Chapter 6 Wave Behaviour

Demonstration 10D 'Loudspeaker and baffle'

You will need

oscilloscope
two simple microphones
SPST switch
small loudspeaker (about 80 mm in diameter)
retort stands, three bosses and three clamps
signal generator
prepared baffle with a hole equal in size to the loudspeaker cone

Practical Advice

This introductory demonstration of cutting off part of a sound and thereby making it louder is suggested to get students discussing the effects of superposition and coming up with plausible explanations of the effect they observe. The demonstration can be used as a 'taster' before embarking on microwave work and then revisited when the class has more confidence in the ideas of superposition.

A slinky spring can be used to show compressions travelling in one direction as rarefactions are travelling in the other.

Having seen the demonstration the students should be able to explain the effect in terms of superposing waves and realise that this is an example of 'less can mean more'.

Technician: The baffle needs to be made. It can be a square card three or four times the diameter of the loudspeaker with a circular hole cut in the centre of approximately the diameter of the cone. The effect depends on the wavelength of the sound being larger than the diameter of the loudspeaker cone.
A software-based oscilloscope can be used.

Alternative Approaches

For a bright class this activity could be set as an open-ended question.

Presentation 20P 'Path difference and phase differences'

You will need
signal generator
loudspeaker
two microphones
oscilloscope
metre rule
leads

Practical Advice
This demonstration is a natural follow-up to the opening puzzle in which a baffle placed over a loudspeaker increases the loudness of the sound. Here students see the effect that changing path difference has on the phase relationship between the two received signals. This gives further opportunities to use the language we are trying to develop (phase, phase difference, path difference) and to focus on sound as a longitudinal waveform represented on the oscilloscope trace as a transverse oscillation.

These experiments can be ruined by reflections from other objects in the room. If clear traces are not obtained, try draping old curtains around the apparatus.
This should be used to reach a value for the wavelength of sound which can be corroborated using c = f l.

Alternative Approaches
Confident students could be given this activity as an opportunity to make a presentation.

Experiment 30E Hearing superposition

You will need

signal generator
two loudspeakers
leads
microphone
oscilloscope

Practical Advice

Here we have two quick but memorable experiments. 1500 Hz is a rather painful frequency to listen to, but allows a clear difference between maxima and minima to be heard.

It may be useful to discuss why this experiment is best performed in the open air to get students to begin thinking about further interference due to reflections.
You may decide to postpone the quantitative part until work on superposition is well under way.

Alternative Approaches

Photographs of students standing along lines where the sound from two sources is loudest can provide an interesting basis for a question to explore the same ground.

Experiment 40E Beats: Mixing waves in time'

You will need

two signal generators
two loudspeakers
oscilloscope
microphone
4 mm leads

Practical Advice

Some care is needed with this experiment. It is difficult for two or more groups to do it in the same room! It could well be part of a circus involving other activities – not necessarily all practical ones.

Students may need guidance in setting up the apparatus. Some types of signal generator have high- and low-impedance outputs: the low-impedance output is required. Similarly, help may be needed with setting up the oscilloscope.
A cheap crystal microphone is more than adequate for this experiment. It should have a reasonable output level (10–100 mV).

The simplest way to explain beats is to think of the two oscillations as phasors spinning at slightly different rates. The faster one will 'lap' the slower one at intervals. The sound will be at its lowest amplitude when the two phasors point in opposite directions (but this is for later – towards the end of this chapter).

Presentation 50P 'Slinky demonstration'

You will need

slinky spring with 'tags' every 10 turns
signal generator
vibration generator
retort stand, boss and clamp

Practical Advice

These demonstrations need not be formally worked through. It is useful to have a slinky available when introducing wave motion and wave superposition, to demonstrate quickly and visibly the wave effects being considered.

It is useful to remind students that a slinky is just a 'slowed down' tow-rope or tow-bar. All changes in forces along a tow-rope or tow-bar are transmitted by mechanical waves. So is the force which makes the back of a trolley start moving when the front is pulled or pushed. Use of a 'string telephone' helps to bridge these ideas.

Alternative Approaches

This could be used as a student presentation. If equipment is available a video recording can be made by fast-working students. This can be used to show what's going on in slow motion or freeze frame. This can be particularly effective in being certain about what happens to transverse pulses.

