**Practical Investigation Topics from Small Group Activities Session at the 2017 Physics Teachers' Conference**

The sporting impacts of a ball with a bat: How does the energy transfer from bat to ball depend of the ball speed, bat speed and the position on the bat of the point of impact?

The motion of weightlifting: How does the acceleration of the bar depend on the spacing of the feet and the spacing of the hands?

Forces and energies of a bouncing ball: How does the drop height and internal air pressure of a basketball affect the rebound efficiency and the impact force?

Sweet spot of a tennis racket: How does the rebound efficiency of a tennis ball hitting a tennis racket depend on the speed of the ball and the position on the racket where it hits?

Motion of a yo-yo: How is the motion of the yo-yo affected by its mass and the distribution of its mass?

Impact of a balloon: How is the impact time of a bouncing balloon affected by the internal air pressure or its diameter and added mass?

How much does the air pressure in a football matter? What might be some dependent variables? What might be an effective measure of the pressure?

The bounce-time of a ball. What factors might affect it? In what ways could it be measured?

The performance of a parachute. How do the terminal velocity and the time to reach it depend on the attached mass and the design parameters of the parachute?

Motion of a balloon through the air. How does the flight vary as you change the initial speed and aspects of the balloon.

Flight of a table tennis ball. How does the flight vary as you change the initial speed and spin of the ball.

Investigate the drag on spheres and other shapes in an air stream

Investigate the drag on objects towed in water (consider changes with length, depth of water and other factors)

Investigate the thrust of a propeller (either in air, or in water)

Investigate the effect of changing the size or shape of the wings of a glider

Magnus Glider: Glue the bottoms of two light cups together to make a glider. Wind an elastic band around the centre and hold the free end that remains. While holding the glider, stretch the free end of the elastic band and then release the glider. Investigate its motion.

Investigate the motion and energy transfer of a mechanical wind up toy

Investigate the energy transfer of a catapult

Hovercraft : A simple model hovercraft can be built using a CD and a balloon filled with air attached via a tube. Exiting air can lift the device making it float over a surface with low friction. Investigate how the relevant parameters influence the time of the 'low-friction' state.

Investigate the performance of a fireworks rocket or a water-driven rocket

Tipcat: Place a small wooden stick over the edge of a desk. Hit the end of the stick overhanging the table so that it flies away. How is the flight distance related to the relevant parameters? What is the condition for a maximum horizontal distance?

Astroblaster: When a large ball is dropped, with a smaller one stacked on top of it, onto a hard surface, the smaller ball will often rise much higher than it would if dropped onto the same surface by itself while the larger ball hardly bounces at all. Investigate this phenomenon and design a multiple-ball system, using up to 4 balls, that will reach the greatest elevation of the top ball.

Rolling magnets: Investigate the motion of a magnet as it rolls down a metal inclined plane.

Water Ski: What is the minimum speed needed to pull an object attached to a rope over a water surface so that is does not sink. Investigate the relevant parameters.

Rolling can: A can partially filled with water rolls down an inclined plane. Investigate its motion.

Adhesive tape : Determine the force necessary to remove a piece of adhesive tape from a horizontal surface. Investigate the influence of relevant parameters.

Dry sand is soft, wet sand is hard, wetter sand is soft again, investigate

Investigate the behaviour of bubbles rising in liquids

Investigate he changeover of a moving ball or a cylinder from sliding to rolling

Wet cleaning: A wet rag is hard to drag when it is spread out and pulled across the floor. What does the resistive force depend on?

Domino amplifier: A row of dominoes falling in sequence after the first is displaced is a well known phenomenon. If a row of "dominoes" gradually increases in height, investigate how the energy transfer takes place and determine any limitations to the size of the dominoes.
Moving cylinder: Place a sheet of paper on a horizontal table and put a cylindrical object (e.g. a pencil) on the paper. Pull the paper out. Observe and investigate the motion of the cylinder until it comes to rest.

