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10th Science

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Numerical Problems

Book for SSLC New SCIENCE Syllabus

(Exemplary Problems – Chapter Wise)

10th SCIENCE

Numerical Problems (Physics)

Electricity

Example 1

A current of 0.5 A is drawn by a filament of an electric bulb for 10 minutes. Find the amount of electric charge that flows through the circuit.

Solution

We are given, I = 0.5 A; t = 10 min = 600 s.

From Eq. (1), we have

Q = It

= 0.5 A × 600 s

= 300 C

Example 2

How much work is done in moving a charge of 2 C across two points having a potential difference 12 V?

Solution

The amount of charge Q, that flows between two points at potential difference V (= 12 V) is 2 C. Thus, the amount of work W, done in moving the charge [from Eq. (2)] is

W = VQ

= 12 V × 2 C

= 24 J.

Example 3

- How much current will an electric bulb draw from a 220 V source, if the resistance of the bulb filament is 1200 Ω?
- How much current will an electric heater coil draw from a 220 V source, if the resistance of the heater coil is 100 Ω?

Solution

- We are given V = 220 V; R = 1200 Ω.
  From Eq. (6), we have the current I = 220 V/1200 Ω = 0.18 A.
- We are given, V = 220 V, R = 100 Ω.
  From Eq. (6), we have the current I = 220 V/100 Ω = 2.2 A.
  Note the difference of current drawn by an electric bulb and electric heater from the same 220 V source!

Example 4

The potential difference between the terminals of an electric heater is 60 V when it draws a current of 4 A from the source. What current will the heater draw if the potential difference is increased to 120 V?

Solution

We are given, potential difference V = 60 V, current I = 4 A.

According to Ohm's law, R =   =15Ω

When the potential difference is increased to 120 V the current is given by

current = V/R = 120V/15 = 8A

The current through the heater becomes 8 A.

Example 5

Resistance of a metal wire of length 1 m is 26 Ω at 20°C. If the diameter of the wire is 0.3 mm, what will be the resistivity of the metal at that temperature? Using Table 2, predict the material of the wire.

Solution

We are given the resistance R of the wire = 26 Ω, the diameter

d = 0.3 mm = 3×10^{-4} m, and the length l of the wire = 1 m.

Therefore, from Eq. (10), the resistivity of the given metallic wire is

$\rho = (RA/l) = (R\pi d2/4l)$

Substitution of values in this gives

$\rho = 1.84 \times 10^{-6}\ \Omega$ m

The resistivity of the metal at 20°C is $1.84 \times 10^{-6}\ \Omega$ m. From Table 2, we see that this is the resistivity of manganese.

Example 6

A 4 Ω resistance wire is doubled on it. Calculate the new resistance of the wire.

Solution

We are given, R = 4 Ω.

When a wire is doubled on it, its length would become half and area of cross-section would double. That is, a wire of length l and area of cross-section A becomes of length l/2 and area of cross section 2A. From Eq. (10), we have

$R = \rho(l/A)$

$R_1 = \rho((l/A) / 2A)$

where R1 is the new resistance.

Therefore, $R_1/R = \rho((l/A)/2A) / \rho(l/A) = 1/4$

Or, $R_1 = R/4 = 4\Omega/4 = 1\Omega$

The new resistance of the wire is 1 Ω.

Example 7

An electric lamp, whose resistance is 20 Ω, and a conductor of 4 Ω resistance are connected to a 6 V battery (Fig. 9). Calculate

- the total resistance of the circuit,
- the current through the circuit, and
- the potential difference across the electric lamp and conductor.

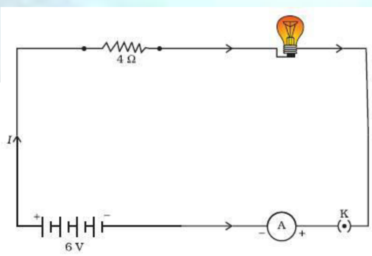


Fig. An electric lamp connected in series with a resistor of 4 Ω to a 6 V battery

Solution

The resistance of electric lamp, R_1 = 20 Ω,

The resistance of the conductor connected in series, R_2 = 4 Ω.

Then the total resistance in the circuit

$R = R_1 + R_2$

R_s = 20 Ω + 4 Ω = 24 Ω.

The total potential difference across the two terminals of the battery

V = 6 V.

Now by Ohm's law, the current through the circuit is given by

$I = V/R_s$

= 6 V/24 Ω

= 0.25 A.

Applying Ohm's law to the electric lamp and conductor separately,we get potential difference across the electric lamp,

V_1 = 20 Ω × 0.25 A

= 5 V;

and, that across the conductor, V_2 = 4 Ω × 0.25 A

= 1 V.

Suppose that we like to replace the series combination of electric lamp and conductor by a single and equivalent resistor. Its resistance must be such that a potential difference of 6 V across the battery terminals will cause a current of 0.25 A in the circuit. The resistance R of this equivalent resistor would be R = V/I = 6 V/ 0.25 A = 24 Ω.

This is the total resistance of the series circuit; it is equal to the sum of the two resistances.

