OXFORD

NEW CENTURY

PHYSICS

FOR QUEENSLAND

UNITS 3 & 4

STUDENT WORKBOOK

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SAMPLE CHAPTER

UNCORRECTED PAGE PROOFS

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UNIT 3

Gravity and electromagnetism

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SUGGESTED PRACTICAL	**2.3** Parallel component on an inclined plane
SUGGESTED PRACTICAL	**3.3** Centripetal force and horizontal circular motion
SUGGESTED PRACTICAL	**4.2** Gravitational force between two objects
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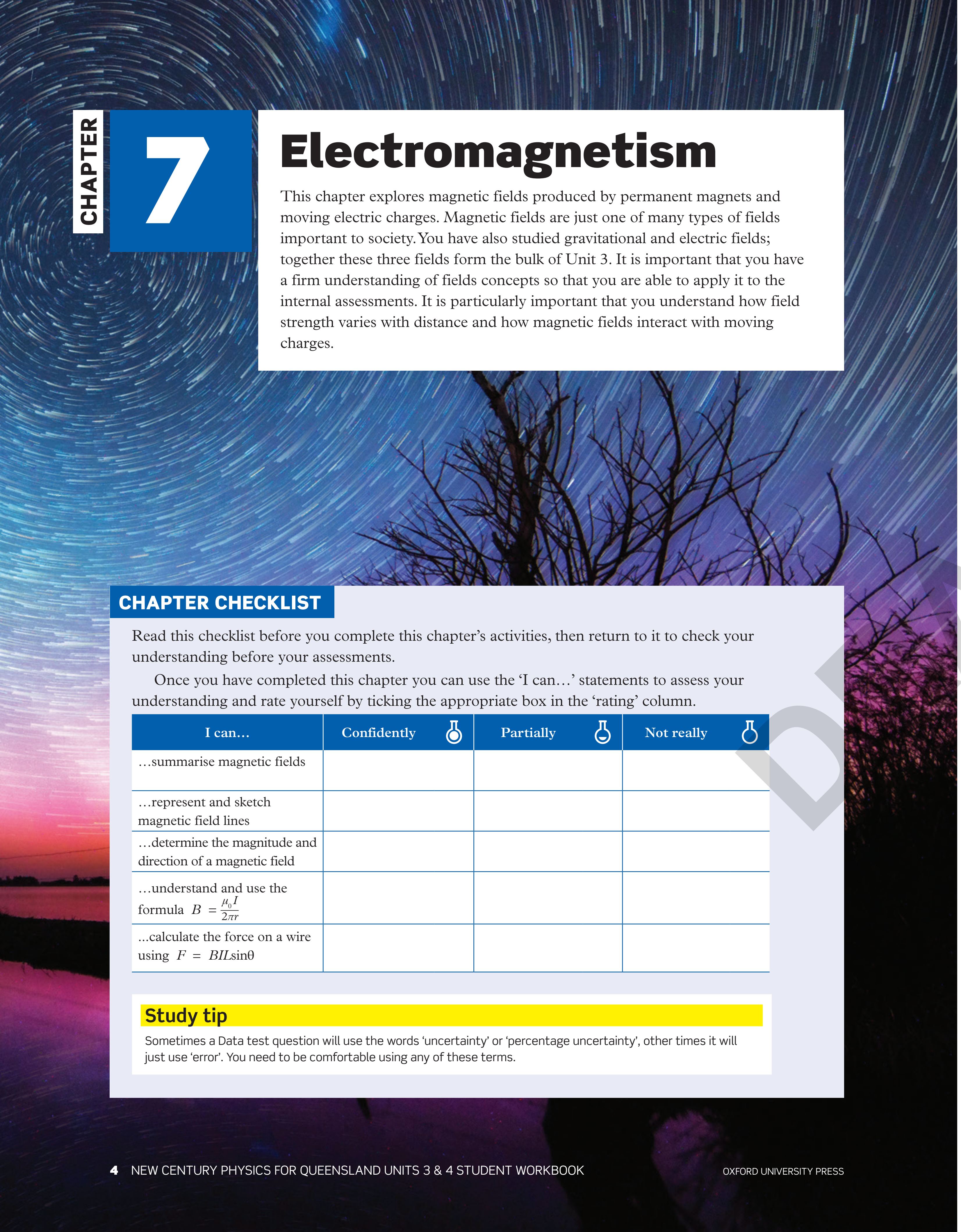
SUGGESTED PRACTICAL	**8.4** Induced EMF from an AC generator

WORD WIZARD

Draw a line to match each term with the correct definition.

ELEVATION ANGLE	A point near a black hole where the gravity is so powerful that nothing can escape
FREE-FALL ACCELERATION	Like electric charges repel and opposite electric charges attract with a force proportional to the product of the electric charges and inversely proportional to the square of the distance between them
IMPACT VELOCITY	A phenomenon associated with magnetic fields which arises from the motion of electric charges
RESULTANT VECTOR	Acceleration of a body falling freely in a vacuum near the surface of an astronomical body
INCLINED PLANE	The SI unit of magnetic field strength
MASS	All planets move about the Sun in an elliptical orbit that focus on the Sun
FRICTION	Time it takes for a planet to complete one orbit of another body relative to the stars
CENTRIPETAL ACCELERATION	When the magnetic flux linking a circuit changes, an electromotive force (EMF) is induced in the circuit proportional to the rate of change of the flux linkage
CENTRIPETAL FORCE	Time taken for a planet to appear in front of the same constellation of stars as seen from Earth
GRAVITATIONAL FIELD	Resistance to motion of a surface moving relative to another
GRAVITY	Region of space surrounding a body in which another body experiences a force of gravitational attraction
SCHWARTZCHILD RADIUS	The strength of a magnetic field or the number of magnetic field lines per unit area
FIRST LAW OF PLANETARY MOTION	Angle at which a projectile is launched with respect to the horizontal
SIDEREAL PERIOD	Flat surface raised at one end, used as an aid for raising or lowering a load
SYNODIC PERIOD	The production of an electromotive force (EMF) or voltage across an electrical conductor due to its dynamic interaction with a magnetic field
COULOMB'S LAW	An object's resistance to motion
ELECTROMAGNETIC INDUCTION	A region of space where a magnetic force is experienced
FARADAY'S LAW	Acceleration experienced by any object moving in a circular path directed towards the centre of motion
MAGNETIC FLUX DENSITY	Velocity of a projectile immediately before striking the ground
MAGNETIC FIELD	A single vector that is a combination of two or more vectors
TESLA	Force acting on an object travelling in a circle that constantly either pulls or pushes the object towards the centre of motion
MAGNETISM	Force of attraction between objects with mass



CHAPTER 7

Electromagnetism

This chapter explores magnetic fields produced by permanent magnets and moving electric charges. Magnetic fields are just one of many types of fields important to society. You have also studied gravitational and electric fields; together these three fields form the bulk of Unit 3. It is important that you have a firm understanding of fields concepts so that you are able to apply it to the internal assessments. It is particularly important that you understand how field strength varies with distance and how magnetic fields interact with moving charges.

