1.8. Conductance and Conductivity

Conductance (G) is reciprocal of resistance*. Whereas resistance of a conductor measures the ***opposition*** which it offers to the flow of current, the conductance measures the ***inducement*** which it offers to its flow.

From Eq. (*i*) of Art. 1.6, $R = \rho \frac{l}{A}$ or $G = \frac{1}{\rho} \cdot \frac{A}{l} = \frac{\sigma A}{l}$

where σ is called the ***conductivity*** **or** ***specific conductance*** of a conductor. The unit of conductance is siemens (S). Earlier, this unit was called mho.

It is seen from the above equation that the conductivity of a material is given by

$$\sigma = G\frac{l}{A} = \frac{G \text{ siemens} \times l \text{ metre}}{A \text{ metre}^2} = G\frac{l}{A} \text{ siemens/metre}$$

Hence, the unit of conductivity is siemens/metre (S/m).

1.9. Effect of Temperature on Resistance

The effect of rise in temperature is :

(*i*) to ***increase*** the resistance of pure metals. The increase is large and fairly regular for normal ranges of temperature. The temperature/resistance graph is a straight line (Fig. 1.6). As would be presently clarified, metals have a positive temperature co-efficient of resistance.

(*ii*) to ***increase*** the resistance of alloys, though in their case, the increase is relatively small and irregular. For some high-resistance alloys like Eureka (60% Cu and 40% Ni) and manganin, the increase in resistance is (or can be made) negligible over a considerable range of temperature.

(*iii*) to ***decrease*** the resistance of electrolytes, insulators (such as paper, rubber, glass, mica etc.) and partial conductors such as carbon. Hence, insulators are said to possess a ***negative*** temperature-coefficient of resistance.

1.10. Temperature Coefficient of Resistance

Let a metallic conductor having a resistance of R_0 at 0°C be heated of t°C and let its resistance at this temperature be R_t. Then, considering normal ranges of temperature, it is found that the increase in resistance $\Delta R = R_t - R_0$ depends

(*i*) directly on its initial resistance

(*ii*) directly on the rise in temperature

(*iii*) on the nature of the material of the conductor.

or $$R_t - R_0 \propto R \times t \quad \text{or} \quad R_t - R_0 = \alpha R_0 t \qquad ...(i)$$

where α (alpha) is a constant and is known as the *temperature coefficient of resistance* of the conductor.

Rearranging Eq. (*i*), we get $\alpha = \frac{R_t - R_0}{R_0 \times t} = \frac{\Delta R}{R_0 \times t}$

If $R_0 = 1\,\Omega,\ t = 1°\text{C}$, then $\alpha = \Delta R = R_t - R_0$

Hence, the temperature-coefficient of a material may be defined as :

the increase in resistance per ohm original resistance per °C rise in temperature.

From Eq. (*i*), we find that $$R_t = R_0 (1 + \alpha t) \qquad ...(ii)$$

* In a.c. circuits, it has a slightly different meaning.

It should be remembered that the above equation holds good for both rise as well as fall in temperature. As temperature of a conductor is decreased, its resistance is also decreased. In Fig. 1.6 is shown the temperature/resistance graph for copper and is practically a straight line. If this line is extended backwards, it would cut the temperature axis at a point where temperature is − 234.5°C (a number quite easy to remember). It means that theoretically, the resistance of copper conductor will become zero at this point though as shown by solid line, in practice, the curve departs from a straight line at very low temperatures. From the two similar triangles of Fig. 1.6 it is seen that :

