Experiment 1: Magnetic Field Mapping

You will need:

- A transparent container with a flat bottom
- An inverter magnet
- Iron fillings
- Cello-tape

Step 1: Take your container and sprinkle the iron filings on the bottom so that they form a thin layer.

Step 2: Attach your inverter magnet to the underside of your container as shown in figure 1 (be careful that you don't hold your inverter magnet above the container, the iron filings may get stuck to the magnets and they can be difficult to remove).

Step 3: Sketch the patterns the iron filings make when the inverter magnet is attached, they should correspond to the magnetic field lines around the inverter magnet.

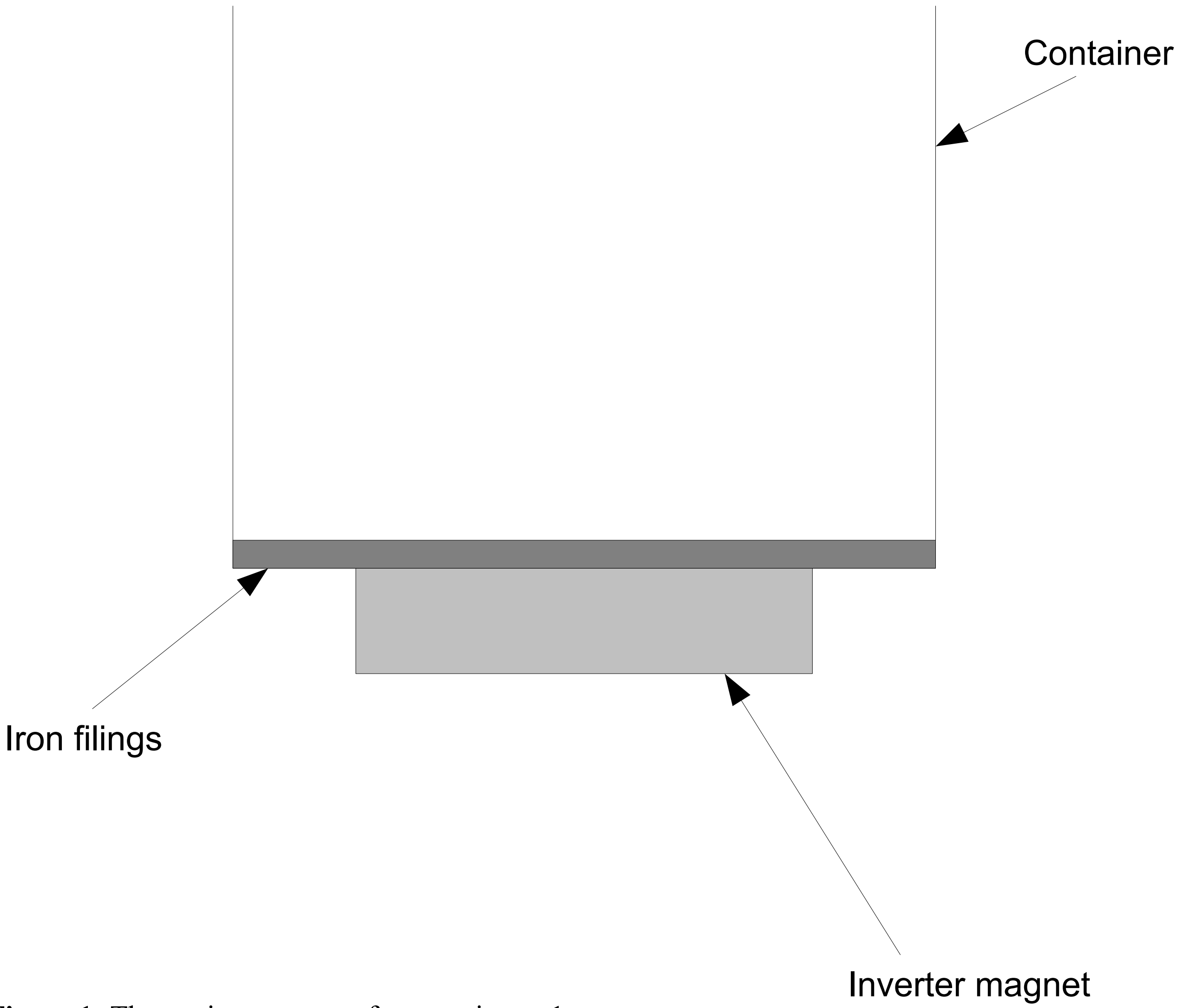

Figure 1: The equipment setup for experiment 1.

