



FHSST Authors

**The Free High School Science Texts:
Textbooks for High School Students
Studying the Sciences
Physics
Grades 10 - 12**

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this a continuously evolving resource!

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Contents

I	Introduction	1
1	What is Physics?	3
II	Grade 10 - Physics	5
2	Units	9
2.1	Introduction	9
2.2	Unit Systems	9
2.2.1	SI Units	9
2.2.2	The Other Systems of Units	10
2.3	Writing Units as Words or Symbols	10
2.4	Combinations of SI Base Units	12
2.5	Rounding, Scientific Notation and Significant Figures	12
2.5.1	Rounding Off	12
2.5.2	Error Margins	13
2.5.3	Scientific Notation	13
2.5.4	Significant Figures	15
2.6	Prefixes of Base Units	15
2.7	The Importance of Units	17
2.8	How to Change Units	17
2.8.1	Two other useful conversions	19
2.9	A sanity test	19
2.10	Summary	19
2.11	End of Chapter Exercises	21
3	Motion in One Dimension - Grade 10	23
3.1	Introduction	23
3.2	Reference Point, Frame of Reference and Position	23
3.2.1	Frames of Reference	23
3.2.2	Position	25
3.3	Displacement and Distance	28
3.3.1	Interpreting Direction	29
3.3.2	Differences between Distance and Displacement	29
3.4	Speed, Average Velocity and Instantaneous Velocity	31

3.4.1	Differences between Speed and Velocity	35
3.5	Acceleration	38
3.6	Description of Motion	39
3.6.1	Stationary Object	40
3.6.2	Motion at Constant Velocity	41
3.6.3	Motion at Constant Acceleration	46
3.7	Summary of Graphs	48
3.8	Worked Examples	49
3.9	Equations of Motion	54
3.9.1	Finding the Equations of Motion	54
3.10	Applications in the Real-World	59
3.11	Summary	61
3.12	End of Chapter Exercises: Motion in One Dimension	62
4	Gravity and Mechanical Energy - Grade 10	67
4.1	Weight	67
4.1.1	Differences between Mass and Weight	68
4.2	Acceleration due to Gravity	69
4.2.1	Gravitational Fields	69
4.2.2	Free fall	69
4.3	Potential Energy	73
4.4	Kinetic Energy	75
4.4.1	Checking units	77
4.5	Mechanical Energy	78
4.5.1	Conservation of Mechanical Energy	78
4.5.2	Using the Law of Conservation of Energy	79
4.6	Energy graphs	82
4.7	Summary	83
4.8	End of Chapter Exercises: Gravity and Mechanical Energy	84
5	Transverse Pulses - Grade 10	87
5.1	Introduction	87
5.2	What is a <i>medium</i> ?	87
5.3	What is a <i>pulse</i> ?	87
5.3.1	Pulse Length and Amplitude	88
5.3.2	Pulse Speed	89
5.4	Graphs of Position and Velocity	90
5.4.1	Motion of a Particle of the Medium	90
5.4.2	Motion of the Pulse	92
5.5	Transmission and Reflection of a Pulse at a Boundary	96
5.6	Reflection of a Pulse from Fixed and Free Ends	97
5.6.1	Reflection of a Pulse from a Fixed End	97

5.6.2	Reflection of a Pulse from a Free End	98
5.7	Superposition of Pulses	99
5.8	Exercises - Transverse Pulses	102
6	Transverse Waves - Grade 10	105
6.1	Introduction	105
6.2	What is a <i>transverse wave</i> ?	105
6.2.1	Peaks and Troughs	106
6.2.2	Amplitude and Wavelength	107
6.2.3	Points in Phase	109
6.2.4	Period and Frequency	110
6.2.5	Speed of a Transverse Wave	111
6.3	Graphs of Particle Motion	115
6.4	Standing Waves and Boundary Conditions	118
6.4.1	Reflection of a Transverse Wave from a Fixed End	118
6.4.2	Reflection of a Transverse Wave from a Free End	118
6.4.3	Standing Waves	118
6.4.4	Nodes and anti-nodes	122
6.4.5	Wavelengths of Standing Waves with Fixed and Free Ends	122
6.4.6	Superposition and Interference	125
6.5	Summary	127
6.6	Exercises	127
7	Geometrical Optics - Grade 10	129
7.1	Introduction	129
7.2	Light Rays	129
7.2.1	Shadows	132
7.2.2	Ray Diagrams	132
7.3	Reflection	132
7.3.1	Terminology	133
7.3.2	Law of Reflection	133
7.3.3	Types of Reflection	135
7.4	Refraction	137
7.4.1	Refractive Index	139
7.4.2	Snell's Law	139
7.4.3	Apparent Depth	143
7.5	Mirrors	146
7.5.1	Image Formation	146
7.5.2	Plane Mirrors	147
7.5.3	Ray Diagrams	148
7.5.4	Spherical Mirrors	150
7.5.5	Concave Mirrors	150

