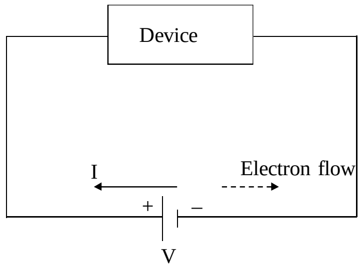
Ohm's Law



The ratio V/I is a constant, where V is the voltage applied across a piece of material (device) such as a wire and I is the resulting current through the material.

$$\frac{V}{I} = R = constant \quad \text{or} \quad V = IR$$

R is the resistance of the piece of material and the unit is in ohm (Ω). This implies that a wire or an electrical device (called resistor) offers resistance to the flow of charges.

Ohm's Law

Symbol 

In an electrical circuit, straight line (-) represents an ideal conducting wire, or one with a negligible resistance.

<u>Resistance and Resistivity</u>

Resistance R of a piece of material is proportional to its length (L) and inversely proportional to its cross-sectional area (A)

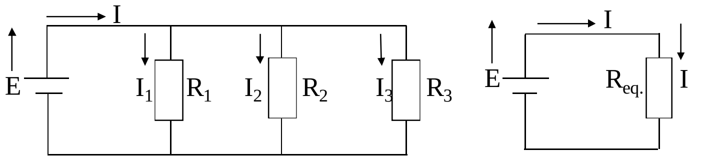
$$R = \rho \frac{L}{A}$$

ρ is the proportionality constant known as the resistivity of the material.

ρ is an inherent property of a material just like density. R depends on resistivity and geometry of the material.

Parallel and Series Arrangement of Resistors

Parallel Arrangement:



For resistors in parallel, the same voltage drops across them (or passes through them) i.e. Total current $I = I_1 + I_2 + I_3$

$$I = \frac{V}{R_1} + \frac{V}{R_2} + \frac{V}{R_3} = V\left(\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\right)$$

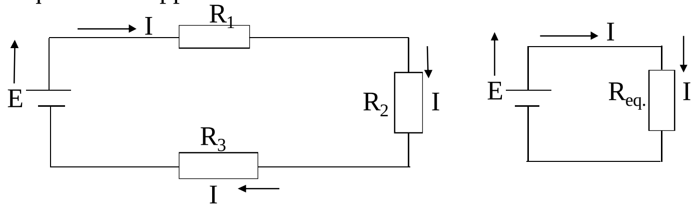
$$I = \frac{V}{R_{Eq.}},\quad \frac{1}{R_{Eq.}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}$$

$$\frac{1}{R_{Eq.}} = \sum_{j=1}^{n} \frac{1}{R_j}, \quad \textit{for n resistors in parallel}$$

Parallel and Series Arrangement of Resistors

Series Arrangement:

When a potential difference V is applied across resistors connected in series, the resistors have identical current I. The sum of the potential differences across the resistors is equal to the applied V.



$$V = I \cdot R_1 + I \cdot R_2 + I \cdot R_3 = I(R_1 + R_2 + R_3)$$

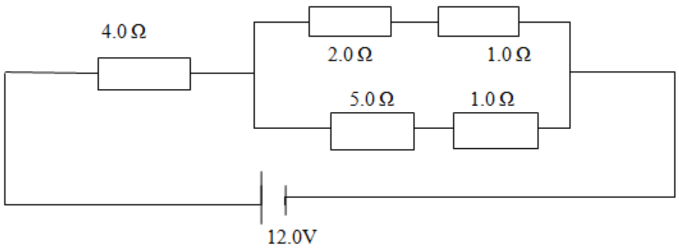
$$I = \frac{V}{R_1 + R_2 + R_3} = \frac{V}{R_{Eq.}}$$

$$R_{Eq.} = \sum_{j=1}^{n} R_j, \quad \textit{for n resistors in series}$$

Examples

Q1. Two resistors, 16.0 Ω and 8.0 Ω, are connected in series across a 12.0V battery. What is the voltage across each resistor.

Ans: V across 16 Ω = 8V, V across 8 Ω = 4 V



Q2. Determine the power dissipated in the 2.0 Ω resistor in the circuit above (Resistive dissipation)

Ans: power dissipated = 2.667 W

Variation of Resistance with Temperature

The ions in a metal lattice vibrate more quickly as the temperature increases. This makes it more likely that an electron will interact with an ion and loses energy.

Therefore, the resistance of a metallic conductor increases, and for pure metals it increases linearly with temperature.

$$R_\theta = R_o(1 + \alpha_R(T - T_o))$$

where

R_θ – R at temp. T (Ω)

R_o – R at temp. T_o (Ω)

α_R – is the temp. coefficient of resistance (°C^{-1})

Variation of Resistivity with Temperature

Similarly

$$\rho = \rho_o(1+\alpha_\rho(T - T_o))$$

Conductivity

$$\sigma = \frac{1}{\rho} \qquad (\Omega.m)^{-1}$$

The unit is written ad mhos per meter

Examples:

•A copper wire and aluminum wire have the same length. Obtain the ratio of diameter of aluminum to that of copper if the resistance of copper is twice that of aluminum and the resistivity of copper ρ_c = 1.72 x 10^{-8} Ωm and that of aluminum ρ_a = 1.72 x 10^{-8} Ωm.
Ans: 9:5

•Calculate the resistance per meter length of constantan wire of diameter 0.4 mm. What length of constantan would be required to make a resistor of resistance of 1.5 Ω.
$\rho_{constantan}$ = 4.70 x 10^{-5} Ωm
Ans: R/L = 374.0 Ωm^{-1} Length = 0.004 m

•A wire 4.0 m long and 6.00 mm diameter has a resistance of 15.0 mΩ. A potential difference of 23.0 V is applied between the ends of the wire, (a) what is the current through the wire. (b) calculate the rsistivity of the wire material.
Ans: a = 1.53 x10^3 A b = 1.06 x 10^{-7} Ωm

•A coil is formed by winding 250 turns of insulated 16-gauge copper wire (diameter = 1.3 mm) in a single layer on a cylindrical form of radius 12 cm. What is the resistance of the coil? (Neglect the thickness of the insulation and ρ_c = 1.72 x 10^{-8} Ωm)
Ans: 2.4 Ω

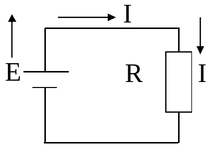
Examples

1. A digital thermometer uses a thermistor as the temperature sensing element. A thermistor is a kind of semiconductor and has a large negative temp. coefficient of resistivity α. Suppose α = -0.06 (°C^{-1}) for the thermistor in a digital Thermometer used to measure the temp. of a sick patient. The resistance of the thermistor decreases by 15% relative to its value at the normal body temp. of 37.0 °C. What is the patient's temp.?
   Ans: 39.5 °C

2. A wire has a resistance of 21 Ω. It is then melted down, and from the metal a new wire is mode that is three times as long as the original wire. What is the resistance of the new wire?
   Ans: 189 Ω

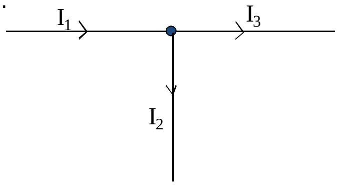
Kirchhoff's Rules

Electric circuit is the path through which charge can flow.



Two basic rules that apply in all electric circuit are called Kirchhoff's laws:

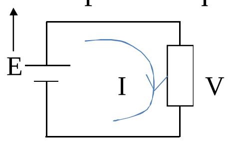
Kirchhoff's 1st law (Junction Rule)
Total current arriving at a junction in a circuit must equal to the total current leaving the junction.



$$I_1 = I_2 + I_3$$

Kirchhoff's Rules

Second Law (Loop Rule / Voltage law):
The sum of potential difference round any closed loop in a circuit must be zero (or the sum of pd rise equal the sum of pd drop)

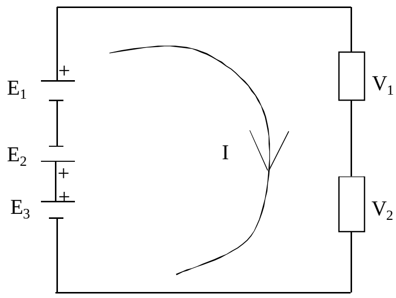


$$E - V = 0$$

Resistance Rule: For a move through a resistor in the direction of current, the change in potential is *–I.R*, in the opposite direction it is *+I.R*.

EMF Rule: For a move through an ideal *emf* device in the direction of *emf* arrow, the change in potential is +E; in the opposite direction it is –E.

Kirchhoff's Rules: Examples



$$E_1 - E_2 + E_3 - V_1 - V_2 = 0$$

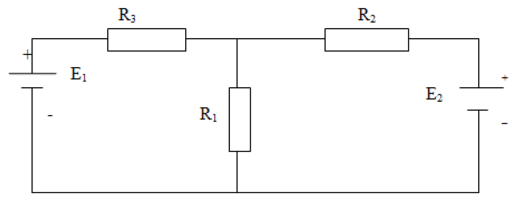
$$E_1 - E_2 + E_3 = I \cdot R_1 + I \cdot R_2$$

$$I = \frac{E_1 - E_2 + E_3}{R_1 + R_2}$$

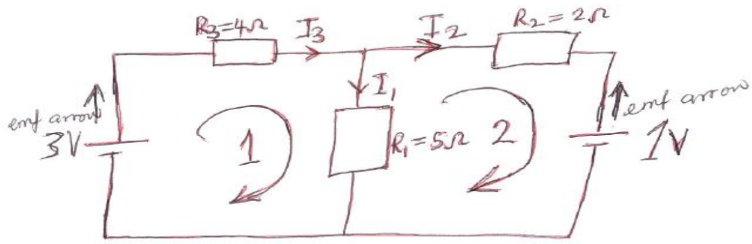
Kirchhoff's Rules: Examples

Q1. E_1 = 3.0V, E_2 = 1.00V, R_1 = 5.0 Ω, R_2 = 2.0 Ω, R_3 = 4.0 Ω and both batteries are ideal. What is the rate at which energy is dissipated in (a) R_1 (b) R_2 (c) R_3

Ans: P_1 = 0.35 W P_2 =0.05 W & P_3 = 0.71 W



Solution



Using junction's law, $I_3 = I_1 + I_2$ —— (1)

From loop 1, moving clockwise through the loop

$3 - 4I_3 - 5I_1 = 0$ —— (2)

From loop 2, moving clockwise also through the loop

$-1 - 2I_2 + 5I_1 = 0$

$\Rightarrow 5I_1 - 2I_2 = 1$ —— (3)

From eqn 2, replace I_3 with $(I_1 + I_2)$ and re-arrange

$$9I_1 + 4I_2 = 3 \quad \text{—} (4)$$

Put (3) and (4) together and solve simultaneously

2 x eqn (3) $\quad 10I_1 - 4I_2 = 2$

1 x eqn (4) $\quad 9I_1 + 4I_2 = 3$

add $\quad 19I_1 = 5$

$$I_1 = 5/19 \text{ A} = 0.263\text{A} \quad (5)$$

put (5) in 4 to obtain I_2

$$9\left(\frac{5}{19}\right) + 4I_2 = 3$$

2.368

$$I_2 = \frac{3 - 2.368}{4} = 0.158\text{A}$$

Put the values of I_1 and I_2 in eqn 1

$$I_3 = 0.263 + 0.158$$
$$= 0.421 \text{ A}.$$

Rate at which energy is dissipated is the same as Power dissipated and,

$$\text{Power } P = I^2 R$$

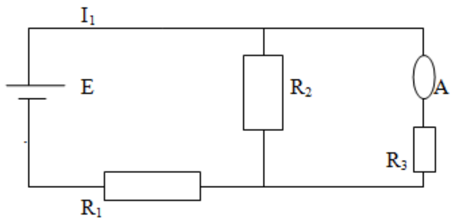
$$P_{R1} = (0.263)^2 \times 5 = 0.35 \text{ W}$$

$$P_{R2} = (0.158)^2 \times 2 = 0.05 \text{ W}$$

$$P_{R3} = (0.421)^2 \times 4 = 0.71 \text{ W}$$

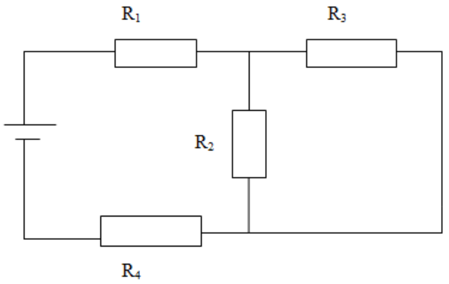
Kirchhoff's Rules: Examples

Q3. Determine what the ammeter will read, assuming E = 5.0V (for the ideal battery), R_1= 2.0 Ω, R_2 = 4.0 Ω and R_3 = 6.0 Ω. Ans: 0.454 A



Q4. R_1 = 20 Ω, R_2 = 20 Ω, R_3 = 30 Ω, R_4 = 8 Ω and E = 12V. What is the current through R_1.

Ans: 0.3 A



Electrical Energy & Power

A battery can deliver power to an electric circuit. Power is the amount of work exerted over an interval of time.

$$P = \frac{W}{\Delta t}$$

Work is equal to the change of potential energy

$$W = \Delta PE = q\Delta V$$

$$P = q\frac{\Delta V}{\Delta t}$$

If we have a current of charges Δq across a voltage difference ΔV, we can re-write

$$P = \Delta q \frac{\Delta V}{\Delta t} = \Delta V \frac{\Delta q}{\Delta t} = \Delta V \cdot I$$

$$P = I \cdot \Delta V \quad or \quad P = I \cdot V$$

Power is measured in Watt (W). $1W = A.V$

Electrical Energy & Power

Using Ohm's law, $$P = I^2 R = \frac{V^2}{R}$$

The power delivered to a conductor of resistance R is often referred to as an I^2R loss.
Electrical Energy E = P . t = IVt

Ohmic device: a device that follows Ohm's law for all voltages across it is called an Ohmic device (i.e. the resistance of the device is independent of the magnitude and polarity of the applied potential difference), and the resistance is said to have a constant value (static resistance).
Examples are wire, electric stove heating element or a resistor, incandescent light bulb etc.

Electrical Energy & Power

Non-Ohmic device: a device that behaves in a way that is not described by Ohm's law (i.e. the resistance is not constant but changes in a way that depends on the voltage across it).

Examples are tungsten filament (bulb), diode, thermistor etc

PHY 152
(ELECTRICITY AND MAGNETISM)

- ELECTRIC MOTORS (AC & DC)
- ELECTRIC GENERATORS (AC & DC)

AIMS

Students should be able to

- Describe the principle of magnetic induction as it applies to DC and AC generators.
- Describe the differences between the two basic types of ac generators.

INTRODUCTION

Regardless of size, all electrical generators, whether dc or ac, depend upon the principle of magnetic induction. An emf is induced in a coil as a result of (1) a coil cutting through a magnetic field, or (2) a magnetic field cutting through a coil. As long as there is relative motion between a conductor and a magnetic field, a voltage will be induced in the conductor. That part of a generator that produces the magnetic field is called the **field**. That part in which the voltage is induced is called the **armature**.

For relative motion to take place between the conductor and the magnetic field, all generators must have two mechanical parts - a rotor and a stator. The ROTor is the part that ROTates; the STATor is the part that remains STATionary. In a dc generator, the armature is always the rotor. In alternators, the armature may be either the rotor or stator.

QUESTION: Magnetic induction occurs when there is relative motion between what two elements?

DC Motor

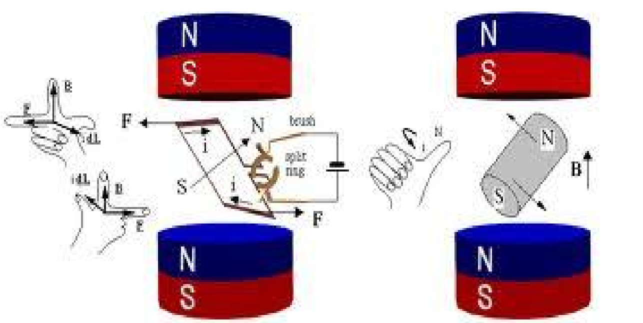
A simple DC motor has a coil of wire that can rotate in a magnetic field. The current in the coil is supplied via two brushes that make moving contact with a split ring (commutator). The coil lies in a steady magnetic field. The forces exerted on the current-carrying wires create a torque on the coil.

The force F on a wire of length L carrying a current *I* in a magnetic field B is

$$F = IBL\sin\theta$$

(i.*e* *ILB* times the sine of the angle between B and *I*, which would be 90° if the field were uniformly vertical.

The direction of F comes from the right hand rule.



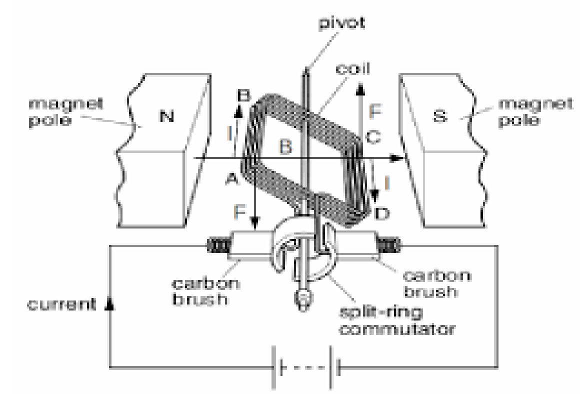


Fig 1: DC Motor

The two forces shown above are equal and opposite, but they are displaced vertically, so they exert a torque.

The ***commutator*** is that device/component that periodically reverses the direction of an electric current.

NOTE

A DC motor requires often an external resistor or rheostat to limit the current. The value, in Ohms, of that resistor is reduced in steps as the speed of the motor increases, until finally that resistor is removed from the circuit as the motor reaches close to its final speed.

DC Generator

A DC generator is also a DC motor (with the same components of a motor), but the coil is turned to generate an e.m.f.

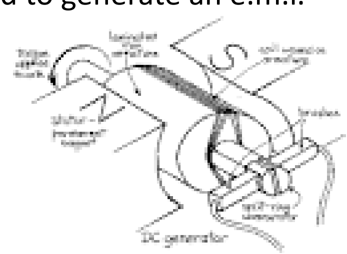


Fig 2: DC Generator

If you use mechanical energy to rotate the coil (N turns, area A) at uniform angular velocity ω in the magnetic field **B**, it will produce a sinusoidal e.m.f in the coil. Let θ be the angle between **B** and the normal to the coil, so the magnetic flux ϕ is NAB.cos θ. Faraday's law gives:

$$e.m.f\ (\mathrm{E}) = -\frac{d\phi}{dt} = -\frac{d}{dt}(\mathrm{NAB}\cos\theta) = -\frac{d}{dt}(\mathrm{NAB}\cos\omega t) = -\mathrm{NAB}\omega\sin\omega t$$

As in the DC motor, the ends of the coil connect to a split ring, whose two halves are contacted by the brushes. Note that the brushes and split ring 'rectify' the e.m.f produced: the contacts are organized so that the current will always flow in the same direction, because when the coil turns past the dead spot, where the brushes meet the gap in the ring, the connections between the ends of the coil and external terminals are reversed.

AC Motor

As in the DC motor case, a current is passed through the coil, generating a torque on the coil. Since the current is alternating, the motor will run smoothly only at the frequency of the sine wave. It is called a synchronous motor. More common is the induction motor, where electric current is induced in the rotating coils rather than supplied to them directly.

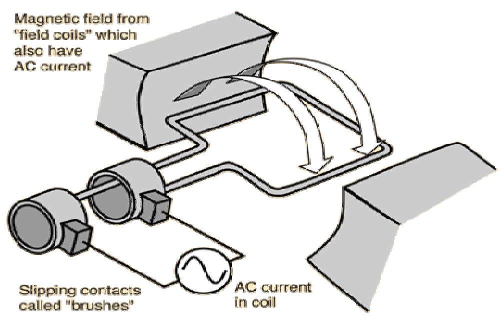


Fig 3: AC Motor

One of the drawbacks of the induced AC motor is the high current which must flow through the rotating contacts. In common AC motors the magnetic field is produced by an electromagnet powered by the same AC voltage as the motor coil. The coils which produce the magnetic field are sometimes referred to as the "stator", while the coils and the solid core which rotates is called the "armature". In an AC motor the magnetic field is sinusoidally varying, just as the current in the coil varies.

AC motors are generally divided into two categories, induction and synchronous motors. The most common AC motor is the "Squirrel cage motor", a type of induction motor. Most AC motors require a starter, or method of limiting the inrush current to a reasonable level.

AC Generator

The turning of a coil in a magnetic field produces motional emfs in both sides of the coil which add. Since the component of the velocity perpendicular to the magnetic field changes sinusoidally with the rotation, the generated voltage is sinusoidal or AC. This process can be described in terms of Faraday's law when you see that the rotation of the coil continually changes the magnetic flux through the coil and therefore generates a voltage.

AC generators are generally called an alternators.

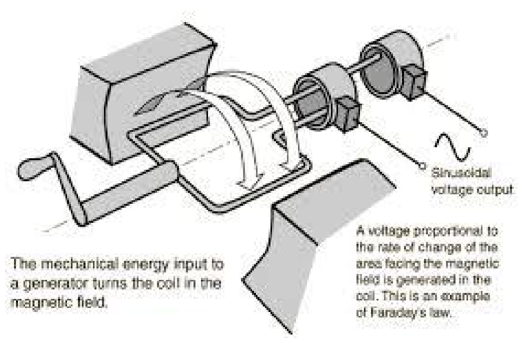


Fig 4: AC Generator

AC GENERATOR AND MOTOR

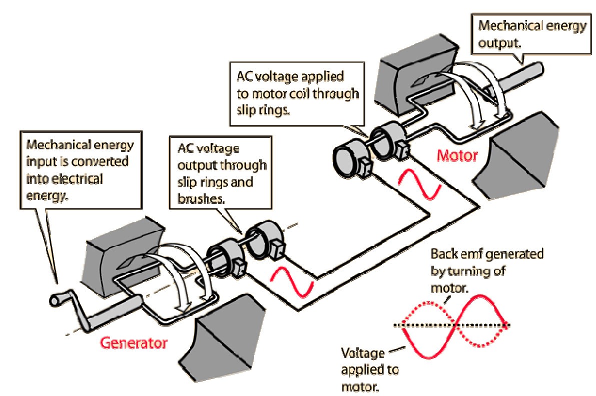


Fig 5: AC motor and generator

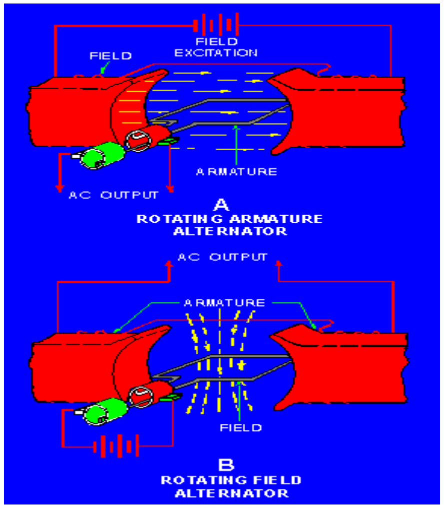
A hand-cranked generator can be used to generate voltage to turn a motor. This is an example of energy conversion from mechanical to electrical energy and then back to mechanical energy. As the motor is turning, it also acts as a generator and generates a "back emf". By Lenz's law, the emf generated by the motor coil will oppose the change that created it.

If the motor is not driving a load, then the generated back e.m.f will almost balance the input voltage and very little current will flow in the coil of the motor. But if the motor is driving a heavy load, the back e.m.f will be less and more current will flow in the motor coil and that electric power being used is converted to the mechanical power to drive the load.

Types of Alternator

1. Rotating – amarture alternators: the rotating-armature alternator is similar in construction to the dc generator in that the armature rotates in a stationary magnetic field.
2. Rotating field alternators: the rotating-field alternator has a stationary armature winding and a rotating-field winding. The advantage of having a stationary armature winding is that the generated voltage can be connected directly to the load.

Alternators



QUESTIONS

- What is the part of an alternator in which the output voltage is generated?
- What are the two basic types of alternators?
- What is the main advantage of the rotating field alternator?

Capacitance and Dielectrics

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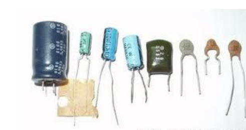
Goals of this Lecture

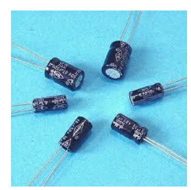
- To understand capacitors and calculate capacitance
- To analyze networks of capacitors
- To calculate the energy stored in a capacitor
- To examine dielectrics and how they affect capacitance

Introduction

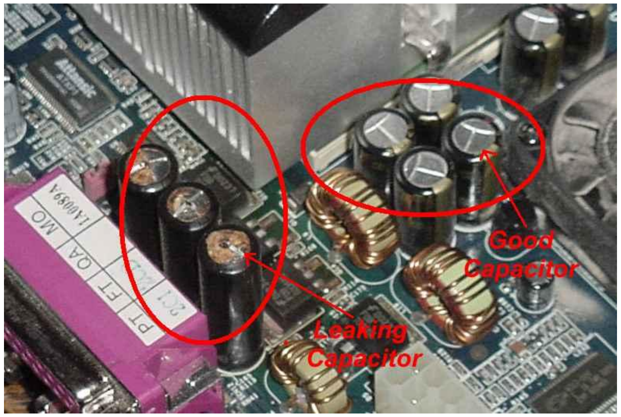
- How do camera flash units store energy?
- Capacitors are devices that store **electric potential energy**.
- Energy of capacitor is stored in E field.

Introduction





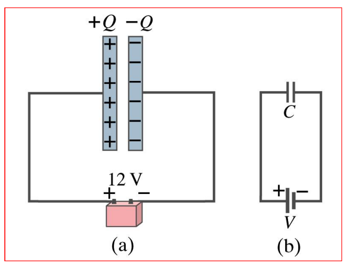
Introduction



Capacitors and capacitance

- Any two conductors separated by an "insulator" form a *capacitor*.
- Insulator *will* allow E field between the conductors,
- Insulator *will not allow* charge to flow from one conductor through itself to the other.
- The more charge you can hold, the larger the capacitor! "*capacity*"
- Charge a capacitor by pushing it there with a potential voltage "*pressure*"

Capacitors and Capacitance



A capacitor in a simple electric circuit.

Charge Q stored:

$$Q = CV$$

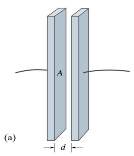
The stored charge Q is proportional to the potential difference V between the plates. The capacitance C is the constant of proportionality, measured in Farads.

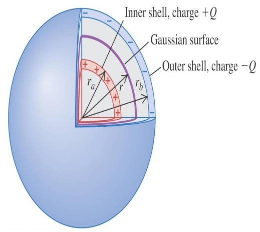
Farad = Coulomb / Volt

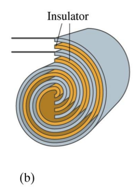
Capacitors and capacitance

- The definition of capacitance is $C = Q/V_{ab}$.
  - Q = "charge stored"
  - Q is held symmetrically (same +Q as –Q)
  - V_{ab} = pressure that pushes and keeps charge there
  - C *increases* as Q increases
    - more capacity!
  - C *decreases* as V_{ab} increases
    - more pressure required to hold the charge there, so less effective in storing it temporarily!

Forms of Capacitors





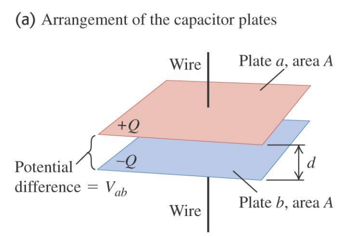


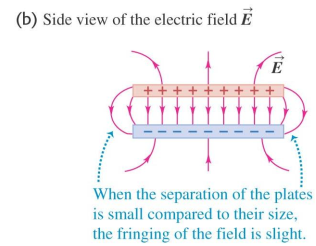
Parallel-Plate Capacitor   Cylindrical Capacitor

A cylindrical capacitor is a parallel-plate capacitor that has been rolled up with an insulating layer between the plates.

Parallel-plate capacitor

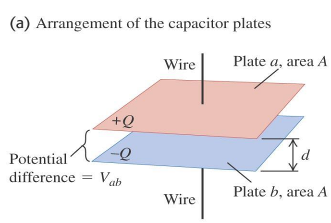
- TWO parallel conducting plates
- Separated by distance that is small compared to their dimensions.





Parallel-plate capacitor

- The capacitance of a parallel-plate capacitor is $C = \varepsilon_0 A/d$.
- Note! C is *engineered!* *You control Area & distance by design!*
- *C* ***increases*** *with Area*
- *C* ***decreases*** *with separation*



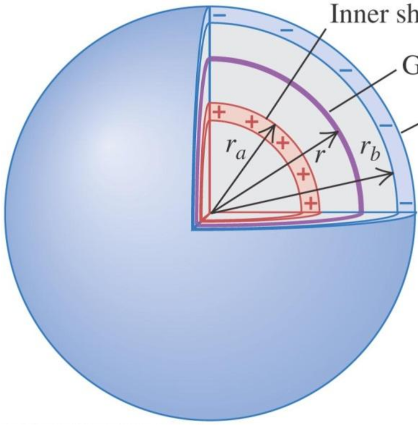
Parallel-plate capacitor

- Plates 2.00 m^2 in area; 5.00 mm apart; 10 kV applied Potential Difference.
  - C= ε_0 A/d = 8.85 x 10^{-12} F/m *2.00 m^2/.005 m = 3.54 x 10^{-9} F
  - Q on each plate from C = Q/V so Q = CV = 3.54 x 10^{-5} C
  - E field between plates from V = Ed so

    E = V/d = 2.00 x 10^{-6} V/m
  - Or… E = σ/ε_0 = (Q/Area)/ε_0 = 3.54 x 10^{-5} C/2.00 m^2 / ε_0

A spherical capacitor

– Two concentric spherical shells separated by vacuum.. What is C?



A spherical capacitor

– Two concentric spherical shells separated by vacuum.. What is C?

– **C = Q/V** so we need V!

– Get V from E field!

– $Er = 1/4\pi\varepsilon_0\ Q/r^2$

– $V_a - V_b$ = - integral (E.dl)

– V = kq/r in general for spherical charge distribution

– $V_{ab} = V_a - V_b = kQ/r_a - kQ/r_b = kQ\,(1/r_a - 1/r_b)$

– $V_{ab} = Q/4\pi\varepsilon_0\,(1/r_a - 1/r_b)$

– $C = Q/V = 4\pi\varepsilon_0\,(1/r_a - 1/r_b) = 4\pi\varepsilon_0\,(r_a\,r_b)/(r_b - r_a)$

– As r_b tends to infinity, i.e, $r_b - r_a$ tends r_b then

– $C = 4\pi\varepsilon_0\,r_a$

A cylindrical capacitor

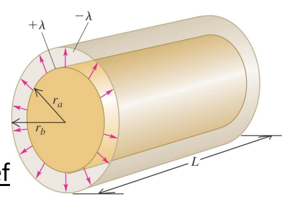
Linear charge density $+\lambda$ on outer cylinder of radius r_b, - λ on inner cylinder of radius r_a. What is C?

– $C = Q/V_{ab}$; find Q and find V_{ab}!

– $Q = \lambda L$

– $V = [\lambda/2\pi\varepsilon_0]\ \ln(r_0/r)$

- r_0 = distance where V was def
- Say $r_0 = r_b$ here, so $V_{ab} = (\lambda/2\pi\varepsilon_0)\ln(r_b/r_a)$



A cylindrical capacitor

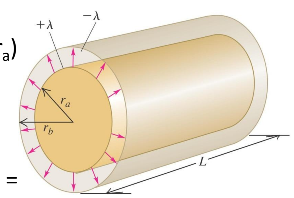
– Linear charge density $+\lambda$ on outer cylinder of radius r_b, - λ on inner cylinder of radius r_a. What is C?

– $C = Q/Vab = \lambda L/[(\lambda/2\pi\varepsilon_0)\ln(r_b/r_a)$

– $C = 2\pi\varepsilon_0 L/\ln(r_b/r_a)$

– Check:

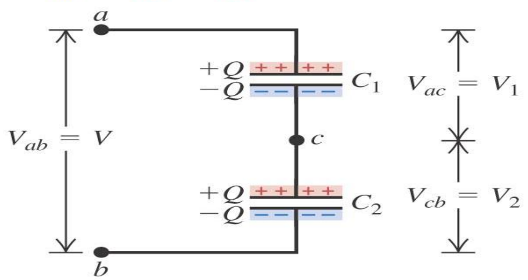
- Units = Farads/Meter x Meters =
- C increases as L increases,
- and C increreaes as r_b closer to r_a!



Capacitors in series

- Capacitors are in ***series*** if connected one after the other

Capacitors in series:
- The capacitors have the same charge Q.
- Their potential differences add: $V_{ac} + V_{cb} = V_{ab}$.



Capacitors in Series

We also have to have that the potential across C_1 plus the potential across C_2 should equal the potential drop across the two capacitors

$$V_{ab} = V_{ac} + V_{cb} = V_1 + V_2$$

We have $$V_1 = \frac{Q}{C_1} \text{ and } V_2 = \frac{Q}{C_2}$$

Then $$V_{ab} = \frac{Q}{C_1} + \frac{Q}{C_2}$$

Dividing through by Q, we have $$\frac{V_{ab}}{Q} = \frac{1}{C_1} + \frac{1}{C_2}$$

Capacitors in Series

The equivalent capacitor will also have the same voltage across it

$$\frac{V_{ab}}{Q} = \frac{1}{C_1} + \frac{1}{C_2}$$

The left hand side is the inverse of the definition of capacitance $\frac{1}{C} = \frac{V}{Q}$

So we then have for the equivalent capacitance

$$\frac{1}{C_{eq}} = \frac{1}{C_1} + \frac{1}{C_2}$$

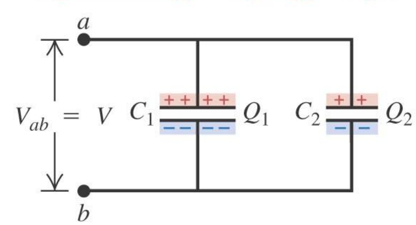
If there are more than two capacitors in series, the resultant capacitance is given by

$$\frac{1}{C_{eq}} = \sum_i \frac{1}{C_i}$$

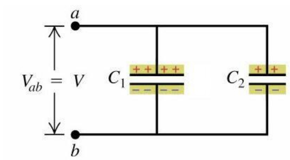
Capacitors in parallel

- Capacitors are connected in *parallel* between *a* and *b* if potential difference V_{ab} is the same for all the capacitors.

Capacitors in parallel:
- The capacitors have the same potential V.
- The charge on each capacitor depends on its capacitance: $Q_1 = C_1 V$, $Q_2 = C_2 V$.



Capacitors in Parallel



The upper plates of both capacitors are at the same potential

Likewise for the bottom plates

We have that $V_1 = V_2 = V_{ab}$

Now $V_1 = \dfrac{Q_1}{C_1}$ and $V_2 = \dfrac{Q_2}{C_2}$

or

$Q_1 = C_1 V$ and $Q_2 = C_2 V$

Capacitors in Parallel

The equivalent capacitor will have the same voltage across it, as do the capacitors in parallel

But what about the charge on the equivalent capacitor?

The equivalent capacitor will have the same total charge

$$Q = Q_1 + Q_2$$

Using this we then have

$$Q = Q_1 + Q_2$$
$$C_{eq} V = C_1 V + C_2 V$$

or

$$C_{eq} = C_1 + C_2$$

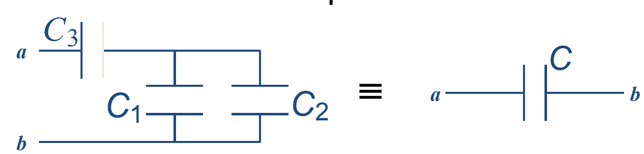
Capacitors in Parallel

The equivalent capacitance is just the sum of the two capacitors

If we have more than two, the resultant capacitance is just the sum of the individual capacitances

$$C_{eq} = \sum_i C_i$$

Example 1



Where do we start?

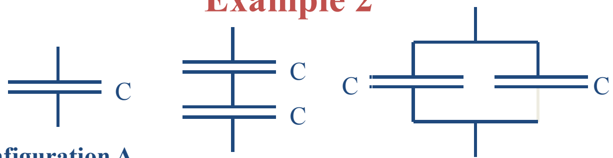
Recognize that C_1 and C_2 are parallel with each other and combine these to get C_{12}

This C_{12} is then in series with with C_3

The resultant capacitance is then given by

$$\frac{1}{C} = \frac{1}{C_3} + \frac{1}{C_1 + C_2} \quad \Rightarrow \quad C = \frac{C_3(C_1 + C_2)}{C_1 + C_2 + C_3}$$

Example 2



Configuration A   Configuration B   Configuration C

Three configurations are constructed using identical capacitors

Which of these configurations has the lowest overall capacitance?

a) Configuration A

b) Configuration B

c) Configuration C

The net capacitance for A is just C

In B, the caps are in series and the resultant is given by

$$\frac{1}{C_{net}} = \frac{1}{C} + \frac{1}{C} = \frac{2}{C} \Rightarrow C_{net} = \frac{C}{2}$$

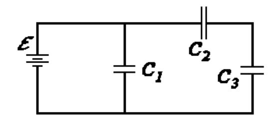
In C, the caps are in parallel and the resultant is given by

$$C_{net} = C + C = 2C$$

Example 3

A circuit consists of three unequal capacitors C_1, C_2, and C_3 which are connected to a battery of emf E. The capacitors obtain charges Q_1 Q_2, Q_3, and have voltages across their plates V_1, V_2, and V_3. C_{eq} is the equivalent capacitance of the circuit.

Check all of the following that apply:



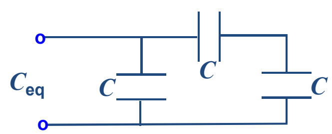
a) $Q_1 = Q_2$ **b) $Q_2 = Q_3$**   c) $V_2 = V_3$

d) $E = V_1$ e) $V_1 < V_2$ **f) $C_{eq} > C_1$**

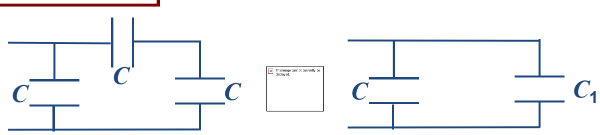
A detailed worksheet is available detailing the answers

Example 4

What is the equivalent capacitance, C_{eq}, of the combination shown?



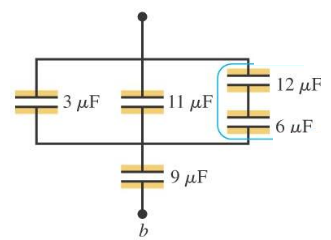
(a) C_{eq} = (3/2)C   (b) C_{eq} = (2/3)C (c) C_{eq} = 3C



$$\frac{1}{C_1} = \frac{1}{C} + \frac{1}{C} \Rightarrow C_1 = \frac{C}{2} \Rightarrow C_{eq} = C + \frac{C}{2} = \frac{3}{2}C$$

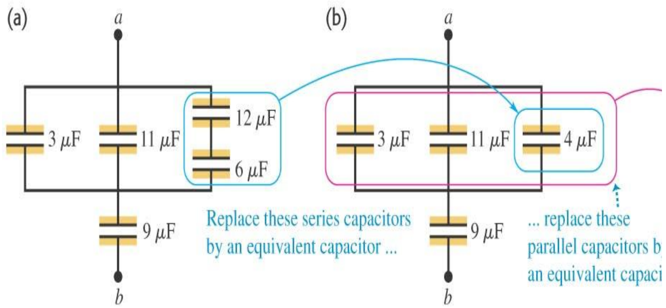
Calculations of capacitance

- Example 24.6, a capacitor network:
- Find C eq?



