MMAN1300 Engineering Mechanics 1

Lab: 1 - Shear force and Bending Moment

Location: Undergraduate Teaching Laboratory, Room 116, Willis Annex (Week 05)

Submission Individual: Due on Friday, September 14th, 2018 (Week 08)

Report writing: Use the template provided for writing your report

Submission Method: Online submission on TEAMS (submission box will be made available in week 08)

Overview

There are two parts in this lab – Part A: Shear-Force and Part B: Bending-Moment. Each part is carried out on a separate rig in the Undergraduate Teaching Laboratory (UTL) i.e. Room 116 in Willis Annex (J18). Choose a partner within the group and attend the experiment as a pair. Each pair will work on one of the rigs for half an hour and on the other rig for further half an hour. Time is short, so come prepared to do measurements and leave your calculations until after you leave the laboratory. Videos explaining the experimental procedure are available on Moodle.

You can obtain access to the undergraduate teaching laboratory, room 116 of the Willis Annex building (J18), from Monday to Friday in Week 05 during your booked time slot.

Before you enter the laboratory you need to have viewed the videos which also contain safety information. You must gain competency in a Safe Work Procedure and Risk Management Form for the rigs prior to using the experimental equipment. The documents may be accessible only after you have been invited. Enclosed footwear is required to enter the laboratory.

The report will be given a mark out of 6. The marking criteria are included at the end of this document.

How students will perform experiments and submit the report

To perform these four experiments in each part you are asked to work in a pair. You will have to select different variables required for the experiments. Before the selection process, described below, you should choose one of the pair and write his/her student number in Table 1 of the report template available on Moodle and use that student number for selecting proper load and distance from supports to perform all 8 experiments.

Students in the same pair should do all the experiments together and record values in the appropriate tables in the report template.

Students should work in a group of two and submit different reports individually. Calculations and figures may be shared, but the discussion and conclusions should be different.

Complete the report template available on Moodle and submit the report (one per student) as a PDF on TEAMS by 5pm Friday 14th September 2018 (Week 08) for assessment. Note that unless all the workings are shown, full marks will not be awarded. You must type your report (including equations) and label all figures. Freehand FBDs and BMDs are accepted, but must be clean and neat.

Load selection variables based on student number

The typical student number has 7 digits. Label these from the left as a,b,c,d,e,f & g (e.g. for the student number 3295406 'a' would equal 3 and 'g' would equal 6). Loads and distances that should be selected by each student are given in the table below.

Load W_1 (for Exp. 2, 3, 4)	Load W_2 (for Exp. 3, 4)	Distance a (for Exp. 2, 3, 4)	Distance b (for Exp. 3)	Distance b (for Exp. 4)
100g, if d=0, 1	100g, if e=0, 1	60mm, if f=0, 1	180mm, if g=0, 1	340mm, if g=0, 1
200g, if d=2, 3	200g, if e=2, 3	80mm, if f=2, 3	200mm, if g=2, 3	340mm, if g=2, 3
300g, if d=4, 5	300g, if e=4, 5	100mm, if f=4, 5	220mm, if g=4, 5	360mm, if g=4, 5
400g, if d=6, 7	400g, if e=6, 7	120mm, if f=6, 7	240mm, if g=6, 7	380mm, if g=6, 7
500g, if d=8, 9	500g, if e=8, 9	140mm, if f=8, 9	260mm, if g=8, 9	400mm, if g=8, 9

PART A: SHEAR FORCE IN A BEAM - INTRODUCTION

Experimental apparatus

Figure 1 shows the complete experimental frame with the Digital Force Display (DFD) unit in position. It consists of a beam which is "cut". To stop the beam collapsing, a mechanism (which allows movement in the shear direction only) bridges the cut on a load cell thus reacting and measuring the Shear Force. DFD shows the force from the load cell.

The diagram on the left-hand support of the beam shows the beam geometry and hanger position. The hanger supports are 20mm apart, and each has a central groove which positions a hook.

Never apply excessive force to any part of the equipment.

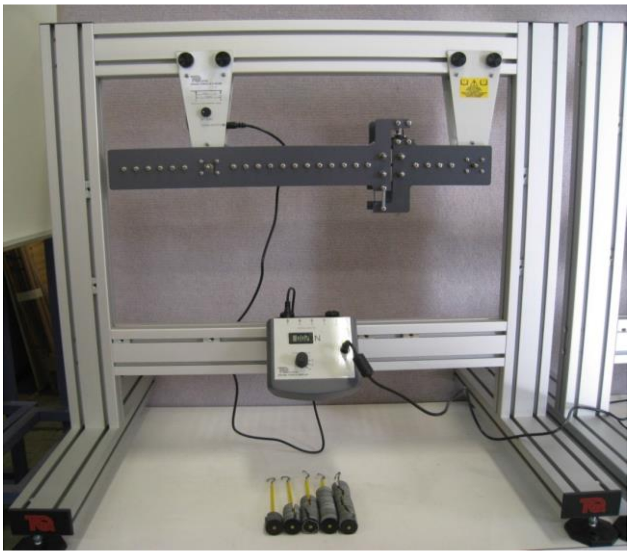


Figure 1: Shear Force in a Beam experimental frame

Figure 2 shows the Force Display Unit in detail while Figure 3 shows load-carrying hooks with masses in position; one unloaded hook with the base has the same mass as one of the discs.