Example 8

In the circuit diagram given in Fig.10, suppose the resistors R_1, R_2 and R_3 have the values 5 Ω, 10 Ω, 30 Ω, respectively, which have been connected to a battery of 12 V. Calculate

- the current through each resistor,
- the total current in the circuit, and
- the total circuit resistance.

Solution

R_1 = 5 Ω, R_2 = 10 Ω, and R_3 = 30 Ω.

Potential difference across the battery, V = 12 V. This is also the potential difference across each of the individual resistor; therefore, to calculate the current in the resistors, we use Ohm's law. The current I_1, through R_1= V/ R_1

I_1 = 12 V/5 Ω = 2.4 A.

The current I_2, through R_2 = V/ R_2

I_2 = 12 V/10 Ω = 1.2 A.

The current I_3, through R_3 = V/R_3

I_3 = 12 V/30 Ω = 0.4 A.

The total current in the circuit,

$I = I_1 + I_2 + I_3$

$= (2.4 + 1.2 + 0.4)$ A

$= 4$ A

The total resistance Rp, is given by [Eq. (18)]

$1/R_p = 1/5 + 1/10 + 1/30 = 1/3$

Thus, $R_p = 3\ \Omega$.

Example 9

If in Fig.12, $R_1 = 10\ \Omega$, $R_2 = 40\ \Omega$, $R_3 = 30\ \Omega$, $R_4 = 20\ \Omega$, $R_5 = 60\ \Omega$, and a 12 V battery is connected to the arrangement. Calculate

- the total resistance in the circuit, and
- the total current flowing in the circuit.

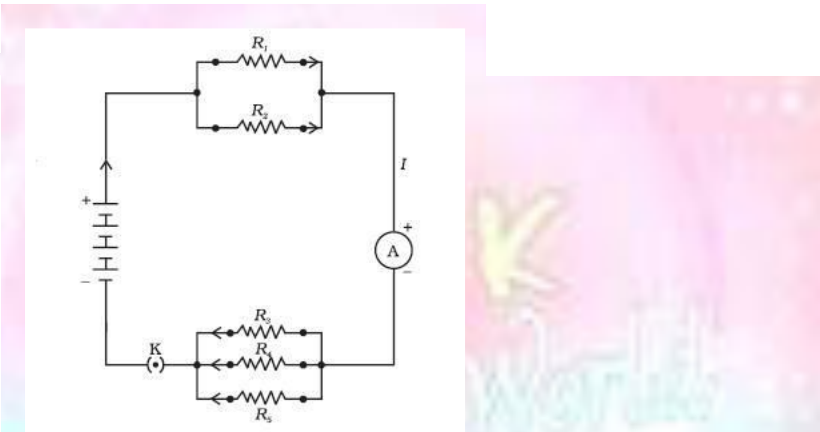


Fig. An electric circuit showing the combination of series and parallel resistors

Solution

Suppose we replace the parallel resistors R_1 and R_2 by an equivalent resistor of resistance, R′. Similarly we replace the parallel resistors R_3, R_4 and R_5 by an equivalent single resistor of resistance R″. Then using Eq. (18), we have

$1/R' = 1/10 + 1/40 = 5/40$; that is $R' = 8\ \Omega$.

Similarly, $1/R'' = 1/30 + 1/20 + 1/60 = 6/60$;

that is, $R'' = 10\ \Omega$.

Thus, the total resistance, $R = R' + R'' = 18\ \Omega$.

To calculate the current, we use Ohm's law, and get

$I = V/R = 12\ V/18\ \Omega = 0.67$ A.

Example 10

An electric iron consumes energy at a rate of 840 W when heating is at the maximum rate and 360 W when the heating is at the minimum. The voltage is 220 V. What are the current and the resistance in each case?

Solution

From Eq. (19), we know that the power input is

P = V I

Thus the current I = P/V

(a) When heating is at the maximum rate,

I = 840 W/220 V = 3.82 A;

and the resistance of the electric iron is

R = V/I = 220 V/3.82 A = 57.60 Ω.

(b) When heating is at the minimum rate,

I = 360 W/220 V = 1.64 A;

and the resistance of the electric iron is

R = V/I = 220 V/1.64 A = 134.15 Ω.

Example 11

100 J of heat are produced each second in a 4 Ω resistance. Find the potential difference across the resistor.

Solution

H = 100 J, R = 4 Ω, t = 1 s, V = ?

From Eq. (21) we have the current through the resistor as

I=√(H/Rt)

=√[100 J/(4 Ω × 1 s)]

=5A

Thus the potential difference across the resistor, V [from Eq. (5)] is

V = IR

= 5A × 4 Ω

= 20 V.

Example 12

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

Solution

P = VI

= 220 V × 0.50 A

= 110 J/s

= 110 W.

Example 13

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 would be

400 W × 8.0 hour/day × 30 days = 96000 W h

= 96 kW h

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

96 kW h × Rs 3.00 per kW h = Rs 288.00

Magnetic Effects of Electric Current

Example 1

A current through a horizontal power line flows in east to west direction. What is the direction of magnetic field at a point directly below it and at a point directly above it?

