Education Transfer Plan
ABSTRACT

Directions:

1) Please fill out this form electronically by downloading it from http://iisme.org under Summer Fellowships, Fellowship Forms.
2) Save As and change the file name to Abstract_yourlastname
3) Print and attach to your ETP.
4) Acquire mentor signature, retain ORIGINAL and submit COPY to Peer Coach by 8/12/05.
5) Acquire administrator signature on ORIGINAL and submit to IISME by 10/3/05 to receive $300 payment.

ETP TITLE:
Moving around with Trig
FELLOW NAME:
David Topham
FELLOW PRIMARY E-MAIL:
dtopham@ohlone.edu
SPONSOR COMPANY:
Santa Clara University
MENTOR NAME:
Chris Kitts
ABSTRACT (50 words or less:)
I was very intrigued by a problem presented to me by my mentor: How can we move a robotic arm manipulator from one point to another in a straight line? The explorations leading to that answer involved gaining an appreciation for trigonometry beyond my experience with that subject in college.

ETP TYPE: Lesson Design Pilot GRADE LEVEL: Community College
Subject: Technology Document Format(s):☐Word doc ☐PowerPoint ☐Excel ☒Other:
If "Other," please describe:PDF

Describe how your ETP aligns with NBC or State standard as stated in your proposal:
This lesson is planned for community college use and is not directly aligned with any NBC or State standards that I am aware of.

Describe the connection between your ETP and the Summer Fellowship.
My summer fellowship is a research project at the SCU Robotic Systems Lab. We are researching the use of remotely-controlled experiments to study the behavior of various physical processes. The idea is to give students the ability to control these experiments from anywhere with internet access.

Checklist for sections contained in ETP:

☐ Clearly Stated Outcomes & Standards
☐ List of Materials/Resources
☐ Hard Copy Turned In to Peer Coach
☐ Specific Procedure/Plan
☐ Rubric or plan for evaluating outcomes.
☐ Soft Copy Turned into Peer Coach

I. FELLOW SIGNATURE-- Required Before August 12, 2005

I, the IISME **Fellow** named above, affirm that the ETP I am submitting is my own work, that I acknowledged sources where appropriate, and that I avoided including any proprietary information of the Sponsor Company. By my submission I am assigning to IISME my entire copyright in the ETP. I understand IISME is simultaneously granting me a license to use the ETP for pedagogical purposes.

Signature____________________________________ Date

II. MENTOR SIGNATURE-- Required Before August 12, 2005

I, the **Mentor** named below [please select one of the following],

- ☐have read the attached ETP, and my comments, if any, appear below.
- ☐have read the attached ETP, and, as outlined in the IISME-Company Fellowship Agreement, have reviewed it on behalf of the Sponsor Company, and have determined that the ETP does not contain any Sponsor-proprietary information. My additional comments, if any, appear below.

Mentor Comments:

Signature____________________________________ Date

Printed Name:

III. ADMINISTRATOR SIGNATURE-- Required Before October 3, 2005, submit to IISME on or before October 3 to be eligible for $300 grant.

I, the **Administrator** named below have read the attached ETP and my comments, if any, appear below.

Administrator comments:

Signature____________________________________ Date

Printed Name:

This lesson plan uses the 5E format to give students a realistic experience using trigonometry to solve an interesting problem related to control of a robotic manipulator. It engages their interest, allows them to explore ideas for solutions, asks them to explain the results, and to extend the solution to similar problems.

Evaluation of each step in the plan will help the teacher to understand how well the concepts are being understood.

No special materials are required aside from the usual blackboard and chalk, although graph paper, protractors, compasses, etc. could be useful in illustrating ways to measure angles.

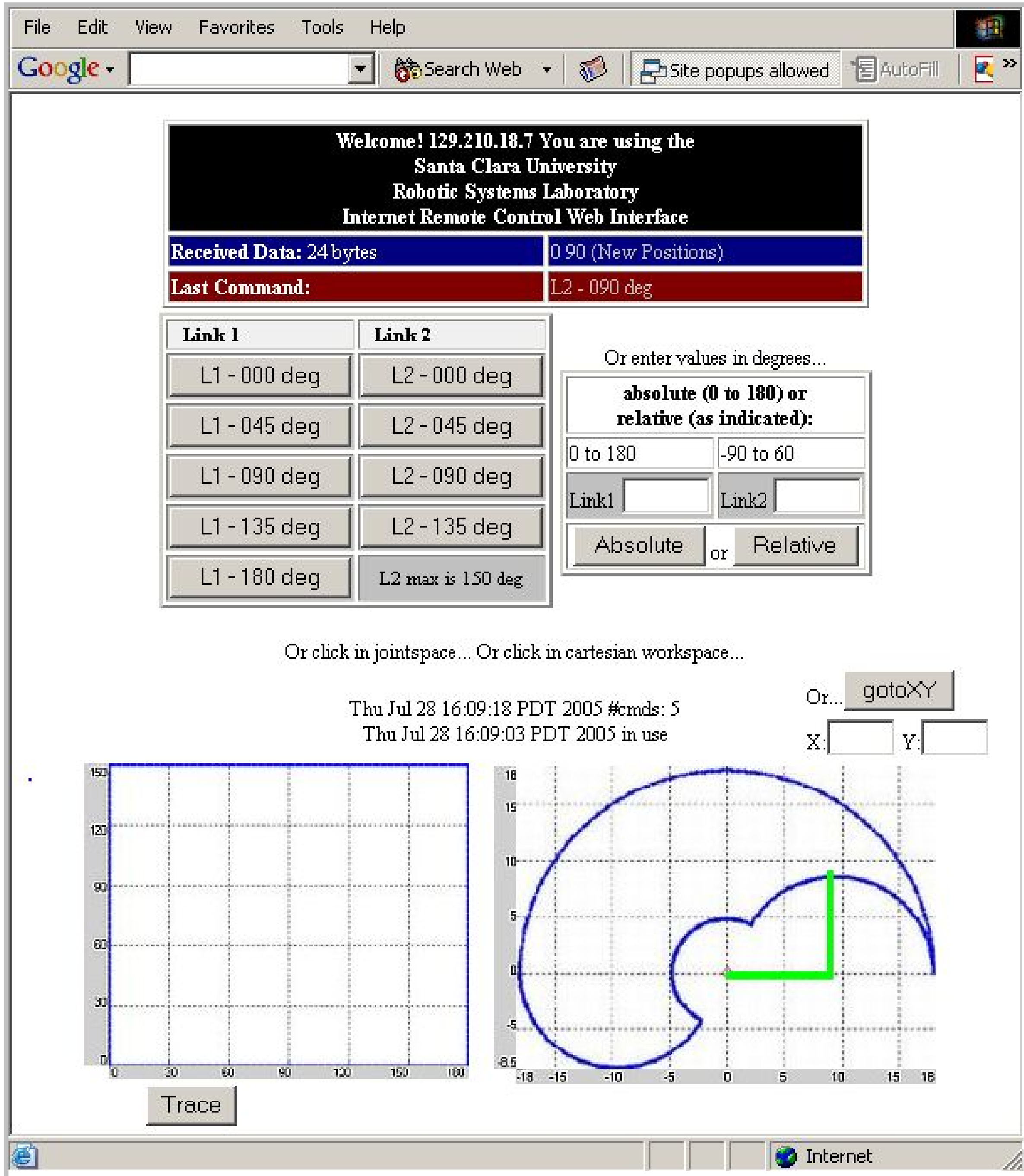
Outcomes: After completing this lesson, students will realize that trigonometry is a useful and necessary tool that can be used to calculate the position of a robotic arm. They will be challenged to do their own problem-solving by using truths from geometry to see that these formulas are not enough in themselves to find the solution. This motivates the introduction of trigonometry in a very compelling way.