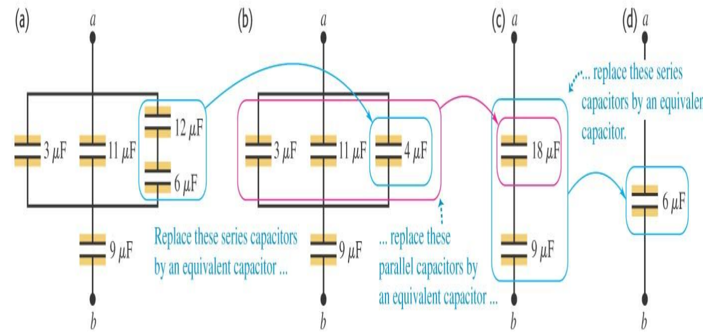
Calculations of capacitance

- Example 24.6, a capacitor network:
- Find C eq?



Calculations of capacitance

- Example 24.6, a capacitor network:
- Find C eq?



Energy Stored in a Capacitor

Electrical Potential energy is stored in a capacitor

The energy comes from the work that is done in charging the capacitor

Let q and v be the intermediate charge and potential on the capacitor

The incremental work done in bringing an incremental charge, dq, to the capacitor is then given by

$$dW = v\,dq = \frac{q\,dq}{C}$$

Energy Stored in a Capacitor

The total work done is just the integral of this equation from 0 to Q

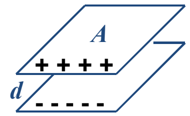
$$W = \frac{1}{C}\int_0^Q q\,dq = \frac{Q^2}{2C}$$

Using the relationship between capacitance, voltage and charge we also obtain

$$U = \frac{Q^2}{2C} = \frac{1}{2}CV^2 = \frac{1}{2}QV$$

where U is the stored potential energy

Example 5



Suppose the capacitor shown here is charged to Q and then the battery is *disconnected*

Now suppose you pull the plates further apart so that the final separation is d_1

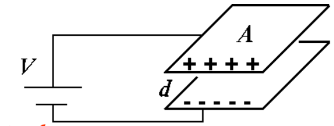
Which of the quantities Q, C, V, U, E change?

- Q: Charge on the capacitor does not change
- C: Capacitance Decreases
- V: Voltage Increases
- U: Potential Energy Increases
- E: Electric Field does not change

How do these quantities change?

Answers: $C_1 = \frac{d}{d_1} C$ $V_1 = \frac{d_1}{d} V$ $U_1 = \frac{d_1}{d} U$

Example 6



Suppose the battery (V) is kept attached to the capacitor

Again pull the plates apart from d to d_1

Now which quantities, if any, change?

- Q: Charge Decreases
- C: Capacitance Decreases
- V: Voltage on capacitor does not change
- U: Potential Energy Decreases
- E: Electric Field Decreases

How much do these quantities change?

Answers: $Q_1 = \frac{d}{d_1} Q$ $C_1 = \frac{d}{d_1} C$ $U_1 = \frac{d}{d_1} U$ $E_1 = \frac{d}{d_1} E$

Electric Field Energy Density

The potential energy that is stored in the capacitor can be thought of as being stored in the electric field that is in the region between the two plates of the capacitor

The quantity that is of interest is in fact the *energy density*

$$Energy\ Density = u = \frac{\frac{1}{2} C V^2}{A d}$$

where A and d are the area of the capacitor plates and their separation, respectively

Electric Field Energy Density

Using $C = \varepsilon_0 \frac{A}{d}$ and $V = E d$ we then have

$$u = \frac{1}{2} \varepsilon_0 E^2$$

Even though we used the relationship for a parallel capacitor, this result holds for *all* capacitors regardless of configuration

This represents the energy density of the electric field in general

Dielectrics

- A **dielectric** is an insulating material *(e.g. paper, plastic, glass)*.
- A dielectric placed between the conductors of a capacitor increases its capacitance by a factor κ, called the **dielectric constant**.

  $C = \kappa C_o$ *(C_o=capacitance without dielectric)*

  $$C = \kappa \frac{\varepsilon_0 A}{d} = \varepsilon \frac{A}{d}$$

- For a parallel-plate capacitor:

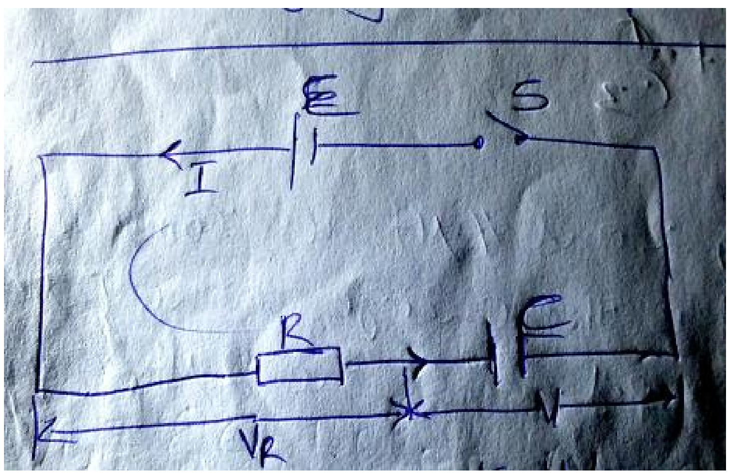
  $\varepsilon = \kappa\varepsilon_o$ = **permittivity** of the material.

Properties of Dielectric Materials

- **Dielectric strength** is the maximum electric field that a dielectric can withstand without becoming a conductor.
- Dielectric materials
  - increase capacitance.
  - increase electric breakdown potential of capacitors.
  - provide mechanical support.

Material	Dielectric Constant κ	Dielectric Strength (V/m)
air	1.0006	3×10^6
paper	3.7	15×10^6
mica	7	150×10^6
strontium titanate	300	8×10^6

Charging a capacitor



Charging a capacitor

- At time $t=0$ the switch is closed, with the capacitor initially uncharged.
- A current will flow $\mathcal{E}=V_c+V_R=I_0R$, as initially $V_c=0$. Thus the initial current is $I_0=\mathcal{E}/R$.
- Now a charge begins to build on the capacitor, introducing a reverse voltage. The current falls, and stops when the P.D. across C is $\mathcal{E}$.
- Final charge is given by "$Q=CV$" => $Q_0=C\mathcal{E}$.

Charging a capacitor (quantitative).

- Apply Kirchoff's loop rule.

$$\varepsilon = V_c + V_R = \tfrac{Q}{C} + iR = \tfrac{Q}{C} + R\tfrac{dQ}{dt}$$
$$\tfrac{dQ}{dt} = \tfrac{1}{R}\left(\varepsilon - \tfrac{Q}{C}\right) = \tfrac{1}{RC}\left(C\varepsilon - Q\right)$$
$$\int \tfrac{dQ}{C\varepsilon - Q} = \int \tfrac{dt}{RC}$$
$$\left[-\ln(C\varepsilon - Q)\right]_{Q=0}^{Q} = \tfrac{1}{RC}\left[t\right]_{t=0}^{t}$$
$$-\ln(C\varepsilon - Q) + \ln(C\varepsilon) = \tfrac{t}{RC}$$

Charging a capacitor (cont)

$$-\ln\left(\frac{C\varepsilon - Q}{C\varepsilon}\right) = \frac{t}{RC}$$
$$\frac{C\varepsilon - Q}{C\varepsilon} = e^{-t/RC}$$
$$1 - \frac{Q}{Q_0} = e^{-t/RC}$$

- Where $Q_0 = C\varepsilon =$ the final charge on the capacitor.

$$Q = Q_0(1 - e^{-t/RC})$$

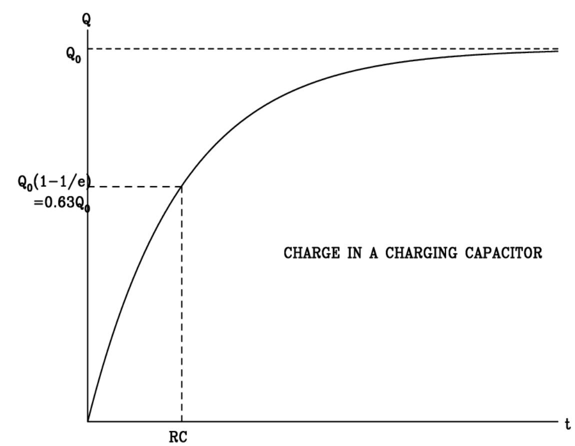
Charging a capacitor (cont).

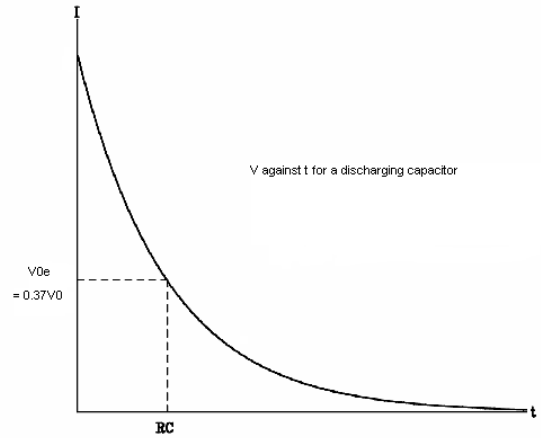
- To find the current, differentiate since $I = dQ/dt$.

$$Q = Q_0(1 - e^{-t/RC})$$
$$I = \frac{Q_0}{RC}e^{-t/RC} = \frac{\varepsilon}{R}e^{-t/RC}$$

- By considering time zero, when the current is I_0,

$$I = I_0 e^{-t/RC}.$$





Incidentally, graphs can be V or Q against t, they all have the same basic shape

Introduction

- Bridge are used to measure resistance, inductance, capacitance and impedance.
- Their operation is based on a null indication principle. This means the indication is independent of the calibration of the indicating device or any characteristics of it.
- Very high degrees of accuracy can be achieved using the bridges

Types of bridges

Two types of bridge are used in measurement:

1) DC bridge:
   a) Wheatstone Bridge
   b) Kelvin Bridge

2) AC bridge:
   a) Similar Angle Bridge
   b) Opposite Angle Bridge/Hay Bridge
   c) Maxwell Bridge
   d) Wein Bridge
   e) Radio Frequency Bridge
   f) Schering Bridge

DC BRIDGES

The Wheatstone Bridge
The Kelvin Bridge

Wheatstone Bridge

A **Wheatstone bridge** is a measuring instrument invented by *Samuel Hunter Christie (British scientist & mathematician) in 1833* and improved and popularized by **Sir Charles Wheatstone in 1843**. It is used to measure an unknown electrical resistance by balancing two legs of a bridge circuit, one leg of which includes the unknown component. Its operation is similar to the *original* potentiometer except that in potentiometer circuits the meter used is a sensitive galvanometer.

Sir Charles Wheatstone (1802 – 1875)

Wheatstone Bridge

Definition: Basic circuit configuration consists of two parallel resistance branches with each branch containing two series elements (resistors). To measure instruments or control instruments

Basic dc bridge used for accurate measurement of resistance:

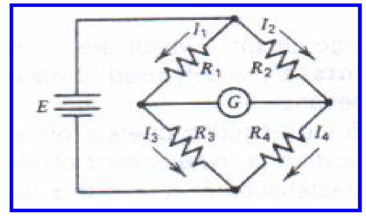


Fig. 5.1: Wheatstone bridge circuit

$$R_1 R_4 = R_2 R_3$$

$$R_4 = \frac{R_2 R_3}{R_1}$$

How a Wheatstone Bridge works?

- The dc source, E is connected across the resistance network to provide a source of current through the resistance network.
- The sensitive current indicating meter or null detector usually a galvanometer is connected between the parallel branches to detect a condition of balance.
- When there is no current through the meter, the galvanometer pointer rests at 0 (midscale).
- Current in one direction causes the pointer to deflect on one side and current in the opposite direction to otherwise.
- The bridge is balanced when there is no current through the galvanometer or the potential across the galvanometer is zero.

Cont.

At balance condition;

voltage across R1 and R2 also equal, therefore

$$I_1 R_1 = I_2 R_2 \qquad \textbf{(1)}$$

Voltage drop across R3 and R4 is equal

$$I_3 R_3 = I_4 R_4 \qquad \textbf{(2)}$$

No current flows through galvanometer G when the bridge is balance, therefore:

$$I_1 = I_3 \quad \text{and} \quad I_2 = I_4 \qquad \textbf{(3)}$$

Cont.

Substitute (3) in Eq (2),

$$I_1R_3 = I_2R_4 \quad (4)$$

Eq (4) devide Eq (1)

$$R_1/R_3 = R_2/R_4$$

Then rewritten as

$$R_1R_4 = R_2R_3 \quad (5)$$

Example 5-1

Figure 5.2 consists of the following, R_1 = 12kΩ, R_2 = 15 kΩ, R_3 = 32 kΩ. Find the unknown resistance R_x.
Assume a null exists(current through the galvanometer is zero).

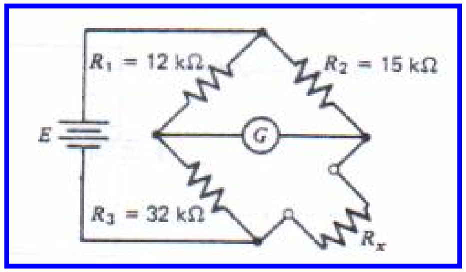
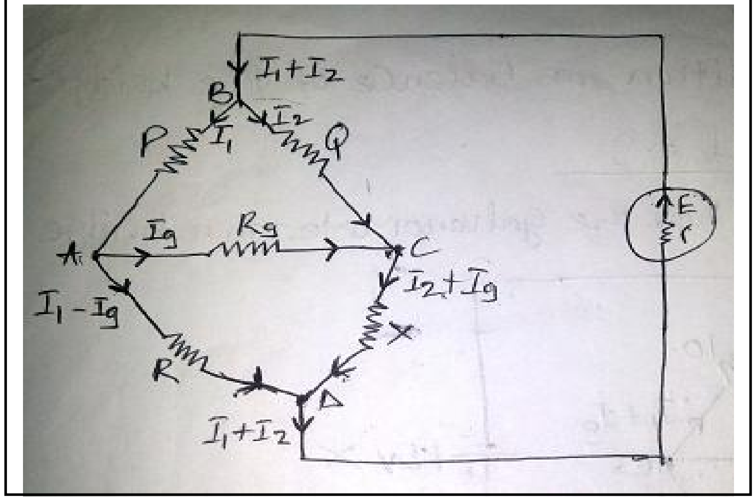


Fig. 5-2: Circuit For example 5-1

Solution 5-1

$$R_xR_1 = R_2R_3$$
$$R_x = R_2R_3/R_1 = (15 \times 32)/12\ k\Omega,$$
$$R_x = 40\ k\Omega$$

Cont....



Cont.......

X is the unknown Resistance, P, Q, R are resistance boxes. One of the resistance box (e.g. R) is adjusted until the galvanometer between A, C, represented by its resistance Rg, shows no deflection that is Ig = 0

Then P/Q = R/X

X = QR/P

Using Kirchoff's law applied to the cct.

Loop ACBA: $R_g I_g - QI_2 + PI_1 = 0$ 1

Loop ACDA:

$$R_g I_g + X(I_2 + I_g) - R(I_1 - I_g) = 0$$

$$R_g I_g + I_2 X + I_g X - RI_1 + RI_g = 0$$

$$I_g(R_g + X + R) + XI_2 - RI_1 = 0 \qquad 2$$

Cont.......

Suppose we wish to find the condition for no deflection on the galvanometer, then we put Ig = 0 in equ (1) and (2), we have

$$-QI_2 + PI_1 = 0 \ or \ PI_1 = QI_2$$

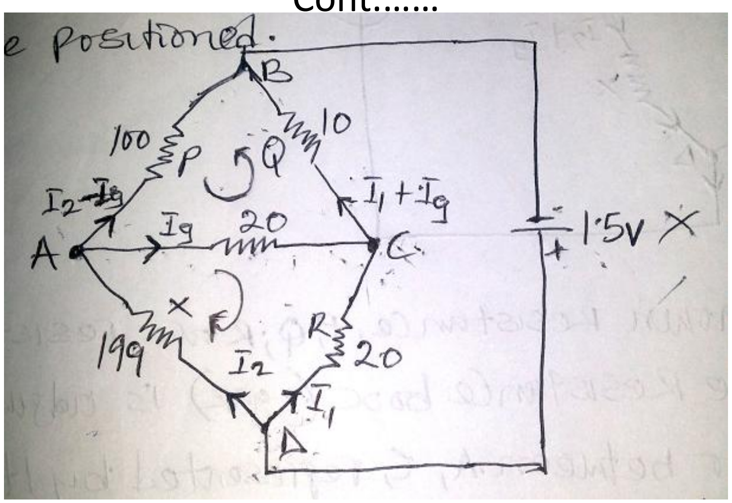
$$\frac{P}{Q} = \frac{I_2}{I_1}$$

And $IX_2 - RI_1 = 0 \text{ or } XI_2 = RI_1$

$$\frac{R}{X} = \frac{I_2}{I_1} \qquad P/Q = R/X$$

Therefore. This is the condition for balance of the bridge.

Cont.......



Cont.......

We want to look at how the galvanometer in a bridge circuit can be positioned. This is an unbalanced Wheatstone bridge where Ig is to be determined. The internal resistance r is negligible.

Applying Kirchoff's law

Loop ACBA: $20I_g + 10(I_1 + I_g) - 100(I_2 - I_g) = 0$

$$130I_q + 10I_1 - 100I_2 = 0$$

$$I_1 = 10I_2 - 13I_g \qquad *$$

Loop ADCA: $-199I_2 + 20I_1 - 20I_g = 0$

Cont…….

Subs for I_1 $\therefore -199I_2 + 20(10I_2 - 13I_g) - 20I_g = 0$

$$-199I_2 + 200I_2 - 260I_g - 20I_g = 0$$

$$I_2 - 280I_g = 0$$

$$I_2 = 280I_g$$

Subs for I_2 in equ (*) $I_1 = 2800I_g - 13I_g = 2787I_g$

Loop DCBXD: $20I_1 + 10(I_1 + I_g) = 1.5$

$$30I_1 + 10I_g = 1.5 \qquad (**)$$

Cont…….

Subs for I1 in equ (**).

$$30 \times 2787I_g + 10I_g = 1.5$$

$$83620I_g = 1.5$$

$$I_g = 1.5/83620$$

$$= 1.79 \times 10^{-5}\ A$$

$$17.9\mu A$$

Sensitivity of the Wheatstone Bridge

When the bridge is in unbalanced condition, current flows through the galvanometer, causing a deflection of its pointer. The amount of deflection is a function of the sensitivity of the galvanometer.

Cont.

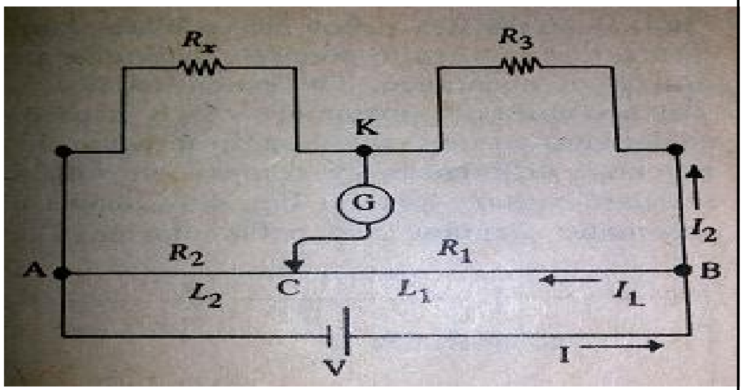
Deflection may be expressed in linear or angular units of measure, and sensitivity can be expressed:

$$S = \frac{\text{milimeters}}{\mu\text{A}} = \frac{\text{degrees}}{\mu\text{A}} = \frac{\text{radians}}{\mu\text{A}}$$

Total deflection, $D = S \times I$

METER BRIDGE

A meter bridge is a simple and cheap form of a Wheatstone bridge. It is sometimes called a slide-wire bridge.



METER BRIDGE

If Rx is to be determined from cct. Shown in the previous slides, then we assume that the slide wire is uniform. At null condition, (I1 – B – C – A) and (I2 – B – K – A)

Therefore, applying

Loops BKCB = $-I_2 R_3 + I_1 R_1 = 0$

$$or\ I_2 R_3 = I_1 R_1$$

and AKCA $I_2 R_x = I_1 R_2$

$$hence\ R_x = R_3 \left(\frac{R_2}{R_1} \right)$$

METER BRIDGE

But if $R_1 = \rho \frac{L_1}{A}$

$$and\ R_2 = \rho \frac{L_2}{A}$$

Therefore, $\frac{R_2}{R_1} = \frac{L_2}{L_1}$

$$R_x = R_3 \frac{L_2}{L_1}$$

METER BRIDGE

If $R_3 = 34.5\Omega$ and $length\ AC = 28.2cm,\ CB = 71.8cm$

Then $R_x = (34.5)\left(\frac{28.2}{71.8}\right) = 13.6\Omega$

Example.

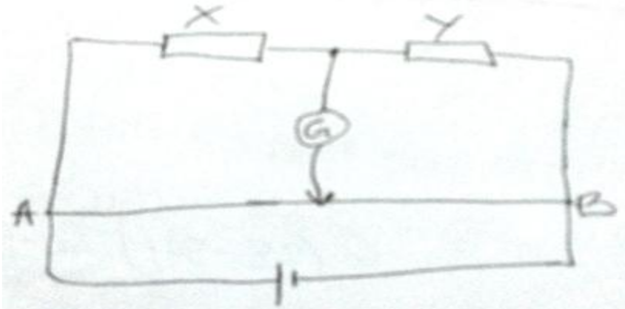
In a meter bridge cct. A balance (zero deflection in the galvanometer) is obtained at 0.6 m mark. When a 6 ohm resistor is connected in the left gap. Cal. The value of the resistance in the right gap of the cct

$$\frac{6}{R} = \frac{0.6}{0.4}$$

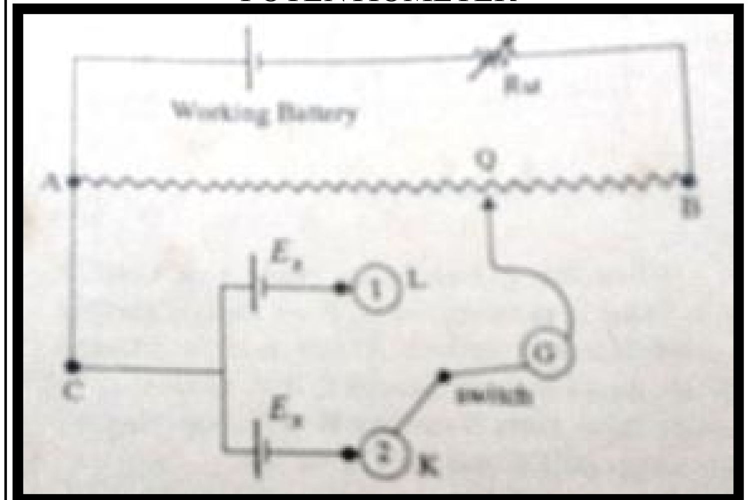
$$R = \frac{0.6}{6 \times 0.4} = 0.25\Omega$$

METER BRIDGE

From the cct. Shown below, the resistance of X and Y are 5 Ohms and 3 Ohms resp. the length of AB = 1.00m. When shunt is connected in parallel to X, the balanced length is 0.527m from A. what is the resistance of the shunt.



POTENTIOMETER



POTENTIOMETER

A potentiometer is another null-type instrument which is under zero current condition, to measure the potential differences by comparison with a standard voltage source. The working battery supplies current I to wire AB.

When the switch is then thrown to position (2) and the unknown voltage Ex is connected. Point Q is moved along AB until no current flows through G. Therefore,

Loop AQKCA $-IR_x + E_x = 0$

$$IR_x = E_x \qquad \text{a}$$

If the switch is now thrown to position (1), Es is connected. The pointer Q is moved along AB to a new position Q' Rs is the resistance between A and Q'

So Loop AQ'LCA

$$-IR_s + E_s = 0$$

$$IR_s = E_s \qquad \text{b}$$

:

POTENTIOMETER

Dividing equ (a) by equ (b)

$$\frac{E_x}{E_s} = \frac{IR_x}{IR_s} = \frac{R_x}{R_s}$$

$$E_x = E_s\left(\frac{R_x}{R_s}\right)$$

$$= E_s\left(\frac{AQ}{AQ'}\right)$$

$$= E_s\left(\frac{L_x}{L_s}\right)$$

POTENTIOMETER

Ex. A slide-wire potentiometer is balanced against a 1.0182V standard cell when the slide wire is set at 40.20 cm out of a total length of 100 cm. for an unknown source, the setting is 11.9 cm. what is the emf of the unknown cell.

Solution.

$$E_x = E_s\left(\frac{R_x}{R_s}\right) = E_s\left(\frac{L_x}{L_s}\right)$$

$$= (1.0182)\left(\frac{11.9}{40.2}\right)$$

$$= 0.3014V$$

PHY 152: Electricity and Magnetism

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Course sub-outline

- Electric current and conductivity
- Types of material
- Properties of conductors
- Semiconductors
- Application of semiconductor-Diode

Suggested textbooks and references

1. "Solid State Electronic Devices", Streetman and Banerjee, 5th ed., Prentice-Hall Intl Editions, ISBN 0-13-025538-6, 2000.
2. Physics for Scientists and Engineers by Fishbane et al., 2nd edition. Publisher: Prentice Hall, Upper Saddle River, New Jersey 07458
3. International Edition Physics, 5th Edition by Giancoli
4. Electronic Devices and Circuit by J.B. Gupta. Katson Educational Series.
5. Lecture notes on Introduction to diodes by F. Najimabadi, ECE65_W12_pdF

- 6. Lecture note EE2-Semiconductor device k.fobelets@imperial.ac.uk

Objectives

- At the end of this programme, ***students should be able to :***

1. Classify materials according to their electrical conductivity.
2. Define and apply terms that are applicable to conduction of electricity such as conductivity, mobility, resistivity etc.
3. Discuss the properties of semiconductors as distinct from that of conductors
4. Appreciate the application and importance of semiconductor devices in the field of electronics.

Electric Current and conduction

- Electric current is charge in motion.
- Electric charges are the carriers of electrical force, which is an example of field forces.
- In the presence of electric field E, a charge q=e will experience a force F= eE due to the field of E.
- The force sets the charge into motion with an acceleration a, leading to kinetic force F=ma, where m is the mass of the charge.
- Thus:

$$F_e = F_m$$

and

$$eE = ma$$

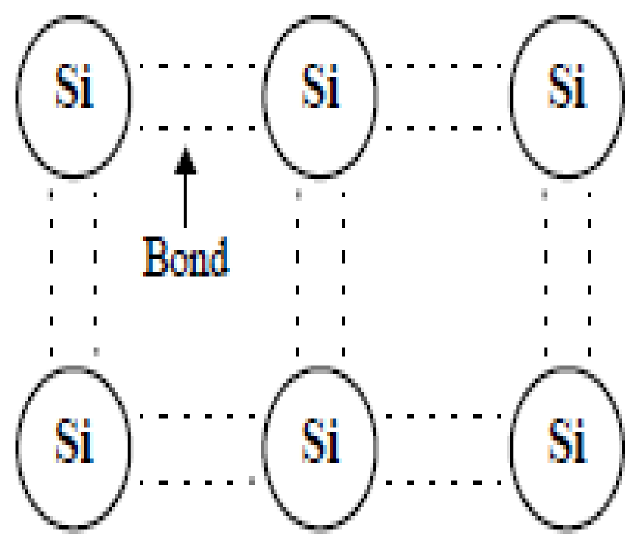
- Thus an electric current will flow through a material in the presence of an electric field provided there are free electrons to set into motion.
- Movement of charges in this manner is referred to as electrical conduction.

Material and electrical conduction

- Materials differ over an enormous range in their ability to conduct electricity.
- Four categories can be identified namely: **insulators**, **conductors**, **semiconductors** **and** **superconductors**.
- The properties which distinguish between these materials are explained by quantum mechanics.
- **Quantum description of materials shows that energy of an electron in an atom of the material can only take discrete values**.
- When a set of atoms forms a regular background lattice (through covalent bonds), the possible energy values of the electron are modified, however the allowed energies of an electron are still discrete
- But instead of tiny separation between neighbouring levels***, there are energy gaps, which are regions of energy forbidden to the electron.***
- The regions where the energy levels are close together are called allowed bands of energy level.

Covalent bond

- Sometimes valence electrons are shared, becoming a bond between two atoms - covalent bonding.
- This is the bonding type in diamond-crystal lattice semiconductors such as silicon semiconductors.
- An almost continuous band of allowed energies of electrons comes about when atoms are brought in close proximity to each other, this is because of the inter-atomic forces coupled with the prediction of **Pauli exclusion principle.**

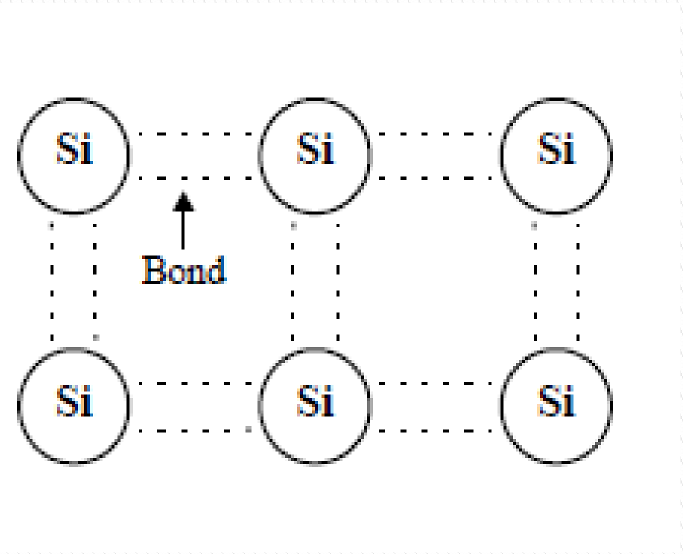


Covalent bond

Covalent bond in Silicon

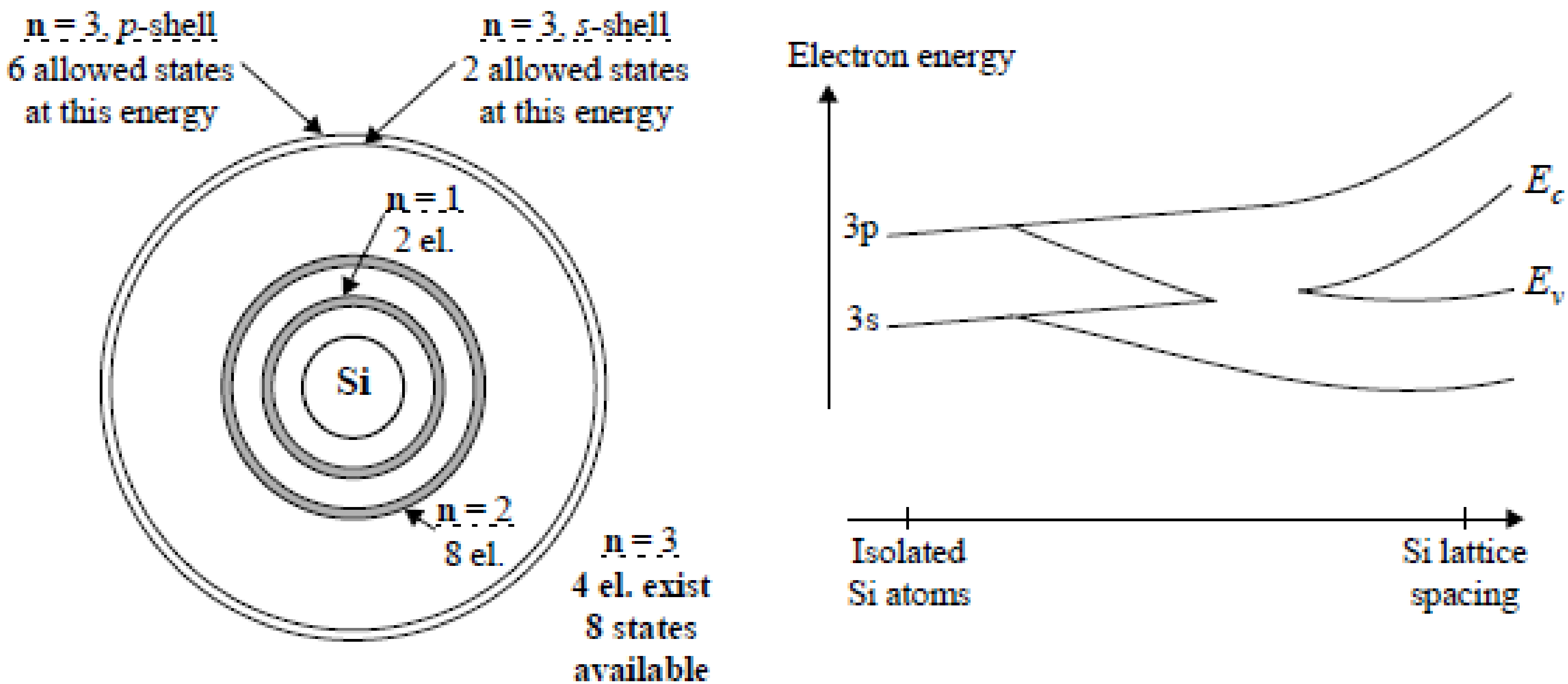
Covalent bond

- ***According to Pauli exclusion principle at most only two electrons can occupy an energy level at the same time.***
- So one energy level is split into N levels when N atoms are brought together, and these N levels can accommodate at most 2N electrons due to spin degeneracy.



Covalent bond in Silicon

Covalent bond and Energy band



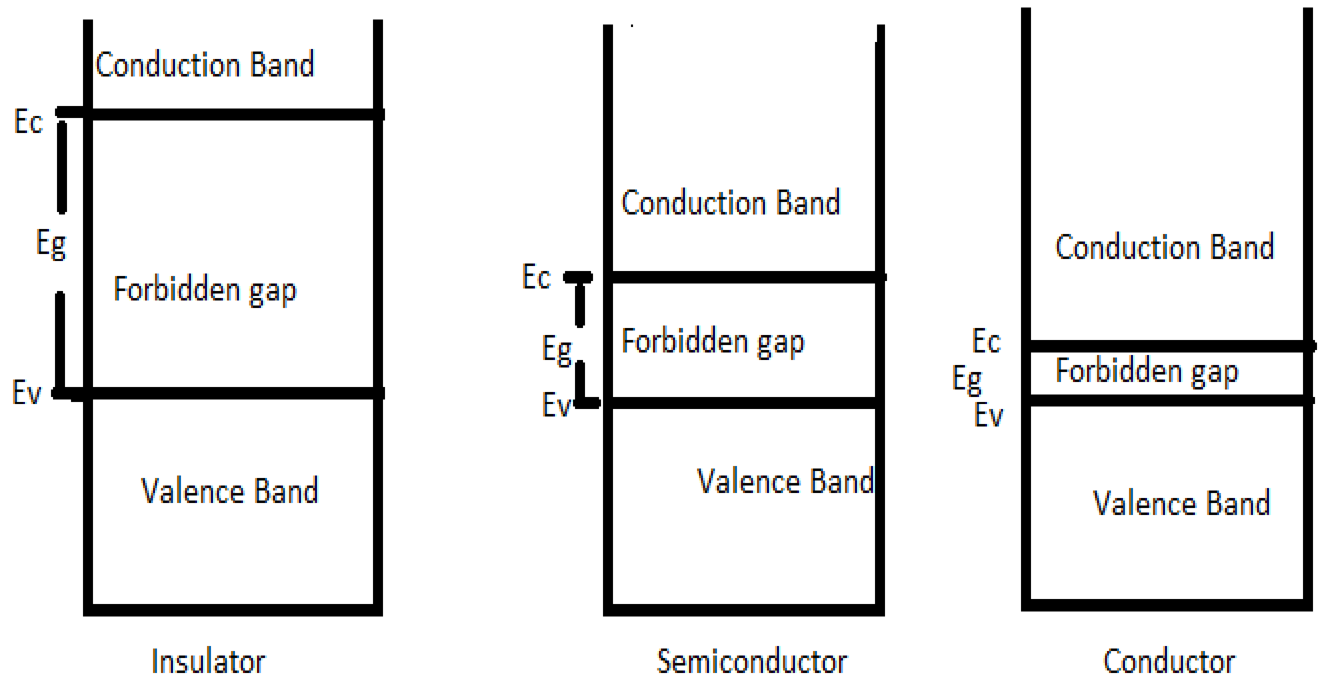
(Left) Isolated Si atom, having 14 electrons. (Right) Energy bands are forming when a huge number of atoms are brought together.

Energy band

- Now, since the separation between the energy levels within the band is much smaller than the thermal energy possessed by an electron ***at room temperature the band can be viewed as continuous.***
- Ec is the lowest possible conduction band energy, while Ev is the highest possible valence band energy.
- The band gap energy, Eg, is furthermore defined as (Ec - Ev).
- Eg is the energy it takes to break a bond in the spatial view of the crystal. It is the factor that determine whether a material is or not a conductor at ordinary room temperatures. The lower the energy gap the more readily the material conducts.
- The band gap energies for some semiconductors at T=300 K are:

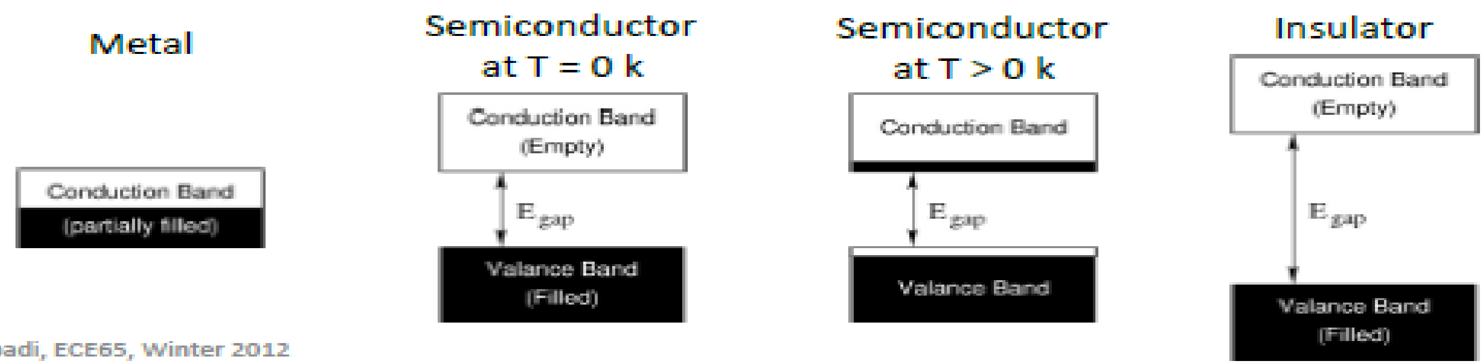
  Eg = 1.42 eV in Galanium- Ascenide (GaAs) and 1.12 eV in Silicon (Si).
- For insulators: Eg ~ 8 eV (SiO2) and ~ 5 eV (diamond)
- (where 1 eV = 1.602 x10-19 J)

Material and electrical conduction



Difference between conductors, semiconductors and insulators

- In a metal, the conduction band is partially filled. These electron can move easily in the material and conduct heat and electricity (Conductors).
- In a semi-conductor at 0 k the conduction band is empty and valance band is full. The band-gap is small enough that at room temperature some electrons move to the conduction band and material conduct electricity.
- An insulator is similar to a semiconductor but with a larger band-gap. Thus, at room temperature very few electrons are in the conduction band.



