# *Advancing Physics*

## AS2000

## Apparatus List

This list may be useful to technicians looking at which apparatus is required for which activity without having to turn to the CD every time. Could also be used to provide lists for trays of apparatus for the lab.

Compiled by Malcolm Jenkinson
Leeds Grammar School

# Chapter 1 IMAGING

## Electronic image capture

Activity 20D: Demonstration
Requirements:-
Digital camera connected via USB or other fast serial port
PC running image processing software
Alternative
Digital still camera, images downloaded to computer

## Distance measurement with ultrasound

Activity 30D: Demonstration
Requirements:-
Datalogger
Ultrasonic motion sensor
PC running data analysis software

## How fast sound moves in a solid

Activity 40D: Demonstration
Requirements:-
Duralumin rod 0.5 m to 1.0 m length
Small hammer
Signal generator
Loudspeaker

## Grey step: Edge enhancement in the retina

Activity 130D: Demonstration
Requirements:-
Sheet of Pantone 404U-G graduated paper
Scissors & ruler

## Models of the eye

Activity 150D: Demonstration
Requirements:-
Large spherical flask filled with dilute solution of fluorescein 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 fluorescein in water

### Image in mid-air

Activity 160D: Demonstration
Requirements:-
35mm slide projector, with attractive colour slide
White painted ‘wand’, i.e. stick about 0.5 m long about 10mm diameter
Dark drapes

### Where are the parts of an object in its image?

Activity 180D: Demonstration
Requirements:-
Beam source, 2D
Plano-convex cylindrical lens
Colour filters, red & green
White paper, A3 or larger

### Focusing water ripples

Activity 200D: Demonstration
Requirements:-
Ripple tank, with lamp and screen
Circular reflector
Lens shaped strip of plastic

### Modelling the eye with a video camera

Activity 210D: Demonstration
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

### The intelligent eye

Activity 140E: Experiment
Requirements:-
Just your own eyes

### Converging lenses: Power and focal length

Activity 170E: Experiment
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

## A converging lens adds constant curvature 1/*f*

Activity 190E: Experiment
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)

# Chapter 2 SENSING apparatus list

## Logging the Lab

Activity 10D: Demonstration
Requirements:-
Data logger with many sensors (for example: microphone, thermometer, potential divider indicating angle of door to room, light dependant resistor with potential divider)
Large display from data logger, perhaps computer and monitor

## Current and charge in electron beams

Activity 20D: Demonstration
Requirements:-
Electron deflection tube
EHT power supply, 0 – 5kV d.c.
2 demonstration digital multimeters
leads, 4mm

## 'Spooning' charge

Activity 30D: Demonstration
Requirements:-
Digital colomb-meter
Plastic rods, polythene and acetate or perspex with cotton cloth
EHT power supply, 0 – 5kV d.c.
Metal disc on 4mm plug
Leads 4mm
Teaspoon and tablespoon each mounted on insulating polythene rods
Shuttling balls and ions in flame
Activity 40D: Demonstration
Requirements:-
EHT power supply, 0 – 5kV d.c.
Pair of conducting discs, insulated and clamped vertically
Leads, 4mm
Colloidal graphite coated table tennis ball suspended on 1.5m of nylon monofilament
Tall retort stand, boss and clamp
Microvoltmeter
Stroboscope
Candle and matches

## Conduction by 'coloured' ions

Activity 50D: Demonstration
Requirements:-
Power supply, 0 –150V d.c.

2 demonstration multimeters
1 M ammonium hydroxide solution (Aqueous ammonia)
Microscope slide covered with filter paper soaked in ammonium hydroxide solution
Small crystals of copper sulphate and potassium permanganate
2 pins to use as connectors
Crocodile clips
Stop-watch
Tweezers

### Speed of pulse on coaxial cable

Activity 70D: Demonstration
Requirements:-
Pulse generator, 200 kHz
Coaxial cable on drum, 200 m
4mm leads
single pole switch, mounted with 4mm sockets
Oscilloscope or PC-scope

### Lamp lighting

Activity 130D: Demonstration
Requirements:-
Filament lamp, 12 V, of various nominal powers, 5W, 24W, 36W, 48W, 100W
2 demonstration multimeters
Hand held stop watch
4mm leads
power supply, 0 – 12 V d.c. and a.c., 6A

### Conduction by students

Activity 60E: Experiment
Requirements:-
Power supply, 5 V d.c.
Microvoltmeter
4mm leads
Class of student volunteers

### Using a wide range of sensors

Activity 100E: Experiment
Requirements:-
Thermocouple (e.g. copper-constantan)
Semiconductor thermopile
Photovoltaic cell
Phototransistor
Crystal microphone
Other types of microphone

Rotary potentiometer mounted as angle sensor
Other commercially available active sensors
Detectors of potential difference, such as
Multimeter
Datalogger
Perhaps moving coil meters
Light beam galvanometer
PC-scope
Perhaps a gold leaf electroscope

### Using the digital multimeter to measure resistance

Activity 110E: Experiment
Requirements:-
Clip component holder
Selection of resistors
4mm leads
digital multimeter

