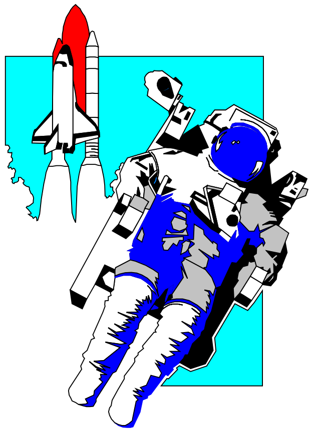
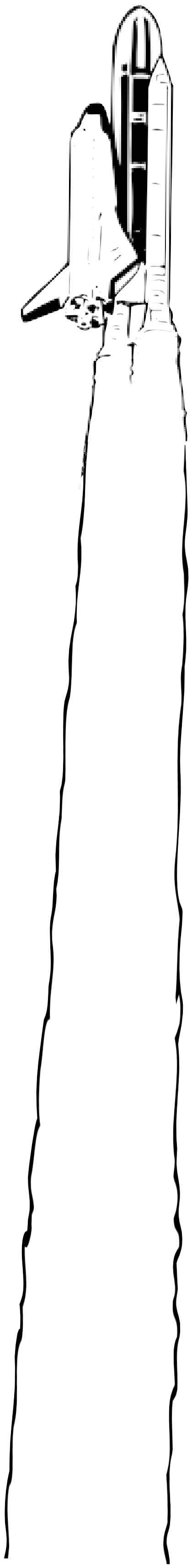


Student Mathematics Activity: Glide Slope

Student Mathematics Activity: Glide Slope



Grade Levels: 4 - 8

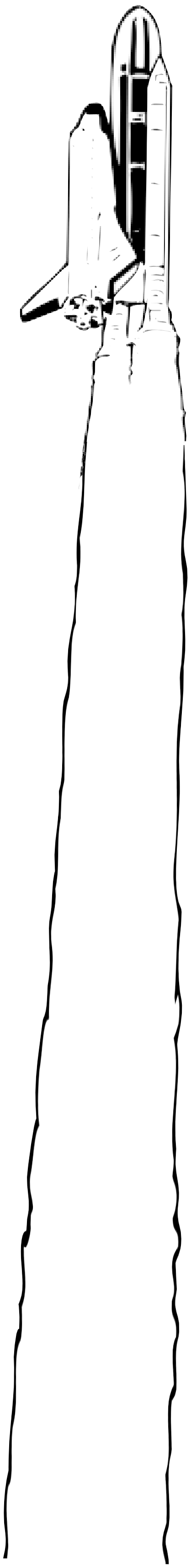
Teacher Overview Outline

I. Introduction (pages 23 - 37)
- Space Shuttle Glider Activity-Teacher Information
- Key Questions
- Time Frame
- Getting Ready
- Prerequisite Knowledge for Students
- Materials
  - For each student
  - For each team
  - For the class
- Teacher's Answer Key

II. Classroom Activity (pages 38 - 39)
- Session 1
- Session 2
- Session 3
- Session 4
- Session 5
- Session 6
- Session 7

III. Student Handouts (pages 40 - 72)
- Student Reading
  - Landing the Orbiter
  - Angle of Attack
  - Glide Slope
- Vocabulary List
- Space Shuttle Glider Activity - Student Information
- Instructions for Building the Space Shuttle Glider
- Team Members and their Roles
- Instructions for Landing Procedures
- Landing Data Collection Sheet
- Math Worksheet of Prerequisite Knowledge - practice exercises
- How to Compute Glide Slope - practice exercises
- How to Compute Flight Time
- How to Compute Average Speed - practice exercises
- Table for Determining Glide Slope
- Purpose of a Scatter Plot
- How to Create a Scatter Plot - practice exercises

Student Mathematics Activity: Glide Slope

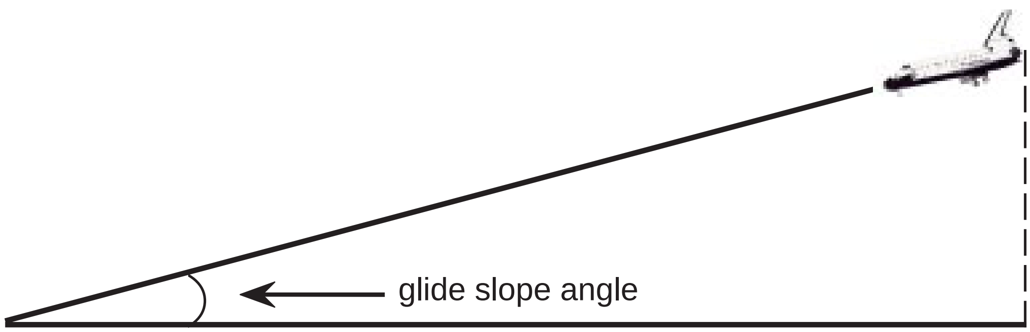


Introduction

This activity is designed to introduce students to the concept of glide slope, which is the angle that the U.S. Space Shuttle orbiter approaches for landing upon return from space orbit. This five to seven session activity is appropriate for students in grades 4-8. The lesson consists of a hands-on math activity with worksheets and photos depicting the experiment process.

Example #1

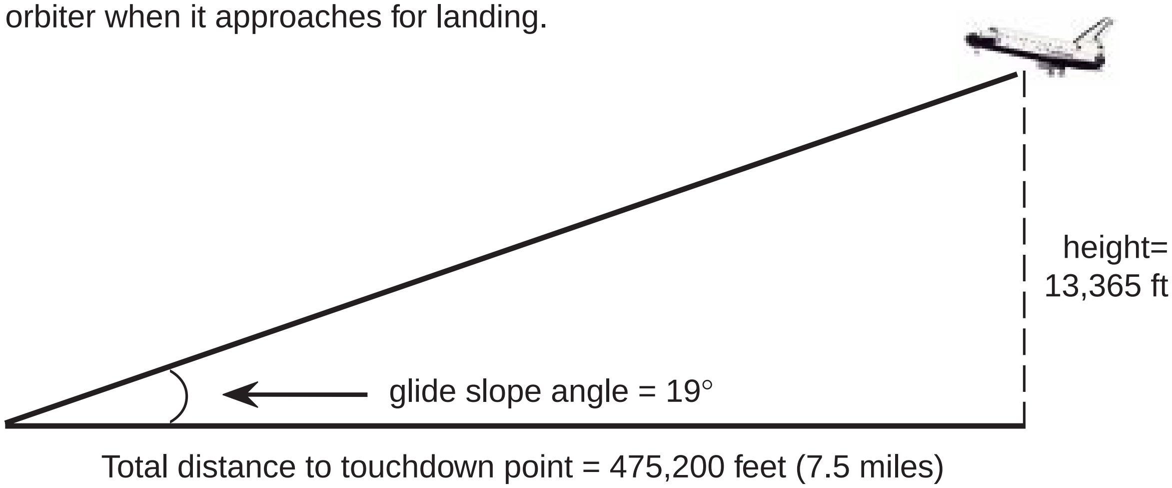
Glide slope angle can be determined when the orbiter's nose is pointing down.

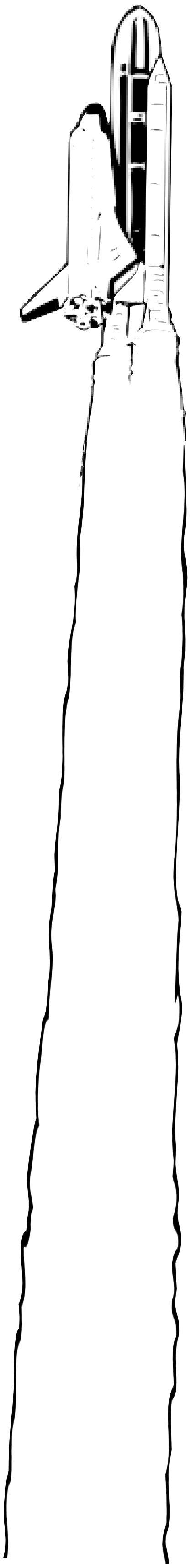


Example #2

Here is an example of the glide slope angle when the orbiter's nose is pointing up.

The measurements shown are possible dimensions for the U.S. Space Shuttle orbiter when it approaches for landing.

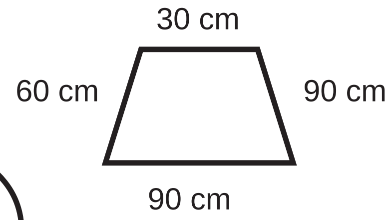




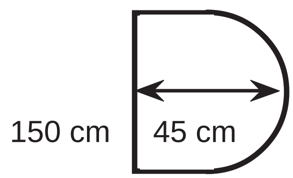
Space Shuttle Glider Activity - Teacher Information

In this activity the students will achieve a greater understanding of glide slope by manipulating the measurements that affect the landing of the shuttle orbiter. The students will construct a space shuttle glider (that you can download from the Web) which is a 1cm:300cm scale of the actual U.S. Space Shuttle orbiter. Teachers: You may want to draw the actual size of the cockpit window or the tip of the nose to give the students an idea of the actual size of the orbiter.

The cockpit window on the side of the orbiter would have the following actual size measurements:



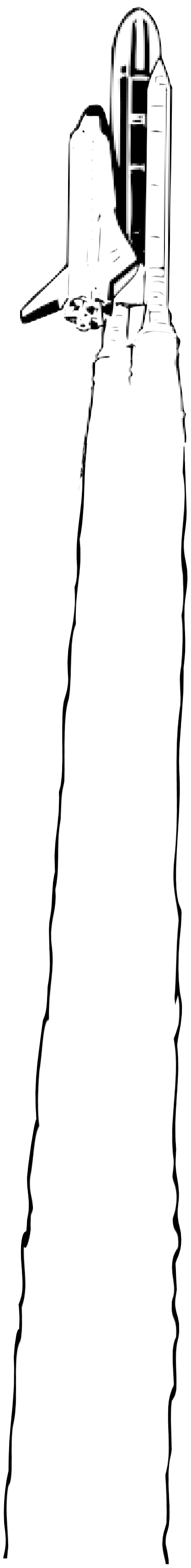
The nose of the orbiter would have the following actual size measurements:



Then, they will have the opportunity to reenact the landing procedure by controlling glide slope, and piloting the glider in for a smooth landing. They will record their results to further explore the meaning of glide slope, flight time and distance, and compare their data to the glide slope, flight time and distance of NASA's space shuttle orbiter landings (see table below).

Landing Data Collection Sheet: Space Shuttle

Team	Height of orbiter from ground parallel to **y-axis** (inches) 160,380 (13,365 feet)
Pilot	Total distance to touchdown point along **x-axis** (inches) 475,200 (7.5 miles) (measure distance on the ground)
Copilot	Slope = **y-axis** / **x-axis** = 160,380 / 475,200 (fraction) 0.3375 (decimal equivalent)
Mission Control Center	Glide Slope (use table) 19 degrees
Mission Specialsit	Flight Time (in seconds) 120 seconds
	Average Speed: Total Distance / Flight Time (in inches / second) 3960 (225 mph)



This entire activity is done in conjunction with other activities under Space Shuttle Aeronautics found on NASA Quest's Female Frontiers Web Site at:
http://www.quest.arc.nasa.gov/space/frontiers

Key Questions

- Why does the orbiter reenter the atmosphere at such a high velocity?
- Why is it necessary for the orbiter to reenter the atmosphere at such a steep angle of attack?
- What strategies does the orbiter take to slow down before landing?
- Does glide slope affect the speed of the glider?

Time Frame

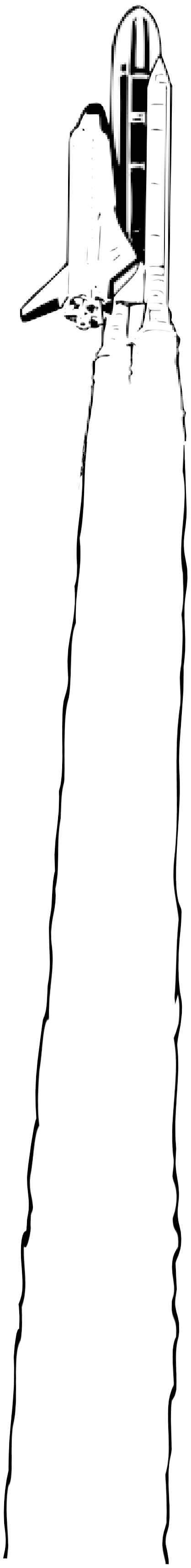
Five to Seven class sessions of 45 to 60 minutes each.

Getting Ready

1. Run all multiple copies of each student handout.
2. Read through the lesson plan.
3. Review Math Worksheets and other math concepts needed for this activity.
4. Assemble a glider for yourself.
5. Decide where the landings will take place.
6. Prepare the area for glider landings.
7. Try a few practice runs yourself on each landing site.
8. Place students into groups of 3-4 for each landing site.
9. Be sure each group has the necessary materials: gliders, pencils, watch or clock with second-hand, tape measure, rulers, calculators, student handouts

Prerequisite Knowledge for Students

- Using tape measures or rulers to measure distances
- Reading a second-hand on a watch or clock
- Converting a fraction to a decimal using long-hand or a calculator
- Rounding to the nearest ten-thousandths place (possibly with repeating decimals)
- Estimating
- Reading a table to determine the value of the glide slope
- Subtracting decimals
- Understanding the concept of the x-axis and y-axis
- Graphing a scatter plot and line of best fit



<u>Materials</u>

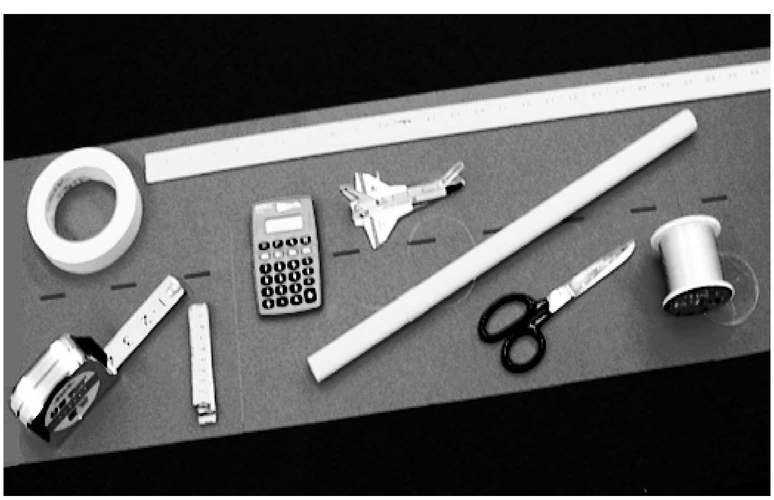
For each student:

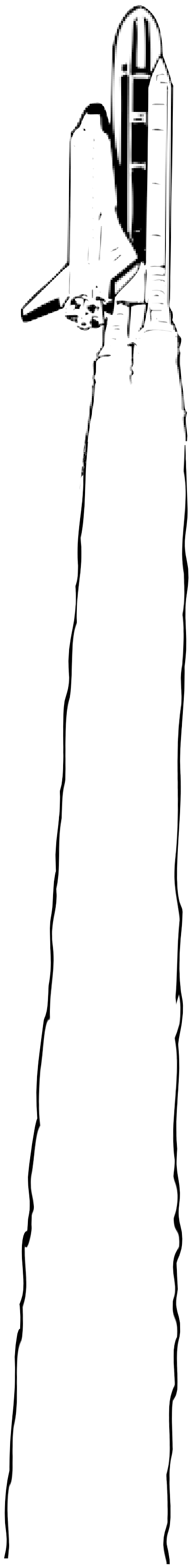
1. Student Handouts (see list in Teacher Overview Outline)
2. Space Shuttle Glider Kit -print from Web site on thick cardstock paper (65-80 lb. paper)

For each team (3-4 students per team)

1. Designate each team of students with a team name or number. (Idea: Use the names of NASA's shuttles: Columbia, Discovery, Atlantis, Endeavor and/or create names that would be appropriate for future shuttles: Explorer, Horizon, Revelation, Genesis, Voyager, Adventure, etc.)

2. Landing site:
    - fishing line
    - masking tape (that will not leave adhesive on the floor)
    - "control stick"
(sawn off wooden broom handle, thick dowel, yardstick)
optimum length: 1.5 feet (18 in.)
    - runway
    - tape measure or ruler
    - calculators
    - scissors
    - ladder or chair
(without wheels) to stand on
    - space shuttle glider





Instructions for Building the Landing Site:

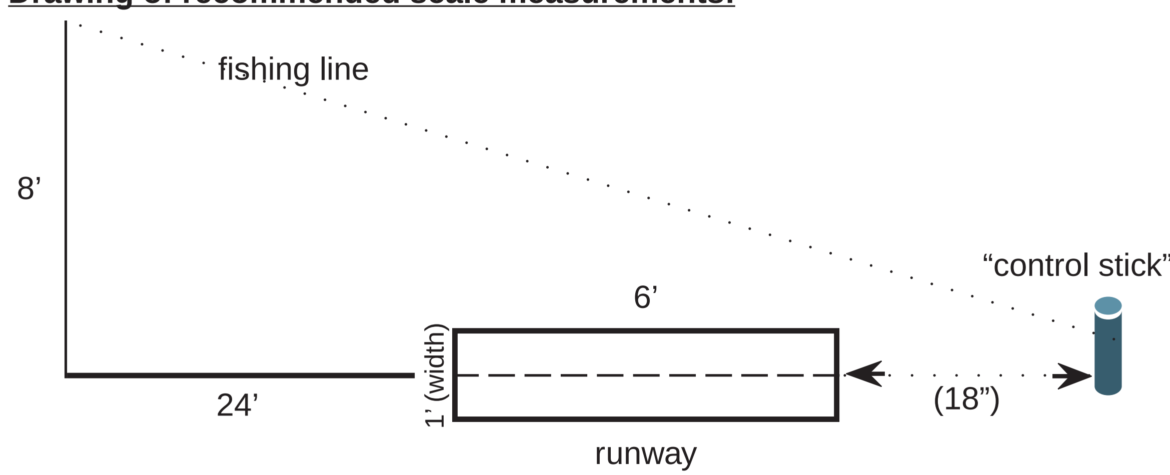
- The following suggested measurements used in this activity are as close as possible to a scale representation of the actual Space Shuttle.