F. Najmabadi, ECE65, Winter 2012

Properties of conductors (1): Current density

- **Electric current**, i the total charge that passes through a unit cross-sectional area per unit time.

  $$i = dq/dt \qquad (1)$$

- Unit of current is Ampere, A

- **The charge,** q passing through a plane in a time interval between 0 and t is defined as

  $$q = \int dq = \int i dt \qquad (2)$$

- Unit of charge is Coulomb, C
- **Current density,** J is the rate of flow of charge per unit area through an infinitesimal area of a conductor:

  $$di/dA = \mathbf{J}$$

  $$di = \mathbf{J} dA\cos\theta \qquad (3)$$

Properties of conductors (2)

- Equation (3) shows that current density is a vector, putting the magnitude and direction of charge flow into consideration.
- Integrating equation (3) gives another definition of current:

$$I = \int \mathbf{J} \cdot d\mathbf{A}$$

$$= \mathbf{J}.A \qquad (4)$$

- Current density is then defined as: the total current flowing through a conduct per unit cross-sectional area:

$$\mathbf{J} = I/A \qquad (5)$$

Properties of conductors (3): Charge Density

- Consider charge q = ne flowing through a conductor of finite area A at a velocity v, the current through the area is given as:

  $i = dq/dt$

  $= nevA$

- The current density then can be expressed as:

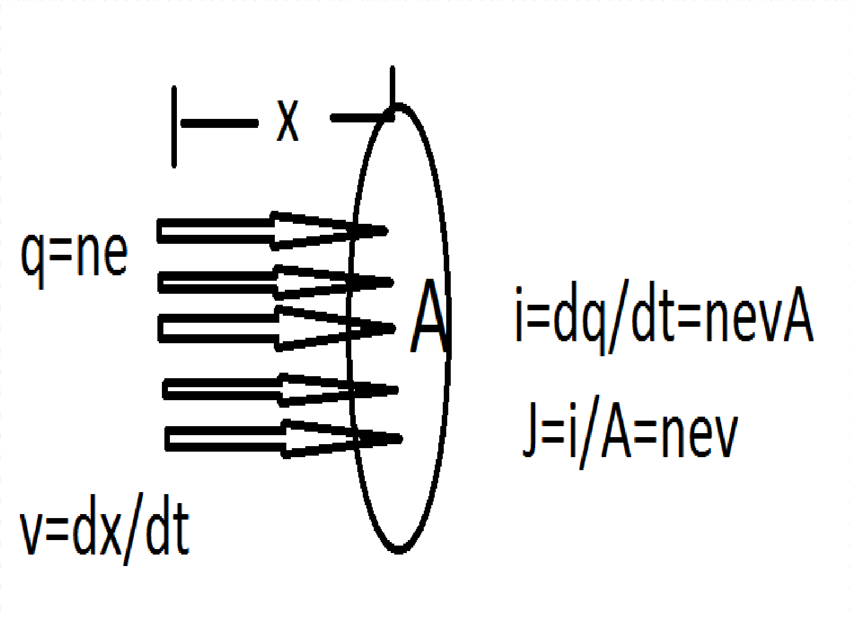
  $J = i/A = nev \quad (6)$

Or

$J = \rho v \quad (7)$

Where we have defined $\rho = ne$,

the charge density (unit= Coulomb/m3)



Defining current density

Net charge flowing through a conductor of cross-section area A

Properties of conductors (4): Drift Velocity

- The electrical force, F on the charge q = e flowing through a conductor is given as

$$F = eE \qquad (8)$$

here E, is the electric field, e is electron charge and n is number of electrons.

- This force must be equal to the force,

$$F = ma \qquad (9)$$

producing the motion of charge, thus:

$$ma = eE$$

$$a = eE/m \qquad (10)$$

Where a is the acceleration of the charge.

$$a = v / T$$

$$= eE/m \qquad \text{or}$$

$$v = (eE/m)T \qquad (11)$$

Where v is known as the **Drift velocity** of charges and T is the **relaxation time.**

Properties of conductors(5): Electrical Conductivity

- Applying equation (11) in (6) and (7):

$$J = env \quad (6)$$
$$= en(eE/m)\tau$$
$$= \rho(eE/m)\tau$$

- Leading to:

$$J = \rho \frac{eE}{m} \tau = \frac{ne^2 E}{m} \tau \quad (12)$$

- We reduce the equation to

$$J = \sigma E \quad (13)$$

- Here

$$\sigma = \frac{\tau n e^2}{m} \quad (14)$$

a constant known as the ***electrical conductivity of the material.***

Properties of conductors(6):Mobility & Resistivity

- From equation (14), we define the term

$$\mu_e = \frac{e\tau}{m} \qquad (15)$$

known as the mobility of electrons due to the presence of electric field, E.

- ***Mobility of electrons in metallic conductor is defined as the steady state drift velocity per unit electric field.***
- Recall equation (13):

$$J = \sigma E$$

- We define the term resistivity ρ (not to be mistaken with charge density) as

$$\rho = 1/\sigma \qquad (16)$$

- Giving another expression for the current density:

$$J=(1/\rho)E \qquad (17)$$

Properties of conductors (7):Resistivity

- Where the electric field intensity,

$$E = V/L$$

and current,

$$I = JA$$
$$= (1/\rho)AE$$
$$= (1/\rho)(V/L)A \qquad (18)$$

- Recall Ohm's law:

$$V = IR$$
$$= (VA/\rho L)R$$

- Leading to:

$$\rho = (A/L)R \qquad (19)$$

Where ρ is known as the resistivity of the material.

Properties of conductors (8): Resistivity

- Thus for a conductor of unit cross sectional area and of unit length, *the resistivity is independent of the dimension but is dependent on the material of which it is made.* The unit is Ωm.

- However, the resistivity of some materials depend on temperature; for instance the resistivity of copper varies directly with temperature to about 8500C. For such materials we can express the temperature dependence of resistivity as

$$\rho = \rho_0[1 + \alpha(T - T_0] \qquad (20)$$

- Since the resistance of any material is proportional to its resistivity, resistance also varies with temperature and this variation may be expressed as

$$R = R_0[1 + \alpha(T - T_0] \qquad (21)$$

- Where R and R0 are the resistance at temp. T and T0 respectively; α is the temperature coefficient of resistivity.

Worked example:1

- A copper conductor of square cross section 1 mm on a side carries a constant current of 20 A. The density of free electrons is 8x 10^{28} electrons per cubic meter. Find the current density and the drift velocity.

- ***Solution***:

The current density in the wire is

$$J = \frac{I}{A} = 20x10^{6} A.m^{-2}$$

- From equation (6):

$$v = \frac{J}{nq} = \frac{(20x10^{6})}{(8x10^{28})(1.6x10^{-19})} = 1x10^{-3} ms^{-1}$$

Example:2

Calculate the drift velocity of the free electrons in a copper wire of cross sectional area 1.0 mm^2 when the current flowing through the wire is 2.0 A. (Number of free electrons in copper is 1 x 10^{29} m^{-1}).

Solution:

Using equation 6: $I = envA$

Drift velocity $v = \frac{I}{enA}$

$$= \frac{2.0}{(1.0 \; x \; 10^{29})(1.0 \; x \; 10^{-6})(1.6 \; x \; 10^{-19})}$$

$$= 1.25 \; x \; 10^{-4} ms^{-1}$$

Example:3

The following data is known for a conductor: Fermi energy = 5.5 eV, Mobility of electrons = 7.04 x 10^{-3} m^2/V-s, Number of electrons/m^3 = 5.8 x10^{28}. Calculate (i) Relaxation time (ii) Resistivity of conductor and (iii) velocity of electrons with the Fermi energy (e = 1.6 x10^{-19}C, m = 9.1x10^{-31} kg).

Solution.

(i) Using equation (15), relaxation time is given as

$$\tau = \frac{\mu_e}{e} x\, m = \frac{7.04x10^{-3}x9.1x10^{-31}}{1.6x10^{-19}} = 40.04x10^{-15} sec.$$

(ii) Resistivity of conductor, using equation (17) and (14):

$$\rho = \frac{1}{\sigma} = \frac{1}{ne\mu_e}$$

$$= \frac{1}{5.38x10^{28}x1.6x10^{-19}x7.04x10^{-3}}$$

$$= 1.531x10^{-8}\Omega m$$

(iii) Velocity of electrons with Fermi energy. The velocity v_F of an electron with Fermi energy F_E is given as $\frac{1}{2}mv_F^2 = E_F$, hence

$$v_F = \sqrt{\frac{2E_F}{m}} = \sqrt{\frac{2x5.5x1.6x10^{-19}}{9.1x10^{-31}}} = 1.3907\, x\, 10^6 m/s$$

Example:4

- A copper conductor of square cross-section 1 mm on a side carries a constant current of 20 A. Suppose the resistance is 1.72 Ω at a temperature of 20 ^oC. Find the resistance at 0^oC and at 100 ^oC (Temperature coefficients of resistivity for copper is 0.00393 /^oC.
- **Solution**:
- Using equation (21) with $T_0 = 20^0C \text{ and } R_0 = 1.72\,\Omega. \text{Thus at } T = 0^0C,$

$$R = 1.72[1 + (0.00393)(0 - 20)] = 1.58\,\Omega$$

- And at $T = 100^0C$

$$R = 1.72[1 + (0.00393)(100 - 20)] = 2.26\,\Omega$$

Semiconductors

- See lecture 2 (page 7) on the PDF note

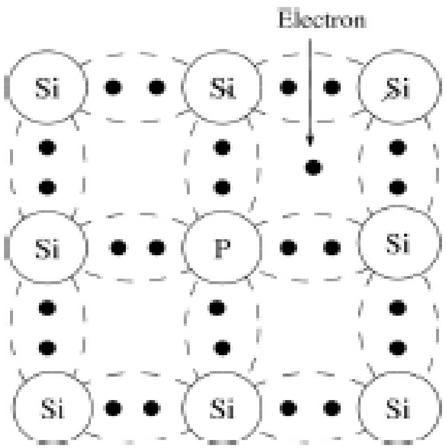
Semiconductor: Electrons & Holes

- Conduction of electric current in semiconductor is made possible by the presence of electrons and holes.
- For intrinsic semiconductors, this occurs at temperature above room temperatures
- For extrinsic semiconductors, electrons and holes are generated by means of doping; a process whereby an impurity is added to the semiconductor.

- At T > 0 k, some electrons are promoted to the conduction bands.
- A current flows when electrons in the conduction band move across the material (e.g., due to an applied electric field).
- A current also flows when electrons in the valance band jump between available slots in the valance bands (or "holes").
  - An electron moving to the left = a hole moving to the right!
  - We call this is a "hole" current to differentiate this current from that due to conduction band electrons.

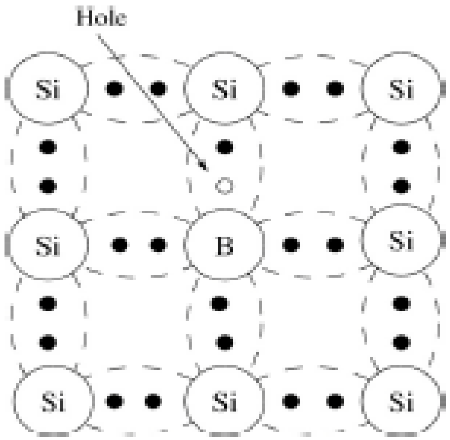
Semiconductor: Doping & effect

Doped n-type Semiconductor



- Donor atom (P doping) has an extra electron which is in the conduction band.
- Charge Carriers:
  - Electrons due to donor atoms
  - Electron-hole pairs due to thermal excitation
  - e: majority carrier, h: minority carrier

Doped p-type Semiconductor



- Acceptor atom (B doping) has one less electrons: a hole in the valance band.
- Charge Carriers:
  - Holes due to acceptor atoms
  - Electron-hole pairs due to thermal excitation
  - h: majority carrier, e: minority carrier

Semiconductor devices : P-N Junction (1).

- Most semiconductor devices employ one or more P-N junctions.
- **P-N junction is the control element for the performance of all semiconductor devices such as rectifiers, amplifiers, switching devices, linear and digital integrated circuits.**
- P-N junction is produced by placing a layer of P-type semiconductor next to the layer of N-type semiconductor.
- The interface separating the N and P regions is referred to as **the metallurgical junction**.

P–N junction (2)

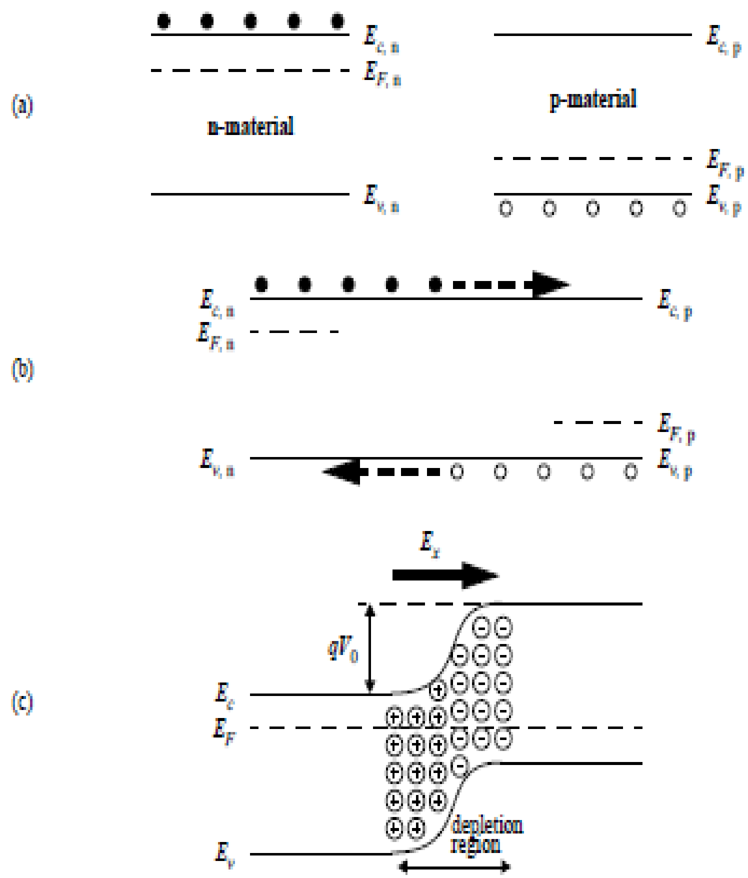


Fig.4: Different stages involved in p-n.

- When the two pieces are put together, in a so-called step junction, diffusion of carriers will immediately start taking place, as depicted in Fig.4 (b).
- Electrons diffuse from the n-material to the p-material in the conduction band, while holes diffuse from the p-material to the n-material in the valence band.
- Uncompensated dopant ions are left behind on each side and the electric field that is starting to build up, because of these ions, will soon balance the diffusion.
- Fig.4(c) shows the final stage in which a balance between drift and diffusion has been established.

P-N junction (3)

- The electric field Ex is forcing electrons to the left and holes to the right, which exactly balances the electron diffusion to the right and the hole diffusion to the left.
- We now have a p-n junction with a built-in potential which is called the contact or barrier potential, V0.
- The region around the junction is called the depletion region and according to the depletion approximation it completely lacks free carriers (which is almost true).
- Fig. 5 shows the doping profile of an ideal uniformly doped P-N junction.

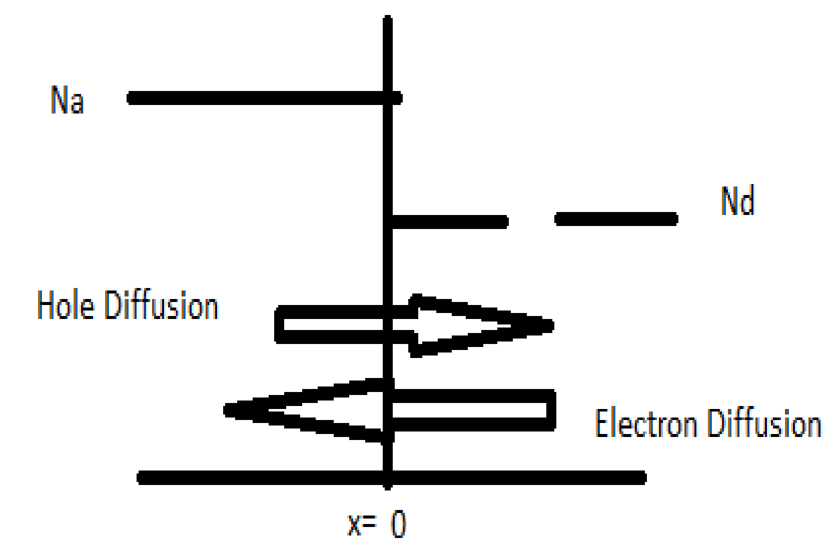


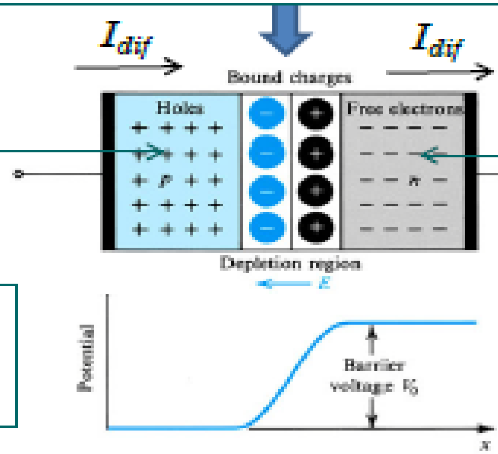
Fig.5:Doping profile of an ideal uniformly doped P-N junction.

P–N junction (4)

High concentration of h on the p side
Holes diffuse towards the junction

High concentration of e on the n side
Electrons diffuse towards the junction

Holes from the p side and electrons from the n side combine at the junction, forming a depletion region



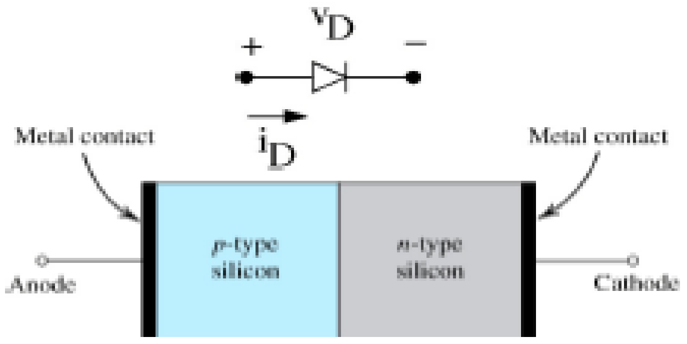
p side is negatively charged because it has lost holes.

n side is positively charged because it has lost electrons.

- A potential is formed which inhibits further diffusion of electron and holes (called junction built-in voltage)

P–N junction diode: Application (1)

- P-N junction diode is a device which conducts when forward biased and practically does not conduct when reverse biased.
- When an external field, with P-region connected to positive terminal and N-region connected to negative terminal of the battery is applied across the junction, the junction is said to be forward biased.
- In this circuit arrangement, the holes on the P-side being positively charged particles are repelled from the positive bias terminal and driven toward the junction. Similarly, the electrons on the N-side are repelled from the negative bias terminal and driven towards the junction.
- The result is that the depletion region is reduced in width and the barrier potential is also reduced.



Simplified physical structure

Application of diodes: Rectifier

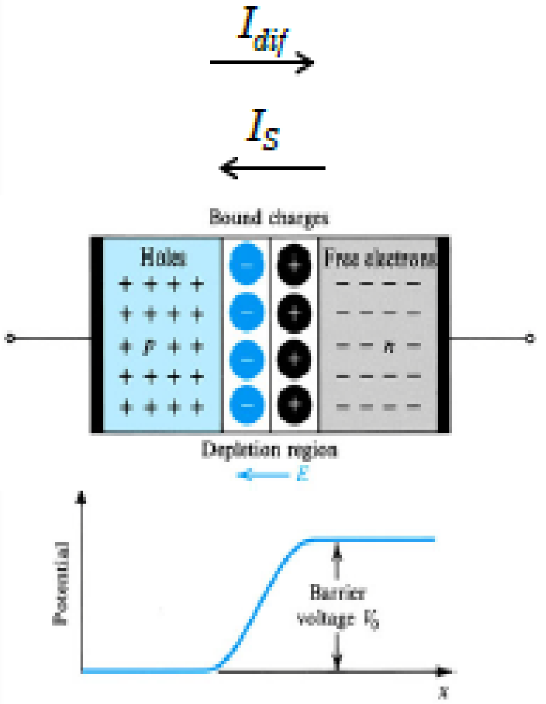
Diode in forward bias

P–N junction diode (2)

- If the applied bias voltage is increased from zero, the barrier potential gets progressively smaller until it effectively disappears and charge carriers can easily flow across the junction.
- Electrons from the N-side are then attracted to the positive bias terminal while holes from the P-side flows across to the negative bias terminal on the N-side.
- This leads to the flow of a current of majority carrier.
- Since barrier potential is very small (0.3 V for Ge and 0.7 V for Si), a small forward voltage is sufficient to eliminate the barrier completely.
- Once the barrier is eliminated, junction resistance becomes almost zero and a low resistance path is established in the entire circuit.
- The current, called forward current flows in the circuit.

P-N Junction diode (3)

- Thermally-generated minority carriers on the n side (holes) move toward the depletion region, and are swept into the p side by the potential where the combine with electrons. (similar process for minority carriers on the p side). This sets up a drift current, I_S.
- To preserve charge neutrality, a non-zero $I_{dif} = I_S$ should flow (height of potential is slightly lower).
- **I_{dif} scales exponentially with changes in the voltage barrier.**
- **I_S is independent of the voltage barrier but is a sensitive function of temperature.**



Diode i–v characteristic (1)

$$i_D = I_S\left(e^{v_D/nV_T} - 1\right)$$

I_S: Reverse Saturation Current (10^{-9} to 10^{-18} A)

V_T: Volt-equivalent temperature (= 26 mV at room temperature)

n: Emission coefficient ($1 \le n \le 2$ for Si ICs)

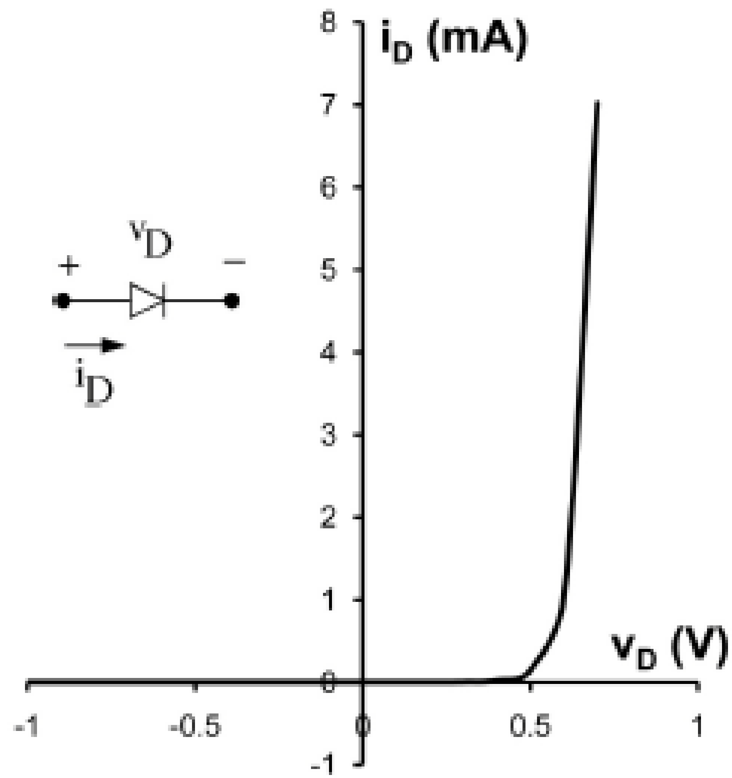
For $|v_D| \ge 3nV_T$

Forward bias: $i_D \approx I_S\, e^{v_D/nV_T}$

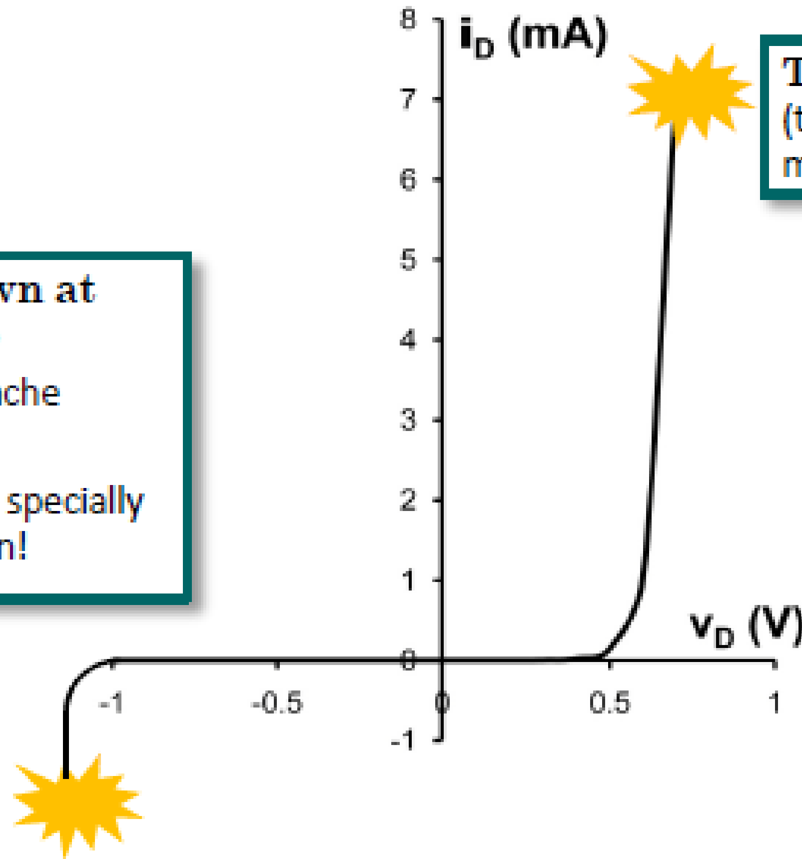
Reverse bias: $i_D \approx -I_S$

Sensitive to temperature:

- I_S doubles for every 7°C increase
- $V_T = T/11{,}600$



Diode limitation



Thermal load, $P = i_D v_D$
(typically specified as maximum i_D)

Reverse Breakdown at Zener voltage (V_Z)
(due to Zener or avalanche effects)

Zener diodes are made specially to operate in this region!

P-N junction diode and rectification.

- The ideal diode has the property of being unidirectional in the sense that a voltage applied with given polarity will cause flow of current with a negligible resistance while a voltage of opposite polarity will give no (or negligible) current.
- As a result diodes are made to meet specific applications such as rectifiers is electronic circuits.
- As rectifiers, p-n junction diodes render current in one direction in electronic circuits.

Solved examples

1. A 100 ohm resistor is to be made at room temperature in a rectangular silicon bar of 1 cm in length and 1 mm^2 in cross-sectional area by doping it appropriately with phosphorous atoms. If the electron mobility in silicon at room temperature be 1,350 cm^2/V-second, calculate the dopant density needed to achieve this. Neglect the insignificant contribution by the intrinsic carriers.

Solution.

Length of silicon bar, l= 0.01 m

Area of cross section of silicon bar, A = 1 mm^2 = 1 x 10-6 m^2

Resistance of silicon bar, R = 100 Ω

Resistivity of silicon, $\rho = \frac{RA}{l} = \frac{100x1x10^{-6}}{0.01} = 0.01\ \Omega - m$

Dopant density, $n = \frac{\sigma}{e\mu_e} = \frac{1}{\rho e\mu_e}$

$$= \frac{1}{0.01x1.6x10^{-19}x1.350x10^{-4}}$$

$$= 0.0463\ x\ 10^{23} m^3$$

$$= 4.63\ x10^{21} cm^3$$

Example 2

2. What is the concentration of holes in Si crystals having donor concentration of 1.4 x $10^{24}/m^3$ when the intrinsic carrier concentration is 1.4 x $10^{18}/m^3$? Find the ratio of electrons to holes concentration.

Solution:

Intrinsic carrier concentration, n_i =1.4 x $10^{18}/m^3$

Donor concentration, N_D = 1.4 x $10^{24}/m^3$

Concentration of electron, n=N_D = 1.4 x $10^{24}/m^3$

Concentration of holes, $n = \frac{n_i^2}{n} = \frac{(1.4x10^{18})^2}{1.4x10^{24}} = 1.4x10^{12}\, m^3$

Ratio of electron to hole concentration =$\frac{n}{p} = \frac{1.4\, x\, 10^{24}}{1.4x10^{12}} = 1\, x\, 10^{12}$

Appendix 1

Note: For extrinsic semiconductor:

$$N_D + p = N_A + n$$

Where N_D is the concentration of donor atoms and N_A is the concentration of acceptor

In an N-type semiconductor there is no acceptor doping i.e. N_A=0, also the number of electrons is much greater than the number of holes i.e. n>>p, so n =N_D.

Therefore, the concentration of holes in N-type semiconductor will be given by the equation

$$p = \frac{n_i^2}{n} = \frac{n_i^2}{N_D}$$

Similarly in case of p-type semiconductors

$$p \cong N_A$$

And $n = \frac{n_i^2}{N_A}$

PHY 152 (S. Olatunji)

Content: Magnetism, Hysteresis, Power, AC circuit (Vector)

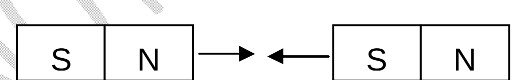
Magnetism

Magnetism is expressed inform of force of attraction or repulsion between various substances, especially those made of iron and certain other metals; ultimately it is due to the motion of electric charges. Unlike electric forces, which or not, magnetic forces act only on moving charges.

Magnetic forces arise in two stages. First, a moving charge or a collection of moving charges (i.e. an electric current) produces a magnetic field. Next, a second current or moving charge responds to this Magnetic field, and so experiences a magnetic force.

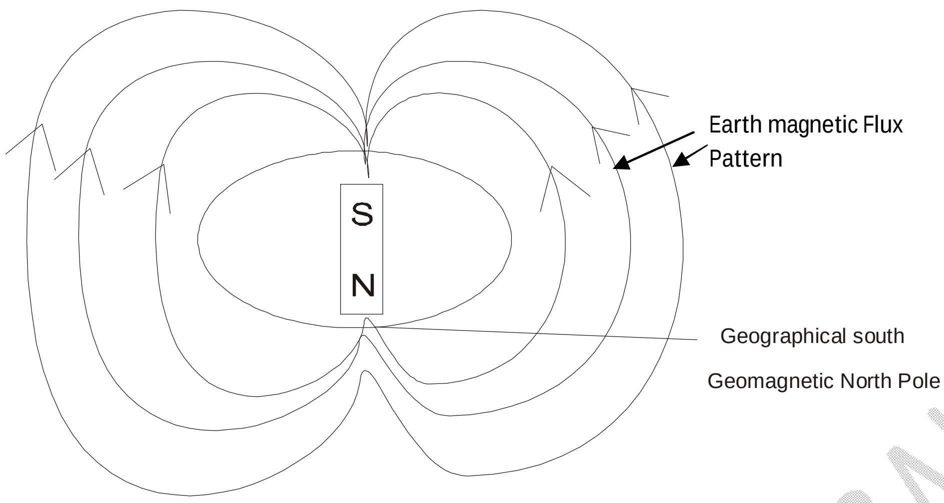
A permanent magnet may have two or more poles, although it must have at least one North Pole and one South Pole. The earth itself behaves like a magnet. Its north geographic pole is close to a magnetic south pole, which is why the north pole of a compass needle points to the geographical north (magnetic South Pole) because magnetic field lines (i.e. flux) exit North Pole and enter South poles.

Magnetic poles of the same type (North or South) repels each other while unlike poles attract each other (Benjamin's rule)



Unlike poles attract

Like poles repel



The sketch above is the Earth's Magnetic field. The lines, called magnetic field lines, show the direction that a compass would point at each location. The direction of the field at any point can be defined as the direction of the force that the field would exert on a magnetic north pole.

Magnetic Field $(\vec{B})$

A Magnetic field $(\vec{B})$ exists in an otherwise empty region of space if a charge moving through that region can experience a force due to its effect on a compass needle the magnetic field is a vector field (i.e., a vector quantity) associated with each point in space, hence, the use of the symbol B. A moving charge or a current creates a magnetic field in the surrounding space and the magnetic field exerts a force F on any other moving charge or current that is present in the field.

Magnetic Forces on moving Charges

There are four characteristics of the magnetic force on a moving charge. First, its magnitude is proportional to the magnitude of the charge. If a 1μC charge and a 2μC charge move through a given magnetic field with the same velocity, experiments show that the force on the 2μC charge is twice as great as the force on the 1μC charge.

Second, the magnitude of the force is also proportional to the magnitude, or "Strength", of the field; if we double the magnitude of the field. (e.g. using two identical bar magnets instead of one) without changing the charge or its velocity, the force doubles.

A third characteristic is that the magnetic force depends on the particles velocity. A charged particle at rest experiences no magnetic force.

Fourth, we find, by experiment, that the magnetic force $\vec{F}$ does not have the same direction as the magnetic field $\vec{B}$ but instead is always perpendicular to both $\vec{B}$ and the velocity $\vec{V}$. The Magnitude $\vec{F}$ of the force is found to be proportional to the component of $\vec{V}$ perpendicular to the field; when that component is zero (i.e, when $\vec{V}$ and $\vec{B}$ are parallel or antiparallel), the force is zero.

The Magnitude of the force (F) on a charge moving on a magnetic field depends upon the product of four factors:

1. q, the charge (in Coulombs)
2. V, the magnitude of the velocity of the charge (in m/s)
3. B, the strength of the magnetic field.
4. Sinθ, where θ is the angle between the field lines and the velocity V.

$$F = q\,V\,B\sin\theta.$$

Where F is in Newton, q is in Coulomb, V is in m/s, and B is in Tesla (T).

$1T = 1Wb/m^2$, $1G = 10^{-4}T$, where G is Gauss.

Since current is simply a stream of positive charges, a current experiences a force due to a magnetic field. The direction of the force is found by the Fleming's right-hand rule.

The magnitude ΔF_m of the force on a small length ΔL of wire carring current I is given by

$$\Delta F_m = I\,(\Delta L)\,B\sin\theta.$$

Where, θ is the angle between the direction of the current I and the direction of the field. For a single wire of length L in a uniform magnetic field, this becomes.

$$F_m = I\,L\,B\sin\theta$$

The force is zero if the wire is in line with the field lines and the force is maximum if the field lines are perpendicular to the wire.

Force and Torque of a Loop

The net force on a current loop in a uniform magnetic field is zero. However, the net torque is not in general equal to zero.

The magnetic moment of a flat current – carrying loop (current =I, area = A) is IA. The magnetic moment is a vector quality that points along the field line perpendicular to the plane of the loop. In terms of the magnetic moment, the torque on a flat coil with N loop in a magnetic field B is

μ= IA

τ= (IA) B sinθ

τ = μB sinθ

Where, μ= magnetic moment

τ = Torque

θ is the angle between the field and the magnetic moment vector.

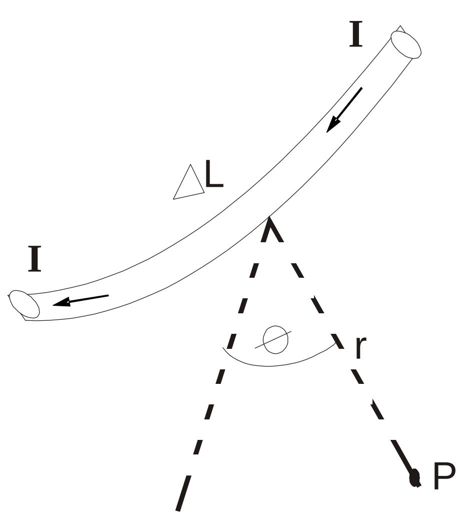
For a coil of N loop, each carrying I, in an external magnetic field B. the torque τ is given as

τ =NIAB sinθ

Magnetic Field of a Current Element

The current element of length ΔL contributes $\Delta \vec{B}$ to the field at a point is given by the Biot - savart law *viz:*

$$\Delta B = \frac{\mu_0 I \Delta L \sin\theta}{4\pi r^2}$$



Where r and θ are radius and angle to the point as show above. The direction of ΔB is $\overrightarrow{\text{perpendicular}}$ to the place determined by ΔL and r. when r is in line with ΔL, then $\theta = 0$ and thus $\Delta B = 0$; which means that the field due to a straight wire at a point on the line of the wire is zero.

Magnetic Flux

The magnetic flux $\emptyset_m$ through an area A is defined to be the product of $B_\perp$ and A, where $B_\perp$ is the component of $\vec{B}$ perpendicular to the surface of area A

$$\emptyset_m = B_\perp A = BA\cos\theta$$

$$B_\perp = B\cos\theta.$$

Where θ is the angle between the direction of $\vec{B}$ and a line perpendicular to the surface.

Magnetic flux is a Vector quantity. If $\vec{B}$ is uniform over a plane surface with total area A, then B and $\theta_\perp$ are the same at all points on the surface, and

$$B_\perp = B\cos\theta.$$

If $\vec{B}$ happens to be perpendicular to the surface, then $\cos\theta = 1$ and $B = B_\perp$ i.e. $\emptyset_m = BA$. Its S.I unit is weber or Tesla metre square ($1Wb = 1T.m^2$).

The total magnetic flux through a closed surface is always zero

$$\text{i.e} \quad \int \vec{B}.\ \overrightarrow{dA} = 0$$

This equation is called Gauss's law of magnetism.

Induced EMF

An induced emf exists in a loop of wire whenever there is a change in the magnetic flux through the area surrounded by the loop. The induced emf exists only during the time that the flux through the area is changing.

Faraday's law of induction states that the induced emf in a closed loop equals the negative of the time rate of change of magnetic flux through the loop.

$$\varepsilon = \frac{-d\,\emptyset_m}{dt}$$

The emf ε is measured in volts if $d\emptyset_m/dt$ is in Wb/s.

The minus sign indicates that the induced emf opposes the change which produces it, as stated generally in Lenz's law.

Lenz's law stated that the direction of any magnetic induction effect is such as to oppose the cause of the effect. For example, if the flux is increasing through a coil, the current produced by the induced emf will generate a flux that tends to cancel the increasing flux. Or, if the flux is decreasing through the coil, that current will produce a flux that tends to restore the decreasing flux. Lenz's law is a consequence of conservation of energy.

Motional EMF

When a conductor moves through a magnetic field so as to cut field lines, an induced emf will exist in it, in accordance with Faraday's law. But, in this case

$$|\varepsilon| = \frac{d\emptyset_m}{dt}$$

The symbol $|\varepsilon|$ means that we are concerned only with the magnitude of the average induced emf.

The induced emf in a straight conductor of length L moving with velocity $\vec{V}$ perpendicular to a field $\underline{B}$ is given by

$$|\varepsilon| = BLv$$

Where $\vec{B}$, $\vec{V}$ and the wire must be mutually perpendicular.

In this case, Lenz's law still tells us that the induced emf opposes the process. But now the opposition is produced by way of the force exerted by the magnetic field on the induced current in the conductor. The current direction must be such that the force opposes the motion of the conductor knowing the current direction, we also know the direction of ε.

Sources of Magnetic Fields

Magnetic fields are produced by moving charges, and of course, that includes electric currents. The constant $\mu_0 = 4\pi \times 10^{-7}$T.m/A is called the permeability of free space. It is assumed that the surrounding material is a vacuum of air.

