4 Fig. 4.1 shows a demonstration of a man shooting a dart using a blowgun.

Fig. 4.1

When the man blows into a horizontal blowgun held at a distance *y* above the ground with a dart at one end, the dart accelerates along the barrel of the blowgun and then exits at the other end of the barrel. Once the dart leaves the barrel, it travels a horizontal range *x* as shown in Fig. 4.2.

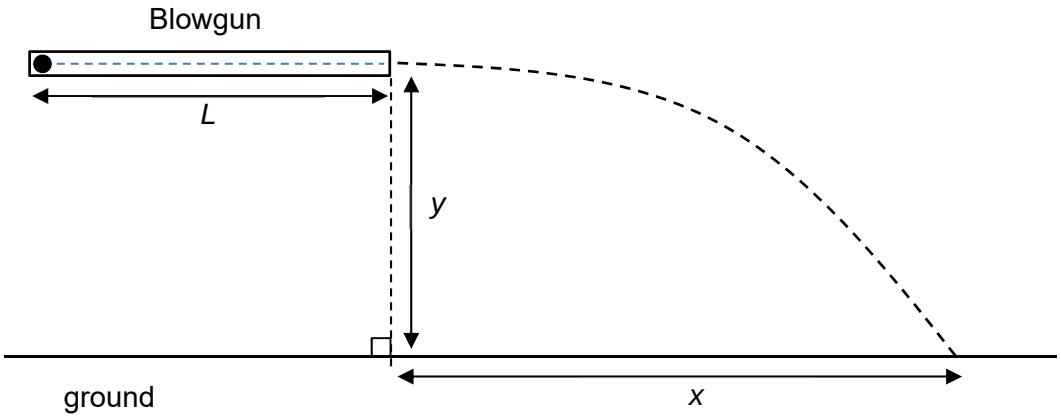


Fig. 4.2

The range *x* is given by

$$x = kF^p m^q L^r d^n$$

where *k*, *p*, *q*, *r* and *n* are constants, while *F* is the average force on the dart as it travels along the barrel, *d* is the inner diameters of the barrel, *m* is the mass of the dart and *L* is the length of the blowgun.

Design an experiment to determine the values of *r* and *n*.

You are provided with several plastic straws of various inner diameters but of the same length to model as the blowgun and a small metal spherical ball that can fit into the straws as a dart.

Draw a diagram to show the arrangement of your apparatus. Pay particular attention to

(a) the equipment you would use
(b) the procedure to be followed
(c) how the length of straw, the inner diameter of the straw and range *x* are measured
(d) control of variables
(e) any precautions that should be taken to improve the accuracy and safety of the experiment.

[Turn over

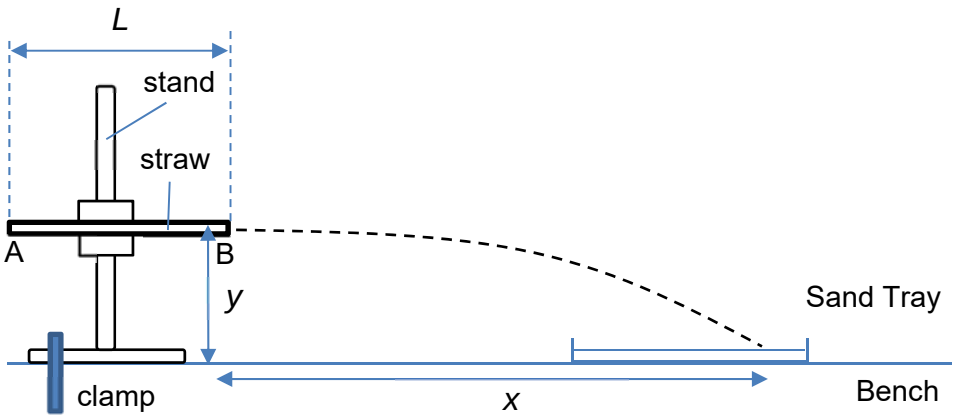
Diagram

[12]

4

Suggested Solution:

Diagram:



1. Set up the apparatus as shown in the diagram above.
2. Tape the straw on a cardboard which can be clamped horizontally. Use a spirit level to verify that the straw on the cardboard is horizontal. Measure the length of the straw *L* using a metre rule.
3. Measure the inner diameter *d* of the straw using the Vernier caliper. Measure the inner diameter at both ends to have an average *d*.
4. Insert the small spherical ball onto one end of the straw.
5. Blow into the straw at the end where the small spherical ball is such that the ball shoots out at the other end of the straw.
6. Repeat step 4 with the same cotton bud a few points multiple times (more than twice) to get an average position that the small spherical ball lands. Calculate the average x.
7. Place a tray of sand at the average position that it lands.
8. Use a set square and a metre rule to identify the position vertically below the other end of the straw on the bench. This position is the initial position of the cotton bud immediately when it leaves the straw.
9. Step 4 such that the small spherical ball lands and makes a mark on the tray of sand.
10. Measure the distance *x* from the position marked in step 7 to the mark on the tray of sand by the cotton bud. Level the same after *x* is measured.
11. Repeat step 8 and 9 to have an average *x* for the same straw at the same inner diameter.
12. Repeat step 2 to 11 by changing to a straw with a different inner diameter until at least 6 set of *x* and *d* is obtained.
13. Plot a graph of lg x against lg *d*. n is obtained as it is the same value as the gradient of this graph.

To determine *r*,

14. Choose one of the straws earlier and use the same straw throughout the rest of the experiment. Cut about 1.0 cm of the straw off to make *L* smaller.
15. Repeat step 2 to step 11 to have at least 6 sets of *L* and *x*.
16. Plot a graph of lg *x* against lg *L*. r is obtained as it is the same value as the gradient of this graph.

Safety:

- Wear goggles to prevent projectile from entering the eye
- At one end of the straw where blow by mouth, have a net to prevent accident sucking in of the small spherical ball.

Mark Scheme:

P1 – Overall Problem Identification, Diagram etc

IV1 – Measure length of straw
IV1 – Measure the inner diameter
DV 2 mark – Measure x.
VIV1 – Method of varying Length and diameter of straw
A1 – Plot lg x against lg d
A1 – Plot lg x against lg L
CV1 – How to keep controlled variable constant
CV1 – How to have “F” to be constant
AD1 – Any acceptable AD
S1 – Acceptable safety measure