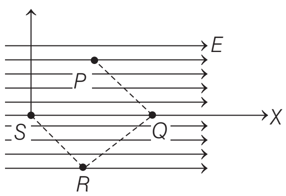
Unit Test 4
(Electrostatics and Current Electricity)

1 Two concentric spheres of radii r_1 and r_2 carry charges q_1 and q_2, respectively. If the surface charge density (σ) is the same for both the spheres, the electric potential at the common centre will be

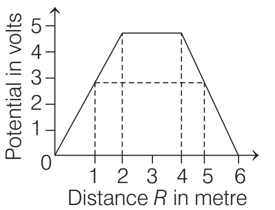
(a) $\frac{\sigma}{\varepsilon_0} \times \frac{r_1}{r_2}$ (b) $\frac{\sigma}{\varepsilon_0} \times \frac{r_2}{r_1}$
(c) $\frac{\sigma}{\varepsilon_0}(r_1 - r_2)$ (d) $\frac{\sigma}{\varepsilon_0}(r_1 + r_2)$

2 Point charge q moves from point P to point S along the path $PQRS$ (figure shown) in a uniform electric field E pointing coparallel to the positive direction of the X-axis. The coordinates of the points P, Q, R and S $(a, b, 0)$ $(2a, 0, 0)$ $(a, -b, 0)$ and $(0, 0, 0)$ respectively. The work done by the field in the above process is given by the expression



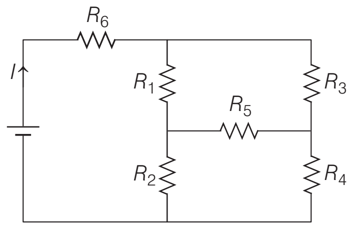
(a) qEa (b) $-qEa$
(c) $qEa\sqrt{2}$ (d) $qE\sqrt{[(2a)^2 + b^2]}$

3 The variation of potential with distance R from a fixed point is as shown below. The electric field at $R = 5$ m is



(a) 2.5 V/m (b) −2.5 V/m
(c) 2 / 5 V/m (d) −2 / 5 V/m

4 In the given circuit, it is observed that the current I is independent of the value of resistance R_6. Then, the resistance value must satisfy



(a) $\frac{1}{R_5} + \frac{1}{R_6} = \frac{1}{R_1 + R_2} \times \frac{1}{R_3 + R_4}$
(b) $R_1R_4 = R_2R_3$
(c) $R_1R_2R_5 = R_3R_4R_6$
(d) $R_1R_3 = R_2R_4 = R_5R_6$

5 Two cells of internal resistance r_1 and r_2; and at same emf are connected in series, across a resistor of resistance R. If the terminal potential difference across the cells of internal resistance r_1 is zero, then the value of R is

(a) $R = 2(r_1 + r_2)$ (b) $R = r_2 - r_1$
(c) $R = r_1 - r_2$ (d) $R = 2(r_1 - r_2)$

6 The electric dipole moment of an electron and proton 4.30 nm apart is

(a) 6.88×10^{-28} C-m (b) 5.88×10^{-28} C-m
(c) 6.88×10^{28} C-m (d) 5.88×10^{28} C-m

7 At what distance along the central axis of a uniformly charged plastic disk of radius R is the magnitude of the electric field equal to one-half the magnitude of the field at the centre of the surface of the disk?

(a) $\frac{R}{\sqrt{2}}$ (b) $\frac{R}{\sqrt{3}}$ (c) $\sqrt{2}R$ (d) $\sqrt{3}R$

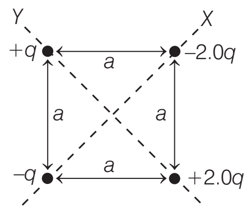
8 Work done in placing a charge of 8×10^{-18} C on a condenser of capacity 100 μF is

(a) 16×10^{-32} J (b) 3.1×10^{-28} J
(c) 64×10^{-32} J (d) 32×10^{-32} J

9 A drop, having a mass of 4.8×10^{-10}g and a charge of 2.4×10^{-18}C is suspended between two charged horizontal plates at a distance 1.0 cm apart. Find the potential difference between the plates. If polarity of the plates be changed, then calculate the instantaneous acceleration of the drop.

(a) 1.96×10^{6}V, 18.6 ms^{-2} (b) 1.86×10^{4}V, 18.6 ms^{-2}
(c) 1.96×10^{4}V, 19.6 ms^{-2} (d) 2.96×10^{4}V, 17.6 ms^{-2}

10 What is the direction of the electric field at the centre of the square of figure, if $q = 1.0 \times 10^{-8}$C and $a = 5.0$ cm?



