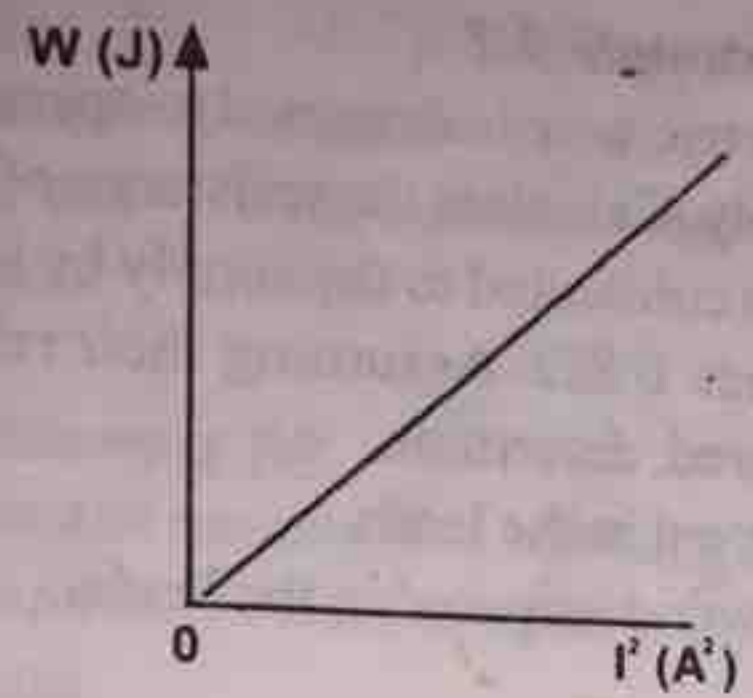


Fig. 9.3 Graph of W against I^2

Energy conversion

(i) Conversion of electrical energy into mechanical energy i.e, in lifting of a load using an electric motor.

(ii) The conversion of solar energy to electricai and heat energy, as in solar cells, solar heaters, etc.

(iii) The conversion of electrical energy to heat energy, e.g. a solar plate, electric heater, electric cables, etc

Worked example 9.3

An electric generator with a power of 3.0kw at a voltage of 1.5kv distributes power along cables of total resistance 20Ω. Calculate the power loss in the cable.

Solution

$R = 20\Omega$, $V = 1.500V$, $P = 3kw = 3000w$

$$P = IV$$

$$I = \frac{P}{V} = \frac{3000}{1500} = 2A$$

$$P_{lost/dissipated} = I^2R$$

$$= (2)^2 \times 20$$

$$= 80w$$

9.3 Electrical Power

Electrical power is the time rate at which the energy is used up. Power is measured in watts (w).

$$\text{Power} = \frac{\text{workdone}}{\text{time}} = \frac{Ivt}{t}$$

$\therefore$ Power = Iv .... (i)

or power = I^2R ....(ii)

Power = $\frac{V^2}{R}$ ....(iii)

Worked example 9.4

Calculate the power dissipated by a heater of 220V and a resistance of 10 Ohms

Solution

$$P = \frac{V^2}{R} = \frac{220 \times 220}{10} = 4840 \text{ watts}$$

$$= 4.84 \text{ kilowatt (kw)}$$

Types of power

(i) real (ii) apparent (iii) active

(iv) reactive power

1. Real power: This is the power used in driving machines in the factories in which (cosθ) power factor is considered, e.g. induction motor fluorescent, etc.

It is represented as IV cosθ

2. Apparent power: Apparent power is just the power available for any electrical appliance which is simply structured, eg. a transistor radio, computer, etc.

$$\text{Power factor} = \frac{\text{Real power}}{\text{Apparent power}}$$

Power factor = cosθ

Real power = IV cos θ

$$\therefore \text{Apparent power} = \frac{\text{Real power}}{\text{Power factor}}$$

$$\text{Apparent power} = \frac{IV\cos\theta}{\cos\theta}$$

Apparent power = IV

3. Active and reactive power: This is too advanced for this level, but little of it has been dealt with under Simple Ac Circuit (Chapter 43)

9.4 Measurement of Electrical Power

Electrical power consumed by an electrical appliance is measured in watt.

Watt is the product of electrical current and the p.d between the two points.