- The measurements in the table, under “Space Shuttle Glider Activity-Teacher Information”, are the basis for the glider’s landing site measurements given below. The ratio of the Height of the orbiter compared to the Total distance to touchdown point is 1 to 3. Thus the measurements for the glider’s landing site, 8 feet high and 24 feet long, are also in a ratio of 1 to 3. If you are not able to appropriate this much space in your classroom, at least try to maintain the same ratio of 1 to 3.

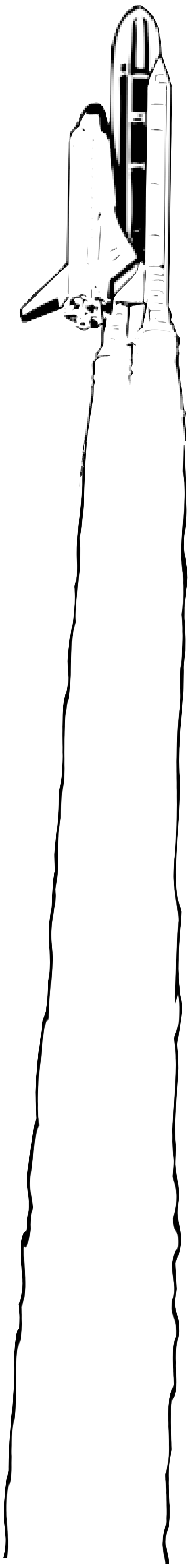
- The runway for the Space Shuttle Orbiter has measurements that are nearly twice the length of width of a conventional runway used for commercial airlines. The runway is 91 meters (300 feet) wide and 4,600 meters (15,000 feet) long. However, the orbiter aims for a point 1,500 meters passed the runway threshold, and usually rolls to a stop with 600 meters left. Thus the amount of runway that is actually used by the orbiter is 2,500 meters. The ratio of 91 meters to 2,500 meters is about 1 to 25. As you can see, the length of the runway is dramatically longer than the width of the runway. For our practical purposes, we found that a ratio of 1 to 6, although not to scale, is sufficient.

- For a wider, range of results, vary the measurements of each Landing Site, within the suggested parameters. You may want to try different ratios of 1 to 3. In other words, for the scatter plot worksheet, each group will have similar results if their landing sites have the same measurements.

Drawing of recommended scale measurements:



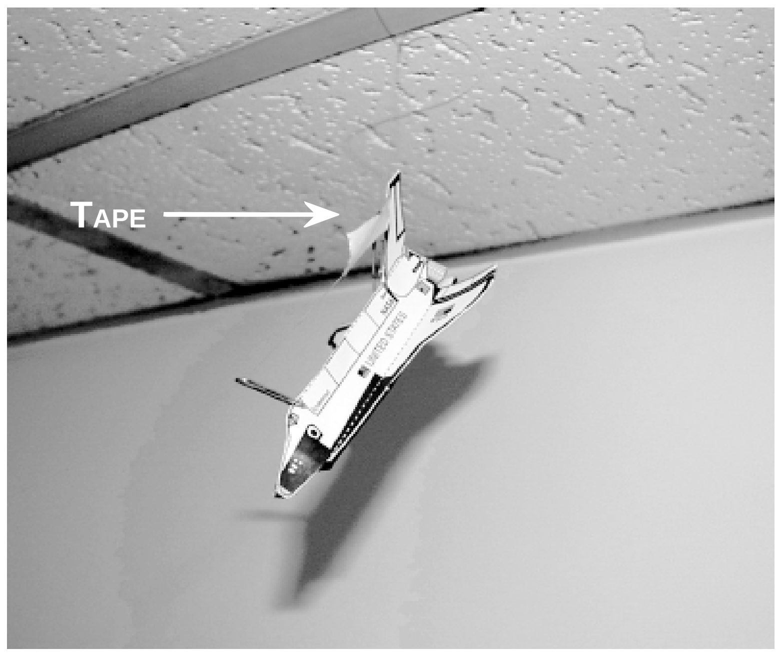
NOTE: DRAWING ITSELF IS NOT TO SCALE



a. Find a location that has about 30-35 feet in length of floor space, 3-5 feet in width and 8-10 feet in height.

b. Tie one end of nylon fishing line to someplace high, at least 7-8 feet high. (Suggestion: Try pinning a hook to your classroom wall, and looping the fishing line onto the hook.)

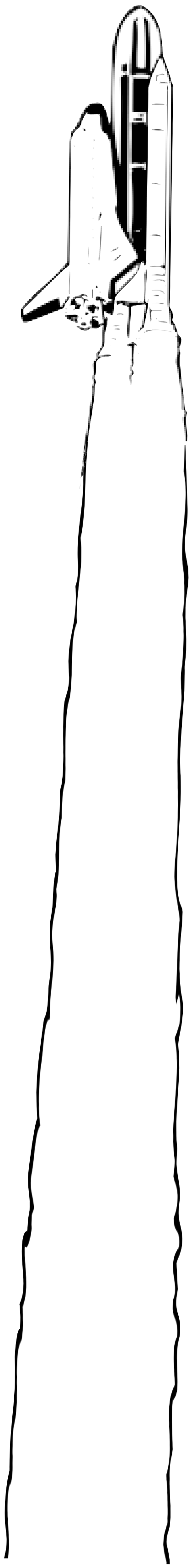
c. Wrap a piece of tape onto the fishing line at a point 3 inches away from where the top end of the fishing line is secured. This point is called the “measuring point”. The purpose of the tape is to hold the glider in place by “hooking” the paper clip over the tape to keep the glider from accidentally sliding down the fishing line.



d. Run the fishing line to the end of the desired runway area.

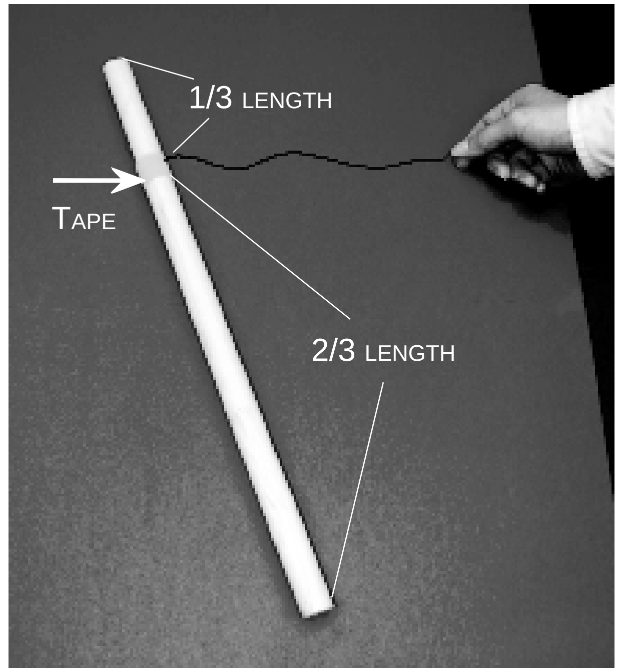
e. Lay the fishing line along the ground to help you position the runway so that the fishing line runs down the center of it.

f. Place the tape on the ground to create the runway. Remember to keep an eye on the fishing line so that it runs down the center of the runway. (Another idea for creating a runway is to use construction paper, 12" x 9", and tape 8 sheets along the 12" side so that the finished runway is 12" x 72". Draw a dashed line down the center of the runway.)

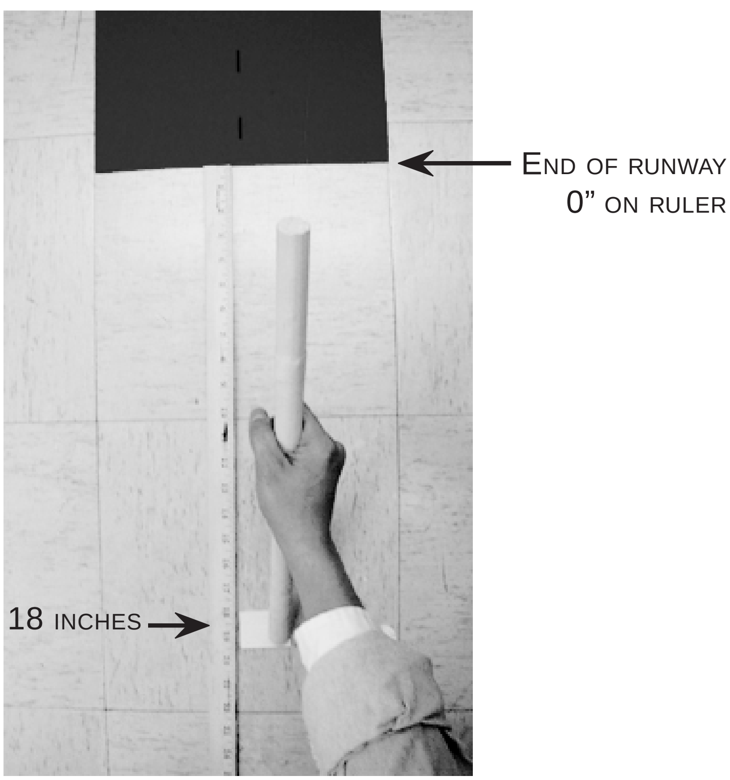


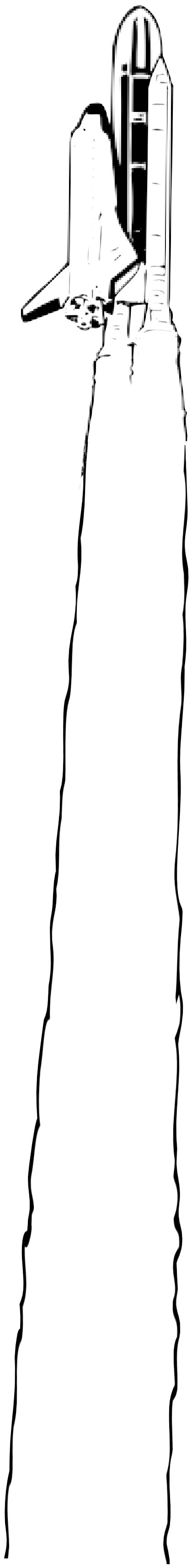
g. Make any necessary adjustments to the fishing line or the runway to make sure it is lined up.

h. Secure the fishing line onto the "control stick" about 2/3 of the length of the stick, from the bottom of the stick. For example, if your "control stick" is 18", the line should be tied 12" from the bottom of the stick. (Try tying the line around the stick then using a push pin, or tape to keep the line from sliding. Or cut a groove into the stick using scissors or an xacto knife to hold the line in place.)



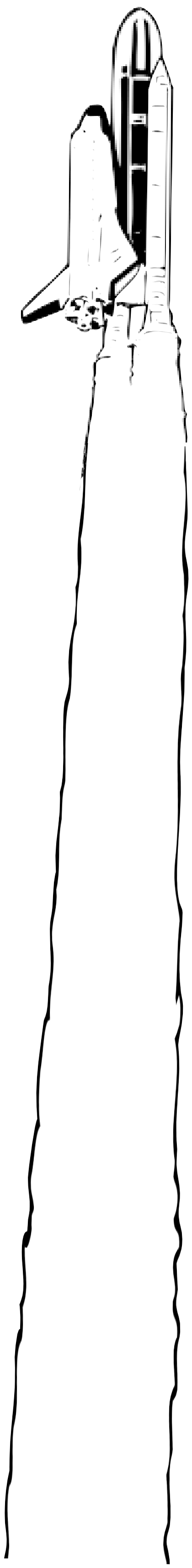
i. Place a piece of masking tape 18" past the end of the runway (on the opposite side from where the fishing line is tied to the higher end). This marks the spot where the pilot will place the bottom of the "control stick" when guiding the glider for landing. Be sure the fishing line can touch the runway, if the pilot leans the "control stick" forward.





j. Have the pilot sit down at the end of the runway with the stick held upright in front of him/her. Again, make sure the fishing line is running down the center of the runway.

k. Also check that the tension of the fishing line has enough slack to allow the glider to land on the runway. Otherwise the glider will fly right into the "control stick".



For each class

1. Large paper to display class results on scatter plot graph
2. Calculators
3. Glue (stick or white)
4. Tape (cellophane)
5. Masking tape
6. Paper clips
7. Fishing line
8. “Control sticks”
9. Tape measures or Rulers
10. Second-hand stop watches or Clock
11. Space Shuttle Glider Kit
12. Scissors
13. Pens or Pencils
14. Cardstock Paper (65 - 80 lbs.)
15. Double-sided tape
16. “Weight” (to attach to the bottom of the glider - see Step #11 in Instructions for Building Space Shuttle Glider)

Teacher’s Answer Key

Answers for Math Worksheet of Prerequisite Knowledge

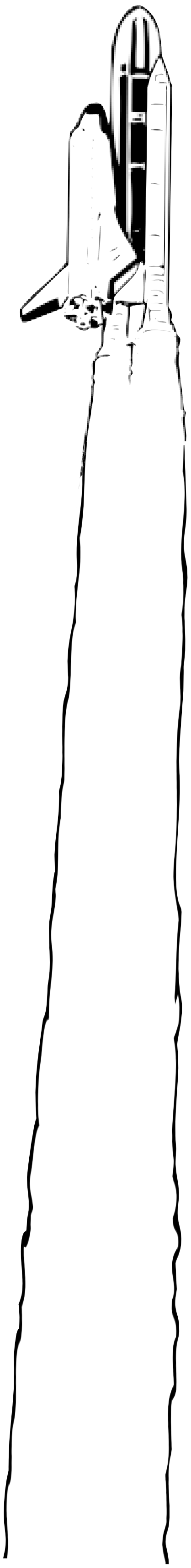
1. 36 inches
2. 66 inches
3. 30 seconds
4. 75 seconds
5. 0.5556
6. 0.5385
7. 36 degrees
8. 64 degrees
9. 45 degrees
10. 50 degrees

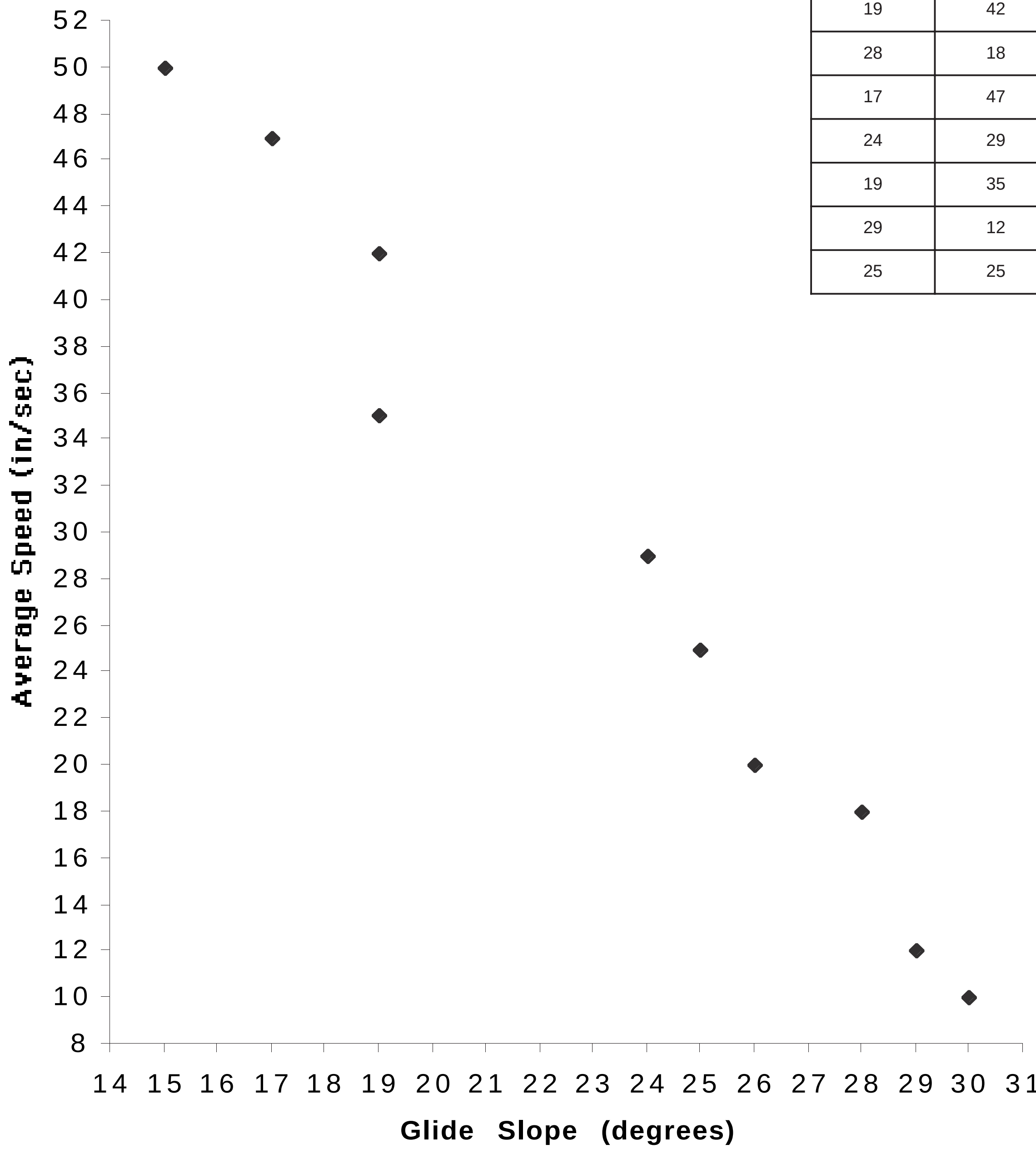
11. (on next page)

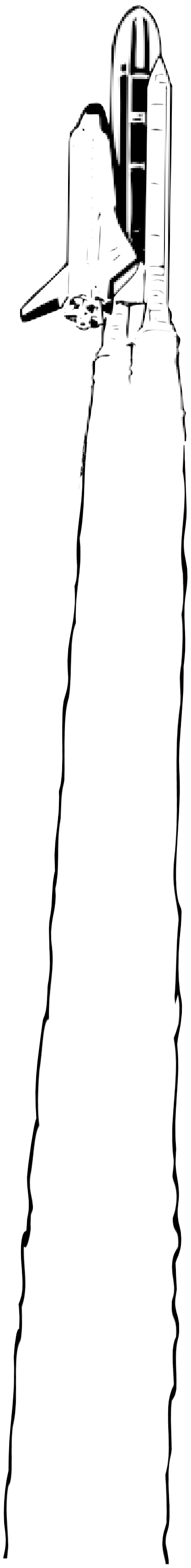
11.

