PHYSICS

CHAPTER 1 EFFECTS OF ELECTRIC CURRENT

Energy conversions in different device

Device	Use	Energy change
Electric bulb	To get light	Electrical energy → Light energy
Induction cooker	To get heat	Electrical energy → Heat
Storage battery (while charging)	To store charge	Electrical energy → Chemical energy
Mixie	To rotate motor/ mixing the substance	Electrical energy → mechanical energy
Fan	To rotate motor	Electrical energy → Mechanical energy
Storage battery (discharging)	Charging mobile phone	Chemical energy → Electrical energy

Heating Effect of Electric Current

- **Here electrical energy is converted into heat energy**
- **The devices which convert electrical energy into heat energy are called heating devices. Example: electric iron, soldering iron, electric heater, induction cooker etc.**

Potential difference(V), charge(Q), current(I) and resistance(R)

Consider a nichrome coil of resistance R is connected to a battery as shown in the figure

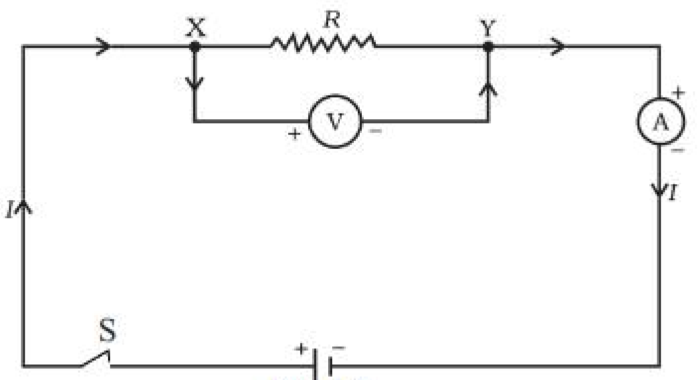


Fig. 1.2

R- resistor

V- voltmeter (always connected parallel to a device)

A- ammeter (always connected series to a device)

- **If the switch is closed (ON) charge(Q) will flow through nichrome wire**
- **The flow of current through nichrome wire will develop heat energy around it**
- **As time increases the amount of heat energy developed also increases**

- Current flowing through the conductor in t seconds is given by
  $current, I = \frac{charge\ (Q)}{time(t)}$
- The S.I unit of electric current is Ampere(A) (Coulomb/ second) (C/s)
- Charge in the conductor is given by,
  $charge\ (Q) = Current(I) \times Time(t)$

Potential difference (V)

The potential difference between two points will be one volt if one joule of work is done in moving one coulomb of charge from one point to the other.

One joule of work is required to move one coulomb of charge under one volt potential difference. Hence the work W to be done to move one coulomb of charge under a potential difference V will be, W = V joule.

Work done (W) = charge (Q) × potential difference (V)

Power (P) = $\frac{work(W)}{time(t)} = \frac{Q \times V}{t} = I \times V = VI$

So heat developed in the conductor in t seconds is given by

Heat (H) = power × time = VIt

Joule's Law

Joule's Law

The heat generated (H) in a current carrying conductor is directly proportional to the product of the square of the current (I) in the conductor, the resistance of the conductor (R) and the time (t) of flow of current.

$H \propto I^2Rt$ $\therefore H = I^2Rt$ joule

I is the current in ampere, R is the resistance in ohm and t is the time in second.

General expressions for heat generated in a current carrying conductor.

$H = I^2Rt$

$H = VIt$

$H = \frac{V^2t}{R}$

$H = P \times t$

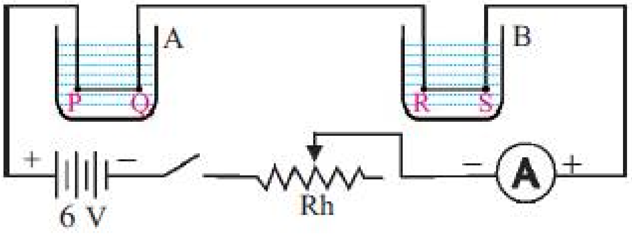
1 calorie = 4.2 J

- **If Current flow is increased by X times then heat flow will increased by X^2 times.**
  Example: if current is increased by 2 times heat developed will be increased by 4 times
- **If current flow is decreased by X times then heat flow will decreased by X^2 times**
  Example: if current flow is reduced to half then heat developed will decreased by 4 times (H/4)

