# Measure the Earth with your Students

**Eratosthenes Experiment** 





#### Eratosthenes Experiment Multidisciplinary Project





#### Eratosthenes Experiment Multidisciplinary Project

★Real data collection★Reproduce famous science experiment

International project with possibility to collaborate with another school to get results





### **The Genius of Eratosthenes**



#### Eratosthenes Experiment Eratosthenes



- ★ Greek astronomer, geographer, mathematician, philosopher...
   ★ Lived from 276 BC to 194 BC
- ★ Chief librarian of the Library of Alexandria
- ★ With simple observations and geometry, he measured the size of the Earth to amazing accuracy.



#### Eratosthenes Experiment Eratosthenes' Observations



At the summer solstice at the time of local noon, **\***objects form a small shadow in Alexandria; ★the Sun is directly overheard in Syene and lights the bottoms of wells (the Sun is at the zenith and there are no shadows)



#### Eratosthenes Experiment Differences in Shadows in Two Locations



#### Credit: ASTROLab du Mont-Megantic



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#### Eratosthenes Experiment Eratosthenes' Observations

Eratosthenes measured this angle to be 7.2°. This represents 1/50 of a full circle (360°). He also knew the distance between Alexandria and Syene, which was about 5000 stadia\*.

\* Ancient unit of distance, equivalent to about 160 metres.



#### Eratosthenes Experiment Eratosthenes' Observations

If the distance between Alexandria and Syene represents 1/50 of the total circumference, then:

C = 50 x 5000 stadia = 250,000 stadia or about 40,000 km Calculation:  $\frac{7.2}{360} = \frac{5000}{?}$ 

The circumference of the Earth at the equator is 40,075 km.

Credit: ASTROLab du Mont-Megantic



# **The Experiment**



★We need two observations from different locations, on the same day.

★Take the measurement when the Sun is at its highest point in the sky (local noon).

★The locations need to be at the same longitude (north-south line), as much as possible, and far from each other.





on the equator (angle =  $0^{\circ}$ ). 5. Calculate the circumference of the Earth.

2. Measure the shadow of a stick at

(March 21 or Sept.23) at your loc

3. Calculate the angle formed by the shad w.

4. Collaborate with another school at a similar

longitude OR use the data for a virtual school

1. Find the time of local noon on the equiper

Use the Excel

spreadsheet if you

want less math!

the Sun will be at its highest poin

### Eratosthenes Experiment **1. Find the time of your local noon**

We want to take the measurement when the Sun is at its highest point in the sky during the day. This is not at noon exactly (reasons: daylight time, position in time zone, time of the year...)



Sky at noon on September 23, 2019, from Thetford Mines, QC.

Credit: Stellarium



## Eratosthenes Experiment **1. Find the time of your local noon**

### **NOAA Solar Calculator**



Enter your time zone (and adjust for DST if necessary) Eastern: -5 Pacific: -8

#### **Select the date**



#### Eratosthenes Experiment **1. Find the time of your local noon**

### Use Stellarium http://www.stellarium.org/ or https://stellarium-web.org/



Magnitude: -26.75 (reduced to -26.56 by 1.43 Airmasses) Absolute Magnitude: 4.83 RA/Dec (j2000.0): 0h01m54.07s/+0°12'15.3" RA/Dec (j2000.0): 0h01m54.17s/+0°12'15.3" BA/Dec: (....3ct): 0h02m54.15s/+0°18'46.8" HA/Dec: 0h00m05.715.10°19'48.4" (apparent) Az./Alt: +180°01'59.4"/2 44°14'11.0" (apparent) Gal. long./lat.: +97°22'49.0"/-60°11'11.3" 07°00'16.1"/+12°49'51.3" ergal, long,/lat Ecl. long./lat. (J2000.0): +0°31'02.3"/-0°00'05.9" Ecl. long./lat. (on date): +0°47'24.8"/-0°00'05.1" Ecliptic obliquity (on date): +23°26'09.5" Mean Sidereal Time: 0h03m00.8s Apparent Sidereal Time: 0h02m59.8s Rise: 6h45m Transit: 12h52m Set: 18h59m Daytime: 12h14m IAU Constellation: Psc. Distance: 0.996 AU (149.009 M km) Equatorial rotation velocity: 1.856 km/s Apparent diameter: +0°32'06.86" Diameter: 1392000.0 km Sidereal period: 1.00 days (0.003 a) Sidereal day: 654h36m36.1s

# Find the time when the Sun will have an azimuth of 180°.



#### **Credit: Stellarium**



#### Eratosthenes Experiment **2. Measure the shadow of a stick**

At the time of local noon on March 21, measure the shadow of a stick (suggestion: 1m ruler, placed perpendicular to the ground).



