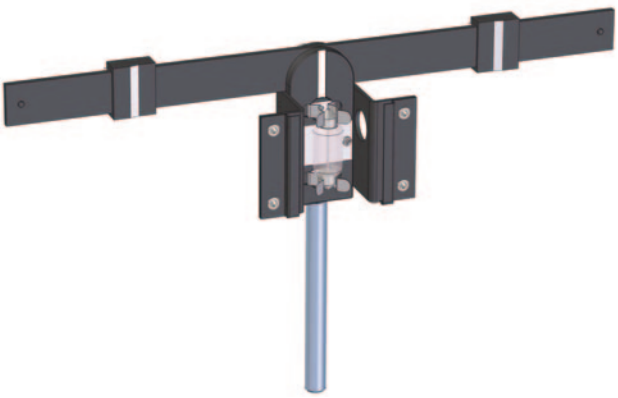
Determining wavelength

14.12.10 | Ae 3240.00



Principle

The apparatus is placed so it can be operated from behind, with a distance of about 3.5 meters to the double slit. In order to make it easier to measure the distance accurately, the double slit can be mounted in a Slits and filter holder (Item no: 295080).

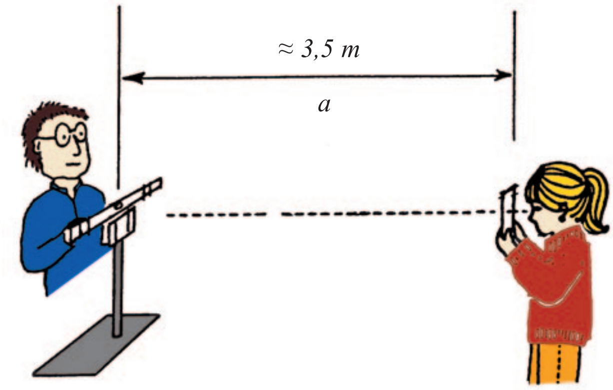
The frame with the double slit is oriented with the rectangular window upwards, making it possible at the same time to see the ruler through the window and the festoon lamp through the double slit.

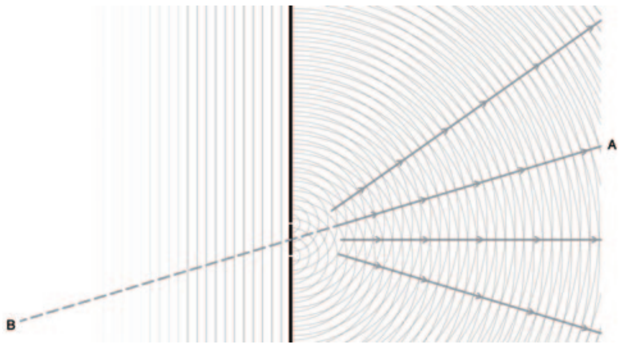
Just before the light from the bulb hits the double slit, it spreads largely like a plane wave.

Behind the double slit it spreads as two circular waves interfering with each other.

In points that have a difference in distance to the two individual slits of 0, 1, 2, 3 … whole wavelengths, the two circular waves will move in step and add to each other – this is called constructive interference

In points that have a difference in distance to the two individual slits of ½, 1½, 2½, 3½ … wavelengths, the crest of one wave will meet the trough of the other, summing up to nothing – this is called destructive interference.





The figure shows how points with constructive interference occur on straight lines. In other words, rays of light spread in these directions. Between the rays of light, lie regions of destructive interference, i.e. darkness. The transition between light and darkness will in fact be gradual.

Now, if you look through the double slit towards the light bulb, the ray of light marked A will appear as a spot of light coming from a direction (marked B) that points a little away from the direction of the bulb. There will be numerous of these spots on both sides of the bulb.

The average distance between these spots of light is determined by means of this apparatus.

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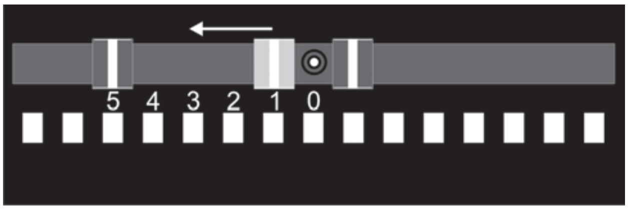
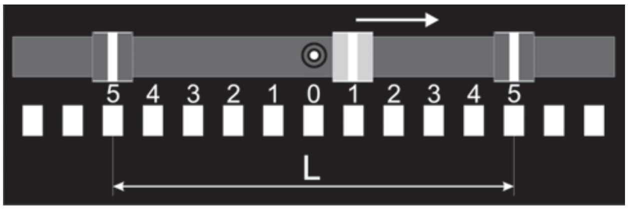
Procedure

The room must be blacked out. Connect the bulb to a 12 V power supply. A color filter (e.g. the red one) is mounted in front of the light bulb. With a tape measure, determine the distance a; write it down.

