My experiments focus is to obtain an accurate measurement for a specific lenss po...

My experiments’ focus is to obtain an accurate measurement for a specific lens’s power. This will be achieved by focusing on the lens equation: 1/v (curvature of wavefront after lens) = 1/u (curvature of wavefront before lens) + 1/f (power of the lens/curvature added by lens). By performing an experiment with a source of light, a lens, and a screen, I will obtain several 1/u and 1/v values.

When these values are plotted on a 1/v against 1/u graph, they will hopefully give me an accurate estimation of the power of the lens by looking at the axes intercepts. Equipment:* Power pack: For each experiment I kept the output setting to 9 Volts to control the power being delivered to the filament lamp (as power = current x voltage). Power is proportional to intensity and so a brighter/darker output could result in a different range where the created image is in focus.* 2x Wires: These took the electric current from the power pack to the light source I was using.* Filament lamp: I chose a filament lamp over other sources of light as it is easy to tell when its’ image is formed. This is because the filament is a very definable object.

I used it for my first, third and fourth experiments. With a constant voltage output; the intensity of light was relatively constant.* Light Emitting Diode: I used an LED for my second experiment. This also maintained a relatively constant intensity of light as the voltage setting on the power pack was not altered.* Lens: I used a convex lens with a diameter of 50mm and a claimed focal length of 150mm. It converges incoming light to a specific point based on its power.

An image is formed at this point (in my case the filament of the lamp/when LED is most intense).* Lens holder: This is a vital piece of apparatus as it keeps the lens firmly in position. I placed this on top of a wooden block so the lens axis was at the same height as the centre of the light source, allowing an image to be formed.* Screen: This was simply a thin wooden block with white paper on the front of it. It is beneficial that the paper is white as it reflects most of the light cast on it.

The result is a more defined image.* Wooden Ruler: The ruler was used to measure the U (distance between light source and lens) values and V (distance between lens and where image is formed) values. It has a resolution of 1mm and therefore creates an uncertainty of +/- 0. 5mm in my ‘ U’ measurements. This turned out to be a very small percentage uncertainty in the U values ((0. 5mm/200mm) x 100) gave the highest value of 0.

25%. Such a small percentage is negligible and hence I have ignored uncertainties in U in my calculations. Method: 1. Firstly I placed the ruler horizontally on a desk starting at one end. The ruler was selotaped down at both ends so it didn’t move whilst experimenting.

2. Next I connected the filament lamp to the power pack which was at a setting of 9 volts and plugged into a nearby socket. These components were placed on one end of the desk with the middle of the filament lamp aligned with “ 0” millimetres on the ruler. 3.

Then I put the lens in the holder and placed it on top of a wooden block. This was aligned to the desired ' U' starting point. (i. e. 500mm away from filament lamp)4. At this stage the equipment was set up for the first results.

I moved the screen up and down the ruler (on the opposite side of the lens to the filament lamp) until the image is formed on the screen. I would then find the range of where the image is formed, and note down the minimum and maximum distances of this range. 5. With the maximum and minimum V values figured out for a specific U value; I could then work out the mean of these and the uncertainty of V by halving the range. 6. Next I would decrease U by a specific amount by moving the lens closer to the filament lamp.

(e. g. from 500mm to 450mm) Then I would work out the V values for this particular U value. 7. Finally I would repeat step 6 until I have data for a range of approximately 10 U values. 8.

1/U and 1/V values must be calculated. These represent the curvature of waves before and after. Referring to the curvature equation, the V and U values areessentially the radii of curvature (values stated in metres). Safety: While this is certainly not an experiment that requires a high level of caution, it can be slightly harmful if no care is taken.

The light sources used are quite bright. These should not be looked at directly for an extended period of time as it could cause damage to the eyes. Furthermore a bright filament lamp can become rather warm, it is best to avoid touching it while in use. Variables: Independant variable: This is the U and so 1/U value. It is varied by placing the lens at different distances away from the light source.

