21

Electricity

BRIEF REVIEW

Electric Current The time rate of change of charge is called current .

$$I = \frac{dQ}{dt}.$$

Its unit is Ampere (A). DC current is a scalar quantity. However, AC current is a phasor (vector).

Current from generation point of view is of three types.

(a) **Drift current** When electric field is applied in a conductor, then current due to drift velocity flows. Such a current is called drift current and is given by $I = neAv_d$, where n is number electron density, e charge on an electron, v_d is drift velocity and A is area of cross-section.

Drift velocity (v_d) is the average directed velocity along the length of the conductor in the presence of applied electric field and is given by $v_d = \frac{eE\tau}{m}$

where τ is relaxation time, E is applied electric field and m is mass of the electron.

Relaxation time The average time between two successive collisions of electrons.

(b) **Diffusion current** Such a current is generated due to charge density gradient. In thermocouples and in semiconductors diffusion current is found.

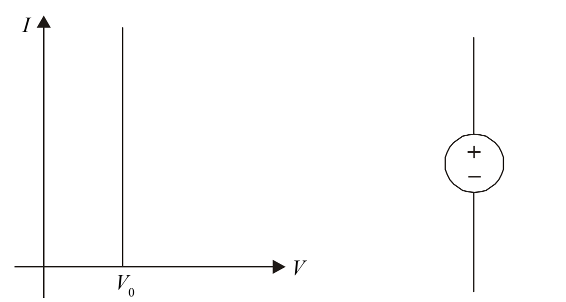
$I_{\text{diffusion}} = De\frac{dn}{dx}$ where D is diffusion constant and $e\frac{dn}{dx}$ is charge density gradient.

(c) **Displacement current** This type of current is generated due to varying electric/magnetic flux.

$I_{\text{dispalcement}} = \varepsilon_0 \frac{d\phi_E}{dt}$ where ϕ_E is electric flux and ε_0 is permittivity of free space.

Cells and generators are common sources of electricity.

Ideal voltage source An ideal voltage source is one in which voltage does not vary irrespective of the value of current drawn. An **ideal voltage source** has zero internal resistance.



(a) Characteristic (b) Representation

Fig. 21.1 **Ideal voltage source**

Emf The maximum potential drop across a cell/device when no current is drawn. Emf is equivalent to open circuit voltage. An ideal voltmeter will be required to measure emf. Since practically we do not have an ideal voltmeter, we use potentiometer to measure emf. Unit of emf is Volt (V), $1\text{V} = \frac{1J}{1C}$

An **ideal voltmeter** has infinite resistance.

Current density $J = \frac{I}{A} = nev_d = \frac{ne^2\tau}{m}E$

Also $J = \sigma E$ where σ is conductivity. Thus $\sigma = \frac{ne^2\tau}{m}$

Note that current density is a vector. $\oint J \cdot ds = I$

Conductivity σ is reciprocal of resistivity ρ.

Thus $\sigma = \frac{1}{\rho}$ and hence $\rho = \frac{m}{ne^2\tau} = \frac{E}{J}$

Unit of conductivity is $(\text{ohm-m})^{-1}$

Resistivity of a substance is the resistance offered by a unit cube of the material., i.e., $\rho = R$ if $l = 1\text{m}$ and $A = 1\text{m}^2$

Its unit is ohm-m. Resistivity or specific resistance varies inversely with pressure. Moreover $\rho = \rho_0(1+\alpha T)$ where α is thermal coefficient of resistance .

Resistance R of a conductor $\propto l$ (length of the conductor) and $R \propto \frac{1}{A}$ where A is area of cross-section

$$R = \rho\frac{l}{A}$$ where ρ is the resistivity.

Resistance offers oppositon to the flow of current. Resistances are of three types ohmic, nonohmic and negative. Ohmic resistances follow Ohm's law $V=IR$ or $V \propto I$. Vaccum tubes and semiconductors are examples of nonohmic resistances. For such devices dynamic resistance or incremental resistance $r = \frac{dV}{dI}$ or $r = \frac{\Delta V}{\Delta I}$ is determined. A negtative resistance device shows inverse relation between V and I, i.e., $I \propto \frac{1}{V}$. Tunnel diode, tetrode and thyristors are examples of negative resistance devices.

Potential (V) Amount of work done to bring a unit positive charge from infinity to that point against the electric field of a given charge without changing velocity or kinetic energy is called potential. Its unit is volt (V). Practically we can measure only potential difference. Potential cannot be measured as infinity cannot be defined.

Potential difference is the difference of potentials between two points. Thus potential difference $V = V_1 - V_2$

Emf of a cell depends upon the nature of electrolyte and nature of electrodes. Table 21.1 shows the comparative study of different cells

Table. 21.1 Comparative study of different cells

S.No	Cell	Nature	Anode	Cathode	Emf
1	Voltaic	Primary	Cu	Zn	1.1V
2	Daniel	Primary	Cu	Zn (amalgamated)	1.1V
3	Laclanche	Primary	C (graphite)	Zn (amalgamated)	1.35V
4	Dry cell	Primary	C (graphite)	Zn (amalgamated)	1.5V
5	Lead Acid accumulator	Secondary	PbO_2	Pb	2.2V when fully charged, 1.8V when and discharged.
6	Alkali accumulator	Secondary	Ni + NiO	FeO_2	1.35V when charged and 1.25V when Discharged.

Resistance in conductors is caused by

(a) electron-electron collision

(b) collision between core and electron

(c) interaction between electrons and lattice vibration

(d) trap centres. $R = \frac{V}{I}$.

The device which offers resistance is called resistor.

Alloys have more trap centres and therefore their resistivity and hence resistance is higher as compared to metals forming them. Manganin is used to make standard resistances as its specific resistance is high and it varies very little with temperature. Alloy used in making rheostat is constantan. Nichrome is commonly used to make heaters used in press, geyser, room heaters etc. Manganin (84% Cu, Mn 12%, Ni 4%) constantan (Cu 60%, Ni 40%)

Silver is the best conductor followed by Cu, Au, Al, W(tungsten), steel, lead (Pb) and Hg. The best insulator is fused quartz with resistivity 75×10^{16} ohm-m.

Carbon resistors are colour coded. **First colour can not be black**. If there are four colour bands then $R = ab \times 10^C \pm d\%$ and $R \geq 10\Omega$ colours a, b, c and d, their values are listed in Table 21.2

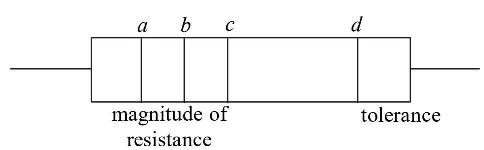


Fig. 21.2 Colour code in carbon resistors

Table. 21.2 Colour code of resistors

Black	Brown	Red	Orange	Yellow	Green	Blue	Violet	Grey	White
0	1	2	3	4	5	6	7	8	9

Table. 21.3 Tolerance in resistors

Gold	Silver	no fourth colour
5%	10%	20%

For example, Red Brown Orange Gold will stand for

$21 \times 10^3\ \Omega \pm 5\%$

and colour code for $10\Omega \pm 5\%$ will be $10 \times 10^o \pm 5\%$

Brown Black Black Gold

If resistance is less than 10Ω then another scheme is used

$R = ab \times 10^C$

where a and b are taken form Table 21.2 and C is taken from Table 21.4.

Note it has no fourth colour.

Table. 21.4 Third colour value for carbon resistors

Gold	Silver
–1	–2

< 10Ω

for instance 0.5Ω will have colour code

50×10^{-2} = Green Black Silver.

Every source of emf has internal resistance r.

Terminal voltage $V = \varepsilon - Ir$ (See Fig. 21.3)

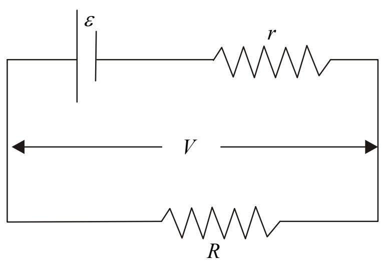


Fig. 21.3 Illustration of terminal voltage V

where ε is emf. During charging of the battery or if the current is in opposite direction to normal direction of current from the cell or a battery, the terminal voltage is greater than emf.

Conductance (G) is reciprocal of resistance i.e. $G = \dfrac{1}{R}$.

Its unit is mho or $(\text{ohm})^{-1}$ or Siemen (S).

Superconductors have zero resistance. The highest critical temperature for a superconductor known till 2003 is (minus) 160ºC. It is a complex oxide of Yttrium, Copper and Barium.

Cells in series If n identical cells are connected in series, each having emf E and internal resistance r, then current in an external resistance R is given by,

$$I = \frac{nE}{R + nr}$$

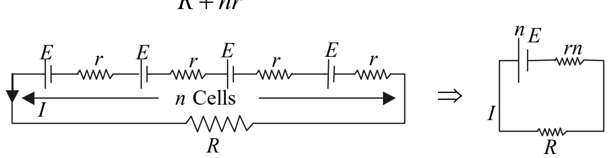


Fig. 21.4 Cells in series

Cells in parallel If n identical cells are connected in parallel, each having emf E and internal resistance r,

$$\text{then } I = \frac{E}{R + r/n}. \text{ (See Fig. 21.5)}$$

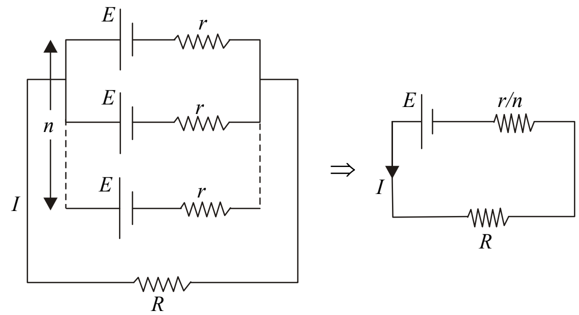


Fig. 21.5 Cells in parallel

Cells in mixed grouping m rows of n identical cells in series connected to an external resistance R.

$$\text{Then } I = \frac{nE}{\frac{nr}{m} + R}$$

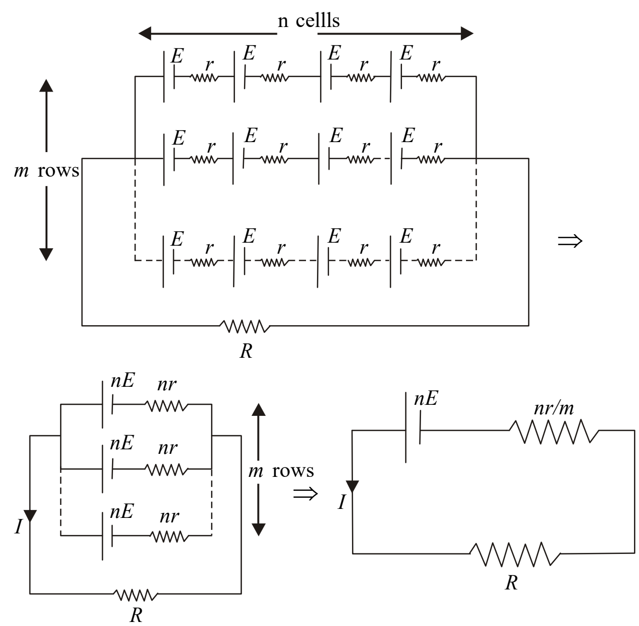


Fig. 21.6 Cells in mixed grouping

Maximum current is deliverd by a source when it is short circuited i.e. $R_{external} = 0$. Maximum power is delivered by a source under matched conditions i.e. $r_{int} = R_{ext}$

Law of Resistances

In series $R_S = R_1 + R_2 + ... + R_n$

If n equal resistances are in series then $R_S = nR$

$$\text{In parallel } \frac{1}{R_P} = \frac{1}{R_1} + \frac{1}{R_2} + ... \frac{1}{R_n}$$

If n equal resistances are in parallel then $R_P = \dfrac{R}{n}$

For two resistances in parallel $R_P = \dfrac{R_1 R_2}{R_1 + R_2}$

Kirchhoff's Current Law (KCL) Algebraic sum of all the currents entering at any instant at a node (junction) is zero. or Sum of currents entering a junction at any instant = Sum of current leaving the junction at that instant. The law is based on conservation of charge.

Kirchhoff's Voltage Law (KVL) or Loop Law Algebraic sum of all the potential drops in a closed circuit (or a loop) is zero. It is based on conservation of energy.

Wheatstone bridge The bridge is said to be balanced if $V_X = V_Y$ or $I_G = 0$. Under balanced condition $\frac{P}{Q} = \frac{R}{S}$. (See Fig. 21.7)

Fig. 21.7(a) Wheatstone bridge

Fig. 21.7(b), (c) are other representations of Wheatstone bridge.

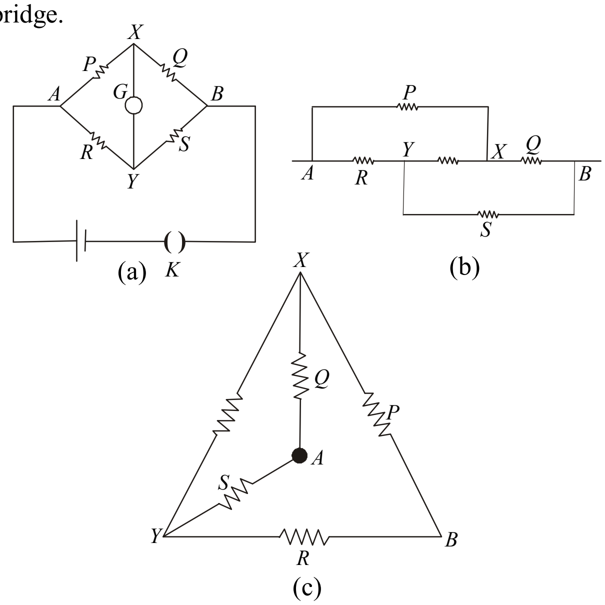


Fig. 21.7

Potentiometer The fall of potential along the length of a conductor of uniform area of cross-section and uniform density is proportional to its length when current I passes through it, provided physical conditions like temperature, pressure etc remain unchanged.

Potential gradient $k = \frac{V}{l}$. More the length or smaller the value of k, more sensitive is the potentiometer.

To find emf by comparison method:

$$\frac{\varepsilon_1}{\varepsilon_2} = \frac{l_1}{l_2}$$

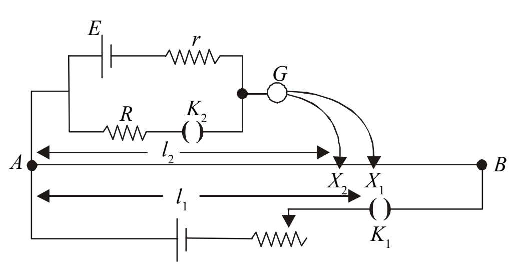


Fig. 21.8 To find internal reistance of a cell using potentiometer

To find internal resistance of a cell

$$r = R\left(\frac{l_1 - l_2}{l_1}\right)$$

where l_1 is the length when key k_2 is open and only k_1 is closed and null point is found while l_2 is the length of the potentiometer wire when k_2 is also inserted and null point determined.

Meter bridge or slide wire bridge

If balance point or null point is determined at X, then

$$\frac{P}{Q} = \frac{l}{100-l}$$

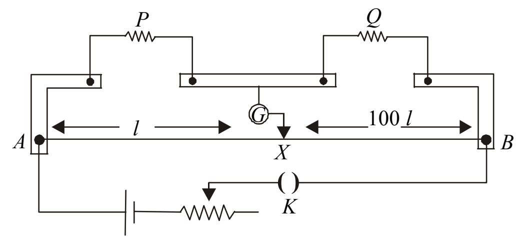


Fig. 21.9 Find unknown resistance using slide wire bridge

SHORT CUTS AND POINTS TO NOTE

1. If n identical cells are connected in series and m of them are wrongly connected then $\varepsilon_{\text{net}} = n\varepsilon - 2m\varepsilon$ where ε is emf of each cell.
2. If a branch of a circuit contains capacitor then in steady state current through that branch is zero.
3. The current in a branch is zero if $V_1 = V_2$
4. If n identical cells are connected in order in a loop then potential drop across any two points is zero.
5. An ideal current source has infinite resistance. An ideal ammeter has zero resistance.
6. An ideal voltage source has zero resistance. An ideal voltmeter has infinite resistance.
7. Normally a voltmeter is connected in parallel. However, in order to find high resistance it may be connected in series as shown in Fig 21.11. If voltmeter has internal resistance R and it reads V then

$$V = \frac{V_0 R}{X + R}$$ and hence X can be determined.

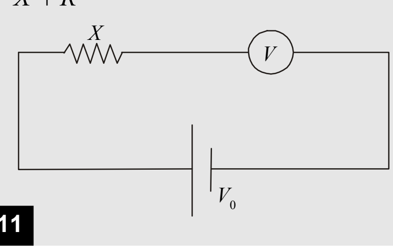


Fig. 21.11

8. In parallel, the net resistance is smaller than the smallest.
9. If two points in a circuit are short circuited then resistance across those points is zero irrespective of the resistance shown between those points.
10. Strictly speaking, resistance of metals vary nonlinearly with temperature $R(T) = R_0(1 + \alpha T + \beta T^2 + ...)$,
11. If two nonidentical cells are, in parallel, positive terminal connected to positive, then

$$E_{eq} = \frac{E_1 r_2 - E_2 r_1}{r_1 + r_2}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

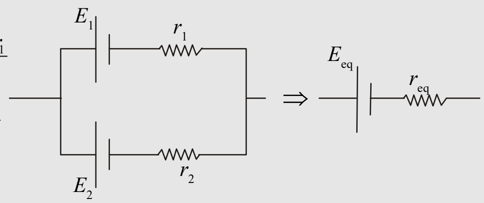


Fig. 21.12 (a)

If positive terminal of one cell/battery is connected to negative terminal of the other,

$$E_{eq} = \frac{E_1 r_2 + E_2 r_1}{r_1 + r_2}$$

$$r_{eq} = \frac{r_1 r_2}{r_1 + r_2}$$

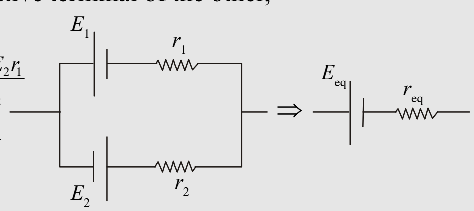


Fig. 21.12 (b)

12. To solve a resistive network. There could be four methods.
    (a) Series/parallel method (when clearly visible).
    (b) Wheatstone bridge method.
    (c) Current division method. Though it could be used for any circuit, it suits symmetrical circuits.
    (d) Star-delta method.

Star to delta conversion

From Fig. 21.13

$$R_{AB} = R_1 + R_2 + \frac{R_1 R_2}{R_3}$$

$$R_{AC} = R_1 + R_3 + \frac{R_1 R_3}{R_2}$$

$$R_{BC} = R_2 + R_3 + \frac{R_2 R_3}{R_1}$$

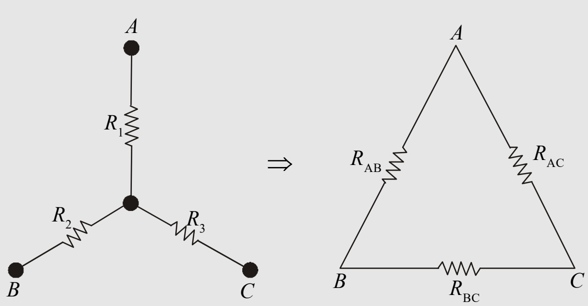


Fig. 21.13 Star to delta form

Delta to star conversion

From Fig. 21.14

$$R_A = \frac{R_1 R_2}{R_1 + R_2 + R_3}$$

$$R_B = \frac{R_1 R_3}{R_1 + R_2 + R_3}$$

$$R_C = \frac{R_2 R_3}{R_1 + R_2 + R_3}$$

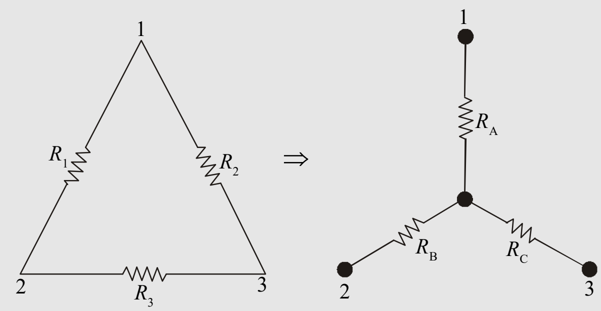


Fig. 21.14 Delta to star form

13. If current in its path meets positive terminal as shown in fig. 21.15 then take E_1 positive in the Loop law or Kirchhoff's Voltage Law as it represents potential drop.

