**AH Physics Project Advice for Staff (Version 2019)**

**Understanding Standards Exemplification issued by SQA can be obtained here:**

<http://www.understandingstandards.org.uk/Subjects/Physics/Advanced/Project>

This shows how the marking schemes are applied for the project and examination.

**Useful Reference Books:**

* Physics - A Textbook for Advanced Level Students (2nd or later Edition)                  Tom Duncan
* Understanding Physics *for Advance Level* (Fourth or later Edition)                          Jim Breithaupt
* A Laboratory Manual of Physics (Any edition if you can get your hands on one) F. Tyler
* Advanced Practical Physics (Ancient but good) Leslie Beckett
* Practical Physics in SI (As good as Tyler) E. Armitage
* Project and Investigations for Advanced Physics (Old but good) Jim Breithaupt
* Physics Through Investigation (2000ish - good) Green Ireson
* Physics by Experiment (A level old but good) J R L Hartley & D L Moselle
* A Level Practical Work for Physics (2015)

 (Great wee book on techniques - graphs, measurement etc rather than procedures) Chris Mee & Mike Crundell.

* Practical Physics As above but older and more detail. G L Squires.
* CFE AH Physics Bright Red A. McGuigan
* *'An Introduction to Error Analysis - A Study of Uncertainties in Physical Measurements*' John R. Taylor.

 available on Amazon. (Recommended by Peter Law)

* Advanced Higher Physics Theory (Amazon) Peter Burnett
* Advanced Higher Physics - Questions and Solution (Amazon) Peter Burnett
* Advanced Higher Physics Investigations Companion (Amazon) Peter Burnett

**Useful Websites**

**Teaching Advanced Physics – IOP -** <https://spark.iop.org/teaching-advanced-physics> loads of good teaching ideas for coursework and experiments.

**Scottish Teacher physics resources**

<https://www.talkphysics.org/groups/teaching-physics-in-scotland/>

**SSERC AH Physics pages**

<http://info.sserc.org.uk/advanced-higher-physics>

Mrs Physics (Jennie Hargreaves of Lockerbie Academy)

<http://www.mrsphysics.co.uk/advanced/>

**Georgia State University – Hyperphysics** <http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html> - useful for theory.

Sinclair McKenzie’s site is useful for course theory and older past papers with solutions.

http://mrmackenzie.co.uk/advanced-higher/

**YouTube**

<https://www.youtube.com/user/1veritasium/videos>

<https://www.youtube.com/user/minutephysics>

<https://www.youtube.com/user/DrPhysicsA>

**Apparatus Suppliers**

DJB <http://www.djb.co.uk/>

Scichem Pasco <http://education.scichem.com/Catalogue/Search>

Timstar <http://www.timstar.co.uk/>

Philip Harris <http://www.philipharris.co.uk/>

Lambda Scientific <http://lambdasys.com/downloads> American, expensive but downloads have useful ideas.

Mindsets <http://mindsetsonline.co.uk/Site/Home>

3bScientific [https://www.3bscientific.co.uk/physics,pg\_83.html](https://www.3bscientific.co.uk/physics%2Cpg_83.html)

**Uncertainties**

**General Comments**

* A good grasp of uncertainty treatment is a requirement of the course.
* At this level candidates should be confident in the use of Excel/Google Sheets or an equivalent spreadsheet package in relation to calculations and graphical presentation.
* They should also have a clear idea of how to use LINEST or equivalent to find the gradient and uncertainty in a line. The LINEST box of 4 values should be included in the report.

 Some schools treat the time just after the change of timetable to introduce Excel.

See <http://info.sserc.org.uk/advanced-higher-physics/3358-data-handling>

**Also**

**Education Scotland Resource**

N Fancey , G Millar - Book on Uncertainties.

This and other support can be accessed through Jennie Hargreaves, Mrs Physics site.

<http://www.mrsphysics.co.uk/advanced/category/backgrounddocuments/upsnanduncertainties/>

**AH Physics Project Advice**

| **Title** | **Apparatus List / Supplier if possible** | **Support notes / tips /safety issues** |
| --- | --- | --- |
| **Finding g**Compound pendulum | Metre stick drilled with holes 10 cm apart. Or 30 cm ruler can also be used. Thin needle to suspend pendulum by fitting through holes. Retort stand or swing between two desks. Timer.<https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/advanced-higher-on-a-budget/>  | Standard experiment available in most reference books.Ask Technician or CDT department to drill the holes along the centre of the metre stick |
| Simple pendulum | Long piece of stringBob or mass to be suspended.Fit string into a slit made in a rubber bung or split cork to allow ease of adjustment of the length of string. The bung can be held in place using a retort stand.Retort stand, G clamp to secure set up.Scales to weigh mass, callipers to find midpoint. | Use a retractable measuring tape or equivalent to measure different lengths – useful for lengths greater than 1m.Be aware of toppling retort stand, if not secured properly.Analysis – graphical approach essential. |
| Kater’s Pendulum | Not easy to make a home-made version that is of sufficient quality to get great data although that doesn’t matter if analysis is good. Might be able to borrow one from a University if you can?  | Use graphical analysis. |
| Bifilar Pendulum | Long Metal/plastic rod.Means of suspending the rod horizontally.Two retort standsTimer | Pupils find it a bit fiddly to setup, try to allow enough time to collect a set of results each time. Vary the distance, d, of separation of suspension and measure the period T. Graphical analysis possible |
| Ball Bearing on Concave Mirror | Curved concave mirror.Ball bearing.Timer | Fairly simple measurements.Find mirror radius using Spherometer or from focal length |
| Oscillating Spring | Long spring (30cm), retort stand, G clamp, masses, stop clock.Alternative method for timing:Motion sensor connected to laptop a possibility – PASCO/Alba | G clamp to secure the retort stand for safety.Motion sensor pointing upwards below the mass.Ensure the motion sensor is at least 25 cm from the mass. |
| Water stream | Measure diameter of a vertical stream of water at various points | <http://info.sserc.org.uk/images/Physics/g_by_flow_rate.doc> |
| Sphere rolling down a slope | Sloped track , sphere (large marble or ball bearing).Micrometre or Vernier callipers.Timer (light gates) metre stick.Scales | Use the conservation of energy, the formula for I to find g. |
| Pressure at depth of water | Measuring cylinderPressure sensor and data-logger. (DJB Low pressure sensor or similar)<http://www.djb.co.uk/ppm_low_pressure.html>  | Not especially complex use a graphical method to analyse. However pressure and depth no longer in N5 or Higher course. <https://mrsphysics.co.uk/n5/wp-content/uploads/2018/02/N5-Assign-Pressure-and-depth-A-2018.pdf> |

| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| --- | --- | --- |
| **Waves in Strings / Vibrating Stings**Length and tensionFrequency and tensionFrequency and linear density (mass per unit length) of the stringSpeed of stationary wave | SonometerDifferent thicknesses of wires at least 5.(Can use guitar strings if they can be attached)Pair of pliers.Safety specs.A means of increasing the tension in the wire. (Hanging mass, adjustable screw clamp)SSERC have a relatively cheap, home-made version, using Westminster kit magnets. Can easily set up make school.<http://info.sserc.org.uk/advanced-higher-physics/4241-advanced-higher-on-a-budget>Frequency can be measured:* Using a horse shoe magnet across the wire and a signal generator, looking for the point of resonance.
* Lissajous figures (CRO required)
* Audacity or frequency spectrum analyser app
 | **Must have eye protection when dealing with stretched wires.**Related to Melde’s Experiment<https://spark.iop.org/meldes-experiment#gref>The wire can get hot if using the signal generator method. Can be as easy to use Audacity or app to determine frequency and manual string plucking moving supporting bridges to adjust length or changing tension by hanging masses.  |
| Standing Waves | White elastic thread. (Most Scientific suppliers ok with this) Signal generator and frequency meter required. Again, frequency spectrum analyser app could be used.Pulley wheel | Use elastic thread connected to a vibration generator. Connect the other end over a pulley to masses.Impressive standing waves can be produced.Relationship between frequency and number of nodes? etc |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Refractive Index**Apparent Depth | Travelling MicroscopeBeakerFine powder (Lycopodium powder ok)Sand on bottom.  | Lycopodium powder okay to use – not banned as originally thought. Can use pollen instead.  |
| Triangular PrismHollow Prism | Use of spectrometer with collimated light source.Solid – find n for material.Hollow – find n for different liquids, concentrations, temperature, etc.It is possible to use a laser to find the angle of deviation for different liquids in a hollow prism.An adjustable platform for the prism or laser can make things easier.Increasing the projection distance is advantageous. | Normal safety procedures with a laser.(SSERC link on safety to follow)<https://www.sserc.org.uk/health-safety/physics-health-safety/optical-radiation/school-sources-of-optical-radiation/> (requires log in)Can be done in the school hall provided laser precautions are taken. |
| Newton’s Rings | Newton’s ring experiment with water over the Newton’s rings allowing calculation of refractive index of water. LensPlateSuitable light source often a sodium lampTravelling microscope.  | [http://www.schoolphysics.co.uk/age16-19/Wave%20properties/Interference/text/Newton's\_rings/index.html](http://www.schoolphysics.co.uk/age16-19/Wave%20properties/Interference/text/Newton%27s_rings/index.html) |
| Liquids | Curved mirrorRetort standCork and pin as objectMetre stick  |  |
| Wavelength of light in water using diffraction to then determine refractive index of water.  | Diffraction grating 300 lines mm-1LaserScreenTransparent container<http://info.sserc.org.uk/advanced-higher-physics/4241-advanced-higher-on-a-budget> | Measurement of the separation of fringes in air and liquid allows the calculation of the refractive index of the liquid. |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Gases**Michelson Interferometer | Michelson Interferometer Vacuum pumpUse of gas cell  | Introduce carbon dioxide or helium into the gas cell from vacuum and measure the movement of fringes.Leakage can be a frustrating problem.Use the Helium from “party” balloons – otherwise can be expensive. |
| Air cell | <http://info.sserc.org.uk/advanced-higher-physics/4241-advanced-higher-on-a-budget>Cork, bottle top, pin, balsa wood, cork borer. Microscope slide, wire, blu-tack.  | Nice cheap version – pupils could easily construct this. |

|  |  |  |
| --- | --- | --- |
| Title | Apparatus List / supplier | Support notes / tips /safety issues |
| **Lenses**Focal length by lens formula methodFocal length by two position methodFocal length of paraxial raysFocal length of marginal rays | Lens holders, metre stickVarious convex lenses - focal length ranging from 20 – 80 cm.Optical bench nice if you have one.Bright source for object. | Lens formula.Focal length of lensesMagnificationSpherical aberrationChromatic aberration<http://ncert.nic.in/ncerts/l/lelm308.pdf> |
| Hollow lens with different sugar solutions and their effect on focal length and refractive index.  | Hollow lensSpectrometer |  |

| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| --- | --- | --- |
| **Moment of Inertia**Disc | Use Pasco rotating platform to find I of disc Compare experimental value with using data to calculate *I = ½ mr2*more directly. | See Pacso worksheets for info.Use *T = I * |
| Disc | Conservation of angular momentumPasco rotating platform and Inertia | See Pacso worksheets for info. |
| Cylinder | Conservation of energy (runway light gates).Use rotating cylinders down a slope.Compare experimental value with using data to calculate *I = ½ mr2*more directly.Repeat with a sphere – less frictionSee:<http://www.sserc.org.uk/images/AH_Physics/Advanced_Higher_Physics_experiments.doc> page 11 | Can be difficult to get any reasonable results but good for uncertainty calculations. |
| Rod | Bifilar suspension rod.TimerRelatively easy set up. |  |
| Bicycle Wheel(Through centre) | Straight forward set up, if you have a bicycle wheel.Remove tyre, mount wheel vertically, apply force to rim.See also “Tobermory method” using a rotating air puck and Tracker<http://info.sserc.org.uk/higher157/3331-tracker-easy-motion-analysis-and-more> (page 6) | Reference:Apply torque, calculate angular acceleration by timing angular displacement. Account for friction? |
| Bicycle Wheel(Suspended, oscillating) | Straight forward set up, if you have a bicycle wheel.Support stand.String.Timer. | Suspend the wheel and find the period of oscillation. |
| Wheel and Axle | Some schools might still have one of these.String.MassesTimer. | Apply torque, measure angular acceleration, estimate frictional torque – find I.Compare with “geometrical estimate” |
| Cardboard disc and coins | <http://info.sserc.org.uk/advanced-higher-physics/4241-advanced-higher-on-a-budget> |  |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Friction** | Wooden blocks of the same mass but different cross-sectional area. StringTrack (Bench)Pulley, masses, string, plastic bottle.Tilted wooden surface.ProtractorPossibility of using different methods of measuring force.(Force sensor – Pasco)Effect of angle of slope on static friction of block. Rotate block and turn over block and measure slope angle where it starts to slide. Variable speed rotating turntable plus block on surface.Method of timing. | Different methods of measuring coefficient of static and kinetic friction.Horizontal / tilted track.<http://www.philipharris.co.uk/products/physics/forces-energy/motion-acceleration/b8h25109_inclined-plane-and-friction-board>Add water to the bottle until the block just moves etc.Compare surfaces.Independence of surface area?Relatively easy investigation to carry out – not over demanding.Increase speed of turntable until the block is just held in place.Central force provides frictional force .Find Vary the area of the block. |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Lasers**Compare properties of different lasers. | Suitable lasers for project work will be Class 2(and not Class 2A, "C or 2M).These might be:A helium neon laserA semiconductor laserA laser diode module.All should be bought from reputable suppliers. Laser pointers and devices such as laser spirit levels should not be used as the classification cannot be trusted.Intensity profile across the beam  Lasers plus suitable light sensor (Photo diode plus meter) | <https://www.sserc.org.uk/wp-content/uploads/2019/11/SSERC_optical_radiation_safe_use.pdf>Quite difficult to set up.Attach a light sensor to a micrometer. Move the screw to move the sensor across the beam Or photograph and use TrackerPlot I vs d<https://www.sserc.org.uk/wp-content/uploads/2019/06/Bulletin_190.pdf> (Page 17 for photodiode setup to find beam profile).  |
| Intensity variation with distance | Laser, metal adjustable ruler, light sensor |  |
| Wavelength using diffraction grating | Laser300mm-1 grating (600 mm-1 does not give enough values of  ScreenMetre Stick / metal ruler to measure grating distance to screen) Graph paper for screen to mark the pattern. | dsin = mUse graphical approach to find Plot sinagainst m(Tan  should not be used as an approximation for sin . This is not Young’s Slits)**DO NOT USE A LASER WITH AN OPTICAL SPECTROMETER** |
| Diffraction pattern around a hair. | Screen, hair, some device to hold the hair in place. Screen plus paperTravelling microscope. | Attach the hair to a suitable holder to enable the projection of beam onto screen. Gives better control. |
| Spiral separation of CD, DVD, blue ray disc. | CD, DVD, blue ray disc plus screen with a hole in the centre to enable beam to be directed onto the disc.Disc position vertically on its end.Possible to also use CD as a transmission grating.  | Nice practical with reasonable results.Should attain a difference in the spiral separation.Blue ray carries more information.<https://iopscience.iop.org/article/10.1088/0031-9120/26/4/010/pdf> (IoP login required)<https://iopscience.iop.org/article/10.1088/0031-9120/28/1/003/meta> (IoP login)<https://www.nnin.org/sites/default/files/files/Karen_Rama_USING_CDs_AND_DVDs_AS_DIFFRACTION_GRATINGS_0.pdf> |
| Metal Rule Interference | LaserMetal rule with fine graduations.Screen | Ensure screen is (2 – 3 )m from ruler<https://www.sserc.org.uk/wp-content/uploads/2019/06/Bulletin_191-2.pdf> (Page 12) |
| Single Slit Diffraction | Single slit – commercial.Screen + paper to record position of fringes. Metre stick , measuring tape?Travelling microscope |  |
| Young’s Slits | LaserDouble slitScreen +paper to record position of fringes. Metre stick , measuring tape?Travelling microscope | Although in syllabus, an addition might be considered where x against D is plotted, using the gradient to find the wavelength.Better to use a slit of known separation – difficult to measure directly using a travelling microscope - gives high uncertainty. |
|  | Note – diffraction and interference experiments (including Young’s Slits, Newton’s Rings, single slit) can be analysed quantitatively using Tracker. See guide mentioned in section on angular motion). |  |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Polarisation** | Helium neon gas laserSemiconductor laserLight sensorOne polaroid analyser plus scale – can be home made.<http://info.sserc.org.uk/health-safety/health-a-safety-home136/optical-radiation-safe-use81/lasers70/1732-laser-radiation-sensor-534> | Compare the properties of each laser.Are both beams polarised?Plot graphs of I vs Use a data logger to record intensity over a period of time to see if there is a change in the polarisation angle for each beam. |
| Malus Law | Laser + polariser if required. Check to see if laser output is plane polarisedAnalyser (plus angle scale)Light sensor (Photodiode plus meter).Can make your own apparatus see link | Laser light should be polarised, so just analyser plus scale needed.Could use a white light source with polariser plus analyser.<https://pdfs.semanticscholar.org/451e/9208914ee2ecc8dc0acda207c6604d051530.pdf> |
| Brewster’s angle | Rotating platform, (protractor)Laser (can emits polarised light – check with analyser.If not plane polarised then use a polariserSome gas lasers polarisation plane rotates – something worth checking.Glass block | Project the reflected beam from the glass block onto a wall.Record angle where the intensity is a minimum.Calculate the refractive index of the block, compare with theoretical value.**Search youtube for set up.** |
| Optical Activity of certain solutions | Polarimeter (can be homemade)Light sensorGlucose, sucrose solutions.Measuring cylinder.Balance<http://info.sserc.org.uk/images/AH_Physics/Advanced_Higher_Physics_experiments.doc>See <https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/advanced-higher-on-a-budget/> | Plane of rotation dependent on concentration, length of solution.Nice experiment to attempt if you have the correct set up.See<http://www.philipharris.co.uk/products/b8r05155_polarimeter> |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Interference** | Sodium light source Diffraction grating, 300 lines mm-1 grating Spectrometer300, 600 lines mm-1 gratings | dsin = mUse a graphical approach to find Plot sinagainst mGiven wavelength, could also try to calibrate different diffraction gratings |
| Wedge fringes | Flat glass platesSodium sourceTravelling microscopeGlass beam splitter | Although in the syllabus, this can be extended by finding the width of any thin object.(Paper, hair, card . ) |
| Newton’s Rings | Sodium sourceTravelling microscopeGlass beam splitterNewton’s Rings apparatusSpherometerFor this and wedge fringes, see:<http://info.sserc.org.uk/images/AH_Physics/Advanced_Higher_Physics_experiments.doc>(pages 1 and 7) | Fairly easy to do – good graphical approach required.Leads on nicely from wedge fringes<http://www.philipharris.co.uk/products/b8a46229_newtons-rings-apparatus> |

| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| --- | --- | --- |
| **Speed of Sound**Resonance | Comparison of methodsLong resonance tube, closed at one end.Can be Glass tube in measuring cylinder of water, tuning forks. Signal GeneratorFrequency meterMetre stickSpeakerRetort stand to support speaker.Commercial set up available from Pasco | Exp1 Measure lengths for fundamental frequency and the first overtone.Subtract to find the wavelength x 2.Find , then use v = fExp 2Vary the length of the tube and find the fundamental resonance frequency.Use a graphical approach to find v. |
| Kundt’s tube | Commercial set up available to buy. Homemade possibilities too although easier with tube and moveable microphone than looking at nodes/antinodes by piles of powder.  | Cardboard tube 10 cm in diameter, small round speaker at end and microphone on metre stick pushed into other end to find maxima and minima. Can be tricky to get a homemade Kundt’s tube to work if using polystyrene or powder to indicate nodes and anti-nodes. Have found microphone works more easily if not using bought equipment. |
| Temperature constant | Heriot Watt notes contain apparatus that looks at the variation of the speed of sound with temperature – requires set apparatus.(Based on standing waves).Two microphones, audacity.Temperature altered using air conditioning.(Haven’t tried, this, limited in the range of temperatures) | Theory can be found <http://hyperphysics.phy-astr.gsu.edu/hbase/hframe.html> .From main menu select sound and hearing, then at bottom of new page is a box that says speed of sound, on the page that appears is the equation but about half way down there is a link which explains equation in detail.A graph of velocity against temperature can then be plotted to prove the constant is 0.6.  A humidity sensor is now available from Vernier so possibly this could be investigated also.**See the Understanding Standards document for example.**Better not to use a familiar set up such as two microphones and timer to find the speed. Might be included as an “extra” after 3 good commensurate experiments. Clearly state that this is really to demonstrate uncertainty handling. Of course plotting distance against time to determine speed from gradient of graph. One might argue should it be included at all if the previous 3 experiments are up to the mark. Depends on your student and time spent on experiments. |
| Speed of sound through solids and liquids**.** | See:<https://www.sserc.org.uk/subject-areas/physics/physics-cfe-levels-3-4-2/speed-of-sound/> |  |
| Speed of sound by Lissajous figures | OscilloscopeSignal generatorMicrophoneLoudspeakerAmplifier (another signal generator) | <https://physicslearning2.colorado.edu/QOTWSite/services/demos/demosh1/LissajousProof.pdf>Both source of sound (signal generator) and detection of sound (microphone) are inputted into the oscilloscope as the X and Y inputs. The screen shows Lissajous figures if signals, make sure signals are of equal amplitudes. Use these to find the phase difference and thus wavelength and speed.  |
| Speed of sound in air using a Helmholtz resonator.  | 500 ml plastic bottlem measuring cylinder, Audacity, water. <https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/advanced-higher-on-a-budget/> | <https://asa.scitation.org/doi/10.1121/1.3112687> |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Young’s Modulus**By deflection of end of bar | Rod – metal, plastic or wood.G clamp to fix rod to end of benchTravelling microscope.Masses | Add masses to end and note deflection |
| By vibrating bar | Vibrating bar and motion sensorG clamp to fix rod to end of bench. | Place motion sensor below barEnsure motion sensor is at least 25 cm from bar. |
| By sag in centre | Rod – metal, plastic or wood.Blade supports for the end of each bar.Travelling microscope.Masses | Add masses to the centre and measure the deflection.Might be possible to use vernier callipers to measure the deflection. |
| By stretching wires | Elastic limit and breaking points of copper wire.Vernier scale required to measure the change in lengths.Commercial devices available. | Accuracy / precision can be a problem here due to the small change in lengths.http://www.philipharris.co.uk/products/f4h25213\_youngs-modulus-apparatus |
|  | Horizontal wire alternative given here. | https://www.youtube.com/watch?v=U5SOFeZJelY |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Surface tension**Direct rise | Capillary tubes – 5 different bores if possible.Travelling microscope. | Ensure the tubes are degreased before using. Immerse in sodium hydroxide solution and thoroughly rinse and dry. |
| Direct pull | Glass slide in contact with surface of liquid.Top pan balanceShallow containerJack to raise and lower the container some use an adapted butcher’s balance.  | Supporting the glass slide can be tricky, to ensuring that the bottom edge just comes into contact with the liquid.  |
| Jaeger’s method | Mainly glassware requiredRelatively easy set up.Refer to websites. | SSERC working on method that replaces U-tube manometer with pressure sensor from Pasco / Vernier etcNB More difficult to get graphs – more calculation based. |
| Water drop method | Syringe, capillary tube or burette/pipette Can use phone camera for drop size | Sometimes called Stallagmometer method. <https://hal.archives-ouvertes.fr/hal-01845986/document><https://iopscience.iop.org/article/10.1088/0031-9120/41/5/010/pdf> (Needs IoP membership) |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Viscosity**Stoke’s Law | Tall, large diameter measuring cylinder or long glass tube.Metal ball bearing.Magnet to retrieve the ball.Timer or can be done using camera video on phone. | Normally done with glycerine – not nice to work with.Large quantity required.Better to dilute it with water. |
| Deflating soap bubble for viscosity of air | Details on website | SSERC has a method using video of a deflating soap bubble for viscosity of air.<http://info.sserc.org.uk/advanced-higher-physics/3930-advanced-tracker>NB More difficult to get graphs – more calculation based. |
| Oswald Viscometer | Unsuitable for very viscous liquids. <https://education.scichem.com/Catalogue/ProductDetail/oswald-viscometer?productID=fcb97944-c893-46b0-9cd0-14bbe833677b&catalogueLevelItemID=c6dbf71a-31bf-4b17-b0d7-47ce833fe817> | Used to determine the relative viscosities of liquids.Pretty easy to use.  The hardest part is to clean it and then fill it.  Use a pipette filler to suck up the liquid into the correct chamber, then let it fall back down through the capillary tube. Do this for water and then another liquid and can calculate the viscosity of the other liquid relative to water.  Can use organic liquids from the chemist’s cupboard.  It isn't suitable for very viscous liquids. Again a calculation rather than a graphical method.  |
| Poiseuille’s formula | Water bottle or plastic beaker with hole in the bottom to provide a constant head of water. Capillary tube.  | Mass of water exiting a capillary tube that is at a given height. Height is varied and mass measured. <https://www.ttu.ee/public/m/Marek_Vilipuu/FI_doks/FI/FI_labs_in_english/Experiment_12.pdf> |

| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| --- | --- | --- |
| **Constants****Planck’s Constant** | 5 different (protected) LEDSAmmeter, voltmeter.BatteryMeans of measuring the wavelength of the light. – spectrometer /local authority spectrophotometer should be available.Could also determine the diffraction grating slit separation using a laser. Then use that in the spectrometer for the LED wavelengths. Possible evaluation of Philip Harris version – simplistic.See also tungsten lamp method – doable in most schools: <https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/planck-s-constant-tungsten-lamp/> | See SSERC info below<http://info.sserc.org.uk/bulletins226/2003/208-spring-2003/1345-plancks-constant-finding-it-using-leds328> Theory makes some approximations, but good measurement procedures / graphical approach / evaluation potential.<http://www.philipharris.co.uk/products/b8h29024_plancks-constant-experiment>If you have the cash then Leybold has the following:<https://www.ld-didactic.de/literatur/hb/e/p6/p6143_e.pdf> |
|  | Using the Photoelectric Effect | SSERCSee <http://info.sserc.org.uk/bulletins226/2001/201-spring-2001/1439-photoelectric-effect-kits-404>Prices will obviously have increased. |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| Speed of Light by o and  | Use values of **o and** o to find c | Use values of **o and** o to find c.Good to combine uncertainties. |
| Permeability, o | Make your own current balance using Helmholtz coils.Alternatively use a solenoid of known dimensions or a long wire plus calibrated Hall probe or search coil.Pasco supplies a calibrated Hall probe. | <https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/advanced-higher-on-a-budget/>SSERC Current balance.  |
| Permittivity,  | Large parallel plate capacitor. 21 cm square x 2 mm Aluminium plate. Plastic spacers.(1) Coulomb meter, voltmeter(2) Vibrating switch method. Ammeter(3) Multimeter – capacitance meter  reading in nF | Measure the effect on C of plate separation, area of overlap.Use graphical method to find o for air.Find  of glass, paper or any material that will fit between the plates<https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/advanced-higher-on-a-budget/>Reed switch £20 from Philip Harris or similar. <https://www.philipharris.co.uk/product/physics/electricity-and-magnetism/electrostatics/reed-relay/b8r07096> |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **e : m** | Teltron deflection tube.Helmholtz coilsPower supplyPossible to do a magnetic field profile of the Helmholtz coils using Hall probe or field coil to demonstrate uniformity. Fine beam tube if you can borrow or gain access to one.Expensive[https://www.3bscientific.co.uk/teltron,pg\_675.html](https://www.3bscientific.co.uk/teltron%2Cpg_675.html)Some Universities offer Millikan’s experiment. There is enough in a project that uses the deflection tube only with coils to get an good mark.  | Use screened connectors.e:m using electric field deflectione:m using magnetic deflectionMany schools should have these tubes.Uncertainties can accumulate here, but still a good investigation to attempt. Good practice to get student to do a risk assessment to heighten awareness of risk of HT supplies. Check your HT supply complies with shrouded sockets and leads. <https://www.sserc.org.uk/wp-content/uploads/2008/12/4-6_Working_with_HT_supplies.pdf> |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Capacitance**Effect of area on capacitanceEffect of separation on capacitanceEffect of dielectric on capacitance to determine the relative permittivity.  | Two parallel plates (aluminium sheet works well). Multimeter that can measure capacitanceMetal plates (aluminium) of different areas. HT / EHT supplyCoulomb meterMicroscope cover slips to separate slides. Variety of dielectricsPolythene / polystyrene / wood / paper / cardCan use liquids but more messy and need to check hazards.  | Use screened connectors if using HT or EHT supplies. Good practice to get student to do a risk assessment to heighten awareness of risk of HT supplies. Check your HT supply complies with shrouded sockets and leads. <https://www.sserc.org.uk/wp-content/uploads/2008/12/4-6_Working_with_HT_supplies.pdf>Easier to use a capacitance meter rather than measure charge and voltage.  |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Capacitors in series and parallel** | 3 capacitors of similar size.Joule meter.Voltmeter.Battery | Measure E stored in various arrangements of capacitors. (Series parallel)Plot a graph of E vs V2 to give slope. |
| **Resonance**Resonance in a wire  | See previous listsAir columnsSonometerElastic thread, masses, pulley wheelSignal generator, vibration generatorVarious sizes of coils, variable capacitor.DC supplyStorage oscilloscope.AmmeterTwo Westminster Kit magnets and yoke1.5 m 28 swg bare copper wire (diameter 0.38 mm), four 50g slotted masses and a 50 g carrier 50 Hz ac low voltage supply, 2 V, 24 W lamp bulb | Resonance in air columnsRelationship between resonant frequency and length of column.Relationship between resonant frequency and length of wire.Relationship between resonant frequency and length of thread.Measure resonant frequency of capacitor discharging through a coil (dc circuit)- Analyse damped oscillation trace using a storage oscilloscope.Compare this value using an ac circuit set up.Analogy between mechanical and electrical oscillations described in most Advanced Level text books. Resonance curves can be plotted for a mechanical system.e.g. Physics for Advanced Level 4th edition, Jim Breithaupt, Page 80.See also:<http://www.schoolphysics.co.uk/age16-19/Mechanics/Simple%20harmonic%20motion/text/Resonance_/index.html><https://www.sserc.org.uk/subject-areas/physics/physics-advanced-higher/advanced-higher-on-a-budget/> |
| Damped Oscillations | Motion sensor30 cm springMasses, different sizes of card.Various values of L and variable capacitor.Air-track and vehicleAluminium “mask” with slits on vehicleElectromagnets | Aerodynamic damping – use of card.Ensure the motion sensor is at least 25 cm from the mass.Electromagnetic damping of a vehicle on the air-track also possible not completely straightforward to set up. <https://pdfs.semanticscholar.org/1ca1/b53d57b3303dbfa7809872364fc1f8f78c00.pdf>Damped oscillations in LCR circuits. |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Magnetic Fields** | Hall probe or search coil.Long wire. Power supply.Long CoilSlinky | Current carrying wire – B dependence on I and r.Coil – B dependence on number of turns, I,Slinky – B dependence on turns per metre. |
| **LCR circuits**f and I for a capacitorf and I for a resistorf and I for an inductorRLC series: Resonant fRLC parallel: Resonant f | Various sizes of coils, variable capacitor.Signal Generator, frequency meter. Voltmeter, AmmeterData-logger can also be used.  | Find value of C and L graphically.Investigate series and parallel resonance.Standard project.(Inductor Quality factor could also be investigated as an extra). |
| **Electromagnetic induction** | Coil, trolley with neodymium magnets mounted, datalogger and voltage probe | <https://www.sserc.org.uk/wp-content/uploads/2011/02/Art_of_Induction.pdf> |
| **Wind Tunnel Experiments** | Different shaped aerofoils required.Anemometer.Means of measuring lift force. | Investigate Bernoulli Effect Vary angle of attack, aerofoil shape, wind speed, measure lift.Only attempt this if you have access to a reasonable wind tunnel.It is possible to build your own aerodynamic balance as shown here. <https://pdfs.semanticscholar.org/fa60/7d24feee824d2b61ff198191b50f68198309.pdf> |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Hooke’s Law**Force constant by static experimentForce constant by dynamic SHMDetermination of g from force constant and oscillating spring.  | SpringsRange of suitable massesRetort stand and clampTimer (could also use ultrasonic position sensor and datalogger).  | Make sure spring does not reach the elastic limit. Safety googles should be warn when stretching the spring especially at large extensions.  |