I watt = volts x Ampere

$$\text{Kilowatts-hour} = \frac{\text{volt x Ampere}}{1000} \times \text{time (hours)}$$

Horse power is equivalent to 746 watts $\simeq$ 750 watts

I watt = volts x Amperes

$$\text{kilowatt hour} = \frac{\text{power (kw) x time (hrs)}}{1000}$$

kilowatt-hour is the unit of electrical energy watt-hour = volt x Amperes x hours

watt hour = watts x hours

Worked example 9.5

Calculate the workdone when a current at 5Amps flows through a conductor for 10secs if the p.d applied is 5v.

Solution

I = 5A, V = 5V and t = 10sec

$$W = IVt$$

$$\therefore W = 5 \times 5 \times 10$$
$$= 25 \times 10$$
$$= 250J$$

Worked example 9.6

A lamp is marked 12V, 240w. How many joules does it consume in an hour and what is the current it passes?

Solution

Given that Voltage = 12V

Power = 24w, t = 1 hr = 3600s

Energy = ?

Power = IV

$$24 = 12I$$

$$I = \frac{24}{12}$$

$$= 2\text{Amps}$$

$$\text{Energy} = Ivt$$
$$= 12 \times 2 \times 3600$$
$$= 86400J$$
$$= 86.4kJ$$

Worked example 9.7

A 3kw electric wire is designed to operate from 240V supply. Calculate the resistance of the wire. The wire is connected to the supply by long lead of resistance 0.8Ω. Assuming their resistance remain altered, determine

(i) the current in the leads

(ii) the power dissipated in the leads.

Solution

Given that

Power = 3kw = 3000w

Voltage = 240V

Resistance = ?

Resistance of lead = 0.8Ω

(i) $\text{power} = IV = \frac{V^2}{R}$

$$\text{Power} = \frac{V^2}{R} \Rightarrow 3000 = \frac{(240^2)}{R}$$

$$R = \frac{240 \times 240}{3000}$$

$$R = 19.2\Omega$$

(ii) Resistance of wire = 19.2Ω

Resistance of lead = 0.8Ω

Total resistance = (0.8 + 19.2) Ω

= 20Ω

Power dissipated = ?

$$\text{Power} = IV = \frac{V^2}{R}$$

$$= \frac{(240)^2}{20}$$

$$\therefore \text{Power} = 2880W = 2.88KW$$

9.5 Electrical Energy Consumed

Power is consumed in kilowatt-hours (KWh). Meters are calibrated in (KWh) so that I Kwh is the energy supplied at working rate of 1000watts for 1 hour

1 hour = (60 x 60) secs = 3600sec

1 kilowatt = 1000 watts

1 kwh = 1 kilowatt x 1 hour

= 1000 x 60 x 60

= 3600000Joules (J)

= 3.6MJ.

Larger value

Kilowatt = 1000watts = 10^3watts

Megawatt = 1000000 watts = 10^6 watts

Gigawatt = 10^9watts

Worked example 9.8

Find the cost of running five 50w lamps and three 100w lamps for 6 hours if electric energy costs ₦20 per unit.

Solution

Total power consumed = (5 x 50) + (3 x 100)

= 250 + 300

= 550watts (w)

Time = 6 hours

Total energy consumed = 550 x 6

= 3300 watt hour

$= \frac{3300}{1000}$ kilowatts hour

= 3.3kwh

since ₦20 per unit

Then, cost = 3.3 x 20 = ₦66

Worked example 9.9

A household refrigerator is rated 200w. If electricity costs 5k per kwh, what is the cost of operating it for 20 days?

Solution

P = 200w = 0.2kw,

t = 20days = (24 x 20)hrs = 480hrs

energy consumed = power (kw) x time (hr)

= 480 x 0.2

= 96kwh

1kwh = 5k

96kwh = (96 x 5)k = 480k

= ₦4.80

Worked example 9.10

An electric welding machine has a power factor of 0.5. When the apparent power is 100w, find the real power

Solution

Given that Cosθ = 0.5

Real power = ?

Apparent power = 100w

Real power = power factor x apparent power

= 0.5 x 100

= 50w.

9.6 Heating Effect of an Electric Energy and its Application

1. Riverting/Electric welding: To rivert, a strong electric current is passed through two metal bands. When they are in contact as the resistances of the metal bars are in very high temperature suitable for welding, a reverting is obtained. This is said to be the process whereby two metals are joined together by a revert.