Objectives: Develop problem-solving skills, practice applying geometric and trigonometric formulas to real problems, realize the need for algorithms, and gain an appreciation for the techniques used to control robotic manipulators.

This is a photo of an experiment being conducted at the Santa Clara University Robotic Systems Lab.

This manipulator is a simple model of a robot with one arm jointed in the middle. We can move the "end effector" to various positions and study how to do that using software developed to control it remotely over the internet.

http://mech337.engr.scu.edu

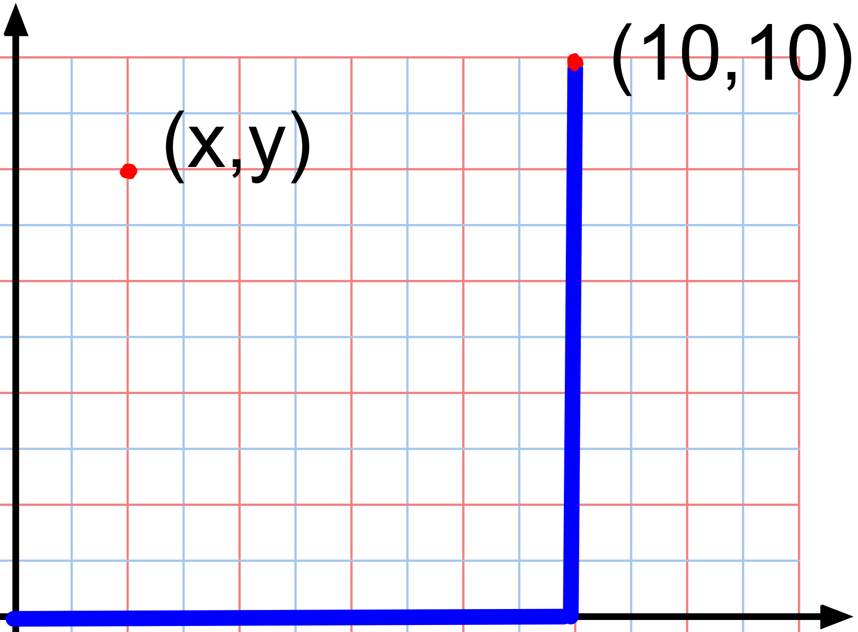


This is the remote interface

The green lines represent the arm and the blue outline shows where the endpoint can reach -- the robots "workspace".

Engage

Imagine two arms on a flat surface.
The endpoint is at coordinates (10,10) since each arm is 10 units long.



Can the endpoint be moved to point (x,y)?

Note: There are some points that cannot be reached by the end effector due to length or angle limitations.

Evaluate

Engage

This section stimulates the student interest in solving a problem in robot manipulation

Explore

This sections allows the student to find there own way through the problem solution after reviewing some basic formulas from geometry and trigonometry. (they don't have to already know those subjects)

Explain

This section gives students a chance to review what they learned while exploring by writing down the steps used to solve the problem.

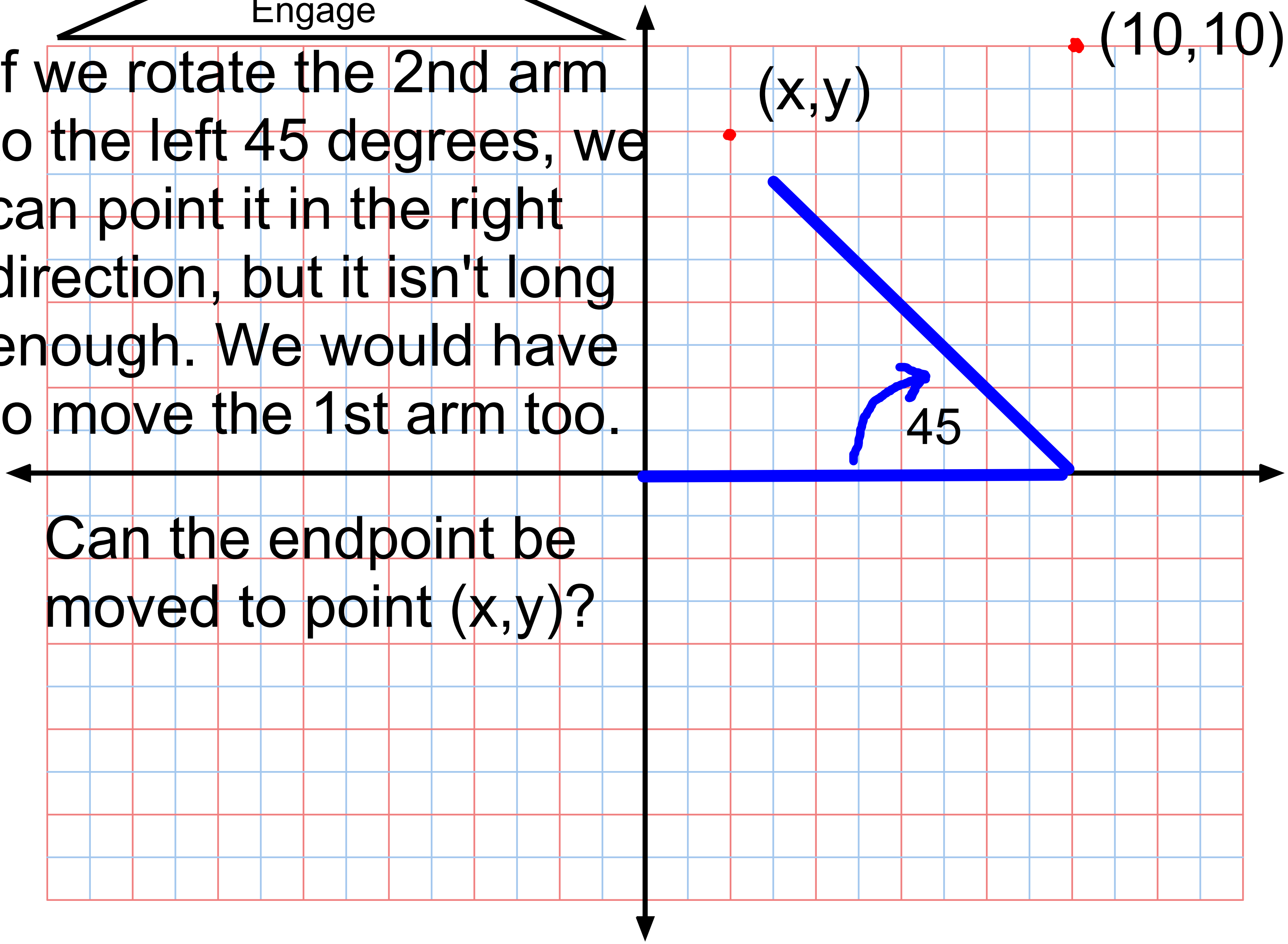
Extend

This section opens up challenges in how to program a computer to show the solution the student came up with.

