COURSE GUIDE

PHY132 electricity, magnetism and modern physics is a one semester 2 credits, foundation level course. It will be available to all students to take towards the core module of their B.Sc. Education, and other programmes
B.Sc computer science, environmental studies and The course comprises 20 study units , which involve basic principles of Electricity, Magnetism and Modern Physics. The material ha been developed in such a way that students with at least a credit pass at the ordinary level of equivalent will follow quite easily.
There are no compulsory pre requisites for the course. However, you are strongly advised to have adequate grasp of Further Mathematics or Applied Mathematics.
This course guide tells you briefly what the course is about, what course materials you will be using and how to work your way through these materials. Is suggests some general guidelines for the TIME to complete it successfully.

Newto nian nics to

Quant um nics.
Giving you insight into possibl future develo pment these areas.
Course Objectives The course sets overall objectives, to achieve the aims set out above.
In addition, each unit also has specific objectives. The unit objectives are always included at the beginning of a unit; you should read then before you start working through the unit.

Describe the theory of electricity, magnetism and electromagnetic radiation

Explain the concepts of electric and magnetic fields.
Measure and compute electric current in d.c and a.c. circuit.

Identifying the advantages and disadvantages of x-rays

Describe the structure of the nuclear atom.
Distinguish between geographic and geomagnetic meridians.
Describe the terrestrial magnetic field.
Distinguish between nuclear fusion and nuclear fission.
Describe the generation and distribution of electric power.
Working Through This Course To complete this course you are required to read the study units, read set books and read other materials provided by NOUN.

[...]

Each study unit consists of two to three weeks' work, and includes specific objectives. Each unit contains a number of self-tests. In general, these selftests, question you on the material you have just covered or require you to apply it in some way and, thereby, help you to gauge your progress and reinforce your understanding of the material. Together with tutor-marked assignments, these exercises will assist you in achieving the stated learning objectives of the individual units and of the course.

Set Textbooks Duncan Tom Physics.

S.M. Geddes Advanced Physics. Macmillan Education Ltd. London

McKenzie A.E.E A Second Course of Electricity. The University Press, Cambridge

Assignment File The assignment file will be supplied by NOUN. In this file you will find all the details of the work you must submit to your tutor for marking. The marks you obtain for these assignments will count towards the final mark you obtain for this course. Further information on assignments will be found in the assignment file itself and later in this course guide in the section on assessment.

Presentation Schedule The presentation schedule included in your course materials may show the important dates for the completion of tutor-marked assignments. Remember, you are required to submit all your assignments by the due date as dictated by your facilitator. You should guide against falling behind in your work.

There are two aspects to the assessment of the course.

[...]

Dr. C. A. Okonkwo

References

A physicist, Benjamin Franklin demonstrated as long ago as 1752 that thunder clouds are charged with electricity. These charged clouds, when discharged in the atmosphere, give rise to a great spark, which is referred to as lightening. It will interest you to know that the amount of electric current during the discharge is about 20KA.

The electric discharge which gives rise to lightning also produces a great amount of heat. In a fraction of a second, temperature rises to about 15000 0C.

The lightening develops in a small area which is about 20cm in width.

However, as a result of the heat amount of great produced in that small area the air molecules move fast and cause the intense sound which we call thunder.

Show that the total electric charge in an isolated system is conserved State Coulomb’s law and use it to find the electrostatic force between two charges State the superposition principle

Calculate the vector sum of the electric field strength due to a number of point charges.

Sketch the field lines for some simple distribution of charge.

Types of charges The ancient Greeks discovered that amber when rubbed with silk acquired the property of attracting light objects such as pieces of chaff . William Gilbert discovered that other substances exhibit the same effect, and that the magnitude of the effect is roughly proportional to the area of the surface rubbed. He was then led to the idea of a charge of electricity.

Du Fay discovered that there are two kinds of electricity. Two ebonite rods when rubbed with fur exert a force of repulsion on each other. Two glass rod rubbed with silk also repel one another. However, an ebonite rod which has been rubbed with fur attracts a glass rod which has been rubbed with silk.

Any substance rubbed with a different substance acquires a charge of electricity, and is found either to repel charged ebonite and attract charged glass, or vice versa. Since the two kinds of electricity can neutralize each others effect, one is called positive and the other negative. Note that the choice as to which is positive was purely arbitrary. Glass rubbed with silk is said to have a positive charge and ebonite rubbed with fur a negative charge.

In symbols, q=

It ………………………………………….3.1

Where q is in coulombs, if I is in ampere a.d t is in seconds. The main reason for defining the coulomb in terms of ampere is that it is easy to maintain, control and measure a current through a conductor rather than the amount of charge.

Conservation of Charge In the method of charging by friction which is discussed in section, no new charges are created. The algebraic sum of the individual charges, that is the net charge, always remains constant.

The charge conservation law may be stated as follows

Quantization of charge The smallest charge that is possible to obtain is that of an electron or proton.

The magnitude of this charge is denoted by e. A charge smaller than e has not been found. If one determines the amount of charge on any charged body or any charged particle or any ion, its charge is always found to be an integral multiple of e, that is e, 2e, 3e, and so on. No charge will be a fractional multiple of e like 0.7e or 2.5e. This is true for both negative and positive charges and is expressed as q = ne

We can turn the above expression of proportionality to as equation by writing F = Q1 Q2

………………………………….3.3

K =

1 ………………………………….3.4

Where the constant depends on the material surrounding the charges, and is called permittivity.

The permittivity of air at standard temperature and pressure is

005o. Therefore, we can usually take Eo as the value for air.

We shall see in Module 2 that a more widely used unit for permittivity is the Farad per metre .

You should note that Coulomb's law applies to point charges.

F =

The minus sign shows that the force is in the negative x-direction that is towards west.

Therefore, it is a force of attraction.

In the last section, we considered the electrostatic forces between two charges.

Worked example

10 cm F12 q3 = +4.0μc q1 = -1.0uc In figure 3., q1 = 1.0μc, q2.0μc and q3 = 4.0μc. Find the electrostatic force on q1 to the two other charges. You should express your result as a magnitude and direction.

Similarly, the force on q1 due to q2 is

√2 + 2 2.01N and it make an angle = tan -1 at that point is defined by the equation.
= f/q or F = qE ……………………………………..3.5
The magnitude of E is the force per unit charge and its direction is that of F.
Thus E is a vector.
Calculation of the Electric Field In order to measure the electric field in a given region, we introduce a test charge and measure the force on it. However, we should realize that the test charge q exerts forces on the charge that produce the field, so it may change the configuration of the charges.

E = F

Equation 3.7 gives the field arising due to the charge q at any location which is at a distance r from q.

What is the situation when the electric field is due to two or more charges?

The answer is simple. Since the electric force obeys the superposition principle, so does the electric field . Therefore, the field at a given point due to two or more charges is the vector sum of the fields of individual charges.

[...]

= 1.08 x 10 NC in the direction shown in Fx, 3.

START

Now we have to add the two forces vertically. If we resolve E1 and E2 into components along the x-axis and y-axis, it is clear from Fig.

EB =

Field lines An electric field can be represented by electric field lines or lines of force. The lines are drawn so that The field line at a point gives the direction of E at the point. This is the direction in which a positive charge would accelerate.

EA

Since a field lines is also defined as a path along which a free, positive, point charge would travel in an electric field, it is always drawn with an arrowhead indicating the direction of travel of the position charge.

Two unlike charges

Two like charges You have now gone through the first unit of the course – electricity and magnetism. The most central point pertains to the electric charge. As you would see the concept of electric charge cuts across virtually all aspect of the course. You have also leant about the electric fields due to a single charge and those due to a system of charges.

E=

Where r is a unit vector pointing from the point charge q to the location at which the electric field is being calculated.
qn Electric lines of force are only a visual way of representing an electric field. The tangent to a line of force at any point shows the direction of the electric field at that point.