CHAPTER CHECKLIST

Read this checklist before you complete this chapter's activities, then return to it to check your understanding before your assessments.

Once you have completed this chapter you can use the 'I can…' statements to assess your understanding and rate yourself by ticking the appropriate box in the 'rating' column.

I can…	Confidently	Partially	Not really
…summarise magnetic fields			
…represent and sketch magnetic field lines			
…determine the magnitude and direction of a magnetic field			
…understand and use the formula $B = \frac{\mu_0 I}{2\pi r}$			
…calculate the force on a wire using $F = BIL\sin\theta$			

Study tip

Sometimes a Data test question will use the words 'uncertainty' or 'percentage uncertainty', other times it will just use 'error'. You need to be comfortable using any of these terms.

DATA DRILL 7

Uncertainty and percentage uncertainty

A common Data test question will require you to analyse a set of data and perform some type of calculation. One such calculation is finding uncertainty or percentage uncertainty. Uncertainty or percentage uncertainty gives a measure of variation or error around the mean, in a similar way to standard deviation. However, uncertainty and percentage uncertainty calculations are used when there are only two repetitions, while standard deviation is used for more than two. Uncertainty and percentage uncertainty are normally used to calculate error in Physics.

The formulas for uncertainty and percentage uncertainty are:

$$\text{Absolute uncertainty} = \delta x = \frac{(\text{maximum} - \text{minimum})}{2}$$

$$\text{Percentage uncertainty} = \delta\% = \frac{\text{absolute uncertainty}}{\text{mean}} \times 100\%$$

Since uncertainty gives a measure of the spread of results around the mean it is reported as mean ±uncertainty.

TABLE 1 Results showing the strength of the magnetic force between two magnets at various distances.

Distance	Scale reading (g)		Force between magnets (N)		
r (cm)	Test 1	Test 2	Test 1	Test 2	Mean
1	49.28	45.08	0.482 944	0.441 784	0.462 364
2	19.7	21.23	0.193 06	0.208 054	0.200 557
4	4.4	6.66	0.043 12	0.065 268	0.054 194
6	1.43	2.07	0.014 014	0.020 286	0.017 135
8	0.73	1.16	0.007 154	0.011 368	0.009 261

1 **Calculate** the percentage uncertainty for the force between the magnets when distance, r, is 2 cm. Show all your working.

2 **Analyse** the data and **predict** the force between the magnets when distance, r, is 11 cm. **Justify** your response.

3 **Identify** the relationship between the distance, r, between the two magnets, and the force, F, exerted by one magnet on the other. **Use** evidence from Table 1 to support your answer.

EXPERIMENT EXPLORER 7

Modifying an experiment

There are three ways to modify an experiment: redefine, extend or redirect.

When you are deciding which modification to use, you need to consider which will make your results have greater validity and reliability, and to be able to explain your reasoning. Having a clear idea of your reasoning will be useful when you write up the *methodology*, because you will be able to justify your decision-making process.

1 Refer to Mandatory Practical 7.2 *Strength of a magnet at various distances* that you will complete in class. **Modify** this experiment to either redefine, extend or redirect. **Justify** your modification with two bullet points.

Modification:

Justification:

Study tip

Remember there is no such thing as 'bad results'. Let your data do the talking; results do not have to be significant. It is fine to accept the null hypothesis in research. Sometimes we learn the most from understanding why things didn't happen or from findings that didn't turn out as expected.

RESEARCH REVIEW 7

Choosing sources

When you receive your Research Investigation task during Unit 4, you will most likely have between three and five claims to choose from. Usually, the hardest decision is choosing a claim, and you may feel pressured about choosing the 'right one' or the 'easiest one'. The truth is, there is no 'easy' or 'right' claim.

Study tip

Before you decide on a claim for the Research Investigation, take the time for some effective research beforehand. You don't want to select a claim only to find that you are struggling to find resources. Keep in mind that resources are about quality and not quantity. Finding five or so resources that have data relating directly to your claim is more valuable than dozens that are only somewhat relevant.

Choosing a claim can be challenging. Ask yourself the following questions to help choose the best claim for you:

1 Which claims am I interested in?
Read through the list and identify those claims that instantly grab your attention; shortlist these to research.

2 What published research is available?
Take claims that you have shortlisted and spend some time researching these. Use reputable sources including your school library, government and university websites.

3 Make a final decision. Now that you have analysed the claims you are interested in and resources available for them, your need to decide on a claim.

Choose two of the following claims that you could use for a Research Investigation. Highlight two that attract your immediate interest.

Claims:

- The Earth's magnetic field will eventually flip.
- Magnetic field exposure has detrimental effects on human health.
- Mammal brains can detect and respond to changes in magnetic fields.
- Migratory animals use the Earth's magnetic field.

1 **Investigate** the two chosen claims, making notes as you go. Make a final decision on which claim to investigate, using your notes to help you.

Research notes:

2 Now that you have done some background research, **select** which claim you are going to research further:

3 **Justify** why this is the claim you selected based on your initial research.

EXAM EXCELLENCE 7

Multiple choice Circle the correct answer.

1 **Analyse** Figure 1 and **determine** in which direction the force on the wire acts.
   A into the page
   B out of page
   C left hand side
   D right hand side

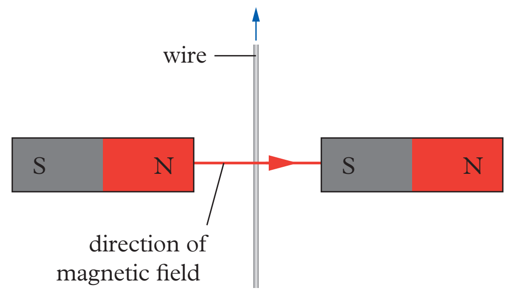


FIGURE 1 A current-carrying wire in a magnetic field

2 A student investigated the pattern of attraction between four different bars of metal, shown in Figure 2. One of the materials is not magnetised. **Analyse** Figure 2 and **determine** which bar is not magnetised.
   A bar 1
   B bar 2
   C bar 3
   D bar 4

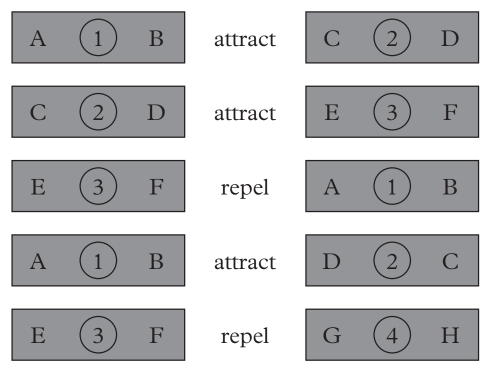


FIGURE 2 Observations from a student investigation, showing the attraction and repulsion of four different bars of metal

3 A current-carrying wire is placed in a magnetic field, as shown in Figure 3. **Determine** in which direction the force is acting on the wire.
   A perpendicular to angle θ
   B at angle θ to the direction of the field
   C into the page
   D out of the page

4 **Determine** the number of coils on a 150cm solenoid that has a current of 10.0A passing through it with a magnetic field strength of 0.00567T.
   A 400
   B 450
   C 500
   D 550

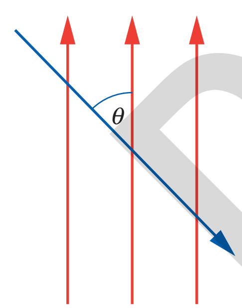


FIGURE 3 A current-carrying wire in a magnetic field

5 **Determine** the direction of the force acting on a moving positive charge which is fired from the right-hand side into a magnetic field, *B*, that is ‘into the page’.
   A up the page
   B down the page
   C to the right-hand side
   D to the left-hand side

Short answer

6 **Calculate** the magnetic field strength at the point shown between wire A and wire B Figure 4, given that wire A carries a current of 3.5A and wire B carries a current of 2.5A. Show all of your working.