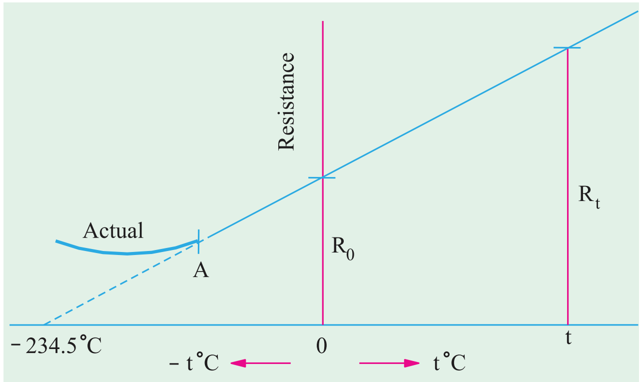


Fig. 1.6

$$\frac{R_t}{R_0} = \frac{t + 234.5}{234.5} = \left(1 + \frac{t}{234.5}\right)$$

$$\therefore \quad R_t = R_0\left(1 + \frac{t}{234.5}\right) \text{ or } R_t = R_0\,(1 + \alpha\, t) \text{ where } \alpha = 1/234.5 \text{ for copper.}$$

1.11. Value of α at Different Temperatures

So far we did not make any distinction between values of α at different temperatures. But it is found that value of α itself is not constant but depends on the initial temperature on which the increment in resistance is based. When the increment is based on the resistance measured at 0°C, then α has the value of α_0. At any other initial temperature t°C, value of α is α_t and so on. It should be remembered that, for any conductor, α_0 has the maximum value.

Suppose a conductor of resistance R_0 at 0°C (point A in Fig. 1.7) is heated to t°C (point B). Its resistance R_t after heating is given by

$$R_t = R_0\,(1 + \alpha_0\, t) \qquad ...(i)$$

where α_0 is the temperature-coefficient at 0°C.

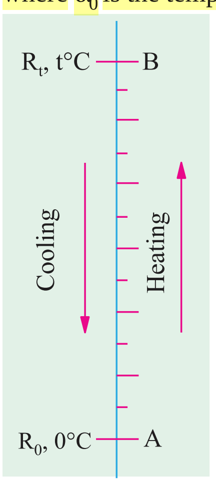


Fig. 1.7

Now, suppose that we have a conductor of resistance R_t at temperature t°C. Let this conductor be ***cooled*** from t°C to 0°C. Obviously, now the initial point is B and the final point is A. The final resistance R_0 is given in terms of the initial resistance by the following equation

$$R_0 = R_t\,[1 + \alpha_t\,(-t)] = R_t\,(1 - \alpha_t\,.\,t) \qquad ...(ii)$$

From Eq. ***(ii)*** above, we have $\alpha_t = \dfrac{R_t - R_0}{R_t \times t}$

Substituting the value of R_t from Eq. (i), we get

$$\alpha_t = \frac{R_0\,(1 + \alpha_0 t) - R_0}{R_0\,(1 + \alpha_0\, t) \times t} = \frac{\alpha_0}{1 + \alpha_0\, t} \qquad \therefore \alpha_t = \frac{\alpha_0}{1 + \alpha_0\, t} \qquad ...(iii)$$

In general, let α_1 = tempt. coeff. at t_1°C ; α_2 = tempt. coeff. at t_2°C. Then from Eq. ***(iii)*** above, we get

$$\alpha_1 = \frac{\alpha_0}{1+\alpha_0\, t_1} \quad \text{or} \quad \frac{1}{\alpha_1} = \frac{1+\alpha_0\, t_1}{\alpha_0}$$

Similarly,
$$\frac{1}{\alpha_2} = \frac{1+\alpha_0\, t_2}{\alpha_0}$$

Subtracting one from the other, we get

$$\frac{1}{\alpha_2} - \frac{1}{\alpha_1} = (t_2 - t_1) \text{ or } \frac{1}{\alpha_2} = \frac{1}{\alpha_1} + (t_2 - t_1) \text{ or } \alpha_2 = \frac{1}{1/\alpha_1 + (t_2 - t_1)}$$

Values of α for copper at different temperatures are given in Table No. 1.3.