John Murray Ltd, London 1982

Electrostatics in Free Spare – PHE-07. India Ghandi National Open University .

Electric Flux

Applications Of Gauss's Law The Electric Field Of A Spherical Charge Distribution Tutor Marked Assignments Gauss's law expresses the relation between an electric charge and the electric field that it sets up. It is a consequence of Coulomb's law. Although it contains no additional information, its mathematical form enables us to solve many problems of electric field calculation far more conveniently than through the use of Coulomb's law.
In unit 1, you learnt that electric field at any point is given by the force experience by a unit positive charge placed at that point. In this unit, we will develop the concept of flux of an electric field and then arrive at the Gauss's law.

When = 0; the number of lines of force crossing the surface is maximum

When = 900, the number of lines of force crossing the surface is zero.
We can now see that the number of lines of force crossing a surface is proportional to the projection of the field on to the perpendicular to the surface, i.e cos -.
Putting together quantities on which the number of lines of force depends gives the relationship.
= E . S – 3.1.
Where E is the electric field vector and S is a vector whose magnitude is equal to the area of the surface and whose direction is that of the perpendicular to the surface.

The quantity on the left side of Eq. is an indefinite number because we can draw as many lines of force as we like.

= -E ds = - ER2

Since the area of the cap is R2.

Similarly, for the right hand cap

Since the angle = 0 for all points on the cap.

We can now sum up the total flux through the cylindrical surface S as

Therefore, the total outward flux of the electric field through the closed surface of figure 3.2 is zero.
In section 3.

We can

= ∫ E. ds q enclosed…………………………….3.4
To evaluate the proportionality constant in equation 3.3 or 3.4, let us consider a positive point charge q in free space and a spherical surface of radius R centred on q as shown in fig. 3.3.
The flax through any surface is given by equation, i.e
= ∫ E .ds = ∫ E .ds cos ………………….3.5
Where is the angle between the direction of the electric field and the outward normal to the surface.

Then the flax becomes

4R2 = q/Eo ……….3.6
Comparing eqns 3.4 and 3.6, we observe that the proportionality constant is
1/o.
= ∫ E. ds = q enclosed ……………………3.7
Equation 3.7 is known as Gauss's law. It tells us that the electric flax through the sphere is proportional to the charge and is independent of the radius of the surface.
Application of Gauss's Law Gauss's law applies to any hypothetical closed surface and enclosing a charge distribution. However, the evaluation of the surface integral becomes simple only when the charge distribution has sufficient symmetry. In such situation, Gauss's law allows us to calculate the electric field far more easily than we could using Coulomb's law. Since gauss's law is valid for an arbitrary closed surface, we will use this freedom to choose a surface having the same symmetry as that of the charge distribution to evaluate the surface integral. We shall now illustrate the use of Gauss's law for some important symmetries.
A charge distribution is spherically symmetric if the charge density at any point depends only on

the distance of the point from a central point and not on the direction.
Figure 3.4 represents a spherically symmetric distribution of charge such that the charge density is high at the centre and zero beyond r.

The Electric Field of a Spherical Charge Distribution

Let us consider a total charge Q which s spread uniformly throughout a sphere of radius R as shown is figure 3.6.

What is the direction of the electric field?

Answer: At any point on the Gaussian surface, the field is radically directed, i.e perpendicular to the surface, so that the angle between the normal to the surface and the electric field direction is zero.

Since the charge enclosed within the sphere S1 is Q

Equation 3.11 shows that the field at all points on surface S1 is the same as if all the charges within the surface S1 were concentrated at the centre.
For points inside the charge distribution, the electric field depends on how the charge is distributed. This is because any Gaussian sphere with r< R1 such as surface S2 in figure 3.6 does not enclose the entire charge Q. The charge enclosed depends on the charge distribution.

Q r2

Illustrate with a sketch the variation of the electric fields both inside and outside a spherical charge distribution.
fig . 3.7
The electric field inside the distribution increases generally with distance from the centre .

Gussian Surface

By symmetry, the electric field will point radially outward from the axis and its magnitude will depend only on the perpendicular distance from the axis.. Let us find expression for the electric field, E at a distance r from the line charge.

The flax through the cylindrical surface is

………..3.13
Where 2 rℓ is the area of the curved surface.
The flax through the end of the cylinder is zero because the field lines are parallel to the plane caps of the Gaussian surface. Mathematically, E and ds are perpendicular, so that cos = 0 in the scalar product E. ds.

2 o rℓ

Suppose the charge is distributed uniformly within the wire with charge density .
Figure 3.

Or E = r

……………………….3.16
Thus the electric field at a point inside an infinite uniformly charged wire is radially directed and varies as the distance from its axis.

How does the electric field due to a charged wire or cylinder depend on its radius?

Equations 3.15 and 3.16 show that electric field due to a charged wire or cylinder does not depend upon its radius. In effect, the field behaves as if the charge on the wire or cylinder were concentrated in a line along its axis.
When the charge density depends only on the perpendicular distance from a plane, the charge distribution is said to have plane symmetry. The electric field is everywhere normal to the plane sheet as shown in figure 3.10, pointing outward, if positively charged and inward, if negatively charged.
Fig 3.10 A charged distribution with plane Symmetry showing electric field To find the electric field at a distance in front of the plane sheet, it is required to construct a Gaussian surface.

The electric field outside a spherically symmetrical shell with radius r and total charge q is directed radially and has magnitude

4 o The charge behaves as if it were all concentrated at the centre of the sphere.

E = / 2o

Where is the surface charge density.
The electric field in a certain space is given by E = 200 r. How much flux passes through an area A if it is a portion of The xy – plane The xz – plane The yz – plane A flat sheet of area 50cm2 carries a uniform surface charge density .

Use Gauss's law to prove that the electric field inside the volume and at a distance r from the centre, is E = er

What is the electric field at a point outside the spherical volume at a distance r from the centre ? Express your answer in terms of the total charge q within the spherical volume.

Reference And Other Resources

College Physics. Sears F.W, Zemansky M.W and Young H.D.
Addison-Wesley publishing Company, London.
Electrostatic in Free Space.

ELECTRIC POTENTIAL

Equipotential Surface Potential due to a Point Charge Potential due to a System of Charge You will recall from your study of PHY 101. Elementary mechanics that work isI done when the point of application of a force undergoes a displacement in its own direction. If a body A exerts a force on another body B and work is done, a transfer of energy occurs which is measured by the work done. For example, if we lift a mass, m through a vertical height, h, the work done, W by the force we apply is W = mgh. The energy transfer is mgh and we consider that the system gains and store that amount of gravitational potential energy which is obtained from the conversion of chemical energy by our muscular activity.

The choice of the zero of potential is purely arbitrary and whilst infinity may be a few hundred metres in some cases, in atomic physics where distances of

10m are involved, it need only be a very small distance away from the charge responsible for the field.

Compute the electric potential at a point due to a dipole and a quadrupole Equipotential Surfaces

All point in a field which have the same potential can be imagined as lying on a surface, called an equipotential surface. When a charge moves on such a surface no energy change occurs and no work is done. The force due the field must therefore act at right angles to the equipotential surface at any point.
Therefore, equipotential surfaces and field lines always interst at right angles.

Potential due to a point charge

+Qo We wish to find the potential at point A in the field of an isolated point charge +Q situated at point 0, such that 0 A = r as shown in fig. 3.2.
Let us imagine a very small point charge +Qo is moved by an external agent from C distance x from A, through a very small distance x to B without affecting the field due to +Q.

Potential due to a system of charges

Let us now consider a system of charges. Like in the previous case of electric field we shall find the superposition principle very useful.

4oN

You will note in eq. 3.4 that each charge is acting as if no other charge is present.
The potential at point P. may be written in a summation form as qi/ri ……………………….3.5 i = 1

[...]

