15.12 SOLVED NUMERICALS OF BOOK:

PROBLEM # 15.1

A galvanometer has a resistance of 50Ω and it deflects full scale when a current of 10 mA flows in it. How can it be converted into an ammeter of range 10A?

Given that:

$R_g = 50\Omega$

$I_g = 10mA = 0.01\ A$

$I = 10A$

Required:

$R_s = ?$

Solution:

$$R_s = \frac{I_g R_g}{I - I_g}$$

$$R_s = \frac{0.01 \times 50}{10 - 0.01}$$

$$\boxed{R_s = 0.05\Omega}$$

SELF TEST (1)

A galvanometer of resistance 50 ohm gives full scale deflection with a current of 10 m A. A shount of 0.05 ohm is connected in parallel to convert it into an ammeter. Find the range of the ammeter. **(2012)**

PROBLEM # 15.2

A galvanometer whose resistance is 40Ω deflects full scale for a potential difference 100 mV across its terminals. How can it be converted into an ammeter of 5A range?

Given that:

$R_g = 40\Omega$

$V_g = 100\ mV = 0.1\ V$

$I = 5A$

Required:

$R_s = ?$

Solution:

$$I_g = \frac{V_g}{R_g}$$

$$I_g = \frac{0.1}{40}$$

$$I_g = 2.5 \times 10^{-3} A$$

$$R_s = \frac{Ig\, R_g}{I - I_g}$$

$$R_s = \frac{2.5 \times 10^{-3} \times 40}{5 - 2.5 \times 10^{-3}}$$

$$\boxed{R_s = 0.02\Omega}$$

SELF TEST (2)

A galvanometer has a resistance of 50 ohms, and gives full scale deflection for potential difference of 150mv. If the galvanometer is to be converted into an ammeter reading upto 4A. What should be the resistance of the parallel resistor used.

(Ans. $R_S = 0.037\Omega$)

PROBLEM # 15.3

The coil of a galvanometer which has a resistance of 50Ω and a current of 500μA produces full scale deflection in it. Show by a diagram how it can be converted to **(a)** an ammeter of 5A range and compute the shunt resistance. **(b)** a voltmeter of 300V range and compute the series resistance.

Given that:

$R_g = 50\Omega$

$I_g = 500\mu A = 5 \times 10^{-4} A$

(a) $I = 5A$

(b) $V = 300V$

Required:

(a) $R_s = ?$

(b) $R_x = ?$

Solution:

(a)

$$R_s = \frac{I_g R_g}{I - I_g}$$

$$R_s = \frac{5 \times 10^{-4} \times 50}{5 - 5 \times 10^{-4}}$$

$$\boxed{R_s = 0.005\Omega}$$

(b)

$$R_x = \frac{V}{I_g} - R_g$$

$$R_x = \frac{300}{5 \times 10^{-4}} - 50$$

$$\boxed{R_x = 599950\Omega}$$

SELF TEST (3)

The coil of a galvanometer having a resistance of 50 ohms and a current of 500 micro-amperes produces a full scale deflection in it. Find

(i) The shunt required to concert it into an ammeter of 5 amperes range.

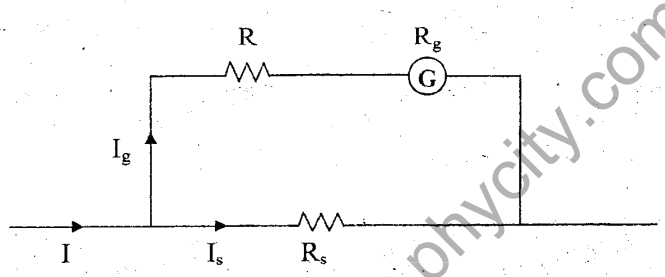
(ii) The series resistance required to convert it into a voltmeter of 300 volt range.

(Ans. $R_S = 0.005\Omega$, $R_X = 599950\Omega$) **(2002 P.E)**

YEAR 2002 P.E.

PROBLEM # 15.4

A galvanometer of resistance 2.5Ω deflects full scale for a current of 0.05A. It is desired to convert this galvanometer into an ammeter reading 25A full scale. The only shunt available is of 0.03Ω. What resistance R must be included in series with the galvanometer as shown in figure for using this shunt?



Given that:

$R_g = 2.5\Omega$

$I_g = 0.05A$

$I = 25A$

$R_s = 0.03\Omega$

Required:

$R = ?$

Solution:

Let R' be the equivalent resistance of R and R_g connected in series.