Relationship between Glide Slope and Average Speed

Glide Slope	Average Speed
26	20
30	10
15	50
19	42
28	18
17	47
24	29
19	35
29	12
25	25







Answers for Practice Exercises on Computing Glide Slope

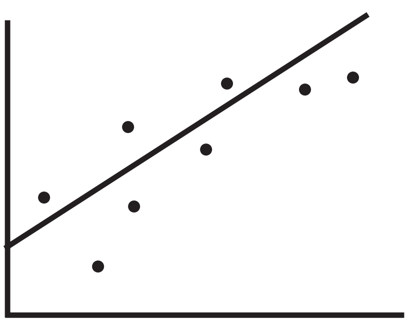
1. 62/92 = 0.6739 (closest to 0.6745, glide slope = **34** degrees)
2. 55/105 = 0.5238 (closest to 0.5317, glide slope = **28** degrees)
3. 73/90 = 0.8111 (closest to 0.8098, glide slope = **39** degrees)
4. 63/90 = 0.7000 (closest to 0.7002, glide slope = **35** degrees)

Answers for Practice Exercises on Computing Average Speed

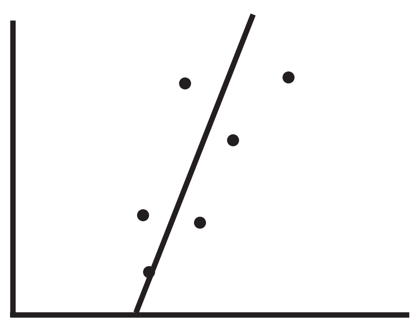
1. 92/10 = 9.2 in/sec
2. 80/6 = 13.33 in/sec
3. 75/8 = 9.38 in/sec
4. 77/9 = 8.56 in/sec

Possible Answers for Practice Exercises on Drawing a Line of Best Fit

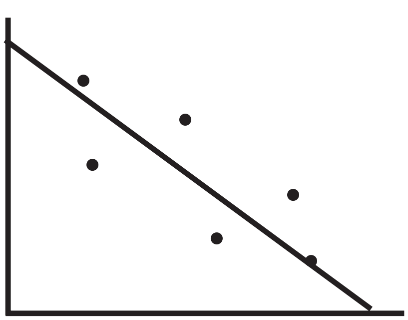
#1:



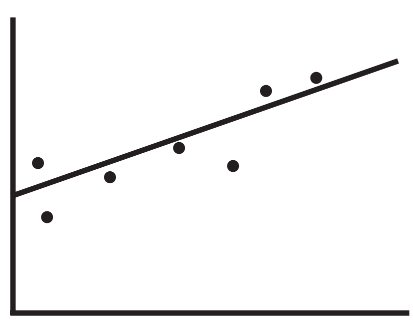
#2:



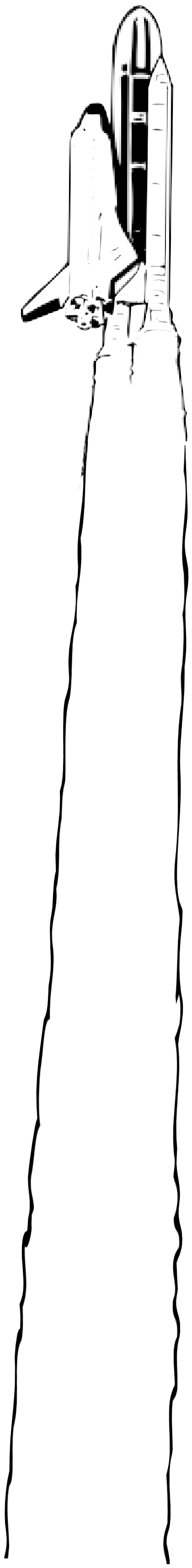
#3:



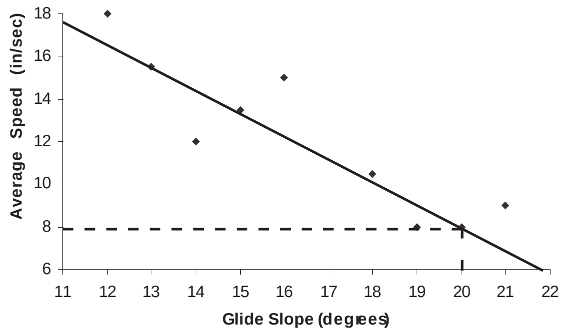
#4:



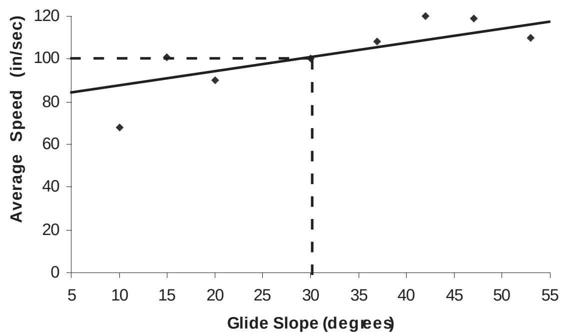
Answers for Practice Exercises on Using a Line of Best Fit for Making Predictions



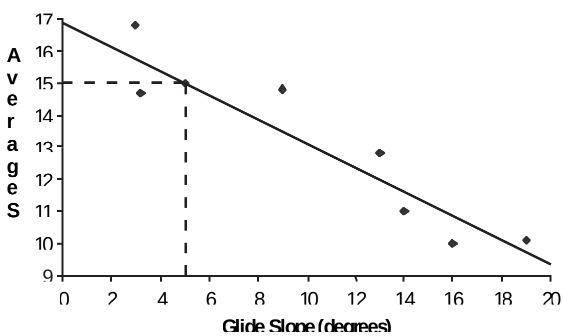
#1: If glide slope value = 20 degrees
Then, average speed = __8__ in/sec



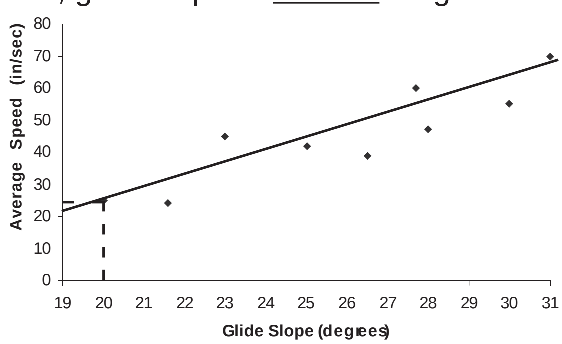
#2: If glide slope value = 30 degrees
Then, average speed= __100__ in/sec



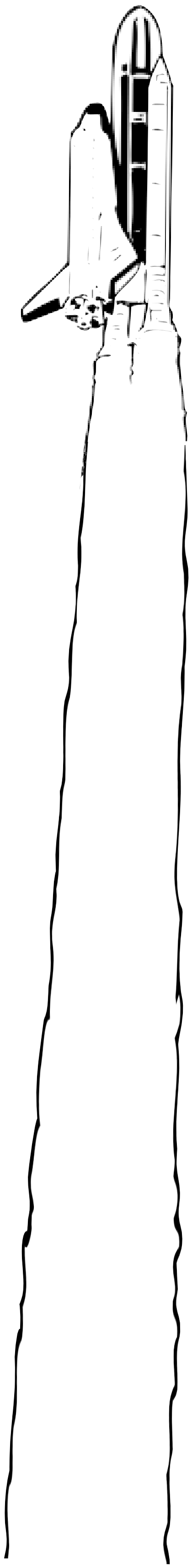
#3:If average speed = 15 in/sec
Then, glide slope = __5__ degrees



#4:If average speed= 25 in/sec
Then, glide slope = __20__ degrees



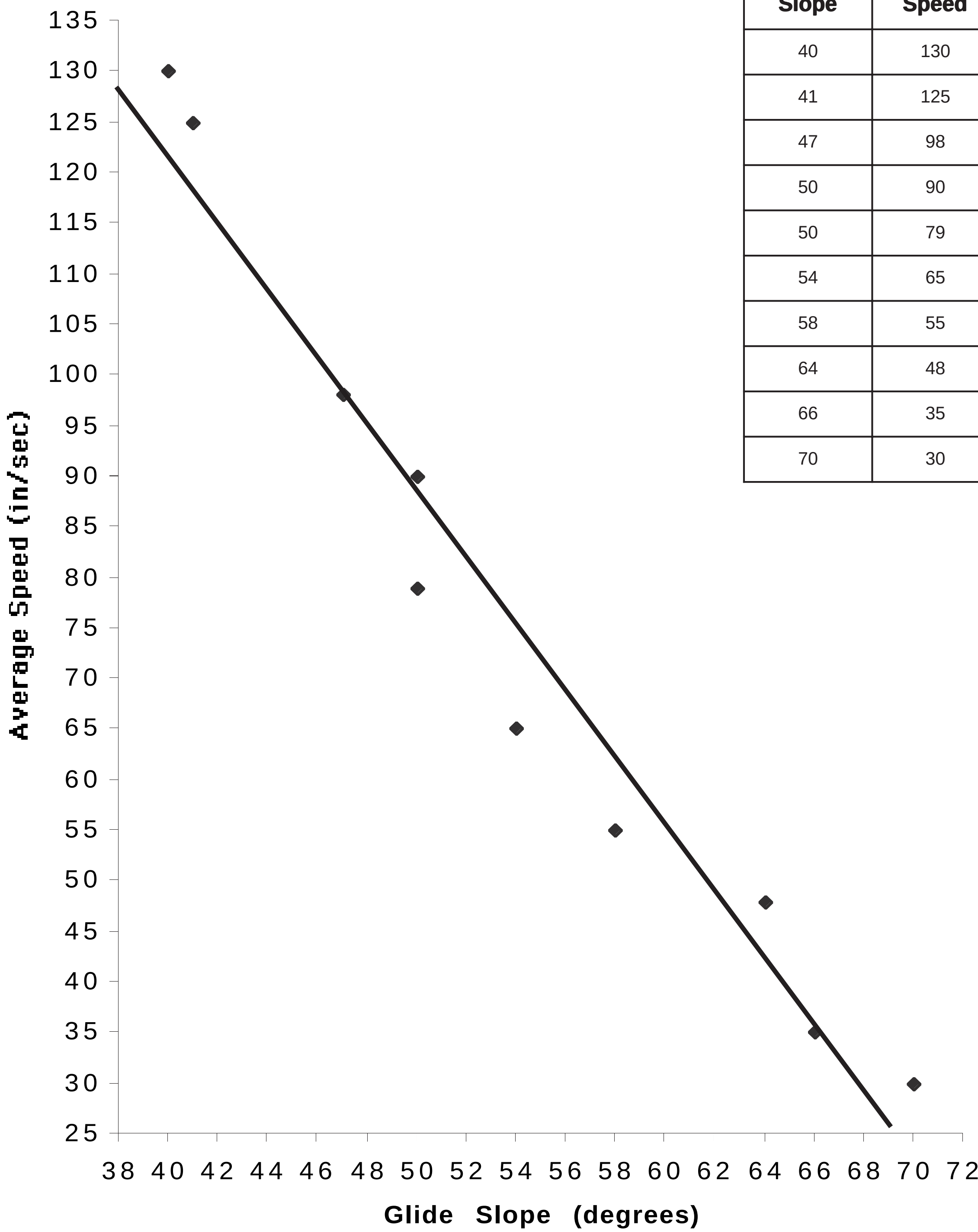
Answers for Practice Exercise on How to Create a Scatter Plot

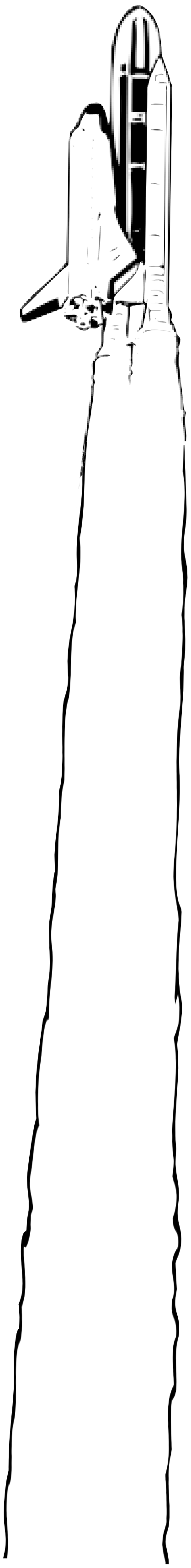


1.

Relationship between Glide Slope and Average Speed

Glide Slope	Average Speed
40	130
41	125
47	98
50	90
50	79
54	65
58	55
64	48
66	35
70	30





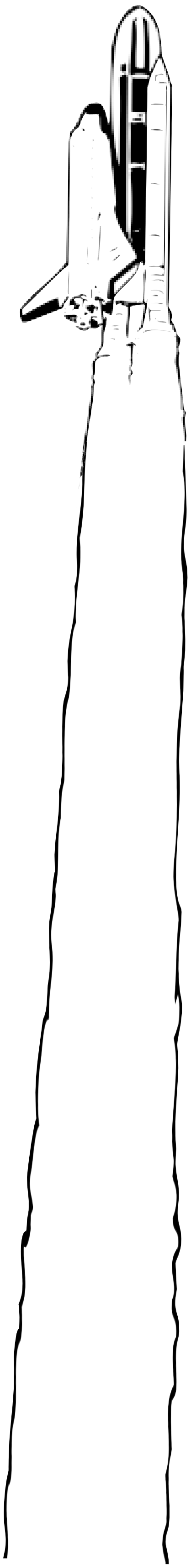
2. Negative Correlation

3. Answers may vary. Possible range of answers:

Glide Slope	Average Speed
44	(105 - 115)
52	(80 - 90)
60	(50 - 60)

4. Answers may vary. Possible range of answers:

Average Speed	Glide Slope
40	(64 - 66)
60	(58 - 60)
110	(42 - 46)



Classroom Activity

Session 1
Introduce your students to the unique qualities of the space shuttle orbiter. If possible, obtain a video clip ("Space Basics" video - http://quest.arc.nasa.gov/space/teachers/liftoff/basics.html), Web site, or other source that shows its reentry and landing. Be sure the students understand the reasoning behind the design of the orbiter and its unusual landing style. Go over the Student Reading found in the Student Handouts section.

Challenge students with the key questions and discuss:
- Why does the orbiter reenter the atmosphere at such a high velocity?
- Why is it necessary for the orbiter to reenter the atmosphere at such a steep angle of attack?
- What strategies does the orbiter take to slow down before landing?
- Does glide slope affect the speed of the glider?

Again using the Student Reading, have them discuss and compare some of the speeds and distances of the space shuttle to values that are more familiar to our lifestyles. Also review the Vocabulary List.

Session 2
Go over the necessary prerequisite math knowledge with students. Use the Math Worksheet, if appropriate.

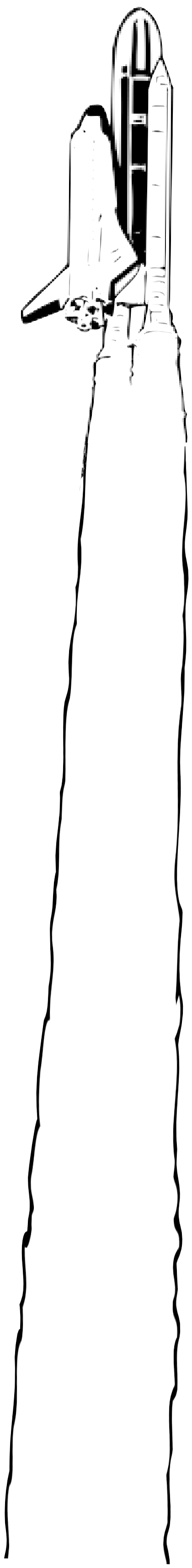
If time allows, explain to students the nature of the experiment with the shuttle glider so they know what to expect in the next two days. Show students a completed shuttle glider model and give them a sneak peek of the landing site.

Session 3
Assign students into teams of 3-4 people. Determine team names or numbers. Go over Team Members and their Roles.

Go over Space Shuttle Glider Activity - Student Information and Teacher Information

Go over Instructions for Building the Space Shuttle Glider.
Give students necessary materials (glider kit, glue, cellophane tape, paper clips, etc.) and the instruction sheet to build their gliders. Be sure each student has their name on their own glider, and remind them to puncture holes in the glider, before they glue or tape it together.

If students finish early, have them help you set up other landing sites around the room for Session 4's landings. (fishing line, sticks, masking tape)



Session 4
Go over Instructions for Landing Procedures.
Perform a trial run for your students so that they can see how the glider will “fly” on the fishing line. Try not to reveal the technique for being able to successfully land the glider. You may want to get a student to volunteer to be a “test pilot” for the first initial flight test.

Assign groups of 3-4 people. Hand out the Landing Data Collection Sheets (one per student) and have each student write their name in the **Pilot** box. Go over How to Compute Flight Time. Make other materials (tape measure, rulers, stop watches, calculators, etc.) available and allow them to perform their landings.

Session 5
Finish up Landings.

Go over How to Compute Glide Slope and How to Compute Average Speed. Hand out Table for Determining Glide Slope.

Session 6
Go over Purpose of Scatter Plot and How to Create a Scatter Plot

Hand out graph paper to allow each student to make their own scatter plot. Make a large class size graph and have each student plot their own point onto the graph. Place glide slope measurements on the x-axis and speed measurements on the y-axis.

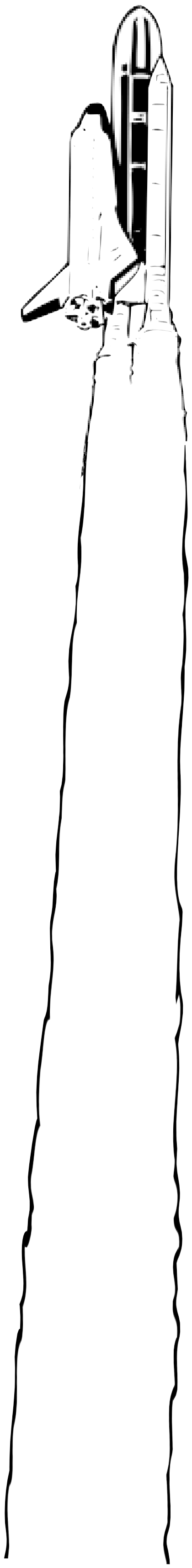
Session 7
Have each team of students share and discuss their group’s results.

