An inexpensive linear air track

Having a near frictionless environment for dynamics experiments removes one of the obstacles to seeing that the laws of physics really work. However, professionally produced linear air tracks are very expensive, being marketed for between £250 and over £500, but they can easily be made (see figures 1 and 2) for around £35 using plastic downpipe, shelving uprights, aluminium corner, some Lego bricks and card (see parts list at end). The Lego bricks are very standard items found in virtually all kits and provide a 'clip together' system with a professional-looking finish.

On purchase of the downpipe, check that it is as straight as possible. Similarly with the long shelving upright—I found that the 1600 mm lengths were fine but that the 1980 mm ones were slightly bowed. A straight and unbowed shelving upright is essential as it is this which will maintain the straightness of the whole assembly. Saw the downpipe to a length of 1640 mm and place sticky labels with 1, 2, 3 and 4 respectively onto the corners at each end. Leave these labels in place until the whole unit is virtually complete, as they will allow you to match other parts together (figure 3). Now drill two rows of approximately 1 mm holes along two adjacent sides of the downpipe so that they are 1 cm and 2 cm respectively from their common apex, and spaced 2 cm apart in each row with the rows offset from each other by 1 cm. A hand-held model-maker's electric drill is ideal, and making a drilling tem-

Figure 1. *Linear air track set up for collision experiments.*

Figure 2. *Linear air track set up for force, mass and acceleration experiments.*

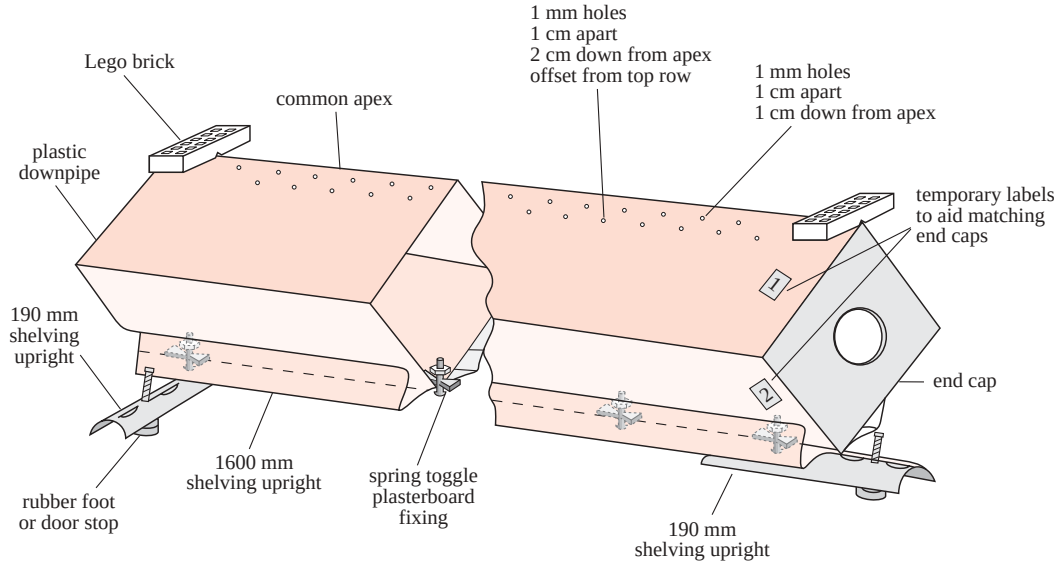

Figure 3. *Annotated diagram of construction.*

Figure 4. *Drilling holes with the aid of a template.*

Figure 5. *Making the end caps.*

plate (figure 4) from a spare piece of downpipe eases the task considerably. Ensure that all the plastic swarf is cleaned out—a metre rule with a sticky pad on its end run down the inside of the downpipe does this job well.