Figure 2: Digital Force Display Unit

Figure 3: Load carrying hooks with masses

Make sure that the DFD is "ON". Connect the mini DN lead from "Force Input 1" on the DFD to the socket marked "Force Output" on the left-hand support of the equipment. Ensure that the lead does not touch the beam.

Carefully zero the force meter using the dial on the left-hand support. Gently apply a small load with a finger to the centre of the beam and release. Zero the meter again if necessary. Repeat to ensure the meter returns to zero.

Note: If the meter does not show zero, but is nearly zero at ±0.1N, lightly tap the frame (there may be a little "stiction" and this should overcome it).

1. EXPERIMENT 1: Shear force variation with an increasing point load

This experiment examines how Shear Force varies with increasing point load. Figure 4 shows the equipment set-up and the force diagram for the beam. All groups will perform the same experiment, using the same values for $a, l,$ and W.

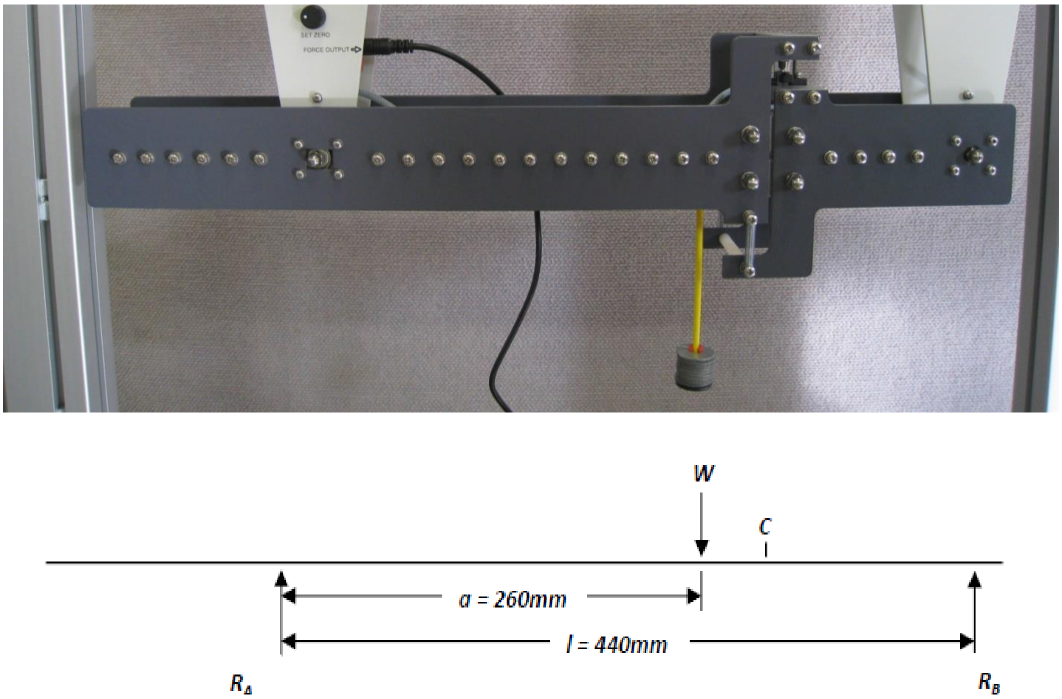


Figure 4: Experiment 1 set-up and Force Diagram

The equation to be used to determine the theoretical Shear Force at the cut is:

$$Theretical\ shear\ force\ at\ the\ cut\ C\ is = S_c = \frac{Wa}{l}\ \text{(N)} \qquad \ldots\ldots\ldots\ldots\ldots \quad (1)$$

where a is the distance from the load, not the cut, to the left support. Note: This equation is only for experiment 1 and should not be used for the rest of the experiments.

You may find the following table useful in converting the masses used in the experiments to loads.

Table 1: Grams to newtons Conversion Table

Mass (g)	Load (N)
100	0.98
200	1.96
300	2.94
400	3.92
500	4.90

Check that the DFD meter reads zero with no load.

Place a hanger with a 100g mass to the left of the cut (40mm away). Record the force reading on the meter in Table 2 of the template. Repeat using masses of 200g, 300g, 400g and 500g. Convert the mass into a load (in N). Remember, the experimental Shear Force at the cut in newtons for all experiments is:

$$Experimental\ shear\ force\ at\ the\ cut = Display\ force \qquad \ldots\ldots\ldots\ldots\ldots \quad (2)$$

2. EXPERIMENT 2: Shear Force variation away from the point of loading

This experiment examines how Shear Force varies at the cut position, C, for various loading conditions. W_1 and a vary depending on the student number.

