Sustainability

Portfolio summary

In this portfolio, students show that they can design questions for investigation using appropriate inquiry skills. They systematically record and tabulate data, analyse trends in collected data and summarise findings of a survey. Students draw conclusions from their results and discuss potential consequences of them.

Students use effective project planning techniques for a designed solution. They outline a research plan, design criteria and success criteria. Students explain the need for a designed solution, using photographic evidence and survey results. They demonstrate research into a range of options and provide a number of preliminary sketches before deciding on the solution. They are able to justify their designed solution. Students prepare an implementation plan. They make effective use of technologies.

Students use scale and scale factor to calculate area. They plan, budget and cost an event and use efficient strategies to calculate profit and loss. They cost the design choice and justify the cost.

This portfolio has its basis in Technologies with Mathematics and Science playing secondary roles.

Experimental investigation: Light intensity

Sample summary

Students had learned content related to atomic structure and electricity so they understood how a solar panel works. They had completed introductory practicals on setting up solar panel circuits, using data loggers and voltage/current curve for the solar panel. In this extended investigation, students were asked to explore the relationship between light intensity, distance from the source and electrical output and write a report for their investigation.

Achievement Standards

Science

Mathematics

By the end of Year 9, students explain chemical processes and natural radioactivity in terms of atoms and energy transfers and describe examples of important chemical reactions. They describe models of energy transfer and apply these to explain phenomena. They explain global features and events in terms of geological processes and timescales. They analyse how biological systems function and respond to external changes with reference to interdependencies, energy transfers and flows of matter. They describe social and technological factors that have influenced scientific developments and predict how future applications of science and technology may affect people’s lives.

Students design questions that can be investigated using a range of inquiry skills. They design methods that include the control and accurate measurement of variables and systematic collection of data and describe how they considered ethics and safety. They analyse trends in data, identify relationships between variables and reveal inconsistencies in results. They analyse their methods and the quality of their data, and explain

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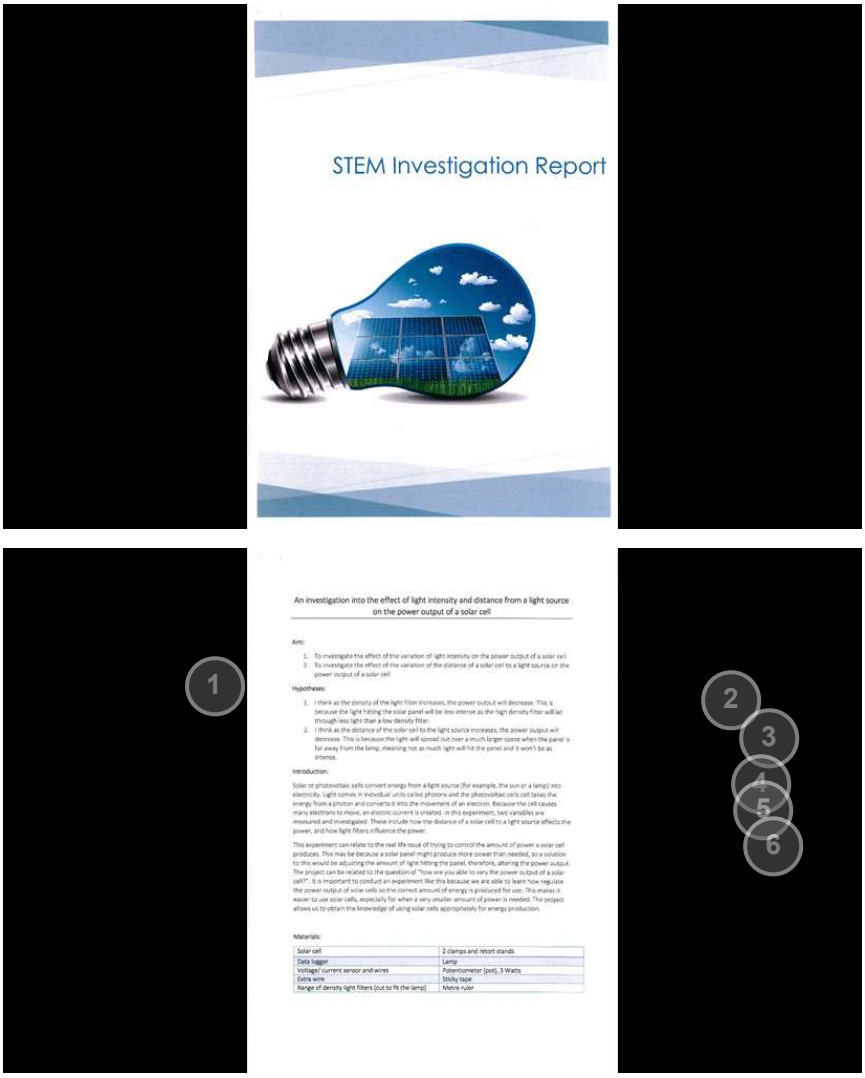
specific actions to improve the quality of their evidence. They evaluate others' methods and explanations from a scientific perspective and use appropriate language and representations when communicating their findings and ideas to specific audiences.

