Kujifunza kuhusu kupatwa kwa Mwezi na kupatwa kwa Jua

A study of lunar and solar eclipses

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Malengo
Goals

- Kuelewa kwa nini kuna awamu za mabadiliko ya umbo la Mwezi
- Kuelewa sababu ya kupatwa kwa Mwezi
- Kuelewa sababu ya kupatwa kwa Jua
- Kutafuta umbali na vipenyo katika mfumo wa Dunia-Mwezi-Jua

- Understand why the Moon has phases
- Understand the cause of Lunar eclipses
- Understand why there are Solar eclipses
- Determine distances and diameters of the Earth-Moon-Sun system

Uonekano ya mwanga na vivuli

Vision of lights and shadows

- **Mfumo wa Dunia-Mwezi-Jua:**

Awamu za mabadiliko ya umbo la Mwezi na kupatwa

- **Mlingano kati ya vivuli na pahali**

- The Earth-Moon-Sun System:
  Phases and eclipses

- Relative positions and shadows

Zoezi 1: Mfano wa upande wa nyuma ya Mwezi

Activity 1: Model of the far side of the Moon

- Watu 2 wajitolee: Mmoja anakuwa kati (Dunia) na mwingine (Mwezi).
- Mwezi umzunguke Dunia ukiwa kila mara unamuangalia Dunia. Mwezi umzunguke pembemraba 90°, hivyo Mwezi pia utahitaji kujizungusha kwa pembemraba 90°. Rudia hivyo hivyo hadi Mwezi ufike ulipoanzia

- 2 volunteers: one in the centre (the Earth) and the other revolving around it (the Moon)
- Place the Moon facing the Earth and have it revolve around the Earth by 90° and rotate itself also by 90º. Repeat the process until the starting position is reached

Zoezi 2: Mfano na tochi kali (Jua) kuelezea awamu za maumbo ya Mwezi

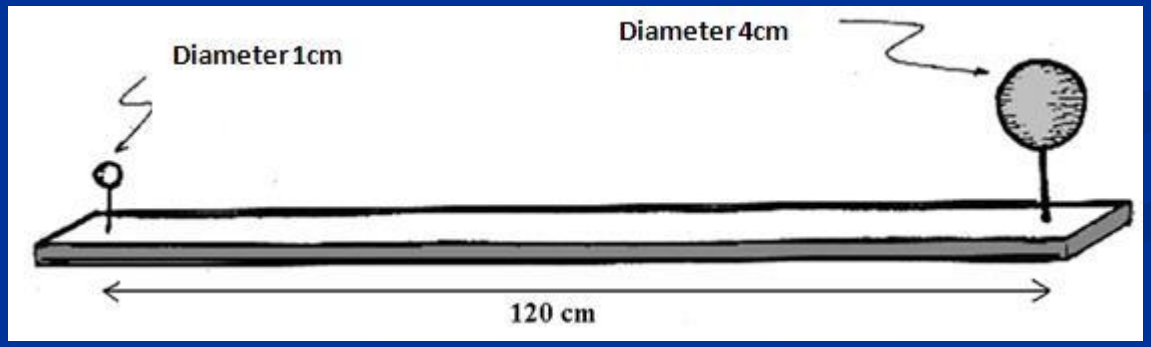
Activity 2: Model with flashlight (Sun) to explain the phases of the Moon

- Watu 5 wajitolee: Mmoja anakuwa kati (Dunia) na wengine 4 (wakiwa wamevaa barakoa nyeupe) wataiga awamu 4 za maumbo ya Mwezi (1 amemulikwa moja kwa moja, 2 wamemulikwa pembeni na 1 hatakuwa na mwanga)
- 5 volunteers: one in the centre (the Earth) and 4 others to simulate the 4 phases of the Moon with masks (1 completely illuminated, 2 partially illuminated and 1 completely dark)

Umbali na vipenyo katika Mfumo wa Dunia-Mwezi-Jua

Distances and diameters of the Earth-Moon-Sun system

Kipenyo cha Dunia **Earth Diameter**	**12 800 km**	→	**4 cm**
Kipenyo cha Mwezi **Moon Diameter**	**3 500 km**	→	**1 cm**
Umbali Dunia-Mwezi **EM Distance**	**384 000 km**	→	**120 cm**
Kipenyo cha Jua **Sun Diameter**	**1 400 000 km**	→	**440 cm = 4.4 m**
Umbali Dunia-Jua **ES Distance**	**150 000 000 km**	→	**47 000 cm = 0.47 km**

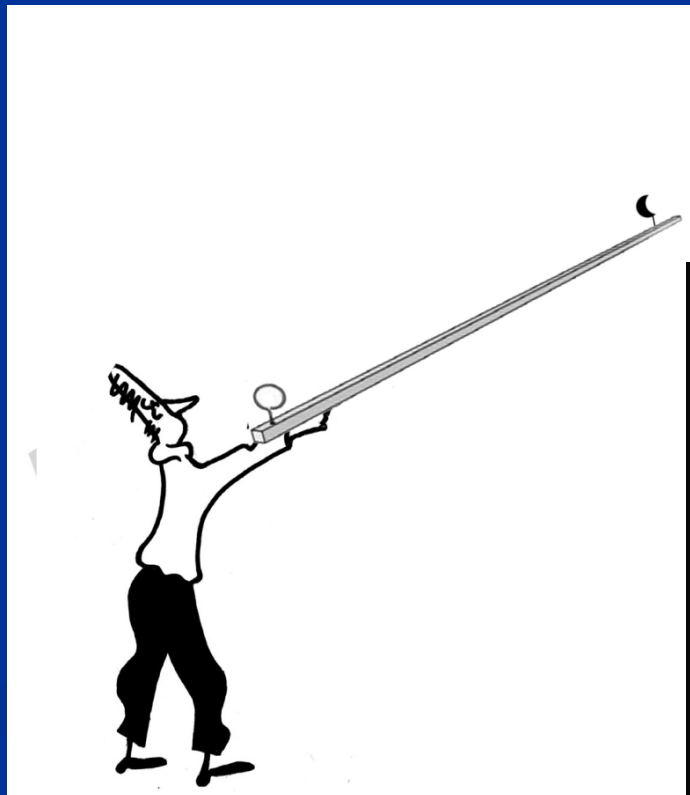


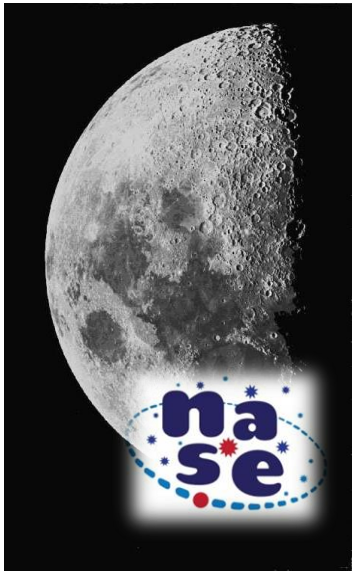
Zoezi 3: Kuigiza Awamu za Maumbo ya Mwezi

Activity 3: Simulation of Phases of the Moon

- Tengeneza mfano wa tufe mbili, moja ndogo (Mwezi) na nyingine kubwa (Jua)
- Elekeza tufe ndogo ya Mwezi kuelekea Mwezini na utaona zote mbili zikiwa na umbo sawa.

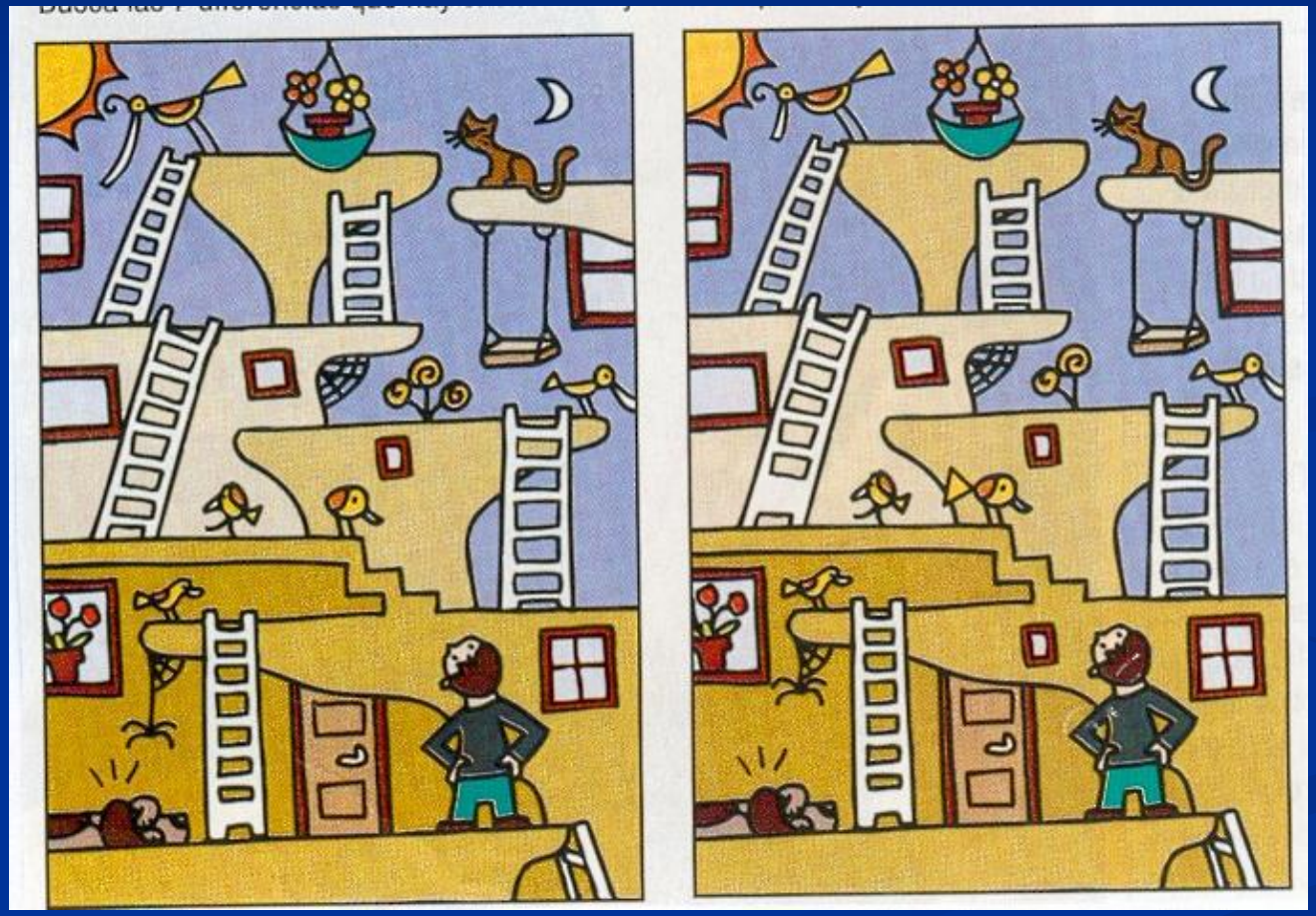
- Direct the small moon of the model to the Moon and we can see both with the same phase





