Evaluation:

I will firstly work out the overall experimental error and how far it was from the true value, using the same formula used in the preliminary.

$$=2\pi\sqrt{\frac{\frac{1}{12}x0.201\ x0.204^{2}x32}{44.7x10^{9}x\pi x0.00049^{4}}} = 10.36$$

Therefore the total error from what the true value should be is [(11.368-10.36)/11.368] x 100= 8.89%

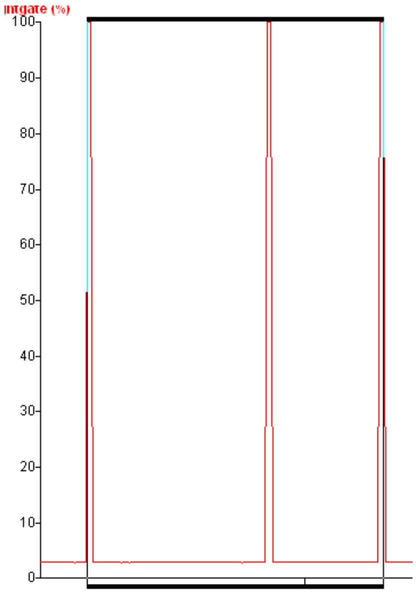
This shows that my experimental results had an overall 8.89% error, where as in my preliminary I had an error of 15.89%, therefore I believe my improvements have improved the accuracy of my results.

From the 2 graphs above I can see that the result for 0.1 meter length seems to be the furthest away from the line of best fit, and may be considered as an anomalous result, however I don’t think it’s necessary to remove this result. The reason for this error could be any of the ones stated below, or possibly as it was the first reading I took, there could have been an initial fault in my experiment set up.

Even though I have improved the accuracy of my experiment there are still many errors which will have decreased the accuracy of my results. I will now state each one and estimate percentage errors for the reading error and also experimental error if possible.

- The meter ruler is accurate to ±0.5mm, therefore error on the smallest length would be (0.5/100)x100=0.5% and largest length (0.5/500)x100=0.1% . Therefore the error here can be no greater than 0.5%, so this is not a very significant error. However there is also a large span for experimental error, the length of string may not have been fully straight due to not being stretched fully, and also every time I change the length of the wire there will be a new random error generated. These can’t be avoided but overall these experimental errors may have been about 0.3cm , meaning the maximum error would be (3/100)x100=3% error, which is therefore very significant.

- The micrometer is accurate to ±0.005mm, therefore the error on my diameter of 0.49mm was (0.005/0.49)x100=1.02%, this shows a reduced error that of the preliminary, however a 1% error on the diameter can still be a major factor. This is due to the fact that the diameter is raised to the power of 4 in the equation. Therefore a very small change in the diameter may cause a larger than expected change in time period. Therefore I think the error of the diameter may have been the most significant error. If the diameter had been 0.48mm then the percentage error calculated above would have been only 5%, this shows how significant it was. The experimental error is also a factor due to the fact I had to twist two wires together to make a larger diameter. After taking 5 readings of the diameter, which were 0.49, 0.49, 0.48,0.49,0.47mm. I decided to use 0.49 as my value being the mode, however the fact that the diameter varied slightly meant there was an error. The range was 0.02mm, this could therefore have caused an error (0.02/0.49)x100=4.08%, therefore also very significant. Also the fact that I twisted two wires together, after some use, parts of the wire may have untwisted meaning the diameter would change again, this again contributes to the error above.



One of the major improvements was the recording of the time period. Using the light gate and an interval of 0.01seconds, the error was only to ±0.005seconds therefore the maximum error was (0.005/4.15)x100=0.12% and smallest error (0.005/8.40)x100=0.060%, this shows the improvement in recording the time period, where the human error is eliminated. However one small difficulty in taking the actual reading was knowing where to take the intervals. However there was also an experimental error where I had to estimate where the middle of the peak was, and this was slightly different for each run. However the peak was never longer than about 0.1 seconds, therefore the largest error would only have been (0.1/4.15)x100=2.4%. Again the experimental error is greater than the reading error, but the overall error was much lower than the preliminary.