$R' = R + R_g$

$V' = V_s$

$I_g R' = I_s R_s$

$$R' = \frac{(I - I_g)R_s}{I_g}$$

$$R' = \frac{(25 - 0.05)x0.03}{0.05}$$

$R' = 14.97\Omega$

$R + R_g = 14.97$

$R = 14.97 - 2.5$

$\boxed{R_s = 12.47\Omega}$

PROBLEM # 15.5

An ammeter deflects full scale with a current of 5A and has a total resistance of 0.5Ω. What shunt resistance must be connected to it to measure 25A full scale?

Given that:

$I_A = 5A$

$R_A = 0.5\Omega$

$I = 25A$

Required:

$R_s = ?$

Solution:

$$R_s = \frac{I_A \times R_A}{I - I_A}$$

$$R_s = \frac{5 \times 0.5}{25 - 5}$$

$\boxed{R_s = 0.125\Omega}$

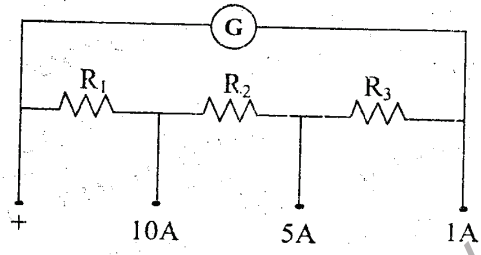
SELF TEST (4)

A ammeter deflects full scale a current of 5 amperes and has a total resistance of 0.5 ohm. What shunt resistance must be connected to it to measure full scale current upto 30 amperes? **(2003 P.M)**

(Ans. $R_S = 0.01\Omega$)

PROBLEM # 15.6

A moving coil galvanometer has a resistance of 50Ω and deflects full scale with a current of 0.005A. What resistance R_1, R_2 and R_3 must be connected to it as shown in figure to convert into a multi range ammeter having ranges of 1A, 5A and 10A?



Given that:

$R_g = 50\Omega$

$I_g = 0.005A$

(i) $I = 10A$

(ii) $I = 5A$

(iii) $I = 1A$

Required:

(i) $R_1 = ?$

(ii) $R_2 = ?$

(iii) $R_3 = ?$

Solution:

$$R_s = \frac{I_g R_g}{I - I_g} \rightarrow (i)$$

(i) $R_s = R_1$

$$eq(1) \Rightarrow R_1 = \frac{I_g R_g}{I - I_g}$$

$$R_1 = \frac{0.005 \times 50}{10 - 0.005}$$

$$\boxed{R_1 = 0.0251\Omega}$$

(ii) $R_s = R_1 + R_2$

$$eq(1) \Rightarrow R_1 + R_2 = \frac{I_g R_g}{I - I_g}$$

$$0.0251 + R_2 = \frac{0.005 \times 50}{5 - 0.005}$$

$$0.0251 + R_2 = 0.0505$$

$$\boxed{R_2 = 0.0249.2}$$

(iii) $R_s = R_1 + R_2 + R_3$

$$eq\ (1) \Rightarrow R_1 + R_2 + R_3 = \frac{I_g R_g}{I - I_g}$$

$$0.0502 + R_3 = \frac{0.005 \times 50}{1 - 0.005}$$

$$0.0502 + R_3 = 0.2513$$

$$\boxed{R_3 = 0.201\Omega}$$

PROBLEM # 15.7

A 300V Voltmeter has a total resistance of 20,000Ω. What additional series resistance must be connected to it to increase its range to 500V?

Given that:

$V_v = 300V$

$R_v = 20{,}000\Omega$

$V = 500V$

Required:

$R_x = ?$

Solution:

$$I_v = \frac{V_v}{R_v}$$

$$I_v = \frac{300}{20{,}000}$$

$$\boxed{I_v = 0.015\ A}$$

$$R_x = \frac{V}{I_v} - R_v$$

$$R_x = \frac{500}{0.015} - 20{,}000$$

$$\boxed{R_x = 13333.3\Omega}$$

SELF TEST (5)

Q.1 A 250 volt voltmeter has a total resistance of 20.000Ω. What additional series resistance must be connected to it to increase its range to 400 volts? **(2004)**

(Ans. R_X = 12000 Ω = 12 KΩ)

Q.2 A 300 volts voltmeter has a total resistance of 20 Kilo-ohms. What additional resistance is required to convert it into a voltmeter, reading upto a maximum of 600 volts? **(2003 P.E, 2009)**

