

Physics EE1
Course Guide
Session (2006 - 2007)

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PHYSICS EE1

Session (2006 - 2007)

General Information

Class and Laboratory Head: Dr. Val O'Shea, Room 329a, Kelvin Building.
Tel: 5882 v.oshea@physics.gla.ac.uk

ENTRY REQUIREMENTS

The entry requirements are those specified by the Faculty of Engineering for initial entry to courses leading to a degree in Electronics and Electrical Engineering.

GENERAL

The Physics EE1 course is a service course provided by the Department of Physics and Astronomy for first year students studying for a degree in Electronics and Electrical Engineering. This course contributes 20 credits of the 120 making up the 1st year course.

The class meets for Physics lectures on Mondays and Tuesdays at 09.00 hrs in Lecture Theatre B (Room 412), Boyd Orr Building each week during Semesters 1 and 2.

Students will also attend eight, 2½ hour practical classes and ten, 1 hour small group tutorial sessions through the course of the year.

A class web page can be found at <http://ppewww.ph.gla.ac.uk/~oshea/ee1/>

A MOODLE page for the EE1 Course is under construction which will offer the preferred access to course material and be set up for the routine administration of the course.

LECTURE COURSES

Following discussions with the Department of Electronics and Electrical Engineering the Physics lecture courses were developed to meet the specific requirements of the first year of the Electrical Engineering course.

Particle Kinematics	7 Lectures	Dr C. Parkes
Electrostatics	9 Lectures	Dr D. Land
Magnetism	5 Lectures	Dr V. O'Shea
Electromagnetism	4 Lectures	Dr K. Mathieson
Thermal Physics	9 Lectures	Dr I. MacLaren
Oscillations	4 Lectures	Dr K. Mathieson

TEXTBOOK

'University Physics', Revised Edition by Harris Benson, Wiley, 1996

This book is used for tutorials so it is essential that you acquire a copy.

LABORATORY CLASSES AND TUTORIALS

Details of the times for the practical classes and tutorials can be found in the timetable given out with this course guide.

All students will attend the Physics Engineering Laboratory in Room 219, Department of Physics & Astronomy from 14.00 to 16.30 on alternate Thursdays during Semester 1 and Semester 2.

The Practical Class contributes 20% to the final grade for the course and is an important contribution to your final assessment for the class.

Small group tutorial/discussion sessions, with about 10 students will be held between 13.00 - 14.00 hrs on Fridays approximately every 2 weeks throughout the year in the Kelvin Building in the 1st Year Laboratories. The class timetable gives the dates of tutorials.

Students will be allocated to tutorial groups in Semester 1 according to their entrance qualifications.

Students will be set exercises for these tutorials by the appropriate course lecturer. These will be marked by the tutor. **It is important that you submit even incomplete attempts.**

Note that you are required to attend at least 50% of the tutorials and practical classes. Otherwise, you may be awarded no credit for the course. This is the absolute minimum attendance required and much will be gained by attending all or almost all tutorials and laboratories.

Details of the allocation of Laboratory sections and tutorial groups will be posted on the class notice boards in the Kelvin Building shortly after the start of the class.

ASSESSMENT TESTS

Two assessment tests lasting one hour are given during the course.

All students are expected to sit these tests. Each contributes 10% towards the final assessment grade for this course. Failure to attend them will reduce your final grade.

Any absence should be explained to the Class Head in writing and should be supported by medical certificates if it is due to illness. If the reason for the absence is acceptable, the contribution of the tests to your assessment will be adjusted. Otherwise, no credit will be given for a missed test.

The dates for the tests are given in the class timetable.

ASSESSMENT

Assessment of performance in the Physics EE1 course is based on the following components. All contribute to the grade awarded at the end of the year.

Assessment Tests	20%
Laboratory Work	20%
Degree Examination	60%
Total	100%

Each piece of assessment is marked by one person and checked by the class or laboratory head. In the case of the degree examination the paper, each question is marked anonymously by a single marker and checked by the class head.

Students are awarded grades in the standard way for Glasgow University. These grades are A, B, C, D, E, F, G, N (No credit) and CR (Credit Refused). The grade points for grades A to G are respectively 16, 14, 12, 10, 8, 6, 2. N or CR grades receive no grade points.

There is no exemption from the Degree examination for this course.

MINIMUM REQUIREMENTS FOR AWARD OF CREDITS

Students require a grade of G or better to be awarded credits for the course. There are three requirements for this.

All of these must normally be satisfied.

- **Attendance for at least 50% of the practical laboratory periods and submission of the associated work for marking.**
- **Attendance for at least 50% of the small group tutorials.**
- **Attendance at the degree examination.**

Students who do not meet these requirements (except due to certified illness or other acceptable cause) will normally be awarded an N grade if only the examination is not taken or CR otherwise. This means that you will receive no credits or grade points for the course. In the case of a CR grade, it indicates that your performance in the work of the class was unacceptably inadequate. It will be very difficult to change this.

ABSENCES AND MEDICAL CERTIFICATES

All absences from lectures, tutorials, laboratories, class tests and the examination at the end of the course **must** be justified. You must comply with the university regulations for absence as stated on the Registry web pages. These are found in Appendix A at the end of this course guide.

Missed examinations

It is particularly important, if you miss a degree examination due to illness, that a medical certificate is submitted promptly. If this is done, you will be given a medical exemption so that there will be no charge to resit the examination and you will not be restricted to a D grade in the resit.