2. Electric heater: Heat is produced when electric current flows through a wire—the construction is that an element made of coils of nichrone (an alloy) is passed through the metal and large currents flow through them. This enables the heater to perform actively.

3. Fuse: This is made up of an alloy of tin and lead. It is connected in a series with the electrical installation so that the same current flows through it. It also contains a piece of wire of low melting point. When the current in the circuit exceeds the related value and the fuse being heated to a higher temperature and its melting point, the circuit cuts off.

9.7 Electrical Installation

Electrical installation is the branch of physics that leads to electrical engineering. It deals with how two wires, one live and the other neutral can be connected together in a building in order to bring light into the housing system.

Live wires are usually insulated with red colour insulator, while neutral wires are insulated with black insulators. The right connection of the two brings about electricity.

10. E. M. F AND CIRCUITS

10.1 E. m. f

E. m. f simply means electromotive force, which is the total energy per current obtained from a cell. It can also be defined as the force necessary to drive the current, thereby setting up a p.d across the various elements, i.e, the sum of the potential differences across the external terminals and internal resistances. It is denoted by E and measured in volts (v).

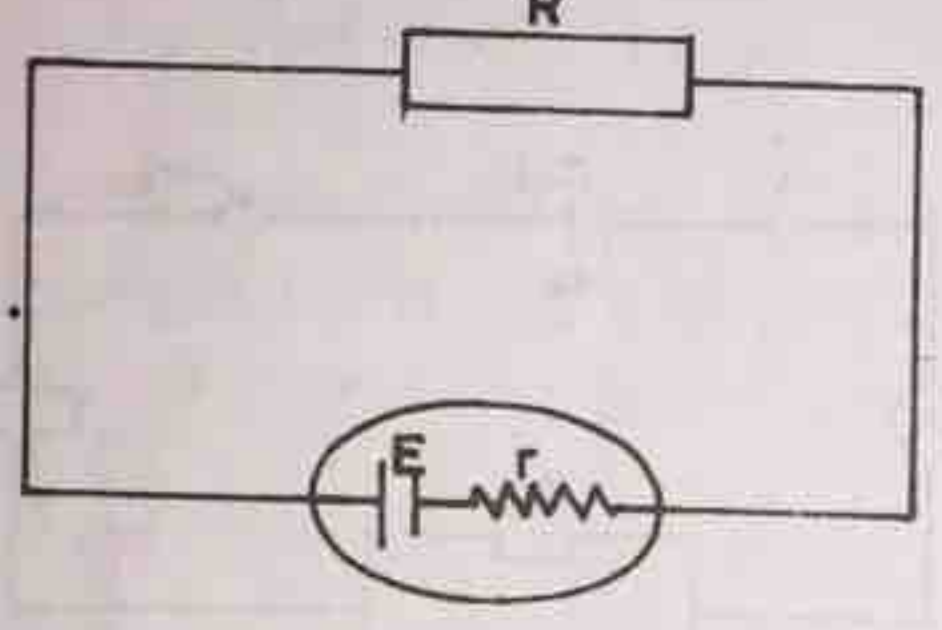


Fig. 10.1 E.m.f

R = external resistance, r = internal resistance.
Therefore

E = p.d across external resistance + p.d across internal resistance

$E = IR + Ir$

$E = I(R + r)$

$$I = \frac{E}{R + r}$$

Lost voltage: Lost voltage is defined as the p.d across the internal resistance. It is denoted by Vr and measured in volts (v) Vr – Ir.

E. m. f. is used as source of current for battery or cell, generators or dynamo, solar cells, photo cell, etc which work as follows:

(i) The battery or cell converts chemical energy to mechanical energy.

(ii) Generators convert mechanical energy to electrical energy.

(iii) Solar cells convert light energy to electrical energy.

10.2 Experiment to Measure the Internal Resistance of a Cell

Aim: To measure the internal resistance of a cell

Apparatus: Rheostat, ammeters, voltmeter, cell and a key.

Method: When the key is opened i.e. no current flowing in the cell, record the voltmeter reading which is equal to the e.m.f of the cell.

Close the key and adjust the rheostat so that small current flows. Record the readings of I and V in a table. After each pair of reading, open the key.