### Resistors in series and parallel

Activity 120E: Experiment
Requirements:-
A set of resistors marked with the letters A through to E
3 clip component holders
4mm leads
digital multimeter

### The filament lamp: The relationship between power and applied potential difference

Activity 140E: Experiment
Requirements:-
4mm leads
Stopwatch
Filament lamp 12 V, 24W
2 digital multimeters
Power supply, 0 – 12 V d.c.
Smoothing unit
Joulemeter (as an alternative for which instructions are provided)

### Electrical characteristics

Activity 150E: Experiment
Requirements:-
Coil of Constantan wire, 0.4mm (28 S.W.G.)
Clip component holder
4mm leads
Heatproof mat

2 digital multimeters
Power supply, 5 V d.c.
Rheostat

**Additional apparatus for experiment 2:**

Carbon film resistor
As above substituting for the coil with a 100Ω carbon film resistor in a clip component holder

**Additional apparatus for experiment 3:**

Filament lamp
Filament lamp 12 V, 24 W
Power supply, 0 – 12 V d.c.

**Additional apparatus for experiment 4:**

Silicon diode
Diode – 1N4001 (NB: max current 1A) with a protective resistor - 50Ω or greater
Microammeter – to explore the reverse bias

**Additional apparatus for experiment 5:**

Thermistor
Rod or bead thermistor
Protective wire wound resistor 10Ω or greater

### Potential dividers

Activity 200E: Experiment
Requirements:-
Resistors (suggested values 300 kΩ, 150 kΩ, 100 kΩ, 75 kΩ )
100 kΩ rotary potentiometer
5 V smoothed d.c. power supply
Clip component holders
Digital multimeters
4mm leads
LDR
Thermistor (47 kΩ )
Hairdryer
Filament lamp 12 V, 48 W

### Internal resistance of a source of emf

Activity 240E: Experiment
Requirements:-
2 digital multimeters
Potato
0.5 cm x 2 cm copper sheet, 0.5 cm x 2 cm zinc sheet
2 pairs crocodile clips
Resistance substitution box
5 x 4 mm leads

### Monitor rapid changes in intensity

Activity 260E: Experiment
Requirements:-
Light dependent resistor
Phototransistor
Clip component holder
Resistor 10 kΩ
Power supply, 5 V d.c.
PC-scope
4 mm leads
Stroboscope
TV remote control

### Calibrating a position sensor

Activity 270E: Experiment
Requirements:-
Linear position sensor
Rotary potentiometer
Digital multimeter
Power supply, 5 V d.c.
Screw thread arrangement

Measurement amplifier
Power supply unit for measurement amplifier
Vernier calipers

### Measuring rainfall

Activity 280E: Experiment
Requirements:-
Rotary variable resistor, 5 kΩ
Resistance substitution box
Power supply, 5 V d.c.
Digital multimeter
Beaker, 400 $cm^3$
Materials to make lever arm and float

### Comparing a photodiode and a phototransistor

Activity 290E: Experiment
Requirements:-
Mounted photodiode
Mounted phototransistor
Resistor 10 kΩ
Power supply, 5 V d.c.
Filament lamp, 12 V, 48W
Power supply 0 – 12 V d.c.
Metre rule
Digital multimeter

### Using temperature sensors

Activity 300E: Experiment
Requirements:-
Bead thermistor
Thermistor probe
Thermocouple
Clip component holder
Resistance substitution box
Measurement amplifier
Power supply, 5 V d.c.
Power supply unit for measurement amplifier
Digital multimeter
PC-scope
Beakers, 400 $cm^3$
Electric kettle

### Monitoring vibration

Activity 300E: Experiment
Requirements:-
Bimorph element mounted on hardboard square
Bimorph element mounted on cardboard square
Signal generator
Vibration generator

PC-scope

### The oscillations of a hacksaw blade

Activity 320E: Experiment
Requirements:-
2 x strain gauge mounted on hacksaw blade
2 resistance substitution boxes
Digital multimeter
Power supply, 5 V d.c.
Power supply unit for measurement amplifier
Measurement amplifier
Wheatstone bridge board (with zeroing resistor)
PC-scope or datalogger
G clamp – 4”

### Monitoring air flow

Activity 330E: Experiment
Requirements:-
Mounted pressure gauge
Measurement amplifier
Digital multimeter
Power supply, 5 V d.c.
Power supply unit for measurement amplifier
Vacuum cleaner (cylinder, adapted to blow air through tube)
Variac transformer a.c. 0 – 240 V
2 retort stands, bosses and clamps

### Sensor project briefing

Activity 340E: Experiment
Requirements:-
Student project so requirements are varied

# Chapter 3 SIGNALLING

## What do digital signals look like?

Activity 20D: Demonstration
Requirements:-
Mounted phototransistor
Resistor 10 kΩ
Power supply, 5 V d.c.
Oscilloscope
TV or VCR remote control

## Data transfer on an optical cable

Activity 30D: Demonstration
Requirements:-
Fibre-optic transmitter with variable gain
Fibre-optics receiver/amplifier
Optical fibre, a length between 5m and 25m
Tuned circuit for AM reception around 100 kHz using ferrite aerial and variable capacitor
Radio receiver
Connectors
Audio amplifier
Loudspeaker
**And also**
Oscilloscope
Connecting leads
2 power supplies, 5 V d.c.