Dependant variable: This is the V and so 1/V value. Its value changes when the U value is varied and hence is dependant of it. Controlled variables: Voltage output: If I were to alter the voltage setting, the light source's intensity will vary which could result in a change of where the image is formed. Also I must use the same diameter and focal length lens; lenses with different focal lengths will of course have different powers. First Experiment* Power pack set to 9 Volts* Using a filament lamp as light source* Distance the U value decreases per stage is 50mmU (x10-3 M)+/- 11/U (Dioptres)V Minimum (x10-3 M)V Maximum(x10-3 M)V Mean (x10-3 M)V +/-(x10-3 M)%V +/-1/V Min.(D)1/VMax.

(D)1/V Mean (D)1/V +/- (D)700-1. 4319620019821. 015. 105. 005. 050.

0510650-1. 5419820420131. 495. 054. 914.

980. 0743600-1. 6720220820531. 464.

964. 824. 890. 0714550-1.

8221021821441. 874. 764. 584. 670.

0873500-2. 0021522121831. 384. 654. 534. 590.

0631450-2. 2222423022731. 324. 474. 354. 410.

0582400-2. 50244251247. 53. 51. 414.

103. 984. 040. 0571350-2.

86273282277. 54. 51. 623.

663. 543. 600. 0584300-3.

3331232231751. 583. 203. 103. 150. 0498250-4.

0039340339851. 262. 542. 482. 510.

0316200-5. 00662700681192. 791. 511.

511. 470. 0410First Experiment Results AnalysisThe results from my first experiment have produced graphs which match a typical 1/v = 1/u + 1/f graph. This is because the equation is essentially a straight line; ‘ y= mx+c’, and the actual graph is indeed a straight line. It is a positive correlation where as 1/u curvature becomes less negative, 1/v becomes more positive. Additionally as 1/V increases, the uncertainty in its measurement generally increases.

First Graph: In order to intercept both axes in the same graph, I had to make the y axis the same scale as the x axis. This meant I could not sketch the uncertainties, yet I could analyse the uncertainty between the two intercepts. Power Result: Y axis: At the intercept, 1/U= 0 and so the 1/V reading will give us the estimated power (1/F). X axis: Referring to 1/V= 1/U+1/F, looking at the X axis intercept I can obtain an estimation of the-1/F value and hence the power.

At the intercept 1/V= 0 and so 1/U+1/F= 0. Rearranging, we find that 1/U= -1/F and so I just need to covert the 1/U value to positive to find the power. The two readings of 6. 50 D and 6. 46 D give an average of 6.

48 D +/- 0. 02D. This is a relatively small uncertainty- (0. 02/6.

48)x100= 0. 309%. In comparison to the claimed power of 6. 67 Dioptres, the result is 0.

19 Dioptres out; hence there is an error of (0. 19/6. 67)x100= 2. 85% provided the claimed power is correct.

Accuracy: All but one of the plotted points come into contact with the line of best fit. This indicates that my results are quite accurate. The U= 500 result is not intercepted and so can be classed as an outlier. Reliability: The reliability of the first graph cannot be summarised as the uncertainties are impossible to accurately plot for its scale. For this reason the average result from this graph should not be summarised as the actual power, but rather an indication of uncertainity between the two axes intercepts. However the uncertainty of 0.

02 Dioptres in the measurement is rather small, indicating the final result will be quite reliable. Second Graph: Power result: The plotted values have produced minimum, mean, and maximum gradients that are quite close together. They intercept the x axis at -6. 39 D, -6. 49 D and -6. 54 D respectively.

The average of these results turns out to be 6. 47 D with an uncertainty of +/- 0. 075 (achieved by halving the difference between 6. 54 and 6. 39)This result is only 0. 01 Dioptres less than the value achieved in the first graph (6.

48 D). Two graphs producing very similar results suggest it is quite accurate. Provided the claimed power of the lens is correct at 6. 67 Dioptres, my result is 0.