Missed practical classes

Additionally, since the laboratory mark contributes to the course assessment, in **all** cases of absence from the Physics laboratory, an additional self-certificate (available from the laboratory) should be completed and handed to the technician.

Absence from laboratories, without medical or other good cause, will result in a lower laboratory mark and final grade.

Attendance at less than 50% of the practical classes, without justifiable cause, will normally mean that no credit is awarded for the class (CR grade).

You may make up missing work from the practical class outside your usual laboratory hours, at a time when the laboratory is open and provided that the apparatus is available. Such work should be arranged with the laboratory technician (Room 223 Kelvin Building). Students are required to sign in for safety reasons. Note that demonstrators will not be available at times other than the standard laboratory sessions.

DEGREE EXAMINATION

The Physics EE1 Degree examinations are held in May/June and a resit in August/September.

The examination consists of one 2-hour paper. Candidates are expected to attempt 5 questions from the 8 questions in the paper.

Copies of past degree papers will be made available to students and sketch solutions will be posted on the Physics EE1 website for consultation.

All students are expected, if necessary, to make themselves available to take the resit examinations in the University of Glasgow, unless special arrangements have been made previously with the registrar, with the approval of the Senate Office, for resit examinations to be held elsewhere; the additional cost thereof to be at the student's expense.

DEPARTMENTAL REGULATIONS

Students are required to provide themselves with such books and other material necessary for the course and to submit items of work, such as tutorial examples and laboratory reports, as requested.

COMMUNICATION

If you need help with any aspect of the course, **PLEASE ASK**. Contact either the lecturer responsible for the particular lectures, discuss the problem with your tutor or speak to the class head or the laboratory head *See the addresses at the start of these notes.*

Notice board

The Class Notice Board is in the Physics Laboratory (219) in the Kelvin Building. All information (e.g. tutorial and laboratory group allocations, assessment test results, progress reports, etc) will be posted on these notice boards.

Communication by e-mail

Information will be circulated to the class by the class and laboratory heads using the university e-mail system.

SOME OF THIS MAY BE VERY IMPORTANT. It is essential that you check your university e-mail frequently and that you do not redirect messages from your university e-mail address.

PLAGIARISM

The University's degrees and other academic awards are given in recognition of the candidate's personal achievement. **Plagiarism is therefore considered as an act of academic fraudulence and as an offence against University discipline.**

Plagiarism is defined as the submission or presentation of work, in any form, which is not one's own, without acknowledgement of the sources. (With regard to essays, reports and dissertations, a simple rule dictates when it is necessary to acknowledge sources. If a student obtains information or ideas from an outside source, that source must be acknowledged. Another rule to follow is that any direct quotation must be placed in quotation marks, and the source immediately cited.)

Where a candidate for a degree or other award uses the work of another person or persons without due acknowledgement:

- the relevant Board of Examiners may impose a penalty in relation to the seriousness of the offence;
- the relevant Board of Examiners may report the candidate to the Clerk of Senate, for action under the Code of Discipline, where there is prima facie evidence of an intention to deceive and where sanctions beyond those in (1) might be invoked.

Working together as a community.

The Faculty of Physical Sciences is committed to working to promote race and gender equality and to providing opportunity and support for students with disabilities. This means we all have a part to play.

The content of our courses is either culturally independent, in the sense that experimental results should be the same for everyone, (if we can get it to work!) or they are ones where cultural positioning is important (such as in parts of Human Geography) and we explicitly study the effect of this. So we must use our time at University to look outside our own cultural origins, and to welcome contact and friendship with those from other backgrounds. Indeed, the new friends one makes at University, perhaps ones we never expected to make, can be amongst the greatest assets of our lives.

Students with disabilities are welcomed equally with all others, to share our enthusiasm for the ideas and challenges of our courses. I expect everyone in the Faculty to lend a hand of support to one another where needed. If you have any personal concerns on these matters, in the first instance contact your Adviser of Studies or your class head.

May I wish you all the best in your studies here.

David Saxon

Dean, Faculty of Physical Sciences

TIMETABLE

EE1 Timetable 2006/7					
Week	Wk Beginning	Monday	Tuesday	Thursday	Class Tut.
1	25 th Sept	Holiday	Enrolment		
2	2 nd Oct	Mag1	Mag2	Lab enrol	
3	9 th Oct	Mag3	Mag4	Lab A	
4	16 th Oct	Mag5	PD1	Lab B	Tutorial
5	23 th Oct	PD2	PD3	Lab A	
6	30 th Oct	PD4	PD5	Lab B	Tutorial
7	6 th Nov	PD6	PD7	Lab A	
8	13 th Nov	ES1	ES2	Lab B	Tutorial
9	20 th Nov	ES3	ES4	Lab A	
10	27 th Nov	ES5	ES6	Lab B	Class Tut.
11	4 th Dec	Test1	ES7		
12	11 th Dec	ES8	ES9		
		Vacation	Vacation	Vacation	Vacation
		8 th Jan	EXAMS	EXAMS	EXAMS
		15 th Jan	EXAMS	EXAMS	EXAMS
1	22 nd Jan	EM1	EM2	Lab A	
2	29 th Jan	EM3	EM4	Lab B	Tutorial
3	5 th Feb	TH1	TH2	Lab A	
4	12 th Feb	TH3	TH4	Lab B	Tutorial
5	19 th Feb	TH5	TH6	Lab A	
6	26 th Feb	TH7	TH8	Lab B	Tutorial
7	5 th Mar	TH9	Class tut	Lab A	
8	12 th Mar	Test 2	Spare	Lab B	
		Vacation	Vacation	Vacation	Vacation
9	9 th Apr	Holiday	Osc1		
10	16 th Apr	Osc2	Osc 3		Tutorial
11	23 rd Apr	Osc 4	Spare		
12	30 th Apr	Spare	Spare		
		EXAMS	EXAMS	EXAMS	EXAMS