## Sampling vibrations on a string

Activity 30D: Demonstration
Requirements:-
Signal generator
Vibration generator
Oscilloscope
Stroboscope
4mm leads
about 2m of thick white string
Single pulley on bench clamp
Mass hanger with slotted masses, 100g

### Noise:
### A problem and a solution

Activity 60D: Demonstration
Requirements:-
2 signal generators
2 x 5m long leads twisted tightly together and terminating with 4mm plugs
Oscilloscope
Measurement amplifier, gain 10
Power supply unit for measurement amplifier
Signal diode
AND gate
Power supply, 5 V d.c.

### The C.D. with the hole

Activity 100D: Demonstration
Requirements:-
Unwanted music C.D. with hole 1mm to 2mm drilled in it
PC with C.D. drive and sound card, or C.D. player

### Polarisation of reflected light

Activity 140D: Demonstration
Requirements:-
Polarising filter, marked with its permitted direction of vibration (electric vector)

## Polarisation of waves

Activity 120P: Presentation
Requirements:-
3 polarising slots (hardboard sheets with slots)
3 or 4 m length of rubber pressure tube that can be threaded though the slots
G clamp, or retort stand, boss and clamp to secure one end of the rubber tubing
3 polarisers, optical 50mm x 50mm, to place on OHP
Plastic moulded transparent ruler with notch
Microwave transmitter
Microwave receiver
Power supply 12 V d.c.
Microwave polarising grill
Audio amplifier
Loudspeaker (in amplifier)
1 GHz UHF oscillator (30 cm kit) with dipole transmitter/receiver and rod to rotate plane of polarisation
Microvoltmeter as detector for rectified 1GHz waves

## Guess a waveform from a sample

Activity 50E: Experiment
Requirements:-
Paper
Tracing paper

## Looking at signal conversion

Activity 80E: Experiment
Requirements:-
Analogue to digital converter (ADC) box
Power supply unit for measurement amplifier
Two digital multimeters
Digital to analogue converter (DAC) box
Oscilloscope
Signal generator

## Polarisation by scattering

Activity 130E: Experiment
Requirements:-
Parallel beam projector
Power supply 0 – 12 V d.c. and a.c., 6 A
Plastic tank, rectangular
Polariser, optical
Milk (a few drops)

### Spectrum analysis:
### Simple signals

Activity 170E: Experiment
Requirements:-
PC-scope
Three signal generators
Loudspeaker
Measurement amplifier as a signal adder

### Hearing impairment:
### Using an electronic filter

Activity 200E: Experiment
Requirements:-
Tape recorder with suitably pre-recorded tape of speech
Signal generator
Loudspeaker
Oscilloscope
Active filter unit

### Making an electronic sounds generator

Activity 230E: Experiment
Requirements:-
Sound generator chip
Suitable power supply or cells
Piezo buzzer or loudspeaker
PC running Cool Edit 96
or
Oscilloscope
Crocodile clips, breadboard, perhaps a soldering iron

# Chapter 4 TESTING MATERIALS apparatus list

## Disappearing glass

**Activity** 300D: Demonstration
Requirements:-
250 ml beaker half filled with glycerol (propane 1,2,3-triol)
A hard Pyrex test tube or other Pyrex glass object – the type of glass is crucial. If a test tube is used, fill it with glycerol up to the level of the liquid in the beaker

## Measuring the speed of light

**Activity** 220P: Presentation
Requirements:-
Speed of light apparatus

## Tensile testing: Getting a feel for materials 1

Activity 10E: Experiment
Requirements:-
G clamp, 4" jaw
Wooden blocks
Single pulley on clamp
Mass hangers with slotted masses, 100g
Wire samples: 0.08 mm stainless steel (44 SWG), 0.28 mm copper (32 SWG), 0.20 mm iron (36 SWG)
Nylon monofilament, 2 kg breaking strain
Optional: glass, cotton, hair

## Compressive testing: Getting a feel for materials 2

Activity 20E: Experiment
Requirements:-
Hardboard squares, 2 cm x 2 cm
Mass hangers with slotted masses, 100g
Retort stand, boss and clamp
Metre rule
Set of specimens for crushing

### Hardness testing:
### Getting a feel for materials 3

Activity 30E: Experiment
Requirements:-
A metal punch or a sharp hard nail
Large steel ball bearing
Drilled block of wood
Aiming tube
Optical microscope or magnifying glass
Set of specimens for hardness testing

### Tear testing:
### Getting a feel for materials 4

Activity 40E: Experiment
Requirements:-
Pair of sheet material clamps
Retort stand, boss and clamp
G clamp, 2" jaw
Mass hangers with slotted masses, 100g
Specimen strips, approximately 10 cm x 2 cm: paper, cellophane wrapping, cotton, perhaps other textile
Scissors

### Measuring density:
### Getting a feel for materials 5

Activity 50E: Experiment
Requirements:-
Mass balance, electronic ± 1 g
Metre rule
Blocks for density measurement