Experiment 90E 'Interference patterns in a ripple tank'

You will need
ripple tank kit
hand held stroboscope

Practical Advice
The experiment can be performed as a demonstration, as a class experiment or as part of a circus.

If the students have not used a ripple tank before this experiment it is worth spending a little time on. Students should appreciate that there are lines of maxima and minima at particular angles. Young's interpretation of the interference of light draws heavily on the picture developed here.

This observation can be linked to the superposition of sound waves from two loudspeakers, although the longitudinal nature of sound waves must be stressed once again. A simulation of what is going on may help weaker candidates and can be used to discuss with the class what they have seen. Some students will find it easier to 'see' the interference effects having used the simulation because they have a better idea of what they are looking for.

Alternative Approaches
If you have a demonstration (projecting) ripple tank it is possible that the effect will be seen more clearly than with a student tank.

Presentation 60P Superposition of microwaves'

You will need

microwave transmitter
microwave receiver
metal reflector (about 0.3 m square)
digital multimeter, used as microammeter
diode probe
metre rule
leads

Practical Advice

This presentation can be performed by all students if sufficient apparatus is available. If this is not the case, students can perform a 'circus' of experiments (see 'Alternative Approaches') and use the presentation as a useful exercise in summarising their findings to the class. Unwanted reflections can cause problems, but with reasonable care clear maxima and minima are observed. The wavelength of the microwaves may well be 28 mm. Useful discussions can centre around whether or not the presentation could give a wavelength precise to 1 mm.

It is important that students consider how coherence is achieved. In this case a single source is used so coherence is not a problem. Some other examples use two coherent sources (loudspeakers, ripple tank dippers).

Alternative Approaches

This can form part of a circus in which students do not perform every investigation but concentrate on one and have others presented to them by others. Alternatively, if time and equipment allow, the experiments can be set out in the laboratory in such a fashion that students visit one after the other, having been given a fixed amount of time on each activity.

This very much depends on the confidence of the students; weaker classes may prefer to have the teacher helping them understand one experiment well enough to describe what they see to their colleagues. On the other hand, stronger groups may relish the challenge of working through all the problems.

Presentation 70P 'Partial reflection of microwaves'

You will need
microwave transmitter
microwave receiver
metal reflector (about 0.3 m square)
4 mm hardboard sheet (about 0.3 m square)
digital multimeter, used as a microammeter
metre rule
4 mm leads
slotted bases (for reflectors)

Practical Advice
This presentation can yield very convincing results. It is a useful 'confidence building' activity for the weaker students as the measurements are easy and the calculation is straightforward. It is another good point to stress that 'more can be less and less can be more'.

Most books focus the explanation on path difference and wavelength. It is useful (see the Advancing Physics AS student's book, chapter 6) to focus also on time delays. This makes it easier to discuss thin films in which the radiation travels more slowly than in air.

Technician's note: The thickness of the hardboard is not crucial, but 4 mm does give clear minima.

Alternative Approaches
This can form part of a circus in which students do not perform every investigation but concentrate on one and have others demonstrated for them by colleagues. Alternatively, if time and equipment allow, the experiments can be set out in the laboratory in such a fashion that students visit one after the other, having been given a fixed amount of time on each activity.

This very much depends on the confidence of the students; weaker classes may prefer to have the teacher help them understand one experiment well enough to describe what they see to their colleagues. On the other hand, stronger groups may relish the challenge of working through all the problems.

Presentation 80P Superposition of 1 GHz radio waves'

You will need

dipoles and oscillator, 15 cm wavelength
digital multimeter, used as a microammeter
metal screen, 0.3 m square
4 mm leads
metre rule

Practical Advice

This experiment is analogous to a similar experiment with microwaves. It tends to be a little trickier to get results from and so, if used, should be given to confident students. It can therefore be omitted if equipment provision is a constraint.

Alternative Approaches

This can form part of a circus in which students do not perform every investigation but concentrate on one and have others demonstrated for them by colleagues. Alternatively, if time and equipment allow, the experiments can be set out in the laboratory in such a fashion that students visit one after the other, having been given a fixed amount of time on each activity.