Engage

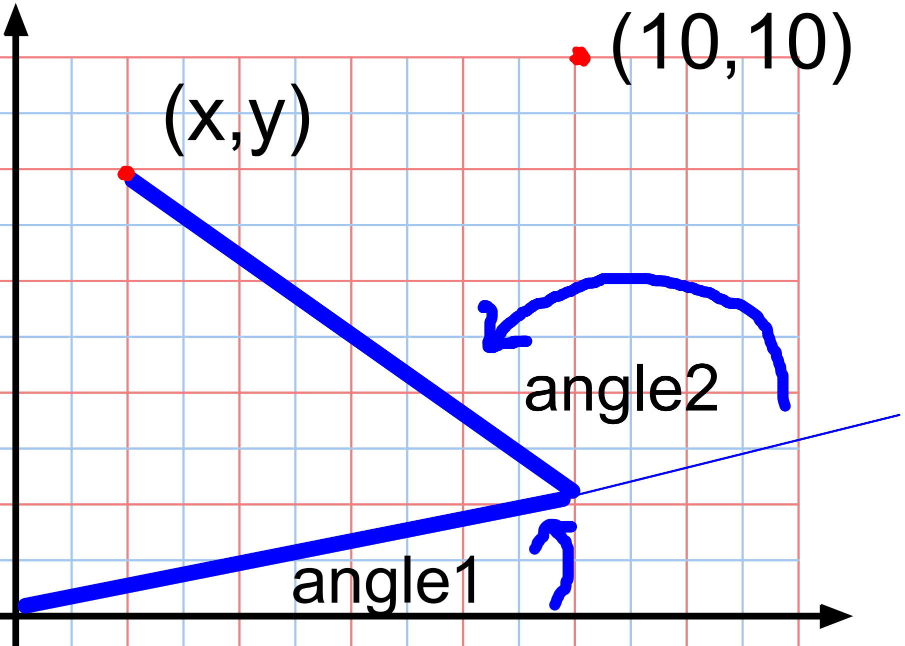
If we rotate the 2nd arm to the left 45 degrees, we can point it in the right direction, but it isn't long enough. We would have to move the 1st arm too.

Can the endpoint be moved to point (x,y)?



Engage

What are the values of angle1 and angle2 that allow the endpoint to reach point (x,y)?

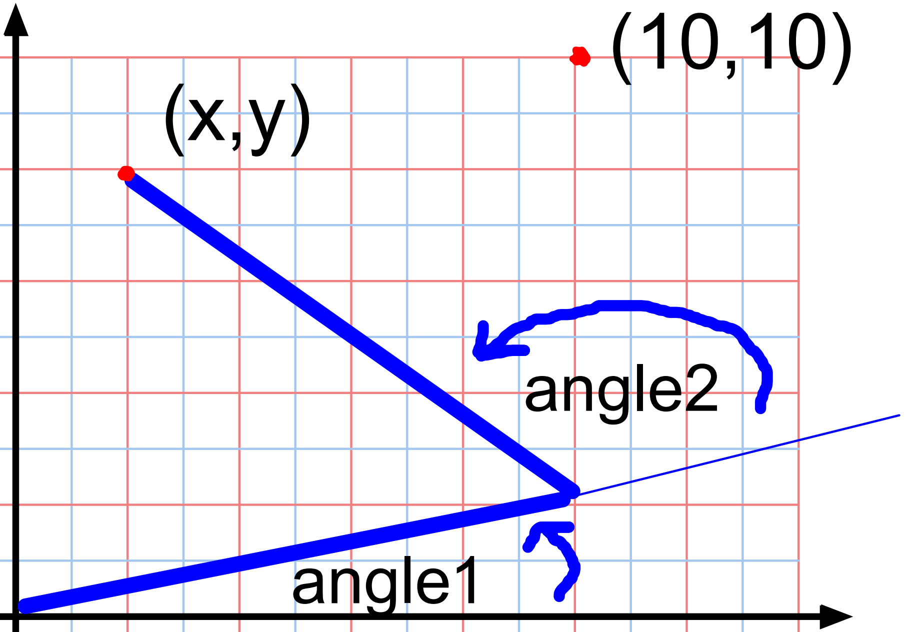


These angle measurements could be given to a robotic arm to control where it must move to pick up some object.

Let's measure angle1 from the x-axis and angle2 from arm1

Explore

What are the values of angle1 and angle2 that allow the endpoint to reach point (x,y)?