Factors affecting Heat developed in a current carrying conductor

- **Current flowing through the conductor(I)**
- **Resistance of the conductor (R)**
- **Time of flow of current (t)**

Q) two wires PQ (nichrome) and RS (copper) having same length and thickness are connected in series as shown below.



a. **Of the water in beaker A and B which one got heated more? Why?**
   Ans) beaker A because in beaker A nichrome wire is used it has more resistance than copper wire.
b. **What happen to the heat produced if current is increased using rheostat (Rh)?**
   Ans) heat produce will increases
c. **What happen to the heat produced if time of flow of current is increased?**
   Ans) heat produce will increase

Problems

- How much will be the heat developed if 0.2 A current flows through a conductor of resistance 200 Ω for 5 minute?

$\therefore H = I^2Rt$	$R = 200\ \Omega$
$= (0.2)^2 \times 200 \times 300$	$I = 0.2\ A$
$= 2400\ J$	$t = 5 \times 60\ s$
	$= 300\ s$

$\therefore$ Heat generated = 2400 J

- Let's find out the heat developed in 3 minute by a device of resistance 920 Ω working under 230 V

$V = 230\ V$
$R = 920\ \Omega$
$t = 3 \times 60\ s$

On using the given values

$$H = \frac{V^2 t}{R}$$

$$= \frac{230^2 \times 3 \times 60}{920}$$

$H = 10350\ J$

Note:

- **If two resistors of resistance R_1 and R_2 are connected with same supply voltage, then heat produced will be directly proportional to their resistance.**
- **Example:**

  Details of two electric heaters are given below. How much will be the heat developed if they are made to work for 5 minute each?

Heater - A	Heater - B
Working voltage : 230 V Resistance : 1150 Ω Working time : 5 minute	Working voltage : 230 V Resistance : 460 Ω Working time : 5 minute
$H = \frac{V^2 t}{R}$ $= \frac{230^2 \times 300}{1150}$ $= 13800$ J	$H = \frac{V^2 t}{R}$ $= \frac{230^2 \times 300}{460}$ $= 34500$ J

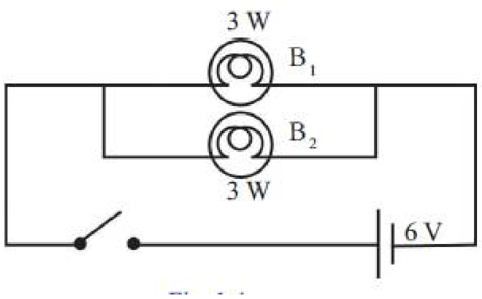
- **Here both heaters work on same voltage so by joules law**

  $H = \frac{V^2 t}{R}$, since voltage are same then $H \propto 1/R$

  So, as R increases heat developed in the heater decreases.

<u>Arrangement of resistors in a circuit</u>

<u>Parallel and Series arrangement of resistors in a circuit</u>



Parallel connection

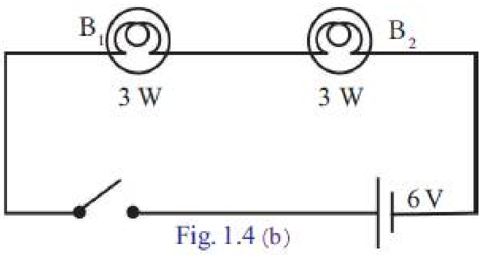


Fig. 1.4 (b)

Series connection

- **In parallel connection the intensity of glow will increases since the effective resistance of the circuit is decreased**
- **In series connection the intensity of glow will decreases since the effective resistance of the circuit is increased**

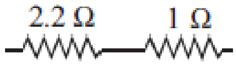
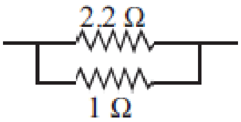
Mode of connection of resistances	Effective Resistance	Voltage obtained in each resistance	Current through each resistance
	increases/	different	same /
	decreases	same /	different