Investigation



Annotations

1 **Science**
Shows understanding of the principles of light absorption and establishes an appropriate hypothesis

2 **Mathematics**
Hypothesises about inverse relationships of the variables

3 **Science**
Identifies spatial diffusion of light as the key concept to consider in the relationship between power output and distance from the light source

4 **Science**
Explains the principle of solar cells in terms of the energy transfer from photons of light to the movement of electrons

5 **Science**
Identifies the variables

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under investigation

6 **Science**
Establishes the relevance of the investigation for the solution of real-world problems

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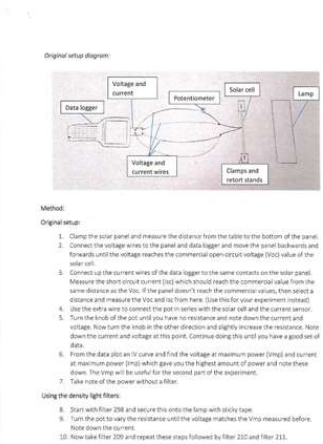

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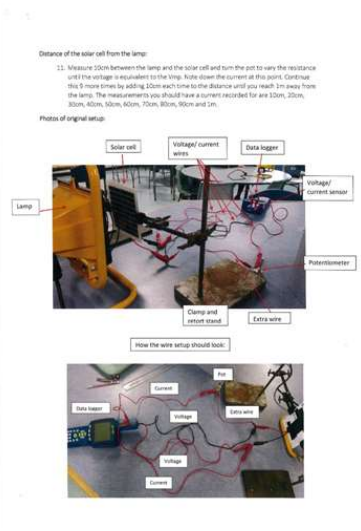
Annotations

1 **Mathematics**
Provides a schematic diagram of the experimental set-up

2 **Science**
Gives a detailed description and sequence of steps undertaken in the experiment



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Annotations

1 **Science**
Provides photographic record of the experimental set-up complementing the schematic diagram

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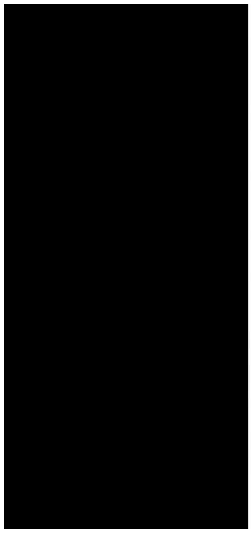
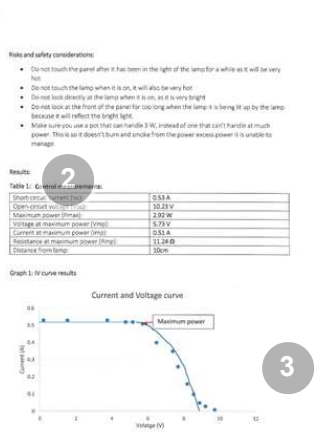
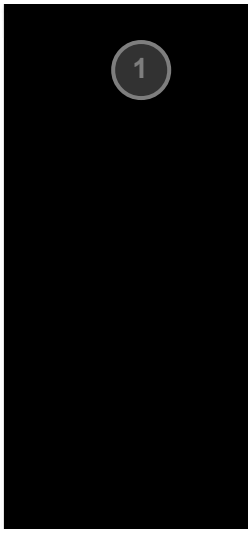




