SASTA OLIPHANT SCIENCE AWARDS

SOUTH AUSTRALIAN SCIENCE TEACHERS ASSOCIATION

Prize Winner

Scientific Inquiry

Year 3-4

Arthur Kerrigan

Prince Alfred College

Improving My Shoebox Projector

Arthur Kerrigan

Introduction

This investigation was inspired by my desire to make a shoebox projector. The reason I wanted to make a shoebox projector is that I read in a book that the first ever television was made out of a box, so I swapped television to projector and that was what I wanted to experiment with.

I first made an experiment with plastic wrap with a triangle and my name drawn on it, and when I shone a torch through it, it made a blurry image. I wanted to have a clear image so that anybody that I showed would be able to read the text and see the image. This made me wonder why this happened, so I asked my dad why this happened. He said that this happened because the torch was not a “point source” of light, and he said I should look into shadows, umbras and penumbras.

Background Research

A shadow is an area that is darker because something is in the way of the light source that would shine on it. There are two main parts of shadows, the umbra, and the penumbra:

- Umbra: The darkest part of a shadow, where the light source is fully obscured.
- Penumbra: The lighter part of a shadow, where the light source is partially obscured.

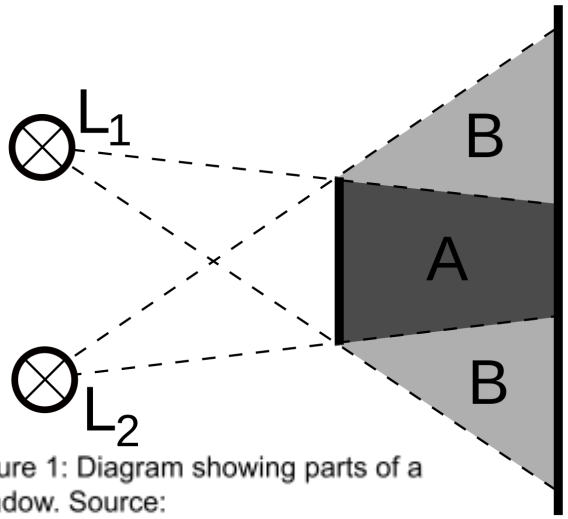

Figure 1: Diagram showing parts of a shadow. Source: https://upload.wikimedia.org/wikipedia/commons/thumb/e/e5/Kernschatten_und_Halbschatten.svg/1113px-Kernschatten_und_Halbschatten.svg.png

The penumbra is the blurry bit of the shadow around the edge of the projected image. Figure 1 shows an example with the umbra (A) and penumbras (B) around it due to a light that is not a point source, here shown as two lights L1 and L2. This shows that a barrier needs to be further away to cover up a bigger light.

This is related to Solar Eclipses by there being an umbra and a penumbra. For a solar eclipse, the umbra is where you can’t see the Sun, this is called the totality. For people in the penumbra the moon is in front of part of the Sun, like a crescent moon in reverse.

For this project, I found that it was hard to get a point source of light. Small lights were too dim to project, but in testing I found that just moving a larger light further away, the penumbra got smaller. This is because objects that are further away appear smaller.

From here, I made this an experiment about distance because I wanted to see what distance would be best for my projector, trying to balance the size of the projector and the size of the penumbra.

Aim
To investigate the impact on how far a barrier is on the size of the penumbra of a shadow.

Question
How can I minimise the size of a penumbra of a shadow to help improve my shoebox projector?

Hypothesis
If the barrier is further away, then the penumbra will be smaller.

Variables

Type	**What**	**How**	**Why**
Independent	*How far away a barrier is*	*Use a card as a barrier a distance away from the light*	*NA*
Dependent	*The penumbra`s size*	*Measured with a ruler*	*NA*
Controlled	*Distance from light to wall*	*The LED was held in the same place.*	*At different distances the angle from the light to the LED will change impacting the size of the penumbra*
Controlled	*Different barrier shapes*	*Used the same card*	*Changing shape would change the shadow, making it harder to measure and compare*
Controlled	*Same LED*	*Used the same LED*	*The image may have been blurrier and made shadow brighter in some spots, as some LEDs may be different sizes*

Risk Assessment

Risk	Impact	Mitigation
The barrier melting	*Melted plastic can be dangerous and flammable.*	*I will use a source of light that lets off no heat.*
Bright light in eyes	*It will hurt people`s eyes*	*Limited brightness of light*
Electrical shocks	*It will electrocute people*	*Low voltage*

Materials

- A 10 mm single point LED
- 2 AA battery holders
- Electrical leads as required
- A plastic card
- A card holder
- A moveable platform
- A table or other surface

Method

1. An LED was wired to a battery case with 4 batteries containing 1.5V each
2. The light was placed 800mm away from the wall
3. A card was put 200 mm away from the light on a platform and the penumbra and the dimensions of the umbra were measured in mm
4. Steps 1 - 3 were repeated until it reached 700mm
5. Steps 1 to 4 were repeated 3 times, excluding the dimensions of the umbra

Figure 2: Image of measuring shadow on wall.

Figure 3: Positioning of barrier.