Experiment 2: Inverting fields and inverse relations

You will need:

- An inverter magnet
- A test magnet the same height as the inverter (packaged with the inverter magnet)
- Duct tape
- A plastic or wooden ruler

Step 1: Take your inverter magnet and attach it securely to a smooth horizontal surface (e.g. a flat tabletop) with duct tape.

Step 2: Using duct tape, attach the ruler alongside the inverter magnet with the peripheral magnets aligned relative to the ruler as shown in figure 2.

Step 3: Place the test magnet on flat on the surface the inverter magnet is attached to, with its poles aligned the same way as the poles of the inverter magnet's peripheral magnets (i.e. if their north poles are facing upwards the north pole of the test magnet should also face upwards).

Step 4: Keeping hold of the test magnet, position it as shown in figure 2, about 2cm away from the inverter magnet (use the ruler to judge the distance). Which way is the magnet being pulled?

Step 5: Push the test magnet closer to the inverter magnet until they almost touching, which way is the magnet being pulled now? You should have noticed the force changing direction as you pushed the magnet closer, why did that happen and at what separation between the inverter magnet and the test magnet did it change direction? (You can use the ruler to gauge distance). Make a note of the separation where the force changed from being attractive to being repulsive, this is called the equilibrium separation (you will need this figure for experiment 3).

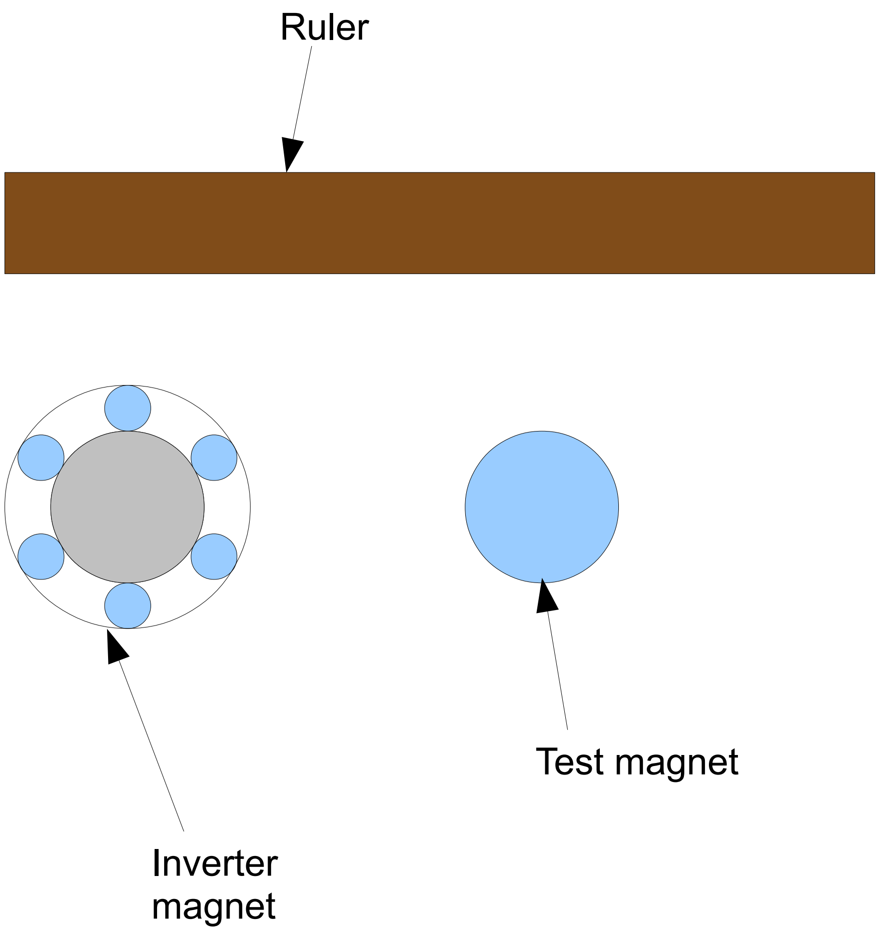

Figure 2: The setup of experiment 2.

Experiment 3: Adding fields

You will need:

- An inverter magnet with removable magnets
- A test magnet the same height as the inverter (packaged with the inverter magnet)
- Duct tape
- A plastic or wooden ruler
- A spring scale (also called a Newton meter)
- Thick copper wire

Step 1: Place the test magnet on a smooth horizontal surface (e.g. a flat tabletop), loop a length of copper wire around the magnet and attach the wire to the hook of the spring scale as shown in figure 3. Keeping it horizontal, pull on the spring scale until the magnet begins to move. The peak force the spring scale recorded should be the maximum friction between the test magnet and the surface it's on, make a note of this value.