Zoezi 4: Kielelezo cha kasoro za elewa ya maumbo ya Mwezi

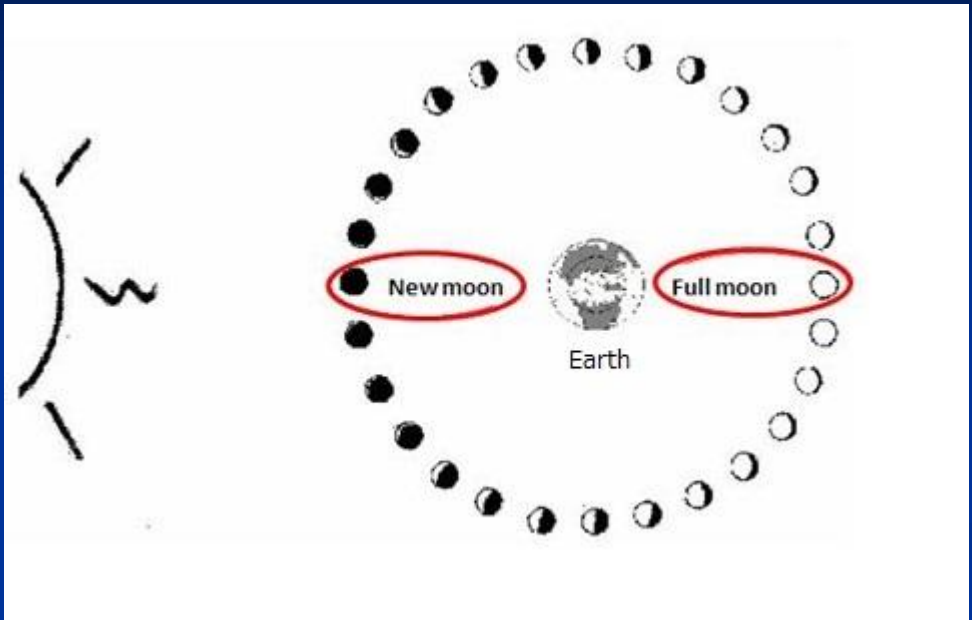
Activity 4: Illustration Errors

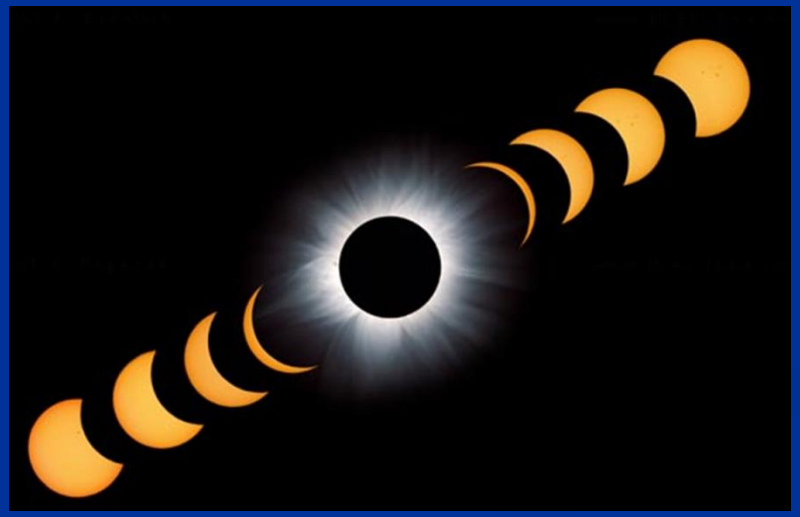


- Awamu za maumbo ya Mwezi zinategemea mahala Jua lilipo
- Phases of the Moon depend on the position of the Sun

Awamu za Mwezi na Kupatwa

Moon Phases and Eclipses

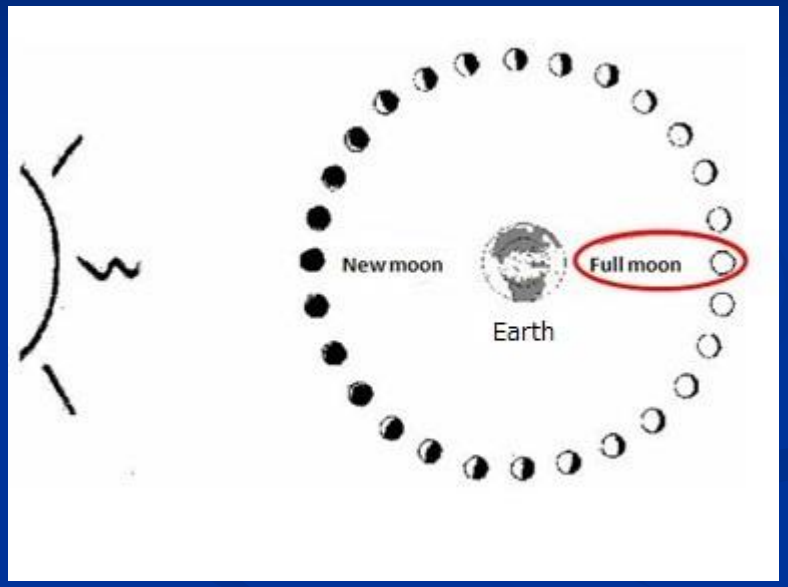


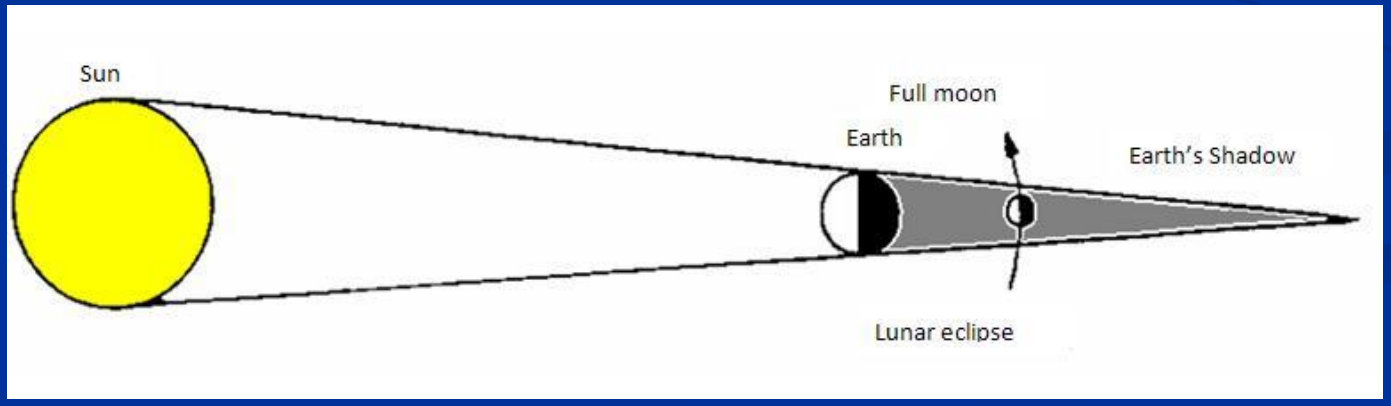


Zoezi 5: Kupatwa kwa Mwezi

Activity 5: Lunar Eclipses

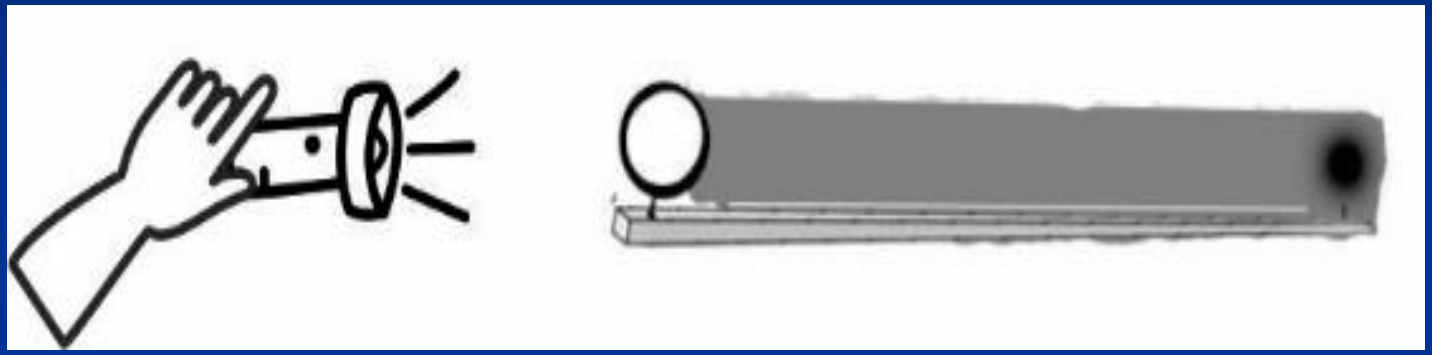
- **Kupatwa kwa Mwezi kunaweza kutokea iwapo tu Mwezi ni mpevu**
- Lunar eclipses only occur when the Moon is full





