Subject: **Physics**

Topic: **Forces**

Application: **Designing buildings**

Using the worksheet and podcast resources

This worksheet is based on the Inventive podcast.

It supports Gatsby Benchmark 4: Careers in the curriculum by introducing a career and role model. The worksheets are based on topics in the KS3 curriculum.

The short audio clips can be used to provide context to the worksheet and could be played during a lesson.

A QR code on the student sheet links directly to the podcast.

KS3 National Curriculum statements

Physics

- Forces as pushes or pulls;
- Using force arrows in diagrams, adding forces in 1D, balanced and unbalanced forces;
- Forces associated with deforming objects;
- Stretching and squashing;
- Forces measured in newtons.

Audio clips from Inventive podcast.

Available from: nustem.uk/inventive/#roma *(scan QR code)*

- **Roma Clip 1:** Roma describes her role and the foundations of the Shard.
- **Roma Clip 2**: Concrete
- **Roma Clip 3:** The Nightbuilder. Listen to the story inspired by Roma's interview.

Other resources

Roma's career poster
More information about Roma

Meet the engineer

Roma Agrawal

Structural engineer, writer and broadcaster

Roma started her career as a structural engineer working in teams to design and build bridges and buildings. She is currently an author and broadcaster using her engineering experience to explain science and engineering to children and adults.

Scan the QR code

to access all the resources and the full podcast from: *nustem.uk/inventive/#roma*

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This work was supported by EPSRC Engineering and Physical Sciences Research Council

Know

1. Contact: wind/air resistance, reaction (between the ground and the building), tension.
Non-contact: weight.
Other correct answers are acceptable.

2. Answer: downward = weight; upwards = reaction force.
The forces are the same size but act in opposite directions.
NB - The arrows are drawn so weight acts from the Shard's centre of mass; the reaction forces acts from its contact with the ground.

3a. Compression: opposite side to wind arrow; Tension: on same side as wind arrow.
3b. The Shard bends the same way to the wind. The side the wind blows on is stretched and is in tension. The other side is squashed and is in compression.

Apply

4a. mass = 530 x 1000 = 530 000 kg
4b. weight = 530 000 kg x 10 N/kg = 5 300 000 N, or 5.3 million N or 5.3 MN

5. (Possible correct ideas): makes the building more stable, maximum compression forces act on the foundation as the whole weight of the building is pushing down.

6a. Cost, strength in compression or in tension, how easy it is to form into structures.
6b. Foundations mix - foundations takes the whole weight of the structure above.

7. This is an open-ended question so pupils can be creative in their answers. Accept anything sensible that compresses the concrete till it breaks, and allow labelled diagrams instead of text if appropriate.
e.g. support concrete samples at each end. Place/hang 100g masses on the (unsupported) centre. Add masses till concrete snaps. Strongest concrete supports largest mass. Equipment needed: supports, masses/ hanger.
OR drop mass on concrete samples from different heights/drop samples from different heights. Strongest concrete needs mass dropped from greatest height. Equipment needed: ruler, mass to drop onto samples
Working safely: safety goggles because concrete will snap; avoid dropping masses onto feet, etc.
Fair test: ensure samples are the same size; supports are equally spaced, etc.

Extend

8a. Brittle: easily snaps; does not extend before breaking;
Composite: material made from more than one material.
8b. When weight is applied to a beam and it bends, the top of the beam is compressed and the bottom of the beam is stretched. Reinforced concrete has concrete (strong in compression) and metal (strong in tension).

Worksheet version: 2.0, 2022-06

Forces and buildings

Forces can change the shape of an object and how it moves.

Contact forces affect objects that are touching each other. Friction, reaction force, air resistance, upthrust and tension are all contact forces.

Non-contact forces affect objects that are not touching. Non-contact forces include gravity, electrostatic force and magnetic force.

Weight is calculated using:

weight (N) = mass (kg) x gravitational field strength (N/kg)

W = m x g

The Shard is a skyscraper in London. It is currently (in 2022) the tallest building in the UK at 310 m high.

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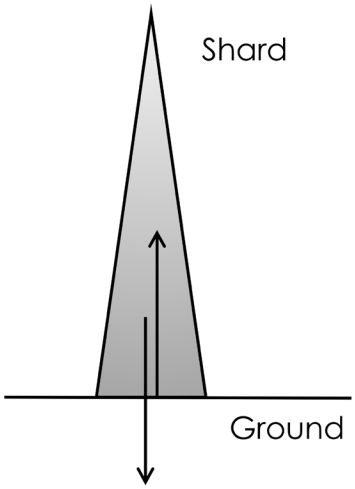
Link to Roma' story

Know

1. List two contact forces and one non-contact force that all buildings feel:

- Contact: _____, _____
- Non-contact: _____

2. The diagram shows a building in London called the Shard. The arrows show the direction and size of two of the forces acting on the Shard.



2a. Label the arrows to show:

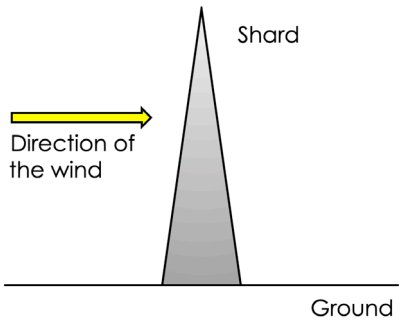
i. Weight

ii. Reaction force

2b. Compare the size and direction of these two forces.

(Hint: The arrows will help you.)

3. The Shard can bend slightly in the wind. The arrow shows the wind blowing on the Shard.



3a. Label the diagram to show which side of the Shard is squashed (compressed) and which side is stretched (in tension).

3b. Choose the correct words to explain your answer:

The Shard bends *the same*/*different way* to the wind.

The side the wind blows on is *stretched*/*squashed* and is in *tension*/*compression*.

The other side is *stretched*/*squashed* and is in *tension*/*compression*.

Apply

4. At the top of the Shard there is a steel spire. It has a mass of 530 tonnes.

4a. 1 tonne equals 1000 kg. Calculate the mass of the spire in kg.

4b. Calculate the weight of the spire in N. Use gravitational field strength, g, as 10 N/kg.

5. The Shard's foundation is a large concrete block underground. The rest of the Shard is built on the foundation. Explain why the foundation needs to be the strongest part of the building.

6. Concrete is made from cement, water and sand. The table shows the different mixes used in some buildings.

Mix	What the concrete is used for:	Proportion of different ingredients		
		crushed rock	cement	sand
A	Foundations	10	2	6
B	Walls underground (e.g. basement)	7	2	5
C	walls above ground (e.g. storage tank)	6	2	5
D	small structures (e.g. pots)	4	2	4

Suggest, with a reason, which of the four concrete mixes (A, B, C, D) is strongest in compression.

7. Plan an experiment to compare the strength of the 4 types of concrete. You have one piece of each type of concrete, 10cm x 2 cm x 1 cm, and can use other equipment found in a science lab.

- List the equipment you need and what you will measure;
- Explain how your results will help you compare the strength of each sample;
- Describe how you will work safely and make this a fair test.

Extend

8. Concrete is a **brittle** material that is strongest in compression. Reinforced concrete is a **composite** material, used for large structures, including beams, bridges and columns. Reinforced concrete has metal bars placed in the concrete mix before it sets. Metal is strong in tension.

8a. What do the words brittle and composite mean?

8b. When a weight is placed on a concrete beam, the concrete beam bends. Explain which parts of the beam compress or extend, and why reinforcing concrete with metal bars makes concrete beams stronger.

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