The sizes of things:

This is totally misleading!
The real picture:

$1.5 \times 10^8 \text{ km} = 8 \text{ light minutes} \equiv 1 \text{ light year (LY)}$

- Earth
- Moon
- Mercury

$R_\text{E} = 6,000 \text{ km}$
$R_\text{moon} = 1,700 \text{ km}$

$R_\text{Em} = 3.8 \times 10^5 \text{ km}$

$m = 1.3 \text{ light sec} = \text{distance to moon}$

$R_\odot \equiv 2 \times \text{Distance to moon}$

$= 2 \times \text{Em}$

1 mile = 1.6 km

$1 \text{ light sec} = 3 \times 10^8 \text{ km}$
Angular Size of Sun = \frac{\text{Diameter of Sun}}{\text{Distance to Sun}} = \frac{2R_\odot}{1 \text{ RES}}

= \frac{2 \times 7 \times 10^5 \text{ km}}{1.5 \times 10^8 \text{ km}} = \frac{1}{108}

Angular Size of moon = \frac{\text{Diameter of Moon}}{\text{Earth moon Distance}}

\approx \frac{2R_{\text{moon}}}{R_{\text{F to moon}}} = \frac{2 \times 1.7 \times 10^3 \text{ km}}{3.8 \times 10^5}

\approx \frac{1}{111} = \text{approximately the same angular size of sun}
How to measure ratios of sizes with angles

Way out of Scale

Place a quarter in the sunlight it makes a shadow. The shadow has a conical shape.

Angle of Cone = \frac{\text{Diameter of Sun}}{\text{Earth Sun Distance}}

\text{in Radians} \quad \text{in Degrees} = 0.53°

So since \(\triangle ABC\) and \(\triangle ADE\) are similar triangles...
Now blow up or magnify this picture. Quart.

Thus, by measuring the conical shape/angle of the shadow, one can measure the ratio of two distances.

In general, measuring ratios of sizes is much easier than absolute distances.
Angular Separations

\[ \theta = \frac{\text{Diameter of Sun}}{\text{Earth sun distance}} \]
Expanded Earthling View

\[ \theta = \text{still the same} = \frac{\text{Diameter of Sun}}{\text{Earth sun distance}} \]
Measuring the size of the Solar System

How big is the Earth? Eratosthenes 3 BC

Observations

- At midday (in summer) the sun went directly into a deep well in the town of Syene (close to and reflected off the bottom of a dam

- In Alexandria which is 833 km north of Syene (Aswan)

the closest the sun came to being directly overhead is 7.2°

\[ \theta = 7.2° = 0.13 \text{ radians} \]
\[ \theta \text{ in radians} = 0.13 = \frac{S}{R_E} = 833 \text{ km} \]

So solving for \( R_E \)

\[ R_E = \frac{833 \text{ km}}{0.13} = 6400 \text{ km} \]

Accepted value today is 6378 km.
Measuring the Earth-Moon Distance:

- Aristarchus of Samos 310-230 BC
  using the lunar Eclipse

108 x earth diameter Earth

107 x Moon

moon diameter

- During a lunar eclipse the moon is blocked from the sun by the earth's shadow

- Watch the video
Lunar Eclipse

- See this applet by Michael Fowler
- See this Nasa video
- The real thing Lunar Eclipse
Ok, so by timing:

1. We know that $EF \approx 2.5 \, DC$, from timing the eclipse.

2. We also know that (by accident) the Sun and the moon have approximately the same angular size.

Thus, $AEF$ and $DEC$ are similar triangles. Therefore:

$$AE = 2.5 \, DC$$ since $$EF = 2.5 \, DC$$

So, $$AC = 2.5 \, DC + DC = 3.5 \, DC$$

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length
earth-moon
distance
of earth's
shadow
$= 108 \times$ earth's diameter
So with earth's diameter $2 \times 6400$ km

Earth Moon Distance $= \frac{108 \times \text{Earth's Diam}}{3.5}$

$= 3.9 \times 10^5$ km

Accepted value $3.8 \times 10^5$ km

A by product of this is the moon's radius can be estimated
How far away is the Sun? Aristarchos of Samos (310 - 230)

Half Moon

- Basic idea: Observer measures half a moon at daylight.
- Then measure the angle to the Sun.