7.5.6	Convex Mirrors	153
7.5.7	Summary of Properties of Mirrors	154
7.5.8	Magnification	154
7.6	Total Internal Reflection and Fibre Optics	156
7.6.1	Total Internal Reflection	156
7.6.2	Fibre Optics	161
7.7	Summary	163
7.8	Exercises	164
8	Magnetism - Grade 10	167
8.1	Introduction	167
8.2	Magnetic fields	167
8.3	Permanent magnets	169
8.3.1	The poles of permanent magnets	169
8.3.2	Magnetic attraction and repulsion	169
8.3.3	Representing magnetic fields	170
8.4	The compass and the earth's magnetic field	173
8.4.1	The earth's magnetic field	175
8.5	Summary	175
8.6	End of chapter exercises	176
9	Electrostatics - Grade 10	177
9.1	Introduction	177
9.2	Two kinds of charge	177
9.3	Unit of charge	177
9.4	Conservation of charge	177
9.5	Force between Charges	178
9.6	Conductors and insulators	181
9.6.1	The electroscope	182
9.7	Attraction between charged and uncharged objects	183
9.7.1	Polarisation of Insulators	183
9.8	Summary	184
9.9	End of chapter exercise	184
10	Electric Circuits - Grade 10	187
10.1	Electric Circuits	187
10.1.1	Closed circuits	187
10.1.2	Representing electric circuits	188
10.2	Potential Difference	192
10.2.1	Potential Difference	192
10.2.2	Potential Difference and Parallel Resistors	193
10.2.3	Potential Difference and Series Resistors	194
10.2.4	Ohm's Law	194

10.2.5 EMF	195
10.3 Current	198
10.3.1 Flow of Charge	198
10.3.2 Current	198
10.3.3 Series Circuits	199
10.3.4 Parallel Circuits	200
10.4 Resistance	202
10.4.1 What causes resistance?	202
10.4.2 Resistors in electric circuits	202
10.5 Instruments to Measure voltage, current and resistance	204
10.5.1 Voltmeter	204
10.5.2 Ammeter	204
10.5.3 Ohmmeter	204
10.5.4 Meters Impact on Circuit	205
10.6 Exercises - Electric circuits	205
III Grade 11 - Physics	209
11 Vectors	211
11.1 Introduction	211
11.2 Scalars and Vectors	211
11.3 Notation	211
11.3.1 Mathematical Representation	212
11.3.2 Graphical Representation	212
11.4 Directions	212
11.4.1 Relative Directions	212
11.4.2 Compass Directions	213
11.4.3 Bearing	213
11.5 Drawing Vectors	214
11.6 Mathematical Properties of Vectors	215
11.6.1 Adding Vectors	215
11.6.2 Subtracting Vectors	217
11.6.3 Scalar Multiplication	218
11.7 Techniques of Vector Addition	218
11.7.1 Graphical Techniques	218
11.7.2 Algebraic Addition and Subtraction of Vectors	223
11.8 Components of Vectors	228
11.8.1 Vector addition using components	231
11.8.2 Summary	235
11.8.3 End of chapter exercises: Vectors	236
11.8.4 End of chapter exercises: Vectors - Long questions	237

12 Force, Momentum and Impulse - Grade 11	239
12.1 Introduction	239
12.2 Force	239
12.2.1 What is a <i>force</i> ?	239
12.2.2 Examples of Forces in Physics	240
12.2.3 Systems and External Forces	241
12.2.4 Force Diagrams	242
12.2.5 Free Body Diagrams	243
12.2.6 Finding the Resultant Force	244
12.2.7 Exercise	246
12.3 Newton's Laws	246
12.3.1 Newton's First Law	247
12.3.2 Newton's Second Law of Motion	249
12.3.3 Exercise	261
12.3.4 Newton's Third Law of Motion	263
12.3.5 Exercise	267
12.3.6 Different types of forces	268
12.3.7 Exercise	275
12.3.8 Forces in equilibrium	276
12.3.9 Exercise	279
12.4 Forces between Masses	282
12.4.1 Newton's Law of Universal Gravitation	282
12.4.2 Comparative Problems	284
12.4.3 Exercise	286
12.5 Momentum and Impulse	287
12.5.1 Vector Nature of Momentum	290
12.5.2 Exercise	291
12.5.3 Change in Momentum	291
12.5.4 Exercise	293
12.5.5 Newton's Second Law revisited	293
12.5.6 Impulse	294
12.5.7 Exercise	296
12.5.8 Conservation of Momentum	297
12.5.9 Physics in Action: Impulse	300
12.5.10 Exercise	301
12.6 Torque and Levers	302
12.6.1 Torque	302
12.6.2 Mechanical Advantage and Levers	305
12.6.3 Classes of levers	307
12.6.4 Exercise	308
12.7 Summary	309
12.8 End of Chapter exercises	310

13 Geometrical Optics - Grade 11	327
13.1 Introduction	327
13.2 Lenses	327
13.2.1 Converging Lenses	329
13.2.2 Diverging Lenses	340
13.2.3 Summary of Image Properties	343
13.3 The Human Eye	344
13.3.1 Structure of the Eye	345
13.3.2 Defects of Vision	346
13.4 Gravitational Lenses	347
13.5 Telescopes	347
13.5.1 Refracting Telescopes	347
13.5.2 Reflecting Telescopes	348
13.5.3 Southern African Large Telescope	348
13.6 Microscopes	349
13.7 Summary	351
13.8 Exercises	352
14 Longitudinal Waves - Grade 11	355
14.1 Introduction	355
14.2 What is a <i>longitudinal wave</i> ?	355
14.3 Characteristics of Longitudinal Waves	356
14.3.1 Compression and Rarefaction	356
14.3.2 Wavelength and Amplitude	357
14.3.3 Period and Frequency	357
14.3.4 Speed of a Longitudinal Wave	358
14.4 Graphs of Particle Position, Displacement, Velocity and Acceleration	359
14.5 Sound Waves	360
14.6 Seismic Waves	361
14.7 Summary - Longitudinal Waves	361
14.8 Exercises - Longitudinal Waves	362
15 Sound - Grade 11	363
15.1 Introduction	363
15.2 Characteristics of a Sound Wave	363
15.2.1 Pitch	364
15.2.2 Loudness	364
15.2.3 Tone	364
15.3 Speed of Sound	365
15.4 Physics of the Ear and Hearing	365
15.4.1 Intensity of Sound	366
15.5 Ultrasound	367