Let us write down the amount of work done in bringing a unit positive charge from infinity, first to point A and then to point B, shown in figure 3.3.

[...]

We observe that the work done is carrying the charge in an electric field is independent of path.
It is just this path independence that enables us to define the concept of potential.
= q1 ……….3.7

[...]

= EQx If the p.d between B and A is V, we have by the definition of p.d.

Is potential gradient a vector or a scalar?

You notice that potential gradient involves displacement .
Therefore, it is a vector.
It is measured in volts per metre . The Vm-1 and NC-1 are both units of E, but the Vm-1 is the one that is commonly used.
If the electric field E is uniform, that is it is constant in magnitude and direction at all points, it follows that dv is constant i.e dv = -E ………………….3.8

16 x 1015m2 5-2 x 101ms-1

A pair of equal and opposite charge, q, separated by a vector distance a is called a dipole. . The vector a, which is also along the axis of the dipole, is drawn from the negative to the positive charge.
A molecule consisting of a positive and negative ion is an example of an electric dipole in nature.

Electric Field at a point P along the axis of the dipole

figure 3.
Electric dipole AB with centre C and axis a .
The point P is along the axis.

Let the distance between the mid-point of the dipole and the point which is along axis be equal to r.

Potential due to a dipole

Let us evaluate the potential Vp at P, a distance r from the mid-point C of the dipole. . the line joining P to C makes an angle with the dipole axis, a .

0 when = /2

We can conclude from equation 3. 10 and 3.
The dipole potential varies as 1/r2 and the field as 1/r3 as compared to a point charge for which the potential varies as 1/r and the field as 1/r2.
Thus the potential and field decrease more rapidly with r a dipole than for a point charge.
The dipole potential vanishes on points which lie on the perpendicular bisector of the dipole axis. Hence no work is done in moving a test charge along the perpendicular bisector.
In this unit, you have learnt to compute the electrostatic potential of a charge distribution. You have seen that if you first derive the expression for the potential, being a scalar quantity, it facilitates the derivation of the expression for the electric field at a point. The concept of potential is also important because electric potential is loosely linked to the work done by the electric charge. For the computation of the total potential due to a system of charges, we have again found the superposition principle very handy.

50 cm

References and other Resources An Introduction to Higher Secondary . Physics. J. M. Das Sarma Modern Book Agency Private Ltd.

[...]

Method of Images In the previous units, we have discussed the electric field, E and the potential, due to discrete charge distributions. In the process, you had to evaluate a line integral. On the other hand, you can also calculate E from by a simple differentiation.

Calculate the electrostatic potential energy for a given charge distribution

Show that the electrostatic force is conservative.

We saw that

……………..3.1
is a unit vector along the direction of increasing r.
We want to drive an expression for the potential due to the wire at a point P.
Define the Potential at point P.
We saw in unit 3 of this module that the negative of the line integral of the electric field between

infinity and any point gives the value of the potential at that point, i.e, r = - ∫r E . dr …………………………3.2

Since Ŷ and dr are in the same direction, we have r - =

Now let us try to evaluate the potential with respect to infinity by letting r 1 go to infinity. We notice from equation 3.3 that r1 anywhere in the vicinity of the linear charge distribution , goes to infinity.

Does this mean there is no Solution to the Problem?

The issue of an infinite potential does not pose any problem. In practical situation, we are interested only in the difference in potential. Do not forget that the choice of infinity for zero potential is only for convenience.

What is an equipotetnial Surface ?

By now you have understood that an equipontial surface is the locus all point having the same potential.

I n

We wish to find the potential at some point P lying on the axis of a uniformly charged circular disc. The point P is at a distance r from the centre 0 of the disc and the line joining p to 0 is perpendicular to the plane of the disc.
For calculating the potential, first consider a narrow circular strip of the thickness dx at a distance x from its centre.

[...]

A large number of terms are involved . Therefore, the summation has to be replaced by integration. In other words, we have to integrate equation 3.

[...]

-r ………………..3.7
Equation 3.7 shows that, for a point at the centre of the disc for which r = 0, reduces to = a/2o.

Electrostatic Potential Energy

Work done is assembling charges is stored as potential energy of the charges.
Suppose there are two charges q1 and q2 which are initially very far apart. Let q1 be fixed at r1 and q2 be brought from infinity to a position r2. see fig 3.5
You recall that the amount of work required to bring q2 from infinity is equal to the charge q2

multiplied by the potential at r2 due to q1, that is q1…………………3.8
This is equal to the work done in assembling the two point charges q1 and q2 at r1 and r2 by bringing them close together. The work done is stored in the system and is usually interpreted as the electrostatic potential energy of the system of two charges.

4o r-3-r1-1

……….. 3.9

j =1 k = 1

4o / r1-rk/ Equation 3.10 requires some clarification. Please read the following explanation carefully.
There is a factor 2 before the summation sign to make sure that the contribution from each pair of charges is included only once. For example, for pair q1 and q2, we get contribution when j = 1 and k = 2, and similarly when k = 1 and j = 2.

j=1 k=1

4o / rj-rk/ Note that in equation 3.11 for each value of j , the summation on k avoids that value of k which is equal to j.

J=1

Equation 3.12 implies that for calculating the electrostatic potential energy for a group of point charges, we consider each charge in turn, and the corresponding potential at its position due to all other charges.

Nature of Electric Force You have seen in unit 3 that the work, W done is moving a charge q from point A to a point B in the region of the electric field E is

-∫BA F.dr = -q ∫BA E. dr
Where F is the electrostatic force on q. You also saw in the same unit that the line integral of the electric filed, i.e.
∫BA E .dr is independent of the path between A and B. This implies that the line integral of the electrostatic force, that is ∫BA E.dr, is also independent of the path between A and B.

Name another type of conservative force in Physics?

The gravitational force You have now learnt how to derive expressions for and evaluate the electric potential for some continuous charge distributions with simple geometry.

The potential at a point which is at a distance r on the axis of a charged circular disc of radius a is

Where is the charge per unit area on the disc.
The electrostatic potential energy is the energy stored in a system of charges.

The electrostatic potential energy for a group of charges is written as

Where j is the potential at the position of charge qj due to all the other charges.
The electrostatic force is conservative. This is a consequence of the fact that the work done in taking a charge around a closed path is If an electric field E equals zero at a given point, does it imply that the potential, equals zero at the same point? Give an example to illustrate your answer An infinite charged sheet has a surface charge density of 1.0 x 10-7

[...]

Variable Air Capacitor In unit 1 of this course, we derived the Coulomb's law of electrostatic force for a situation in which the surrounding medium is vacuum or air. Of course, this is not always the case. In practice, is come across situations when the electric field is in a material medium. However, we must distinguish two different situation. The first is when the medium consists of insulating materials , also known as dielectric, that is those materials like glass, wood, mica, etc, which do not conduct electricity. The second is when the medium consist of conduction materials, i.e materials such as metals which are conductors of electricity.

[...]

on it. The amount of charge it will take depends on the electric field thereby created at the surface of the conductor. If this is too great there is a breakdown in the insulation of the surrounding medium, resulting in sparking and discharge of the conductor. The change in potential due to a given charge depends on the size of the conductor, the material surrounding it and the proximity of other conductors.

But E is also given by, Vab l

Where Vab is the potential difference between the plates and is their separation.

Ql Hence the capacitance of a parallel –plate capacitor in vacuum is C =

In practice, equation 3.2 is not strictly true due to non-uniformity of the field at the edge of the plates.

[...]

This corresponds to a square with side 10.6 x 103m= 10.6km. You can now appreciate that the farad is such a large unit of capacitance and it is necessary to have sub-multiples of it as discussed earlier.