Bohr Magneton

We picture the election (mass m_1 charge – e) as moving in a circular orbit with radius r and speed V. This moving charge is equivalent to a loop. We know that magnetic dipole moment μ is given by μ =IA; for the orbiting electron the area of the loop is $A=\pi r^2$. To find the current associated with the electron, the orbital period T is the circumference divided by the electron speed: T = 2 πr/v the equivalent current I is the magnitude e of the electron charge divided by the orbital period T:

$$I = e/T = eV/2\pi r$$

Magnetic moment μ=IA, $\mu=\frac{eV}{2\pi r}(\pi r^2) = eVr/2$

For a particle moving in a circular path, the angular momentum L is L=mvr,

$\mu = eL/2m$

But atomic angular momentum is quantized; its component in a particular direction is always an integer multiple of $h/2\pi$ where h is planek's constant.

h= 6.626×10^{-34} Js

$$\mu=\frac{e}{2m}(h/2\pi) = eh/4\pi m$$

This quantity is called the Bohr magneton, denoted by μ_B. Its numerical value is

$\mu_B = 9.274 \times 10^{-24}$ Am^2

Paramagnetism

Some atoms have a net magnetic moment that is of the order of μ_B and when placed in magnetic field, the field exerts a torque on each magnetic moment

$$\vec{\tau} = \vec{\mu} \text{ X } \vec{B}$$

This torque tends to align the magnetic moments with the field. In this position, the directions of the current loops are such as to add to the externally applied magnetic field. B field produced by a current loop is proportional to the loop's magnetic dipole moment. In the same way, the additional $\vec{B}$ field produced by microscopic electron current loops is proportional to the total magnetic moment μ_{total} per unit volume V in the material. This vector quantity is called the magnetization of the material, denoted by $\vec{M}$

$$\vec{M} = \vec{\mu}_{total}/V$$

The additional magnetic field due to magnetization of the material turns out to be equal simply to $\mu_0\vec{M}$, where μ_0 is the permeability of free space. When such material magnetic field B in the material is

$$\vec{B} = \vec{B_0} + \mu_0 \vec{M}$$

$\vec{B_0}$ is the field caused by the current in the conductor, magnetization $\vec{M}$ is magnetic moment per unit volume.

A material showing the behaviour just described is said to be paramagnetic. This shows that the magnetic field at any point in such material is greater by a dimensionless factor k_m, called the relative permeability of the material, than it would be if the material were placed by vacuum. The value k_m is varies for different materials; for common paramagnetic solids and liquids at room temperature, km typically ranges from 1.00001 To 1.003. For a particular material,

The permeability of such material is $\mu = k_m \mu_0$.

The amount by which the relative permeability differ from unity is called the magnetic susceptibility, denoted by $\mathcal{X}_m$

$$\mathcal{X}_m = k_m - 1$$

Paramagnetic susceptibility always decreases with increasing temperature. In many cases it is inversely propotional to the absolute temperature T, and the magnetization M can be expressed as $M = C^B/_T$

This relationship is called curie's law and the quantity C is a constant, different for different materials, called the curie constant.

Diamagnetism

In some materials the total magnetic moment of all the atomic current loops is zero when no magnetic field is present. But even those materials have magnetic effects because an external field alters electron motions within the atoms, causing additional current loops and induced magnetic dipoles. In this case, the additional field caused by these current loops is always opposite in direction to that of the external field. Such materials are said to be diamagnetic. They always have negative susceptibility, and their relative permeability km is slightly less than unity, typically of the order of 0.99990 to 0.99999 for solids and liquids. Diamagnetic susceptibilities are very nearly temperature independent.

Ferromagnetism

Ferromagnetic materials include iron, nickel, cobalt and all alloys containing these elements. In these materials strong interactions between atomic magnetic moments cause them to line up parallel to each other in regions called magnetic domains, even when no external field is present.

When there is no externally applied field, the domain magnetizations are randomly oriented. But when a field caused by external currents is present, the domains tend to orient themselves parallel to the field. The domain boundaries also shift; the domains that are magnetized in other direction grow, and those that are magnetized in other directions shrink. Because the total magnetic moment of a domain may be thousands of Bohr magnetons, the torques that tend to align the domains with an external field are much stronger than occur with paramagnetic materials. The relative permeability km is much larger than unity, typically of the order of 1000 to 100,000

Hysteresis

For many ferromagnetic materials, the relationship of magnetization to external magnetic field is different when the external field is increasing from when it is decreasing. The figure below shows this relationship for such materials when the material is magnetized to saturation and then the external field is reduced to zero, some magnetization remains. This behavior is characteristic of permanent magnets, which retain most of their saturation magnetization when the magnetizing field is removed. To reduce the magnetization to zero requires a magnetic field in the reverse direction.

This behavior is called hysterics, and the curve below is called hysteresis loop. Magnetizing and demagnetizing a material that has hysteresis involve the dissipation of energy, and the temperature of the material increases during such a process.

Magnetization M

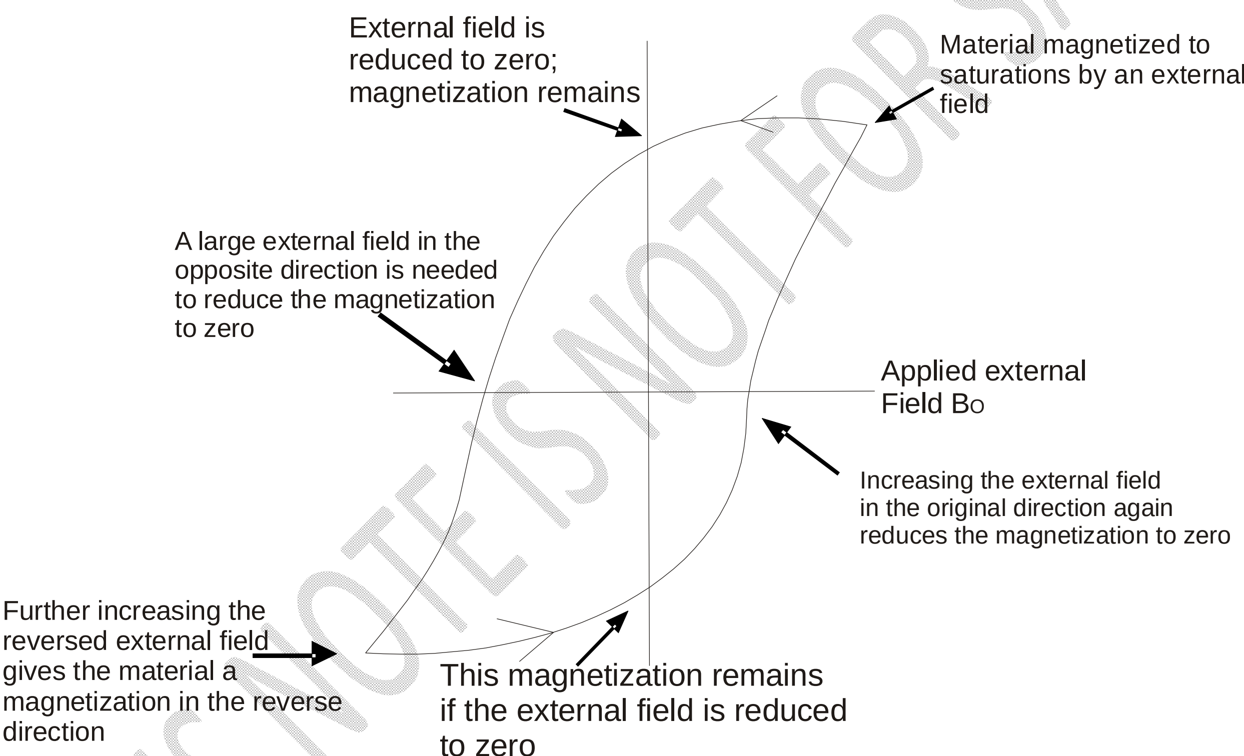


Fig.: Hysteresis loop

A.C. Circuits

The emf generated by a rotating coil in a magnetic field has a sinusoidal graph which is called an ac voltage because there is a reversal of polarity (i.e., the voltage changes sign). We use the term ac source for any device that supplies a sinusoidal varying voltage (potential difference) V or current i. The sinusoidal voltage might be described by a function such as

$$V = V_0 \cos wt$$

V is the instantaneous potential difference

V_0 is the maximum potential difference called the voltage amplitude.

w is the angular frequency = $2\pi f$

similarly, a sinusoidal current might be described as

$$i = I_0 \cos wt$$

i is the instantaneous current

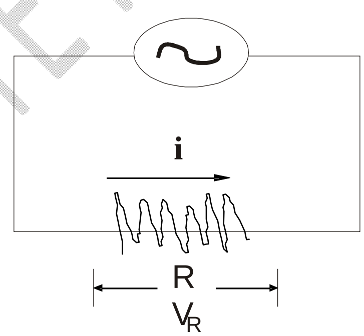
I_0 is the maximum current or current amplitude. The frequency f of the voltage is related to its period T by $T = {}^1/_F$

Meters for use in ac circuits read the effective, or root mean square (rms), values of the current and voltage. These values are always positive and are related to the amplitudes of the instantaneous sinusoidal values through

$V_{rms} = V_0 / \sqrt{2} = 0.707V_0$

$i_{rms} = I_0 / \sqrt{2} = 0.707I_0$

Resistor in an ac circuit is given by V = IR



i = I cos wt
$V_R = iR = (IR) \cos wt$

V_R is the instantaneous voltage

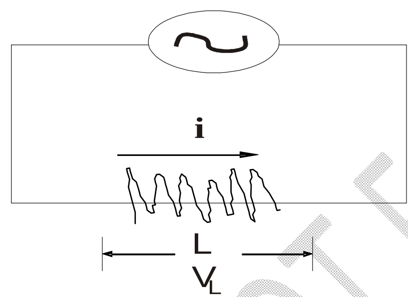
$V_m = IR$

V_m is the voltage amplitude or maximum voltage

Inductor in an a.c Circuit (L-Circuit)

This is an a.c circuit with only a pure inductor with self-inductance L and zero resistance. Let the current be I = I cos wt, no resistance, there is a potential difference V_L between the ends of the inductor terminal because the current varies with time, giving rise to a self-induced emf. The induced emf in the direction of i is directed to the left to oppose the increase in current.

Thus $V_L = +L\, {}^{di}/_{dt}$



$$V_L = L\frac{di}{dt} = L\,\frac{d}{dt}\ (I \cos wt) = - IwL \sin wt.$$

But $\cos (A+90^0) = - \sin A$.

$$V_L = IwL \cos (wt + 90^0)$$

Thus if the current I in a circuit is i = I cos wt and the voltage V of one point with respect to another is

$$V = V\cos (wt + \theta)$$

∅ is the phase angle; it gives the phase of the voltage relative to the current. For a pure resistor, ∅ = 0, and for a pure inductor, ∅ = 90^0. The amplitude V_L of the inductor voltage is V_L = IwL

Inductive reactance X_L of an inductor is X_L = WL

$V_L = IX_L$ (amplitude of voltage across an inductor).

The inductive reactance X_L is a description of the self-induced emf that opposes any change in the current through the induction.

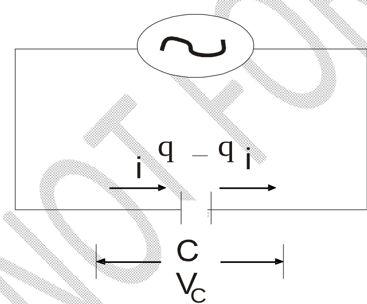
Capacitor in an ac Circuit (C-Circuit)

This is an a.c circuit with only a capacitor with capacitance C to the source, producing a current i = I cos wt through the capacitor. To find the instantaneous voltage V_C across the capacitor, we first let q denote the charge on the left-hand plate of the capacitor and –q is the charge on the right-hand plate. The current i is related to q by i = $\frac{dq}{dt}$

Positive current corresponds to an increasing change on the left hand capacitor plan. Then i = $\frac{dq}{dt}$ = I cos wt

Integrating, q = i = $\frac{I}{w}$ sin wt

q = CV_C



V_C = i = $\frac{I}{wC}$ sin wt.

But cos (A - 90^0) = sin A

V_C = $\frac{I}{wC}$ cos (wt - 90^0)

The instantaneous current i is equal to the rate of change $\frac{dq}{dt}$ of the capacitor charge q, since q = CV_C, i is also proportional to the rate of change of voltage. This corresponds to a phase angle Ø = 90^0. This cosine function has a "late start" of 90^0 compared with the current i = I cos wt.

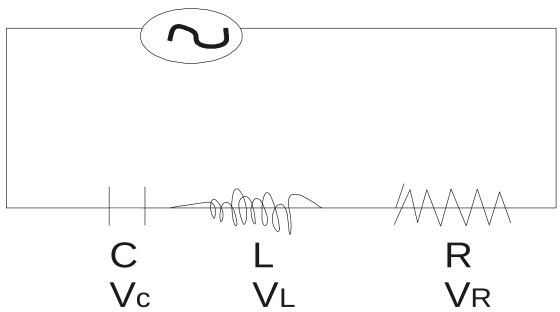
The maximum voltage V_m is V_m = $\frac{I}{wC}$

Capacitive reactance of the capacitor is X_c = $\frac{I}{wC}$

V_c = I X_c (amplitude of voltage across a capacitor).

The greater the capacitance and the higher the frequency, the slower the capacitive reactance X_c. Capacitors tend to pass high frequency current and to block low – frequency currents and dc, just the opposite of indicator.

L – R – C Series Circuit



The Potential difference acreoss a resistor, maximum voltage V_R= IR.

The Voltage across the inductor, its voltage amplitude V_L= I X_L.

The voltage across a capacitor, its voltage amplitude V_C= I X_C.

$$V=\sqrt{V_R^2 + (V_L - V_C)^2} = \sqrt{(IR)^2 + (I X_L - I X_C)^2}$$

$$V= I\sqrt{R^2 + (X_L - X_C)^2}$$

Impedance Z of an ac circuit is the ratio of the voltage amplitude across the circuit to the current amplitude in the circuit.

$$Z = \sqrt{R^2 + (X_L - X_C)^2}$$

$$V= I Z$$

$$Z = \sqrt{R^2 + (W_L - (\frac{1}{WC})^2}$$

$$\text{Phase= } \tan \emptyset = \frac{V_L - V_C}{V_R} = I \frac{(X_L - X_C)}{IR} = \frac{X_L - X_C}{R}$$

$$\emptyset = \tan^{-1} (\frac{X_L - X_C}{R}) \qquad \emptyset = \frac{R}{Z}$$

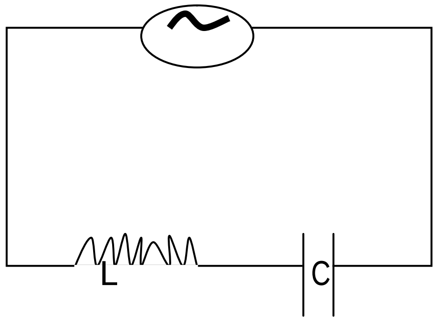
$$\tan \emptyset = \frac{WL - \frac{1}{WC}}{R}$$

$$\emptyset = \tan^{-1} (\frac{WL - \frac{1}{WC}}{R})$$

If the current of an L-R-C circuit is i= I cos wt, then the source voltage is

V=vcos (wt + ∅).

For an L-C circuit

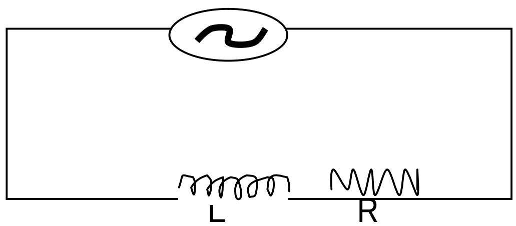


V= I $\sqrt{(X_2 - X_C)^2}$

Ƶ = $\sqrt{(WL - (\frac{1}{WC})^2}$

Ƶ =$\sqrt{(X_L - X_C)^2}$

For an L-R circuit

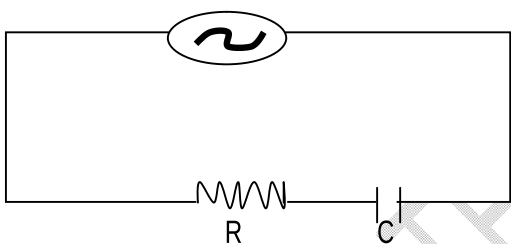


V= I $\sqrt{R^2 + X_L^2}$

Ƶ= $\sqrt{R^2 + (wL)^2}$

Ƶ= $\sqrt{R^2 + X_L^2}$

For an R-C circuit



V= I $\sqrt{R^2 + (-X_L)^2}$

V = I $\sqrt{R^2 + X_C^2}$

Ƶ = $\sqrt{R^2 + (\frac{1}{WC})^2}$

Ƶ= $\sqrt{R^2 + (X_C)^2}$

For an ac circuit, $V_{rms} = \frac{V}{\sqrt{2}}$

$$I_{rms} = \frac{I}{\sqrt{2}}$$

$$V_{rms} = I_{rms}\ Ƶ$$

Resonance occurs in a series R-L-C circuit when X_L=X_C, under this condition, Ƶ =R is minimum, so that I is maximum for a given value of V.

X_L=X_C, wL=$\frac{1}{w_0 C}$, w_o= $\frac{1}{\sqrt{LC}}$

The resonance frequency f_0 is $\frac{w_0}{2\pi}$, $f_0 = \frac{1}{2\pi\sqrt{LC}}$

Power in an a.c Circuit

For an ac circuit with instantaneous current I and current amplitude I and instantaneous voltage V with voltage amplitude V. The instantaneous power P is P=vi

Power in a Resistor

For a pure resistor R, then voltage and current are in phase

The average power $P_{av} = \frac{1}{2}VI$

$$P_{av} = \frac{V}{\sqrt{2}} . \frac{I}{\sqrt{2}} = V_{rms}\ I_{rms}$$

$$P_{av} = I_{rms}^2 R = \frac{V_{rms}^2}{R} = V_{rms}\ I_{rms}$$

Power in an Inductor

For a pure inductor L, voltage leads the current by 90°.The power is positive half the time and negative the other half, and the average power is zero. When P is positive, energy is being supplied to set up the magnetic field in the inductor; when P is negative, the field is collapsing and the inductor is returning energy to the source. The net energy transfer over one cycle is zero.

Power in a Capacitor

In a pure capacitor C, the voltage lags the current by 90°. The average power is also zero. Energy is supplied to charge the capacitor and is returned to the source when the capacitor discharges the net energy transfer over one cycle is again zero.

Power in a General AC Circuit

In any ac circuit, with any combination of resistors, capacitors, and inductors, the voltage V across the entire circuit has some phase angle Ø with respect to the current i. The instantaneous power P is

$P = Vi = [V \cos (wt + Ø)]\ [I \cos wt]$

$P = [V(\cos wt \cos Ø - \sin wt \sin Ø)][I\cos wt]$

$= VI\cos Ø \cos^2 wt - VI \sin Ø \cos wt \sin wt)$

The average value of $\cos^2 wt$ cover one cycle) is ½ and the average value of cos wt sin wt is zero. Because it is equal to ½ VIcos Ø= Vrms Irms cos Ø

The factor cos Ø is called the power factor of the circuit.

Exercises

1. In an a. c. circuit, the peak value of the potential difference is 180V.what is the instantaneous p. d when it has reached 1/8th of a cycle
   (90.2V)

2. In a series L-C circuit, the inductance and capacitance are 0.5henry and 2.0microfarad respectively. Calculate the resonant frequency of the circuit
   (50.3Hz)

3. The current in a series R-L-C circuit attains its maximum value when the
   (A) impedance is greater than the capacitive reactance (B) inductance reactance is equal to the capacitive reactance (C) inductance reactance is greater than the capacitive reactance (D) capacitive reactance is less than the resistance

4. An inductor of inductance 10H carries a current of 0.2A.Calculate the energy stored in the inductor
   (2.0J)

5. Calculate the inductance of an inductor whose reactance is one ohm at 50Hz
   (3.18×10^{-3}H)

6. The parts of bar magnet at which the magnetic effect is strongest are called the
   (A) Poles (B) Neutral points (C) Magnetic declination (D) Magnetic meridian

7. Which of the following modes is the most economical method of transmitting electric power over long distances?
   (A) Alternating current at low voltage and high current (B) alternating current at high voltage and high current (C) alternating current at high voltage and low current (D) direct current at low voltage and high current

8. An alternating current with a peak value of 5A passes through a resistor of resistance 10.0ohms.Calculate the rate at which energy is dissipated in the resistor (A) 250.0W (B) 125.0W (C)50.0W (D)35.4W

9. In a R-C circuit (A) I_{rms} leads V_{rms} by 60 (B) I_{rms} lag V_{rms} by 60 (C) V_{rms} lags I_{rms} by 90 (D) V_{rms} leads I_{rms} by 90

10. The energy E stored in an inductor of inductance L when current I passes through it is given by the equation
    ($E = \frac{1}{2}L^2I$)

11. An ammeter connected to an a.c. circuit records 5.5A.The peak current in the circuit is:
    (7.8A)

Better By Far

UNIVERSITY OF ILORIN-NIGERIA
DEPARTMENT OF PHYSICS
Course Code: PHY152

Course Title: Electricity and Magnetism 1 **Credit: 3**

Prepared by: Dr. Olawepo, A.O

Address: Room 5F19

Section of the curriculum covered in this lecture note:

Semiconductors,

Conductivity,

Mobility and

Rectification.

Expected Period of delivery: 8 Hours, 4 Lectures

Teaching Objectives: Students should be able to

1. Define and explain the term ***electrical conductivity***.
2. Classify materials into ***conductors, non-conductors and semiconductors***.
3. Distinguish between the two ***types of semiconductor*** and identify the group of such materials on the periodic table.
4. Discuss how ***electrical conductivity and charge mobility*** are achieved ***in semiconductors***
5. Appreciate the ***role of semiconductors in the field of electronics*** and electronic technology
6. Understand the principle of and the characteristics of ***the junction diode*** as a device based on semiconductors and its function in electronic circuits.

Suggested Texts:

1. Physics for Scientists and Engineers by Fishbane et al., 2nd edition. Publisher: Prentice Hall, Upper Saddle River, New Jersey 07458
2. International Edition Physics, 5th edition by Giancoli
3. Electronic Device sand Circuit by J.B. Gupta. Katson Educational Series.

Assessment.

Assessment shall be by means of assignments, Test and Examination.

Test shall be conducted prior to examination. Both the Test and Exams shall be Computer Based.

Lecture 1: Definition and derivation of terms.

Electric current

Electric current are *charges in motion*.

When the two ends of a conducting material are connected to the terminals of a battery, there is a net transport of charges and thus an electric current through the wire.

Current is also defined as the total charge that passes through a given cross-sectional area per unit time.

Thus current is given as

$$i = \frac{dq}{dt} \qquad \text{--------------------- (1)}$$

where q is the charge and t is the time.

The ***charge, q*** that passes through a plane in a time interval extending from 0 to t by integration:

$$q = \int dq \ = \int_0^t idt \qquad \text{--------------------- (2)}$$

Recall that ***charge is conserved***. Even when charges flow through a region of empty space, the conservation of charge allows us to follow the flow systematically.

Unit of charge is Coulomb while that of current is Coulomb per unit sec. or Ampere (A).

Current density J

Current density is the rate of flow of charge per unit area through an infinitesimal area.

In considering current density through a medium, we must take into account the local magnitude and direction of the charge flow. Thus unlike current which is a scalar, *current density is a vector* (unit = Ampere per sq meter).

Current density is defined as:

$$di = \boldsymbol{j}.\mathrm{d}\boldsymbol{A} = \boldsymbol{J}\mathrm{dAcos}\theta \qquad \textbf{------------------------ (3)}$$

where A is the surface area and θ is the angle between J and the area element dA.

We see that di is maximum when J and dA are parallel (i.e. $\theta = 0$) and di is zero when J and dA are perpendicular (i.e. $\theta = 90^0$). Then total current passing through the area A is a sum over the differential current di:

$$\boldsymbol{i = \int J.dA} \qquad \textbf{------------------------------ (4)}$$

The integral being over the surface.

For moving charges over a unit cross sectional area, the current density is defined as

$$\boldsymbol{J = nqv} \qquad \textbf{------------------------------- (5)}$$

Where n is the number density of the charge, q is the charge and v is the velocity of the moving charges.

Materials and conductivity

Materials differ over an enormous range in their ability to conduct electricity. A good conductor might have a resistivity of 10^{-8} Ω.m; a good insulator, about 10^{14} Ω.m. The resistivity of semiconductors ranges from 10^{3} to 10^{-5} Ω.m and depends sensitively on temperature. Superconductors have no measurable resistance at all below certain temperatures.

The properties which distinguish conductors, insulators, semiconductors and superconductors can be explained by quantum mechanics.

In classical physics, the energy of an electron in a metal can take on any value thus forming a continuum. In contrast, a quantum description of electrons in metals shows the possible energy values of electrons confined to a metal are quantized; i.e. the possible energy values have discrete values. That is an electron cannot have any energy value, just a set of discrete values.

When a set of atoms forms a regular background lattice, the possible energy values of the electrons are modified. The allowed energies of an electron are still discrete but, instead of a tiny separation between neighboring levels, there are energy gaps, which are regions of energy forbidden to the electron. The regions where the energy levels are close together are called allowed bands of energy levels.

(Note: the bands specify only the possible values of electron energies).

According to ***Pauli Exclusion Principle*** (by Wolfgang Pauli, in 1925), there are at most two electrons in any one energy level. This law plays a crucial role in determining the properties of materials. For a solid with many "free" electrons which is in equilibrium state, the electrons fill one or more bands completely.

An addition of energy to the free electrons- by imposing electric field, for example will not affect the electrons in the lower levels. The only electrons that can accept energy are those that lie in the top levels, and then only if there are no nearby unoccupied levels into which they can move. Materials with a partially filled band are called conductors. When the top layer of their electrons moves freely into the empty energy levels immediately above, there is a current. The electrons that jump from a lower to a higher level are said to be excited. Conductors are characterized by having a highest-energy band with levels only partially occupied.

If the highest-energy electrons of a material fill a band completely, then a small electric field will not give these electrons enough energy to jump the large energy gap to the bottom of the next (empty) band. We have an insulator. A good example of this is diamond.

Conductivity of metals

The force F on the particle of charge q when an electric field E is applied is given is given as F = qE, so the acting on an electron having charge *e* on it given as

$$F = eE \qquad \ldots\ldots\ldots\ldots (1)$$

$$F = ma \qquad \ldots\ldots\ldots\ldots (2)$$

Where a is acceleration of electrons due to applied field E .

From these we have:

$$\text{Acceleration, } a = \frac{eE}{m} \qquad \ldots\ldots\ldots (3)$$

Drift velocity,

$$v = a\ x\ \tau = \frac{eE}{m} x\ \tau \qquad \ldots\ldots\ldots\ldots (4)$$

Where τ is the relaxation or collision time. The total charge flowing through the section in time dt is given by

$$dq = envAdt \qquad \ldots\ldots\ldots (5)$$

Thus:

$$I = \frac{dq}{dt} = envA \qquad \ldots\ldots\ldots\ldots (6)$$

$$J = \frac{I}{A} = enV = \rho v \qquad \ldots\ldots\ldots\ldots (7)$$

Where ρ is the charge density in coulomb/m^3.

Using the value of v in equation (4) above,

$$J = \rho\frac{eE}{m}\tau = \frac{ne^2E}{m}\tau \qquad \text{............ (8)}$$

The quantity $\frac{ne^2E}{m}$ is constant at particular temperature and is known as *electrical conductivity*, σ of the material.

Thus,

$$J = \sigma E \qquad \text{........... (9)}$$

So, the current density J is proportional to the conductivity of the material and the magnitude of the applied elect4ric field, E. in term of resistivity ρ, current density J is given as

$$J = \frac{E}{\rho} \qquad \text{.......... (10)}$$

Resistivity, Conductivity and Mobility

The resistivity of a conducting wire of a given material is both directly proportional to its length L and inversely proportional to its cross-sectional area A.

$$\rho \cong R\frac{A}{L} \qquad \text{------------ (11)}$$

where R is known as the resistance of the body. Thus the resistivity of a wire is independent of the dimension but is dependent on the material of which it is made. The unit of resistivity is Ωm.

From equation (3)

$$I = JA = \frac{EA}{\rho} = \frac{EL}{R} \qquad \text{........... (12)}$$

But $\quad E = \frac{V}{L}$ this leads to

$$I = \frac{V}{L} x \frac{L}{R} = \frac{V}{R} \qquad \text{...........(13)}$$

Electrical conductivity,

$$\sigma = \frac{ne^2\tau}{m} = ne\mu_e \qquad \text{...............(14)}$$

Where

$$\mu_e = \frac{e\tau}{m} \qquad \text{...............(15)}$$

is the mobility required by electrons due to the presence of electric field. The *mobility of electron in the metal is defined as the steady state drift velocity per unit electric field*.

Mobility is also defined in term of the electric field as

$$\mu = \frac{v}{E} \qquad \text{………………….(16)}$$

The reciprocal of the resistivity is the conductivity σ:

$$\sigma = \frac{1}{\rho} \qquad \text{------------------ (17)}$$

Writing Ohm's law in terms of conductivity and resistivity, we have

$$V = IR = \rho\left(\frac{L}{A}\right)I \qquad \text{------------------ (18)}$$

$$\frac{V}{L} = \rho({}^{I}/_{A}) \qquad \text{-------------- (19)}$$

Where V/L is the magnitude of E, the electric field applied to the material, and I/A is the magnitude of current density J,

Thus $E = \rho J$ ------------------- (20)

The resistivities and conductivities of materials vary over many order of magnitude.`

Resistivity and temperature.

The resistivity of some materials has strong temperature dependence; an example is that of copper whose resistivity varies directly with temperature to about 850^0 C. The temperature dependence of resistivity for different materials can be related by a linear approximation:

$$\rho = \rho_0\ [1 + \alpha(T - T_0)] \qquad - \qquad \text{---------------------- (21)}$$

Where α is the temperature coefficient of resistivity and ρ_0 is the resistivity at the reference temperature T_0., normally 20^0 C.

Worked examples

1. Calculate the drift velocity of the free electrons in a copper wire of cross sectional area 1.0 mm^2 when the current flowing through the wire is 2.0 A. (Number of free electrons in copper is 1×10^{29} m^{-1}).
   Solution:
   Using equation 6: ***I = envA***
   Drift velocity $v = \frac{I}{enA}$
   $$= \frac{2.0}{(1.0\ x\ 10^{29})(1.0\ x\ 10^{-6})(1.6\ x\ 10^{-19})}$$

$$= 1.25\ x\ 10^{-4} ms^{-1}$$

2. The following data is known for a conductor: Fermi energy = 5.5 eV, Mobility of electrons = 7.04 x 10^{-3} m^2/V-s, Number of electrons/m^3 = 5.8 x10^{28}. Calculate (i) Relaxation time (ii) Resistivity of conductor and (iii) velocity of electrons with the Fermi energy (e = 1.6 x10^{-19}C, m = 9.1x10^{-31} kg).
   Solution.

(i) Using equation (15), relaxation time is given as

$$\tau = \frac{\mu_e}{e} x\ m = \frac{7.04x10^{-3}x9.1x10^{-31}}{1.6x10^{-19}} = 40.04x10^{-15} sec.$$

(ii) Resistivity of conductor, using equation (17) and (14):

$$\rho = \frac{1}{\sigma} = \frac{1}{ne\mu_e}$$

$$= \frac{1}{5.38x10^{28}x1.6x10^{-19}x7.04x10^{-3}}$$

$$= 1.531x10^{-8} \Omega m$$

(iii) Velocity of electrons with Fermi energy. The velocity v_F of an electron with Fermi energy F_E is given as $\frac{1}{2} m v_F^2 = E_F$, hence

$$\boldsymbol{v_F = \sqrt{\frac{2E_F}{m}} = \sqrt{\frac{2x5.5x1.6x10^{-19}}{9.1x10^{-31}}} = 1.3907\ x\ 10^6 m/s}$$

Assignment:

1. (a) Define the term electric current. How is current related to electrical charges?
   (b) Distinguish between current and current density.

Lecture 2: Semiconductors and properties

Semiconductors

Definition: Semiconductors are materials which will not conduct electricity at room temperatures but become conductive when their temperatures are increased.

In semiconductors, the highest - energy electrons fill a band (the valent band) at temperature T= 0, as in insulators. However, unlike insulators, semiconductors have a small energy gap between that band and the next, the conduction band. Because the energy gap is so small, a modest electric field (or finite temperature) will allow some electrons to jump the gap thereby conduct electricity (see Fig. 1).

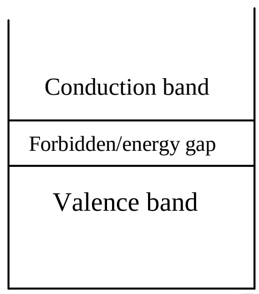


Fig. 1: Structure of the semiconductor

Silicon and germanium have energy gaps of 1.1 eV and 0.7 eV, respectively, and are semiconductors. For an ordinary conductor, a rise in temperature increases the resistivity because the atoms, which are obstacles to electron flow, vibrate more vigorously. A temperature increase in a semiconductor allows more electrons into the empty band and thus lowers the resistivity.

When electrons in the valence band of a semiconductor crosses the energy gap and conducts electricity, it leaves behind a hole. Other electrons in the valence band can move into this hole, leaving behind their own holes and so on. The hole behaves like positive charge that conducts electricity on its own as a positive charge carrier.

Properties of Semiconductor

1. Resistivity: lies in a wide range from 10^{-4} to about 0.5 Ωm
2. Resistance: their resistance depends largely on various factors and therefore it can be controlled. The resistance decreases with increase in temperature in a manner that temperature coefficient of resistance is negative; so that a semiconductor behaves like insulators at very low temperatures but act as conductors at high temperatures
3. Illumination: resistivity decreases in brighter (the "light" resistivity of a semiconductor is smaller than its "dark" resistivity).

4. Electric field: resistivity depends on the magnitude of the electric field in the semiconductor, so that the current in it is not proportional to the voltage, but increases far more than the voltage i.e. semiconductors are non-linear resistors.
5. Impurities: resistivity of semiconductors changes considerably when even minute amounts of certain other substance, called impurities, are added to them.

Types of semiconductors

Semiconductors can be grouped into two broad categories:

1. Intrinsic Semiconductors ad
2. Extrinsic semiconductors.

An intrinsic semiconductor is one which is made of semiconductor material in its extremely pure form. Such semiconductors have impurity content that is less than one part in 10 billion parts of semiconductor i.e. the impurity level is very low. There are many semiconductor materials such as germanium, silicon, grey crystalline tin, selenium, tellurium, boron e.t.c. but silicon (Si) and germanium (Ge) are the two most widely used semiconductor materials in electronics. This is because

(i) the energy required to break their covalent bonds is very small(1.12 eV for silicon and 0.72 eV for germanium)

(ii) both elements have the same crystal structure and similar characteristics.

Production of holes and free electrons

Breaking of covalent bond is equivalent to raising an electron from the valence band to the conduction band. i.e. the energy required to break a covalent bond is the same as the forbidden energy gap. This energy may be supplied by raising the temperature and thereby imparting thermal energy and by incidence of photon in the visible range or bombarding with alpha particles, electrons or x-rays. When this is done, a vacancy is created in the broken covalent bond. The vacancy so caused constitutes a hole. *A hole is simply defined as an absence of electron in a shell where one could exist.* Thus, free electrons and holes are always generated in pairs. So that concentration of holes and electrons will always be equal in semiconductors. This type of generation of electron-hole pair is called *thermal generation*.

Silicon: is a tetravalent element with atomic number 14. The crystal lattice structure of silicon is such that each atom is equidistance from its four neighbouring atoms. So that each atom has four valent electrons with four adjacent atoms. This is because tetravalent semiconductor atoms need a total of 8-outer shell electrons. This sharing of electrons is called co-valent bonding.

Extrinsic semiconductors

Intrinsic (pure) semiconductor by itself is of little significance as it has little current conduction capability at ordinary temperatures. However, the electrical conductivity of intrinsic semiconductor can be increased many times by adding very small amount of impurity to it in the process of crystallization. This process is called doping and the doped material is called the impurity or extrinsic semiconductor.

Germanium and silicon are tetravalent. So the impurity or doping material may be either pentavalent or trivalent. Accordingly the impurity introduced may be of two types, either (i) donor or N- type or (ii) acceptor or P-type. Depending or the type of impurity added, the extrinsic semiconductor can be divided into two classes namely (i) N-type and (ii) P-type semiconductors.

Conduction in intrinsic semiconductor

When the electrons are liberated on breaking of covalent bonds, they move randomly through the crystal lattice. These electrons are neither attracted by the nuclei of the atoms nor repelled by the electrons bound by the covalent bonds because their electrical effects are fully engaged in maintaining covalent bonds.

When an electrical field is applied to a pure semiconductor, the conduction takes place by free electrons and holes. The free electrons in the conduction band move towards the positive terminal of the battery while the holes in the valence band move toward the negative terminal of the battery. As the holes reach the negative terminal, the electrons reaching there combine with the holes thereby destroying the holes. At the same time the loosely held electrons near the positive terminal are attracted away from the atoms into the positive terminal of the battery thus creating new holes (Fig.2). The process is repeated for as long as the electric field is present.

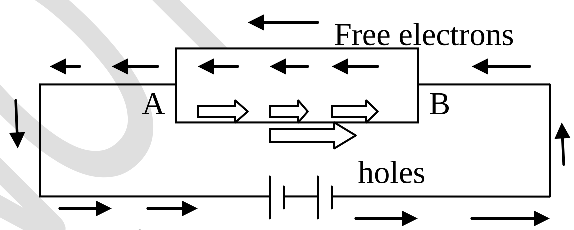


Fig.2: Flow of electrons and holes in an intrinsic semiconductor.

Fermi level in an intrinsic semiconductor

The Fermi level refers to a reference energy level. It is the level at which the probability of finding an electron *n* energy units above it in the conduction band is equal to the probability of finding a hole (electron absence) n energy units below it in the valence band.

If at any temperature T, number of electrons in the conduction band is n_c and number of electrons in the valent band is $n_{v,}$ then, total number of electrons

$$n = n_c + n_v$$

Now n_c=n.P(E_G) where P(E_G) is equivalent to the probability of an electron having E_G (energy gap). The determination of P(E_G) is beyond the scope of this course.

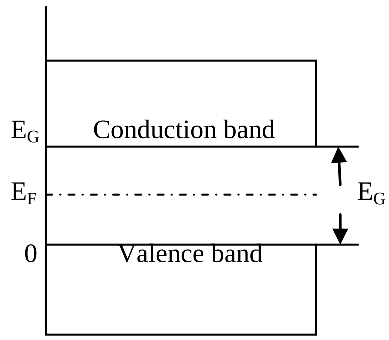


Fig. 3:Fermi level in semiconductor (E_F =1/2E_G)

Conductivity of semiconductors

Conduction through a semiconductor is due to two mechanisms:

- diffusion and
- drift

the movement of charge carriers (i.e. electrons and holes) under the influence of an applied electric field E, is termed as *the drift current*.

The conductivity σ_e of the semiconductor due to electrons in the conduction band is given as

$$\sigma_e = ne\mu_e \qquad \text{…………} \quad (20)$$

Where n is the number of electrons per unit volume of the conductor, e is electron charge and μ_e is the electron mobility.

Similarly, the conductivity due to holes $\sigma_h$is given as

$$\sigma_h = pe\mu_h \qquad \text{………………...(21)}$$

Total conductivity σ is thus given as

$$\sigma = \sigma_e + \sigma_h$$

$$= ne\mu_e + pe\mu_h = e(n\mu_e + p\mu_h) \quad \text{……….. (22)}$$

For intrinsic semiconductor

$$n = p = n_i \qquad \text{………… (23)}$$

Where n_i is intrinsic concentration of holes and electrons.