### Comparing thermal conductivities:
### Getting a feel for materials 6

Activity 60E: Experiment
Requirements:-
Thermal heater unit
Power supply, 0 – 12 V d.c. and a.c., 6A
3 temperature sensors, 0 – 100 $^0$C
Heat sink compound
Bubble wrap or other insulator
Selection of rods of identical diameter to test
Masking tape

### Electrical conduction: Getting a feel for materials 7

Activity 70E: Experiment
Requirements:-
Power supply, 5 V d.c.
Digital multimeter
Loose crocodile clip
Strips or rods of materials, e.g. copper, glass, balsa wood, graphite, dry paper, wet paper

### Optical properties: Getting a feel for materials 8

Activity 80E: Experiment
Requirements:-
Mortar and pestle
Copper sulphate crystals
Rock salt crystals
Sugar crystals
Glass rod
Glass powder

### How strong is a paper structure?

Activity 140E: Experiment
Requirements:-
Sheet of thin A4 paper
Sheet of corrugated paper, at least 80 mm x 200 mm
Hardboard squares, about 80 mm x 80 mm
2 masses, 1 kg
Mass hangers with slotted masses, 100 g
Adhesive tape, suitable for paper

### Measuring the stiffness of a material

Activity 150E: Experiment
Requirements:-
G clamp, 4" jaw
2 wooden blocks
Single pulley on a bench clamp
Metre rule
Adhesive tape marker
Cardboard bridges
Mass hanger with slotted masses, 1`00 g
Wire samples, 0.08 mm (44 SWG) stainless steel, 0.28 mm (32 SWG) copper,
0.20 mm (36 SWG) iron
Nylon monofilament, 2 kg breaking strain
Safety spectacles

### Crushing:
### How materials interact with light 1

Activity 170E: Experiment
Requirements:-
Crystals of copper (II) sulphate; several large crystals and some crushed crystals about the grain size of table salt
Sheet of paper containing legible writing on which to place the crystals

### Reflection:
### How materials interact with light 2

Activity 180E: Experiment
Requirements:-
Plane mirror
Blank sheet of white paper
Beam source, 2D

### Refraction:
### How materials interact with light 3

Activity 190E: Experiment
Requirements:-
Semicircular transparent block
Beam source, 2D

### Absorption:
### How materials interact with light 4

**Activity** 200E: Experiment
Requirements:-
Rectangular plastic tank, approximately 15 cm x 10 cm x 10 cm
Plastic measuring jug, 1 litre
2/3 drops of milk
12 V 48 W lamp
Power supply, 0 – 12 V d.c. and a.c., 6 A
Annular stop: cardboard disc with 1 cm hole punched in middle to produce a beam

### Propagation:
### How materials interact with light 5

Activity 210E: Experiment
Requirements:-
Rectangular plastic tank, approximately 15 cm x 10 cm x 10 cm
1 litre jug of water
2/3 drops of fluorescein solution
Laser
Blu-tak

### Total internal reflection

Activity 230E: Experiment
Requirements:-
A semicircular transparent block, perhaps glass or Perspex
Optional extension: a second semicircular block made from a different substance or a semicircular shaped plastic tank containing water
Beam source, 2D
Power supply, 0 – 12 V d.c. and a.c., 6 A
Sheet of white paper

### Absorption in a liquid

Activity 240E: Experiment
Requirements:-
Absorption tank
2 power supplies, 5 V d.c.
Light suitable phototransistor
Digital multimeter
Copper (II) sulphate solution, about 5% by volume

### Measuring refractive index

Activity 250E: Experiment
Requirements:-
A semicircular transparent block, perhaps glass or Perspex
Optional extension: a second semicircular block made from a different substance or a semicircular shaped plastic tank containing water
Beam source, 2D
Power supply, 0 – 12 V d.c. and a.c., 6 A
Sheet of white paper

### Getting information down transparent pipes

Activity 260E: Experiment
Requirements:-
Signal generator, 0.1 Hz – 100kHz, 1 A
Microvoltmeter (here used as a microammeter)
Digital multimeter
Power supply, 5 V d.c.
Mounted infrared or optical emitter/detector pair with optical fibre clamps
2 x G clamps, 2” jaw
30 cm length of polyester optical fibre
For making your own fibre
15 cm length of soda glass
Portable gas burner
Safety spectacles
Fine nosed pliers
Heatproof mat

### Looking at a spectrum formed by a prism

Activity 270E: Experiment
Requirements:-
Prism, $60^0$, glass or Perspex
Beam source
Power supply, 0 – 12 V d.c. and a.c., 6 A or
Parallel beam projector (for demonstration)
Retroreflectors and rainbows
Activity 280E: Experiment
Requirements:-
Circular Perspex block
$90^0 – 45^0 – 45^0$ prism, plastic or glass
Optional extension; plastic petri dish containing water
Beam source, 2D
Power supply, 0 – 12 V d.c.and a.c., 6 A
Plane mirror or aluminium foil

### Measuring resistance of good conductors

Activity 310E: Experiment
Requirements:-
Aluminium cooking foil, approximately 2 cm x 30 cm
A graphite film on paper
Power supply, 0 – 12 V d.c.and a.c., 6 A
digital multimeters
crocodile clips
x 4 mm leads