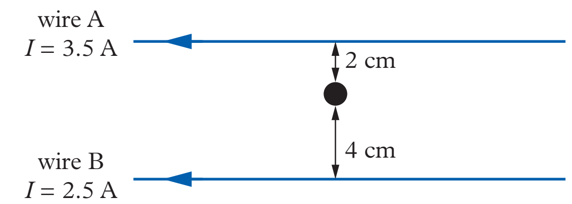


FIGURE 4 A field between two wires

7 **Sketch** the magnetic field lines for the U-shaped magnet and permanent bar magnets shown in Figure 5.

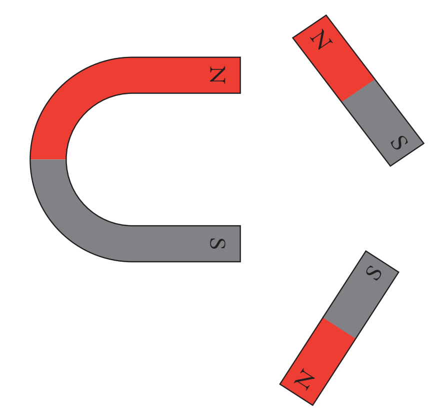


FIGURE 5 U-shaped magnet and two permanent bar magnets

8 A current-carrying wire is placed perpendicular to a magnetic field, as shown in Figure 6.

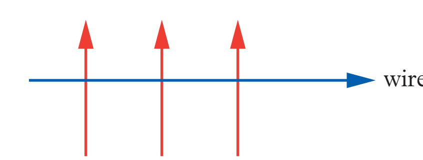


FIGURE 6 A current-carrying wire in a magnetic field

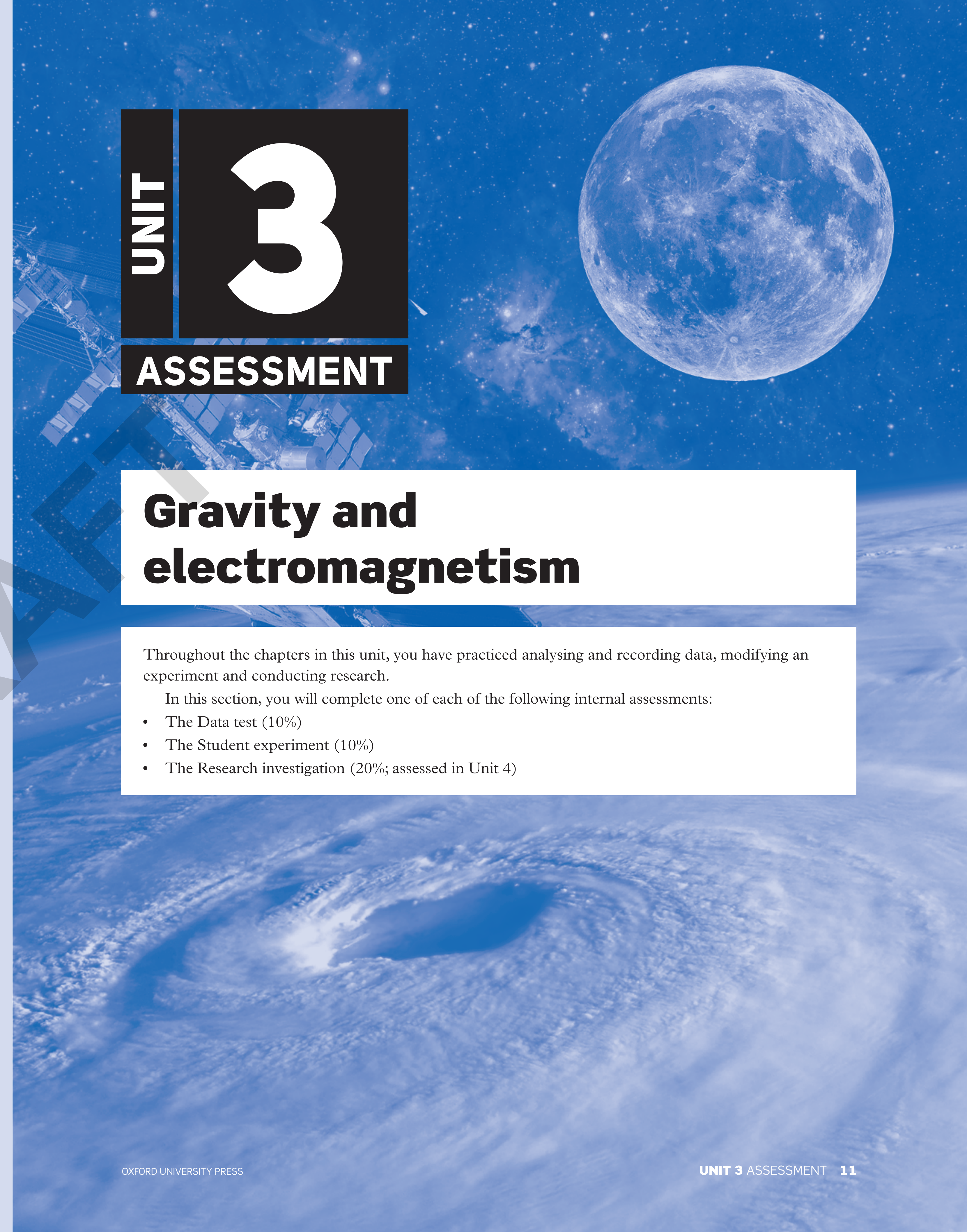
a **Calculate** the magnitude and direction of the force on the wire. The magnetic field strength is 2.0×10^{-3} T and the 50.0cm wire is carrying a current of 12.0A.

b **Propose** what would happen to the direction of the force if the current was reversed. **Justify** your answer.

9 a A solenoid with 500 turns and length of 20.0cm carries a current of 2.0A. **Calculate** the magnetic field strength at the centre of the solenoid.

b **Describe** how halving the number of turns but keeping the length constant would impact the magnetic field strength of the solenoid. **Justify** your response.

10 **Draw** a diagram to **symbolise** the relationship between magnetic field strength and distance.



UNIT 3 ASSESSMENT

Gravity and electromagnetism

Throughout the chapters in this unit, you have practiced analysing and recording data, modifying an experiment and conducting research.