|  |  |  |
| --- | --- | --- |
| **Title** | **Apparatus List / supplier** | **Support notes / tips /safety issues** |
| **Radioactivity****Dead time of a GM tube****Plateau voltage of a GM tube****Determining the attenuation /absorption coefficient of different materials****Half-value thickness****Angle of spread from source** | GM tube and scalarGM tube and data-loggerRadioactive sourcesAluminium / paperWater / Lead nitrate solutions of different concentrations etc. Different absorbers.  | <https://iopscience.iop.org/article/10.1088/0031-9120/25/1/010> (IoP log in required)<https://www.sserc.org.uk/health-safety/physics-health-safety/ionising-radiation/working-with-radioactive-materials-in-schools/>Pupils over the age of 16 can use radioactive sources but you should ensure you comply with the safety information issued by SSERC. This includes:* There are no under 16s in the room;
* They are supervised;
* A risk assessment is carried out;
* Training is given.

Absorption in liquids can be easier to set up in a vertical manner with source pointing down to bench. Do not point upward to eyes/face. <https://www.nevis.columbia.edu/~ahanks/shp/BetaGamma><http://www.phys.utk.edu/labs/modphys/AttenuationRadiation.pdf> |

**SSERC Support**

Contact:

gregor.steele@sserc.org.uk

**See**

<http://info.sserc.org.uk/advanced-higher-physics>

**SSERC has guidance on data handling:**

<http://info.sserc.org.uk/advanced-higher-physics/3358-data-handling>

This is due for review as some of the graphs used for illustration would be marked down by SQA for lack of minor grid lines etc

SSERC can occasionally lend equipment or host students requiring to use a piece of apparatus not available in their school. Students must be aware of what they will be doing and the measurements they need to take before coming to SSERC. In general, students should only be visiting SSERC to carry out one experiment to complete a project – the organisation does not have entire projects set up “ready to go” for students.

SSERC is also happy to be contacted by students to discuss aspects of project work, for example to suggest alternative experiments or to help troubleshoot those that are proving difficult. A teacher should make the initial contact and must agree to be cc’d or bcc’d into all replies to the student. SSERC staff are happy to discuss novel projects with teachers but ask that we are not contacted directly by students with queries along the lines of “I would like to do a project on… Do you have any ideas?”

**Reminder of the apparatus available, held within your local authority, distributed by SSERC.**

To see who has yours, log in to our site and go here:
<http://www.sserc.org.uk/technicians> (scroll down to Resources)

* Spectrovis Spectrophotometer, Labquest 2 Interface, Optical fibre probe.
* Thermal imaging camera.
* Cloud chamber.
* Sensors for Labquest 2 (some specifically chosen for AH): pressure sensor, magnetic field probe, GM tube, voltage probe, UV-A sensor.

**University Support**

**PLEASE NOTE THE UNIVERSITY VISIT SHOULD BE USED AFTER RESEARCH / EXPERIMENTAL WORK AT SCHOOL.**

**St Andrews**

**Contact: Bruce Sinclair**

**bds2@st-andrews.ac.uk**

“We are happy to consider requests for various things.  We are keen to continue to collaborate with school teachers.

 It is not unusual for us to host occasional AH project students for a morning or two using some of our kit as part of their project.

 I am usually the point of contact”.

“We have had staff members here contribute to the Fife Physics Teacher INSET days with short presentations and Q&A on topics suggested by school teachers.  If any would be of interest to a wider audience I imagine my colleagues would be happy to consider”.

**University of Edinburgh**

Contact: victoria.j.martin@gmail.com

Will respond to any requests made from teachers.

Victoria still has funding to run a course for teachers who want to learn the new astronomy and particle physics part of the curriculum.

She will try to arrange a date for that asap

**University of Dundee**

Contact: n.m.taylor@dundee.ac.uk

Will respond to any requests made from teachers.

