SUBJECT : SCIENCE (PHY)

CHAPTER-12:
ELECTRICITY

<u>TOPIC-7:</u>

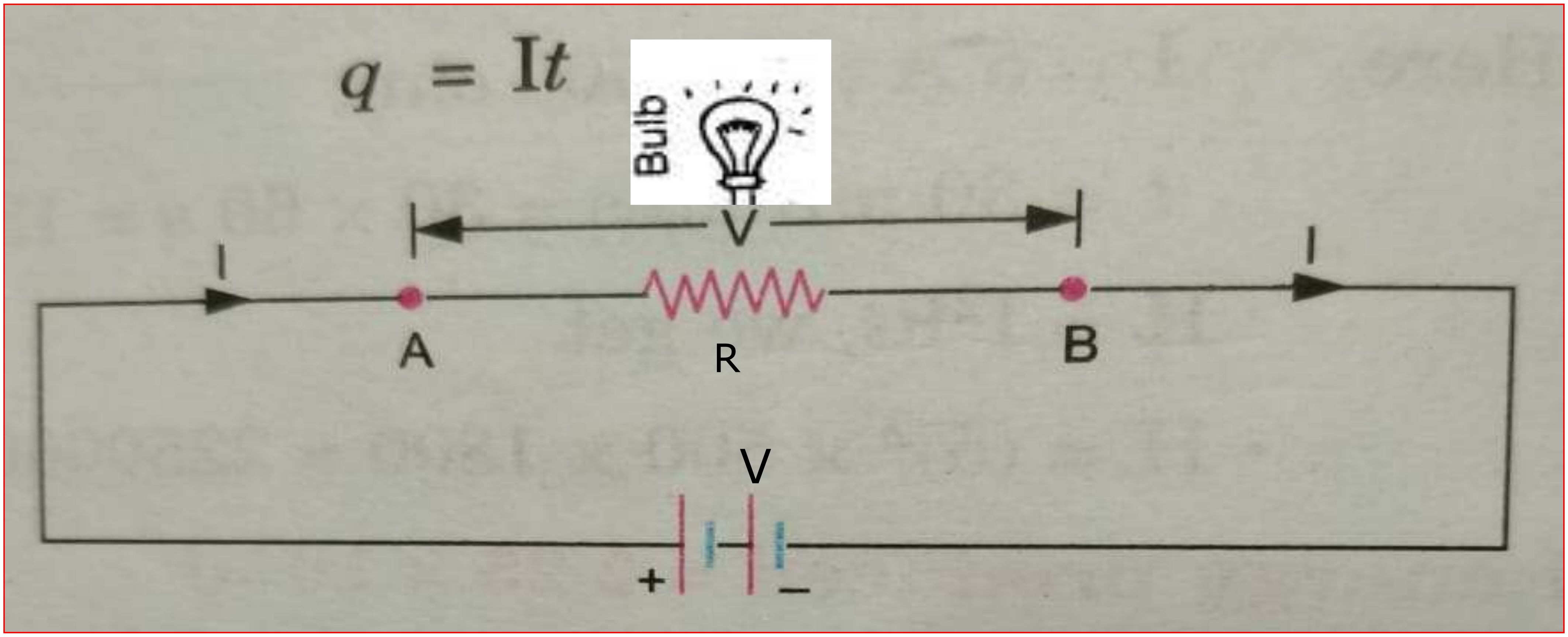
<u>ELECTRIC WORK DONE</u>
<u>&</u>
<u>ELECTRIC POWER</u>

OBJECTIVES:

