

TOPICS & “WRINKLES” FOR EXPERIMENTAL INVESTIGATIONS

(INSET notes by Dr Rick Marshall)

PHILOSOPHY

An investigation is NOT an “SC1” (ie a rerun of GCSE coursework). It is not “an experiment” – even an extended one, so formal predictions are not necessarily required (but they could be part of the planning when outlining an initial strategy).

The aim should be to explain **how something happens** – not simply how does x depend on y (although this may well be an interim result in the investigation).

Investigations are not just data gathering exercises: the aim is to try and find plausible answers based upon experimental evidence obtained to a physics related question, or, equally acceptable, plausible explanations why an answer so far is not forthcoming.

So **try to quantify** what is going on, and remember that **qualitative observations** are also important.

A good rule of thumb would be to exploit the physics contained in at least two different chapters of the course.

HANDY PRACTICAL INFORMATION

[Not to be implemented without a satisfactory safety assessment]

VISCOSITY: glycerol and water mixtures can vary viscosity by a factor of 1000.

HIGH TEMPS: a sand bath heated by a Bunsen for up to 250 °C.

FREEZING MIXTURES for $T < 0^{\circ}\text{C}$. (33 parts salt in 100 parts water $\sim -21^{\circ}\text{C}$)

DRY ICE (SOLID CO_2) = -78°C

ABSORB UNWANTED INFRA-RED RADIATION with CuSO_4 solutions.

EXPERIMENTAL DESIGN

Encourage a bit of “finesse” e.g. in the design of pointers etc, the use of mirrors, an optical lever, plumb lines to set and monitor vertical etc.

Topics, including some variations on popular themes

Edit and or adapt etc to suit local circumstances. Lists for students are best quoted as questions.

FLUIDS

How efficient is a perforated sail? Could a fishing net be used as a sail?

What is the fastest way to empty a bottle full of water?

What is the lowest pressure you can get from a water stream pump?

Investigate splashes as an alternative to “craters”.

Magneto-rheological fluids. Mix some iron filings with a thick liquid (eg corn oil). Place near a magnet and the iron filings line up and stiffen the mixture. Remove the magnet and the fluid will “relax”.

Investigate a water vortex (or “tornado”) produced by a magnetic stirrer.

Why is the diameter of a jet of liquid leaving a hole is less than the diameter of the hole itself?

How does the passage of water through capillary tubes depend upon the rate of flow?

How do siphons work?

Why do rivers meander?

Investigate the physics of buoyant objects falling into water.

How is a ping pong ball supported by the airflow from a hair drier? Could this effect be exploited to make an air flow meter?

Investigate fluid flow thorough a porous media.

Do jets of water from holes at greater depths below the liquid surface really travel further away from the container than those higher up?

Investigate the motion of water drops on an inclined surface (pacé Galileo’s inclined plane experiment). Use glass, a cuprinol treated surface, wax proof paper or hydrophobic leaf surface. Unlike rigid spheres that will roll, how do the drops move?

Investigate the Leidenfrost phenomenon (eg time to evaporate drops v temperature of the plate).

How do drops of liquid evaporate?

The decay of a foam (eg the head on a glass of coca cola) – is it exponential?

Viscous properties of hair gel.

How do sand castles keep their shape?

DYNAMICS

What happens to simple pendulum if its string is made from elastic or a long spring?

Investigate the trickling of sand in a “sand clock” (ie an egg timer) when on a vibrating base.

How far can a jet of water be squirted? Investigate using a water jet “ski jump”.

Rolling a ball bearing on an inclined V shaped runway - alter angle of the V to tease out the rotational KE etc.

Rather than bouncing balls – investigate the bouncing of balloons or water drops. The latter are important to fire fighters: collision dynamics of water drops with hot surfaces – whether you get spreading, splashes, or rebounds depends on the impact energy, surface temp and roughness. expts have been done with 2.7mm diameter droplets [Proc Roy Soc A **458** pp2417-2444 2002] See Nature vol 419 10 Oct 2002 p576

What determines the angle of repose of sand poured through a hole or funnel?

Why do small pebbles in sand migrate to the surface when the mixture is shaken?

Autorotation (the spinning of certain shapes of paper when dropped).

Investigate the motion of a ball bearing on a submerged inclined plane.