Zoezi 5: Kuigiza Kuptwa kwa Mwezi

Activity 5: Simulation of a Lunar Eclipse



Zoezi 5 Mwezi uliopatwa

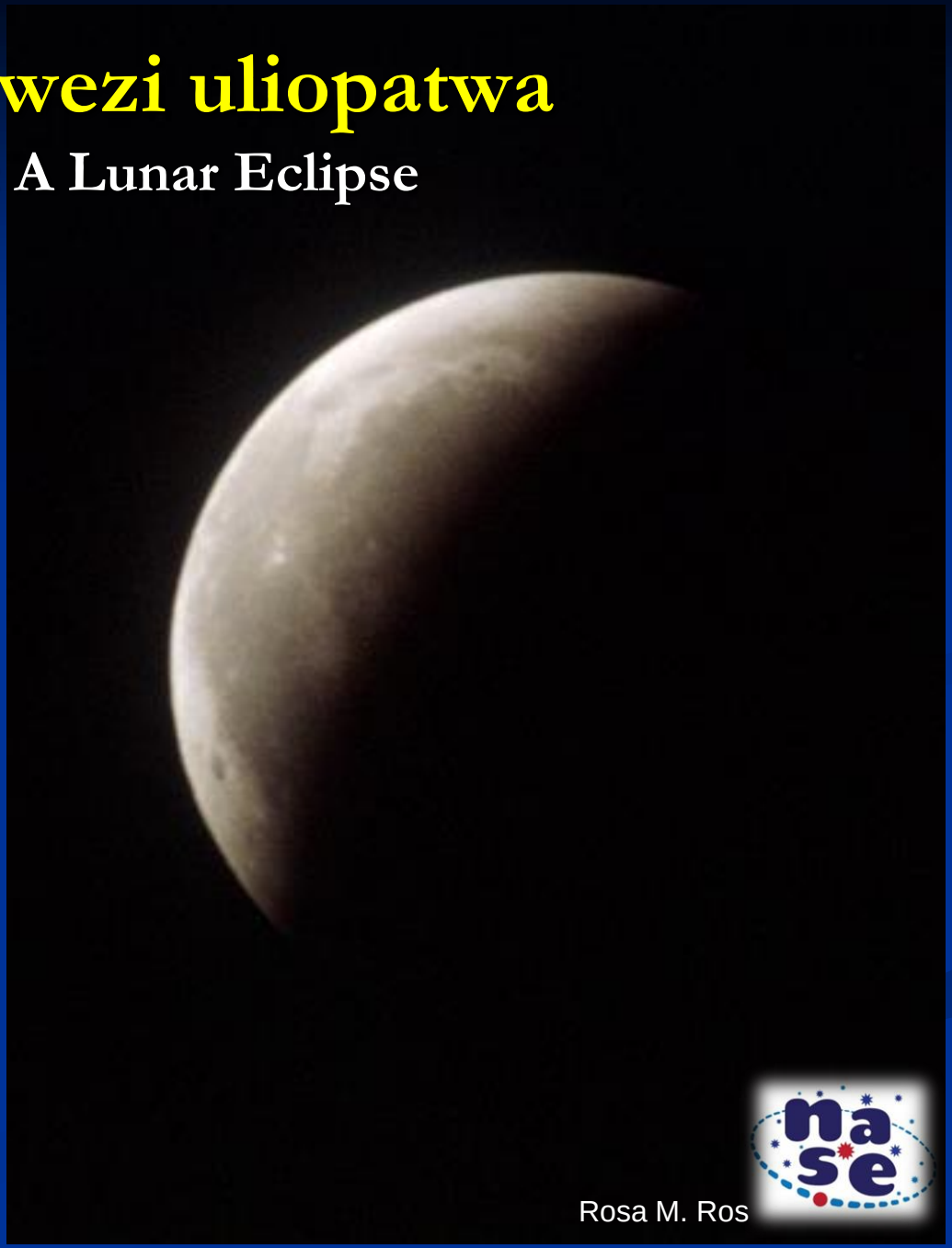
Activity 5: A Lunar Eclipse

Zoezi 5 Mwezi uliopatwa

Activity 5: A Lunar Eclipse

- Kupatwa kwa Mwezi kunaweza kuangaliwa na nusu Dunia (ya upande wa usiku)

- Lunar eclipses can be visible to half of the Earth (night side)



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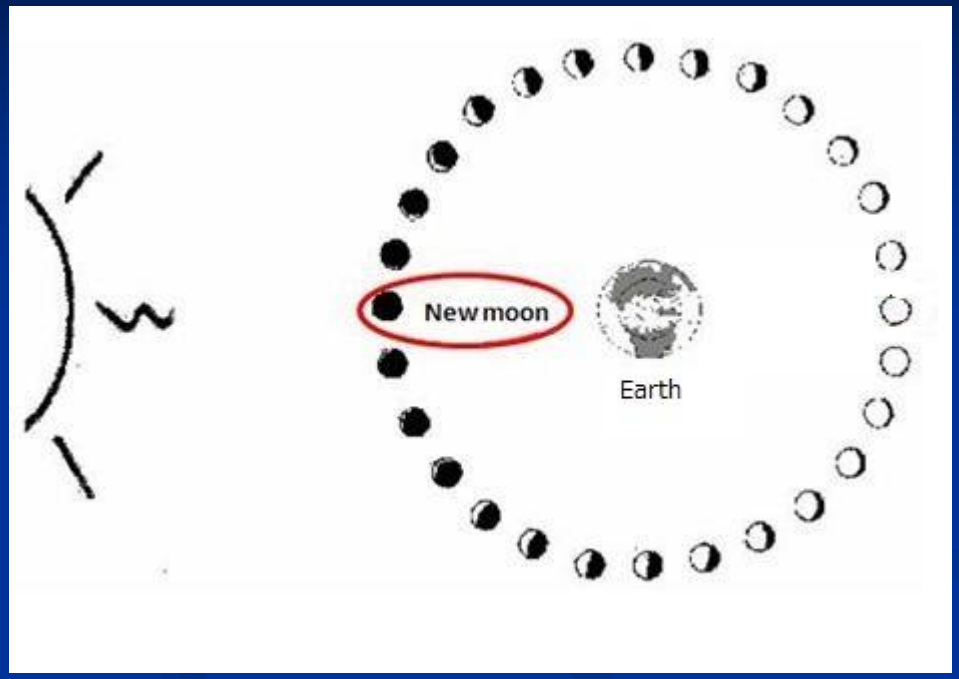
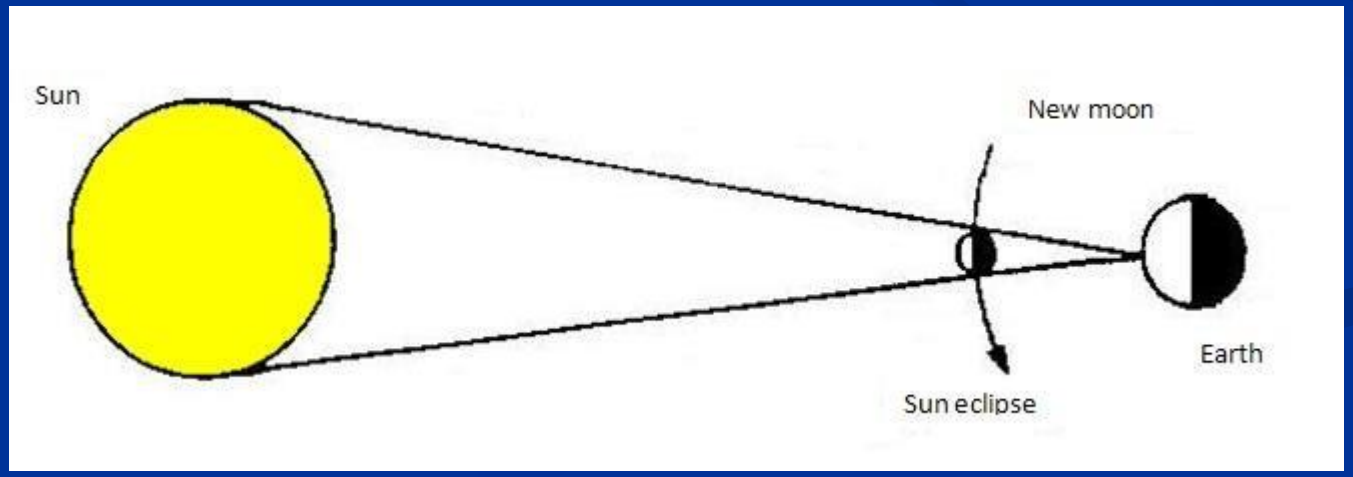
Zoezi 6: Kupatwa kwa Jua
Activity 6: Solar Eclipses

- **Kupatwa kwa Jua kunaweza kutokea iwapo tu Mwezi ni mwandamo**

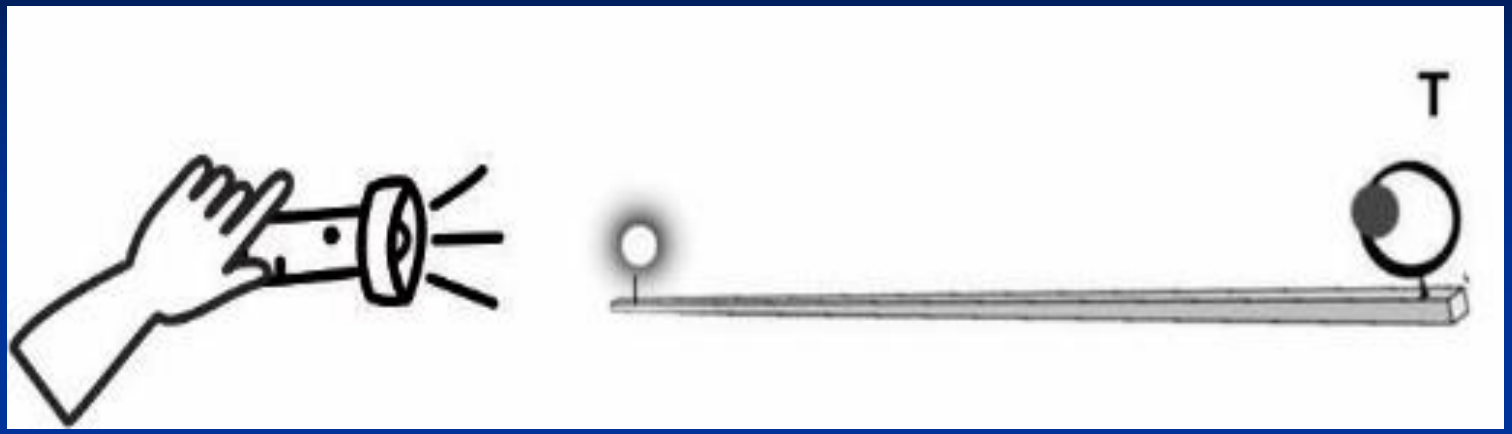
- Solar eclipses occur only when there is a New Moon