Results

Table 1: Raw data

Distance of barrier (mm)	**Penumbra (mm)**			**Height**	**length**
200	14	17	14	----------	----------
300	10	12	9	----------	210
400	7	6	5	100	165
500	3	4	4	79	126
600	2	2	2	70	112
700	1	1	1	59	97

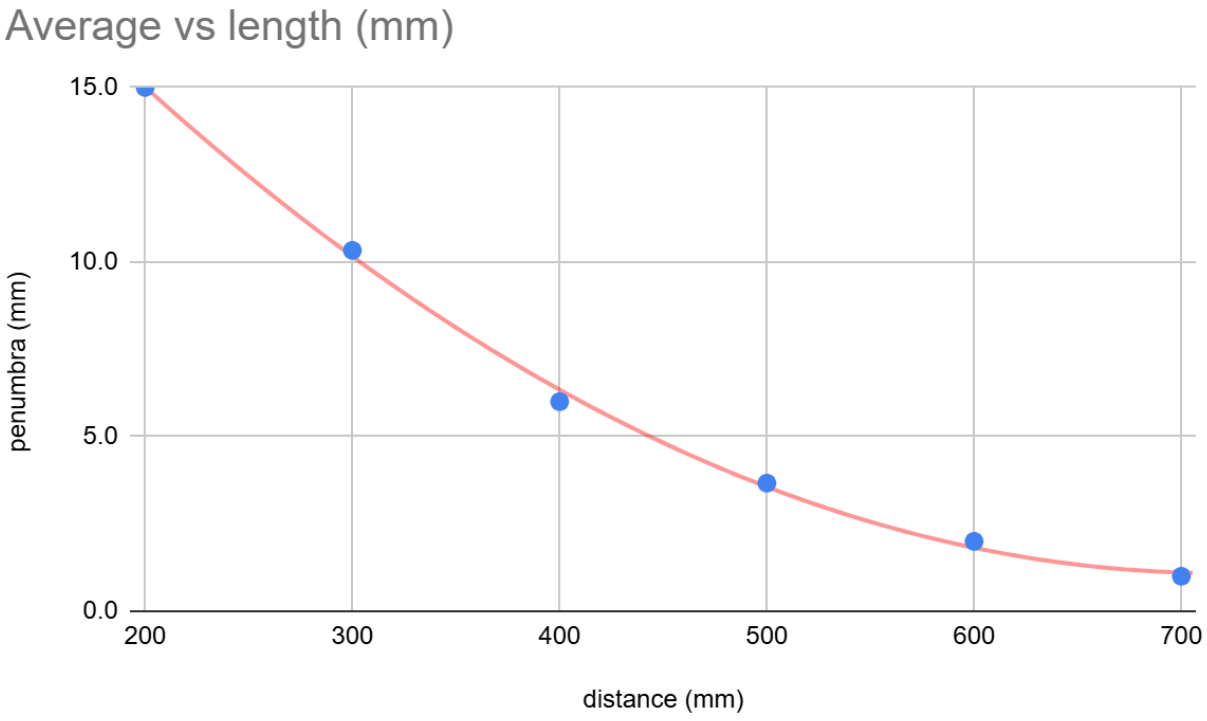

Figure 4: Graph of average width of the penumbra.

Table 2: Penumbra size as a ratio

Distance of barrier (mm)	Penumbra (mm)	Umbra (mm)	Ratio
200	15.0	————————	————————
300	10.3	210	4.92%
400	6.0	165	3.64%
500	3.7	126	2.91%
600	2.0	112	1.79%
700	1.0	97	1.03%

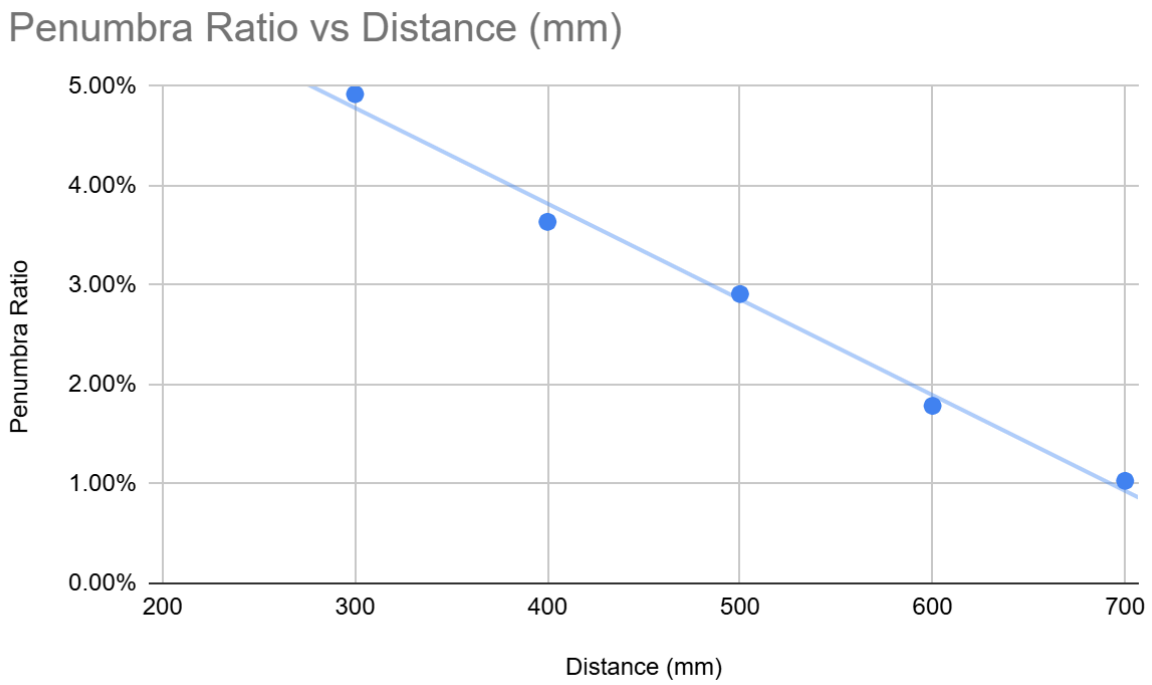

Figure 5: Graph showing the penumbra size as a percentage of the umbra.