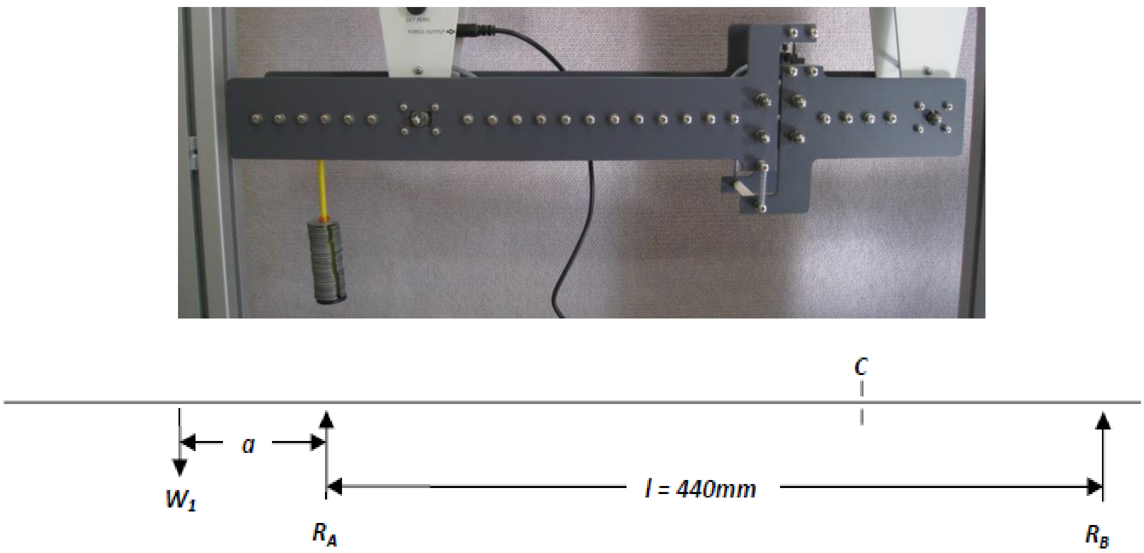


Figure 5: Experiment 2 set-up and Force Diagram

The Shear Force at the cut position, C, is equal to the algebraic sum of the forces acting to the left and the right of C.

Check the DFD meter reads zero with no load.

Carefully load the beam with the hanger in the position specified in Figure 5. Record the force reading on the meter in Table 3 of the template.

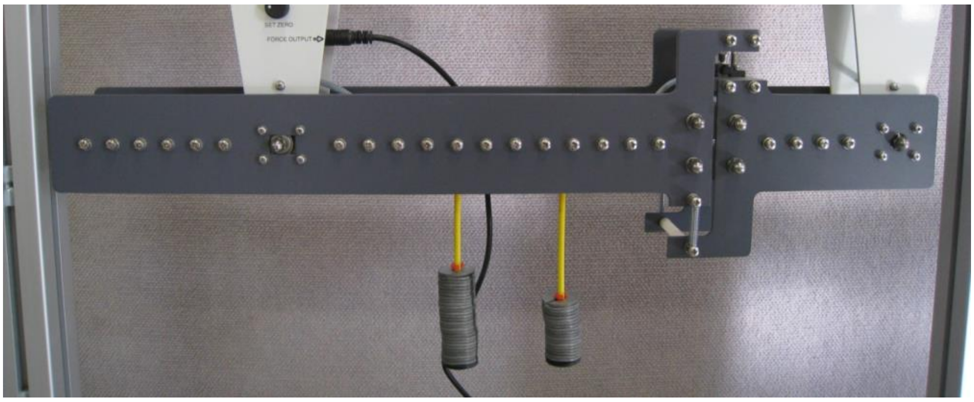
Calculate the support reactions R_A and R_B and calculate the theoretical Shear Force at the cut.

Note: Depending on the sign convention chosen, the experimental and theoretical Shear Forces could have opposite signs. Therefore, you must specify your sign convention.

3. EXPERIMENT 3: Shear Force variation away from the point of loading

This experiment examines how Shear Force varies at the cut position, C, for various loading conditions.

Dimensions a and b and loads W_1 and W_2 vary depending on the student number.



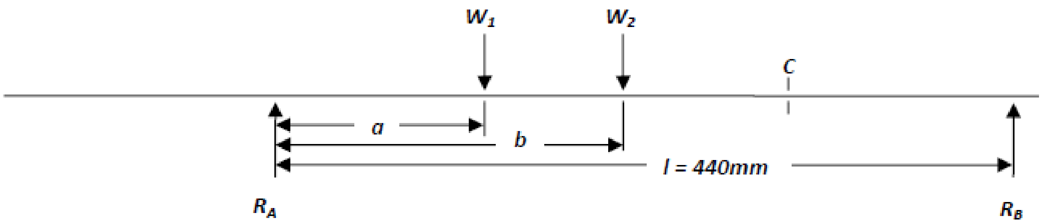


Figure 6: Experiment 3 set-up and Force Diagram

The Shear Force at the cut position, C, is equal to the algebraic sum of the forces acting to the left and the right of C.

Check the DFD meter reads zero with no load.

