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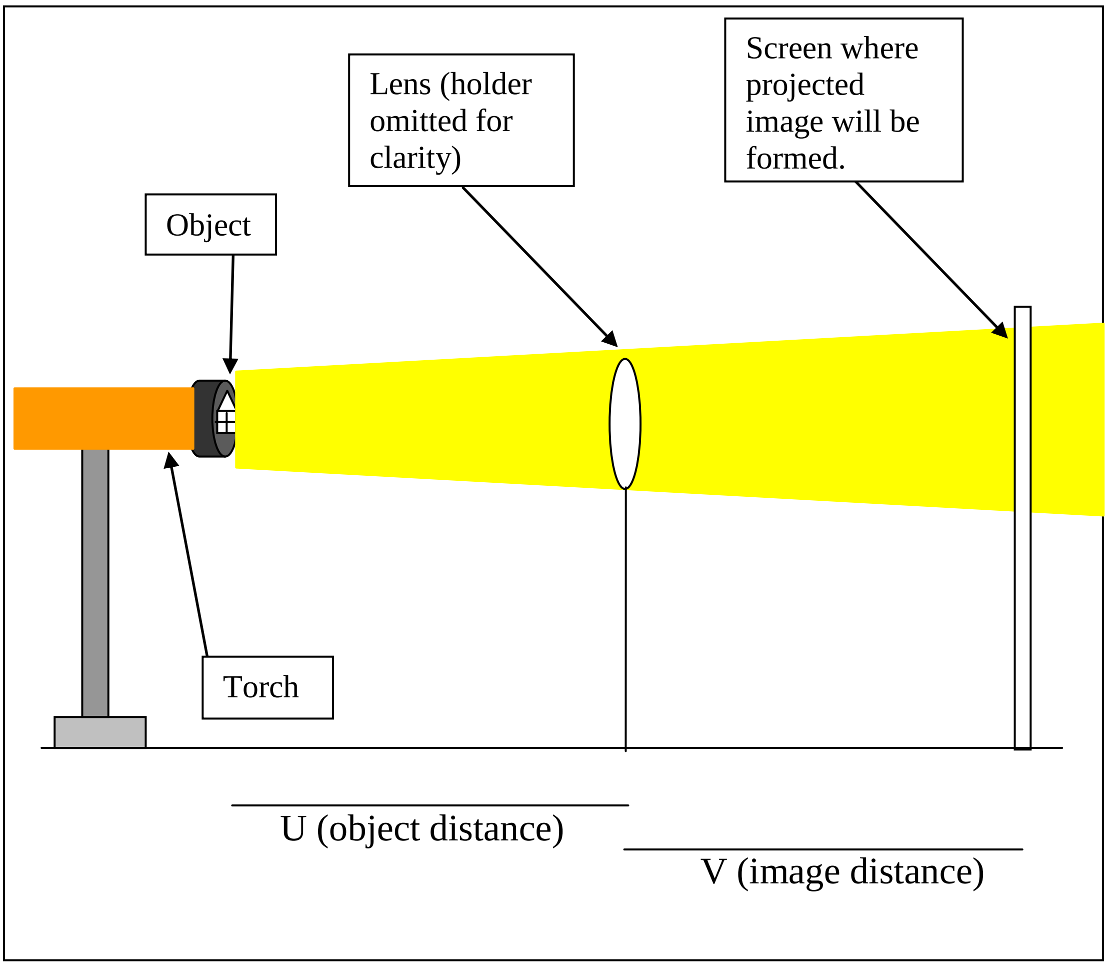
Introduction

In this experiment, we are looking at light and how it can be manipulated and refracted using lenses and prisms. We looked at how we can use lenses to magnify an object and project it onto a screen using light. We took measurements from the lens to the object and from the lens to the screen; we also measured how big the projected image was. From this we were able to use the lens maker's formula to find the focal length of the lens and check against the manufacturers stated focal length. We would also be able to draw up a ray diagram to confirm this from these results.
In the second part of this experiment we looked at prisms and laser light to see how the light can be refracted to different angles and by measuring the angles of refraction, we can work out the refractive index of the prism material.
Below shows a basic diagram of the formation of the apparatus.