Solution

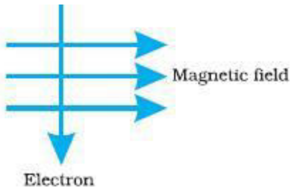
The current is in the east-west direction. Applying the right-hand thumb rule, we get that the direction of magnetic field at a point below the wire is from north to south. The direction of magnetic field at a point directly above the wire is from south to north.

Example 2

An electron enters a magnetic field at right angles to it, as shown in Fig. 14. The direction of force acting on the electron will be

- to the right
- to the left

- out of the page
- into the page



Solution

Answer is option (d). The direction of force is perpendicular to the direction of magnetic field and current as given by Fleming's left hand rule. Recall that the direction of current is taken opposite to the direction of motion of electrons. The force is therefore directed into the page.

Light

Example 1

A convex mirror used for rear-view on an automobile has a radius of curvature of 3.00 m. If a bus is located at 5.00 m from this mirror, find the position, nature and size of the image.

Solution

Radius of curvature, R = + 3.00 m;

Object-distance, u = – 5.00 m;

Image-distance, v = ?

Height of the image, h′= ?

Focal length, f = R/2 = + 3.00 m / 2 = + 1.50 m

Since 1/v + 1/u = 1/f

or, 1/v = 1/f - 1/u = + 1 / 1.50 - 1 / (-5.00) = 1 / 1.50 + 1/ 5.00

= (5.00 + 1.50) / 7.50

v = +7.50 / 6.50 = +1.15 m

The image is 1.15 m at the back of the mirror.

Magnification, m = h'/ h = -v / u; = - 1.15 m / -5.00 m

= +0.23

The image is virtual, erect and smaller in size by a factor of 0.23.

Example 2

An object, 4.0 cm in size, is placed at 25.0 cm in front of a concave mirror of focal length 15.0 cm. At what distance from the mirror should a screen be placed in order to obtain a sharp image? Find the nature and the size of the image.

Solution

Object-size, h = + 4.0 cm;

Object-distance, u = – 25.0 cm;

Focal length, f = –15.0 cm;

Image-distance, v = ?

Image-size, h′ = ?

From Eq. (1):

$1/v + 1/u = 1/f$

$1/v = 1/f - 1/u = 1/-15.0 - 1/-25.0 = -1/15.0 + 1/25.0$

$1/v = -(5.0+3.0)/75.0 = -2.0/75.0$ or, $v = -37.5$ cm

The screen should be placed at 37.5 cm from the mirror. The image is real.

Also, magnification, $m = h'/h = -(v/u)$

or $h' = -(vh)/u = -((-37.5cm)(+4.0cm))/(-25.0cm)$

Height of the image, h′ = – 6.0 cm The image is inverted and enlarged.

Example 3

A concave lens has focal length of 15 cm. At what distance should the object from the lens be placed so that it forms an image at 10 cm from the lens? Also, find the magnification produced by the lens.

Solution

A concave lens always forms a virtual, erect image on the same side of the object.

Image-distance v = –10 cm;

Focal length f = –15 cm;

Object-distance u = ?

Since, $1/v - 1/u = 1/f$

or, $1/u = 1/v - 1/f$

$1/u = 1/-10 - 1/(-15) = -1/10 + 1/15$

$1/u = (-3+2)/30 = 1/(-30)$

or, u = – 30 cm.

Thus, the object-cdistance is 30 cm.

Magnification $m = v/u$

m = -10 cm / -30 cm = 1 / 3 = +0.33

The positive sign shows that the image is erect and virtual. The image is one-third of the size of the object.

Example 4

A 2.0 cm tall object is placed perpendicular to the principal axis of a convex lens of focal length 10 cm. The distance of the object from the lens is 15 cm. Find the nature, position and size of the image. Also find its magnification.

Solution

Height of the object h = + 2.0 cm;

Focal length f = + 10 cm;

object-distance u = –15 cm;

Image-distance v; = ?

Height of the image h′ = ?

Since $\frac{1}{v} - \frac{1}{u} = \frac{1}{f}$

or, $\frac{1}{v} = \frac{1}{u} + \frac{1}{f}$

$$\frac{1}{v} = \frac{1}{(-15)} + \frac{1}{10} = -\frac{1}{15} + \frac{1}{10}$$

$$\frac{1}{v} = \frac{-2+3}{30} = \frac{1}{30}$$

or, v = + 30 cm.

The positive sign of v shows that the image is formed at a distance of 30 cm on the other side of the optical centre. The image is real and inverted.

Magnification m = h' / h = v / u

or, h′ = h (v/u)

Height of the image, h′ = (2.0) (+30/–15) = – 4.0 cm

Magnification m = v / u

or, m = (+30cm) / (-15cm) = - 2

The negative signs of m and h′ show that the image is inverted and real. It is formed below the principal axis. Thus, a real, inverted image, 4 cm tall, is formed at a distance of 30 cm on the other side of the lens. The image is two times enlarged.