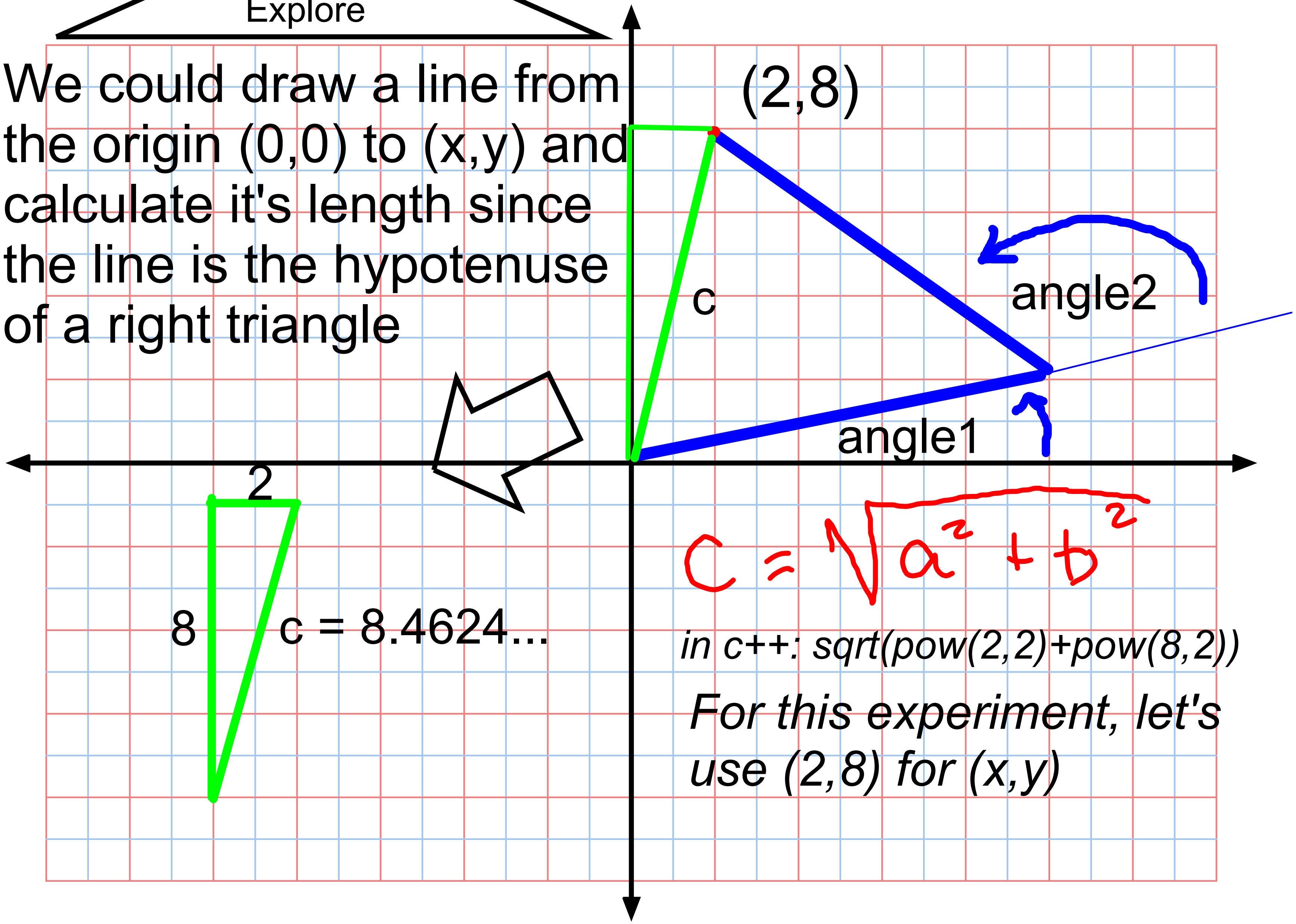


There are formulas which have been developed to find these angles. If you are curious look up the phrase "Inverse Kinematics"

...But let's use common sense and make some observations on our own to better understand the relationships involved.

Explore

We could draw a line from the origin (0,0) to (x,y) and calculate it's length since the line is the hypotenuse of a right triangle



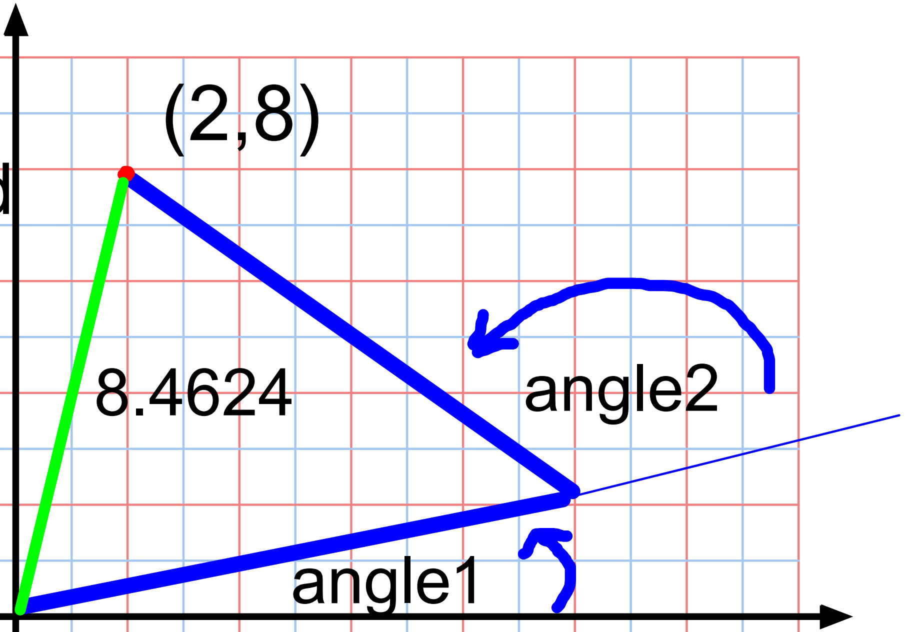
$$c = \sqrt{a^2 + b^2}$$

in c++: sqrt(pow(2,2)+pow(8,2))

For this experiment, let's use (2,8) for (x,y)

Explore

We could draw a line from the origin (0,0) to (x,y) and calculate it's length since the line is the hypotenuse of a right triangle



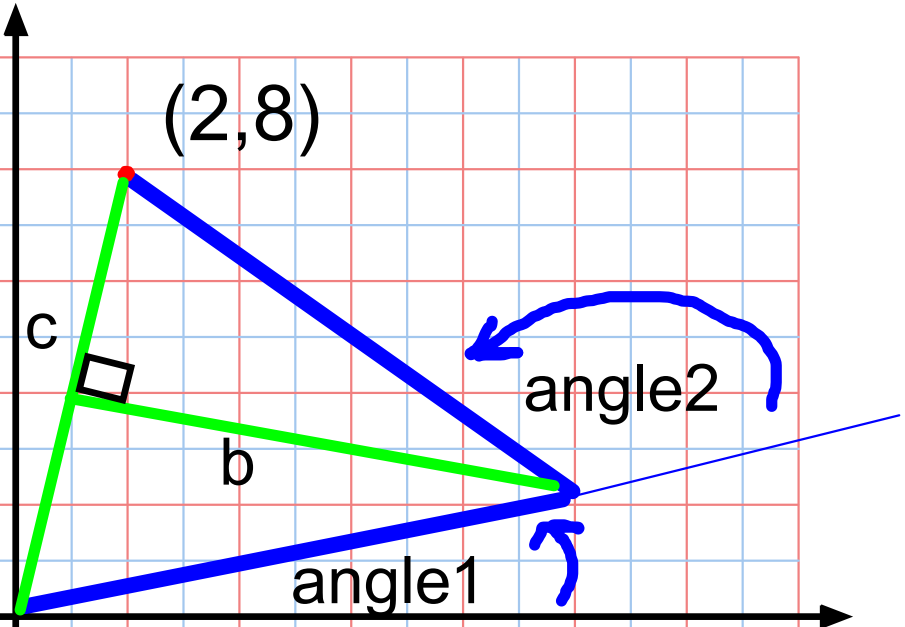
But will this help us find the angles?

Explore your own ideas to develop this further.

in c++: sqrt(pow(2,2)+pow(8,2))

Explore

We could draw line b and calculate it's length.



$$b = \sqrt{arm1^2 - \left(\tfrac{1}{2}c\right)^2}$$

(why?)