Then trigonometry

\[
\cos \Theta = \frac{X}{R_{ES}} \Rightarrow R_{ES} = \frac{X}{\cos \Theta}
\]

The problem was that \( \Theta \) is almost 90° (89.853°)
From an estimate that $\theta > 87^\circ$, found that the sun

$$R_{Es} > 20 \text{ Rem}$$

So he concluded that the sun is very far away.

In fact $R_{Es} = 390 \text{ Rem} = 7 \times 10^5 \text{ km}$
Copernicus (1530)

- First to suggest that the sun was at the center of the solar system, challenging the Ptolemaic View. Pope Clement VII approved of Copernicus and asked for a copy.
- Questions:
  - There is one exception: the moon orbiting the earth. Why?
  - Stress would cause the earth to fly apart (Aristotle).
- The real answer to these questions came from Galileo and the telescope.
Copernican View – Heliocentric view
Galileo and the telescope

- Excerpt from "Sidereus Nuncius"
  "the stary messenger" pg 21

- The invention of the telescope by Hans Lipperhey but was unable to get a patent because it was considered too easy to fabricate.

  I

- Galileo greatly improved the design pg 29

- Galileo views the moon

- Galileo views the moons of Jupiter
AND OPINIONS OF GALILEO

...anything showed clearly that he had printing. If his two minor works had... who shared that opinion, The Starry... succeeded.

From: Discoveries + Opinions of Galileo. Translation + Notes by Stillman Drake.

THE STARRY MESSENGER

Revealing great, unusual, and remarkable spectacles, opening these to the consideration of every man, and especially of philosophers and astronomers;

AS OBSERVED BY GALILEO GALILEI

Gentleman of Florence

Professor of Mathematics in the University of Padua,

WITH THE AID OF A SPYGLASS

lately invented by him,

In the surface of the Moon, in innumerable Fixed Stars, in Nebulae, and above all in FOUR PLANETS swiftly revolving about Jupiter at differing distances and periods, and known to no one before the Author recently perceived them and decided that they should be named

THE MEDICEAN STARS

Venice 1610
that its diameter appears almost
surface nearly nine hundred times,
seven thousand times as large as
asked eye. In this way one may learn
of sense evidence that the moon is
and polished surface but is in fact
red everywhere, just like the earth's
ninences, deep valleys, and chasms.

Of a matter of no small importance to
is about the Milky Way by making
the very senses as well as to the
will be a pleasant and elegant thing to
ature of those stars which astronom-
called "nebulous" is far different from
ed hitherto. But what surpasses all
hat particularly moves us to seek the
iers and philosophers, is the discov-
stars not known or observed by any
enus and Mercury, which have their
sun, these have theirs about a cer-
icious among those already known,
ecedo and sometimes follow, with-
nt it beyond certain limits. All these
and observed by me not many days
 spyglass which I devised, after first
divine grace. Perhaps other things,
ill in time be discovered by me or
ith the aid of such an instrument, the
a of which I shall first briefly explain,
on of its having been devised. After-
the story of the observations I have
ago a report reached my ears that a

It would be superfluous to enumerate the number and
importance of the advantages of such an instrument at sea
as well as on land. But forsaking terrestrial observations, I
turned to celestial ones, and first I saw the moon from as
near at hand as if it were scarcely two terrestrial radii away.
After that I observed often with wondering delight both the
planets and the fixed stars, and since I saw these latter to
be very crowded, I began to seek (and eventually found)

Credit for the original invention is generally assigned to
Hans Lipperhey, a lens grinder in Holland who chanced upon
this property of combined lenses and applied for a patent on it
in 1608.

Badovere studied in Italy toward the close of the sixteenth
century and is said to have been a pupil of Galileo's about 1598.
When he wrote concerning the new instrument in 1609 he was
in the French diplomatic service at Paris, where he died in 1620.