### Measuring the resistance of two insulators

Activity 330E: Experiment
Requirements:-
Samples of two insulators; glass sheet about 10 cm x 10 cm x 1 mm,
rubber samples of similar dimensions
EHT power supply, 5 kV d.c.
Digital multimeter
Means of attaching the samples to the circuit
mm leads

## How the dimensions of a conductor affect the resistance

Activity 340E: Experiment
Requirements:-
About 50 g of conducting putty
Pair of putty contacts
2 digital multimeters
x 4 mm leads
Power supply, 0 – 12 V d.c.and a.c., 6 A
Cutting board for the putty (on which it can rest during the experiment)
Sharp knife
Disposable plastic gloves (**warning**: the putty is not toxic but it stains hands and clothing)

## Introduction to resistivity using conducting paper

Activity 340E: Experiment
Requirements:-
Graphite film on paper
Colloidal graphite to connect the paper to the optical pins
Hairdryer
Power supply, 0 – 12 V d.c. and a.c., 6 A
5 x 4 mm leads
Two optical pins
Two bulldog clips, each with a lead soldered to the 'handle'

## Measuring electrical resistivity

Activity 340E: Experiment
Requirements:-
Constantan wire diameter 0.27 mm (32 SWG) and 0.56 mm (24 SWG)
Power supply, 0 – 12 V d.c. and a.c., 6 A
2 digital multimeters
Micrometer screw gauge
mm leads
Clip component holder
For optional extra: nichrome, iron, copper wire in the same gauge as constantan

# Chapter 5 LOOKING INSIDE MATERIALS

## Crystal, polycrystal and amorphous

**Activity** 90D: Demonstration
Requirements:-
JPEG file

## Photoelastic stress

Activity 130D: Demonstration
Requirements:-
Two of polariser, optical, 50 mm x 50 mm
Slide projector
Two strips of heavy duty polythene
Transparent plastic ruler and similar objects, one with hole

## A model for stretching rubber

Activity 260D: Demonstration
Requirements:-
20 x 10 mm polystyrene balls
20 cocktail sticks
A coloured marker pen
A sharp metal point on a handle to make holes in the polystyrene ball

## Looking at bone

**Activity** 10E: Experiment
Requirements:-
Samples of bone
Hand lens

## Looking at wood and wood products

Activity 30E: Experiment
Requirements:-
Samples of wood and wood products such as blockboard, plywood, chipboard, flooring grade chipboard, veneered chipboard, corrugated cardboard, MDF, egg box, paper, cellophane
Hand lens

### Looking at textiles

Activity 40E: Experiment
Requirements:-
Samples of different textiles – for example, nylon tights, kitchen cloth, tea towel, cotton hankies, woollen scarf
Hand lens

### Measuring a molecule

Activity 80E: Experiment
Requirements:-
Waxed shallow tray (for example, a waterproofed serving tray)
Rubber wedges to level tray
Waxed booms to sweep the water surface
Lycopodium powder
Olive oil
Talc
Hand lens
Scale – 0.5 mm
Loop of very fine wire, 0.28 mm (32 S.W.G.)
Sponge for soaking up water spills

### Glass thickness and colour

Activity 110E: Experiment
Requirements:-
Thick sheet of window glass, in excess of 0.5 m in one other direction
Filament lamp, 12 V , 48 W and holder
Power supply, 12 V
Optional extras:-
Neutral density filter
Stack of microscope slides – at least 50

### More than one spring

Activity 140E: Experiment
Requirements:-
Steel springs, tensile
Mass hangers with slotted masses, 100 g
Retort stand base, rod, boss and clamp
Short length of stiff wire (or similar) to combine springs in parallel

## Growth of grains

Activity 150E: Experiment
Requirements:-
A few grams of phenyl salicylate (phenyl-2-hydroxybenzoate) – enough to provide just a few drops
Test tube
Two microscope slides
Beaker, 250 $cm^3$
Kettle
Means of removing the glass plate from the hot water
Drying cloth
Hand lens
Experiment 2
Copper filings
Dilute nitric acid
Silver nitrate solution, 0.05 M
Microscope slide
Microscope (above-stage illumination may be best)

## Growing grains in a zinc ingot

Activity 170E: Experiment
Requirements:-
50 g of granulated zinc
Small Pyrex test tube and test tube holder
Bunsen burner
Heat-resistant gloves
Face mask
Heat-resistant mat
Wooden splint or spill
Tin can (or similar); sufficient vermiculite granules to fill the can
Retort stand, boss and clamp
A selection of emery paper of varying coarseness

## A bubble-raft model of dislocations

**Activity** 190E: Experiment
Requirements:-
Petri dish
Hypodermic needle, 25 gauge and length of rubber tubing to connect it to gas tap
Hoffman clip (to regulate the gas flow)
Retort stand, boss and clamp
Bubble solution

## Heat treatment of steel

Activity 200E: Experiment

Requirements:-
Steel wire samples
Gas burner
Beaker of water (minimum volume 250 ml)
Mat on which you can safely place hot objects
Tongs
Heat-resistant gloves
Two pairs pliers
Optional extension
Tensile testing machine. If you wish to use this option, you must use steel samples which will conform to the dimensional requirements of your machine.