Upon completion of the topic, you will be able to

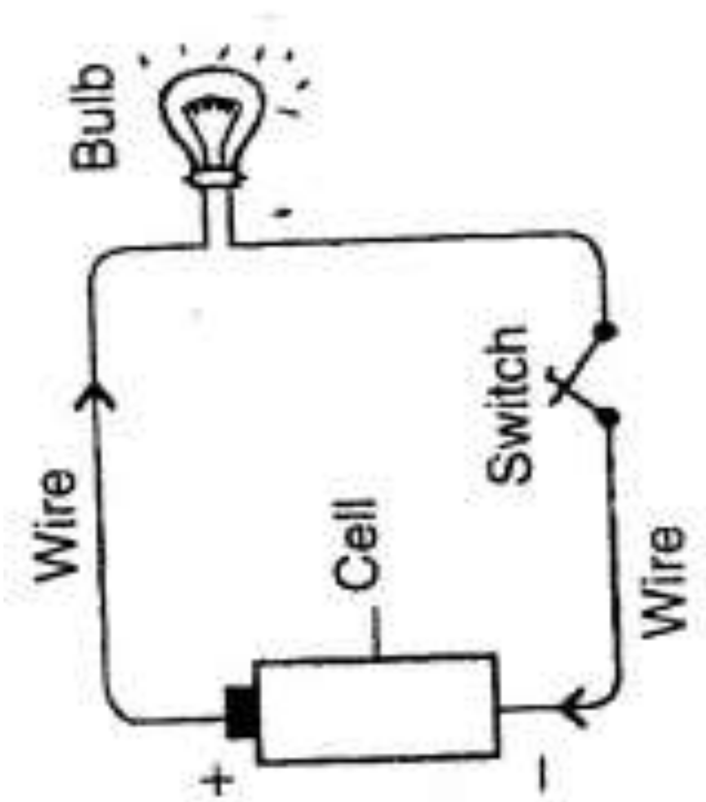
1. DEFINE ELECTRIC WORK DONE(ELECTRIC ENERGY)
2. DEFINE ELECTRIC POWER
3. WRITE THE UNITS OF ELECTRIC ENERGY AND POWER AND THEIR RELATION
4. WRITE THE DIFFERENT MATHEMATICAL EXPRESSION OF POWER
5. DEFINE COMMERCIAL UNIT OF ENERGY
6. ESTABLISH A RELATION BETWEEN COMMERCIAL UNIT OF ENERGY AND JOULE
7. SOLVE NUMERICALS

HEAT PRODUCED DUE TO CURRENT IN A CONDUCTOR:



WORK DONE OR Electric energy, $W = VIt$

WORK DONE OR Heat energy, $H = \mathbf{W} = I^2\mathbf{Rt} = VIt$



ELECTRIC WORK DONE(ELECTRIC ENERGY) AND ELECTRIC POWER:

3.14. Electric Power

* *Electric power is defined as the amount of electric energy consumed in a circuit per unit time.*

If W be the amount of electric energy consumed in a circuit in t seconds, then the electric power is given by

$$P = \frac{W}{t} \quad ...(1)$$

Since W = electric energy = VIt

W = VIt

$$\therefore \quad P = \frac{VIt}{t}$$

or $$\mathbf{P = VI} \quad ...(2)$$

P = VI

* Thus, *electric power is defined as the product of potential difference applied across the circuit and current flowing through it.*

Other Forms of Electric Power

According to ohm's law

$$V = IR$$

∴ From eqn. (2),

$$\mathbf{P = I^2R} \quad ...(3)$$

$P = I^2R$

Also $$I = \frac{V}{R}$$

∴ From eqn. (2), $$\mathbf{P} = \frac{V^2}{R} \quad ...(4)$$

$P = V^2/R$

Thus, $$P = VI = I^2R = \frac{V^2}{R}$$

Units of Power

SI unit of power is watt (or W)

We know, $P = VI$

$\therefore$ 1 watt = 1 volt × 1 ampere = 1 VA

Thus, *electric power is said to be 1 watt if 1 ampere current flows through a circuit having 1 volt potential difference.*

Bigger units of Power

1. 1 kilowatt (kW) = 10^3 W
2. 1 megawatt (MW) = 10^6 W
3. 1 gigawatt (GW) = 10^9 W

Practical unit of power

Practical unit of power is horse power (h.p.)

1 h.p. = 746 W

Relationship between electric energy and electric power

We know, electric energy = VIt

and electric power = VI

$\therefore$ Electric energy = electric power × time.