Place the long shelving upright along the apex edge opposite to that where the holes have been drilled and position it centrally so that the downpipe overlaps by 2 cm at each end. Mark the positions of the bolt holes through the shelving upright and drill 5 mm holes at these points through the downpipe. Now anchor the shelving upright to the downpipe via the middle three holes using Spring Toggle Plasterboard fixings, but with the bolts supplied having been reduced to a length of 2.5 cm. Do not use ordinary nuts and bolts as they will pull through the plastic downpipe. To position the toggles prior to bolting, attach each to a sticky pad on the edge at the end of a metre rule. Move the metre rule with the toggle until you can see the toggle nut matched with the downpipe and shelving upright holes, then screw the bolt home (an assistant is needed for this part). To provide for levelling attach 190 mm shelving uprights through the end holes in a similar fashion, but such that at one end the upright sticks out symmetrically sideways and at the other sticks out beyond the end. Drill 6 mm holes through three rubber feet or doorstops and screw the 6 mm machine bolts through them and into the two outer holes of the sideways support and into the far end

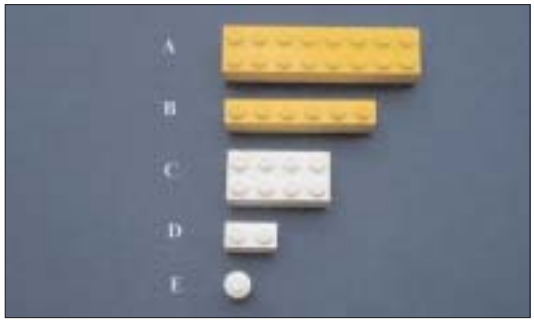

Figure 6. *Range of Lego bricks used.*

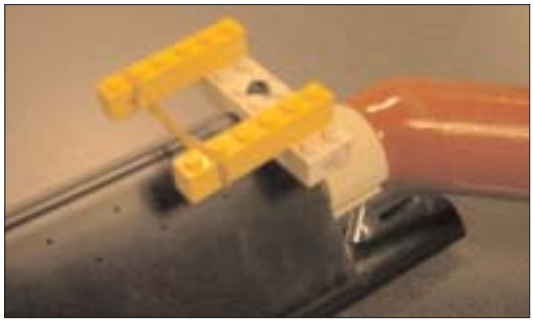

Figure 7. *Buffer/catapult.*

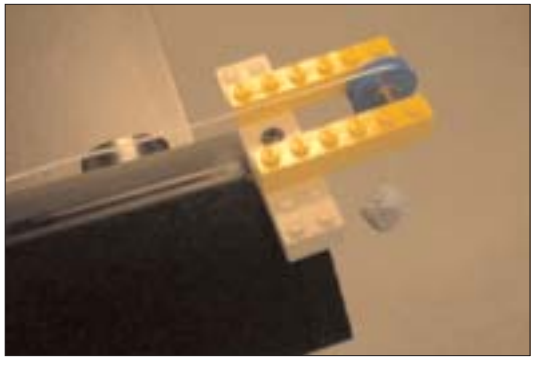

Figure 8. *Pulley system.*

Figure 9. *Linear air track vehicle for collision experiments.*

hole of the end support. These now form the adjustable feet.

End caps to the downpipe can be made from mortar. First label (1, 2, 3 and 4 as appropriate) and cut off two 2 cm lengths of downpipe to form moulds. Clean off any swarf, coat their inner surfaces with lubricating oil and lay both on a flat impervious surface. In the centre of one of these position the hosepipe from the air blower/vacuum cleaner and clamp securely. Mix the mortar cement and pour into the two moulds and allow to set (see figure 5). When set, remove the end caps and hosepipe—it may be best to saw through the plastic downpipe to do this—and rub down the outer surfaces with glass paper to reduce their size slightly until they slide fairly easily into the downpipe ends, matching the 1s, 2s, 3s and 4s appropriately. Also enlarge the hosepipe hole slightly to allow an easier fit. Spread a thin layer of adhesive sealant on the edges of each end cap, fit into place and leave to dry. When dry, paint the outer ends black, brown or white to match the colour of the downpipe. The labels can now be removed.

File grooves centrally on the underside of two Lego bricks 'A' (see figure 6) so that they can fit horizontally on the ridge of the air track. These are to form the bases of the buffers, catapults and pulley system at the ends of the air track. Roughen about 1.5 cm of ridge at each end of the downpipe and glue these Lego bricks into place. For greater robustness you may find it useful to drill a hole though the Lego bricks, the downpipe and into the mortar end cap and secure these Lego bricks with a screw. The buffers and catapults are then made by fitting (not gluing) two Lego bricks 'B' to these together with a small rubber band (see figure 7). The pulley system is also made from two Lego bricks 'B' but with 3 mm holes drilled near their ends on their insides but not completely through. A 2 cm diameter plastic pulley wheel then needs to have its centre drilled out and a ball-race pressed into place. The latter is then fitted onto a 2.8 cm axle rod fitted between the Lego bricks (see figure 8).