Using the relation $Q = CV$, we have

$Q2/2C = ½ CV = ½ QV$ joules …….3.3

[...]

Figure 3.2 shows three capacitors of capacitances $C1$ $C2$ and $C3$ which are connected in parallel.

$Q = V$

If C is the capacitance of the single equivalent capacitor, it would have charge Q when the p.d across it is V.

VC

In other words, the charges on capacitors in parallel are in the ratio of their capacitances.
Capacitors in Series The capacitors in figure 3.3 are in series and have capacitances $C1$, $C2$ and $C3$.
Suppose a p.d of V volt applied across the combination causes the motion of charge from plate Y to plate A so that a charge $+Q$ appears on A and an equal but opposite charge $– Q$ appears on Y.

$C2$ $C3$

If C is he capacitance of the single equivalent capacitor, it would have a charge Q when the p.d. across it is V. $/C = 1/C1 + 1/C2 + 1/C3$
Note that: For capacitors in parallel, the p.d across each is the same.
For capacitors in series, each has the same charge.

$V1 = 2V$, and $V4 = 4V$

The p.d. across the combined capacitance $C4$ equals that across each of $C2$ and $C3$. Hence $V2 = V3 = V4 = 4V$

[...]

Where Eo is the permittivity of free space.

Relative Permittivity, Er

Experiment shows that inserting an insulator or dielectric between the plates of a capacitor increases its capacitances.

Taking a parallel-plate capacitor as an example, we have Er = c/co =

EA/ = E/o ……………..3.3 oA/ Where E is the permittivity of the dielectric and o is that of a vacuum .

A parallel capacitor consists of two square plates each of side

25cm, 3.0mm apart. If a p.d. of 200v is applied, calculate the charge on the plates with

Air; and

Paper of relative permittivity 2.5, filling the space between them Fig. 3.5 I V = 200volts Figure 3.5 is a schematic representation of the parallel –plate capacitor.

The charge on one plate is Q = CV

= Er o A where Er is the relative permittivity of the paper Therefore, the charge on one plate is increased by the factor Er on the introduction of the paper between the plates.
x 3.
Q = 9.
When a dielectric material is subjected to a sufficiently strong electric field, it becomes a conductor. This phenomenon is known as dielectric breakdown.
The onset of conductor, associated with cumulative ionization of molecules of the material, is often quite sudden, and may be characterized by spark or arc discharges.

Electrolytic

Variable Capacitor fig.

Trimmer

Waxed paper, plastics and mica are all used as dielectrics. Typical constructions are shown in figure 3.6
also, their stability is poor – up to 10 percent changes occurring with age.
Plastic, ceramic and mica types have better stability and can be used at much higher frequencies.
The values of the capacitances for these four types seldom exceed a few microfarads and in the case off mica the limit is about 0.01μF.
Electrolytic Capacitors An electrolytic capacitor consists of two electrodes of aluminum, called

the positive and the negative plates. The positive plate is electrolytically coated with a thin layer of aluminium oxide. This coating serves as the dielectric.
The two electrodes are in contact through the electrolyte which is a solution of glycerine and sodium . There are two types of electrolytic capacitors- the wet type and the dry type.
Electrolytic capacitors have capacitances up to 105μF and are quite compact because the dielectric can have a thickness as small as 10-4mm and net suffer breakdown even got applied p.d.s of a few hundred volts.
The are not used in alternating current circuits where the frequency exceeds about 10 KHz.
Their stability is poor but in many cases this does not matter.
Variable Air Capacitor A very common capacitor whose capacitance can be varied continuously is used for tuning radio receivers.

If two capacitors with capacitances C1 and C2 are connected in series, the effective capacitance is C = C1 C2

The permittivity, E of a dielectric medium is E = r o where Er is the relative permittivity and o is the permittivity of vacuum A capacitor has n similar plates at equal spacing, with the alternate plates connected together.

C1 = 1μf

The capacitance of a variable radio capacitor can be changed from 50PF to 950PF by turning the dial from 00 to 1800.

What is the energy of the capacitor in this position?

Electrostatics in Free Space. PHE-07. Indira Gandhi National Open University. 2001
College Physics.

ELECTRIC CURRENT

Resistance, Resistivity and Conductivity Electromotive force We have seen that apart from gravity, the only force between two electric charges is the Coulomb force. In terms of applications, the importance of electrostatics is not well known to the ordinary person. Historically, things really got exciting when the charges started moving to form an electric current.

Define resistance, resistivity and conductivity

Explain what are meant by the electromotive force and internval resistance of a battery or generator.

Explain the terminal potential of a current source

Do calculations involving resistances and e.m.f.s.

When there is a net flow of charge across any area, we say there is a current across that area. For example, if the ends of a conductor, say copper wire are connected to a battery, an electric field E will be set up at every point within the conductor. As a result of the field, the electrons in the wire will move in the direction opposite to that of the field and give rise to an electric current in the wire.

The electric current is defined as the amount of charge passing through a given cross-section of the wire per unit time.

For the wire shown in figure 3.1, the current, 1 is defined as the rate at which charge passes through a plane perpendicular to the axis of the wire. For example, if a charge q crosses the cross-section, S in figure 3.1 in time t then the average current 1 is given by net charge transferred

Time taken q/t ………..3.1

When the current is not constant, i.e. the current varies with time; we define an instantaneous value I . If a charge of Δq crosses the shaded area, S in a time Δt, the instantaneous current is given by I = lim

Δq = dq ……………………………3.2

Δt ◊o Δt Equation 3.1 and 3.2 show that the unit of current is coulombs per second. In the SI system of units, I coulomb per second is known as the ampere Current is a scalar quantity. Although you will soon see that a current in a wire is represented by an arrow. Such an arrow only shows direction of flow of charges along a conductor.

By convention, the direction of current is defined as that direction in which a positive charge moves.

I A

Let us consider a conductor with unifom cross-sectional area A and length l as shown in fig.

JA

And the p.d., V between the ends is V = El ……………………………3.9

Solving these equations for J and E, respectively, and substituting the results in equation 3.8, we obtain V = el ………………………..3.10

Thus the total current, I is proportional to the potential difference. The quantity el/A for a particular specimen of material is called its resistance R el ……………………3.11

Equation 3.10 then becomes V = IR ………………………..3.12

This is Ohm’s law.

Show that the unit of resistivity is ohm metre A ‘perfect’ conductor would have zero resistivity, and a perfecrt’

insulator an infinite resistivity. Metals and alloys have the lowest resistivities and are the best conductors. The resistivities of insulators exceed those of metals by a factor of the order of 1022.

You should note that resistivity depends on the nature of the conducting material whereas the resistance depends not only on the nature of the medium but on its physical dimensions.

metal superconductor semiconductor The resistivity of all metallic conductors increases with increasing temperature as shown in fig. 3.4. . Over a temperature range that is not too great, the resistivity of a metal can be represented approximately by the equation T = o …………..3.14

AR with the symbols having their usual meanings

Now, l = 0.80m, A = x 0.457 2 x 10 -6 m2
= 2.39 x x 0.2285 x 10-6
= 4.90 x 10 -7Ω m The resistance of a copper coil at 20°C is 300l.

RT = Ro

When using this equation where accuracy is importance the reference temperature To should be 00C and Ro, the resistance at 00C.

R6o = 30

Conductivity We can write eq. 3.8 in the form J = 1/ E = E ……………………….3.15

The SI unit of conductivity is Electromotive Force

There is no doubt that you are familiar with the two terms –batteries and generators which are used in our homes, officers, towns and villages. They are sources of electric current. Perhaps you are putting on a wrist watch that operates on a battery.
Batteries and generators are able to maintain one terminal positive and the other negative .
If we consider the motion of positive charges, then a battery, for example, moves positive charges from a place of low potential through the battery to a place of high potential .