- What did your group enjoy about this activity?
- What did your group find difficult about this activity?
- Name 2-3 things your group learned about the space shuttle that you did not know before.
- What were your glide slope angles? How did it affect the landings of the glider?

Discuss the results of the group as seen on the scatter plot. Is there a positive, a negative or no correlation between the two measurements? Have a student draw a line of best fit. Using this line, see if the students can:
- predict the speed of the glider given a glide slope.
- predict the glide slope given the speed of the glider.

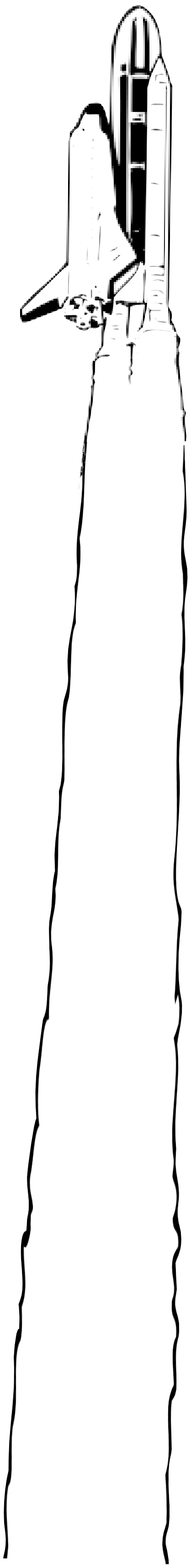
If students finish early, change the flight distance (fishing line) either shorter or longer, or move the runway, either towards the high end or towards the “control stick”, to see if students can adjust the flight of the glider and still land successfully.

Glide Slope Activity: Student Handouts



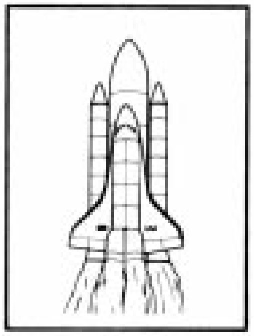
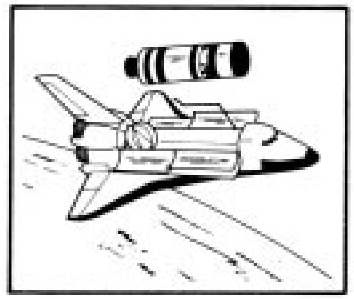
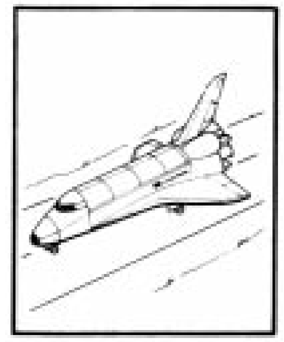
Contents:

- Student Reading, with graphics, that explains the intricacies of Landing the Orbiter, Angle of Attack, and Glide Slope
- Vocabulary List
- Space Shuttle Glider Activity - Student Information
- Instructions for Building the Space Shuttle Glider
- Team Members and their Roles
- Instructions for Landing Procedures
- Landing Data Collection Sheet
- Math Worksheet of Prerequisite Knowledge
- How to Compute Glide Slope
- How to Compute Flight Time
- How to Compute Average Speed
- Table for Determining Glide Slope
- Purpose of a Scatter Plot
- How to Create a Scatter Plot



<u>Student Reading</u>

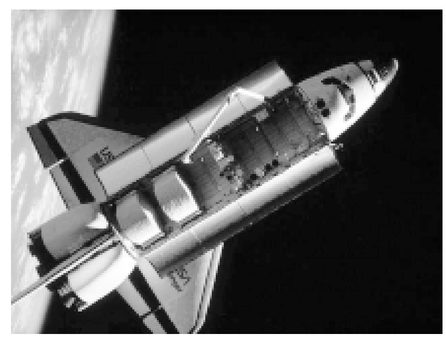
The Space Shuttle is a true aerospace vehicle:

It launches like a rocket	It functions in orbit as a spacecraft	It lands like an airplane
		

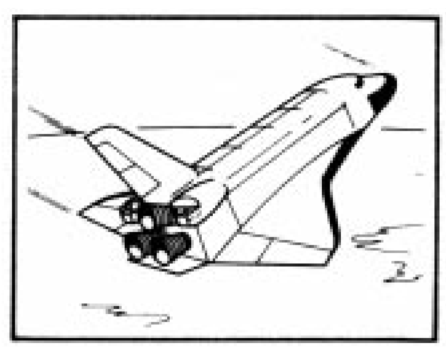
<u>Landing the Orbiter</u>

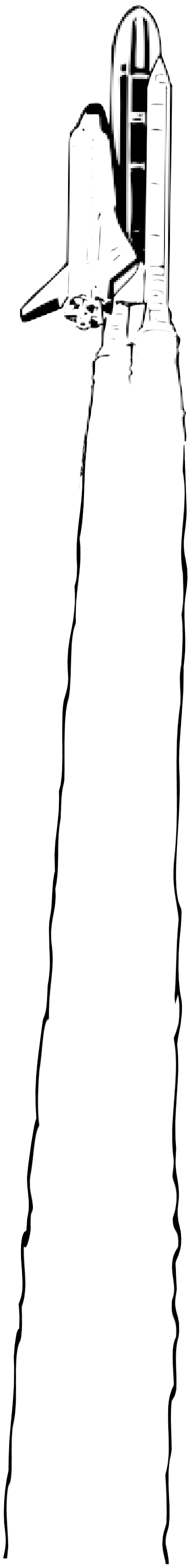
Landing the shuttle like an airplane begins 60 minutes prior to touchdown on the runway and is the final and most critical phase of the mission.

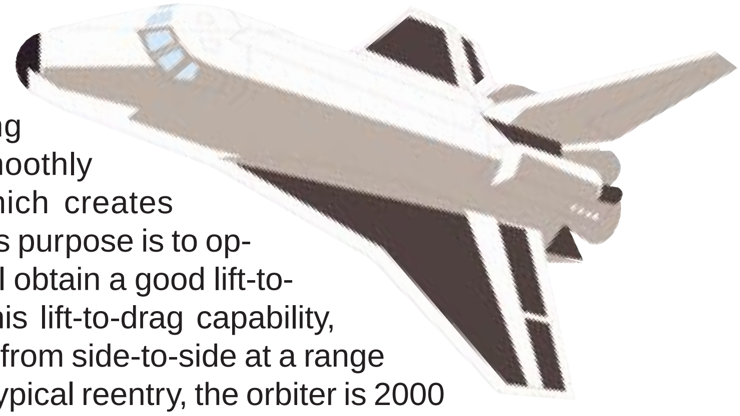
To examine this phase, let's begin the de-orbit process. The shuttle orbits the earth at a velocity of 27,000 km/hr.(That's over 17,000 mph! Race cars in the Daytona 500 speed race travel at "only" **230mph**.) Because the orbiter is traveling so fast, several things must be done in order to slow its descent and guide the orbiter safely back to earth.



One of things the orbiter does to slow itself down is to position the orbiter with its nose up at a high angle of attack and its travel-path at a glide slope between 28 to 38 degrees for reentry into the atmosphere. Because this brings the orbiter in belly-first, it increases drag as a wider surface is passing through all those air molecules. Imagine if you tried to sink a "boogie-board" (Styrofoam™ toy that floats on water) to the bottom of a swimming pool. It is much more difficult to sink the board if you tried to push it down belly-first, than if you tried to sink it on its side edge. This is the same concept that keeps the orbiter from landing at such a high speed.

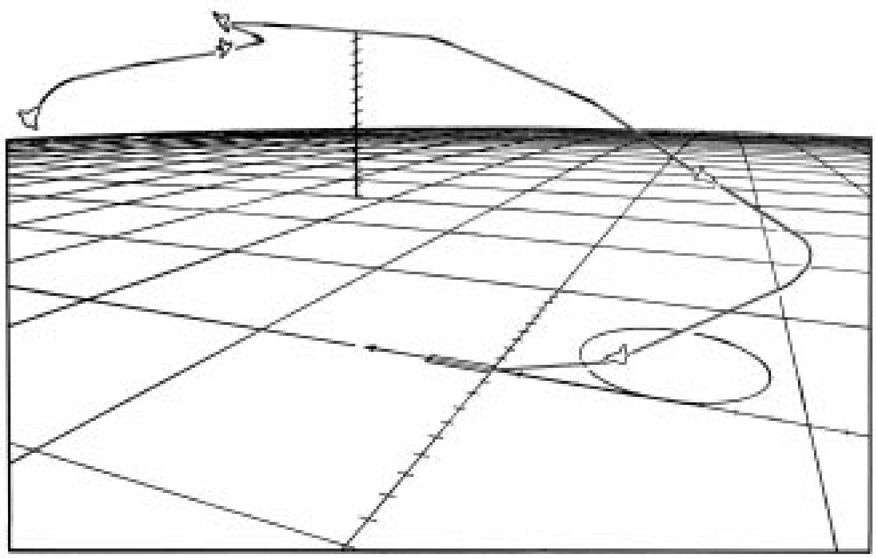






Secondly, the orbiter is designed with a double-delta wing configuration in which the forward placed delta wing creates vortices that flow smoothly over the main delta wing which creates greater lift and reduces drag. Its purpose is to optimize hypersonic flight and still obtain a good lift-to-drag ratio for landing. With this lift-to-drag capability, the orbiter is able to maneuver from side-to-side at a range of 2000 km (1240 miles). In a typical reentry, the orbiter is 2000 km away from the path of the runway and must fly, to its right, at its capacity range in order to position itself in line with the runway. This maneuver occurs 52 minutes before landing, with the shuttle at its maximum bank angle of 71 degrees.

The orbiter also performs a maneuver called a roll reversal, or S-turn. When the orbiter is 16 minutes away from touchdown, it begins its first of four S-turns which slows it down, just like a skier can slow down by making turns when coming downhill.



The rudder, which is on the tail of the orbiter, controls the yaw of the vehicle. The orbiter has a unique split-design rudder which allows it to also act as a speed brake. By pressing on both rudder pedals with both feet, the rudder "splits" open in a flat position just like a birthday card opens up. The rudder is opened to a full-out position ten minutes before the orbiter lands, but is soon adjusted to another position to provide assistance in directing yaw, as well as help reduce its speed.

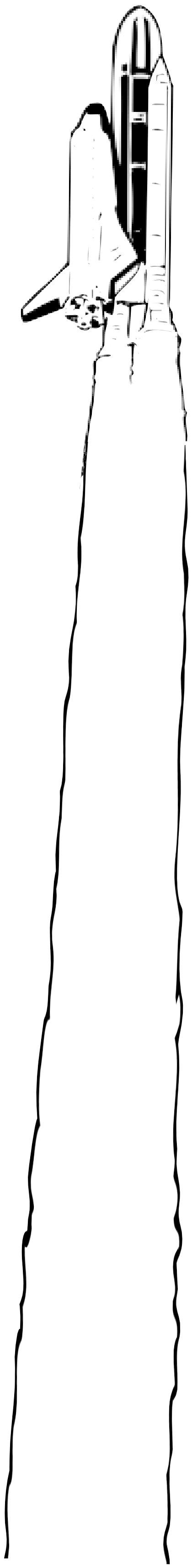
The shuttle is flying on auto-pilot for much of the descent, because the air is not thick enough for the orbiter's controls to be effective. But at 4 minutes before landing, the shuttle commander takes manual flight control of the spacecraft and keeps the orbiter in line with the center of the runway. The commander takes the orbiter out of the steep, 22 degree, glide slope by sharply pulling the nose up. This, flare maneuver, reduces the glide slope to 1.5 degrees (which is nearly parallel with the runway) with the nose pointed up. The pilot then lowers the landing gear at 27 meters (90 feet) off the runway. The landing gear creates a lot of drag and slows the orbiter down from 530 km/hr (330 mph) to 340 km/hr (215 mph). At this speed, the commander can land the orbiter at a safe speed. The speed at which the shuttle lands is typically two times faster than commercial airliners.

On touchdown, the orbiter activates its rudder once again to its full open position, and finally, the orbiter deploys a parachute to slow to a stop.

The accuracy of the landing is crucial because the orbiter lands like a glider does. It is not equipped with engines to give it thrust while flying in the Earth's atmosphere. Because it does not have engines like regular airplanes, the commander cannot abort a landing, give full thrust to the (non-existent) engines and circle the runway for another attempt. It has only one chance to land. Amazingly enough, the orbiter, which is traveling at such a high velocity, reenters the atmosphere at a point halfway around the world from its landing site. From this distant reentry, it is committed to its landing site.

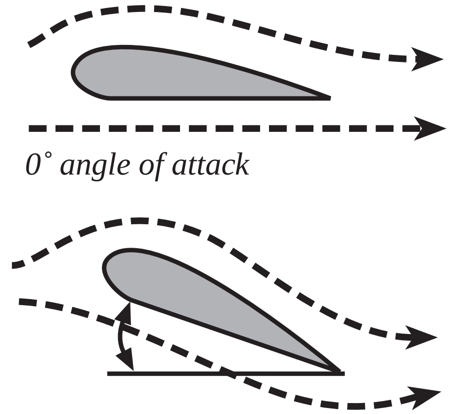
Angle of Attack

The picture shows the wing of an aircraft as it travels in a straight path parallel to the ground. The angle of attack refers to the angle between the wing and its flight direction.



Angle of attack can change in two ways:

1. If the aircraft pitches its nose up or down, it will change its angle of attack. Imagine if you are holding your hand out the window of a moving car. The “flight” direction of the car is parallel to the ground just like in the picture. Now, if you were to hold your hand out flat so that your fingertips pointed into the wind, you could simulate the change in angle of attack by “pitching” your fingertips higher (towards the sky) or lower (towards the ground). You can also feel what an aircraft might feel when the angle of attack is changed, by how strong the wind is blowing on your hand, and where on your hand the wind is blowing.



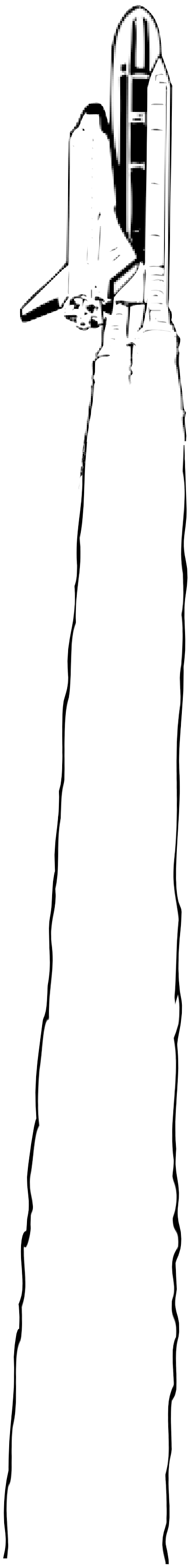
0˚ angle of attack

20˚ angle of attack

2. Now imagine you are on a roller coaster, and you are holding your hand out, just like you did in the car example, but, this time, don’t move the angle of your hand. The angle of attack is changing, even though your hand isn’t moving, because the direction of the roller coaster is changing. Sometimes, you are going in a steep climb, other times, you are steep drop, and then at other times, you are whizzing upside-down. Again, you can feel the effects of the changing angle of attack by the feel of wind on your hand.

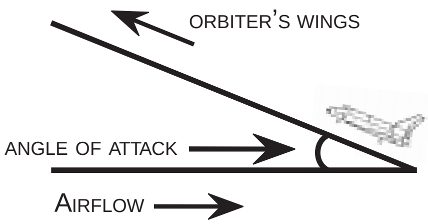
Glide Slope

The picture shows the shuttle as it approaches the runway for landing. Glide slope of the shuttle refers to the angle between the flight direction of the shuttle with respect to the ground. To understand glide slope, read this scenario: Imagine you are on a 3-meter high diving board (This is the typical size diving board found at local pools). Let’s say you were to dive, head-first, body completely straight, and with your arms out in front of your body. If someone were to take a picture of you the moment your hands hit the water, the angle your body makes with the water, would be the glide slope. In competition, divers try to enter the water at a 90 degree glide slope.

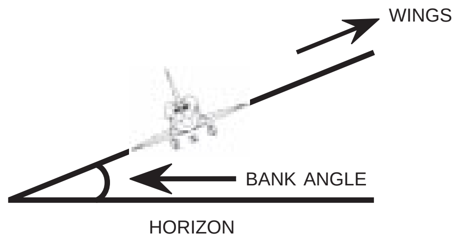


Vocabulary List

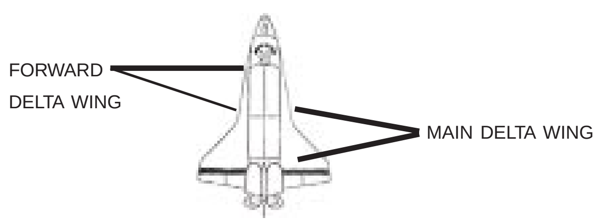
- **angle of attack** - the angle of the orbiter's wings to the oncoming airflow.



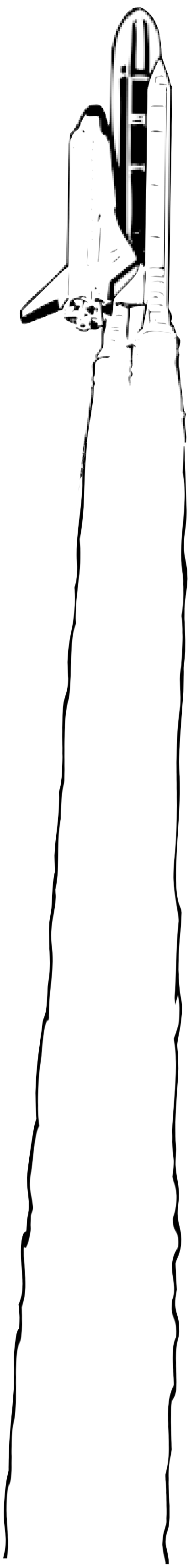
- **bank angle** - (roll) the angle between the wings and the horizon.