Carefully load the beam with the hanger in the position specified in Figure 6. Record the force reading on the meter in Table 4 of the template.

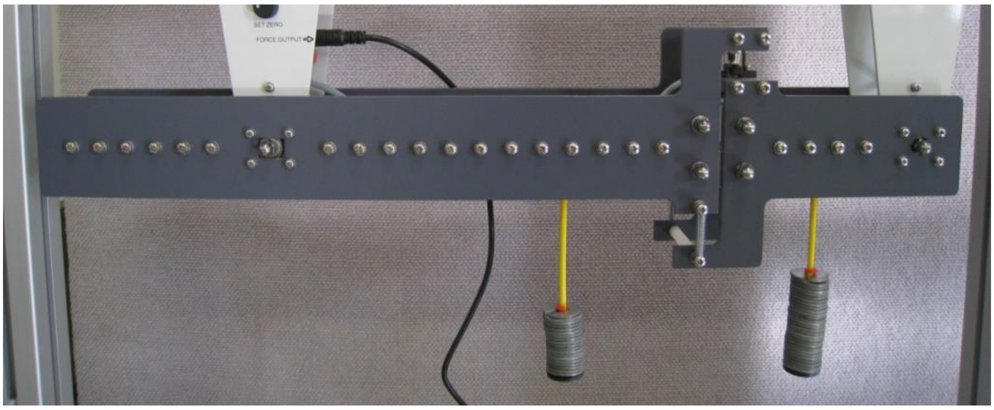
Calculate the support reactions R_A and R_B and calculate the theoretical Shear Force at the cut.

Note: Depending on the sign convention chosen, the experimental and theoretical Shear Forces could have opposite signs. Therefore, you must specify your sign convention.

4. EXPERIMENT 4: Shear Force variation away from the point of loading

This experiment examines how Shear Force varies at the cut position, C, for various loading conditions.

Dimensions a and b and loads W_1 and W_2 vary depending on the student number.



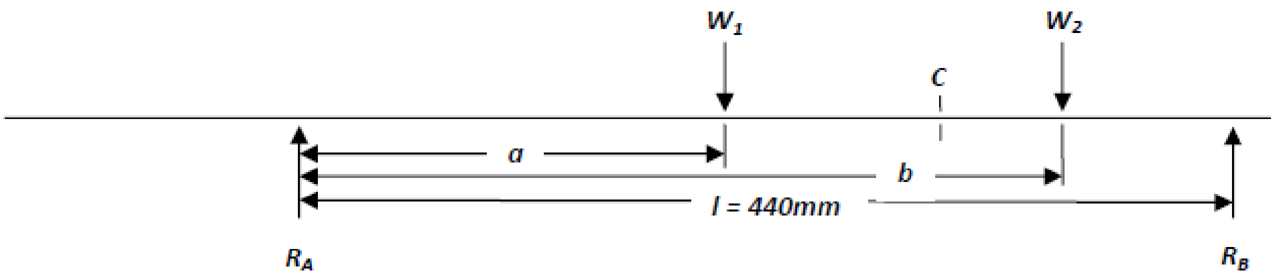


Figure 7: Experiment 4 set-up and Force Diagram

The Shear Force at the cut position, C, is equal to the algebraic sum of the forces acting to the left and the right of C.

Check the DFD meter reads zero with no load.

Carefully load the beam with the hanger in the position specified in Figure 7. Record the force reading on the meter in Table 5 of the template.

Calculate the support reactions R_A and R_B and calculate the theoretical Shear Force at the cut.

Note: Depending on the sign convention chosen, the experimental and theoretical Shear Forces could have opposite signs. Therefore, you must specify your sign convention.

PART B: BENDING MOMENT IN A BEAM – INTRODUCTION

This experiment examines how Bending Moment varies with increasing point load in a beam.

Instrumentation

Figure 8 shows the complete experimental frame with the DFD unit in position.

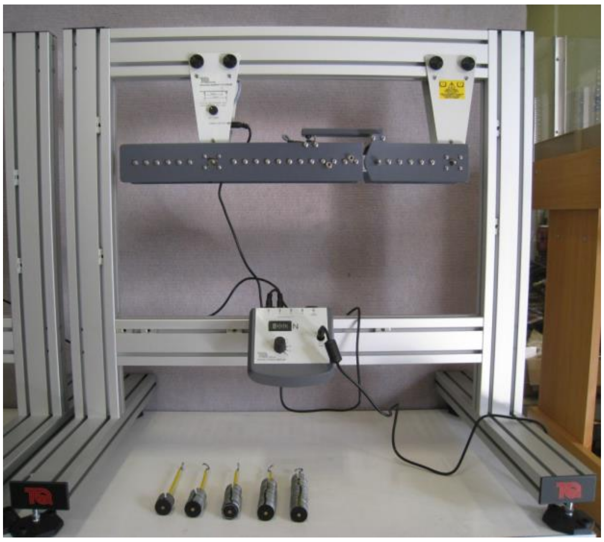


Figure 8: Bending Moment of a beam experimental frame

5. EXPERIMENT 1: Bending Moment variation at the point of loading

This experiment examines how Bending Moment varies at the point of loading. Figure 9 shows the equipment set-up and the force diagram for the beam. All groups will perform the same experiment, using the same values for a, l, and W.