Obervations: The e.m.f E has the same value at the beginning of the experiment.

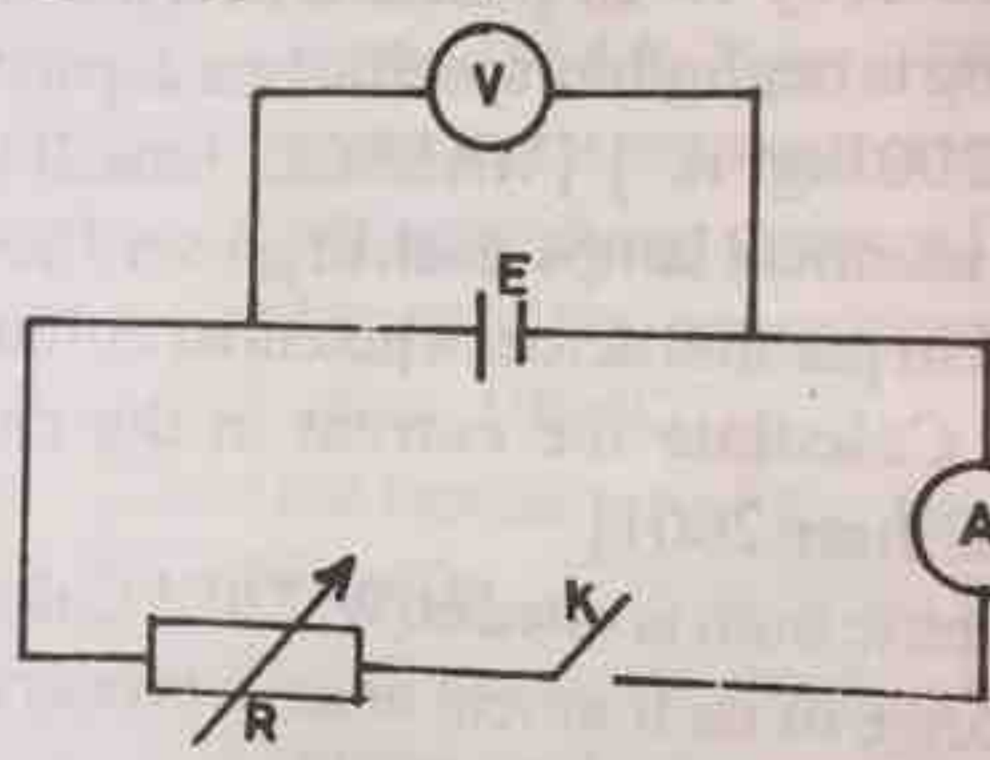


Fig. 10.2 To measure the internal resistance of a cell

Data:

S/N	V(volts)	I(A)
1	V_1	I_1
2	V_2	I_2
3	V_3	I_3
:	:	:
:	:	:
:	:	:
:	:	:
n	V_n	I_n