In this section, you will complete one of each of the following internal assessments:

- The Data test (10%)
- The Student experiment (10%)
- The Research investigation (20%; assessed in Unit 4)

Unit 3 Data test

Dataset 1

An experiment was conducted to investigate the research question:

What is the effect of launch angle on the horizontal range of a projectile?

A small metal ball was fired at various angles from the launcher with a fixed initial speed of 4.77 m s^{-1}. The horizontal range was measured with a tape measure. The trial was repeated, and the distances averaged. Seven more trials were done at different angles and the uncertainty in the range (δx) for each angle was calculated. The results are shown in Table 1.

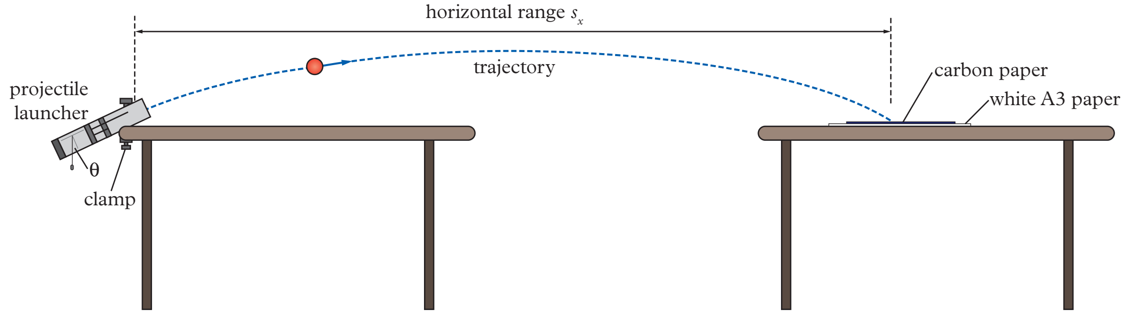


FIGURE 1 Experimental setup for projectile investigation

TABLE 1 Raw data for the experiment

Angle (°)	Horizontal range (m)			δx (m)
	Test 1	Test 2	Average	
20.0	1.72	1.68	1.70	0.020
30.0	2.07	2.14	2.10	0.035
40.0	2.33	2.25	2.29	0.040
45.0	2.25	2.35	2.32	0.050
50.0	2.33	2.25	2.29	0.043
60.0	1.99	2.05	2.01	0.030
70.0	1.50	1.48	1.49	0.010
80.0	0.79	0.81	0.79	0.010

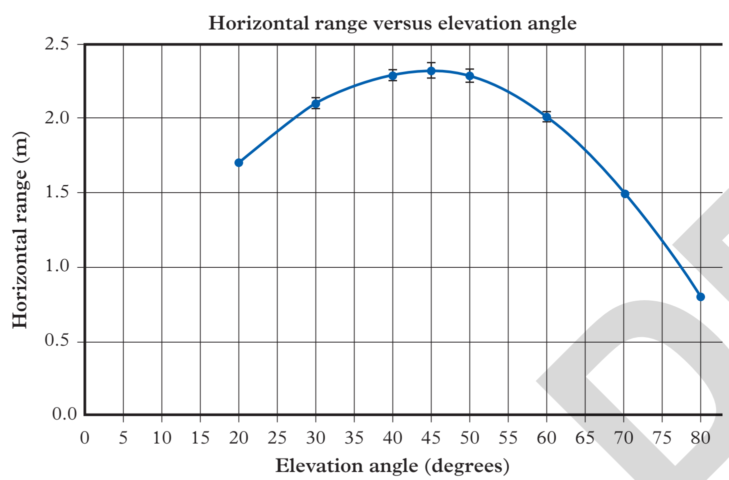


FIGURE 2 Graph of raw data

Item 1 (apply understanding)

- **Identify** the angle that produces the same horizontal range as 60°.

1 mark

Projected angle: ________________° (0 d.p.)

Item 2 (apply understanding)

- **Calculate** the missing value in the table for the uncertainty in the horizontal range at an elevation angle of 60°. Show your working.

1 mark

Uncertainty δx: ± ________________ m (3 d.p.)

Item 3 (apply understanding)

- **Calculate** the initial horizontal component of the velocity that gives maximum range. Show your working.

1 mark

Answer: ________________ m s^{-1} (1 d.p.)

Item 4 (analyse evidence)

- **Analyse** the data to test the claim that complementary angles produce the same range.

1 mark

Item 5 (interpret evidence)

- **Infer** whether the uncertainty in the range increases or decreases with the magnitude of the range. State the evidence used to support your answer. Calculations are not needed.

2 marks

Dataset 2

Students conducted an experiment to address the research question:

How does the force between two magnets vary with separation distance?

A magnet was placed upright on the pan of an electronic balance and the scale reading zeroed. A second magnet was placed in line with this magnet. The distance between the two was varied and the scale reading (in grams) at each distance was noted. The data is presented in Table 1 and a graph of the relationship is shown in Figure 4.

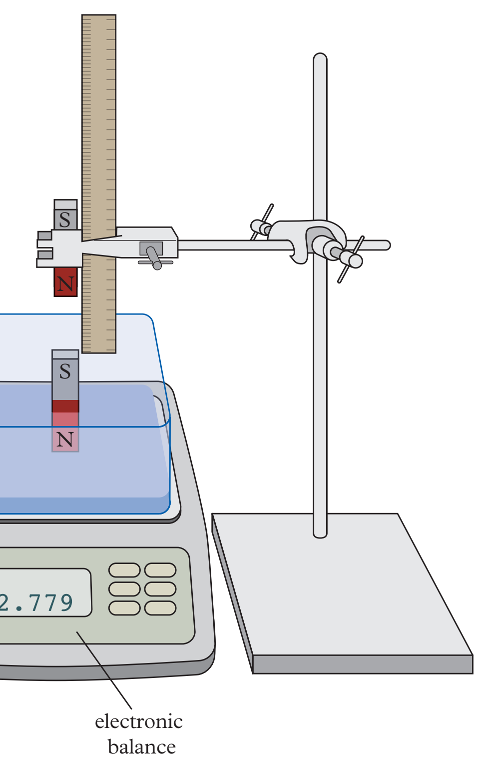


FIGURE 3 Apparatus for the experiment

TABLE 1 Results from the magnetic force experiment

r (cm)	Scale reading (g)			Average Force (N)
	Test 1	Test 2	Average	
1.0	102.37	92.62	97.50	0.955
1.5	44.90	46.94	45.92	0.450
2.0	28.20			0.282
3.0	14.17	13.20	13.69	0.134
4.0	7.64	8.60	8.12	0.080
6.0	3.46	3.41	3.43	0.034

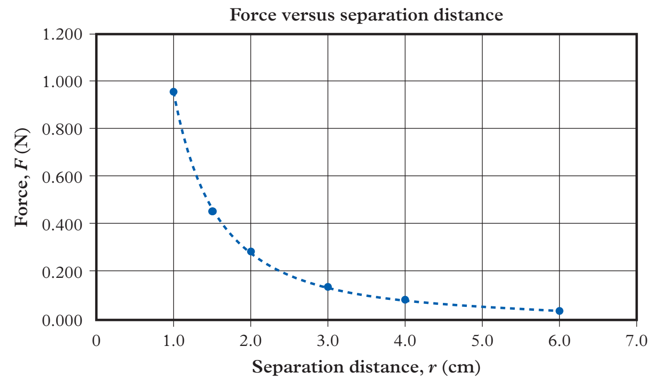


FIGURE 4 Graph of the raw data

Item 1 (apply understanding)

- Determine the two values missing from the table.