Table 1.3. Different values of α for copper

Tempt. in °C	0	5	10	20	30	40	50
α	0.00427	0.00418	0.00409	0.00393	0.00378	0.00364	0.00352

In view of the dependence of α on the initial temperature, we may define ***the temperature coefficient of resistance at a given temperature as the charge in resistance per ohm per degree centigrade change in temperature from the given temperature.***

In case R_0 is not given, the relation between the known resistance R_1 at t_1°C and the unknown resistance R_2 at t_2°C can be found as follows :

$$R_2 = R_0\,(1 + \alpha_0\, t_2) \quad \text{and} \quad R_1 = R_0\,(1 + \alpha_0\, t_1)$$

$$\therefore \quad \frac{R_2}{R_1} = \frac{1+\alpha_0 t_2}{1+\alpha_0 t_1} \qquad \text{...}(iv)$$

The above expression can be simplified by a little approximation as follows :

$$\frac{R_2}{R_1} = (1 + \alpha_0\, t_2)\,(1 + \alpha_0\, t_1)^{-1}$$

$$= (1 + \alpha_0\, t_2)\,(1 - \alpha_0\, t_1)$$ [Using Binomial Theorem for expansion and

$$= 1 + \alpha_0\,(t_2 - t_1)$$ neglecting squares and higher powers of $(\alpha_0\, t_1)$]

$$\therefore \quad R_2 = R_1\,[1 + \alpha_0\,(t_2 - t_1)]$$ [Neglecting product $(\alpha_0^{\,2} t_1 t_2)$]

For more accurate calculations, Eq. (*iv*) should, however, be used.

1.12. Variations of Resistivity with Temperature

Not only resistance but specific resistance or resistivity of metallic conductors also increases with rise in temperature and ***vice-versa***.

As seen from Fig. 1.8 the resistivities of metals vary linearly with temperature over a significant range of temperature-the variation becoming non-linear both at very high and at very low temperatures. Let, for any metallic conductor,

ρ_1 = resistivity at t_1°C

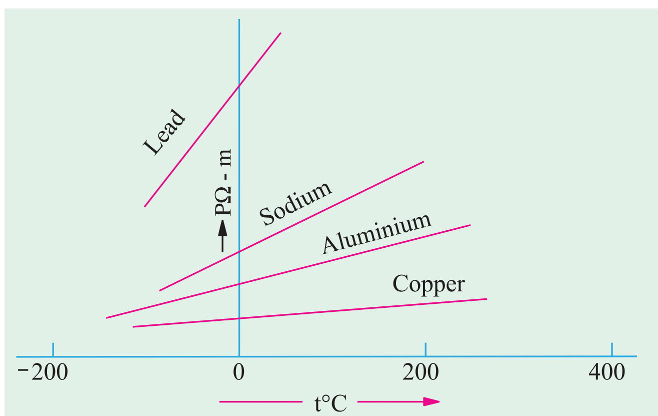


Fig. 1.8

ρ_2 = resistivity at t_2°C

m = Slope of the linear part of the curve

Then, it is seen that

$$m = \frac{\rho_2 - \rho_1}{t_2 - t_1}$$

or $\quad \rho_2 = \rho_1 + m\,(t_2 - t_1) \quad$ or $\quad \rho_2 = \rho_1\left[1 + \frac{m}{\rho_1}(t_2 - t_1)\right]$

The ratio of m/ρ_1 is called the ***temperature coefficient of resistivity*** at temperature t_1°C. It may be defined as numerically equal to the fractional change in ρ_1 per °C change in the temperature from t_1°C. It is almost equal to the temperature-coefficient of resistance α_1. Hence, putting $\alpha_1 = m/\rho_1$, we get

$$\rho_2 = \rho_1[1 + \alpha_1(t_2 - t_1)] \quad \text{or} \quad \text{simply as } \rho_t = \rho_0(1 + \alpha_0 t)$$

Note. It has been found that although temperature is the most significant factor influencing the resistivity of metals, other factors like pressure and tension also affect resistivity to some extent. For most metals except lithium and calcium, increase in pressure leads to decrease in resistivity. However, resistivity increases with increase in tension.