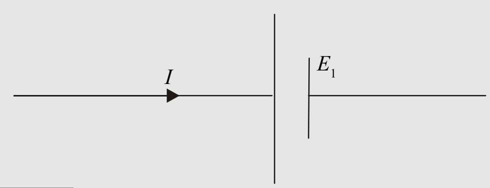


Fig. 21.15

14. If current enters the negative terminal of the battery then take $-E_2$ as it represents potential rise in the Loop law. (Fig. 21.16)

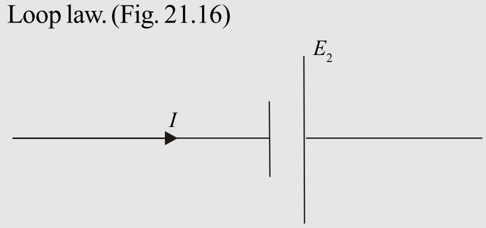


Fig. 21.16

15. To find I_1, I_2 and I_3 in the circuit shown in Fig. 21.17 find V_{AB} and then

$$I_1 = \frac{V_{AB}}{R_1}, I_2 = \frac{V_{AB}}{R_2} \text{ and } I_3 = \frac{V_{AB}}{R_3}$$

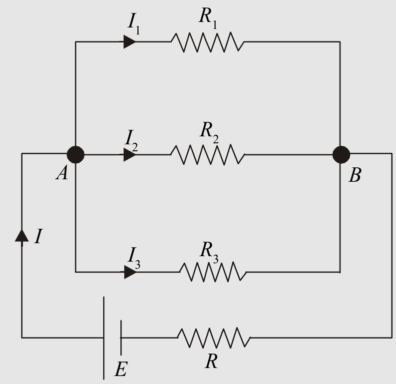


Fig. 21.17

16. If all the resistances in the Wheatstone bridge are identical or $R_1 = R_2 = R_3 = R_4 \neq R_5$ then

$$R_{AB} = R_{eq} = R. \text{ (See Fig. 21.18)}$$

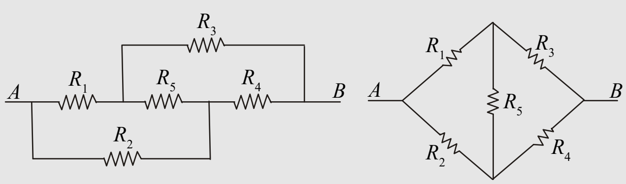


Fig. 21.18

17. **Current division Rule**

In Fig. 21. 19

$$I_1 = \frac{IR_2}{R_1 + R_2}, I_2 = \frac{IR_1}{R_1 + R_2}$$

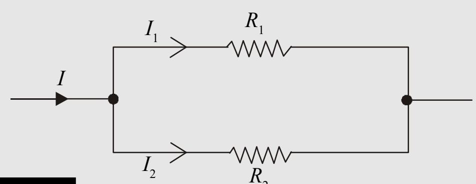


Fig. 21.19

18. **Potential division Rule**

In Fig. 21.20

$$V_1 = \frac{V_0 R_1}{R_1 + R_2 + R_3}, V_2 = \frac{V_0 R_2}{R_1 + R_2 + R_3},$$

$$V_3 = \frac{V_0 R_3}{R_1 + R_2 + R_3},$$

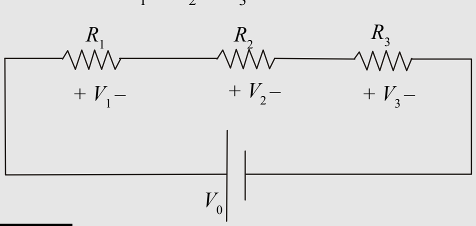


Fig. 21.20

19. To convert a galvanometer (or de Arsenol moment) into ammeter, a shunt (very small resistance) in parallel is connected. If I_g is full scale deflection through the galvanometer and R_g is its internal resistance then to convert it into an ammeter to measure I, a shunt S will be required in paralled such that $S = \dfrac{I_g R_g}{I - I_g}$

20. To convert a galvanometer into voltmeter to measure V volts a resistance R is to be connected in series given by

$R = \dfrac{V}{I_g} - R_g$ where I_g is full scale deflection current in galvanometer and R_g is the resistance of the galvanometer.

21. If a skelton cube is made with 12 equal resistances/ wires each having resistance R then net resistance across

(a) the longest diagonal is $\dfrac{5}{6}R$

(b) the face diagonal is $\dfrac{3}{4}R$

(c) One side is $\dfrac{7}{12}R$

(d) the open side as shown in Fig. 21.21 is $\dfrac{7}{5}R$

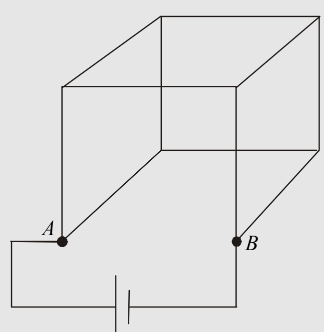


Fig. 21.21

22. Temperature can be determined using Wheatstone bridge arrangement with a vernier (small variable resistance) and Platinum resistance thermometer in one arm as shown in Fig. 21.22.

$$\frac{P}{R + \Delta R} = \frac{Q}{S(1 + \alpha \Delta T)} \text{ If } P = Q \text{ then } R = S\alpha\Delta T$$

or $$\Delta T = \frac{\Delta R}{S\alpha}$$

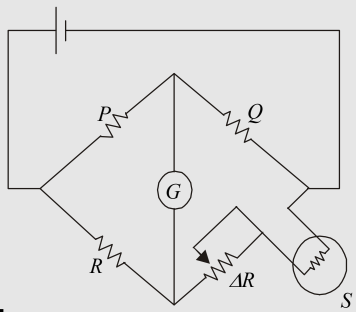


Fig. 21.22 **Platinum resistance thermometer or a filament in hot bath**

23. The equivalent resistance for the circuit shown in Fig. 21. 23 is

$$R_{AB} = \frac{R_1(R_1+3R_2)}{(R_2+3R_1)}$$

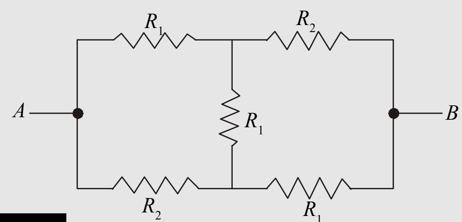


Fig. 21.23

The equivalent resistance for the circuit shown in Fig. 21.24 (a) is $R_{AB} = \dfrac{2R_1R_2 + R_3(R_1+R_2)}{2R_3 + R_1 + R_2}$

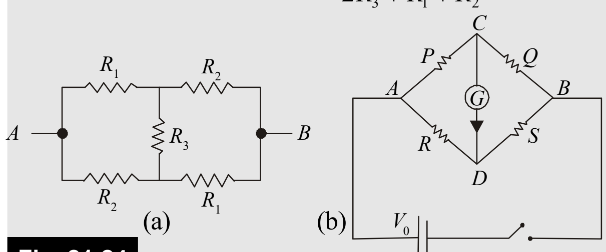


Fig. 21.24

Current through galvanometer in unbalanced wheatstone bridge of fig 21.24 (b)

$$I_g = \frac{V_0(RQ-PS)}{R_g(P+Q)(R+S)+PQ(R+S)+RS(P+Q)}$$

and $V_{CD} = V_C - V_D = \dfrac{V_0(QR-PS)}{(P+Q)(R+S)}$

24. Substances like Carbon (graphite), Ge, Si have negative thermal coefficient of resistance (α) i.e. their rersistivity and hence resistance falls with rise in temperature. Manganin has $\alpha = 0$. Iron has very large value of α.

25. At high frequency applications like Radio, TV etc. carbon resistors are used. Wire wound resistors at high frequency behave like a resonant circuit and alter the value of resistance by offering impedance. The equivalent circuit of wire wound resistance is shown in Fig 21.25 at high frequencies.

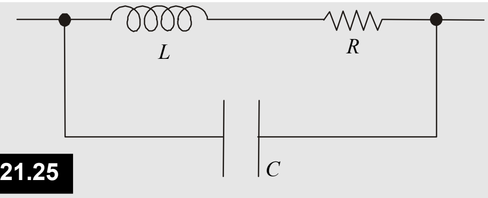


Fig. 21.25

26. If a resistive wire is stretched n times its resistance increases n^2 times, i.e., $R_{new} = n^2 R_{old}$.

27. Current is a 'through' variable and potential difference or voltage is an 'across' variable.

28. Terminal voltage $V = \varepsilon - Ir$ is the potential drop across the cell/source. Normally it is less than emf. However, when the direction of current is opposite as during charging, terminal voltage is greater than emf.

29. Galvanometer can measure small currents ~μA and small voltage ~ mV. That is why we can convert it to both voltmeter and ammeter.

30. DC current in steady state cannot pass through a capacitor.

31. Mean free path of electrons is $\lambda = v_d \tau = \dfrac{mv_d}{ne^2\rho}$

CAUTION

1. Adding emfs to find net emf when negative terminal of one is connected to negative terminal of other battery or positive terminal of one battery connected to positive terminal of other battery/cell.

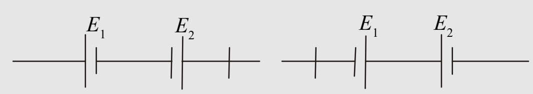


Fig. 21.26 (a)

⇒ In such cases use $E_1 - E_2$ or $E_2 - E_1$ keeping in mind which is greater on the direction of current chosen.

Emfs are added when positive terminal of one battery is connected to negative terminal of other in series. For example in Fig. 21.26 (b) $E_{net} = E_1 + E_1$

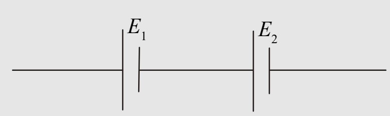


Fig. 21.26 (b)

2. Wrongly detecting Wheatstone bridge, for example, considering AXYO, XYBO, AOWZ and OBWZ as Wheatstone bridge in Fig. 21.27 (a).

⇒ If A and B are point of interest where equivalent resistance is to be determined and R_G is connected between XY terminals (other than the points of interest) and $\dfrac{P}{Q} = \dfrac{R}{S}$

only then R_G can be removed as no current will pass through R_G. Removing R_G suggests it acts like open circuit between X and Y.

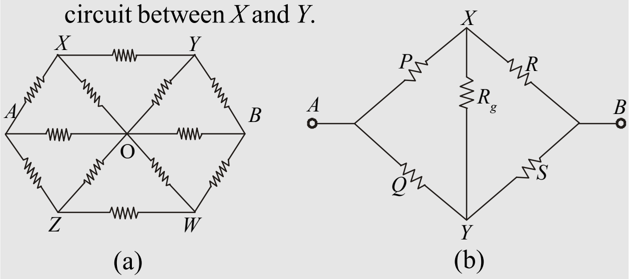


Fig. 21.27

3. Not applying current division properly when branching occurs at a point.

⇒ Stick to junction law in such cases and divide the current properly.

4. Not taking into account the resistance of voltmeter or ammeter when they are not ideal.

⇒ Remember voltmeter is connected in paralled. If its resistance is small it alters the resistance of the circuit drastically. Therefore, their resistances must be taken into account.

5. Not taking into account internal resistance of the cell.

⇒ When current in the circuit is flowing internal resistance of the cell must be taken into consideration. It alters the terminal voltage and even decreases the current in the circuit. For example in Fig. 21.28

$I = \dfrac{E}{R+r}$ and terminal voltage $V = E - Ir$

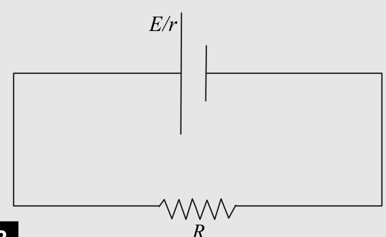


Fig. 21.28

6. Assuming DC current passes through capacitor in steady state.

⇒ $T_{dc} = 0$ in steady state through capacitor or branch containing a capacitor. However, during transient current passes through capacitor. You know $Q = CV$ or

$I = \dfrac{dQ}{dt} = C\dfrac{dV}{dt}$. i.e., if V is constant $\dfrac{dV}{dt} = 0$ and hence $I = 0$

7. Considering potentiometer or meterbridge has no resistance.

⇒ Must take into account the resistance of potentionmeter wire. To find potential gradient, find potential drop across the length of the wire.

The potential gradient

$$k = \frac{\text{potential drop across the length of the wire}}{\text{length of the wire}}$$

Note $k \neq \dfrac{\text{emf applied}}{\text{length of the potentiometer wire}}$

8. Considering resistivity varies with length of the wire or with area of cross-section.

⇒ Resistivity depends upon nature of the substance and is independent of the length and area of cross-section of the wire. However, it depends upon pressure and temperature.

Note: $\rho \propto T$ and $\rho \propto \dfrac{1}{P}$ in conductors.

9. Considering current through capacitor as zero, therefore no potential drop will occur across the capacitor.

⇒ Remember that potential drop across the capacitor may occur even though the current is zero.

10. Not understanding the meaning of a switch.

⇒ Potential drop across AB is –2V when switch is open and zero when switch is closed. Note that a closed switch is equivalent to short circuit or zero resistance.

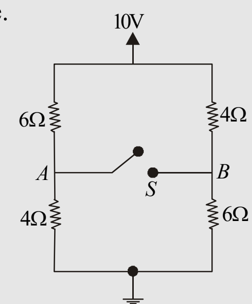


Fig. 21.29

11. Considering that current starts from positive terminal of the battery and is used up by the time it reaches negative terminal.

⇒ In fact current remains same at every point in a simple loop because it is based on conservation of charge. Charge entering per second is equal to charge leaving per second.

12. Considering that in a conductor, when current is increased, electron density increases.

⇒ If the conductor has uniform area of cross-section then increasing the current results in increasing the drift velocity.

13. In a conductor as shown in Fig. 21.30 considering that the drift velocity remains same everywhere.

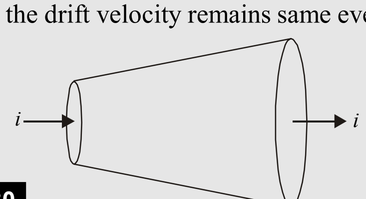


Fig. 21.30

⇒ Drift velocity is larger at smaller cross-sections than at higher cross-sections.

SOLVED PROBLEMS

1. Find the drift velocity in Cu wire if it has 1A current through 2 mm^2 cross-section. Free electron density is 8.5×10^{22} cm^{-3}.

(a) 0.36 mms^{-1} (b) 0.36 cms^{-1}
(c) 0.036 mms^{-1} (d) 0.036 cms^{-1}

Solution (c) $v_d = \dfrac{i}{neA}$

$$= \frac{1}{8.5\times10^{28}\times1.6\times10^{-19}\times2\times10^{-6}}$$

$$= \frac{1\times10^{-3}}{27.2} = 0.036 \text{ mms}^{-1}.$$

2. A 5 Ω constantan wire is bent to form a ring. Find the resistance across the diameter of the wire.

(a) 2.5Ω (b) 1.25 Ω
(c) 5 Ω (d) 0.625 Ω

Solution (b) $R \propto l$. Therefore 2.5 Ω resistances are in parallel across AB. Thus $R = \dfrac{2.5}{2} = 1.25\ \Omega$

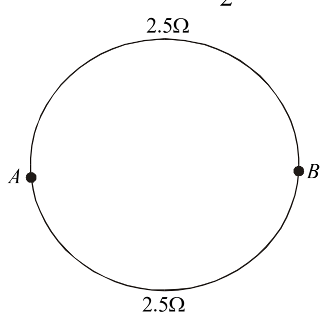
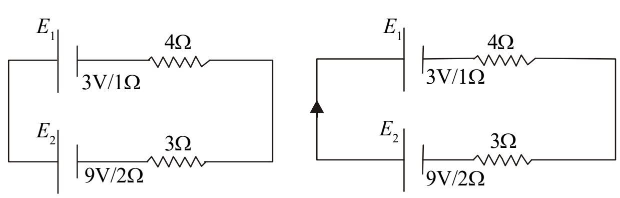


Fig. 21.31

3. Find the terminal voltage across E_1 and E_2 in Fig. 21.32 (a)

(a) 3.6 V, 7.8 V (b) 2.4 V, 7.8 V
(c) 3.6 V, 10 V (d) 2.4 V, 10.2 V



(a) (b)

Fig. 21.32

Solution (a) Current in the circuit in Fig. 21.32 (b)

$$I = \frac{9-3}{10} = 0.6 \text{ A}$$

$$V_1 = E_1 + Ir_1 = 3 + 0.6 \times 1 = 3.6 \text{ V};$$

$$V_2 = E_2 - Ir_2 = 9 - 0.6 \times 2 = 7.8 \text{ V}$$

4. Find I_1 and I_2 in Fig. 21.33

(a) $2.0\,A, \dfrac{4}{3}A$ (b) $1\,A, \dfrac{2}{3}A$
(c) $2\,A, \dfrac{2}{3}A$ (d) $1A, \dfrac{1}{3}A$

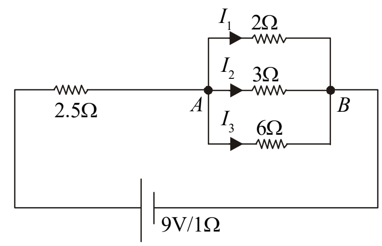


Fig. 21.33

Solution (c) $\dfrac{1}{R_{AB}} = \dfrac{1}{2} + \dfrac{1}{3} + \dfrac{1}{6} = \dfrac{3+2+1}{6}$ and

$$I = \frac{9}{1+1+2.5} = 2\text{A}$$

$$V_{AB} = \text{I}.R_{AB} = 2 \times 1 = 2\text{V}$$

$$I_1 = \frac{2V}{2\Omega} = 1\text{A } I_2 = \frac{2}{3}\text{A}$$

5. Find the value of R so that no deflection is noticed in the galvanometer when the switch S is closed or open.

(a) 4Ω (b) 8Ω
(c) 6Ω (d) none of these

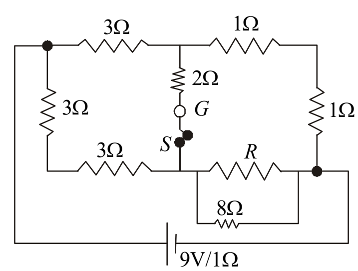


Fig. 21.34

Solution (b) It is a Wheatstone bridge case, therefore

$$\frac{3}{3+3} = \frac{1+1}{\frac{8R}{8+8}} \text{ or } \frac{8R}{8+R} = \Rightarrow R = 8\Omega$$

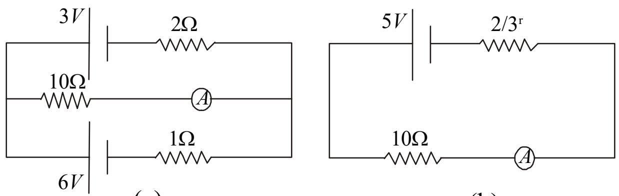
6. The ammeter reading in the circuit of Fig. 21.35 (a) is

(a) $\dfrac{15}{32}$ A (b) $\dfrac{14}{33}$ A
(c) $\dfrac{17}{33}$ A (d) $\dfrac{15}{31}$ A

Solution (a) $E_{eq} = \dfrac{3\times1+6\times2}{1+2} = 5\text{V}$; req $= \dfrac{2\times1}{2+1} = \dfrac{2}{3}\Omega$

From equivalent circuit of Fig. 21.35 (b)

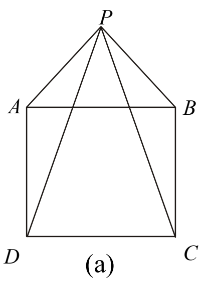
$$\text{I} = \frac{5}{10+2/3} = \frac{15}{32}\ \text{A}$$



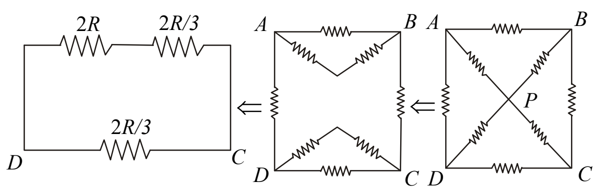
(a) (b)

Fig. 21.35

7. Find the equivalent resistance about any branch of the base of the square pyramid shown. Assume resistance of each branch is R.



