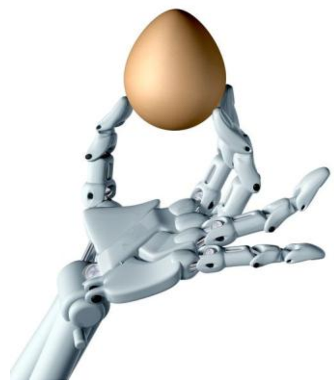
Importance of Speed Control in Robotics

Industrial robots are used for assembling various products, from mobile phones to wooden pallets to gas meters. Robots can be designed not only to have power and speed but also accuracy, dexterity and sensitivity. They are regularly used in a variety of industries for the manipulation of a plethora of items from car doors to eggs, from springs to champagne. The most important ability for the robot is to follow a path accurately with good control over speed. In industry, "automated sealing" has been very difficult to get right in the past, a process that works very well at one speed may run into problems if it is accelerated. Over many years these problems have been ironed out and now sealing systems are capable of laying down a good even bead of sealant in a variety sizes and patterns.



Dexterous Robot
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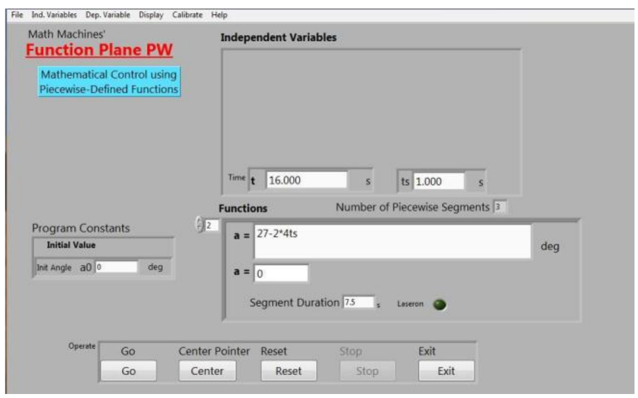
Robots are also often used in industry for painting to minimize human contact with volatile and hazardous solvent based paints. Painting robots typically have quite thin arms since they don't have to carry much weight and at times need to access remote areas. They also have to be capable of very fluid movements to mimic a skilled human painter laying down a consistently even layer of paint where speed is very important.

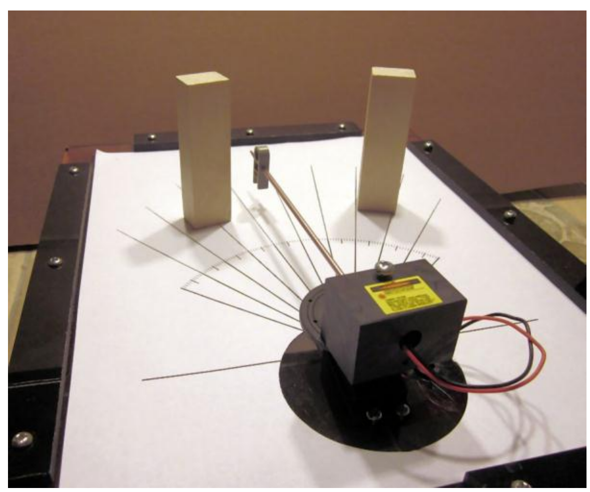
Task: In this activity the Function Plane will simulate a robotic arm that you will use to carefully move around blocks to perform a variety of tasks. Care must be given in controlling speed, going slow enough so that the blocks don't tip over, but also going fast enough to perform the overall task as fast as possible --"time is money".



Additional Materials: Jenga® blocks (or equivalent), metal double-point #2 knitting needle and attachment, protractor template (-50° to +50°).

Math Machines Program: **Function Plane PW**

Activity File: Lineup001



Load Activity File Lineup001.

Place the blocks at the initial positions indicated in each of the following tasks and move them to the required final positions. You will need to do this as quickly as possible without knocking blocks over!

TASK 1 How Fast Can You Do a Good Job?

1. Place blocks at positions -20° & 10°. Program Function Plane PW to move these blocks to positions -30° & +30° respectively as fast as possible while at the same time maintaining accuracy and repeatability (it should work well no matter how many times it is done). The position of the arm must begin and end at 0.

   Function Plane PW allows you to have up to 5 functions. Determine how many you need and then go ***to File/Run Options/Piecewise Functions***, indicate the number of functions (segments) you want and the time duration for each.

   Write your functions, along with the segment durations below. Note that the variable '**ts**', gives the value of time starting with 0 sec. for each function segment, '**t**' is the total elapsed time.