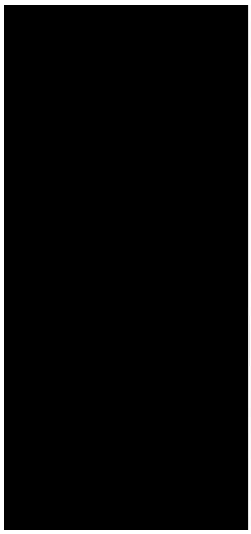


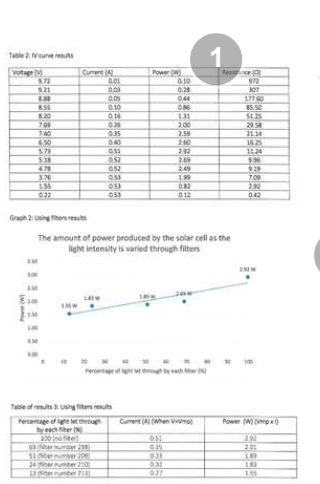
Annotations

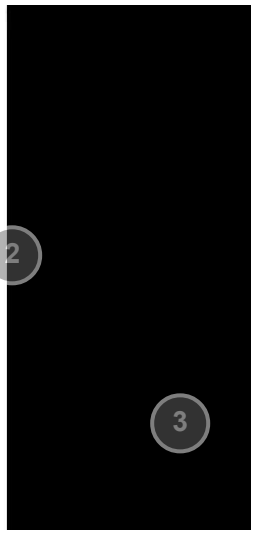
1 Science
Provides exhaustive list of health and safety issues to be considered

2 Mathematics
Systematically collects and records experimental data in a table

3 Mathematics
Draws a graph as a curve that fits as closely as possible to a scatter plot





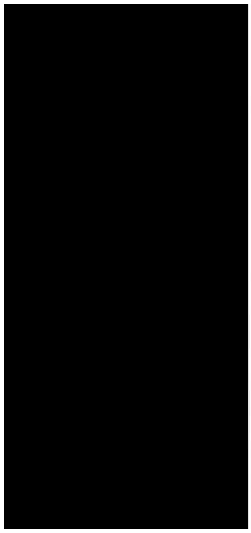


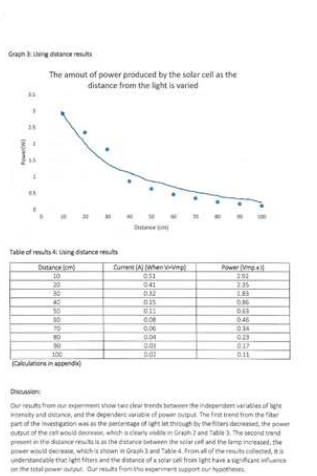
Annotations

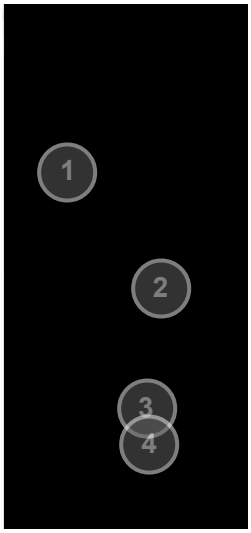
1 Mathematics
Records and displays results in an appropriate table

2 Mathematics
Identifies a linear relationship and draws a line of best fit through the data variables

3 Mathematics
Calculates power by substitution into a formula







Annotations

1 Mathematics
Identifies a non-linear trend in the relationship and draws a curve to represent the data points

2 Mathematics
Calculates values for power from data values in the table

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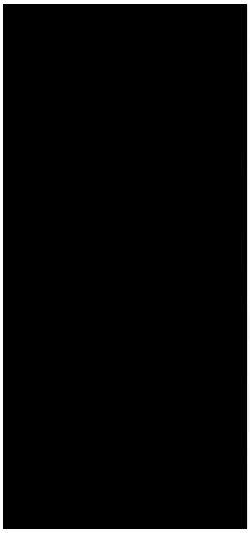
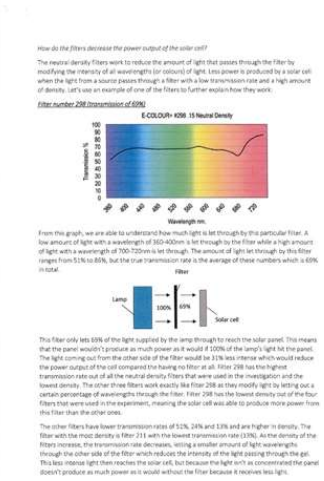
3 **Mathematics**
Identifies dependent and independent variables

4 **Science**
Analyses and interprets the experimental results and establishes corroboration of the hypotheses





How do the filters decrease the power output of the solar cell?