Lectures 9.00 am Room 412 Boyd Orr Building
 Tutorials 1.00 pm Teaching Laboratory, Kelvin Building

Lecture course	Lecturer
Particle Kinematics (PD) - 7	C. Parkes
Electrostatics (ES) - 9	D. Land
Magnetism (Mag) - 5	V. O'Shea
Electromagnetism (EM) - 4	K. Mathieson
Thermal Physics (Th) - 9	I. MacLaren
Oscillations (Osc) - 4	K. Mathieson

Tutorials	Semester 1	Semester 2
	P. Bussey	C. Buttar
	R. Kaiser	K. Livingston
	V, O'Shea	I. MacLaren

Course Aims and Objectives

Aims

This course is specifically designed to teach relevant and basic aspects of Physics for first year students taking a Degree in Electronics and Electrical Engineering. The topics covered in the course are important for this branch of engineering and are not covered elsewhere in your Engineering course.

Objectives

On completion of this course you should understand the basic principles and laws of physics in the following areas: particle kinematics, electrostatics, magnetism, electromagnetism, thermal physics and oscillations.

In these aspects of Physics, you should:

- understand the experimental basis of the laws;
- be able to apply these laws and principles to a wide range of examples;
- be familiar with basic experimental equipment normally found in a Physics laboratory and
- be able to apply experimental techniques and know how to make physical measurements and estimate their accuracy.

In more general terms, you should develop the following transferable skills that are essential for all scientists and engineers:

- Assimilation of information from lectures, textbooks, laboratory instructions etc;
- Recording and analysis of data (in practical sessions);
- Practical knowledge in the use of laboratory equipment such as verniers, micrometers, spectrometers, oscilloscopes, multimeters, computers etc;
- Experience in theoretical and practical problem solving;
- Developing expertise in communication both written, in the form of laboratory reports and answers to exam questions, and verbal, during tutorial discussions and laboratory sessions.

Use of Aims and Objectives

Students are encouraged to use these guides for study and as a checklist for revision. **However, please note the following.** In response to feedback from students during the year, lecturers may omit or modify some material listed in the Course Component Aims and Objectives. Any such changes will be announced in the course of the year.

Students are advised not to restrict their studies to the topics mentioned, and are expected to think about, read around, and solve problems in these topics so that they can apply the concepts in unfamiliar contexts.

PARTICLE KINEMATICS

(7 LECTURES)

TEXTBOOK: UNIVERSITY PHYSICS by HARRIS BENSON

References to Benson are given in italics

TOPIC TITLES

- Elementary differentiation and integration (3.3-3.5)
- Scalars and vectors (2.1-2.4)
- Displacement, velocity and acceleration (3.1-3.7, 4.2)
- Newton's laws (4.1, 5.1-5.5)
- Inertia, momentum and conservation of momentum (4.5, 9.1-9.2)
- Gravitational forces (5.3, 13.1-13.4)
- Projectiles (4.3)
- Friction (6.1)
- Work, energy and power (7.1-7.4, 8.1-8.5)
- Circular motion, central forces (4.4, 6.2-6.3, 13.4)

AIMS

- To provide an introduction to the motion of particles in 1- and 2- dimensions (under gravity) using Newton's laws of motion.
- To introduce the inverse square law of gravitational force between two bodies and the concepts of gravitational field and weight.
- To understand friction, work, power and the principle of conservation of energy.
- To introduce circular motion and centripetal acceleration.

OBJECTIVES

- To know and be able to apply Newton's laws of motion for particles moving in one and two dimensions (under gravity) as well as Newton's law for the gravitational force.
- To be able to treat frictional forces correctly in kinematical problems and to understand the concepts of work, power and the principle of conservation of energy.
- To be able to analyse the forces involved in the case of a particle moving in a circle and to calculate the centripetal acceleration for such a particle.

SYLLABUS DETAILS

- Mathematical ideas and techniques: elementary calculus; vectors, components, addition and scalar product. derivatives of scalars and vectors, velocity and acceleration.
- Newton's Laws (first, second and third laws) - inertia, inertial mass and momentum.
- Applications of the second law. The third law and collisions
- Gravitational force, Newton's inverse square law, gravitational field, gravitational and inertial mass. motion in 2-dimensions under gravity, projectiles.
- Friction.
- Work, energy and power. work done by a force; kinetic energy, power, potential energy - gravitational potential energy, conservation of energy.
- Circular motion. centripetal acceleration, equation for circular motion, satellites. central forces.

