

Experiments for a special day

Science or physics open days, physics club evenings, teacher meetings or road shows are some of the events for which it is useful to have a repertoire of unusual or spectacular demonstrations. ‘Science on stage’ gatherings and some recent articles [1-3] have provided ideas for this purpose to readers of this journal, some of whom will also have their own favourites for such occasions like these. Over the years I have collected several such demonstrations, shown them to various audiences and would like to share some of them here, hoping that it will be helpful to gather them in one place. The experiments are grouped according to topics. We give only brief descriptions. More details can be provided on request. There is enough material here for two or three hours. A bullet marks those experiments in which there is some measure of audience participation.

One may either choose a single motif to run through the show, or opt to demonstrate the breadth of physics in a variety of topics. The effectiveness of such a show depends on the method of presentation, on the effort made to involve the audience, on the tension built up before and on its resolution after an experiment. Clearly, the level of explanations must be adjusted to the audience.

A question of time.

The following group of four demonstrations illustrate the use of the momentum-impulse relation $F\Delta t = \Delta p$, either where Δt is so small that the state of motion of objects is virtually unchanged, or, for a given Δp , that a large Δt implies a small F .

1. *Broomstick smash*. A softwood rod has a pin sticking out from each end, these are placed on rims of wineglasses resting on tables suitably separated. A swift blow by a sharp heavy club on the middle of the rod will break it, without overturning or upsetting the glasses, Figure 1. Make sure the rod ends are clear of the table edges, the audience is at least 2 meters away, and wear goggles for safety.



Figure 1

2. *Pen into bottle*. Place a 25cm diameter thin circular wooden embroidery hoop

vertically on a narrow necked beer bottle, and a flat bottomed pen on top of the hoop directly above and in line with the bottle opening, as shown in Figure 2. A sudden sharp sideways blow with a forefinger to the inside of the hoop at the twenty-to-eight position will deflect the hoop and allow the pen to fall into the bottle.

3. *Egg into beaker*. Place a small round disposable aluminium cake tin on a 500ml beaker two thirds full of water. In its middle place upright a 8cm long 2.5cm diameter plastic pipe, and on top of that an egg with its wide end sitting on the pipe, Figure 3. A sudden, short (so you don't hit the beaker) horizontal blow on the rim of the tin will send the tin plus pipe flying to the side and the egg falling into the water unscathed.



Figure 2



Figure 3

4. • *Unbreakable egg*. Two people from the audience hold a sheet vertically, with its bottom slightly curled up to form a catchment area, Figure 4. A third person hurls an egg into the sheet, unable to break it no matter how hard the throw - it falls safely into the bottom.

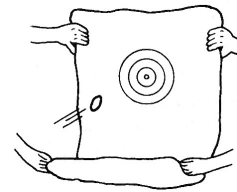


Figure 4

Circular motion.

5. *Pick up ball*. Remove the bottom from a large plastic flower pot and place it on the table. Put a tennis ball inside, Figure 5. Hold the top rim of pot and rotate it fast: the ball will be picked up and spin on the inner wall.

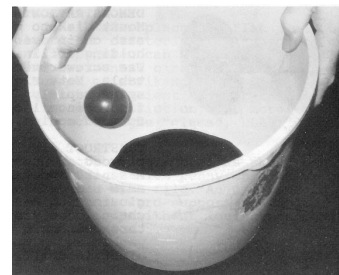


Figure 5

6. *Rotating sparkler*. Bend the wire handle of a sparkler at 90° to the flammable part and insert into the chuck of a variable-speed drill. Ignite the sparkler, then switch on the drill at its *slowest* speed (in a darkened room for best effect). Make sure that the plane of rotation faces audience. A shower of sparks fly off at a tangent.

