Chapter 1 - IMAGING

1.1 Activity 20D: Demonstration Electronic image capture

Requirements
Digital camera connected via USB or other fast serial port
PC running image processing software

Alternative
Digital still camera, images downloaded to computer

Practical Advice
This is intended as a quick demonstration to show that images can be captured electronically, and then displayed and manipulated by software. The important point to get across is that these images are made of pixels, each carrying a certain amount of information about a small part of the image. This makes an easy and vivid introduction to the idea of resolution, which will be important later in the course (especially in chapter 2 in work on instrumentation). Here it is very concrete.
It is a positive advantage of QuickCam that its speed and resolution are obviously limited. Looking at a television programme one is not aware of the pixels of which the images are composed, nor of the frame rate. With QuickCam these become very obvious.
You may wish to use this opportunity to introduce further capabilities of image processing software, for example smoothing (blurring) or sharpening (edge detection).
Technician's note: The demonstration is written for QuickCam, available from Connectix and UK agents. Versions for PC and Macintosh are available. It is important to do the installation well ahead of time, and to learn from the instruction booklet how to set up the camera and software. Once this is done, the camera images are always immediately available if the camera is plugged into the computer.
A more difficult alternative is to use a video camera to record videotape, and then to use software to read images from the tape into the computer.
Another alternative is to beg or borrow a digital still camera and download images into the computer. This of course lacks the immediacy which QuickCam offers.

Alternative Approaches
There are some very interesting books about electronic imaging. One of the best is 'Visualisation' by Richard Friedhoff and William Benzon (W H Freeman, 1991).

1.1 Activity 30D: Demonstration Distance measurement with ultrasound

Requirements
Datalogger
Ultrasonic motion sensor
PC running data analysis software

Practical Advice
This is suggested as a quick demonstration, especially if students have seen datalogging equipment previously. It is best to concentrate on the principle (time measurement using the known speed of sound) and on introducing resolution as an idea (the smallest shift of the object which can be detected).
Technician's note: It is worth looking up the details of how to get the best from your apparatus from the equipment manufacturer's notes. Some ultrasound devices can benefit from very careful alignment, particularly at longer ranges.

Alternative Approaches
A DIY electronic tape measure, if available, could be used.

1.1 Activity 40D: Demonstration How fast sound moves in a solid

Requirements
Duralumin rod 0.5 m to 1.0 m length
Small hammer
Signal generator
Loudspeaker

Practical Advice
Before doing the demonstration, identify the range of frequencies needed to match the sound with the audio signal generator. It is all too easy to be one octave wrong! Use of beats to match the frequency exactly is possible, but may not be necessary. The sound in the rod is of course also an example of standing waves, but it is best not to stress that here. It is enough to realise that the distance the waves travel in the time of one oscillation is twice the length of the rod – up and down. Further information about standing waves is provided in chapter 6
Technician's note: It is worth spending some time finding a rod which gives a loud, long-lasting sound. Duralumin rods generally seem to work well. A rod unscrewed from a retort stand is likely to be suitable. Mild steel rods may work, but sometimes the sound damps out too quickly. In any case, having found a rod which works well, reserve it for this demonstration.

Alternative Approaches
You might be able to find data on pressure (P) waves in earthquakes. The Earth is sometimes said to 'ring', other extraterrestrial bodies may also experience 'earthquakes'.

1.3 Activity 140E: Experiment The intelligent eye

Requirements
Just your own eyes

Practical Advice
This material appears also in the Advancing Physics AS student's book, section 1.3. It should not be laboured, but is useful to help link the topic of the eye and vision to other work on image processing.