Discussion

The graphs above show that the closer the barrier was to the light the bigger penumbra was. In figure 4, the drops got smaller each time the distance from the light was increased. Figure 5 shows that the further away the barrier, the smaller the penumbra as a percentage. This is close to a straight line, with a good fit for the data. These graphs support the hypothesis because as the barrier gets further away, the penumbra gets smaller.

Figure 5 shows us more about the blurriness as it is the percentage of the shadow that is this blurred part. This is different to figure 4, because it shows that the penumbra got smaller faster than the umbra.

Based on these results, I will use a distance of 600 mm for my shoebox projector. I can make this by taping two shoeboxes together, and the penumbra should only be 2% the size of the umbra.

Evaluation

Strength	**Why**
Measuring 3 times.	This helped because it showed that repeating the measurements got similar results.
Using a plastic card.	The umbra and penumbra had clear edges making it easy to measure.

Weakness	**Impact**	**Improvement**
It was hard to measure small penumbras for longer distances.	Can't be precise with my measurements.	Use calipers to measure the penumbra to smaller distances.
The umbras were too large to measure when the card was close to the light.	No measurement for the size of the umbra for 200 mm.	Use a measuring tape, and have someone assist with measuring.

Conclusion

This experiment successfully investigated the impact on how far a barrier is on the size of the penumbra of a shadow. The hypothesis was supported, as when the barrier was further away, the penumbra was smaller. I found that a distance of 600 mm would be best to minimise the size of the penumbra of the shadow for my shoebox projector. In future, I would like to investigate whether the shape of the barrier impacts the size of the penumbra.

Word Count: 1062

Bibliography

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OSA RISK ASSESSMENT FORM

for all entries in (✓) ☐ Models & Inventions and ☑ Scientific Inquiry

This must be included with your report, log book or entry. One form per entry.

STUDENT(S) NAME: Arthur Kerrigan ID: 0526-012

SCHOOL: Prince Alfred College

Activity: Give a brief outline of what you are planning to do.

Measure size of blurry bit of shadows using a ruler. I will use leds to make the shadow on my wall.

Are there possible risks? Consider the following:

- Chemical risks: Are you using chemicals? If so, check with your teacher that any chemicals to be used are on the approved list for schools. Check the safety requirements for their use, such as eye protection and eyewash facilities, availability of running water, use of gloves, a well-ventilated area or fume cupboard.
- Thermal risks: Are you heating things? Could you be burnt?
- Biological risks: Are you working with micro-organisms such as mould and bacteria?
- Sharps risks: Are you cutting things, and is there a risk of injury from sharp objects?
- Electrical risks: Are you using mains (240 volt) electricity? How will you make sure that this is safe? Could you use a battery instead?
- Radiation risks: Does your entry use potentially harmful radiation such as UV or lasers?
- Other hazards.

Also, if you are using other people as subjects in an investigation you must get them to sign a note consenting to be part of your experiment.

Risks	How I will control/manage the risk
The barrier melting	To limit the risk of the plastic melting I will use a source of light that lets off no heat.
Bright light in eyes	Limit brightness of light
Electrical shocks	Low voltage

(Attach another sheet if needed.)

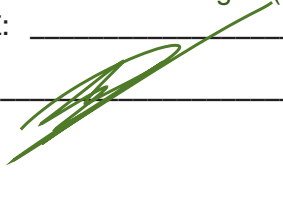
Risk Assessment indicates that this activity can be safely carried out

RISK ASSESSMENT COMPLETED BY (student name(s)): Arthur Kerrigan

SIGNATURE(S): 

☑ By ticking this box, I/we state that my/our project adheres to the listed criteria for this Category.

TEACHER'S NAME: Daniel Kerrigan (dad and science teacher), after discussion with Firas Andari (Oliphant Coordinator and Lab Manager at School)