Zoezi 6: Kuigiza kupatwa kwa Jua

Activity 6: Simulation of a Solar Eclipse



Detail of a Solar eclipse

Maelezo ya Kupatwa kwa Jua

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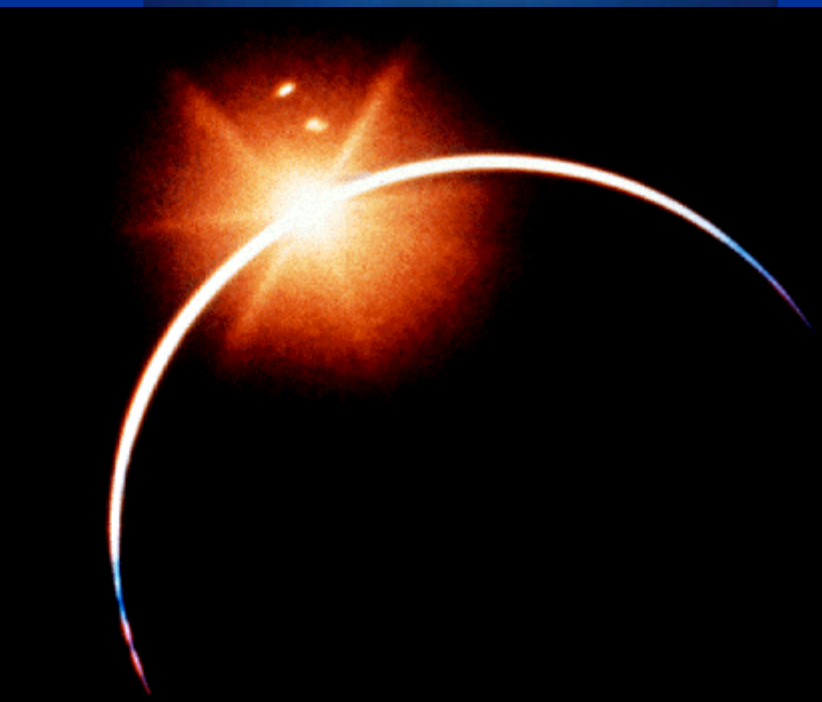
Zoezi 6: Kupatwa kwa Jua

Activity 6: Solar Eclipse

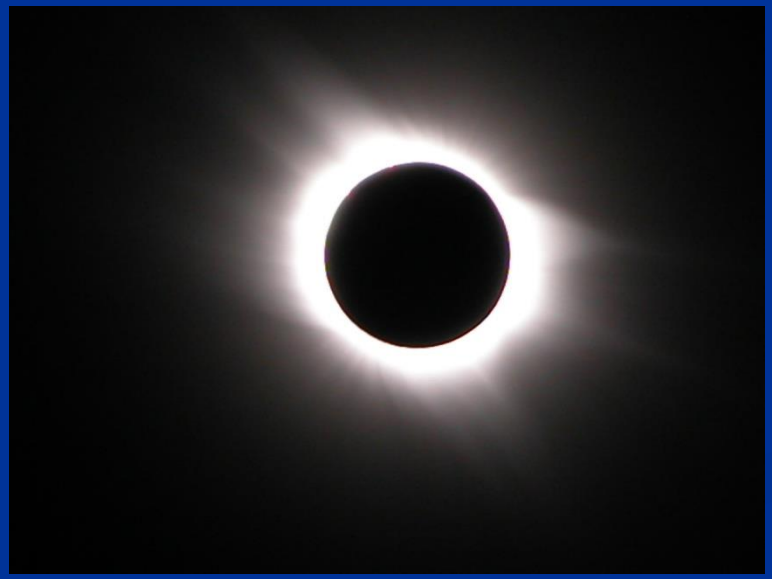
- **Kupatwa kwa Jua kunaonekana katika sehemu ndogo tu ya Dunia**

- Solar eclipses are visible only in a small region of the Earth



...tunahisi mhemko!

... we are feeling emotion!



Maangalio

Observations

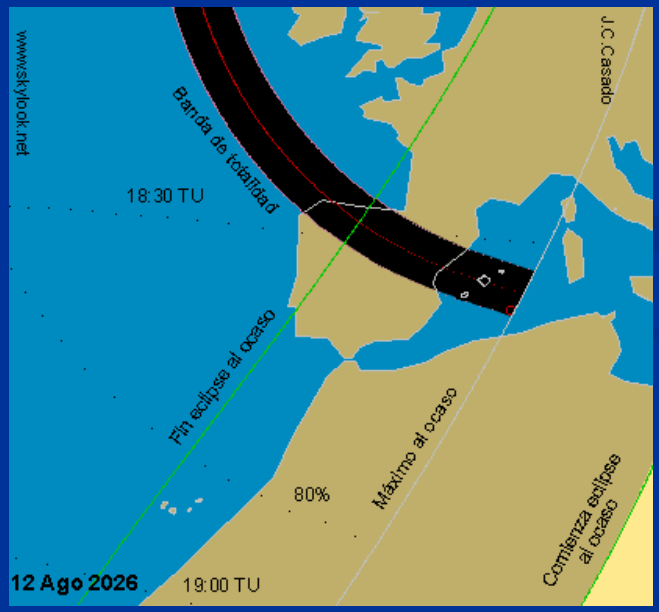
- Kupatwa kwa Mwezi kunatokea wakati wa Mwezi Mpevu na kupatwa kwa Jua kunatokea wakati wa Mwezi Mwandamo
- Kupatwa kwa Jua kunaonekana katika sehemu ndogo tu ya Dunia
- Ni vigumu sana kwa Dunia na Mwezi kuwa "kuoanika kamili" na kuwa katika mstari mnyoofu, kwa hiyo kupatwa hakutokei kila mara kunapokuwa na Mwezi Mwandamo au Mpevu

- A lunar eclipse when there is Full Moon and a solar eclipse when there is a New Moon
- A solar eclipse is seen only in a small area of the Earth
- It is very difficult for the Earth and Moon to be "well aligned", thus an eclipse does not occur every time that there is New or Full Moon

Mwishoni ...kama mfano...

Finally ... as an example ...

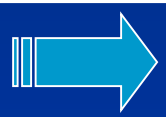
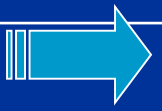
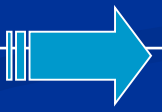
- **Hapa Tanzania tutaona tena kupatwa kwa Jua Agosti 2, 2027 (ya mwisho ilikuwa Juni 21 mwaka huu 2020**
- **Next total solar eclipse in Spain: August 12, 2026 (last one 2004 in a different area)**



- **Kila mwaka kuna kuwa na kupatwa kwa Mwezi 0 hadi 3**
- **Each year there are between 0 to 3 lunar eclipses**

Umbali na vipenyo kwa ajili ya kuweza kuwaza na kuelewa vizuri umbali hadi Juani

Distances and diameters in order
to visualize and better understand the distances to the Sun

Kipenyo cha Dunia Earth Diameter	12 800 km		2.1 cm
Kipenyo cha Mwezi Moon Diameter	3 500 km		0.6 cm
Umbali Dunia-Mwezi E-M Distance	384 000 km		60 cm
Kipenyo cha Mwezi Sun Diameter	1 400 000 km		220 cm
Umbali Dunia-Jua E-S Distance	150 000 000 km		235 m

Kuchora Jua

Painting the Sun

Zoezi 7: Kuifanya "Jua" kubwa lionekane mdogo kama "Mwezi"

Activity 7: Making the large “Sun” look like the small “Moon”

Kama kila mwezi kuna Mwezi Mwandamo na Mwezi Mpevu....

Kwa nini hakuna kupatwa kwa Jua na kupatwa kwa Mwezi kila mwezi?

If every month there is
a New Moon and a Full Moon …

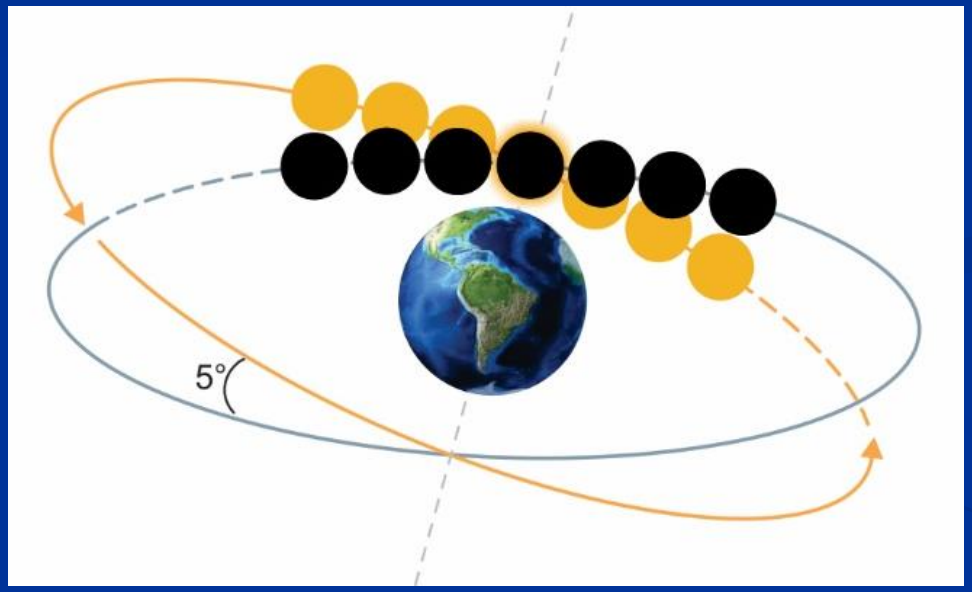
Why there is not
a Solar eclipse and a Lunar eclipse
every month?