- The value for shear modulus I used was 44.7x10^9GPa, however when doing research for this value, there were more than one of the same value, so there is no guarantee that the value I used was the value of my copper wire. The following website gave me a range of 40-47GPa.

http://www.efunda.com/materials/common_matl/common_matl.cfm?MatlPhase=Solid&MatlProp=Mechanical However, as the shear modulus is so large the error will be so small. It's difficult to work out the percentage error, therefore my error is just a range of 40-47GPa

- The scale is accurate to 0.05 grams so error on my bar was (0.05/196.3)=0.0254% error, there is no real experimental error in this reading.

The percentage errors above show that the overall error should have decreased, where time period is now a very small error, reduced from about 8% in the preliminary.

From my log log graph I got 0.4532 as my gradient. However theoretically it should have been 0.5. I also found that if I exclude the 0.1meter length and time period from the log log graph then my gradient would change from 0.4532 to 0.4963, which is very close to 0.5. This again shows that the 0.1m length may be considered as an anomalous result. To work out the percentage error for the gradient, I have to consider the error on the time period and the length, by adding these errors. Therefore the error on the gradient is approximately [{(0.5+3)/2}+{(0.12+2.4)/2}]=3.01%, this was using the average of the reading and experimental errors.

From the percentage errors above I believe the main source of error was the diameter of the wire, this had the highest total percentage error and as seen from the equation any error in the diameter will cause a major difference due to being raised to power 4.

Reliability of results

Time Period(seconds)				
Experiment Results	**T=11.368 x l^0.4532**	**T=2π(l/K)^0.5**	**Difference1**	**Difference 2**
4.20	4.00	3.27	0.19	0.92
4.65	4.81	4.01	-0.16	0.64
5.23	5.48	4.63	-0.25	0.60
6.16	6.06	5.18	0.10	0.99
6.51	6.59	5.67	-0.07	0.84
7.10	7.06	6.13	0.04	0.98
7.50	7.50	6.55	0.00	0.95
8.04	7.92	6.95	0.12	1.09
8.38	8.30	7.32	0.07	1.05

The table above shows my actual experimental results in the first column. Then the expected experimental result using the relationship I found in the second column. The third column is the theoretical result using the equation derived in my research. The forth column shows the difference between the values I obtained in my experiment and the expected values from the relationship I determined through experiment. And as you can see the maximum difference is only 0.25 seconds away. Therefore this relationship has very strong correlation, as shown on the previous graphs. However, in the fifth column, which shows the difference between my experimental value and the theoretical value according to the equations I noticed that I was constantly above the expected value. Also I was constantly about 1 second above for almost every length measured. From this I came to the conclusion that there must clearly have been some sort of systematic error. This will have increased the time period by approximately a constant amount each time. From my error analysis earlier I believe this may have been the diameter of the wire, as even being 0.1mm away from the true value will cause a large change in time period, which is what may have happened.

Improvements to final method

If I was to perform this experiment again I would try to further decrease the reading and experimental errors in the following ways.

- As I found diameter to be the largest error I would ensure that the wire I am using has a constant diameter, by using only one wire and ensuring it has not been stretched in any way before using it. I would then also measure the diameter of the wire at least 5 times for each length, as when the length is decreased the weight will be pulling down on a wire of shorter length, and may stretch the wire more. Therefore I will record the diameter for each length I do and if it changes take these new diameters into consideration.

- The shear modulus of copper ranged from 40-47GPa, therefore I was unable to even come up with an actual error for this. Therefore to reduce the error to almost zero I would measure the actual shear modulus of the copper wire I am using to do the experiment. This can be done using the following formulae $G = E / [2(1+v)]$
  where G is the shear modulus, E is the tensile modulus, and v is the Poisson's ratio of the material. http://www.ides.com/property_descriptions/ISO537.asp