**Heriot Watt University**

Contact: Bill McMacPherson on W.N.MacPherson@hw.ac.uk

See

<https://www.hw.ac.uk/schools/engineering-physical-sciences/teaching/physics-schools-laboratory.htm>

Heriot Watt and the IOP (thanks to Nick Forwood) have put together a teacher and pupil guide – **available on GUZLED.**

**Heriot Watt Support - Teacher’s Handbook – list of titles**

1. Period and length of a simple pendulum - Measurement of g ................................... 9

2. The Compound Pendulum ....................................................................................... 11

3. Determination of the gravitational constant *G* ......................................................... 14

4. Angular acceleration and torque .............................................................................. 16

5. Mass on a spiral spring ............................................................................................ 17

6. Hooke's Law............................................................................................................. 19

7. Coulomb’s Law ........................................................................................................ 20

8. Force on a current-carrying conductor ..................................................................... 22

9. A) Current and frequency in an inductive circuit .................................................... 24

9. B) Self-inductance of a coil ..................................................................................... 26

10. Electrostatics .......................................................................................................... 28

11. A) Thin Lenses ....................................................................................................... 30

11. B) Reflection and Refraction ................................................................................. 32

12. A) Optical polarization & Brewster’s angle .......................................................... 34

12. B) Polarization – Malus’ Law ................................................................................ 35

13. A) Wavelength of red light using a helium-neon laser .......................................... 37

13. B) Determining the track spacing on a CD using a laser ....................................... 39

14. A) Ideal Gas Law ................................................................................................... 41

14. B) Determination of Absolute Zero ....................................................................... 42

15. Viscosity ................................................................................................................ 43

16. Refractive Index of Liquids ................................................................................... 44

17. Experimental Aerodynamics .................................................................................. 46

18. Resonance Tube ..................................................................................................... 50

19. Speed of Sound ...................................................................................................... 53

**University of Glasgow**

**Arrangements for day visits**

**Contact: Peter Law on** **peter.law@glasgow.ac.uk**

**Pater has some excellent advice on preparation before a day visit.**

|  |  |
| --- | --- |
| AH Experiment Title | Description[continued overleaf… |
| 'g' by Compound Pendulum | *Determination of ‘g’ by analysing the T- h and the hT² - h² graphs* |
| 'g' by Owen's Bar Pendulum | *A special case of the compound pendulum where the radius of gyration, k can be determined from the dimensions of the pendulum* |
| ‘g’ by Kater Pendulum | *Determination of ‘g’ by adjusting the reversible Kater pendulum until both periods are equal* |
| 'g' by Rolling Sphere | *Determination of ‘g’ by timing the oscillations of a ball-bearing on a spherical mirror and determining the radius of the ball-bearing & the radius of curvature of the mirror* |
| Boltzmann's Constant, *kB*  | *Determination of kB by obtaining the Vbe – ic graph for the base-emitter junction of a collector grounded NPN transistor* |
| e/m by Electric Field Deflection | *Determination of e/m by plotting the parabolic electric field deflection and determining the electron velocity by crossed electric & magnetic fields* |
| e/m by Fine Beam Tube | *Determination of e/m by examining the circular path of electrons in a transverse magnetic field* |
| e/m by Magnetic Field Deflection | *Determination of e/m by altering the transverse magnetic field and the accelerating voltage to maintain the curvature of the electron trajectory constant*  |
| Electro-magnetic Damping | *An investigation of the electro-magnetic damping of the coil of a ballistic galvanometer* |
| Electron de Broglie Wavelength | *Determination of electron de Broglie wavelengths and verification of de Broglie’s hypothesis* |
| Hall Effect | *Investigation of the Hall effect using a two-dimensional electron gas and the determination of the 2-dimensional Hall coefficient, RH,sq* |
| Magnetic Field Measurement by Ballistic Galvanometer | *Measurement of magnetic induction in a solenoid using a search coil and a charge-calibrated ballistic galvanometer* |
| Malus’ Law | *Using LED laser light and polariser & analyser to verify Malus’ Law*  |

|  |  |
| --- | --- |
| AH Experiment Title | Description |
| Millikan’s Oil Drop Experiment (Assistant required) | *Determination of specific charge on an electron by direct timing of drop velocities(An assistant is required to record the times & reset the stopwatch)* |
| Mechanical Resonance | *An investigation of mechanical resonance of a ballistic galvanometer coil driven by low frequency ac voltage under different degrees of electro-magnetic damping* |
| Permeability of Free Space | *Determination of using a solenoid and search coil (Belham’s method)* |
| Permittivity of Free Space | *Determination of by charging and discharging an air-spaced parallel plate capacitor at high frequency* |
| Planck’s Constant by Electron Diffraction | *Determination of ‘h’ by measurements on the circular electron diffraction pattern produced by crystalline graphite*  |
| Planck’s Constant by Stopping Potential | *Determination of ‘h’ by measuring the potential required to stop the photoelectric current from a photocathode exposed to a range of visible wavelengths* |
| Planck’s Constant by Tungsten Filament Lamp | *Determination of ‘h’ by measuring the photocurrent produced at different temperatures by a tungsten filament.* |
| Refractive index by Michelson Interferometer | *Determination of the refractive index of air and/or the refractive index of glass using a Michelson interferometer* |
| Refractive Index by Newton’s Rings | *Determination of the refractive index of water using Newton’s Rings* |
| Refractive index by Prism Spectrometer | *Determination of the refractive index of prism glass by minimum deviation and/or by determination of the polarising (Brewster) angle at the prism surface* |
| Speed of Light in Fibre Optic Cable | *Determination of the speed of light in fibre optic cable by measuring the time delay of LED light pulses travelling over different lengths of fibre optic cable.* |
| Speed of Microwaves | *Determination of the speed of microwaves in air by measuring the wavelength of microwaves from a standing wave pattern in a waveguide over a range of frequencies* |
| Speed of Voltage Waves on an Artificial Delay Line | *Determining the speed of waves on an artificial delay line by plotting the voltage standing wave pattern for a range of frequencies and by measuring the time voltage pulses take to travel along the line* |
| Speed of Sound by Kundt’s Tube | *Determination of the speed of sound in air by measuring the inter-nodal distance on the standing wave pattern produced in a Kundt’s tube* |