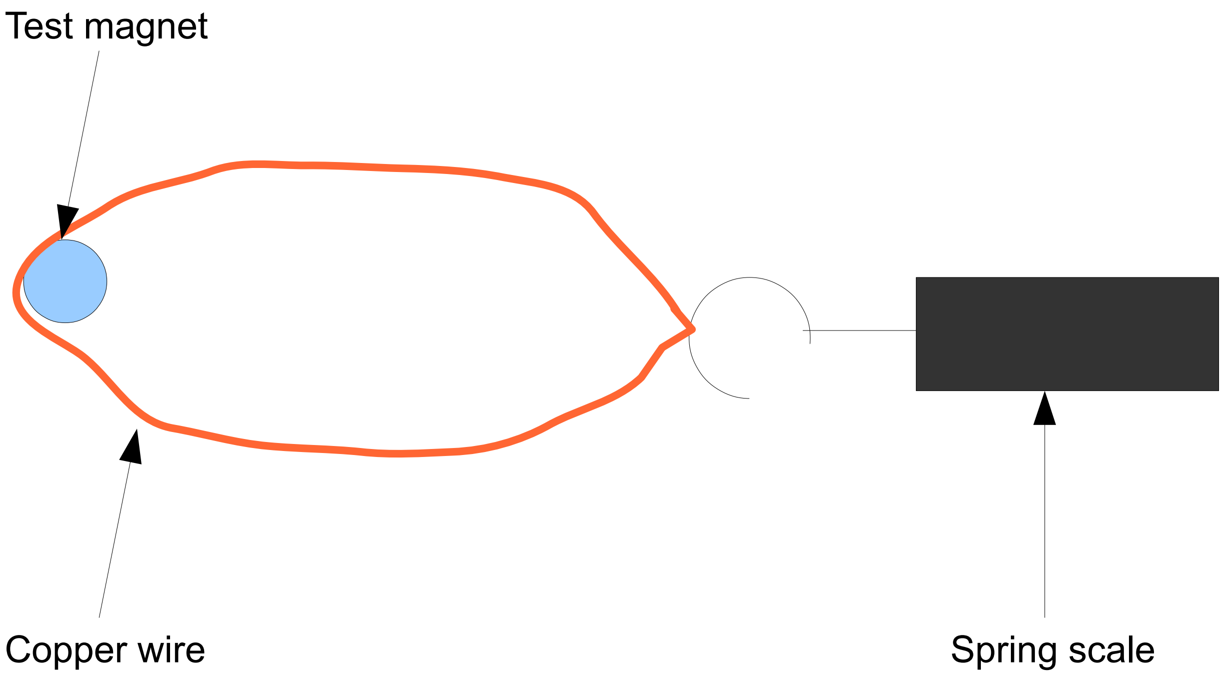

Figure 3: Setup for measuring friction between the test magnet and surface it is resting on.

Step 2: Remove the central magnet from the inverter magnet and set up the inverter magnet and ruler as described in steps 1-3 of experiment 2 (shown in figure 2).

Step 3: Place the test magnet at the equilibrium separation you found in experiment 2 (keeping the same alignment you used for that experiment). Use the loop of copper wire attached to the spring scale to keep the test magnet from drifting further away as shown in figure 4.

Step 4: Keeping the spring scale horizontal, pull the test magnet closer to the inverter magnet until it begins to move. Note down the peak force the spring scale recorded and the separation between the inverter magnet and the test magnet when the test magnet stopped moving. This should be equal to the force exerted by the inverter magnet at this point, plus the peak friction experienced by the test magnet (found in step 1). Subtract the friction force you found in step 1 from the peak force the spring scale recorded to get the force exerted by the inverter magnet on the test magnet at this point, record this value alongside the previous two values.

Step 5: Move the test magnet 1mm closer to the inverter magnet, re-set the peak force recorded by the spring scale, and repeat step 4. Repeat this process, moving the test magnet incrementally closer to the inverter magnet, until the two magnets are almost touching.