Kwa vile...

Bapa ya mzunguko wa Dunia kuizunguka Jua na bapa ya Mwezi kuizunguka Dunia hazioani

Because …

The plane of the Earth around the Sun and the plane of the Moon around the Earth are not in the same plane.



Bapa hizo mbili zimeinamiana kwa nyuzi 5º na kipenyopembe ya Jua na Mwezi ni nusu nyuzi tu 0.5º

Both planes are inclined by 5º and the angular diameter of the Sun and the Moon is only 0.5º

Kupatwa kunaweza kutokea iwapo mahala pa Jua na Mwezi ni karibu na mstari wa kutano za bapa hizo.

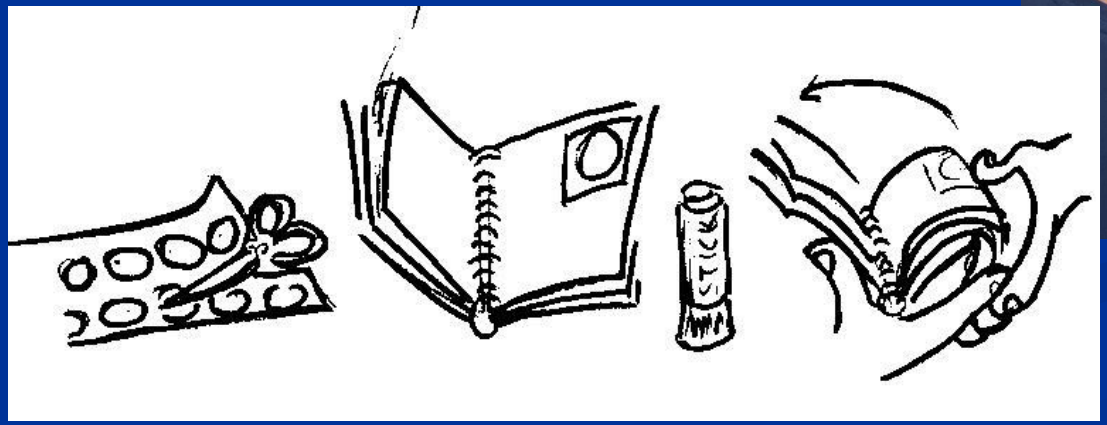
The eclipses only can take place if the Sun and Moon are close to the line of intersection of the two planes.

Zoezi 8: Kuigiza kupatwa kwa kutumia njia ya kitabu cha ku"pindua kurasa"

Activity 8: “Flip page” eclipse simulator

1. Kata (kunga) picha zako na ziwekee namba kwa mpangilio
2. Bandika kila picha katika daftari ya "spiral"
3. Pindua kurasa haraka ili kuona aridhio ya likipatwa

1. Trim and number the pictures in order
2. Paste each picture on a spiral notebook
3. Turn the pages quickly to see the demonstration.

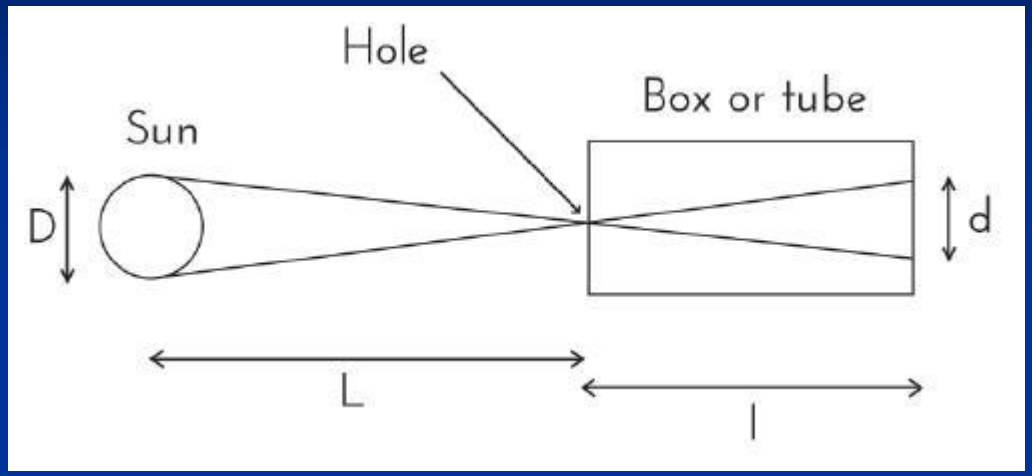


Zoezi 9: Kupata kipenyo cha Jua na kujaribia na kupima

Activity 9: Determination of the Sun's diameter - observations and measurements

Zoezi 9: Kutafuta kipenyo cha Jua

Activity 9: Determination of the Sun's diameter



$$\frac{D}{L} = \frac{d}{l}$$

$$D = \frac{d\,L}{l}$$

Tunaweza kuunga uwiano kati ya umbali na vipenyo vya Jua na taswira ya Jua na kukokotoa kipenyo cha Jua

L = 150 000 000 km umbali Dunia-Jua, l = urefu wa bomba, d = kipenyo cha Jua katika karatasi nyangavu

We can establish the proportion and calculate the Sun's diameter

L = 150 000 000 km Earth-Sun distance, l = tube length, d = diameter of the Sun on semi-transparent paper

Zoezi 10: Jaribio la Aristarchus's wa enzi za zamani (310 hadi 230 BC)

Activity 10: Aristarchus's Experiment 310 to 230 BC

- **Aliunganisha uwiano kati ya umbali za Dunia-Mwezi-Jua na vipenyo vyake (ila hutaweza kupata jibu halisi). Hii ilibidi kusubiri hadi alipotokeza Eratosthenes (280 hadi 192 BC)**
- **Established relationships between the Earth-Moon-Sun distances and their diameters (but could not determine any absolute value). This had to wait until Eratosthenes.**

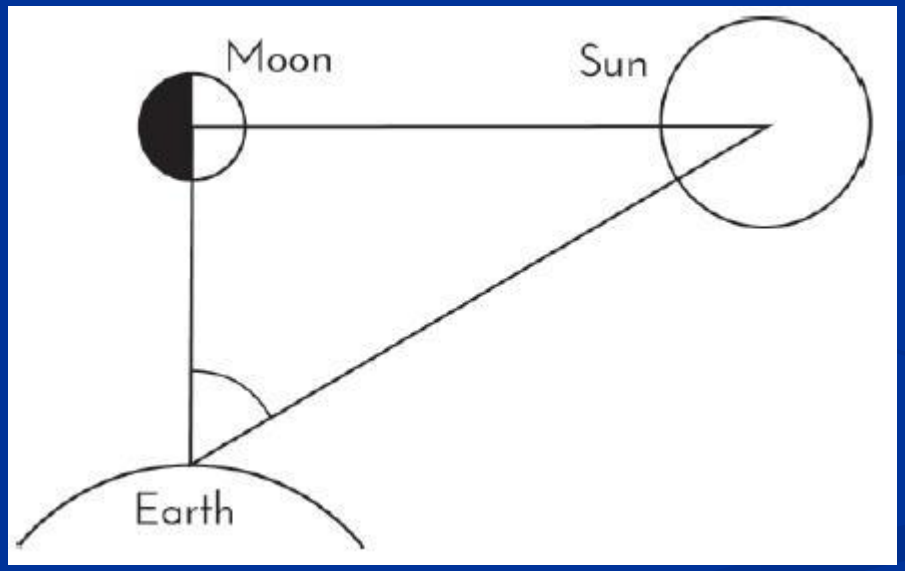
1) Umbali kutoka Dunia hadi Mwezi na Dunia hadi Jua
2) Nusukipenyo cha Mwezi na cha Jua
3) Umbali kati ya Dunia na Mwezi na nusukipenyo cha Mwezi
4) Pia ya Kivuli cha Dunia
5) Wianisha vyote hivi

- **1) Distance of the Earth to Moon and the Earth to Sun**
- **2) Radius of the Moon and of the Sun**
- **3) Earth to Moon distance and the Moon's radius**
- **4) The Cone of the Terrestrial Shadow**
- **4) Relate them all**

1) Umbali Dunia-Mwezi na Dunia-Jua

1) Distance Earth-Moon and Earth-Sun

- $\cos \alpha = EM / ES$ kwa hiyo $ES = EM / \cos \alpha$



1) Umbali Dunia-Mwezi na Dunia-Jua

1) Earth-Moon and Earth-Sun Distances

- Aristarchus $\alpha = 87^{\circ}$
  basi ES = 19 EM
- Now $\alpha = 89^{\circ}\ 51'$
  kwa hiyo **ES = 400 EM**

- Aristarchus $\alpha = 87^{\circ}$ then ES = 19 EM
- Now $\alpha = 89^{\circ}\ 51'$ therefore ES = 400 EM

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2) Nusukipenyo cha Mwezi na cha Jua

2) Radius of the Moon and of the Sun

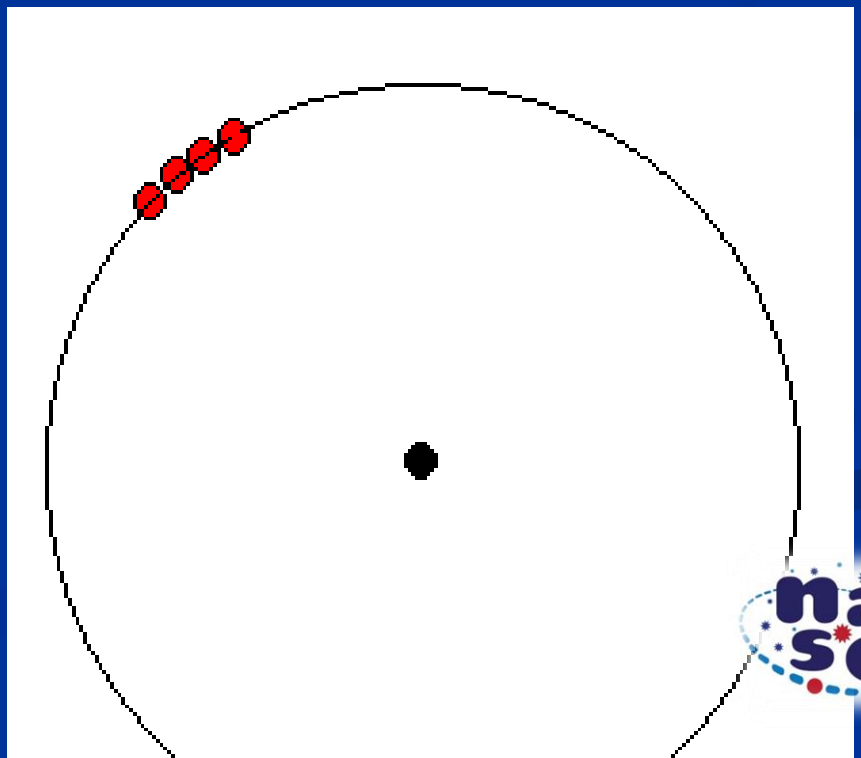
- Kutoka Dunia, vipenyo vya Mwezi na Jua viaonekana kuwa sawa na kipenyopembe 0.5°
- Kwa hiyo, nusukipenyo ni $R_S = 400\ R_M$

