2 In this experiment, you will investigate the deformation of paper cylinders.

(a) You have been provided with two pieces of paper.

The width of a piece of paper is the length *w* of the shorter side, as shown in Fig. 2.1.

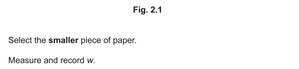

Fig. 2.1

- Select the **smaller** piece of paper.
- Measure and record *w*.

w = ... cm

- Roll the paper into a cylinder and use two paper clips to hold the paper in place, as shown in Fig. 2.2.

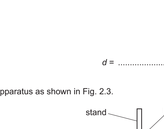

Fig. 2.2

- The diameter of the cylinder is *d*, as shown in Fig. 2.2.

  Adjust the paper and paper clips until *d* is as close as possible to 7.0 cm.

- Measure and record *d*.

d = ... cm
[2]

(b) (i) • Set up the apparatus as shown in Fig. 2.3.

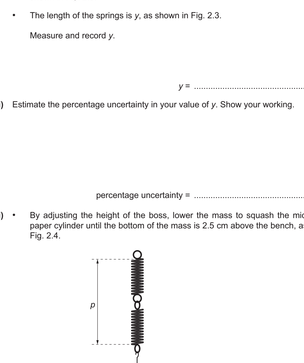

Fig. 2.3

- Slide the loop of the upper spring onto the wooden rod.
- Hang a mass of 200 g from the lower spring.
- Adjust the height of the boss until the bottom of the mass is approximately 10 cm above the bench.
- Place the paper cylinder so that the middle of the cylinder is under the mass, as shown in Fig. 2.3.
- The length of the springs is *y*, as shown in Fig. 2.3.

  Measure and record *y*.

y = ... cm [1]

(ii) Estimate the percentage uncertainty in your value of *y*. Show your working.

percentage uncertainty = ... % [1]

(c) (i) • By adjusting the height of the boss, lower the mass to squash the middle of the paper cylinder until the bottom of the mass is 2.5 cm above the bench, as shown in Fig. 2.4.

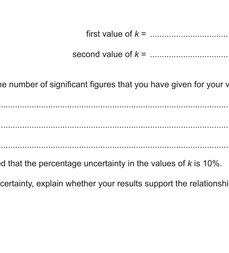

Fig. 2.4 (not to scale)

- The length of the springs is *p*, as shown in Fig. 2.4.

  Measure and record *p*.

p = ... cm [1]

(ii) Calculate (*y* – *p*).

(*y* – *p*) = ... cm [1]

(d) Using the **larger** sheet of paper, repeat **(a)**, **(b)(i)**, **(c)(i)** and **(c)(ii)**.

w = ... cm

d = ... cm

y = ... cm

p = ... cm

(*y* – *p*) = ... cm
[3]

(e) It is suggested that the relationship between *w*, *y* and *p* is

$$w = k(y - p)$$

where *k* is a constant.

(i) Using your data, calculate **two** values of *k*.

first value of *k* = ...

second value of *k* = ...
[1]

(ii) Justify the number of significant figures that you have given for your values of *k*.

.....

.....

..... [1]

(f) It is suggested that the percentage uncertainty in the values of *k* is 10%.

Using this uncertainty, explain whether your results support the relationship in **(e)**.

.....

.....

.....

..... [1]

(g) (i) Describe **four** sources of uncertainty or limitations of the procedure for this experiment.

For any uncertainties in measurement that you describe, you should state the quantity being measured and a reason for the uncertainty.

1 .....

.....

2 .....

.....

3 .....

.....

4 .....

.....
[4]

(ii) Describe **four** improvements that could be made to this experiment. You may suggest the use of other apparatus or different procedures.

1 .....

.....

2 .....

.....

3 .....

.....

4 .....

.....
[4]

[Total: 20]