Now saw off two 21.4 cm lengths of aluminium angle to form the bases of two linear air track vehicles. Smooth down any rough edges with a file. Saw

Figure 10. *Linear air track vehicle for force, mass and acceleration experiments.*

vertical slots of width just greater than 1 mm halfway along four Lego bricks 'C' and then saw and chisel 90° slots on the undersides so that they rest on the apex of the aluminium angle making up the vehicles. Glue these Lego pieces to the ends of the vehicles with the slots facing inwards. The slots are for mounting the timing cards. Glue button magnets to two Lego bricks 'D' such that they have the same magnetic poles facing outwards—these are for making elastic collisions. When the glue is set mount one of each of these 'magnetic bricks' onto the bricks on the ends of the vehicles. Mount another Lego brick 'D' on the vehicles' other ends—these could have small blobs of Blu-Tack, or other reusable tacky putty, attached for inelastic collisions. Cut up four small polythene bags and tape together so that they make two 'saddles' with open pouches which can be placed across the two vehicles. In these pouches combinations of 10 g masses will be placed, being careful to balance the numbers on each side. Cut out two timings cards from 1 mm plastic sheet or cardboard, 18 cm long by 3 cm overall, but with a 3 cm by 5 cm raised section in the centre. This completes the construction of the vehicles for any collision experiments. Their overall mass can be made up to 100 g or 200 g with the addition of 10 g masses and Blu-Tack. See figure 9.

For force, mass and acceleration experiments just one vehicle is used with Lego bricks 'D' removed and a Lego brick 'E' mounted on one end. A timing card 18 cm by 3 cm overall, but with 3 cm by 5 cm raised sections at each end, should now be made (see figure 10). Again the overall mass should be made up to 100 g or 200 g with 10 g masses and Blu-Tack, but note that the Blu-Tack should also form an accelerating load of from 1 g (approximately 0.01 N) to 5 g (approximately 0.05 N) attached to a cotton thread over the pulley.

If you are using an ultrasound position-sensing device, then cut out a card 8 cm by 5 cm and glue to another Lego brick 'D'. This would then be mounted on the end of a vehicle with the card facing the end of the air track where the ultrasound device was transmitting from.

In use the whole system needs first to be levelled, an air blower attached and light-gates positioned appropriately. Professional air blowers are expensive but vacuum cleaners providing a 'blow' facility are available more cheaply, e.g. Hitachi CV850.

Parts list

- 65 mm square section Marley downpipe (RPE3)
- 1 m length aluminium 90° corner 35 mm × 35 mm × 1.5 mm thick
- 1600 mm Spur shelving steel-lok upright (9016BL)
- 2 × 190 mm Spur shelving steel-lok upright (8610MB)
- 3 × pan-headed bolts 40 mm × 6 mm
- 3 × rubber feet or doorstops
- 5 × Rawlplug Heavyweight Spring Toggle Plasterboard Fixings (94-369)
- Glue—Rapid Araldite or similar
- Adhesive sealant—Evo-Stik Nail and Seal or similar
- Lubricating oil
- Sheet 1 mm black plastic card or cardboard
- Lego bricks (see figure 6)
- 4 × small polythene bags
- 2 cm diameter plastic pulley wheel
- 3 mm bore ball-race
- 3 mm diameter axle rod
- 2 × neodymium button magnets 12 mm diameter × 4 mm thickness
- Bostik Blu-Tack or other reusable tacky putty
- 2 × rubber bands
- Cotton thread
- Paint
- Mortar cement
- 10 g masses
- air blower/vacuum cleaner with 'blow' facility

Suppliers

In the UK the DIY items are available from branches of B&Q; the magnets from Scientific and Chemical Supplies Limited and many other science equipment suppliers; and the plastic sheet, pulley wheel, ball-race and axle rod from W Hobby Limited and most model shops. W Hobby Limited will also deal with mail order from abroad. Lego is available around the world from most toy shops.

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