Definition

The electromotive force of a source is the energy converted into electrical energy, when unit charge passes through it.
Unit of e.m.f like the unit of p.d is the volt.
Note 1.
Although e.m.f and p.d. have the same unit, they deal with different aspects of an electric circuit.
Whilst, e.m.f applies to a source supplying electrical energy, p.d refers to the conversion of electrical energy in a The term e.m.f. might appear to be misleading to some extent, since it measures energy per unit charge and not force.

What has happend to the “lost” energy per coulomb?

Answer 1 A battery or generator is on open circuit when it is not maintaing current.
The deficiency is due to the cell itself having some resistnace.

Energy

+ per coulomb on internal resisnce battery p.d. across r v 3.15
Where V is the p.d. across the internal resistance of the cell, a quantity whcih cannot be measured directly but only by substracting V from E.

[...]

Can you now explain why i said at the begining of this section that a high resistance voltmeter connected across a cell on open circuit records its e.m.f only very nearly?
This is becasue the volmeter must take some current, however small, to give a reding. A small part of the e.m.f is, therefore, lost in driving current through the internal resistance of the battery.
A potentiometer is used to measure e.m.f to very high accuracy.

RT

Ro The variation of resistivity with temperature follows the same linear form.
For a device obeying ohm's law, the current through the device depends on the p.d. between its terminals.

What is the internal resistance of the battery?

What is the e.m.f of the battery?

A second wire of the same material has the same weight as the

100m length, but twice its diametric. Evaluate its resistance.
A wire has a resistance of 10.0 ohms at 20.0 0c and 13.1 ohms at 1000c. Obtain a value for its temperature coefficient of resistance.
A television set shoots out a beam of electrons.
10uA.

Ammeter and Voltmeters The Wheatstone's Bridge The metre Bridge The Potentiometer

Most electric circuits do not consist simply of a single source and a single external resistor as we saw in unit 6. Usually, an electric circuit may comprise a number of sources, resistors, or other elements such as capacitors, motors, etc. interconnected in a network.
We shall begin this unit with the study of some techniques of handling problems involving networks that cannot be reduced to simple series and parallel combinations.

By the time you have studied this unit, you will be able to

Do simple calculations involving series and parallel combinations of resistors in an electric

circuit.
Solve problems pertaining to networks by the application of kirchoff’s rules.
Understand the principle of the wheatstones bridge and the use of its practical form in the laboratory for the measurement or comparison of The method of using the potentiometer for the comparison of e.m.f.s or the measurement of e.m.f, current or resistance.
Figure 3.1 shows two different ways in which three resistors having resistances R1, R2 and R3 might be connected between points a and b. In fig the resistors only provide a signle path between the points.

Vab = IR or R = Vab J

Where Vab is the p.d between the terminals of the network and I is the current at the point a or b.

Showing that the equivalent resistance of any number of resistors in series equals the sum of their individual resistances

For the parallel combination of resistances in fig. 3.1 , the p.d. between the terminals of each must be the same and equal to Vab.

E = 18V, r = 0

Figure 3.2 shows the successive steps on the reduction to a single equivalent resistance. The 6Ω and 3Ω resistors in part are equivalent to the single 2Ω
resistor in part and the series combination of this with the 4Ω resistor results in the single equivalent 6Ω resistor in part .
Work out and check the statements in the above paragraph by calculations.
In the simple series circuit of part C, the current is 3A.

Branch Points

A branch point in a network is a point where three or more conductors are joined.

Loop

A loop is any closed conducting path.
Identify the branch points and loops in fig.

Point rule

The algebraic sum of the currents toward any branch point is zero.

Loop rule

The algebraic sum of the e.m.f.s in any loop equals the algebraic sum of the IR products in the same loop.

$\sum E = \sum IR$ ………………3.

The point rule merely states formally that no charge accumulates at a branch point. The second rule is a generalization of the circuit equation $E = IR$, and reduces to this equation of the current I is the same in all resistances.

At point b, $\sum I = I_1 + I_2 + I_3 = 0$ ……………………

Since there are only two branch points, there is only one independent point equation. If the point rule is applied to the other branch point, point a, we have $\sum I = -I_1 - I_2 - I_3 = 0$.
Which is the same equation with signs reversed.

[...]

The rule can be applied to FADCF also, but only these equations are required. Moreover, as you would see, this fourth equation can be derived from the above so that it contributes nothing new.

Ammeters and Voltmeters

Most ammeters and voltmeters are basically galvanometers of the moving – coil type which have been modified by connecting suitable resistors in parallel or in series with them. Moving coil instruments are accurate and sensitive.
Connecting an ammeter or voltmeter should cause the minimum disturbance to the current or p.d it has to measure. An ammeter is normally connected in series so that the current passes through the meter. The resistance of an ammeter must therefore be small compared with the resistance of the rest of the circuit. Otherwise, inserting the ammeter changes the current to be measured. The perfect ammeter would have zero resistance, the p.d. across it would be zero and no energy would be absorbed by it.

Ammeter terminal

To obtain the value S of the shunt, we use the fact that the meter and the shunt are in parallel.

$999 \times S$

As you would see, the combined resistance of the meter and the shunt in parallel will now be very small and the current in a circuit will be virtually undisturbed when the ammeter is inserted.
Conversion of a Microammeter into a Voltmeter To convert the same moving-coil meter of resistance 1000Ω and fullscale deflection 100μA to a voltmeter reading 0-1V,a resistor of high value must be connected in series with the meter.

$M + 1000 = 1$

The Wheatstone Bridge The most used method of measuring resistance is the Wheatstone bridge.
This has the great advantage of being a null method; that is to say adjustments are made until a galvanometer is undeflected and hence the result does not depend on the accuracy of an instrument.

Also potential at B = potential at D

I1 P = I2 R ………………..

P/Q

= R/S from where P can be calculated The meter bridge A practical form of the Wheatstone bridge is the meter bridge A wire AC of uniform cross-section and 1m long, made of some alloy such as constantan so that its resistance is of the order of 1.0hm, lies between two thick brass or copper strips bearing terminals, above a meter ruler.

Then P length AD length CD

The Potentiometer.
The potentiometer is a ‘null’ method of measuring p.d In its simplest form, the potentiometer consists of a resistance wire of uniform cross-section through which a steady current is passed. In fig. 3.10, A B represents the potentiometer wire and C the cell supplying the steady current. There is a drop of potential down the wire from A to B; the p.d between two points on the wire is proportional to their distance apart, and can be used to counter-balance an unknown p.d.

When a resistor and a capacitor are connected in series to a source of voltage

Vo, we have the e.m.f equation.

[...]

= CVo ……………….3.6

= CVo

Since e = 2.718, e-1 = 0.37 approximately and = 0.63, so that after a time equal to the time-constant of the circuit, the charge on the capacitor will have reached 0.63 of its final value see fig. 3.12
The discharging process follows the inverse curve figure 3.
CV e –t/CR where V is the potential difference across the capacitor when it was fully charged.
Circuits with long time-constants are sued in many practical applications, e.g.
to activate the flashing lights set up near roadwork’s, and the regular sound pulses emitted by

sonar.

Rn

Ri Kirchhoff’s rules consist of the following statements The algebraic sum of the current toward any branch point in a network is zero. This is the point rule.
The algebraic sum of the e.m.f.s in a loop equals the algebraic sum of the IR products in the same loop – This is the loop rule.
A moving coil galvanometer can be converted to an ammeter by connecting a resistor of very low value in parallel with it.

During the discharging process, the remaining charge on the capacitor at time t is given by

CVe-t/RC where V is the p.d. across the capacitor when it was fully charged.
Two resistance coils, P and Q are placed in the gaps of a metre bridge A balance point is found when the movable contact touches the bridge wire at a distance of 35.5cm from the end joined E o P. When the coil P is shunted with a resistance of 10ohms, the balance point is moved through a distance of 15.5cm .