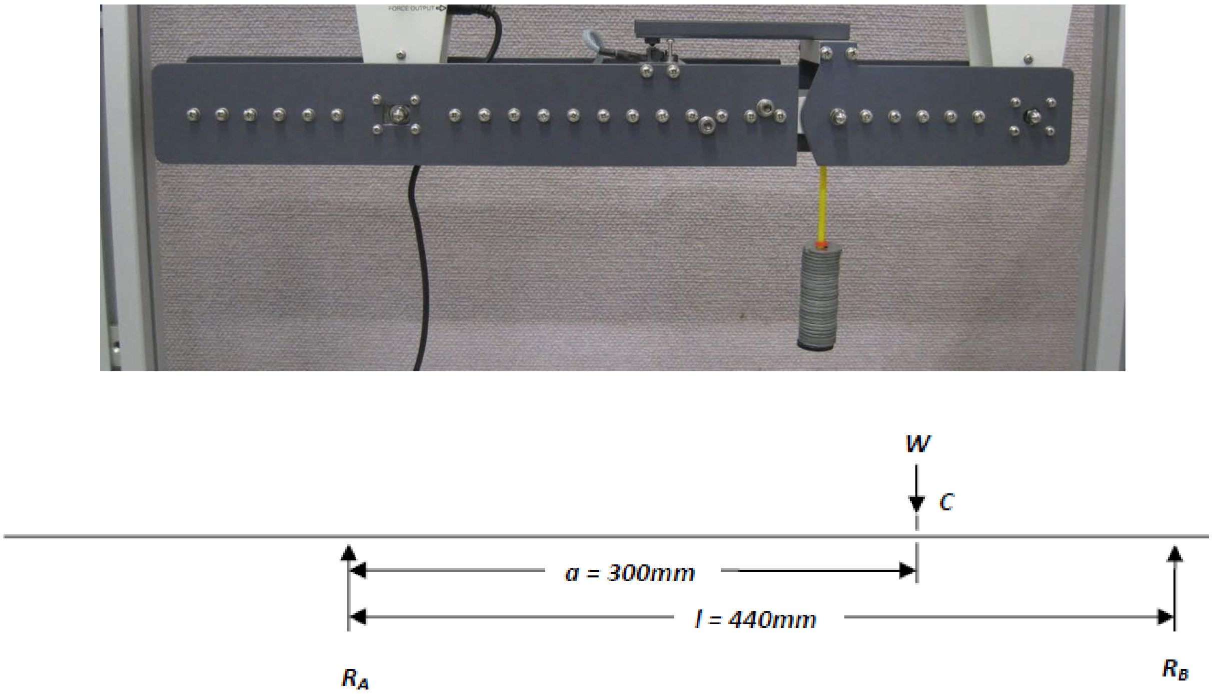


Figure 9: Experiment 1 set-up and Force Diagram

The equation to be used to calculate the theoretical Bending Moment at the cut is:

$$Theretical\ bending\ moment\ at\ the\ cut\ C\ is = \ S_c = \frac{Wa(l-a)}{l} \ \ (\mathrm{N.m})$$

………….. (3)

Note: This equation is only for experiment 1 and should not be used for the rest of the experiments.

Check that the DFD meter reads zero with no load.

Place a hanger with a 100g mass at the cut. Record the force reading in Table 6 of the template. Repeat, using masses of 200g, 300g, 400g and 500g. Convert the mass into a load (in N) and the force reading into a Bending Moment (N·m). Remember, the experimental Bending Moment at the cut for all experiments is:

$$Experimental\ B.M\ \ at\ the\ cut\ (\mathrm{N.m}) = Display\ force \times 0.125 \quad \ldots\ldots\ldots. \ (4)$$

6. EXPERIMENT 2: Bending Moment variation away from the point of loading

This experiment examines how bending moment varies at the cut position, C, for various loading conditions. W_1 and a vary depending on the student number.