20 dioptres out, and the percentage inaccuracy is (0. 20/6. 67)x100= 3%Reliability: The uncertainties in general are rather small and so this suggests that my result cannot be influenced by them significantly, meaning my results should be reliable. Focusing on results 5 and 6; these two results on their own create a much different line of best fit to the overall one. I believe they are scattered due to the fact that the higher ‘ U’ values lead to higher uncertainties in 1/V. This means the graph cannot be entirely reliable.

Considering these factors I would say that my results are generally reliable taking into account that it is the first experiment. Accuracy: Looking at the mean gradient line, the majority of plots are intercepted suggesting the results are accurate. However the U= 300 and U= 450 results do not come into contact with the line, and several others intercepted at the minimum/maximum limits. Summary: I would summarise that my results are satisfactorily accurate and reliable considering it is the first experiment. There are definitely improvements to be made, such as the high uncertainties in the higher 1/V values.

My experiment had an element of zero error which is a type systematic error. In this first experiment I did not account for the end of the wooden ruler which has no markings on it. This lead to an unknown decrease in my actual results, producing false values. I can eliminate this error by ensuring the source of light is aligned with 0mm on the ruler for each test. The largest source of uncertainty in my 1/V results is of course the range at which the image is formed. To limit this random error I should perform the experiment in a darker area.

With less interfering light it will make it easier to tell exactly when the image is in and out of focus, hopefully leading to a lower range. Improvements for the next experiment: I believe one reason why I did not obtain a more accurate result is because I started at a too high U value. These lead to higher 1/V values which have higher uncertainties. Focusing on lower U distances will lead to lower uncertainties and hence a more reliable line of best fit. Additionally because I decreased my U value by 50mm each time, there is a large gap between each plot on the graph. A large gap means my line of best fit may well be inaccurate.

To achieve a more accurate line of best fit I will decrease my U value by 25mm each time, leading to smaller gaps between plots and hence give me a better indication of the power of the lens. As previously mentioned, I will attempt to combat errors by ensuring my source of light is aligned with the rulers' 0mm reading for each result, and that I operate in a darker environment so it is easier to distinguish the range of focus for images. In addition to my improvements, for the second experiment I shall be using an LED instead of a filament lamp. Using a different light source may increase or decrease uncertainties. I hope that by using the LED my 1/V uncertainties will be smaller and so my final result can be more reliable. Second

Experiment* Power pack set to 9 volts* Using LED* Distance the U value decreases per stage is 25mmU (x10-3 M)+/- 11/U (Dioptres)V Minimum (x10-3 M)V Maximum(x10-3 M)V Mean (x10-3 M)V +/-(x10-3 M)%V +/-1/V Min.

(D)1/VMax.(D)1/V Mean (D)1/V +/- (D)425-2. 3523624223931. 264. 234.

134. 180. 0525400-2. 5024525324941. 614.

083. 954. 020. 0645375- 2. 6725726526141. 533.

893. 773. 830. 0587350-2. 86268277272. 54.

51. 653. 733. 613.

670. 0606325-3. 0829030029551. 693. 453.

333. 390. 0575300-3. 3331232231751. 583.

23. 13. 150. 0498275- 3.

63341354347. 56. 51. 872. 932.

832. 880. 0538250-4. 0039241040192. 242. 552.

432. 490. 0560225-4. 44480523501.

521. 54. 292. 081. 91. 990.

0855200-5. 00670764717476. 561. 481. 31.

390. 0914Second Experiment Results AnalysisFirst Graph: Power result: The two intercepts give readings of 6. 56 D and 6. 31 D.

This results in an average of 6. 435 +/- 0. 125 D. This uncertainty is considerably larger than the first experiment (0. 02D). Percentage wise it is also larger (0.

125/6. 435)x100= 1. 94% in comparison to 0. 309%.

In comparison to the claimed power of 6. 67 Dioptres, the result is 0. 235 Dioptres out; hence there is an error of (0. 235/6.