c = 8.4624

b = 9.06

*in c++: sqrt(pow(10,2)-pow(0.5*8.4624,2))*

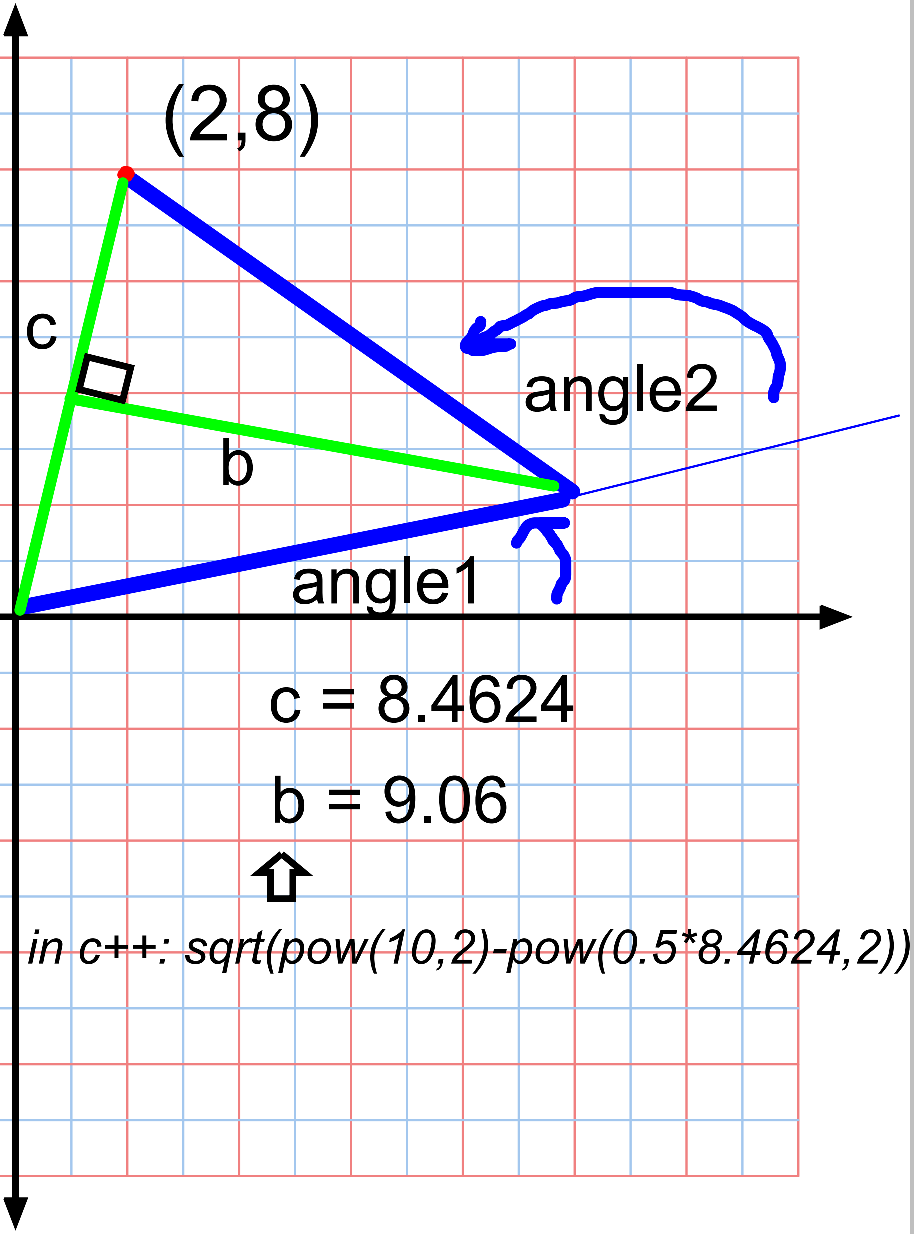
Explore

We could draw line b and calculate it's length.

Notice also that the supplement of angle2 (180-angle2) would be bisected by line b.

(read about isosceles triangles to see why)

That means if we can find angle between arm1 and line b we could also find angle 2



c = 8.4624

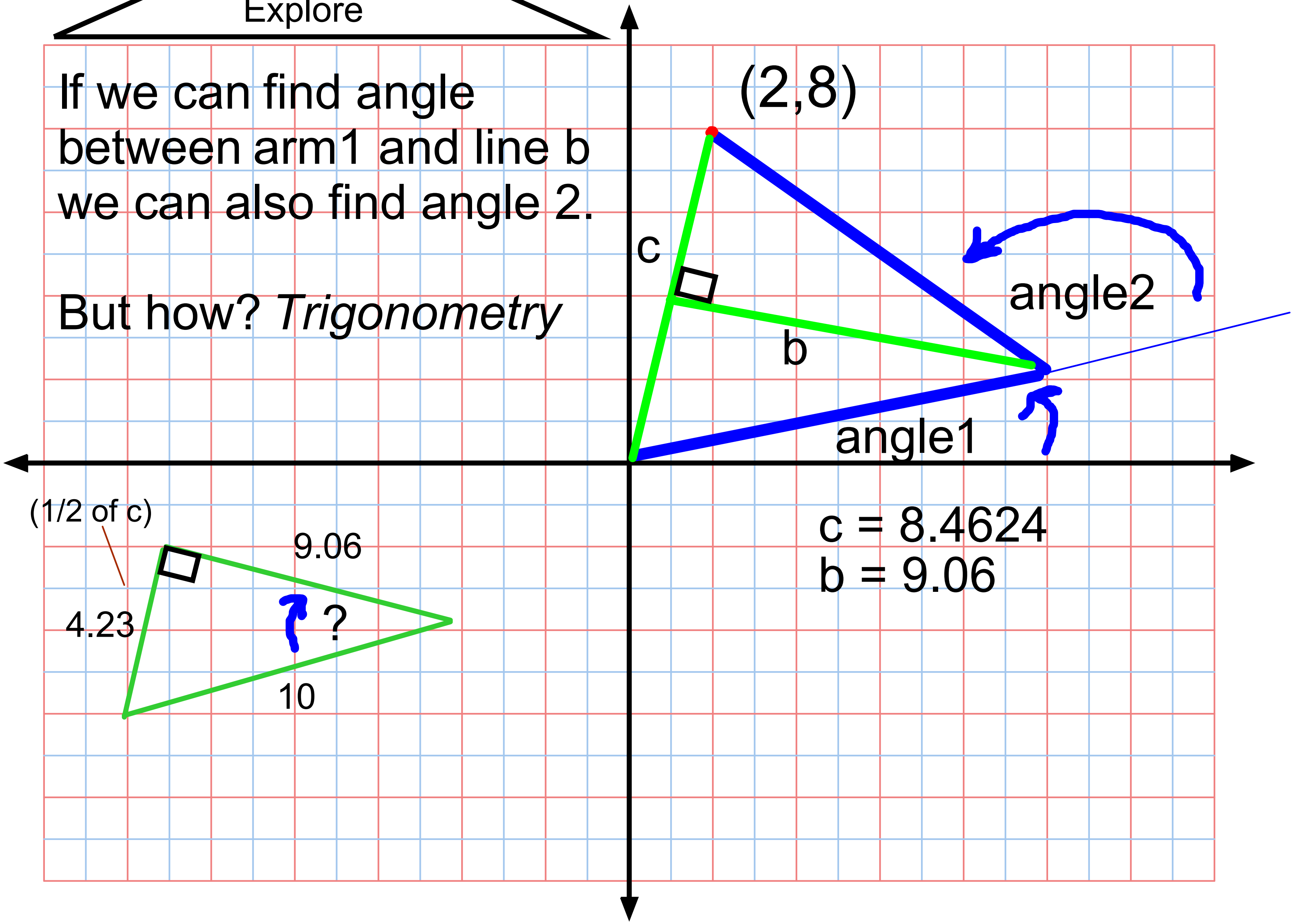
b = 9.06

*in c++: sqrt(pow(10,2)-pow(0.5*8.4624,2))*

Explore

If we can find angle between arm1 and line b we can also find angle 2.