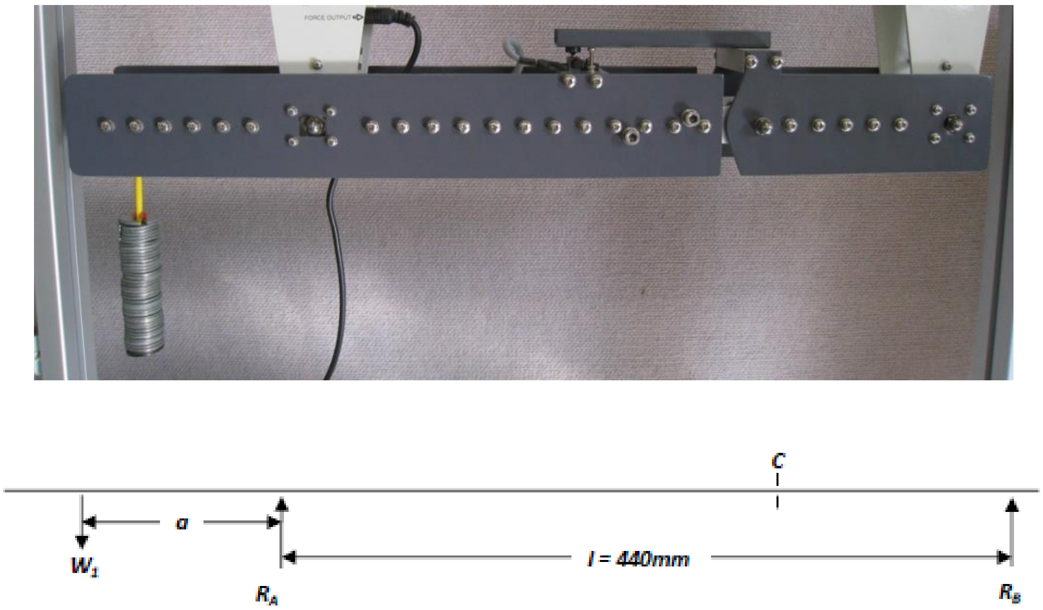


Figure 10: Experiment 2 setup and force diagram

The Bending Moment at the cut position, C, is equal to the algebraic sum of the moments caused by the forces acting to the left and the right of C.

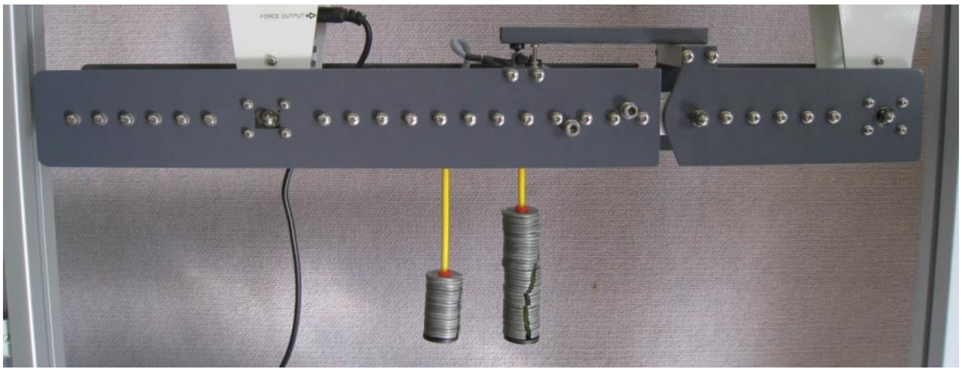
Check the DFD meter reads zero with no load.

Carefully load the beam with the hanger in the position specified in Figure 10. Record the force reading on the meter in Table 7 of the template.

Determine the value of R_B for the calculation of the B.M. at C since it will be easier to evaluate the bending moment with the single value of R_B than using W and R_A to the left of C.

7. EXPERIMENT 3: Bending Moment variation away from the point of loading

This experiment examines how Bending Moment varies at the cut position, C, for various loading conditions. Dimensions a and b and loads W_1 and W_2 vary depending on the student number.



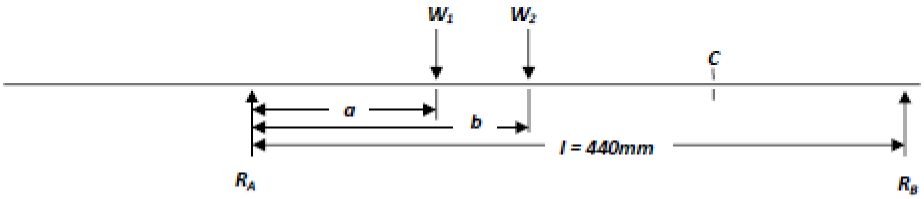


Figure 11: Experiment 3 setup and force diagram

The Bending Moment at the cut position, C, is equal to the algebraic sum of the moments caused by the forces acting to the left and the right of C.

Check that the DFD meter reads zero with no load.

Carefully load the beam with the hangers in the positions shown in Figure 11. Record the force reading on the meter in Table 8 of the template.

Convert the force readings into bending moments (N·m). First, calculate the support reactions R_A and R_B and then determine the B.M. at the cut, C.

8. EXPERIMENT 4: Bending Moment variation away from the point of loading

This experiment examines how Bending Moment varies at the cut position, C, for various loading conditions.

Dimensions a and b and loads W_1 and W_2 vary depending on the student number.