Intrinsic conductivity is therefore given as

$$\sigma_i = \sigma_e + \sigma_h = n_i e\mu_e + n_i e\mu_h = n_i e(\mu_e + \mu_h) \quad \text{…. (24)}$$

Current density,

$$J = n_i e(\mu_e + \mu_h)E = \sigma E \quad \text{……………… (25)}$$

Current,

$$I = JA = n_i e(\mu_e + \mu_h)EA = n_i e(\mu_e + \mu_h)A\,{}^{V}/_{l} \quad \text{…….. (26)}$$

where E is applied electric feild, V is applied p.d across the two ends of the conductor,

A is the cross − sectional area.

Mobility of charge carriers varies as T^{-m} over a temperature range of 100 K and 400 K. for silicon, m=2.5 for electrons and 2.7 for holes. For germanium, m=1.66 for electron and and 2.33 for holes.

The carrier currents are also due to concentration gradients in the doped material which leads to diffusion of carriers from region of high concentration to region of low concentration.

Mass action law

For intrinsic semiconductor

$$n = p$$

Under thermal equilibrium:

$$np = n_i^2$$

Where n_i = intrinsic concentration

Assignment:

Lecture 3: The P-N junction and rectification

Basic structure of P-N junction

The P-n junction is the control element for the performance of all semiconductor devices such as rectifiers, amplifiers, switching devices, linear and digital integrated circuits. P-N junction is produced by placing a layer of P-type semiconductor next to the layer of N-type semiconductor. The interface separating the N and P regions is referred to as the metallurgical junction.

P-N junction diode

P-N junction diode is a device which conducts when forward biased and practically does not conduct when reverse biased.

Forward bias

When an external field, with P-region connected to positive terminal and N-region connected to the negative terminal of the battery is applied across the junction, the junction is said to be forward biased. In this circuit arrangement, the holes on the P-side being positively charged particle are repelled from the positive bias terminal and driven toward the junction. Similarly, the electrons on the N-side are repelled from the negative bias terminal and driven toward the junction. The result is that the depletion region is reduced in width, and the barrier potential is also reduced. If the applied voltage is increased from zero, the barrier potential gets increasingly smaller until it effectively disappears and charge carriers can easily flow across the junction.

Application of P-N junctions is found in diodes. Diodes are used in circuits to rectify a.c. signals.

For further reading

- Extrinsic semiconductor
- Diodes and applications
- Rectifiers

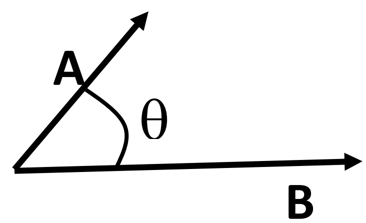
THE MAGNETIC FIELD

Important concept

(i) The product of a scalar m and a vector **A** is a new vector whose direction is the same as that of **A** if m is +ve and opposite to **A** if m is –ve.

(ii) The scalar product of these two vectors represented by A and B is defined as

$$\mathbf{A.B} = AB\cos\theta$$



Where A and B are magnitudes of vectors **A** and **B** respectively.

Since A and B are scalars and cos θ is a pure number, the dot or scalar product of two vectors is a scalar and not a vector.

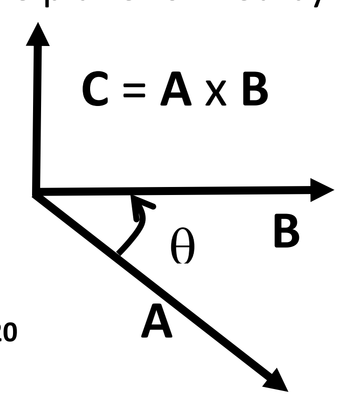
e.g. $W = \mathbf{F.S} = FS\cos\theta$

(iii) The vector product of vectors **A** and **B** written as **A x B** is a third vector **C**. and the magnitude of **C** is given by

$C = AB\sin\theta$. Where θ is the angle between **A** and **B**.

i.e. $\mathbf{A \times B} = \mathbf{C} = AB\sin\theta$.

The direction of C is at right angles to the plane formed by vectors **A** and **B**.



(iv) Note: **A x B ≠ B x A**, but **A x B = - B x A**

By now you should know that magnetic field, **B**, is a vector. The SI unit of **B** is webers per square metre (Wb/m^2) called Tesla (T).

$1T = 1\ Wb/m^2$.

Also note that a Tesla is equal to a Newton .second per coulomb. Meter

i.e 1T = 1 N.s/ C.m

Magnetic Forces on Moving Charges in a Magnetic Field

Recall that the force exerted by electric field $\vec{E}$ on a point charge q is given by

$$\vec{F}_E = q\vec{E}$$

This force is independent of the velocity of the particle and its direction is parallel to $\vec{E}$**.**

A magnetic field $\vec{B}$ can also exert a force on a point charge q. In this case the magnetic force $\vec{F}_B$ depends upon the velocity **v** of the particle and its direction is perpendicular to both $\vec{v}$ and $\vec{B}$**.** The magnetic force exerted on a point charge moving with velocity $\vec{v}$ is given by

$$\vec{F}_B = q\vec{v} \times \vec{B} = qvB \sin \theta$$

where θ is the angle between the velocity and the magnetic field. Equation (10.6) shows that if the velocity of the charge is perpendicular to the field, i.e. θ = 90° and sin 90 = 1, the force exerted on the charge is maximum. On the other hand, the force experienced by the particle is zero if its velocity is parallel to the magnetic field, i.e. θ = 0° or 180° and sin 0° = 0.

Work done by a magnetic field $\vec{B}$ on a charge q

The work done on a charge q by a $\vec{B}$ field is given as

$$W_B = \vec{F}_B \bullet \vec{\Delta l} = q(\vec{v} \times \vec{B}) \bullet \vec{\Delta l}$$

In this case $(\vec{v} \times \vec{B})$ is perpendicular to $\vec{v}$

while $\vec{\Delta l}$ is parallel to $\vec{v}$. Note that $\vec{v} = \frac{\vec{\Delta l}}{\Delta t}$.

Since $(\vec{v} \times \vec{B})$ and $\vec{\Delta l}$ are then perpendicular, their dot product vanishes.

No matter what $\vec{B}$ field is, $W_B = 0$.

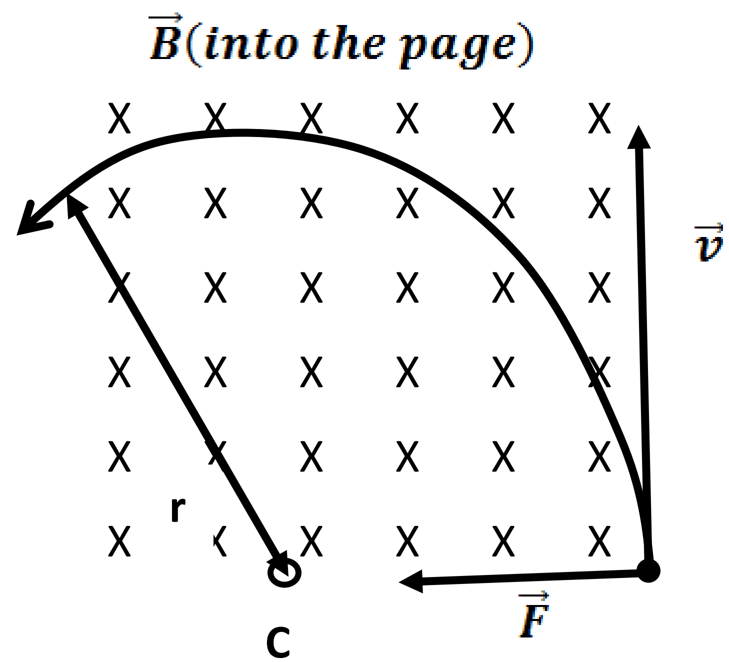
The work done on a charge by $\vec{B}$ field is always zero. Therefore $\vec{B}$ field cannot change the kinetic energy $\frac{1}{2} mv^2$ of a particle.

Motion in a uniform $\vec{B}$ field

Consider a particle (mass m, charge q) moving in a uniform magnetic field $\vec{B}$. For simplicity, suppose that the velocity $\vec{v}$ is in a plane perpendicular to $\vec{B}$.

Therefore, the force $\vec{F} = q\vec{v} \times \vec{B}$ exerted on the particle will change the direction (nut not the magnitude) of the velocity.

The particle will follow a circular path of some radius r as shown in the figure below.



From Newtown's laws of motion, we have

$\vec{F} = ma = qvB$

The centripetal force needed for the circular path is provided by the magnetic force $qvB = \frac{mv^2}{r}$

Hence the radius is given by

$$r = \frac{mv}{qB}$$

We see that the radius depends only on the momentum mv of the particle, its charge and magnetic field $\vec{B}$.

The kinetic energy of the particle is

$$K.E = \frac{1}{2}mv^2 = \frac{1}{2}\left(\frac{q^2B^2}{m}\right)r^2$$

The angular velocity or angular frequency (or cyclotron frequency) ω is given as

$$\omega = \frac{v}{r} = \frac{q}{m}B \qquad \text{Or } f = \frac{B}{2\pi}\frac{q}{m}$$

These results showed that the angular speed of the charge and the period of the circular motion do not depend on the linear speed of the charge or on the radius of the orbit.

Period of motion $T = \frac{1}{f}$, then we can write

$$T = \frac{2\pi m}{qB}$$

EXAMPLE

An electron with kinetic energy 1.50 keV circles in a place perpendicular to a uniform magnetic field. The orbit radius is 30.0 cm. Find the speed of the electron and the magnitude of the magnetic field B.

Solution

$K.E = 1.50\text{keV} = 1.50 \text{ x } 10^3\text{eV}$

$= 1.50 \text{ x } 10^3 \text{ x } 1.6 \text{ x } 10^{-19} \text{ J}$

$= 2.4 \text{ x } 10^{-16}\text{J}$

$R = 30.0 \text{ cm} = 30 \text{ x } 10^{-2} \text{ m}$

$$K.E = \frac{1}{2}mv^2$$

$$2.4\times10^{-16} = \frac{1}{2}\times9.11\times10^{-31}\times v^2$$

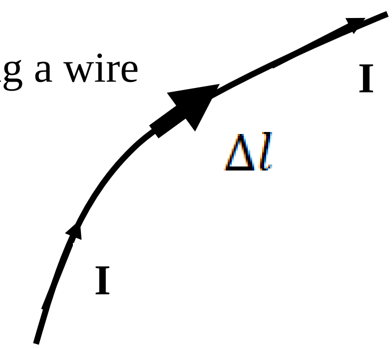
$$v = 2.295 \text{ x } 10^7\text{m/s}$$

$$Bqv = \frac{mv^2}{R}$$

$$B = \frac{mv}{qR} = \frac{9.11\times10^{-31}\times2.3\times10^7}{1.6\times10^{-19}\times30\times10^{-2}} = 4.4\times10^{-4}T = 0.44mT$$

Magnetic Forces and electric Currents

Since the charge is in motion we expect that there must be magnetic fields and forces associated with the flow of current. Now consider small segments along a wire carrying current. The force on a moving charge can be written as



$\Delta\vec{F} = \Delta q\vec{v} \times \vec{B}$

Now consider a wire carrying current I.

Let $\Delta\vec{l}$ be a segment of this wire, the sense of $\Delta\vec{l}$ is that of the current.

$I\Delta\vec{l}$ is called a current element where $\Delta\vec{l}$ is differential element of the wire.

The conduction charge Δq in the segment $\Delta\vec{l}$ will move through the segment in some time Δt.

Assume Δq is positive, its drift velocity is given as $\vec{v} = \frac{\Delta\vec{l}}{\Delta t}$

From the above equation, the term $\Delta q\vec{v}$ becomes

$$\Delta q\vec{v} = \Delta q\frac{\Delta\vec{l}}{\Delta t} = \frac{\Delta q}{\Delta t}\Delta\vec{l} = I\Delta\vec{l}$$

where $I = \frac{\Delta q}{\Delta t}$ is the current in the wire.

Now using $\Delta\vec{F} = \Delta q\vec{v} \times \vec{B}$, we have

$$\Delta\vec{F} = I\Delta\vec{l} \times \vec{B} \qquad \{This\ two\ equations\ are\ equivalent\}$$

One is expressed in term of quantities I and $\Delta\vec{l}$ and the other in terms of Δq and $\vec{v}$.

Since a current is a motion of charge, it is reasonable that there is a magnetic force exerted on a current carrying wire.

For uniform $\vec{B}$ field we can sum the equation over the wire and obtain

$$\vec{F} = I\vec{l} \times \vec{B}$$

And the magnitude of the force becomes

$$F = IlB \sin\theta$$

Ampere's Law

Ampère's law states that the line integral of **B.ds** around any closed path equals $\mu_o I$, where I is the total continuous current passing through any surface bounded by the closed path.

i.e. $\oint \vec{B}.ds = \mu_o I$

In order words the law states that the magnetic field strength $\vec{B}$ at a point near a wire is directly proportional to the current I in the wire and inversely proportional to the distance r from the wire.

$$B \propto \frac{I}{r}$$

The proportionality constant is written as $\frac{\mu_o}{2\pi}$.

i.e. $B = \frac{\mu_o}{2\pi}\frac{I}{r}$

μ_o is the permeability of free space, $\mu_o = 4\pi \times 10^{-7}\ H/m$ or $T.m/A$

Forces between Two Parallel Conductors

Consider two long parallel conductors separated by a distance d. They currents I_1 and I_2 respectively. Each current produces a magnetic field that is felt by the other so that each should be expected to exert a force on the other.

The magnetic field $\vec{B}_1$ produce by I_1, is given by ampere's law at the location of the second wire.

This field is $B_1 = \frac{\mu_o}{2\pi}\frac{I_1}{r}$

The force on the conductor carry current I_2 is

$F = lI_2B_1$

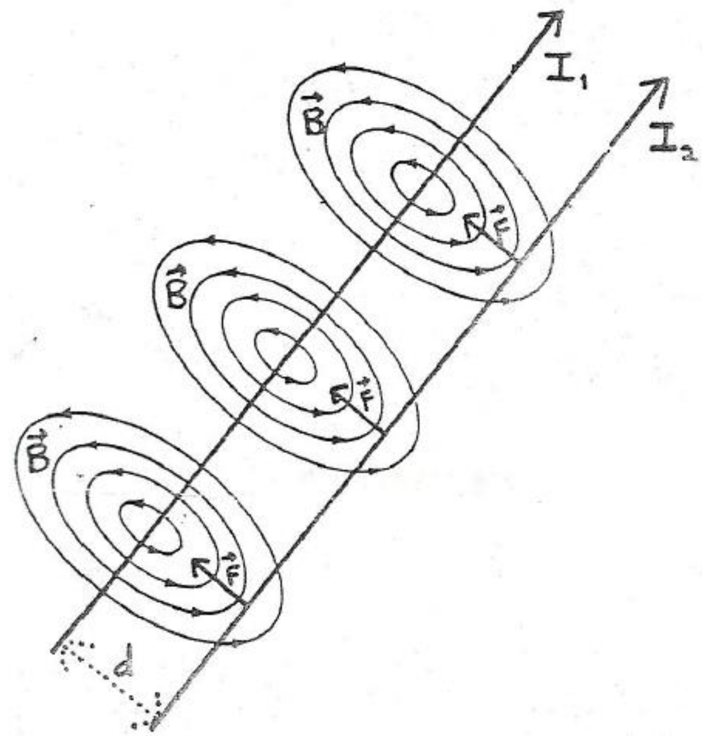


Figure: Force between current

Therefore force per unit length is $\frac{F}{l} = I_2\, B_1$

Note force on I_2 is due only to the field of I_1; I_2 also produces a field but it does not exert a force on itself.

Therefore $$\frac{F}{l} = \frac{\mu_o}{2\pi}\frac{I_2 I_1}{d} = k'\frac{2I_2I_1}{d}$$

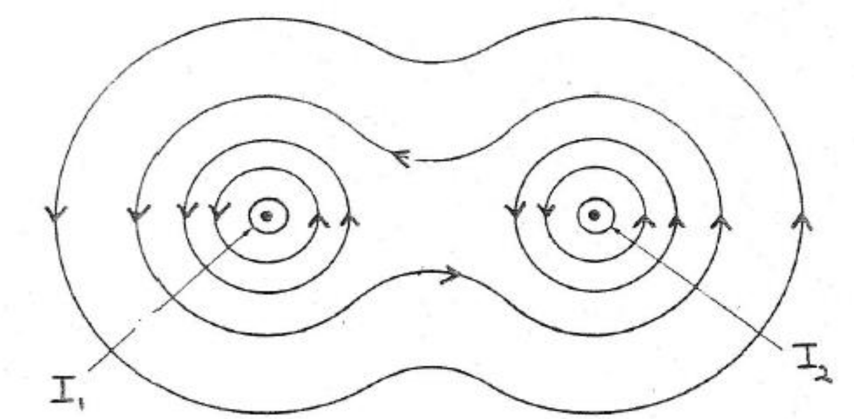
Where $$k' = \frac{\mu_o}{4\pi}, \qquad \mu_o = 4\pi k'$$

Whe the current s in the wire are identical then the equations are:

$B = k' \frac{2I}{d}$ and $\frac{F}{l} = k' \frac{2I^2}{d}$

The forces that the two wires exert on each other are equal and opposite.

We only showed the field due to one current carrying conductor, in actual fact the field looks more like this figure.



Magnetic field lines around two long parallel wires whose equal currents, I_1 and I_2 are coming out of the paper toward the viewer.

NOTE: The directions of the $\vec{B}$ field around the current carrying wires is opposite, hence two wires carrying current in the same direction are attracted to each other.

EXAMPLE

1. Two parallel horizontal wires are 10cm apart. They carry the same current in the same direction. If the force between the wires per unit length is 2 x 10^{-4}Nm^{-1}, determine the current carried by the wires. Is the force attractive or repulsive?

Solution

The magnitude of the force per unit length on either wire is

$$\frac{F}{L} = \frac{\mu_o I_1 I_2}{2\pi a}$$

$$2\times10^{-4} = \frac{4\pi\times10^{-7}\times I^2}{2\pi\times0.1}$$

$$I^2 = \frac{2\times10^{-5}}{2\times10^{-7}} = 10^2$$

$$I = 10\text{A}$$

The force is attractive since the current are in the same direction.

EXAMPLE

2. A long straight wire carries a current of 1.5 A. An electron travels with a speed of 5 x 10^6 cm/s parallel to the wire, 10cm from it and in the same direction as the current. What force does the magnetic field of the current exert on the moving electron?

Solution

Magnetic field,

$$B = \frac{\mu_o I}{2\pi a}$$

$$B = \frac{4\pi\times10^{-7}\times1.5}{2\pi\times0.1}T = 3\times10^{-6}T$$

Force,

$$F = Bqv = 3 \text{ x } 10^{-6} \text{ x } 1.6 \text{ x } 10^{-19} \text{ x } 5 \text{ x } 10^{4}\text{N} = 2.4 \text{ x } 10^{-20}\text{N}$$

Torque on a Current Loop in a Uniform Magnetic Field

The **torque** τ on a coil of *N* loops, each carrying a current *I* and area *A*, in an external magnetic field *B* is

$$\tau = NIAB\sin\theta$$

where θ is the angle between the normal to the plane of the loop and the direction of the magnetic field.

In vector form,

$$\tau = N(I\mathbf{A} \times \mathbf{B})$$

where **A** is a vector perpendicular to the plane of the loop and has a magnitude equal to the area of the loop.
The quantity IA is called the **magnetic dipole moment** of the coil. The magnetic dipole moment is a vector denoted by $\vec{\mu}$.
Thus,

$$\vec{\mu} = IA\hat{n}$$

where $\hat{n}$ is the normal unit vector to the surface of the loop.
Then equation for **torque** τ can be rewritten as

$$\tau = N\left(\vec{\mu} \times \vec{B}\right)$$

The potential energy of a magnetic field is given by

$$U = -\vec{\mu} . \vec{B}$$

From this expression, we see that a magnetic dipole has its lowest energy $U_{\min} = -\mu B$ when $\vec{\mu}$ points in the same direction as $\vec{B}$.

The dipole has its maximum energy $U_{\max} = \mu B$ when $\vec{\mu}$ points in the direction opposite $\vec{B}$.
The magnetic dipole moment μ of an electron orbiting the proton of a hydrogen atom is given by

$$\vec{\mu} = \frac{e}{2m}\vec{L}$$

where $L = mvr$ = angular momentum

m = mass of the electron

v = velocity of the electron

e = electronic charge = 1.6×10^{-19} C

The magnetic dipole moment μ of an electron orbiting the proton of a hydrogen atom is given by

$$\mu = IA = \left(\frac{e}{T}\right)\pi r^2 = \frac{e\pi r^2}{T}$$

If period $T = \frac{ev}{2\pi r}$ then Equation (10.21) can be written as

$$\mu = \frac{evr}{2}$$

The S.I. unit of magnetic dipole moment is ampere-meter^2 (A.m^2).

EXAMPLE

1. A vertical rectangular coil of cross-sectional area 0.002 m^2 has 100 turns and carries a current of 2 A. Calculate the torque on the coil when it is placed in a uniform horizontal magnetic field of 0.5 T with its plane

   i. perpendicular to the field,

   ii. parallel to the field,

   iii. 50^o to the field.

Solution

$$\tau = NIAB\cos\theta = 100 \times 2 \times 0.002 \times 0.5\cos 90^o = 0$$

$$\tau = NIAB\cos\theta = 100 \times 2 \times 0.002 \times 0.5\cos 0^o = 0.2Nm$$

$$\tau = NIAB\cos\theta = 100 \times 2 \times 0.002 \times 0.5\cos 50^o = 0.13Nm$$

2. A closely wound coil has a diameter of 40 cm and carries a current of 2.5 A. How many turns does it have if the magnetic field at the center of the coil is 1.26 x 10^{-4} T?

Solution

B due to current loop

$$B = \frac{\mu_o IN}{2r} = \frac{\mu_o IN}{D}$$

$$N = \frac{BD}{\mu_o I} = \frac{1.26 \times 10^{-4} \times 40 \times 10^{-2}}{4\pi \times 10^{-7} \times 2.5} = 16.04 \approx 16$$

Galvanometer

A galvanometer consists of a coil of wire loops on an iron core that pivots between the pole faces of a permanent magnet. The coil experiences a torque when a current passes through it. A small spring produces a restoring torque and in equilibrium, the deflecting torque on the coil is equal to the restoring torque due to the elastic forces in the springs.

The total torque on the coil is

$$\tau = NIAB$$

The restoring torque of the spring in a galvanometer is given by the rotational form of Hooke's law:

$$\tau_s = k\phi$$

where k is the spring constant and ϕ is the deflection angle as measured by the pointer.

At equilibrium

$$k\phi = NIAB$$

$$\phi = \frac{NIAB}{k}$$

The sensitivity of a current meter is the deflection per unit current. From above equation, sensitivity of a current meter is given as

$$\frac{\phi}{I} = \frac{NAB}{k}$$

- According to this Equation, the following must be done in order to increase the sensitivity of a current meter
  i. Increase the magnetic field **B**
  ii. Decrease the value of k, that is, use weak springs
  iii. Increase the number of turns of the coil
  iv. Increase the area of coil

The sensitivity of a voltmeter is the deflection per unit p.d., or ϕ/V, where ϕ is the deflection produced by a p.d. V.

Using the relation $V = IR$, we have sensitivity for voltmeter as

$$\frac{\phi}{V} = \frac{NAB}{kR}$$

The expression above shows that the voltage sensitivity depends on the resistance ***R*** of the meter coil, unlike the current sensitivity.

Example

What is the torsional constant k of the spring of a moving coil galvanometer of circular coil of diameter 4.5 cm mounted in a uniform radial magnetic field of 0.35 T, if a current of 10 μA produces an angular deflection of 30º?

Solution

d = 4.5 cm, B = 0.35 T, I = 10 μA, N = 1, θ = 30º,

$$1^o = \frac{\pi}{180} rad$$

$$\theta = 30^o = \frac{30\pi}{180} rad = \frac{\pi}{6} rad$$

$$A = \frac{\pi d^2}{4} = \frac{\pi \left(4.5\times 10^{-2}\right)^2}{4}$$

$$NIAB = k\theta$$

$$k = \frac{NIAB}{\theta}$$

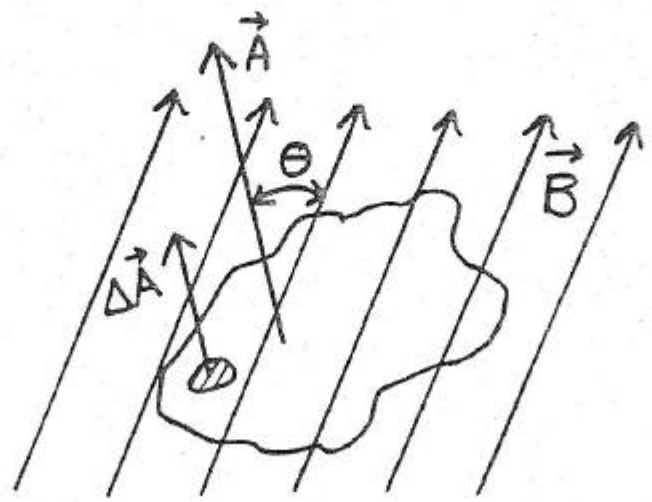
$$k = \frac{1\times 10\times 10^{-6}\times \pi \times \left(4.5\times 10^{-2}\right)^2 \times 0.35}{4\times \pi/6} N.m.rad^{-1} = 1.06\times 10^{-8} N.m.rad^{-1}$$

Electromagnetic Induction

Electromagnetic induction is the production of an electric current across a conductor moving through a magnetic field. It underlies the operation of generators, transformers, induction motors, electric motors, synchronous motors, and solenoids.

Magnetic Flux

The number of magnetic field lines that passes through a given surface is measured by the magnetic flux Φ_B for the surface. The **magnetic flux** is defined as



$$\emptyset_B = \sum \vec{B} \bullet \Delta\vec{A} = \int_S \vec{B} \bullet d\vec{s}$$

$$\emptyset_B = \sum B \Delta A \cos\theta$$

Where θ is the angle between

vectors $\vec{B}$ and $\Delta\vec{A}$.

If we take the summation $\sum \Delta\vec{A} = \vec{A}$ i.e total area

Then, $\emptyset_B = BA\cos\theta$

The S.I. unit for magnetic flux is tesla-metre squared ($T.m^2$) or weber (Wb).

Magnetic flux for different angles

1. If $\vec{B}$ and **A** are parallel (θ= 0^o), then the magnetic flux is positive and a maximum: $\Phi_B = B.A = BA\cos 0^o = +BA$.
2. If $\vec{B}$ and **A** are opposite (θ = 180^o), then the magnitude of the magnetic flux is maximum again, but of opposite sign:

   $\Phi_B = B.A = BA\cos 180^o = -BA$.
3. If $\vec{B}$ and **A** are perpendicular, there are no field lines through the loop, and the flux is zero: $\Phi_B = B.A = BA\cos 90^o = 0$.
4. For situations at intermediate angles, the flux is given as: $\Phi_B = B.A = BA\cos\theta$.

Faraday's Law of Induction and Lenz's Law

Suppose we have a loop of wire. Let A be the area of this loop.

From Faraday's experiments, **Faraday's law** of induction can be stated as follows: There is an induced emf, ε in this loop of wire whenever the flux of $\vec{B}$ through the area A is changing.

In order word: induced emf, ε directly proportional to the rate of change of magnetic flux linking the coil.

That is $\varepsilon \; \alpha \; N \dfrac{d\Phi}{dt}$

$$\varepsilon = -kN \frac{d\Phi}{dt}$$

where k = 1, *N* is the number of turns in the loop.

The minus sign expresses the **Lenz's law**.

Lenz's law states that an induced e.m.f. always gives rise to a current whose magnetic field opposes the original change in the magnetic flux.

Example

A coil of area 10 cm^2 is in a uniform magnetic induction 0.1 T. The field is reduced to zero in 1 ms. Determine the value of the induced e.m.f.

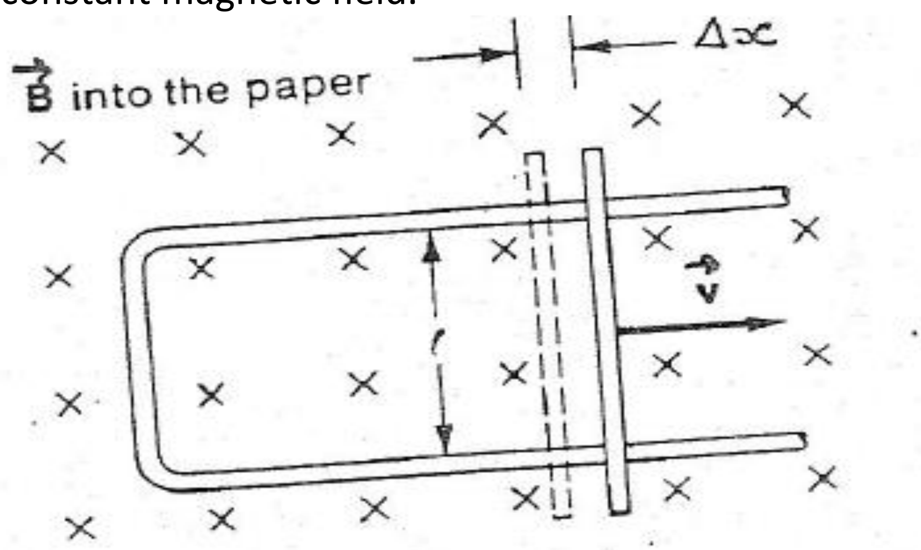
Solution

$B_2 = 0$, $B_1 = 0.1\text{T}$, $A = 0.001\text{m}^2$, $t_2 - t_1 = 1\text{ms} = 0.001\text{s}$

$$\varepsilon = -\frac{d\Phi_B}{dt} = \frac{B_2 A - B_1 A}{t_2 - t_1} = \frac{0.001(0-0.1)}{0.001}V = 0.1V$$

Motional EMF

A motional e.m.f. is the electromotive force induced in a conductor moving through a constant magnetic field.



As the rod moves with velocity v, it travels a distance $\Delta x = v\Delta t$ in a time Δt. Therefore the area increased by an amount

$l\Delta x = \Delta A = lv\Delta t$ in time Δt.

Hence magnetic flux through the loop increases.

By Faraday's law the amount of emf developed around the loop is

$$\varepsilon = -\frac{\Delta \emptyset}{\Delta t} = -\frac{\Delta(BA)}{\Delta t} = -B\frac{\Delta A}{\Delta t} = -B\frac{l\Delta x}{\Delta t} = -Blv$$

This shows that the motion of the bar perpendicular to the magnetic field generates an emf between the ends of the moving bar.

If the conductor has a resistance *R*, then the current that flows is

$$I = \frac{\varepsilon}{R} = \frac{BLv}{R}$$

We know that any conductor carrying a current in a magnetic field experiences a magnetic force $\vec{F}$ given by

$$\vec{F} = I\vec{L} \times \vec{B}$$

$$F = ILB \qquad \text{where } \theta = 90^o$$

$$F = \frac{vB^2L^2}{R}$$

The rate at which the work is done is on the conductor bar is

$$P_{ext} = Fv$$

$$P_{ext} = \frac{v^2B^2L^2}{R}$$

However, the rate at which energy is dissipated as heat in the resistor is

$$P = I^2R$$

$$P = \left(\frac{BLv}{R}\right)^2 R \qquad \text{i.e} \qquad P = \frac{v^2B^2L^2}{R}$$

EXAMPLES

1. A metallic rod 40 cm long is perpendicular to a field of 0.65 Wb/m^2 and moves at right angles to the field with a speed of 0.50 m/s. Determine the e.m.f. induced in the rod.

Solution

$$\varepsilon = BLv = 0.65 \times 0.40 \times 0.50 = 0.13V$$

2. A copper rod of length 40 cm makes a contact with a partial circuit and completes the circuit. The circuit is perpendicular to a magnetic field with B = 0.55 T. If the resistance is 3.0 Ω, calculate the maximum force required to move the rod with a constant speed of 3.0 m/s. Calculate the power loss in the resistor.

Solution

The e.m.f. induced in the rod is

$$\varepsilon = BLv = 0.55 \times 0.40 \times 3.0 = 0.66V$$

The current flowing through the rod is

$$I = \frac{\varepsilon}{R} = \frac{0.66}{3.0} = 0.22A$$

The maximum force required is

$$F_m = BIL = 0.55 \times 0.22 \times 0.4 = 0.0484N$$

The power loss in the resistor is

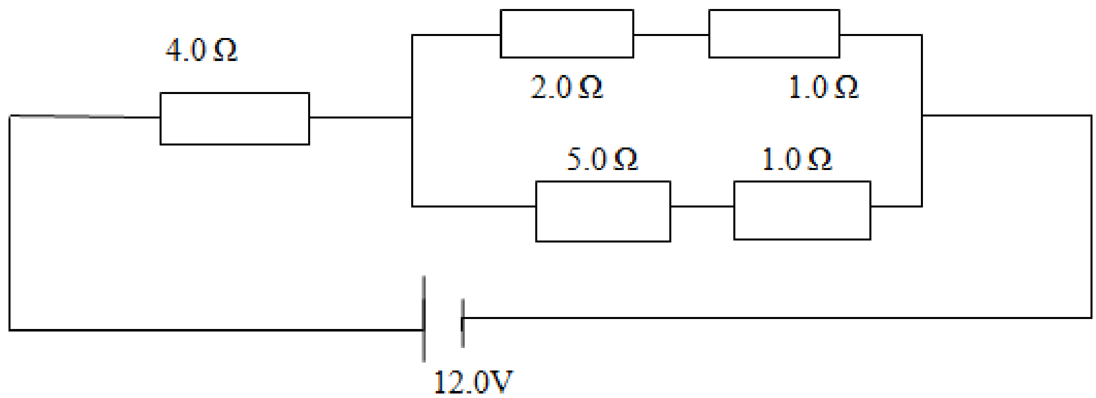
$$P = Force \times velocity = 0.0484 \times 3.0 = 0.1452W$$

Alternatively, $P = I^2 R = 0.22^2 \times 3.0 = 0.1452W$

PHY 152: Electricity and Magnetism I

Please take note of typo error in some questions and answers provided under "Ohm's Laws, Kirchhoff's Laws and Electrical Energy".

The affected questions together with the answers are given below.



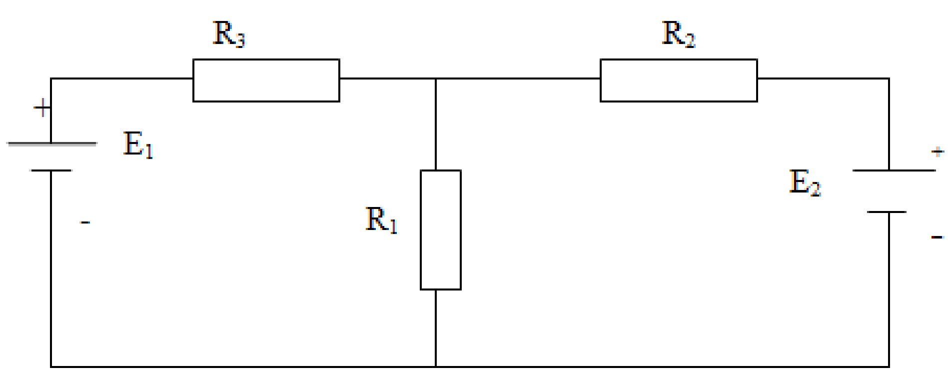
Determine the power dissipated in the 2.0 Ω resistor in the circuit above (Resistive dissipation)

Ans: power dissipated = 3.56 W

A copper wire and aluminum wire have the same length. Obtain the ratio of diameter of aluminum to that of copper if the resistance of copper is twice that of aluminum and the resistivity of copper $\rho_c = 1.72 \times 10^{-8}\ \Omega m$ and that of aluminum $\rho_a = 2.82 \times 10^{-8}\ \Omega m$.   Ans: 9:5

In the diagram below, $E_1 = 3.0V$, $E_2 = 1.00V$, $R_1 = 5.0\ \Omega$, $R_2 = 2.0\ \Omega$, $R_3 = 4.0\ \Omega$ and both batteries are ideal. What is the rate at which energy is dissipated in (a) R_1 (b) R_2 (c) R_3

Ans: $P_1 = 0.35$ W $P_2 = 0.05$ W & $P_3 = 0.71$ W



PHY152: ELECTRICITY AND MAGNETISM

SUB-TOPIC

Coulombs Laws, Gauss Laws and Electric Potentials

Coulombs Law:

• The magnitude of the Electric Force exerted by one point charge on the other is directly proportional the product of the charges and inversely proportional to the square of the distance r between

$$F = k\frac{Q_1 Q_2}{r^2}$$

if F = +ve → repulsive Force

F = −ve — attractive force

$k = 8.99 \times 10^9\ Nm^2/C^2 = \frac{1}{4\pi\varepsilon_0}$

ε_0 permittivity of free spa

$\varepsilon_0 = 8.85 \times 10^{-12}\ C^2/Nm^2$ //

Exercise:

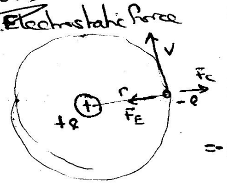
1. In the Bohr model of the Hydrogen atom, the electron is in orbit about the proton at a radius of 5.29×10^{-11} m. ($m_e = 9.11 \times 10^{-31}$ kg)

a. Determine the force on the electron.

b. Find the speed of the electron

Soln

a. Electrostatic force   Hydrogen = 1 proton = 1 electron



$$F_E = k \cdot \frac{q_1 q_2}{r^2}$$

$$= -8.99 \times 10^9 \times \frac{(1.6 \times 10^{-19})^2}{(5.29 \times 10^{-11})^2}$$

$$= -8.22 \times 10^{-8}\ N$$ //

Gravitational force ≃ 0 since both the mass of proton and the mass of electrons are very small

---

b. Centrepetal force

$$F_c = \frac{mv^2}{r}$$

since the radius is constant,

$$F_E = F_c$$

$$\Rightarrow F_E = \frac{mv^2}{r}$$

$$\Rightarrow v^2 = \frac{rF_E}{m}$$

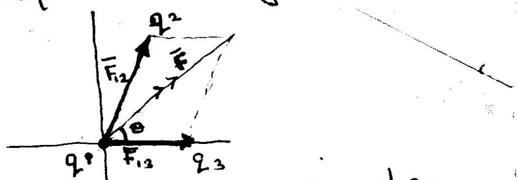
$$\Rightarrow v = \sqrt{\frac{(5.29 \times 10^{-11})(8.22 \times 10^{-8})}{9.11 \times 10^{-31}}}$$

$$= 2.18 \times 10^6\ m/s$$ //

Vectors Quantities

They have both magnitude and direction

eg



Resultant force on q_1 from q_2 and q_3

$\bar{F} = \bar{F}_{12} + \bar{F}_{13}$ (x compnt, y compnt)

$\bar{F}$ can be resolved into its x and y compnts (x compnt, y compnt)

as $\bar{F} = \bar{F}_x + \bar{F}_y$

Hence, we can draw a table such as

Hence, we can draw a table such as

Force	x component	y component
$\bar{F}_{12}$	$+\lvert F_{12}\rvert\cos\theta_{12} = F_{12x}$	$+\lvert F_{12}\rvert\sin\theta_{12} = F_{12y}$
$\bar{F}_{13}$	$+\lvert F_{13}\rvert\cos\theta_{13} = F_{13x}$	$+\lvert F_{13}\rvert\sin\theta_{13} = F_{13y}$
$\bar{F}$	$\bar{F}_x$	$\bar{F}_y$

ii The magnitude F and the angle of the net force are

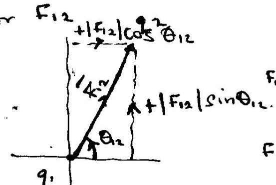
$$F = \sqrt{F_x^2 + F_y^2}$$

and

$$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$$

---

i For F_{12}



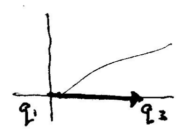
x component

$F_{12x} = |F_{12}|\cos\theta_{12}$

y component

$F_{12y} = +|F_{12}|\sin\theta_{12}$

ii For F_{13}



x component

$\theta_{13} = 0$ $F_{13x} = +|F_{13}|\cos\theta_{13}$

$= +|F_{13}|\cos 0$

$= +|F_{13}|$

y component

$F_{13y} = +|F_{13}|\sin\theta_{13}$

$= +|F_{13}|\sin 0$

$= 0$ //

Summary:

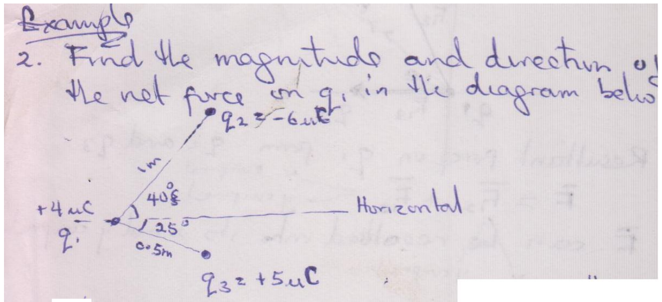
Net force on any one charge

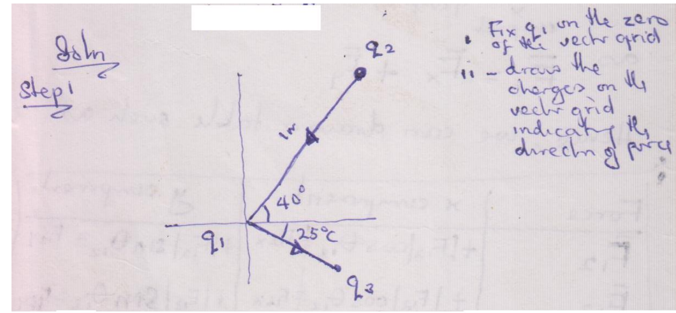
~~$\bar{F} = \sum\bar{F}_x + \sum\bar{F}_y$~~

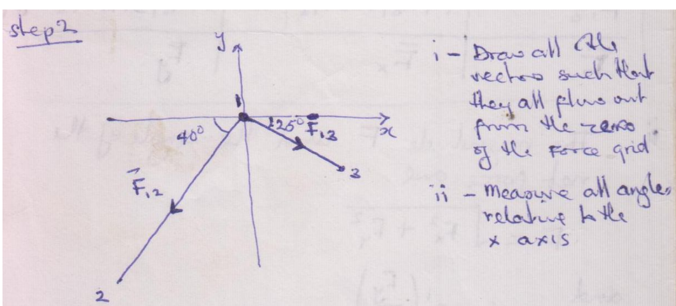
$\bar{F} = \bar{F}_x + \bar{F}_y$

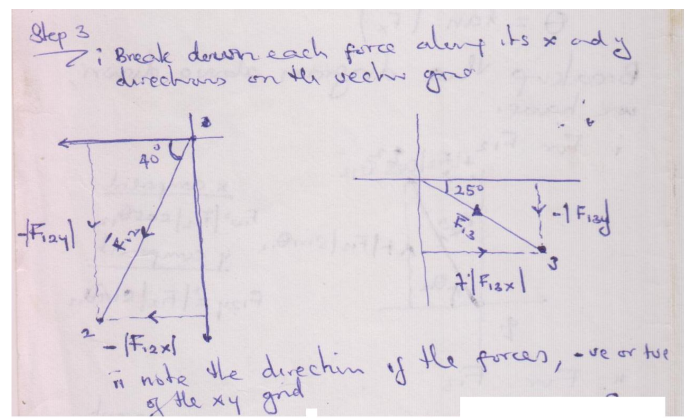
$\bar{F}_x = \sum$ Force component in the x direction

$\bar{F}_y = \sum$ Force component in the y direction.


