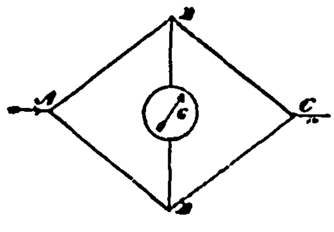
and consists essentially of wires arranged in multiple arc. Suppose current enters at A, it then divides, part going through A B C, and part through A D C, dividing itself into parts that shall be to one another inversely as the resistances in the branches. Since the current is going from A to C the point A must be at a higher potential than the point C and therefore there will be a gradual fall of



potential along the branches A B C and A D C. It is therefore possible to find various parts along these branches that will be at the same potential. By altering the resistances in the branches it may be so adjusted that the point B is at the same potential as the point D. When this is so the bridge is in a condition for taking the observation. When B and D are at the same potential there is no E M F between these points and consequently no current will flow in the wire connecting them. The attainment of this condition is indicated by no deflection on the galvanometer G that connects B to D.

Let AB = the resistance in the arm AB

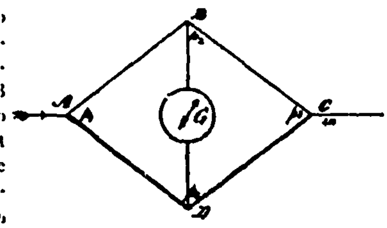
BC = the resistance in the arm BC, and so on.

We have the following simple relation when the above condition has been satisfied:

AB. DC = AD. BC, and as the resistances in three of the arms are known it is an easy matter to find the fourth. Suppose DC to be the unknown, then

$$DC = \frac{AD.\ BC}{AB.}$$

The following is a proof of the principle of the bridge: Suppose the figure represents the instrument when there is no deflection on the galvanometer, i. e., when no current is passing through B and D, and suppose p to represent the potential at B which would also be the potential at D since no current flows in BD, and let p_1 represent the potential at C.



By Ohm's law we have $C = \frac{E}{R}$; but the E M F in AB is the difference of potential between p and p_2 ∴ C in AB $= \frac{E}{R} = \frac{p_1 - p_2}{R \text{ of } AB}$ and similarly the current in BC $= \frac{p_2 - p_3}{R \text{ of } BC}$, but the same current must pass through BC as that passed through AB, since none goes through BD.

$$\therefore \frac{p_1 - p_2}{AB} = \frac{p_2 - p_3}{BC} \quad (1)$$

In the same way the current in AD $= \frac{p_1 - p_2}{AD}$ and it must be equal to

$$\frac{p_2 - p_3}{DC} \text{ that is } \frac{p_1 - p_2}{AD} = \frac{p_2 - p_3}{DC} \quad (2)$$

and if we divide (1) by (2) we get $\frac{AD}{AB} = \frac{DC}{BC}$ ∴ AD. BC = AB. DC.

Numerical example:

AB = 100 ohms BC = 9756 ohms

AD = 10 ohms DC = unknown

$$DC = \frac{10 \times 9756}{100} = 975.6 \text{ ohms.}$$

---

13. How are very high resistances measured? A galvanometer of 6000 ohms shows a deflection of 10° when a certain resistance is in circuit with it. Knowing that the same galvanometer shows the same deflection with a resistance of 1-10th megohm in circuit when shunted with a 1-99th shunt, find this certain resistance. The resistance of the battery is neglected.

ANS.—As the ordinary bridge is only capable of measuring resistances up to 1,111,100 ohms a different method is adopted for measuring resistances above this, viz: by the galvanometer.

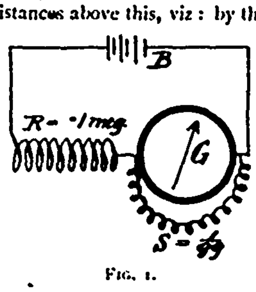


FIG. 1.

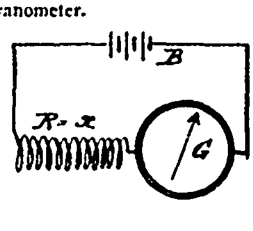


FIG. 2.