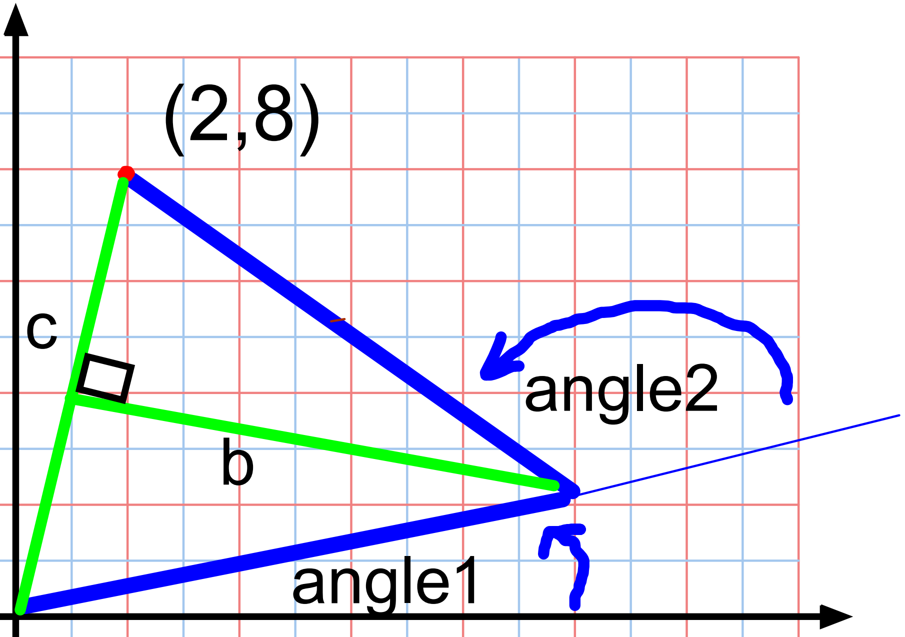
But how? *Trigonometry*

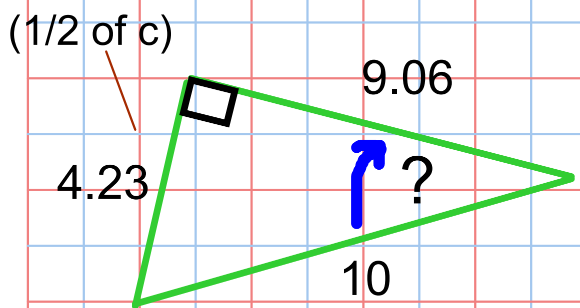


Explore

We can find the angle between arm1 and line b using formulas from trigonometry.

For a wonderful intro, see:
http://aleph0.clarku.edu/~djoyce/java/trig/





sin ? = opposite/hypotenuse

sin ? = 4.23 / 10

sin ? = .423

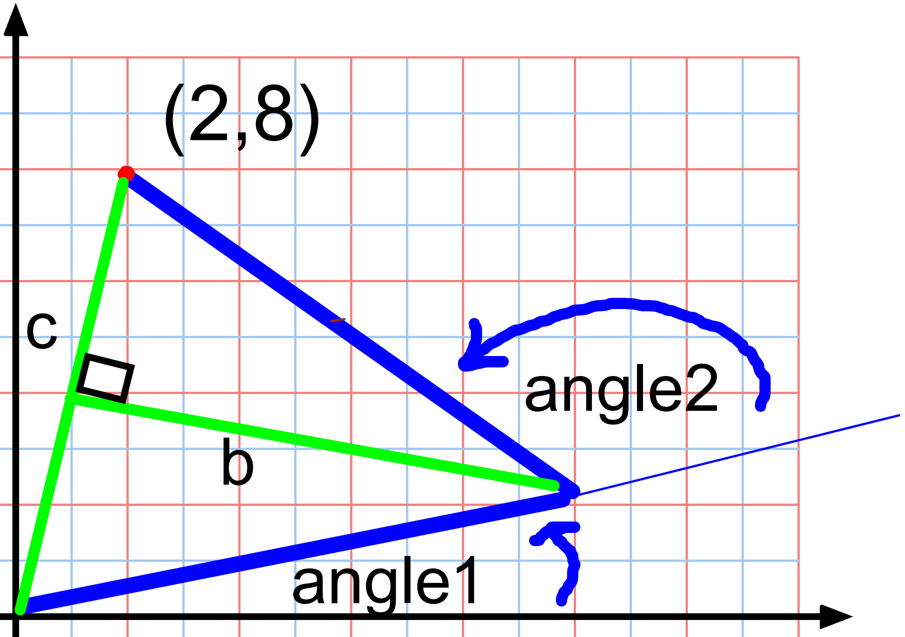
? = arcsin(.423)

in c++: `cout << asin(.423) << endl;`

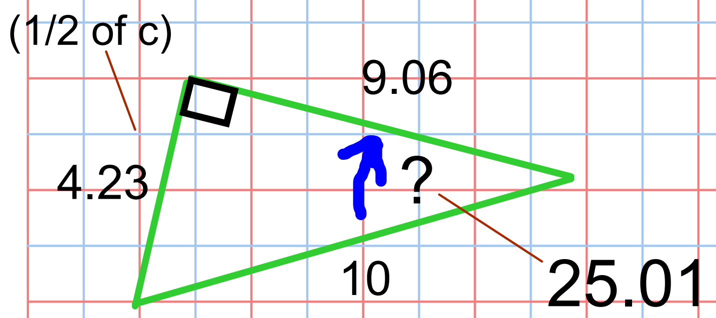
Explore

But .43657 isn't the angle is it? Well yes, but in radians rather than degrees.

to convert:
deg = (180 / PI) radians



.43657 = arcsin(.423)