Example 1.11. *A copper conductor has its specific resistance of 1.6 × 10^-6 ohm-cm at 0°C and a resistance temperature coefficient of 1/254.5 per °C at 20°C. Find **(i)** the specific resistance and **(ii)** the resistance - temperature coefficient at 60°C.* **(F.Y. Engg. Pune Univ. Nov.)**

Solution. $\quad \alpha_{20} = \dfrac{\alpha_0}{1 + \alpha_0 \times 20}$ or $\dfrac{1}{254.5} = \dfrac{\alpha_0}{1 + \alpha_0 \times 20} \quad \therefore \quad \alpha_0 = \dfrac{1}{234.5}$ per °C

(i) $\quad \rho_{60} = \rho_0(1 + \alpha_0 \times 60) = 1.6 \times 10^{-6}(1 + 60/234.5) = \mathbf{2.01 \times 10^{-6}\ \Omega\text{-cm}}$

(ii) $\quad \alpha_{60} = \dfrac{\alpha_0}{1 + \alpha_0 \times 60} = \dfrac{1/234.5}{1 + (60/234.5)} = \mathbf{\dfrac{1}{294.5}}$ **per°C**

Example 1.12. *A platinum coil has a resistance of 3.146 Ω at 40°C and 3.767 Ω at 100°C. Find the resistance at 0°C and the temperature-coefficient of resistance at 40°C.*

(Electrical Science-II, Allahabad Univ.)

Solution. $\quad R_{100} = R_0(1 + 100\,\alpha_0) \quad$ ...(*i*)

$R_{40} = R_0(1 + 40\,\alpha_0) \quad$ ...(*ii*)

$\therefore \quad \dfrac{3.767}{3.146} = \dfrac{1 + 100\,\alpha_0}{1 + 40\,\alpha_0}$ or $\alpha_0 = 0.00379$ or 1/264 per°C

From (*i*), we have $\quad 3.767 = R_0(1 + 100 \times 0.00379) \quad \therefore \quad R_0 = \mathbf{2.732\ \Omega}$

Now, $\quad \alpha_{40} = \dfrac{\alpha_0}{1 + 40\,\alpha_0} = \dfrac{0.00379}{1 + 40 \times 0.00379} = \mathbf{\dfrac{1}{304}}$ **per°C**

Example 1.13. *A potential difference of 250 V is applied to a field winding at 15°C and the current is 5 A. What will be the mean temperature of the winding when current has fallen to 3.91 A, applied voltage being constant. Assume α_{15} = 1/254.5.* **(Elect. Engg. Pune Univ.)**

Solution. Let R_1 = winding resistance at 15°C; R_2 = winding resistance at unknown mean temperature t_2°C.

$\therefore \quad R_1 = 250/5 = 50\ \Omega;\ R_2 = 250/3.91 = 63.94\ \Omega$

Now $\quad R_2 = R_1[1 + \alpha_{15}(t_2 - t_1)] \quad \therefore \quad 63.94 = 50\left[1 + \dfrac{1}{254.5}(t_2 - 15)\right]$

$\therefore \quad t_2 = \mathbf{86°C}$

Example 1.14. *Two coils connected in series have resistances of 600 Ω and 300 Ω with tempt. coeff. of 0.1% and 0.4% respectively at 20°C. Find the resistance of the combination at a tempt. of 50°C. What is the effective tempt. coeff. of combination ?*

Solution. Resistance of 600 Ω resistor at 50°C is = 600 [1 + 0.001 (50 – 20)] = 618 Ω

Similarly, resistance of 300 Ω resistor at 50°C is = 300 [1 + 0.004 (50 – 20)] = 336 Ω

Hence, total resistance of combination at 50°C is = 618 + 336 = **954 Ω**

Let β = resistance-temperature coefficient at 20°C

Now, combination resistance at 20°C = 900 Ω

Combination resistance at 50°C = 954 Ω

∴ 954 = 900 [1 + β (50 – 20)] ∴ β = **0.002**

Example 1.15. *Two wires A and B are connected in series at 0°C and resistance of B is 3.5 times that of A. The resistance temperature coefficient of A is 0.4% and that of the combination is 0.1%. Find the resistance temperature coefficient of B.* **(Elect. Technology, Hyderabad Univ.)**