Let the first figure indicate the circuit with 1-10th megohm in series with the shunted galvanometer, and the second figure that of the circuit with the unknown resistance in series with the galvanometer without the shunt. By Ohm's law we have

$$C = \frac{E}{R} = \frac{E}{R + \frac{G\,S}{G+S} + B} = k.\ d_1.\ \frac{G+S}{S}$$

Where $\frac{G\,S}{G+S}$ = Joint R of Galvanometer and Shunt,

B = Resistance of Battery,

k = a Constant to bring d. $\frac{G+S}{S}$ to Amperes,

d_1 = Deflection of Galvanometer,

$\frac{G+S}{S}$ = Multiplying Power of the Shunt.

In the second figure we have

$$C^1 = \frac{E}{R_1} = \frac{E^1}{R_1 + G_1 + B_1} = k.\ d_2.$$

In the first equation we have

$$E = \left(R + \frac{G\,S}{G+S} + B\right).\ k\ d_1.\ \frac{G+S}{S}$$

and in the second equation we have

$$E = (R_1 + G_1 + B)\ k.\ d_2.$$

$$\therefore (R_1 + G_1 + B_1)\ k.\ d_2 = \left(R + \frac{G\,S}{G+S} + B\right).\ k\ d_1 \left(\frac{G+S}{S}\right)$$

Substituting the numbers in the question and omitting the resistance of the battery and cancelling k, we have

$$(R^1 + G_1)\ d_2 = \left(R + \frac{G\,S}{G+S}\right)\ d.\ \frac{G+S}{S}$$

$$(R_1 + 6000)\ d_2 = \left(100000 + \frac{6000 \times 60.6}{6000 + 60.6}\right) d_1 \frac{6000 \times 60.6}{60.6}$$

and as $d_2 = d_1$, we get

$$R_1 + 6000 = (100000 + 60).\ 100$$

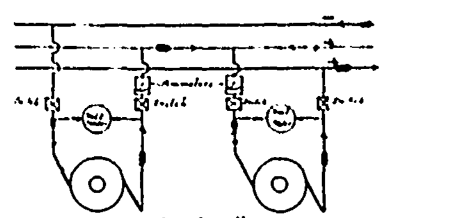
$$R_1 = 10{,}000{,}000.$$

Therefore, the resistance of R or x is 10 megohms.

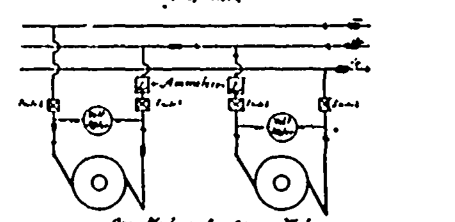
---

14. Show by a diagram the general arrangement and connections of generators running on a 3-wire system. Show by an arrow the direction of the currents if (1) both machines are doing exactly the same amount of work; (2) if one machine is doing more than the other. Place in position ampere and voltmeters.

ANSWER.—



Both Machines doing the same amount of Work



One Machine doing more Work than the other

---

15. 880,000 lines of force (N) are to forced through a bar 20 in. long and 8 sq. inches in area. Find the reluctance and the magnetizing force in ampere turns to effect this magnetization. Permeability = 166.

ANS.—Reluctance $= \frac{\text{length}}{\text{area} \times u} = \frac{20}{8 \times 166} = \frac{1}{66.4}$

Ampere turns = N × reluctance × .3132

$= 880000 \times \frac{1}{A.\ u} \times .3132$

$= 880000 \times \frac{1}{66.4} \times .3132 = 4150$

16. In a generator which is driven by a 100 H.P. engine, belt speed 5,000 ft per minute, there are 200 conductors in the armature winding 100 sections in commutator, the gap is 45°. Find the torque and the drag on the active conductors.

ANS.—100 h.p. = 5000' × torque

$$\text{Torque} = \frac{100 \times 33000}{5000}$$

$$= 660 \text{ lbs.}$$

The active conductors $= \frac{270}{360}$ of 200 = 150 ∴ $\frac{660}{150}$ = 4.4 lbs. drag on each conductor.