ELECTROSTATICS

(9 LECTURES)

TEXTBOOK: UNIVERSITY PHYSICS by HARRIS BENSON

References to Benson are given in italics

TOPICS

Electrostatics (22.1 -22.5)

- Introduction
- *charge, conductors and insulators*
- *Coulomb's law, law of superposition.*

Electric field (23.1-23.5)

- *Electric field, \underline{E} , lines of force*
- Conductor in \underline{E} -field
- Motion of charge in \underline{E} -field
- Continuous charge distributions
- *Dipole*, torque and potential energy of a dipole in \underline{E} -field

Gauss's law in free space (24.1-24.3)

- "Free space" flux of \underline{E}
- *Gauss's law in free space*
- Applications of Gauss's law:
- Charged, spherical, conducting shell
- Non-conducting charged sphere
- Line of charge
- Sheet of charge
- Conductors.

Electric Potential (25.1-25.4)

- *Electric potential, V.*
- *Electrostatic potential energy*
- *Equipotentials*, potential due to point charges
- \underline{E} -Field and potential gradient
- Conductors - potential and charge distributions

Capacitance (26.1-26.4)

- *Capacitance.*
- Parallel plate, spherical and cylindrical capacitors.
- Series and parallel combinations,
- Energy stored, energy density in \underline{E} -Field.
- Dielectric, polarisation.

Dielectrics (26.5-26.7)

- *Dielectric, polarisation.*
- Electric flux density \underline{D} .

AIMS

- To provide an introduction to the principles of electrostatics.
- to illustrate these principles by means of examples and practical applications.

OBJECTIVES

Electrostatics, Charge and Coulomb's Law

Understand:

- Properties of electric charge: attraction, repulsion,
- *Quantisation and conservation of charge.*
- Charging by friction, induction and contact
- *Coulomb's law* for point charges in free space: $\underline{F} = \frac{kQ_1Q_2}{r^2} \hat{r}$ where $k = 1/4\pi\epsilon_0$

Calculate:

- Net force on a point charge due to a set of other point charges.

Electric Field

Know:

- *Electric field strength* is force/unit charge: $\underline{E} = \underline{F}/q$
- Properties of \underline{E} ; 'lines of force'
- Motion of charged particle in \underline{E} -field; acceleration. = $q\underline{E}/m$
- For conductors in \underline{E} field: $\underline{E} = 0$ inside conductor,
- \underline{E} -field lines **normal** to surface of conductor

Calculate:

- \underline{E} -field due to a set of point charge.
- Motion of charged particle in \underline{E} -field.

Understand:

- Concept of *electric dipole*, permanent and induced dipoles.
- Forces on dipoles in uniform and non-uniform \underline{E} -fields.

Gauss's Law in "Free Space"

Understand:

- Concept of *electric flux* $\Phi_E = \Sigma \underline{E} \cdot \underline{dA}$
- *Gauss's law* for free space $\oint \underline{E} \cdot \underline{dA} = \Sigma q / \epsilon_0$

Applications:

- Apply Gauss's Law to: lines, spheres, cylinders, planes of charge and conductors.

Understand:

- Concept of electric flux $\Phi_E = \Sigma \underline{E} \cdot \underline{dA}$
- Gauss's law for free space $\oint \underline{E} \cdot \underline{dA} = \Sigma q / \epsilon_0$

Applications:

Apply Gauss's law to: lines, spheres, cylinders, planes of charge and conductors.

Electric Potential

Understand:

- Concept of electric potential energy, U , of a set of charges.
- Concept of electric potential, V , and electric potential difference.
- The electric potential difference between two points A and B is the work required to take charge Q from A to B divided by Q .

or

the change in electric potential energy per unit charge

Know:

- Relationship between V and \underline{E} :
- $\Delta V = - \int \underline{E} \cdot \underline{ds}$ and $\underline{E}_s = - dV/ds$
- *Equipotentials* and *electric field lines of force*.
- Electric potential, V , at distance r from point charge Q : $V = k Q/r$
- Conductors are equipotential volumes

Calculate:

- Potential at a point due to a set of point charge
- Evaluate \underline{E}_s from $V(s)$ and ΔV from \underline{E}

Capacitance

Know:

- Definition of capacitance, $C = Q/V$

Prove:

Using Gauss's Law :

- Capacity of a parallel plate capacitor is $C = \epsilon_0 A/d$
- Evaluate the capacity of spherical capacitor and cylindrical capacitor

Know and Prove:

- Capacitors in series: $1/C_{\text{tot}} = 1/C_1 + 1/C_2 + \dots$
- Capacitors in parallel: $C_{\text{tot}} = C_1 + C_2 + \dots$
- Energy stored in C is: $U_E = Q^2/2C = QV/2 = CV^2/2$

Dielectrics

Understand (Qualitatively):

- Effect of dielectric material on E field and capacitance
- Dielectric constant K

Know:

Definition of Electric Flux Density, D: $\underline{D} = K\epsilon_0 \underline{E}$

MAGNETISM

(5 LECTURES)

TEXTBOOK: UNIVERSITY PHYSICS by HARRIS BENSON

References to Benson are given in italics

TOPIC TITLES

The magnetic field (29.1-29.5)

- Introduction - magnetic effects
- Force on a moving charge
- Definition of **B**- *magnetic flux density*
- Force on a current carrying conductor
- Torque on a current loop
- Galvanometer and electric motor
- Motion of charged particle in a magnetic field
- Combined electric and magnetic fields.
- Applications - velocity selector,
- *Mass spectrometer and Hall probe.*

Sources of magnetic fields (30.1-30.4)

- **B**-field due to a straight wire
- Magnetic force between current carrying parallel wires
- *Biot-Savart law* for a current element
- Field due to a current loop

Ampère's Law

- Applications of Ampère's Law:
- Straight wire, current loop, solenoid, toroid

Magnetic materials - Generalisation of Ampère's law

- Effect of magnetic materials - **H**-Field
- **H** - *magnetic field strength* (c.f. **E**)
- **B** - *magnetic flux density* (c.f. **D**)
- General form of Ampère's Law

AIMS

- Introduce the concept of a magnetic field and explain how charges and currents interact with the field.