Table 1.5

<u>Differences between series connection and parallel connection of resistance</u>

Series Connection	Parallel Connection
Effective resistance **$R = R_1 + R_2 + R_3 + \ldots\ldots.. R_n$**	**Effective resistance** $\frac{1}{R} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3} + \cdots \ldots \ldots .. + \frac{1}{R_n}$
Effective resistance increases	**Effective resistance decreases**
Current through each resistor are same	**The current through each resistor is different. It gets divided as per the value of resistors**
The potential difference across each resistor is different. It gets divided as per the value of resistors.	**Potential difference across each resistor are same.**
Each resistor cannot be controlled by individual switches.	**Each resistor can be controlled by individual switches.**
If one resistor is failed it will affect the entire circuit	**If one resistor is failed it will not affect the entire circuit**

Note:

- **If n number of resistors of resistance R are connected in series, then equivalent resistance/ effective resistance is given by, $R_{effective} = n \times R$**
- **If n number of resistors of resistance R are connected in parallel, then equivalent resistance/ effective resistance is given by, $R_{effective} = \frac{R}{n}$**
- **If two resistors of resistance R_1 and R_2 are connected in parallel then effective resistance is given by, $R = \frac{R_1 \times R_2}{R_1 + R_2}$**

<u>Heating Effect of Electricity -Use</u>



Fig 1.8

- **Soldering iron, induction cooker, electric heater are examples of device working on heating effect of electric current**
- **The main component of such devices is heating coil. Usually nichrome is used as heating coil**

Heating coils are made of nichrome. Nichrome is an alloy of nickel, chromium and iron

Q) why nichrome is used as heating coil?

- High resistivity
- High melting point
- Ability to remain in red hot condition for a long time without getting oxidised.

<u>Safety Fuse</u>

- **The main part of safety fuse is fuse wire**
- **It is an alloy of Tin and Lead**
- **They have low melting point**
- **They are connected series to the circuit.**
- **When over current flows through the circuit they will melt and circuit will break. i.e they will ensure the safety of the device.**

Working of a fuse wire

During the entire time of the passing of current through a circuit, a small amount of heat is generated in the fuse wire. But this heat will be transmitted to the surroundings. When the current that flows into the circuit exceeds the permissible limit, the heat generated becomes excessive. Since more heat is generated in unit time than the heat transmitted, the fuse wire melts.

Q) what are the circumstances cause over current flowing through the circuit?

- **<u>Short circuit</u>**
  If the +ve and -ve terminals of a battery or two wires from the mains come into contact without the presence of a resistance in between, they are said to be short circuited.
- **<u>Over loading</u>**
  A circuit is said to be over loaded if the total power of all the appliances connected to it is more than what the circuit can withstand.
- **<u>Lightning</u>**
  When high voltage lightning hits the conductor then the amount of current flowing through the conductor shoots up.

Q) what are the precautions to be taken while connecting fuse wire?

- **The ends of the fuse wire must be connected firmly at appropriate points**
- **The fuse wire should not project out of the carrier base**
- **The fuse wire of appropriate amperage should be selected**
- **They should be connected in series with the circuit.**

Amperage

Amperage (A) is the ratio of the power of an equipment to the voltage applied. Amperage increases with the thickness of the conductor.

Amperage = $\frac{wattage}{voltage} = \frac{P}{V}$

Its unit is ampere(A)

Electric Power

The amount of energy consumed by an electrical appliance in unit time is its power.

- **Its S.I unit is Watt**

General expressions for power

Power, P = $V \times I$

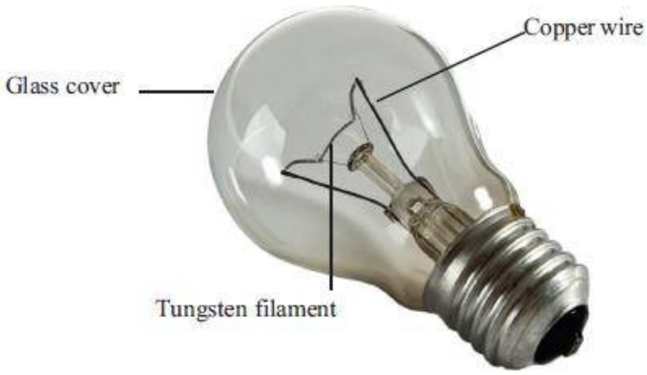
Power, P = I^2R

Power, P = $\frac{V^2}{R}$

Power, P = $\frac{H}{t}$

Lightning Effect of Electric Current

a. Incandescent lamp (filament lamp/ bulb)