(a)



(b)

Fig. 21.36

(a) $\dfrac{7R}{15}$ (b) $\dfrac{8R}{15}$

(c) $\dfrac{R}{2}$ (d) none of these

Solution (b) From the eqnivalent circuits of Fig. 21.36 (b)

$$R_{eq} = \frac{\frac{8R}{3}\times\frac{2R}{3}}{\frac{8R}{3}+\frac{2R}{3}} = \frac{16R}{30} = \frac{8R}{15}$$

8. A hollow cylinder of radiis a and b is filled with a material of resistivity ρ. Find the current through ammeter.

(a) $\dfrac{E\pi l\left(b^2-a^2\right)}{\rho\lambda}$ (b) $\dfrac{E\pi l}{\left(\rho\log_\varepsilon\frac{b}{a}\right)}$

(c) $\dfrac{E2\pi l}{\rho\log_\varepsilon\frac{b}{a}}$ (d) $\dfrac{E2\pi l}{\rho\log_\varepsilon\frac{a}{b}}$

Solution (c) Assume a hypothetical cylinder of radius x and thickness dx then

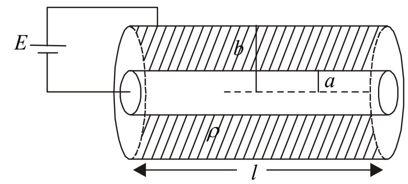
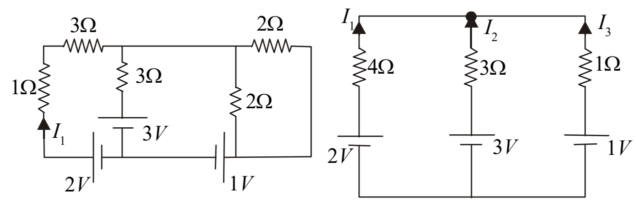


Fig. 21.37

$$\int dR = \int_a^b \frac{\rho dx}{2\pi x l}\quad R = \frac{\rho\log_e\frac{b}{a}}{2\pi l}\ \text{and}\ I = \frac{E}{R} = \frac{E2\pi l}{\rho\log_e\frac{b}{a}}$$

9. Find current I, in Fig. 21.38 (a)



(a) **Fig. 21.38** (b)

(a) $\dfrac{1}{19}A$ (b) $\dfrac{2}{19}A$

(c) $\dfrac{3}{19}A$ (d) none of these

Solution (b) Draw equivalent circuit as shown in Fig. 21.38 (b). Let node potential be V, then apllying KCL (Junction law)

$$I_1 + I_2 + I_3 = 0$$

or $\dfrac{2-V}{4} + \dfrac{3-V}{3} + \dfrac{1-V}{1} = 0$

or $6 - 3V + 12 - 4V + 12 - 12V = 0$

or $V = \dfrac{30}{19}$ Volt.

$$I_1 = \frac{2-\frac{30}{19}}{4} = \frac{2}{19}\text{A}$$

10. Find the potential drop across 4μF capacitor and 6Ω resistor in Fig. 21.39

(a) 0,0 (b) 0, 3V

(c) 0, 2V (d) 2V, 0

Solution (d) $I = \dfrac{3}{2+4} = \dfrac{1}{2}A$

Potential drop across 4Ω resistor is $V = 4\times\dfrac{1}{2} = 2V$

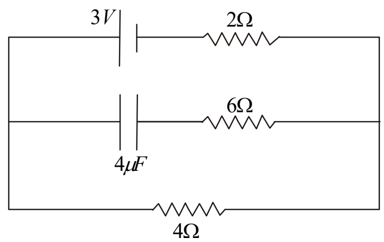


Fig. 21.39

The whole potential drop occurs across 4μF capacitor as current does not flow through the branch containing capacitor.

11. The temperature of a conductor is increased. The product of resistivity and conductivity

(a) increases (b) decreases

(c) remains constant

(d) may increase or decrease.

Solution (c)

12. Two non-ideal batteries are connected in parallel. Then

(A) the equivalent emf is less than either of the two emfs.

(B) the equivalent internal resistance is less than either of the two internal resistances.

(a) both A and B are correct

(b) only A is correct

(c) only B is correct

(d) both A and B are wrong

Solution (c)

13. A resistor connected to a battery is heated due to current through it. Which of the following quantity does not vary?

(a) resistance (b) drift velocity

(c) resistivity

(d) number of free electrons

Solution (d)

14. Find the electric field in the copper wire of area of cross-section 2mm^2 carrying a current of 1A. The resistivity of copper is $1.7 \times 10^{-8}\,\Omega$m.

(a) 4.25×10^{-3} V/m (b) 8.5×10^{-3}V/m

(c) 8.5 V/m (d) 8.5×10^{-3} V/m

Solution (b) $J = \sigma E$ or $E = \dfrac{J}{\sigma} = J\rho = \dfrac{I}{A}$

$$\rho = \frac{1 \times 1.7 \times 10^{-8}}{2 \times 10^{-6}} = 8.5 \times 10^{-3}\text{ V/m}$$

15. A high resistance voltmeter reads 1.52V when switch S is open and 1.48V when switch S is closed. The ammeter resistance is (Fig 21.40)

(a) 0.2 Ω (b) 0.3 Ω

(c) 0.4 Ω (d) 0.8 Ω

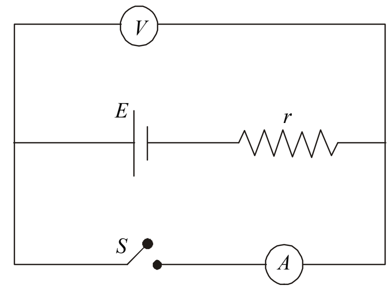


Fig. 21.40

Solution (c) $E = 1.52$V and $V = E - Ir$

$1.48 = 1.52 - 1\,(r)$ or $r = 0.4\Omega$

16. Find the resistance across A B in Fig. 21.41 (a)

(a) R (b) $\dfrac{2}{3}R$

(c) $\dfrac{R}{3}$ (d) $\dfrac{4}{3}R$

(e) $3R$

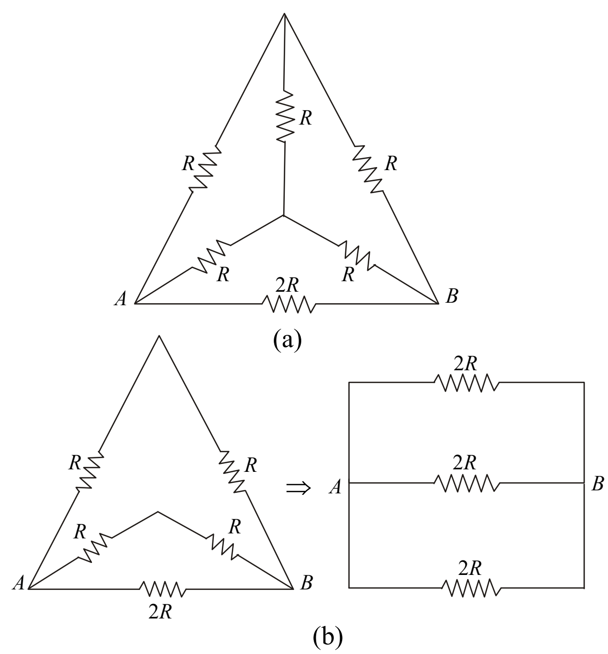


Fig. 21.41

Solution (b) Draw equivalent circuit of Fig. 21.41 (b).

then $R_{eq} = 2\,\dfrac{R}{3}$

17. When the current in a wire is 1A, the drift velocity is 1.2×10^{-4} ms^{-1}. The drift velocity when current become 5 A is

(a) 1.2×10^{-4} ms^{-1} (b) 3.6×10^{-4} ms^{-1}

(c) 6×10^{-4} ms^{-1} (d) 4.8×10^{-4} ms^{-1}

Solution (c) $I \propto v_d$ $\therefore$ new drift velocity is 6×10^{-4} ms^{-1}.

18. An ideal voltmeter is connected in Fig. 21.42. The current in circuit is

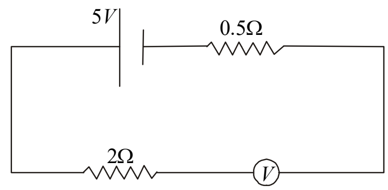


Fig. 21.42

(a) 2A (b) 2.5A

(c) ∝ (d) zero.

Solution (d) Ideal voltmeter has infinite resistance. Therefore current will be zero.

19. In Fig. 21.43 AB is 300 cm long wire having resistance 10Ω per meter. Rheostat is set at 20Ω. The balance point will be attained at

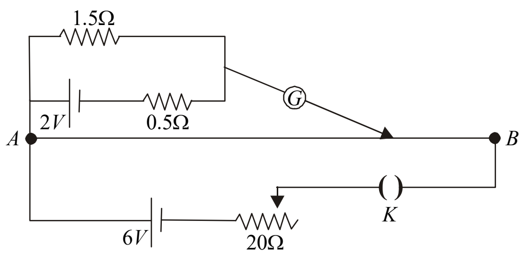


Fig. 21.43

(a) 1.0m (b) 1.25m

(c) 1.5m (d) cannot be determined.

Solution (b) $V_{AB} = \dfrac{6\times 30}{50} = 3.6\text{V}$. Terminal voltage of

cell $= \dfrac{2\times 1.5}{2} = 1.5\text{V}$

Using $V = kl \Rightarrow 1.5 = \dfrac{3.6}{300}\, l$ or $l = 125\text{cm}$

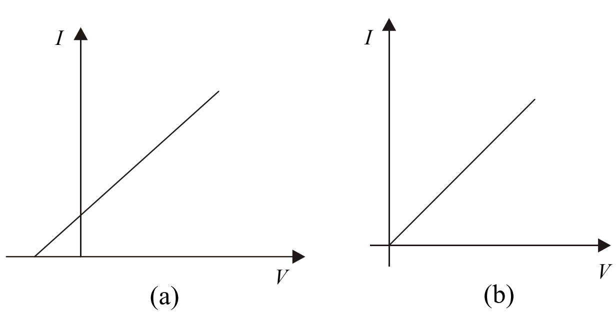
20. Ohm's law can be applied to

(a) ohmic devices (b) non-ohmic devices

(c) both (a) and (b) (d) none

Solution (c)

21. Which of the $V - I$ graph obeys Ohm's law?



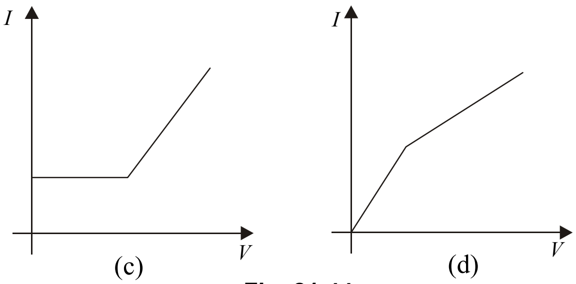


Fig. 21.44

Solution (b)

22. The $V - I$ graph of a conductor at two different temperatuses is shown in Fig. 21.45. The ratio of temperature $\dfrac{T_1}{T_2}$ is

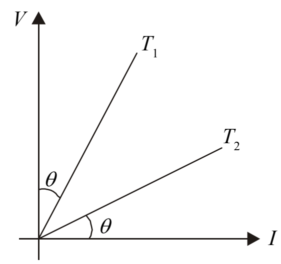


Fig. 21.45

(a) $\tan^2\theta$ (b) $\cot^2\theta$

(c) $\sec^2\theta$ (d) $\text{cosec}^2\theta$

Solution (b)

23. Two cells of emf's 1.25V and 0.75V having equal internal resistance are connected in parallel. The effective emf is

(a) 0.75V (b) 1.25V

(c) 2.0V (d) 1.0V

(e) 0.5 V

Solution (d) $E = \dfrac{1.25\times r + .75\times r}{2r}$

24. A 250 cm long wire has diamaeter 1mm. It is connected at the right gap of a slide wire bridge. When a 3π resistance is connected to left gap, the null point is obtained at 60cm. The specific resistance of the wire is

(a) 6.28×10^{-6} Ωm (b) 6.28×10^{-5} Ωm

(c) 6.28×10^{-8} Ωm (d) 6.28×10^{-7} Ωm

Solution (d) Using $\dfrac{R_1}{R_2} = \dfrac{l}{100-l} \Rightarrow \dfrac{3}{R_2} = \dfrac{60}{40}$

$\therefore \quad R_2 = 2\Omega$

$$\rho = \frac{R\times \pi r^2}{l} = \frac{2\times 3.14\times(.5\times 10^{-3})^2}{2.5}$$

$$= 6.28\times 10^{-7}\ \Omega\text{m}$$

25. An ammeter reads 500 mA. When a shunt of 0.1 Ω is connected across the ammeter its reading drops to 50 mA. The resistance of the ammeter is

(a) 1 Ω (b) 1.1 Ω

(c) 0.9 Ω (d) none of These

Solution (c) In parallel voltage remains same

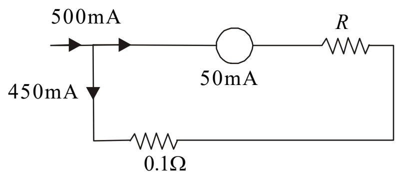


Fig. 21.45

$$50R = 450(0.1)$$
$$R = 0.9\,\Omega$$

26. Find the current in 100 Ω resistance in Fig. 21.46 (a).

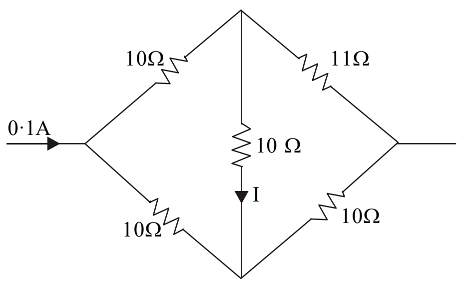


Fig. 21.46 (a)

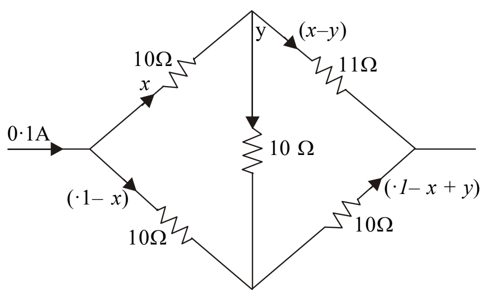


Fig. 21.46 (b)

(a) 0.01 A nearly (b) 0.001 A nearly

(c) 0.02 A nearly (d) 0.002 2A nearly.

Solution (b) Solve using Loop law $= 10x + 100y = 10\,(.1 - x)$

or $20x + 100y = 1$ ....(1)

$100y + 10\,(.1 - x + y) = 11\,(x - y)$

$21x - 121y = 1$ ....(2)

Solving eq. 1 & 2 for y we get $-y = 0.001\,A$

27. A plastic tube 25 m long and 4 cm in diameter is dipped into Ag solution deposting a silver layer 0.1 mm thick uniformly over its outer surface. Find the current if this coated tube is connected across a 12V battery. $\rho_{Ag} = 1.47 \times 10^{-8}\ \Omega$–m

(a) 4.14 A (b) 41.4 A

(c) 414 A (d) 414 mA

Solution (c) $R = \rho\dfrac{l}{\pi(r_2^2 - r_1^2)} = \dfrac{1.47\times10^{-8}\times25}{3.14(2.01^2 - 2^2)\times10^4}$

$$= \frac{1.47\times25\times10^{-4}}{3.14\times4.01\times(.01)}$$

$$I = \frac{12}{2.9\times10^{-2}} = 4.14\times10^2 = 414\text{ A}$$

28. Open circuit voltage of a source is 7.86 V and its short circuit current is 9.25 A. Find the current when an external resistance of 2.4 Ω is connected.

(a) 1.4 A (b) 1.82 A

(c) 2.01 A (d) 2.4 A

Solution (d) $r = \dfrac{7.86}{9.25} = 0.847\,\Omega$

$$I = \frac{7.86}{2.4 + .847} = 2.4\text{ A}$$

29. In the Fig. 21.47 find I, R, ε_1 and ε_2

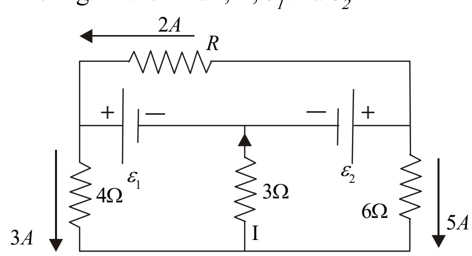


Fig. 21.47

(a) 8A, 9Ω, 54V, 36V (b) 8A, 9Ω, 36V, 54V

(c) 9A, 8Ω, 36V, 54V (d) none of these

Solution (b) $2R + \varepsilon_1 - \varepsilon_2 = 0$ ....(1)

$4\,(3) + 3\,I = \varepsilon_1$ ....(2)

$5\,(6) + 3\,I = \varepsilon_2$ ....(3)

$2R + (3) = 5\,(6)$ ....(4)

Solving eq (1), (2), (3) and (4), we get $R = 9\ \Omega$, $I = 8A$, $\varepsilon_1 = 36$V and $\varepsilon_2 = 54$V

30. A current of 2A passes through a wire for 20 minutes. The number of electrons that crossed the cross-section in this period is

(a) 1.5×10^{21} (b) 1.5×10^{20}

(c) 1.5×10^{22} (d) 1.5×10^{23}

Solution (c) $n = \dfrac{It}{e} = \dfrac{2\times20\times60}{1.6\times10^{19}} = 15 \times 10^{21}$

31. To measure a small resistance ~ 10^{-5}Ω, one should use

(a) Wheatstone bridge (b) Postoffice Box

(c) Wein's bridge (d) Carrey Foster bridge

Solution (d)

32. The free electron gas theory explains conduction in

(a) metals only (b) semiconductors only

(c) insulators only (d) all of these

Solution (a)

32. Find current through 12 Ω resistor in Fig. 21.48 (a)

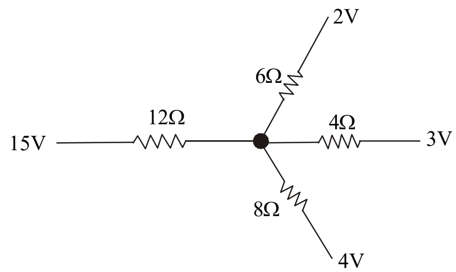


Fig. 21.48 (a)

(a) $\frac{49}{60}$ A (b) $\frac{41}{60}$ A

(c) $\frac{21}{40}$ A (d) $\frac{23}{40}$ A

Solution (a) Let V be the potential at P then applying KCL at junction P.

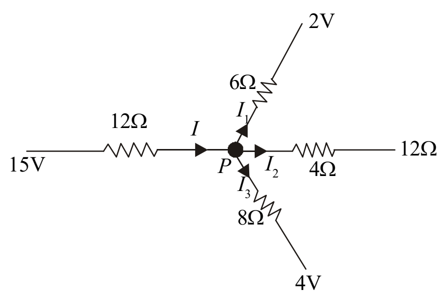


Fig. 21.48 (b)

$$I = I_1 + I_2 + I_3 \frac{15-V}{12}$$

$$= \frac{V-2}{6} + \frac{V-3}{4} + \frac{V-4}{8}$$

$$15-V = 2(V-2) + 3(V-3) + 1.5(V-4)\ 7.5\text{V} = 39$$

or $$V = \frac{39}{7.5} = 5.2\text{V}$$

and $$\text{I} = \frac{15-5.2}{12} = \frac{4.9}{6} A$$

33. To terminate the network shown in Fig. 21.49, The resistance required is

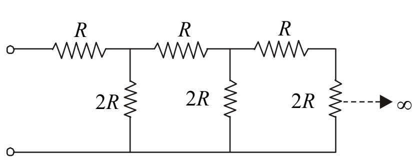


Fig. 21.49

(a) R (b) $2R$

(c) $3R$ (c) $\frac{R}{2}$

Solution (b) $2R$ (equivalent resistance).

34. The ammeter in Fig. 21.50 will read

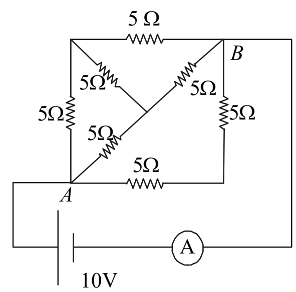


Fig. 21.50

(a) 3A (b) $\frac{10}{3}$ A

(c) 30A (d) $\frac{100}{3}$ A

Solution (a) $R_{AB} = \frac{10}{3}$ (use Wheatstone bridge)

$$I = \frac{10}{10/3} = 3\text{A}$$

35. Find x in the Fig. 21.51 so that galvanometer shows null deflection.

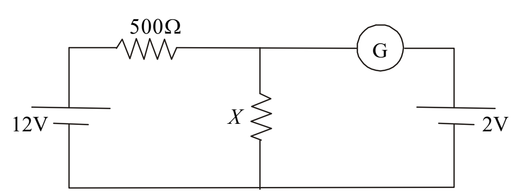


Fig. 21.51

(a) 100 Ω (b) 400 Ω

(c) 200 Ω (d) 250 Ω

[AIEEE 2005]

Solution (a) Potential drop across x should be 2 V.

$$\therefore \quad 2 = \frac{12x}{X+500}$$

or $$X = 100\Omega$$

36. When Cu and Ge are cooled to –150ºC then resistance of Cu____and that of Ge____

(a) increases, increases (b) decrease, increases

(c) decrease, decreases (d) increases, decreases.

Solution (b) ∵ metals have positive thermal coefficient of resistance while semiconductors have negative thermal coefficient of resistance.