Bouncing ball : If you hold a Ping-Pong ball above the ground and release it, it bounces. The nature of the collision changes if the ball contains liquid. Investigate how the nature of the collision depends on the amount of liquid inside the ball and other relevant parameters.

Hoops : An elastic hoop is pressed against a hard surface and then suddenly released. The hoop can jump high in the air. Investigate how the height of the jump depends on the relevant parameters.

The effect on the mechanical properties of ice of adding sawdust

The effect of various sorts of perforations on tearing paper

Cantilever: How does the 'spring constant' of a beam or cantilever vary with its length, cross sectional area, cross sectional shape and other parameters.

The penetration of projectiles into soft materials. Model the collision of a head with the padding of a dashboard and investigate the effect of various parameters on the deceleration of the model head.

Loaded hoop : Fasten a small weight to the inside of a hoop and set the hoop in motion by giving it an initial push. Investigate the hoop's motion.

How does the efficiency of a bicycle dynamo depend on the wheel speed and the resistance of the globe?

How does the efficiency of a DC motor depend on the load and the voltage?

Charged plastic and paper fragments. A charged plastic ruler can make a small piece of paper stand on its end. The separation of the ruler and the paper when the paper just stands up is a measure of the electrostatic force. Investigate the factors that affect the strength of this electrostatic force.

Electromagnetic cannon: A solenoid can be used to fire a small ball. A capacitor is used to energise the solenoid coil. Build a device with a capacitor charged to a maximum 50V. Investigate the relevant parameters and maximise the speed of the ball.

Faraday Generator: Construct a homopolar electric generator. Investigate the electrical properties of the device and find its efficiency.

Electromagnetic motor: Attach a strong light magnet to the head of a steel screw. The screw can now hang from the terminal of a battery. Completing the circuit by a sliding contact on the magnet causes the screw to rotate. Investigate the parameters that determine the angular velocity of the screw.

Rolling magnets: Investigate the motion of a magnet as it rolls down a metal inclined plane.

Magnetohydrodynamics: A shallow vessel contains a liquid. When an electric and magnetic field are applied, the liquid can start moving. Investigate this phenomenon and suggest a practical application.

Investigate what factors affect the penetration of sound through double glazed panels

Sound-absorbing tiles sometimes have perforated hardboard over an absorbent layer. Investigate the effect of changing the frequency and the size of the air hole.

Flute: Drill a hole into the side of a tube that is open at one end and produce a sound by blowing the open end. Investigate the pitch and timbre of the sound of your flute and how they depend on the position and the diameter of the hole

Singing Glass : When rubbing the rim of a glass containing a liquid a note can be heard. The same happens if the glass is immersed in a liquid. How does the pitch of the note vary depending on different parameters?

Liquid light guide : A transparent vessel is filled with a liquid (e.g. water). A jet flows out of the vessel. A light source is placed so that a horizontal beam enters the liquid jet (see picture). Under what conditions does the jet operate like a light guide?

Wet and Dark : Clothes can look darker or change colour when they get wet. Investigate the phenomenon.

How does the speed of water waves depend on the depth of the water?

The contraction of a spiral carrying a current. Investigate.

Two magnets are arranged on top of each other such that one of them is fixed and the other one can move vertically. Investigate oscillations of the magnet.

Granular splash: If a steel ball is dropped onto a bed of dry sand, a "splash" will be observed that may be followed by the ejection of a vertical column of sand.  Reproduce and investigate this phenomenon.

Bouncing drop: Investigate the motion of water droplets falling on a hydrophobic surface (e.g.coated with soot or teflon).

Investigate the energy stored in the magnetic field as two moving magnets approach each other

Woodpecker toy: A woodpecker toy (see picture) exhibits an oscillatory motion. Investigate and explain the motion of the toy.

Rocking bottle: Fill a bottle with some liquid.  Lay it down on a horizontal surface and give it a push. The bottle may first move forward and then oscillate before it comes to rest. Investigate the bottle's motion.