- **drag** - the force that resists the motion of the aircraft through the air, friction.
- **double delta wing** - a wing design that combines a forward placed delta wing with a main delta wing. The forward placed delta wing creates vortices that flow smoothly over the main delta wing, which creates greater lift and reduces drag.



- **glide slope** - the angle at which the orbiter descends with respect to the ground.
- **hypersonic flight** - refers to speeds above Mach 5 - five times the speed of sound.
- **lift** - upward force produced by air passing over and under the wing of an airplane.
- **orbit** - the circular path of the shuttle in space, around the Earth.
- **Mach** - term used to describe the speed of objects relative to the speed of sound.
- **Mach 1** - the speed of sound; approximately 1226km/hr (762 mi/hr).
- **unit rate** - a ratio written as a fraction comparing two different values, the value in the denominator is always 1. (examples: 55 miles/ 1 hour or $.99/ 1 pound.



<u>**Space Shuttle Glider Activity - Student Information**</u>

1. You are to construct a space shuttle glider which is reduced to a scale of 1cm:300cm compared to the actual U.S. Space Shuttle orbiter. There are Instructions for Building the Space Shuttle Glider that will guide you step-by-step through the process.

2. You will be assigned to a team of 3 or 4 people where you will rotate positions as the pilot, copilot, Mission Control Center, and Mission Specialist for each landing. Find out what each person does on the Team Members and their Roles Sheet.

3. Using a constructed landing site, you will re-enact the landing procedure. Remember to take turns being the pilot, copilot, Mission Control Center, and Mission Specialist. If you have only 3 people in your group, the Mission Control Center will be the Mission Specialist at the same time.

4. When you are the Mission Specialist, be sure you have the **pilot's** Landing Data Collection Sheet. You are in charge of recording the data for the pilot on his/her Landing Data Collection Sheet.

5. When you are the pilot, be sure to give your Landing Data Collection Sheet to the Mission Specialist.

6. There is a Handout called **Math Worksheet of Prerequisite Knowledge** that each team member must complete. It will assist you in completing the Landing Data Collection Sheet.

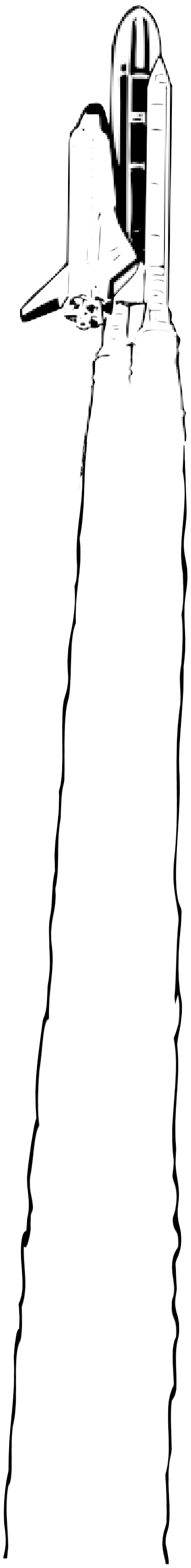
7. There are other aids to help you complete the Landing Data Collection Sheet:
   - How to Compute Glide Slope
   - How to Compute Flight Time
   - How to Compute Average Speed
   - Table for Determining Glide Slope

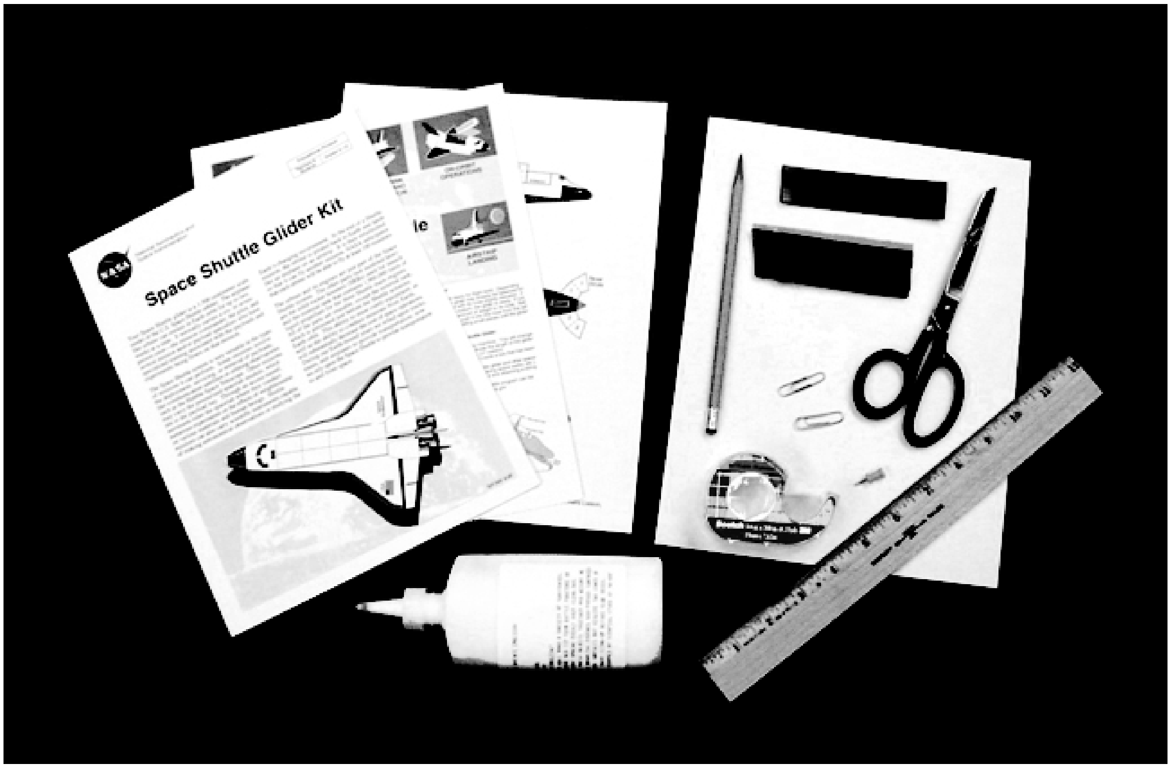
8. After you've completed the Landing Data Collection Sheet, you will use your numbers for the Glide Slope and Average Speed to create a scatter plot. There are two handouts to help you:
   - Purpose of a Scatter Plot
   - How to Create a Scatter Plot

9. Finally, your group will have the opportunity to share your results with the class and help create a class-wide scatter plot.

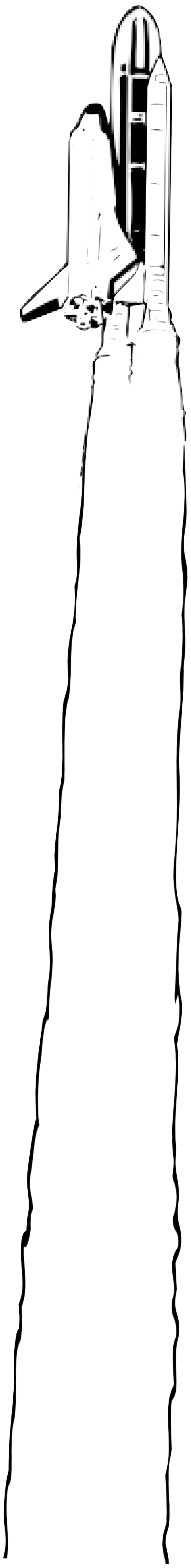
Instructions for Building the Space Shuttle Glider:

Materials needed:





- Space Shuttle Glider Kit printed on cardstock (65-80 lbs.)
- Pen or Pencil
- Scissors
- Rulers
- Glue (stick or white)
- Tape (cellophane)
- Double-sided tape
- “Weight” (heavy/thick paper, heavy cardboard, flat magnet etc. approximately 0.6 oz)
- 2 small paper clips per glider



1. Before cutting, write your name in any of the empty rectangles near the “flaps”.

2. Using scissors, cut out the entire pattern on the outside lines. (Do not cut along the dashed lines.) The more careful you are cutting, the better the finished glider will look.

3. Line up the ruler with the dashed fold lines. Use the edge of another ruler to press a groove into the lines. This will make folding more accurate.

4. After creasing all folds in the glider, line up the 2 top pieces side to side and use a push pin to puncture a hole near the cockpit windows. Making sure that the flaps are folded inside the glider, puncture another hole through the last rectangle (that has the word NASA in it) so that it goes through the flap to the other side.

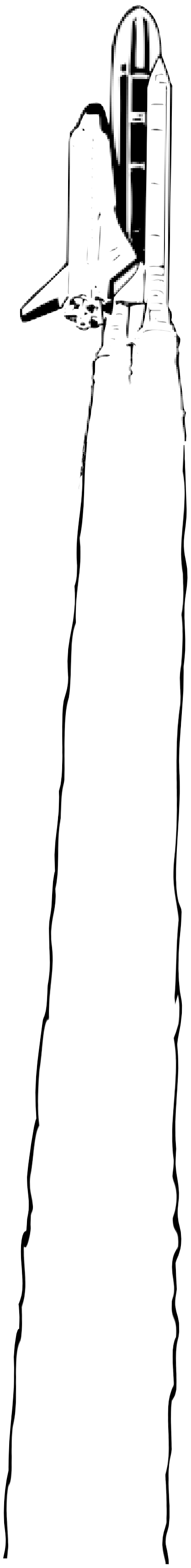
5. Fold the paper on all dashed lines. The dashed lines will be up for a mountain fold and down for a valley fold.

6. Lightly cover both pieces of nose strut 1 with glue. Fold it over the nose of the glider to form a triangle shape. Bend nose strut 2 over and press to strut 1 until the glue holds.

7. Coat the inside of each wing with glue and press top and bottom together. Be very careful to line up the parts.

8. Coat the inside of the tail pieces with glue. Also coat the outside of the four flaps along the payload bay with glue. Bring the two sides of the payload bay together so that all flaps slide **inside** the glider. Lightly press the payload bay and the tail pieces together until the glue holds.

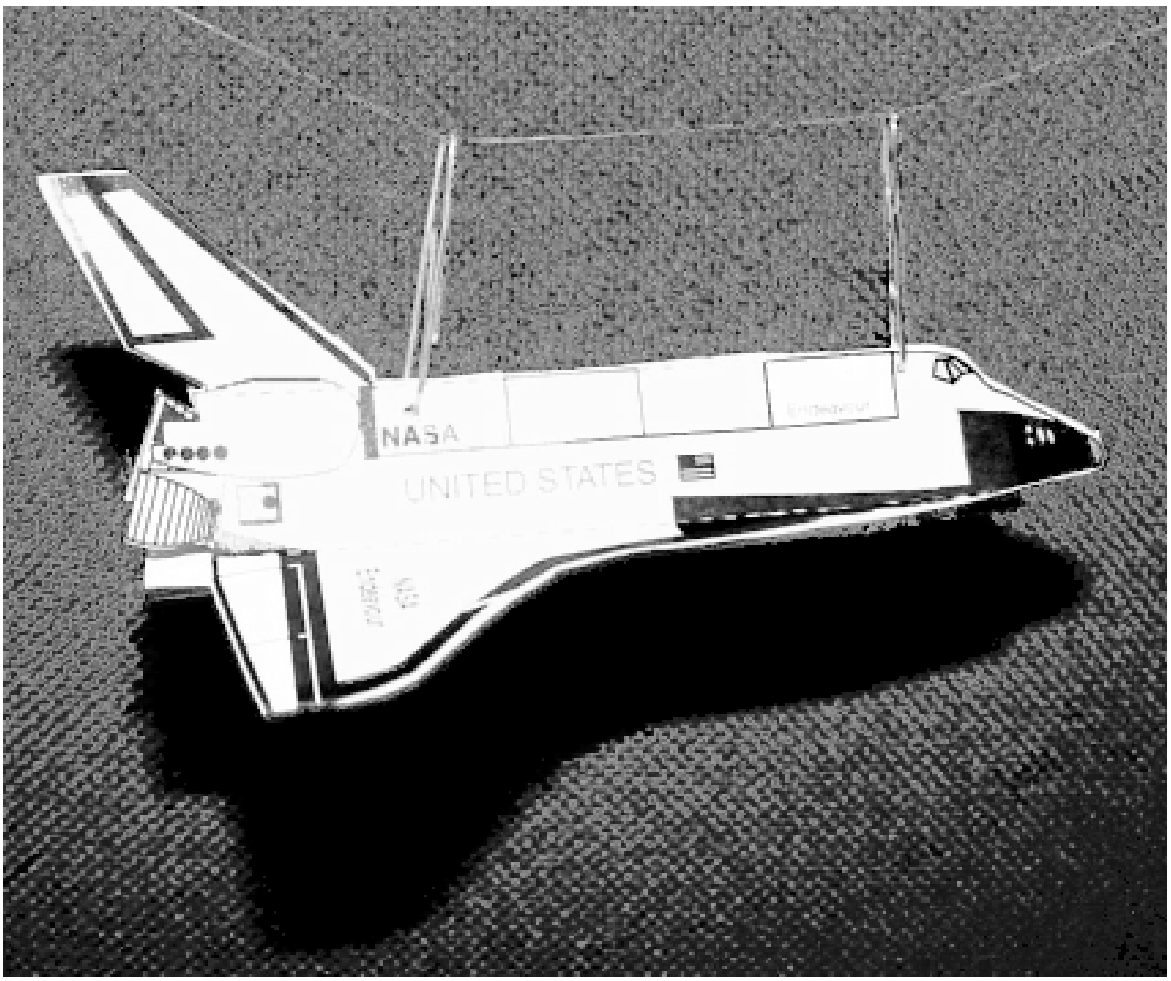
9. Coat the inside surface of the nose on each side with glue and press them to the struts until the glue holds. If you wish, strengthen the nose with a small amount of cellophane tape.



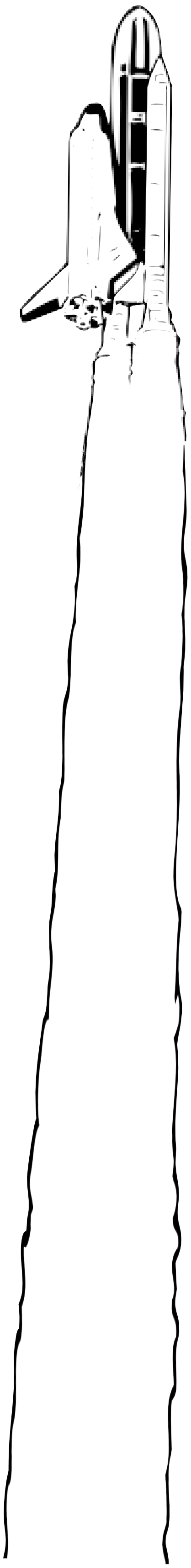
10. Put a small amount of glue on the inside of the tiny triangle at the nose of the glider. Bend it upward to close the hole. As the glue dries, the triangle will stay put.

11. Glue or use Double-sided tape to attach a “weight” to the bottom of the orbiter. A weight of approximately 0.6 oz is recommended when using the suggested landing site parameters. Some ideas for weights include (heavy/thick paper, heavy cardboard, flat magnets, or anything heavy enough, but still flat enough so that it does not produce too much drag). This weight is needed to give the shuttle enough momentum to reach the runway without “stalling” on the fishing line.

12. Hook a small paper clip into each of the holes in the glider.



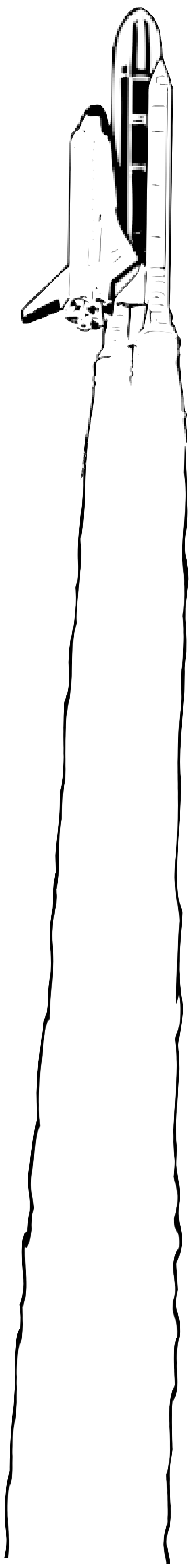
Team Members and their Roles: (pilot, copilot, Mission Control Center, and mission specialist) If there is a group with only 3 people, have one person be both Mission Control Center and the mission specialist.



- Pilot - The pilot sits at the end of the runway and holds the "control stick" to position the fishing line so that it is centered down the middle of the runway. It is also necessary to cooperate with the copilot in checking the fishing line connections at both the "control stick" end and the higher end, as well as the tension of the fishing line. The pilot maneuvers the "control stick" to guide the glider in for a smooth landing.

- Copilot - The copilot is in charge of preparing the glider for flight. This person should cooperate with the pilot in checking the fishing line connections at both the "control stick" end and the higher end as well as checking the tension of the fishing line.

After "hooking" the paper clip, from the glider onto the fishing line at the "measuring point", the copilot holds the top end of the tape measure or ruler at the tip of the glider's nose, so that the mission specialist can find the Height of the Glider from the ground. Once measurements have been taken, the copilot continues to hold the glider at the "measuring point" until given clearance from Mission Control Center to unhook the glider for landing.



<u>Team Members and their Roles</u>: (continued)

- Mission Control Center (MCC) - This person must double check everyone's duties:
  - be sure the pilot
    - is positioned correctly
    - has checked the fishing line connections and tension
    - is prepared to "fly" the glider
  - be sure the copilot
    - has checked the fishing line connections and the tension
    - has correctly prepared the glider for flight
  - be sure the mission specialist
    - has the necessary equipment to collect data on glide slope, flight time, and flight distance

  Mission Control Center is the only person who can give the clearance signal - "cleared to land" - that allows the copilot and pilot to initiate the landing sequence. (The clearance signal could be a countdown such as "3-2-1-Cleared for Landing!" or simply "Ready-Set-Go!")