[Fig 1.0 apparatus set-up part 1]



Method

The equipment for this experiment comprised of:

- A torch with simple symbol stuck onto the glass cover
- 2 different lenses, fat and thin lens
- A clamp-stand and measuring rail for which the clamp-stand was attached to.
- A white screen for the image to be projected onto it
- A meter stick to measure distances
- A prefabricated board made for the second part of the experiment
- A3 size piece of paper to project the laser dot onto
- A protractor
- A wooden sight to line up the beam for a more accurate result.

We started by aligning the equipment; we placed the screen at the end of the measuring track and the torch at the opposite end with the first lens in a clamp in between these two apparatus. We then had to find the minimum distance between the lens and the torch whilst still projecting a focused image on the screen. This was done by leaving the screen at the end of the rail and the torch at the opposite end and simply moved the lens from the torch end toward the screen until a focused image was formed. We then measured the distance between the lens and the torch and between the lens and the projected image on the white screen we then used the lens maker's formula to calculate to focal distance of the lens and compared our results to the manufactures focal length claim. Knowing then height of the symbol on the torch and by measuring the height of the projected image we were also able to determine the true transverse magnification of the lens being used. Then, using the formula

$$m = \frac{v}{u}$$

We were able to compare the two ways of working out the value of magnification.

We repeated this procedure with different object lengths and then drew up a graph of the results and compared this to the results expected from the lens maker's formula.

We then repeated this for the fatter lens.

We then investigated what happened when we held both lens together to form an image on the screen we tried it both ways and noted the difference between the two.

On the second part of this experiment, we were looking at prisms and trying to work out what the refractive index of the prism was.
We started by placing a sheet of A3 paper on a flat bench then we placed the prefabricated apparatus at the top left of the paper as shown in fig 1.1.
We then set the protractor on the wheel to 90˚ and lined it up with the mark on the apparatus.
Then we had to create a reference point to measure our angle from so we removed the prism and switched on the laser then using the sighting bar we aligned the laser such that it was beaming down the edge of the piece of paper now when we replaced the prism into its v shaped slot on the rotary table the angle of incidence to the prism was 0˚.
We then used another piece of paper as a screen and rotated the wheel clockwise until we saw the red dot on the right hand side we then took note of the protractors reading on at the wheel. From this we calculated our new angle of incidence by $\vartheta 1 = 90 - \textit{protractors reading}$.
In this case, it was 26˚. We then had to find the angle of deviation, to do this we simply got our sighting bar and located the laser beam in the centre of the face nearest to the prism then moved the furthest face until the laser spot appeared central to it we then marked the paper and wrote down the scale mark on the line so as to know which line represented which scale mark.
We then rotated the protractor 5˚clockwise and repeated the procedure until the dot had gone down the screen to the left and came back again on the right and disappeared.
To work out the refractive index of the material used for the prism we first had to draw a graph of the angle of deviation against each scale mark or ø1, as it will be known. From the graph, we can establish what the minimum angle of deviation is, then using the equation

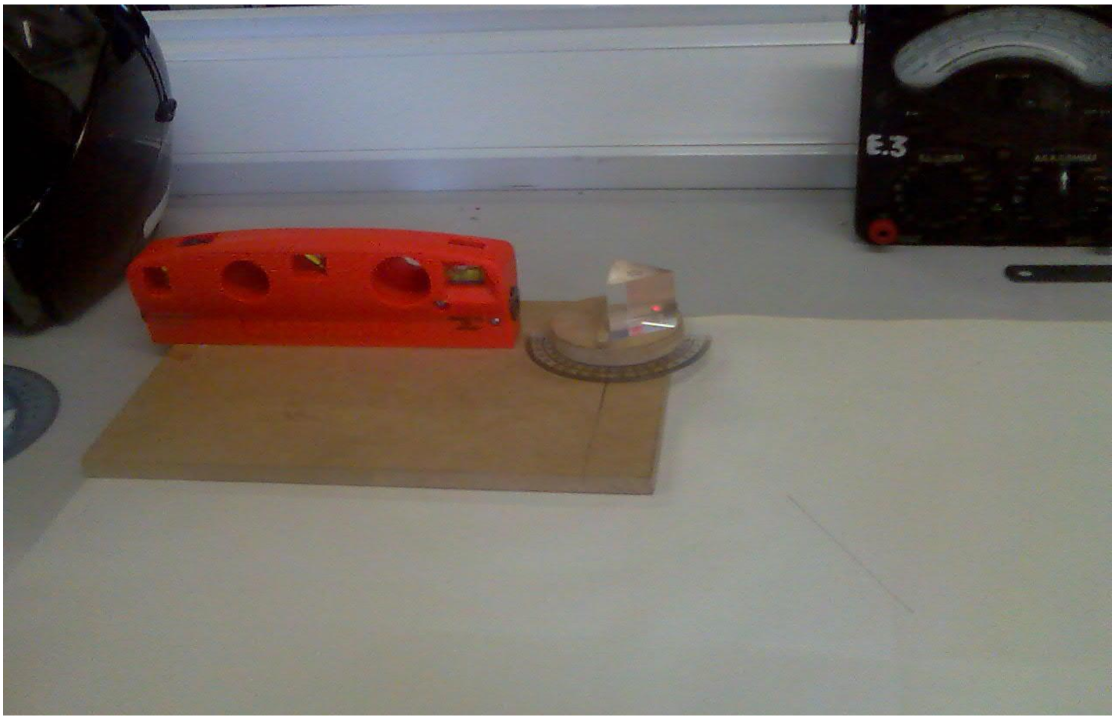
$$np = \frac{\sin(\frac{D\min + A}{2}}{\sin(\frac{A}{2})}$$