Solution. A simple technique which gives quick results in such questions is illustrated by the diagram of Fig. 1.9. It is seen that R_B/R_A = 0.003/(0.001 – α)

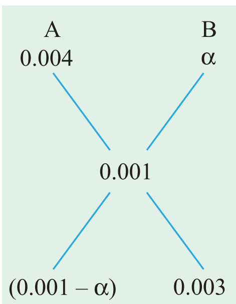


Fig. 1.9

or 3.5 = 0.003/(0.001 – α)

or α = 0.000143°C^{-1} or **0.0143 %**

Example 1.16. *Two materials A and B have resistance temperature coefficients of 0.004 and 0.0004 respectively at a given temperature. In what proportion must A and B be joined in series to produce a circuit having a temperature coefficient of 0.001 ?* **(Elect. Technology, Indore Univ.)**

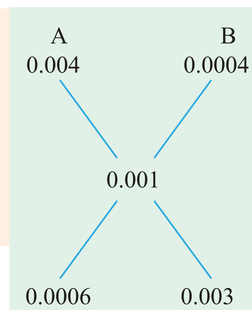


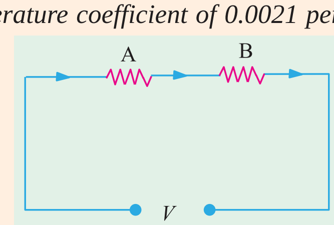
Fig. 1.10

Solution. Let R_A and R_B be the resistances of the two wires of materials *A* and *B* which are to be connected in series. Their ratio may be found by the simple technique shown in Fig. 1.10.

$$\frac{R_B}{R_A} = \frac{0.003}{0.0006} = 5$$

Hence, R_B must be **5 times R_A.**

Example 1.17. *A resistor of 80 Ω resistance, having a temperature coefficient of 0.0021 per degree C is to be constructed. Wires of two materials of suitable cross-sectional area are available. For material A, the resistance is 80 ohm per 100 metres and the temperature coefficient is 0.003 per degree C. For material B, the corresponding figures are 60 ohm per metre and 0.0015 per degree C. Calculate suitable lengths of wires of materials A and B to be connected in series to construct the required resistor. All data are referred to the same temperature.*



Solution. Let R_a and R_b be the resistances of suitable lengths of materials *A* and *B* respectively which when joined in series will have a combined temperature coeff. of 0.0021. Hence, combination resistance at any given temperature is (R_a + R_b). Suppose we heat these materials through *t*°C.

When heated, resistance of *A* increases from R_a to R_a (1 + 0.003 *t*). Similarly, resistance of *B* increases from R_b to R_b (1 + 0.0015 *t*).

∴ combination resistance after being heated through *t*°C

$$= R_a\,(1 + 0.003\,t) + R_b\,(1 + 0.0015\,t)$$

The combination α being given, value of combination resistance can be also found directly as

$$= (R_a + R_b)(1 + 0.0021\,t)$$

$$\therefore \quad (R_a + R_b)(1 + 0.0021\,t) = R_a(1 + 0.003\,t) + R_b(1 + 0.0015\,t)$$

Simplifying the above, we get $\dfrac{R_b}{R_a} = \dfrac{3}{2}$ ...(*i*)

Now $R_a + R_b = 80\ \Omega$ ...(*ii*)

Substituting the value of R_b from (*i*) into (*ii*) we get

$$R_a + \frac{3}{2}R_a = 80 \quad \text{or} \quad R_a = 32\ \Omega \quad \text{and} \quad R_b = 48\ \Omega$$

If L_a and L_b are the required lengths in metres, then

$$L_a = (100/80) \times 32 = \mathbf{40\ m} \quad \text{and} \quad L_b = (100/60) \times 48 = \mathbf{80\ m}$$

Example 1.18. *A coil has a resistance of 18 Ω when its mean temperature is 20°C and of 20 Ω when its mean temperature is 50°C. Find its mean temperature rise when its resistance is 21 Ω and the surrounding temperature is 15° C.* **(Elect. Technology, Allahabad Univ.)**

Solution. Let R_0 be the resistance of the coil and α_0 its tempt. coefficient at 0°C.