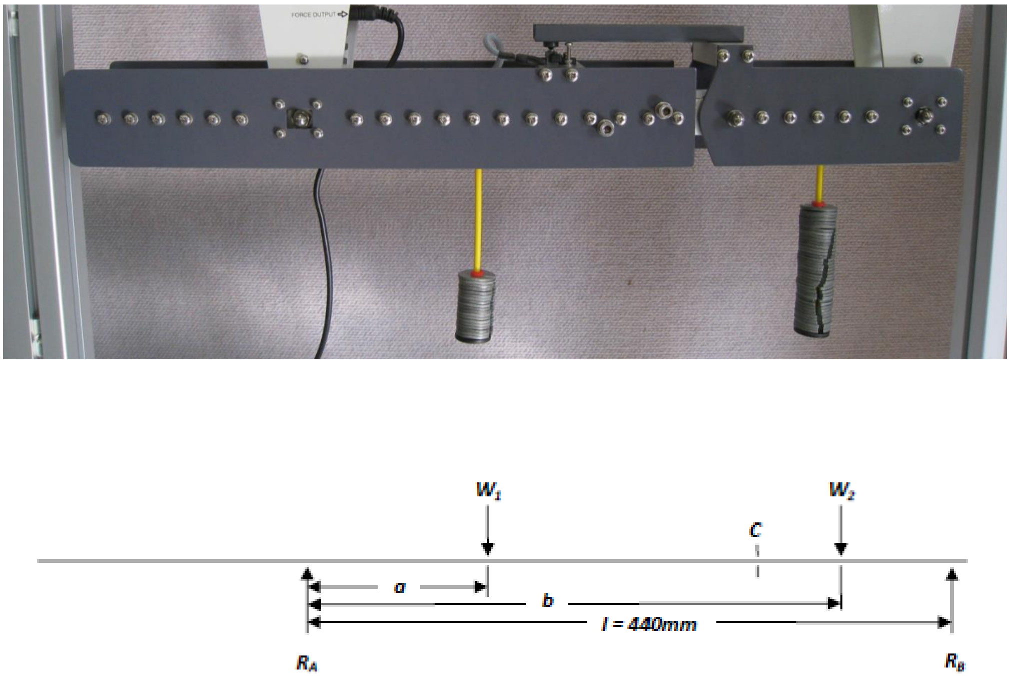


Figure 12: Experiment 4 setup and force diagram

The Bending Moment at the cut position, C, is equal to the algebraic sum of the moments caused by the forces acting to the left and the right of C.

Check that the DFD meter reads zero with no load.

Carefully load the beam with the hangers in the positions shown in Figure 12. Record the force reading on the meter in Table 9 of the template. Convert the force readings into Bending Moments (N·m). First, calculate the support reactions R_A and R_B and then determine the B.M. at the cut, C.