Water flowing from a tap forms a narrow jet? Investigate.

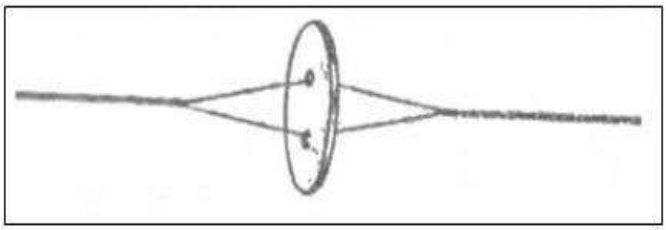
Water from a tap running into a flat basin sometimes forms a smooth ring of water, with a circular edge beyond which the flow is rougher. What decides the size of the ring?

Motion on a trampoline: How does the rebound height of a dropped mass depend on its mass and where on the trampoline it hits?

The physics of a sprint start:  How does the initial acceleration depend on parameters such as separation of the feet, spacing of the hands and height of the set position?

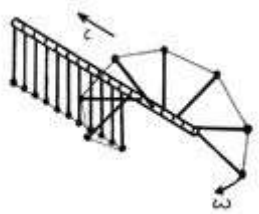
**Experimental investigations for Units 3 & 4**
**These topics have more challenge**

- Gaussian cannon: A sequence of identical steel balls includes a strong magnet and lies in a nonmagnetic channel. Another steel ball is rolled towards them and collides with the end ball. The ball at the opposite end of the sequence is ejected at a surprisingly high velocity. Optimise the magnet's position for the greatest effect.
- Stearin engine :A candle is balanced on a horizontal needle placed through it near its centre of mass. When the candle is lit at both ends, it may start to oscillate. Investigate the phenomenon. Maximise the output mechanical power of the system.
- Skateboarder: A skateboarder on a horizontal surface can accelerate from rest just by moving the body, without touching external support. Investigate the parameters that affect the motion of a skateboard propelled by this method.
- Throwing stone: A student wants to throw a stone so that it reaches the greatest distance possible. Find the optimum mass of the stone that should be used.
- Slinky: Suspend a Slinky vertically and let it fall freely. Investigate the characteristics of the Slinky's free-fall motion.
- Spring thread: Pull a thread through the button holes as shown in the picture. The button can be put into rotating motion by pulling the thread. One can feel some elasticity of the thread. Explain the elastic properties of such a system.



- Blowpipe: Investigate the motion of a projectile inside a blowpipe. Determine the conditions for maximum exit velocity when blown by mouth.
- Car : Build a model car powered by an engine using an elastic air-filled toy-balloon as the energy source. Determine how the distance travelled by the car depends on relevant parameters and maximise the efficiency of the car.
- Slow descent: Design and make a device, using one sheet of A4 80 gram per $m^2$ paper that will take the longest possible time to fall to the ground through a vertical distance of 2.5m. A small amount of glue may be used. Investigate the influence of the relevant parameters.
- Energy Converter : A body of mass 1 kg falls from a height of 1 m. Convert as much as possible of the released potential energy into electrical energy and use that to charge a capacitor of 100 μF.
- Paper Bridge : It is more difficult to bend a paper sheet, if it is folded “accordion style” or rolled into a tube. Using a single A4 sheet and a small amount of glue, if required, construct a bridge spanning a gap of 280 mm. Introduce parameters to describe the strength of your bridge, and optimise some or all of them.
- Rubber motor : A twisted rubber band stores energy and can be used to power a model aircraft for example. Investigate the properties of such an energy source and how its power output changes with time.
- Bubbles: Is it possible to float on water when there are a large number of bubbles present? Study how the buoyancy of an object depends on the presence of bubbles.
- Two Balloons : Two rubber balloons are partially inflated with air and connected together by a hose with a valve. It is found that depending on initial balloon volumes, the air can flow in different directions. Investigate this phenomenon.
- Rotating saddle : A ball is placed in the middle of a rotating saddle. Investigate its dynamics and explain the conditions under which the ball does not fall off the saddle.
- Elastic space : The dynamics and apparent interactions of massive balls rolling on a stretched horizontal membrane are often used to illustrate gravitation. Investigate the system further. Is it possible to define and measure the apparent “gravitational constant” in such a “world”?