15.6 SONAR	368
15.6.1 Echolocation	368
15.7 Summary	369
15.8 Exercises	369
16 The Physics of Music - Grade 11	373
16.1 Introduction	373
16.2 Standing Waves in String Instruments	373
16.3 Standing Waves in Wind Instruments	377
16.4 Resonance	382
16.5 Music and Sound Quality	384
16.6 Summary - The Physics of Music	385
16.7 End of Chapter Exercises	386
17 Electrostatics - Grade 11	387
17.1 Introduction	387
17.2 Forces between charges - Coulomb's Law	387
17.3 Electric field around charges	392
17.3.1 Electric field lines	393
17.3.2 Positive charge acting on a test charge	393
17.3.3 Combined charge distributions	394
17.3.4 Parallel plates	397
17.4 Electrical potential energy and potential	400
17.4.1 Electrical potential	400
17.4.2 Real-world application: lightning	402
17.5 Capacitance and the parallel plate capacitor	403
17.5.1 Capacitors and capacitance	403
17.5.2 Dielectrics	404
17.5.3 Physical properties of the capacitor and capacitance	404
17.5.4 Electric field in a capacitor	405
17.6 Capacitor as a circuit device	406
17.6.1 A capacitor in a circuit	406
17.6.2 Real-world applications: capacitors	407
17.7 Summary	407
17.8 Exercises - Electrostatics	407
18 Electromagnetism - Grade 11	413
18.1 Introduction	413
18.2 Magnetic field associated with a current	413
18.2.1 Real-world applications	418
18.3 Current induced by a changing magnetic field	420
18.3.1 Real-life applications	422
18.4 Transformers	423

18.4.1 Real-world applications	425
18.5 Motion of a charged particle in a magnetic field	425
18.5.1 Real-world applications	426
18.6 Summary	427
18.7 End of chapter exercises	427
19 Electric Circuits - Grade 11	429
19.1 Introduction	429
19.2 Ohm's Law	429
19.2.1 Definition of Ohm's Law	429
19.2.2 Ohmic and non-ohmic conductors	431
19.2.3 Using Ohm's Law	432
19.3 Resistance	433
19.3.1 Equivalent resistance	433
19.3.2 Use of Ohm's Law in series and parallel Circuits	438
19.3.3 Batteries and internal resistance	440
19.4 Series and parallel networks of resistors	442
19.5 Wheatstone bridge	445
19.6 Summary	447
19.7 End of chapter exercise	447
20 Electronic Properties of Matter - Grade 11	451
20.1 Introduction	451
20.2 Conduction	451
20.2.1 Metals	453
20.2.2 Insulator	453
20.2.3 Semi-conductors	454
20.3 Intrinsic Properties and Doping	454
20.3.1 Surplus	455
20.3.2 Deficiency	455
20.4 The p-n junction	457
20.4.1 Differences between p- and n-type semi-conductors	457
20.4.2 The p-n Junction	457
20.4.3 Unbiased	457
20.4.4 Forward biased	457
20.4.5 Reverse biased	458
20.4.6 Real-World Applications of Semiconductors	458
20.5 End of Chapter Exercises	459
IV Grade 12 - Physics	461
21 Motion in Two Dimensions - Grade 12	463
21.1 Introduction	463

21.2 Vertical Projectile Motion	463
21.2.1 Motion in a Gravitational Field	463
21.2.2 Equations of Motion	464
21.2.3 Graphs of Vertical Projectile Motion	467
21.3 Conservation of Momentum in Two Dimensions	475
21.4 Types of Collisions	480
21.4.1 Elastic Collisions	480
21.4.2 Inelastic Collisions	485
21.5 Frames of Reference	490
21.5.1 Introduction	490
21.5.2 What is a <i>frame of reference</i> ?	491
21.5.3 Why are frames of reference important?	491
21.5.4 Relative Velocity	491
21.6 Summary	494
21.7 End of chapter exercises	495
22 Mechanical Properties of Matter - Grade 12	503
22.1 Introduction	503
22.2 Deformation of materials	503
22.2.1 Hooke's Law	503
22.2.2 Deviation from Hooke's Law	506
22.3 Elasticity, plasticity, fracture, creep	508
22.3.1 Elasticity and plasticity	508
22.3.2 Fracture, creep and fatigue	508
22.4 Failure and strength of materials	509
22.4.1 The properties of matter	509
22.4.2 Structure and failure of materials	509
22.4.3 Controlling the properties of materials	509
22.4.4 Steps of Roman Swordsmithing	510
22.5 Summary	511
22.6 End of chapter exercise	511
23 Work, Energy and Power - Grade 12	513
23.1 Introduction	513
23.2 Work	513
23.3 Energy	519
23.3.1 External and Internal Forces	519
23.3.2 Capacity to do Work	520
23.4 Power	525
23.5 Important Equations and Quantities	529
23.6 End of Chapter Exercises	529