TYPICAL PROBLEMS

37. Find current I and current through 6Ω resistance in Fig. 21.52 (a)

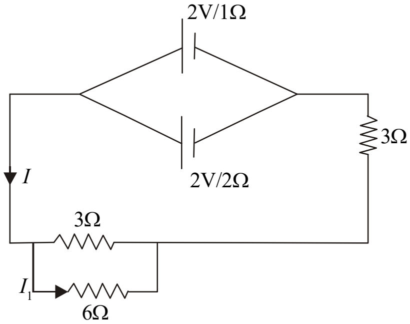


Fig. 21.52 (a)

(a) $\frac{6}{17}$ A, $\frac{1}{17}$ A (b) $\frac{3}{17}$ A, $\frac{1}{17}$ A

(c) $\frac{6}{17}$ A, $\frac{2}{17}$ A (d) none

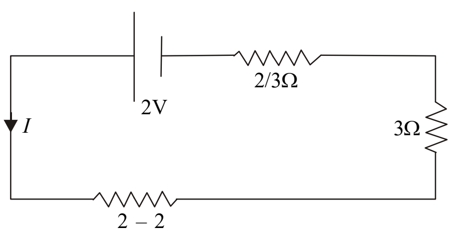


Fig. 21.52 (b)

Solution (c) $E_{eq} = \frac{2\times1+2\times2}{2+1} = 2\text{V}; r_{eq} = \frac{1\times2}{1+2} = \frac{2}{3}\,\Omega$

$$\text{I} = \frac{2}{5+2/3} = \frac{6}{17}\text{ A } \text{I}_1 = \frac{6}{17}\times\frac{3}{9} = \frac{2}{17}\text{ A}$$

38. Find potential difference across AB in Fig. 21.53 (a)

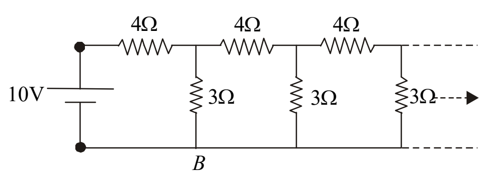


Fig. 21.53 (a)

(a) 6V (b) 4.5V

(c) $\frac{10}{3}$ V (d) 4V

Solution (c) Let the resistance of infinite network be R. Adding one more section will not alter the resistance ∴ from Fig. 21.53 (b) from Fig. 21.53 (c)

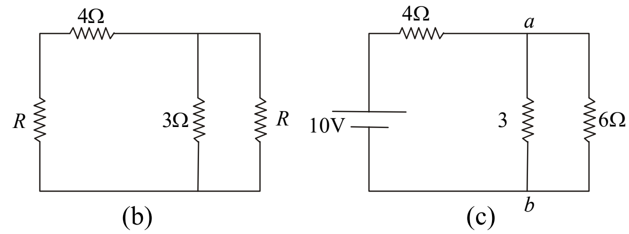


Fig. 21.53

$$R = \frac{3R}{3+R} + 4 \text{ or } 3R + R^2 = 3R + 12 + 4R$$

or $R^2 - 4R - 12 = 0$ or $(R-6)(R+2) = 0$ or $R = 6\Omega$

$$3\Omega \parallel 6\Omega = 2\Omega \; V_{ab} = \frac{10\times2}{6} = \frac{10}{3}\,V$$

39. A metal ball of radius a is surrounded by a thin concentric metal shell of radius b. The space between these electrodes is filled with a material of specific resistance ρ. Find the resistance of the inter electrode gap.

Solution $dR = \frac{\rho dr}{4\pi r^2}$ or $R = \int_a^b \rho \frac{dr}{4\pi r^2} = \frac{\rho}{4\pi}\left[\frac{1}{a} - \frac{1}{b}\right]$

40. Fig. 21.54 shows an infinite wire grid with infinite cells. The resitance of each wire in the cell is R_0. Find the resistance R_{AB} of the whole grid between the terminals A and B.

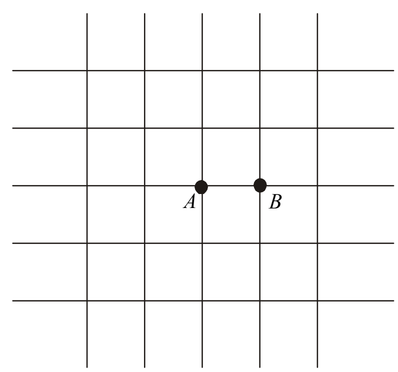


Fig. 21.54

Solution If V is the voltage applied across AB then $V = IR = I_0 R_0$ is resistance of segment AB. The symmetrical conditions yield $\frac{I}{4}$ which is the current flowing through all the four segments meeting at B. Thus $\frac{I}{2}$ current flows through conductor AB. i.e. $I_0 = \frac{I}{2}$ or $R = \frac{R_0}{2}$

41. Find the current through CD in Fig. 21.55 (a).

Solution $I_1 R_1 = (I - I_1) R_3$

$I_1 R_1 + (I_1 - I_2) R_2 = V_0$

$(I - I_1) R_3 + (I - I_1 + I_2) R_4 = V_0$

solving these equations we get

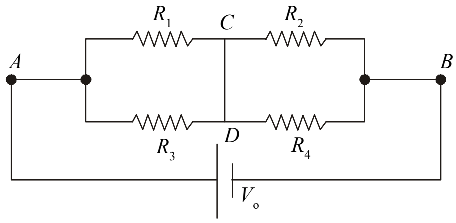


Fig. 21.55 (a)

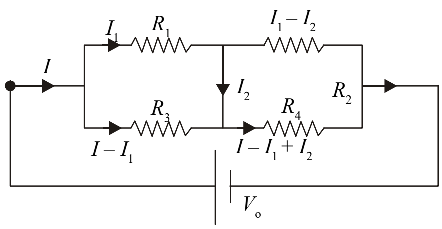


Fig. 21.55 (b)

$$I_2 = \frac{R_3(R_1 + R_2) + R_1(R_3 + R_4)}{R_3R_4(R_1R_2) + R_1R_2(R_3 + R_4)}$$

42. An ideal voltmeter and an ideal ammeter are connected in Fig 21.56. The reading of the voltmeter is

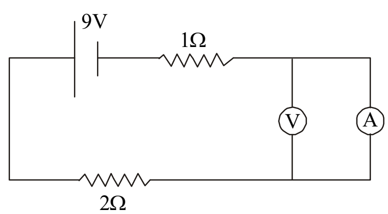


Fig. 21.56

(a) 9V (b) 6V

(c) 3V (d) zero

Solution (d) Since ideal ammeter has zero resistance and we are measuring potential drop across it, $V = 0$.

43. A voltmeter has a 25Ω coil and 575Ω in series. The coil takes 10mA for full scale deflection. The maximum potential difference which can be measured is

(a) 250mV (b) 5.75V

(c) 5.5V (d) 6.0V

Solution (d) $V_{max} = I_g (R_g + R) = 10 \times 10^{-3} (600) = 6V$

44. Find the current I_A Fig. 21.57 (a) All the resistors shown have values in ohms.

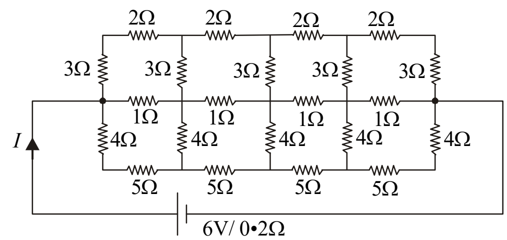


Fig. 21.57 (a)

(a) 1A (b) 1.25 A

(c) 2.0 A (d) 1.75 A

Solution (c) Draw the equivalent circuit as shown in Fig. 21.57 (b) and (c).

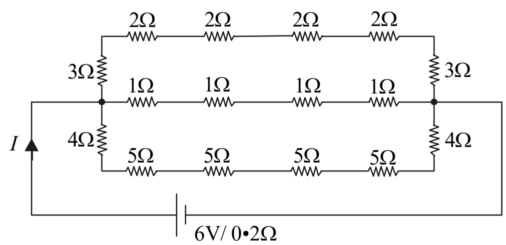


Fig. 21.57 (b)

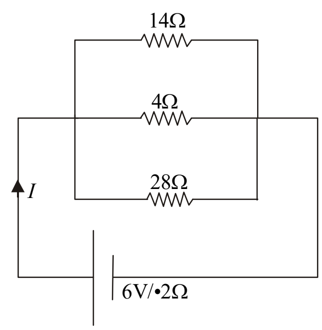


Fig. 21.57 (c)

$$\frac{1}{R_{eq}} = \frac{1}{28} + \frac{1}{4} + \frac{1}{14} = \frac{1+7+2}{28} \quad \text{or } R_{eq} = 2.8\ \Omega$$

$$\therefore \quad I = \frac{6}{3} = 2A$$

45. Find the current in Fig. 21.58 (a).

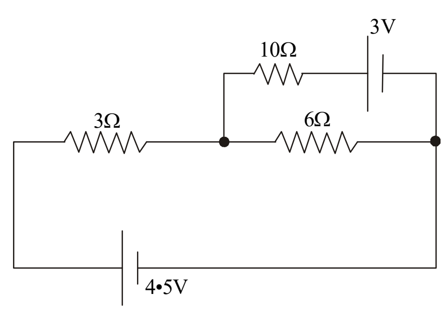


Fig. 21.58 (a)

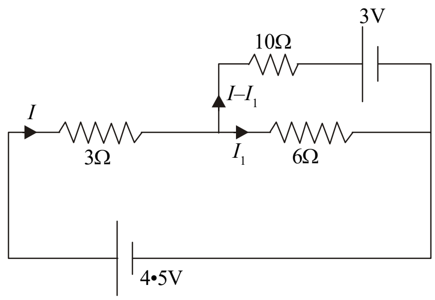


Fig. 21.58 (b)

(a) 0.25A (b) 0.5A

(c) 0 (d) none of there

Solution (c) Apply loop law in Fig. 21.58 (b).

$3I + 6I_1 = 4.5$ or $I + 2I_1 = 1.5$ ....(1)

$10(I - I_1) + 3 = 6I_1$

or $10I - 10I_1 = -3$ ....(2)

solving eq 1 and 2 we get

$$I = \frac{1}{2}\text{ A}$$

and $I - I_1 = \dfrac{1}{2} - \dfrac{1}{2} = 0.$

46. Find the charge on the $5\mu F$ capacitor

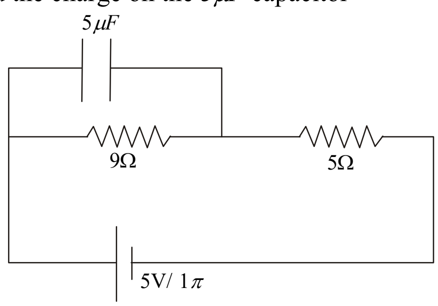


Fig. 21.59

(a) $5\mu C$ (b) $10\mu C$

(c) $15\mu C$ (d) none of these

Solution (c) Using potential division rule we find potential drop across 9Ω resistor $V = \dfrac{5\times 9}{15} = 3\text{V}$ and

$q = CV = 5 \times 3 = 15\mu C$

47. Find the change in ammeter reading when the switch S is closed is Fig. 21.60.

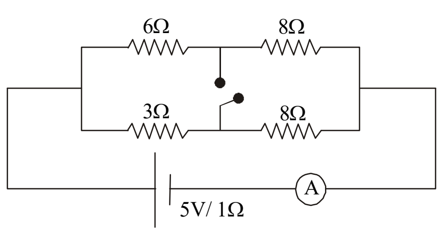


Fig. 21.60

(a) 0.0A (b) 0.01A

(c) 0.014A (d) 0.013A

Solution (c) When switch is open

$$I_1 = \frac{5}{1 + \frac{11\times 14}{25}} = \frac{125}{179} = 0.7\text{A}$$

When switch is closed $I_2 = \dfrac{5}{2+4+1} = \dfrac{5}{7} = 0.714\text{A}$

48. The potential drop in $5\mu F$ capacitor in Fig. 21.61 (a) is.

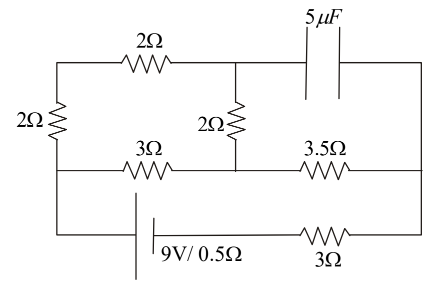


Fig. 21.61 (a)

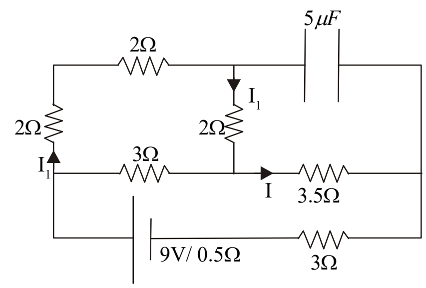


Fig. 21.61 (b)

(a) 4.17V (b) 5.17V

(c) 3.17V (d) 3.5V

Solution (a) $R_{eq} = \dfrac{6\times 3}{6+3} + 3.5 + 3 + 0.5 = 9\Omega$

$I = 1A$ current I_1 through 2 Ω resistor $I_1 = \dfrac{1}{3}A$ (using current division rule.

$$V_{cap} = I_1(2) + I(3.5) = 2\left(\frac{1}{3}\right) + 1(3.5) = \left(\frac{12.5}{3}\right)V$$

49. The current voltage relationship of a diode is $I = I_s[\exp\left(\dfrac{eV}{kT}\right) - 1]$ where e is charge on an electron, V is voltage applied, k is Boltzmann's constant, T is temperature in Kelvin. Find the resistance of the diode if $I_s = 1.5$ mA and $T = 398$ K.

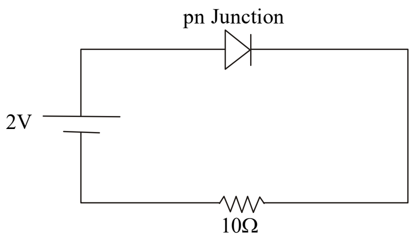


Fig. 21.62

(a) $\frac{100}{3}\ \Omega$ (b) $\frac{50}{3}\ \Omega$

(c) $\frac{500}{3}\ \Omega$ (d) $\frac{200}{3}\ \Omega$

Solution (b) $\frac{dI}{dV} = \frac{eI_s}{kT}\exp\left(\frac{eV}{kT}\right) = \frac{I}{\frac{kT}{e}} = \frac{1.5}{25}$

or $r = \frac{25}{1.5} = \frac{50}{3}\Omega$

PASSAGE 1

Read the following passage and answer the questions given at the end.

Note that for nearly all materials the current – voltage relation is temperature dependent. Thus at low temperatures the curve in Fig. 21.63 (a) rises more steeply for positive V than at higher temperatures, and at successively higher temperatures the asymmetry in the curve becomes less and less pronounced.

The current – voltage relation for a source may also be represented graphically. For a source represented by $V_{ab} = E - Ir$, that is, $V = E - Ir$, The graph appears in Figure. 21.63 (b). The intercept on the V –axis, corresponding to the open-circuit condition ($I = 0$), is at $V = E$, and the intercept on the I-axis, corresponding to a short-circuit situation ($V = 0$), is at $I = \frac{E}{r}$.

This relation may be used to find the current in a circuit containing a non linear device, as in Fig. 21.63 (c). Its current voltage relation is shown in Fig. 21.63 (d) and terminal voltage $V = E - Ir$ is also plotted on this graph, each curve represents a current-voltage relation that must be satisfied, so the intersection represents the only possible values of V and I. This amounts to a graphical solution of two simultaneous equations for V and I, one of which is nonlinear.

When a device has a nonlinear voltage-current relation, the quantity V/I is not constant. This ratio may still be called resistance, but now it varies with current; it is constant only for a device obeying Ohm's law. Often a more useful quantity is dV/dI, which expresses the relation between a small change in current and the resulting voltage change. This is called dynamic or incremental resistance.

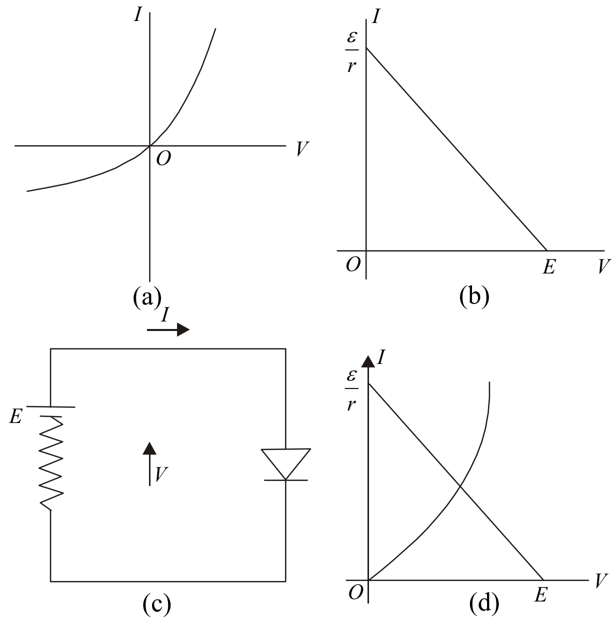


Fig. 21.63

1. Which of the following vacuum tube devices shows negative resistance?

(a) diode (b) triode

(c) tetrode (d) pentode

2. What is the non linear $V - 1$ relation in a pn Junction in forward bias?

(a) $I = I_s\, e^{V/V_T}$ (b) $I = I_s\,(e^{V/V_T} - 1)$

(c) $I = I_s\,(1 - e^{V/V_T})$ (d) $I = I_s\left(\frac{V}{V_0}\right)^{3/2}$

3. In a device $I = 40\ \mu A\ [e^{V/V_T} - 1]$ where $V_T = 0.025$ V. Find the dynamic resistance when $V = 0.5\ V$

(a) zero (b) $8\ \Omega$

(c) $10\ \Omega$ (d) $30\ \Omega$

(e) none of these

Solution **1.** (c)

Solution **2.** (a)

Solution **3.** (a)

$$I = I_S[e^{V/V_T} - 1]$$

$$\frac{dI}{dV} = \frac{I_S}{V_T}e^{V/V_T}$$

or $$\frac{dV}{dI} = \frac{V_T}{I_S e^{V/Vt}} = \frac{0.025}{40\times10^{-6}\left[e^{20}\right]}$$

$$= \frac{0.025\times 0}{40\times10^{-6}\times5\times10^{8}}$$

PASSAGE 2

Read the following passage and answer the questions given at the end.

Let us consider further the use of the *d* Arson val meter as a current-measuring instrument, often called an ammeter. To measure the current in a circuit, an ammeter must be inserted in series in the circuit so that the current to be measured actually passes through the meter. If a galvanometer is inserted in this way, it will measure any current from zero to 1m *A*. However, the resistance of the coil adds to the total resistance of the circuit, with the result that the current after the galvanometer is inserted, although it is correctly indicated by the instrument, may be less than it was before insertion of the instrument. It is evidently desirable that the resistance of the instrument should be much smaller than that of the remainder of the circuit, so that when the instrument is inserted it does not change the very thing we wish to measure. An ideal ammeter would have zero resistance.

1. A 100 μA galvanometer with internal resistance 1000 Ω is to be converted into an ammeter of 10 *A*. Find the shunt to be connected.

(a) 0.1Ω (b) 1 Ω

(c) 0.01 Ω (d) 0.001 Ω

2. The ways A, B and C of measuring a resistance are shown. Assuming *R* is low. The correct way of measuring is

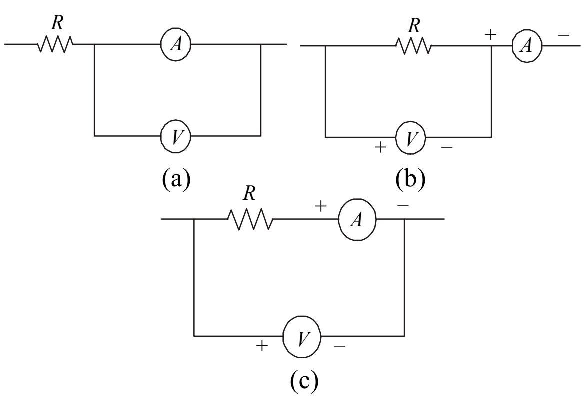


Fig. 21.64

(a) C (b) A

(c) B (d) any of these is correct

3. Galvanometer shows null deflection. Find the resistance *X*

(a) 6 Ω (b) 8 Ω

(c) 10 Ω (d) 12 Ω

4. A galvanometer is an instrument capable to measure

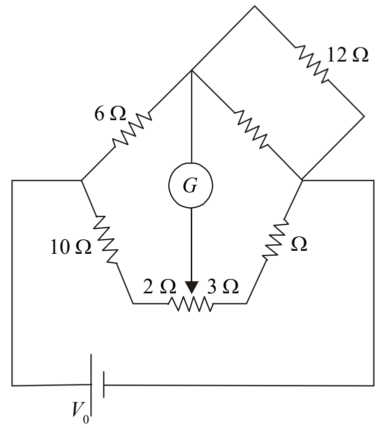


Fig. 21.65

(a) small voltage (b) small current

(c) both (a) and (b) (d) none of these

Solution **1.** (c)

$(I-I_g)S = I_gR_g$

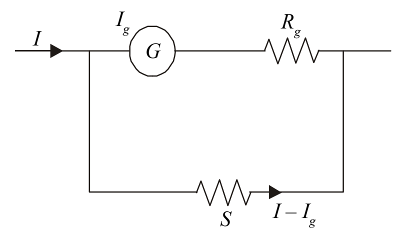


Fig. 21.66

$$S = \frac{I_gR_g}{I-I_g}$$

$$= \frac{100\times10^{-6}\times1000}{10} = 10^{-2}\,\Omega$$

Solution **2.** (c)

Solution **3.** (d)

Solution **4.** (c)

PASSAGE 3

Read the following passage and answer the questions given at the end.