Then, $18 = R_0(1 + \alpha_0 \times 20)$ and $20 = R_0(1 + 50\,\alpha_0)$

Dividing one by the other, we get

$$\frac{20}{18} = \frac{1 + 50\,\alpha_0}{1 + 20\,\alpha_0} \qquad \therefore\ \alpha_0 = \frac{1}{250}\ \text{per°C}$$

If t°C is the temperature of the coil when its resistance is 21 Ω, then,

$$21 = R_0(1 + t/250)$$

Dividing this equation by the above equation, we have

$$\frac{21}{18} = \frac{R_0(1 + t/250)}{R_0(1 + 20\,\alpha_0)}; \qquad t = 65°\text{C; temp. rise} = 65 - 15 = \mathbf{50°C}$$

Example 1.19. *The coil of a relay takes a current of 0.12 A when it is at the room temperature of 15°C and connected across a 60-V supply. If the minimum operating current of the relay is 0.1 A, calculate the temperature above which the relay will fail to operate when connected to the same supply. Resistance-temperature coefficient of the coil material is 0.0043 per°C at 6°C.*

Solution. Resistance of the relay coil at 15°C is $R_{15} = 60/0.12 = 500\ \Omega$.

Let t°C be the temperature at which the minimum operating current of 0.1 A flows in the relay coil. Then, $R_1 = 60/0.1 = 600\ \Omega$.

Now $R_{15} = R_0(1 + 15\,\alpha_0) = R_0(1 + 15 \times 0.0043)$ and $R_t = R_0(1 + 0.0043\,t)$

$$\therefore \quad \frac{R_t}{R_{15}} = \frac{1 + 0.0043\,t}{1.0654} \quad \text{or} \quad \frac{600}{500} = \frac{1 + 0.0043\,t}{1.0645} \qquad \therefore\ t = \mathbf{65.4°C}$$

If the temperature rises above this value, then due to increase in resistance, the relay coil will draw a current less than 0.1 A and, therefore, will fail to operate.

Example 1.20. *Two conductors, one of copper and the other of iron, are connected in parallel and carry equal currents at 25°C. What proportion of current will pass through each if the temperature is raised to 100°C ? The temperature coefficients of resistance at 0°C are 0.0043/°C and 0.0063/°C for copper and iron respectively.* **(Principles of Elect. Engg. Delhi Univ.)**

Solution. Since the copper and iron conductors carry equal currents at 25°C, their resistances are the same at that temperature. Let each be R ohm.

For copper, $R_{100} = R_1 = R[1 + 0.0043(100 - 25)] = 1.3225\,R$

For iron, $R_{100} = R_2 = R[1 + 0.0063(100 - 25)] = 1.4725\,R$

If I is the current at 100°C, then as per current divider rule, current in the copper conductor is

$$I_1 = I\frac{R_2}{R_1+R_2} = I\frac{1.4725\,R}{1.3225\,R + 1.4725\,R} = 0.5268\,I$$

$$I_2 = I\frac{R_2}{R_1+R_2} = I\frac{1.3225\,R}{2.795\,R} = 0.4732\,I$$

Hence, copper conductor will carry **52.68%** of the total current and iron conductor will carry the balance *i.e.* **47.32%.**

Example 1.21. *The filament of a 240 V metal-filament lamp is to be constructed from a wire having a diameter of 0.02 mm and a resistivity at 20°C of 4.3 μΩ-cm. If α = 0.005/°C, what length of filament is necessary if the lamp is to dissipate 60 watts at a filament tempt. of 2420°C ?*