24 Doppler Effect - Grade 12	533
24.1 Introduction	533
24.2 The Doppler Effect with Sound and Ultrasound	533
24.2.1 Ultrasound and the Doppler Effect	537
24.3 The Doppler Effect with Light	537
24.3.1 The Expanding Universe	538
24.4 Summary	539
24.5 End of Chapter Exercises	539
25 Colour - Grade 12	541
25.1 Introduction	541
25.2 Colour and Light	541
25.2.1 Dispersion of white light	544
25.3 Addition and Subtraction of Light	544
25.3.1 Additive Primary Colours	544
25.3.2 Subtractive Primary Colours	545
25.3.3 Complementary Colours	546
25.3.4 Perception of Colour	546
25.3.5 Colours on a Television Screen	547
25.4 Pigments and Paints	548
25.4.1 Colour of opaque objects	548
25.4.2 Colour of transparent objects	548
25.4.3 Pigment primary colours	549
25.5 End of Chapter Exercises	550
26 2D and 3D Wavefronts - Grade 12	553
26.1 Introduction	553
26.2 Wavefronts	553
26.3 The Huygens Principle	554
26.4 Interference	556
26.5 Diffraction	557
26.5.1 Diffraction through a Slit	558
26.6 Shock Waves and Sonic Booms	562
26.6.1 Subsonic Flight	563
26.6.2 Supersonic Flight	563
26.6.3 Mach Cone	566
26.7 End of Chapter Exercises	568
27 Wave Nature of Matter - Grade 12	571
27.1 Introduction	571
27.2 de Broglie Wavelength	571
27.3 The Electron Microscope	574
27.3.1 Disadvantages of an Electron Microscope	577

27.3.2	Uses of Electron Microscopes	577
27.4	End of Chapter Exercises	578
28	Electrodynamics - Grade 12	579
28.1	Introduction	579
28.2	Electrical machines - generators and motors	579
28.2.1	Electrical generators	580
28.2.2	Electric motors	582
28.2.3	Real-life applications	582
28.2.4	Exercise - generators and motors	584
28.3	Alternating Current	585
28.3.1	Exercise - alternating current	586
28.4	Capacitance and inductance	586
28.4.1	Capacitance	586
28.4.2	Inductance	586
28.4.3	Exercise - capacitance and inductance	588
28.5	Summary	588
28.6	End of chapter exercise	589
29	Electronics - Grade 12	591
29.1	Introduction	591
29.2	Capacitive and Inductive Circuits	591
29.3	Filters and Signal Tuning	596
29.3.1	Capacitors and Inductors as Filters	596
29.3.2	LRC Circuits, Resonance and Signal Tuning	596
29.4	Active Circuit Elements	599
29.4.1	The Diode	599
29.4.2	The Light Emitting Diode (LED)	601
29.4.3	Transistor	603
29.4.4	The Operational Amplifier	607
29.5	The Principles of Digital Electronics	609
29.5.1	Logic Gates	610
29.6	Using and Storing Binary Numbers	616
29.6.1	Binary numbers	616
29.6.2	Counting circuits	617
29.6.3	Storing binary numbers	619
30	EM Radiation	625
30.1	Introduction	625
30.2	Particle/wave nature of electromagnetic radiation	625
30.3	The wave nature of electromagnetic radiation	626
30.4	Electromagnetic spectrum	626
30.5	The particle nature of electromagnetic radiation	629

30.5.1 Exercise - particle nature of EM waves	630
30.6 Penetrating ability of electromagnetic radiation	631
30.6.1 Ultraviolet(UV) radiation and the skin	631
30.6.2 Ultraviolet radiation and the eyes	632
30.6.3 X-rays	632
30.6.4 Gamma-rays	632
30.6.5 Exercise - Penetrating ability of EM radiation	633
30.7 Summary	633
30.8 End of chapter exercise	633
31 Optical Phenomena and Properties of Matter - Grade 12	635
31.1 Introduction	635
31.2 The transmission and scattering of light	635
31.2.1 Energy levels of an electron	635
31.2.2 Interaction of light with metals	636
31.2.3 Why is the sky blue?	637
31.3 The photoelectric effect	638
31.3.1 Applications of the photoelectric effect	640
31.3.2 Real-life applications	642
31.4 Emission and absorption spectra	643
31.4.1 Emission Spectra	643
31.4.2 Absorption spectra	644
31.4.3 Colours and energies of electromagnetic radiation	646
31.4.4 Applications of emission and absorption spectra	648
31.5 Lasers	650
31.5.1 How a laser works	652
31.5.2 A simple laser	654
31.5.3 Laser applications and safety	655
31.6 Summary	656
31.7 End of chapter exercise	657
V Exercises	659
32 Exercises	661
VI Essays	663
Essay 1: Energy and electricity. Why the fuss?	665
33 Essay: How a cell phone works	671
34 Essay: How a Physiotherapist uses the Concept of Levers	673
35 Essay: How a Pilot Uses Vectors	675

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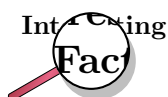
Chapter 8

Magnetism - Grade 10

8.1 Introduction

Magnetism is the force that a magnetic object exerts, through its magnetic field, on another object. The two objects do not have to physically touch each other for the force to be exerted. Object 2 feels the magnetic force from Object 1 because of Object 1's surrounding magnetic field.

Humans have known about magnetism for many thousands of years. For example, *lodestone* is a magnetised form of the iron oxide mineral *magnetite*. It has the property of attracting iron objects. It is referred to in old European and Asian historical records; from around 800 BCE in Europe and around 2 600 BCE in Asia.

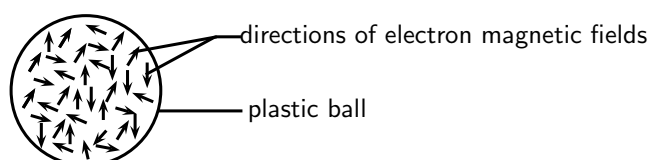


The root of the English word *magnet* is from the Greek word *magnes*, probably from Magnesia in Asia Minor, once an important source of lodestone.