The current across an area can be expressed in terms of the drift velocity of the moving charges as follows. Consider a position of a conductor of cross-sectional area *A* within which there is a resultant electric field *E* from left to right. We suppose first that the conductor contains free positively charged particles; these move in the same direction as the field. *A* few positive particles are shown in Figure 21.67. Suppose there are *n* such particles per unit volume, all moving with a drift velocity *v*. In a time Δt each advances a distance $v\Delta t$. Hence all of the particles within the marked cylinder of length $v\Delta t$, and only those particles, will flow across the end of the cylinder in time Δt. The volume of the cylinder is $Av\Delta t$, the number of particles within it is $nAv\Delta t$, and if each has a charge *q*, the charge ΔQ flowing across the end of the cylinder in time Δt is

$\Delta Q = nqvA\Delta t,$

The current carried by the positively charged particles is therefore

$$I = \frac{\Delta Q}{\Delta t} = nqvA.$$

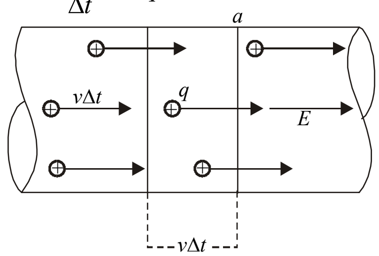


Fig. 21.67

1. The total resistivity of the material (conductor) is sum of thermal based, impurity based and plastic deformation based resistivities i.e., $\rho = \rho_t + \rho_c + \rho_p$. How does resistivity vary at low temperatures?
   (a) $\rho \propto \frac{1}{T}$ (b) $\rho \propto \frac{1}{T^2}$
   (c) $\rho \propto T^{-3}$ (d) $\rho \propto T^{-5/2}$
2. Name the material in which no Thomson effect is observed.
   (a) Pb (b) Fe
   (c) Ni (d) Au
   (e) none
3. Carrier concentration in a material of conductivity 0.018 (ohm m)$^{-1}$ is 10^{19} electrons m^{-3}. A voltage of 0.16 V is applied across 0.29 mm thick material. Find drift velocity.
   (a) 6.19 ms^{-1} (b) 4.19 ms^{-1}
   (c) 6.19 cm s^{-1} (d) 4.19 mms^{-1}
   (e) none
4. The resistivity of Cu is 0.015 μ ohm – m at 300 K. Addition of each atomic % of Ni and Ag causes an increase in resistivity by 0.012 μ ohm – m and 0.16 μ ohm – m respectively. Compute resistivity of Cu – Ni – Ag alloy at 300 K when 0.25% Ni and 0.4 atomic % Ag is added to Cu.
   (a) 0.0244 μ ohm – m (b) 0.018 μ ohm m
   (c) 0.006 μ ohm – m (d) none
5. Constant current is flowing through a metal piece shown in Fig. 21.68.

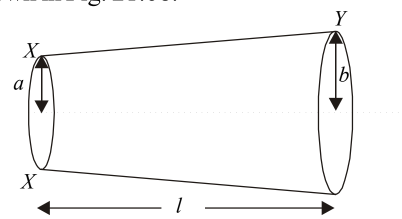


Fig. 21.68

   (a) Electron density at Y is less than that at X.
   (b) Electron mobility at Y is less than that at X.
   (c) Resistivity of the material varies along the length.
   (d) Resistivity of the material is $\rho \frac{l}{\pi ab}$.

Solution 1. (c)

Solution 2. (a)

Solution 3. (a) $J = nev_d$ and $J = \sigma E$

$$\therefore \quad \sigma = \frac{nev_d}{E} = \frac{nev_d t}{V}$$

$$\text{or} \quad v_d = \frac{\sigma V}{net} = \frac{.018 \times 16}{10^{19} \times 1.6 \times 10^{-19} .29 \times 10^{-13}} = \frac{1.8}{.29}$$

$$= 6.19 \text{ ms}^{-1}$$

Solution 4. (a)

$$\rho_{\text{alloy}} = (0.015 + 0.012 \times .25 + 0.16 \times 0.4)\ \mu \text{ ohm m}$$

$$= 0.015 + .003 + 0.0064 = 0.0244\ \mu \text{ ohm} - \text{m}$$

Solution 5. (b), (d)

QUESTIONS FOR PRACTICE

1. A straight conductor AB lies along the axis of a hollow metal cylinder L, which is connected to earth through a conductor C. A quantity of charge will flow through C
   (a) if a current begins to flow through AB
   (b) if the current through AB is reversed
   (c) if AB is removed, and a beam of electrons flows in its place
   (d) if AB is removed, and a beam of protons flows in its place

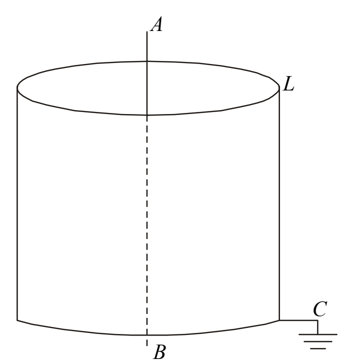


Fig. 21.69

2. A beam of electrons emitted from the electron gun G is accelerated by an electric field E. The area of cross-section of the beam remains constant. As the beam moves away from G,

(a) the speed of the electrons increases

(b) the current constituted by the beam increases

(c) the number of electrons per unit volume in the beam increases

(d) the number of electrons per unit volume in the beam decreases

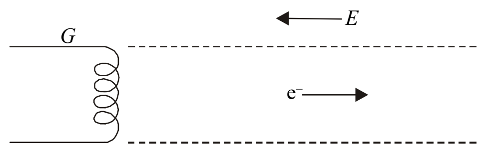


Fig. 21.70

3. When some potential difference is maintained between A and B, current I enters the network at A and leaves at B.

(a) The equivalent resistance between A and B is 8 Ω.

(b) C and D are at the same potential.

(c) No current flows between C and D.

(d) Current 31/5 flows from D to C.

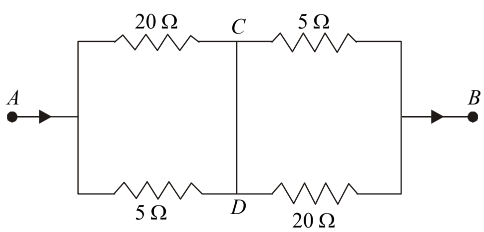


Fig. 21.71

4. The charge flowing in a conductor varies with time as $Q = at - bt^2$. Then, the current

(a) decreases linearly with time

(b) reaches a maximum and then decreases

(c) falls to zero after time $t = \dfrac{a}{2b}$

(d) changes at a rate $-2b$

5. The charge flowing in a conductor varies with time as

$$Q = at - \frac{1}{2}bt^2 + \frac{1}{6}ct^3,$$

where a, b, c are positive constants. Then, the current

(a) has an initial value a

(b) reaches a minimum value after time b/c

(c) reaches a maximum value after time b/c

(d) has either a maximum or a minimum value $\left(a - \dfrac{b^2}{2c}\right)$

6. In the circuit shown, the diode is ideal. The potential of A is higher than the potential of B. If the switch S is (i) closed, (ii) open the equivalent resistance between A and B is

(a) R, R (b) $R/2$, $R/2$

(c) $R/3$, $R/4$ (d) $R/4$, $R/3$

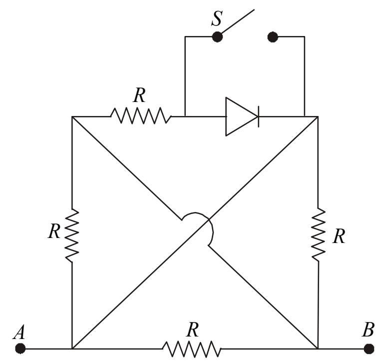


Fig. 21.72

7. In the circuit shown the cell has emf = 10 V and internal resistance = 1 Ω.

(a) The current through the 3-Ω resistor is 1 A.

(b) The current through the 3-Ω resistor is 0.5 A.

(c) The current through the 4-Ω resistor is 0.5 A.

(d) The current through the 4-Ω resistor is 0.25 A.

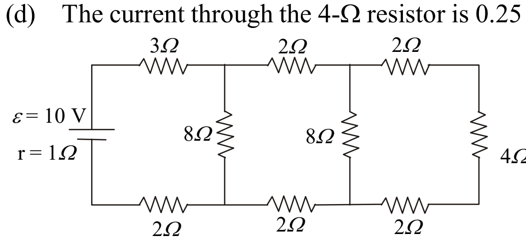


Fig. 21.73

8. In the circuit shown, the diodes are ideal. A_1 and A_2 are ammeters of resistance 5 Ω each. The potentials of the points A, B, C and D are V_A, V_B, V_C and V_D respectively. $|V_A - V_B| = 10$ V.

(a) A_1 and A_2 will always show the same reading.

(b) The readings of A_1 and A_2 will depend on whether $V_A > V_B$ or $V_A < V_B$.

(c) The readings of A_1 or A_2 or both will be 1 A in all cases.

(d) If $V_A > V_B$, A_1 will show no deflection.

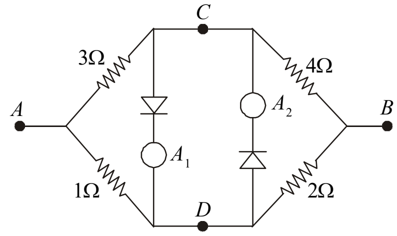


Fig. 21.74

9. In the circuit shown below, V_A and V_B are the potentials at A and B, R is the equivalent resistance between A and B, S_1 and S_2 are switches, and the diodes are ideal.

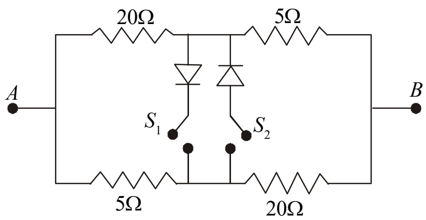


Fig. 21.75

(a) If $V_A > V_B$, S_1 is open and S_2 is closed then $R = 8\ \Omega$.

(b) If $V_A > V_B$, S_1 is closed and S_2 is open then $R = 12.5\ \Omega$.

(c) If $V_A < V_B$, S_1 is open and S_2 is closed then $R = 12.5\ \Omega$.

(d) If $V_A > V_B$, S_1 is closed and S_2 is open then $R = 8\ \Omega$.

10. In the circuit shown, some potential difference is applied between A and B. The equivalent resistance between A and B is R.

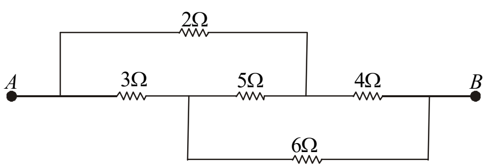


Fig. 21.76

(a) No current flows through the 5-Ω resistor.

(b) $R = 15\ \Omega$

(c) $R = 12.5\ \Omega$ (d) $R = \frac{18}{5}\ \Omega$

11. Two cells of unequal emfs, E_1 and E_2, and internal resistances r_1 and r_2 are joined as shown. V_A and V_B are the potentials at A and B respectively.

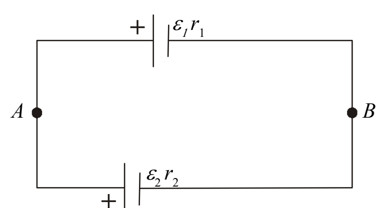


Fig. 21.77

(a) One cell will continuously supply energy to the other.

(b) The potential difference across both the cells will be equal.

(c) The potential difference across one cell will be greater than its emf.

(d) $V_A - V_B = \dfrac{(E_1 r_2 + E_2 r_1)}{(r_1 + r_2)}$

12. A uniform wire of resistance R is shaped into a regular n-sided polygon (n is even). The equivalent resistance between any two corners can have

(a) the maximum value $\frac{R}{4}$

(b) the maximum value $\frac{R}{n}$

(c) the minimum value $R\left(\frac{n-1}{n^2}\right)$

(d) the minimum value $\frac{R}{n}$

13. In the circuit shown below, the cell is ideal, with emf = 2 V. The resistance of the coil of the galvanometer G is 1 Ω.

(a) No current flows in G.

(b) 0.2-A current flows in G.

(c) Potential difference across C_1 is 1 V.

(d) Potential difference across C_2 is 1.2 V.

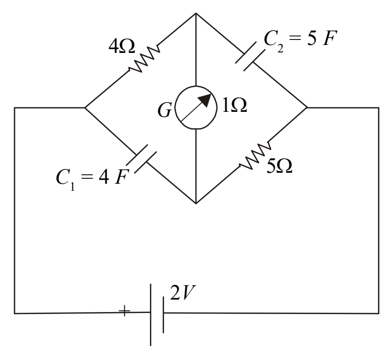


Fig. 21.78

14. In the circuit shown, the cell is ideal, with emf = 15 V. Each resistance is of 3 Ω. The potential difference across the capacitor is

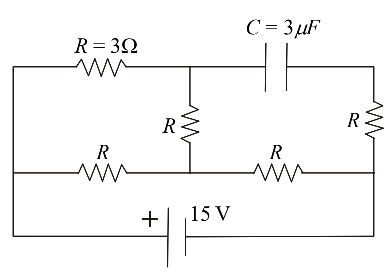


Fig. 21.79

(a) zero (b) 9 V

(c) 12 V (d) 15 V

15. An accumulator battery (storage cell) B of emf E and internal resistance r is being charged from a DC supply whose terminals are T_1 and T_2.

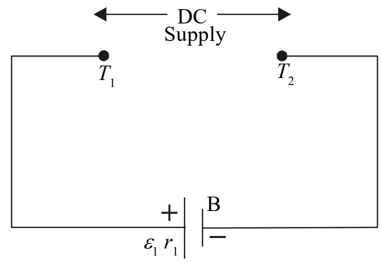


Fig. 21.80

(a) Potential difference between T_1 and T_2 must be > E.

(b) T_1 must be positive with respect to T_2.

(c) In the battery, current flows from the positive to the negative terminal.

(d) All the above options are incorrect.

16. In question 15, the connecting wires have uniform resistance. Moving from T_1 to T_2 through B, the potential (V) is plotted against distance (x). The correct curve is

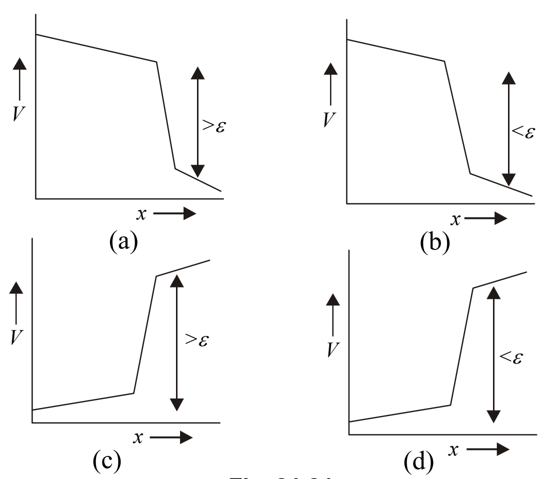


Fig. 21.81

17. Three voltmeters, all having different resistances, are joined as shown. When some potential difference is applied across A and B, their readings are V_1, V_2, V_3.

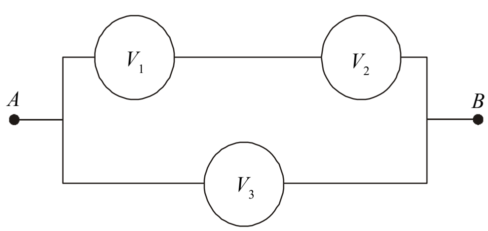


Fig. 21.82

(a) $V_1 = V_2$ (b) $V_1 \neq V_2$

(c) $V_1 + V_2 = V_3$ (d) $V_1 + V_2 > V_3$

18. A voltmeter and an ammeter are connected in series to an ideal cell of emf E. The voltmeter reading is V and the ammeter reading is l.

(a) $V < E$.

(b) The voltmeter resistance is V/I.

(c) The potential difference across the ammeter is $(E - V)$.

(d) Voltmeter resistance plus ammeter resistance = E/I.

19. Three ammeters A, B and C of resistances R_A, R_B and R_C respectively are joined as shown. When some potential difference is applied across the terminals T_1 and T_2, their readings are I_A, I_B and I_C respectively.

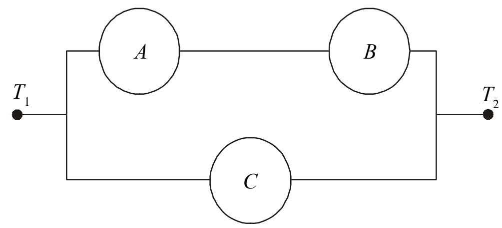


Fig. 21.83

(a) $I_A = I_B$ (b) $I_A R_A + I_B R_B = I_C R_C$

(c) $\dfrac{I_A}{I_C} = \dfrac{R_C}{R_A}$ (d) $\dfrac{I_B}{I_C} = \dfrac{R_C}{R_A + R_B}$

20. A voltmeter and an ammeter are joined in series to an ideal cell, giving readings V and A respectively. If a resistance equal to the resistance of the ammeter is now joined in parallel to the ammeter,

(a) V will not change

(b) V willl increase slightly

(c) A will become exactly half of its initial value

(d) A will become slightly more than half of its initial value

21. In the circuit, the battery is ideal. A voltmeter of resistance 600 Ω is connected in turn across R_1 and R_2, giving readings of V_1 and V_2 respectively.

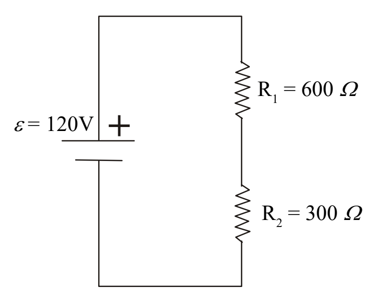


Fig. 21.84

(a) $V_1 = 80$ V (b) $V_1 = 60$ V

(c) $V_2 = 30$ V (d) $V_2 = 40$ V

22. A microammeter has a resistance of 100 Ω and a full-scale range of 50 μA. It can be used as a voltmeter or as a higher range ammeter provided a resistance is added to it. Pick the correct range and resistance combination(s).

(a) Range 50 V, with a 10-kΩ resistance in series

(b) Range 10 V, with a $(2 \times 10^5 - 100)$-Ω resistance in parallel

(d) Range 5 mA, with a 1.01-Ω resistance in parallel

(d) Range 10 mA, with a 1-Ω resistance in parallel

23. A milliammeter of range 10 mA and resistance 9 Ω is joined in a circuit as shown. The metre gives full-scale deflection for current l when A and B are used as its terminals, i.e., current enters at A and leaves at B (C is left isolated). The value of I is

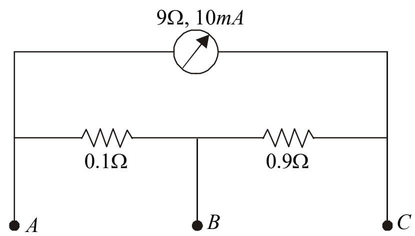


Fig. 21.85

(a) 100 mA (b) 900 mA

(c) 1 A (d) 1.1 A

24. In the potentiometer arrangement shown, the driving cell D has emf E and internal resistance r. The cell C, whose emf is to be measured, has emf $E/2$ and internal resistance $2r$. The potentiometer wire is 100 cm long. If balance is obtained, the length $AJ = l$.

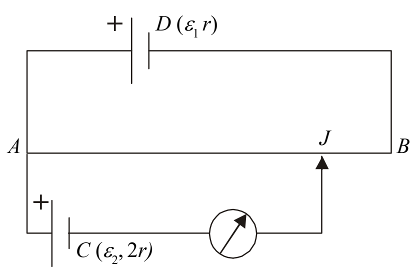


Fig. 21.86

(a) $l = 50$ cm. (b) $l > 50$ cm.

(c) Balance will be obtained only if resistance of AB is $> r$.

(d) Balance cannot be obtained.

25. In the previous question, if A and C are used as terminals, with B isolated, full-scale deflection is obtained for a current of

(a) 90 mA (b) 100 mA

(c) 900 mA (d) 1 A

26. A cell drives a current through a circuit. The emf of the cell is equal to the work done in moving unit charge

(a) from the positive to the negative plate of the cell

(b) from the positive plate, back to the positive plate

(c) from the negative plate, back to the negative plate

(d) from any point in the circuit back to the same point

27. The figure shows a potentiometer arrangement. D is the driving cell. C is the cell whose emf is to be determined. AB is the potentiometer wire and G is a galvanometer. J is a sliding contact which can touch any point on AB. Which of the following are essential conditions for obtaining balance?

(a) The emf of D must be greater than the emf of C.

(b) Either the positive terminals of both D and C or the negative terminals of both D and C must be joined to A.

(c) The positive terminals of D and C must be joined to A.

(d) The resistance of G must be less than the resistance of AB.

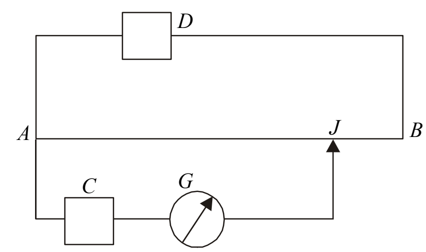


Fig. 21.87

28. A cell of emf E and internal resistance r drives a current i through an external resistance R.

(a) The cell supplies Ei power.

(b) Heat is produced in R at the rate Ei.