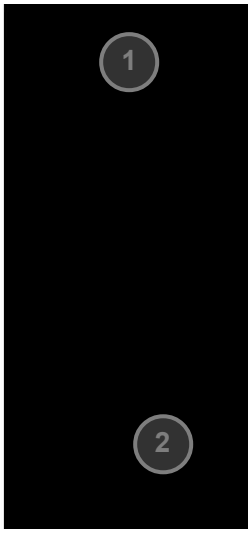
The neutral density filters work to reduce the amount of light that passes through the filter by modifying the intensity of all wavelengths (or colours) of light. Less power is produced by a solar cell when the light from a source passes through a filter with a low transmission rate and a high amount of density. Let's use an example of one of the filters to further explain how they work:

Filter number 298 (transmission of 69%)

From this graph, we are able to understand how much light is let through by this particular filter. A low amount of light with a wavelength of 360-400nm is let through by the filter while a high amount of light with a wavelength of 700-720nm is let through. The amount of light let through by this filter ranges from 51% to 86%, but the true transmission rate is the average of these numbers which is 69% in total.

This filter only lets 69% of the light supplied by the lamp through to reach the solar panel. This means that the panel wouldn't produce as much power as it would if 100% of the lamp's light hit the panel. The light coming out from the other side of the filter would be 31% less intense which would reduce the power output of the cell compared the having no filter at all. Filter 298 has the highest transmission rate out of all the neutral density filters that were used in the investigation and the lowest density. The other three filters work exactly like filter 298 as they modify light by letting out a certain percentage of wavelengths through the filter. Filter 298 has the lowest density out of the four filters that were used in the experiment, meaning the solar cell was able to produce more power from this filter than the other ones.

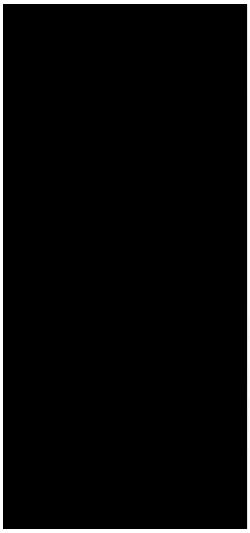
The other filters have lower transmission rates of 51%, 24% and 13% and are higher in density. The filter with the most density is filter 211 with the lowest transmission rate (13%). As the density of the filters increase, the transmission rate decreases, letting a smaller amount of light wavelengths through the other side of the filter which reduces the intensity of the light passing through the gel. This less intense light then reaches the solar cell, but because the light isn't as concentrated the panel doesn't produce as much power as it would without the filter because it receives less light.

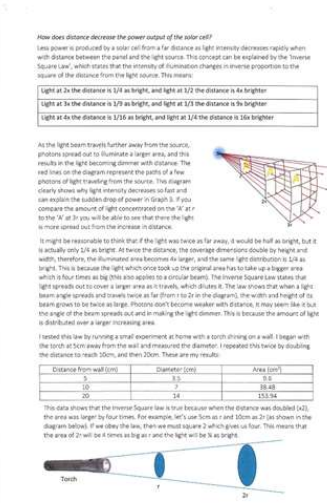


Annotations

1 **Science**
Explains the functionality of optical filters and demonstrates understanding of the concept of light as a composition of monochromatic waves

2 **Science**
Clearly explains the relationship between density of the filter, transmission rate and the power output of the solar cell





How does distance decrease the power output of the solar cell?

Less power is produced by a solar cell from a far distance as light intensity decreases rapidly when with distance between the panel and the light source. This concept can be explained by the 'Inverse Square Law', which states that the intensity of illumination changes in inverse proportion to the square of the distance from the light source. This means:

Light at 2x the distance is 1/4 as bright, and light at 1/2 the distance is 4x brighter
Light at 3x the distance is 1/9 as bright, and light at 1/3 the distance is 9x brighter
Light at 4x the distance is 1/16 as bright, and light at 1/4 the distance is 16x brighter

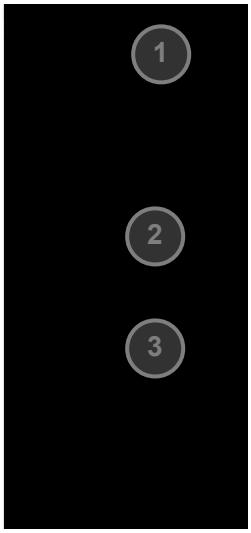
As the light beam travels further away from the source, photons spread out to illuminate a larger area, and this results in the light becoming dimmer with distance. The red lines on the diagram represent the paths of a few photons of light traveling from the source. This diagram clearly shows why light intensity decreases so fast and can explain the sudden drop of power in Graph 3. If you compare the amount of light concentrated on the 'A' at r to the 'A' at 2r you will be able to see that there the light is more spread out from the increase in distance.