Example
2. Find the magnitude and direction of the net force on q1 in the diagram below
q2 = -6uC
1m
40°
+4uC
q1
25°
Horizontal
0.5m
q3 = +5uC


Soln
Step 1
q2
1m
40°
q1
25°C
q3
i Fix q1 on the zero of the vector grid
ii - draw the charges on the vector grid indicating the direction of force


step 2
y
x
40°
25°
F13
F12
1
2
3
i - Draw all the vectors such that they all flow out from the zero of the force grid
ii - Measure all angles relative to the x axis


Step 3
i Break down each force along its x and y directions on the vector grid
40°
-|F12y|
-|F12x|
25°
F13
-|F13y|
+|F13x|
ii note the direction of the forces, -ve or +ve of the xy grid

Step 4: Write the equation for each of these force

$F_{12x} = -|F_{12}|\cos 40°$ $F_{13x} = +|F_{13}|\cos 25°$

$F_{12y} = -|F_{12}|\sin 40°$ $F_{13y} = -|F_{13}|\sin 25°$

Step 5 To obtain the resultant Force F.

$\bar{F} = \bar{F}_x + \bar{F}_y$

$\bar{F}_x = F_{12x} + F_{13x}$ and $\bar{F}_y = F_{12y} + F_{13y}$.

$F_x = -|F_{12}|\cos 40° + |F_{13}|\cos 25°$

$F_y = -|F_{12}|\sin 40° - |F_{13}|\sin 25°$

Step 5 = Compute the magnitude $|F_{12}|$ and $|F_{13}|$

$|F_{12}| = k\frac{q_1 q_2}{r_{12}^2} = 8.99\times10^{9}\frac{4\times10^{-6}\times 6\times10^{-6}}{(1.0)^2}$

$= 0.216N$

$|F_{13}| = k\frac{q_1 q_3}{r_{13}^2} = 8.99\times10^{9}\frac{4\times10^{-6}\times 5\times10^{-6}}{(0.5)^2}$

$= 0.719N$

$\Rightarrow F_x = -0.216\cos 40 + 0.719\cos 25$

$= -0.165 + 0.652$

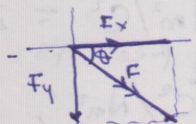
$= 0.49N$

$F_y = -0.216\sin 40 - 0.719\sin 25$

$= -0.139 - 0.304$

$= -0.44N$

Step 6



Magnitude of Force $F = \sqrt{F_x^2 + F_y^2}$

$= \sqrt{0.49^2 + 0.44^2}$

$= 0.66N$

Direction θ:

$\theta = \tan^{-1}\left(\frac{F_y}{F_x}\right)$

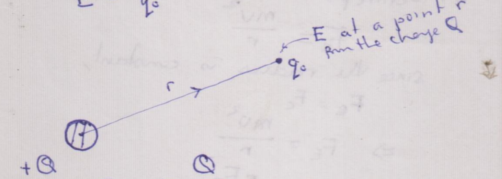
$= \tan^{-1}\left(\frac{0.44}{0.49}\right)$

$= -41.9°$

Electric Field E

The electric field of a charge Q at a point is the force it exerts per unit charge when a small test charge is placed at that point.

i.e. $\bar{E} = \frac{F}{q_0}$ unit (N/C)



$\bar{E} = k\frac{Q}{r^2}$

E = +ve for a +ve charge E radiates outward from Q

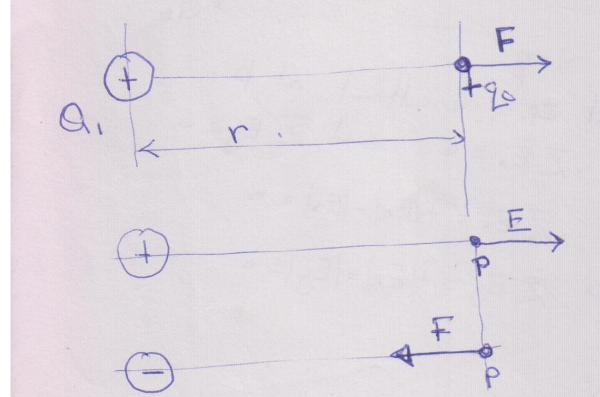
= −ve for a −ve charge E radiates inward to Q.

Electric Field:

The electric field E that exists at a point is the electrostatic force F experienced by a small test charge q_0 placed at that point divided by the charge itself:

$$E = \frac{F}{q_0} = k\frac{Q}{r^2}$$

There is



Electric Field Produced by Point Charges

Exercise:

1. There is an isolated point charge of $Q = +15\mu C$. Using a test charge, $q_0 = +0.8\mu C$, (a) determine the electric field at a point P, which is 20 cm away.
(b) What happens if the test charge is $0.1\mu C$.

Soln.

a. $$E = \frac{F}{q_0} = k\frac{q_0 Q}{q_0 r^2}$$

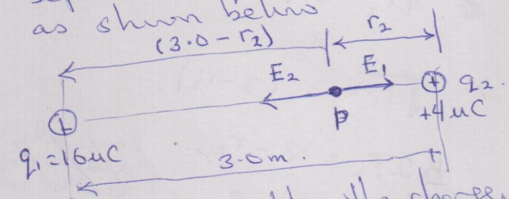
$$= k \times \frac{(0.8\times10^{-6})\times(15\times10^{-6})}{(0.2)^2 \cdot (0.8\times10^{-6})}$$

$$= 3.4\times10^{6}\ N/C$$

b.

$$E = \frac{F}{q_0} = k\frac{q_0 Q}{q_0 r^2} = \frac{(15\times10^{-6})}{(0.02)^2} = 3.4\times10^{6}\ \text{N/C}$$

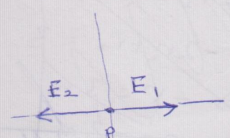
2. Two positive point charges $q_1 = +16\mu C$ and $q_2 = +4\mu C$, are separated by a distance of 3.0 m. as shown below



Find the spot btw the charges where the net electric field is zero.

Soln

Draw the vector diagram with p at the centre of your grid



The net electric field is zero when

$\sum E_x = 0$, $\sum E_y = 0$ and $\sum E_z = 0$

Hence $\sum E_x = E_1 - E_2 = 0$

$\Rightarrow E_1 = E_2$

$$E_1 = K\frac{Q_1}{(3.0 - r_2)^2}$$

$$E_2 = K\frac{Q_2}{r_2^2}$$

Since $E_1 = E_2$

$$K\frac{Q_1}{(3-r_2)^2} = K\frac{Q_2}{r_2^2}$$

$$\frac{16\times10^{-6}}{(3-r_2)^2} = \frac{4\times10^{-6}}{r_2^2}$$

Re-arranging gives.

$$\frac{r_2^2}{(3-r_2)^2} = \frac{4\times10^{-16}}{16\times10^{-16}}$$

$$\Rightarrow \frac{r_2^2}{(3-r_2)^2} = \frac{1}{4}$$

$$4r_2^2 = (3-r_2)^2$$

$$\Rightarrow \sqrt{4r_2^2} = (3-r_2)$$

$$2r_2 = 3-r_2$$

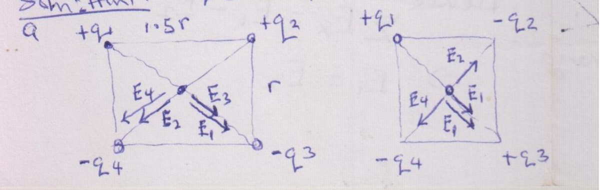
$$\Rightarrow 2r_2 + r_2 = 3$$

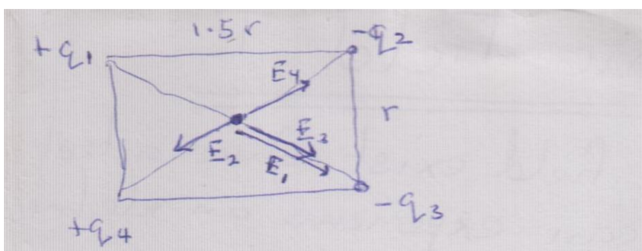
$$\Rightarrow 3r_2 = 3$$

$$\Rightarrow r_2 = \frac{3}{3} = 1\,m$$

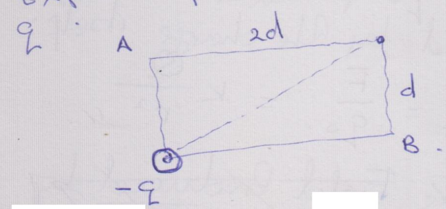
3. Find the electric field strength at the centre of each of the figures of point charges (where All q's are equal)

Soln: Hint.

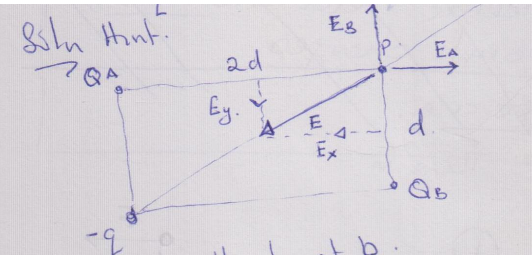




4. A negative charge $-q$ is fixed to one corner of a rectangle as in the drawing below. What +ve charge must be fixed to corner A and what +ve charge must be fixed to corner B, so that the electric field at the remaining corner is zero. Express your answers in terms of q.



Soln Hint.



for zero resultant at P.

$\sum E_x = 0$ and $\sum E_y = 0$

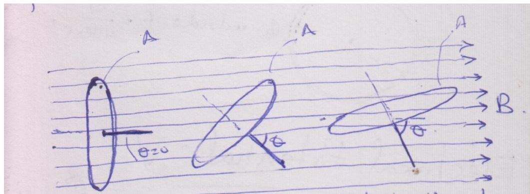
$\Rightarrow \sum E_x = +|E_A| - |E_x| = 0$

$\Rightarrow \sum E_y = +|E_B| - |E_y| = 0$

Gauss's Law

The Coulombs laws may be expressed in a form known as Gauss's Law. However, the number of problems that can be solved using the Gauss formulation is quite limited, because the charge distribution must have a special symmetric property.

Consider a plane surface area cutting into some magnetic field lines as shown below

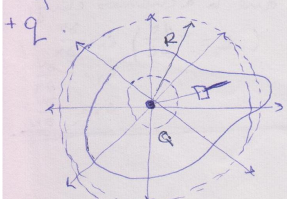


θ = Angle btw the normal to the plane and the magnetic field line (flux).

The (number of flux lines){flux} passing through each surface area is given by

$$\phi = EA\cos\theta$$

Consider an arbitrary closed surface of area A enclosing a charge +q



$\phi = \oint (E \cdot \hat{n})\, ds$ where ds = elemental surface area

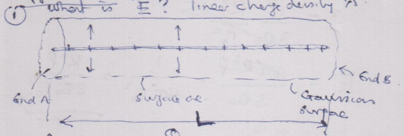
$$\phi = \oint E \cdot \oint ds = E \cdot 4\pi R^2 = \frac{Q}{4\pi\varepsilon_0 R^2} \cdot 4\pi R^2 = \frac{Q}{\varepsilon_0}$$

Hence

$$\oint (E \cdot \hat{n})\, ds = \frac{Q}{\varepsilon_0}$$

Application:

① What is E? linear charge density λ.



$$\oint (E\cdot\hat{n})\,ds = \frac{Q}{\varepsilon_0}$$

$$\Rightarrow \int E\cdot n\,ds_A + \int E\cdot n\,ds_c + \int E\cdot n\,ds_B = \frac{Q}{\varepsilon_0}$$

$$0 + E\cdot(2\pi R L) + 0 = \frac{Q}{\varepsilon_0}$$

$$\Rightarrow E = \frac{Q}{2\pi\varepsilon_0 R L} \quad //$$

If linear charge density $= \lambda$.

$$\Rightarrow \lambda = \frac{Q}{L}$$

$$\Rightarrow Q = \lambda L$$

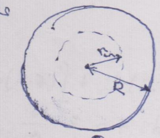
$$\Rightarrow E = \frac{\lambda L}{2\pi\varepsilon_0 R L} = \frac{\lambda}{2\pi\varepsilon_0 R} \quad //$$

② Solid Sphere of radius R uniformly charged to a volume density ρ.

ⓐ What is E inside ⓑ What is E outside

Soln

ⓐ Inside



$$\rho = \frac{Q}{V_{in}} = \frac{Q}{4/3\,\pi r^3} = \frac{3Q}{4\pi r^3}$$

$$\Rightarrow Q = \frac{4\pi r_m^3 \rho}{3}$$

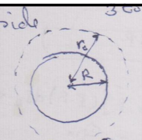
$$\oint (E\cdot\hat{n})\,ds = \frac{Q_{in}}{\varepsilon_0}$$

$$\Rightarrow E\cdot(4\pi r_m^2) = \frac{\frac{4}{3}\pi r^3 \rho}{\varepsilon_0} = \frac{4\pi r^3 \rho}{3\varepsilon_0}$$

$$\Rightarrow E = \frac{4\pi r_m^3 \rho}{3\varepsilon_0}\cdot\frac{1}{4\pi r_m^2}$$

$$= \frac{\rho r}{3\varepsilon_0} \quad //$$

b. Outside



$$\oint (E\cdot\hat{n})\,ds = \frac{Q_{in}}{\varepsilon_0}$$

$$\therefore E\cdot(4\pi r_0^2) = \frac{\frac{4}{3}\pi R^3 \rho}{\varepsilon_0} \qquad r_0 > R.$$

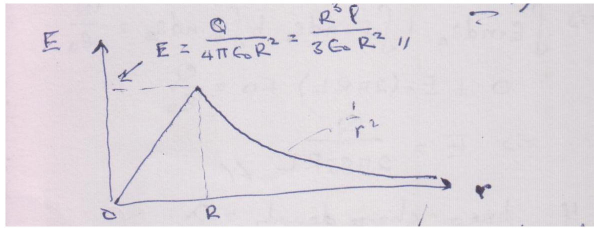
$$E = \frac{4\pi R^3 \rho}{3\varepsilon_0}\cdot\frac{1}{4\pi r_0^2}$$

$$= \frac{\rho}{3\varepsilon_0}\cdot\frac{R^3}{r_0^2}$$

$$E = \frac{4\pi R^3 \rho}{3\varepsilon_0}\cdot\frac{1}{4\pi r_0^2} = \frac{R^3 \rho}{3\varepsilon_0 r_0^2} \quad //$$

in terms of Q.

$$E = \frac{Q}{\varepsilon_0}\cdot\frac{1}{4\pi r_0^2} = \frac{Q}{4\pi\varepsilon_0 r^2} \quad //$$



(3) A very long cylindrical uniformly charged cylinder, with charge density ρ, what is E inside and outside?

Soln

(a) Inside $(r < R)$

$$\rho = \frac{Q_{enclosed}}{vol} = \frac{Q_{enclosed}}{(\pi r^2 L)} \Rightarrow Q = \pi r^2 L \rho$$

By Gauss law

$$\oint (E \cdot \hat{n}) \cdot ds = \frac{Q}{\epsilon_0}$$

$$\Rightarrow \int (E \cdot \hat{n}) ds_A + \int (E \cdot \hat{n}) ds_s + \int (E \cdot \hat{n}) ds_B = \frac{Q}{\epsilon_0}$$

$$0 + E \int ds + 0 = \frac{Q}{\epsilon_0}$$

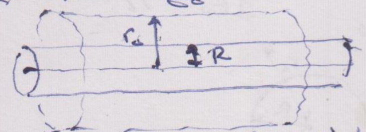
$$E \cdot (2\pi r L) = \frac{\pi r^2 L \rho}{\epsilon_0}$$

$$E = \frac{\pi r^2 L \rho}{2 \pi r L \epsilon_0} = \frac{\rho r}{2 \epsilon_0} ///$$

(b) Outside

By Gauss law

$$\oint (E \cdot \hat{n}) ds = \frac{Q_{in}}{\epsilon_0}$$



$$\int (E \cdot \hat{n}) ds_A + \int (E \cdot \hat{n}) ds_s + \int (E \cdot \hat{n}) ds_B = \frac{Q_{in}}{\epsilon_0}$$

$$0 + \hat{E} \cdot \int ds + 0 = \frac{Q_{in}}{\epsilon_0}$$

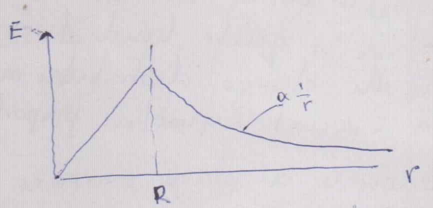
$$E \cdot (2\pi r L) = \frac{Q_{in}}{\epsilon_0}.$$

$$E = \frac{1}{2\pi r L} \cdot \frac{Q_{in}}{\epsilon_0}.$$

$$Q = \pi R^2 L \rho$$

$$\Rightarrow E = \frac{1}{2\pi r L} \cdot \frac{\pi R^2 L \rho}{\epsilon_0}$$

$$= \frac{\rho R^2}{2 r \epsilon_0} = \frac{\rho R^2}{2 \epsilon_0} \cdot \frac{1}{r}$$



(4) Hollow spherical charged surface

(a) inside $E = 0$

(b) outside $E = \frac{Q}{4\pi\epsilon_0 r^2}$

Electrical Potential: V

PHY 152 PRACTICE QUESTIONS

1. Which of these is not correct as a basic property of electric charges?
(a) Total charges in an insulated system is invariable
(b) A charged body is electrically unstable
(c) A charged body has equal number of positive and negative charges
(d) Positively charged body is deficient of electrons

x+q1+q2 = 2 q1

2.Calculate the distance x between charges q1 and q2 shown, given the
repulsive force between them as 1.2 x 10-4 N, take the permittivity of vacuum where they were as 8.842x 10 -12 F/M and charge on q1= 1.6x10-19c
(a) 1.96x10-12M (b) 9.1x104N (c) 16.8x10-4 N. (d) 4.3x108 N

3. Two charges separated by distance x are located in vacuum. One is a quarter in a magnitude of the other. In terms of two charges above Coulomb's law can correctly represented by:
(a) (b) (c) (d)

4. Find the ratio (Fe/Fg) of the Coulomb electrical force Fe, to the gravitational force, Fg, between two electrons separated by distance r
(a) (b) (c) (d)

5. Two identical balls, carrying equal charge each of mass 0.10g, are suspended freely by two threads of equal length repelled each other so that each thread make angle 300 with vertical line. At equilibrium, calculate the tension in one of the threads.
(Acceleration of gravity pull g = 9.8 m/s2)
(a) 1.13x10-3 N (b) 6.3x10-6 N (c) 0.41 N (d) 5.1x10-12 N

6. When two identically charged bodies suspended freely by thread of equal length repel each other all of these forces are acting on one of then except:

(a) Tension (b) Gravitational pull (c) Coulomb attraction force (d) Repulsive force

7. two charges are separated as shown. Where a third positive charge must
be placed if the force it experiences is to be zero?

(a) At D (b) At C (c) At E (d) At B

8. For series of charges in a closed surface within a vacuum, given that Îo andYe are the electric permitivity and field flux, Gauss' law can be stated as
(a) (b) (c) (d)

9. One of the following is not a practical use of a capacitor:

(a) To establishment of electric field of a required pattern.

(b) As oscillatory device in circuit.

(c) Used in time-base circuit to initiate an event at a specific time.

(d) To produce and store charges when electric field is lacking.

10. 2mF and 3mF capacitors are both connected in parallel across a 100 V supply line. Calculate the charge on the plates of the capacitors:

(a) 1.5x10-6 C (b) 1.0x10-6 C (c) 5.0x10-4 C (d) 0.7x10-4 C

11. Capacitance of a parallel plate capacitor is in directly proportional to:

(a) The magnitude of the permittivity of the of the dielectric within the plates

(b) The magnitude of the surface area of the plates in the capacitor

(c) Separation of the plates in the capacitor

(d) The magnitude of the voltage applied

12. One plate of a parallel- plate air capacitor has a surface area of 0.2m2 and is separated from the second plate by 0.01m if the electric permittivity of the dielectric used is 8.85x10-12 F/M. Calculate the voltage that will develop 8.85x10-9c charge on its plate.

(a) 7.1x10-2 (b) 50V (c) 4.1V (d) 60.2V

13. A parallel plate air-capacitor has square plate whose area is 0.2m2 and plates separated by 1cm, is connected to 50V battery. Calculate the energy stored in the capacitor if the permittivity of the dielectric used is 8.85x10-12 F/M.

(a) 1.6x10-7 J (b) 2.21x10-7 J (c) 3.0X10-7J (d) 4.6X10-7J

14. Which of the following is not a characteristic of air-capacitor?
(a) It is stable
(b) It has high insulation strength
(c) It is simple to make
(d) It can be easily adapted as a variable capacitor

15. Which of the following is not a characteristic of an electrolytic capacitor?

(a) Its dielectric is of high insulation strength.

(b) It is cheap to make.

(c) Its dielectric is made of oxide deposit of aluminium borate.

(d) (a) and (c)

16. Two capacitors 0.2mF and 0.4mF are connected in series to a supply of 10V. Calculate the energy stored in the field within the dielectrics of the capacitors

(a) 6.7X10-5J (b) 14.2X10-5J (c) 26.3X10-5J (d) 9.8X10-5J

17. What area of the plate of parallel-plate capacitor gives 1mF, if the plate's separation is 0.001m and permittivity of the dielectric used is 8.85x10-12?

(a) 9.13x10-3m2 (b) 113 m2 C 6.6X10-3 (d) 21 m2

18. The inverse of constant of proportionality in ohm's law for metallic conductors can be called:

(a) Inductance (b) Conductance (c) Reactance (d) Remittance

19. One major difference between Ohm metallic conductors and semi conductors is:
(a) Temperature increase increases the conductivity of semiconductor
(b) Temperature increase makes valence electrons to fall to ground state in semiconductor
(c) Temperature increase reduces the speed of the conducting electrons in the semi conductor.
(d) Temperature increase ejects the valence electrons in metals.

20 Which of these figures best represent Temperature T/ Resistance R characteristics curve for a dry wood?

22. Obtain the equivalent resistance between points X and Y in the diagram shown.
(a). 11.6 Ω B 37 Ω C 18.6 Ω D 8.3 Ω

23. Conductivity of metal conductor does not depend on one of the following:
(a) Permeability (b) Temperature (c) Length (d) Cross section area

24. The diameter of a 5 m long constantan wire is 0.1mm. Calculate its conductivity if
Its resistance per unit length is 2 Ω/m.
(a) 1.5X106/ Ω m (b) 99x10-9/ Ω m (c) 6.4x107/ Ω m (d) 5.5x10-7/ Ω m

25. The initial resistance R of a conductor increases by 3 Ω when its initial temperature T was raised to twice its initial value. Calculate is initial resistance if the temperature co-efficient of resistance of the conductor is µ
(a) 3µt (b) (c) (d)

26. A wire conductor has initial resistivity of 1.003 Ωm, its resistivity changes to a new one when temperature is increased by 15 0K. If its resistance per unit length and radius are 1.02x107 W/m and 0.25 mm, calculate its temperature co-efficient or resistivity.

(a) 1.6x10-2/K (b) 8.6x10-6/K
(c) 7.0x10-2/K (d) 4.1x10-6/K

27. A 500-watt boiling ring was used to raise the temperature of 200g of a liquid by 250K within 2 seconds. What is the specific heat capacity of the liquid?

(a) 2.0x102 J/KgK (b) 6.3x10-3 J/KgK (c) 4.41x104 J/KgK (d) 1.333x105 J/KgK28 500-watt power source connected to a conductor for 0.5 seconds energized a 9.1x10-3Kg electron for it to attain a velocity. Calculate the velocity of the electron.

(a) 5.31x1012m/s (b) 8.40x1021m/s C(c) 7.11x1029m/s (d) 2.34x1016m/s29 One of the following cannot be a unit of electrical potential (a) Joule per Coulomb (b) Volt (c) Watt per coulomb (d) Newton meter
per Coulomb30 Which of the following is the correct statement for Kirchoff's rule for current at a junction of circuit network?

(a) Algebraic sum of current at a junction is zero
(b) Algebraic sum of current flowing into a junction is equal to that, leaving that junction
(c) Algebraic sum of current at a junction is constant
(d) (a) and (b) are correct31. A total of 1.92x 10-18J work is required to carry 1.6x10-19 charges across the two terminals of a cell within 1 minute. What is the maximum current in the circuit?

(a) 8.99x10-12 A (b) 2.67x10-21A (c) 7.12x10-14 A (d) 4.13x10-13A32. Consider a charge e at a point in vacuum, absolute electrical potential at point x away from e can be correctly obtained using: 33. Three equal 2μF charges are located at the angles of an equilateral triangle whose sides are 7cm each in vacuum. Determine the absolute electric potential at the centre of the triangle (K = 9 x 109Nm2/C2)
(a) 6.09 x 105V (b) 9.66 x 103V (c) 444V
(d) 2.6 x 104V

35. A metre bridge has 3 Ω and 1 Ω resistors in its left and right gaps. When a wire of length 218cm was connected in parallel with the 3 Ω resistor the balance point is 54.6cm from the left. What is the resistance of the wire connected across the 3 Ω resistor?

(a) 3.5 λ Ω (b) 2.0 Ω (c) 5.5 Ω (d) 6.5 Ω

36. All of these are the uses of potentiometer with exception of:
(a) Comparison of emf of two cells
(b) Comparison of capacitance of two capacitors
(c) Measurement of internal resistance of a cell
(d) Measurement of small current

37. Which of the following is a necessary condition for working potentiometer?
(a) Positive terminals of the driver and test cells must be connected to a common point
(b) emf of driver cell must always be greater than of the test cell
(c) When galvanometer is balanced no current could flow in the potentiometer
(d) (a), (b), and (c) are correct

38. While determining the internal resistance r of a cell using potentiometer graph was plotted for the relation . If the slope was found to be 0.25 Ω/m and the balance point L1 from the left side is 34.2 cm calculate the internal resistance.
(a) 6.05 Ω (b) 8.55 Ω (c) 14.9 Ω (d) 50.33 Ω

39. In electromagnetism one of the following is not among the three entities that are mutually dependent:
(a) Current (b) Charges (c) Motion
(d) Magnetic field

41. The magnitude of the electromagnetic force produced when a current carrying conductor is in a magnetic field is not increased by: (a) Thickness of the conductor
(b) Length of the conductor
(c) Magnetic field strength
(d) Magnitude of sine of the angle made by the conductor with the field. 42. What angle will the current carrying conductor laying in a
magnetic field make for the electromagnetic force F it experience to be a minimum?
(a) 90o (b) 180o (c) 0o (d) -60o43. Calculate the force on a power cable 2 km long carrying 200
A current in N30oE direction if earth's
horizontal magnetic component is 10-5T
(a) 2N (b) 4N (c) 6N (d) 8N

45. What is the magnetic flux density B at 2m from a straignt wire in vacuum carrying 3A current? (μo = 4n x 10-7 H/m)
a) 5 x 10-7 T (b) 3 x 10-7 T (c) 6 x 10-7 T (d) 2 x 10-7 T46. a current carrying solenoid is wound N times in
cylindrical form with radius r as shown. The magnetic flux density at point P is given by: 47. Electromagnetic induction is a process of converting:
(a) Electrical energy to potential energy
(b) Mechanical energy to electronic energy
(c) Kinetic energy to electrical energy
(d) Mechanical energy to light energy

48. Three current carrying wires shown are in vacuum. If is 0.25m long,
calculate the net electromagnetic force on it
((μo = 4π x 10-7 H/m)
(a) 42 x 10-4N (b) 4.2 x 10-4N (c) 8.2 x 10-4N (d) 3 x 10-4N

49. Motion of the magnetic flux during induction can be achieved in any of the following ways:
(i) Dynamo effect (ii) Sliding effect (iii) Transformer effect.
(a) I only (b) II only (c) I and II only (d) I and III only50. Using Faraday's law of induction of emf and self induced emf in
a current carrying wire, obtain an expression for self inductance L in terms of flux ϕ and current I.

51. Use Faraday's law of induction of emf in a solenoid and mutually induced emf in a second nearby solenoid as a result of current changes in the first coil to obtain an expression for mutual inductance m in terms of flux ϕ and current I.

52. Major similarity between self inductance and mutual inductance is that: (a) They are both measured in Teslas
(b) They are both produced when current change at the rate of 1A per second
(c) They both oppose the current producing them
(d) They are both measured in Henry53. Static electricity is the study of the energy associated
with electrons:
(a) In translational motion
(b) In vibrational motion
(c) At rest
(d) In charged bodies

54. Current I flow changes with time t in a fully charged parallel plate capacitor when disconnected from the power source I/t characteristic curve for this case is:

55. According to its definition the unit of the emf of a cell can be
(a) Joule/Kelvin (b) Joule/coulomb (c) Joule/second (d) volt/second

56. A major difference between electric current and voltage (potential difference) is:
(a) Current is time rate of flow of charges while voltage is a measure of energy required to move a charge within a given place.
(b) Current can be measured in Coulomb/second voltage is Joule/Coulomb
(c) Current is point phenomenon while voltage is a gap phenomenon
(d) All above are correct.

58. The volume control in a radiowave receiver is an example of:
(a) Air capacitor (b) Potentiometer (c) Resistor (d) Inductor ϕ

59. Which of these is/are sample(s) unit (s) of capacitance of a capacitor?
(a) Picofarad (b) Coulomb/volt (c) Joule/metre (d) a and b are correct

60. Which of the following statement is wrong about self induced/back emf?
(a) It reduces the efficiency of the current that produced it.
(b) It is induced as a result of variation in magnetic field caused by varying electric current.
(c) It opposes the applied emf
(d) All above are wrong about self induced/back emf.

Q61. Ferromagnetic materials are materials which can be permanently magnetized.
(A) When the material is doped with positive materials
(B) When the material is doped with negative materials
(C) When an internal magnetic field is applied to the material.
(D) When an external magnetic field is applied to the material.

Q62. If the temperature of a ferromagnetic material is raised past the Curie temperature, the material abruptly loses its permanent magnetisation and becomes
(A) Paramagnetic (B) Electromagnetic
(C) Diamagnetic (D) Curiemagnetic

Q63. Which of the following statements is correct about Paramagnetic Materials?

(A) Paramagnetic materials are attracted toward magnets, but do not become permanently magnetised. (B) Paramagnetic materials are attracted toward magnets, and become permanently magnetised. (C) Paramagnetic materials are repelled from magnets, and do not become permanently magnetised. (D) None

Q64. Which of the following statement is correct about Diamagnetic materials?

(A) Diamagnetic materials are repelled by magnets, but do not become permanently magnetised.
(B) Paramagnetic materials are attracted toward magnets, and become permanently magnetised. (C) Diamagnetic materials are attracted toward magnets, but do not become permanently magnetised (D) None

Q65. Which of the following statement is incorrect about Remanent Magnetism?

(A) Remanent Magnetism is the magnetisation remaining after the removal of an externally applied field (B) Remanent Magnetism is exhibited by ferromagnetic materials.
(C) If the external field is reduced more, the remanent magnetisation will be removed (D) Remanent Magnetism is not exhibited by ferromagnetic materials.

Q66. Which of the following statement is correct about hysteresis?
(A) As the external magnetic field is increased, the induced magnetization also decreases.
(B) The induced magnetisation is eventually lost
(C) As the external magnetic field is increased, the induced magnetization also increases.
(D) All

Q67. The lack of retraceability is known as

(A) Magnetisation (B) Hysteresis (C) Remanence (D) Coercive force

Q68. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. A material with B < Bo is known as

(A) Paramagnetic material (B) Electromagnetic material (C) Diamagnetic material
(D) ferromagnetic material

Q69. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. The correct relation is given by?

(A) B o = BM + B (B) B + Bo = BM
(C) B = Bo = BM

(D) B = Bo + BM

Q70. These materials and their alloys are termed ferromagnetic materials except

(A) Iron (B) cobalt (C) nickel (D) None

Q71. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. A material with B > Bo is known as
(A) Paramagnetic material (B) Electromagnetic material
(C) Diamagnetic material (D) ferromagnetic material

Q72. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. A material with B>> Bo is known as

(A) Paramagnetic material (B) Electromagnetic material
(C) Diamagnetic material (D) ferromagnetic material

Q73. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. The ratio B/Bo is known as

(A) Magnetic susceptibility (B) Absolute permeability
(C) Relative permeability (D) Unity permeability

Q74. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. The ratio BM /Bo is known as

(A) Magnetic susceptibility (B) Absolute permeability
(C) Relative permeability (D) Unity permeability

Q75. From the Absolute permeability, μ, can be defined as

(A) μo /μr (B) μr /μo (C) μ/μr (D) μr μo

Q76.

From the curve, Points c and f represent

(A) Current (B) Permanent magnetism (C) hysteresis loss (D) maximum

Q77. From the curve, Point b represents
(A) Saturation (B) Coercivity (C) Remanence (D) Magnetic susceptibility

Q78. From the curve, ac is a measure of the
(A) Saturation (B) Coercivity (C) Remanence (D) Magnetic susceptibility

Q79. From the curve, ac is a measure of the
(A) Saturation (B) Coercivity (C) Remanence (D) Magnetic susceptibility

yQ80. The curve between points "a" and "b" in figure1 is called
(A) The magnetisation curve. (B) The remanent magnetisation curve (C) the external magnetization field (D) The coercive magnetisation curve

Q81. In hysteresis, if the external mmagnetic field is reduced the material retains a certain permanent magnetisation termed the remanent magnetisation.
(A) The induced magnetisation also is increased.
(B) The induced magnetisation also is reduced, but it does not follow the original curve. (C) The induced magnetisation also is reduced, and it will follow the original curve.
(D) The induced magnetisation will reach saturation.

Q82. Which of the following statement is incorrect about the current in hysteresis loop?
(A) current is increased from a to b (B) current is increased from e to f (C) current is reduced to zero from b to c (D) current is increased from f to b

Q83. Which of the following statement is incorrect about the current in hysteresis loop?
(A) current is increased from a to b (B) current is increased from c to e (C) current is reduced from c to e (D) current is increased from f to b

Q84. Which of the following does not correctly describe a conductive solid metal?
(A) It contains a large population of mobile, or free, electrons. (B) The electrons are bound to the metal lattice but not to any individual atom. (C) The electrons move about randomly due to thermal energy (D) Thermal energy, on the average, causes the current within the metal to flow when external field is not applied.

Q85. The correct unit of electric current is?

(A) Coulomb per second (B) Coulomb-second

(C) Volt per coulomb (D) Volt - coulomb

Q86. Which of the following does not correctly describe the Current density?

(A) Current density is a measure of the density of an electric current. (B) It is defined as a vector whose magnitude is the electric current per cross-sectional area.
(C) Current density is measured in amperes per meter. (D) Current density is measured in Coulomb per second per square meter.

Q87. Which of the following does not correctly describe semiconductor?

(A) A semiconductor allows an electric current to flow very strongly in one direction

(B) A semiconductor allows an electric current to flow very weakly in the opposite direction

(C) The direction in which a semiconductor allows the forward current to flow depends on whether it is a p- type semiconductor or an n-type semiconductor.

(D)The direction in which a semiconductor allows the forward current to flow does not depend on whether it is a p-type semiconductor or an n-type semiconductor.

Q88. Which of the following does not correctly describe semiconductor?