2 marks

Answer: ______________________ g (2 d.p) Answer: ______________________ g (2 d.p)

Item 2 (apply understanding)

- Determine the percentage uncertainty in the force when the magnets are 6.0 cm apart.

1 mark

Answer: ____ % (2 d.p)

Item 3 (analyse evidence)

- Identify the relationship between force and separation distance. Use evidence from the table and the graph to support your answer.

2 marks

Item 4 (interpret evidence)

- Predict the scale reading when the separation distance is 8.0 cm. Show your working.

2 marks

Dataset 3

A student set up the apparatus shown in Figure 5 to address the following research question:

What is the relationship between the force on a wire in a constant uniform magnetic field when the current through it is varied?

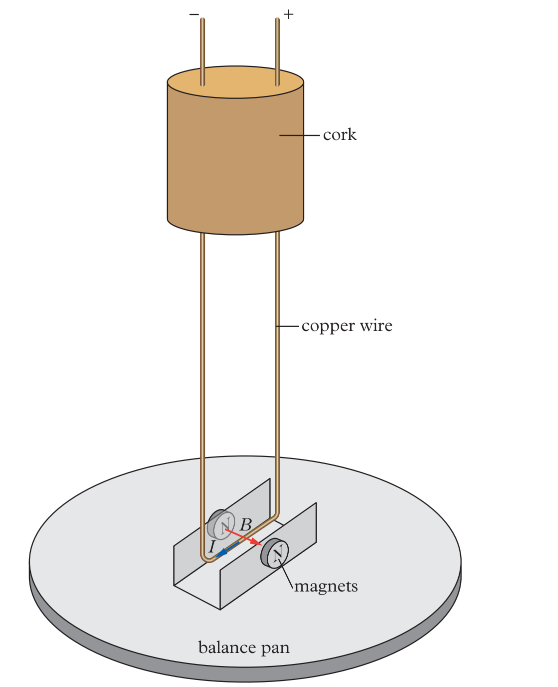
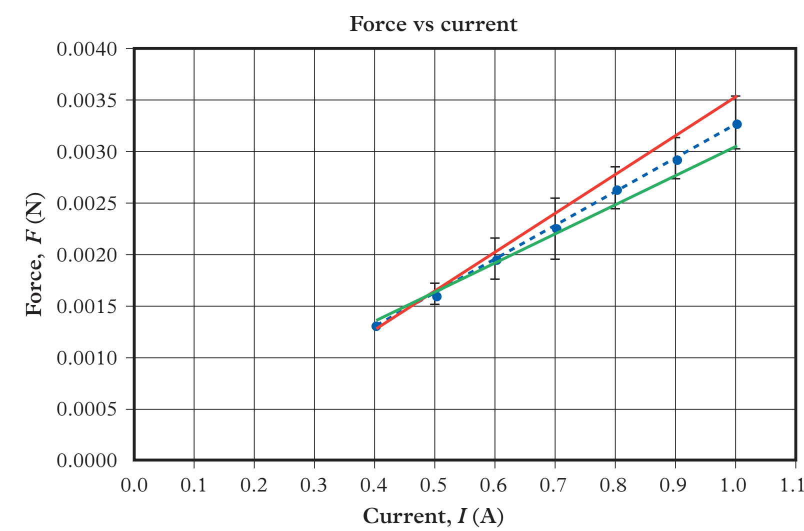


FIGURE 5 Apparatus used for experiment

A length of wire held rigidly in a cork and clamped was placed in a magnetic field between two button magnets, as shown in the figure. The wire is at 90° to the field and has an effective length of 15 mm.

The electronic balance was zeroed.

As the current was increased, a scale reading was taken and converted to a force (weight) reading in newtons. The results were plotted in a graph as shown in Figure 6.



Equation for the linear (dotted) trendline:
$y = 0.0033x - 0.0001$
Equation for the maximum linear trendline:
$y = 0.0037x - 0.0004$
Equation for the minimum trendline:
$y = 0.0029x + 0.0002$

FIGURE 6 A plot of the raw data

Item 1 (analyse evidence)

- Identify a mathematical relationship between the force acting on the conductor and the current passing through the conductor, showing the absolute uncertainty in the gradient and the absolute uncertainty in the y-intercept.

3 marks

Item 2 (interpret evidence)

- Draw a conclusion that expresses the magnitude of the magnetic field experienced by the wire between the two magnets and the percentage uncertainty.

2 marks

Item 3 (interpret evidence)

- Draw a conclusion by judging whether this experiment can be considered accurate, given the following information: the magnetic field strength has an accepted value of 0.20 T.

2 marks

Unit 3 Student experiment

Your task is to modify the following experiment. Please note that you must conduct a risk assessment before conduting the student experiment.

6.1 Effects of electrostatic charge on various materials

CAUTION: Kerosene is highly flammable as a liquid. It is extremely dangerous if swallowed or if it enters airways. It is suspected of causing cancer, causes skin irritation, causes eye irritation, may cause respiratory irritation and is toxic to aquatic life. Safety measures must be taken.

Methylated spirits is highly flammable and can cause serious eye irritation if contact occurs.

Unit 3, Topic 2: Conduct an experiment to investigate the effects of electrostatic charge on various materials (e.g. on trickling water, Coulomb meter).

Source: *Physics 2019 v1.2 General Senior Syllabus* © Queensland Curriculum & Assessment Authority

Context

You may have noticed that when you get off a trampoline there is often a spark between your fingers and the metal frame. You might have experienced the same thing when taking off a jumper, walking across carpet and touching a window frame, or getting out of a car and touching the handle after a long trip. The rubbing of two materials together to produce an electric charge is called the 'triboelectric' effect, from the Greek *tribo* meaning 'to rub'. This experiment sets out some tests on the effects of electrostatic charge and matter.

Aim

Investigate the effects of electrostatic charge.

Materials

Station 1

- 1 × plastic rod
- 1 × glass rod
- 1 × 20 cm by 20 cm square of wool blanket or similar
- 1 × 20 cm by 20 cm square of silk
- Small pieces of paper (e.g. circles from a hole punch)

Station 2

- 1 × plastic rod
- 1 × glass rod
- 1 × 20 cm by 20 cm square of wool blanket or similar
- 1 × 20 cm by 20 cm square of silk
- 3 × burettes
- 3 × clamps
- 3 × stands

- 3 × 100 mL beakers
- 50 mL of tap water
- 50 mL of methylated spirits
- 50 mL of kerosene

Station 3
- Hard rubber rod (ebonite)
- 1 × glass rod
- 20 × 20 cm square of wool blanket or similar
- 20 × 20 cm square of silk
- Coulomb meter
- Electroscope

Station 4
- Balloon
- Small square of wool blanket

Method

Station 1
1. Rub the plastic rod briskly on the woollen square and bring it close to the paper pieces. Note the effect.
2. Repeat step 1 using the glass rod rather than the plastic rod.