- Levitation : A light ball (e.g. a Ping-Pong ball) can be supported on an upward airstream. The airstream can be tilted yet still support the ball. Investigate the effect and optimise the system to produce the maximum angle of tilt that results in a stable ball position.
- Water rise : Fill a saucer up with water and place a candle vertically in the middle of the saucer. The candle is lit and then covered by a transparent beaker. Investigate and explain the further phenomenon.
- Fire hose : Consider a hose with a water jet coming from its nozzle. Release the hose and observe its subsequent motion. Determine the parameters that affect this motion.
- Falling chimney : When a tall chimney falls it sometimes breaks into two parts before it hits the ground. Investigate and explain this.
- Twisted rope : Hold a rope and twist one end of it. At some point the rope will form a helix or a loop. Investigate and explain the phenomenon.
- Water bombs : Some students are ineffective in water balloon fights as the balloons they throw rebound without bursting. Investigate the motion, deformation, and rebound of a balloon filled with fluid. Under what circumstances does the balloon burst?
- Coupled compasses: Place a compass on a table. Place a similar compass next to the first one and shake it gently to make the needle start oscillating. The original compass' needle will start oscillating. Observe and explain the behaviour of these coupled oscillators.
- Transformers: The "simple transformer law" relates output voltage to input voltage and turns ratio. Investigate the importance of frequency and other parameters in determining the non-ideal behaviour of transformers.
- Heated Needle: A needle is hanging on a thin wire. When approached by a magnet, the needle will be attracted. When heated, the needle will return to its original position. After a while the needle is attracted again. Investigate this phenomenon, describe the characteristics and determine the relevant parameters.
- Levitating spinner: A toy consists of a magnetic spinning top and a plate containing magnets (e.g. "Levitron"). The top may levitate above the magnetic plate. Under what conditions can one observe the phenomenon?
- Magnet and coin: Place a coin vertically on a magnet. Incline the coin relative to the magnet and then release it. The coin may fall down onto the magnet or revert to its vertical position. Study and explain the coin's motion.
- Singing Blades of Grass: It is possible to produce a sound by blowing across a blade of grass, a paper strip or similar. Investigate this effect.
- Soliton : A chain of similar pendula is mounted equidistantly along a horizontal axis, with adjacent pendula being connected with light strings. Each pendulum can rotate about the axis but can not move sideways (see figure). Investigate the propagation of a deflection along such a chain. What is the speed for a solitary wave, when each pendulum undergoes an entire 360º revolution?



- Shrieking rod: A metal rod is held between two fingers and hit. Investigate how the sound produced depends on the position of holding and hitting the rod?
- Cup drum : A plastic cup is held upside-down and tapped on its base. Investigate the sound produced when the open end of the cup is above, on or below a water surface.
- Cymbal: Discharging an electronic flash unit near a cymbal will produce a sound from the cymbal. Explain the phenomenon and investigate the relevant parameters.
- Singing tube: A tube open at both ends is mounted vertically. Use a flame to generate sound from the tube. Investigate the phenomenon.
- Tuning fork: A tuning fork with resonant frequency of about 100 Hz is struck and held horizontally, so that its prongs oscillate up and down. A drop of water is placed on the surface of the upper prong. During the oscillation of the tuning fork standing waves appear on the surface of the drop and change with time. Explain the observed phenomena.
- Detection of small motions by interference methods (thermal expansion, compressibility)

