4 - Estimating Size and Distances

Purpose: To estimate the distance to an object in terms of its size, or to estimate the size of and object in terms of its distance using equipment always available: your body. To receive full credit, answer all 25 questions (Q1 - Q25).

Materials:

1 one-dollar bill
1 meter stick, string
tape

What do you think?

Write your best guess answers to Q1 and Q2 in the spaces provided.

Q1. If you hold out your hand at arm's length, what part or parts of your hand or fingers will just cover the Moon?

Q2. How many Moon diameters fit into the distance between Earth and the Moon?

Procedure

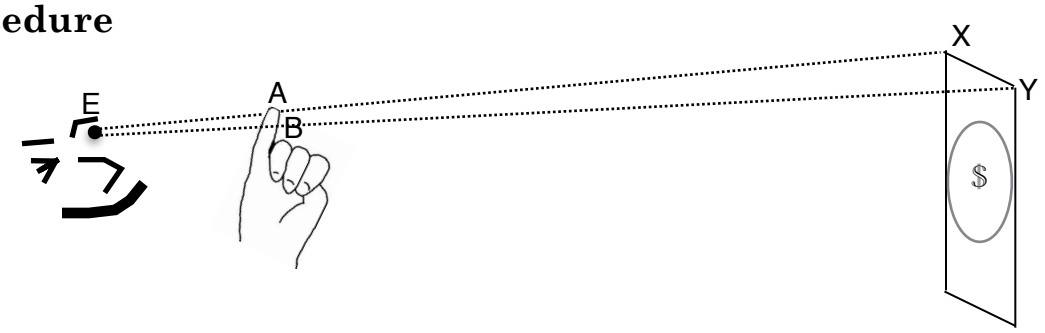

Figure 1: *Triangle formed by your eye (E), your finger width (AB), and the dollar bill's width (XY). The line AB is the width of your little finger stretched at arm's length and line XY is the width of the dollar bill taped to the wall. The distance from your eye to your finger is EA or EB and the distance from your eye to the dollar bill is EX or EY.*

1. Tape a one dollar bill to a wall with the short side of the bill parallel to the floor.

2. Stretch an arm out to full length and make a fist, palm up. Straighten your little finger, keeping the rest of your hand closed in a fist. Position your hand so that your little finger is straight up and down. With your arm stretched in front of you, close one eye.

3. Stand close to the dollar bill where your little finger is *not* covering the bill and walk away from the bill until you see that the upper joint of your little finger appears to just exactly cover the width of the dollar bill. Don't move.

4. Let your lab partner measure the distance from your finger to your eye. Keep your arm straight and horizontal. Be careful not to poke each others' eyes. Don't move.

Q3. The distance from your finger to your eye is _____ cm.

Let your lab partner measure the distance from where your eye to the dollar bill. You can now move.

Q4. Distance from your eye to the bill: _____ cm.

5. Measure the width of the upper joint of your little finger.

Q5. The width of your little finger is _____ cm.

6. Calculate the number of "Finger Widths" that fit into your "Eye-to-Finger Distance."

Q6. $$\frac{\text{Eye-to-Finger Distance}}{\text{Finger Width}} = \_\_\_\_\_$$

Using the answer to Q6, you may say that _____ Finger-Widths will fit into the distance between your eye and your finger. This number will be called the "ratio of Eye-to-Finger Distance to Finger-Width" (ratio 1).

7. Measure the width of the dollar bill.

Q7. Width of the dollar bill: _____ cm

Q8. How many "Dollar Bill Widths" fit between your eye and the dollar bill?

$$\frac{\text{Eye-to-Bill Distance}}{\text{Dollar Bill Width}} = \_\_\_\_\_$$

Using the answer from Q8, you can say that _____ dollar bill-widths fit into the distance between you and the dollar bill when you are standing at a position where your outstretched little finger just covers the dollar bill.

8. Repeat the procedure (steps 1-7) so your partner can determine her/his own "Finger-to-Eye" relationship.

Q9. What are the similarities in your answers for Q6 and Q8? Use measurements of you and your partner.