7. • *A paper saw*. Two circular 3mm thick wooden disks of diameter 6cm enclose a concentric circular piece of paper of diameter 8cm by a double nut and bolt arrangement, Figure 6. The bolt is held fast in the chuck of a variable speed drill. Switch on, use the highest speed, then bring the spinning paper disk near the middle of a long piece of chalk or a plaster board, preferably held by a volunteer (or in a lab stand), and start cutting by gently bearing down on it. The paper saw will slice through the chalk with a clean cut.

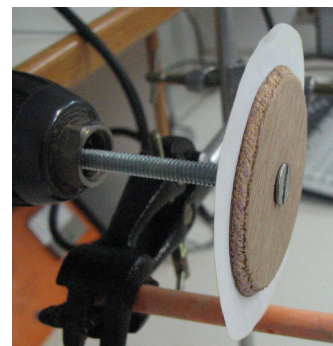


Figure 6

8. *Chain into hoop*. Make a wooden circular disk, diameter 25 cm, with a flange around one side of its perimeter and a bolt through its centre which can be inserted into the chuck of a drill, to make the disk rotate. Join two ends of a bathroom or similar chain to make a loop, and of such length that the loop fits comfortably but not tightly around the perimeter of the disk, Figure 7.

Kneel on the floor, hold the plane of the disk and its chain slightly tilted from the perpendicular to the floor (so the chain does not fall off while acquiring rotational speed, as it's retained by the flange), switch on, attain a high speed, then tilt disk back to vertical and ease chain off it. This will careen across the floor as a stiff hoop, until frictional torque destroys its angular momentum. You can also do this on slightly sloping tables with a gap between them, and have the chain-hoop jump across the gap. This version really brings the house down.



Figure 7

Jet propulsion

9. *Two sparklers.* Double bend two birthday cake sparklers in two planes, as shown in Figure 8. Attach them to a 20-25cm long thin light wooden lath or a (bamboo barbecue) stick, pivoted in its middle from the tip of a pin nestling in the hole of a snap fastener, so it can rotate freely. Ignite the sparklers.

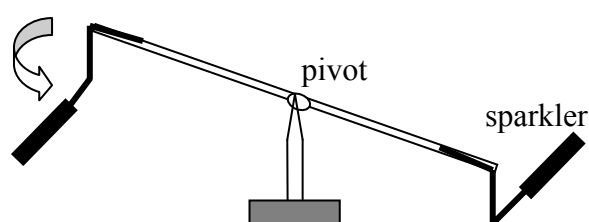


Figure 8

The recoil from the sparks flying off causes the whole assembly to rotate as long as the sparklers burn [4].

10. *CO₂ flask on cart.* Get a 7kg flask from a gas supply company, with a tap on top. Sit with it on a cart with smooth wheels (I made mine from discarded in-line roller skate wheels attached to axles fastened to a plank of wood), embracing it against your chest or shoulders, Figure 9. The exit pipe of the gas points away from you. Make sure nothing obstructs you from behind, then open full throttle. You will be propelled backwards by the emerging visible gas jet. This demo is an effective entry piece onto the stage from behind the curtains, at the start of your show.



Figure 9

11. *Mineral water jug missile.* Wear gloves and goggles. Pour 20ml of methanol into an empty 20 liter rigid plastic jug having a narrow mouth, which you then close with your palm. Hold the jug with both hands, shake and rotate it for 2 minutes so as to spread the liquid evenly all around its inner surface, thereby enhancing vapour formation. You will soon feel the vapour pressure on the palm: then quickly place the jug on a slight upward incline, remove your hand from the opening, stand on the side and ignite the vapour at the opening with a long gas lighter. Figure 10 shows the safe stance. The jug



Figure 10

will be propelled across the stage with a small comet-like blazing streak issuing from its mouth. The demo is quite safe indoors: We performed it many times right under sensitive smoke and fire detectors which never went off. Nevertheless, you may want to perform it outdoors.

Light entertainment

12. *Glowing lantern.* Darken the room. Make a cylinder from a sheet of A4 paper. Place it on a mirror, then shine a laser pointer from above at almost zero angle of incidence. The laser spot will be seen on the ceiling, the cylinder remains dark. Now replace the mirror with a white sheet of paper and repeat. Due to diffuse reflection from the sheet a glow will be observed all around the cylinder envelope, a Chinese lantern effect.