67)x100= 3. 25% provided the claimed power is correct. Accuracy: All but one of the plotted points come into contact with the line of best fit. This indicates that my results are quite accurate.

The U= 325 result is not intercepted and so can be classed as an outlier. Reliability: The reliability of the first graph cannot be summarised well as the uncertainties are impossible to accurately plot for its scale. However the measurement has an uncertainty of 0. 125 Dioptres, this will make the result slightly less reliable. Second Graph: Power result: The plotted values have produced minimum, mean, and maximum gradients that are slightly more spread in comparison to the first experiment. They intercept the x axis at -6.

26 D, -6. 38D and -6. 46 D respectively. The average of these results turns out to be 6. 37 D with an uncertainty of +/- 0. 1.

The power value is 0. 10 Dioptres less than the first experiment. The uncertainty is higher than the first experiment’s (+/- 0. 075). This could mean that the second experiment results are unreliable. This result is (6.

435-6. 37) = 0. 065 Dioptres less than the value achieved in the first graph. Two graphs producing similar results suggest it is quite accurate, but certainly not as much as the first experiment where the difference was merely 0.

01 Dioptres. Provided the claimed power of the lens is correct at 6. 67 Dioptres, my result is 0. 3 dioptres out, and the percentage inaccuracy is (0.

30/6. 67)x100= 4. 5%. This inaccuracy is 150% the size of the first experiment's (3%)Reliability: The uncertainties in general are certainly smaller than the first experiment overall and so this suggests that my values cannot be influenced by them significantly, meaning my results should be reliable.

Accuracy: Looking at the mean gradient line, every single plot is intercepted suggesting the results are accurate. However, quite a few results only just touch the line with the maximum/minimum limits, indicating a minor lack of accuracy. Summary: I would summarise that my results are quite accurate and reliable on the basis of the second graph. However when comparing the results to the first experiment, all uncertainties are larger, and the result has a larger error against the claimed power. While I opted to work in a darker environment to try and obtain a more accurate uncertainty in V, a different imaging problem arose. The LED does not produce a distinctive image like the filament lamp; instead I had to judge it to be in focus when the light was most intense.

This proved to be rather difficult and hence created some uncertainty, which largely contributed to the higher uncertainties in the results. To combat this error I decided it was best to revert back to using the filament lamp. Improvements for the next experiment: Utilising the suggested improvements from my first experiment, I obtained results which had lower uncertainties. However the imaging problem opposed this improvement and lead to a higher uncertainty in the final measurement. Also the fact its largest uncertainty (0.

0914) is larger than the filament lamp’s largest (0. 0873) insinuates that it is generally less reliable for measurements. Based on this I will revert back to using the filament lamp as my light source in hope of achieving more reliable results. In combination with the 25mm gap between each U distance method, I believe I will achieve more accurate results. Third Experiment:* Power pack set at 9 volts* Decreasing U value by 25mm each stepU (x10-3 M)+/- 11/U (Dioptres)V Minimum (x10-3 M)V Maximum(x10-3 M)V Mean (x10-3 M)V +/-(x10-3 M)%V +/-1/V Min.

(D)1/VMax.(D)1/V Mean (D)1/V +/- (D)425-2. 3523824624241. 654. 214.

074. 140. 0683400-2. 524325124741. 624. 123.

984. 050. 0656375-2. 6725125925541. 5713.

983. 863. 920. 0615350-2. 8626527527051.

853. 773. 633. 700.

0686325-3. 0827928928451. 763. 583. 463.

520. 0620300-3. 3330031030551. 643.

333. 233. 280. 0537275-3. 6433134133651. 493.

022. 942. 980. 0443250-4379390384.

55. 51. 432. 642. 562.

600. 0372225-4. 4444545945271. 552. 242.

182. 210. 0343200-5605627616111. 791. 651. 591.