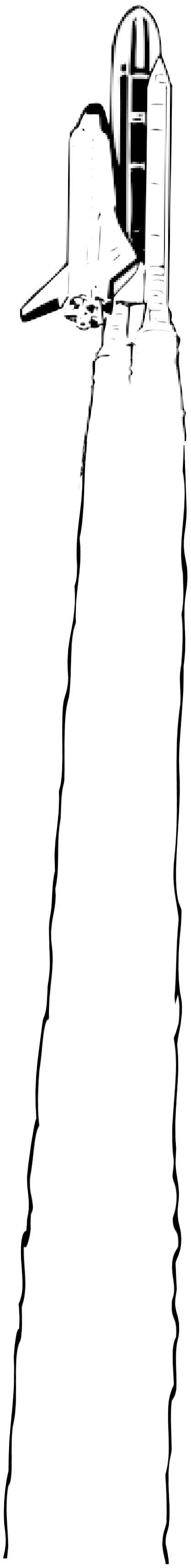
- Mission Specialist - This person has the duty of recording the data from the flight. Data must be collected on:
  - Height of glider from ground (using tape measure or yardstick)
  - Total distance to touchdown point (using tape measure or yardstick)
  - Slope (using calculator to determine decimal equivalent
  - Glide Slope (using Table for Determining Glide Slope)
  - Flight Time (using watch or clock with second-hand)
  - Speed (using data from Total Distance and Flight Time)

  Be sure the specialist has a pencil and the Landing Data Collection Sheet.

Each team member is responsible for:

- Reading the Student Reading
- Reading the Vocabulary List
- Building the glider
- Knowing the responsibilities of each different position
- Assisting in the landing procedure
- Completing the Math Worksheet of Prerequisite Knowledge
- Helping to compute glide slope, flight time, and speed
- Creating the scatter plot
- Helping to clean-up

Instructions for Landing Procedures:

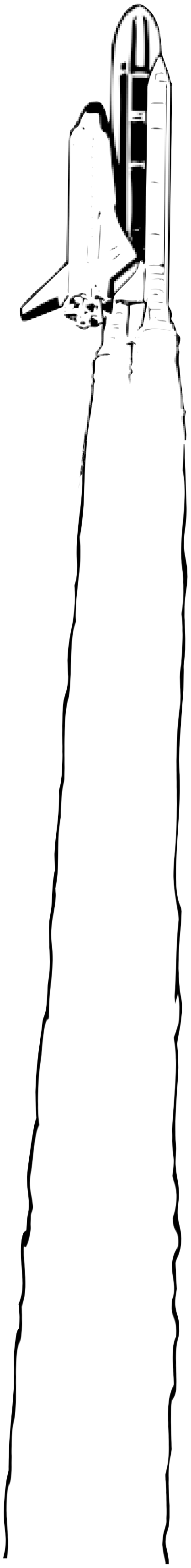


1. The copilot “clips” the glider onto the fishing line (from the high end) and positions the glider at the “measuring point” until Mission Control gives the clearance signal.

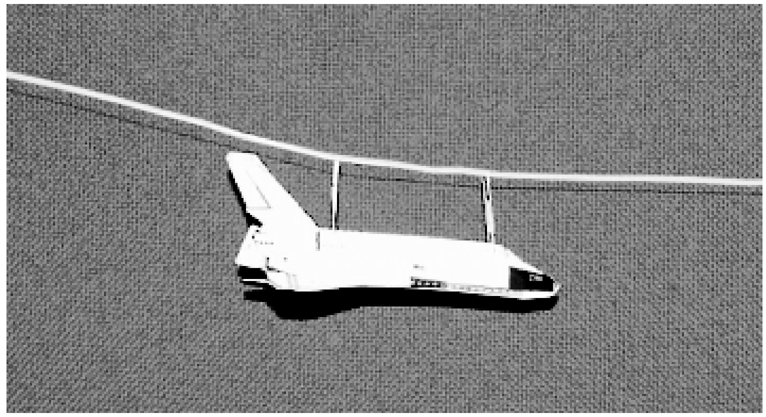
2. The pilot holds the “control stick” upright with one end on the floor, so that the fishing line is running down the center of the runway. Make any necessary adjustments so that the fishing line and the center of the runway are lined up, and so that the fishing line has enough slack to allow the glider to land on the runway and not glide into the “control stick”.

3. Once the copilot and pilot are in position, the mission specialist and Mission Control Center will begin taking measurements (see “How to Compute Glide Slope”). The mission specialist must be ready with the Landing Data Collection Sheet and equipment (pencil, tape measure or ruler, second hand watch, calculator).

4. Mission Control Center watches over the pilot, copilot, and the mission specialist to make sure everyone is properly set-up and ready before giving the clearance signal. (The clearance signal could be a countdown such as “3-2-1 Cleared for Landing!” or simply “Ready-Set-Go!”)



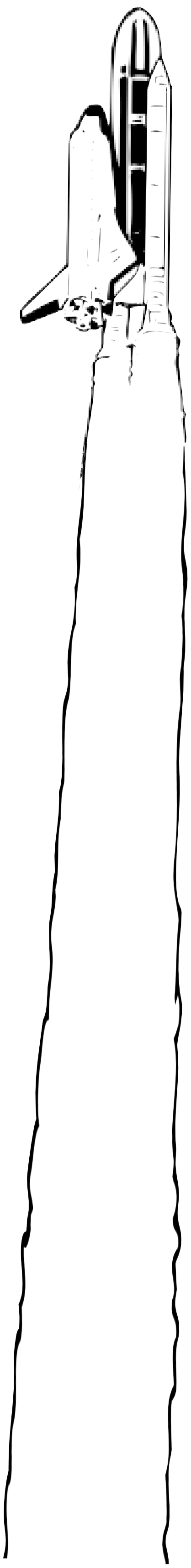
5. Once Mission Control Center gives the clearance signal, the copilot releases the glider. The glider starts its descent as it zooms down the fishing line toward the pilot.



Please Note: Fishing line has been "enhanced" in this picture so that it can be seen.

6. At the moment the copilot releases the glider, the mission specialist must be watching the second-hand of a watch or clock to begin timing the number of seconds the glider is in motion. When the glider comes to a complete stop, the mission specialist should record the Flight Time (in seconds) on the Landing Data Collection Sheet.

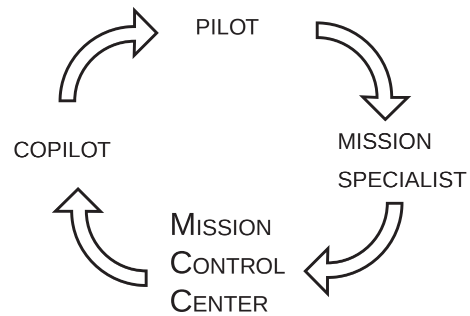
7. The pilot must control the glider's flight path and speed with the "control stick" to make it land on the runway. A successful landing is defined as the pilot smoothly landing the glider on the centerline of the runway.



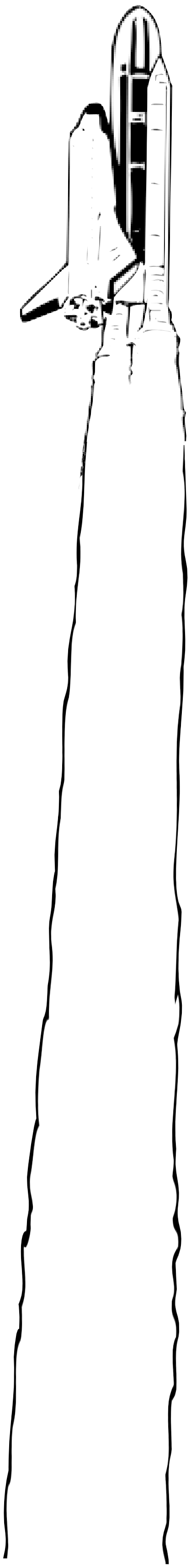
8. If the landing is successful, have the mission specialist record all the data, then have everyone rotate positions to experience the landing from another viewpoint.

9. If the landing is unsuccessful, reset the glider and allow the pilot another chance to land the glider. The mission specialist should not record the data unless the landing is a successful one.

10. The positions should rotate in this order:
    - pilot to mission specialist
    - copilot to pilot
    - Mission Control Center to copilot
    - Mission specialist to Mission Control Center



11. The "new" mission specialist will need to use the "new" pilot's Landing Data Collection Sheet to record the next set of data.

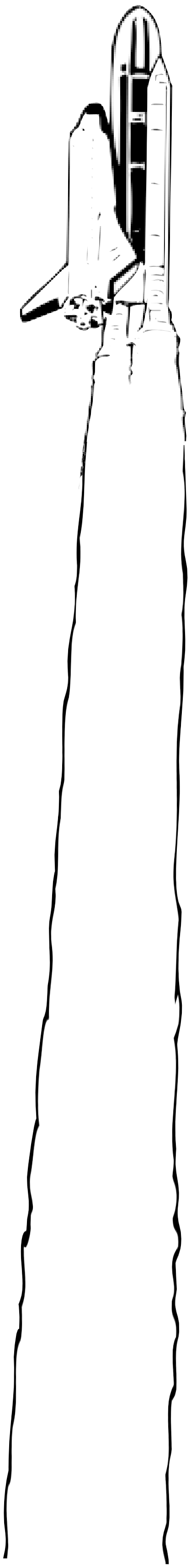


<u>Landing Data Collection Sheet</u>

For the Mission Specialist : Please fill in the left column with Team name (or number) and with names of the pilot, copilot, Mission Control Center, and Mission Specialist.

Be sure to write in all measurements and calculations listed below.

Team ____________	Height of glider from ground parallel to **y-axis** (inches) ____________
Pilot ____________	Total distance to touchdown point along **x-axis** (inches) ____________ (measure distance on the ground)
Copilot ____________	Slope = --------- = ----------- (fraction) ________
Mission Control Center ____________	Glide Slope (use table) ____________
Mission Specialist ____________	Flight Time (in seconds) ____________
	Average Speed: Total Distance / Flight Time (in inches / second) ____________



<u>Math Worksheet of Prerequisite Knowledge</u>

Round answers to the nearest hundredths place, when necessary.

1. Convert 3 feet into ________ inches.
2. Convert 5.5 feet into ________ inches.
3. Convert 0.5 minute into ________ seconds.
4. Convert 1.25 minutes into ________ seconds.

Round answers to the nearest ten-thousandths place.

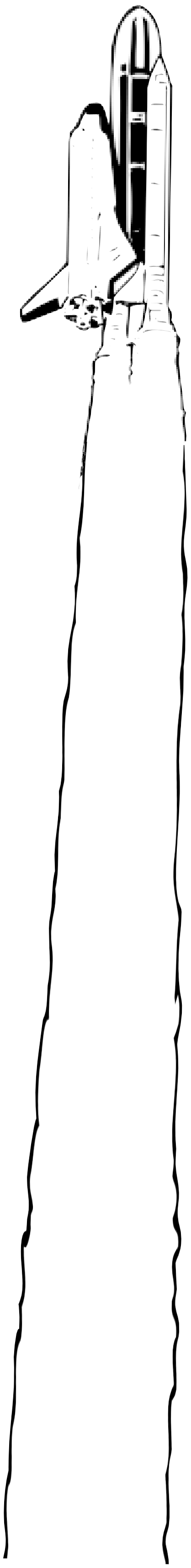
5. Convert 5/9 into a decimal. ________
6. Convert 7/13 into a decimal.________

Use the Table for Determining Glide Slope.

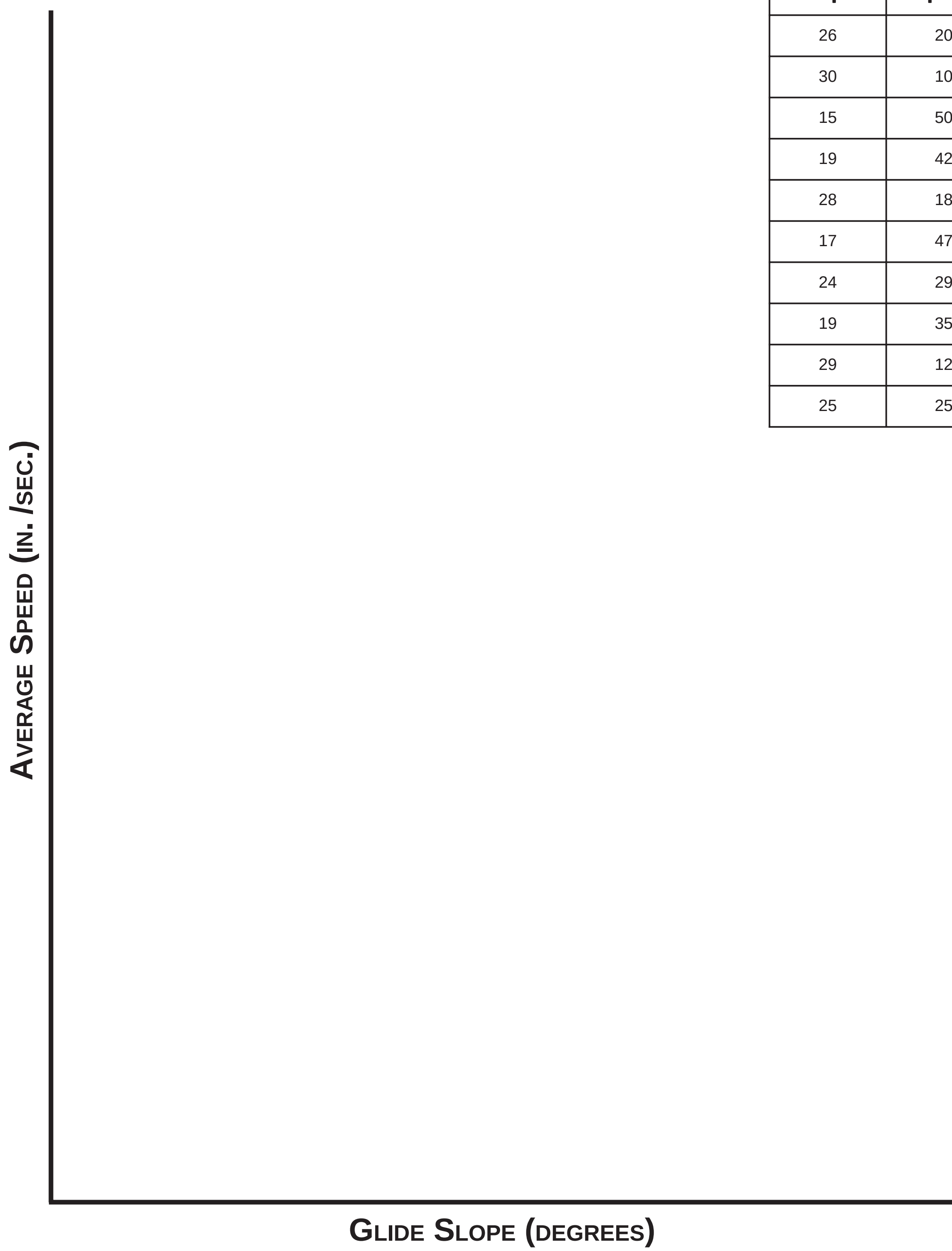
7. Find the glide slope for 0.7265: ________
8. Find the glide slope for 2.0503: ________
9. Estimate and subtract to find the glide slope for 0.9899: ________
10. Estimate and subtract to find the glide slope for 1.2058: ________

11. Create a Scatter Plot for the following data:

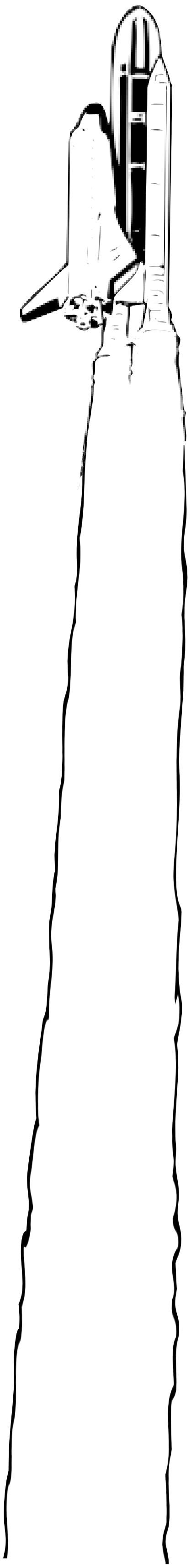
Relationship between Glide Slope and Average Speed



Glide Slope	Average Speed
26	20
30	10
15	50
19	42
28	18
17	47
24	29
19	35
29	12
25	25



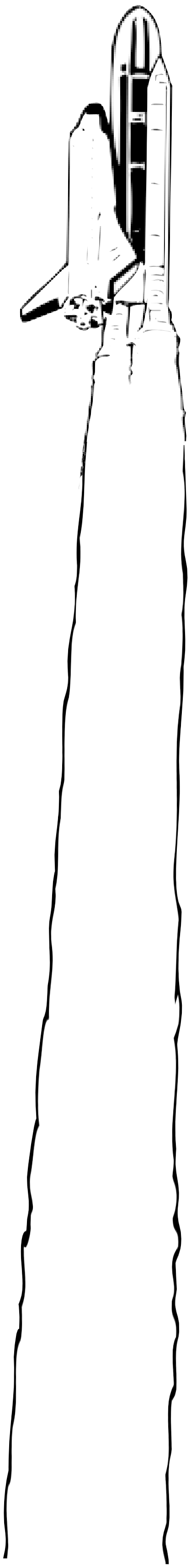
How to Compute Glide Slope



1. Have the pilot hold "his/her" end of the fishing line with even tension (no slack in fishing line) at the desired touchdown point on the runway (on the ground).

2. At the "measuring point", have the copilot hold a tape measure or ruler to find the height of the glider, (from the glider's nose) to the ground in inches. The mission specialist should hold the tape measure or ruler on the ground so that it is vertical, and not slanted to the side. (Imagine you are measuring your own height, you want to stand up straight and tall to get the correct measurement. Ask Mission Control Center to stand about 5 feet away and "eyeball" the tape measure from the front view and from the side view to make sure it is vertical.)

3. Before writing the measurement down, put a piece of tape (like the one used to make the runway) at the place where the tape measure or ruler touches the ground. (This is the starting point for measuring the glider's horizontal distance.) Now write your measurement down as the Height of Glider, on the Landing Data Collection Sheet.