### Work hardening of copper

Activity 210E: Experiment
Requirements:-
Copper specimens
Mass hanger with slotted masses, 100 g
Two wooden dowels
Gas burner
Heat-resistant mat
Heat-resistant gloves
Tongs
Safety glasses
Optional:-
Furnace capable of maintaining at least 800 °C for one hour or simple heating using a gas burner

### Amorphous and crystalline structures in polymers

Activity 220E: Experiment
Requirements:-
JPEG file

### Sketching a semicrystalline polymer

**Activity** 230E: Experiment
Requirements:-
Rings from a four-pack of drinks
or
Strips cut from polythene food bags using a razor or sharp knife

### Molecular memory

Activity 240E: Experiment
Requirements:-
Two yoghurt pots (they should be slightly conical type, volume about 150 ml)
A pressure cooker

### History in a plastic cup

Activity 250E: Experiment
Requirements:-
Extruded polystyrene cup
Expanded polystyrene cup

### Effect of the vulcanisation of rubber on stiffness

Activity 270E: Experiment
Requirements:-
Mass hanger with slotted masses, 100 g
Three mass hanger with slotted masses, 10 g
Ring of rubber made by cutting through an old car inner tube
Rubber band
Retort stand, boss and clamp
Metre rule
G-clamp
Use of micrometer or vernier

### Design your own rubber

Activity 280E: Experiment
Requirements:-
Copydex
A supply of microscope slides coated with Copydex
Materials clamp
25 $cm^3$ of a 5% solution of disulphur dichloride ($S_2Cl_2$) in petroleum ether
Mass hangers with slotted masses, 100 g
Retort stand, boss and clamp
Small ruler
Petri dish
Stopwatch
Plastic tongs

## Calibration of a thermistor

Activity 320E: Experiment
Requirements:-
Thermistor
Digital multimeter set on resistance range
Two crocodile clips
Connecting leads, 4 mm
250 ml beaker
Source of hot water, an electric kettle is simplest
Mercury-in-glass thermometer (0.5 °C divisions)
Ice cubes
Clamp, stand and boss

# Chapter 6 – WAVE BEHAVIOUR

## Loudspeaker and baffle

Activity 10D: Demonstration
Requirements:-
Double beam 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 hole equal in size to the loudspeaker cone

## More complicated standing waves

Activity 150D: Demonstration
Requirements:-

## Standing waves in a loop

Signal generator
Vibration generator
Stroboscope
Loop of copper wire
Two 4 mm leads

## Chladni figures

Signal generator
Vibration generator
Metal plate, to be fixed to the vibration generatot
Sand
leads

**Vibrations in a rubber sheet**

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
leads

### String model of a lens

Activity 190D: Demonstration
Requirements:-
Whiteboard
Blu-tak
Adhesive tape
Five pieces of regularly marked out string

### Path differences and phase differences

Activity 20P: Presentation
Requirements:-
Signal generator
Loudspeaker
Two microphones
Double beam oscilloscope (sensitivity of 10 mV $cm^{-1}$ needed)
Metre rules
Leads

### Slinky demonstrations

Activity 50P: Presentation
Requirements:-
Slinky spring with tags every 10 turns
Signal generator
Vibration generator
Retort stand, boss and clamp

### Superposition of microwaves

Activity 60P: Presentation
Requirements:-
Microwave transmitter
Microwave receiver
Metal reflector (about 0.3 m square)
General purpose amplifier
Loudspeaker (if not with above)
Microammeter (if not incorporated in receiver)
Diode probe
Metre rule
Leads

### Partial reflection of microwaves

Activity 70P: Presentation
Requirements:-
Microwave transmitter
Microwave receiver
Metal reflector (about 0.3 m square)
4 mm hardboard sheet (about 0.3 m square)
General purpose amplifier
Loudspeaker (if not with above)
Microammeter (if not incorporated in receiver)
Metre rule
Leads
Slotted base (for reflectors)

### Superposition of 1 GHz radio waves

Activity 80P: Presentation
Requirements:-
Dipoles and oscillator, 15 cm wavelength
Digital multimeter, used as microammeter
Metal screen, 0.3 m square
4 mm leads
Metre rule

### Standing waves in sound

Activity 110P: Presentation
Requirements:-
Oscilloscope
Loudspeaker (about 80 mm in diameter)
Signal generator
Microphone
Metre rule
Hardboard reflector (about 0.3 m square)
**Standing waves in tubes:**

### Kundt's experiment

Activity 120P: Presentation
Requirements:-
1000 $cm^3$ glass measuring cylinder
Signal generator
Small loudspeaker and paper cone
Cork dust

### Standing waves with microwaves

Activity 130P: Presentation
Requirements:-
Microwave transmitter
Slotted base
Metal reflector (about 0.3 m square)
General purpose amplifier
Loudspeaker (if not with above)
Digital multimeter used as a microammeter
Diode probe
Metre rule
Leads

### A stationary 1 GHz wave pattern

Activity 140P: Presentation
Requirements:-
Dipoles and oscillator, 15 cm wavelength
Digital multimeter used as microammeter
Metal screen, 30 cm square
Slotted base
Leads