620. 0290* Using filament lamp as light sourceThird Experiment Results AnalysisFirst Graph: Power result: The two intercepts give readings of 6. 5 D and 6. 61 D. This results in an average of 6.

555+/- 0. 055 D. This uncertainty is larger than the first experiment (0. 02D); yet smaller than the second (0.

125D). Percentage wise it is also larger than the first experiment and smaller than the second: (0. 0555/6. 555)x100= 0. 839% in comparison to 0.

309% and 1. 94% respectively. In comparison to the claimed power of 6. 67 Dioptres, the result is 0. 115 Dioptres out; hence there is an error of (0.

115/6. 67)x100= 1. 72% provided the claimed power is correct. Accuracy: All but two of the plotted points come into contact with the line of best fit.

This suggests that my results are quite accurate but not as much as the previous two experiments, where only one result does not touch the line of best fit. The U= 425 and 400 results are not intercepted and so can be classed as outliers. Reliability: The reliability of the first graph cannot be summarised well as the uncertainties are impossible to accurately plot for its scale, however considering the measurement has an uncertainty of just 0. 055 Dioptres suggests that the result is partially reliable.

Second Graph: Power result: The plotted values have produced minimum, mean, and maximum gradients that are closer together than the previous experiments. They intercept the x axis at -6. 64 D, -6. 70 D and -6.

76 D respectively. The average of these results turns out to be 6. 70 D with an uncertainty of +/- 0. 04. The power value is 0. 23 Dioptres more than the first experiment and 0.

37 Dioptres more than the second. The uncertainty is lower than both the first experiments (+/- 0. 075) and the second’s (+/- 0. 1). This suggests the third experiment’s result is more reliable. This result is (6.

70-6. 55) = 0. 215 Dioptres less than the value achieved in the first graph. Two graphs producing similar results suggest it is quite accurate, but certainly not as much as the first experiment where the difference was merely 0.

01 Dioptres. It is also larger than the second experiment’s difference of 0. 065Provided the claimed power of the lens is correct at 6. 67 Dioptres, my result is 0. 03 dioptres out, and the percentage inaccuracy is (0.

03/6. 67)x100= 0. 450%. This inaccuracy is much smaller than the first experiment’s 3% and just 1/10 the size of the second experiment’s 4. 5%.

Reliability: The uncertainties in general are smaller than previous experiments. The highest uncertainty of the third experiment is 0. 0686 D, whilst the second experiment's is 0. 091 D and the first experiment's is 0.

0873 D. The uncertainty is only +/- 0. 04 Dioptres in the power result. Considering these two points, it is clear that these are my most reliable results so far. Accuracy: Looking at the mean gradient line, every single plot is intercepted which would suggest the results are accurate. The second experiment's plots were all intercepted, but quite a few were only just so due to their minimum/maximum limits.