Where A= prism angle (60º)
Dmin=minimum angle of deviation
Np=refractive index

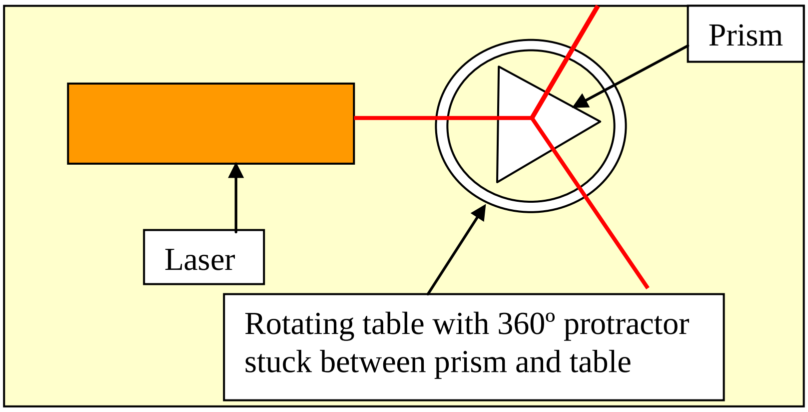
We can work out the refractive index and therefore work out what material the prism could be made from.

Diagrams of apparatus

[Fig 1.1 shows the apparatus set-up for the second part]

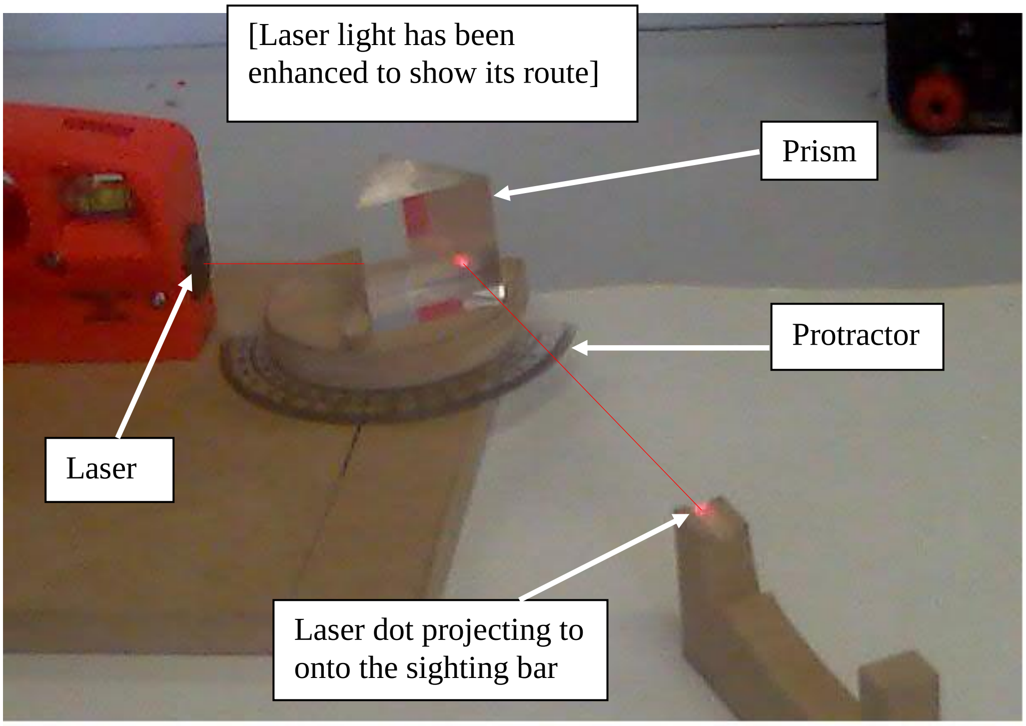


[Fig 1.2 shows how light is refracted in a 60º prism]