SIGNATURE:  DATE: 23/3/2025

Log of people that helped me

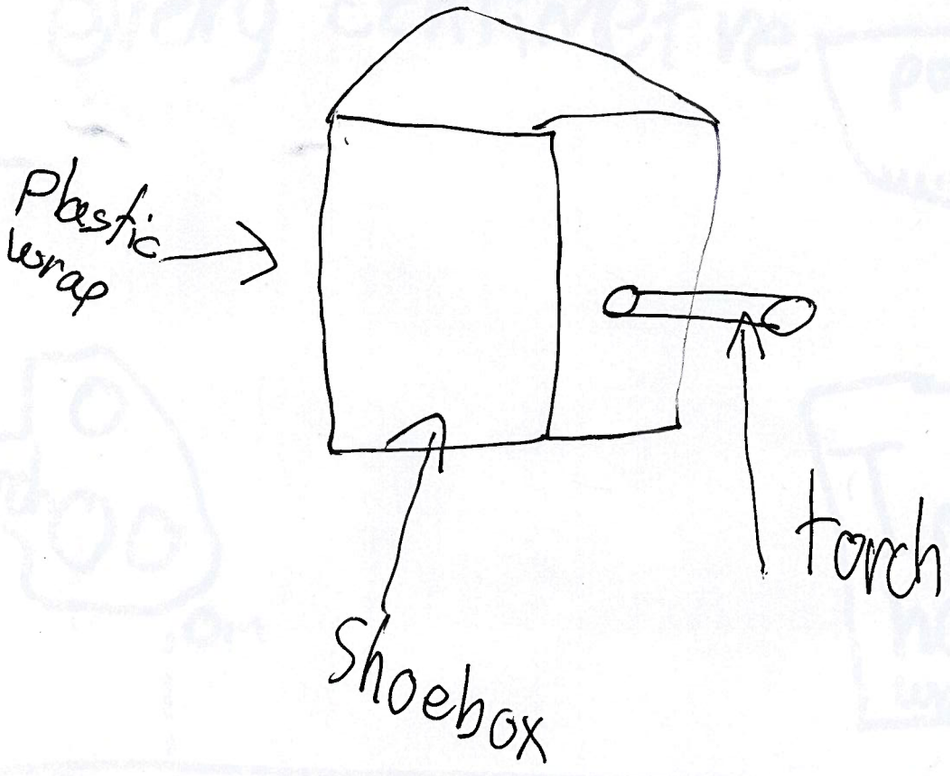
Help Given	Person	How	When
Choosing a subject	Dad	Helped when I was trying to figure out how to make my shoebox projector idea into an experiment.	February
Learning about shadows	Dad	Told me about umbras and penumbras.	February
Finding research sites	Dad	Suggested the first site for me to look at and showed me how to find others.	February and April
Risk Assessment	Dad and Mr Andari	Making sure it was safe and helping me think about what I was going to do.	23/3
Writing Method	Dad	Gave me examples of methods and we talked about what could work.	23/3 and 30/3
Buying equipment	Mum and Dad	I researched the leds myself and asked my dad if they would work. Mum took me to Jaycar and helped me find and buy the leds.	29/3
Set up of experiment	Dad	He set up the batteries for the led, and helped wire it.	30/3
Measuring	Dad	Helped with some measurements, when it needed two people. He took photos.	30/3
Sections of report	Dad and Mum	Showed me examples of how to write a report.	April
Editing	Mum and Dad	Helped me proof read and edit report.	May

15/2/25

Science project

Can I make a shoebox TV?

(Shining a torch through a shoebox with plastic wrap at the opening)