   Function 1 = ____________________ T1 ________

   Function 2 = ____________________ T2 ________

   Function 3 = ____________________ T3 ________

   Function 4 = ____________________ T4 ________

   Function 5 = ____________________ T5 ________

2. What measurements did you have to make to determine each function? How was this function created? (Show your work)

3. Are your functions linear functions? If so, explain what the slope and intercept values represent.

4. What was the total time, 't,' to successfully complete the overall task? t = _______

TASK 2 How Fast Can You Do A Good Job, Safely?

The Occupational Safety and Health Administration (**OSHA**) is the main federal agency of the United States that regulates works place safety and health. Suppose that a potentially hazardous condition occurs when the robotic arm moves too quickly. Given the constraints on the system, management has determined that OSHA requirements are satisfied if for any movement of the robotic arm from one position to another requires at least 1 second.

5. Modify your Function Plane PW program to meet OSHA standards while at the same time maintaining accuracy and repeatability (it should work well no matter how many times it is done). Note: There can be no “jumps” in the movement of the robotic arm.

   Write your functions, along with the segment durations below.

   Function 1 = ____________________ T1 ________

   Function 2 = ____________________ T2 ________

   Function 3 = ____________________ T3 ________

   Function 4 = ____________________ T4 ________

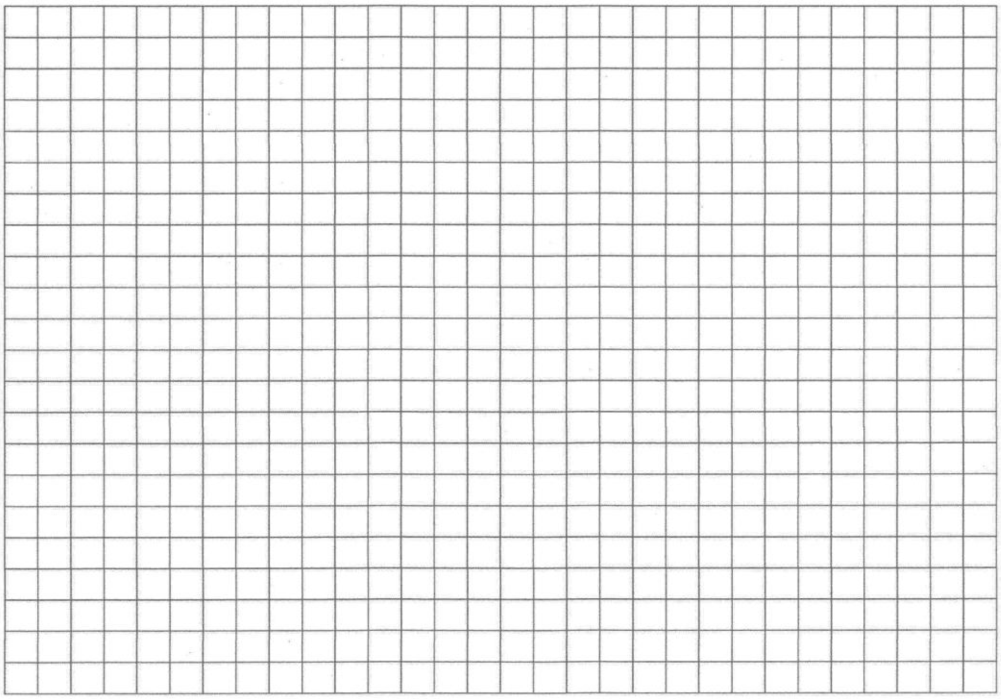
   Function 5 = ____________________ T5 ________

6. What functions were added/changed and what measurements did you have to make to determine each of these new functions? (Show your work)

7. What was the total time, ‘t,’ to successfully complete the overall task? t = _______

   What additional time did these new regulations require? _______

8. Make a graph of **degree position, ‘a,’** as a function of **total elapsed time, ‘t’**.



TASK 3 Other Practical Considerations!

9. Previously you constructed a sequence of several functions using the variable named 'ts' but defined on time intervals each having initial value 0. In some situations it may be practical to create one piecewise function giving the position of the arm at any time '***t***' from the beginning of the entire process (***t*** =0) to the end of the process (***t*** = your answer to question #4). To this end, write the function represented by the graph you created in #8 as a piecewise-defined function ***a(t)*** where '***t***' is the total time elapsed after the process begins.

Be careful! Notice that the independent variable for *a(t)* is '***t***', not '***ts***'. The variable '**t**' is the total elapsed time!