(a) 30° with X-axis (b) 45° with X-axis
(c) 60° with X-axis (d) 90° with X-axis

11 In a potentiometer experiment, the balancing with a cell is at length 240 cm. On shunting the cell with a resistance of 2 Ω, the balancing length becomes 120 cm. The internal resistance of the cell is

(a) 4 Ω (b) 2 Ω (c) 1 Ω (d) 0.5 Ω

12 The resistance of a wire at 20°C is 20 Ω and at 500°C is 60 Ω. At which temperature its resistance will be 25Ω?

(a) 50°C (b) 60°C
(c) 70°C (d) 80°C

13 A charged cloud system produces an electric field in the air near earth's surface. A particle of charge -2×10^{-9}C is acted on by a downward electrostatic force of 3×10^{-6}N, when placed in this field. The ratio of the magnitude of the electrostatic force to the magnitude of the gravitational force in the case of proton is

(a) 1.6×10^{-19} (b) 1.5×10^{-10} (c) 1.6×10^{19} (d) 1.4×10^{10}

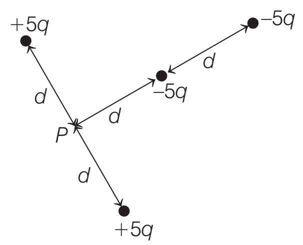
14 An infinite non-conducting sheet has a surface charge density $\sigma = 0.10\ \mu$C m^{-2} on one side. How far apart are equipotential surfaces whose potentials differ by 50 V?

(a) 5.8×10^{-3}m (b) 6.8×10^{-3}m
(c) 7.8×10^{-3}m (d) 8.8×10^{-3}m

15 An electron is released from rest in a uniform electric field of magnitude 2.00×10^{4} NC^{-1}. Acceleration of the electron is (ignore gravitation)

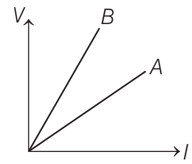
(a) 2.51×10^{15}ms^{-2} (b) 2.51×10^{-15}ms^{-2}
(c) 3.51×10^{15}ms^{-2} (d) 3.51×10^{-15}ms^{-2}

16 In figure, the net potential at point P due to the four point charges, if $V = 0$ at infinity is



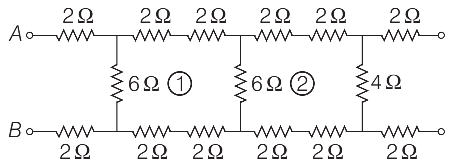
(a) $\frac{3q}{8\pi\varepsilon_0}$ (b) $\frac{5q}{8\pi\varepsilon_0}$ (c) $\frac{7q}{8\pi\varepsilon_0}$ (d) $\frac{9q}{8\pi\varepsilon_0}$

17 V-I graphs for parallel and series combination of two identical resistors are as shown in figure. Which graph represent parallel combination?



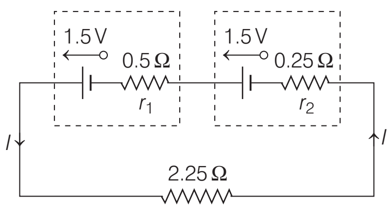
(a) Graph-A (b) Graph-B
(c) Both graph A and B (d) None of these

18 The equivalent resistance between points A and B in the following diagram is



(a) 2 Ω (b) 8 Ω (c) 9 Ω (d) 10 Ω

19 Two cells connected in series have electromotive force of 1.5 V each. Their internal resistance are 0.5 Ω and 0.25 Ω respectively. This combination is connected to a resistance of 2.25 Ω. Potential difference across the terminals of each cell



(a) 1 V, 0.25 V (b) 1 V, 1.25 V
(c) 1.5 V, 2.25 V (d) 1.5 V, 2.56 V

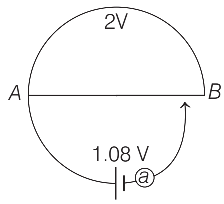
20 A charge of 0.8 C is divided into two charges Q_1 and Q_2. These are kept at a separation of 30 cm. The force on Q is maximum, when

(a) $Q_1 = Q_2 = 0.4$ C (b) $Q \approx 0.8$ C, Q_2 is negligible
(c) Q_1 is negligible, $Q_2 \approx 0.8$ C (d) $Q_1 = 0.2$ C, $Q_2 = 0.6$ C

21 A particular 12 V car battery can send a total charge of 84 A-h through a circuit, from one terminal to other. If this entire charge undergoes a potential difference of 12 V, how much energy is involved?

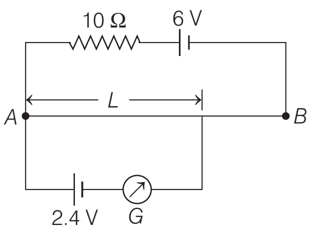
(a) 1.6×10^6 J (b) 2.6×10^6 J
(c) 3.6×10^6 J (d) 4.6×10^6 J

22 *AB* is uniform resistance wire of length 1 m. A 2 V accumulator, a Daniell cell of 1.08 V and a galvanometer *G* are connected as shown. If the sliding contact is adjusted for null deflection then the potential gradient in *AB* and the balancing length, measured from end *A* are respectively.