And take pictures for the contest!

http://eratosthenes.ea.gr/ content/photo-contest-2019

**Credit: Eratosthenes Experiment** 



### **3.** Calculate the angle formed by the shadow

### Using simple trigonometry, calculate the angle.





 $\theta = \arctan \frac{S}{H}$ 

**Credit: Eratosthenes Experiment** 



Now that you have the angle for your location, you need to know the angle from another location.

Two options:

- ★ Eratosthenes Experiment match your school with another one with a similar longitude
- ★ Use the value for a virtual school on the equator.



#### Eratosthenes Experiment Why do the experiment at the equinox?

At the equinox, the Sun is directly over the equator. For a virtual school on the equator, the measurement would be 0°.



You can use this value if you are not matched with any school.

#### **Credit: Wikipedia**



### **4.** Collaborate with another school

You need to know the distance between the two schools, or between your school and the equator.

### National Geographic MapMaker





### **4. Collaborate with another school**

## You need to know the distance between the two schools, or between your school and the equator. Google Earth





### **5.** Calculate the circumference of the Earth

Compare the arc of the circle with the full circumference:



**Credit: Eratosthenes Experiment** 



Eratosthenes Experiment **5. Calculate the circumference using the equator** 

Use the equator for the second school (angle of 0):





## Eratosthenes Experiment **Excel spreadsheet**

	Α	В	с	D	E	F	G	н	I	J	к	L	м	N	0	F
1	Eratosthenes Experiment															
2			•													
3	Instructio	ons														
4 You need to enter your data in the vel		ellow boxes	. The calcu	lated values	s will appea	ar automati	cally in the	blue boxes.								
5																
6	To calculat	te angle														
7																
8	Height of stick:		cm													
9	Length of shadow:		cm													
10																
11		Angle:	#DIV/0!	degrees												
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14	•			6												
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Both schools in the same nemisphere (both in northern ho			degrees	both in south	ern nemisphe	ire)		Angle of school A			3)	degrees				
19	Angle of school B			degrees					Angle of school B				degrees			
20	ingle of self				008.005					ringle of sen				008,000		
21	Distance between the two schools:			km					Distance bet	ween the two	o schools:		km			
22																
23			Circumference:	#DIV/0!	km						Ci	rcumference:	#DIV/0!	km		
24																
25	25 Error percentage with scientific value of 40,			075 km:		#DIV/0!				Error percent	tage with scie	entific value o	f 40,075 km:		#DIV/0!	
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27																
20	To colculat	to circumfor	anco with data	from onuol												
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Distance between your school and equator:			#010/0:	km												
33		in cen your ser	cquator.													
34			Circumference:	#DIV/0!	km											
35																
36	6 Error percentage with scientific value of 40,0			075 km:		#DIV/0!										
37																



# Eratosthenes Experiment **Excel spreadsheet – my values**

	A	В	с	D	E	F	G	н	I I	J	к	L	м	N	0	
1	Eratost	henes E	xperiment	t												
2																
3 Instructions																
4	You need to	o enter your	data in the ye	llow boxes.	The calcula	ted values v	vill appear a	utomaticall	y in the blu	e boxes.						
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6 To calculate angle																
7																
8 Height of stick:		100	cm													
9	9 Length of shadow:		103	cm												
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11		Angle:	45.8	degrees												
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10	Angle of school A			4.2	degrees					Angle of school B			degrees			
20	Angle of school B			45.0	uegrees					Angle of sch				uegrees		
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22																
23			Circumference:	39972	km					Circum		rcumference:	#DIV/0!	km		
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5 Error percentage with scientific value of 40,075 km:						0.26%				Error percen	ror percentage with scientific value of 40,075 km:				#DIV/0!	
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Angle (as calculated above		:	45.8	degrees												
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34			circumterence:	40259	KII)											
36	Frror percent	tage with scien	tific value of 40	075 km:		0.46%										
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### International Collaboration - Eratosthenes Experiment -



### Eratosthenes Experiment Eratosthenes Experiment

### http://eratosthenes.ea.gr





### Eratosthenes Experiment **Eratosthenes Experiment**





**\***More from the Eratosthenes Experiment

★Season simulator- Khan Academy

★Sunray simulator – over the year (requires Flash)

**★Sun's apparent motion simulator** (requires Flash)

★ Video from Cosmos (Carl Sagan)



# THANK YOU

### Questions?