- From the Earth, lunar and solar diameters are observed to be equal to 0.5°
- Therefore, the radius is $R_S = 400\ R_M$

3) Umbali kati ya Dunia na Mwezi na nusukipenyo cha Mwezi

3) Earth-Moon Distance and Moon's Radius

- Kipenyopembe cha Mwezi kutoka Duniani ni 0.5º
- Kwa kuktumia mara 720 ya kipenyopembe hiki tunaweza kukokotoa mzingo duara ya Mwezi
- 2 RM 720 = 2 π EM
- $EM = 720\ R_M / \pi$



- Moon's diameter from the Earth is 0.5 º
- With 720 times this diameter, we can calculate the circular trajectory of the Moon
- 2 RM 720 = 2 π EM
- $EM = 720\ R_M / \pi$

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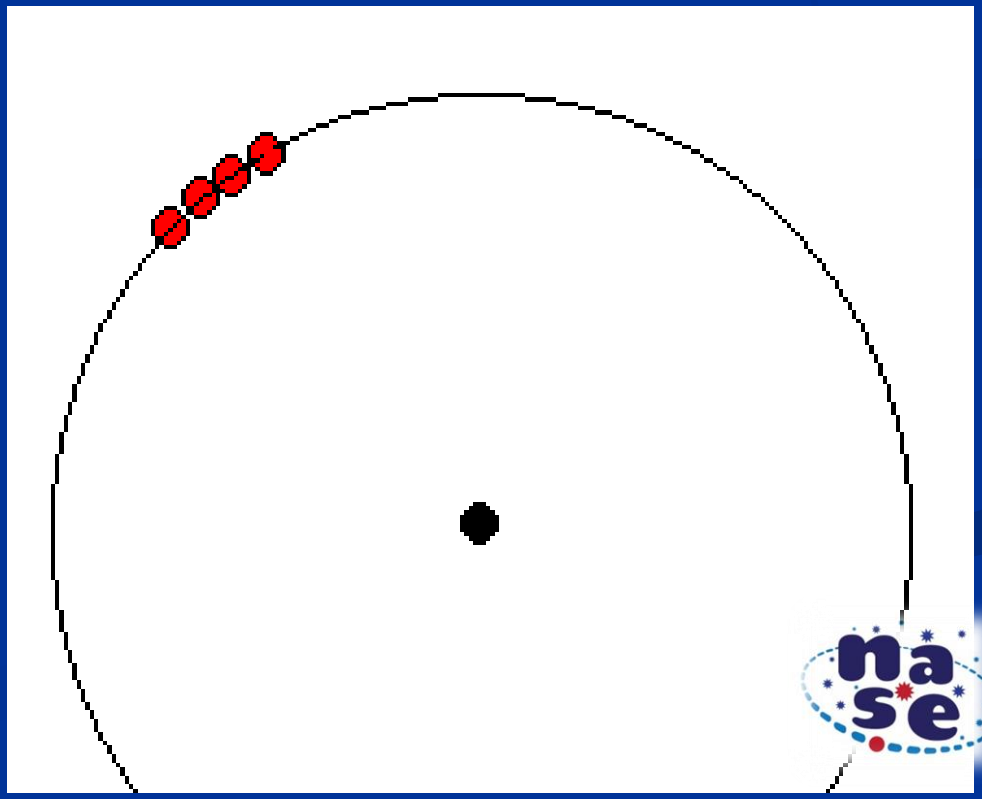
3) Umbali wa Dunia-Jua na radius ya Jua

3) Earth-Sun distance and Sun radius

- By analogy
- ES = 720 Rs/ π

Aristarchus's
1st Heliocentric model

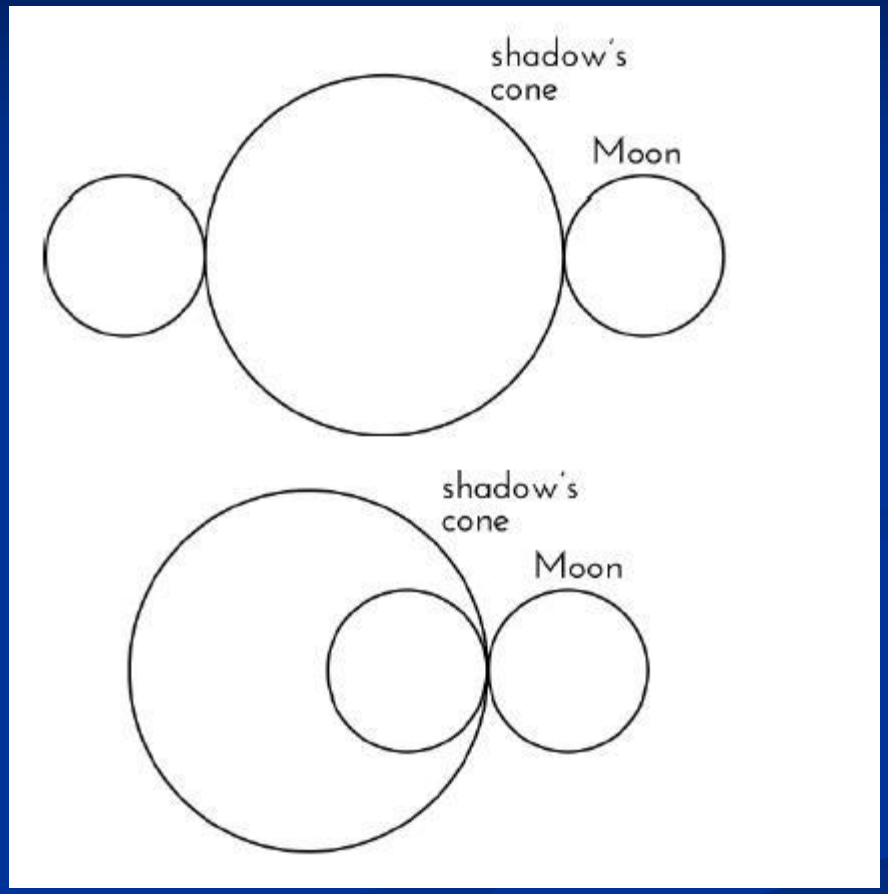
Mfano wa Aristarchus wa kwanza kabisa wa sayari kuzunguka Jua



4) Pia ya Kivuli cha Dunia

4) Cone of Terrestrial Shadow

- Katika kupatwa kwa Mwezi, Aristarchus aliona kuwa muda unaotakiwa kwa Mwezi kupitia pia ya kivuli cha Dunia ni mara mbili ya muda unaohitajika kwa sura nzima ya Mwezi kufunikwa (yaani 2:1)
- -Kihalisi ni 2.6:1



- In a Lunar eclipse,

Aristarchus observed that the time required for the Moon to cross the shadow cone of the Earth was twice the time necessary for the surface of the Moon remain covered (i.e. 2:1)

- It is actually 2.6:1

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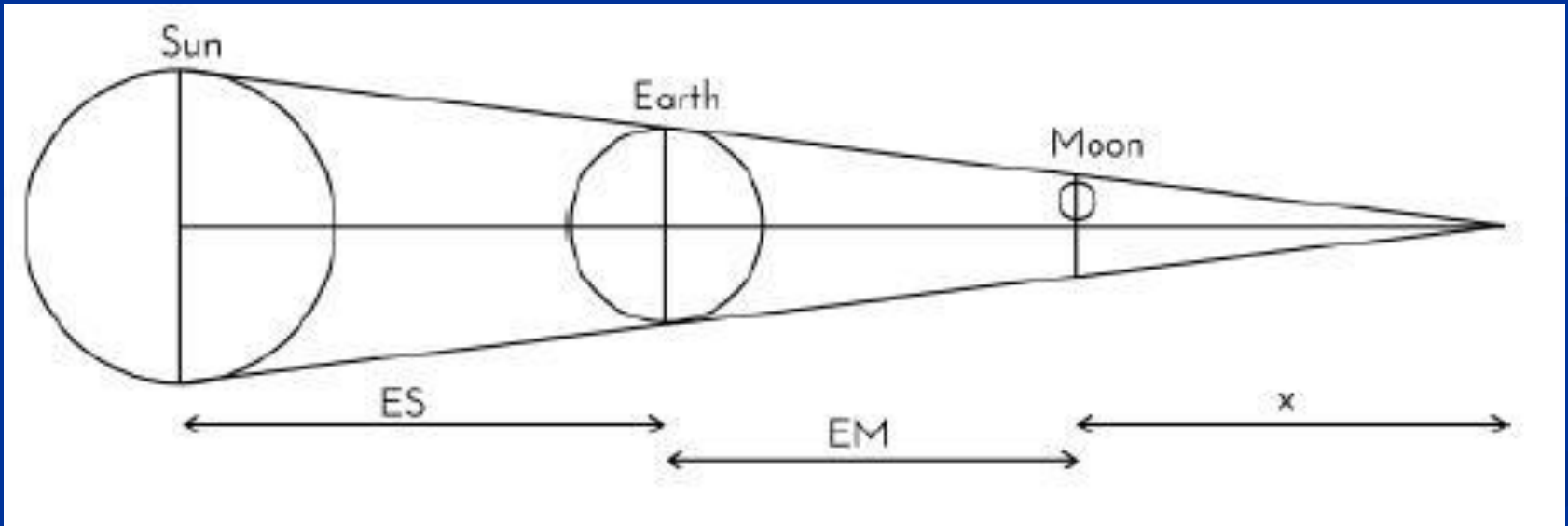
5) Wianisha vyote hivi