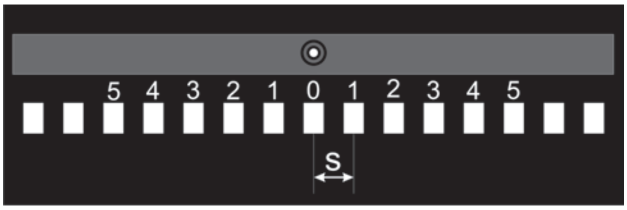
It takes two persons to make the measurements: One looks through the double slit and directs the other, who operates the apparatus.



Start with the two movable markers as close to the middle as possible. The assistant moves one of the markers slowly outwards. Say “stop” when the line of the marker stands right above the centre of the light spot number 5. Repeat to the other side.



The distance L between the two markers can now be determined, and the average distance s between the light spots can be calculated (divide by 10).



The distance between the apparatus and the double slit is called a and the distance between the two slits in the double slit is called d. For the double slit provided, $d = 0.1$ mm.

The wavelength λof the red light can now be calculated by this formula (see “Theory”):

$$\lambda = \frac{s \cdot d}{a}$$

Extension

Repeat the experiment with the blue color filter (change roles). In order to find s as accurately as possible you may want to let L span more than 10 times s.

As an option, a yellow and a green color filter can be obtained (item number 3085.10 and 3085.20).

Warning: Never use the method of looking through a double slit to determine the wavelength of light from a **laser.** It can result in permanent damage to the eye.

Example

Assume the distance a to be 3 m = 3000 mm, and the distance s to be 2.0 cm = 20 mm.

The wavelength is then calculated like this:

$$\lambda = \frac{s \cdot d}{a} = \frac{20\,\text{mm} \cdot 0{,}1\,\text{mm}}{3000\,\text{mm}}$$

$$= 6{,}67 \cdot 10^{-4}\ \text{mm} = 6{,}67 \cdot 10^{-7}\ \text{m} = 667\text{nm}$$

As wavelengths in the interval 620–750 nanometer are perceived as red, this seems reasonable.

Theory

In the figure, A marks a point with constructive interference. Notice that the distance from A to the lower slit is exactly 1 wavelength longer than to the upper.

Constructive interference also occurs on points situated on the centre line – here the difference in distance is always 0.

Try yourself to find a point with constructive interference that has a difference in distance of 2 wavelengths.

The “extra” wavelength from the slower slit on the way to A makes up one of the smaller sides of a right-angled triangle in which the hypotenuse is exactly the distance d between the individual slits.