This very much depends on the confidence of the students; weaker classes may prefer to have the teacher help them understand one experiment well enough to describe what they see to their colleagues. On the other hand, stronger groups may relish the challenge of working through all the problems.

Experiment 100E Standing waves on a rubber cord'

You will need
signal generator
vibration generator
stroboscope
rubber cord (0.5 m long, 3 mm square cross section)
two retort stand bases, bosses and clamps
four metal strips (as jaws)
two G-clamps, 10 cm jaws
leads

Practical Advice
This is a visually effective demonstration which can be done quickly or used as a basis for a more detailed consideration of standing wave phenomena and superposition. You may have done a similar demonstration in work on chapter 3 on signals, looking at the freezing of the motion. All students should understand that standing waves are another example of a superposition phenomenon produced by travelling waves being reflected and superposing with waves travelling in the opposite direction. The slinky demonstrations can be brought to bear on this discussion in addition to the computer animation.

Quick students can look deeper into the phenomenon, to consider why standing waves are only seen at certain frequencies.

Standings waves occur when all parts of the cord have a fixed phase difference between the waves passing through them. Consider a point at the middle of the string. When the cord oscillates at its fundamental frequency an antinode is seen in the middle. Transmitted and reflected waves are always in phase at this point so maximum amplitude develops. When the frequency of the oscillation is doubled a node forms at the centre. At the centre point the cord is not oscillating, even though waves are passing through it. This is because the waves are always superposing in antiphase. Animations may make things clearer and can be used at this point.

Alternative Approaches
Interested students could be encouraged to consider more complex standing wave phenomena.

Presentation 120P Standing waves in tubes: Kundt's experiment'

You will need
1000 cm3 glass measuring cylinder
signal generator
small loudspeaker and paper cone
cork dust

Practical Advice

Technician: place some cork dust (made by filing a cork) into the dry cylinder (a long closed glass tube can be substituted for the 1000 cm3 glass measuring cylinder). Arrange the cylinder horizontally and tap gently so that a thin layer of dust settles along the tube. Make a paper cone to channel the sound energy from the loudspeaker (approximately 50 mm diameter) into the cylinder.

Although this experiment was originally developed to measure the speed of sound, the main purpose of the demonstration is to help students understand standing waves in sound as areas of maximum and minimum pressure or velocity variation.

Alternative Approaches
There is a nice demonstration at the San Francisco Exploratorium using a tube on its side partly filled with water.

Presentation 110P Standing waves in sound

You will need
oscilloscope
loudspeaker (about 80 mm in diameter)
signal generator
microphone
metre rule
hardboard reflector (about 0.3 m square)

Practical Advice
This is a quick and simple demonstration for a pupil to perform in front of a class. 3 kHz is a sensible frequency to use as it produces waves of wavelength around 100 mm. However, it is not particularly comfortable on the ear.

The demonstration leads to a dependable value for the wavelength. It also gives another example of 'more can be less and less can be more' as the rise in amplitude of the signal at a minimum when the reflector is removed can be quite dramatic. Before tackling this presentation students should have observed standing waves on a cord or slinky. They can use the idea of nodes and antinodes but must remember that they are dealing with longitudinal waves – this is another chance to discuss that the trace on the oscilloscope shows variation in pressure so that pressure antinodes (where the pressure variation is the greatest) are seen.

These experiments can be ruined by reflections from other objects in the room. If clear traces are not obtained, try draping old curtains around the apparatus. When discussing sound, remember that the pressure antinodes are velocity nodes, and vice versa. There will be a pressure antinode but a velocity node where sound reflects from a hard surface or the closed end of a pipe. There will be a velocity antinode but a pressure node where sound reflects from the open end of a pipe. Clear thinking about the air rushing to and from pressure antinodes helps make this connection.

Alternative Approaches
This can be performed as part of a circus of experiments on standing waves in which each group of students moves from one piece of apparatus to the next.

Alternatively, the experiment can be performed and demonstrated to the rest of the class by one group of students.

Presentation 140P A stationary 1 GHz wave pattern'

You will need

dipoles and oscillator, 15 cm wavelength
digital multimeter used as a microammeter
metal screen, 30 cm square
slotted base
4 mm leads

Practical Advice

This is less easy to do than other standing wave demonstrations. With care it can yield pleasing results. It should, if used, be given to students with sufficient patience and skill to produce clear results.