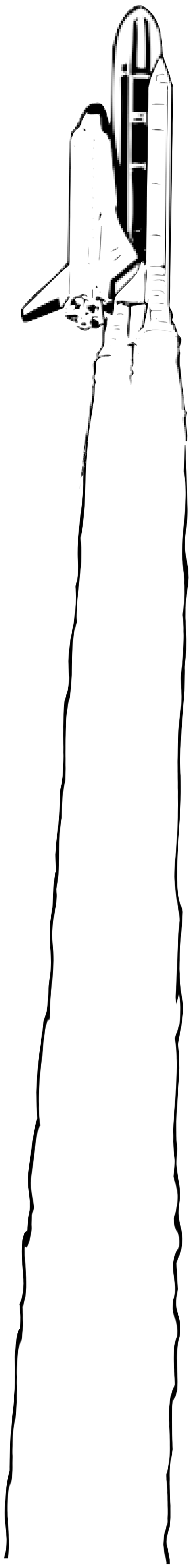
4. To find the glider's horizontal distance to the approximate touchdown point in inches, have Mission Control Center hold the top end of the tape measure or ruler at the place where you put the piece of tape on the ground. Measure the distance to where the pilot is holding the end of the fishing line (attached to the "control stick") on the ground. Make sure the fishing line has an even tension (no slack in fishing line). And also check to see if the pilot is holding the fishing line in the center of the runway. Write this measurement as the Total Distance to the touchdown point on the Landing Data Collection Sheet.

5. Write a fraction using the **y-axis** value as the numerator and the **x-axis** value as the denominator. (Both of these values should already be written on the Landing Data Collection Sheet.) Write this fraction as the **slope** on the Landing Data Collection Sheet.

6. Find the decimal equivalent to the fraction by dividing the denominator **in to** the numerator. If necessary, round the decimal to the nearest ten-thousandths place. Write this decimal number next to the fraction on the Landing Data Collection Sheet.

7. Find this number, or the number **closest** to it, in the left column of the "Table for Determining Glide Slope". (See below for example on how to determine which number is the **closest**.)

8. The number, in the right column, that corresponds with the decimal number is the glide slope. Write this number as the **Glide Slope** on the Landing Data Collection Sheet.



Example:

If y-axis = 71 inches and x-axis = 91 inches, then slope = 71/91.

1. Find the decimal equivalent for 71/91 can be found by dividing the denominator **into** the numerator:

   $91 \overline{)\,71}$

If you are using a calculator, type the numerator number first:

71
÷ symbol
91
= symbol

The decimal equivalent is 0.7802197802....

2. Round the number to the nearest ten-thousandths place, which will give us **0.7802**. (Note: The digit in the hundred-thousandths place is a "1", which is lower than 5, so the digit "2" in the ten-thousandths place stays the same.)

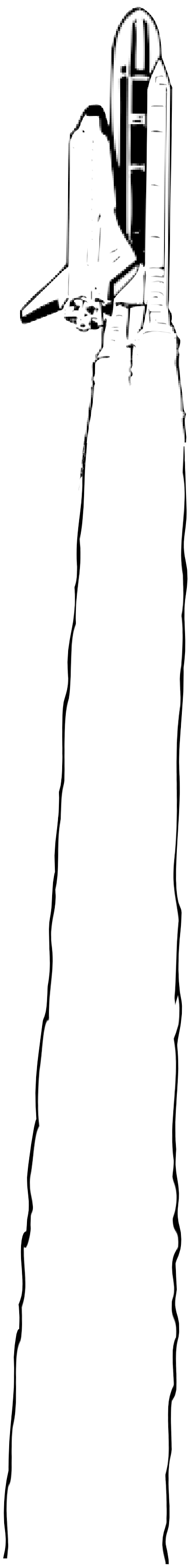
3. Estimate where the decimal might be found in the left column of the "Table for Determining Glide Slope". It would be found between 0.7536 (37 degrees) and 0.7813 (38 degrees).

4. Use subtraction to find the difference between **0.7802** and each of the other numbers. (Always subtract the bigger number minus the smaller number.)

$$\begin{array}{r} \mathbf{0.7802} \\ -\ \underline{0.7536} \\ 0.0266 \end{array} \qquad \begin{array}{r} 0.7813 \\ -\ \underline{\mathbf{0.7802}} \\ 0.0011 \end{array}$$

Since 0.0011 is smaller than 0.0266, **0.7802** is closer to 0.7813 than 0.7536.
Thus the glide slope that corresponds to 0.7813 is 38 degrees.

5. Write this glide slope value on the Landing Data Collection Sheet.



Practice finding the Glide Slope using the following fractions:

a) $\frac{62}{92}$

b) $\frac{55}{105}$

c) $\frac{73}{90}$

d) $\frac{63}{90}$

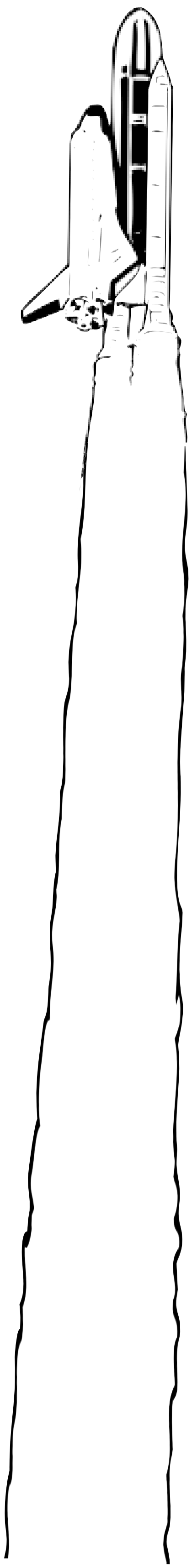
<u>How to Compute Flight Time</u>

1. When Mission Control Center gives the clearance signal, the copilot will release the glider.

2. At the same time, the mission specialist should start keeping track of the time.

3. The mission specialist must carefully watch the glider and “stop the timer” as soon as it comes to a complete stop on the runway.

4. The mission specialist should write the flight time (in seconds) on the Landing Data Collection Sheet.



How to Compute Average Speed

1. Write a fraction using the Total Distance to touchdown point as the numerator and the Flight Time as the denominator.

2. Average speed is written as a unit rate. To find the unit rate, divide the denominator **in to** the numerator. (If necessary, round the decimal to the nearest hundredths place. Label your answer with inches/second)

3. Ask the mission specialist to write this number on the Landing Data Collection Sheet.

Example:

If the Total Distance to touchdown point is 90 inches, and the Flight Time is 8 seconds, the fraction would be 90/8.

1. Find the average speed by dividing the denominator **in to** the numerator:

$$8\overline{)\,90}$$

If you are using a calculator, type the numerator number first:

90
÷ symbol
8
= symbol

The average speed is 11.25 in/sec.

Practice finding the average speed using the following fractions:

a) $\frac{92}{10}$

b) $\frac{80}{6}$

c) $\frac{75}{8}$

d) $\frac{77}{9}$

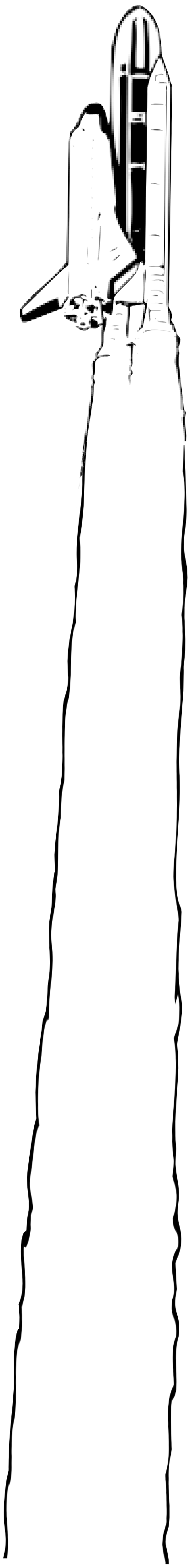
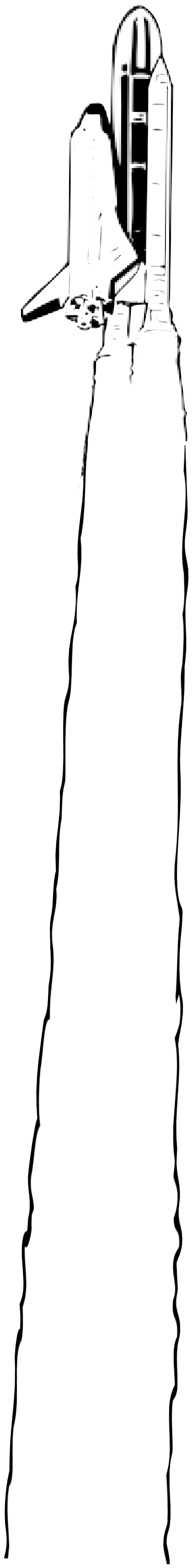


Table for Determining Glide Slope

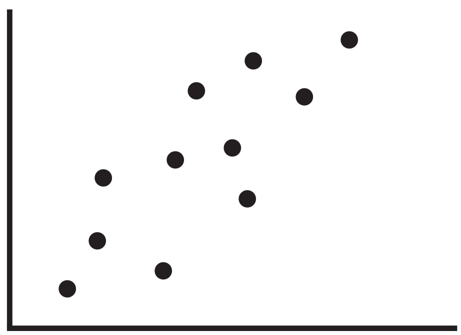
Decimal	Glide Slope	Decimal	Glide Slope
0.3839	21	1.0355	46
0.4040	22	1.0724	47
0.4245	23	1.1106	48
0.4452	24	1.1504	49
0.4663	25	1.1918	50
0.4877	26	1.2349	51
0.5095	27	1.2799	52
0.5317	28	1.3270	53
0.5543	29	1.3764	54
0.5774	30	1.4281	55
0.6009	31	1.4826	56
0.6249	32	1.5399	57
0.6494	33	1.6003	58
0.6745	34	1.6643	59
0.7002	35	1.7321	60
0.7265	36	1.8040	61
0.7536	37	1.8807	62
0.7813	38	1.9626	63
0.8098	39	2.0503	64
0.8391	40	2.1445	65
0.8693	41	2.2460	66
0.9004	42	2.3559	67
0.9325	43	2.4751	68
0.9657	44	2.6051	69
1.0000	45	2.7475	70

Purpose of a Scatter Plot

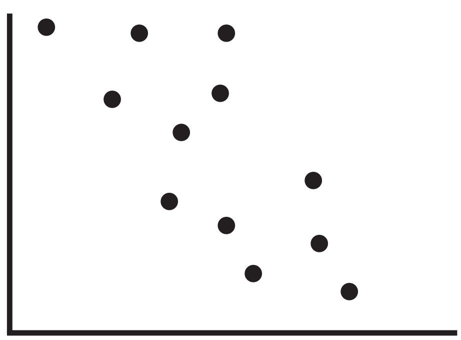


1. The purpose of a scatter plot is to show the type of relationship, or correlation, that exists between two sets of data.

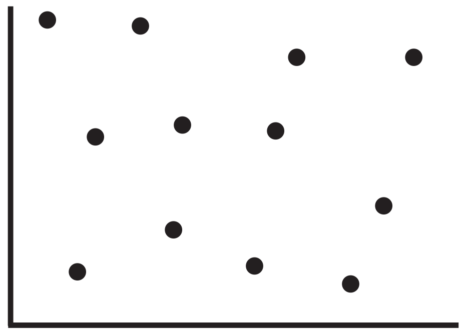
   a. For instance, a positive correlation means that as the value of one set of data increases, the other data will also increase. An example of a "positive correlation" is the amount of rain and the size of puddles. Obviously, the more it rains, the larger the size of the puddles. In a scatter plot, "positive correlation" could look like this:

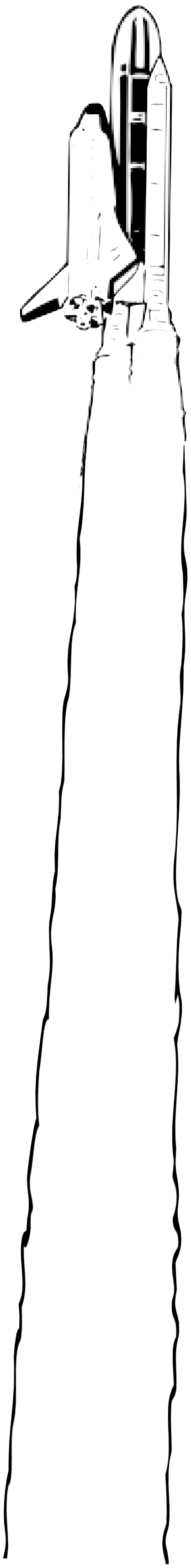


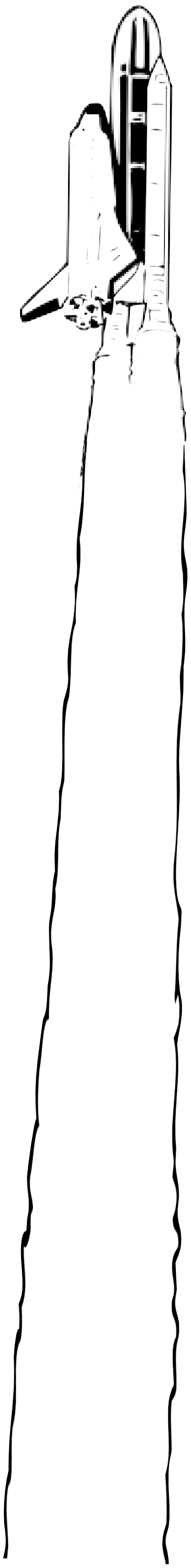
   b. There is a different type of relationship between the life of a watch and its battery. This specific example shows a "negative correlation" because the more the watch is in use, the less energy is left in its battery. In a scatter plot, "negative correlation" could look like this:



c. Lastly, there may be two sets of data that has "no correlation". In this relationship, the value of one set of data has neither "positive" nor "negative" effect on the other set of data. Imagine yourself drinking a glass of water. Do you now feel like doing more or less homework? Your answer to this question at that time would have nothing to do with drinking more water. This is because there is "no correlation" between how much water you drink and how much homework you do. In a scatter plot, "no correlation" could look like this:







Drawing a Line of Best Fit

2. If the scatter plot shows that the relationship between two sets of data has a positive or negative correlation, another use for the scatter plot is to be able to make predictions using a "line of best fit" or "fitted line". The line of best fit allows you to make predictions because every point on the line is associated with a glide slope value and average speed value. Thus, any value I choose for glide slope will have a corresponding average speed value, which can be found by locating the point on the line of best fit.

Here are the steps for drawing the line of best fit:

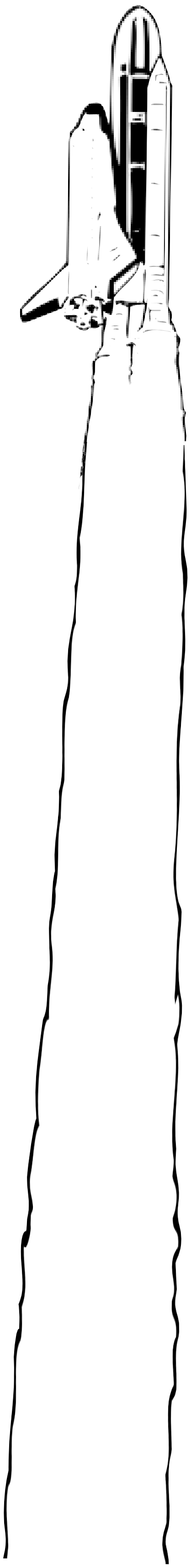
a. Be sure a positive or negative correlation exists.
b. Using a ruler, draw a line of best fit. You must use a ruler!

The line of best fit is an approximation. There isn't just one correct answer for drawing the line. Not everyone's line of best fit will be exactly the same. To draw a more accurate line, imagine the points are cities on a map and you want to be able to drive as close as you can to each city on **one, straight** road. Using a ruler, draw one, straight road that would take you as close as possible to every city. It is okay if your line goes through a city, and it is also okay if your line doesn't touch any of the cities. The goal is not to go through all the cities, so do not connect the dots. The goal is to get close to **all** the cities, using one, straight road.

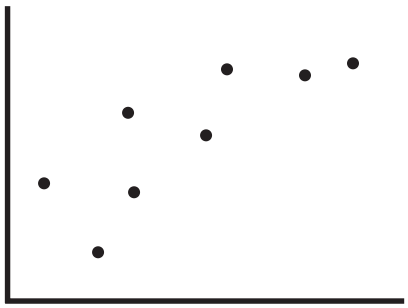
One technique you can use to draw the line is to hold the ruler on it's side and pretend it is the road you want to draw. Place it somewhere in the cities and look on either side of the road to make sure that it comes as close to all the cities as possible. You can move the road, simply by moving the ruler. Once you've found the perfect spot for your road, carefully mark the top and bottom of the ruler with a dot and draw your line.

c. Draw the line so that it goes as far left and as far right as possible without drawing the line through the axes and without drawing the line past the axes lines.

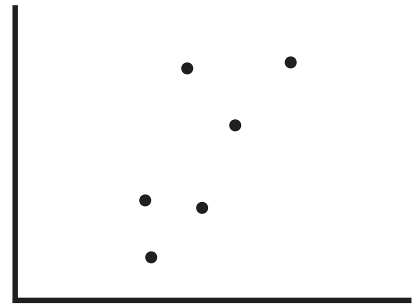
d. Practice drawing a line of best fit in each of the scatter plots below:



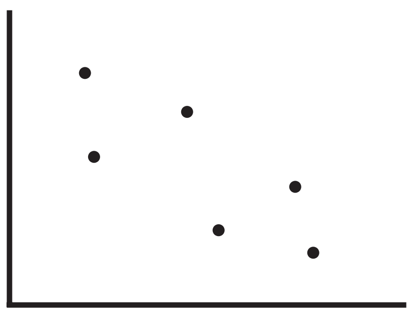
Practice Exercise #1:



Practice Exercise #2:



Practice Exercise #3:



Practice Exercise #4:

<u>Using the Line of Best Fit for Making Predictions</u>

3. Here are the steps for using the line of best fit for making predictions

   a. Choose a glide slope value from the x-axis.

   b. Hold your ruler vertically (parallel to the sides of your paper) to find the point on the line of best fit that is exactly above the glide slope value you selected from the x-axis. Mark that point.

   c. Hold your ruler horizontally (parallel to the bottom of your paper) and line it up with the mark you made on the line of best fit to find the point on the y-axis. Mark that point.

