SURFING

Physics

Motors and Generators

New Revised Edition

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Science Press

Contents

Use the table of contents to record your progress through this book. As you complete each topic, write the date completed, then tick one of the three remaining columns to guide your revision for later. The column headers use the following codes:

?? = Don't understand this very well at all. RR = Need to revise this. OK = Know this.

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Introduction

Each book in the *Surfing* series contains a summary, with occasional more detailed sections, of all the mandatory sections of the syllabus, along with questions and answers.

It is envisaged this book will be useful in class for both initial understanding and revision, while the more traditional textbook can remain at home for more detailed analysis.

All types of questions – multiple choice, short response, structured response and free response – are provided (there will be no multiple choice questions in the option questions in the HSC). Questions are written in exam style and use the verbs specified by the Board of Studies so that you will become familiar with the concepts of the topic and answering questions in the required way.

Answers to all questions are included.

A topic test at the end of the book contains an extensive set of summary questions, including multiple choice and free response questions. These cover every aspect of the topic, and are useful for revision and exam practice. Marking guidelines are supplied where appropriate.

Verbs To Watch

account/ account for	State reasons for, report on, give an account of, narrate a series of events or transactions.
analyse	Identify components and the relationships among them, draw out and relate implications.
apply	Use, utilise, employ in a particular situation.
appreciate	Make a judgement about the value of something.
assess	Make a judgement of value, quality, outcomes, results or size.
calculate	Determine from given facts, Figures or information.
clarify	Make clear or plain.
classify	Arrange into classes, groups or categories.
compare	Show how things are similar and different.
construct	Make, build, put together items or arguments.
contrast	Show how things are different or opposite.
critically (analyse/ evaluate)	Add a degree or level of accuracy, depth, knowledge and understanding, logic, questioning, reflection and quality to an analysis or evaluation.
deduce	Draw conclusions.
define	State the meaning of and identify essential qualities.
demonstrate	Show by example.
describe	Provide characteristics and features.
discuss	Identify issues and provide points for and against.
distinguish	Recognise or note/indicate as being distinct or different from, note difference between things.
evaluate	Make a judgement based on criteria.
examine	Inquire into.
explain	Relate cause and effect, make the relationship between things evident, provide why and/or how.
extract	Choose relevant and/or appropriate details.
extrapolate	Infer from what is known.
identify	Recognise and name.
interpret	Draw meaning from.
investigate	Plan, inquire into and draw conclusions about.
justify	Support an argument or conclusion.
outline	Sketch in general terms; indicate the main features.
predict	Suggest what may happen based on available information.
propose	Put forward (a point of view, idea, argument or suggestion) for consideration or action.
recall	Present remembered ideas, facts or experiences.
recommend	Provide reasons in favour.
recount	Retell a series of events.
summarise	Express concisely the relevant details.
synthesise	Put together various elements to make a whole.

1 Moving Charges in Magnetic Fields

Charges which move through magnetic fields interact with those magnetic fields because their movement gives rise to a second magnetic field. It is the two magnetic fields interacting which produces forces which change the motion of the charge. This is what electromagnetism is all about – the production of magnetic fields or electric currents due to relative movement between charges and other magnetic fields.

While we need only look at the qualitative aspects of the force on a charge in a magnetic field for this topic, in Ideas to Implementation we also look at the quantitative aspects – solving problems. Because it is sometimes easier to understand concepts by looking at the mathematics of it, we shall also use the equation here (it will help with Question 1 for example). The equation relating the variables affecting the force on a charge moving in a magnetic field is:

Force on charge in magnetic field,
Where F = force in newtons (N)
B = magnetic field strength in teslas (T)
q = charge in coulombs (C)
v = velocity of charge in m s^{-1}
θ = angle between directions of B and v

$$F = Bqv\sin\theta$$

Note that if the charge is travelling parallel to the field no electromagnetic force will be acting on it. There must be a component of the velocity cutting the field in order to produce a force.

The direction of the force on a charge moving through a magnetic field is given by the **right hand palm rule** (RHPR). In the RHPR the outstretched thumb represents the direction of movement of positive charge, the fingers the direction of the magnetic field, and a line at right angles to the palm represents the direction of the force acting on the charge (Figure 1.1).

If the moving charge is negative, the outstretched thumb is pointed in the direction from which the charge comes. (For this purpose, we regard a flow of negative charge as a flow of positive charge in the opposite direction – hence we point the thumb in the opposite direction to the movement.)

As the force, and therefore the acceleration, on a charged particle moving in a magnetic field is perpendicular to the motion, the particle will undergo uniform circular motion while it remains in the field. The magnetic force acting on a charge moving in a magnetic field is therefore a centripetal force (Figure 1.2).