Station 2
1. Set the burettes up on stands: one with tap water, one with kerosene, and one with methylated spirits. Ensure each burette is labelled.
2. Let the first liquid (water) flow into the beaker by opening the stopcock. Charge the plastic rod with the wool and bring it up to the stream of water. Note if there is any deflection.
3. Repeat step 2 for the kerosene and the methylated spirits.
4. Water molecules are said to be polar; that is, they have a negative end and a positive end. Methylated spirits are mostly ethanol, whose molecules are slightly polar. Kerosene molecules are non-polar.
5. Repeat steps 1–3 using the glass rod rather than the plastic rod, and the silk square rather than the woollen square. Note if there is any deflection.

Station 3
1. Charge the plastic rod and place it on the cap of a zeroed coulomb meter. Note the magnitude and sign of the charge.
2. Repeat step 1 with a glass rod.

Station 4
1. Inflate the balloon and tie it off.
2. Rub the balloon with a piece of wool. Note whether it attracts a person's hair.

Modification of the original experiment

Note: This section provides prompts for your modification. You may require extra space to write your full practice assessment.

Aim

Research question

Background research

Methodology

Results

Discussion/rationale

Risk assessment

Student's name: ______________________________

Experiment: ______________________________

Note: Risks should be managed by use of personal protective equipment and/or specified control measures. Always consult your teacher before conducting an experiment.

Equipment required

Hazardous chemicals required/produced

Reactant or product name and concentration	GHS classification	GHS hazard statement	Control measures

Non-hazardous substances

Other hazards and possible risks

Protective measures

Lab coat	Safety glasses	Gloves	Fume cupboard	Other

Clean up and disposal of wastes

Teacher's signature: ______________________________

Student's signature: ______________________________

Date: ___________________

* This assessment is not valid until it has been completed and signed by your teacher.

Unit 3 Research investigation

Note: The research investigation for the Physics course (IA3) is to be completed in Unit 4 and covers content from Unit 4. There is no assessable research investigation in Unit 3. This research investigation has been included so that you can practise skills required for the Unit 4 assessment.

CASE STUDY

Optimum angles of projection in sport

From studying experimental data, and the physics and mathematics associated with projectile motion, physicists have determined that the optimal release angle of a projectile, to maximise its range, is 45° to the horizontal.

There is a number of sports in which an athlete has to project either their own body or an object to achieve the greatest range possible. Some examples are long jump, discus, shotput, javelin and soccer.

Sport scientists have studied the performances of elite athletes in these sports over many years. From these studies, they have found that actual performers in projectile-related sports seldom use a release angle of 45°. For example, the average projection angle of a world-class long jumper is about 25°, that of a shotputter is about 37° and that of a soccer player throwing the ball in is about 30°.

So why is there this apparent contradiction between theory and practice? Shouldn't the experimental (athletic competition) results be the same as those predicted by theory? Is there something that the theoreticians have overlooked?

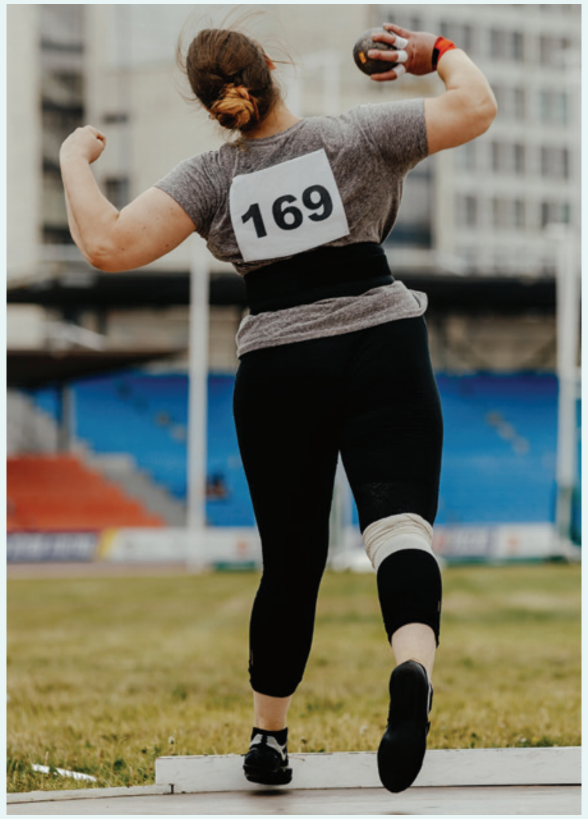


FIGURE 8 A shotputter

Your task is to conduct a research investigation about the following claim, which is related to the case study above:

The physicists, sports scientists and athletes are all correct in their understanding and application of projectile motion – however, there are other aspects of projectile motion that can affect the range achieved, other than its angle of release.

Research question

Research

Note: this section provides space for you to investigate two sources. You will need to research further to complete the assessment.

Resource 1

Title:

Authors:

Source and credibility:

Publication date:

Aim:

Methodology:

– What data was collected?

– How was the data collected?

Results:

– Did the resource support your research question?

– Why does/doesn't it support the provided claim?

Resource 2

Title:

Authors:

Source and credibility:

Publication date:

Aim:

Methodology:

- What data was collected?

- How was the data collected?