OBJECTIVES

Motion of point charge q in a magnetic field

Know:

- Definition of $\underline{\mathbf{B}}$ - *magnetic flux density* in terms of magnetic force on a point charge q moving with velocity $\underline{\mathbf{v}}$:
- $\underline{\mathbf{F}} = q\underline{\mathbf{v}}\mathbf{B}\sin(\theta)$ or $\underline{\mathbf{F}} = q(\underline{\mathbf{v}} \times \underline{\mathbf{B}})$
- S.I. units of $\underline{\mathbf{B}}$ - Tesla(T) $1\text{T} = 10^4$ Gauss

Understand:

- *Vector product* and *right hand rule* to obtain direction of $\underline{\mathbf{F}}$

Forces on currents and current loops in a magnetic field

Know:

- Force acting on a straight wire, length L carrying current I in a magnetic field is:
 $F = ILB\sin\theta$ or $\underline{\mathbf{F}} = I\underline{\mathbf{L}} \times \underline{\mathbf{B}}$

Apply:

- Obtain the torque experienced by a current loop of N turns carrying a current I in a uniform magnetic field: $\tau = NIAB\sin(\theta)$

Know:

- Definition of magnetic dipole moment, $\underline{\boldsymbol{\mu}}$, with $\underline{\boldsymbol{\mu}} = NI\underline{\mathbf{A}}$ where $\underline{\mathbf{A}}$ is a vector, magnitude A , the area of the loop and whose direction is given by the direction of I and *right hand rule*.

Understand:

- $\underline{\boldsymbol{\tau}} = \underline{\boldsymbol{\mu}} \times \underline{\mathbf{B}}$

Apply:

- Galvanometer movement: $NIAB = K\phi$

Understand:

- Operation of simple electric motor and commutator.

Motion of a charge, q , in a magnetic field

Know:

- A charge moving perpendicular to $\underline{\mathbf{B}}$ moves in a circle

Derive:

- From forces on particle: $qvB = mv^2/r$
- Hence radius of path: $r = mv/qB$ and *Cyclotron Frequency* : $f_c = qB/2\pi m$

Understand:

- Helical path of q when v is at an angle to B
- The *magnetic bottle*, Van Allen radiation belts and aurora

Motion of a charge, q , in combined electric and magnetic fields

Know:

- The *Lorentz Force*: $\underline{\mathbf{F}} = q(\underline{\mathbf{E}} + \underline{\mathbf{v}} \times \underline{\mathbf{B}}) = \underline{\mathbf{F}}_E + \underline{\mathbf{F}}_B$

Understand:

- By using *crossed* electric and magnetic fields can have $\underline{\mathbf{F}}_E = -\underline{\mathbf{F}}_B$ i.e. $\underline{\mathbf{F}} = 0$ when $\underline{\mathbf{E}} = -\underline{\mathbf{v}} \times \underline{\mathbf{B}}$

Applications:

- *Velocity Selector*: In *crossed fields*, charged particles with speed $v = E/B$ are undeflected.
- *Mass Spectrometer*:
- Velocity selector ($v = E/B_1$) followed by motion in a uniform magnetic field, B_2 where $r = mv/qB_2$; giving $m/q = B_1 B_2 r/E$

Understand:

- **Hall effect**: A conducting strip carrying a current, I , perpendicular to a uniform magnetic field develops a *Hall potential difference*, V_H .

Derive:

- $V_H = IB/nqt$ where n is the density of charge carriers, q is their charge and t is the thickness of the strip

Understand:

- The significance of positive and negative values of V_H and use of the *Hall Probe* to measure $\underline{\mathbf{B}}$

Sources of magnetic fields

AIMS

- Introduce *Biot-Savart* and *Ampère's Laws*
- Apply them to simple circuits.
- Explain the properties and effects of magnetic materials.

OBJECTIVES

The Biot-Savart law

Recognise:

- $\underline{\mathbf{B}}$ at a distance r from a long straight wire carrying a current I is: $B \propto I/r$
- In *free space*, $B = \mu_0 I / 2\pi r$ where $\mu_0 = 4\pi \times 10^{-7} \text{Tm/A}$ is a constant - the *permeability of free space*

Understand:

- The direction of $\underline{\mathbf{B}}$ due to current in wire given by the **right hand rule**.