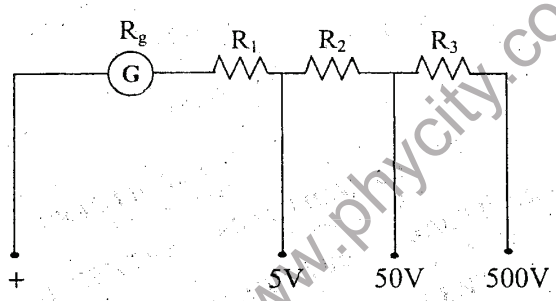
(Ans. R_X = 20K Ω)

Q.3 A 200 volt voltmeter has a total resistance of 20.000Ω. What additional series resistance must be connected to it to increase its range to 600 volts? **(2013)**

(Ans. R_X = 40,000 Ω = 40 KΩ)

PROBLEM # 15.8

The resistance of a moving coil galvanometer is 25Ω and current of 1mA causes scale deflection in it. It is to be converted into a multi range Voltmeter. Find the series resistances R_1, R_2 and R_3 to give the range of 5V, 50V and 500V at the terminals as shown in figure.



Given that:

$R_g = 25\Omega$

$I_g = 1mA = 1x10^{-3}A$

(a) V = 5Volt

(b) V = 50Volt

(c) V = 500Volt

Required:

(a) R_1 = ?

(b) R_2 = ?

(c) R_3 = ?

Solution:

$$R_x = \frac{V}{I_g} - R_g$$

(a) $R_x = R_1$

$$eq(1) \Rightarrow R_1 = \frac{V}{I_g} - R_g$$

$$R_1 = \frac{5}{1\times10^{-3}} - 25$$

$$\boxed{R_1 = 4975\Omega}$$

(b) $R_x = R_1 + R_2$

$$eq(1) \Rightarrow R_1 + R_2 = \frac{V}{I_g} - R_g$$

$$4975 + R_2 = \frac{50}{1 \times 10^{-3}} - 50$$

$$4975 + R_2 = 49950$$

$$R_2 = 49950 - 4975$$

$$\boxed{R_2 = 44975\Omega}$$

(c) $R_x = R_1 + R_2 + R_3$

$$eq(1) \Rightarrow R_1 + R_2 + R_3 = \frac{V}{I_g} - R_g$$

$$49750 + 44975 + R_3 = \frac{500}{1 \times 10^{-3}} - 25$$

$$94725 + R_3 = 499975$$

$$R_3 = 499975 - 94725$$

$$\boxed{R_3 = 405250\Omega}$$

PROBLEM # 15.9

The galvanometer of ohmmeter has a resistance of 25Ω and deflects full scale with a current of 2mA in it. The emf of its cell is 1.5V.

(i) What is the values of the series resistance?

(ii) What is the values of x connected to its terminals do the deflection of $\frac{1}{5}, \frac{1}{2}$, and $\frac{4}{5}$ full scale correspond?

(iii) Is the scale of the ohmmeter linear?

Given that:

(i) $R_g = 25\Omega$

$I_g = 2mA = 2x10^{-3}A$

$V = 1.5Volt$

(ii) (a) $I' = \frac{1}{5} I_g$

(b) $I' = \frac{1}{2} I_g$

(c) $I' = \frac{4}{5} I_g$

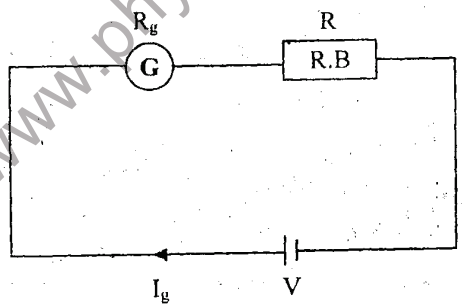
Required:

(i) $R = ?$

(ii) (a) $X_1 = ?$

(b) $X_2 = ?$

(c) $X_3 = ?$



Solution:

(i) $V = I_g (R_g + R)$

$$R = \frac{V}{I_g} - R_g$$

$$R = \frac{1.5}{1 \times 10^{-3}} - 25$$

$$\boxed{R = 725\Omega}$$

(ii) $V = I' (R_g + R + X)$

$$R + X = \frac{V}{I'} - R_g \quad \text{---------- (1)}$$

(a) $I' = \frac{1}{5} X 2 \times 10^{-3}$

$I' = 0.0004$ A

$$\text{eq(1)} \Rightarrow 725 + X = \frac{1.5}{0.0004} - 25$$

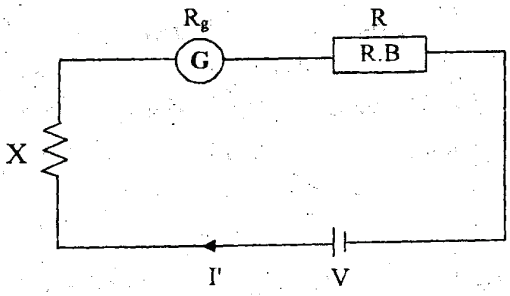
$$\boxed{X = 3000\Omega}$$

(b) $I' = \frac{1}{5} \times 2 \times 10^{-3}$

$I' = 0.001$ A

$$\text{eq(1)} \Rightarrow 725 + X = \frac{1.5}{0.001} - 25$$

$$\boxed{X = 750\Omega}$$



(c) $I' = \frac{4}{5} \times 2 \times 10^{-3}$

$I' = 0.0016A$

$$\text{eq(1)} \Rightarrow 725 + X = \frac{1.5}{0.0016} - 25$$

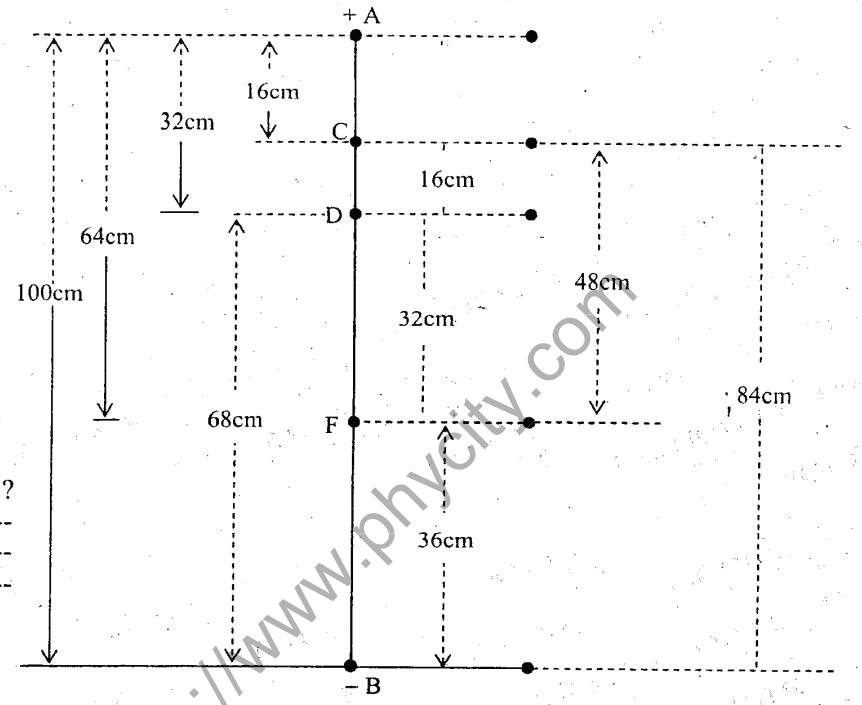
$$\boxed{X = 187.5\Omega}$$

(1) The scale of ohmmeter is not linear.

PROBLEM # 15.10

A constant potential difference of 25V is applied across a uniform resistance wire AB, 100cm long. Terminals are soldered to three points C,D,F on the wire respectively 16, 32 and 64 cm from A. find the potential differences

(i) V_{AC} **(ii)** V_{AD} **(iii)** V_{AF} **(iv)** V_{CD} **(v)** V_{CF}
(vi) V_{DF} **(vii)** V_{CB} **(viii)** V_{DB} and **(ix)** V_{FB}



Given that:

$V_{AB} = 25$ volt
$L_{AB} = 100$cm
$V_{Ac} = ?$ $V_{AD} = ?$

$V_{FB} = ?$

Solution:

For a wire of constant linear density

$R = L$

$V = I\,L$

$I = \frac{V_{AB}}{L_{AB}}$

$I = \frac{25}{100}$

$I = 0.25$

(i) $V_{AC} = I\,L_{AC}$
$V_{AC} = 0.25 \times 16$
$\boxed{V_{AC} = 4V}$

(ii) $V_{AD} = I\,L_{AD}$
$V_{AD} = 0.25 \times 32$
$\boxed{V_{AD} = 8V}$

(iii) $V_{AF} = I\,L_{AF}$
$V_{AF} = 0.25 \times 64$
$\boxed{V_{AF} = 16V}$

(iv) $V_{CD} = I\,L_{CD}$
$V_{CD} = 0.25 \times 16$
$\boxed{V_{CD} = 4V}$

(v) $V_{CF} = I\,L_{CF}$
$V_{CF} = 0.25 \times 48$
$\boxed{V_{CF} = 12V}$

(vi) $V_{DF} = I\,L_{DF}$
$V_{DF} = 0.25 \times 32$
$\boxed{V_{DF} = 8V}$

(vii) $V_{CB} = I\,L_{CB}$
$V_{CB} = 0.25 \times 84$
$\boxed{V_{CB} = 21V}$

(viii) $V_{DB} = I\,L_{DB}$
$V_{DB} = 0.25 \times 68$
$\boxed{V_{DB} = 17V}$

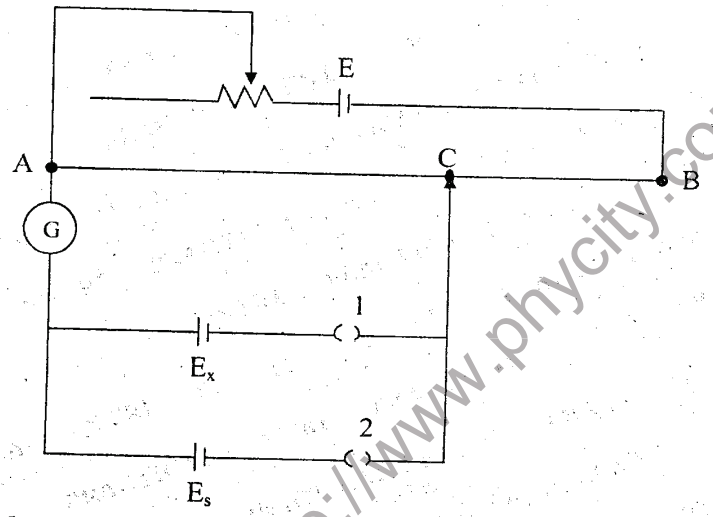
(ix) $V_{FB} = I\,L_{FB}$
$V_{FB} = 0.25 \times 36$
$\boxed{V_{FB} = 9V}$

PROBLEM # 15.11

A potentiometer is set up to measure the emf. E_x of cell. The potentiometer wire is 120 cm long. E_s is the emf of a standard cadmium cell equal to 1.018V. When the key 1 only is closed to include the emf E_x in the galvanometer circuit, the galvanometer gives no deflection with the sliding contact at C, 56.4 cm from A. When the key 2 only is closed to include the emf E_s in the galvanometer circuit, the balance is obtained at C, 43.2 cm from A.

(a) What is the emf E_x of the cell?

(b) What is the Potential difference across the length of the wire AB?



Given that:

$L_{AB} = 120$ cm

$L_x = 56.4$ cm

$L_s = 43.2$ cm

$E_s = 1.018$V

Required:

(a) $E_x = ?$

(b) $V_{AB} = ?$

Solution:

(a)
$$\frac{E_x}{E_s} = \frac{L_x}{L_s}$$

$$\frac{E_x}{1.018} = \frac{56.4}{43.2}$$

$$\boxed{E_x = 1.329\text{V}}$$

(b) $E_s = I L_s$

$$I = \frac{E_s}{L_s}$$

$$I = \frac{1.018}{43.2}$$

$$I = 0.02565$$

$V_{AB} = I L_{AB}$

$V_{AB} = 0.02565 \times 120$

$$\boxed{V_{AB} = 2.828}$$

SELF TEST (6)

Q.1 A galvanometer whose resistance is 50Ω deflects full scale for a potential difference 100mv across it terminals. How can it be converted into a voltmeter of 50V. **(2010)**

(Ans. $R_X = 24950\ \Omega$)

Q.2 A moving coil galvanometer has a resistance of 50Ω and it gives a full scale deflection for potential difference of 100mV. If galvanometer is to be converted into voltmeter reading upto 50volts, what should be the resistance of series resistor? **(2000)**

(Ans. $R_X = 24950\ \Omega$)