### A focusing mirror with string

Activity 170P: Presentation
Requirements:-
Whiteboard
Blu-tak
Adhesive tape
Seven pieces of regularly marked out pieces of string

### Hearing superposition

Activity 30E: Experiment
Requirements:-
Signal generator
Two loudspeakers
Leads
Microphone
Oscilloscope

## Beats
## Mixing waves in time

Activity 40E: Experiment
Requirements:-
Two signal generators
Two loudspeakers
Oscilloscope
Microphone
Leads

### Interference patterns in a ripple tank

Activity 90E: Experiment
Requirements:-
Ripple tank kit
Hand held stroboscope

### Standing waves on a rubber cord

Activity 100E: Experiment
Requirements:-
Signal generator
Vibration generator
Xenon flasher (stroboscope)
Rubber cord (0.5 m long, 3 mm square cross section)
Two retort stands, bosses and clamps
Four metal strips (as jaws)
Two G clamps, 4” jaws
Leads

### Interference patterns in a soap film

Activity 210E: Experiment
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

### Diffraction by a slit

Activity 210E: Experiment
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

### Measuring wavelength with Young's slits

Activity 230E: Experiment
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

### Measuring the wavelength of laser light

Activity 240E: Experiment
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

### Visualising phasors: Coloured threads

Activity 290E: Experiment
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

# Chapter 7 Quantum behaviour

## Listening to photons arrive

Activity 20D: Demonstration
Requirements:-
Pure gamma source
One or more Geiger-Muller tubes with counter with audio signal

## Superposing electrons

Activity 240D: Demonstration
Requirements:-
Electron diffraction tube
E.H.T supply, 5kV
Leads
Slab magnet
Laser
Transmission gratings, 300 and 500 lines per mm
White screen

## Microwave paths

Activity 40P: Presentation
Requirements:-
Microwave transmitter and receiver
Microwave beam splitter
Two microwave refelectors
Multimeter to measure the output from the microwave

## Reflection gratings: A selection

Activity 150P: Presentation
Requirements:-
Incandescent and fluorescent lamps
A CD-ROM for each member of the audience
Metal ruler
Laser
Red, green and blue filters
Small white screen

## Relating energy to frequency

Activity 10E: Experiment
Requirements:-
Multiple LED array
Peering tube

Power supply, 5V
Multimeter
Leads

### Calculating for a mirror on the bench

Activity 80E: Experiment
Requirements:-
Pencil, ruler, vector sheet
or
Vector Hex file
Red or blue photon wheel
Many paths for a mirror sheet

# Chapter 8 Mapping Space and Time

## Adding velocities

Activity 210P: Presentation
Requirements:-
Three dynamic trolleys
Trolley runway, about 1.25 m long
A3 drawing paper, pins and drawing board
Ink water, plastic syringe, tubing and Blu-tac
Ruler and protractor

## Time maps

Activity 230P: Presentation
Requirements:-
OHT of UK map, plus overlay of time map
Atlases
Access to local rail timetables (available on the Internet)

## Measuring speed with a light gate

Activity 10E: Experiment
Requirements:-
Computer
Date-logging software, e.g. Insight (Timing)
Light gate and interface
1.5 m runway
Dynamics trolley
Black card 5 cm x 10 cm
Ruler

## Motion graphs using an ultrasonic motion sensor

Activity 30E: Experiment
Requirements:-
Computer running a data-logging program, e.g. Insight (Sensing)
Ultrasonic motion sensor
Dynamics trolley
Flat bench surface

### Using a video camera to make a speed-time graph

Activity 60E: Experiment
Requirements:-
Digital camera capable of recording video
or
Video camera and video playback machine which allows frames to be played back one frame at a time ('jog' facility)
and
Dynamics trolley
Single pulley on bench clamp
Mass hangers with slotted masses, 100 g
String
Black paper and chalk
White golf ball and white ping-pong ball
Prepared spreadsheets for entering the data

### Displacement and vector addition

Activity 110E: Experiment
Requirements:-
Large space – playground or playing field is ideal
Long tape measure or trundle wheel
Navigational compass

### Using video to estimate components of velocity

Activity 150E: Experiment
Requirements:-
Video camera (two if possible)
Video playback machine which allows frames to be played back one at a time ('jog' facility)
Stop watch
Long tape measure
Means of marking distances across a wall or across an open space (e.g. black paper and chalk for an wall or poles placed into the ground

### Vector components and co-ordinate systems

Activity 160E: Experiment
Requirements:-
Ruler
Protractor
Acetate sheet
Graph paper
OHT pens
Calculator or PC

# Chapter 9 Computing the next move

## A thrown ball follows a parabolic path

Activity 130D: Demonstration
Requirements:-
Overhead projector transparency of a parabola
Overhead projector
Screen
Small ball
Some practice

## Mid-air collisions

Activity 170D: Demonstration
Requirements:-
Electromagnet
Iron can
Power supply, 12V
Aluminium foil
Blowpipe tube
Ball bearing
Pair of crocodile clips mounted in holder
4 mm leads