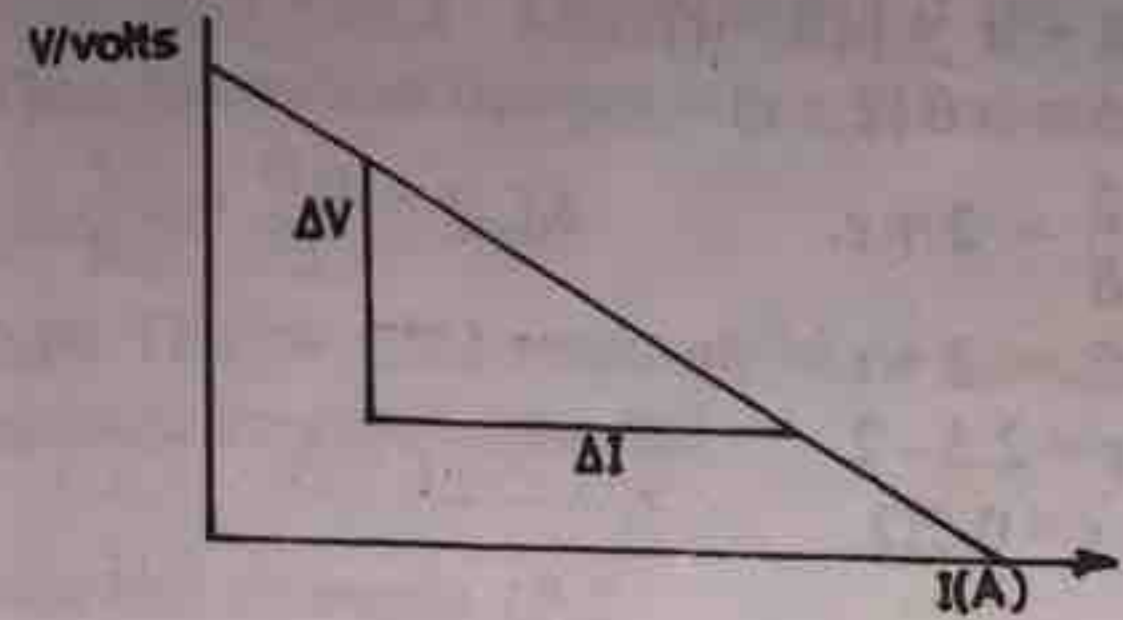


Fig. 10.3 Graph of V against I

$E = V + Ir$

$E = V - Ir \equiv mx + C$

slope / gradient $= \dfrac{\Delta V}{\Delta I} = -r$

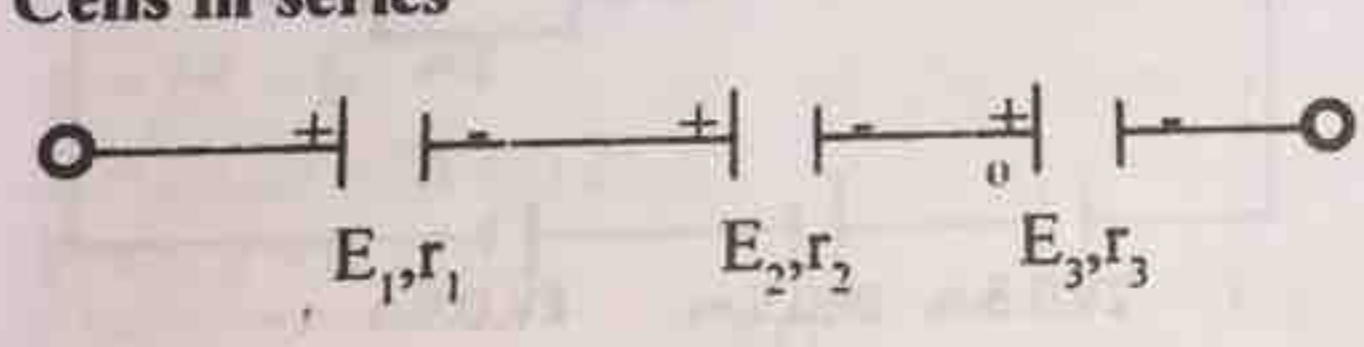
Precautions

(i) Check zero errors of ammeters and voltemeters.

(ii) Make sure all connections are tightened.

(iii) Avoid errors due to parallax when taking your readings.

Cells in series



When cells are arranged in series, they are used to obtain greater e.m.f. Thus, the resultant e.m.f terminals AB in the series above is equal to the sum of the individual e.m.f of the cells.

$$E_e = E_1 + E_2 + E_3 + \dots\dots\dots\dots + E_n$$

Similarly, the resultant of the internal resistance of the cell is also equal to the sum of internal resistance of the cell.

$$r_c = r_1 + r_2 + r_3 + \dots\dots\dots\dots + r_n$$

But if two cells are arranged opposite to each other as shown in the series below.

Cells in parallel

When cells are arranged in parallel, they supply current for a longer period. Thus, the resultant e.m.f of the terminals is equal to the number of the cell - for equal e.m.f.