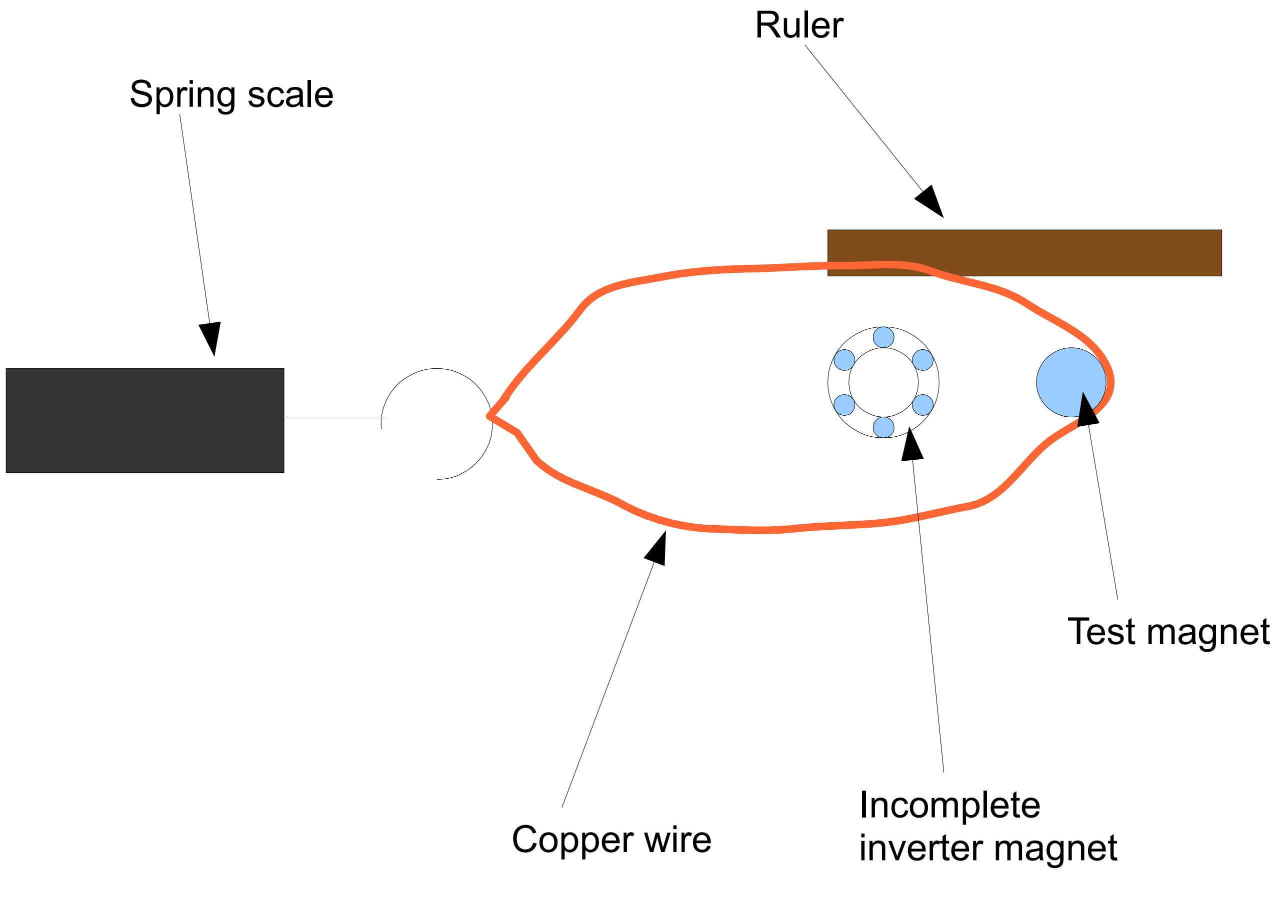

Figure 4: The initial setup for measuring the force exerted by an inverter magnet with the central magnet removed.

Step 6: Remove the peripheral magnets from the inverter magnet and put the central magnet back in the now empty frame and set up the inverter magnet and ruler as described in steps 1-3 of experiment 2.

Step 7: Place the test magnet in the same position it was in when you took the last reading during step 5 (i.e. the reading taken when the separation between the inverter magnet and the test magnet was smallest). Loop the copper wire around the test magnet to prevent it from drifting closer to the inverter magnet as shown in figure 5.

Step 8: Keeping the spring scale horizontal, pull the test magnet away from the inverter magnet until it begins to move. Note down the peak force the spring scale recorded and the initial separation between the inverter magnet and the test magnet before the test magnet started moving. This should be equal to the force exerted by the inverter magnet at this point, plus the peak friction experienced by the test magnet. Subtract the friction force you found in step 1 from the peak force the spring scale recorded to get the force exerted by the inverter magnet on the test magnet at this point, record this value alongside the previous two values.