13. ● *Pulfrich pendulum.* Hand out slides containing any translucent coloured paper. Suspend with a string from the ceiling an empty soft drink can so it dangles at eye level. Carefully pull it aside and release, so it swings in a plane perpendicular to the viewers. These observe its motion with both eyes, close to of one of which they hold the slide, so as to reduce the intensity of light reaching one retina. Instead of the actual planar motion an elliptical illusory path of the can is observed, due to the delay in perception by one eye caused by the reduced light intensity.

14. ● *Pinocchio.* Ask for a volunteer who wishes to ‘extend her nose’ or ‘make her chin more prominent’, without plastic surgery, and position her in profile some 50cm away from a white screen or wall. An overhead projector (OHP) 50-100cm from her head projects a sharp shadow of it on the screen. Hold a sheet of paper vertically between head and OHP, so that its shadow on the screen is separated a little from that of the head. Now slowly and gradually move the sheet sideways, so that the two shadows approach each other. At a critical stage the two shadows touch, Figure 11, and the shadow of the nose (or the chin)



Figure 11

is seen to extend and move towards that of the paper, the ‘elongation’ effect. The effect is due to the perception by the eye of an umbra when two penumbras overlap, as generated by an extended source like the OHP.

15. ● *Black brighter than white?*

Preparation before the show: Generate a round spot of light from a slide projector by inserting into it a ‘slide’ made of thin aluminium plate into which a hole of suitable diameter has been drilled. Work the projector on a dimmer and shine its beam onto the middle of a matt black sheet of cardboard paper 50x50cm, hung on a wall some two meters away. Where the spot illuminates the cardboard cut the paper to make a hole of that size. To the middle of the backside of the cardboard affix a black paper pocket into which one can easily slide, or remove from it, a sheet of white paper somewhat larger than the hole, then replace the cardboard in its previous position on the wall, Figure 12. The hall is darkened.

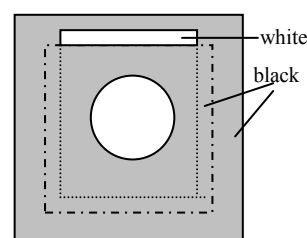


Figure 12

Step one: with the white sheet *in* the pocket, the audience sees the hole white. Shine the spot of light on the hole, having adjusted the hidden dimmer to provide the lowest possible illumination on it, and ask the audience to note the brightness of the hole.

Step two: With all lights off ask the audience to close their eyes, while in a swift action you remove the white sheet, secretly increase the dimmer to its maximum intensity and flip the projector on. Ask them to observe the (increased) brightness or 'whiteness' of the hole.

Step 3: Turn the hall lights on, the projector light off. Listen to the gasp from the audience, as it discovers that it was the black hole that was 'whiter' than the white hole. The perception of dark or light, white or black, is relative, and depends on the available contrast.

16. *Fly away Peter...*

From 12 wooden sticks each 65 cm long and having a cross section of say 17x25mm (exact dimensions are not crucial) screw together the outline of a cubical box (so you can dismantle it after the show), set it on a table with one edge facing the audience table and insert along its diagonal a plastic mirror of suitable size, whose plane faces the audience. Climb on the table, into the box and astride the mirror, with one leg in front of it and one leg behind it. Rest your body on the leg behind, lift up the front one: a floating effect results, because of the reflection, Figure 13. You can then make flapping or flying movements with your arms and appear to fly, while saying goodbye to your audience amidst general mirth. This could be the closing piece of your show.



Figure 13

17. *'Sunset'*

Place a 500ml beaker on an OHP and pour 100ml of 0.05M hydrochloric acid into it. Then add to it 100ml of 5% $\text{Na}_2\text{S}_2\text{O}_3$ (sodium thiosulphate) and wait in a darkened room. A spot on the screen the size of the beaker will gradually turn from transparent to yellow to dark red to opaque, as increasing numbers of sulphur particles precipitate in the chemical reaction and scatter the light.