Derive:

- Force/unit length between two long parallel wires distance d apart carrying currents I_1 , I_2 is $F/L = \mu_0 I_1 I_2 / 2\pi d$

Understand:

- The direction of this force

Know:

- The *Biot-Savart Law* for the contribution to $\underline{\mathbf{B}}$ at a point due to a small current element $\underline{\mathbf{dl}}$ is: $d\mathbf{B} = \mu_0 I dl \sin(\theta) / 4\pi r^2$ or $d\underline{\mathbf{B}} = \mu_0 I \underline{\mathbf{dl}} \times \underline{\hat{\mathbf{r}}} / 4\pi r^2$

Apply:

Derive $\underline{\mathbf{B}}$ at centre of current loop: $B = \mu_0 I / 2\pi r$

Ampère's Law

Know:

- *Ampère's Law* for magnetism in free space $\oint \underline{\mathbf{B}} \cdot \underline{\mathbf{dl}} = \oint \underline{\mathbf{B}} \cdot \underline{\mathbf{dl}} = \mu_0 I$

Apply:

To derive $\underline{\mathbf{B}}$:

- At distance r from long straight wire, current I : $B = \mu_0 I / 2\pi r$

- Inside an ideal air solenoid with current I : $B = \mu_0 n I$ where $n = N/L$ is the number of turns/unit length
- Inside a toroid, with current I , total turns N : $B = \mu_0 N I / 2\pi R$

Magnetic Materials - Generalisation of Ampère's Law

Understand (qualitatively):

- The effect of magnetic materials with $\mu_r = \textit{relative permeability}$
- **H**-Field, $\mathbf{H} = \mathbf{B} / \mu_0 \mu_r$ - magnetic field strength
- General form of Ampère's law for magnetism: $\oint \mathbf{H} \cdot d\mathbf{l} = I$
- Comparison **D** and **B** with **E** and **H**

ELECTROMAGNETISM

(4 LECTURES)

TEXTBOOK: UNIVERSITY PHYSICS by HARRIS BENSON

References to Benson are given in italics

TOPIC TITLES

Electromagnetism (31.1-31.8)

- Introduction
- Electromagnetic effects
- Magnetic flux

Faraday's and Lenz's Laws

Applications:

- Moving conductor in **B**-field, electric generator
- Changing magnetic flux
- Induction coil, transformer

Induced Electric Fields

- Application: betatron
- Motional EMF
- Eddy currents

Inductance (32.1-32.4)

- Inductance
- Self and mutual inductance
- Self inductance of solenoid
- Energy stored in inductor
- Energy density in magnetic field

AIMS

- To introduce the basic concepts of *electromagnetic induction* and to illustrate the importance of these concepts by examples and practical applications.
- To introduce the concept of inductance and the application of an inductor as a circuit element and, a store of magnetic energy.

OBJECTIVES

Electromagnetic Effects, Faraday's and Lenz's Laws

Know:

An emf is generated and a current induced to flow in a circuit in a magnetic field by a change of

- Magnetic flux
- The area, A , of circuit
- The orientation of a circuit relative to \mathbf{B}

Know:

- Magnetic flux: $\phi_B = \int \mathbf{B} \cdot d\mathbf{A} = BA \cos(\theta)$ (for uniform \mathbf{B} at an angle, θ , to \mathbf{A})

Know:

- **Faraday's Law :** The induced emf in a circuit is equal to minus the rate of change of magnetic flux through the area bounded by the circuit. $\mathcal{E} = - d\phi_B/dt$
- **Lenz's Law:** The induced emf and direction of induced current is such as to oppose the change producing it. (Hence the negative sign in Faraday's Law)

Applications of Faraday's Law

- Apply Faraday's Law to changing magnetic flux: *induction coil*

Calculate:

- The induced emf in a secondary coil surrounding the primary is; $\mathcal{E} = \mu_0 nN dI/dt$

Ideal Transformer

$$V_1/V_2 = N_1/N_2 \quad , \quad I_1/I_2 = N_2/N_1$$

Changing Area A of circuit

Conducting rod, length L , sliding on rails in magnetic field B

Calculate: $\mathcal{E} = BLv$, $I = BLv/R$, where R is the circuit resistance.

Apply: Lenz's law to get the polarity of \mathcal{E} and the direction of I

Apply: Faraday's Law to

Changing Orientation of the circuit in relative to \mathbf{B} : *electrical generator*

Calculate: $\mathcal{E} = NBA\omega \sin(\omega t) = \mathcal{E}_0 \sin(\omega t)$

Understand: "Back emf " in electric motors

Understand: Induced E-fields

Note:

The difference between an induced \underline{E} field, \underline{E}_{ind} , and \underline{E} -fields produced by static charges:

- For an electrostatic field, $\oint \underline{E} \cdot d\underline{l} = 0$, (\underline{E} -lines start and end on charges or go to infinity)
- For an induced E-field $\oint \underline{E}_{ind} \cdot d\underline{l} = \epsilon \cdot (\underline{E}$ -lines form closed loops)

Understand: Motional emf

For a conducting rod, length L , perpendicular to a \underline{B} field moving with velocity \underline{v} perpendicular to the rod

Calculate:

- Induced emf $\epsilon = BLv$ or $\epsilon = BLv \cos(\theta)$, where θ is the angle between the rod and \underline{v}

Note: ϵ = the rate at which the conductor cuts B field lines

Deduce:

- The polarity of emf from $\underline{E} = q\underline{v} \times \underline{B}$

Understand:

- The production of 'eddy currents'
- The need for laminations in a transformer core
- Electromagnetic damping

Inductance

- **Understand:** Self and Mutual Inductance
- **Know:** $L = N_1\phi_B / I_1$, $M = N_1\phi_{12}/I_2$
- **Calculate:** The self inductance of solenoid with length l : $L = \mu_0 n^2 A l$
- **Understand:** The energy is stored in magnetic field of the solenoid
- **Calculate:** $U_L = \frac{1}{2}LI^2$
- The energy density in a B-field is: $U_B = \frac{1}{2}B^2/\mu_0$

