MATRIX | STRUCTURES

Plastic Bending of Beams

MATRIX

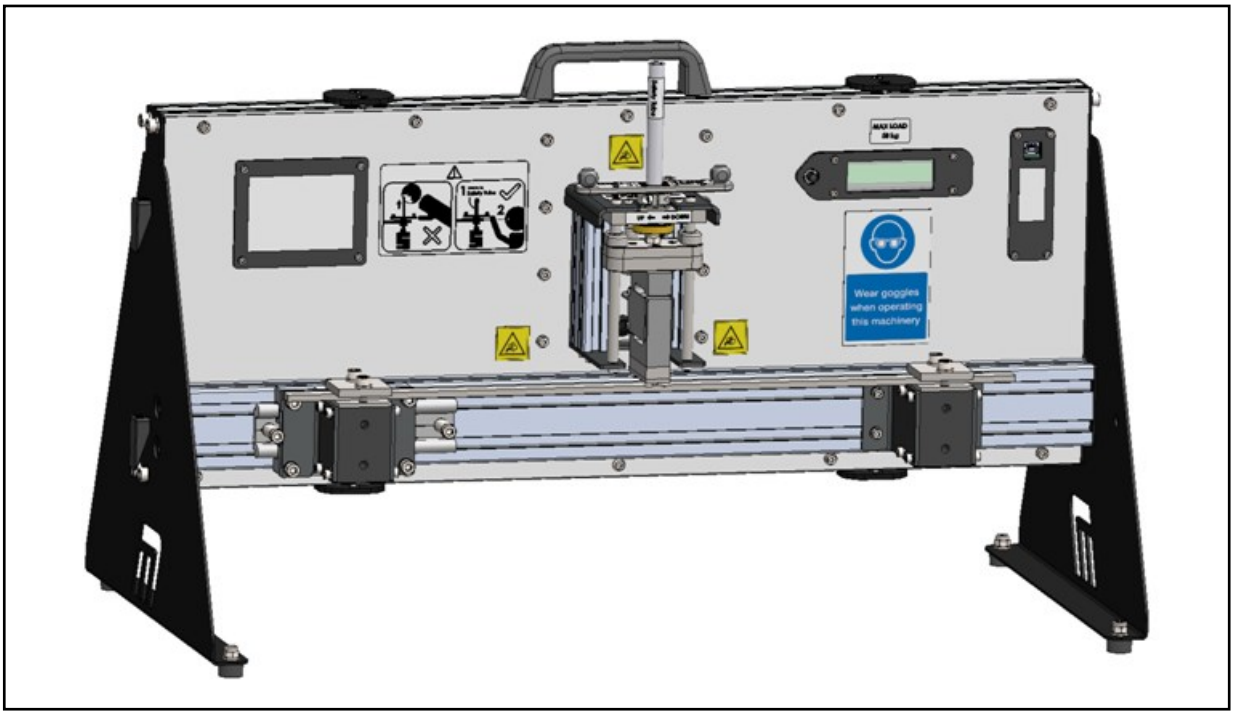
CP9365

www.matrixtsl.com

Contents

Introduction

The kit enables students to investigate the **elastic** and **plastic** properties of different materials in a number of beam configurations.



The beam supports can be set up as either simple or fixed and used to form:

- a simply supported beam, (both ends simply supported);
- a fixed or encastre beam, (both ends fixed);
- a propped cantilever beam (one end support fixed, the other simply supported).

The position of the right-hand support is adjustable. The left-hand support has limited movement along a fixed bracket.

A set of beam specimens is included for use in comparing elastic and plastic properties.

Students apply loads by rotating the screw jack handle. They measure deflection by counting the number of rotations. Each rotation lowers the screw-jack jaw by 1mm.