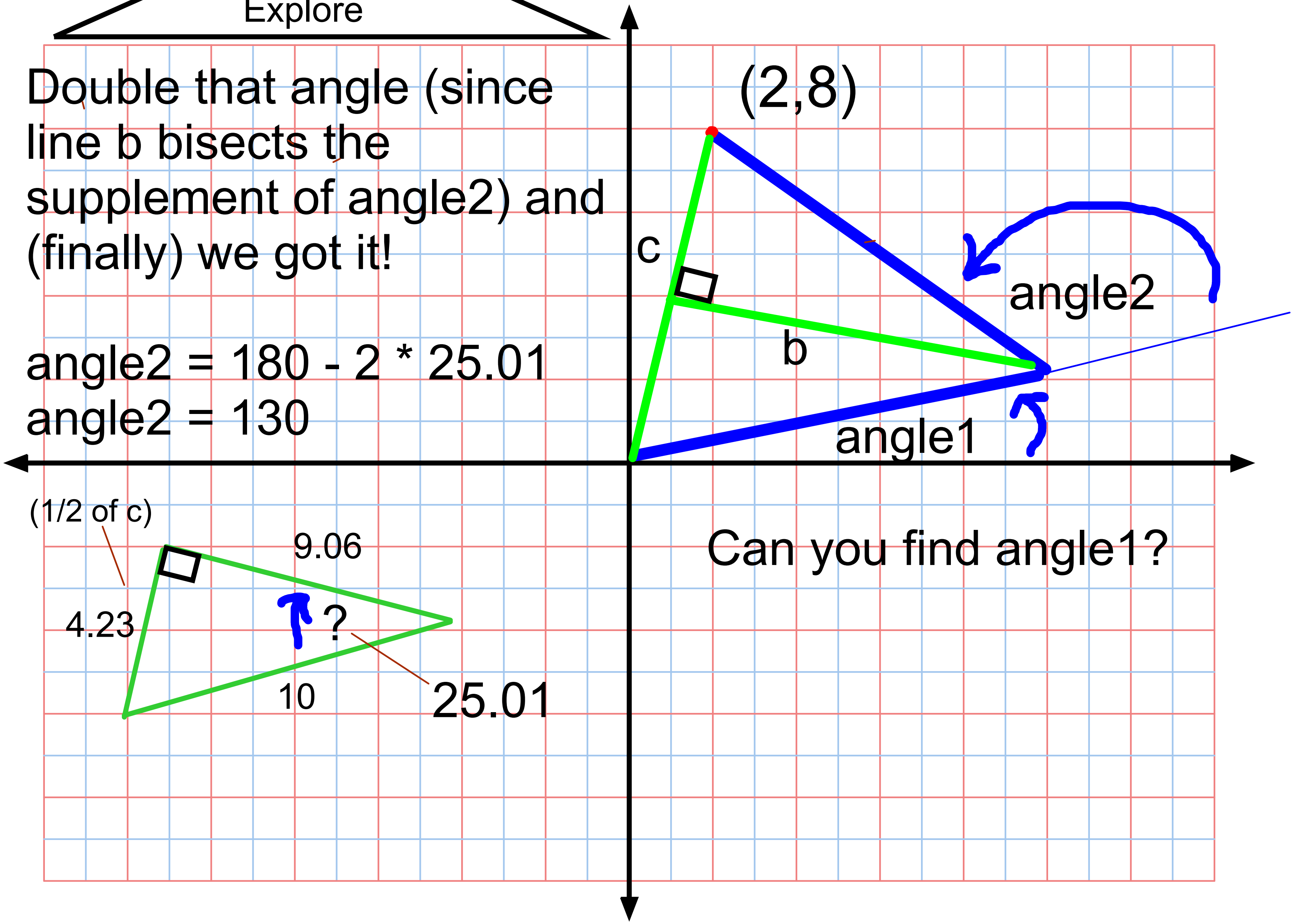
in c++:

```
cout << (180 / 3.1415926535) * .43657;
```

Explore

Double that angle (since line b bisects the supplement of angle2) and (finally) we got it!

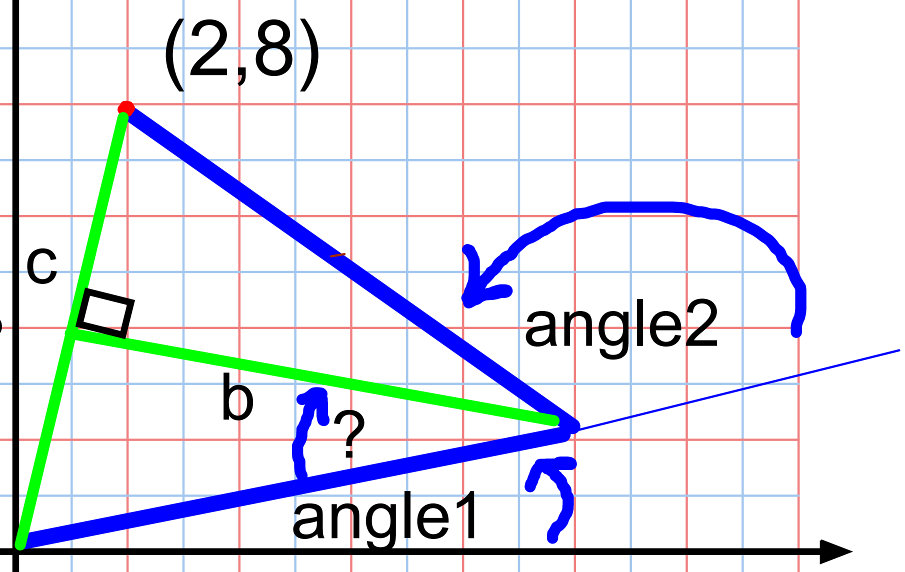
angle2 = 180 - 2 * 25.01
angle2 = 130



Can you find angle1?

Explain

Let's review:
In order to find angle2, we:
- calculated line c
- calculated line b
- used arcsin to find angle ?
- angle2 is supplement of angle ? doubled



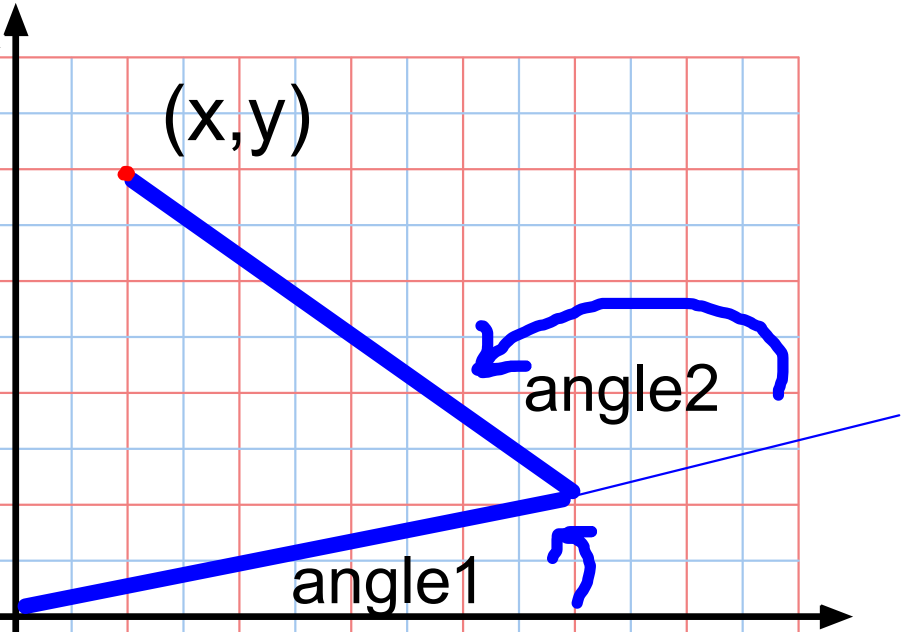
Each of those steps can be broken into further details, but they outline a plan of action.

Can you find angle1?

Work out a plan and list the steps you took to find it.

Explain

An algorithm is a detailed description of the steps needed to solve a problem.



After you have had a chance to think about your explorations, write an algorithm that would allow someone to write a computer program which would calculate the two angles needed to position the robot arm to a particular point given as input to the program.