Solution. Electric power generated = I^2R watts = V^2/R watts

$\therefore \quad V^2/R = 60 \quad \text{or} \quad 240^2/R = 60$

Resistance at 2420°C $\quad R_{2420} = \dfrac{240 \times 240}{60} = 960\ \Omega$

Now $\quad R_{2420} = R_{20}\,[1 + (2420 - 20) \times 0.005]$

or $\quad 960 = R_{20}\,(1 + 12)$

$\therefore \quad R_{20} = 960/13\ \Omega$

Now $\quad \rho_{20} = 4.3 \times 10^{-6}\ \Omega\text{-cm} \quad \text{and} \quad A = \dfrac{\pi(0.002)^2}{4}\ \text{cm}^2$

$$\therefore \quad l = \frac{A \times R_{20}}{\rho_{20}} = \frac{\pi\,(0.002)^2 \times 960}{4 \times 13 \times 4.3 \times 10^{-6}} = \mathbf{54\ cm}$$

Example 1.22. *A semi-circular ring of copper has an inner radius 6 cm, radial thickness 3 cm and an axial thickness 4 cm. Find the resistance of the ring at 50°C between its two end-faces. Assume specific resistance of Cu at 20°C = 1.724 × 10^{-6} ohm-cm and resistance tempt. coeff. of Cu at 0°C = 0.0043/°C.*

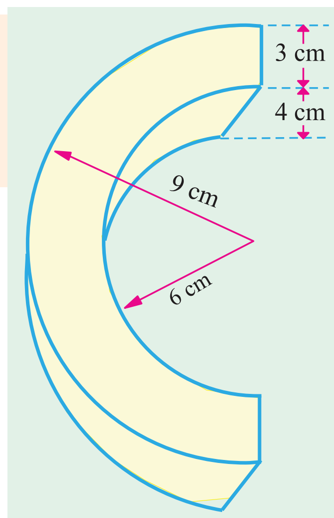


Fig.1.11

Solution. The semi-circular ring is shown in Fig. 1.11.

Mean radius of ring $= (6 + 9)/2 = 7.5$ cm

Mean length between end faces $= 7.5\,\pi$ cm $= 23.56$ cm

Cross-section of the ring $= 3 \times 4 = 12\ \text{cm}^2$

Now $\quad \alpha_0 = 0.0043/°\text{C};\ \alpha_{20} = \dfrac{0.0043}{1 + 20 \times 0.0043} = 0.00396$

$$\rho_{50} = \rho_{20}\,[1 + \alpha_0\,(50 - 20)]$$

$$= 1.724 \times 10^{-6}\,(1 + 30 \times 0.00396) = 1.93 \times 10^{-6}\ \Omega\text{-cm}$$

$$R_{50} = \frac{\rho_{50} \times l}{A} = \frac{1.93 \times 10^{-6} \times 23.56}{12} = \mathbf{3.79 \times 10^{-6}\ \Omega}$$

Tutorial Problems No. 1.2

1. It is found that the resistance of a coil of wire increases from 40 ohm at 15°C to 50 ohm at 60°C. Calculate the resistance temperature coefficient at 0°C of the conductor material.
   [1/165 per °C] (*Elect. Technology, Indore Univ.*)
2. A tungsten lamp filament has a temperature of 2,050°C and a resistance of 500 Ω when taking normal working current. Calculate the resistance of the filament when it has a temperature of 25°C. Temperature coefficient at 0°C is 0.005/°C. **[50 Ω] (*Elect. Technology, Indore Univ.*)**