## Free transport?

Activity 300P: Presentation
Requirements:-
Dynamics trolley (Pasco)
Two retort stands
Six bosses
Hanger masses, 10g
Nylon monofilament
A pendulum, supported on a retort stand
A 6inch nail held in a boss

## Tracking aircraft paths by drawing

Activity 50E: Experiment
Requirements:-
Sheet of A4 graph paper
Sharpened pencil
Ruler
Protractor

### Predicting the motion of a falling card

Activity 110E: Experiment
Requirements:-
Computer
Data-logging software, e.g. Insight (Timing)
Lightgate and interface
Stand with clamps and bosses
Black card, 5cm x 10cm
Plasticene or Blu-tak
Metre rule

### Measuring the acceleration of free fall

Activity 120E: Experiment
Requirements:-
Access to a reasonably large drop, e.g. stair well
Ball bearing
Cardboard box with cloths or some other arrangement to ensure that the ball has a soft, safe landing
Tape measure
Stopwatch reading to at least 0.1 s
Plus – if available (and there is sufficient time to use it)
Electronic timing system, data logging device, video camera or computer-aided system for measuring the time of fall through a measured distance

### Rolling along a parabola

Activity 140E: Experiment
Requirements:-
Computer capable of playing avi movies
Marble, paper and inclined board

### What does a tennis ball know about parabolas?

Activity 160E: Experiment
Requirements:-
Computer running a drawing program
Or
Graph paper, ruler and pencil

### Build and test a marble launcher

Activity 172E: Experiment
Requirements:-
Protractor
Metre rule
Small sand pit
A means of measuring speed
Safety spectacles
Compression spring
1 cm diameter plastic conduit with rubber bung to fit
Marble and/or ball bearing to fit tube
Drill and large nail

### Finding the range of projectiles

Activity 174E: Experiment
Requirements:-
Means of safely projecting a small dense object (such as a metal ball) at various angles
Means of measuring the angle of projection
Means of measuring the range (horizontal distance travelled) of the projectile
And if possible
Some means of recording the path of the projectile through the air, e.g. using a video or digital camera linked to a computer

### Investigating accelerated motion

Activity 180E: Experiment
Requirements:-
Computer running data-logging software , e.g. Insight (Timing)
Lightgate and interface
Retort stand, boss and clamps
Dynamics trolley
Black card with two segments
Single pulley on bench clamp
String
Mass hangers with slotted masses, 100 g
50 cm light metal chain
Ruler

### Acceleration and resultant force using a motion sensor

Activity 190E: Experiment
Requirements:-
Computer running data-logging software , e.g. Insight (Timing)
Motion sensor and interface
Dynamics trolley

String (3 m)
Mass hangers with slotted masses, 100 g (use up to 500 g)
Single pulley on bench clamp
Metre rule

### Acceleration and resultant force using a lightgate

Activity 200E: Experiment
Requirements:-
Computer running data-logging software , e.g. Insight (Timing)
Lightgate and interface
Dynamics trolley
Black card, 5 cm x 10 cm
String (3 m)
Mass hangers with slotted masses, 100 g (use up to 500 g)
Single pulley on bench clamp
Stand and clamp (for the lightgate)
Metre rule

### Just how are force and acceleration connected?

Activity 210E: Experiment
Requirements:-
Dynamics trolley
Force sensor
Acceleration sensor
Computer running data capture and analysis software

### Experiencing a collision

Activity 250E: Experiment
Requirements:-
Large dynamics cart
Supply of empty drinks cans
Solid but protected wall
And perhaps
Motion sensor, interface and computer
Or
Video camera plus analysis software

### Falling cupcakes

Activity 260E: Experiment
Requirements:-
A set of 10 paper cupcake holders
Stopwatch or wristwatch with ability to read to at least 0.1 s
Metre rule or (better) a tape measure
Stairwell or similar so that objects may fall through several metres

### Good on the rebound

Activity 320E: Experiment
Requirements:-
A ball whose internal pressure can be varied
Pump, adapter and pressure meter
Metre rule
Stopwatch

### Poor on the rebound

Activity 330E: Experiment
Requirements:-
Selection of four to five materials
Metre rule
Stopwatch
Ball bearing or marble

### Stripping away kinetic energy

Activity 340E: Experiment
Requirements:-
Adapted model car
Film canister full of sand
Flexitrack, 1 m
Hanger masses, 10 g
Metre rule
and possibly
Means of tracking the position of the car

### Slowing by stirring

Activity 350E: Experiment
Requirements:-
Dynamics trolley
Air braking assembly
Metre rule
and possibly
Means of tracking the position of the trolley
a means of launching the trolley
Flexitrack 1 m

or
Trolley catapult
or
Bench pulley
Hanger masses

### Accelerating through viscous media

Activity 365E: Experiment

Requirements:-
Guttering with supports, 1.5 m
Boat
Litre jug
Paperclips
Slotted hanger masses, 10 g
Metre rule
Stopwatch
Light nylon thread, 2 m
and possibly
Means of tracking the position of the trolley

## Effective ballistics

Activity 370E: Experiment
Requirements:-
A catapult
A home made dart
Poystyrene tile
Metre rule
stopwatch