5) Relate them all

- $(x+EM+ES)/R_S = (x+EM) / R_E = x/(2.6\ R_M)$



Hezabu zote hizi zikitatuliwa (vyote vinawiana na nusukipenyo ya Dunia):

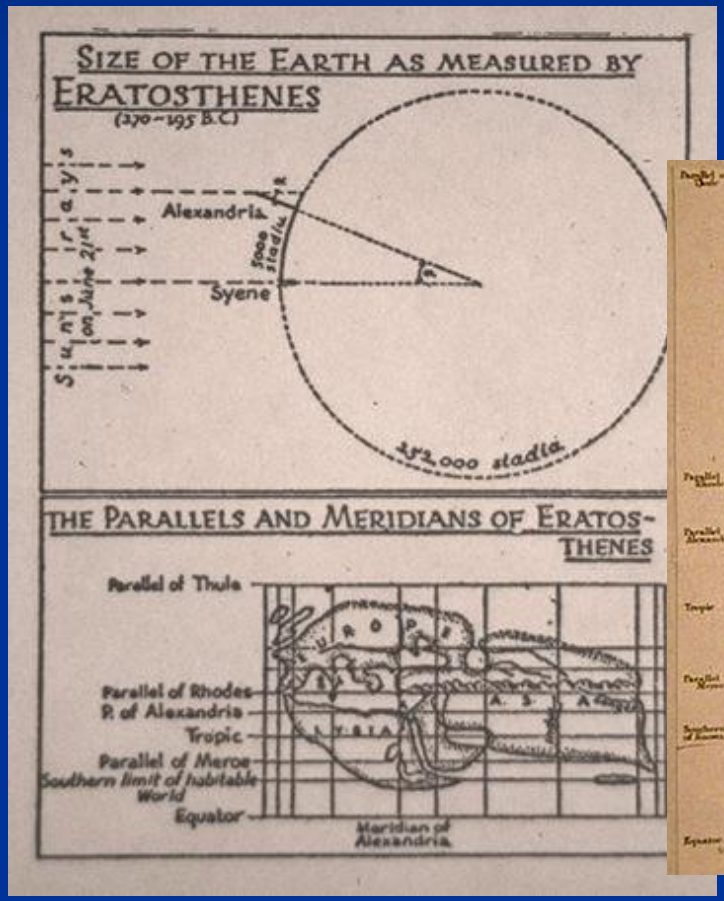
Solving the system shows (everything related to Earth's radius):

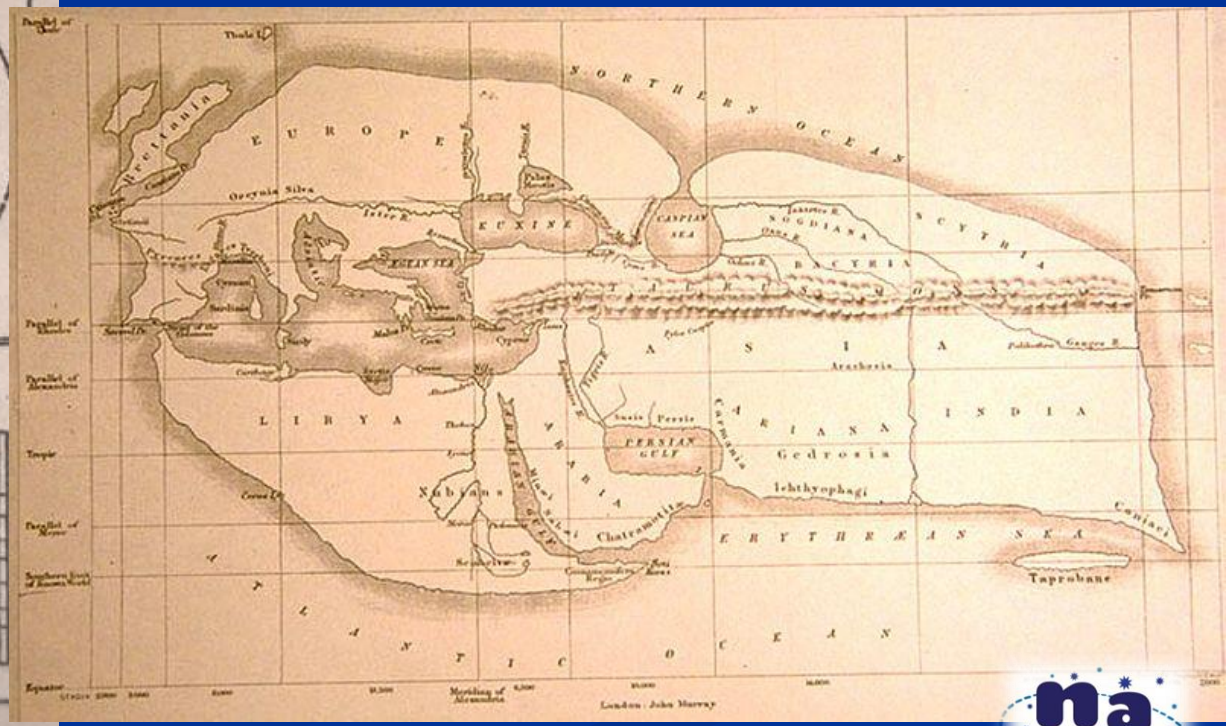
- $R_M = (401 / 1440)\ R_E$
- $EM = (401 / (2\pi))\ R_E$
- $R_S = (2005 / 18)\ R_E$
- $ES = (80200 / \pi)\ R_E$

- Tukichukulia (If we asume) $R_E = 6\ 378$ km basi
- $R_M = 1\ 776$ km (actual 1 738 km)
- $EM = 408\ 000$ km (actual 384 000 km)
- $R_S = 740\ 000$ km (actual 696 000 km)
- $ES = 162\ 800\ 000$ km (actual 149 680 000 km)

Zoezi 11: Jaribio la Eratosthenes 280 hadi 192 BC

Activity 11: Eratosthenes' Experiment 280 to 192 BC





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Zoezi 11: Eratosthenes tena

Activity 11: Eratosthenes again

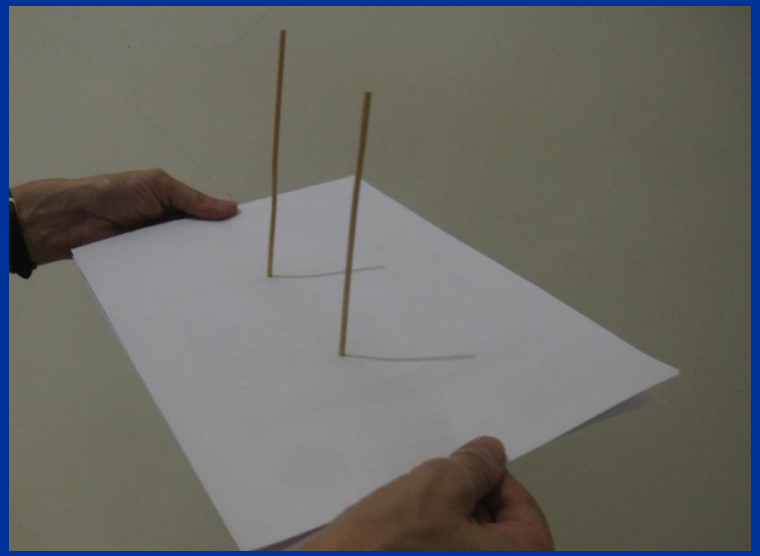
- **Miji miwili kwenye longitudo sawa**
- **Vipimo kote wakati mmoja**

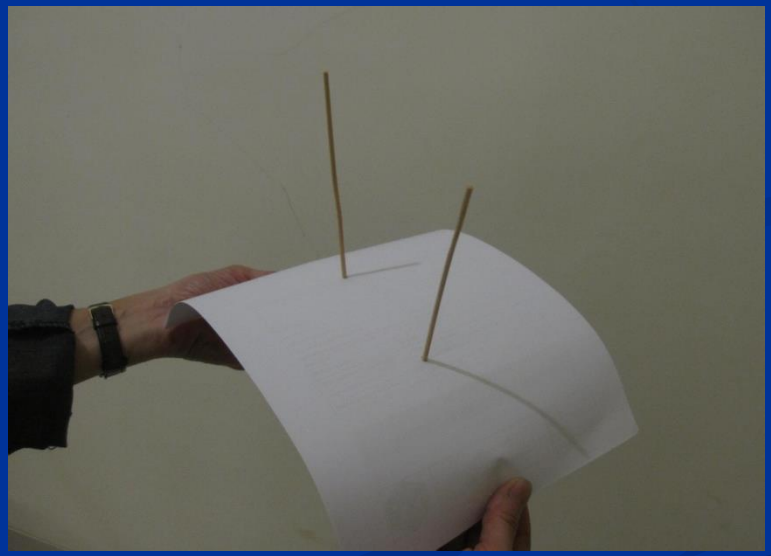
- Two cities on the same meridian
- Simultaneous observations

Vivuli tofauti…

Different shadows …

- **Basi Dunia ni tufe!!**
- Then the Earth is a sphere!