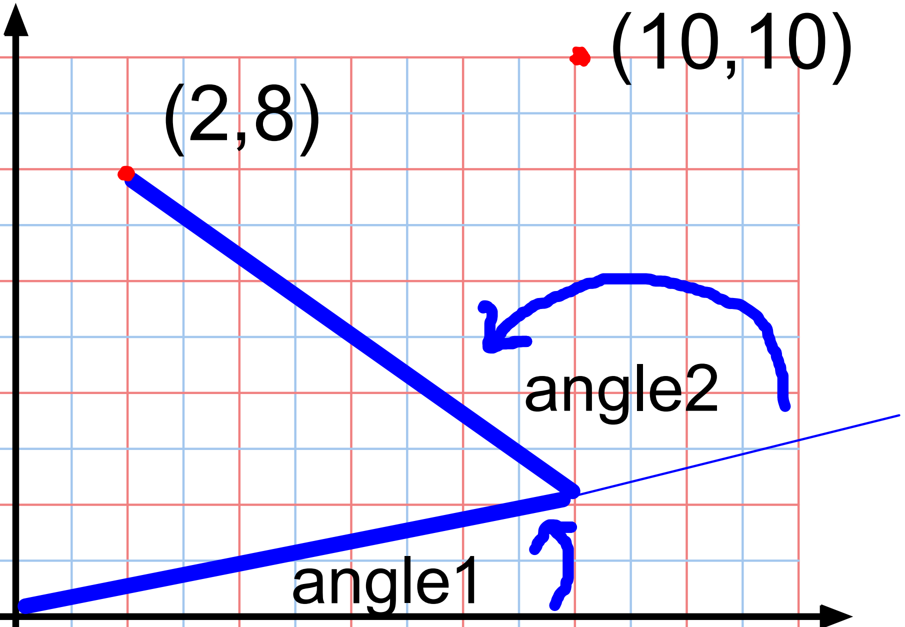
Extend

There is more than one way to get from (10,10) to (2,8) since there are two angles involved. For example, we could move the lower part of the arm through angle1, and then move the upper part through angle2.

What path would the end effector take if we did that?

Would the path change if we moved first through angle2, then angle1?

What if we alternated the traversal one degree at-a-time?



How could you move the end-effector in a straight line to the new point?

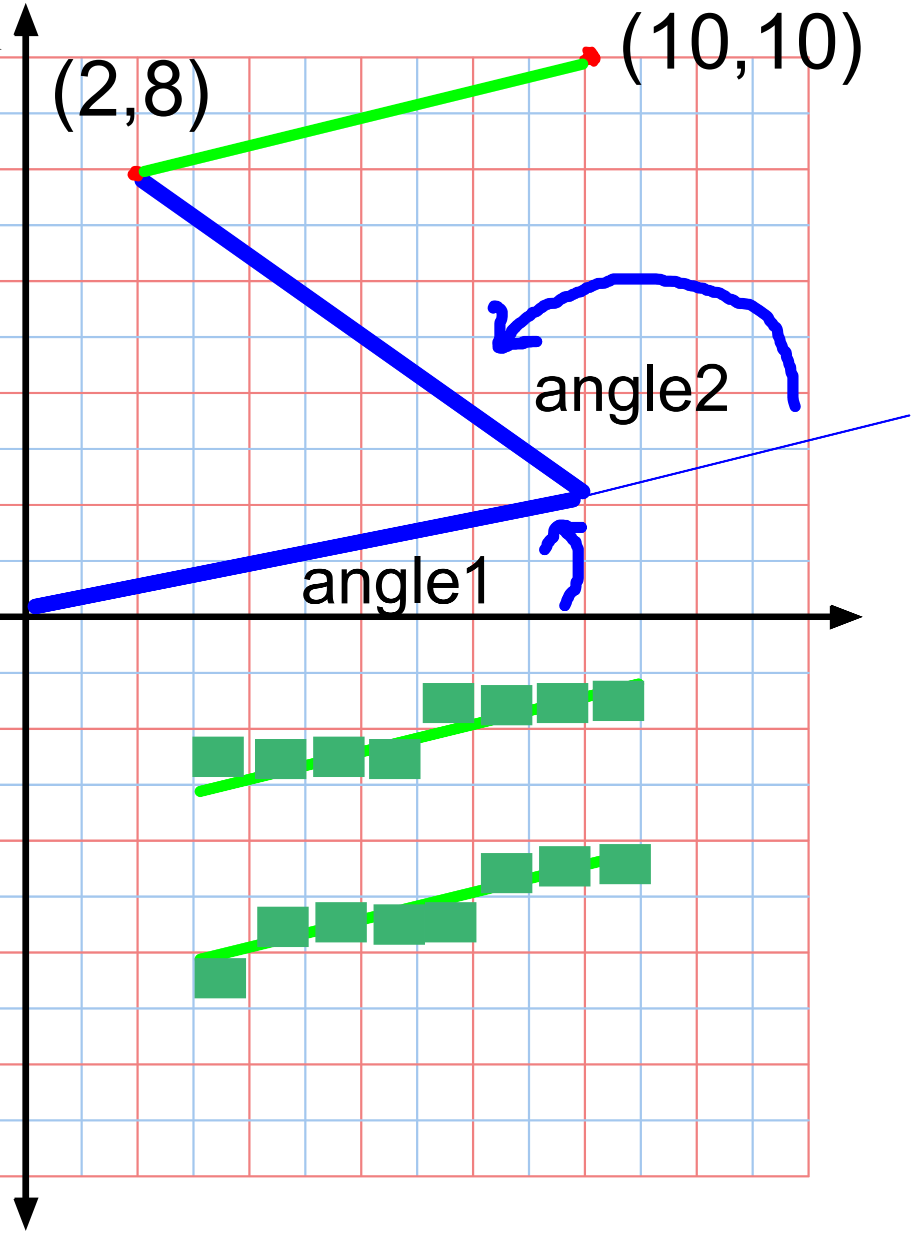
What is a "straight line" when each point is a square (pixel)?

Extend

Write an algorithm to move the end-effector in a "straight line" to the new point.

There is more than one choice for "straight" since computer drawing is choosing which square pixel (picture element) to fill in to approximate the line.

Here are two:



Hint: Use slope formula

Evaluate

Engage

Evaluate the existing knowledge of each student by asking questions about mathematical techniques that can be used for this problem.

Explore

Evaluate each students participation in the problem-solving process by asking for their suggestions about how to go about finding the solution.

Explain

Evaluate each students ability to put the solution into their own words by having them explain it to someone else in the class.

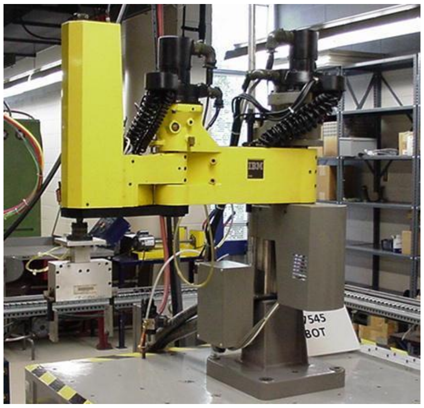
Extend

Evaluate the ability of each student to apply the techniques used to related problems, or to convert the algorithm to a computer program.

Attachments

Abstract_Topham.doc

MECH 337 / ELEN 337
Robotics I



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Syllabus
Schedule

Homework
Homework #1
Homework #2
Homework #3
Homework #4
Homework #5

Class References
Link Description Examples using MATLAB Robotics Toolbox
IBM Robot Reference

Auxiliary References
Robotics Toolbox for Matlab
Robotics Toolbox Manual
Conference Paper Reviewing Robotics Toolbox for Matlab
Index of Matlab Educational Sites