22MΩ

Find the currnt in every branch of the two loop circuit shown in the figure.

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An Introduction to High School Physics.

Fields due to Magnets

Fields due to Current Force on a Current in a Magnetic Field Magnetic Flux Density The Bio-Savart Law The first magnetic phenomena to be observed were those associated with natural magnets. These were rough fragments of iron ore found near the ancient town of Magnesia in Asia. In fact, the word magnet was derived from the name of that town. These natural magnets have the property of attracting to themselves unmagnetised iron, the effect being most pronounced at certain regions of the magnet known as its poles.
It was by observing electric currents that the connection between electricity and magnetism was firmly established. Thus in 1820 Haus Christian Oersted at the University of Copenhagen, Demark found that a wire carrying an electric current deflected a nearby compass needle.
It is now well known that electric current produce magnetic fields and that a changing magnetic field produces an electric current.

[...]

When no other magnet is near, a freely suspended magnet sets so that the line joining its poles is approximately parallel to the earth’s north – south axis.

Can you use your knowledge of the electric field to define a magnetic field?

The space surrounding a magnet where a magnetic force is experienced is called a magnetic field.

Arrow on the lines show the direction of the field and since a north pole is repelled by the north pole of a magnet and attracted by the south, the arrows point away from the north poles and toward south North

Bar magnet Earth's local field Figure 3.1 shows some typical field patterns. The field round a bar magnet varies in strength and direction from point, that is it is not uniform. Locally, the earth's magnetic field is uniform; the lines are parallel, equally spaced and point north.

A neutral point is a place where two magnetic fields are equal and opposite and the resultant force is zero. The two points marked X in fig 3.2 in the combined field due to the earth and a bar magnet with its N pole pointing North.

Where will the neutral points be when the N pole of the magnet points south? Illustrate with a sketch similar to fig. 3.2

Field Due to Currents A conductor carrying an electric current is surrounded by a magnetic filed. The lines due to a straight wire are circles, concentric with the wire as shown in fig. 3. 3. The right-hand screw rule is a useful aid for predicting the direction of the field, knowing the direction of the current.

If a right-handed screw moves forward in the direction of the current, then the direction of rotation of the screw gives the direction of the lines.

wire Figure 3.4 a and b illustrate the rule.

Can your recall the definitions of electric and the gravitational field strengths?

Electric field strength E is defined as the force per unit charge and the gravitaional field strenght, g is the force per unit mass.

In symbols, B is defined by the equation

Thus if F = 1N when I = 1A and = 1m then B = 1NA-1m-1 . The unit 1 newton per ampere metre is given the special name of 1 tesla .

B is a vector whose direction at any point is that of the field line at that point.

Its magnitude may be represented pictorially by the number of field lines passing through unit area; the greater this is, the greater the value of B.

Rearranging the equation 3.

BIl ………………………………….3.

[...]

Ill A ‘ Vs’ is called a “weber” and is abbreviated to Wb.

35 N

Force on an Electron Moving in a Magnetic field An electric current in a wire is convertionally regarded as a flow of positve charge, although it consists in fact of a flow of negative elecctrons in the opposite direction.

But force on a current = BI

Torque on a rectangular coil Figure 3.8 and represnets a vertical rectangular coil length and breadth a and b respectively, carrying a current I with its plane at an angle to a horizontal magnetic field of magentic flux density B. Applying Flemings lefthand rule to figure 3-8 , it will be seen that the left-hand vertical side is urged out of the paper, b/2

Taking the moment of the forces about 0 we have

2 BaNI b cos BANI cos Nm ……………………..3.5 where A = area of coil = ab. Thus the torque on the coil is BANI cos .
Use Eq. 3.5 to derive expressions for the maximum and minimium values of the torque on the coil.
The torque on the coil attains its maximum value when the plane of the coil is parallel to B and = 0. The maximum value is BANI. Its minimum value, when the plane of the coil is perpendicular to B and
= 900, is zero.
Note: The torque on a coil is always BANI cos whatever the shape of the coil.
Find the torque on a galvanometer coil, 2cm square and containing 100 turns, when a current of 1mA passes through it.

The permeability of a vacuum is denoted by μo, and its value is defined to be

4 x 10-7 and its unit is the henry per metre . Air and most other materials except Ferromagnetics have nearly the same permeability as a vacuum.

μoIIsin

Calculation of Flux Density In most cases, the calcualtion of flux density requires the use of calculus.

Circular Coil

Suppose the coil is in air, has radius r, carries a steady current I and is onsidered to consist of current elements of length l.

[...]

Where = 900 and sin = 1. The direction of B is at right angles to the line joining P to the current element and in the plane of the paper .

µI2Nr

µNI Sin 3 r = sin ……..3.8

Very Long Straight Wire I Sin We wish to find the flux density at P, perpendicular distance a in air from an infinitely long straight wire carrying current I.

4a -/2

µoI …………………………………..3.10

Note that equation 3.9 shows that the field is non-uniform and there is cylindrical symmetry .

Find the magnetic flux density, B, at the centre of a square coil, of side 2a, carrying a current I as shown in fig.

2µI

Uo n I …………………..3.11

Where n = N/l = number of turns per unit length. Thus B is equal to µo multiplied by the ampere-turns per metre.

At P, a point at the end of a long solenoid B = µonI ……………………………3.

The forces F acting on length l of the right-hand conductor is therefore B 1 I2 l =

µo I1 I2 l ……………..3.13

The left-hand conductor experiences an equal and opposite force due to being in the field of the right-hand conductor.

The definition of the ampere is based on Equation 3.

Substituting in F = µo I1 I2 l , we have

µo x 1 x 1 / µo = 4 x 10 11m This is the value given earlier This unit has introduced you to an important area of the course, the magnetic field. You should note that electric currents produce magnetic fields and a changing magnetic field produces an electric current.We have defined the magnetic field at a point in terms of the force on a steady current element.

Perpendicular to the field

Inclined at 300 to it.

What do you understand by a magnetic field?

Figure 3.16 shows an appratus that is used to compare the masses of ions of different isotopes of the same element.

Be and that $M = eB 2 r2$

Physics: A Textbook for Advanced Level Students John Murray Ltd. London.
A second Course of Electricity. J. Jenkins and W.H. Jarvis.
University Press, Cambridge 1973.

Motion in an Electric field The Cathode Ray Oscilloscope

By now, you are familiar with three kinds of force – gravitational, electrical and magnetic forces. As you know, the forces are best described in terms of fields. All forces have a property by virtue of which they act on a particular kind of particle located in the region occupied by the field. Once we know exactly how the fields affect the particles on which they act, we are in position to understand the nature of the field and, hence, the nature of the You have studies in PHY101 the motion of objects in the earth's gravitational field. For example, the path of the projectile in air is a parabola.

$= F/m$

$= qE/m$ …………3.2 where m is the mass of the particle.
It follows from Eq. 3.2 that the acceleration is in the same direction as the electric field. The equation also shows that it is the ratio of charge to mass that determines a particle acceleration in a given electric field.

$0 + ½ at2$

With the acceleration given by Eq.

2 x

18m The minus sign indicates that motion is downward, opposite to the field direction. This is expected because an electron carries a negative charge.
We may also have cases of a charged particle moving in an electric field with an initial velocity in any direction that is not along the electric field.

$V = V11 + V1$

The horizontal position of the charged particle at any time t is given by .
$x = V1 t$ ……………………………….3.
The vertical position of the charged particle at any time t is $y = V11t + ½ qE t2$

…………………….3.4
Substituting the value of t from Eq. 3.3 into 3.4, we obtain y = V11 x + ½ qE x2
……………………….3.5
This is the equation of the particle in the electric field. Since V, q, E and m are constant, Eq. 3.5 is of the form y = ax + bx2, a and b are constants.
This is the equation of a parabola.
Motion in a Magnetic Field The force exerted by a magnetic field B on a moving charged particle is F = q v B ………………………………….3.6
The magnitude of this magnetic force is F = qvB sin where is the angle between V and B . The direction of the magnetic force is perpendicular to both V and B.
Form Eq. 3.6, it follows that magnetic force always act perpendicular to the direction of motion. This means that the magnetic field can do no work on a charged particle.

