Rules of Thumb for Estimating Angles and Measuring the rotation rate of the Earth

1 Indoor: Calibrate your hand to measure angles

Materials

you, ruler, string

Instructions

Sextants allow the precise measurement of angles, but not all of us carry one in our back pocket (plus they take some practice). So you are going to calibrate various parts of your hand to allow you to measure angles.

Turn your head 90° and extend your arm straight out from the shoulder. Now extend your thumb like you're hitchhiking. This will be one of your basic measuring devices. Now make a loose fist. There's your other device.

Record all your measurements, the estimate precision of each measurements and your calculations:

Measure the width of your thumb across the nail. Use the string to measure the distance from your eye to your thumb at arm's length. Get as accurate a measurement as possible. Check how much difference it makes if you hold your arm in front of you versus to the side, or move your head slightly. Calculate the angle subtended by your thumb in degrees, and estimate the precision of your measurement.

Repeat this process for your fist (across the knuckles.)

You now have two "devices" for estimating angles that are always with you.

2 Indoor: Another calibration of your hand for angle measurement

Materials

you, ruler, string, paper, tape, hallway

Instructions

Record all your measurements, the estimate precision of each measurements and your calculations:

This time go out in the hall and secure a meter stick to the wall horizontally. Back up until your thumb held at arm's length spans five to ten centimeters.

Without moving, count how many centimeters are spanned by your thumb and by your fist held out at arms length, then get your lab partner to use string to measure the distance from your eye to the meter stick. Get measurements as accurate as you can, and estimate your precision.

Calculate the angle subtended by your thumb and fist in degrees, and estimate the precision of this value.

Which measurement (this one, or the one from the previous exercise) was more precise? Pick final values and precisions for the angles spanned by your thumb and fist.

3 Indoor: Measure angles with your hand

Materials

you, ruler, string, setup in hallway

Instructions

Do the calibration exercises before this one.

I will put a line of tape on the floor in the hallway, and will tape a ruler to the wall. From the line, measure the angular width of the ruler using your thumb.

Now check your results: **Get your partner's help in using the string to measure the distance from your eye to the wall. Calculate the angle that should be subtended by the ruler at that distance. How well do your results agree? How does your accuracy compare to your estimated precision?**

4 Indoor: Plan an observation

Materials

star chart

Instructions

In this exercise you will plan a series of observations that will allow you to measure the rotation rate of the Earth by observing the apparent movement of the sky.

Outline of the observations: you will find a bright star near the horizon to the East or West and measure it's altitude several times over the course of a few hours. From this you will calculate the rate of change of the altitude in degrees per hour. **Explain why this is approximately the rotation rate of the Earth. Why is it important the the star be to the East or West? Why might this number (even if you measured it perfectly) differ slightly from the true rotation rate?** Hint: think of the path of a star through the sky, and its relation to the stars altitude.

Of course, we already know what the rotation rate should be, which will help us plan the observation. Calculate the rotation rate of the Earth using the fact that it rotates roughly 360° in 24 hours.

If you pick a star to the West, you will have to worry about it setting in between your observations. **If your observations span three hours, how high does your star have to start out for it to still be up at the end? How precise would your measurements have to be in order to detect the change in altitude between observations taken 20 minutes apart?**

Read through the procedure for the next exercise and make sure you understand it. If you have any questions, make sure to ask them before you leave. If it is clear, you can go outside and pick a vantage point and a star. If it is not clear, you can still pick a likely vantage point, but you may have to adjust later.

5 Outdoor: Measure the rotation rate of the Earth

Materials

you, star chart, angles subtended by your thumb and fist from previous exercises

Instructions

Pick a clear night when you can go out at least three times over the course of at least three hours. Your observations must be at least 20 minutes apart, and the first and last must be at least three hours apart.

1. Pick a spot to which you can return *exactly* with a relatively clear view of the Eastern or Western horizon. Since we're in New York, your "horizon" might very well be the roof of a building. This is fine as long as the building is fairly far away and it forms a relatively horizontal line that you can use as a stable horizon.
2. Find a bright star that you can identify reliably near the Eastern or Western horizon, but make sure it will still be up for your subsequent observations.
3. **Record the exact time and measure the altitude of your star using your thumb and/or fist.** Repeat your measurement a few times so you can take the average later. **Record the precision of your measurement.**
4. Return to make at least two more observations over a period of at least three hours.

Now you have a list of times and altitudes. **Calculate the rotation rate of the Earth using each pair of observations.** (If you have three observations you can pair them up three ways). **Decide on a final value and estimate your precision. Explain how you did so.**

Now calculate the rotation rate of the Earth using the fact that it rotates roughly 360° in 24 hours. **Does your measurement agree to within your precision? If not, how do you explain the difference?**