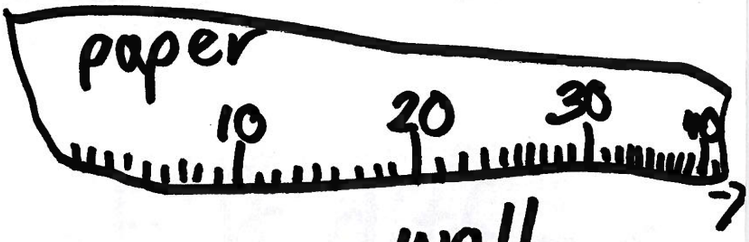
Variables of the TV 23/3

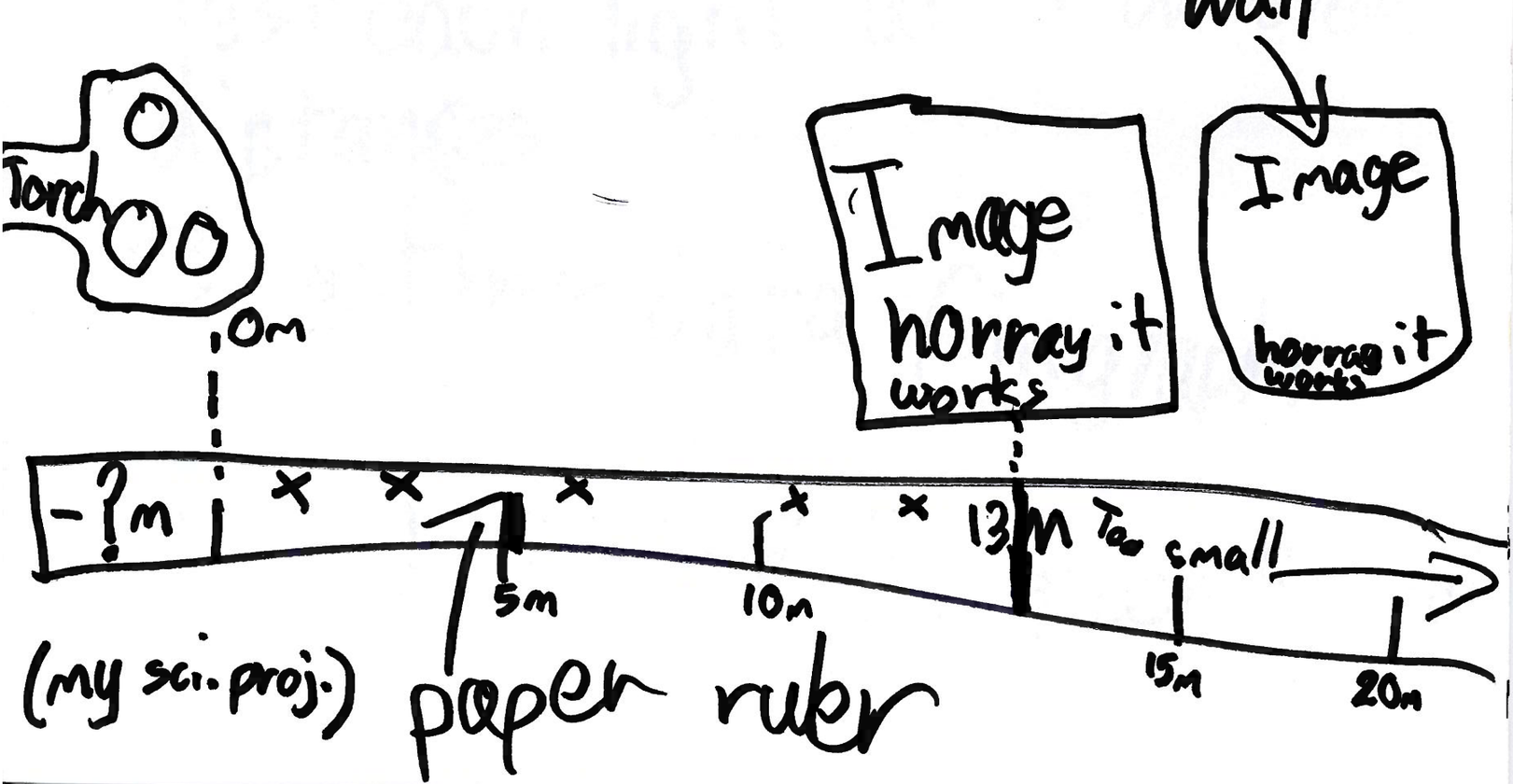
Independent: barrier position

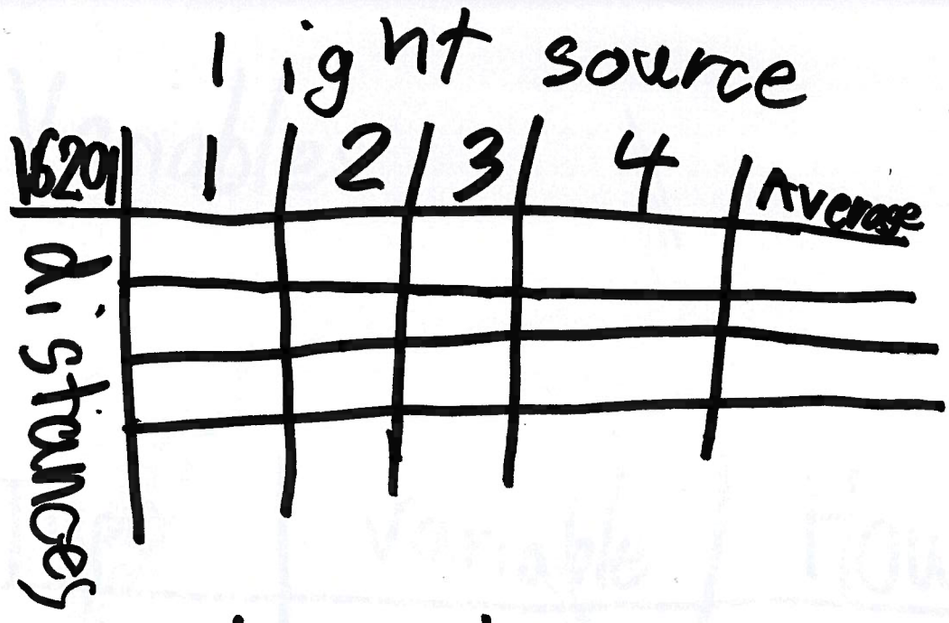
Dependent: the shadow

An Idea

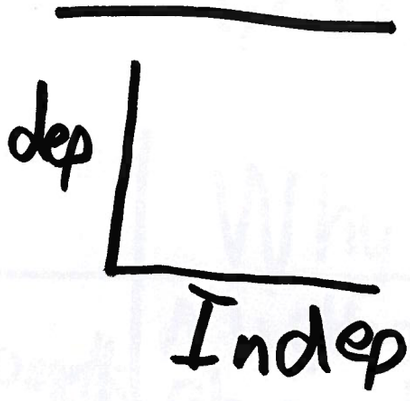
I get a ruler and measure a long piece of paper and mark every centimetre







Overall average



step 1

four different lights

1 (buy)	2 to r 3	3 to r 2	3 to r	

step 2

test each light at 4 different distances

3 gather data (in graphs

1 = red 2 = blue 3 = green 4 = black

Variables

1, 2 ⊗

Type	variable	How	Why
Independent	a barrier	write something on plastic	A light shining at a wall would be useless
Dependent	the penumbra	have the light shine through the barrier	the length of the penumbra needs to be an appropriate size
controlled	Distance from light to wall	move the barrier into different places until it works	At different distances, the angle from the light to the LED will change impacting the size of the penumbra
~~controlled~~ Independent	different penumbra (size) shapes	(dif) drawing different pictures	Stopping the image merging

30/3

Light to wall

First Attempt

775 mm

The card to light was at the wrong angle

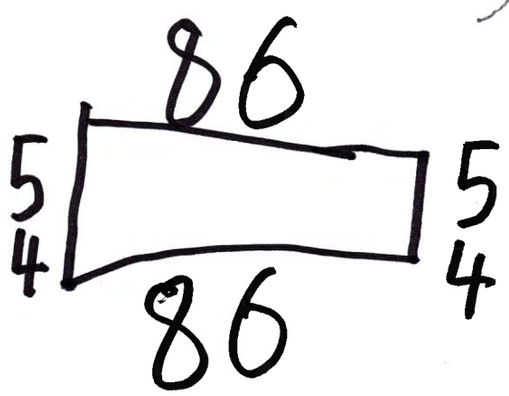
length (mm)	1	2	3	4	5	Height Gain
100	25					—
200	11					—
300	6					130
400	4					96
500	2					77
600	1					70
700						