It might be reasonable to think that if the light was twice as far away, it would be half as bright, but it is actually only 1/4 as bright. At twice the distance, the coverage dimensions double by height and width, therefore, the illuminated area becomes 4x larger, and the same light distribution is 1/4 as bright. This is because the light which once took up the original area has to take up a bigger area which is four times as big (this also applies to a circular beam). The Inverse Square Law states that light spreads out to cover a larger area as it travels, which dilutes it. The law shows that when a light beam angle spreads and travels twice as far (from r to 2r in the diagram), the width and height of its beam grows to be twice as large. Photons don't become weaker with distance, it may seem like it but the angle of the beam spreads out and in making the light dimmer. This is because the amount of light is distributed over a larger increasing area.

I tested this law by running a small experiment at home with a torch shining on a wall. I began with the torch at 5cm away from the wall and measured the diameter. I repeated this twice by doubling the distance to reach 10cm, and then 20cm. These are my results:

Distance from wall (cm)	Diameter (cm)	Area (cm²)
5	3.5	9.6
10	7	38.48
20	14	153.94

This data shows that the Inverse Square law is true because when the distance was doubled (x2), the area was larger by four times. For example, let's use 5cm as r and 10cm as 2r (as shown in the diagram below). If we obey the law, then we must square 2 which gives us four. This means that the area of 2r will be 4 times as big as r and the light will be 1/4 as bright.



Annotations

1 **Mathematics**
Explains the inverse relationship between the variables

2 **Science**
Gives detailed explanation of how the inverse square law can be understood using sophisticated scientific language and clear reasoning and supports the explanation by the choice of an appropriate illustration

3 **Science**
Demonstrates evidence of strong engagement, self-directed

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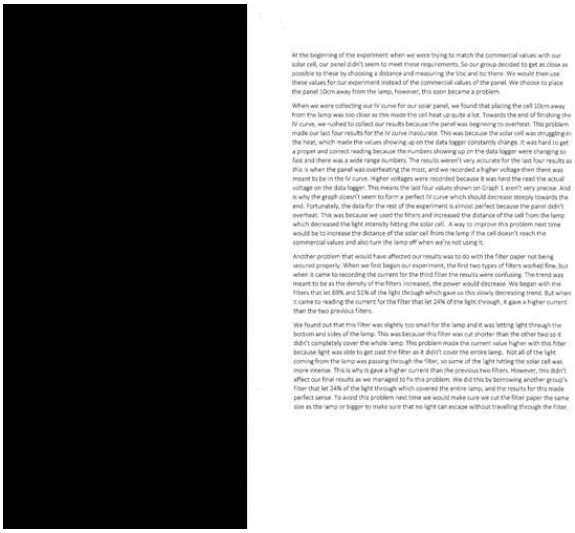
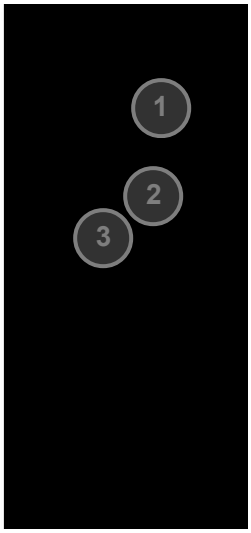
learning and deep understanding of the topic by designing an independent experiment that confirms the findings