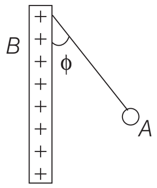
(a) 0.02 V/cm, 54 cm (b) 0.0308 V/cm, 46 cm
(c) 0.0092 V/cm, 49.6 cm (d) 0.02 V/cm, 50.4 cm

23 A potentiometer wire of length 200 cm has a resistance of 20 Ω. It is connected in series with a resistance of 10 Ω and an accumulator of emf 6 V having negligible internal resistance. A source of 2.4 V is balanced against a length *L* of the potentiometer wire. Find the value of *L*.



(a) 100 cm (b) 120 cm (c) 110 cm (d) 140 cm

24 A charged ball *A* hangs from a silk thread, which makes an angle ϕ with a large charged conducting sheet *B* as shown in the figure. The surface charge density of the sheet is proportional to



(a) $\sin\phi$ (b) $\cot\phi$
(c) $\cos\phi$ (d) $\tan\phi$

25 Two concentric conducting thin shells of radius *r* and 2*r* carry charges +2*q* and +6*q*, respectively. The magnitude of electric field at a distance *x* outside and inside from the surface of outer sphere is same, then the volume of *x* is

(a) $\frac{r}{2}$ (b) $\frac{2r}{3}$ (c) $\frac{r}{3}$ (d) $\frac{r}{6}$

26 There are two electric bulbs rated 60 W, 120 V and 90 W, 120 V. They are connected in parallel with 240 V supply, then

(a) both bulbs work properly
(b) both bulbs will fuse
(c) Only 60 W bulb will fuse
(d) Only 90 W bulb will fuse

27 Masses of the three wires of same material are in the ratio of 1 : 2 : 3 and their lengths in the ratio of 3 : 2 : 1. Electrical resistance of these wires will be in the ratio of

(a) 1 : 1 : 1 (b) 1 : 2 : 3 (c) 9 : 4 : 1 (d) 27 : 6 : 1

28 Six wires, each of resistance r_1 are connected so as to form a tetrahedron. The equivalent resistance of the combination when current enters through one corner and leaves through other corner is

(a) r (b) $2r$ (c) $\frac{r}{3}$ (d) $\frac{r}{2}$

29 A unit negative charge with mass *M* resides at the mid-point of the straight line of length 2*a* adjoining two fixed charges of magnitude $+Q$ each. If it is given a very small displacement $x(x << a)$ in a direction perpendicular to the straight line, it will

(a) came back to its original position and stay there
(b) execute oscillations with frequency $\frac{1}{2\pi}\sqrt{\frac{Q}{4\pi\varepsilon_0 Ma^3}}$
(c) execute oscillations with frequency $\frac{1}{2\pi}\sqrt{\frac{Q}{4\pi\varepsilon_0 Ma^2}}$
(d) execute oscillations with frequency $\frac{1}{2\pi}\sqrt{\frac{Q}{2\pi\varepsilon_0 Ma^3}}$

30 A 28 μF capacitor is charged to 100 V and another 2 μF capacitor to 200 V, they are connected in parallel. Then, the total final energy is

(a) 0.1537 J (b) 0.0155 J (c) 0.1865 J (d) 0.123 J

31 A hollow copper tube of 1m length has got external diameter equal to 10cm and its walls are 5mm thick. Then the resistance of tube, if its specific resistance is $1.7\times 10^{-8}\ \Omega$ m, is

(a) $1.139\times 10^{-5}\ \Omega$ (b) $1.327\times 10^{-6}\ \Omega$
(c) $1.150\times 10^{-5}\ \Omega$ (d) $1.125\times 10^{-4}\ \Omega$

32 Manjeet's room heater is marked as 1000 W-200V. If the voltage drops to 160 V, the percentage change in the power of the heater is

(a) 40% (b) 42% (c) 36% (d) 50%

Direction (Q. Nos. 33-40) *Each of these questions contains two statements : Statement I and Statement II. Each of these questions also has four alternative choices, only one of which is the correct answer. You have to select one of the codes (a), (b), (c), (d) given below*

(a) Statement I is true, Statement II is true; Statement II is the correct explanation for Statement I
(b) Statement I is true, Statement II is true; Statement II is not the correct explanation for Statement I
(c) Statement I is true; Statement II is false
(d) Statement I is false; Statement II is true

33 **Statement I** *A* and *B* are two conducting spheres of same radius. *A* being solid and *B* hollow. Both are charged to the same potential. Then,

Charge on *A* = charge on *B*.

Statement II Potentials on both are same.

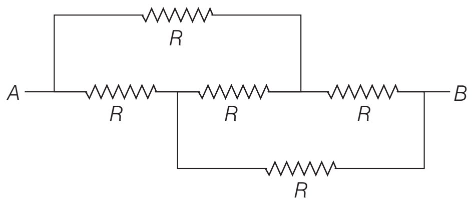
34 **Statement I** A thin metallic wire is bent into semicircular shape, then its resistivity decreases.