Investigation of factors involved in flow of powders and crystals.

Sedimentation.

WAVES

Investigation of Moiré fringes

The string telephone.

Interference fringes in draining soap films.

Tuning forks. Why is the sound louder when it is pressed onto a tabletop?

Investigate the transmission of infra-red radiation through wire meshes. What makes the best “fire guard”?

Microwave absorption in wood – can it locate “defects”?

What is the optimum size of a hole in a pinhole camera?

The motion of a “domino wave” e.g. casual observation suggests that the speed depends on the separation of the dominos.

Performance of a d.i.y. diffraction grating made by wrapping wire between two screw threads separated by a small distance.

Investigate the reflection of light from glossy magazine pages.

Investigate the speed sound in gases by standing waves (see Chapt 13 Q 100S).

What is going on with Kundt’s tube? (see Chapt 13) – the separation of the piles of dust imply a wavelength too small for standing waves in the air.

Investigate the speed of molecules in gases by exploiting $P = (1/3) \rho v^2$

Can coaxial pipes give very low notes by beats?

How effective is a pile of newspapers as a way to isolate vibrations?

How does jelly wobble? Why is jelly wobbly?

Could diffuse reflection be used as a way to measure the roughness (coefficient of friction?) of a surface?

Why doesn’t the microwave polarizing grid (“prison bars”) act as a diffraction grating for the microwaves?

ELECTRONS

Do β particles behave in a similar way to α particles when fired at a metal? (cf α particle scattering to find the size of a nucleus)

Chapt 13 A 290 E Thermionic Emission only uses the saturation current, so investigate the $I(V)$ characteristic. NB $R(T)$ of the tungsten filament can be used as a proxy for the temperature, or as a thermometer.

ELECTRICAL & THERMAL PHYSICS

Investigate the electrostatic charging of poured powders. Fine sand works well.

Electrical resistivity of “soil”. E.g. detect a buried object in wet sand.

The electrical resistance of two surfaces in contact.

The electrical or thermal properties of metal powders or wire wool.

Evaluate a simple solar heating device made from a transparent soft drink bottle (see Physics Education vol 37(2) page 158 March 2002).

Is a solar cooling panel possible? (see Physics Education vol 37(1) page 76-77 January 2002)

How does the electrical conductivity of a low melting point metal (eg solder, woods metal etc) change as it melts, or of ionic solution as it freezes?

The electrical resistivity of paper.

Thermo-electricity. (“thermocouples”)

Measuring small time intervals with a discharging CR circuit.

Investigation of the behaviour of a commercial radiometer.

MECHANICAL PROPERTIES OF MATERIALS

Standing waves on a sonometer allow an easy way to determine the Young Modulus E of the sonometer wire. Or monitor creep, change in diameter (Poisson’s ratio).

What is the best way to find the thickness of a piece of aluminum foil?

How strong is polystyrene foam?

How hard and or tough is blu-tak?

Adhesive properties of blu-tak.

How does a balloon burst? Mark crosses \dagger on the balloon surface to measure strains in 2D.

The mechanical properties of polyfiller composites (eg mixed with talc, hair etc).

Metal fatigue of paper clips.

How does the Young Modulus E vary with temperature? nb you need to correct strains for expansion!

Can you get the Young Modulus E from the easy measurement of the spring constant of a simple spring?

Tearing of plastic sheets pulled in the Y direction to tear in the X direction – the ripped edges exhibit a wave shape. The bending rigidity is \ll than the stretching rigidity – thus the relaxing sheet buckles to remove in plane compression. cf edges of some leaves [Nature 10 Oct 2002 p579]

Clamped elastic (polythene) sheets start to wrinkle parallel to the direction of an applied stress after certain stress is applied. The clamped edges stop the sheet contracting laterally. The "wavelength" depends on the strain. [Nature pp579-580 vol 419 10 Oct 2002]

The mechanical properties of eg: spaghetti, ice cream wafers, home made glass fibres, bamboo.

How do the properties of a piece of rubber vary with temperature?

The strength of glued joints.

Creep in copper wire.

Effect of temperature on the breaking strength of copper wire.

What is the relationship between the pressure and volume of a rubber balloon?

Plastic properties of leather.

What properties of 4 ply wool which make it useful for woolen garments?

Investigate the factors affecting the strength of a hollow pillar.