Alternative Approaches

This can be performed as part of a circus of experiments in which each group of students moves from one piece of apparatus to the next.

Alternatively, the experiment can be performed and demonstrated to the rest of the class by one group of students.

Demonstration 150D More complicated standing waves'

You will need

signal generator
stroboscope
large loudspeaker
large metal ring supporting a disc of thin rubber or latex
three retort stands, bosses and clamps
three small G clamps
two 4 mm leads

Practical Advice

This should be performed as a quick demonstration if there is insufficient apparatus for all the class to use.
However, students should be given the opportunity to vary the frequency as the results are dramatic.

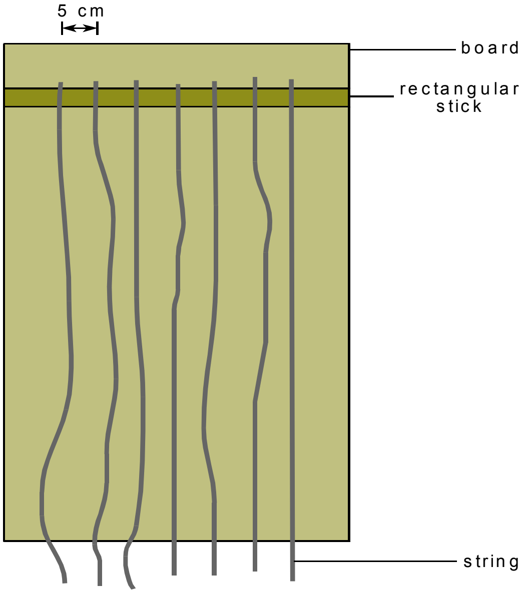
Technician's note: The copper wire ring, used in the first experiment, can be substituted by thinner steel wire. A solder joint produces a neat preformed loop, but may prove fragile.

The metal plate, used in the second experiment, can be circular or square. Use a size that produces clear patterns. This will need adjusting to match the power output of your vibration generator.

The rubber disc is best made out of pale latex so that a grid can be drawn on the surface, making the wave patterns more visible. The ring can be an embroidery ring, in which case the rubber can be stretched over the rim. You will need to experiment with the separation between the ring and the loudspeaker for optimal results.

Activity 170P: A focusing mirror with string

You will need
whiteboard
Blu-tack
adhesive tape
seven pieces of regularly marked out string



Practical Advice
This is intended as a concrete visual display of the way in which a parabolic mirror works. As such it is constructed as a presentation, for a small group of students to prepare an argument, with props, and then to present that argument to their peers. Similar situations for this type of 'string and board' model of optics can easily be devised. One which is of considerable teaching value is the model of the lens.
If you have parabolic mirrors, perhaps for concentrating thermal radiation, then these can be shown to set the scene for this task.

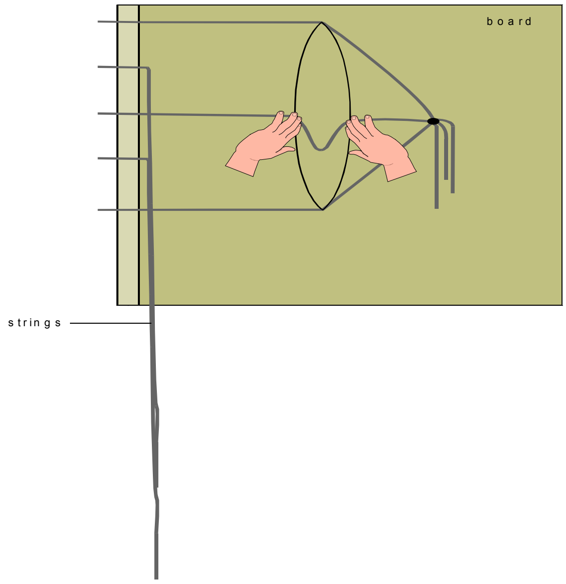
Several possibilities exist for manufacturing and preparing the apparatus for use. It is possible to prepare a board with the top ends of the strings already anchored. A suitable size of board is 60 cm by 40 cm for use with 125 cm long strings. It is a good idea to have the strings longer than strictly necessary so that the strings pass beyond the focus. The strings themselves can be made with the aid of a spray can and templates, or by using an alcohol based pen on string, or by cutting up 1 inch wide striped material across the stripes. At present string marked out in this way does not seem to be available!