(c) Heat is produced in R at the rate $Ei\left(\frac{R}{R+r}\right)$.

(d) Heat is produced in the cell at the rate $Ei\left(\frac{r}{R+r}\right)$.

29. In the network shown, points A, B and C are at potentials of 70 V, zero and 10 V respectively.

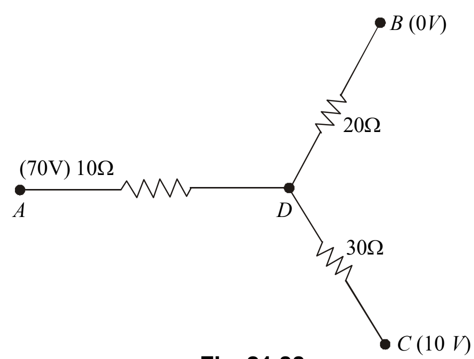


Fig. 21.88

(a) Point D is at a potential of 40 V.

(b) The currents in the sections AD, DB, DC are in the ratio 3 : 2 : 1.

(c) The currents in the sections AD, DB, DC are in the ratio 1 : 2 : 3.

(d) The network draws a total power of 200 W.

30. Current i is being driven through a cell of emf E and internal resistance r, as shown.

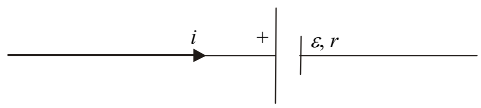


Fig. 21.89

(a) The cell absorbs energy at the rate of Ei.

(b) The cell stores chemical energy at the rate of $(Ei - i^2r)$.

(c) The potential difference across the cell is $E + ir$.

(d) Some heat is produced in the cell.

31. In a household electric circuit,

(a) all electric appliances drawing power are joined in parallel

(b) a switch may be either in series or in parallel with the applliance which it controls

(c) if a switch is in parallel with an appliance, it will draw power when the switch is in the 'off' position (open)

(d) if a switch is in parallel with an appliance, the fuse will blow (burn out) when the switch is put 'on' (closed)

32. Two heaters designed for the same voltage V have different power ratings. When connected individually across a source of voltage V, they produce H amount of heat each in times t_1 and t_2 respectively. When used together across the same source, they produce H amount of heat in time t.

(a) If they are in series, $t = t_1 + t_2$.

(b) If they are in series, $t = 2(t_1 + t_2)$.

(c) If they are in parallel, $t = \dfrac{t_1 t_2}{(t_1 + t_2)}$.

(d) If they are in parallel, $t = \dfrac{t_1 t_2}{2(t_1 + t_2)}$

33. The charge flowing through a resistance R varies with time t as $Q = at - bt^2$. The total heat produced in R is

(a) $\dfrac{a^3 R}{6b}$ (b) $\dfrac{a^3 R}{3b}$

(c) $\dfrac{a^3 R}{2b}$ (d) $\dfrac{a^3 R}{b}$

34. Two electric bulbs rated at 25 W, 220 V and 100 W, 220 V are connected in series across a 220 V voltage source. The 25 W and 100 W bulbs now draw P_1 and P_2 powers respectively.

(a) $P_1 = 16$ W (b) $P_1 = 4$ W

(c) $P_2 = 16$ W (d) $P_2 = 4$ W

35. Two identical fuses are rated at 10 A. If they are joined

(a) in parallel, the combination acts as a fuse of rating 20 A

(b) in parallel, the combination acts as a fuse of rating 5 A

(c) in series, the combination acts as a fuse of rating 10 A

(d) in series, the combination acts as fuse of rating 20 A.

36. A uniform wire of resistance 50 Ω is cut into 5 equal parts. These parts are now connected in parallel. The equivalent resistance of the combination is

(a) 2 Ω (b) 10 Ω

(c) 250 Ω (d) 6250 Ω

37. Consider a capacitor-charging circuit. Let Q_1 be the charge given to the capacitor in a time interval of 10 ms and Q_2 be the charge given in the next time interval of 10 ms. Let 10 μC charge be deposited in a time interval t_1 and the next 10 μC charge be deposited in the next time interval t_2.

(a) $Q_1 > Q_2, t_1 > t_2$. (b) $Q_1 > Q_2, t_1 < t_2$.

(c) $Q_1 < Q_2, t_1 > t_2$. (d) $Q_1 < Q_2, t_1 > t_2$.

38. Two non-ideal batteries are connected in series. Consider the following statements:

(A) The equivalent emf is larger than either of the two emfs.

(B) The equivalent internal resistance is smaller than either of the two internal resistances.

(a) Each of A and B is correct.

(b) A is correct but B is wrong.

(c) B is correct but A is wrong.

(d) Each of A and B is wrong.

39. The net resistance of an ammeter should be small to ensure that

(a) it does not get overheated

(b) it does not draw excessive current

(c) it can measure large currents

(d) it does not appreciably change the current to be measured

40. Electrons are emitted by a hot filament and are accelerated by an electric field as shown in fig. 21.88 The two stops at the left ensure that the electron beam has a uniform cross-section.

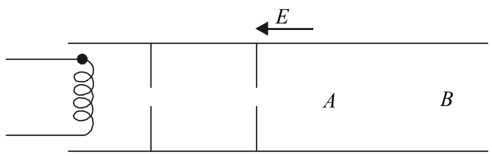


Fig. 21.90

(a) The speed of the electron is more at B than at A.
(b) The electric current is from left to right.
(c) The magnitude of the current is larger at B than at A.
(d) The current density is more at B than at A.

41. Two non-ideal batteries are connected in parallel. Consider the following statements:
(A) The equivalent emf is smaller than either of the two emfs.
(B) The equivalent internal resistance is smaller than either of the two internal resistances.
(a) Both A and B are correct.
(b) A is correct but B is wrong.
(c) B is correct but A is wrong.,
(d) Both A and B are wrong.,

42. As the temperature of a conductor increases, its resistivity and conductivity change. The ratio of resistivity to conductivity
(a) increases (b) decreases
(c) remains constant
(d) may increase or decrease depending on the actual temperature

43. A capacitor with no dielectric is connected to a battery at $t = 0$. Consider a point A in the connecting wires and a point B in between the plates.
(a) There is no current through A.
(b) There is no current through B.
(c) There is a current through A as long as the charging is not complete.
(d) There is a current through B as long as the charging is not complete.

44. Consider the following two statements:
(A) Kirchhoff's Junction Law follows from conservation of charge.
(B) Kirchhoff's Loop Law follows from conservative nature of electric field.
(a) Both A and B are correct.
(b) A is correct but B is wrong.
(c) B is correct but A is wrong.
(d) Both A and B are wrong.

45. A current passes through a wire of nonuniform cross-section. Which of the following quantities are independent of the cross-section?
(a) The charge crossing in a given time interval
(b) Drift speed
(c) Current density
(d) Free-electron density

46. Which of the following quantities do not change when a resistor connected to a battery is heated due to the current?
(a) Drift speed (b) Resistivity
(c) Resistance
(d) Number of free electrons.

47. When no current is passed through a conductor,
(a) the free electrons do not move
(b) the average speed of a free electron over a large period of time is zero
(c) the average velocity of a free electron over a large period of time is zero
(d) the average of the velocities of all the free electrons at an instant is zero

48. Mark out the correct options.
(a) An ammeter should have small resistance.
(b) An ammeter should have large resistance.
(c) A voltmeter should have small resistance.
(d) A voltmeter should have large resistance.

49. The net resistance of a voltmeter should be large to ensure that
(a) it does not get overheated
(b) it does not draw excessive current
(c) it can measure large potential differences
(d) it does not appreciably change the potential difference to be measured.

50. Two identical capacitors A and B are charged to the same potential and then made to discharge through resistances R_A and R_B respectively, with $R_A > R_B$.
(a) A will require greater time than B to discharge completely.
(b) More heat will be produced in A than in B.
(c) More heat will be produced in B than in A.
(d) All the above options are incorrect.

51. A capacitor A with charge Q_0 is connected through a resistance to another identical capacitor B, which has no charge. The charges on A and B after time t are Q_A and Q_B respectively, and they are plotted against time t. Find the correct curves.

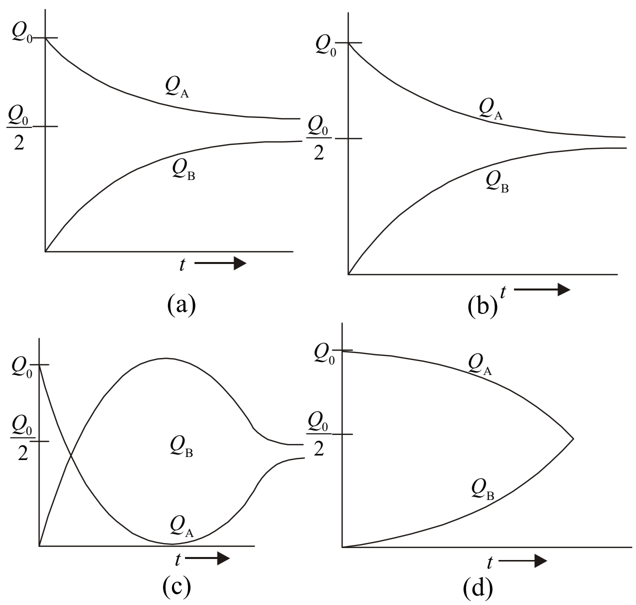


Fig. 21.91

52. The capacitor C is initially without charge. X is now joined to Y for a long time, during which H_1 heat is produced in the resistance R. X is now joined to Z for a long time, during which H_2 heat is produced in R.

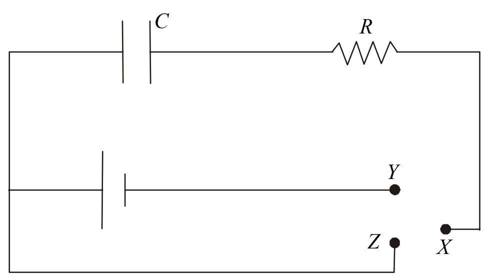


Fig. 21.92

(a) $H_1 = H_2$
(b) $H_1 = \frac{1}{2} H_2$
(c) $H_1 = 2H_2$
(d) The maximum energy stored in C at any time is H_1.

53. Three identical capacitors A, B and C are charged to the same potential and then made to discharge through three resistances R_A, R_B and R_C, where $R_A > R_B > R_C$. Their potential differences (V) are plotted against time t, giving the curves 1, 2 and 3. Find the correlations between A, B, C and 1, 2, 3.

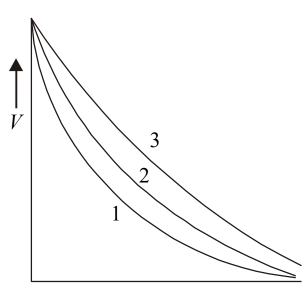


Fig. 21.93

(a) $1 \rightarrow A$
(b) $2 \rightarrow B$
(c) $1 \rightarrow C$
(d) $3 \rightarrow A$

54. A capacitor of capacitance C is connected to two voltmeters A and B. A is ideal, having infinite resistance, while B has resistance R. The capacitor is charged and then the switch S is closed. The readings of A and B will be equal

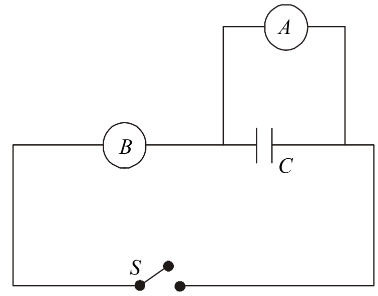


Fig. 21.94

(a) at all times
(b) after time RC
(c) after time RC ln 2
(d) only after a very long time

55. Capacitors $C_1 = 1\ \mu F$ and $C_2 = 2\ \mu F$ are separately charged from the same battery. They are then allowed to discharge separately through equal resistors.

(a) The currents in the two discharging circuits at $t = 0$ is zero.
(b) The currents in the two discharging circuits at $t = 0$ are equal but not zero.
(c) The currents in the two discharging circuits at $t = 0$ are unequal.
(d) C_1 loses 50% of its initial charge sooner than C_2 loses 50% of initial charge.

56. A parallel-plate capacitor, filled with a dielectric of dielectric constant k, is charged to a potential V_0. It is now disconnected from the cell and the slab is removed. If it now discharges, with time constant τ, through a resistance, the potential difference across it will be V_0 after time

(a) $k\tau$
(b) $\tau \ln k$
(c) $\tau \ln\left(1 - \frac{1}{k}\right)$
(d) $\tau \ln (k - 1)$

57. In the circuit shown, A and B are equal resistances. When S is closed, the capacitor C charges from the cell of emf E and reaches a steady state.

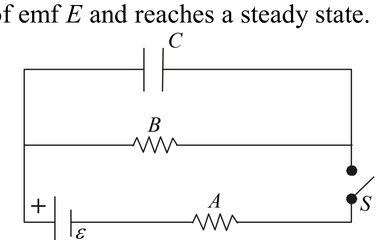


Fig. 21.95

(a) During charging, more heat is produced in A than in B.

(b) In the steady state, heat is produced at the same rate in A and B.

(c) In the steady state, energy stored in C is $\frac{1}{4}$ $C\varepsilon^2$.

(d) In the steady state, energy stored in C is $\frac{1}{8}$ $C\varepsilon^2$.

58. When a capacitor discharges through a resistance R, the time constant is τ and the maximum current in the circuit is i_0.

(a) The initial charge on the capacitor was $i_0\tau$.

(b) The initial charge on the capacitor was $\frac{1}{2}$ $i_0\tau$.

(c) The initial energy stored in the capacitor was $i_0^2 R\tau$.

(d) The initial energy stored in the capacitor was $\frac{1}{2}$ $i_0^2 R\tau$.

59. Two cells of same emf are connected in series. Their internal resistances are r_1 and r_2 respectively and $r_1 > r_2$. When this combination is connected to an external resistance R then the potential difference between the terminals of first cell becomes zero. In this condition the value of R will be

(a) $\frac{r_1 - r_2}{2}$ (b) $\frac{r_1 + r_2}{2}$

(c) $r_1 - r_2$ (d) $r_1 + r_2$

60. The ratio of the drift velocity v_d and r.m.s. velocity of electrons is

(a) 10^{-10} (b) 10^{-5}

(c) 10^{-3} (d) 10^{-6}

61. The $V\,I$ graph for a conductor at temperature T_1 and T_2 are shown in the Fig. 21.96 ($T_2 - T_1$) will be proportional to

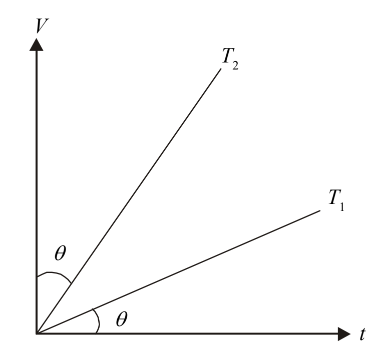


Fig. 21.96

(a) $\cos 2\theta$ (b) $\cot 2\theta$

(c) $\sin 2\theta$ (d) $\tan 2\theta$

62. In a meter bridge experiment, the known and unknown resistances are mutually interchanged to remove

(a) indicator error (b) end error

(c) contact error (d) thermoelectric error

63. The effective resistance Fig. 21.97 between points X and Y will be

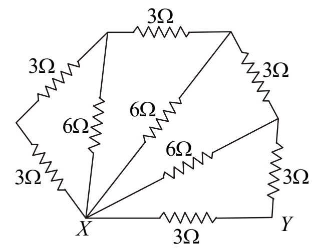


Fig. 21.97

(a) 4 Ω (b) 2 Ω

(c) 8 Ω (d) 16 Ω

64. The equivalent resistance between points X and Y in the following diagram will be

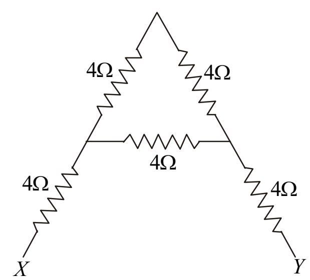


Fig. 21.98

(a) 10.6 Ω (b) 20 Ω

(c) 16 Ω (d) 8 Ω

65. Eleven resistances, each of value 2Ω, are connected as shown in the following diagram. The equivalent resistance between the points A and B will be

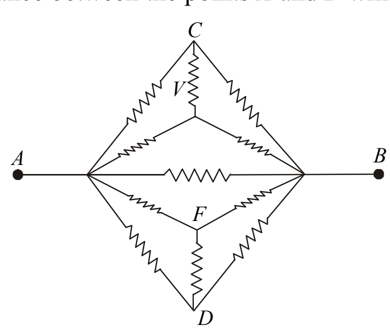


Fig. 21.99

(a) 2 Ω (b) $\frac{2}{3}$ Ω

(c) $\frac{3}{4}$ Ω (d) $\frac{4}{3}$ Ω

66. The equivalent resistance between the points A and B in the adjoining figure will be

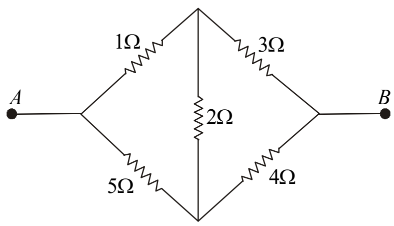


Fig. 21.100

(a) 2.96 Ω (b) 3.71 Ω

(c) 1.68 Ω (d) 5.12 Q

67. The value of current in the 60Ω resistance in the adjoining circuit diagram will be

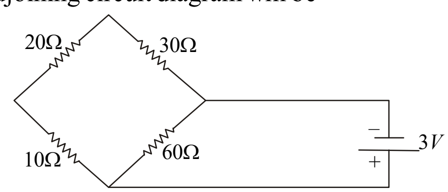


Fig. 21.101

(a) 0.1 A (b) 0.5 A

(c) 0.05 A (d) 0.01 A

68. The value of current in other resistances in the above question will be

(a) 0.1 A (b) 0.5 A

(c) 0.05 A (d) 0.01 A

69. The equivalent resistance between the points 1 and 7 the adjoining circuit (Fig 21.102) will be

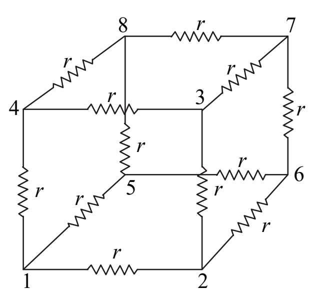


Fig. 21.102

(a) $\frac{7}{12}$ r (b) $\frac{5}{6}$ r

(c) $\frac{3}{4}$ r (d) $\frac{9}{4}$ r

70. In the above question, the effective resistance between the points 1 and 4 will be

(a) $\frac{7}{12}$ r (b) $\frac{5}{6}$ r

(c) $\frac{3}{4}$ r (d) $\frac{5}{7}$ r

71. In the circuit of question 69 the equivalent circuit between the points 1 and 3 will be

(a) $\frac{7}{12}$ r (b) $\frac{5}{6}$ r

(c) $\frac{3}{4}$ r (d) $\frac{3}{7}$ r

72. The equivalent resistance between A and B in the following circuit is

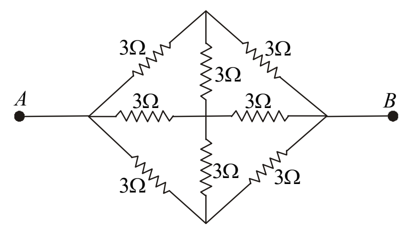


Fig. 21.103

(a) 1 Ω (b) 2 Ω

(c) 3 Ω (d) 4 Ω

73. An ammeter is always connected in series in a circuit because

(a) its resistance is very high

(b) its resistance is very low

(c) it does not draw current from the circuit

(d) its resistance is infinity

74. In order to convert a moving coil galvanometer into ammeter, the following will have to be connected

(a) high resistance in series

(b) low resistance in series

(c) high resistance in parallel

(d) low resistance in parallel

75. An ammeter can be converted into a voltmeter by connecting

(a) a low resistance in series

(b) a high resistance in series

(c) a low resistance in parallel

(d) a high resistance in parallel.

76. An ammeter of resistance 5 Ω can read 5 milli ampere current. If it is to be used to read voltage of 100 volt, then the resistance required to be connected in series with it will be

(a) 19995 Ω (b) 19,9995 Ω

(c) 199.995 Ω (d) 19999.95 Ω

77. The deflection in a moving coil galvanometer is

(a) directly proportional to the number of turns in the coil

(b) inversely proportional to the area of the coil

(c) inversely proportional to the current flowing in it

(d) directly proportional to the twisting couple per unit twist.

78. Whose resistance, out of the following, is maximum?

(a) Ammeter (b) Millimeter

(c) Microammeter (d) All of the above

79. The pole pieces of a horse-shoe magnet are made cylindrical so that the deflection of the coil is proportional to

(a) the current flowing in the coil.

(b) $\frac{1}{\text{current flowing in the coil}}$

(c) the magnetic field

(d) the square of current flowing in the coil

80. The potentiometer is more appropriate for measuring potential difference than a voltmeter because

(a) the resistance of voltmeter is high

(b) the sensitivity of a potentiometer is higher than that of voltmeter

(c) the resistance of potentiometer wire is very low

(d) the potentiometer does not draw any current from the unknown source of emf.