15.13 EXTRA NUMERICALS:

Q.1 A galvanometer has a resistance of 100 ohms. A difference of potential of 50mv gives the full-scale deflection. Calculate the shunt resistance to read 0-5A. What is the value of the series resistance if the galvanometer is to be converted into a voltmeter to read up to 250 volt? **(2008)**

Given that:

$R_g = 100\Omega$

$V_g = 50mv = \frac{50}{1000}\ v = 0.05$ volt

a) $I = 5$ Amp.

b) $V = 250$ volt

Required:

a) $R_S = ?$

b) $R_X = ?$

Solution:

Using Ohm's law

$V = IR$

OR $V_g = I_g R_g$

$I_g = \frac{V_g}{R_g} = \frac{0.05}{100}$

$I_g = 5 \times 10^{-4}$ Amp. $= 0.0005$ Amp.

(a) For Shunt Resistance (R_S)

Using $R_s = \frac{I_g}{I - I_g} R_g$

$R_s = \frac{0.0005}{5 - 0.005} \times 100$

$R_s = \frac{0.05}{4.9995}$

$\boxed{R_S = 0.01\Omega}$

(b) For Series Resistance (R_X)

Using $R_x = \frac{V}{I_g} - R_g$

$R_x = \frac{250}{0.0005} - 100$

$R_X = 500000 - 100$

$\boxed{R_X = 499900\Omega}$

OR $\boxed{R_X = 499.9K\Omega}$

Q.2 An ammeter deflects full scale with voltage of 2.5 volts and has a total resistance of 0.5Ω. What small resistance must be connected to measure 20A full scale? **(2006)**

Given that:

$V_1 = 2.5$ Volt

$R_1 = 0.5\Omega$

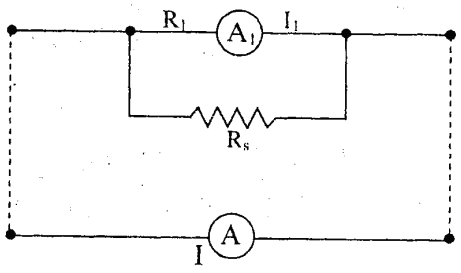
$I = 20$ Amp

Required:

$R_s = ?$

Solution:

From given statement



As

$V = IR$

$V_1 = I_1 R_1$

$$I_1 = \frac{V_1}{R_1} = \frac{2.5}{0.5}$$

$I_1 = 5$ amp ——————— (1)

Using

$$R_s = \frac{I_g}{I - I_g} R_g \text{ ——————— (2)}$$

Where

$I_g = I_1 = 5$ Amp

$R_g = R_1 = 0.5\Omega$

$\therefore$ **(2)** $\Rightarrow$

$$R_s = \frac{5}{20-5} \times 0.5$$

$$R_s = \frac{2.5}{15}$$

$$\boxed{R_s = 0.1666\Omega}$$

Q.3 A maximum 50 milliampere current can be allowed to flow through a 19.8Ω coil of a galvanometer. The galvanometer is to be used to measure 5 Ampere maximum current. Calculate the length of a copper wire to be used as a shunt. The diameter of the wire is 4mm, (For copper $\rho = 1.6 \times 10^{-8}\ \Omega - m$)

Given that:

$$I_g = 50mA = \frac{50}{1000} A = 0.05Amp.$$

$R_g = 19.8\Omega$

$I = 5$Amp.

Diameter $= d = 4mm = 4 \times 10^{-3}$ m

Required:

Length of wire $= L = ?$

Constant: $\rho = 1.6 \times 10^{-8}\ \Omega m$

Solution:

As we know that

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

OR $$L = \frac{RA}{\rho} \text{ ——————— (1)}$$

Now calculate "R" and "A"

As $$R_s = \frac{I_g}{I - I_g} R_g$$

OR $$R = \frac{0.05}{5 - 0.05} \times 19.8$$

$$R = \frac{0.99}{4.95}$$

$R = 0.2\ \Omega$ ——————— (2)

As $$A = \pi r^2 = \pi \left(\frac{d}{2}\right)^2$$

$$A = 3.1415 \left(\frac{4^2 \times 10^{-3}}{2}\right)^2$$

$A = 3.1415 \times 4 \times 10^{-6}$

$A = 1.2566 \times 10^{-5}$ m —— (3)

Put all values in (1)

$$L = \frac{0.2 \times 1.2566 \times 10^{-5}}{1.6 \times 10^{-8}}$$

$$L = \frac{2.5132 \times 10^{-6}}{1.6 \times 10^{-8}}$$

$$\boxed{L = 157.075m}$$