External References
An excellent book on vision:
Hubel 1995 Eye and Brain (W H Freeman)

1.3 Activity 130D: Demonstration Grey step: Edge enhancement in the retina

Requirements
Sheet of Pantone 404U-G graduated paper
Scissors & ruler

Practical Advice
This can be presented as a mixture of conjuring trick and experiment, along the following lines. 'You see these two bits of paper. Do they look the same?' They do. Put them together, darker edge abutting lighter edge. 'Now what do you see?' Students will see one darker than the other. 'But watch carefully as I move one like this'. Slowly slide one piece, keeping its edges parallel to the other, away from the other, above and around it, and bring it up to the other on the opposite edge. Students will see the difference in darkness vanish, then to reappear but in reverse. 'What do you want me to do now?' Students may suggest reversing the changeover – the effect reverses. They may suggest butting the pieces top to bottom: there is no difference in colour. They may suggest rotating one piece through 180 degrees: the difference vanishes, but reappears reversed if both pieces are rotated. Finally, explain how the paper is made.

If you have your own images then you can then slide the squares around on screen, easiest with a draw package, as an effective way of carrying out the demonstration.
Technician's note: The original activity was based on Pantone paper, sadly no longer manufactured. However suitable rectangles can be prepared with painting or drawing packages. Make a square 96 pixels by 96 pixels, and with a linear gradient running from red, green, blue values all equal to 170, to red, green, blue values all equal to 184. Other values may work.

Alternative Approaches
The reading on visual illusions supplements and enhances this approach. You may also choose to replace this direct experience.

1.3 Activity 150D: Demonstration Models of the eye

Requirements

Large spherical flask filled with dilute solution of florescein in water
Converging lenses, 10 to 50 dioptre, with Blu-tak or similar adhesive material
Parallel beam projector
Digital camera, connected via USB or other fast serial port
Or :- video camera feeding television monitor
Optional : large tube with spherical end able to be filled with dilute solution of fluorscein in water

Practical Advice

The idea is not to try to produce a perfect model of the eye, but to think about the eye through a series of imperfect models. In the real eye it is the case both that the cornea has a smaller radius of curvature than the overall radius of the eye, and that the eye has an auxiliary lens.

Alternative Approaches

A demonstration of a dissection of a pig's eye, if feasible and done under appropriate safety conditions, would add a great deal to this demonstration. It is important to give students the choice of whether they see this or not. A video of such a demonstration would be a possible substitute.

1.3 Activity 160D: Demonstration Image in mid-air

Requirements

35mm slide projector, with attractive colour slide
White painted ‘wand’, i.e. stick about 0.5 m long about 10mm diameter
Dark drapes

Practical Advice

Set up the 35 mm slide projector in a dark corner of the room, loaded with an attractive colourful slide, and focus the image rather close to the projector, perhaps a metre from it. Make sure that the nearest wall is some distance behind the image and use dark drapes to reduce the light reflected from the wall. The room needs to be as dark as possible.

A good trick is to put the projector under a table, with dark drapes over the table, and to shine the light under a second table, also draped with dark cloth, which forms a dark tunnel from which little light is scattered back. Focus the image in the space between the tables.

Alternative Approaches

This demonstration makes a nice 'open day' science exhibit. It is modelled on a similar exhibit at the San Francisco Exploratorium.

1.3 Activity 180D: Demonstration Where are the parts of an object in its image?

Requirements

Beam source, 2D
Plano-convex cylindrical lens
Colour filters, red & green
White paper, A3 or larger

Practical Advice

A student could easily do this demonstration for other students. What it shows is simple enough, but it is not something students find easy to put into words. The use of different coloured filters is very helpful and adds to the attractive appearance of the demonstration. The most important thing is to move the sources sideways and see the place where the beam comes to a focus move sideways at the same distance from the lens.

Alternative Approaches

The overhead projector is a good example of an extended source. It seems obvious that as you cover up parts of the object, parts of the image are obscured. It may be worth making a mask with a small hole and moving it about over an overhead transparency. Smoke or chalk dust could pick out the light beam moving as the mask moves.