Waves

18. • *Big Ben*. Attach two sewing threads to a stiff wire, or around the handle of a fork, wind the other ends once or twice around the forefingers, insert these into the ears, let the partner lightly touch or knock on the wire or fork, and listen to wonderful bell sounds. This can be an amusing group activity just prepare enough wires and threads.



Figure 14

19. *The singing rod*. Rubbing a 2m long aluminium rod produces beautiful sounds. See [5].

20. *Screening*. Using chicken wire make a cylindrical cage closed from the top but open at the bottom, by soldering together carefully all along the two ends and around the top lid. The cylinder is around 1m tall, and some 40cm in diameter. Place on a stool a battery operated small transistor radio tuned to any station, or with noise in between stations, see Figure 15. Now gradually lower the cage on the radio and observe the decrease in sound from its speaker. Radio waves do not penetrate the cage even though it is riddled with holes.

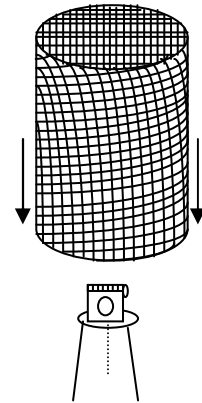


Figure 15

21. *Octaves*. Hold a plastic pipe (length 40-60cm, diameter 4-6cm) in one hand and beat on one end with the palm of your other hand in two ways: a) slowly, so your hand tarries on the opening, and b) very fast with a stiff palm, rebounding from the opening. The sounds generated are separated by an octave, the difference between an open and a closed pipe resonating. If you rhythmically beat slow-fast-slow-fast several times, even the non-musical members of the audience will discern the change of pitch.

22. *Glowing wire A*. Preparation: lead a 50cm long 0.2mm diameter chrome-nickel wire along the middle of a horizontally held 25cm long 2cm diameter glass tube. The wire is held in place by and passes through little stiff-wire loops $\text{---}\bigcirc\text{---}$ stuck to each end of the tube. The far end of the wire exits the tube, passes over a pulley and is held taught by a 100g weight hooked to its end, the other exits the near end of the tube. Alligator clips at each end connect the wire to a 0-25v power supply. Couple a loudspeaker, connected to a signal generator, to the near end of the tube by the top funnel-shaped part of a soft drink bottle, see Figures 16a,b. In a dark room turn on the voltage across the wire until it glows. Warn the audience to plug their ears with their fingers, to prevent discomfort from hearing high pitched sounds. Now switch on the signal generator to a previously found suitable frequency: the result is alternating glowing and dark sections of the wire, the latter due to the cooling effect of the air at pressure nodes.

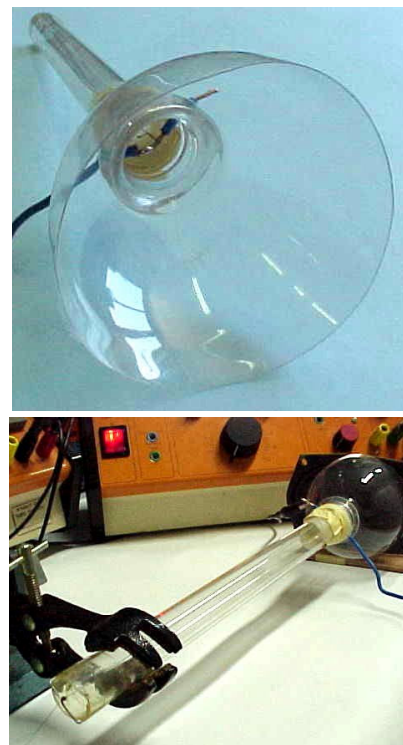


Figure 16a,b

23. *Wobbly tuning fork*. A vibrating tuning fork, held in front of a blank computer monitor (not all monitors perform well), will be strobed by the refresh rate of the latter resulting in the wavy appearance of the tines, see [6].