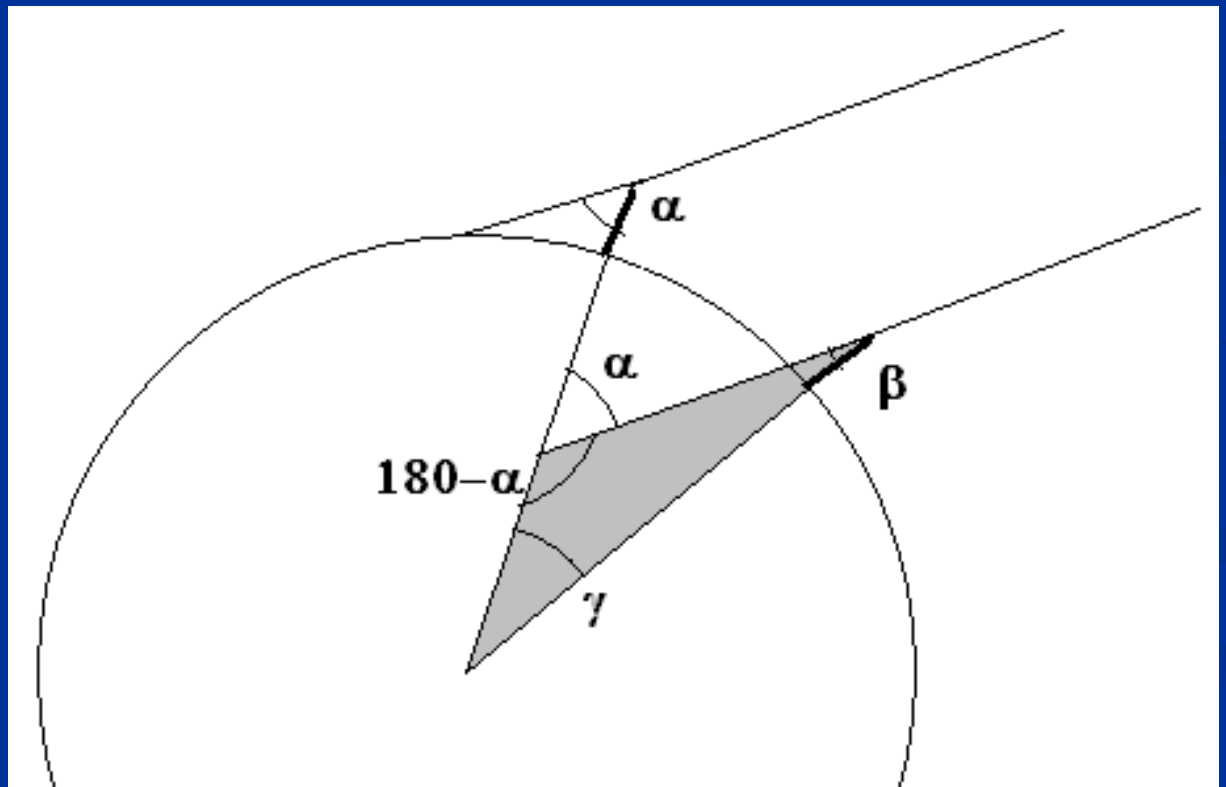


Zoezi 11: Eratosthenes tena

- $\pi = \pi - \alpha + \beta + \gamma$
- Kwa hiyo $\gamma = \alpha - \beta$

ambapo α na β zimepimwa kwa radian

(Nyuzi 180 = π radians)



Activity 11: Eratosthenes again

- $\pi = \pi - \alpha + \beta + \gamma$
- therefore $\gamma = \alpha - \beta$

where α and β are measured in radians

(180 degrees = π radians)

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Zoezi 11: Eratosthenes tena

Activity 11: Eratosthenes again

- **Tunapima urefu wa chubwi (au fimbo) na wa kivuli chake**
- We measure the length of the plumb line (or stick) and its shadow

$$\alpha = \arctan(\text{urefu wa kivuli})/(\text{urefu wa fimbo})$$

$$\alpha = \arctan(\text{shadow})/(\text{stick})$$

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Zoezi 11: Eratosthenes tena

Activity 11: Eratosthenes again

- kwa uwiano

  $2\pi R_E / 2\pi = d / \gamma$

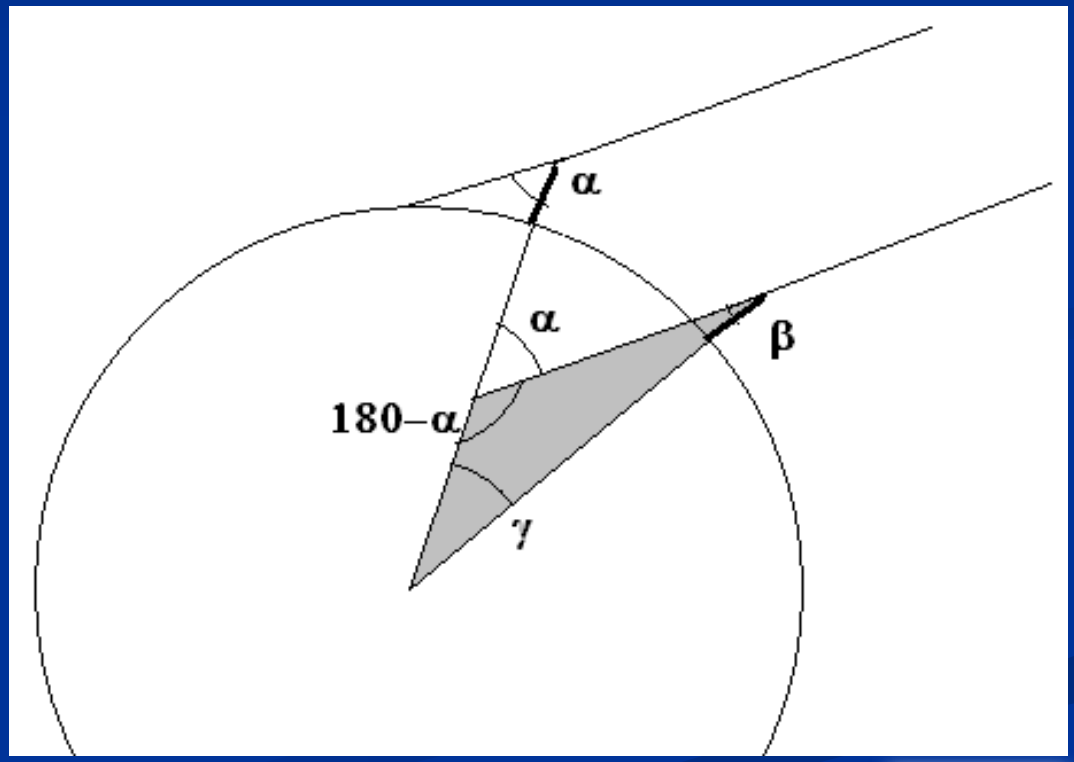
- unapata

  $R_E = d/\gamma$

- γ tunafahamu (kwa radian)

  $\gamma = \alpha - \beta$

- d ni umbali kati ya miji – kwa kutumia ramani



- by proportionality

  $2\pi R_E / 2\pi = d / \gamma$

- is deduced

  $R_E = d/\gamma$

- γ we know (in radians)

  $\gamma = \alpha - \beta$

- d is the distance between cities - using a map

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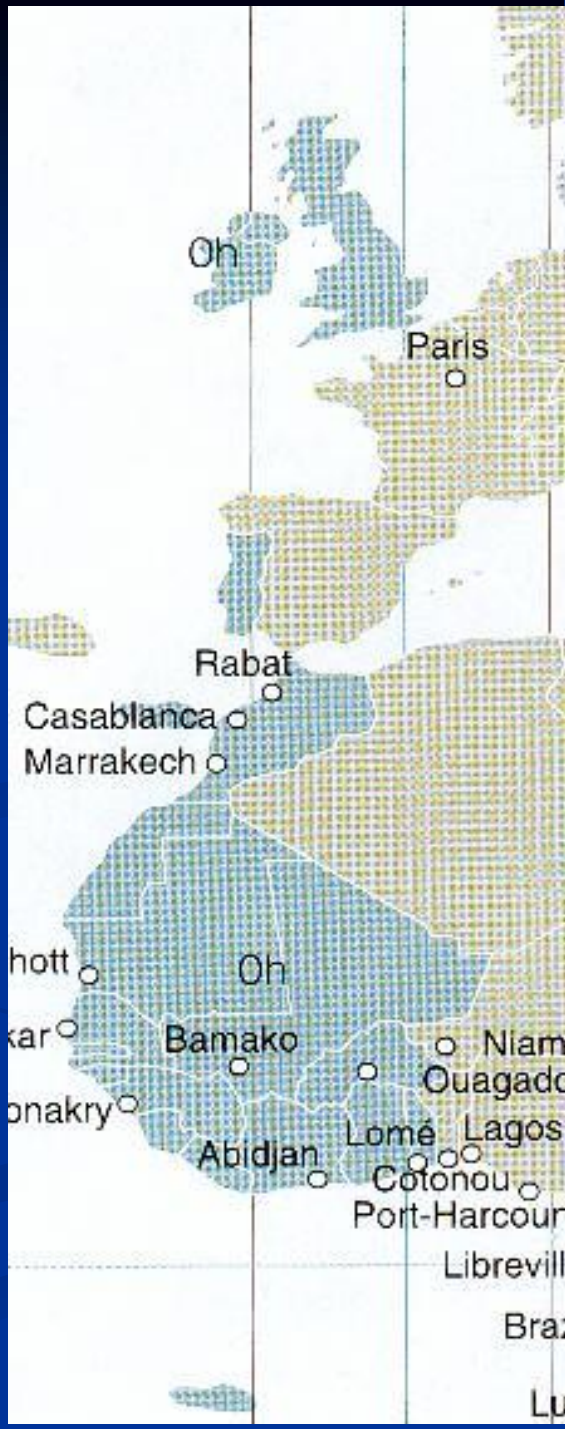
Majibu ya majaribia ya huko Hispania kwa kutumia njia ya Eratosthenes

Our results with the method of Eratosthenes

- Ripoll- Barcelona
- $\alpha = 0.5194$ radians
- $\beta = 0.5059$ radians
- $\gamma = 0.0135$ radians
- $d = 89.4$ km

- $R_E = 6\,600$ km (actual 6 378 km)



Mahitimisho
Conclusions

- Tunaweza sasa kuelewa kupatwa
- Tumeunganisha uwiano katika mfumo wa Dunia-Mwezi-Jua
- Tumethibitisha kuwa kwa kufanya majaribio na kuchanganua data za vipimo tulivyopata na kujifunza mengi sana kuhusu Ulimwengu wetu

- We now understand the eclipses
- Have established size relationships for the Earth-Moon-Sun system
- It is verified that by observing and analysing the data obtained, we can learn much more about the universe

Asanteni Sana

Kwa usikivu wenu!

Many Thanks for your attention!