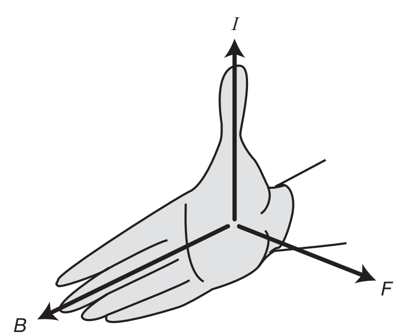


Figure 1.1 Right hand palm rule.

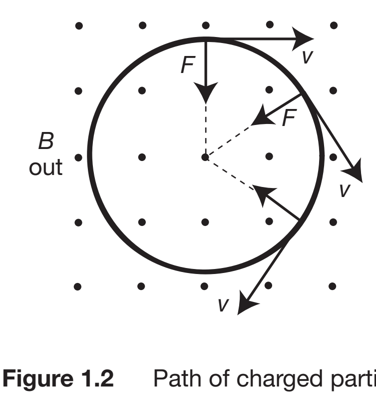
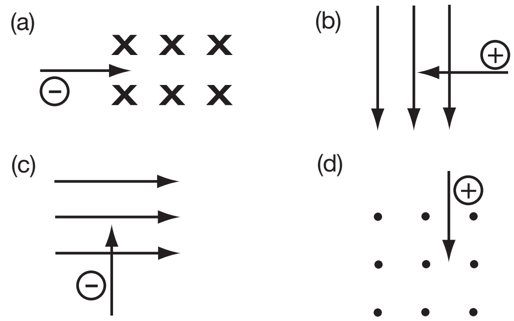


Figure 1.2 Path of charged particle in magnetic field.

For You To Do

1. Recall three ways the force on a charge moving through a magnetic field might be increased.
2. Predict the direction of the force acting on each charge moving through the magnetic fields shown in Figure 1.3.



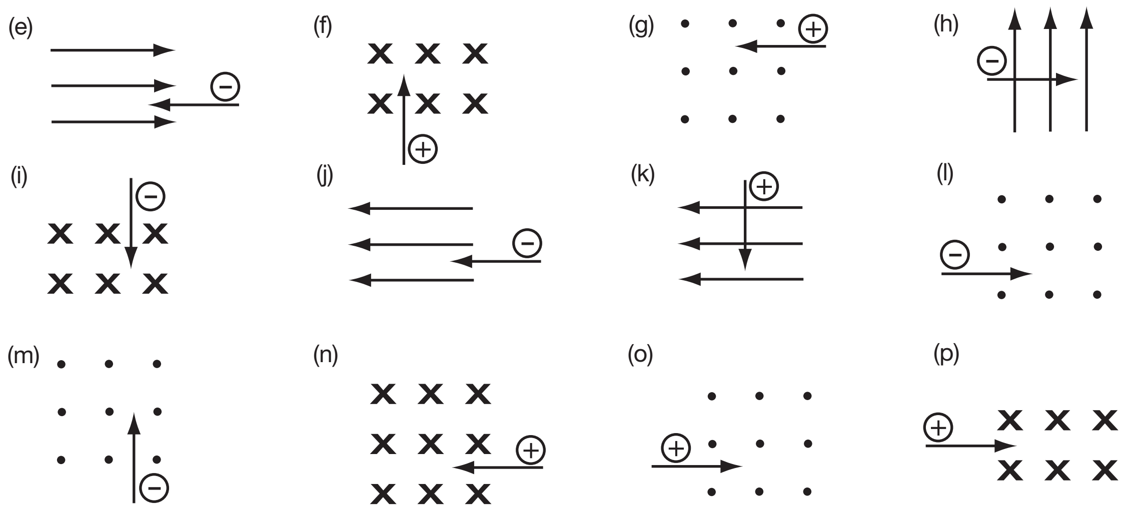


Figure 1.3 Various charges moving through magnetic fields.

Figure 1.4 shows the arrangement of the two pairs of electromagnets on a typical television tube. The labelled coil is acting as the north pole and the electron beam is coming out of the page towards you. It hits the screen in the centre.

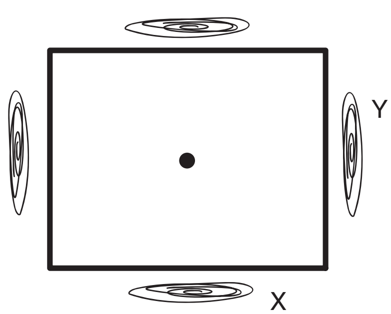


Figure 1.4 Television tube magnets.

3. Identify the pair of magnets which cause lateral movement of the electron beam.
4. Identify the pair of magnets which cause vertical movement of the electron beam.

For Questions 5 to 10 inclusive treat each change as affecting the position of the beam from its position in the previous question.

5. A beam of cathode rays travels to the screen through both sets of electromagnets in polarities indicated in Figure 1.4. Predict where you think the beam will hit the screen and mark it on a similar diagram as *position 5*.
6. Now suppose the field due to magnet pair X is slowly reduced to zero. Describe what happens to the electron beam and mark its final screen position (*position 6)*.
7. Now imagine that the polarity of magnets X reverses and the field strength slowly builds to maximum value. Describe what happens to the electron beam and mark its final *position 7* on your diagram.