The Math:

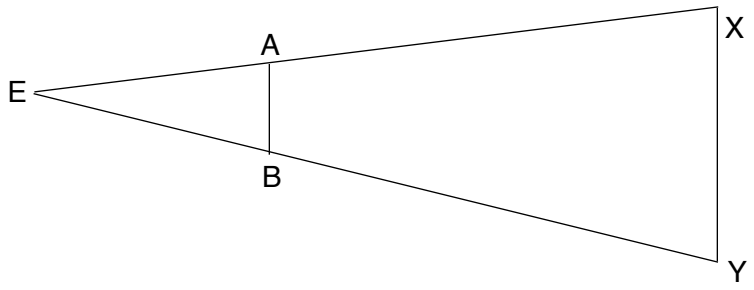

Figure 2: *As seen from above, Figure 1 contains two similar triangles. One is formed by your eye (E) and your finger width (AB), and another by your eye and the dollar bill's width (XY).*

The triangles *AEB* and *XEY* are known as *similar triangles*, i.e. the angles in triangle *AEB* are all the same as those in *XEY*. This equality also means that the ratio of the side to the base of these triangles are the same. It also means that the ratio of the height to the base of the triangles are the same:

$$\frac{\text{Distance from eye to finger}}{\text{Finger Width}} = \frac{\text{Distance from eye to dollar bill}}{\text{Dollar-Bill Width}}$$

9. Now stand at a position where the dollar bill is just exactly covered by two little finger widths. This is illustrated by the following ratio:

$$\frac{\text{Distance from eye to finger}}{\text{2 Finger Width}} = \frac{\text{Distance from eye to dollar bill}}{\text{Dollar-Bill Width}}$$

Q10. Has the apparent size of the dollar bill increased, decreased, or stayed the same?

Q11. What has happened to the distance between you and the dollar bill?

Q12. The distance between you and the dollar bill is _____ cm.

Q13. Compare this distance to that when your little finger covered the dollar bill in Q4. Calculate the ratio between the distance in Q4 to Q12. How many times are you closer or farther from the dollar bill when you cover it with two fingers instead of one?

10. Move to a position where the dollar bill is just covered by only half of your finger width. This comparison is illustrated by the following ratio:

$$\frac{\text{Distance from eye to finger}}{\frac{1}{2}\text{ Finger Width}} = \frac{\text{Distance from eye to dollar bill}}{\text{Dollar-Bill Width}}$$

Q14. Has the apparent size of the dollar bill increased, decreased, or stayed the same?

Q15. What has happened to the distance between you and the dollar bill?

Q16. The distance between you and the dollar bill is _____ cm.

Q17. Compare this distance to that when your little finger covered the dollar bill in Q4. Calculate the ratio between the distance in Q4 to Q16. How many times are you closer or farther from the dollar bill when you cover it with 1/2 fingers instead of one?

11. FIELD WORK A: Go out of the classroom and look for an object far away. Find a location where you can just exactly cover the object's width with your little finger when your arm is fully extended. Choose any units (feet, cm, etc.) that you are comfortable.

Q18. Describe the object you chose and make an educated guess of the width of the chosen object (include the unit of measurement, i.e. cm, feet, etc.):

OBJECT:

WIDTH OF OBJECT:

Q19. Using what you have learned so far, state how many object widths will fit between you and the object.

Q20. Using the same method you used in Q19, calculate the distance to the object (include unit of measurement). Show all your work.

12. FIELD WORK B:

Q21. What do you think? Where do you think the Moon will be on your local sky now? Discuss with your lab partner, consult with the instructor, lab assistant and search in the internet.

PHASE:

TIME:

DATE:

APPROXIMATE CARDINAL DIRECTION OF THE MOON:

APPROXIMATE ALTITUDE OF THE MOON:

Q22. As you go out, orient yourself by finding the cardinal directions and altitude you predicted in Q23. How close was the Moon from where you thought it would be?

Use your little finger with your arm outstretched to measure the full apparent diameter of the Moon.

Q23. How many finger widths or fractions thereof just covered the Moon? Even if the Moon is a crescent, you can estimate its full diameter by measuring from one tip of the crescent across to the other tip.

Q24. State how many Moon diameters the Moon is away from you:

Q25. How do the answers to Questions Q23 and Q24 compare with your predictions in Q1 and Q2?