Diagrams of apparatus

[Fig 1.3 shows the laser refracting through the prism]



Theory

The theory behind this experiment is relatively simple; to find the focal distance of a lens you can use the equation:

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

Where u=object distance
V=image distance in focus
F=focal distance

We were measuring the distance between the torch and the lens and between the image screen and the lens to give us our u and v values then it's a case of putting the numbers in and finding the focal distance.
To find out the magnification of the lens you can either use the equation?

$$m=\frac{v}{u}$$

Alternatively, to obtain the actual magnification or mtrue as its known by simply dividing the height of the image by the height of the actual object thus giving:

$$M_{true}=\frac{Himage}{Hobject}$$

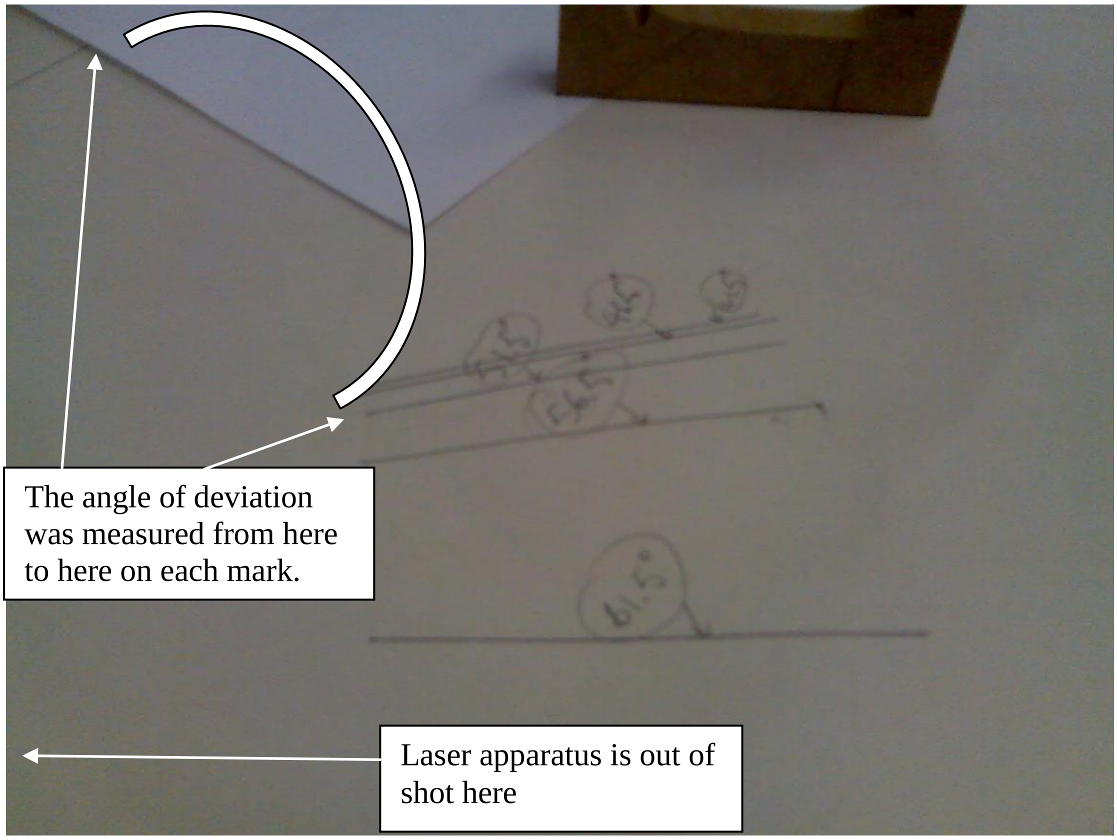
This gives us the amount of magnification the lens has.
When we draw a graph of our results with 1/u vs. 1/v we can find the focal distance by finding the intercept of the graph and inversing this to give us our focal point, we have to inverse the intercept number as the x and y values are given as inverses.
In the second part of the experiment we are trying to find out the refractive index of the material of the prism to do this we can use the equation:

$$np=\frac{\sin((D\min+A)/2}{\sin(60/2)}$$

Where Dmin = minimum angle of deviation
A= prism angle (in this case 60º)
Np= refractive index