E or W = P X t

*__Definition of 1 watt__: Electric power is said to be 1 watt if 1 Joule electrical energy is consumed by an appliance in 1 second.

IMPORTANT INFORMATION:

$P = I^2R$ is applied when appliances are connected in series.

$P = \frac{V^2}{R}$ is applied when appliances are connected in parallel.

From the above two expression of power it is seen that in one case Power is directly proportional to resistance and in the second case power is inversely proportional to resistance. It is possible **as in series current (I) remains constant** and in parallel **potential difference(V) remain constant**

Resistance Rating: **$R = V^2/P$**

3.15. Commercial Unit of Electrical Energy : Kilowatt–hour (kWh)

We know, **electric energy = electric power × time.**

Electric energy is required to run the electric lamps, heaters, refrigerators, televisions and other electric appliances. The department of electricity cells the electric energy to the consumers in units called *kilowatt–hours (kWh)*. If our electricity bill shows that we have to pay for 10 units, then it means the electric appliances of our house have consumed 10 kilowatt–hours electric energy. So, 1 unit = 1 kWh.

A kilowatt–hour is the amount of electric energy used by 1000 Watt electric appliance (say a heater) *when it operates for one hour.*

kWh is also known as **"Board of Trade Unit"** (B.O.T.)

3.16. Relation between kWh and joule

(E = P X t)

$$1 \text{ kWh} = 1000 \text{ Wh} \qquad (\because 1 \text{ kW} = 1000 \text{ W})$$

Now $\quad 1 \text{ W} = 1 \text{ Js}^{-1}$ and $1\text{h} = 60 \times 60 \text{ s} = 3600 \text{ s}$.

$$\therefore \quad 1 \text{ kWh} = 1000 \text{ Js}^{-1} \times 3600 \text{ s} = 3600000 \text{ J} = 3{\cdot}6 \times 10^6 \text{ J}$$

$$\therefore \quad 1 \text{ kWh} = 3{\cdot}6 \times 10^6 \text{ J}$$ **(= 1 Unit)**

How to calculate the electricity bill ?

Suppose electric appliances of a house have consumed 100 kWh of electric energy in a month and the cost of one unit is 50 paise. Then the total bill for a month = 100 × 50 = 5000 paise = Rs. 50·00. Here 1 kWh = 1 unit.

IMPORTANT RELATIONS HIP OF THE TOPIC:

W=E = VIt

W=E =H= I^2Rt

P = W/t

P = VI

P = I^2R

P = V^2/R

E or W = P X t

1Watt = 1V X 1A

1Watt = 1J/1S

1 H.P = 746 Watt

Energy, W=E = P X t

1 J = 1 Watt x 1 s

commercial unit of energy(KWh):

1 KWh = 3.6 x 10^6J= 1 Unit

A

IMPORTANT NOTE

Rated as: 220 V – 60 W

Meaning : If the bulb is connected across a potential difference of 220 volt, it will consume 60 J electric energy in 1 second

NOTE: Every electric appliance has data sheet prepared by manufacturer . Data sheet basically contains specification of the appliances (it is about resistance, power, voltage, temperature etc).
Example : on electric bulb or fan it is rated as:
220 V – 100W, or 220V-120 W etc. The meaning of such rating is as mentioned above.

QUESTION: An electric fan is rated as: 220 V- 120 W. What does it mean?

CONSUMPTION OF ELECTRIC ENERGY IN SERIES & PARALLEL:

2 Ohm

2 Ohm

Battery , V= 8 volt

1. Find electric energy consumed in the circuit when two bulbs of resistance 2 ohm each are connected in series and glows for 1 second when a potential difference of 8 volt is applied across the combination.
2. Find electric energy consumed in the circuit when two bulbs of resistance 2 ohm each are connected in parallel and glows for 1 second when a potential difference of 8 volt is applied across the combination.