1.3 Activity 200D: Demonstration Focusing water ripples

Requirements

Ripple tank, with lamp and screen
Circular reflector
Lens shaped strip of plastic

Practical Advice

To get the best results:

- align the filament of the tank's light source to be parallel to the ripples from the plane wave generator
- raise the generator (dipper) bar so that the water below it is lifted up by surface tension
- choose the frequency so that the ripple wavelength is 10–20 mm
- place barriers either side of the lens so that diffraction around its edges does not confuse the effects.

For the lens demonstration, re-levelling of the tank is often necessary. It is best to remove a little too much water with a sponge or siphon, and then to add more water cautiously until there is just enough to cover the lens-shaped plate.

Alternative Approaches

You may like to show 30 mm microwaves refracted by a wax lens, or by a balloon filled with carbon dioxide.

1.3 Activity 170E: Experiment Converging lenses: Power and focal length

Requirements

A range of converging spherical lenses from 20 dioptre to 2 dioptre
A selection of converging lenses from instruments, e.g. detachable camera lens, large magnifying glass, converging spectacle lenses
Half metre rulers
Pieces of white card to catch images and mask lenses, with scissors to cut holes in card
Lamp bulbs (e.g. mains 60W) around the room to serve as nearby objects

Practical Advice

The experiment is mainly qualitative, with rough measurements of focal length. It is important to put together a good and varied collection of lenses, particularly including pairs of the same power and different apertures as well as pairs with the same aperture and different powers.

Make sure that equal emphasis is given to power and focal length. Get in some practice in mental calculation of reciprocals as well, in this way.
You need to insist that students record what they see, and discuss it afterwards. Many will expect the image to be partly cut off when the lens is masked. You could reinforce the fact that this is not true by masking part of the lens of a projector. A good exercise is to ask all students to write down why they think the image just gets less bright, not cut off in parts.

Try to include some practical lenses, even if they qualify as 'thick' rather than thin lenses (for example a demountable camera lens). If the camera lens is marked with its focal length, students can find out experimentally where the manufacturers have measured the focal length from. Be sure to include some (converging) spectacle lenses.

If you want to include some diverging lenses, have them tried in combination with a converging lens, and show that they have negative power (it subtracts from the power of the converging lens).

1.3 Activity 190E: Experiment A converging lens adds constant curvature 1/*f*

Requirements

Converging spherical lenses about 10 dioptre
Filament lamp, 12V, 24W
Lamp holder, S.B.C., on base
Power supply, 0 – 12V d.c. and a.c., 6A
White card, ground glass or tracing paper screens
Metre rule
Mountings for source, lens and screen (an optical bench may be used but is not essential)

Practical Advice

The experiment is mainly qualitative, with rough measurements of focal length. Make sure that equal emphasis is given to power and focal length. Get in some practice in mental calculation of reciprocals as well, in this way.

1.3 Activity 210D: Demonstration Modelling the eye with a video camera

Requirements

Digital camera, connected via USB or other fast port
Selection of lenses, from 2 dioptre to 20 dioptre
Ground glass screen or mounted tracing paper

Practical Advice

Together with questions and discussion, there is a substantial amount of work here, worth more than one lesson. There are also some useful questions to go with the discussion of the eye; there are plenty of such questions.
The work needs two distinct aspects to be emphasised:

1. a qualitative understanding of how the images are formed and of how changing object positions or adding extra lenses affects the image on the ccd screen;

2. some calculations with powers of the eye and of the digital camera lens.

Some useful technical details about a digital camera currently available: QuickCam:

- Focal length of lens 3.6 mm, power 278 dioptre (compare the eye, focal length 25 mm, power 40 dioptre).
- Field of view 46 degrees. Width of ccd screen about 3 mm.
- 320 ´ 3 colour pixels in about 3 mm width gives width of a pixel about 3 mm, similar to the scale of rods and cones in the eye.

Alternative Approaches

A normal video camera can also be used. However, present technology makes it rather complicated to capture and feed images to a computer for study and analysis. The qualitative effects can, of course, be shared by viewing on a TV screen.