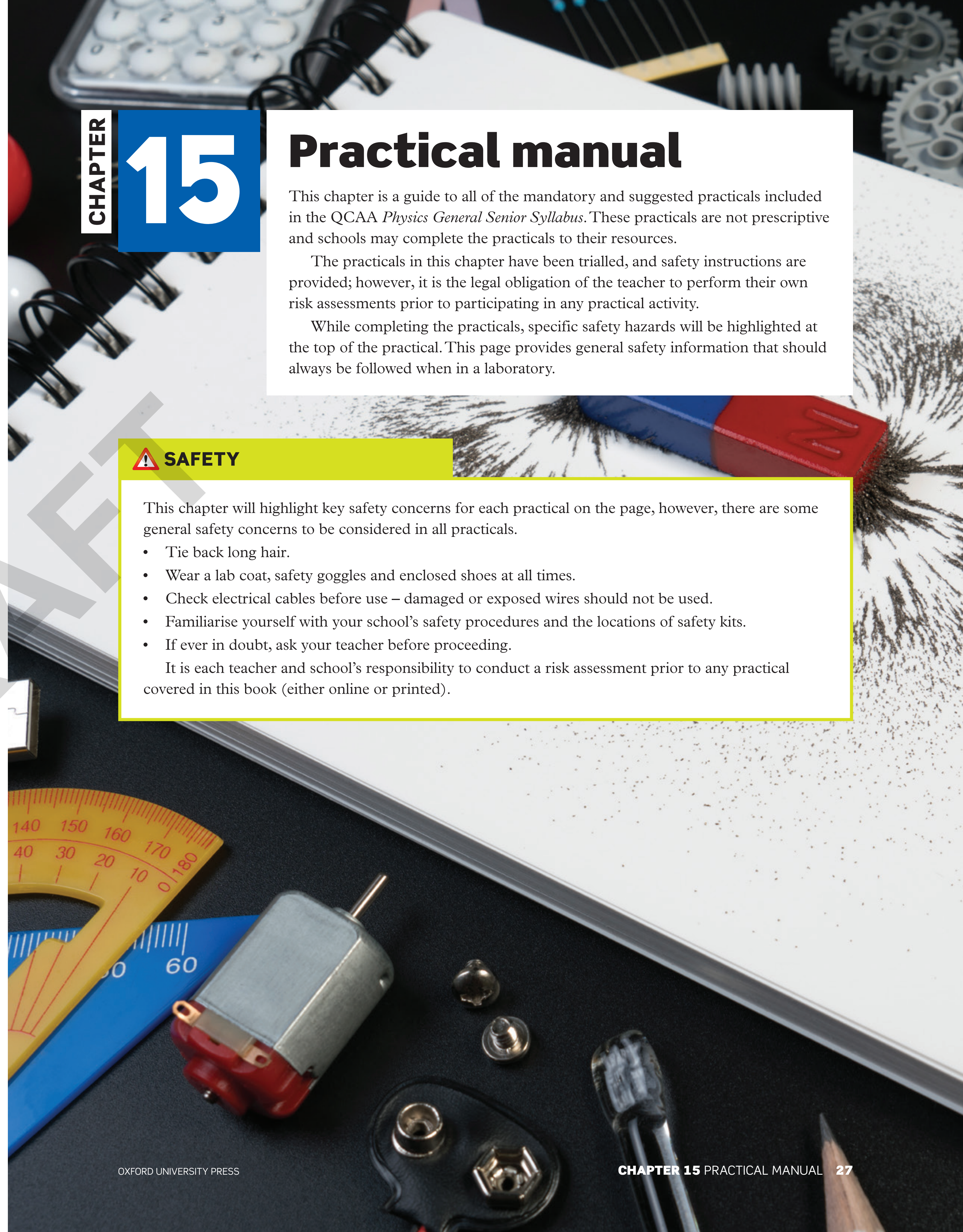
Results:

- Did the resource support your research question?

- Why does/doesn't it support the provided claim?

Planning your internal assessment

Note: this section provides space for you to summarise the key points of your research. You may require extra space to write your full practice assessment.



CHAPTER 15

Practical manual

This chapter is a guide to all of the mandatory and suggested practicals included in the QCAA *Physics General Senior Syllabus*. These practicals are not prescriptive and schools may complete the practicals to their resources.

The practicals in this chapter have been trialled, and safety instructions are provided; however, it is the legal obligation of the teacher to perform their own risk assessments prior to participating in any practical activity.

While completing the practicals, specific safety hazards will be highlighted at the top of the practical. This page provides general safety information that should always be followed when in a laboratory.

SAFETY

This chapter will highlight key safety concerns for each practical on the page, however, there are some general safety concerns to be considered in all practicals.

- Tie back long hair.
- Wear a lab coat, safety goggles and enclosed shoes at all times.
- Check electrical cables before use – damaged or exposed wires should not be used.
- Familiarise yourself with your school's safety procedures and the locations of safety kits.
- If ever in doubt, ask your teacher before proceeding.

It is each teacher and school's responsibility to conduct a risk assessment prior to any practical covered in this book (either online or printed).

7.2 MANDATORY PRACTICAL

Strength of a magnet at various distances

Unit 3, Topic 2: Conduct an experiment to investigate the strength of a magnet at various distances.

Source: *Physics 2019 v1.2 General Senior Syllabus* © Queensland Curriculum & Assessment Authority

Context

Magnetic force, if it is at all like electrostatic force or gravitational force, obeys an inverse squared relationship with distance. However, unlike masses and charges, which can exist as single entities, magnets come as north–south dipoles, which may affect the relationship. The longer the magnet, the closer the relationship should come to being an inverse squared relationship.

Aim

To investigate the strength of a magnet at various distances.

Materials

- 2 × bar magnets
- Electronic balance
- Refort stand, boss head and clamp
- Ruler

Method

1 Place a bar magnet vertically upright on the pan of an electronic balance (Figure 1). Zero the balance.

2 Place another magnet in a clamp directly above the first magnet so that the unlike poles face each other. There will be an attractive force, so the scale reading on the balance should be a negative value. If like poles are facing each other, the magnet on the pan will fall over (unless held firmly in a wooden support or similar).

3 Start with the end of the clamped magnet 30 cm from the magnet on the balance and take a scale reading. If it is not zero, start with a 1 m separation (hold it in your hand).

4 Reduce the separation distance (r) by 5 cm at a time until r = 10 cm, and then in 2 cm increments, and take scale readings of the balance in grams. There is no need to reduce the separation to less than 4 cm. Ensure that the two magnets are in a line.

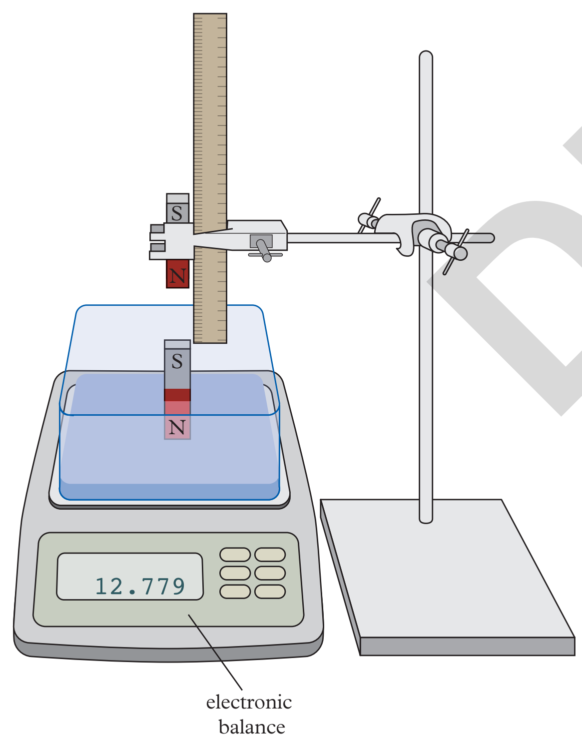


FIGURE 1 Balance and magnet assembly

Results

Distance r (m)	Scale reading (g)		Force between magnets (N)			
	Test 1	Test 2	Test 1	Test 2	Mean	δx

1 Calculate the force in newton (N) from the scale readings in grams.

2 Calculate the mean and determine the uncertainty.

3 Construct a graph of the data with separation distance (m) on the x-axis, and force (N) on the y-axis. Add custom error bars.

4 Deduce the relationship between force and distance. It will be inverse, but does it appear to be inverse or inverse squared?

5 Construct a linearised graph. Note: if the graph looks like an inverse squared relationship ($y \propto \frac{1}{x^2}$) then linearise it. See if your prediction is confirmed.