The third experiment's plots are intercepted through their mean or very near to it (except the third plot when U= 375). These closer intercepts means that this experiment's results are my most accurate so far. Summary: I would summarise that my results are the most accurate and reliable so far on the basis of the second graph. The uncertainties were generally the lowest, and the plotted points were well aligned with the mean line of best fit. Additionally the result is the closest to the claimed power of 6. 67; being only 0. 03 Dioptres more. The only notable source of uncertainty that remains is light interference with the image. Reverting back to the filament lamp proved a good decision as I achieved more accurate results. However I could not experiment in an ideally-dark environment to completely avoid light interference with the image. I cannot guarantee that there was no significant interference and so it is best to adopt an additional method to combat it. Improvements for the next experiment: To further prevent light interference I will place a cardboard ring in front of the lens so that a portion of it is blocked out to light. Using this ring will decrease the exposed area of the lens to light. This means less external light (i. e. from classroom ceiling lights) will reach the lens and interfere with the image being formed. Less interference leads to a clearer image and so hopefully I will be able to obtain more accurate 1/V values. Fourth Experiment* Power pack set to 9 volts* Decreasing U by 25mm each step* Using filament lamp as light source* Using lens cover to decrease interferenceU (x10-3 M)+/- 11/U (Dioptres)V Minimum (x10-3 M)V Maximum(x10-3 M)V Mean (x10-3 M)V +/-(x10-3 M)%V +/-1/V Min.(D)1/VMax.(D)1/V Mean (D)1/V +/- (D)425-2. 3523424223841. 684. 274. 134. 200. 0706400-2. 5024024824441. 644. 174. 034. 100. 0672375- 2. 6724925725341. 584. 013. 893. 950. 0625350-2. 8626627427041. 143. 743. 663. 700. 0422325-3. 0828029028551. 753. 573. 453. 510. 0616300-3. 33302311306. 54. 51. 473. 313. 213. 260. 0479275- 3. 6333534534051. 472. 982. 902. 940. 0432250-4. 0037538738161. 572. 662. 582. 620. 0413225-4. 4445346746071. 522. 202. 142. 170. 0330200-5. 00610630620101. 611. 641. 581. 610. 0260Fourth Experiment Results AnalysisThe results have produced a typical 1/V against 1/U graph with a positive correlation and gradient. As 1/U gets less negative, 1/V becomes more positive. The uncertainty in 1/V generally increases as 1/V gets largerFirst Graph: Power result: The two intercepts give readings of 6. 59 D and 6. 60 D. This results in an average of 6. 595+/- 0. 005 D. This uncertainty is much smaller than the previous experiments; first experiment (0. 02D), second (0. 125D) and third (0. 055). In comparison to the claimed power of 6. 67 Dioptres, the result is 0. 105 Dioptres out; hence there is an error of (0. 105/6. 67)x100= 1. 57% provided the claimed power is correct. Accuracy: All but two of the plotted points come into contact with the line of best fit. This suggests that my results are quite accurate but not as much as the first and second experiments, where only one result does not touch the line of best fit. Reliability: The reliability of the first graph cannot be summarised well as the uncertainties are impossible to accurately plot for its scale, however considering the measurement has an uncertainty of just 0. 005 Dioptres suggests that the result is significantly reliable. Second Graph: Power result: The plotted values have produced minimum, mean, and maximum gradients that are closer together than all of the previous experiments. They intercept the x axis at -6. 65 D, -6. 67 D and -6. 72 D respectively. The average of these results turns out to be 6. 69 D with an uncertainty of +/- 0. 035. This is the smallest uncertainty (second lowest is 0. 04). This suggests the value is very reliable. This result is (6. 69-6. 595) = 0. 095 Dioptres less than the value achieved in the first graph. Two graphs producing very similar suggest it is quite accurate, but certainly not as much as the first experiment where the difference was merely 0. 01 Dioptres. It is also larger than the second experiment's difference of 0. 065Provided the claimed power of the lens is correct at 6. 67 Dioptres, my result is 0. 02 dioptres out, and the percentage inaccuracy is (0. 02/6. 67)x100= 0. 299%. This inaccuracy is the smallest and so the results can be classed as accurate. Reliability: The uncertainties in general are smaller than previous experiments. The lowest uncertainty of the third experiment is 0. 0290 D, while the fourth experiment's lowest is 0. 0260 D. The uncertainty is only +/- 0. 035 Dioptres in the power result. Considering these two points, it is clear that these are significantly reliable results. Accuracy: Looking at the mean gradient line, every single plot is intercepted which would suggest the results are accurate. The third experiment's plots were all intercepted, but one plot just made contact with the line. All of the fourth experiment's plots are intercepted through their mean or very near to it. These closer intercepts means that this experiment's results are my most accurate so far. Summary: I would summarise that my results are the most accurate and reliable so far on the basis of the second graph. The uncertainties were generally low, and the plotted points were well aligned with the mean line of best fit. Additionally the result is the closest to the claimed power of 6. 