Bridges: Beam Bridge Forces
Teacher's Notes

Aims

This pack is aimed at reinforcing National Curriculum material at KS4 in Physics in an enjoyable, applied way. It is aimed at students who may potentially go on to study A-Level Physics and has been designed with 1 hour lessons in mind. Additional material is included for able students as well as suggestions for coping with weaker students.

Curriculum content

This lesson covers:
- Moments
- Forces

Key skills:
- Group work
- Problem solving

Methods covered are:
- Experimental work
- Drawing graphs
- Finding the equation of a line on a graph
- Finding a general equation

Preparation

Photocopy worksheets for students.

Individual worksheets – Worksheet 1 (if using top pan balances)
Individual worksheets – Worksheet 2 (if using Newton metres)
Individual Extension (worksheet 3) for more able students, or homework.

Equipment required

Either:	Or:
Top pan balance (2 per group)	Top pan balance (1 for demonstration)
Block (2 per group)	Block (1 for demonstration)
Metre rules (1 per group)	Metre rules (1 per group + demonstration)
Masses & hanger (1 per group)	Masses & hanger (1 per group + demonstration)
	Newton metres (1 per group)
	Retort stand and clamp (1 per group)

Timing targets

This pack is designed for a 1 hour lesson, although it contains extension material. A model lesson is outlined below to give timing guidelines:

Start	5 mins	
Presentation and demonstration	10 mins	PowerPoint presentation/demonstration
Calculations	15 mins	Worksheet 1/2 (equipment dependent)
Experimental work	20 mins	Continue with worksheet
Tidy up	5 mins	
Wrap up	5 mins	Comments on findings and application

Worksheet 3 – Extension work

Guidance

- There are two possible ways of performing this experiment, one using top pan balances and another using Newton meters. Depending on the resources available in your school either one may be used (see Worksheets 1 & 2 for each setup).
- The 'blocks' for the top pan setup are designed to keep the force concentrated and acting in one place only. Different items are possible for use:
    - Wooden blocks
    - Solid cardboard
    - Multilink/Unifix cubes
    - Erasers

  Many alternative objects will suffice, the main points to consider are:
    - The 'blocks' are the same height so the ruler lies flat
    - The effective length of the ruler stays constant; it does not roll
    - The block is high enough that the ruler does not touch the top pan balance when loaded
- It is particularly important if using the retort stand clamp that the ruler rests on the clamp, rather than being held by it.
- Students may find it difficult to visualise a reaction force so the demonstration and experiments help them to understand them more fully.
- The demonstration with a top-pan balance is very helpful if the individual experiments will be carried out using Newton meters.
- It is left up to the teacher to decide what masses to use for the second experiment. This will depend on the apparatus and whether it would be more interesting to generate a range of data sets throughout the class.
- The equations of lines that the students obtain will vary from student to student and will also differ slightly from the given equations in the answers since these were generated theoretically.

Points to emphasise:

- Reaction forces are just one type of force experienced by the bridge. Examples are:
  Shear forces
  Torsion
  Bending moments
- Reaction forces are much easier to calculate and visualise for beam bridges rather than for other types of bridges that have several piers.

Mixed abilities:

- Some students may take longer to do the calculations and draw the graphs. If time is short it may be more helpful to complete the experiments and then do the hand calculations and draw the graphs. This can also be finished for homework if necessary.

Presentation notes

- Slide 2 – What is a reaction force?

The diagram will be unfamiliar to the students. An explanation of the triangular supports may be needed: these are in order to represent a point load acting on the bridge rather than a distributed load.

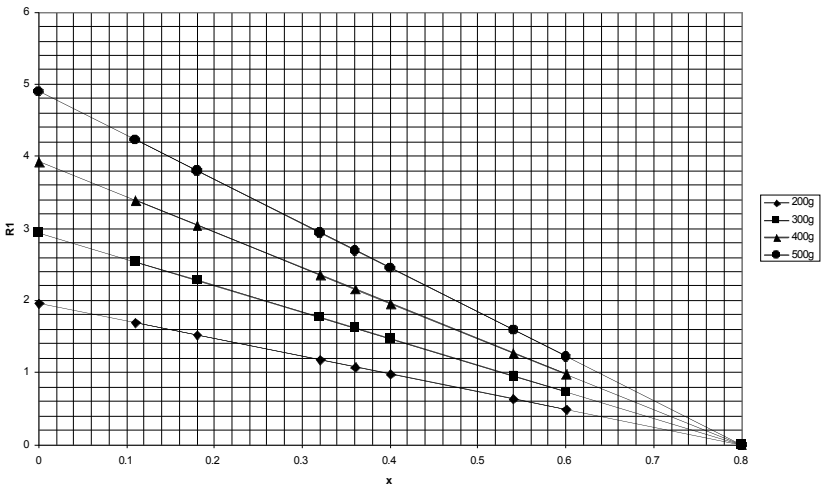
- Slide 5 – Why do we do this?

It must be emphasised that this is only a small part of a bigger picture when it comes to assessing ground conditions and the stability of a bridge.

Answers -Worksheet 1 or 2

Mass (kg)	Distance from L.H support (m)	Reaction Force 1 (N)	Reaction Force 2 (N)
0.2	0.40	0.98	0.98
0.2	0.54	0.64	1.32
0.2	0.60	0.49	1.47
0.2	0.32	1.18	0.79
0.2	0.11	1.69	0.27
0.2	0.18	1.52	0.44
0.2	0.36	1.08	0.88
0.3	0.40	1.47	1.47
0.3	0.54	0.96	1.99
0.3	0.60	0.74	2.21
0.3	0.32	1.77	1.18
0.3	0.11	2.54	0.40
0.3	0.18	2.28	0.66
0.3	0.36	1.62	1.32
0.4	0.40	1.96	1.96
0.4	0.54	1.28	2.65
0.4	0.60	0.98	2.94
0.4	0.32	2.35	1.57
0.4	0.11	3.38	0.54
0.4	0.18	3.04	0.88
0.4	0.36	2.16	1.77
0.5	0.40	2.45	2.45
0.5	0.54	1.59	3.31
0.5	0.60	1.23	3.68
0.5	0.32	2.94	1.96
0.5	0.11	4.23	0.67
0.5	0.18	3.80	1.10
0.5	0.36	2.70	2.21

Worksheet 3 - Extension Answers



Equations of lines: (200g) y = -6.13x + 4.9 (400g) y = -4.91x + 3.9
(300g) y = -3.68x + 2.9 (500g) y = -2.45 + 2.0

Maximum reaction force = 0.20 x 9.81 = 1.96 N

General Equation:

Reaction force (L.H.) = [(Applied force/length) x distance from L.H. support] + applied force

$$R_1 = FLx + F$$