8. Now suppose the field due to magnet pair Y is slowly reduced to zero. Describe what happens to the electron beam and mark its final screen position (*position 8)*.

9. Now imagine that the polarity of magnets Y reverses and the field strength slowly builds to maximum value. Describe what happens to the electron beam and mark its final *position 9* on your diagram.

10. Now imagine that the polarity of magnets X and Y both reverse and the field strength slowly builds to maximum value. Describe what happens to the electron beam and mark its final *position 10* on your diagram.

11. When the cathode rays hit the screen, they cause it to fluoresce. As the rays scan across and up and down the screen, the picture we see forms. Outline how the two sets of magnets cause this scanning.

12. Figure 1.5 shows a beam of electrons (coming towards you) hitting the screen of a television set. Show where a pair of magnets could be placed to centre the beam. Label the magnetic poles.

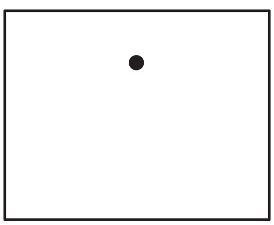


Figure 1.5 End view of TV tube, spot off centre.

13. (a) Compare the forces acting on a proton and an electron fired at equal speeds, in the same direction, into a magnetic field. Justify your answer.

    (b) Compare the forces if the direction of travel of the particles was opposite. Justify your answer.

Some mathematical problems

14. Three electrons (charge -1.6×10^{-19}C) are fired at 2.5×10^5 m s^{-1} from the east, west and south into a magnetic field of strength 0.02 T directed towards the north.

    (a) Calculate the magnitude of the force on each electron.

    (b) Deduce the direction of the force on each electron.

    (c) Describe the path each electron will take while it is in the field.

15. A charge moves at 1.25×10^6 m s^{-1} at right angles to a magnetic field of strength 0.4 T. The charge experiences a force of 8.0×10^{-13} N.

    (a) Calculate the magnitude of the charge.

    (b) What additional information (if any) do we need to determine the sign of the charge?

16. A charge of 8.0×10^{-19} C moves at 5×10^5 m s^{-1} from north to south into a magnetic field directed into the page. The charge experiences a force of 4.4×10^{-13} N.

    (a) Calculate the magnitude of the magnetic field.

    (b) Deduce the direction of movement of the charge in the field.

17. A charge of 4.8×10^{-19} C is travelling north at 2.5×10^7 m s^{-1}, perpendicular to a magnetic field of 0.25 T directed vertically down.

    (a) Calculate the force on the charge.

    (b) Deduce the direction the charge will move while it is in the field.

18. A charge of 3.2×10^{-19} C is travelling south at 4.0×10^7 m s^{-1}, perpendicular to a magnetic field directed vertically down. It experiences a force of 6.4×10^{-12} N.

    (a) Calculate the strength of the magnetic field.

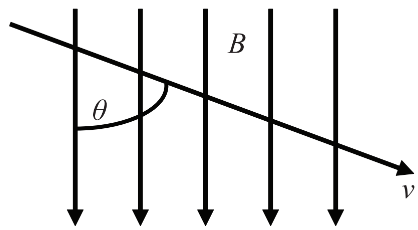
    (b) Deduce the direction the charge will move while it is in the field.

2 A Practical Analysis

Imagine an experiment where a group of students fired electrons (charge, $q =$ (–)1.6×10^{-19}) at various entry angles into a magnetic field at 750 m s^{-1}. Their purpose was twofold:

- To determine the relationship between the force on the electrons and their angle of entry into the magnetic field, and
- To determine the strength of the magnetic field.

The diagram shows the idea behind their experiment, and the equation connects the variables involved.



$$F = Bqv\sin\theta$$

Their results are shown in the table.

Run	Entry angle	Force on the electron (N)
1	10	4.2×10^{-18}
2	20	8.2×10^{-18}
3	30	???
4	40	1.5×10^{-17}
5	60	2.1×10^{-17}
6	70	2.2×10^{-17}
7	90	???

For You To Do

1. List the variables that needed to be controlled in this experiment.
2. Graph the results such that a straight line is obtained (place F on the y-axis).
3. Use your graph to identify the relationship between F and θ.
4. From your graph, estimate the value for the force on the electron for an entry angle of 30°.
5. From your graph, estimate the value for the force on the electron for an entry angle of 90°.
6. Identify which of these two estimates is the more accurate. Explain why.
7. Write a mathematical expression for the gradient of the graph.
8. Use this expression to find the strength of the magnetic field.
9. Write an appropriate conclusion for the experiment.
10. Suggest one way of improving the accuracy of the results.
11. Predict the direction of movement of the electron shown in the diagram in the magnetic field.