67; being only 0. 02 Dioptres more. Final Result: I will compile the estimated power answers of the four experiments. I will be only using the value given by their second graphs. This is because they feature maximum, mean, and minimum lines which produce a more accurate result. To calculate the final value I added the four lens powers up and divided by 4. To work out the uncertainty I worked out the percentage uncertainties for each experiment result, found the average of the percentages, and then applied the average to the calculated average power value. ExperimentPower of lens estimate(Dioptres)Percentage uncertaintyAverage percentage uncertaintyFinal value(Dioptres)16. 47 +/- 0. 0751. 1590. 9626. 56 +/- 0. 063126. 37 +/- 0. 11. 56936. 70 +/- 0. 040. 59746. 69 +/- 0. 0350. 5236. 56 Dioptres is 0. 14 Dioptres less than the claimed lens value of 6. 7D. This is an error of (0. 14/6. 7)x100 = 2. 09%. I believe this error was caused by my first two experiments where I was unaware of the sources of uncertainty. I will therefore perform the same calculations on just my last two experiments; and hopefully achieve a more accurate value. ExperimentPower of lens estimate(Dioptres)Percentage uncertaintyAverage percentage uncertaintyFinal value (Dioptres)36. 70 +/- 0. 040. 5970. 5606. 695 +/- 0. 037546. 69 +/- 0. 0350. 523This has produced a much more accurate result of 6. 695 +/- 0. 0375 D. It is merely 0. 025 Dioptres more than the claimed lens power of 6. 7D This is an error of (0. 025/6. 7)x100 = 0. 373%. TheoryMy experiment focuses on the law that the curvature of a wave front after passing through a lens (1/V) equals the curvature of the wave front prior to being converged by the lens (1/U) plus the power of the lens (1/F). 1/V= 1/U+1/FEvaluationTechnique: I believe my technique was sufficient to obtain accurate results. During each experiment I took care to confirm the exact minimum and maximum values of V, often double checking to confirm or disprove a result. This proved to be a very valuable principle as several times during the course of experimenting I corrected abnormal results that would've negatively affected my eventual result. Sources of uncertainty and Systematic error: One problem was the zero error (systematic error) in the first experiment. As I had not properly aligned the filament lamp to ' 0', the 1/V readings were false. This error was dealt with by ensuring in the other experiments that the lamp was aligned to the 0 reading. Light interference was identified as a source of uncertainty after the first experiment. I combated it by working in a darker environment. The attempted cure had no effect in the second experiment as the LED posed a different imaging problem. I reverted back to the filament lamp afterwards to avoid the LED problem. In the third experiment, I believe that by working in a darkened environment I reduced uncertainties, as uncertainties did indeed decrease. Further action against the light interference problem was taken in the fourth experiment by using a cardboard ring to partially cover the lens. Evidence for this working is that the uncertainty in the power was lower in the fourth compared to the third. Another problem was that during the higher values of U, the range of which the image was formed was rather small and so it was hard to tell when exactly the image was in focus. I identified this problem after my first experiment and avoided it to a certain extent by focusing on lower U values. Additionally I noticed after my first experiment that my distance between each U value was too large and led to lack of information when constructing the line of best fit. My result relies heavily on an accurate line of best fit and so I avoided this problem by decreasing the distance between each U value in the later experiments. There were no real equipment problems, however I observed that depending on the scenario, for a specific value of U the mean V value would vary slightly. I imagine this could be related to the power packs as their voltage output setting is not completely accurate and so the intensity of light could vary slightly, leading to the mean V value potentially changing. To avoid this potential problem I ensured that I completed each experiment's results in one sitting.

Conclusion: By having a cautious approach to my experiments I managed to obtain accurate and reliable results. I identified variables and kept them under control so my results could not be affected by them. After each experiment I identified ways to improve and it is proof that they worked as each experiment improved on the previous one. I would consider my experiment very successful as I have improved on my error until a final inaccuracy of merely 0. 373% in the power. If I were to perform the experiments again, I would include more values of 1/V so that I could construct an even more accurate line of best fit, and hopefully achieving the exact value for the lens's power.