Historical Altitude Measurements

قدِیم ادوار میں ارتفاع کی پیمائش

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Have you ever wondered how people knew the time or navigated across vast oceans before smartphones and GPS?

Long before modern technology, 2nd-century astronomers like Claudius Ptolemy, and later, brilliant scholars of the Islamic Golden Age, looked up at the stars and designed remarkable tools to measure the heavens. Driven by the need to find the direction of the Qibla and calculate the five daily prayer times, they perfected instruments like the **Quadrant** (*rub'*) and the **Triquetrum** (*al-iḍāda al-ṭawīla* - the long alidade).

Let's step back in time, build these medieval instruments, and test their accuracy against modern astronomical software!

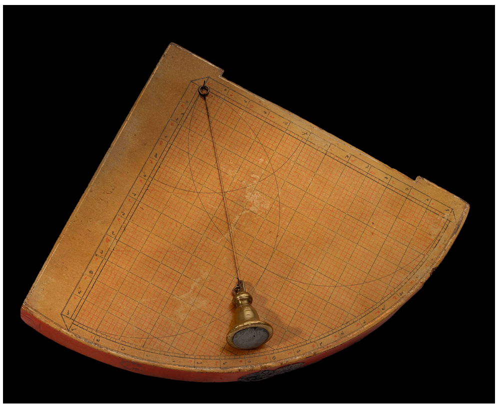

Figure 1: Islamic quadrant from 1813 (as preserved at National Maritime Museum)

کیا آپ نے کبھی سوچا ہے کہ سمارٹ فون اور جی پی ایس کی ایجاد سے پہلے لوگ وقت کا اندازہ کیسے لگاتے تھے یا سمندروں میں راستے کیسے تلاش کرتے تھے؟

جدید ٹیکنالوجی سے صدیوں پہلے، دوسری صدی کے ماہرینِ فلکیات جیسے کلاڈیوس بطلیموس، اور بعد میں اسلامی سنہری دور کے عظیم مسلم سائنسدانوں نے آسمان کی وسعتوں کو ناپنے کے لیے حیرت انگیز آلات تیار کیے۔ پانچ وقت کی نمازوں کے اوقات اور سمتِ قبلہ کے درست تعین کی ضرورت نے انہیں کواڈرنٹ (الرّبع) اور ٹرائیکیٹرم (العضادة الطویلة یا طویل الیڈاد) جیسے آلات بنانے پر متحرک کیا۔

آیئے وقت کے پہیے کو پیچھے گھمائیں، قرونِ وسطیٰ کے یہ آلات تیار کریں، اور دیکھیں کہ یہ آج کے جدید سافٹ ویئر کے مقابلے میں کتنے درست ہیں!

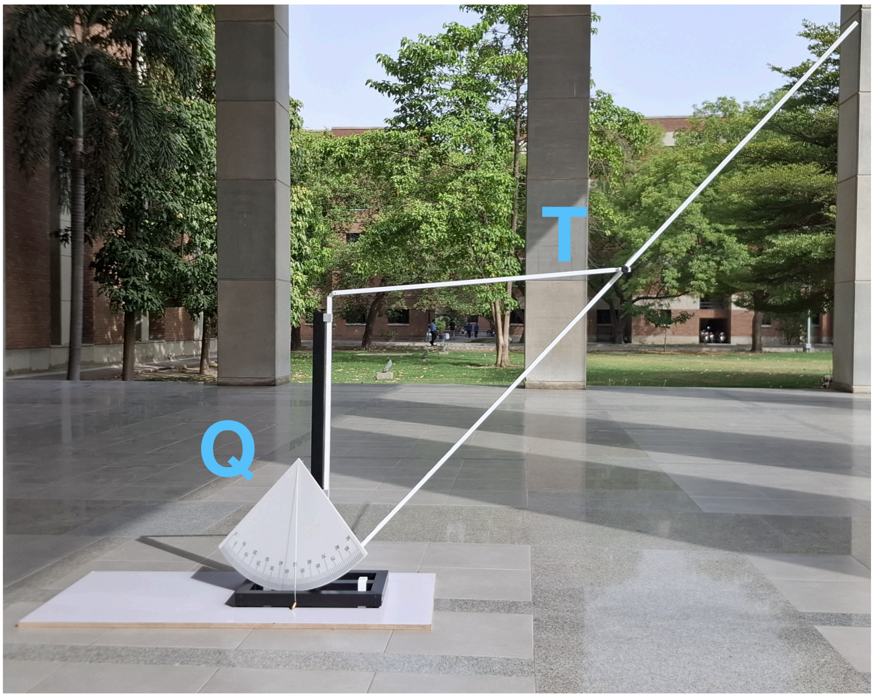

Figure 2: The quadrant (Q) and triquetrum (T).