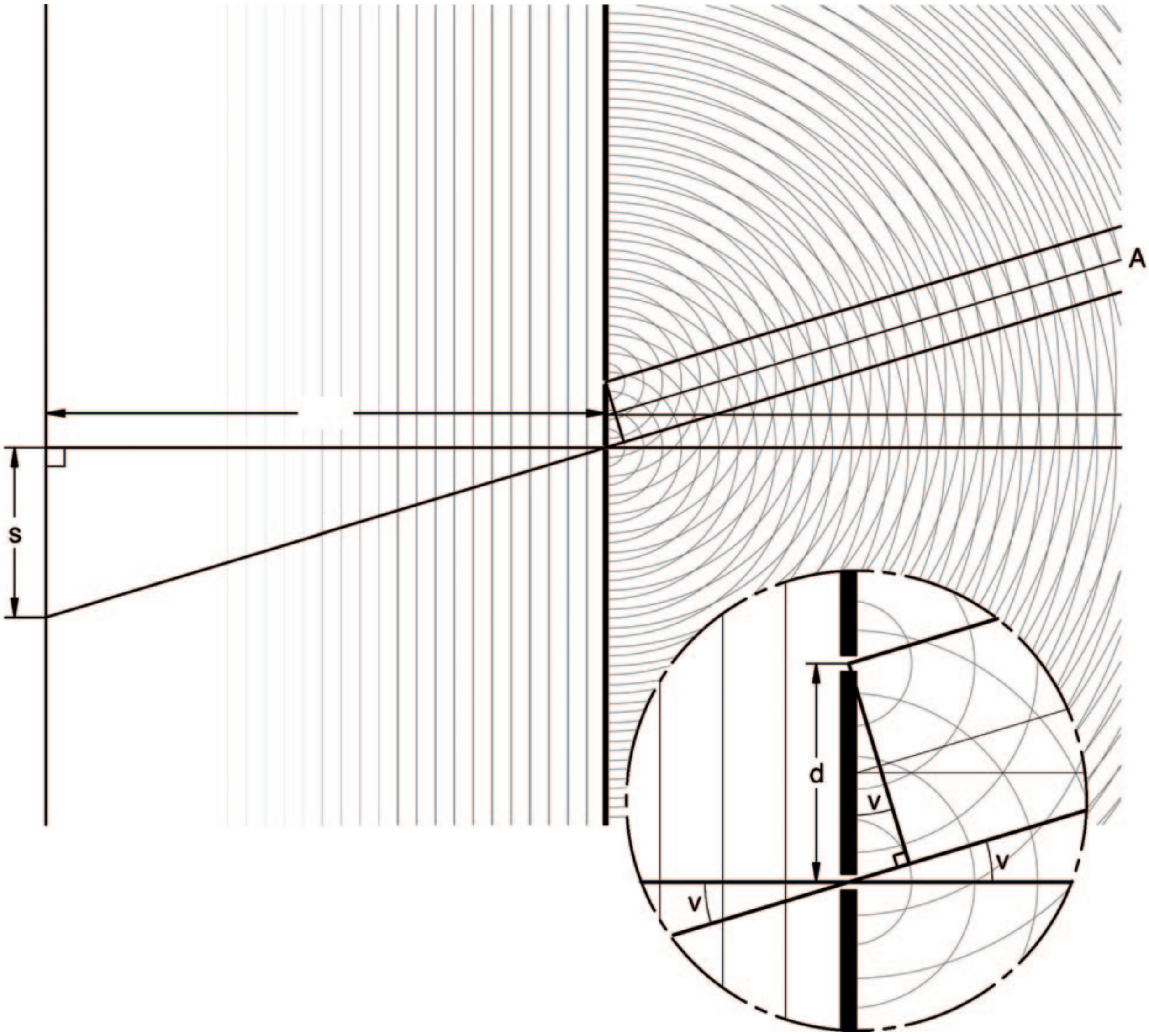
The ray of light heading towards A has been deflected by an angle of v. As illustrated in the figure above, v also appears as one of the angles in the small triangle.

Thus the following relation holds good in the small triangle: $\lambda = d \cdot \sin(v)$

This result may be generalized: Constructive interference would also appear if the difference in distance was 2 or 0 wavelengths – or 3 – or any arbitrary whole number. In the small triangle this corresponds to letting the small side no longer be equal to λ, but λ multiplied with some integer n.

This means, that the condition for constructive interference in the direction v in general can be written as:

$$n \cdot \lambda = d \cdot \sin(v)$$



The ray of light going towards A will be perceived as coming from a point on the apparatus. The distance to the apparatus is as mentioned called a, and the distance from the centre spot to the first deflected spot of light is called s. Thus we have a large right-angled triangle with the smaller sides a and s that also has v as one of its acute angles.

It is obvious that $\tan(v) = \frac{s}{a}$

This expression can in principle be used to find v, which thereupon can be inserted in the formula above. But as v in this experiment is quite small, we can use an **approximation**.

As mentioned in the example section, s has the size of a few centimeters. But to do a “worst case scenario”, we will consider the largest value on the scale of the apparatus. It is 14 cm. With a distance a of 3 meters, we have v = 2.7°.

Now a calculator quickly gives us tan(2.7°) = 0,047159 and sin(2.7°) = 0.047106.

These numbers only differ by 0.1 %. (This corresponds to reading the meter scale on the apparatus with a precision of about 0.1 mm!)

Try for yourself with an angle of e.g. 0.5° – the relative difference decreases with smaller angles.

Therefore, as a good approximation, tan(v) can be substituted for sin(v) in the formula. And as s is the distance to the first deviated spot of light, n = 1. All in all we get:

$$\lambda \approx d \cdot \frac{s}{a}$$

– which is just the expression that was used in the “Procedure” section. Even though it is an approximation, the precision is far better than that of the measured values s and a.

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