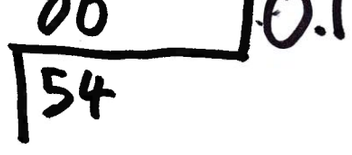
length (mm)	Umambbra			
100				
400				
700				

Shoebox: 305 mm

length (mm)	umbra 1	umbra 2	umbra 3	height	length (width)
(600) 200	14	17	14	/	/
(500) 300	~~8~~ 10	12	9	/	/ (210)
(400) 400	7	6	5	100	>150 (165)
(300) 500	3	4	4	79	126
(200) 600	2	2	2	70	112
(100) 700	1	1	1	59	97

card (mm)





This happens because not all of the light is bright. This means the further the barrier is from the light the smaller the penumbra The penumbra is lighter and the umbra is the darkest bit On the dark side of the moon a total solar eclipse is happening now. A solar eclipse is the moon blocking all of the sun - but only just. When this happens it only covers a very small area like the solar eclipse on April 8 2024 when it was only on a narrow line going through North America.

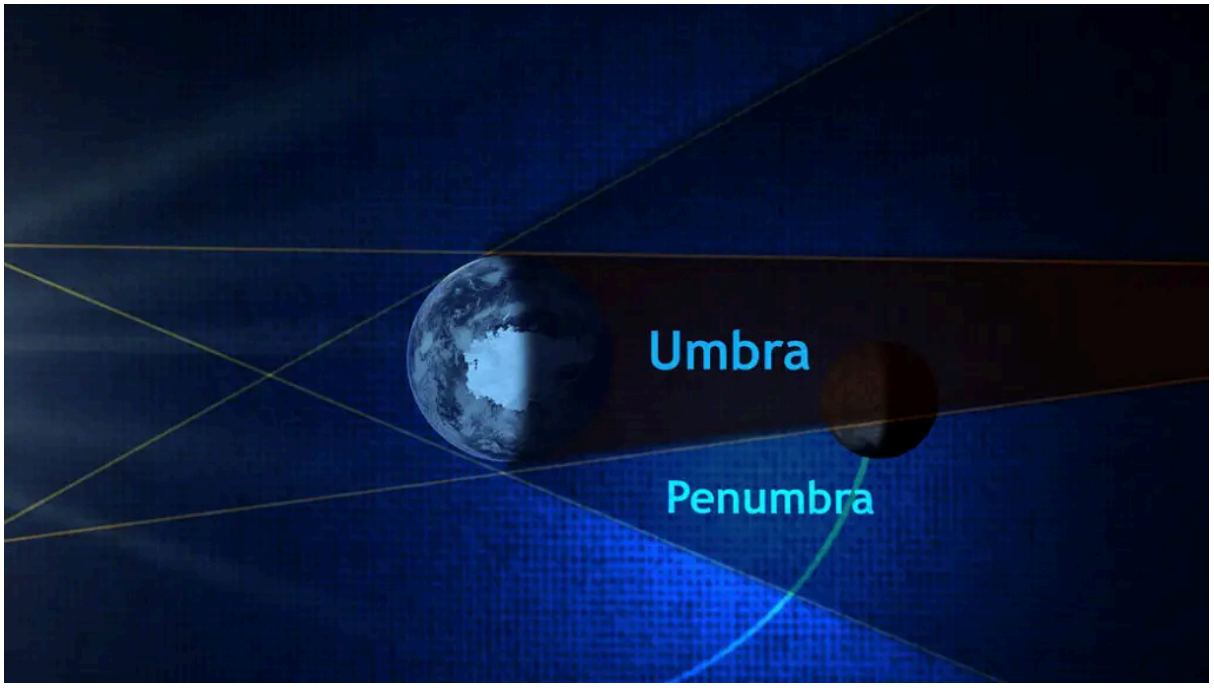
Umbra

- Darkest part of a shadow
- When the whole light source is covered.
- Umbra is latin for shadow
- Anyone in the umbra cannot see the light
- The bigger the object, the bigger the umbra
- If an object is to small it cannot cast an umbra