Statement II On bending, the drift of electron in the wire remains same.

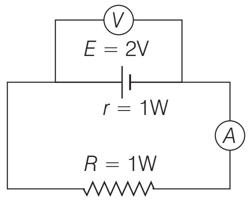
35 **Statement I** The circuits containing capacitor be handed cautiously, even when there is no current.

Statement II A dielectric differs from an insulator.

36 **Statement I** In the following circuit, the net resistance between points *A* and *B* is *R*



Statement II All the resistances are in parallel to each other.



37 **Statement I** In the following circuit, emf is 2V and internal resistance of the cell is $1\,\Omega$ and $R = 1\,\Omega$, then reading of the voltmeter is 1V.

Statement II $V = E - Ir$, where $E = 2\,\text{V}$, $I = \frac{2}{2} = 1$ A and $R = 1\,\Omega$.

38 **Statement I** The power delivered to a light bulb is more just after it is switched ON and the glow of the filament is increasing, as compared to when the bulb is glowing steadily, i.e. after sometime of switching ON.

Statement II As temperature increases, resistance of conductor increases.

39 **Statement I** When a wire is stretched, so that its diameter is halved, its resistance becomes 16 times.

Statement II Resistance of wire decreases with increase in length.

40 **Statement I** A potentiometer is preferred over that of a voltmeter for measurement of emf of a cell.

Statement II Potentiometer is preferred as it does not draw any current from the cell.

ANSWERS

1. (d)	**2.** (b)	**3.** (a)	**4.** (b)	**5.** (c)	**6.** (a)	**7.** (b)	**8.** (d)	**9.** (c)	**10.** (b)
11. (b)	**12.** (d)	**13.** (d)	**14.** (d)	**15.** (c)	**16.** (b)	**17.** (a)	**18.** (b)	**19.** (b)	**20.** (a)
21. (c)	**22.** (a)	**23.** (b)	**24.** (d)	**25.** (b)	**26.** (b)	**27.** (d)	**28.** (d)	**29.** (d)	**30.** (c)
31. (a)	**32.** (c)	**33.** (a)	**34.** (d)	**35.** (b)	**36.** (c)	**37.** (a)	**38.** (a)	**39.** (c)	**40.** (a)

Hints and Explanations

1 Electric potential of the common centre, is

$$V = \frac{q_1}{4\pi\varepsilon_0 r_1} + \frac{q_2}{4\pi\varepsilon_0 r_2}$$

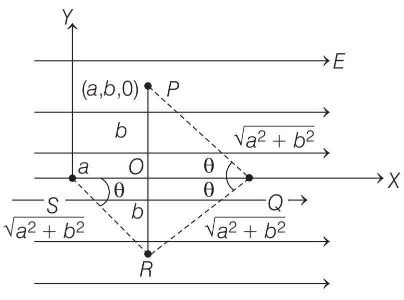
$$V = \frac{\sigma}{\varepsilon_0} \times r_1 + \frac{\sigma}{\varepsilon_0} \times r_2$$

$$= \frac{\sigma}{\varepsilon_0}(r_1 + r_2)$$

$$\left[\because \begin{array}{l} q_1 = 4\pi r_1^2 \times \sigma \\ q_2 = 4\pi r_2^2 \times \sigma \end{array}\right]$$

2 As electric field is a conservative field

Hence, the work done does not depend on path

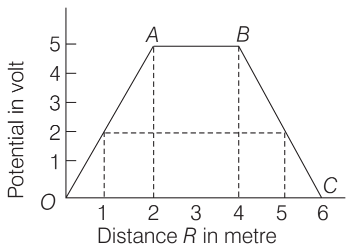


$$\therefore \quad W_{PQRS} = W_{PQS} = W_{PO} + W_{OS}$$

$$= Fb\cos 90^\circ + Fa\cos 180^\circ$$

$$= 0 + q\,Ea(-1) = -q\,Ea$$

3 Intensity at 5 m is same as at any point between *B* and *C* because the slope of *BC* is same throughout (i.e. electric field between *B* and *C* is uniform).



Therefore electric field at $R = 5$m is equal to the slope of line BC hence by $E = \frac{-dV}{dr}$;

$$E = -\frac{(0-5)}{6-4} = 2.5\,\text{V/m}$$

4 From figure, it can be seen that I is independent of resistance R_5, so no current flow through it. This require that the R_1 and R_2 junction is at same potential of the junction at R_3 and R_4. So, according to Wheatstone bridge condition,

$$\frac{R_1}{R_2} = \frac{R_3}{R_4} \Rightarrow R_1R_4 = R_2R_3$$

5 Given, $V_1 = 0$

$V_1 + V_2 = IR$

$\Rightarrow \quad V_2 = IR$

$$-E - Ir_2 = IR$$

But $V_1 = E - Ir_1 \Rightarrow E = Ir_1 \qquad [\because V_1 = 0]$

$\Rightarrow Ir_1 - Ir_2 = IR$

or $\qquad R = r_1 - r_2$

6 Magnitude of a dipole moment is

$$p = qd$$
$$= (1.60 \times 10^{-19})(4.30 \times 10^{-9})$$
$$= 6.88 \times 10^{-28} \text{ C-m}$$