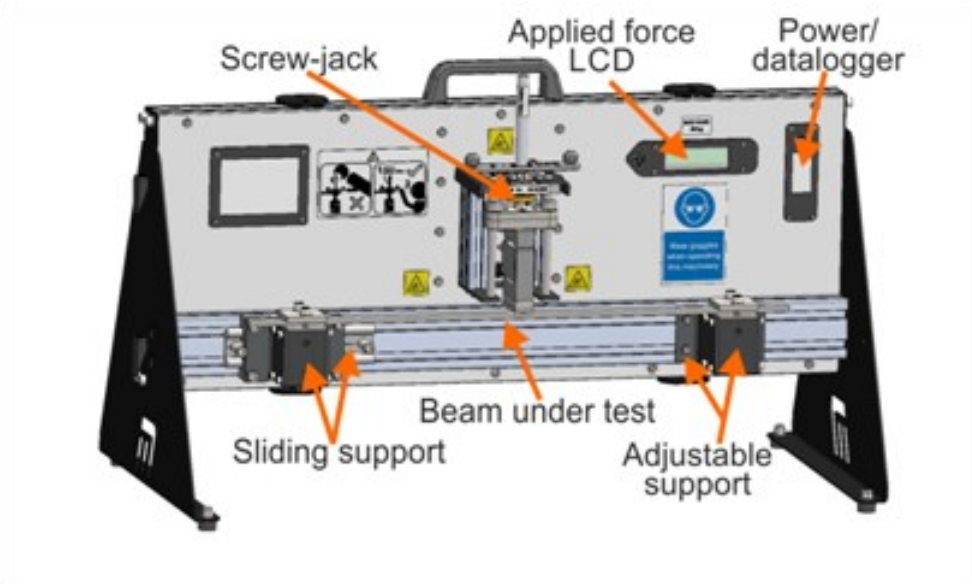
The LCD displays the value of the applied force.

Results can be compared with accepted values of yield working load and collapsed load.

How to Proceed

The equipment:

The general features of the equipment are shown in the following diagram:



Set up:

- Rotate the screw-jack handle clockwise until it comes to a stop.
  The jaw of the jack is now as high as possible.
- Place the beam under test on the supports chosen for the investigation.
- With the left-hand support in the centre of its range of movement on the sliding frame, adjust the right-hand support so that the distance between supports is 400mm.

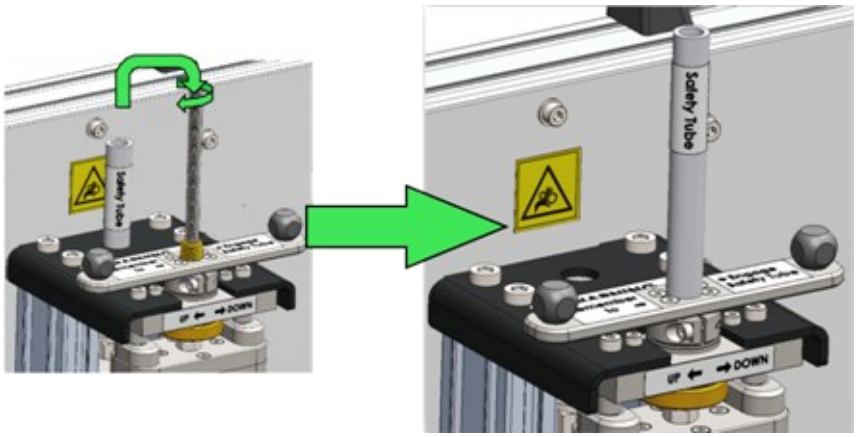
Procedure:

- Press the button on the LCD to zero it if necessary.
- Rotate the screw-jack handle counter-clockwise through one revolution to lower the jaw by 1mm.
- At the end of this rotation, notice the LCD reading - the force needed to accomplish this deformation.
- Record this force in the table in the Student Handout.
- Repeat this procedure to increase the deflection to 2mm, noting the force required.
- Continue in this way until the deflection is 50mm or the applied force reaches 50kg.

Safety!

Initially:

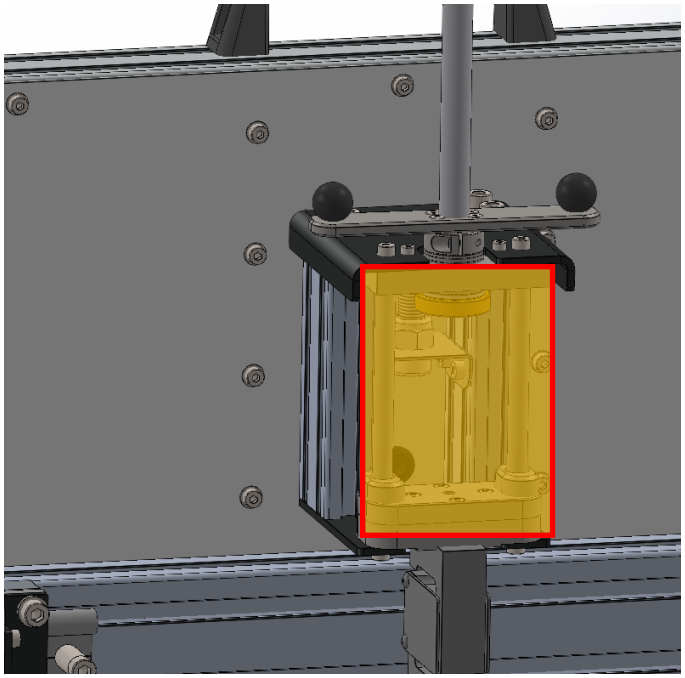
The kit includes a safety tube which should be always cover the exposed parts of the threaded rod when the equipment is used to protect the users in the unlikely event of malfunction.



Inspect the equipment for signs of wear and tear and if found, then stop using this equipment and report the issue.

During use:

- *Keep your eyes level with the equipment!*



- *Keep fingers and hands away from the moving parts!*

- This kit has a maximum load capacity of 50kg.

  Stop adding more load if the LCD shows a value that exceeds this!

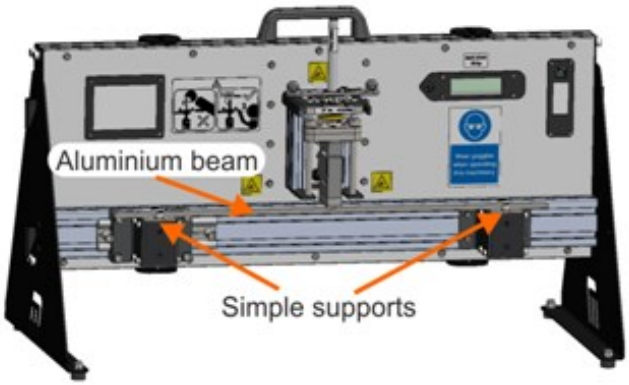
Worksheet 1
Deflection

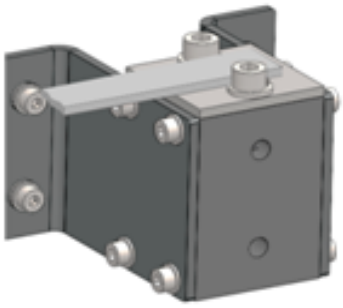
MATRIX | STRUCTURES

Plastic Bending of Beams

Many manufacturing processes require metal components that have been bent into a specific shape.
The technology used in their production requires full knowledge of the properties of the materials used.

Over to you:

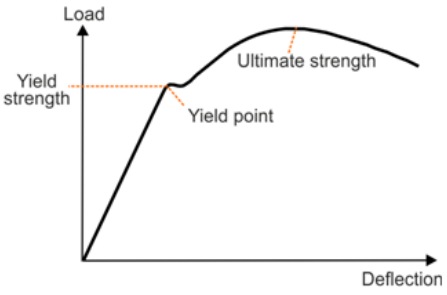




simple support

Over to you:

Investigate the bending of the flat aluminium beam (width 15.8mm, depth 3.2mm) on simple supports.



So what:

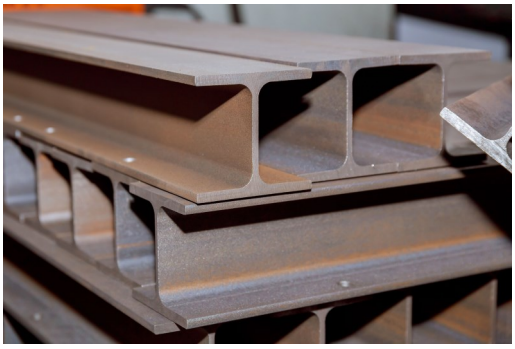
- Use a calliper gauge to measure the dimensions, W and D, of the beams and record them either in the tables in the student handout or in the excel spreadsheet.
- Take readings as in the instructions to plot a graph of deflection versus load. The diagram shows the ideal shape of the graph.
- Use your graph to estimate:
  - the yield strength (at the upper limit of elastic behaviour)
  - the ultimate strength.
- Record these values in the Student Handout.

Challenge:

- Use the formula given in the Student Handout to calculate a value for the yield strength, using the data given.
- Compare this with your estimated value and comment on possible errors that might have affected your estimate.