Let's make sure we have everything we need to make up a setup shown in Fig. 2.

- **White arcylic quadrant** (with a 0° to 90° scale; 0° must be aligned with line of sight)
- **Plumb line** (weighted string attached to the quadrant's vertex)
- **Triquetrum** (fully assembled metal structure, with a wooden base for support)
- **Mobile phone camera** (for capturing readings safely)

Operating the quadrant

With reference to Fig. 3:

1. **Aim:** Look along the edge of the quadrant where the 0° mark begins and align it perfectly with your celestial target. Keep your hands steady!
2. **Record:** Let the plumb line hang freely. Where it crosses the scale is your reading. Use a phone camera or ask a friend to note the value down.
3. **Calculate:** This reading is the zenith distance Z. Subtract it from 90° to find your final altitude:

$$\theta_Q = 90^\circ - Z$$

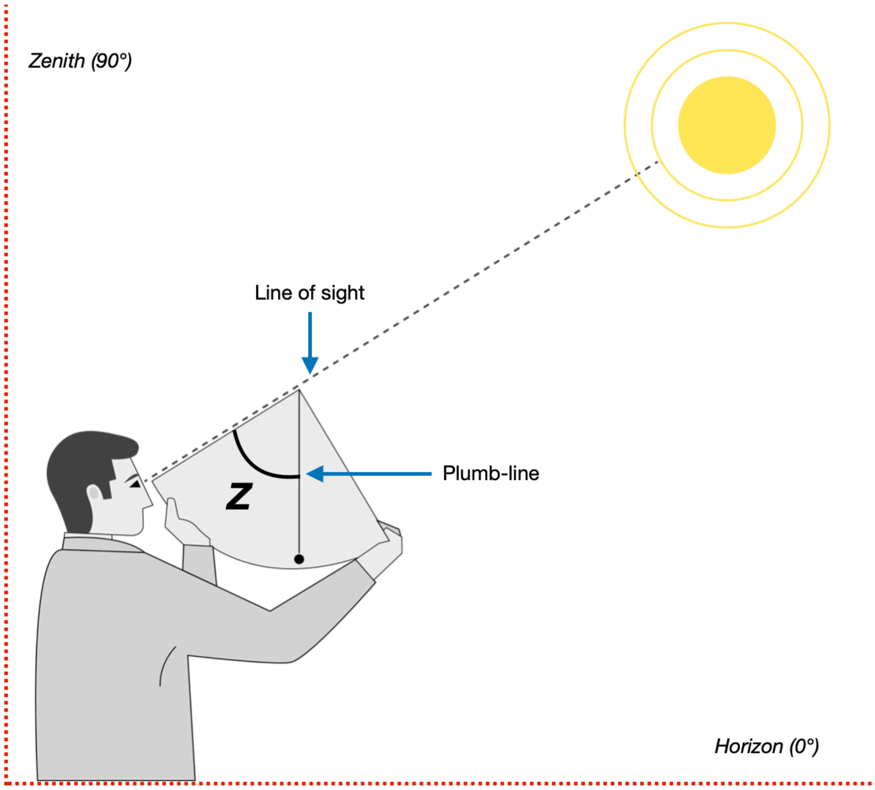

Figure 3: Labeled illustration of the quadrant.