7 At a point on the axis of a uniformaly charged disk at a distance x above the centre of the disk, the magnitude of the electric field is

$$E = \frac{\sigma}{2\varepsilon_0}\left[1 - \frac{x}{\sqrt{x^2 + R^2}}\right]$$

But $\quad E_c = \frac{\sigma}{2\varepsilon_0}$ such that $\frac{E}{E_c} = \frac{1}{2}$

Then, $\quad 1 - \frac{x}{\sqrt{x^2 + R^2}} = \frac{1}{2}$

or $\qquad \frac{x}{\sqrt{x^2 + R^2}} = \frac{1}{2}$

Squaring both side, we get

$$\frac{x^2}{x^2 + R^2} = \frac{1}{4}$$

or $\qquad x^2 = \frac{x^2}{4} + \frac{R^2}{4}$

Thus, $\qquad x^2 = \frac{R^2}{3}$

$$x = \frac{R}{\sqrt{3}}$$

8 Here, $q = 8 \times 10^{-18}$C, $C = 100\mu\text{F} = 10^{-4}$ F

$$V = \frac{q}{C} = \frac{8 \times 10^{-18}}{10^{-4}} = 8 \times 10^{-14} \text{ V}$$

Energy stored $= \frac{1}{2}qV$

$$= \frac{1}{2} \times 8 \times 10^{-18} \times 8 \times 10^{-14}$$
$$= 32 \times 10^{-32}$$

9 Let m and q be the mass and the charge of the drop and E the intensity of electric field between the plates.

Since, the drop is in equilibrium, the electric force qE acting on it balances its weight mg, i.e.

$$qE = mg$$

If the potential difference between the plates is V and the distance between them is d, then $E = V/d$.

$\therefore \qquad q(V/d) = mg$ or $V = mgd/q$

Here, $m = 4.8 \times 10^{-10}$ g $= 4.8 \times 10^{-13}$kg,

$$g = 9.8\,\text{N kg}^{-1},$$
$$d = 1.0 \text{ cm} = 1.0 \times 10^{-2}\,\text{m}$$

and $\qquad q = 2.4 \times 10^{-18}$C

$$\therefore \quad V = \frac{(4.8 \times 10^{-13}) \times 9.8 \times (1.0 \times 10^{-2})}{2.4 \times 10^{-18}}$$
$$= 1.96 \times 10^4 \text{ V}$$

On changing the polarity of the plates, the electric force qE will also be directed downwards. Then, the acceleration of the drop is

$$a = \frac{qE + mg}{m}$$

But $\qquad qE = mg$

$\therefore \qquad a = 2g = 19.6 \text{ ms}^{-2}$

10 Since, each charge distance from centre

$$d = \frac{\sqrt{2}\,a}{2} = \frac{a}{\sqrt{2}}$$

Net field due to these two charges is

$$E_x = \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{a^2/2} - \frac{q}{a^2/2}\right] = \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2/2}$$
$$= \frac{(9 \times 10^9)(1.0 \times 10^{-8})}{\frac{(0.050)^2}{2}}$$
$$= 7.19 \times 10^4\,\text{NC}^{-1}$$

and $\quad E_y = \frac{1}{4\pi\varepsilon_0}\left[\frac{2q}{a^2/2} - \frac{q}{a^2/2}\right]$

$$= \frac{1}{4\pi\varepsilon_0}\frac{q}{a^2/2} = 7.19 \times 10^4\,\text{N/C}$$

The magnitude of the field is

$$E = \sqrt{E_x^2 + E_y^2} = \sqrt{2\,(7.19 \times 10^4)^2}$$
$$= 1.02 \times 10^5\,\text{NC}^{-1}$$

Angle made with the x-axis is

$$\theta = \tan^{-1}\frac{E_y}{E_x}$$
$$= \tan^{-1}(1) = 45°$$

It is upward in the diagram, from the centre of the square towards the centre of the upper side.