Incandescent lamps

In normal voltages, the filament becomes white hot and gives out light. Such bulbs are the incandescent (glowing with heat) lamps. Filaments made of the metal tungsten are used in them. Tungsten can become white hot and emit white light for a long time. In order to avoid oxidation of tungsten, the bulb is evacuated. Vaporisation can be reduced by filling some inert gas at low pressure inside the bulb. Nitrogen is usually used for this purpose now.

Q) why nitrogen / noble gas or inert gas is filled inside the glass tube at low pressure?

- **To reduce the rate of evaporation inside the glass tube**
- **To reduce the oxidation of the filament**
- **To avoid blackening of the filament**
- **To increase the life span of the bulb.**

Q) why tungsten is used as filament?

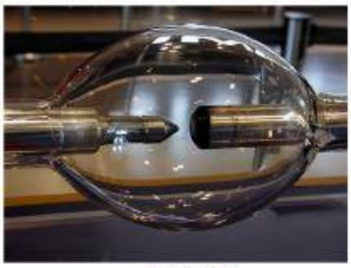
- **High resistivity**
- **High melting point**
- **High ductility**
- **Ability to emit white light in white hot condition.**

A major part of the electrical energy supplied to an incandescent lamp is lost as heat. Hence the efficiency of these devices is less.

Other lighting devices

- **Discharge lamp**
- **Arc lamp**
- **Fluorescent lamp**
- **CFL**
- **LED lamp**

Sodium vapour lamp



Arc lamp

Fluorescent lamp

C F L

Discharge Lamp

Discharge lamps are glass tubes fitted with two electrodes. They emit light as a result of discharge of electricity through the gases filled in tubes. When a high potential difference is applied the gas molecules

get excited. Excited atoms come back to their original states for attaining stability. During this process the energy stored in them will be radiated as light. Depending on the difference in the energy levels lights of different colours and other radiations are emitted.

LED Bulb (light emitting diode)

- LEDs are Light Emitting Diodes.
- As there is no filament, there is no loss of energy in the form of heat.
- Since there is no mercury in it, it is not harmful to environment
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LED Bulb

- **LED have low power consumption.**

Part of on LED bulb	Use
Base unit E22 	This is the metallic part that connects the bulb to the holder
Heat sink 	The part close to the base unit of the bulb. It is an arrangement for absorbing heat from the base.
Base plate 	Metal plate that fixes it to the holder.
Back conductor Screws. 	Screws for fixing wires from LED drive to the base unit.

Part of the LED bulb	Use
Power Supply board (LED driver) 	Function of this is to convert AC into DC and supply necessary output voltage (The same board can be used for 5W, 7W and 9 W bulbs.)
Printed Circuit Board (LED Chip Board) 	LEDs are fixed on this board. In this the positive and negative polarities are marked.
Diffuser cup 	This is the part from which light comes out of the bulb.