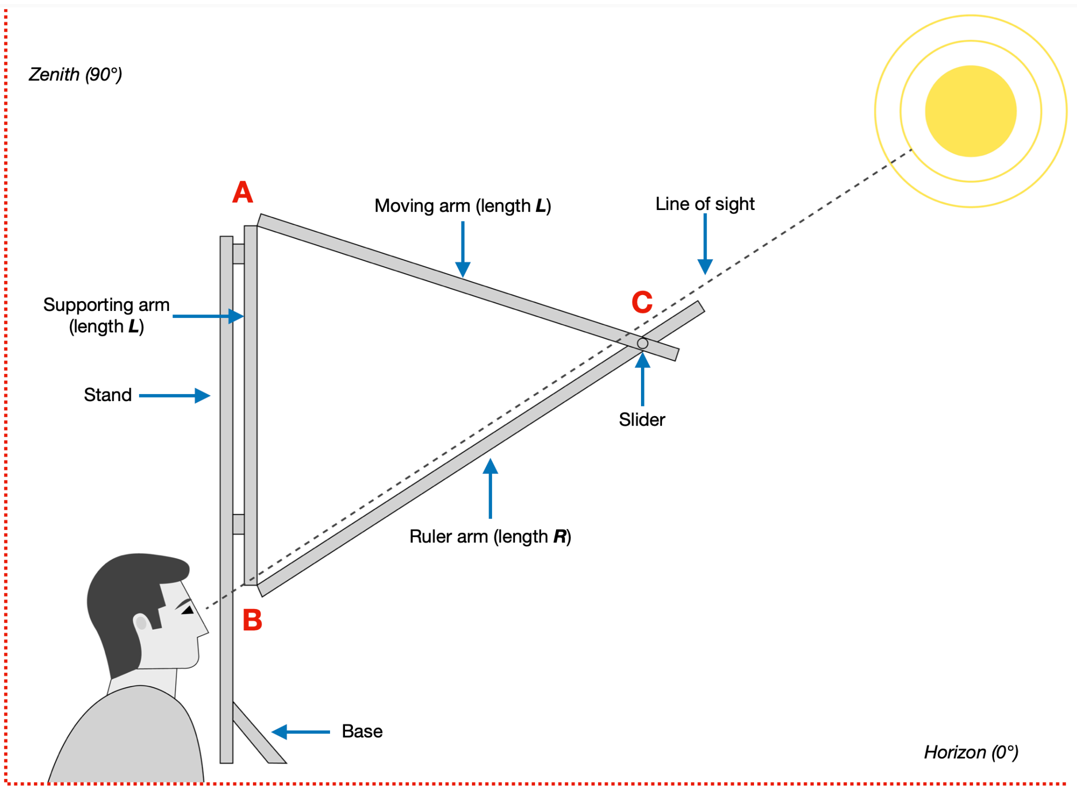

Figure 4: Labeled illustration of the triquetrum.

Operating the triquetrum

With reference to Fig. 4:

1. **Sight**: Look from the bottom hinge along the ruler arm.

2. **Align:** Move the slider until your target aligns completely with the sight. Lock the slider firmly into place.

3. **Measure:** Note the value on the ruler arm where the slider rests. Record this value as R (in cm).

4. **Solve:** Use the cosine rule to determine the zenith distance Z. In our setup, the triquetrum forms an isosceles triangle $\Delta\mathbf{ABC}$, so the equation simplifies to:

$$Z = \arccos(\frac{R}{2L}).$$

   Here, L refers to the constant lengths of the supporting and the moving arms (both of which are 93 cm for one version of our setup).

5. **Final Altitude:** Subtract Z from 90° to get your altitude (θ_T).

Every physical experiment involves minor uncertainties. For our analog scales, we use Type B uncertainty calculated as $\Delta/\sqrt{6}$ (where Δ is half of the least count of the instrument.). Let's see how closely your structural measurements match reality!

[Q 1]. For your first activity, you will observe the Sun with the given instruments and obtain 10 readings.

Fill out the observation matrix on the next page (Table 1) by taking readings every 10 minutes. Compare your adjusted readings with the real-time software coordinates from Stellarium (Appendix A.1).

CRITICAL SAFETY NOTE ⚠

Never look directly at the Sun without a certified solar filter! Doing so will cause permanent and severe eye damage.

[Q 2]. Plot the data gathered in Table 1 (preferably using MATLAB or Python) and generate an altitude versus time graph. What can you deduce from this graph? Do not forget to include the uncertainities!

[Q 3]. Repeat Questions 1 & 2 for the Moon by taking readings every day at fixed time for 2 weeks (using Table 2). What do you expect to see?

Table 1: Your Solar Altitude Tracking Log

Time of Obs.	**Quadrant** $\theta_Q(^\circ)$	**Triquetrum Reading** R (cm)	**Triquetrum Calculated** $\theta_T(^\circ)$	**Stellarium Ref** $(^\circ)$

Table 2: Your Lunar Altitude Tracking Log

Date of Obs. Fixed Time =	**Quadrant** $\theta_Q(^\circ)$	**Triquetrum Reading** R (cm)	**Triquetrum Calculated** $\theta_T(^\circ)$	**Stellarium Ref** $(^\circ)$

A Appendix

A.1 Using Stellarium for Ancient Astronomy

Figure 5: Stellarium user interface on desktop (with highlighed ”markings tab”).

1. Download Stellarium:
   (a) For PC/MacOS/Linux users, navigate to `https://stellarium.org` and follow the download instructions.
   (b) For iOS/iPadOS/Android users, navigate to your respective app stores and download Stellarium from there.
2. Open the software once installed.
3. Set your Location window to your current city.
4. Adjust the Date and Time controls to match the exact minute you took your physical instrument reading.
5. Click on the targeted object (e.g. Sun, Moon) and look at the top left menu string to extract the actual Apparent Altitude.
6. Keep in mind that Stellarium will provide the Apparent Altitude in terms of degrees, arc-minutes, and arc-seconds. Convert it entirely into degrees, and record it in the relevant space in your table(s).
7. Learn more about Stellarium at `https://stellarium.org`.

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