(A) The amounts of current which flow in each direction depend mainly on the amount of the voltage applied. (B) The forward resistance is relatively low. (C) The amounts of current which flow in each direction depend mainly on the forward and the reverse resistance. (D)The amounts of current which flow in each direction depend partly on the amount of the voltage applied but mainly on the forward and the reverse resistance.

Q89. Which of the following does not correctly describe semiconductor?

(A) The forward resistance is relatively low (B) The reverse resistance is always very high (C) like a conductor, the flow of current through a semiconductor is not the same amount of current whichever way the voltage is applied.
(D) The amounts of current which flow in each direction depend partly on the amount of the voltage applied but mainly on the forward and the reverse resistance.

Q90. Which of the following statement is not true?

(A) Conductors allow electrons to pass through them easily because of their low resistance.
(B) Insulators do not allow electrons to pass through them because of their high resistance

(C) Insulators do not allow electrons to pass through them because their atoms hold the electrons strongly.
(D) None

Q91. Which of the following does not correctly describe the conventional current?

(A) Electric charge moves from the positive side of the power source to the negative.

(B) A flow of positive charge gives the same electric current as an opposite flow of negative charge.

(C) The opposite flows of opposite charges contribute to a single electric current.

(D) None

Q92. Which of the following statement is not true?

(A) In solid metals such as wires, the positive charge carriers are immobile.

(B) In solid metals such as wires, the positive charge carriers are mobile.

(C) Because the electron carries negative charge, the electron motion in a metal is in the direction opposite to that of conventional (or electric) current.

(D) In solid metals such as wires, only the negatively charged electrons flow.

Q93 Which of the following does not have a mobile charge carrier?

(A) Metals (B) Insulators (C) Semiconductors (D) None

Q94. Which of the following does not have a charge carrier?

(A) Metals (B) Insulators (C) Semiconductors (D) None

Q95. Which of the following does not have a charge carrier?

(A) Gases (B) Insulators (C) Electrolytes (D) None

Q96. The units of conductance G of a device is?

(A) Mho (B) Siemens (C) Ohms (D) None

Q97. From the usual symbols, the unit of conductivity σ of a device is?

(A) Ω-1 m (B) Ω m-1 (C) Ω m (D) Ω-1m-1

Q98. From the usual symbols, the unit of conductivity σ of a device is?

(A) Ω-1 S (B) S m-1 (C) S m (D) S Ω

Q99. From the usual symbols, the units of conductance G of a device is?

(A) S (B) S m-1 (C) S m (D) S Ω

Q100. The electrons, with number density n, carry a charge of magnitude e, and moves with an average drift velocity vd , through a given length of a conductor, with cross section area, A, when a field E is applied across its ends. What is the current passing through the length?

(A) e σ nA vd (B) σE (C) e nA vd (D) e A vd

Q101. The electrons, with number density n, carry a charge of magnitude e, and moves with an average drift velocity vd , through a given length of a conductor, with cross section area, A, when a field E is applied across its ends. Which of the following expressions is not correct about the current density? Given that conductivity of the conductor is σ.

(A) e σ n vd (B) σ l / RA (C) e n vd (D) σE

Q102. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation best described the torque T experience when the plane is parallel to the field?

(A) T = NIAB (B) T = NABθ (C) T = NIBθ (D) T = NIAθ

Q103. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation best defined the current sensitivity S, when other parameters have their usual meanings?

(A) S = θ/I (B) S = θ/Q (C) S = Q/θ (D) S = BAN/cR

Q104. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation does not defined the voltage sensitivity Sv, when other parameters have their usual meanings?

(A) Sv = θ/IR (B) Sv = S/R (C) Sv = BAN/cR (D) Sv = R/θ

Q105. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation best defined the charge sensitivity Sq, when other parameters have their usual meanings?

(A) Sq = θ/IR (B) Sq = θ/I (C) Sq = BAN/cR (D) Sq = θ/Q

Q106. Dead-beat movement occurs when

(A) the galvanometer is free (B) the galvanometer is critically damped

(C) the galvanometer is steady (D) the galvanometer is electromagnetic

Q107. Which of the following statement is not true of the ballistic galvanometer?

(A) the kinetic energy is used to the rotate the coil
(B) the kinetic energy is converted to the potential energy stored in the system (C) the potential energy stored in the system provides the restoring torque (D) the kinetic energy of the system is used to heat the coil
Q108. Which of the following statement is not true of the dynamo?

(A) Dynamo can be shunt-wound (B) Dynamo can be series-wound (C) Dynamo can be compound-wound
(D) Dynamo can be slip-ring-wound

Q109. Which of the following statement is not true?

(A) Alternating current is one in which magnitude and direction vary periodically (B) Direct current is one in which magnitude and direction vary periodically
(C) Electromotive force is one in which magnitude and direction can vary periodically (D) Alternating current gives the value of magnetic fields that vary in magnitude and direction periodically

Q110. Which of the following statement is not true of Rectification?

(A) Rectification is the process by which one converts a.c to d.c (B) Rectification is the process by which one converts d.c to a.c (C) Rectifier impedes the flow of current in one direction more than in the reverse direction
(D)When a sinusoidal waveform is input to a rectifier, a half-wave output is produced.
Q111. An external magnetic field can be supplied by any of the following except
(A) An electromagnet (B) solenoid (C) Another permanent magnet (D) None
Q112. An electric heater is labeled 240V ac, 1000W. What is the peak current in the heater when connected to a 240V ac supply.
(A) 4.17A (B) 5.89A (C) 2.95A
(D) 8.34A
Q113. Calculate the electromotive force induced in a copper rod of length 6cm rotating at 2 rev/sec in a uniform magnetic field B of 0.02 Tesla.
(A) 4.52 x 10-4 volts (B) 3.50 x 10-4 volts (C) 2.0 x 10-4 volts (D) 6.0 x 10-4 volts
Q114. Calculate the peak value of the emf induced in a circular coil of 1000 turns of radius 4cm rotating at 1800 rpm about an axis in its own plane at right angles to a magnetic field of flux density 0.03T.
(A) 30.62 volts (B) 20.26 volts (C) 25.02 volts (D) 28.43 volts.
Q115. A domestic ac source has a peak value of 325v. What is the rms current in a 100w light bulb?
(A) 0.31A (B) 0.44A (C) 0.22A (D) 0.62A
Q116. A 2kΩvariable resistor is connected across a 10v supply. What is the potential difference between the sliding contact and the negative side of the supply when the slider is 2/3 way long?

(A) 3.3v (B) 6.7v (C) 1.6v (D) 8.4v
Q117. An ac source is connected across a resistor. What is the average power produced in the resistor over one cycle if the peak current in the resistor of resistance R is
Q118. A flat circular coil with 40 loops of wire has a diameter of 32 cm. What current must flow in its wire to produce a field of 3 X10-4Wb/m2 at its Centre?
(A) 1.29A (B) 1.09A (C) 1.19A (D) 1.9A
Q119. An air core solenoid with 2000 loops is 60cm long and has a diameter of 2 cm . If a current of 5A is sent through it, what will be the flux density within it?
(A) 0.21T (B) 0.12T (C) 1.02T (D) 0.021T
Q120. A long wire carries a current of 20A along the axis of a long solenoid. The field due to the solenoid is 4mT. Find the resultant field at a point 3mm from the solenoid axis.
(A) 2.33MT (B) 1.33MT (C) 3.33MT (D) 5.33MT
Q121. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the same direction.
(A) 48μN attractive force. (B) 4.8N attractive force.
(C) 48μN repulsive force (D) 4.8N repulsive force
Q122. A copper bar 30cm long is perpendicular to a field of flux density 0.8Wb/m2 and moves at right angles to the field with a speed of 0.5m/s.Determine the emf induced in the bar.
(A) 0.0012V (B) 0.012V (C) 0.12V (D) 1.2V
Q123. Three long, straight, parallel wires X,Y and Z carry currents +30A,-10A and +20A respectively, Where XY is 3cm apart and YZ is 5cm apart and +/ – indicates their directions. Find the force on a 25cm length of wire Y.
(A) 3.3mN (B) 2.3mN (C) 1.3mN (D) 0.3mN
Q124. A 50-loop circular coil has a radius of 3cm. it is oriented so that the field lines of a magnetic field are normal to the coil. If the magnetic field is varied so that B increases from 0.10T to 0.35T in a time of 2milliseconds.find the average induced emf in the coil. (A) 170.7V (B) 17.7V (C) 1.77V (D) 0.177V
Q125. A coil of 50 loops is pulled in 0.02s from between the poles of a magnet, where its area intercepts a flux of 3X10-4Wb, to a place where the intercepted flux is 0.1X10-4Wb. What is the average emf induced in the coil? (A) 0.75V (B) 7.5V (C) 75.0V (D) 750V
Q126. The net charge on an n-type semiconductor is
(A) Positive (B) negative (C) Zero (D) Minus
Q127. An example of trivalent element used for doping of semiconductor is
(A) Phosphoric (B) Silicon (C) Germanium (D) Boron
Q128. The Resistivity of a semiconductor with increasing temperature
(A) Increases (B) Remain constant (C) Decreases (D) DoublesQ129. A domestic ac source has a peak value of 325v. What is the rms current in a 100w light bulb?
(A) 0.31A (B) 0.44A (C) 0.22A (D) 0.62A
Q130. Which of these cannot be utilized with a variable resistor
(A) Volume control (B) Dimmers on light switches (C) Thermostat
(D) None of the above
Q131. A 2kπ variable resistor is connected across a 10v supply. What is the potential difference between the sliding contact and the negative side of the supply when the slider is 2/3 way long?
(A) 3.3v (B) 6.7v (C) 1.6v (D) 8.4v
Q132. Which of these is the impedance for an inductor – Resistor circuit in series?
Q133. An ac source is connected across a resistor. What is the average power produced in the resistor over one cycle if the peak current in the resistor of resistance R is
Q134. An electric heater is labeled 240V ac, 1000W. What is the peak current in the heater when connected to a 240V ac supply.
(A) 4.17A (B) 5.89A (C) 2.95A
(D) 8.34AQ135. The device used in converting mechanical power into electrical power is called
A) Dynamo (B) Lever (C) Armature
(D) MotorQ136. Calculate the electromotive force induced in a copper rod of length 6cm rotating at 2 rev/sec in a uniform magnetic field B of 0.02 Tesla. (A) 4.52 x 10-4 volts (B) 3.50 x 10-4 volts (C) 2.0 x 10-4 volts (D) 6.0 x 10-4 volts
Q137. Calculate the peak value of the emf induced in a circular coil of 1000 turns of radius 4cm rotating at 1800 rpm about an axis in its own plane at right angles to a magnetic field of flux density 0.03T (A) 30.62 volts (B) 20.26 volts (C) 25.02 volts (D) 28.43 volts.

Q138. Which of the following is suitable for measuring the quantity of charge?

(A) Ballistic Galvanometer (B) Powerful Galvanometer (C) Holistic Galvanometer (D) Meter Bridge

Q139. A particular component of the direct current generator that maintains the direction of the generated emf in the circuit is the

(A) Commutator (B) Slip ring (C) Armature
(D) Rectangular coil
Q140. What is the product of the slope of the graph below and the rate of distance covered across the magnetic flux (ø)

(A) Flux density (B) Potential Difference
(C) Induced Electromotive force (D) Energy

Q143. The direction of magnetic field can determined using

(A) The right hand grip rule (B) just the electron (C) Maxwellian rule (D) Faraday's direction

Q144. The speed of electromagnetic radiation in free space is
(A) (B) (C) (D)

Q145. The potential difference applied to the armature of a motor is 12 volts. If the current and resistance of the armature are 0.4 A and 5 ohms respectively. Calculate the back emf in the winding.
(A) 10 volts (B) 12 volts (C) 15 volts (D) 5 volts.

Q146. In an a.c generator the magnitude of the emf generated increases with
i) Increase in the strength of the magnet
ii) Decrease in the rate of change of the flux
iii) Increase in the number of turns of the coil
iv) Increase in area of the coil
Which of the state is correct.
(A) i, ii, and iii (B) i, iii and iv (C) ii, iii and iv (D) i and iii

Q147. The induced emf generated in an alternator is such in a direction as to oppose the motion producing it. This statement is
(A) Right hand grip rule (B) Faraday's law
(C) Fleming's law (D) Lenz's law

Q148. What is the value of B in air at a point 5 cm from a long straight wire carrying a current of 15A?
(A) 6X10-2T (B) 6X10-4T (C) 6X10-1T (D) 6X10-5T

Q149. A proton enters a magnetic field of flux density 1.5Wb/m2 with a velocity of 2X107 m/s at an angle of 30o with the field. What is the force on the proton?
(A) 2.4 X10-14 N (B) 2.4 X10-13 N (C) 2.4 X10-12 N (D) 2.4 X10-11 N

Q150. Which of the following represents electric potential V between A and B in free space

Q151. The negative sign in Faraday's law of electromagnetic induction indicates
(A) Induced emf (B) direction of induced current (C) Current (D) Faraday's direction

Q152. A flat circular coil with 40 loops of wire has a diameter of 32 cm. What current must flow in its wire to produce a field of 3 X10-4Wb/m2 at its Centre?
(A) 1.29A (B) 1.09A (C) 1.19A (D) 1.9A

Q153. An air core solenoid with 2000 loops is 60cm long and has a diameter of 2 cm . If a current of 5A is sent through it, what will be the flux density within it?
(A) 0.21T (B) 0.12T (C) 1.02T (D) 0.021T

Q154. A long wire carries a current of 20A along the axis of a long solenoid. The field due to the solenoid is 4mT. Find the resultant field at a point 3mm from the solenoid axis.
(A) 2.33MT (B) 1.33MT (C) 3.33MT (D) 5.33MT

Q155. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the same direction.

(A) 48μN attractive force. (B) 4.8N attractive force. (C) 48μN repulsive force (D) 4.8N repulsive forceQ156. A copper bar 30cm long is perpendicular to a field of flux
density 0.8Wb/m2 and moves at right angles to the field with a speed of 0.5m/s.Determine the emf induced in the bar.

(A) 0.0012V (B) 0.012V (C) 0.12V (D) 1.2V

Q157. Three long, straight, parallel wires X,Y and Z carry currents +30A,-10A and +20A respectively, Where XY is 3cm apart and YZ is 5cm
apart and +/ – indicates their directions. Find the force on a 25cm length of wire Y.

(A) 3.3mN (B) 2.3mN (C) 1.3mN (D) 0.3mN

Q158. A 50-loop circular coil has a radius of 3cm. it is oriented so that the field lines of a magnetic field are normal to the coil.
If the magnetic field is varied so that B increases from 0.10T to 0.35T in a time of 2milliseconds.find the average induced emf in the coil.

(A) 170.7V (B) 17.7V (C) 1.77V (D) 0.177V

Q159. A coil of 50 loops is pulled in 0.02s from between the poles of a magnet, where its area intercepts a flux of 3X10-4Wb, to a place where the intercepted flux is 0.1X10-4Wb. What is the average emf induced in the coil?

(A) 0.75V (B) 7.5V (C) 75.0V (D) 750V

Q160. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the opposite direction.

(A) 48μN attractive force. (B) 4.8N attractive force. (C) 48μN repulsive force (D) 4.8N repulsive force

Q161. What is the value of B in air at a point 5 cm from a long straight wire carrying a current of 15A?

(A) 6X10-2T (B) 6X10-4T (C) 6X10-1T (D) 6X10-5T

Q162. A flat circular coil with 40 loops of wire has a diameter of 32 cm. What current must flow in its wire to produce a field of 3 X10-4Wb/m2 at its Centre?

(A) 1.29A (B) 1.09A (C) 1.19A (D) 1.9A

Q163. An air core solenoid with 2000 loops is 60cm long and has a diameter of 2 cm . If a current of 5A is sent through it, what will be the flux density within it?

(A) 0.21T (B) 0.12T (C) 1.02T (D) 0.021T

Q164. Which of the following is correct?

(A) 1Wb=1NmA (B) 1Wb=1Vs (C) 1Wb=1Nm-1A-1 (D) 1Wb=1NAm-1

Q165. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the same direction.

(A) 48μN attractive force. (B) 4.8N attractive force.
(C) 48μN repulsive force (D) None

Q166. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the opposite direction.

(A) 48μN attractive force. (B) 4.8N attractive force.
(C) 48μN repulsive force (D) None

Q167. We can define the unit of magnetic flux density as

(A) tesla (B) weber (C) NA-1 (D) Nm-2

Q168. A 50-loop circular coil has a radius of 3cm. it is oriented so that the field lines of a magnetic field are normal to the coil.
If the magnetic field is varied so that B increases from 0.10T to 0.35T in a time of 2milliseconds.find the average induced emf in the coil.

(A) 170.7V (B) 17.7V (C) 1.77V (D) 0.177V

Q169. A coil of 50 loops is pulled in 0.02s from between the poles of a magnet, where its area intercepts a flux of 3X10-4Wb, to a place where the intercepted flux is 0.1X10-4Wb. What is the average emf induced in the coil?

(A) 0.75V (B) 7.5V (C) 75.0V (D) 750V

Q170. A copper bar 30cm long is perpendicular to a field of flux density 0.8Wb/m2 and moves at right angles to the field with a speed of 0.5m/s.Determine the emf induced in the bar.

(A) 0.0012V (B) 0.012V (C) 0.12V (D) 1.2V

Q171. The drift velocity Vd can be expressed as

(A) Vd=I/ne (B) Vd= J/ne (C) Vd = I/nA (D) Vd= J/nA

where I is the current, J is current density, n is number density, e is electronic charge, and A is cross sectional area.

Q172. The negative sign in Faraday's law of electromagnetic induction indicates

(A) Induced emf (B) direction of induced current (C) Current (D) Faraday's direction

Q173. The hall coefficient for a material having number density n of majority charge-carriers, each carrying a charge e, is given as

(A) RH=1/ne (B) RH= J/ne (C) RH=ne (D) None

Q174. The direction of magnetic field can be determined using

(A) The right hand grip rule (B) just the electron (C) Maxwellian rule (D) Faraday's direction

Q175. Which of the following is suitable for measuring the quantity of charge?

(A) Ballistic Galvanometer (B) Powerful Galvanometer (C) Holistic Galvanometer (D) Meter Bridge

Q176. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30v, 1780 Hz power supply. Find the current in the circuit.

(A) 178A (B) 224A (C) 5A (D) 6A

Q177. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30V, 1780 Hz power supply. Find the phase angle between source voltage and current.

(A) 0o (B) 30o (C) 90o (D) 270o

Q178. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30v, 1780 Hz power supply. Find the power loss in the circuit. (A) 0W (B) 60W (C) 120W (D) 180W

Q179. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30v, 1780 Hz power supply. Find the voltmeter reading across elements of the circuit.

(A) 30V, 13.44V,13.44V (B) 30kV, 13.44kV,13.44V
(C) 30V, 13.44kV,13.44kV (D) 30kV, 13.44kV,13.44kV

Q180. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the current in the circuit.

(A) 100A (B) 20A (C) 10A (D) 2A

Q181. . A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the impedance of the circuit.

(A) 100W (B) 20W (C) 10W (D) 2W

Q182. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the potential difference across the non inductive resistor of 44 W.

(A) 100V (B) 60V (C) 88V (D) 97V

Q183. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the potential difference across the capacitor

(A) 100V (B) 60V (C) 88V (D) 97V

Q184. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the potential difference across the coil

(A) 194V (B) 60V (C) 180V (D) 97V

Q185. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the current across the non inductive resistor.

(A) 100A (B) 20A (C) 10A (D) 2A

Q186. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the impedance of the coil

(A) 194W (B) 60W (C) 180W (D) 97W

Q187. An ac generator produces an output voltage ξ = 170 sin 377tV, where t is in seconds. What is the frequency of the ac voltage?

(A) 60MHz (B) 60kHz
(C) 60Hz (D) 60mHz

Q188. How fast must a 1000 loop coil, each with 20cm2 area) turn in the earth's magnetic field of 0.07 G to generate a voltage that has a maximum value, an amplitude, of 0.50 V? Given 1G=1x10-4 T (A) 576Hz (B) 765Hz
(C) 569Hz (D) 596Hz

Q189. When turning at 1500 rev/min, a certain generator produces 100 V. what must be its angular speed if it to produce 120 V?

(A) 1000 rev/min (B) 1200 rev/min (C) 1500 rev/min
(D) 1800 rev/min

Q190. A certain generator has armature resistance 0.08W and develops an induced emf of 120 V when driven at its rated speed. What is it terminal voltage when 50 A is being drawn from it?

(A) 4V (B) 16V (C) 116V (D) 40V

Q191. Some generators, called shunt generator, use electromagnet in place of permanent magnets, with the field coils for the electromagnets activated by the induced voltage. The magnet coil is in parallel with the armature coil, it shunt the armature. A certain shunt generator has armature resistance 0.06 W and shunt resistance 100 W. What power is developed in the armature when it delivers 40kW at 250 V to an external circuit?

(A) 16kW (B) 25 kW (C) 16.5 kW (D) 42.2kW

Q192. Some generators, called shunt generator, use electromagnet in place of permanent magnets, with the field coils for the electromagnets activated by the induced voltage. The magnet coil is in parallel with the armature coil, it shunt the armature. A certain shunt generator has armature resistance 0.06 W and shunt resistance 100 W. What current is supplied to the external circuit when it delivers 40kW at 250 V to an external circuit?

(A) 160A (B) 250 A
(C) 165 A (D) 422A

Q193. Some generators, called shunt generator, use electromagnet in place of permanent magnets, with the field coils for the electromagnets activated by the induced voltage. The magnet coil is in parallel with the armature coil, it shunt the armature. A certain shunt generator has armature resistance 0.06 W and shunt resistance 100 W. What is the field current, when it delivers 40kW at 250V to an external circuit?

(A) 1.60A (B) 2.50 A
(C) 1.65 A (D) 4.22A

Q194. Some generators, called shunt generator, use electromagnet in place of permanent magnets, with the field coils for the electromagnets activated by the induced voltage. The magnet coil is in parallel with the armature coil, it shunt the armature. A certain shunt generator has armature resistance 0.06 W and shunt resistance 100 W. What is the total induced emf, when it delivers 40kW at 250V to an external circuit?

(A) 260V (B) 250 V (C) 265 V (D) 422V

Q195. A certain 0.25 hp motor has a resistance of 0.50W. Assume the motor to be 100% efficient, with input = output and 1hp = 746W. How much current does it draw on 110Vs when its output is 0.25hp?

(A) 1.695 A (B) 2.695 A (C) 3.695 A (D) 1.165 A

Q196. A certain 0.25 hp motor has a resistance of 0.50W. Assume the motor to be 100% efficient, with input = output and 1hp = 746W. What is its back emf on 110V when its output is 0.25hp?

(A) 109 V (B) 209 V (C) 309 V (D) 0.8 V

Q197. Determine the separate effects on the induced emf of a generator if the flux per is doubled.

(A) Same (B) Doubled (C) Three times (D) Four Time

Q198. Determine the separate effects on the induced emf of a generator if the speed of the armature is doubled.

(A) Same (B) Doubled (C) Three times (D) Four Time

Q199. The emf induced in the armature of a shunt generator is 596 V. The armature resistance is 0.1W. Compute the terminal voltage when the armature current is 460 A. The field resistance is 110 W.

(A) 550 V (B) 5 V (C) 455V (D) 250V

Q200. The emf induced in the armature of a shunt generator is 596 V. The armature resistance is 0.1W and the armature current is 460 A. If the field resistance is 110 W, determine the field current.

(A) 550 A (B) 5 A (C) 455A (D) 250 A

Q201. The emf induced in the armature of a shunt generator is 596 V. The armature resistance is 0.1W and the armature current is 460 A. If the field resistance is 110 W, determine the current delivered to the external circuit.

(A) 550 A (B) 5 A (C) 455 A (D) 250 A

Q202. The emf induced in the armature of a shunt generator is 596 V. The armature resistance is 0.1W and the armature current is 460 A. If the field resistance is 110 W, determine the power delivered to the external circuit.

(A) 550 KW (B) 5 KW (C) 455KW (D) 250 KW

Q203. A generator has an armature with 500 loops, which cut a flux of 8mWb during each rotation. Compute the back emf it develops when run as a motor at 1500 rpm

(A) 100V (B) 100V (C) 100V (D) 100V

Q204. A shunt has a field resistance of 200Ω and an armature resistance of 0.5 Ω and is connected to 120V mains. The motor draws a current of 4.6 A when running at full speed. What current will be drawn by the motor if the speed is reduced to 90 percent of full speed by application of a load?

(A) 20.2A (B) 22.2A (C) 25.2A (D) 28.2A

Q205. A shunt motor develops 80N.m torque when the flux density in the air gap is 1Wb/m2 and the armature current is 15A. What is the torque when the flux density is 1.3 Wb/m2 and the armature current is 18A?

(A) 145 N.m (B) 125 N.m (C) 165 N.m (D) 155 N.m

Q206. A shunt motor has armature resistance 0.20Ω and field resistance 150 Ω and draws 30 A when connected to a 120V supply line. Determine the field current.

(A) 0.80A. (B) 114.2A (C) 3.33A (D) 29.2 A

Q207. A shunt motor has armature resistance 0.20Ω and field resistance 150 Ω and draws 30 A when connected to a 120V supply line. Determine the armature current.

(A) 0.80A. (B) 114.2A (C) 3.33A (D) 29.2 A

Q208. A shunt motor has armature resistance 0.20Ω and field resistance 150 Ω and draws 30 A when connected to a 120V supply line. Determine the back emf developed within the armature.

(A) 0.80V. (B) 114.2V (C) 3.33V (D) 29.2 V

Q209. A shunt motor has armature resistance 0.20Ω and field resistance 150 Ω and draws 30 A when connected to a 120V supply line. Determine the mechanical power developed within the armature.

(A) 0.80KW. (B) 114.2KW (C) 3.33KW (D) 29.2 KW

Q210. A shunt motor has armature resistance 0.20Ω and field resistance 150 Ω and draws 30 A when connected to a 120V supply line. Determine the electrical efficiency of the machine.

(A) 92.5%. (B) 94.2% (C) 96.2% (D) 99.2 %

Q211. A shunt motor has a speed of 900 rpm when it is connected to 120V mains and delivering 12hp. The total losses are 1048W. Compute the power input.

(A) 10kW (B) 83.3 kW (C) 93 kW (D) 900W

Q212. A shunt motor has a speed of 900 rpm when it is connected to 120V mains and delivering 12hp. The total losses are 1048W. Compute the line current.

(A) 10A (B) 83.3A (C) 93 A (D) 12A

Q214. A shunt motor has a speed of 900 rpm when it is connected to 120V mains and delivering 12hp. The total losses are 1048W. Compute the motor torque.

(A) 10 N.m (B) 83.3 N.m (C) 93 N.m (D) 900 N.m

Q215. A shunt is connected to a 110V line. When the armature generates a back emf of 104V, the armature current is 15A. Compute the armature resistance.

(A) 0.1Ω (B) 0.8 Ω (C) 0.9 Ω (D) 0.4 Ω

Q216 A sh.unt dynamo has an armature resistance of 0.12 Ω. If it is connected across 220V main and is running as a motor, what is the induced, back emf when the armature current is 50 A?

(A) 214 V (B) 226V (C) 220V (D) 260V

Q217. A sh.unt dynamo has an armature resistance of 0.12 Ω If it is connected across 220V main and this machine is running as a generator, what is the induced emf when the armature is delivering 50 A at 220V to the shunt field and external circuit? (A) 214 V (B) 226V (C) 220V (D) 260V

Q218. A shunt motor with armature resistance 0.08Ω is connected to 120V mains. With 50A in the armature what is the back emf? (A) 116V (B) 5.8V (C) 130V (D) 58V

Q219. A shunt motor with armature resistance 0.08Ω is connected to 120V mains. With 50A in the armature what are the back emf and the mechanical power developed within the armature?

(A) 116kW (B) 5.8kW (C) 130kW (D) 58kW

Q220. The active length of each armature conductor of a motor is 30cm and the conductors are in a field of 0.40 Wb/m2. A current of 15A flows in each conductor. Determine the force acting on each conductor

(A) 1.8N (B) 0.8N (C) 2.8N (D) 3.8N

Q221. A 120V generator is run by a windmill that has blades 2m long. The wind moving at 12m/s is slowed to 7m/s after passing the windmill. The density of air is 1.29kg/m3. If the system has no losses, what is the largest current generator can produce? Take into account of how much energy the wind loses per second.

(A) 770A (B) 77A (C) 7.7A (D) 0.77A

Q222. A 75 kW, 230 V shunt generator has a generated emf o 243.5 V.
If the field current is 12.5A as rated output what is the armature resistance?

(A) 0.04 Ω (B) 0.4 Ω (C) 4 Ω (D) 40 Ω

Q223. A steady current of 2A in a coil of 400 turns cause a flux of 10-4 Wb to link the loops of the coil. Compute the inductance of the coil if the current is stopped in 0.08s.

(A) 0.5H (B) 0.02H
(C) 0.04H (D) 0.4H

Q224. A steady current of 2A in a coil of 400 turns cause a flux of 10-4 Wb to link the loops of the coil. Compute the energy stored in the coil if the current is stooped in 0.08s..

(A) 0.5J (B) 0.02J (C) 0.04J
(D) 0.4J

Q225. A steady current of 2A in a coil of 400 turns cause a flux of 10-4 Wb to link the loops of the coil. Compute the average back emf induced in the coil if the current is stooped in 0.08s.

(A) 0.5V (B) 0.02V (C) 0.04V (D) 0.4V

Q226. In a shunt motor, the permanent magnet is replaced by an electromagnet activated by a field coil that shunt the armature. The shunt motor shown has armature resistance 0.05 W and is connected to 120 V mains. What is the armature current at the starting instant, i.e., before the armature develops any back emf?

(A) 2400A (B) 240A (C) 24A
(D) 2.4A

Q227. In a shunt motor, the permanent magnet is replaced by an electromagnet activated by a field coil that shunt the armature. The shunt motor shown has armature resistance 0.05 W and is connected to 120 V mains. What starting rheostat resistance R, in series with the armature, will limit the starting current to 60 A?

(A) 1.95W (B) 19.5W
(C) 2.95W (D) 29.5W

Q228. In a shunt motor, the permanent magnet is replaced by an electromagnet activated by a field coil that shunt the armature. The shunt motor shown has armature resistance 0.05 W and is connected to 120 V mains. With no starting resistance, what back emf is generated when the armature current is 20 A?

(A) 119V (B) 121V
(C) 120V (D) 125V

Q229. In a shunt motor, the permanent magnet is replaced by an electromagnet activated by a field coil that shunt the armature. The shunt motor shown has armature resistance 0.05 W and is connected to 120 V mains. If this machine were running as a generator, what would be the total induced emf developed by the armature when the armature is delivering 20 A at 120 V to the shunt field and external circuit?

(A) 119V (B) 121V
(C) 120V (D) 125V

Q230. A dynamo, generator, delivers 30 A at 120 V to an external circuit when operating at 1200 rpm. What torque is required to drive the generator at this speed if the total power losses are 400 W?

(A) 3..18N .m (B) 3.38N .m (C) 31.8N .m (D) 33.8N .m

Q231. A motor armature develops a torque of 100 N.m When it draws 40A
from the line. Determine the torque developed if the armature current is increased to 70 A and the magnetic field strength is reduced to 80 percents of its initial value.

(A) 110N (B) 120N (C) 130N (D) 140N

Q232. A motor has back emf 110V and armature current 90 A when running 1500rpm. Determine the power.

(A) 9.9W (B) 99W (C) 990W (D) 9900W

Q233. A motor has back emf 110V and armature current 90 A when running 1500rpm. Determine the torque develop within the armature.

(A) 6.3N.m (B) 1.6N.m
(C) 16.3N.m (D) 63.0N.m

Q234. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the armature current of the motor.

(A) 20A (B) 8A (C) 2.8A (D) 80.8A

Q235. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the field current of the motor.

(A) 20A (B) 0.8A (C) 2A (D) 80A

Q236. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the total currents taken by the motor.

(A) 20.8A (B) 80.2A (C) 12.8A (D) 8.08A

Q237. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the total power taken by the motor, when only heat losses in the armature and field are considered.

(A) 2496W (B) 2400W
(C) 2800W (D) 1500W

Q238. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the power lost in heat in the armature.

(A) 100W (B) 96W (C) 10W (D) 9.6W

Q239. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the power lost in heat in field circuits

(A) 100W (B) 96W (C) 10W (D) 9.6W

Q240. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the total power lost. When only heat losses in the armature and field are considered.

(A) 101W (B) 196W (C) 110W (D) 19.6W

Q241. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the total power taken by the motor, when only heat losses in the armature and field are considered.

(A) 2496W (B) 2400W
(C) 2800W (D) 2300W

Q242. The shunt motor has armature resistance 0.25Ω and field resistance 150W. It is connected across 120 V mains and its generating a back emf of 115 V. compute the electrical efficiency of this machine, when only heat losses in the armature and field are considered.

(A) 92.1% (B) 82.1%
(C) 72.1% (D) 62.1%

Q243. When a long iron-core solenoid connected across a 6V battery, the current rises to 0.63 of its maximum value after a time of 0.75 s. The experiment is then repeated with the iron core removed. Now the time required to reach 0.63 of the maximum is

0.0025s. Calculate the relative permeability of the iron if the maximum current is 0.5A

(A) 300 (B) 0.03 (C) 630 (D) 0.63

Q244. When a long iron-core solenoid connected across a 6V battery, the current rises to 0.63 of its maximum value after a time of 0.75 s. The experiment is then repeated with the iron core removed. Now the time required to reach 0.63 of the maximum is 0.0025s. Calculate the inductance L for the air core solenoid if the maximum current is 0.5A

(A) 300 H (B) 0.03H (C) 630 H (D) 0.63 H

Q245. A charged capacitor is connected across a 10kW resistor and allowed to discharge. The potential difference across the capacitor drops to 0.37 of its original value after a time of 7s. What is the capacitance of the capacitor?

(A) 200mF (B) 500mF (C) 700mF (D) 900mF

Q246. A series circuit consisting of an uncharged 2mF capacitor and a 10 MW resistor is connected across a 100 V power source. What is the current in the circuit after one time constant.

(A) 3.7mA (B) 126mA (C)1mA (D) 180mA

Q247. A series circuit consisting of an uncharged 2mF capacitor and a 10 MW resistor is connected across a 100 V power source. What is the charge on the capacitor after one time constant.

(A) 3.7mC (B) 126mC (C)1mC (D) 180mC

Q248. A series circuit consisting of an uncharged 2mF capacitor and a 10 MW resistor is connected across a 100 V power source. What is the current in the circuit when the capacitor has acquired 90 percent of its final charges?

(A) 3.7mA (B) 126mA (C) 1mA (D) 180mA

Q249. A series circuit consisting of an uncharged 2mF capacitor and a 10 MW resistor is connected across a 100 V power source. What is the charge on the capacitor when the capacitor has acquired 90 percent of its final charges?

(A) 3.7mC (B) 126mC (C)1mC (D) 180mC

Q250. The iron core of a solenoid has a length of 40 cm and a cross section of 5.0cm2, and is wound with 10 turns of wire per cm of length. Compute the inductance of the solenoid, assuming the relative permeability of the iron to be constant at 500.

(A) 1.26 mH (B) 12.6 mH (C) 126 mH (D) 1260 mH

Q251. A step-up transformer is used on a 120V line to furnish 1800V. The primary has 100 turns. How many turns are on the secondary?

(A) 1200turns (B) 1400turns (C) 1500turns (D) 1800turns

Q252. A coil of 0.48 H carries a current of 5 A. Compute the energy stored in it. Ans.

(A) 60J (B) 6J (C) 0.6J (D) 66.6J

Q253. Two neighboring coils, A and B, have 300 and 600 turns respectively. A current of 1.5 A in A causes 1.2x10-4 Wb to pass through A and 0.9x10-4 Wb to pass through B. Determine the self-inductance of A.

(A) 2.4 mH (B) 24 mH (C) 36 mH (D) 0.27V

Q254. Two neighboring coils, A and B, have 300 and 600 turns respectively. A current of 1.5 A in A causes 1.2x10-4 Wb to pass through A and 0.9x10-4 Wb to pass through B. Determine the mutual inductance of A and B.

(A) 2.4 (B) 24 mH (C) 36 mH (D) 0.27V

Q255. Two neighboring coils, A and B, have 300 and 600 turns respectively. A current of 1.5 A in A causes 1.2x10-4 Wb to pass through A and 0.9x10-4 Wb to pass through B. Determine the average induced emf in B when the current in A is interrupted in 0.2 s.

(A) 2.4 (B) 24 mH (C) 36 mH (D) 0.27V

Q256. A coil of inductance 0.2 H and 1.0W resistance is connected to a 90 V source. At what rate will the current in the coil grow at the instant the coil is connected to the source?

(A) 45.0 A/s (B) 15.0 A/s (C) 450 A/s (D) 150 A/s

Q257. A coil of inductance 0.2 H and 1.0W resistance is connected to a 90 V source. At what rate will the current in the coil grow at the instant the current reaches two- third of its maximum value?

(A) 45.0 A/s (B) 15.0 A/s (C) 450 A/s (D) 150 A/s

Q258. The mutual inductance between the primary and secondary of a transformer is 0.3H. Compute the induced emf in the secondary when the primary current changes at the rate of 4 A/s.

(A) 1.12 V (B) 1.02 V (C) 1.20 V (D) 10.2 V

Q259. A steady current of 2.5A creates a flux of 1.4x10-4 Wb in a coil of 500 turns. What is the inductance of the coil?

(A) 12.8 mH (B) 2.18 mH (C) 28 mH (D) 21.8 mH

Q260. A 2mF capacitor sis charged through a 30 MW resistor by a 45 V battery. Find the time constant

(A) 30s (B) 60s (C) 90s (D) 120s

Q261. A 2mF capacitor sis charged through a 30 MW resistor by a 45 V battery. Find the charge on the capacitor both 83 s after the charging process starts.

(A) 37mC (B) 67mC (C) 97mC (D) 127mC

Q262. . A 2mF capacitor sis charged through a 30 MW resistor by a 45 V battery. Find the current through the resistor, both 83 s after the charging process starts.

(A) 376nA (B) 676nA (C) 976nA (D) 1276nA

Q263 When the current in a certain coil is changing at a rate of 3 A/s, it is found that an emf of 7mV is induced in a nearby coil. What is the mutual inductance of the combination?

(A) 12.33mH (B) 2.33mH (C) 22.33mH (D) 42.33mH

Q264. A capacitor is in series with a resistance of 30 W and is connected to a 220 V ac line. The reactance of the capacitor is 40 W. Determine the impedance of the circuit.

(A) 60 W. (B) 50 W. (C) 40 W. (D) 30 W.

Q265. A capacitor is in series with a resistance of 30 W and is connected to a 220 V ac line. The reactance of the capacitor is 40 W. Determine the current in the circuit

(A) 5.5A (B) 4.4A (C) 3.5A (D) 2.5A

Q266. A capacitor is in series with a resistance of 30 W and is connected to a 220 V ac line. The reactance of the capacitor is 40 W. Determine the phase angle between the current and the supply voltage.

(A) -83o (B) -53o (C) -33o (D) -63o

Q267. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the inductance of the coil.

(A) 22.0W (B) 25.1W (C) 27.2W (D) 29.3W

Q268. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the current in the coil.

(A) 5.5A (B) 4.4A (C) 3.5A (D) 2.5A

Q269. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the impedance of the circuit.

(A) 22.0W (B) 25.1W (C) 27.2W (D) 29.3W

Q270. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the phase angle between the current and the supply voltage.

(A) 18.3o (B) 61.3o (C) 33o (D) 63o

Q271. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the power loss in the coil.