8.2 Magnetic fields

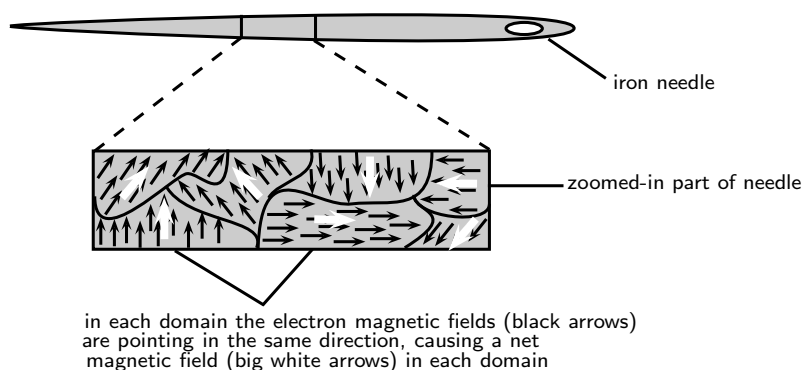
A magnetic field is a region in space where a magnet or object made of ferromagnetic material will experience a non-contact force.

Electrons moving inside any object have magnetic fields associated with them. In most materials these fields point in all directions, so the net magnetic field is zero. For example, in the plastic ball below, the directions of the magnetic fields of the electrons (shown by the arrows) are pointing in different directions and cancel each other out. Therefore the plastic ball is not magnetic and has no magnetic field.

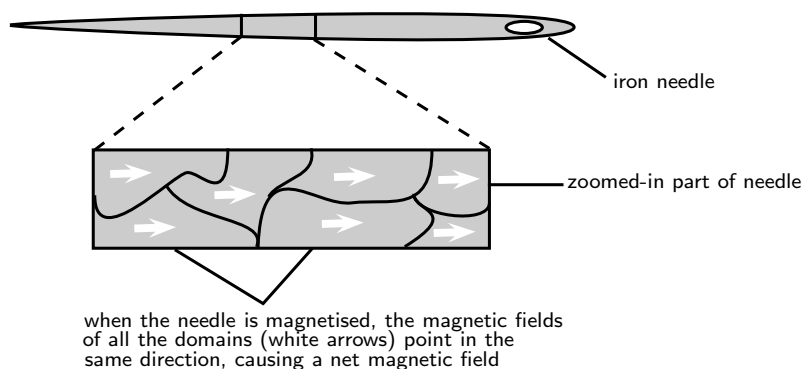


The electron magnetic fields point in all directions and so there is no net magnetic field

In some materials (e.g. iron), called **ferromagnetic** materials, there are regions called *domains*, where these magnetic fields line up. All the atoms in each domain group together so that the magnetic fields from their electrons point the same way. The picture shows a piece of an iron needle zoomed in to show the domains with the electric fields lined up inside them.



In permanent magnets, many domains are lined up, resulting in a *net magnetic field*. Objects made from ferromagnetic materials can be magnetised, for example by rubbing a magnet along the object in one direction. This causes the magnetic fields of most, or all, of the domains to line up and cause the object to have a magnetic field and be *magnetic*. Once a ferromagnetic object has been magnetised, it can stay magnetic without another magnet being nearby (i.e. without being in another magnetic field). In the picture below, the needle has been magnetised because the magnetic fields in all the domains are pointing in the same direction.



Activity :: Investigation : Ferromagnetic materials and magnetisation

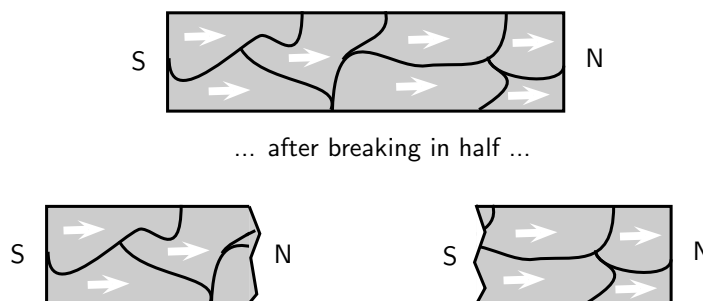
1. Find 2 paper clips. Put the paper clips close together and observe what happens.
 - 1.1 **What happens to the paper clips?**
 - 1.2 **Are the paper clips magnetic?**
2. Now take a permanent bar magnet and rub it once along 1 of the paper clips. Remove the magnet and put the paper clip which was touched by the magnet close to the other paper clip and observe what happens.
 - 2.1 **Does the untouched paper clip feel a force on it? If so, is the force attractive or repulsive?**
3. Rub the same paper clip a few more times with the bar magnet, in the same direction as before. Put the paper clip close to the other one and observe what happens.
 - 3.1 **Is there any difference to what happened in step 2?**

- 3.2 **If there is a difference, what is the reason for it?**
- 3.3 **Is the paper clip which was rubbed by the magnet now magnetised?**
- 3.4 **What is the difference between the two paper clips at the level of their atoms and electrons?**
4. Now, find a *metal* knitting needle, or a plastic ruler, or other plastic object. Rub the bar magnet along the knitting needle a few times in the same direction. Now put the knitting needle close to the paper clips and observe what happens.
- 4.1 **Does the knitting needle attract the paper clips?**
- 4.2 **What does this tell you about the material of the knitting needle? Is it ferromagnetic?**
5. Repeat this experiment with objects made from other materials.
- 5.1 **Which materials appear to be ferromagnetic and which are not? Put your answers in a table.**
-

8.3 Permanent magnets

8.3.1 The poles of permanent magnets

Because the domains in a permanent magnet all line up in a particular direction, the magnet has a pair of opposite poles, called **north** (usually shortened to **N**) and **south** (usually shortened to **S**). Even if the magnet is cut into tiny pieces, each piece will still have *both* a N and a S pole. These poles *always* occur in pairs. In nature we never find a north magnetic pole or south magnetic pole on its own.