Worksheet 2
Effect of profile

MATRIX | STRUCTURES
Plastic Bending of Beams



Selecting the right profile for the job is crucial.

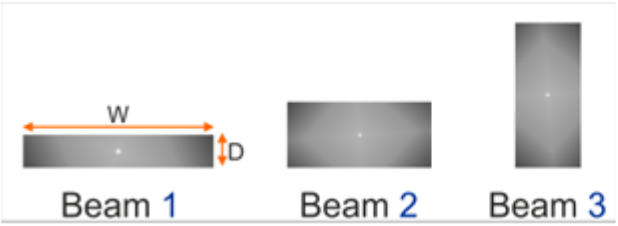
Every shape has different characteristics.

In the I – beam, for example, most material is sited well away from the neutral axis, increasing its resistance to bending and deflection.

Box sections perform best with loading, both horizontally and vertically.

Over to you:

Repeat the same investigation but using beams of the same material, aluminium, but with a different profiles.



Beam 1: W= 15.8mm
D= 3.2mm

Beam 2: W= 12.7mm
D= 9.5mm

Beam 3: W= 12.7mm
D= 4.8mm

- Use a calliper gauge to measure the dimensions, W and D, of the beams and record them either in the tables in the student handout or in the excel spreadsheet.
- Calculate and the record the area moment of inertia for each beam, using the formula:

$$I = \frac{W.D^3}{12}$$

So what:

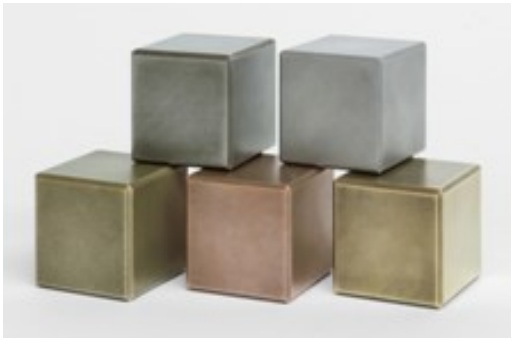
- Use these readings to plot another graph of deflection versus load. For each of the 3 profile. What do you notice?

Challenges:

- Use your graph and the formulae given in the Student Handout to calculate a value for Young's Modulus for aluminium.
- Once again, consider and comment on possible errors that might have affected your value.

Worksheet 3
Effect of Material

MATRIX | STRUCTURES
Plastic Bending of Beams



A critical factor in determining the behaviour of a structural element such as a beam is the material from which it is made.
Carbon steel and titanium have a very high resistance to bending, but may be brittle, whereas brass and aluminium are much more malleable.

Over to you:

Repeat the same investigation as in worksheet 1 but this time using a steel beam with a width of 12mm and a depth of 3mm. Once again, sit the beam on simple supports at both ends.

- Use a calliper gauge to measure the dimensions, W and D, of the beams and record them either in the tables in the student handout or in the excel spreadsheet.

So what:

- Use these readings to plot a graph of deflection versus load.
- Comment on the gradient of the results compared to other materials.
- Comment on the yield value

Challenges:

- Use your graph and the formulae given in the Student Handout to calculate a value for Young's Modulus for steel.
- Again, consider and comment on possible errors that might have affected your value.

Worksheet 4
Unequal spans - single point load

MATRIX STRUCTURES
Plastic Bending of Beams

Different types of support offer different properties.

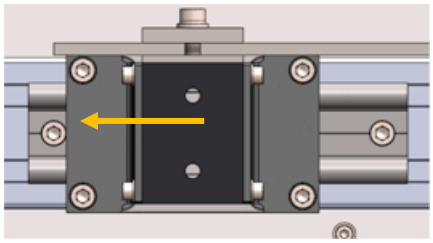
Fixed supports -
resist vertical, horizontal and twisting forces.

Simple supports -
do none of these but produce a reaction force, perpendicular to the surface.

Roller supports -
offer the same, and can also move over the surface, allowing expansion and contraction of the structure, for example.

Over to you:

The support on the left of the product is treated as fixed support, though is slides. This is to overcome real world issues compared to theoretical mathematical models which have assumptions.



fixed support

Repeat the investigation with the 12.7mm x 4.8mm aluminium beam, in two configurations:

A. Fixed / simple supports:

This combination of supports is also known as a propped cantilever beam.