11 Here, $\quad r = \frac{l_1 - l_2}{l_2} \times 2\,\Omega$

where, $l_1 = 240$ cm, $l_2 = 120$ cm

$$= \frac{240 - 120}{120} \times 2 = \frac{120}{120} \times 2 = 2\,\Omega$$

12 Use $\qquad R_t = R_0(1 + \alpha t)$

Here, $\qquad 20 = R_0(1 + 20\,\alpha)$

$\qquad\qquad 60 = R_0(1 + 500\,\alpha)$

Here, $\qquad R_t = 25\,\Omega$

Solving, we find $t = 80°$C

13 We have, $F = qE$

Thus, $E = \frac{F}{q} = \frac{3 \times 10^{-6}}{2 \times 10^{-9}}$

$$= 1.5 \times 10^3\,\text{NC}^{-1}$$

Magnitude of the electrostatic force on a proton is

$$F_e = eE = (1.60 \times 10^{-19})(1.5 \times 10^3)$$
$$= 2.4 \times 10^{-16}\text{N}$$

Magnitude of the gravitational force on the proton is

$$F_g = mg = (1.67 \times 10^{-27})(9.8)$$
$$= 1.63 \times 10^{-26}\text{N}$$

The ratio of the force is

$$\frac{F_e}{F_g} = \frac{2.4 \times 10^{-16}}{1.63 \times 10^{-26}}$$
$$= 1.4 \times 10^{10}$$

14 Electric field, $E = \frac{\sigma}{2\varepsilon_0}$

and electric potential, $V = V_s - \int_0^x E\,dx$

$$= V_s - Ex$$

Here, two surfaces are separated by Δx, then their potentials difference in magnitude by

$$\Delta V = E\Delta x = \left(\frac{\sigma}{2\varepsilon_0}\right)\Delta x$$

Thus, $\qquad \Delta x = \frac{2\varepsilon_0 \Delta V}{\sigma}$

$$= \frac{2(8.85 \times 10^{-12})(50)}{0.10 \times 10^{-6}}$$
$$= 8.8 \times 10^{-3} \text{ m}$$

15 We know that, $F = eE$

By Newton's second law,

$$a = \frac{F}{m} = \frac{eE}{m}$$
$$= \frac{(1.60 \times 10^{-19})(2.00 \times 10^4)}{9.11 \times 10^{-31}}$$
$$= 3.51 \times 10^{15}\text{ms}^{-2}$$

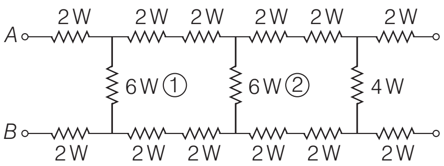
16 Net potential at point P,

$$V = \frac{q}{4\pi\varepsilon_0}\left[-\frac{5}{2d} - \frac{5}{d} + \frac{5}{d} + \frac{5}{d}\right] = \frac{5q}{8\pi\varepsilon_0}$$

17 $R_{Parallel} < R_{Series}$. From graph A it is clear that slope of the line A is lower than the slope of the line B.
Also, slope = resistance, so line A represents the graph for parallel combination.

18 The resistances 2Ω and 2Ω at the last terminals are outside the circuit and so they may be ignored. Now, in loop 2, the resistances $(2\Omega + 2\Omega)$, 4Ω and $(2\Omega + 2\Omega)$ are in series. Their equivalent resistance is 12Ω, which is in parallel with 6Ω. The equivalent resistance is

$$R' = \frac{6 \times 12}{6 + 12} = 4\Omega$$



Similarly, in loop 1, the resistances $(2\Omega + 2\Omega)$, $R'(= 4\Omega)$ and $(2\Omega + 2\Omega)$ are in series and these are in parallel with 6Ω. Hence, their equivalent resistance is

$$R'' = 4\Omega$$

Lastly, between the points A and B, the resistances 2Ω, $R'' = (4\Omega)$ and 2Ω are in series. Hence, their equivalent resistance is

$$2\Omega + 4\Omega + 2\Omega = 8\Omega$$

19 The arrangement is shown in the figure. The effective emf in the circuit is
$E = 1.5 + 1.5 = 3.0$ V
and the total resistance is

$$R = 0.5 + 0.25 + 2.25 = 3.0\ \Omega$$

Hence, the current in the circuit is

$$I = \frac{E}{R} = \frac{3.0}{3.0} = 1.0\text{ A}$$

Potential difference across the terminals of the first cell is
$V_1 = E - Ir_1 = 1.5 - (1.0) \times (0.5) = 1.0$ V
Potential difference across the terminals of the second cell is
$V_2 = E - Ir_2 = 1.5 - (1.0) \times (0.25) = 1.25$ V

20 Given,

$$Q_1 \xleftrightarrow{30\text{ cm}} Q_2$$

(a) $Q_1 = Q_2 = 0.4$ C

The force of Q_1 due to Q_2,

$$F = k_P \frac{Q_1 Q_2}{30 \times 10^{-2}} = K\frac{Q_1 Q_2 \times 100}{30}$$

$$= K \times \frac{0.4 \times 0.4 \times 100}{30} = \frac{8}{15}K$$

(b) When $Q_1 = 0.8$ C, $Q_2 \approx 0$

$$F = k \times \frac{0.8 \times 0}{30 \times 10^{-2}} = 0$$

(c) When $Q_1 \approx 0_1$, $Q_2 = 0.8$ C

$$F = k \times \frac{0 \times 0.8}{30 \times 10^{-2}} = 0$$

(d) When $Q_1 = 0.2$C, $Q_2 = 0.6$ C

$$F = k \times \frac{0.2 \times 0.6\ 100}{30} = \frac{2}{5}k$$

Hence, for $Q_1 = Q_2 = 0.4$C, the force will be maximum.