Magnetic fields are *different* to gravitational and electric fields. In nature, positive and negative electric charges can be found on their own, but you *never* find just a north magnetic pole or south magnetic pole on its own. On the very small scale, zooming in to the size of atoms, magnetic fields are caused by moving charges (i.e. the negatively charged electrons).

8.3.2 Magnetic attraction and repulsion

Like poles of magnets repel one another whilst unlike poles attract. This means that two N poles or two S poles will push away from each other while a N pole and a S pole will be drawn towards each other.



Definition: Attraction and Repulsion

Like poles of magnets *repel* each other whilst *unlike* poles *attract* each other.



Worked Example 39: Attraction and Repulsion

Question: Do you think the following magnets will repel or be attracted to each other?



Answer

Step 1 : Determine what is required

We are required to determine whether the two magnets will repel each other or be attracted to each other.

Step 2 : Determine what is given

We are given two magnets with the N pole of one approaching the N pole of the other.

Step 3 : Determine the conclusion

Since both poles are the same, the magnets will repel each other.



Worked Example 40: Attraction and repulsion

Question: Do you think the following magnets will repel or be attracted to each other?



Answer

Step 1 : Determine what is required

We are required to determine whether the two magnets will repel each other or be attracted to each other.

Step 2 : Determine what is given

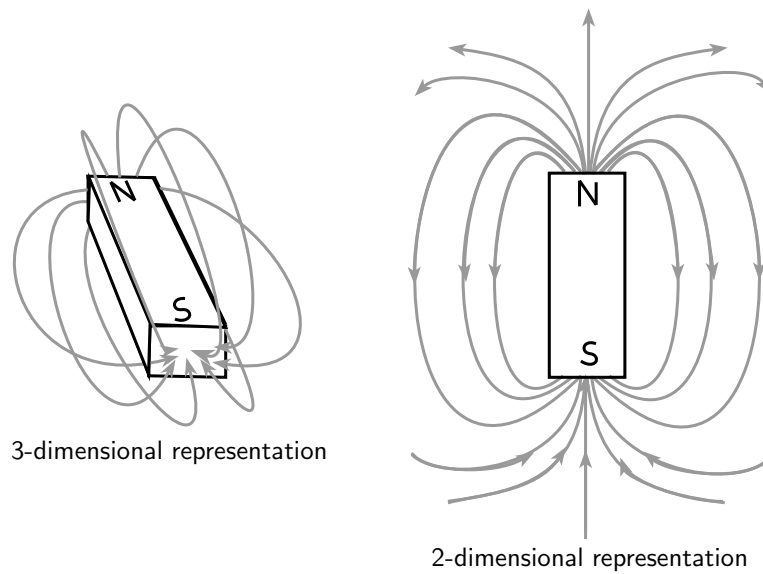
We are given two magnets with the N pole of one approaching the S pole of the other.

Step 3 : Determine the conclusion

Since both poles are the different, the magnets will be attracted to each other.

8.3.3 Representing magnetic fields

Magnetic fields can be *represented* using **magnetic field lines**. Although the magnetic field of a permanent magnet is everywhere surrounding the magnet (in all 3 dimensions), we draw only some of the field lines to represent the field (usually only 2 dimensions are shown in drawings).



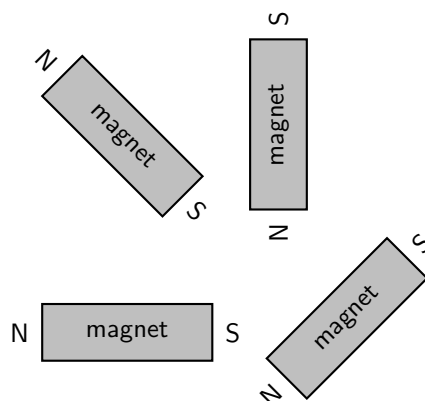
In areas where the magnetic field is strong, the field lines are closer together. Where the field is weaker, the field lines are drawn further apart. The strength of a magnetic field is referred to as the **magnetic flux**

Important:

1. Field lines *never* cross.
2. Arrows drawn on the field lines indicate the direction of the field.
3. A magnetic field points from the north to the south pole of a magnet.

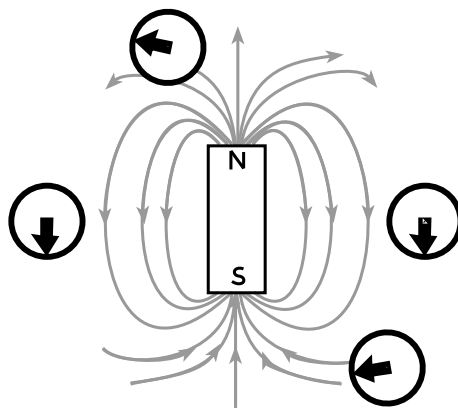
Activity :: Investigation : Field around a Bar Magnet

Take a bar magnet and place it on a flat surface. Place a sheet of white paper over the bar magnet and sprinkle some iron filings onto the paper. Give the paper a shake to evenly distribute the iron filings. In your workbook, draw the bar magnet and the pattern formed by the iron filings. Draw the pattern formed when you rotate the bar magnet as shown.



As the activity shows, one can map the magnetic field of a magnet by placing it underneath a piece of paper and sprinkling iron filings on top. The iron filings line themselves up parallel to the magnetic field.