- Brilliant pattern : Suspend a water drop at the lower end of a vertical pipe. Illuminate the drop using a laser pointer and observe the pattern created on a screen. Study and explain the structure of the pattern.
- Pin-hole Camera : Study the characteristics of a pin-hole camera and find the conditions for the camera to achieve optimum image quality.
- Black spoon: Blacken a spoon using a candle flame. If you immerse the spoon in water it appears glossy. Investigate the phenomenon and determine the optical properties of such a “mirror.”
- Ghostly images: When a photo is taken with a flash, bright "disks" may appear as shown in the picture. Investigate and explain the phenomenon.
- Fluid lens: Develop a fluid lens system with adjustable focus. Investigate the quality and possible applications of your system.
- Transparent film : If you cover printed text with a piece of transparent polyethylene film you can still easily read it. As you gradually lift up the film, the text becomes increasingly blurred and may even disappear. Study the properties of the film. On what parameters of the film is the phenomenon based?
- Bright spots: Blow a soap bubble and allow it to rest on a liquid surface or a glass plate. When illuminated by sunlight, bright spots can be observed on the bubble. Investigate and explain the phenomenon
- Light scattering : Construct an optical device for measuring the concentration of non-soluble material in aqueous colloid systems. Use your device to measure the fat content of milk.
- Shades: If small non-transparent objects are illuminated with light, patterns in the shadows are observed. What information can be obtained about these objects using these patterns?
- Bright Spots: Bright spots can be seen on dew drops if you look at them from different angles. Discuss this phenomenon in terms of the number of spots, their location and angle of observation.
- Fingerprints : Fill a glass with a liquid and hold it in your hands. If you look from above at the inner walls of the glass, you will notice that the only thing visible through the walls is a very bright and clear image of patterns on your fingertips. Study and explain this phenomenon.
- Vikings : According to a legend, Vikings were able to navigate in an ocean even during overcast (dull) weather using tourmaline crystals. Study how it is possible to navigate using a polarizing material. What is the accuracy of the method?
- Bright waves: Illuminate a water tank. When there are waves on the water surface, you can see bright and dark patterns on the bottom of the tank. Study the relation between the waves and the pattern.
- Sugar and Salt: When a container with a layer of sugar water placed above a layer of salt water is illuminated, a distinctive fingering pattern may be seen in the projected shadow. Investigate the phenomenon and its dependence on the relevant parameters.
- Thick Lens : A bottle filled with a liquid can work as a lens. Arguably, such a bottle is dangerous if left on a table on a sunny day. Can one use such a ‘lens’ to scorch a surface?
- Circle of Light :When a laser beam is aimed at a wire, a circle of light can be observed on a screen perpendicular to the wire. Explain this phenomenon and investigate how it depends on the relevant parameters.
- Meniscus optics Cut a narrow slit in a thin sheet of opaque material. Immerse the sheet in a liquid such as water. After removing the sheet from the liquid, you will see a liquid film in the slit. Illuminate the slit and study the resulting pattern.

- Coloured plastic Light and matter In bright light, a transparent plastic object (e.g. a blank CD case) can sometimes shine in various colours (see figure). Study and explain the phenomenon. Ascertain if one also sees the colours when various light sources are used.
- Soap Film : Explain the appearance and development of colours in a soap film, arranged in different geometrical ways.
- Balloon: Measure the change of the optical properties of the skin of a balloon during its inflation.