21 An ampere is coulomb per second, so
84 A - h $= 84 \times 3600 = 3.0 \times 10^5$C
The change in potential energy is
$\Delta U = q\Delta V = 3.0 \times 10^5 \times 12 = 3.6 \times 10^6$ J

22 Potential difference per cm

$$= \frac{2\text{ V}}{100\text{ cm}} = 0.02\text{ V/cm}$$

Balancing length $= \frac{100}{2} \times 1.08 = 54$ cm

23 The current in the potentiometer wire AB is

$$I = \frac{6}{20 + 10} = 0.2\text{ A}$$

The potential difference across the potentiometer wire is
V = current × resistance
$= 0.2 \times 20 = 4$ V

The length of the wire is $l = 200$ cm. So, the potential gradient along the wire is

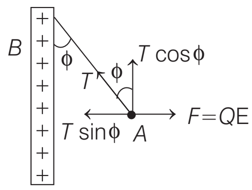
$$k = \frac{V}{l} = \frac{4}{200}$$
$$= 0.02\text{ Vcm}^{-1}$$

The emf 2.4 V is balanced against a length L of the potentiometer wire.
i.e. $2.4 = kL$ or $L = \frac{2.4}{k}$

$$= \frac{2.4}{0.02} = 120\text{ cm}$$

24 Electric field at point A

$$E = \frac{\sigma}{\varepsilon_0} \quad \text{...(i)}$$



For equilibrium of forces at A,

$$T\sin\phi = QE$$

$$T\sin\phi = Q \cdot \frac{\sigma}{\varepsilon_0}, \quad \text{[from Eq. (i)]}$$

$$T\sin\phi = \frac{Q\sigma}{\varepsilon_0} \quad \text{...(ii)}$$

and $\quad T\cos\phi = mg \quad$ ...(iii)
On dividing Eq. (ii) by Eq. (iii), we get

$$\tan\phi = \frac{Q\sigma}{\varepsilon_0 mg}$$

or $\quad \sigma = \frac{\varepsilon_0 mg}{Q}\tan\phi$

$\Rightarrow \quad \sigma \propto \tan\phi$

25 Electric field at a distance x outside from surface of outer shell
= Electric field at a distance x inside from surface of outer shell

i.e. $\frac{1}{4\pi\varepsilon_0} \cdot \frac{2q + 6q}{(2r + x)^2} = \frac{1}{4\pi\varepsilon_0} \cdot \frac{2q}{(2r - x)^2}$

$\Rightarrow \quad \frac{4}{(2r + x)^2} = \frac{1}{(2r - x)^2}$

$\Rightarrow \quad \frac{2}{2r + x} = \frac{1}{2r - x}$

$\Rightarrow \quad 4r - 2x = 2r + x$

$\Rightarrow \quad 2r = 3x$

$\Rightarrow \quad x = \frac{2r}{3}$

26 $R_1 = \frac{V_1^2}{P_1} = \frac{120^2}{60} = 240\Omega$

$R_2 = \frac{V_2^2}{P_2} = \frac{120^2}{90} = 160\Omega$

$\therefore I_1 = \frac{P_1}{V_1} = \frac{60}{120} = 0.5$ A

$I_2 = \frac{P_2}{V_2} = \frac{90}{120} = 0.75$ A

When both bulbs are connected in parallel, then equivalent resistance

$$R_P = \frac{R_1 R_2}{R_1 + R_2}$$
$$= \frac{240 \times 160}{240 + 160} = 96\Omega$$

$\therefore$ When they are connected with 240 V supply, then

$$I = \frac{240}{96} = 2.5\text{ A}$$

Now, current in 60 W bulb,

$$I_1' = I \cdot \frac{160}{400}$$
$$= 2.5 \times \frac{160}{400} = 1\text{ A}$$

Current in 90 W bulb,

$$I_2' = 2.5 \times \frac{240}{400} = 1.5\text{ A}$$

Since, $I_1' > I$ and $I_2' > I_2$

Hence, both bulbs will fuse.

27 Mass, M = Volume × Density

$$= Al \times d \quad \text{or} \quad A = \frac{M}{ld}$$

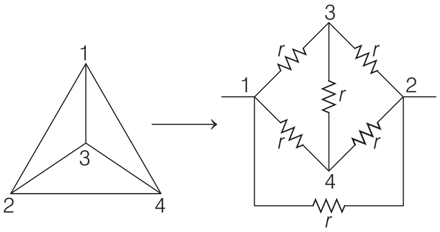
$$\text{Resistance, } R = \frac{\rho l}{A} = \frac{\rho l}{\left(\frac{M}{ld}\right)} = \frac{\rho l^2 d}{M}$$