You can show a similar effect with a parabolic mirror in a ripple tank.

Alternative Approaches
A software model which looks at trip times for the paths followed by the rays could be a supplement to this. Faster students could model such a situation using Pythagoras' theorem. From this it is possible to derive a parabolic relationship for the curve of the mirror.

Activity 190D: Demonstration String model of a lens

You will need
whiteboard
Blu-tack
adhesive tape
five pieces of regularly marked out string



Practical Advice
This is intended as a concrete visual display of the way in which a converging lens must be designed. As such it is constructed as a presentation, for a small group of students to prepare and deliver, with props, and then to present that argument to their peers. Similar situations for this type of 'string and board' model of optics can easily be devised. One that is of considerable teaching value is the model of the parabolic mirror.
The lens has already been met in some considerable detail in chapter 1 and it would be inappropriate to deal with it too extensively here.
If you have impressive lenses, perhaps recycled from old projectors, then these can be assembled to set the scene for this task.
Several possibilities exist for manufacturing and preparing the apparatus for use. It is possible to prepare a board with anchors for the strings. A suitable size of board is 40 cm by 30 cm for use with 125 cm long strings. It is a good idea to have the strings longer than strictly necessary so that the strings pass beyond the focus. The strings themselves can be made with the aid of a spray can and templates, or by using an alcohol based pen on string, or by cutting up 1 inch wide striped material across the stripes. At present string marked out in this way does not seem to be available!
You can show a similar effect with a lens in a ripple tank.
Faster students could calculate the thickness of the centre of the lens of given refractive index – perhaps concentrating on calculating trip times. Extending this to the whole of the lens can be discussed in principle.
Some may point out that a focusing effect may also occur if the waves differ in phase by a whole number of steps. This is true and the basis for achieving a concentration of the beam in another way: the phase plate.

Alternative Approaches
The central idea is trip time, so walking through this sequence, placing a variable-thickness medium in the way, may help some students to make progress.

Activity 210E: Experiment 'Interference patterns in a soap film'

Requirements
Mounted metal ring
Filament lamp, 12 V 48 W
Lamp holder, S.B.C. on base
Power supply, 0 – 12 V d.c. and a.c,, 6 A
Box to obscure lamp, with white paper diffuser

Practical Advice
Students will enjoy setting this up and should be encouraged to discuss what they see.

Having observed colours in polychromatic light it is useful to show them the effect in monochromatic light. When the film is observed in sodium light (from a lamp or a pencil) a series of yellow and dark bands are seen.

Technician's note: The apparatus used in this experiment requires a certain amount of simple construction. The ring is made of thick metal wire. A diameter of 8 cm is suitable. It is firmly attached to a wooden rod which is mounted in a slotted base or fixed to a block of wood.

A suitable bubble mixture is 64 parts water to 1 part washing-up liquid to 4 parts of glycerol.
A box to hold a lamp fitted with a diffusing screen is needed. The cut-out on the front of the box needs to be bigger than the ring, covered with white paper to diffuse the light.

Alternative Approaches
There are a number of photographs of colours in soap films on this CD-ROM.