Fc = qvB = mv2

So that r = mv/qB ……………………………….3.8
The larger the particle's momentum mv, the larger the radius of the orbit. On the other hand, if the field or charge is made larger, the orbit becomes smaller.

The frequency of rotaioin of a moving charge is given by f =

qB …………………………………3.11
The frequency, f is called the cyclotron frequency. It is so called because it is the frequency at which the charged particles circulate in a cyclotron particle accelerator.

Or m dv1 + m dv11 = qv1 B

The force F is clearly perpendicular to B i.e there is no acceleration in the diretion parallel to B. This means.
m dv11 = 0 m dv1 = qv1 B ………………….3.12
Dt Equation 3.12 shows that the force is perpendicular to the field. i.e. it influences the particles motion in a plane perpendicular to the field. But we know that the particle's motion perpendicular to the magnetic field is circular. Equation 3.12 further shows that no force acts along the magnetic field. Therefore, the component of the velocity which is along the field remains unaffected by the field.

The CRO is based on the following two principles

When fast moving electrons strike the glass screen coated with zinc sulphide, they cause fluoresence.
Since the mass of electrons is very small, they are easily deflected by the electric and magnetic fields and follows their variation with practically no time lag.
Figure 3.5 shows the basic elements of a cathode-ray tube.
Electrostatic deflection of an electron beam is used in the cathode-ray tubes of modern oscilloscopes.

Electrostatic Deflection of Cathode Rays

= Vx t ……………………………..3.12
Between the plates, however, the rays experience an upward acceleration ay = qE/m
……………………..3.14
Neglecting the fringing effect of the electric field, we can assume that E is constant, and it is equal to the potential difference between the deflection plates divided by their separation.
qEt2 …………………………..3.15
Elimination of t between Eqs. 3.13 and 3.15 yields the equation for the parabolic trajectory, y = qE x2 …………………………..3.16
The quantity y1, defined in fig. 3.5, is the value of y when x = L. Beyond the plates, the trajectory is a straight line because the charge is then moving in a field-free space. The value of y2 is Dtan , where D and are defined as in fig. 3.5. The slope of the line is tan = dy qEx qEL …..3.17 mV2x The total deflection of the beam,YE, is Y1, + Y2, so that YE = Y1 + Y2 = qEL2 + qELD = qEL =
L+ D …….. 3.18
Equation 3.19 is the vector sum of the electric force qE and the magnetic force q v B. It is called the Lorentz force equation and F is the lorentz We shall now consider an important application of the combined electric and magnetic fields, acting perpendicularly to each other.
The Cyclotron The cyclotrons is the most familiar of all machines for accelerating charged particles and ions to a high velocity. A sketch of the cyclotron is shown in The machine consists of two circular boxes, D1 and D2, called ‘dees’ because of their shape, enclosed in a chamber C containing gas at low pressure. The chamber is arranged between the poles of an electromagnet so that a nearly uniform magnetic field acts at right angles to the plane of the dees. A hot filament Femits electrons so which ionize the gas present, producing protons from hydrogen, deuterons from deuterium, etc. An alternating electric field is created in the gap between the dees by using them as electrodes to apply a high frequency alternating p.d. Inside the dees, there is no electric field, only
Suppose at a certain instant D1 is positive and D2 is negative.

Through what angle has the electron been deflected when it leaves the electric field?

Describe and draw the rough sketch of its subsequent motion.
The pole faces of a cyclotron magnet are 120cm in diameter; the field between the pole faces is 0.80T. The cyclotron is used to accelerate protons.

Electrolyte

Ions, on arrived at he appropriate electrode, receive or give up electrons to form neutral radicals, the electron being given to or absorbed from the current in the external circuit.

[...]

This is called a ‘secondary reaction’ Meanwhile the CU 2+ ions are attracted to the cathode, which is being supplied with electrons by the external electricity supply.

2S04 + 2 H20 -◊ 2 H2 S04 + 02

Oxygen is seen bubbling from the anode, and an indicator will confirm the generation of an acid in the vicinity of the anode. .

Faraday equivalent weight of substance Electrochemical equivalent of substance The mass m of a substance deposited or liberated by electrolysis when a current 1 flows for time t is thus given by

M = ZIt ……………………………3.1 where Z is equal to a universal constant multiplied by the chemical equivalent of the substance and is called its electrochemical equivalent.
Before we go further, let us explain some terms The molecular weight of a substance is the number of times the average mass of one of the molecules is greater than the atomic mass unit.

= M/2F

In the case of an element, the atomic weight, A, replaces M in equations 3.2 and 3.3.

[...]

A cell designed for the study of electrolysis is called a voltameter.

[...]

= 1.50 x 10 -5kg Charge of electricity passed = 0.800 x 30 x 60

Electrochemical equivalent of hydrogen mass of hydrogen liberated

= 31.8 x 50 x 10-5 = 4.77 x 10 -4kg.
Let us consider the direct deposition of an element.

F = NAe

Accurate determinations of the faraday give its value as 96519 coulombs, but for most problems F = 96500 coulombs may be used The relation F = NAe has been used in the determination of the electric charge.

Polarisation

Electrolytic cells or voltameters in which there is the evolution of gas at the electrodes generally exhibit the phenomenon of polarization. It is found that if the voltage applied to the cell is less than a critical value V 1 the induced current will soon die away to a very small value. This is owing to the fact that the freshly formed gases which surround the electrodes effectively form an electric cell providing a back e.m.f. whose polarity is opposed to that applied externally. Unless, therefore, the e.m.f. applied to the cell is greater than that produced by the effective “internal battery” no appreciable current will flow.

NaCl

When an e.m.f is applied between the electrodes dipping into an electrolyte the positive ions, or cations, are attracted to the cathode while the negative ions, or anions, are attracted to the anode. The two streams of oppositely charged ions, travelling in opposite directions, carry the current through the electrolyte. Anions give up their surplus electrons to the anode, and cations receive electrons from the cathode, thus maintaining the flow of electrons in the external circuit. Having given up their charges the ions are liberated as uncharged atoms and molecules.

Zn + 2NH4Cl + 2 Mn02 -◊ Zn 2 Cl2 + H20 + Mn203

The manganese dioxide is referred to as the ‘depolarizer’ because without it, bubbles of hydrogen would form on the carbon rod, forming an insulating layer around it with the Mn02 paste, this hydrogen is at once converted into water, which does not interfere with the cell’s action.
Hydrogen ions give up their + charge at the carbon rod. When the ammonium chloride reacts with the zinc case, the latter is let with an extra electron. Thus the electron flow in the external circuit is from zinc to carbon .

2pbSO4 + 2H2O

During discharge the electrolyte loses sulphuric acid, and its density falls.
Thus a hydrometer can be used to check the charge of a lead-acid cell. The electrolyte density of a fully charged cell is 1250kgm-3, and a fully discharged one, 1100kg m -3.
During the repeated charge and discharge, solid reaction products collect below the plates.