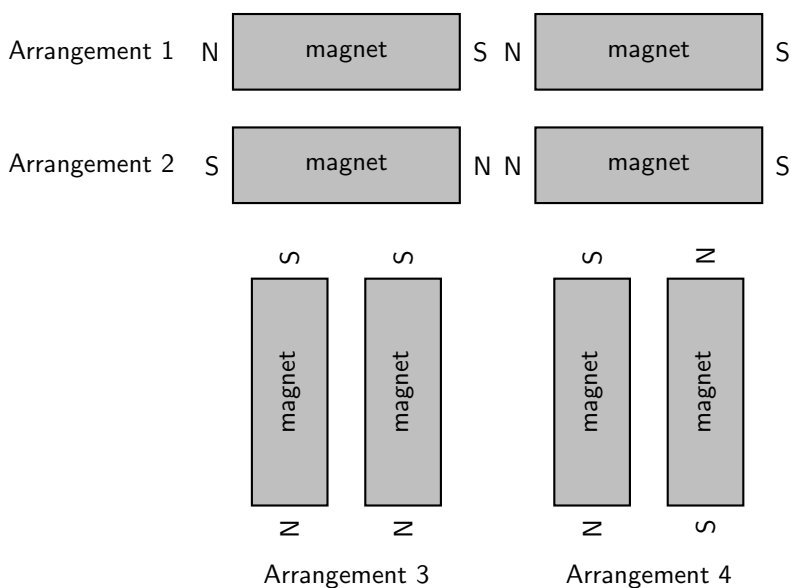
Another tool one can use to find the direction of a magnetic field is a *compass*. The compass arrow points in the direction of the field.



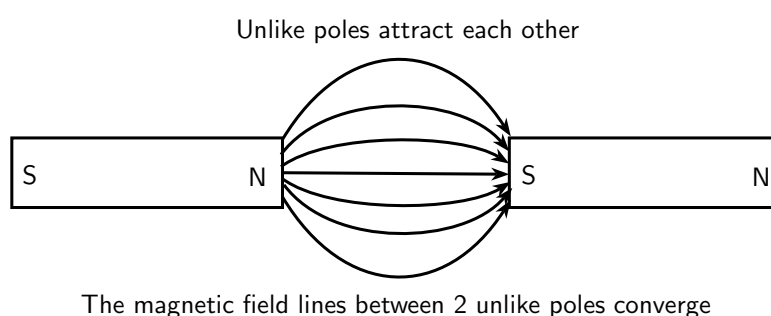
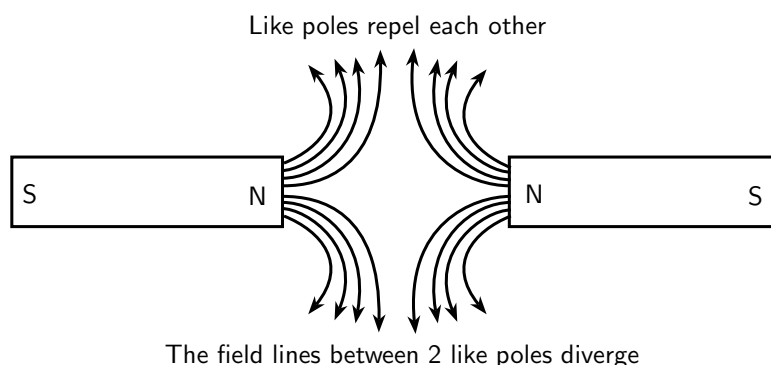
The direction of the compass arrow is the same as the direction of the magnetic field

Activity :: Investigation : Field around a Pair of Bar Magnets

Take two bar magnets and place them a short distance apart such that they are repelling each other. Place a sheet of white paper over the bar magnets and sprinkle some iron filings onto the paper. Give the paper a shake to evenly distribute the iron filings. In your workbook, draw both the bar magnets and the pattern formed by the iron filings. Repeat the procedure for two bar magnets attracting each other and draw what the pattern looks like for this situation. Make a note of the shape of the lines formed by the iron filings, as well as their size and their direction for both arrangements of the bar magnet. What does the pattern look like when you place both bar magnets side by side?



As already said, opposite poles of a magnet attract each other and bringing them together causes their magnetic field lines to *converge* (come together). Like poles of a magnet repel each other and bringing them together causes their magnetic field lines to *diverge* (bend out from each other).



Extension: Ferromagnetism and Retentivity

Ferromagnetism is a phenomenon shown by materials like iron, nickel or cobalt. These materials can form permanent magnets. They always magnetise so as to be attracted to a magnet, no matter which magnetic pole is brought toward the unmagnetised iron/nickel/cobalt.

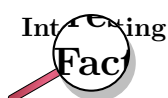
The ability of a ferromagnetic material to retain its magnetisation *after* an external field is removed is called its **retentivity**.

Paramagnetic materials are materials like aluminium or platinum, which become magnetised in an external magnetic field in a similar way to ferromagnetic materials. However, they lose their magnetism when the external magnetic field is removed.

Diamagnetism is shown by materials like copper or bismuth, which become magnetised in a magnetic field with a polarity *opposite* to the external magnetic field. Unlike iron, they are slightly repelled by a magnet.