**More Practical Investigation Topics**
**These topics have short titles that may need some unpacking**

Energy transfer in a pole vault
The physics of a bicep curl
The bounce in track shoes
Kicking a football
The physics of walking
The motion of a bungee jumper
The friction of running shoes
Compare static and kinetic friction of running shoes
The pressure—volume relation for a rubber balloon
The effect of temperature changes on the flow of motor oils
The design of a flow meter
Reduction in pressure with fast flow (Bernoulli effect)
The resistance to water flow of various plumbers' fittings (pipe, bends, etc.)
When does water flow in a tube become turbulent?
Measuring the viscosity of air
The airflow in a room with a heater
Smoke rings (a box with a hole at one end, and a flexible diaphragm at the other)
Vortex rings in water (drop coloured water drops onto clear water)
Wind problems around buildings
When does water flow become turbulent?
The supporting of a ball on a jet of air
Paper plane design
Design of car bumper
Shock absorbers
Maximising the adhesion of blutac
Factors affecting the design of a good paddle wheel
Effectiveness of padded postal envelopes
A narrow water trough as an accelerometer
The performance of a water pump
The performance of a fan
The thrust of a propeller (in air, or in water)
Load and speed variations of a model aero-engine
The energy stored in a spiral clock spring
The sensitivity of the eye
Depth of focus of a microscope
Caustic curves
Moire fringes
Fresnel lenses
Sellotape and polarised light
Double refraction of Iceland spar
Brewster’s angle
Fresnel lenses
The performance of a pin hole camera
How much is scattered light polarised?
Optical activity of sodium chlorate
Light scattering and polarised light
The field of view of a simple telescope
The depth of focus of a simple telescope
The colours of thin films of oil on water
'Shadows' of hot air from flames or heated objects
The resolution of close-spaced objects by the eye

How much light is reflected at various angles by glass?
Patterns in stressed materials between crossed polaroids
How long does a sound last in a large hall?
The propagation of sound at low pressures
The wakes of boats
Waves in moving water
Speed of waves in shallow water
Breaking of waves
Waves in circular dishes
The diffraction of sound waves
Producing and detecting ultrasonic waves
The pressure changes in the sound from an explosion
What are the shadows of waves on a ripple tank shadows of?
A dynamo as a speedometer (conversion to accelerometer?)
Efficiency of a transformer
Saturation effects in a transformer
Effect of air gaps in transformers or electromagnets
Eddy current losses in transformers (solid core)
Stray fields around transformers
Variations in potential in a tank of conducting liquid
The time taken for ions to recombine (e.g. blown down-wind of a flame)
Torque-speed variations of a turntable motor
An electroscope as a voltmeter
The sensitivity of an electroscope as a charge measuring device
The effect of thickness of metal on eddy current forces
How high will a 'jumping ring' jump? (A ring over an iron core with a coil carrying a.c. on the core)
The dependence of the speed of a DC motor on field current
Change in length of a nickel rod in a magnetic field
The design of an alternating current ammeter
Does a flame conduct electricity?
Does hot air conduct electricity?
What factors affect heating by eddy currents?
How does the resistance between two points on a conducting sheet vary with distance?
How does the resistance between two flat plates in a tank of conducting liquid vary with their spacing?
Make an electrostatic dust collector
How does the resistance in an *LC* circuit affect the resonance?
The strength of paper
The creep of rubber
Properties of glued joints
Strength of human hair
Effect of heat treatment on metals and materials
Effect of a twisting force on a bone
Factors affecting the buckling of a beam under compression
Factors affecting the flexing of a rotating shaft
The strength of girders of different construction (use balsa wood)
Making strong concrete bars
The fracture of concrete by impact forces
Effects of reinforcement on concrete
The strength of fibreglass repairs
Variation of flow behaviour with strain (silicone putty)
Perspex is said to 'remember' that it has been deformed, for a while. Does it?
How finely woven must umbrella material be?
Investigate The strength of a soldered joint
Changes of length of hair with moisture content

The sagging of taut wires loaded in the middle
The shape of a suspended loose chain
Will a hole at the end of a crack help to stop the crack from spreading?
What factors influence the production of good, uniform bubble rafts?
Forces and energies in stretched rubber
Water drops falling on water
The profile of a rotating water surface
The precession of a gyroscope
Factors affecting the friction of steel on ice
The effect of oil films between sliding metal surfaces
Does water absorb ultra-violet light?
The motion of a ball rolling on a turntable
The possible orbits of a pendulum bob
The motion of the tip of a vibrating wire