2Ni 3 + Cd ◊ 2 Ni 2 + Cd 2

In a fully-charged cell, the nickel hydrate is highly oxidized and the negative material is reduced to pure cadmium. On discharge the nickel hydrate is reduced to a lower degree of oxidation, and the cadmium in the negative plate is oxidized. Thus the reaction may be regarded as the transfer of - ions from one plate to the other, and the density of the electrolyte does not change being 1200kg m-3 at normal temperature.
Figure 3.3 shows a nickel-cadmium accumulator with plastic containers. .
Solutions that conduct electricity are called electrolytes. In an electrolyte the metallic and hydrogen ions are positive. The other ions are negative. Currents in an electrolyte consist of positive ions moving to the cathode and negative ions moving to the anode .
Univalent atoms gain or lose one electron each in ionization, and bivalent atoms gain or lose two electrons.
Electric cells convert chemical energy into electric energy and consist of two different metals

separated from each other by an electrolyte.
Many different cells have been invented since the first was made by Volta at the end of the eighteenth century.

1A?

Calculate the electrochemical equivalent of hydrogen, given that 1A deposits 0.65gm of copper from a solution of copper sulphate in 33 mins. .
Describe briefly the lead-acid accumulator and explain the chemical reactions which take place in it during charging and discharging.
Give an account of the elementary theory of electrolysis and show that it is consistent with Faraday's laws of electrolysis.

ELECTRIC POWER

Current and Power Power Dissipation a Resistor, Joule's Law Electric Power and energy Electric Power and Electromotive force In PHY 101, you learned that power is the rate of doing work and may be expressed in such units as joules per second and kilowatts. The power of a waterfall depends upon the height of the fall and upon the number of kilogram-weights of water transferred per unit time. Similarly, in electric circuits the power expended in heating a resistor, charging a storage battery, or turning a motor depends upon the difference of potential between the terminals of the device and the electric current through it.

Current Power

Let us consider a current 1 directed from an equipotential at potential Va to an equipotential at potential Vb In a time interval dt, a charge dQ pases the Va equipotential while the same amount of charge passes the Vb equipotential. The charge passing hrough he region between these equipotentials therefore experiences a change in potential energy given by.
dW = VadQ – Vb dQ = Vab 1dt ………………….3.1
This is the work done by the eelctric force on the charge between the V a the and Vb equipotentials. The power supplied by the elctric field to the charge moving between the Va and Va equipotentails is P = dW = VabI ……………………………….3.2
This equation will be applied to many different physical situations. We consider first an example in which the charge move through a vacuum.

Pout = VabI

– Vb is always positve , so there is a power input to the resistor, P = VabI.
Mobile charged particles are accelerated by the electric field within the conductor, but the kinetic energy gained by the charge carriers is transferred by collisions to the atoms of the conductor.

Various expressions for the power dissipated are

P = VI = I2 R = V2/R ………………………..3.3
For an ohmic resistor, Eq. 3.3 is called Joule's law.

PR

50 volts Equation 3.3 gives three alternative expressions for power but the last two are only true when all the electrical energy is changed to heat. The first, P = VI, gives the rate of production of all forms of energy. For example, if the current in an electric motor is 5A when the applied p.d. is 10V then 50W of electric power is supplied to it. However, it may only produce 40 W of mechanical power, the other 10W being the rate of production of heat by he motor windings due to their resistance.
U = Pt ……………………………………3.
The kilowatt-hour is a unit of energy.

Electric Power and Electromotive Force

Let us calcualte the electrical power required to charge a storage battery. You would recall that the terminal voltage of a storage battery during the charging process is greater than its electromotive force E by the amount of the internal voltage drop within the battery.

The power delivered to the battery is V times I

EI + I2 r …………………………..3.6
What do the terms on the right – hand side of eq. 3.6 mean?
The first term, the product of the e.m.f and the current, is the rate at which energy is transformed from electrical energy into stored chemical energy –

On charging, the terminal voltage is E + Ir

= 6.0 + 0.50I
I = 2.
12 watts + 2 watts The rate of converting electrical energy into stored chemical energy is 12W and the rate of heating is 2W.
We can also calculate the power deliver by a discharging battery to an external circuit. Upon discharging, the batery has a terminal voltage V which is also the voltage drop across the external circuit.
E - Ir …………………………….3.7
Or the power delivered by the battery is P = EI - I2 r …………………………..3.8
As you now know, the first term on the right-hand side of Eq.

Ir

wer deli ver ed loa and Eq. 3.8 becomes
__E2_ __E2 r_ …………………3.
2 where P is the power delivered to the load.

= 0 , the power delivered is zero.

R=r

Load resistance, R ohm The first incandescent lamps, devised more than a century ago, were platinum wires heated red hot by currents from voltaic cells. The lamps had little practical use, both because of their small luminous efficiencies and because the batteries were expensive and inconvenient. The development of the generator, based on the scientific discovery of electromagnetic induction by Michael Faraday in 1831, provided an economical source of electrical energy and led to a search for filament materials that could be operated at a higher temperature than platinum.
The expression P = V2/R shows that for a fixed supply p.d of V1 the rate of heat production by a resistor increases as R decrease. Now, R = l/A, therefore P = V2A/l and so where a high rate of heat production at constant p.d. is required, as in an electric fire on the mains, the heating element should have a large cross-section area A, a small resistivity P and a short length . It must also be able to withstand high temperatures without oxidizing in air. Nichrome is the material which best satisfied all these requirements.
Electric lamp filaments have to operate at even higher temperatures if they are to emit light. In this case, tungsten, which has a very high melting point, is used either in a vacuum or more often in an inert gas . The gas reduces evaporation of the tungsten and prevents the vapour condensing on the inside of the bulb and blackening it. In modern projector lamps, there is a little iodine which forms tungsten iodide with the tungsten vapour and remains as vapour when the lamp is working, thereby preventing blackening.
In buildings, electrical devices are connected in parallel across the supply lines. The resistance of high-power devices is smaller than that of low power ones.

These experiments do turn out as expected and led to the same value for the conversion factor between joules and calories

The calorie is not an SI unit of heat.

How many calories of heat does it generate in 100s ?

What time would be required for this percolator to heat 1 litre of water from 200C to 1000C ? Neglect the heat loss to the percolator and its surroundings.

[...]

0 cal / gm-C° x 1000gm x 80°C x 100%91%When a battery is used to maintain an electric current in a conductor, chemical energy stored in the battery is continously converted to the electrical energy of the charge carriers.As the charge carriers move through the conductor, then electrical energy is convereted into internal energy due to collision between the charge carriers and other particles in the conductor. Electric power is the rate of conversion of electrical energy, that is the rate at which the charge carriers do work.

VI = I2 R = V2/R

The commercial unit of electrical energy is the kilowatt-hour which is the energy expended in an electric circuit at the rate of one kilowatt for ine hour. It is the legal unit by which the consumption of electrical energy is measured and charged by the Power Holding Company of Nigeria .
A fuse is a device for protecting an apparatus or wiring from damage by overload. It acts as a cut-out by fusion.

How much heat and light energy is produced by a 100W electric lamp in 5 minutes?

An incandescent lamp is marked “120V, 75W”.

What is the current in the lamp under normal conditions of operation?

A 200W lamp is totally immersed in 1500 gm of water. How much will the temperature of the water rise in 3 mins? Neglect heat losses from the water.

[...]

Demagnetizing a Materials You have leant in unit 8 that magnetic fields are produced by electric currents.
Bound currents arising from the the circulating charges in atoms and molecules as well as from electron spin.
Free electrons, such as the familiar conduction currents in wires, that are due to the drift of mobile charges.
The general theory of unit 8 relates the magnetic field B to all currents that are present.

[...]

Mk = Ik Ak ………………………………3.1
The magnetic moment of a system ncontaining magnetic moments m1. m2, …..mn, is defined as the vector sum ∑ mk of all the magnetic moments of k-1 the system.
A basic physical quantity for the description of the magnetic state of a piece of matter is the magnetic moment per unit volume M, called the magnetization. To define M at a given point in a material, we consider a volume element dV that includes the point and is macroscopically small but microscopically large.

Path of Integration C

The value of this sum obviously depends on the precise location of the path of integration.