Subject: **Physics**

Topic: **Magnetism and electromagnets**

Application: **Medical imaging**

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

- Magnetic poles, attraction and repulsion;
- The magnetic effect of a current;
- Electromagnets.

Audio clips from Inventive podcast.

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

- **Shrouk Clip 1:** Miniaturisation – this is useful for setting the context of Q6.
- **Shrouk Clip 2:** Shrouk's early life and work

Other resources

Shrouk's career poster
More information about Shrouk

Meet the engineer

Shrouk El-Attar

Electronics Design Engineer

Shrouk El-Attar is an electronics design engineer. She has worked to create electronic devices that improve access to healthcare. She also works to change perceptions of engineering and is an advocate of LGBTQ+ rights.

Scan the QR code

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

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Know

1. The diagram should show 6 arrows coming from the N pole end of the magnet, 3 of the arrows loop above/3 arrows loop below the magnet; all arrows turn towards the S pole. Field lines don't cross; they don't go into the magnet (but can touch the ends).

2a. Acceptable answers include: both have poles; can attract magnetic materials; can attract/repel other magnets.
2b. Acceptable answers include: strength/direction of the field of a permanent magnet is fixed but changeable for an electromagnet; electromagnets can be turned off, permanent magnets can't.

3. More turns on the solenoid; larger current; add an iron core inside the solenoid.

4. Acceptable answers include: x-ray, CAT/CT scan, ultrasound, MRI, PET scan/scan using radioactive tracers, etc.

5. Magnetic: iron, nickel, steel/stainless steel, etc;
Non-magnetic: copper, aluminium, gold, silver.

Apply

6. Possible answers e.g. lower cost (from £1 million to £300 per machine); machines fit into more places; easier to move equipment; less power needed to run electromagnets, etc.

7.

Electromagnet design	Prediction	Explanation
1m of wire coiled 50 times round an iron nail, 3V battery	5 paper clips	
1m of wire coiled 25 times round an iron nail, 3V battery	*2/3 paper clips*	*Weaker field - fewer turns*
1m of wire coiled 50 times round an iron nail, 6V battery	*9/10 paper clips*	*Stronger field - larger current*
1m of wire coiled 50 times round an iron nail, 6V battery	*5 paper clips*	*Same field - current doubles, but number of turns halves*
1m of wire coiled 50 times round an iron nail, 3V battery	*2/3 paper clips*	*Weaker field - smaller current (longer wire has more resistance)*

Extend

8. Observation 1: Fewer paperclips were picked up because the battery started to run down so the current got smaller ***OR*** the nail started to heat up, increasing resistance and reducing current.
Observation 2: Paperclips remained stuck to the nail because the nail started to be magnetised.

9. 1 nanometer is 1×10^{-9} m
$1 \times 10^{-9} \times 60\,000 = 6 \times 10^{-5}$ m
Since 1mm is 1×10^{-3} m, this is 0.06 mm

Worksheet version: 2.0, 2022-06

Electromagnets in medical imaging

Electromagnets are created when a current flows through a wire. We can change the electromagnet's strength and direction by changing the current in the wire.

Electromagnets are used in devices such as loudspeakers, microphones, electricity generators in power stations and metal sorters in recycling plants.

Hospitals have equipment that can look inside a patient's body using magnetic resonance imaging (MRI). MRI scanners need strong magnetic fields that can be changed easily. Electromagnets are used for this purpose in MRI scanners.

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Link to Shrouk's story

Know

1. The diagram on the right shows a bar magnet.

Draw the magnetic field lines around it.

Include at least 6 field lines in your diagram.

2a. State two ways in which electromagnets are similar to permanent magnets.

2b. State two ways in which electromagnets are different from permanent magnets.

3. Electromagnets are created when a current flows through a coil of wire (called a solenoid).

State 3 changes that can increase the strength of an electromagnet.

4. Medical imaging creates pictures of the inside a patient without needing to operate on them. Name 3 different methods of medical imaging.

5. The electromagnets in MRI scanners attract magnetic metals very strongly when the machine is switched on. Patients must not take anything magnetic into the room when they have their scan.

State 2 magnetic metals and 2 non-magnetic metals.

Apply

6. Shrouk El-Attar wanted to miniaturise the electromagnets used in medical scanners called ESR (Electron spin resonance) machines.

Suggest two advantages of making medical equipment, like scanners, smaller.

7. A student is investigating electromagnets. They make an electromagnet by coiling wire around an iron nail and then connecting the wire to a battery. The strength of the magnetic field is tested by picking up paper clips. Complete the table to predict how many paperclips are picked up by the electromagnet each time a change is made. Explain your answer for each prediction.

Electromagnet design	Prediction	Explanation
1m of wire coiled 50 times round an iron nail, 3V battery	5 paper clips	
1m of wire coiled 25 times round an iron nail, 3V battery		
1m of wire coiled 50 times round an iron nail, 6V battery		
1m of wire coiled 50 times round an iron nail, 6V battery		
1m of wire coiled 50 times round an iron nail, 3V battery		

Extend

8. After the student did their experiment a few times, they noticed that the number of paperclips picked up was fewer than predicted each time.

When the electromagnet was turned off, some paperclips stayed stuck on the nail.

Explain these two observations.

9. Shrouk worked in industrial robotics measuring objects and distances as small as 1 nanometre across, which is 60 000 times smaller than a human hair width.

Use this information to estimate the width of a human hair in mm.