6 If the relationship does not linearise, the relationship is likely to be a power relationship in the form $y = kx^a$. The power (a) will be −2 for an inverse squared relationship, or −3 for an inverse cubed relationship. It could even be not a whole number, for example −1.8 or −2.3. Calculate the logarithm to base 10 for the force and distance data. We will use a log–log graph to determine the power (k).

$$y = kx^a \text{(power relationship)} \log_{10} y$$
$$= a \log_{10} x + \log_{10} k \text{ (logs taken of both sides)}$$
$$y = mx + c$$
$$\frac{\log_{10} y}{\log_{10} x} = \text{gradient}$$
$$= a$$

7 Construct a graph with $\log_{10} F$ (force) on the vertical axis and $\log_{10} r$ on the horizontal axis.

8 Interpret the relationship, with justification from the data. (Note: gradient is the power, a.)

Discussion

1 Deduce the relationship between F and r.

2 Propose a modification that would reduce random error and propose one that would reduce systematic error.

7.4 MANDATORY PRACTICAL

Force on a conductor in a magnetic field

Unit 3, Topic 2: Conduct an experiment to investigate the force acting on a conductor in a magnetic field.

Source: *Physics 2019 v1.2 General Senior Syllabus* © Queensland Curriculum & Assessment Authority

Context

The force on a current-carrying wire has been derived as $F = BIL \sin\theta$, and the direction of the force has been established by the right-hand rule (Figure 1). In this experiment the wire will be at 90° to the magnetic field, and the length will be measured and kept constant. Hence, the relationship is expected to be linear, with $F \propto I$, providing B, L and θ are kept constant. A graph of F versus I will produce a gradient of $B \times L$. Substitute for L to determine the magnetic field strength (assumed uniform) between the poles of the permanent magnets. Analysis of uncertainty will allow you to estimate the magnetic field strength and its percentage uncertainty.

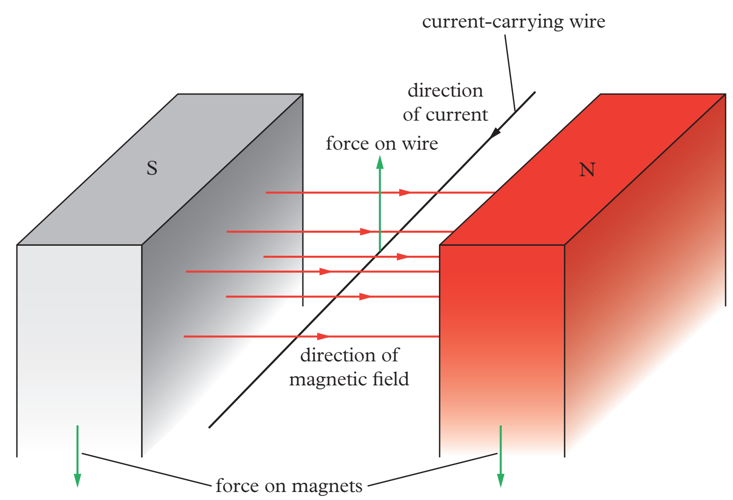


FIGURE 1 Forces on the wire and magnets

Aim

To investigate the relationship between force and current for a conductor in a magnetic field.

Materials

- Laboratory power supply
- Variable resistor (rheostat)
- Connecting wires
- Ammeter
- Electronic balance
- 2 × rare earth magnets
- Stiff copper wire (e.g. 0.5–1 mm diameter, 25 cm length)
- Cork
- Retort stand, boss head and clamp
- Aluminium channel (1 cm × 1 cm × 4 cm long)

Method

The magnets should be placed on the balance with unlike poles facing each other. They need to be kept apart so that the copper wire can pass between them. A small length of aluminium channel 1 cm high × 1 cm wide × 4 cm long to form a 'yoke' is appropriate. The magnets will not need fixing in place as their attraction will be sufficient to stop them sliding .

1. The copper wire needs to be bent into a square loop so that one side can pass freely between the magnets, and the rest supported by a fixed clamp in a boss head on a retort stand.
2. Set up the equipment as shown in Figure 2. Ensure that the current will flow in the correct direction. Note the direction of the magnetic field in the diagram. Remember that it is the inside poles of the magnets that produce the magnetic field. Position the parts as shown in the diagram.
3. With the magnets in place on the yoke (the aluminium channel), zero the balance.
4. Set the power supply to 2 V DC and adjust the resistor so that no current flows.
5. Increase the current in 0.1 A increments and take a scale reading in grams. The current should be in a direction to make the yoke get pushed down by the magnetic field (see Figure 1); that is, the force on the wire should be up. Use a hand rule or, if uncertain, check by trial and error. There may be no response until about 0.4 A. Stop when seven trials have been made. Repeat once more to have duplicates of each trial.

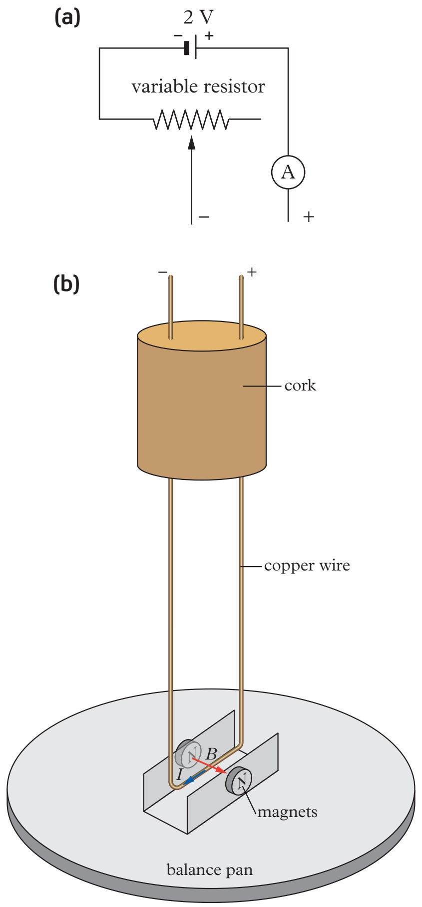


FIGURE 2 (a) Electric circuit and (b) yoke assembly for experiment setup

Results

Length of wire in the field (i.e. diameter of magnet) = ______ mm = ______ m

Current (A)	Scale reading (g)		Force (N)			Uncertainty in force
	Test 1	Test 2	Test 1	Test 2	Average	δx (N)

1 Construct a graph with current on the horizontal axis and force on the vertical axis.
2 Construct custom error bars for the vertical axis.
3 Create a linear trendline, and calculate the R^2 value: ______________________________
4 Construct maximum and minimum lines of best fit within the error bars, and determine the maximum and minimum gradients.

Discussion

1 Deduce the relationship between F and I.

2 Determine the average magnetic field strength of the permanent magnets, using the gradient value.

3 Calculate the maximum and minimum magnetic field strengths.

4 Determine the uncertainty in the value for magnetic field strength.

5 Explain why the balance pan moved down when a current passed through the wire.