Hints: 1.To obtain Electric energy consumed, may use relation:

:E or W = VIt

:E or W = I^2**Rt**

: E or W = P X t

*** You will find that energy consumption is more when connected in parallel as compared to series in this case.**

QUESTION AND NUMERICALS

Question 1:

What determines the rate at which energy is delivered by a current?

Answer 1:

The rate of consumption of electric energy in an electric appliance is called electric power. Hence, the rate at which energy is delivered by a current is the power of the appliance.

Question 2:

An electric motor takes 5 A from a 220 V line. Determine the power of the motor and the energy consumed in 2 h.

Answer 2:

Power of the electric motor is given by

$$P = VI$$

Where, $V = 220$ V and $I = 5$ A

So, Power $P = 220 \times 5 = 1100$ W

Now, the energy consumed = Power × time

Where, $P = 1100$ W

$t = 2$ hours $= 2 \times 60 \times 60$ seconds $= 7200$ seconds

So, the energy consumed $E = 1100 \times 7200$ J $= 7920000$ J

Question 3:

An electric bulb is rated 220 V and 100 W. When it is operated on 110 V, the power consumed will be –

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

Answer 3:

The bulb is rated as: 220 V and 100 W. Resistance R of the bulb can be obtained by using relation : $\mathbf{P = V^2/R}$

$$R = V^2/P = (220 \times 220)/100 = 484$$

Now, if the bulb is operated at 110 Volt , the resistance of the bulb will remain same but the power consumption will be changed. Thus the power consumed is: $\mathbf{P = V^2/R = (110 \times 110)/484 = 25\ Watt}$

Hence option (d) is correct.

Question 4:

Two lamps, one rated 100 W at 220 V, and the other 60 W at 220 V, are connected in parallel to electric mains supply. What current is drawn from the line if the supply voltage is 220 V?

Answer 4:

For the lamp one:

Power P_1 = 100 W and Potential difference V = 220 V Therefore,

Current , I = P/V = 100/220 = 0.455 A

For the second case:

I = P/V = 60/220 = 0.273 A

QUESTIONS AND NUMERICAL

Question 5:

Compare the power used in the 2 Ω resistor in each of the following circuits:
(i) a 6 V battery in series with 1 Ω and 2 Ω resistors, and (ii) a 4 V battery in parallel with 12 Ω and 2 Ω resistors.

Answer 5:

Given that:

Potential difference, $V = 6$ V

(i)1 Ω and 2 Ω resistors are connected in series. Therefore, equivalent resistance of the circuit, $R = 1 + 2 = 3\ \Omega$

According to Ohm's law,

$V = IR$

$$\Rightarrow I = \frac{V}{R} = \frac{6}{3} = 2\ A$$

In series combination, the current in the circuit remains constant. Therefore power is given by

$$P = I^2R = (2)^2 \times 2 = 8\ W$$

(ii)12 Ω and 2 Ω resistors are connected in parallel. Current through 2 ohm resistor

$$\Rightarrow I = \frac{V}{R} = \frac{4}{2} = 2\ A$$

In parallel combination, the voltage in the circuit remains constant. Therefore power is given by

$$P = \frac{V^2}{R} = \frac{4^2}{2} = 8\ W$$

Hence, in both the cases power remains same as 8W.

Question 6:

Which uses more energy, a 250 W TV set in 1 hr, or a 1200 W toaster in 10 minutes?

Answer 6:

Energy consumed by an electrical appliance is given by E or H = P x t

For the TV set:

Power, P = 250 W and time t = 1 hour = 3600 seconds

So, energy consumed H = P x t = 250 × 3600 = 900000 J

For the toaster:

Power , P = 1200 W and time t = 10 minutes = 600 seconds So, energy consumed :

H= p x t = 1200 × 600 = 720000 J

Hence, TV set uses more energy than toaster.

Question 7:

An electric heater of resistance 8 Ω draws 15 A from the service mains in 2 hours. Calculate the rate at which heat is developed in the heater.