THERMAL PHYSICS

(9 LECTURES)

TEXTBOOK: UNIVERSITY PHYSICS by **HARRIS BENSON**

References to Benson are given in italics

Topic Titles

Temperature (*18.1-18.3*)

- Temperature
- Thermal Equilibrium
- Temperature Scales

Thermal Properties of Solids and Liquids (*18.7*)

- Thermal Expansion

Macroscopic Properties of Gases (*18.4, 19.4*)

- Ideal Gas Law
- Work done by Gas

Kinetic Theory of Gases (*20.1-20.3*)

- Assumptions of the theory
- Gas Pressure
- Kinetic Energy

First Law of Thermodynamics (*19.1, 19.5-19.7, 20.4-20.5*)

- Heat Capacity
- 1st Law of Thermodynamics
- Changes of State
- Specific Heats of Gases
- Polyatomic Gases
- Equipartition of Energy

Phase Changes (*19.2*)

- Latent Heats

Heat Transfer (*19.9*)

- Conduction, Convection and Radiation

Heat Engines and 2nd Law of Thermodynamics (21.1-21.5)

- Thermodynamic view of heat engines and 2nd Law of Thermodynamics
- Carnot Engines

Aims

- The aim of this course is to explain to the students what happens to solids, liquids and gases when the temperature is changed.
- The concepts of heat and temperature are discussed in depth by studying the *ideal gas law* and the *kinetic theory of gases* leading to the introduction of the *first and second laws of thermodynamics*.
- A number of concepts are revised and amplified e.g. *specific and latent heats and heat transfer by conduction, convection and radiation*.
- In addition the concepts involved *with heat engines* are introduced. This is all carried out with applications specifically for engineers.

Objectives

Thermal properties of solids and liquids

- Expansion of length, area and volume - coefficients of expansion.
- **Know:** $L = L_0(1 + \alpha\Delta T)$ and how to derive the area and volume coefficient from the linear coefficient.

Macroscopic properties of gases

- **Know:** The ideal gas law:
- $pV = (\frac{m}{M}) RT = nRT$ and the form for one mole: $pV = kT$
- Hence $nR = Nk$
- The work done **by** a gas is $W = \int p.dV$

Understand:

The properties the properties of the following processes

- Isothermal
- Isobaric
- Isochoric (i.e. constant volume)
- Adiabatic processes

Kinetic Theory of Gases

Understand:

- The kinetic interpretation of pressure
- The assumptions of the theory
- The concept of *temperature* and its relationship to *root mean square velocity*.

Derive:

- $pV = \frac{1}{3}Nm v_{\text{rms}}^2$
- $\frac{1}{2} m v_{\text{rms}}^2 = \frac{3}{2} kT$

Understand:

- The Kelvin temperature scale
- The concept of the internal energy of a gas and its dependence on temperature for a monatomic gas
- $U = \frac{3}{2}NkT = \frac{3}{2}nRT$

The concept of heat and the first law of thermodynamics

Know

- $dQ = dU + dW$ (with the appropriate sign convention)

Define:

- The *molar specific heats* of an ideal gas at constant volume, C_V and at constant pressure, C_p

Derive:

$$C_p - C_V = R$$

Understand:

- Why the specific heat of a monatomic gas is independent of temperature.
- How a diatomic gas can absorb heat energy by translational, rotational and vibrational modes.
- What is meant by the equipartition of energy.
- That for a monatomic gas the molar specific heats are:
- $C_V = \frac{3}{2}R$, $C_p = \frac{5}{2}R$ and $\gamma = C_p/C_V = \frac{5}{3}$
- The variation of the specific heats of diatomic gases with temperature.

Revision of the concepts of specific heats for solids and liquids and latent heats at phase transitions

Know:

- $\Delta Q = mc\Delta T$ for a temperature change
- $\Delta Q = mL$ for a phase change

Heat transfer - conduction, convection and radiation.

Know:

- $dQ/dt = kA(T_h - T_c)$ for conduction
- $dQ/dt = eA\sigma(T_1^4 - T_2^4)$ for radiation

Understand:

- Black body radiation

Heat Engines and the Second Law of Thermodynamics

Understand:

- The *Carnot cycle* and the efficiency of heat engines.
- $\varepsilon = W/|Q_h| = 1 - |Q_c|/|Q_h|$

Know:

- For a *Carnot heat engine*, $\varepsilon_c = 1 - T_c/T_h$

Understand:

- How a steam engine and refrigerator work.

Oscillations

(4 LECTURES)

TEXTBOOK: UNIVERSITY PHYSICS by HARRIS BENSON

References to Benson are given in italics

Topic Titles

- Equations of simple harmonic motion (*15.1*)
- Mass on a spring (*15.2*)
- Energy in simple harmonic motion (*15.3*)
- Simple pendulum (*15.4*)
- Damped oscillations (*15.5*)
- Forced oscillations (*15.6*)
- Oscillations in electrical circuits (*32.4-32.5, 33.6-33.7*)

Aims

- To demonstrate the importance of oscillatory behaviour in physical systems and to emphasise the wide applicability of *simple harmonic motion* (SHM).
- To understand the equations that govern SHM and the relationship between kinetic energy, potential energy and the total energy of a system in SHM.
- To introduce the concepts of damped and forced oscillations
- To provide examples of SHM in both mechanical and electrical systems.