Activity 220E: Experiment Diffraction by a slit

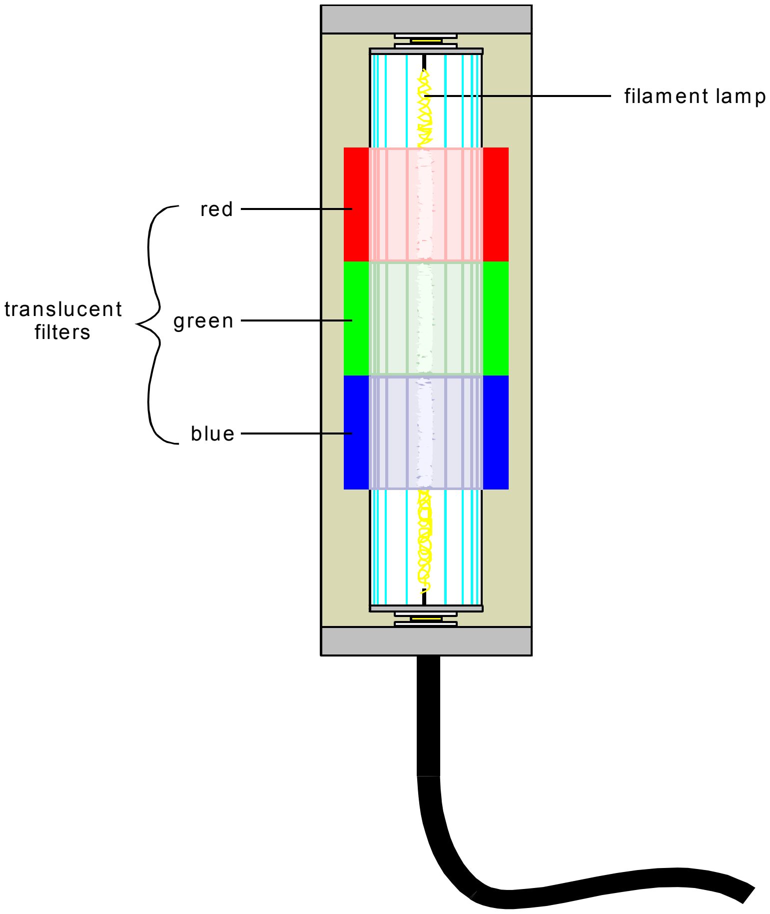
Requirements

Holder with two halves of a razor blade, to be used as a single slit, or as an adjustable slit
Mounted mains lamp with red, green and blue filters
White card, 5 cm square

Practical Advice
Students should be able to describe the single-slit diffraction patterns, which are quite clearly visible, and observe that red light spreads out the most. They should also observe that narrowing the slit broadens the diffraction pattern. This is a useful and quick introduction to the diffraction of light.

At this stage, it is only necessary that students observe the diffraction of light so that they can understand how interference gratings work. We are not expecting any analysis of diffraction at this stage.

Technician's note: A 30 cm (nominal) linear filament mains bulb can be vertically mounted, with sheets of red, blue and green coloured filters to change the colour of the light.



As this is a qualitative experiment the quality of the filters is not an issue.

Activity 230E: Experiment Measuring wavelength with Young's slits

Requirements

Lamp, 12 V 36 W
Power supply, 0 – 12 V,d.c. and a.c., 6W
Aquadag coated microscope slides
Pin and slit ruling apparatus
Two lengths of prepared square section downpipe
Three joints as supports
Cardboard collar
Ground glass screen
Red and blue filters

Practical Advice

This experiment is worth spending time on. Taking the trouble to prepare the apparatus stacks the cards in favour of a successful set of fringes being produced. A reasonable blackout is still required. The assembled apparatus is unwieldy and thought needs to be given to arranging the laboratory to ensure smooth movement in semidarkness and to prevent the lamp of one student preventing another from seeing fringes.

You will need to issue instructions which enable the students to calculate the spacing of their slits from the number of turns on the thread. This will depend on the construction of your ruling device. In any case allowing them to calculate the distance moved for 10 turns is good practice.