To do this we need to find the minimum angle of deviation to do this we need we need to follow the method of the experiment and find the full range of angles of incidence and angles of deviation to enable us to plot a graph to give us clear visual representation of where the minimum angle of deviation is. In this case, our lowest was 36.5º each time we marked the paper as we rotated the wheel clockwise 5º as shown in the picture below.

[Fig 1.4 shows our markings for the angles of deviation]



Results

[Fig 1.5 below are the tables of results for lens 1(thin) of the experiment]

Test no.	U (Object distance mm)	V (Image distance mm)	F (Focal distance mm)	Ho (Height of object mm)	Hi (Height of image mm)	M_{true} (Actual magnification)	Magni $\frac{v}{u}$
1	193	715	151.9	25	97	3.88	3.7
2	205	602	152.9	25	76	3.04	2.93
3	222	486	152.3	25	57	2.28	2.18
4	273	327	148.7	25	30	1.2	1.19
5	243	403	151.59	25	43	1.72	1.65
6	210	543	151.43	25	56	2.24	2.58

To find the focal distance we need to use the lens maker's formula, which states that:

$$\frac{1}{u}+\frac{1}{v}=\frac{1}{f}$$

This is the same as saying $u^{-1}+v^{-1}=f^{-1}$
So to work out our focal distance for test 1 we would write:

$$\frac{1}{193}+\frac{1}{715}=\frac{1}{0.0065799485}=151.97$$

We repeated this to obtain all values of focal point on each test.
The values of magnification were obtained as follows:

$$\frac{Himage}{Hobject}=Mtrue$$

So for test 1:

$$\frac{97}{25}=3.88$$

and to obtain the magnification using u and v:

$$M = \frac{v}{u}$$

So with test 1 figures we get:

$$\frac{715}{193} = 3.7$$

We can clearly see that the focal distance for this lens is around 150mm or 0.15m the packet that it came in said it was 0.1m but this could have easily been jumbled up with other lenses so its hard to say whether it was the correct packet for that particular lens.

[Fig 1.6 shows table of results for lens 2(fat experiment 1]

Test no.	*U (mm)*	*V (mm)*	*F.D (mm)*	*Ho (mm)*	*Hi (mm)*	*Mag*	*Mag V/U*
1	*65*	*200*	*49.05*	*25*	*81*	*3.24*	*3.07*
2	*58*	*360*	*49.95*	*25*	*153*	*6.12*	*6.2*
3	*81*	*120*	*48.35*	*25*	*32*	*1.28*	*1.48*
4	*53*	*482*	*47.74*	*25*	*230*	*9.2*	*9.09*

We obtained the focal distance the same way as before using the lens maker's formula. We also used the same methods to work out magnification.
We can see that the focal distance for this lens is around 49mm which isn't far from the 50mm stated on the lab sheet. We can see our calculations work regarding the magnification as the focal distance always remains the same even though the magnification and distances have changed.

[Fig 1.7 shows table of results for prism experiment]

Data point	Protractor reading	Angle of deviation	Angle of incidence
1	63.5	53.5	26.5
2	58.5	43	31.5
3	53.5	39	36.5
4	48.5	37	41.5
5	43.5	36.5	46.5
6	38.5	36.5	51.5
7	33.5	37.5	56.5
8	28.5	39	61.5
9	23.5	40	66.5
10	18.5	42.5	71.5
11	13.5	46	76.5
12	8.5	48.5	81.5

To calculate the angle of incidence we took the starting protractor reading which, was 90˚ and subtracted the new reading after the wheel was rotated into position so for the first position we have:

$90^{\circ}-63.5^{\circ}=26.5^{\circ}$

this gives us our angle of incidence.

If you look at the graph showing angle of deviation against angle of incidence we can see that our minimum angle of deviation is 36.5˚ from this we can input this into the equation and find our refractive index to determine what material the prism is likely to be made from.

$$np = \frac{\sin((D\min + A)/2}{\sin(60/2)}$$

$$np = \frac{\sin((36.5 + 60)/2}{\sin(60/2)}$$

=1.492