Objectives

- To understand the difference between general oscillatory motion and SHM.
- To know that SHM arises when there is a restoring force proportional to displacement.
- To be able to define the amplitude, period, frequency, angular frequency and phase constant in SHM.
- To know and be able to use expressions for the displacement, velocity and acceleration in SHM as a function of time and to show that: $a = -\omega^2x$.
- To know *Hooke's Law* for a spring and to be able to show that: $\omega^2 = k/m$
- To describe the motion of a simple pendulum and show that it undergoes SHM with: $\omega^2 = g/l$
- To calculate the potential and kinetic energies of a mass on a spring and of a simple pendulum and to show that their sum is always constant.
- To plot graphs of displacement, velocity, acceleration and potential and kinetic energies of a system undergoing SHM as a function of time.

- To give qualitative descriptions of the effect of damping on oscillatory systems and to describe the resonant behaviour of forced oscillations.
- To describe and give examples of SHM in electrical systems.

Syllabus Details

General oscillatory behaviour

- Period and frequency.
- Harmonic oscillations.
- Expressions for displacement, amplitude, angular frequency, phase constant.
- Relation to motion in a circle.

Mechanics of SHM.

- Restoring force proportional to displacement, equation of motion, harmonic solution.
- Velocity and acceleration as a function of time.

Example - mass on a spring.

- Hooke's law, equation of motion, frequency of oscillation.
- Energy in SHM.
- Quadratic form for potential energy of spring.
- Potential energy as a function of time.
- Kinetic energy as a function of time. Constancy of total energy.

Example - simple pendulum.

- Equation of motion.
- Frequency of oscillation.
- Potential and kinetic energy.

Damped oscillations

- Resistive force and its dependence on velocity.
- Qualitative effects of increasing damping.
- Critical damping of mechanical systems.
- Forced oscillations.
- Resonance.

SHM in electrical circuits.

- Treatment of LC and LCR circuits

Appendix A

ACTION IN THE CASE OF ABSENCE.

A student's absence from the University requires to be notified for a variety of purposes including course certificates, examinations, SAAS/LEA Maintenance Allowances and Fees. The following is a guide to what to do if absence occurs. Students should ensure that they also meet any departmental or course requirements concerning notification of absence.

1. GENERAL ABSENCE DUE TO ILL-HEALTH OR OTHER GOOD CAUSE

	Duration	Reason	Form of Notice	Notice to be given to	Follow-up action
1.1	Up to 5 term-time days excluding Saturdays and Sundays	Ill-health	GU student self certification of absence form	Senior Faculty Adviser	Senior Faculty Adviser to inform student's Adviser and depts at discretion
1.2	Up to 5 term-time days excluding Saturdays and Sundays	Other than ill-health	Letter from student	Senior Faculty Adviser	Senior Faculty Adviser to inform student's Adviser and depts at discretion
1.3	6 or more term-time days excluding Saturdays and Sundays	Ill-health	Doctor's Medical Certificate	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*
1.4	6 or more term-time days excluding Saturdays and Sundays	Other than ill-health	Letter from student, family member or Adviser	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*

2. ABSENCE DUE TO ILL-HEALTH OR OTHER GOOD CAUSE WHICH PREVENTS THE SUBMISSION OF A COURSEWORK ASSIGNMENT BY THE DUE TIME

	Duration	Reason	Form of Notice	Notice to be given to	Follow-up Action
2.1	Up to 5 term-time days excluding Saturdays and Sundays	Ill-health	GU student self certification of absence form	Senior Faculty Adviser	Senior Faculty Adviser to inform student's Adviser and depts at discretion
2.2	Up to 5 term-time days excluding Saturdays and Sundays	Other than ill-health	Letter from student	Senior Faculty Adviser	Senior Faculty Adviser to inform student's Adviser and depts at discretion
2.3	6 or more term-time days excluding Saturdays and Sundays	Ill-health	Doctor's medical certificate	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*
2.4	6 or more term-time days excluding Saturdays and Sundays	Other than ill-health	Letter from student, family member or Adviser	Registry	Registry to inform depts, student's Adviser and Senior Faculty Adviser*

3. ABSENCE FROM ANY EXAMINATION DUE TO ILL-HEALTH OR OTHER GOOD CAUSE

	Duration	Reason	Form of Notice	Notice to be given to	Follow-up Action
3.1	Any	Ill-health	Doctor's Medical report explaining the reason for absence or medical certificate only in the case of class exams	Registry within one week	Registry to inform all relevant depts and Senior Faculty Adviser
3.2	Any	Other than ill-health	letter from student, family member or Adviser or Student Counsellor	Registry within one week	Registry to inform all relevant depts and Senior Faculty Adviser

* The Head of the Registry and the Senior Faculty Adviser will consult and decide when it is necessary to notify an absence to the SAAS/LEA.

A Head of Department reserves the right to require the student to provide a doctor's medical certificate or report, for which the doctor may charge a fee. If payment of such a fee will cause the student financial hardship, he/she should seek advice from Registry on taking out an emergency Student Loan or applying to the Student Hardship Fund.

Student Self Certification of Absence forms can be downloaded from the Registry Forms Library.