describe the motion of objects?
- What is the relationship between speed, velocity and acceleration?
- How do scientific principles of work, force, and motion apply to safety technology?
- How can Newton's Laws be used to predict and describe the motion of a common object?

Materials

Newsprint or large sheet of paper for designing data table
Graph paper for data table, calculations, and graph
Meter stick or metric tape measure
Stop watch or timer (2)
Black marker or pen
Masking tape with which to mark off a distance of 0, 5 and 10 meters respectively

Directions

1. Using a large sheet of newsprint, work with a partner to design a data table to record the following data: four trials <u>each</u> for walking, skipping, and hopping 5 meters <u>and</u> 10 meters. Your table will need to include a column for the mean for all four trials and a place to record the average speed and acceleration for each distance (5 m *and* 10 m).

2. Share your design with the other two members of your group and discuss the merits of each design. Collaboratively determine the best design for your group's data.

Show your design to your teacher before constructing the data table to make sure you have included all the criteria.

3. Using the meter stick and masking tape, measure a straight line and mark at 0 m, 5 m, and 10 m distances.

4. Decide who in the group will be the (1) recorder, (2) timer #1 at the 5 m mark, (3) timer #2 at the 10 m mark, and (4) mover to walk, skip, and hop

5. When everyone is ready, the mover should walk from the 0 m to 5 m to 10 meter mark. This is considered the first trial. Timer #1 should record the time it takes the mover to reach the 5 m mark and Timer #2 the time is takes the mover to reach the 10 m mark. The recorder should record this information on the group data table.

6. The mover then skips along the same distance with the timers collecting data at the 5 m and 10 m mark. The mover will then hop along the 10 meter track.

7. Once the mover has completed one trial each for walking, skipping, and hopping, the members of the group rotate their roles. Continue rotations until all 4 members have completed one trial each for walking, skipping, and hopping.

8. Return the materials to the place indicated by your teacher and collaboratively work to perform the following calculations using the data you have collected.

   a) Calculate and record the mean time in seconds of all four trials for walking, skipping, and hopping.

   b) Calculate the average speed for each type of motion for 5 meters *and* for 10 meters. Use the formula to make your calculations

   $$\text{Speed} = \frac{\text{distance}}{\text{time}} \qquad s = \frac{d}{t}$$

   c) Calculate the acceleration for each type of motion from 0 to 5 meters using the formula to make your calculations.

   $$\text{Acceleration} = \frac{\text{velocity @ 5m - velocity @ 0 m}}{\text{Time @ 5m - Time @0m}} \qquad a = \frac{v_5 - v_0}{T_5 - T_0}$$

   d) Calculate the acceleration for each type of motion from the 5m mark to the 10 m mark using the formula

   $$\text{Acceleration} = \frac{\text{velocity @ 10m - velocity @ 5 m}}{\text{Time @ 10m - Time @5m}} \qquad a = \frac{v_{10} - v_5}{T_{10} - T_5}$$

9. Collaboratively or individually create a distance-time graph that includes each of the three types of motion. Remember to include a title that accurately describes the data displayed. Create a key to indicate which line represents walking, skipping, and hopping.

Discussion Questions

1. Looking at the data table, which task was performed at the greatest speed? How does that line appear on the graph compared to the other lines?

2. Which task was performed the slowest? How does that line appear on the graph compared to the other lines?

3. Did the speed change between the 5 meter mark and the 10 meter mark for walking, skipping, or hopping? If so, highlight that section on your graph and describe how the speed changed.

4. Which task showed the greatest amount of acceleration? The least? How did you determine this?

5. Consider how velocity is different from speed. Did velocity change for any of the types of motion? If so, explain.

6. If the mover's mass was 80 kg, how much force was produced at the greatest rate of acceleration? Use this formula. How much force was produced with the lowest rate of acceleration?

   Force = mass × acceleration F = ma

7. If you were balancing a book on your head as you tested each task, discuss with your group what may have happened to the motion of the book when you stopped moving? Explain your reasoning.

8. Issac Newton's three laws of motion state:
   - First law—An object at rest will stay at rest, and an object in motion will stay in motion at a constant velocity, unless acted upon by an unbalanced force.
   - Second law—Force equals mass times acceleration.
   - Third law—For every action there is an equal and opposite reaction.

   A student is riding her bicycle on a slippery surface. Use Newton's Laws of motion to Discuss which of Newton's laws best explains why it's important to wear a seatbelt or a helmet. Explain your reasoning.

   force
   motion
   acceleration
   inertia
   mass
   1st law of motion
   2nd law of motion

9. Explain what would happen to an unrestrained, 25 kg dog in the back of a pick-up truck as it comes to a stop. Include each of the terms in the list (at right) in your explanation:

10. Jake, an eighth grader, often complains about wearing a helmet while he practices kick flips and grinds at the skate park.

    If Jake has a mass of 65 kg and is accelerating across the park at 15 m/sec^2, use Newton's second law of motion to calculate the force with which his head would impact a wall if he were to hit it without wearing a helmet.

11. Based on your speed of walking at the 10 meter mark, how many seconds would it take you to walk 1 kilometer? Can you convert that time into minutes?

12. Consider the data table your group created. Discuss how might you improve the design of your data table if you were to conduct this investigation in the future? How would this improve your ability to record data or make calculations and connections?

Assessment

Choose your favorite Olympic or other sport. Draw and annotate a picture or write a story or short play that makes clear connections between the sport and each of Newton's Laws of Motion, and how the concepts of speed, velocity, acceleration, inertia, and mass apply.