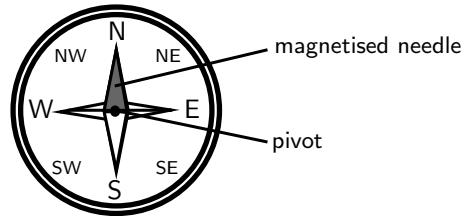
8.4 The compass and the earth's magnetic field

A **compass** is an instrument which is used to find the direction of a magnetic field. It can do this because a compass consists of a small metal needle which is magnetised itself and which is free to turn in any direction. Therefore, when in the presence of a magnetic field, the needle is able to line up in the same direction as the field.



Lodestone, a magnetised form of iron-oxide, was found to orientate itself in a north-south direction if left free to rotate by suspension on a string or on a float in water. Lodestone was therefore used as an early navigational compass.

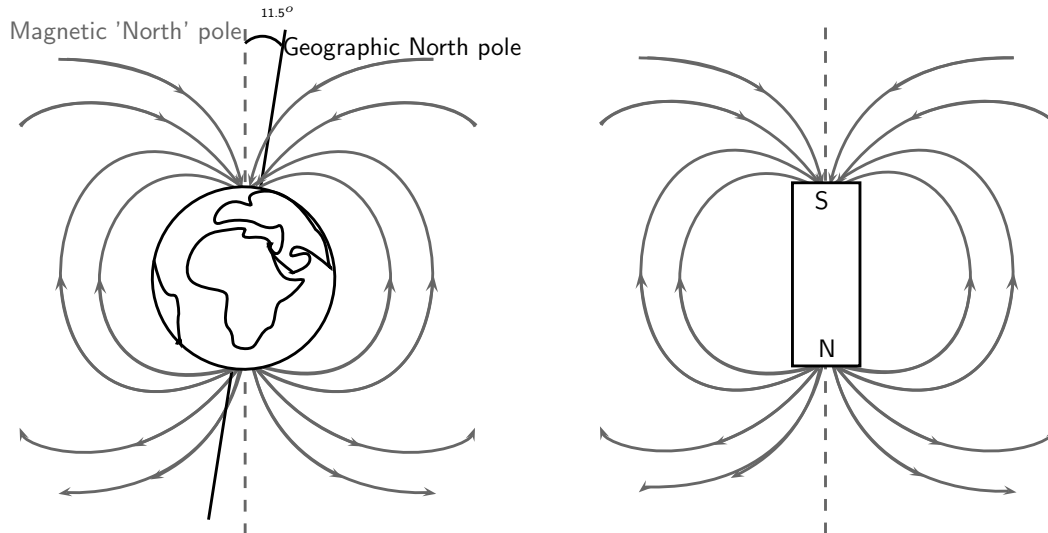
Compasses are mainly used in navigation to find direction on the earth. This works because the earth itself has a magnetic field which is similar to that of a bar magnet (see the picture below). The compass needle aligns with the magnetic field direction and points north (or south). Once you know where north is, you can figure out any other direction. A picture of a compass is shown below:



Some animals can detect magnetic fields, which helps them orientate themselves and find direction. Animals which can do this include pigeons, bees, Monarch butterflies, sea turtles and fish.

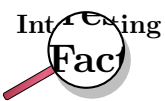
8.4.1 The earth's magnetic field

In the picture below, you can see a representation of the earth's magnetic field which is very similar to the magnetic field of a giant bar magnet like the one on the right of the picture. So the earth has two sets of north poles and south poles: **geographic poles** and **magnetic poles**.



The earth's magnetic field is thought to be caused by churning liquid metals in the core which causes electric currents and a magnetic field. From the picture you can see that the direction of magnetic north and true north are not identical. The **geographic north pole**, which is the point through which the earth's rotation axis goes, is about $11,5^\circ$ away from the direction of the **magnetic north pole** (which is where a compass will point). However, the magnetic poles shift slightly all the time.

Another interesting thing to note is that if we think of the earth as a big bar magnet, and we know that magnetic field lines always point *from north to south*, then the compass tells us that what we call the *magnetic north pole* is actually the *south pole* of the bar magnet!



The direction of the earth's magnetic field flips direction about once every 200 000 years! You can picture this as a bar magnet whose north and south pole periodically switch sides. The reason for this is still not fully understood.

The earth's magnetic field is very important for humans and other animals on earth because it stops charged particles emitted by the sun from hitting the earth and us. Charged particles can also damage and cause interference with telecommunications (such as cell phones). Charged particles (mainly protons and electrons) are emitted by the sun in what is called the solar wind, and travel towards the earth. These particles spiral in the earth's magnetic field towards the poles. If they collide with other particles in the earth's atmosphere they sometimes cause red or green lights or a glow in the sky which is called the aurora. This happens close to the north and south pole and so we cannot see the aurora from South Africa.

8.5 Summary

1. Magnets have two poles - North and South.

2. Some substances can be easily magnetised.
3. Like poles repel each other and unlike poles attract each other.
4. The Earth also has a magnetic field.
5. A compass can be used to find the magnetic north pole and help us find our direction.

8.6 End of chapter exercises

1. Describe what is meant by the term *magnetic field*.
2. Use words and pictures to explain why permanent magnets have a magnetic field around them. Refer to *domains* in your explanation.
3. What is a magnet?
4. What happens to the poles of a magnet if it is cut into pieces?
5. What happens when like magnetic poles are brought close together?
6. What happens when unlike magnetic poles are brought close together?
7. Draw the shape of the magnetic field around a bar magnet.
8. Explain how a compass indicates the direction of a magnetic field.
9. Compare the magnetic field of the Earth to the magnetic field of a bar magnet using words and diagrams.
10. Explain the difference between the geographical north pole and the magnetic north pole of the Earth.
11. Give examples of phenomena that are affected by Earth's magnetic field.
12. Draw a diagram showing the magnetic field around the Earth.

Appendix A

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