- Use a fixed support at the left-hand end of the beam and a simple support at the right-hand end.
- Position the sliding support as far as possible to the left.
- Investigate the loads needed to deform the beam to a deflection of 45mm.

B. Fixed / fixed supports:

This combination of supports is also known as an encastre beam.

- Next, use fixed supports at both ends of the beam.
- Once again, move the sliding support as far as possible to the left.
- Investigate the loads needed to deform the beam to a deflection of 45mm.

Challenge:

- Compare the results for “C - effect of material” with those for this investigation and comment on differences and similarities in the Student Handout.

Student Handout

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 1 - Deflection

Material = aluminium
Beam width = 15.8mm
Beam depth = 3.2mm
Supports - simple supports both ends

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength **=** ..... g

Estimate of ultimate strength **=** ..... g

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 1 - Deflection

Challenge:

Use the following formula to calculate the yield strength:

$$\text{Yield strength } W_Y = \frac{4\ (\mathbf{b} \times \mathbf{d}^2) \times \sigma_Y}{6 \times \mathbf{L}}$$

where **b** = width of beam = 0.0155m

d = depth of beam = 0.00315m

L = length of beam under stress = 0.4m

σ_Y = yield stress of aluminium = 250×10^6 Pa

Result:

Yield strength = ...

Comment on errors that might have affected your estimates:

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 2 - Profile

Material = aluminium
Beam width =
Beam depth =
Supports - simple supports both ends

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength = ... g

Estimate of ultimate strength = ... g

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 2 - Profile

Material = aluminium
Beam width =
Beam depth =
Supports - simple supports both ends

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength = ... g

Estimate of ultimate strength = ... g

Worksheet 2 - Profile

Challenge:

Use your graph and the following formulae, to obtain a value for Young's Modulus, **E**, for aluminium:

Deflection **d** at the centre of a beam of length **L**, width **b** and depth **d** is given by:

$$\mathbf{d} = \frac{\mathbf{F} \times \mathbf{L}^3}{48 \times \mathbf{E} \times \mathbf{I}}$$

where $\mathbf{I}$ = second moment of inertia of the beam $= \frac{\mathbf{b} \times \mathbf{d}^3}{12}$

Estimate of Young's Modulus, **E =** ..... Pa

Comment on errors that might have affected your estimates:

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

.....

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 3 - Material

Material = Steel
Beam width =
Beam depth =
Supports - simple supports both ends

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength = ... g

Estimate of ultimate strength = ... g

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 3 - Material

Material = Brass
Beam width =
Beam depth =
Supports - simple supports both ends

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength = ... g

Estimate of ultimate strength = ... g

Worksheet 3 - Material

Challenge:

Use your graph and the formulae given earlier to obtain a value for Young's Modulus, **E**, for steel:

Estimate of Young's Modulus, **E =** ..... Pa

Estimate of Young's Modulus, **E =** ..... Pa

Comment on errors that might have affected your estimates:

……

……

……

……

……

……

……

……

……

……

……

……

……

……

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 4 - Supports

Material = Aluminum
Beam width =
Beam depth =
Supports - fixed support at the left-hand end, simple support at the right-hand end.

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength = ... g

Estimate of ultimate strength = ... g

MATRIX | STRUCTURES

Plastic Bending of Beams

Worksheet 4 - Supports

Material = Aluminum
Beam width =
Beam depth =
Supports - fixed supports at both ends.

Deflection (mm)	Load (g)
0	
1	
2	
3	
4	
5	
6	
7	
8	
9	
10	
11	
12	
13	
14	
15	
16	
17	
18	
19	

Deflection (mm)	Load (g)
20	
21	
22	
23	
24	
25	
26	
27	
28	
29	
30	
31	
32	
33	
34	
35	
36	
37	
38	
39	

Deflection (mm)	Load (g)
40	
41	
42	
43	
44	
45	
46	
47	
48	
49	
50	
51	
52	
53	
54	
55	
56	
57	
58	
59	

Estimate of yield strength = ... g

Estimate of ultimate strength = ... g

Worksheet 4 - Supports

Challenge:

Compare the results of worksheet 3 and 4 and comment on differences and similarities:

……

……

……

……

……

……

……

……

……

……

……

……

……