(A) 48W (B) 23W (C) 248W (D) 230W

Q272. A 120V ac voltage source is connected across a pure 0.70 H inductor. Find the current through the inductor if the frequency of the source is 60Hz.

(A) 2.5A (B) 0.25A (C) 4.55A (D) 0.455A

Q273. A 120V ac voltage source is connected across a pure 0.70 H inductor. Find the current through the inductor if the frequency of the source is 60kHz.

(A) 2.5mA (B) 0.25mA (C) 4.55mA (D) 0.455mA

Q274. A 120V ac voltage source is connected across a pure 0.70 H inductor. Find the inductance of the inductor if the frequency of the source is 60Hz.

(A) 2.64x105Ω (B) 2.64x104Ω (C) 2.64x103Ω (D) 2.64x102Ω

Q275. A 120V ac voltage source is connected across a pure 0.70 H inductor. Find the inductance of the inductor if the frequency of the source is 60kHz.

(A) 2.64x105Ω (B) 2.64x104Ω (C) 2.64x103Ω (D) 2.64x102Ω

Q276. A 120V ac voltage source is connected across a pure 0.70 H inductor. What is the power loss in the inductor?

(A) 0W (B) 10W (C) 0.5W (D) 5W

Q277. A coil has inductances of 1.5H and a resistance of 0.6W. If the coil is suddenly connected across a 12 V battery, find the time required for the current to rise to 0.63 of its final value.

(A) 2.5s (B) 25s (C) 3.5s (D) 35s

Q278. A coil has inductances of 1.5H and a resistance of 0.6W. If the coil is suddenly connected across a 12 V battery. What will be final current through the coil?

(A) 0.2A (B) 2A (C) 20A (D) 200A

Q279. A voltage v=(60V) sin 120pt is applied across a 20 W resistor. What will an ac ammeter in series with the resistor read?

(A) 21.2A (B) 22A (C) 2.12A (D) 60A

Q280. A voltage v=(60V) sin 120pt is applied across a 20 W resistor. What will voltage across the resistor be?

(A) 14.4V (B) 42.4V (C) 32.4V (D) 22.4V

Q281. A 40 W resistor is connected across a 15V variable-frequency electronic oscillator. Find the current through the resistor when the frequency is 100Hz.

(A) 375A (B) 37.5A (C) 3.75A (D) 0.375A

Q282. A 40 W resistor is connected across a 15V variable-frequency electronic oscillator. Find the current through the resistor when the frequency is 100 kHz.

(A) 375A (B) 37.5A (C) 3.75A (D) 0.375A

Q283. A 2mH inductor is connected across a 15V variable-frequency electronic oscillator. Find the current through the inductor when the frequency is 100Hz.

(A) 11.9A (B) 11.9mA (C) 1.19A (D) 1.19mA

Q284. A 2mH inductor is connected across a 15V variable-frequency electronic oscillator. Find the current through the inductor when the frequency is 100 kHz.

(A) 11.9A (B) 11.9mA (C) 1.19A (D) 1.19mA

Q285. A 0.3 mF capacitor is connected across a 15V variable-frequency electronic oscillator. Find the current through the capacitor when the frequency is 100Hz.

(A) 2.83A (B) 2.83mA (C) 28.3A (D) 28.3mA

Q286. A 0.3 mF capacitor is connected across a 15V variable-frequency electronic oscillator. Find the current through the capacitor when the frequency is 100 kHz.

(A) 2.83A (B) 2.83mA (C) 28.3A (D) 28.3mA

Q287. A voltmeter reads 80 V when it is connected across the terminals of a sinusoidal power source with f=1000Hz. Write the equation for the instantaneous voltage provided by the source.

(A) V= (133 V) sin 1000pt for t in seconds

(B) V= (133 V) sin 2000pt for t in seconds

(C) V= (80 V) sin 1000pt for t in seconds

(D) V= (80 V) sin 2000pt for t in seconds

Q288. An ac current in a 10 W resistance produces heat at the rate 360W. Determine the effective values of the current.

(A) 6A (B) 60V (C) 6mA (D) 60mV

Q289. An ac current in a 10 W resistance produces heat at the rate 360W. Determine the effective values of the voltage.

(A) 6A (B) 60V (C) 6mA (D)

60mV

Q290. A coil has resistance 20 W and inductance 0.35H. Compute its reactance and its impedance to an alternating current of 25 cycles/s.

(A) 55 W (B) 58.5 W (C) 5.5 W (D) 5.85 W

Q291. A coil has resistance 20 W and inductance 0.35H. Compute its reactance and its impedance to an alternating current of 25 cycles/s.

(A) 55 W (B) 58.5 W (C) 5.5 W (D) 5.85 W

Q292. Calculate the resonant frequency of a circuit of negligible resistance containing an inductance of 40mH and a capacitance of 600pf.

(A) 32.5 kHz. (B) 325kHz. (C) 32.5Hz. (D) 325Hz.

Q293. A transformer used on a 120V line delivers 2A at 900V. what current is drawn from the line? Assume 100 percent efficiency.

(A) 4A (B) 40A (C) 1.5A (D) 15A

Q294. A step-down transformer operates on a 2.5 KV line and supplies a load with 80 A. the ratio of the primary winding to the secondary winding is 20:1 Assuming 100 efficiency, determine the secondary voltage V2, the primary current 1I, and the power output P2.

(A) 125V, 40A (B) 12.5V, 4A (C) 125V, 4A (D) 1.25V, 4A

Q295. A step-down transformer operates on a 2.5 KV line and supplies a
load with 80 A. the ratio of the primary winding to the secondary winding is 20:1 Assuming 100 efficiency, determine the secondary voltage V2, the primary current 1I, and the power output P2.

(A) 1kW (B) 10kW (C) 1W (D) 10W

Q296. A series circuit consisting of a 100W noninductive resistor, a coil of 0.10 H inductance and negligible resistance, and a 20 mF capacitor is connected across a 110 V, 60 Hz power source Find the impedance of the circuit.

(A) 37.7Ω (B) 138Ω (C) 132.7Ω (D) 137.7Ω

Q297. A series circuit consisting of a 100W noninductive resistor, a coil of 0.10 H inductance and negligible resistance, and a 20 mF capacitor is connected across a 110 V, 60 Hz power source; find the current.

(A) 7A (B) 9A (C) 0.79A (D) 0.97A

Q298. A series circuit consisting of a 100W noninductive resistor, a coil of 0.10 H inductance and negligible resistance, and a 20 mF capacitor is connected across a 110 V, 60 Hz power source Find the phase angle between the current and the source voltage

(A) 55o (B) -55o (C) -43.5o (D) -73.5o

Q299. A series circuit consisting of a 100W noninductive resistor, a coil of 0.10 H inductance and negligible resistance, and a 20 mF capacitor is connected across a 110 V, 60 Hz power source Find the voltmeter readings across the noninductive resistor.

(A) 79V (B) 105V (C) 30V (D) 138V

Q300. A series circuit consisting of a 100W noninductive resistor, a coil of 0.10 H inductance and negligible resistance, and a 20 mF capacitor is connected across a 110 V, 60 Hz power source Find the voltmeter readings across the inductor.

(A) 79V (B) 105V (C) 30V (D) 138V

Q301A series circuit consisting of a 100W noninductive resistor, a coil of 0.10 H inductance and negligible resistance, and a 20 mF capacitor is connected across a 110 V, 60 Hz power source Find the voltmeter readings across the capacitor.

(A) 79V (B) 105V (C) 30V (D) 138V

SOLUTIONS

1.	C	71.	A	141.	A	211. A	
2.	A	72.	D	142.	B	212. B	
3.	C	73.	C	143.	A	214.C	
4.	A	74.	A	144.	A	215. D	
5.	A	75.	D	145.	A	216 A	
6.	C	76.	B	146.	B	217.B	
7.	B	77.	A	147.	D	218. A	
8.	B	78.	C	148.	D	219.B	
9.	D	79.	B	149.	C	221.B	
10.	C	80.	A	150.	C	222. A	

11.	C	81.	B	151. B	223. B	
12.	B	82.	B	152. D	224. C	
13.	B	83.	C	153. D	225.A	
14.	B	84.	D	154. B	226. A	
15.	B	85.	A	155. A	227. A	
16.	A	86.	C	156. B	228. A	
17.	B	87.	D	157. D	229.B	
18.	B	88.	A	158. B	230. C	
19.	A	89.	C	159. A	231.D	
20.	D	90.	D	160. C	232.D	
21.	B	91.	D	161. D	233.D	
22.	A	92.	B	162. D	234.A	
23.	A	93.	B	163. D	235. B	
24.	C	94.	D	164. B	236. A	
25.	B	95.	D	165. A	237. A	
26.	C	96.	B	166. C	238. A	
27.	A	97.	D	167. A	239 .B	
28.	D	98.	B	168. B	240. B	
29.	C	99.	A	169. A	241. D	
30.	D	100.	C	170. C	242.A	
31.	B	101.	A	171. B	243. A	
32.	D	102.	A	172. B	244. B	
33.	B	03.	A	173. A	245.C	
34.	D	04.	D	174. A	246. A	
35.	B	05.	D	175. A	247. B	
36.	B	06.	B	176. D	248. C	
37.	D	07.	D	177. A	249. D	
38.	B	08.	D	178. D	250. C	
39.	B	09.	B	179. C	251. C	
40.	C	10.	B	180.D	252. B	
41.	A	11.	D	181.A	253.B	
42.	C	12.	B	182.C	254. C	
43.	A	13.	A	183.B	255.D	
		14.	D	184.A	256. C	
44.	C	15.	B	185.D	257. D	
45.	B	16.	B	186.D	258.C	
46.	B	17.	B	187. C	259. C	
47.	C	18.	D	188. C	260.B	
48.	D	19.	D	189. D	261. B	
49.	D	20.	B	191.D	262.A	
50.	B	21.	A	192. A	263 B	
51.	B	22.	B	193. B	264.B	
52.	D	23.	D	194.A	265.B	
53.	C	27.	D	195. A	266. B	
54.	C	24.	B	196. A	267.A	
55.	B	25.	A	197. B	268.B	
56.	D	26.	B	198. B	269. B	
57.	A	27.	D	199.A	270.B	
58.	B	28.	C	200. B	271 D	
59.	D	29.	B	201.C	272. D	
60.	D	30.	D	202. D	273.D	
61.	D	131.	B	203. B	274. D	
62.	A	132.	C	204.D	275. A	
63.	A	133.	B	05.B	276. A	
64.	A	134.	B	206.A	277. A	
65.	D	135.	A	207. D	278.C	
66.	C	136.	A	208. B	279.C	
67.	B	137.	D	209.C	280. B	
68.	C	138.	A	210.A		

69. D 70. D	139. A 140. C		

281.D
282. D
283.A
284.B
285B
286 A
287.B
288.A
289.B
290.A
291. A
292.A
293.D
294.C
295.B
296.B
297.C
298.C
299.A
300.C
301B

1. Which of these is not correct as a basic property of electric charges?

(a) Total charges in an insulated system is invariable
(b) A charged body is electrically unstable
(c) A charged body has equal number of positive and negative charges
(d) Positively charged body is deficient of electrons

2. When two identically charged bodies suspended freely by thread of equal length repel each other all of these forces are acting on one of then except:

(a) Tension (b) Gravitational pull **(c) Coulomb attraction force** (d) Repulsive force

3. Two capacitors 0.2mF and 0.4mF are connected in series to a supply of 10V. Calculate the energy stored in the field within the dielectrics of the capacitors

(a) 6.7X10-5J (b) 14.2X10-5J (c) 26.3X10-5J (d) 9.8X10-5J

4. What area of the plate of parallel-plate capacitor gives 1mF, if the plate's separation is 0.001m and permittivity of the dielectric used is 8.85x10-12?

(a) 9.13x10-3m2 **(b) 113 m2** (C) 6.6X10-3 (d) 21 m2

5. The inverse of constant of proportionality in ohm's law for metallic conductors can be called:

(a) Inductance **(b) Conductance** (c) Reactance (d) Remittance

6. One major difference between Ohm metallic conductors and semi conductors is:

(a) Temperature increase increases the conductivity of semiconductor

(b) Temperature increase makes valence electrons to fall to ground state in semiconductor

(c) Temperature increase reduces the speed of the conducting electrons in the semi conductor.

(d) Temperature increase ejects the valence electrons in metals.

7. Conductivity of metal conductor does not depend on one of the following:

(a) Permeability (b) Temperature (c) Length (d) Cross section area

8. The diameter of a 5 m long constantan wire is 0.1mm. Calculate its conductivity if

Its resistance per unit length is 2 Ω/m.

(a) 1.5X106/ Ω m (b) 99x10-9/ Ω m **(c) 6.4x107/ Ω m** (d) 5.5x10-7/ Ω m

9. A 500-watt boiling ring was used to raise the temperature of 200g of a liquid by 250K within 2 seconds. What is the specific heat capacity of the liquid?

(a) 2.0x102 J/KgK (b) 6.3x10-3 J/KgK (c) 4.41x104 J/KgK (d) 1.333x105 J/KgK

10. One of the following cannot be a unit of electrical potential

(a) Joule per Coulomb (b) Volt **(c) Watt per coulomb** (d) Newton meter per Coulomb

11. Which of the following is the correct statement for Kirchoff's rule for current at a junction of circuit network?

(a) Algebraic sum of current at a junction is zero

(b) Algebraic sum of current flowing into a junction is equal to that, leaving that junction

(c) Algebraic sum of current at a junction is constant

(d) (a) and (b) are correct

12. All of these are the uses of potentiometer with exception of:

(a) Comparison of emf of two cells

(b) Comparison of capacitance of two capacitors

(c) Measurement of internal resistance of a cell

(d) Measurement of small current

13. Which of the following is a necessary condition for working potentiometer?

(a) Positive terminals of the driver and test cells must be connected to a common point

(b) emf of driver cell must always be greater than of the test cell

(c) When galvanometer is balanced no current could flow in the potentiometer

(d) (a), (b), and (c) are correct

14. In electromagnetism one of the following is not among the three entities that are mutually dependent:

(a) Current **(b) Charges** (c) Motion (d) Magnetic field

15. The magnitude of the electromagnetic force produced when a

current carrying conductor is in a magnetic field is not increased by:

(a) Thickness of the conductor

(b) Length of the conductor

(c) Magnetic field strength

(d) Magnitude of sine of the angle made by the conductor with the field.

16. What angle will the current carrying conductor laying in a magnetic field make for the electromagnetic force F it experience to be a minimum?

(a) 90^0 (b) 180^0 **(c) 0^0** (d) -60^0

17. What is the magnetic flux density B at 2m from a straignt wire in vacuum carrying 3A current? (μo = 4n x 10-7 H/m)

(a) 5 x 10-7 T **(b) 3 x 10-7 T** (c) 6 x10-7 T (d) 2 x 10-7 T

18. Electromagnetic induction is a process of converting:

(a) Electrical energy to potential energy

(b) Mechanical energy to electronic energy

(c) Kinetic energy to electrical energy

(d) Mechanical energy to light energy

19. Motion of the magnetic flux during induction can be achieved in any of the following ways:

(i) Dynamo effect (ii) Sliding effect (iii) Transformer effect.

(a) I only (b) II only (c) I and II only **(d) I and III only**

20. Major similarity between self inductance and mutual inductance is that:

(a) They are both measured in Teslas

(b) They are both produced when current change at the rate of 1A per second

(c) They both oppose the current producing them

(d) They are both measured in Henry

21. Static electricity is the study of the energy associated with electrons:

(a) In translational motion

(b) In vibrational motion

(c) At rest

(d) In charged bodies

22. According to its definition the unit of the emf of a cell can be

(a) Joule/Kelvin **(b) Joule/coulomb** (c) Joule/second (d) volt/second

23. A major difference between electric current and voltage (potential difference) is:

(a) Current is time rate of flow of charges while voltage is a measure of energy required to move a charge within a given place.

(b) Current can be measured in Coulomb/second voltage is Joule/Coulomb

(c) Current is point phenomenon while voltage is a gap phenomenon

(d) All above are correct.

24. The volume control in a radiowave receiver is an example of:

(a) Air capacitor **(b) Potentiometer** (c) Resistor (d) Inductor

ϕ

25. Which of these is/are sample(s) unit (s) of capacitance of a capacitor?

(a) Picofarad (b) Coulomb/volt (c) Joule/metre **(d) a and b are correct**

26. Which of the following statement is wrong about self induced/back emf?

(a) It reduces the efficiency of the current that produced it.

(b) It is induced as a result of variation in magnetic field caused by varying electric current.

(c) It opposes the applied emf

(d) All above are wrong about self induced/back emf.

27. Ferromagnetic materials are materials which can be permanently magnetized.

(A) When the material is doped with positive materials

(B) When the material is doped with negative materials

(C) When an internal magnetic field is applied to the material.

(D) When an external magnetic field is applied to the material.

28. If the temperature of a ferromagnetic material is raised past the Curie temperature, the material abruptly loses its permanent magnetisation and becomes

(A) Paramagnetic (B) Electromagnetic (C) Diamagnetic (D) Curiemagnetic

29. Which of the following statements is correct about Paramagnetic Materials?

(A) Paramagnetic materials are attracted toward magnets, but do not become permanently magnetised. (B) Paramagnetic materials are attracted toward magnets, and become permanentlymagnetised. (C) Paramagnetic materials are repelled from magnets, and do not become permanently magnetised. (D) None

30. Which of the following statement is correct about Diamagnetic materials?

(A) Diamagnetic materials are repelled by magnets, but do not become permanently magnetised.
(B) Paramagnetic materials are attracted toward magnets, and become permanently magnetised. (C) Diamagnetic materials are attracted toward magnets, but do not become permanentlymagnetised (D) None

31. Which of the following statement is incorrect about Remanent Magnetism?

(A) Remanent Magnetism is the magnetisation remaining after the removal of an externally applied field (B) Remanent Magnetism is exhibited by ferromagnetic materials. (C) If the external field is reduced more, the remanentmagnetisation will be removed **(D) Remanent Magnetism is not exhibited by ferromagnetic materials.**

32. Which of the following statement is correct about hysteresis?

(A) As the external magnetic field is increased, the induced magnetization also decreases.
(B) The induced magnetisation is eventually lost
(C) As the external magnetic field is increased, the induced magnetization also increases.
(D) All

33. The lack of retraceability is known as

(A) Magnetisation **(B) Hysteresis** (C) Remanence (D) Coercive force

34. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. A material with B < Bo is known as

(A) Paramagnetic material (B) Electromagnetic material **(C) Diamagnetic material**
(D) ferromagnetic material

35. Given that B is the resultant flux density, B_o is the flux density when the toroid is empty and B_m is the additional flux density set up by the material of the core. The correct relation is given by?

(A) $B_o = B_M + B$ (B) $B + B_o = B_M$
(C) $B = B_o = B_M$

(D) $B = B_o + B_M$

36. These materials and their alloys are termed ferromagnetic materials except

(A) Iron (B) cobalt (C) nickel **(D) None**

37. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. A material with B >Bo is known as

(A) Paramagnetic material (B) Electromagnetic material
(C) Diamagnetic material (D) ferromagnetic material

38. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. The ratio B/Bo is known as

(A) Magnetic susceptibility (B) Absolute permeability
(C) Relative permeability (D) Unity permeability

39. Given that B is the resultant flux density, Bo is the flux density when the toroid is empty and BM is the additional flux density set up by the material of the core. The ratio BM /Bo is known as

(A) Magnetic susceptibility (B) Absolute permeability
(C) Relative permeability (D) Unity permeability

40. From the Absolute permeability, μ, can be defined as

(A) μ_o / μ_r (B) μ_r / μ_o (C) μ/μ_r (D) $\mu_r\mu_o$

41. From the curve, Points c and f represent

(A) Current **(B) Permanent magnetism** (C) hysteresis loss (D) maximum

42. From the curve, Point b represents

(A) Saturation (B) Coercivity (C) Remanence
(D) Magnetic susceptibility

43. From the curve, ac is a measure of the

(A) Saturation (B) Coercivity **(C) Remanence**
(D) Magnetic susceptibility

44. From the curve, ac is a measure of the

(A) Saturation **(B) Coercivity** (C) Remanence (D) Magnetic susceptibility

45. The curve between points "a" and "b" in figure1 is called

(A) The magnetisation curve. (B) The remanent magnetisation curve (C) the external magnetization field (D) The coercive magnetisation curve

46. In hysteresis, if the external magnetic field is reduced the material retains a certain permanent magnetisation termed theremanentmagnetisation.

(A) The induced magnetisation also is increased.
(B) The induced magnetisation also is reduced, but it does not follow the original curve. (C) The induced magnetisation also is reduced, and it will follow the original curve.
(D) The induced magnetisation will reach saturation.

47. Which of the following statement is incorrect about the current in hysteresis loop?

(A) current is increased from a to b **(B) current is increased from e to f** (C) current is reduced to zero from b to c (D) current is increased from f to b

48. Which of the following does not correctly describe a conductive solid metal?

(A) It contains a large population of mobile, or free, electrons. (B) The electrons are bound to the metal lattice but not to any individual atom. (C) The electrons move about randomly due to thermal energy **(D) Thermal energy, on the average, causes the current within the metal to flow when external field is not applied.**

49. The correct unit of electric current is?

(A) Coulomb per second (B) Coulomb-second

(C) Volt per coulomb (D) Volt - coulomb

50. Which of the following does not correctly describe the Current density?

(A) Current density is a measure of the density of an electric current. (B) It is defined as a vector whose magnitude is the electric current per cross-sectional area. **(C) Current density is measured in amperes per meter.** (D) Current density is measured in Coulomb per second per square meter.

51. Which of the following does not correctly describe semiconductor?

(A) A semiconductor allows an electric current to flow very strongly in one direction

(B) A semiconductor allows an electric current to flow very weakly in the opposite direction

(C) The direction in which a semiconductor allows the forward current to flow depends on whether it is a p- type semiconductor or an n-type semiconductor.

(D)The direction in which a semiconductor allows the forward current to flow does not depend on whether it is a p-type semiconductor or an n-type semiconductor.

52. Which of the following does not correctly describe semiconductor?

(A) The amounts of current which flow in each direction depend mainly on the amount of the voltage applied. (B) The forward resistance is relatively low. (C) The amounts of current which flow in each direction depend mainly on the forward and the reverse resistance. (D)The amounts of current which flow in each direction depend partly on the amount of the voltage applied but mainly on the forward and the reverse resistance.

53. Which of the following does not correctly describe semiconductor?

(A) The forward resistance is relatively low (B) The reverse resistance is always very high **(C) like a conductor, the flow of current through a semiconductor is not the same amount of current whichever way the voltage is applied.**
(D) The amounts of current which flow in each direction depend partly on the amount of the voltage applied but mainly on the forward and the reverse resistance.

54. Which of the following statement is not true?

(A) Conductors allow electrons to pass through them easily because of their low resistance.
(B) Insulators do not allow electrons to pass through them because of their high resistance

(C) Insulators do not allow electrons to pass through them because their atoms hold the electrons strongly.
(D) None

55. The potential difference applied to the armature of a motor is 12 volts. If the current and resistance of the armature are 0.4 A and 5 ohms respectively. Calculate the back emf in the winding.

(A) 10 volts (B) 12 volts (C) 15 volts (D) 5 volts.

56. The units of conductance G of a device is?

(A) Mho **(B) Siemens** (C) Ohms (D) None

57. From the usual symbols, the unit of conductivity σ of a device is?

(A) Ω-1 m (B) Ω m-1 (C) Ω m **(D) Ω-1m-1**

58. From the usual symbols, the unit of conductivity σ of a device is?

(A) Ω-1 S **(B) S m-1** (C) S m (D) S Ω

59. From the usual symbols, the units of conductance G of a device is?

(A) S (B) S m-1 (C) S m (D) S Ω

60. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation best described the torque T experience when the plane is parallel to the field?

(A) T = NIAB (B) T = NABθ (C) T = NIBθ (D) T = NIAθ

61. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation best defined the current sensitivity S, when other parameters have their usual meanings?

(A) S = θ/I (B) S = θ/Q (C) S = Q/θ (D) S = BAN/cR

62. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation does not defined the voltage sensitivity Sv, when other parameters have their usual meanings?

(A) Sv = θ/IR (B) Sv = S/R (C) Sv = BAN/cR **(D) Sv = R/θ**

63. The moving coil galvanometer that has a coil of N turns each of area A and carrying I, experiences a torque T when its plane is in the field B. Which equation best defined the charge sensitivity Sq, when other parameters have their usual meanings?

(A) Sq = θ/IR (B) Sq = θ/I (C) Sq = BAN/cR **(D) Sq = θ/Q**

64. Dead-beat movement occurs when

(A) the galvanometer is free **(B) the galvanometer is critically damped**

(C) the galvanometer is steady (D) the galvanometer is electromagnetic

65. Which of the following statement is not true of the ballistic galvanometer?

(A) the kinetic energy is used to the rotate the coil
(B) the kinetic energy is converted to the potential energy stored in the system (C) the potential energy stored in the system provides the restoring torque **(D) the kinetic energy of the system is used to heat the coil**

66. Which of the following statement is not true of the dynamo?

(A) Dynamo can be shunt-wound (B) Dynamo can be series-wound (C) Dynamo can be compound-wound **(D) Dynamo can be slip-ring-wound**

67. Which of the following statement is not true?

(A) Alternating current is one in which magnitude and direction vary periodically **(B) Direct current is one in which magnitude and direction vary periodically**
(C) Electromotive force is one in which magnitude and direction can vary periodically (D) Alternating current gives the value of magnetic fields that vary in magnitude and direction periodically

68. Which of the following statement is not true of Rectification?

(A) Rectification is the process by which one converts a.c to d.c **(B) Rectification is the process by which one converts d.c to a.c** (C) Rectifier impedes the flow of current in one direction more than in the reverse direction
(D)When a sinusoidal waveform is input to a rectifier, a half-wave output is produced.

69. An external magnetic field can be supplied by any of the following except

(A) An electromagnet (B) solenoid (C) Another permanent magnet **(D) None**

70. An electric heater is labeled 240V ac, 1000W. What is the peak current in the heater when connected to a 240V ac supply.

(A) 4.17A **(B) 5.89A** (C) 2.95A
(D) 8.34A

71. Calculate the electromotive force induced in a copper rod of length 6cm rotating at 2 rev/sec in a uniform magnetic field B of 0.02 Tesla.

(A) 4.52 x 10-4 volts (B) 3.50 x 10-4 volts (C) 2.0 x 10-4 volts (D) 6.0 x 10-4 volts

72. Calculate the peak value of the emf induced in a circular coil of 1000 turns of radius 4cm rotating at 1800 rpm about an axis in its own plane at right angles to a magnetic field of flux density 0.03T.

(A) 30.62 volts (B) 20.26 volts (C) 25.02 volts **(D) 28.43 volts.**

73. A domestic ac source has a peak value of 325v. What is the rms current in a 100w light bulb?

(A) 0.31A **(B) 0.44A** (C) 0.22A (D) 0.62A

74. A 2kΩvariable resistor is connected across a 10v supply. What is the potential difference between the sliding contact and the negative side of the supply when the slider is 2/3 way long?

(A) 3.3v **(B) 6.7v** (C) 1.6v (D) 8.4v

75. A flat circular coil with 40 loops of wire has a diameter of 32 cm. What current must flow in its wire to produce a field of 3 X10-4Wb/m2 at its Centre?

(A) 1.29A (B) 1.09A (C) 1.19A **(D) 1.9A**

76. An air core solenoid with 2000 loops is 60cm long and has a diameter of 2 cm . If a current of 5A is sent through it, what will be the flux density within it?

(A) 0.21T (B) 0.12T (C) 1.02T **(D) 0.021T**

77. The net charge on an n-type semiconductor is

(A) Positive **(B) negative** (C) Zero (D) Minus

78. An example of trivalent element used for doping of semiconductor is

(A) Phosphoric (B) Silicon (C) Germanium **(D) Boron**

79. The Resistivity of a semiconductor with increasing temperature

(A) Increases (B) Remain constant **(C) Decreases** (D) Doubles

80. A domestic ac source has a peak value of 325v. What is the rms current in a 100w light bulb?

(A) 0.31A **(B) 0.44A** (C) 0.22A (D) 0.62A

81. Which of these cannot be utilized with a variable resistor

(A) Volume control (B) Dimmers on light switches (C) Thermostat **(D) None of the above**

82. Which of these is the impedance for an inductor – Resistor circuit in series?

83. An electric heater is labeled 240V ac, 1000W. What is the peak current in the heater when connected to a 240V ac supply.

(A) 4.17A **(B) 5.89A** (C) 2.95A
(D) 8.34A

84. The device used in converting mechanical power into electrical power is called

(A) Dynamo (B) Lever (C) Armature
(D) Motor

85. Calculate the peak value of the emf induced in a circular coil of 1000 turns of radius 4cm rotating at 1800 rpm about an axis in its own plane at right angles to a magnetic field of flux density 0.03T.

(A) 30.62 volts (B) 20.26 volts (C) 25.02 volts **(D) 28.43 volts.**

86. Which of the following is suitable for measuring the quantity of charge?

(A) Ballistic Galvanometer (B) Powerful Galvanometer (C) Holistic Galvanometer (D) Meter Bridge

87. A particular component of the direct current generator that maintains the direction of the generated emf in the circuit is the

(A) Commutator (B) Slip ring (C) Armature (D) Rectangular coil

88. The direction of magnetic field can determined using

(A) The right hand grip rule (B) just the electron (C) Maxwellian rule (D) Faraday's direction

89. The negative sign in Faraday's law of electromagnetic induction indicates

(A) Induced emf **(B) direction of induced current** (C) Current (D) Faraday's direction

90. In an a.c generator the magnitude of the emf generated increases with

i) Increase in the strength of the magnet

ii) Decrease in the rate of change of the flux

iii) Increase in the number of turns of the coil

iv) Increase in area of the coil

Which of the state is correct.

(A) i, ii, and iii **(B) i, iii and iv** (C) ii, iii and iv (D) i and iii

91. The induced emf generated in an alternator is such in a direction as to oppose the motion producing it. This statement is

(A) Right hand grip rule (B) Faraday's law (C) Fleming's law **(D) Lenz's law**

92. Which of the following does not correctly describe the conventional current?

(A) Electric charge moves from the positive side of the power source to the negative.

(B) A flow of positive charge gives the same electric current as an opposite flow of negative charge.

(C) The opposite flows of opposite charges contribute to a single electric current.

(D) None

93. Which of the following statement is not true?

(A) In solid metals such as wires, the positive charge carriers are immobile.

(B) In solid metals such as wires, the positive charge carriers are mobile.

(C) Because the electron carries negative charge, the electron motion in a metal is in the direction opposite to that of conventional (or electric) current.

(D) In solid metals such as wires, only the negatively charged electrons flow.

94. Which of the following does not have a mobile charge carrier?

(A) Metals **(B) Insulators** (C) Semiconductors (D) None

95. Which of the following does not have a charge carrier?

(A) Metals (B) Insulators (C) Semiconductors **(D) None**

96. A flat circular coil with 40 loops of wire has a diameter of 32 cm. What current must flow in its wire to produce a field of 3 X10-4Wb/m2 at its Centre?

(A) 1.29A **(B) 1.09A** (C) 1.19A (D) 1.9A

97. An air core solenoid with 2000 loops is 60cm long and has a diameter of 2 cm . If a current of 5A is sent through it, what will be the flux density within it?

(A) 0.21T (B) 0.12T (C) 1.02T **(D) 0.021T**

98. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the same direction.

(A) 48µN attractive force. (B) 4.8N attractive force. (C) 48µN repulsive force (D) 4.8N repulsive force

99. Three long, straight, parallel wires X,Y and Z carry currents +30A,-10A and +20A respectively, Where XY is 3cm apart and YZ is 5cm apart and +/ – indicates their directions. Find the force on a 25cm length of wire Y.

(A) 3.3mN (B) 2.3mN (C) 1.3mN **(D) 0.3mN**

100. Two long parallel wires X and Y are 10cm apart and carry currents 6A and 4A respectively. Find the force on a 1m length of wire Y if the currents are in the opposite direction.

(A) 48µN attractive force. (B) 4.8N attractive force. **(C) 48µN repulsive force** (D) 4.8N repulsive force

101. What is the value of B in air at a point 5 cm from a long straight wire carrying a current of 15A?

(A) 6X10-2T (B) 6X10-4T (C) 6X10-1T **(D) 6X10-5T**

102. An air core solenoid with 2000 loops is 60cm long and has a diameter of 2 cm . If a current of 5A is sent through it, what will be the flux density within it?

(A) 0.21T (B) 0.12T (C) 1.02T **(D) 0.021T**

103. Which of the following is correct?

(A) 1Wb=1NmA **(B) 1Wb=1Vs** (C) 1Wb=1Nm-1A-1 (D) 1Wb=1NAm-1

104. We can define the unit of magnetic flux density as

(A) tesla (B) weber (C) NA-1 (D) Nm-2

105. A copper bar 30cm long is perpendicular to a field of flux density 0.8Wb/m2 and moves at right angles to the field with a speed of 0.5m/s.Determine the emf induced in the bar.

(A) 0.0012V (B) 0.012V **(C) 0.12V** (D) 1.2V

106. Which of the following is suitable for measuring the quantity of charge?

(A) Ballistic Galvanometer (B) Galvanometer (C) Holistic Galvanometer (D) Meter Bridge

107. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30v, 1780 Hz power supply. Find the current in the circuit.

(A) 178A (B) 224A (C) 5A **(D) 6A**

108. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30V, 1780 Hz power supply. Find the phase angle between source voltage and current.

(A) 0^0 (B) 30^0 (C) 90^0 (D) 270^0

109. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30v, 1780 Hz power supply. Find the power loss in the circuit.

(A) 0W (B) 60W (C) 120W **(D) 180W**

110. A 5 W resistance is in a series circuit with a 0.2 H pure inductance and a 40 nF pure capacitance. The combination is placed across a 30v, 1780 Hz power supply. Find the voltmeter reading across elements of the circuit.

(A) 30V, 13.44V,13.44V (B) 30kV, 13.44kV,13.44V

(C) 30V, 13.44kV,13.44kV (D) 30kV, 13.44kV,13.44kV

111. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the current in the circuit.

(A) 100A (B) 20A (C) 10A **(D) 2A**

112. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the impedance of the circuit.

(A) 100W (B) 20W (C) 10W (D) 2W

113. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the potential difference across the non inductive resistor of 44 W.

(A) 100V (B) 60V **(C) 88V** (D) 97V

114. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the potential difference across the capacitor

(A) 100V **(B) 60V** (C) 88V (D) 97V

115. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the potential difference across the coil

(A) 194V (B) 60V (C) 180V (D) 97V

116. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the current across the non inductive resistor.

(A) 100A (B) 20A (C) 10A **(D) 2A**

117. A series circuit connected across a 200V, 60Hz line consists of a capacitor of capacitive reactance 30 W, a non inductive resistor of 44 W, and a coil of inductive reactance 90 W, having a resistance 36 W. Determine the impedance of the coil

(A) 194W (B) 60W (C) 180W **(D) 97W**

118. When turning at 1500 rev/min, a certain generator produces 100 V. what must be its angular speed if it to produce 120 V?

(A) 1000 rev/min (B) 1200 rev/min (C) 1500 rev/min **(D) 1800 rev/min**

119. A shunt is connected to a 110V line. When the armature generates a back emf of 104V, the armature current is 15A. Compute the armature resistance.

(A) 0.1Ω (B) 0.8 Ω (C) 0.9 Ω **(D) 0.4 Ω**

120. A shunt dynamo has an armature resistance of 0.12 Ω. If it is connected across 220V main and is running as a motor, what is the induced, back emf when the armature current is 50 A?

(A) 214 V (B) 226V (C) 220V (D) 260V

121. A shunt dynamo has an armature resistance of 0.12 Ω If it is connected across 220V main and this machine is running as a generator, what is the induced emf when the armature is delivering 50 A at 220V to the shunt field and external circuit?

(A) 214 V **(B) 226V** (C) 220V (D) 260V

122. A shunt motor with armature resistance 0.08Ω is connected to 120V mains. With 50A in the armature what is the back emf?

(A) 116V (B) 5.8V (C) 130V (D) 58V

123. A shunt motor with armature resistance 0.08Ω is connected to 120V mains. With 50A in the armature what are the back emf and the mechanical power developed within the armature?

(A) 116kW **(B) 5.8kW** (C) 130kW (D) 58kW

124. In a shunt motor, the permanent magnet is replaced by an electromagnet activated by a field coil that shunt the armature. The shunt motor shown has armature resistance 0.05 W and is connected to 120 V mains. What is the armature current at the starting instant, i.e., before the armature develops any backemf?

(A) 2400A (B) 240A (C) 24A (D) 2.4A

125. In a shunt motor, the permanent magnet is replaced by an electromagnet activated by a field coil that shunt the armature. The shunt motor shown has armature resistance 0.05 W and is connected to 120 V mains. With no starting resistance, what back emf is generated when the armature current is 20 A?

(A) 119V (B) 121V (C) 120V (D) 125V

126. A motor has back emf 110V and armature current 90 A when running 1500rpm. Determine the power.

(A) 9.9W (B) 99W (C) 990W **(D) 9900W**

127. A step-up transformer is used on a 120V line to furnish 1800V. The primary has 100 turns. How many turns are on the secondary?

(A) 1200turns (B) 1400turns **(C) 1500turns** (D) 1800turns

128. A capacitor is in series with a resistance of 30 W and is connected to a 220 V ac line. The reactance of the capacitor is 40 W. Determine the impedance of the circuit.

(A) 60 W. **(B) 50 W.** (C) 40 W. (D) 30 W.

129. A capacitor is in series with a resistance of 30 W and is connected to a 220 V ac line. The reactance of the capacitor is 40 W. Determine the current in the circuit

(A) 5.5A **(B) 4.4A** (C) 3.5A (D) 2.5A

130. A capacitor is in series with a resistance of 30 W and is connected to a 220 V ac line. The reactance of the capacitor is 40 W. Determine the phase angle between the current and the supply voltage.

(A) -83^0 **(B) -53^0** (C) -33^0 (D) -63^0

131. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the current in the coil.

(A) 5.5A **(B) 4.4A** (C) 3.5A (D) 2.5A

132. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the impedance of the circuit.

(A) 22.0W **(B) 25.1W** (C) 27.2W (D) 29.3W

133. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the phase angle between the current and the supply voltage.

(A) 18.3^0 **(B) 61.3^0** (C) 33^0 (D) 63^0

134. A coil having inductance 0.14H and resistance 12 W is connected across a 110V, 25Hz line. Compute the power loss in the coil.

(A) 48W (B) 23W (C) 248W **(D) 230W**

135. A 120V ac voltage source is connected across a pure 0.70 H inductor. Find the current through the inductor if the frequency of the source is 60Hz.

(A) 2.5A (B) 0.25A (C) 4.55A **(D) 0.455A**

136. A 120V ac voltage source is connected across a pure 0.70 H inductor. Find the current through the inductor if the frequency of the source is 60kHz.

(A) 2.5mA (B) 0.25mA (C) 4.55mA **(D) 0.455mA**

137. A 2mH inductor is connected across a 15V variable-frequency electronic oscillator. Find the current through the inductor when the frequency is 100Hz.

(A) 11.9A (B) 11.9mA (C) 1.19A (D) 1.19mA

138. A 0.3 mF capacitor is connected across a 15V variable-frequency electronic oscillator. Find the current through the capacitor when the frequency is 100Hz.

(A) 2.83A **(B) 2.83mA** (C) 28.3A (D) 28.3mA

139. Calculate the resonant frequency of a circuit of negligible resistance containing an inductance of 40mH and a capacitance of 600pf.

(A) 32.5 kHz. (B) 325kHz. (C) 32.5Hz. (D) 325Hz.