Current affairs

The next two experiments should be performed only by experienced teachers.

24. *Glowing wire B.* This shows the lowering of electrical resistance with temperature. Prepare in advance two pieces of flat-faced ice: pour water in a large rectangular flat plastic container, divide it across its diagonal (which is some 30cm long) with a smooth partition, freeze for 3 days, then remove the divider. Stretch a meter long 0.5 mm thick chrome-nickel wire between

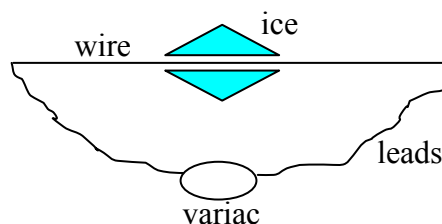


Figure 17

lab stands, connect the two ends to a variac (0-220V) and apply a voltage (70-80 volts is usual) low enough so that the wire is just on the verge of glowing [7]. For safety include a sturdy switch in the circuit which also has a circuit breaker in it, and make sure you wear insulating wear rubber gloves. Now hold the central third of the wire between the two pieces of ice. Figure 17 shows a top view. Due to the cooling the resistance drops and the sections on either side of the ice will start to glow, *without* having to increase the voltage.

25. *Glorious pickle.* Place a long fairly straight pickled cucumber into a pyrex bowl, stick two long nails into it to a depth of 1-2 cm and connect them to the output of a variac (0-220V). For safety include a sturdy switch in the circuit with also has a circuit breaker in it, as in the previous experiment. At high enough voltages the pickle will emit a yellow glow at one end, amidst boiling bubbling sounds (a spectrometer will show the sodium D line from the light).

Forces

26. • *The egg as an arch.* Prepare the gadget as shown in Figure 18a,b. Use a Perspex tube 25 cm long and diameter 7-8cm. Some 8cm from the bottom of the tube cut into it a window 6x8cm for inserting the egg. Hold the tube vertically stable by inserting it into a thick wooden base 20x20cm having a circular groove for snugly accepting the tube. Make a 12cm long piston from aluminium or a hard plastic rod, its diameter 1mm less than that of the tube. Stick a hard rubber washer a few centimeters thick to the end of the piston - this serves to absorb the shock on the egg when standing on the piston. Fill the tube below the window with sand, place the egg with wide side down into a little dimple in the sand. Make sure the symmetry axis of the egg is exactly vertical, place the piston on it. Now let a volunteer step slowly on top of the cylinder from an adjacent box of the same height and stand on that foot only.



Figure 18a,b

The egg will support him, a testimony to the strength of arches in carrying loads. Helpers may support his arms for equilibrium, without supporting his weight, which can be up to 60-70kg.

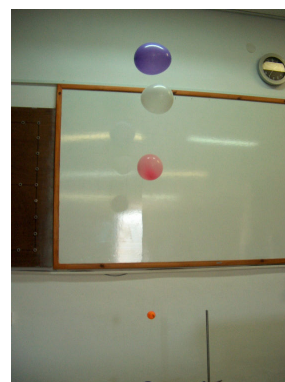
27. • *Pulley model with broomsticks*. Figure 19 shows the idea, described in [8]. Two people holding the sticks cannot maintain their separation against the multiplied force of the third person pulling on the rope wound around them several times.



Figure 19

28. *Balloons in an air stream*. Use a variable-speed air track blower, its nozzle near the floor pointing vertically up, to support in its air stream up to four balloons of increasing sizes. In order to make a smooth balloon surface all round, cut off its neck close to the body, tuck the rest into the latter and secure with adhesive tape. Start by sliding the smallest one gently into the air stream, then go up with height and size, see Figure 20 and [9].

Figure 20



We end with a plea to reader colleagues: Many teachers have organized physics shows. Let them send to this journal some of their best ideas which they have not seen elsewhere, so we can all benefit.

References

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