Answer 7:

Heat developed in the heater is given by $H = I^2Rt$

Where, I = 15 A, R = 8 Ω and time t = 2 hours The rate at which heat is developed is given by : P =H/t = $\mathbf{I^2Rt/t = I^2R}$

P = 15X15 X 8 = 1800 Watt

QUESTION-8:

An electric bulb is connected to a 220 V generator. The current is 0.50 A. What is the power of the bulb?

Solution:

$$
\begin{aligned}
P &= VI \\
&= 220\ \text{V} \times 0.50\ \text{A} \\
&= 110\ \text{J/s} \\
&= 110\ \text{W.}
\end{aligned}
$$

QUESTION-9

An electric refrigerator rated 400 W operates 8 hour/day. What is the cost of the energy to operate it for 30 days at Rs 3.00 per kW h?

Solution

The total energy consumed by the refrigerator in 30 days:

E = P X t = 400 W X 8 X 30 hr = 96000 Whr = 96000/1000 = 96 KWh

Thus the cost of energy to operate the refrigerator for 30 days is:

96 kW h X´ Rs 3.00 = Rs 288.00

IMPORTANT FORMULA & RELATIONS OF THE CHAPTER: **SUMMARY**

1. Q = ne
2. I = Q/t = ne/t
3. Q = It
4. e = p = 1.6 x 10^{-19} C
5. Potential or potential difference ,V = W/q
6. W = Vq
7. Ohm's law : V = IR , I = V/R
8. R = p l/A , p = specific resistance
9. Series: Equivalent resistance : R = R1 + R2 + R3 ....
10. Parallel: Equivalent resistance: 1/R = 1/R1 + 1/R2 + 1/R3 ....
11. **Electric work done, Energy : W=E = VIt**
12. **or W = E = H(heat) = I^2Rt**
13. **Power P = W/t**
14. **Power P = VI**
15. **Power P = I^2R**
16. **Power P = V^2/R**
17. **Electric energy consumed = power x time , W = E = P X t**
18. **1 watt = 1 Joule / 1 second**
19. **1 watt = 1 volt x 1 Ampere**
20. **1 Joule = 1 watt x 1 second (1J = 1W X 1S)**
21. 1 kilowatt=1KW = 10^3 W
22. 1megawatt=1MW = 10^3 KW= 10^6
23. 1gigawatt=1GW = 10^3 MW= 10^6 KW = 10^9 W
24. 1 H.P = 746 W
25. **UNITS:**
    a. electric charge : Coulomb (C), mili coulomb, micro coulomb
    b. electric current : C/t, A, mA, micro Ampere etc
    c. Potential or potential difference : volt(V), mili volt, microvolt, kilovolt, megavolt etc
    d. resistance: ohm,mili ohm, kilo ohm etc
    e. resistivity (specific resistance): ohm-metre
26. Joule's Law of Heating (H = $\mathbf{I^2Rt}$):
    a. H ∞ $\mathbf{I^2}$
    b. H ∞ **R**
    c. H ∞ **t**

1 KWh = 3.6 x 10^6 J

HOME WORK

1. What do you understand by

(a) Electric energy

(b) Electric power

(c) Commercial unit of energy

(d) 1 joule electric energy

(e) 1 watt power

2. Power of an electric bulb is 60 W and another bulb has power of 100W.

(a) Which bulb has more resistance(give reason also)

(b) Which bulb will consume more electric energy when will be connected in an electric circuit separately (give reason)

(c) In which combination (series or parallel)electric energy consumed by the bulbs will be less if a potential difference of 220 volt is applied across the combination in each case for a time of 5 second.

3. Write the units of electric power and show their relation

4. Show that 1 KWh = 3.6×10^6 J

5. How is electric power related with consumption of electric energy.

6. At sainik school Goalpara, in class X-B, there are 4 fans of power 120W each , 3 tube light of power 40 W each and 2 CFL of power 20 W each. All the appliances were used for 6 hrs daily in the month of February 2020. Calculate the amount of electric bill to be paid to electricity office for that month if cost per unit is Rs. 30/-