81. The range of a voltmeter of resistance $G\,\Omega$ is V volt. The resistance required to be connected in series with it in order to convert it into a voltmeter of range nV volt, will be

(a) $(n-1)G$ (b) $\frac{G}{n}$

(c) nG (d) $\frac{G}{(n-1)}$

82. The deflection of a moving coil galvanometer reduces to half, on shunting it with a resistance of 60Ω. The resistance of galvanometer is

(a) 30Ω (b) 120Ω

(c) 60Ω (d) 15Ω

83. In the experiment of calibration of voltmeter, a 1.1 volt standard cell gets balanced at 440 cm length of the wire. The balancing length corresponding to a potential difference between the ends of a resistance comes out to be 190 cm. A voltmeter shows 0.5 volt for this potential difference. The error in the reading of voltmeter will be

(a) 0.025 Volt (b) 25 Volt

(c) 2 5 Volt (d) 0.25 Volt

84. The current flowing in the primary circuit of potentiometer is 2 A and the resistance of its wire is 0.2 Ω/m. If a one ohm standard coil gets balanced at 250 cm length of the wire, then the current flowing in the coil will be

(a) 0.5 A (b) 1A

(c) 1.5 A (d) 0.05 A

85. On comparing the emf.'s E_1 and E_2 ($E_1 > E_2$) of two cells by a potentiom eter, the balancing lengths come out to be l_1 and l_2 respectively, then

(a) $l_1 < l_2$ (b) $l_1 - l_2$

(c) $l_1 > l_2$ (d) none of the above

86. The internal resistance of a primary cell depends on

(a) the concentration of solution

(b) the current drawn from the cell

(c) the distance between the electrodes of the cell

(d) all of the above

87. The length of a potentiometer wire is 10 m. The distance between the null points on its wire corresponding to two cells comes out to be 60cm. If the difference of emf's of the cells is 0.4 volt then the potential gradient on potentiometer wire will be

(a) 0.67 V/m (b) 0.5 V/m

(c) 2.5 V/m (d) 0 V/m.

88. The two cells are connected in series, in a potentiometer experiment, in such a way so as to support each other and to oppose each other. The balancing lengths in two conditions are obtained as 150 cm and 50 cm respectively. The ratio of emf's of two cells will be

(a) 1 : 2 (b) 2: 1

(c) 1 : 4 (d) 4 : 1

89. In the following circuit diagram (Fig. 21.104) if the ammeter reading is zero, then the voltmeter reading will be

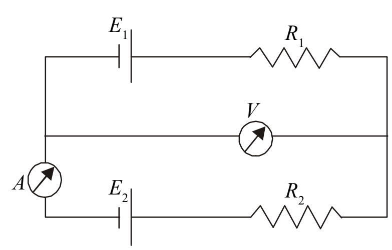


Fig. 21.104

(a) zero (b) $E_1 + E_2$

(c) E_1 (d) E_2

90. Which physical quantity cannot be determined with the help of potentiometer?

(a) I (b) V

(c) L (d) R

91. If I current is flowing in a potentiometer wire of length L and resistance R, then potential gradient will be

(a) $\dfrac{IR}{L}$ (b) IRL

(c) $\dfrac{RL}{I}$ (d) $\dfrac{IL}{R}$

92. In the adjoining diagram $R_1 = 10\ \Omega$, $R_2 = 20\ \Omega$, $R_3 = 40$ W, $R_4 = 80\ \Omega$ and $V_A = 5$V, $V_B = 10$V, $V_C = 20$V, $V_D = 15$V. The current in the resistance R_1 will be

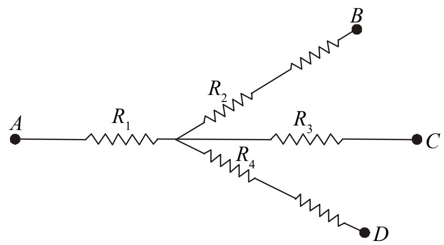


Fig. 21.105

(a) 0.4 A towards O (b) 0.4 A away from O

(c) 0.6 A towards O (d) 0.6 A away from O

93. In the circuit of Q.92, the current in R_2 will be

(a) 0.1 *A* towards *O* (b) 0.1 *A* away from *O*

(c) 0.05 A towards O. (d) 0.05 *A* away from *O*

94. In the adjoining figure, the equivalent resistance between the points *A* and *H* will be

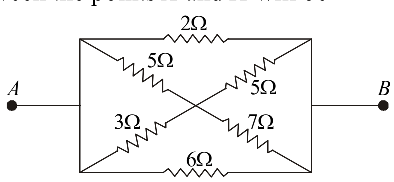


Fig. 21.106

(a) $\dfrac{7}{8}\ \Omega$ (b) $\dfrac{8}{7}\ \Omega$

(c) $\dfrac{9}{11}\ \Omega$ (d) $\dfrac{11}{9}\ \Omega$

95. In the following star circuit diagram, the equivalent resistance between the points *A* and *H* will be

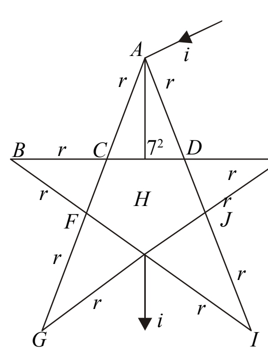


Fig. 21.107

(a) 1.944 *r* (b) 0.973 *r*

(c) 0.486 *r* (d) 0.243 *r*

96. In the adjoining circuit diagram each resistance is of 10 Ω. The current in the arm *AD* will be

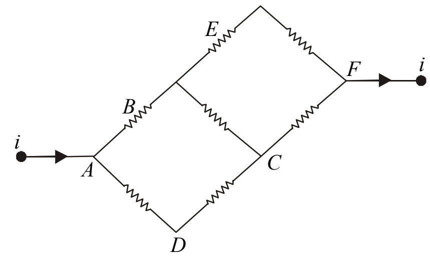


Fig. 21.108

(a) $\dfrac{2i}{5}$ (b) $\dfrac{3i}{5}$

(c) $\dfrac{4i}{5}$ (d) $\dfrac{i}{5}$

97. In the circuit of above question the current in the arm *BC* will be

(a) $\dfrac{2i}{5}$ (b) $\dfrac{3i}{5}$

(c) $\dfrac{4i}{5}$ (d) $\dfrac{i}{5}$

98. In Fig. 21.109 circuit of Wheatstone's bridge is represented. When the ratio arms *P* and *Q* are almost equal then the bridge gets balanced at $R = 400\ \Omega$. If *P* and *Q* are mutually interchanged then the bridge gets balanced at $R = 441\Omega$. The value of unknown resistance *X* will be

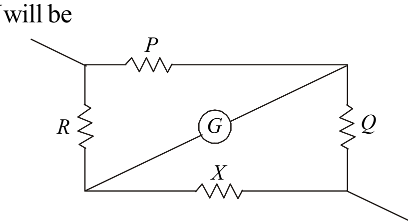


Fig. 21.109

(a) 402.49 Ω (b) 403 Ω

(c) 404 Ω (d) 420 Ω

99. In the above question, the ratio Q/P will be

(a) 1.05 : 1 (b) 1.005 : 1

(c) 1.5 : 1 (d) 1.25 : 1

100. A Wheatstone's bridge is constructed out of four resistances 10 Ω, 50 Ω, 100 Ω and 500 Ω. If a 25 volt battery is connected across 500 Ω resistance then current in 500 Ω resistance will be

(a) 5 mA (b) 0.5 A

(c) 5 A (d) 0.05 A

101. In the above problem current in rest of the resistances will be

(a) 8.8 A (b) 0.15 A

(c) 0.37 A (d) 3.5 A

102. In the following circuit if key K is pressed then the galvanometer reading becomes half. The resistance of galvanometer is

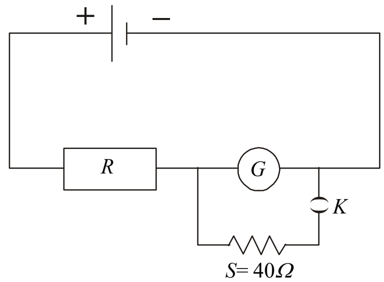


Fig. 21.110

(a) 20 Ω (b) 30 Ω

(c) 40 Ω (d) 50 Ω

103. If the central resistance is 15 Ω then the equivalent resistance between A and B will be

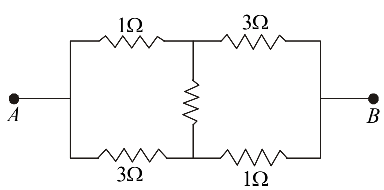


Fig. 21.111

(a) $\frac{3}{5}$ Ω (b) 4 Ω

(c) $\frac{33}{17}$ Ω (d) $\frac{1}{4}$ Ω

104. Each resistance in the following figure is of 3 Ω. The equivalent resistance between A and B will be

(a) 1.0 Ω (b) 2 Ω

(c) 3 Ω (d) 4 Ω

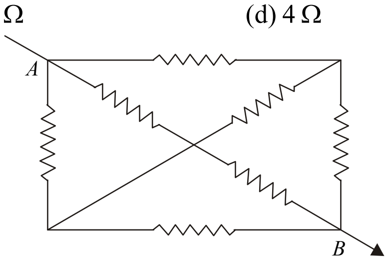


Fig. 21.112

105. The value of i in the following circuit diagram will be

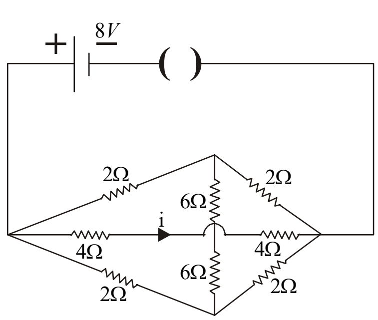


Fig. 21.113

(a) $\frac{3}{2}$ A (b) $\frac{3}{4}$ A

(c) $\frac{1}{2}$ A (d) 1 A

106. In the adjoining figure the potential difference between the points A and B will be

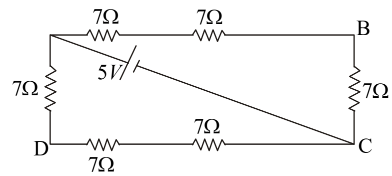


Fig. 21.114

(a) $\frac{10}{3}$ V (b) $\frac{4}{3}$ V

(c) $\frac{8}{9}$ V (d) $\frac{2}{3}$ V

107. In the above problem the potential difference between the points A and D will be

(a) $\frac{1}{3}$ V (b) $\frac{5}{3}$ V

(c) $\frac{7}{3}$ V (d) $\frac{10}{3}$ V

108. If Ohm's law is presumed to be valid, then drift velocity V_d and electric field E are related as

(a) $v_d \propto E^2$ (b) $v_d \propto \sqrt{E}$

(c) $v_d \propto E$ (d) $v_d \propto E_0$

109. In the circuit shown, the current in 2 Ω resistance will be

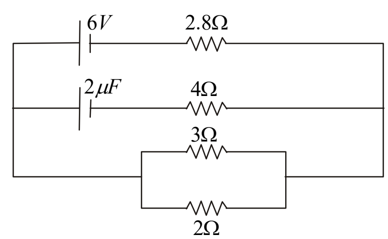


Fig. 21.115

(a) 1.25 A (b) 1.5 A

(c) 1.8 A (d) 0.9 A

110. In copper, each atom releases one electron. If a current of 1.1A is flowing in the copper wire of diameter 1mm then the drift velocity of electrons, will approximately be

(density of copper = 9×10^3 Kgm^{-3} and its atomic weight = 63).

(a) 10.3 mm/s (b) 0.1 mm/s

(c) 0.2 mm/s (d) 0.2 cm/s

111. If a copper wire is stretched to increase its length by 0.1% then percentage increase in its resistance will be

(a) 0.2% (b) 2%

(c) 1% (d) 0.1%

112. An electric cable contains a single copper wire of radius 9 mm. Its resistance is 5 Ω. This cable is replaced by six insulated copper wires, each of radius 3 mm. The resultant resistance of cable will be

(a) 7.5 Ω (b) 45 Ω

(c) 90 Ω (d) 270 Ω

113. A metallic wire of resistance 20 Ω is stretched such that its length becomes three times. The new resistance of the wire will be

(a) 6.67 Ω (b) 60.0 Ω

(c) 120 Ω (d) 180 Ω

114. The specific resistance of the material of a wire is ρ, its volume is 3 m^3 and its resistance is 3 Ω. The length of the wire will be

(a) $\frac{\sqrt{1}}{\rho}$ (b) $\frac{3}{\sqrt{\rho}}$

(c) $\frac{\sqrt{3}}{\rho}$ (d) $\frac{\rho}{\sqrt{3}}$

115. The dimensions of a rectangular parallelepiped are 1 cm × 1 cm × 100 cm. If its specific resistance is 3×10^{-7} Ω × m then the resistance between its rectangular faces will be

(a) 3×10^{-9} Ω (b) 3×10^{-7} Ω

(c) 3×10^{-5} Ω (d) 3×10^{-3} Ω

116. The emf of a cell of negligible internal resistance is 2 V. It is connected to the series combination of 2 Ω, 3 Ω and 5 Ω resistances. The potential difference across 3 Ω resistance will be (in volt)

(a) 0.6 (b) $\frac{2}{3}$

(c) 3 (d) 6

117. Four similar wires, each of resistance 10 Ω, are used to construct a square. The effective resistance between two corners will be

(a) 10 Ω (b) 40 Ω

(c) 20 Ω (d) 7.5 Ω

118. Two resistances are connected in (a) series (b) in parallel. The effective resistances in two cases are 9 Ω and 2 Ω respectively. The value of resistances will be

(a) 2 Ω and 7 Ω (b) 3 Ω and 6 Ω

(c) 3 Ω and 9 Ω (d) 5 Ω and 4 Ω

119. The resistance of a uniform wire of length *L* and diameter *d* is *R*. The resistance of another wire of same material but of length 4*L* and diameter 2*d* will be

(a) 2*R* (b) *R*

(c) $\frac{R}{2}$ (d) $\frac{R}{4}$

120. Each resistance in the adjoining network is of 1Ω. The effective resistance between A and B will be

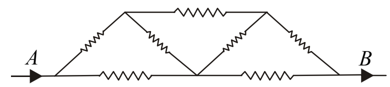


Fig. 21.116

(a) $\frac{4}{3}$ Ω (b) $\frac{3}{2}$ Ω

(c) 7 Ω (d) 8/7 Ω

121. The resistance between the points *A* and *B* in the adjoining figure will be

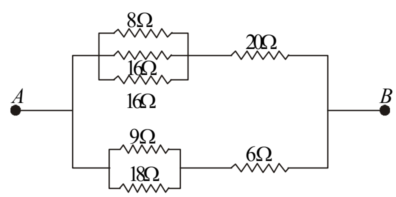


Fig. 21.117

(a) 6 Ω (b) 8 Ω

(c) 16 Ω (d) 24 Ω

122. A flash light cell of emf. 1.5 volt gives 15 ampere current when connected to an ammeter of resistance 0.04 Ω. The internal resistance of the cell will be

(a) 0.04 Ω (b) 0.06 Ω

(c) 0.10 Ω (d) 10 Ω

123. In the circuit shown, the value of resistance *X* in order that the potential difference between the points *B* and *D* is zero, will be

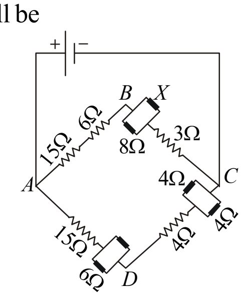


Fig. 21.118

(a) 4 Ω (b) 6 Ω

(c) 8 Ω (d) 9 Ω

124. If *n*, *e*, *t* and *m* are respectively the density, charge, relaxation time and mass of an electron then the resistance of wire of length / and cross-sectional area *A*, will be

(a) $\frac{ml}{ne^2\tau A}$ (b) $\frac{m\tau^2 A}{ne^2 l}$

(c) $\frac{ne^2\tau A}{ml}$ (d) $\frac{ne^2 A}{m\tau l}$

125. In the circuit shown the value of current given by the battery will be

(a) 1A (b) 2A

(c) 1.5A (d) 3A

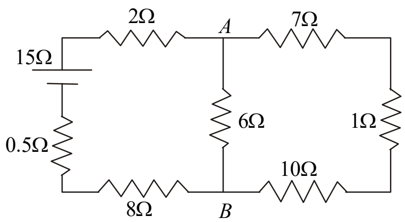


Fig. 21.119

126. In the circuit shown, if key K is open, then ammeter reading will be

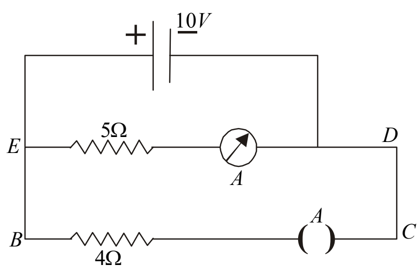


Fig. 21.120

(a) 50A (b) 2A

(c) 0.5A (d) $\frac{10}{9}$ A

127. The resistance of an iron wire is 10 Ω and its temperature coefficient of resistance is 5×10^{-3}/°C. A current of 30mA is flowing in it at 20°C. Keeping potential difference across its ends constant, if its temperature is increased to 120° C then the current flowing in the wire will be (in mA)

(a) 20 (b) 35

(c) 10 (d) 40

128. A copper wire of length 1m and radius 1mm is connected in series with another wire of iron of length 2 m and radius 3 mm. A steady current is passed through this combination. The ratio of current densities in copper and iron wires will be

(a) 18 : 1 (b) 9 : 1

(c) 6 : 1 (d) 2 : 3

129. A battery of emf. 10V is connected to a network as shown in Fig. 21.121 The potential difference between the points A and B will be

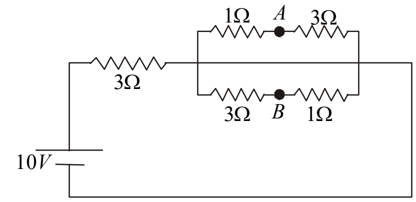


Fig. 21.121

(a) –2 V (b) 2 V

(c) 5 V (d) $\frac{20}{11}$ V

130. In the following circuit diagram, E = 4 V, r = 1 Ω and R = 45 Ω, then reading in the ammeter A will be

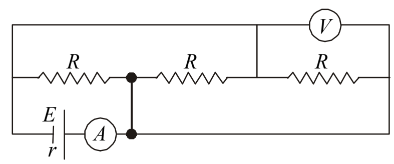


Fig. 21.122

(a) 1A (b) $\frac{1}{2}$ A

(c) $\frac{1}{8}$ A (d) $\frac{1}{4}$ A

131. In the above problem the voltmeter reading will be

(a) 4 V (b) 3 V

(c) 15 V (d) $3\frac{3}{4}$ V

132. A student connects four cells, each of internal resistancen $1/4\,\Omega$, in series. One of the cells is incorrectly connected because its terminals are reversed. The value of external resistance is 1Ω. If the emf of each cell is 1.5 volt then current in the circuit will be

(a) $\frac{4}{3}$ A (b) zero

(c) $\frac{3}{4}$ A (d) 1.5 A

133. An aluminum rod and a copper rod are taken such that their lengths are same and their resistances are also same. The specific resistance of copper is half that of aluminum, but its density is three times that of aluminum. The ratio of the mass of aluminum rod and that of copper rod will be

(a) $\frac{1}{6}$ (b) $\frac{2}{3}$

(c) $\frac{1}{3}$ (d) 6

134. In the following circuit shown, if point B is earthed then potential at D will be

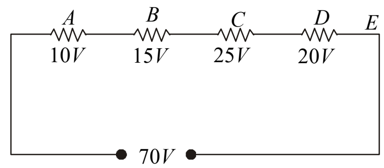


Fig. 21.123

(a) 40 V (b) – 40 V

(c) zero (d) 80 V

135. The potential drop across 4V battery in the following circuit will be

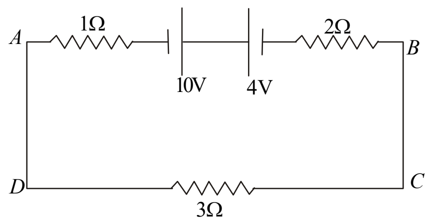


Fig. 21.124

(a) 2V (b) 5V

(c) 9V (d) 6V

136. In the following circuit, AB is a long resistance wire of 300 Ω. It is tapped at one third distance and is connected as shown in Fig. 21.125 The equivalent resistance between X and Y will be

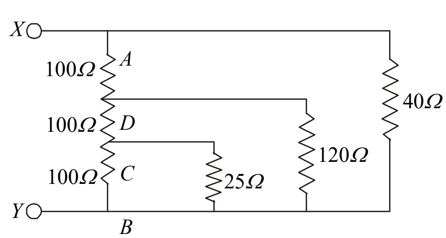


Fig. 21.125

(a) 20 Ω (b) 32 Ω

(c) 60 Ω (d) none of above

137. In the following circuit the resistance of wire AB is 10 Ω and its length is 1m. Rest of the quantities are given in the diagram. The potential gradient on the wire will be

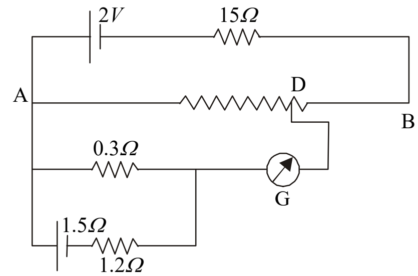


Fig. 21.126

(a) 0.08 $\frac{V}{m}$ (b) 0.008 $\frac{V}{m}$

(c) 0.8 $\frac{V}{m}$ (d) none of the above

138. In the above problem the length of wire AO, at null point, will be

(a) 37.5 cm (b) 3.75 cm

(c) 75 cm (d) 15 cm

PASSAGE 1

Read the following passage and answer the questions given at the end.