|  |  |
| --- | --- |
| AH Experiment Title | Description |
| Speed of Sound by Resonance Tube | *Determination of the speed of sound in air by measuring the resonant frequency over a range of air column lengths* |
| Speed of Sound by Lissajous’ Figures | *Determination of the speed of sound in air by observing phase shifts between transmitted and received sound using Lissajous’ figures* |
| Wavelength by Fabry-Perot interferometer | *Determination of the mean wavelength of the sodium doublet and the wavelength difference between the two lines of the sodium doublet using a Fabry-Perot interferometer* |
| Wavelength by Michelson Interferometer | *Determination of the mean wavelength of the sodium doublet and the wavelength difference between the two lines of the sodium doublet using a Michelson interferometer* |
| Wavelength by Newton's Rings | *Determination of the mean wavelength of the sodium doublet using Newton’s Rings* |
| Young’s Modulus by oscillating beam | *Determination of Young’s Modulus for a clamped metre rule by timing the period of oscillation for a range of free lengths* |

**University of Strathclyde**

Contact: shirley.wylie@strath.ac.uk

Labs are available are Wednesday afternoons from 1.00pm and Friday all day from 10.00am.

We do have most dates available from January onwards.

1. Young’s Modulus by Searle’s method, bending bar or vibrating bar.
2. Determination of acceleration due to gravity by use of simple pendulum, Kater’s pendulum or oscillating ball.
3. Determination of speed of sound by either acoustic resonance or Kundt’s tube.
4. Verification of relationship between length of string and frequency of vibration.
5. Measurement of magnetic induction in a solenoid.
6. Measurement of inductance / capacitance through LC resonance.
7. Measurement of charge to mass ratio by Magnetron effect.
8. Measurement of charge to mass ratio by fine beam tube method.
9. Measurement of surface tension by either Jaeger’s method and drop method.
10. Measurement of wavelength of light by interference – thin film, Newton’s rings and Michelson interferometry, spectroscopy.
11. Measurement of wavelength of light by diffraction.
12. Determination of refractive index by Snell’s law, angular deviation, beam displacement or critical angle.
13. Determination of focal length of thin lenses and mirrors, verification of chromatic dispersion.
14. Determination of Planck’s constant by LED turn-on and by atomic spectroscopy.
15. Determination of Rydberg constant by atomic spectroscopy.
16. Determination of charge on electron by Millikan’s oil drop.
17. Determination of speed of light.
18. Verification of Fresnel reflection relationships.
19. Determination of coefficient of viscosity of castor oil.

## University of Aberdeen

Contact: cpdservices@abdn.ac.uk

# Continuing Professional Development (CPD) for Physics Teachers/Technicians

**CfE Advanced Higher Physics**

**This was held in May 2017 – awaiting confirmation whether or not there will be a repeat.**

Details; <https://www.abdn.ac.uk/business-info/training/cpd/events/10572/>

**Fee: The course cost was £125.00 per person, this included lunch and refreshments.**

## List of In-depth Experiments

If you wish to do an in-depth experiment please insert a ‘1’ and a ‘2’ in the choice column opposite your first and second choice of experiment. Every attempt will be made to give everyone their first choice.

|  |  |  |
| --- | --- | --- |
| No | Title/Description | Choice |
| 1 | Linear Kinematics and Dynamics\* (Trolley experiments) |  |
| 2 | Moment of Inertia of a Bicycle Wheel\* (several methods used) |  |
| 3 | Rotational Dynamics of a Simple Pendulum\* (Tension and Damping) |  |
| 4 | Multiple slit Interference and Diffraction\* (using an optical laser) |  |
| 5a | Transverse Vibrations of a Wire\* (Tension is variable) |  |
| 5b | Transverse Vibrations of a Wire (3 factors possible – l, T and ) |  |
| 6a | Induced Voltage\* (magnet free-falling through coil) |  |
| 6b | Induced Voltage (magnet free-falling through coil) |  |
| 7 | Magnetic Field of a Circular Coil\* (Axial and Transverse Fields) |  |
| 8 | LCR Circuits\*(Phase Relationships, Series Resonance & waveforms) |  |
| 9 | Measurement of and Factors Affecting Capacitance\* (A, d and r) |  |
| 10 | Photoelectricity – LEDs and Planck’s Constant\* |  |

\* These experiments have been available on previous occasions.

Where the same title appears twice, the ‘a’ versions involve the use of a computer for data collection, whereas with the ‘b’ versions data collection is done by the experimenter.

# List of Shorter Experiments

If you have opted for an in-depth experiment, choose a maximum of 4 of the following experiments by placing an ‘X’ in the corresponding choice boxes. If you have **not** chosen an in-depth experiment, choose a maximum of 7 of the following experiments by placing an ‘X’ in the corresponding choice boxes

|  |  |  |  |
| --- | --- | --- | --- |
|  | Topic | Experiments | Choice |
| A | Resistance | 1. Variation with length
2. Variation with X section\*\*
3. Variation with material\*\*
4. Variation with temperature\*\*
 |  |
| B | Sound | 1. Speed in air
2. Speed in steel
3. Speeds in different metals
4. Transducer characteristics
5. Interferometry
 |  |
| C | E M Waves | 1. Speed in air
2. Speed in cable
3. Polarization
4. Antenna radiation pattern
 |  |
| D | Photoelectricity | 1. Photovoltaic mode\*\*
2. Photoconductive mode\*\*
3. Photometry\*\*
 |  |
| E | Reactance | 1. Capacitive with frequency
2. Capacitive with capacitance
3. Inductive with frequency
4. Inductive with inductance
 |  |

\*\* These are new this year

# List of Demonstrations

If you wish to see any of the following demonstrations please choose a maximum of 2 from the list.

|  |  |  |
| --- | --- | --- |
| Topic | Brief description of experiment | Choice |
| CentripetalForce andAcceleration | A variable speed turntable has bubble accelerometers of different sensitivities that can be positioned in different positions and orientations |  |
| Fine Beam Tube | A beam of electrons forced into a circular path by a magnetic field |  |
| Conservation ofAngular Momentum | A spinning body in which the moment of inertia can be altered. The effect of torques on the system |  |