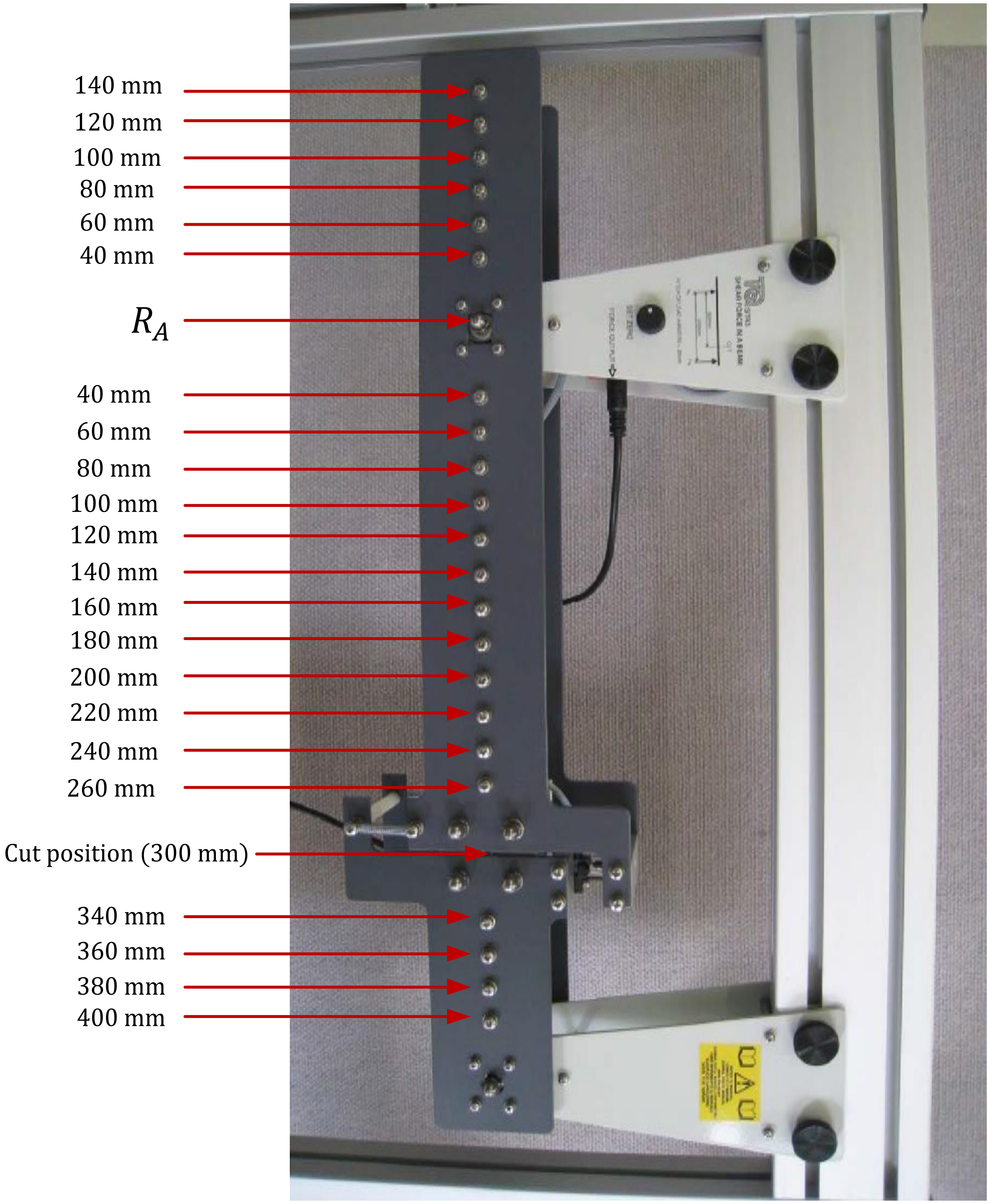


Figure 13: Distances from R_A

Appendix: Marking criteria for PART A: Shear-Force in a Beam

Criterion	**0 marks**	**1 mark**	**2 marks**	**3 marks**
SF expt 1. Theoretical values match calculation in marking spreadsheet	Do not match	All values match (should be correct to 1 decimal place)	-	-
SF expt 1 Plot of theoretical vs experimental results	Incomplete / very messy plot	Non-linear results for either set of data points or widely divergent results.	Clear plot showing similar results, both theoretical and experimental results are linear.	-
SF expt 1 discussion	No attempt to justify error	Basic restating of the facts evident in the plot.	Mention of error but no discussion of error sources	Errors discussed to an appropriate level in the space provided.
SF expt 2 calculations and theoretical results with an FBD	Clear error in calculation causing incorrect theoretical value	Correct theoretical value but incorrect experimental value or vice versa with a wrong diagram	A mistake in theoretical or experimental values with the correct diagram	Both theoretical and experimental values correct with the correct diagram
SF expt 3 calculations and theoretical results with an FBD	Clear error in calculation causing incorrect theoretical value	Correct theoretical value but incorrect experimental value or vice versa with a wrong diagram	A mistake in theoretical or experimental values with the correct diagram	Both theoretical and experimental values correct with the correct diagram
SF expt 4 calculations and theoretical results with an FBD	Clear error in calculation causing incorrect theoretical value	Correct theoretical value but incorrect experimental value or vice versa with a wrong diagram	A mistake in theoretical or experimental values with the correct diagram	Both theoretical and experimental values correct with the correct diagram
SF overall conclusion (no need to draw a SFD)	Invalid comments and No attempt to justify error	Restating the conclusions without answering the question and Basic restating of the facts.	Mostly correct comments without full understanding and Mention of error but no discussion of error sources	Excellent correct discussion and Errors discussed to an appropriate level in the space provided.

Appendix: Marking criteria for PART B: Bending-Moment in a Beam

Criterion	0 marks	1 mark	2 marks	3 marks
BM expt 1 Theoretical values match calculation in marking spreadsheet with a correct diagram	A wrong value and a wrong diagram	All values match (should be correct to 1 decimal place), but a wrong diagram (Or vice versa)	All values match (should be correct to 1 decimal place) with a correct diagram	-
BM expt 1 Plot of theoretical vs experimental results	Incomplete / very messy plot	Non-linear results for either set of data points or widely divergent results.	Clear plot showing similar results, both theoretical and experimental results are linear.	-
BM expt 1 discussion	No attempt to justify error	Basic restating of the facts evident in the plot.	Mention of error but no discussion of error sources	Errors discussed to an appropriate level in the space provided.
BM expt 2 calculations and theoretical results with the correct diagram.	Clear error in calculation causing incorrect theoretical value	Correct theoretical value but incorrect experimental value or vice versa with a wrong diagram	A mistake in theoretical or experimental values with the correct diagram	Both theoretical and experimental values correct with the correct diagram
BM expt 3 calculations and theoretical results with the correct diagram.	Clear error in calculation causing incorrect theoretical value	Correct theoretical value but incorrect experimental value or vice versa with a wrong diagram	A mistake in theoretical or experimental values with the correct diagram	Both theoretical and experimental values correct with the correct diagram
BM expt 4 calculations and theoretical results with the correct diagram.	Clear error in calculation causing incorrect theoretical value	Correct theoretical value but incorrect experimental value or vice versa with a wrong diagram	A mistake in theoretical or experimental values with the correct diagram	Both theoretical and experimental values correct with the correct diagram
BM overall conclusion	Invalid comments and No attempt to justify error	Restating the conclusions without answering the question and Basic restating of the facts.	Mostly correct comments without full understanding and Mention of error but no discussion of error sources.	Excellent correct discussion (in association with Part A) and Errors discussed to an appropriate level in the space provided.
Overall quality of report / formatting / plotting quality	Basic, followed template with minimal modification	Average formatting and comment.	Professional quality of presentation, but the introduction is not at the highest level.	Professional quality of presentation with a good introduction.