Step 9: Move the test magnet to the next smallest separation between the test magnet that you recorded results for during steps 4 and 5, re-set the peak force recorded by spring scale, and repeat step 8. Repeat this process until you have a set of results for pulling the test magnet away from the inverter magnet to match each set of results for pulling the test magnet towards the inverter magnet taken during steps 4 and 5.

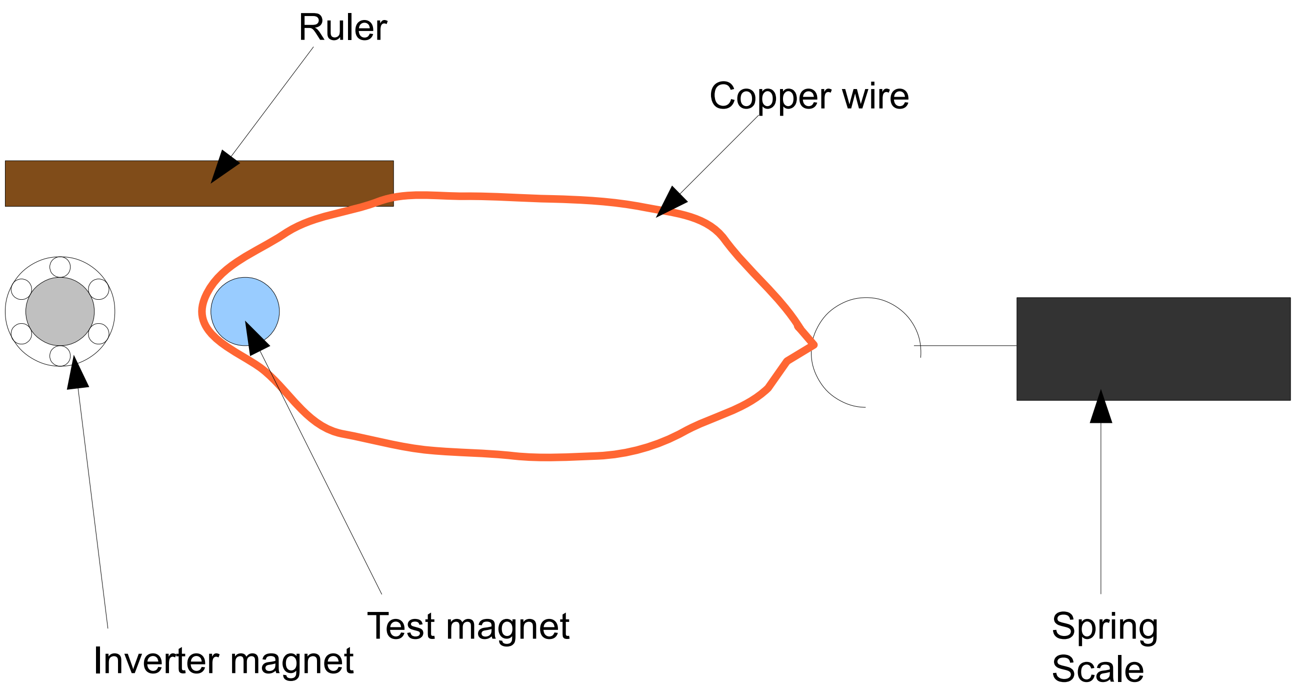

Figure 5: The initial setup for measuring the force exerted by an inverter magnet with the peripheral magnets removed.

Step 10: Add the peripheral magnets to the inverter magnet so that device is once again complete and set it up alongside the ruler as shown in figure 2. Place the test magnet at the equilibrium position you found in experiment 2.

Step 11: Loop the the copper wire round the test magnet round the test magnet as shown in figure 4 and measure the force exerted by the inverter magnet (with and without friction) on the test magnet the same way you did in steps 4 and 5 (try to take measurements in the same positions as you have for the previous readings).

Step 12: Add the force exerted by the peripheral magnets of the inverter on the test magnet (found in steps 4 and 5) to the force exerted by the central magnet of the inverter (found in steps 8 and 9) for each of your measurement positions (make sure you use the force discounting the friction experienced by the test magnet, and take into account that the two forces are going in different directions). Compare these figures with the force exerted by the completed inverter magnet (found in step 11), they should roughly match up, indicating that the forces exerted by the components of the inverter magnet were added to each other when the magnets were combined in the frame, and hence that when the fields from two magnets overlap they simply add together.