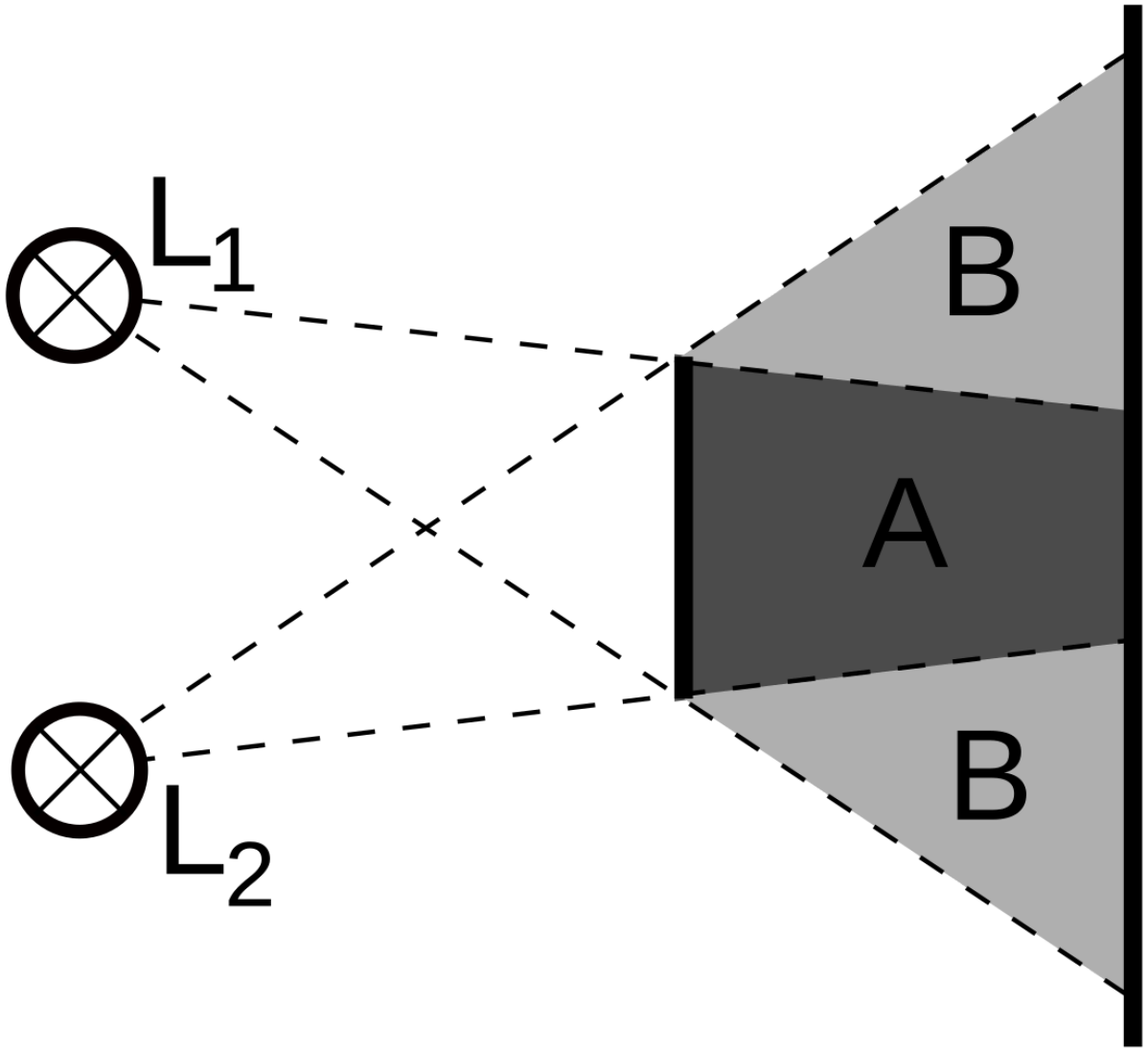
Penumbra

- Some light
- Anybody in the penumbra experiences a partial eclipse
- The further the barrier, the smaller the penumbra

Diagrams:



https://www.nasa.gov/wp-content/uploads/2023/03/umbra-penumbra.jpg



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https://en.wikipedia.org/wiki/Solar_eclipse

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https://www.timeanddate.com/eclipse/shadows.html
https://www.nasa.gov/image-article/diagram-of-umbra-penumbra/

pgs 1-2 n-1

- add a photo
- add evidence of reading about the topic
- add more information

Shoebox Projector

Introduction

The reason I chose a shoebox projector is that I read in a book that the first ever television was made out of a box, so I swapped television to projector and that was how I made my experiment.I have also done some research on light and shadows.

Aim

I am aiming to create a fully functioning projector out of a box and any other necessary resources. If an object is moved father away from the light source, then the penumbra it casts will become smaller.

Hypothesis

If i use a item to make a shadow far away from the light, it should make a smaller penumbra.

Variables

Type	What	How	Why
Independent	*How far away a barrier is* The barrier's distance	*Hold a card in the way a distance away from the light*	*NA*
Dependent	*The penumbra`s size*	*Measured with a ruler*	*NA*
Controlled	*Distance from light to wall*	*The LED was held in the same place.*	*At different distances the angle from the light to the LED will change impacting the size of the penumbra*
Controlled	*Different penumbra shapes*	*Used the same card*	*Changing shape would change the shadow, making it harder to measure*
Controlled	*Same LED*	*Used the same LED*	*The image may have been blurrier and made shadow brighter in some spots*

Arthur no 2

Risk Assessment

Risk	Impact	Mitigation
The barrier melting	*Messing up my dad`s bed and possibly damaging the equipment I use inside the projector.*	*To limit the risk of the plastic melting I will use a source of light that lets off no heat.*
Bright light in eyes	*It will hurt people`s eyes*	*Limited brightness of light*
Electrical shocks	*It will electrocute people*	*Low voltage*

Materials

- **A 10 mm single point LED**
- **A wiring kit**
- **A Mitre 10 membership card**
- **A card holder**
- **A laundry basket**

Method

1. I used a single point LED and shone it onto a card
2. I measured the shadows and recorded the sizes of the umbras and penumbras
3. I wrote this