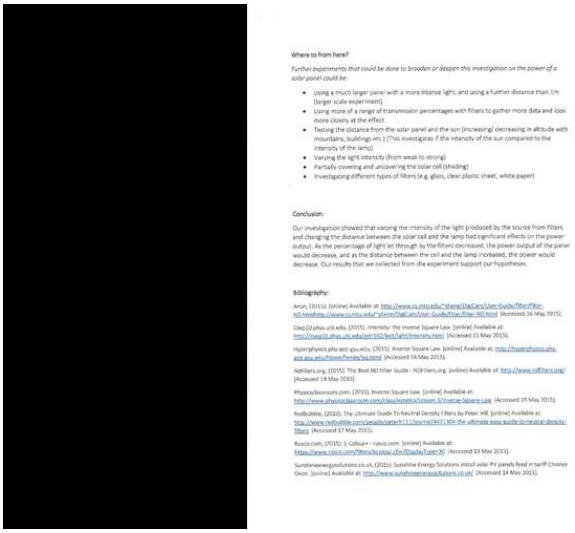


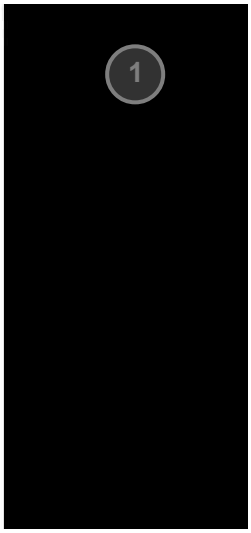
Annotations

1 **Science**
Gives detailed account of problems observed during the experiment and analyses the causes for those problems using scientific reasoning

2 **Mathematics**
Explains why the graph has anomalies

3 **Science**
Suggests improvements to the experimental method





Annotations

1 **Science**
Suggests a range of investigations that would deepen the understanding of the topic

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Appendix: Calculations

Control measurements:

Finding maximum power:

-Vmp= 5.73 V

-Imp= 0.51 A

5.73 x 0.51= 2.92 W

Finding resistance a maximum power:

-Vmp= 5.73 V

-Imp= 0.51 A

5.73÷0.51= 11.24 Ω

IV curve:

Finding the power:

9.72 V x 0.01 A = 0.10 W

9.21 V x 0.03 A = 0.28 W

8.88 V x 0.05 A = 0.44 W

8.55 V x 0.10 A = 0.86 W

8.20 V x 0.16 A = 1.31 W

7.69 V x 0.26 A = 2.00 W

7.40 V x 0.35 A = 2.59 W

6.50 V x 0.40 A = 2.60 W

5.73 V x 0.51 A = 2.92 W

5.18 V x 0.52 A = 2.69 W

4.78 V x 0.52 A = 2.49 W

3.76 V x 0.53 A = 1.99 W

1.55 V x 0.53 A = 0.82 W

0.22 V x 0.53 A = 0.12 W

Finding the resistance:

9.72 V ÷ 0.01 A = 972 Ω

9.21 V ÷ 0.03 A = 307 Ω

8.88 V ÷ 0.05 A = 177.60 Ω

8.55 V ÷ 0.10 A = 85.50 Ω

8.20 V ÷ 0.16 A = 51.25 Ω

7.69 V ÷ 0.26 A = 29.58 Ω

7.40 V ÷ 0.35 A = 21.14 Ω

6.50 V ÷ 0.40 A = 16.25 Ω

5.73 V ÷ 0.51 A = 11.24 Ω

5.18 V ÷ 0.52 A = 9.96 Ω

4.78 V ÷ 0.52 A = 9.19 Ω

3.76 V ÷ 0.53 A = 7.09 Ω

1.55 V ÷ 0.53 A = 2.92 Ω

0.22 V ÷ 0.53 A = 0.42 Ω

Using filters results:

Finding the power:

(Current x Vmp)

0.51 A x 5.73 V = 2.92 W

0.35 A x 5.73 V = 2.01 W

0.33 A x 5.73 V = 1.89 W

0.32 A x 5.73 V = 1.83 W

0.27 A x 5.73 V = 1.55 W

Using distance results:

Finding the power:

(Current x Vmp)

0.51 A x 5.73 = 2.92 W

0.41 A x 5.73 =2.35 W

0.32 A x 5.73 = 1.83 W

0.15 A x 5.73 = 0.86 W

0.11 A x 5.73 = 0.63 W

0.08 A x 5.73 = 0.46 W

0.06 A x 5.73 = 0.34 W

0.04 A x 5.73 = 0.23 W

0.03 A x 5.73 = 0.17 W

0.02 A x 5.73 = 0.11 W

Calculating the area of the torch light on the wall:

5cm: Diameter= 3.5, so the radius=1.75

Area= 1.75^2 x π=9.6

10cm: Diameter= 7, so the radius =3.5

Area= 3.5^2 x π= 38.48

20cm: Diameter= 14, so radius=7

Area= 7^2 x π=153.94

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