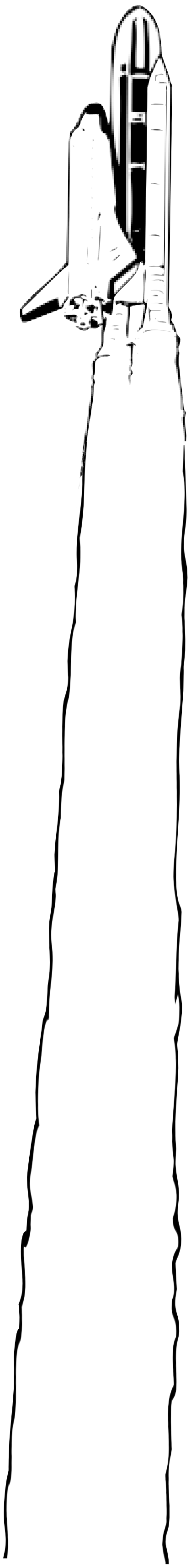
   d. Determine the value of the speed.

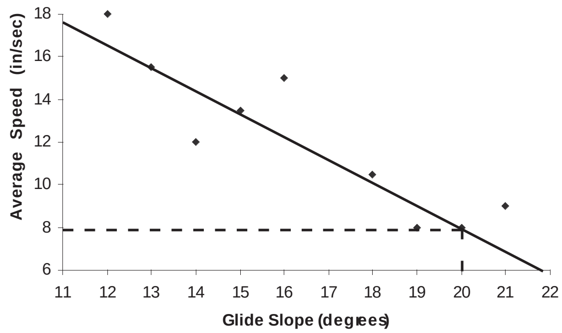
   e. This value is an educated approximation of the average speed of the glider according to the glide slope.

   f. The same procedure can be done in reverse to find the approximation of the glide slope if you choose an average speed value from the y-axis.

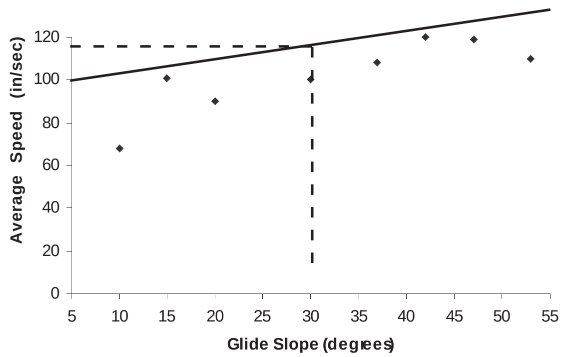
   g. Practice making predictions by using the scatter plots on the following page:

Practice Exercise #1:
If glide slope value = 20 degrees
Then, average speed = ________ in/sec

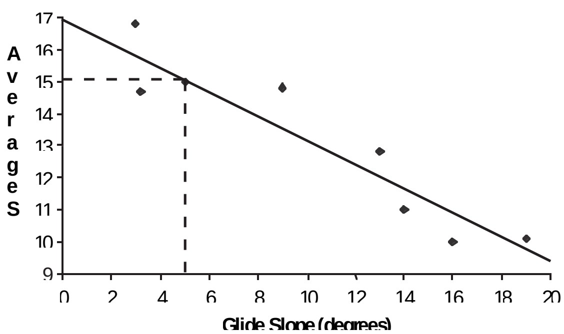




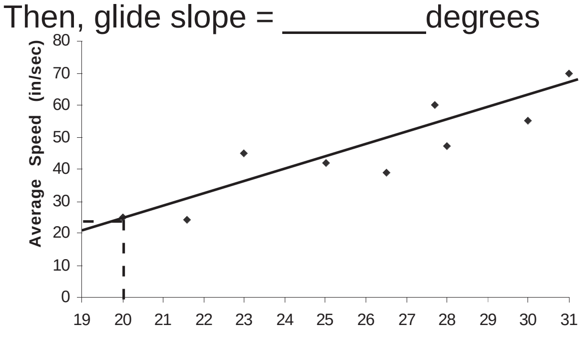
Practice Exercise #2:
If glide slope value = 30 degrees
Then, average speed= _______ in/sec

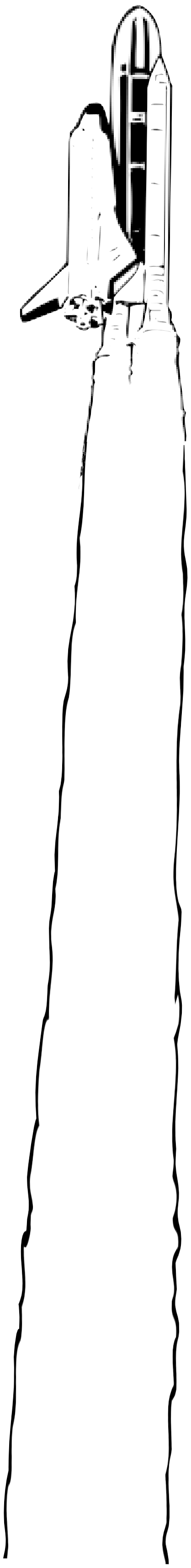


Practice Exercise #3:
If average speed = 15 in/sec
Then, glide slope = ________ degrees



Practice Exercise #4:
If average speed = 25 in/sec
Then, glide slope = ________degrees





How to Create a Scatter Plot

To create a scatter plot for this activity:

1. Draw a graph with an x-axis and a y-axis like the one on the following page.

2. Label the graph with a title such as “Relationship between Glide Slope and Average Speed.”

3. Label the x-axis as Glide Slope (degrees) and label the y-axis as Average Speed (inches/second).

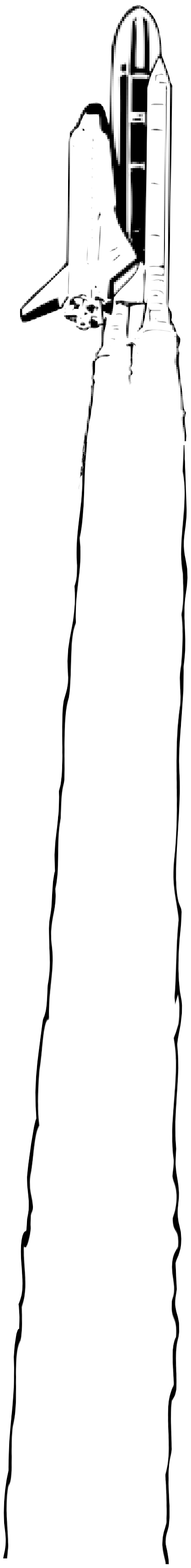
4. Determine marks for intervals that will effectively use the amount of space on your paper.
   a. A good distance to use between “marks” is 1 cm.

   b. Each “mark” has an interval that is determined by the highest and lowest values of both the x-axis and y-axis (in this case Glide Slope and Average Speed).

   c. Intervals that are commonly used include: 1s, 2s, 5s, 10s, 20s, 25s, 50s, 100s.

   d. An 8 1/2" x 11" paper can easily fit 15- 1cm “marks” horizontally, and 20- 1cm “marks” vertically.

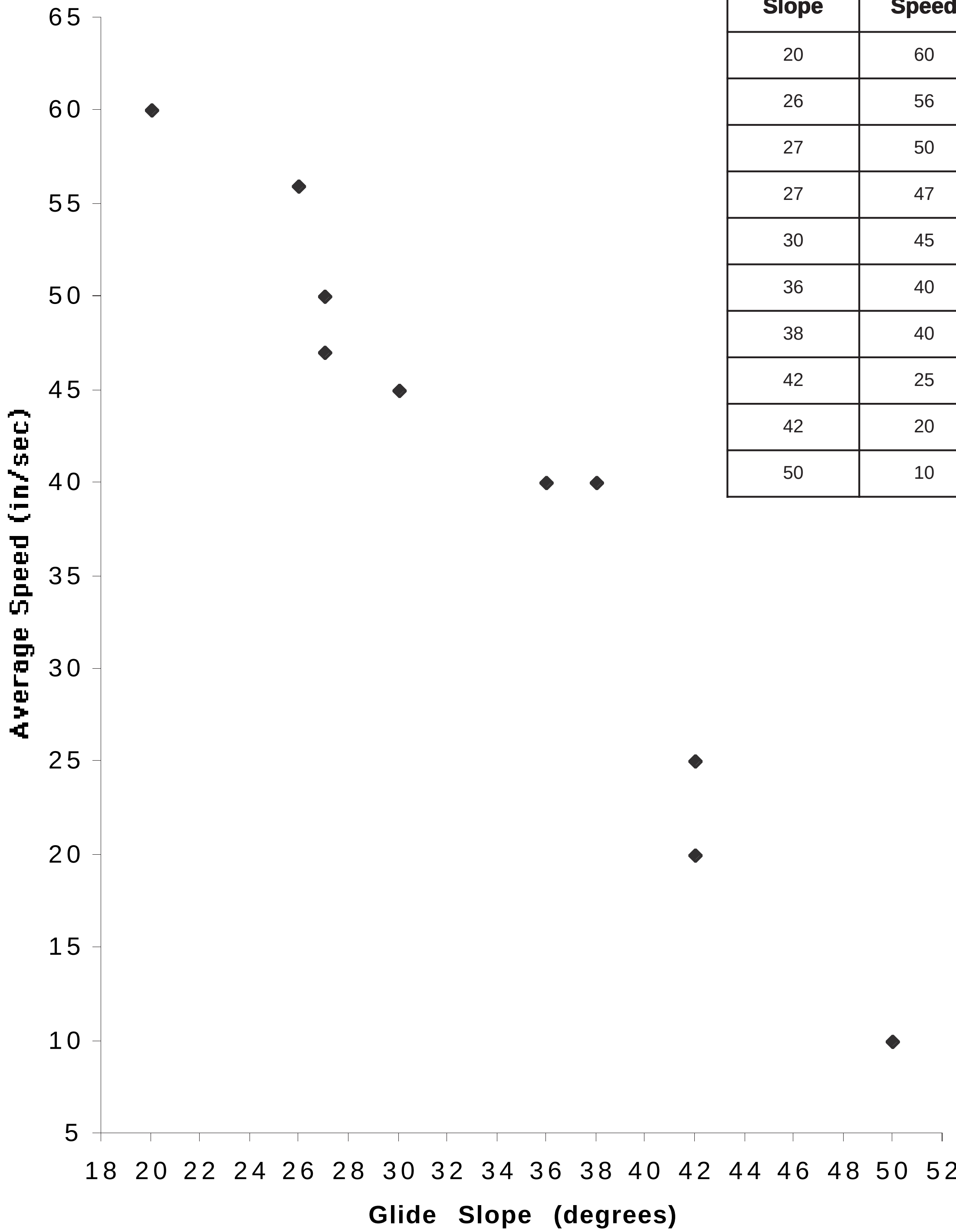
Example:
If the values on the x-axis range from 20 to 50, then intervals of 2s would require 15 intervals. This means all the values from 20 to 50 can fit by counting by 2s, and by making “marks” 1cm apart.



If the values on the y-axis range from 10 to 60, then intervals of 2s would require 25-1cm intervals. Another option would be to use intervals of 5s which would require only 10 intervals. In this case, to maximize the amount of space on the paper, 2 cm intervals could be used instead of 1cm intervals.

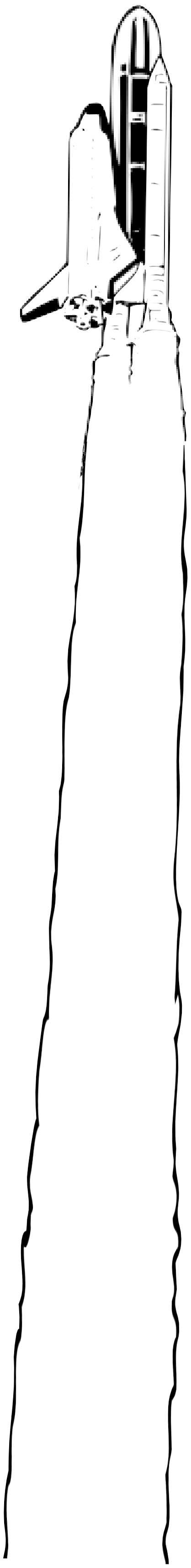
Relationship between Glide Slope and Average Speed

Glide Slope	Average Speed
20	60
26	56
27	50
27	47
30	45
36	40
38	40
42	25
42	20
50	10



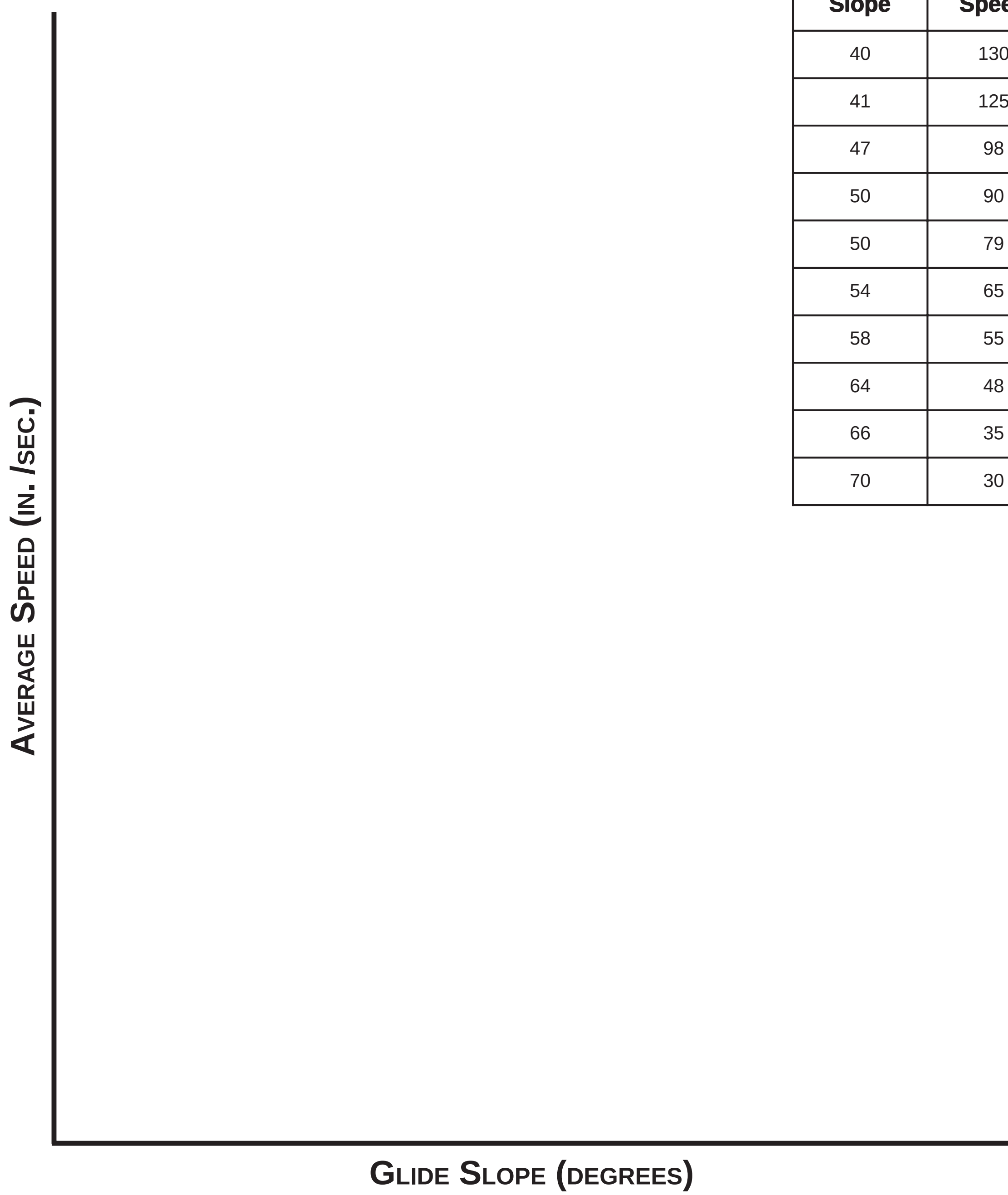
Practice:
Using a ruler, "mark" off both axes to include the entire range of values from highest to lowest for both the Glide Slope and the Average Speed.

Plot each point using both the Glide Slope value (x-axis) and the Average Speed value (y-axis). In other words, you need both the Glide Slope and Average Speed numbers to make just one point. You should have 10 points all together.

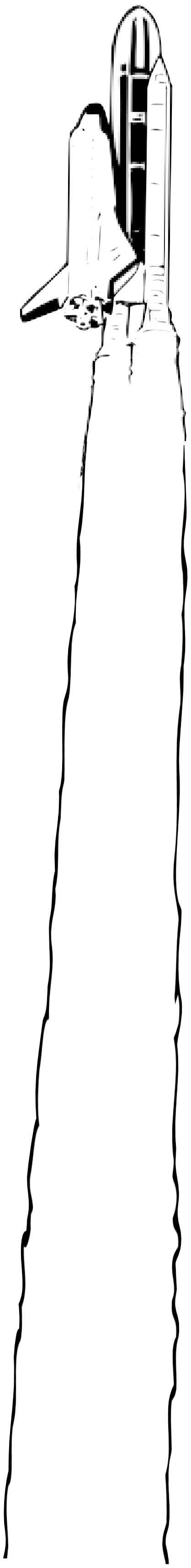


1.
<u>Relationship between Glide Slope and Average Speed</u>

Glide Slope	Average Speed
40	130
41	125
47	98
50	90
50	79
54	65
58	55
64	48
66	35
70	30



2. Do you notice any type of correlation in the points?
   If yes, what type of correlation do you see? ________



3. Using a ruler, draw a line of best fit.
Using the line of best fit, what would be the average speed for a glide slope of:

Glide Slope	Average Speed
44	________________
52	________________
60	________________

4. Using the line of best fit, what would be the glide slope for an average speed of:

Average Speed	Glide Slope
40	________________
60	________________
110	________________