3. An armature has a resistance of 0.2 Ω at 150°C and the armature Cu loss is to be limited to 600 watts with a temperature rise of 55°C. If α_0 for Cu is 0.0043/°C, what is the maximum current that can be passed through the armature ? **[50.8 A]**
4. A d.c. shunt motor after running for several hours on constant voltage mains of 400 V takes a field current of 1.6 A. If the temperature rise is known to be 40°C, what value of extra circuit resistance is required to adjust the field current to 1.6 A when starting from cold at 20°C ? Temperature coefficient = 0.0043/°C at 20°C. **[36.69 Ω]**
5. In a test to determine the resistance of a single-core cable, an applied voltage of 2.5 V was necessary to produce a current of 2 A in it at 15°C.
   (*a*) Calculate the cable resistance at 55°C if the temperature coefficient of resistance of copper at 0°C is 1/235 per°C.
   (*b*) If the cable under working conditions carries a current of 10 A at this temperature, calculate the power dissipated in the cable. **[(*a*) 1.45 Ω (*b*) 145 W]**
6. An electric radiator is required to dissipate 1 kW when connected to a 230 V supply. If the coils of the radiator are of wire 0.5 mm in diameter having resistivity of 60 μΩ-cm, calculate the necessary length of the wire. **[1732 cm]**
7. An electric heating element to dissipate 450 watts on 250 V mains is to be made from nichrome ribbon of width 1 mm and thickness 0.05 mm. Calculate the length of the ribbon required (the resistivity of nichrome is 110×10^{-8} Ω-m). **[631 m]**
8. When burning normally, the temperature of the filament in a 230 V, 150 W gas-filled tungsten lamp is 2,750°C. Assuming a room temperature of 16°C, calculate (*a*) the normal current taken by the lamp (*b*) the current taken at the moment of switching on. Temperature coefficient of tungsten is 0.0047 Ω/Ω°C at 0°C. **[(*a*) 0.652 A (*b*) 8.45 A] (*Elect. Engg. Madras Univ.*)**
9. An aluminium wire 5 m long and 2 mm diameter is connected in parallel with a wire 3 m long. The total current is 4 A and that in the aluminium wire is 2.5 A. Find the diameter of the copper wire. The respective resistivities of copper and aluminium are 1.7 and 2.6 μΩ-m. **[0.97 mm]**
10. The field winding of d.c. motor connected across 230 V supply takes 1.15 A at room temp. of 20°C. After working for some hours the current falls to 0.26 A, the supply voltage remaining constant. Calculate the final working temperature of field winding. Resistance temperature coefficient of copper at 20°C is 1/254.5. **[70.4°C] (*Elect. Engg. Pune Univ.*)**
11. It is required to construct a resistance of 100 Ω having a temperature coefficient of 0.001 per°C. Wires of two materials of suitable cross-sectional area are available. For material *A*, the resistance is 97 Ω per 100 metres and for material *B*, the resistance is 40 Ω per 100 metres. The temperature coefficient of resistance for material *A* is 0.003 per °C and for material *B* is 0.0005 per °C. Determine suitable lengths of wires of materials *A* and *B*. **[A : 19.4 m, B : 200 m]**
12. The resistance of the shunt winding of a d.c. machine is measured before and after a run of several hours. The average values are 55 ohms and 63 ohms. Calculate the rise in temperature of the winding. (Temperature coefficient of resistance of copper is 0.00428 ohm per ohm per °C). **[36°C] (*London Univ.*)**
13. A piece of resistance wire, 15.6 m long and of cross-sectional area 12 mm^2 at a temperature of 0°C, passes a current of 7.9 A when connected to d.c. supply at 240 V. Calculate (*a*) resistivity of the wire (*b*) the current which will flow when the temperature rises to 55°C. The temperature coefficient of the resistance wire is 0.00029 Ω/Ω/°C. **[(*a*) 23.37 μΩ-m (*b*) 7.78 A] (*London Univ.*)**
14. A coil is connected to a constant d.c. supply of 100 V. At start, when it was at the room temperature of 25°C, it drew a current of 13 A. After sometime, its temperature was 70°C and the current reduced to 8.5 A. Find the current it will draw when its temperature increases further to 80°C. Also, find the temperature coefficient of resistance of the coil material at 25°C. **[7.9 A; 0.01176°C^{-1}] (*F.Y. Engg. Univ.*)**
15. The resistance of the filed coils with copper conductors of a dynamo is 120 Ω at 25°C. After working for 6 hours on full load, the resistance of the coil increases to 140 Ω. Calculate the mean temperature rise of the field coil. Take the temperature coefficient of the conductor material as 0.0042 at 0°C. **[43.8°C] (*Elements of Elec. Engg. Banglore Univ.*)**