Under certain conditions voltages as small as 10 V can be dangerous, and should not be regarded with anything but respect and caution.

On the positive side, rapidly alternating currents can have beneficial effects. Alternating currents with frequencies of the order of 10^6 Hz do not interfere appreciably with nerve processes, and can be used for therapeutic heating for arthritic conditions, sinusitis, and a variety of other disorders. If one electrode is made very small, the resulting concentrated heating can be used for local destruction of tissue, such as tumors, or even for cutting tissue in certain surgical procedures.

Study of particular nerve impulses is also an important diagnostic tool in medicine. The most familiar examples are electro cardiography (*ECG*) and electro encephalography (*EEG*). Electrocardiograms, obtained by attaching electrodes to the chest and back and recording the regularly varying potential differences, are used to study heart function. Similarly, electrodes attached to the scalp permit study of potentials in the brain and the resulting patterns can be helpful in diagnosing epilepsy, brain tumors, and other disorders.

1. Epilepsy can be diagnosed using

(a) ECG (b) ultrasound

(c) EEG (d) x-ray

2. Give one example in which 10 V may be fatal.

(a) when touched to tongue

(b) when touched with wet hand

(c) when touched with unaided hand

(d) when it is a storage battery

3. For treating arthritis

(a) radio waves are used

(b) direct current is used

(c) microwaves are used

(d) AC of very low frequency is used

4. Skin effect is shown by

(a) DC

(b) AC of frequencies < 10^3 Hz

(c) AC of frequencies > 10^6 Hz

(d) any frequency signal

5. In an AC circuit we have a black box of 200 Ω, 60°. Frequency of AC is 250 Hz. When a capacitor of $2n$ μF is added maximum power is obtained. The values of components of black box are

(a) $R = 100\,\Omega, X_L = 100\sqrt{3}\ \Omega$

(b) $R = 100\sqrt{3}\,\Omega, X_L = 100\,\Omega$

(c) $R = 100\,\Omega, X_C = 100\sqrt{3}\ \Omega$

(d) $X_C = 100\,\Omega, R = 100\sqrt{3}\ \Omega$

6. The most stable frequency can be generated using

(a) LC series circuit

(b) LC parallel circuit

(c) crystal

(d) RC phase shift oscillator

(e) Wein's bridge oscillator

7. The AC of 500 Hz is applied in the circuit shown. A ferrite core is then inserted in the coil.

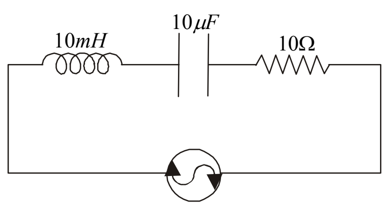


Fig. 21.127

(a) curent increases

(b) current decreases

(c) current remains uncharged

(d) current cannot be determined

8. To achieve DC from AC, AC be applied across

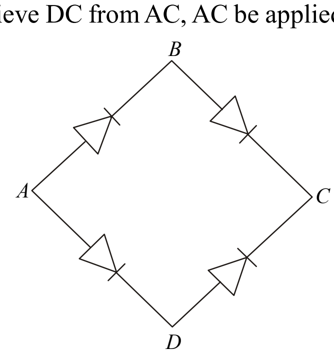


Fig. 21.128

(a) BD (b) AC

(c) BC (d) CD

(e) AD

9. To obtain a good quality DC from AC we shall use

(a) RC filter (b) LC filter

(c) π filter (d) Butterworth filter

10. In which filter attenuation is maximum

(a) RC (b) LC

(c) π (d) Butterworth

Solution **1.** (c)

Solution **2.** (a), (b), (d)

Solution **3.** (a)

Solution **4.** (c)

Solution **5.** (a) $\tan\phi = \tan 60 = \dfrac{X_L}{R}$

or $X_L = R\sqrt{3}\,;\ \sqrt{X_L^2 + R^2} = 200\,\Omega$

or $\sqrt{4R^2} = 200$

i.e., $R = 100\,\Omega$ and $X_L = 100\sqrt{3}$

Solution **6.** (c)

Solution **7.** (b)

On adding ferrite core L will increase. The case will he off resonance then.

Solution **8.** (a)

Solution **9.** (c), (d)

Solution **10.** (d)

PASSAGE 2

Read the following passage and answer the questions given at the end.

The thermal coefficient of resistivity α is given by $\alpha = \dfrac{1}{\rho}\dfrac{d\rho}{dT}$ where ρ is resistivity at a temperature T.

$\rho = \rho_0\,[1 + \alpha(T - T_0)]$ can be written if α is constant and much smaller than $(T - T_0)^{-1}$, if α is not constant, rather varies as $\alpha = -\dfrac{n}{T}$ where T is temperature in Kelvin and n is a constant. For carbon $\alpha = -0.0005\ K^{-1}$ and $\rho = 3.5 \times 10^{-5}$ (Ω – m) at 20° C

1. Find ρ using $\alpha = \dfrac{-n}{T}$

(a) $\rho \propto T^n$ (b) $\rho \propto T^{n-1}$

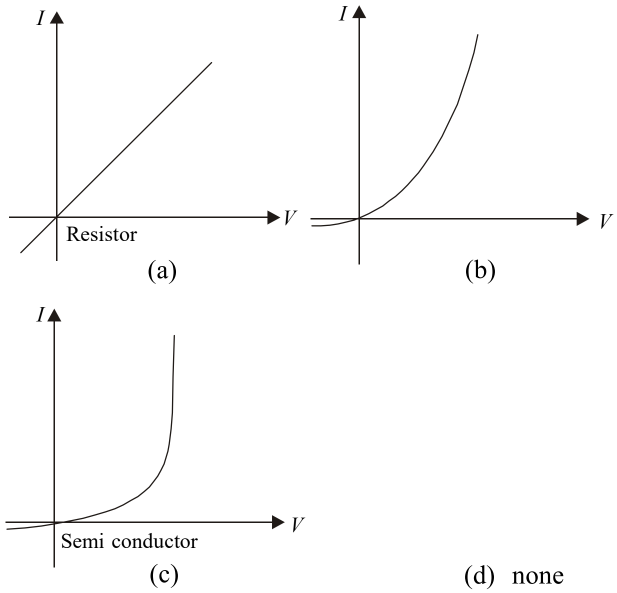
(c) $\rho \propto T^{-n}$ (d) $\rho \propto \dfrac{n}{T}$

2. Find the value of n for carbon.

(a) 0.15 (b) 0.3

(c) 0.9 (d) 0.6

3. The relation for ρ determined in Q.1 can be used approximately for



(d) none

Fig. 21.129

Solution **1.** (c)

$$\frac{-n}{T} = \frac{1}{\rho}\frac{d\rho}{dt} \text{ or } \int_{\rho_0}^{\rho}\frac{d\rho}{\rho} = -n\int_{T_0}^{T}\frac{dT}{T}$$

or $$\rho = \frac{\rho_0 T_0^n}{T^n} = \frac{a}{T^n}$$

Solution **2.** (a)

$$\alpha = \frac{-n}{T} \text{ or } -.0005 = \frac{-n}{300} \text{ or } n = .15$$

Solution **3.** (c)

PASSAGE 3

Read the following passage and answer the questions given at the end.

The average bulk resistivity of the human body (apart from the surface resistance of the skin) is about 5 $\Omega - m$. The conducting path between the hands can be represented approximately as a cylinder 1.6 m long and 0.1 m diameter. The skin resistance may be made negligible by soaking the hands in salt water. A lethal shock current needed is 100 mA. Note that a small amount of potential difference could be fatal if the skin is damp.

1. What is the resistance between the hands?

(a) $10^2\ \Omega$ (b) $10^3\ \Omega$

(c) $10^4\ \Omega$ (d) none of these

2. What potential difference is needed between the hands for a lethal shock current?

(a) 100 V (b) 10 V

(c) 120 V (d) 150 V

3. The power dissipated in the body is

(a) 1 W (b) 0.1 W

(c) 100 W (d) 10 W

Solution **1.** (b) $R = \rho\ \dfrac{l}{a} = \dfrac{5\times 1.6}{\pi(.05)^2} = 10^3\ \Omega$

Solution **2.** (b) $V = IR = 100\times 10^{-3}\times 10^3 = 100$ V

Solution **3.** (d) $P = VI = 10$ W

Answers to Questions for Practice

1.	(c,d)	**2.**	(a,d)	**3.**	(a,b,d)	**4.**	(a,c,d)	**5.**	(a,d,b)	**6.**	(d)	**7.**	(a,d)
8.	(b,c,d)	**9.**	(a,b,c,d)	**10.**	(a,d)	**11.**	(a,b,c,d)	**12.**	(a,c)	**13.**	(b,c,d)	**14.**	(c)
15.	(a,b,c)	**16.**	(a)	**17.**	(b, c)	**18.**	(a,b,c,d)	**19.**	(a,b,d)	**20.**	(b,d)	**21.**	(b, c)
22.	(b,c)	**23.**	(b)	**24.**	(b,c)	**25.**	(c)	**26.**	(b,c,d)	**27.**	(a,b)	**28.**	(a,c,d)
29.	(a,b,d)	**30.**	(a,b,c,d)	**31.**	(a,c,d)	**32.**	(a,c)	**33.**	(a)	**34.**	(a,d)	**35.**	(a,c)
36.	(a)	**37.**	(b)	**38.**	(b)	**39.**	(d)	**40.**	(a)	**41.**	(c)	**42.**	(a)
43.	(b,c)	**44.**	(a)	**45.**	(a,d)	**46.**	(d)	**47.**	(c,d)	**48.**	(a,d)	**49.**	(d)
50.	(d)	**51.**	(a)	**52.**	(a,d)	**53.**	(b,c,d)	**54.**	(a)	**55.**	(c,d)	**56.**	(b)
57.	(a,b,d)	**58.**	(a,d)	**59.**	(c)	**60.**	(a)	**61.**	(b)	**62.**	(b)	**63.**	(b)
64.	(a)	**65.**	(b)	**66.**	(a)	**67.**	(c)	**68.**	(c)	**69.**	(b)	**70.**	(a)
71.	(c)	**72.**	(b)	**73.**	(b)	**74.**	(d)	**75.**	(b)	**76.**	(a)	**77.**	(b)
78.	(c)	**79.**	(a)	**80.**	(d)	**81.**	(a)	**82.**	(c)	**83.**	(a)	**84.**	(d)
85.	(c)	**86.**	(d)	**87.**	(a)	**88.**	(b)	**89.**	(d)	**90.**	(c)	**91.**	(a)
92.	(b)	**93.**	(c)	**94.**	(b)	**95.**	(b)	**96.**	(a)	**97.**	(d)	**98.**	(d)
99.	(a)	**100.**	(d)	**101.**	(b)	**102.**	(c)	**103.**	(c)	**104.**	(b)	**105.**	(d)
106.	(a)	**107.**	(b)	**108.**	(c)	**109.**	(d)	**110.**	(b)	**111.**	(a)	**112.**	(a)
113.	(d)	**114.**	(b)	**115.**	(b)	**116.**	(a)	**117.**	(a)	**118.**	(b)	**119.**	(b)
120.	(d)	**121.**	(b)	**122.**	(b)	**123.**	(c)	**124.**	(a)	**125.**	(a)	**126.**	(b)
127.	(a)	**128.**	(b)	**129.**	(b)	**130.**	(d)	**131.**	(d)	**132.**	(d)	**133.**	(b)
134.	(b)	**135.**	(d)	**136.**	(b)	**137.**	(c)	**138.**	(a)				

EXPLANATION

1. When current flows through the conductor AB, it remains electrically neutral. Therefore, no charges are induced by it in the cylinder. A beam of electrons or protons has net negative or positive charge. They will induce bound and free charges on L. The free charges will flow through C to the earth.

2. The speed of the electrons increases as they are accelerated. The current I remains constant, as the number of electrons emitted per second by the gun is constant. Now, $I = Avne$. As I, A and e are constant, while v increase, n must decrease.

3. As C and D are joined, they must be at the same potential, and may be treated as the same point. This gives the equivalent resistance as 8 Ω. If we distribute current in the network, using symmetry,

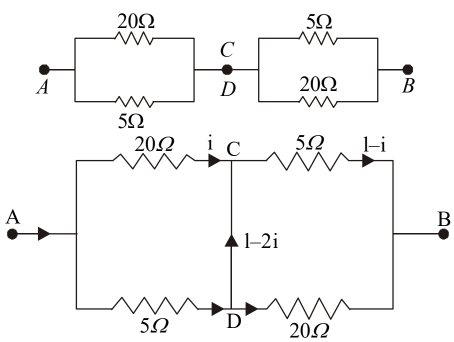


Fig. 21.130

$V_A - V_D = V_A - V_C$

or $20\,i = 5(I - i)$ or $i = I/5$

$\therefore \quad I - 2i = I - \dfrac{2I}{5} = \dfrac{3I}{5}$ = current flowing from D to C.

4. $i = \dfrac{dQ}{dt} = a - 2bt$

$i = v$ for $t = \dfrac{a}{2b} \cdot \dfrac{di}{dt} = -2b.$

5. $Q = at - \left(\dfrac{1}{2}\right) bt^2 + \left(\dfrac{1}{6}\right) ct^3$

$i = \dfrac{dQ}{dt} = a - bt + \dfrac{1}{2}ct^2$

$i = a$ for $t = 0$

$\dfrac{di}{dt} = -b + ct$

For i to be maximum or minimum, $\dfrac{di}{dt} = 0$ or $t = \dfrac{b}{c}$

For this value of t, $i = a - \dfrac{b^2}{c} + \dfrac{1}{2} c.\left(\dfrac{b^2}{c^2}\right) = a - \dfrac{b^2}{2c}.$

As this value of i is less then at $t = 0$, it must be a minimum

6. Treat all points joined by a connecting wire as the same point. Give names (eg., A, B, etc.) to each such set of points. Rearrange the circuit in terms of these points.

Rearranging the circuit as shown in Fig 21.29 (b), current can flow from A to B through the branch containing diode only if the swithch S is closed. In this case, $R_{AB} = R/4$.

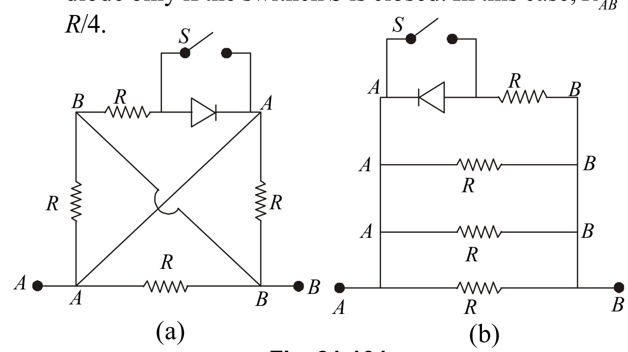


Fig. 21.131

If S is open, the resistor in diode branch can be removed from the circuit as no current can flow through it. $R_{AB} = R/3$.

8. If we remove the two branches containing the ammeters, then, for $V_A > V_B$,

$V_A - V_C = 3 \times \dfrac{10}{7}$ and $V_A - V_D = 1 \times \dfrac{10}{3}$.

$\therefore \quad V_D - V_C = 10\left(\dfrac{3}{7} - \dfrac{1}{3}\right) > 0$

or $V_D > V_C$, and current flows only through A_2.

Similarly, if $V_B > V_A$, $V_C > V_D$, and current flows only through A_1.

For current flowing through either A_1 or A_2, the total resistance is 10 Ω and current is 1A.

9. Apply the concepts used in questions 3 and 6.

10. Rearrangement of the circuit as shown gives a balanced Wheatstone bridge, and no current flows through the 5 Ω resistor. It can thus be removed from the circuit.

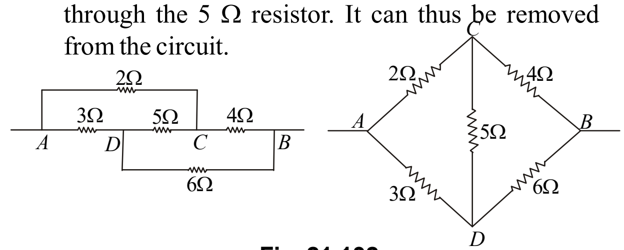


Fig. 21.132

11. Let $E_1 < E_2$.

Current in the circuit $= i = \dfrac{E_1 - E_2}{r_1 + r_2}$

$V_A - V_B = E_2 + ir_2 =$ p.d. across each cell.

Here, $V_A - V_B > E_2$.

Current flows in the cell of emf ε_2 from the positive plate to the negative plate inside the cell and hence it absorbs energy.

12. The resistance of each side = R/n.

For resistance between opposite corners, we have two resistance of $R/2$ in parallel.

For resistance between adjacent corners, we have two resistance of $\dfrac{R}{n}$ and $\dfrac{(n-1)R}{n}$ in parallel.

13. Disregard the capacitors and find the current through G. The potential difference across each capacitor is then found from the potential differences across the resistances in parallel with them.

14. A fully charged capacitor draws no current. If the capacitor is removed from the circuit, we can distribute current and find the potential difference across each resistance.

18. Treat all voltmeters as resistances. Draw the circuit and find the currents and potential differences for each section.

The voltmeter reading is the potential difference across its terminals when it is connected in the circuit. The ammeter reading is the current passing through it.

25.

$$i_g = 10 \text{ mA} = 0.01 \text{ A}.$$

$$V_A - V_B = (I - i_g)\,0.1 = i_g \times 9.9.$$

or $$I \times 0.1 = 10 i_g$$

or $$I = \frac{10 \times 0.01}{0.1} = 1 \text{ A}.$$

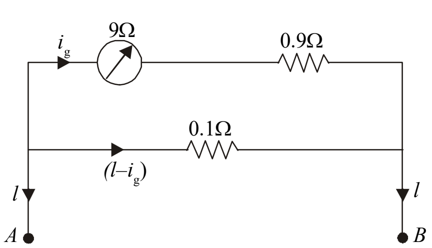


Fig. 21.133

29. Let $V=$ potential at D.

$$70 - D = 10 i_1.$$

$$V - 0 = 20 i_2.$$

$$V - 10 = 30(i_1 - i_2).$$

Solve for i_1, i_2 and V.

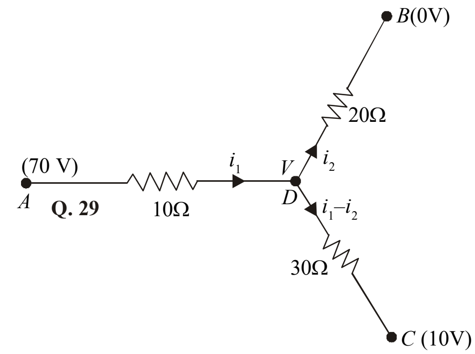


Fig. 21.134

32. Let R_1 and R_2 be the resistances of the two heaters. Let H be the heat produced.

$$\therefore \quad H = \left(\frac{V^2}{R_1}\right) t_1 = \left(\frac{V^2}{R_2}\right) t_2.$$

When used in series, $H = \dfrac{V^2}{(R_1 + R_2)}\, t.$

When used in parallel, $H = \left(\dfrac{V^2}{R_1} + \dfrac{V^2}{R_2}\right) t.$

33.

$$Q = at - bt^2.$$

$$i = \frac{dQ}{dt} = a - 2bt.$$

$i = 0$ for $t = t_0 = a/2b$, i.e., current flow from $t = 0$ to $t = t_0$.

The heat produced $= \int_0^{t_0} i^2 R\,dt$.

34. Let $V = 220$ V; R_1 and R_2 = resistances of the 25 W and 100 W bulbs.

$P_1 = 25 = V^2/R_1$ or $R_1 = V^2/25$ and $R_2 = V^2/100$

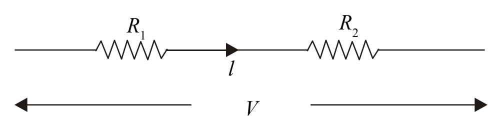


Fig. 21.135

When the bulbs are joined in series, the current

$$I = \frac{V}{R_1 + R_2}.$$

Power in the 25 W bulb $= R_1 I^2$ and in the 100 W bulb $= R_2 I^2$.

53. When X is joined to Y for a long time (charging), the energy stored in the capacitor = heat produced in $R = H_1$.

When X is joined to Z (discharging), the energy stored in $C(= H_1)$ reappears as heat (H_2) in R. Thus, $H_1 = H_2$.

54. A and B are effectively in parallel and hence give the same reading at all times.

56. When the slab is removed, the potential of the capacitor increases k times, i.e., it becomes kV_0. For the potential to fall to V_0