A Feeling for Fields

This activity involves:

- reading the article 'a feeling for fields'
- producing demonstrations to show effect of 'action at distance'
- answering questions related to demonstrations and article.

Introduction

This activity explores some of the characteristics of 'field theories'. Students are encouraged to perform a simple experiment. The critical thing is for the students to explain the well-known data in terms of 'field'.
This activity also considers the 'scientific' nature of a theory that seeks not to explain but to describe.

With some groups it may be better to omit question 3 and provide the completed table to support their answers to question 2. Some groups will need you to demonstrate the set up for question 4.

Answers to questions.

2. An inverse square field is a volume of space in which a test object experiences a force from a second object, the magnitude of the force being proportional to 1/(distance from second object)^2 . Or words to that effect!
3.

Distance between objects/m	Force/N
1.0	128
2.0	32.0
4.0	8.0
6.0	3.6
8.0	2.0
10.0	1.18

4. The idea here is to use the orientation of the compass needle as some measure of field strength. If the magnets are set up with North facing North and the compass put in between, the needle will point to the Earth's North as the magnetic fields from the two magnets will cancel at the mid point. As one magnet is moved the remaining magnet 'takes over' and the compass needle swings round to face the stationary magnet. The demonstration does not prove that there is a field present – but it can be described using the field concept. The demonstration could be performed with one magnet thanks to the magnetic field of the Earth. It could not be performed on a spaceship with only one magnet as the compass needle would always be drawn to the magnet, however weak the force.

5. We are not concerned with electrostatic theory here. The point is that there is a force that acts at a distance. The paper is the 'test object' and can be observed to experience a force in the field.

References

Textbook
Chapter 15/16

Specification
10.6 The move away from an Earth-Centred View of the Universe

12.1c know that scientists value observations and measurements that are replicable (on different occasions and/or by different people), and be able to explain why;
12.1k recognise and appreciate the reasons for, people's reluctance to reject a well established explanation on the face of apparent anomalies, until a better explanation is available;
12.1l understand that reported findings and explanations must withstand critical scrutiny by other scientists, before they are accepted as scientific knowledge.
12.2b recognise that a person's view and expectations (and their social interests and commitments) can influence the data they collect and their interpretations of it;
12.2c recognise that we often consider personal characteristics of scientists (such as their reputation, their seniority, and the interests of organisations they work for) when we evaluate their statements, and consider how far this is justified.

Resources needed

Student sheet
text book
bar magnets
plotting compass
plastic rod (or comb) paper

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6. This is the problem with ‘action at a distance’. There is no explanation for how the force is propagated so it seems magical. The demonstrations don’t prove the field picture but do provide new phenomena which can be described using the field picture.

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1. Read the article 'a feeling for fields'.

2. In the article the gravitational field is described as 'inverse square'. Explain what is meant by an inverse square *field*.

3. Complete the table below.

   Table showing how the gravitational attraction between two masses varies with distance.

Distance between objects/m	**Force/N**
1.0	
2.0	32.0
4.0	8.0
6.0	3.6
8.0	2.0
10.0	

4. Take two magnets and a 'plotting compass'. Use these three pieces of apparatus to design a demonstration that shows that the magnetic field of a magnet decreases as the distance from the magnet increases. Describe your demonstration in the space below:

   Explain whether your demonstration proves that there is a field present.

   Explain whether you could perform the demonstration with only one magnet.

   Could you perform the experiment in spaceship far from any planet with only one magnet? If not, why not ?

5. Rip up some paper into pieces no bigger than about 0.5cm by 0.5cm. Take a plastic comb and rub it on a piece of cloth. Hold it near the paper and observe what happens.

   Record your observations and explain them using the idea of a field.

6. Refer to the article again. Explain why the idea of a field was not universally accepted. Do you think the demonstrations you have made strengthen the idea of a field?

7. If Newton's Law of gravity doesn't really 'explain' gravity how can it be scientific? (How does it differ from Bode's Law described in a previous activity?)

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A Feeling for Fields

The story of how Isaac Newton 'discovered' gravity goes all the way back to his first biographer, William Stukeley. The famous tale of the apple falling begins with Stukeley:

> *" After dinner, the weather being warm, we went into the garden and drank tea, under the shade of some apple trees, only he and myself. Amidst other discourse, he told me, he was just in the same situation, as when formerly, the notion of gravitation came into his mind. It was occasioned by the fall of an apple as he sat in contemplative mood. Why should that apple always descend perpendicularly to the ground, he thought to himself. Why should it not go sideways upwards, but constantly to the earth's centre?"*

Previous thinkers had given scant attention to the fall of bodies near the Earth. Most followed the Greek philosopher Aristotle in considering the Earth to be the 'natural' place for bodies to fall towards.

Newton suggested that all matter has a 'drawing power'. Now this isn't saying very much. But Newton went further, he suggested that the 'drawing power' was proportional to the mass of the object and that the force is mutual. The Earth pulls the apple and the apple pulls the Earth.

Newton's 'theory of Universal Gravitation' can be put into mathematical form:

$F = - Gm_1m_2/r^2$

This means that the force, F between two bodies of mass m_1 and m_2 is equal to the masses multiplied together with a constant G and then divided by the distance between them , r, squared. The negative sign shows that the force is attractive.

This equation describes a 'field'. Describing the effects of forces in terms of 'fields' was new and not all physicists and mathematicians felt comfortable with this way of explaining the effects of forces.

The Concise Science Dictionary gives this definition of field:

> **A region in which a body experiences a force as the result of the presence of some other body or bodies. A field is thus a method of representing the way in which bodies are able to influence each other.**
> **For example, a body that has mass is surrounded by a region in which another body that has mass experiences a force that tends to draw the two bodies together.**

The gravitational field is 'inverse-square'. This means that the force weakens with the square of the distance.

The field picture is also used to describe the electric and magnetic fields. These are now known to be two effects of the same field – the electromagnetic field.

Newton's mathematical description of the effects of masses on one another has been very successful. For example, the flight paths of all spacecraft are calculated using Newton's description. But when asked what 'caused' the attraction between all masses Newton replied 'Hypotheses non fingo' which means 'I frame no hypotheses' which in can be paraphrased as ' I don't know, I'm just describing the effect, not explaining it'. Newton described an effect that is known as 'action at a distance'. For example, a magnet attracts paper clips from a distance. Newton described the action of the gravitational field with great precision, but he did not explain how it occurred.

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This lack of explanation caused some concern amongst other physicists and commentators. It was seen by some as an occult or magical force. This was because there seemed to be no explanation for the mysterious force that propagated throughout space.

In many ways the question of the 'cause' of the attraction between masses is still unanswered. Einstein's General Relativity (1917) improved the description but physicists are still debating what 'mass' really is.

However, Newton's mathematical framework yielded testable predictions. For instance, Kepler's Laws of Planetary Motion are consequences of the inverse square nature of the field. In fact, Newton's work was so phenomenally successful that over the coming years many tried to apply the 'mechanical science' to different areas from chemistry to politics. In some cases this worked, in other cases the benefits of a mechanical approach were less obvious.

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