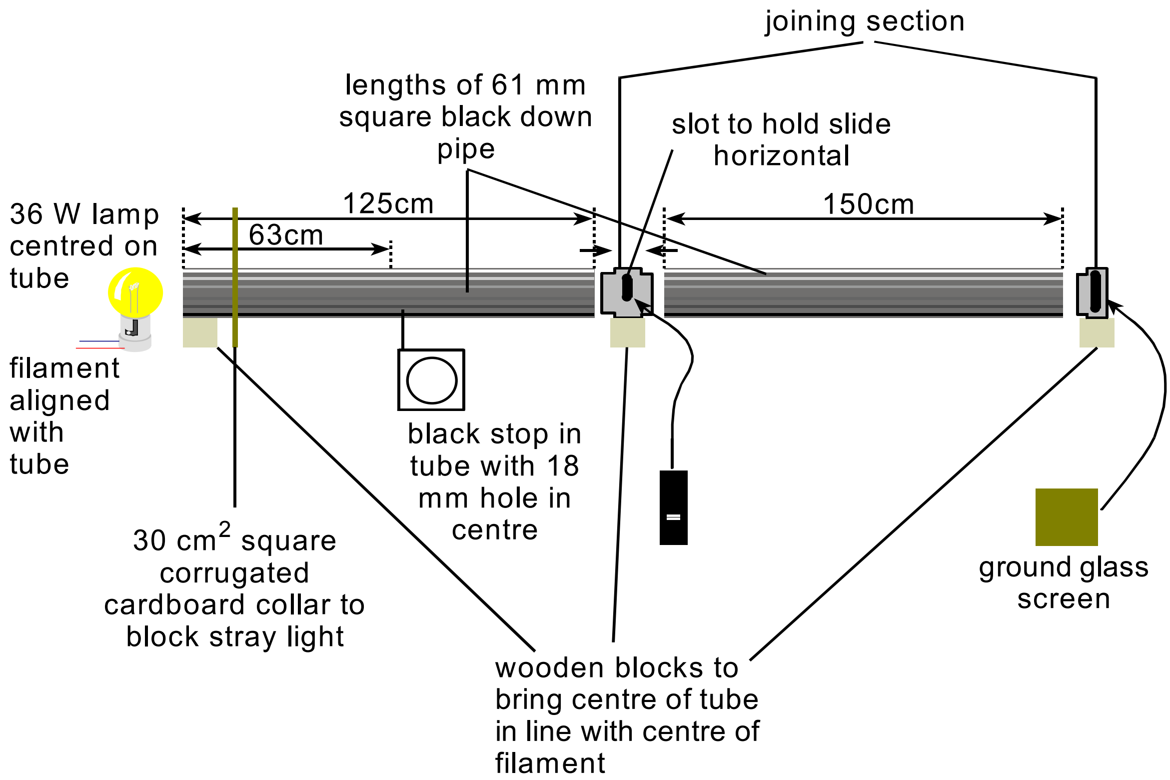
A common failure is to rule too heavily, thus coalescing the slits.
Practised teachers can usually tell slits which are likely to work by holding them up to the light. Students usually achieve success within three attempts.

It may be worthwhile producing some composite filters, half red and half blue, so that the colour can be shifted rapidly and the fringe spacing noted. Another approach is to have a red filter above a blue filter, producing two sets of fringes on the screen at once. Whichever strategy is adopted the aim is to make plain the increase in fringe spacing, as the wavelength increases.

Technician's note: Three coated slides per working group is probably enough.
Here are details of how to construct the Young's slits apparatus suggested.

2.5 inch or 61 mm square downpipe is available from builders merchants in 4 and 5.5 m lengths in brown, black or white. Black works well. As a guide to costs; 4 m was quoted at £13.12 plus VAT; 5.5 m at £18.04 plus VAT.

Making Young's slits apparatus



Activity 240E: Experiment Measuring the wavelength of laser light

Requirements

Laser
Diverging lens, -20D
Converging lens, +4D
Metre rule
Lens holders
Support for slits
Set of coarse gratings
Projector screen or light coloured wall

Practical Advice

This is a simple, effective demonstration. It should focus on the effect of grating spacing, not on the number of slits. It is worth drawing attention to the fact that grating spectra are bright and sharp, compared with the two-slit pattern.

Activity 290E: Experiment Visualising phasors: Coloured threads

Requirements

Two x 6 m lengths of strong cotton of different light colours
Felt tip pen for marking the threads
Means of securing the ends of the threads in the position of the slits (leg of bench, lab stool etc.)
Large sheets of paper for recording the results

Practical Advice

The point of the activity is to 'act out' the way path differences stay constant along lines in space. Use it only if you think this will help students visualise the situation. It is obviously best to decide that the 'slit separation' is that of convenient anchors, such as table legs, and to decide the 'wavelength' to use in relation to that. This exercise can be very easily tweaked to suit your particular situation. This may mean a modification to the dimensions given in the notes.

The preparation takes a little while and, if carried out in class, the threads could usefully be prepared ahead of the lesson.