Other accessory tools required to construct an LED bulb


Insulation tape


Pliers

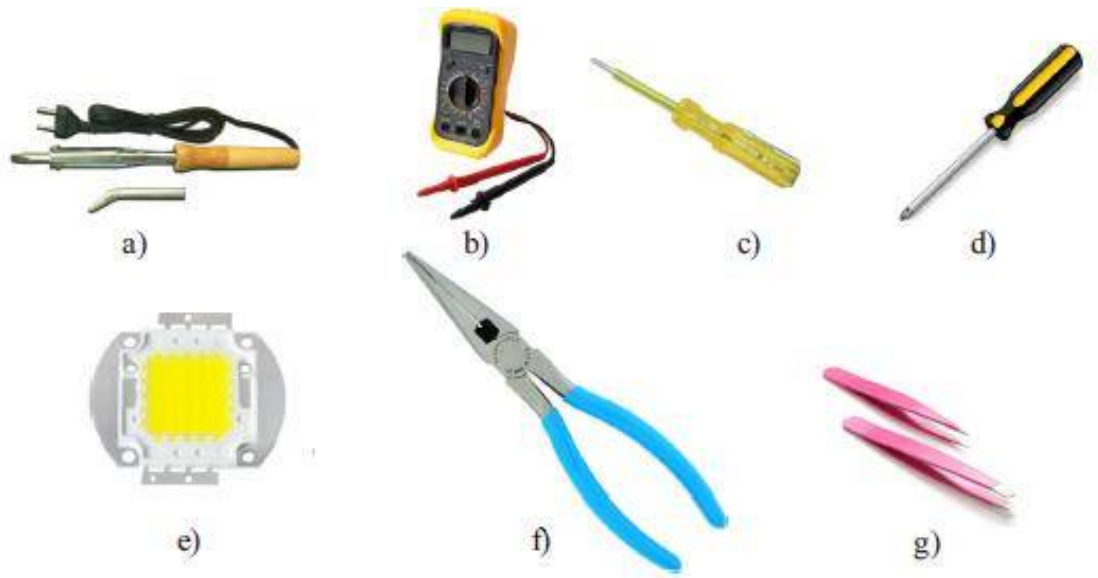

Heat sink compound


Wire stripper


Soldering iron


Solder Lead

Soldering wax



a) Soldering iron
b) Multimeter
c) Tester
d) Screw driver
e) LED Chip
f) Nose pliers
g) Tweezer
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Energy saved is equivalent to energy produced

<u>Practice Problems</u>

2. 0.5 A current flows though an electric heating device connected to 230 V supply.
   (a) the quantity of charge that flows through the circuit in 5 minute is
       (i) 5 C (ii) 15 C (iii) 150 C (iv) 1500 C
   (b) How much is the resistance of the circuit?
   (c) Calculate the quantity of heat generated when current flows in the circuit for 5 minute.
   (d) How much is the power of the heating device connected to the circuit if we ignore the resistance of the circuit wire?

b) The amperage of the fuse wire used in a circuit that works on 230 V is 2.2 A. If so the power of the device is

(i) less than 300 W

(ii) 300 W to 500 W

(iii) between 500 W and 510 W

(iv) more than 510 W

6. A 230 V, 115 W filament lamp works in a circuit for 10 minute.

(a) What is the current flowing through the bulb?

(b) How much is the quantity of charge that flows through the bulb in 10 minute?

7. An electric heater conducts 4 A current when 60 V is applied across its terminals. What will be the current if the potential difference is 120 V?

8. Three resistors of 2 Ω, 3 Ω and 6 Ω are given in the class.

(a) What is the highest resistance that you can get using all of them?

(b) What is the least resistance that you can get using all of them?

(c) Can you make a resistance 4.5 Ω using these three? Draw the circuit.

9. A girl has many resistors of 2 Ω each. She needs a circuit of 9 Ω resistance. For this draw a circuit with the minimum number of resistors.

10.

If a bulb is lit after rejoining the parts of a broken filament, what change will occur in the intensity of the light from the lamp? What will be the change in the power of the bulb?

11. Which of the following does not indicate the power of a circuit?

(a) I^2R (b) VI (c) IR^2 (d) V^2/R

12. How much will be the power of a 220 V, 100 W electric bulb working at 110 V?

(a) 100 W (b) 75 W (c) 50 W (d) 25 W

13. Which of the following should be connected in parallel to a device in a circuit?

(a) voltmeter (b) ammeter (c) galvanometer

14. When a 12 V battery is connected to resistor, 2.5 mA current flows through the circuit. If so what is the resistance of the resistor?

15. If 0.2 Ω,0.3 Ω, 0.4 Ω, 0.5 Ω and 12 Ω resistors are connected to a 9 V battery in parallel, what will be the current through the 12 Ω resistor?

16. How many resistors of 176 Ω should be connected in parallel to get 5A current from 220 V supply?

a) 2 b) 3 c) 6 d) 4

17. Depict a figure showing the arrangement of three resistors in a circuit to get an effective resistance of (i) 9 Ω (ii) 4 Ω