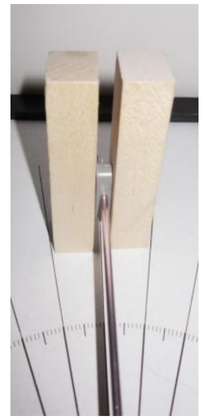
$$a(t)=\begin{cases} \_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \le t \le \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \le t \le \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \le t \le \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \le t \le \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \le t \le \_\_\_\_ \end{cases}$$

10. To verify that your function a(t) is the correct one, modify your functions in the program so that 't' is the independent variable. Did, the program operate exactly as it did before?

11. What is the domain and range of ***a(t)***?

Domain:______________ Range:_________________

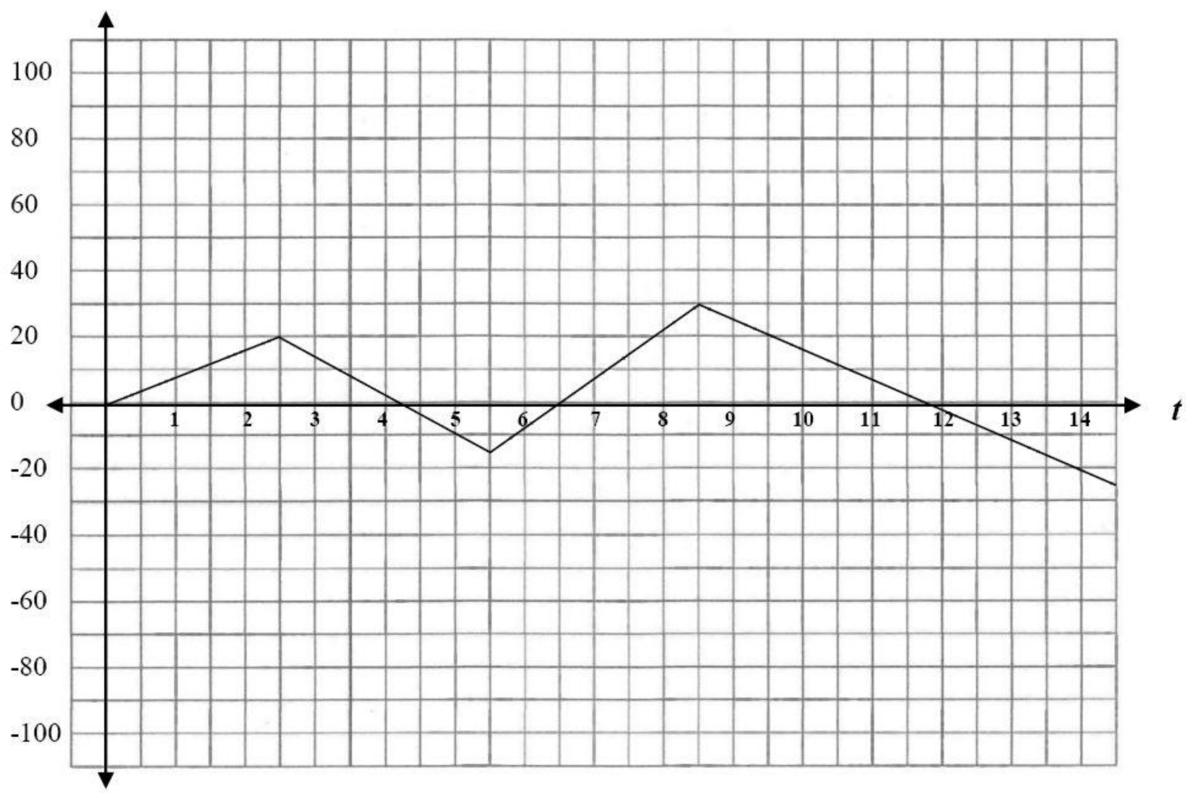
Additional Exercise



12. Consider the Function graphed below that gives the position of the robot arm at time '***t***'. With the robot arm in '0' position, place two blocks up against the attachment as shown.

    a. What is the initial position of the edges of the blocks?

    b. Based on the graph below, predict what the final positions of the edges will be.



13. Without making any calculations, program the Function Plane PW so that the robotic arm will move according to the graph above with '***t***' as the independent variable. To do this, create a piecewise defined function similar to what you did in problem #9. Use only the graph above and a ruler (straight edge) to help you create each of the 4 pieces in "**y = mx + b**" form. Fill in the form below. Note: You are approximating these values.

$$a(t) = \begin{cases} \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \leq t \leq \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \leq t \leq \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \leq t \leq \_\_\_\_ \\ \_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_ & \_\_\_\_ \leq t \leq \_\_\_\_ \end{cases}$$

14. Test the program. Did what you predict in #11 happen?

15. What is the domain and range of ***a(t)***?

Domain:______________ Range:___________________