Thus, $E_r = E$ where $E = E_1 = E_2 = E_3$

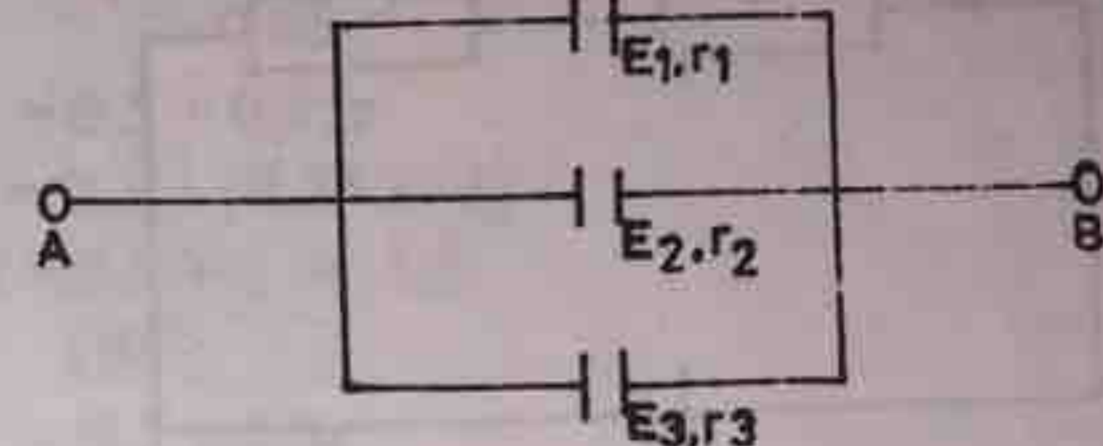


Fig. 10.4 Cells in parallel

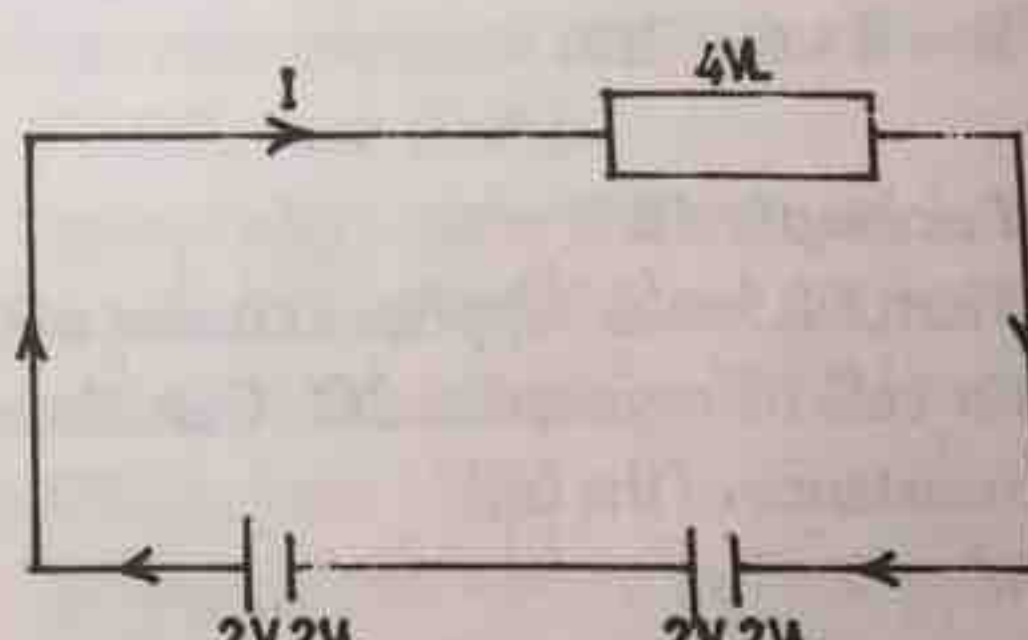
Similarly, the reciprocal of the resultant internal resistance is equal to the sum of the reciprocal of the individual internal resistance of the cells.

$$\frac{1}{r_e} = \frac{1}{r_1} + \frac{1}{r_2} + \frac{1}{r_3} + \dots\dots\dots\dots + \frac{1}{r_n}$$

Worked example 10.1

Two cells, each of e.m.f 2.0v and internal resistance 2Ω are connected in a series. A 4Ω resistor is connected in a series to the cell. Calculate the: (i) current flowing in the circuit (ii) voltage drop.

Solution



$E_C = 2 + 2 = 4V$, $r_C = 2 + 2 = 4\Omega$, $R = 4\Omega$

(i) $I = \dfrac{E}{R + r} = \dfrac{4}{4 + 4} = \dfrac{4}{8} = 0.5A$

(ii) voltage drop (lost voltage) = Ir

$= 0.5 \times 4 = 2V$