Results

Distance of barrier (mm)	Penumbra (mm)			Height	length
200	14	17	14	----------	----------
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400	7	6	5	100	165
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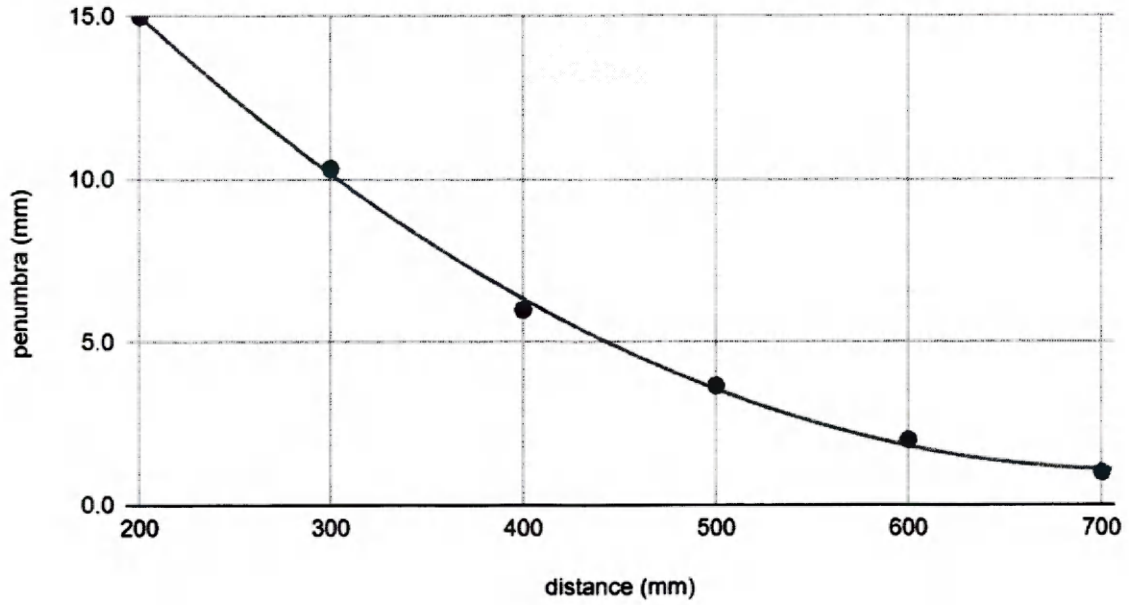
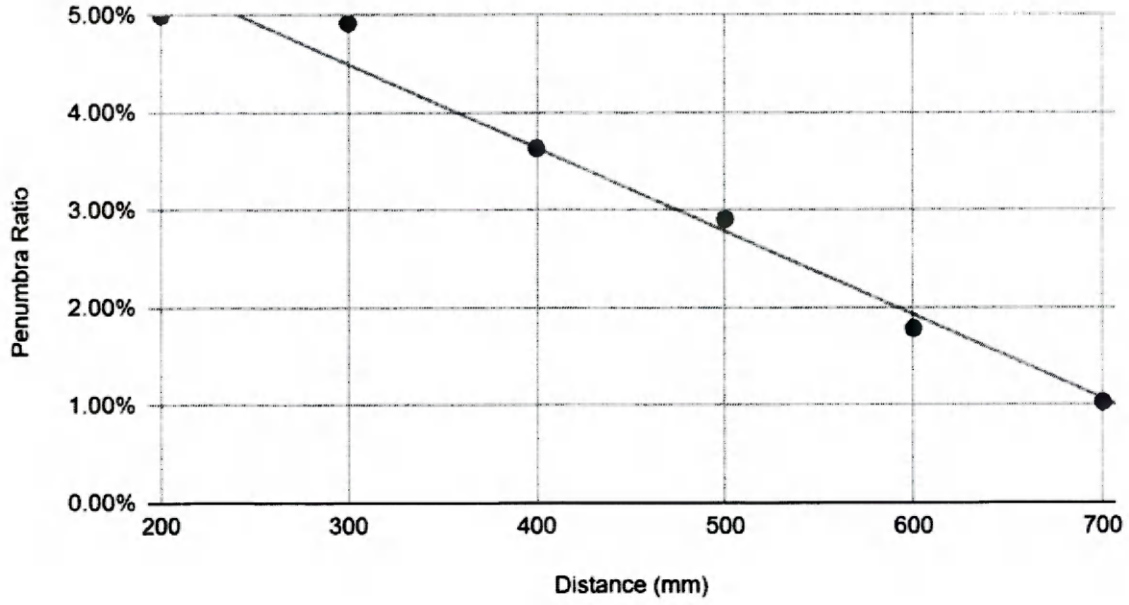
Arthur 3-4 no 5

Average vs length (mm)



Penumbra Ratio vs Distance (mm)



Arthur no.4

→ write it in the opposite way to prove your hypothesis

Discussion

The graphs above show that the closer the barrier was to the light the bigger penumbra was.

These graphs show that I should use 2.5 to 3.5 hundred mm long shoebox to fit the circuitry and leave 2 to 3 hundred mm between the light and barrier, all of which inside the shoebox. The penumbra is the ~~dark~~ light bit of the shadow and the umbra is ~~lighter~~ dark. The hypothesis was supported it said 'If i use a item to make a shadow far away from the light, it should make a smaller penumbra.' Once again these graphs show that I should use 2.5 to 3.5 hundred mm long shoebox to fit the circuitry and leave 2 to 3 hundred mm between the light and barrier, all of which inside the shoebox.

* bring a big cardboard

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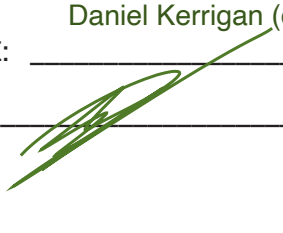
SIGNATURE:  DATE: 23/3/2025