$$\text{So,} \quad R \propto \frac{l^2}{M}$$

$$\text{Thus, } R_1 : R_2 : R_3 = \frac{l_1^2}{M_1} : \frac{l_2^2}{M_2} : \frac{l_3^2}{M_3}$$

$$= \frac{3^2}{1} : \frac{2^2}{2} : \frac{1^2}{3} = 27 : 6 : 1$$

28 Six wires each of resistance r from a tetrahedron as shown in the following figure.



In Wheatstone circuit, the equivalent resistance of upper circuit

$$\frac{I}{R} = \frac{I}{2r} + \frac{1}{2r} = \frac{2}{2r} = \frac{1}{r}$$

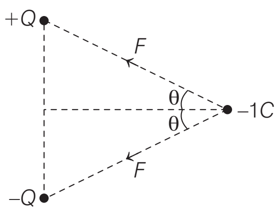
$$\Rightarrow \quad R = r$$

It will be in parallel with outer resistance,

$$\frac{1}{R_{eq}} = \frac{1}{r} + \frac{1}{r} = \frac{2}{R}$$

$$\Rightarrow \quad R_{eq} = \frac{r}{2}.$$

29 From figure the net force,



$$F_{net} = -F\cos\theta + (-F\cos\theta)$$

$$= -2F\cos\theta$$

$$= -2\frac{kQ(-1)}{x^2 + a^2} \times \frac{x}{\sqrt{x^2 + a^2}}$$

$$= \frac{2kQ}{(x^2 + a^2)^{3/2}} \cdot x$$

$$\text{Or} \quad F_{net} = +\left(\frac{2kQ}{a^3}\right) \cdot x \qquad [\because x << a]$$

Frequency of oscillation,

$$= \frac{1}{2\pi}\sqrt{\frac{2KQ}{Ma^3}} = \frac{1}{2\pi}\sqrt{\frac{2 \times 1 \times Q}{4\pi\varepsilon_0 Ma^3}}$$

$$= \frac{1}{2\pi}\sqrt{\frac{Q}{2\pi\varepsilon_0 Ma^3}}$$

30 Here $C_1 = 28\,\mu\text{F} = 28 \times 10^{-6}\text{F}$

$C_2 = 3\,\mu\text{F} = 3 \times 10^{-6}\text{F}$

$V_1 = 100\text{V}$ and $V_2 = 200\text{V}$

⇒ Charge of C_1,

$$q_1 = C_1V_1 = 28 \times 10^{-6} \times 100$$

$$= 28 \times 10^{-4}\text{C}$$

Charge of C_2

$$q_2 = C_2V_2 = 3 \times 10^{-6} \times 200$$

$$= 6 \times 10^{-4}\text{C}$$

Potential,

$$V = \frac{q_1 + q_2}{C_1 + C_2} = \frac{28\times10^{-4} + 6\times10^{-4}}{28\times10^{-6} + 3\times10^{-6}}$$

$$= 109.68\,\text{V}$$

Total final energy, $U = \frac{1}{2}(C_1 + C_2)V^2$

$$= \frac{1}{2}(28\times10^{-6} + 3\times10^{-6})(109.68)^2$$

$$= 0.1865\text{J}$$

31 External radius,

$$r_2 = \frac{10}{2} = 5\text{cm} = 0.05\text{m}$$

Internal radius $r_1 = r_2$ – thickness of tube

$= 0.05 - 0.005$

$= 0.045\,\text{m}$

Area of cross-section $= \pi\,(r_2^2 - r_1^2)$

$$= \pi\,[(0.05)^2 - (0.045)^2]$$

$$= 1.492 \times 10^{-3}\,\text{m}^2$$

Resistance of copper tube,

$$R = \rho\frac{l}{a} = \frac{1.7\times10^{-8}\times1}{1.492\times10^{-3}}$$

$$= 1.139 \times 10^{-5}\,\Omega$$

32 Resistance of heater,

$$R = \frac{V^2}{P} = \frac{(200)^2}{1000} = 40\Omega$$

Power of heater at $V' = 160\text{V}$

$$P' = \frac{V'^2}{R} = \frac{(160)^2}{40} = 640\,\text{W}$$

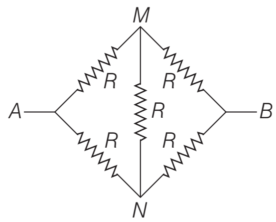
Percentage fall in the power of the heater,

$$\frac{P - P'}{P} \times 100 = \frac{1000 - 640}{1000} \times 100 = 36\%$$

34 Resistivity of metallic wire does not depend on shape of wire because it is a material property. On bending, the cross-sectional area of wire changes but drift velocity of electron does not depend on area of cross-section, so it remains same.

35 A capacitor does not discharge itself. In case the capacitor is connected in a circuit containing a source of high voltage, the capacitor charges itself to a very high potential. So, if a person handles it without discharging, he may get a severe shock.Dielectrics and insulators cannot conduct electricity but in case of a dielectric, when an external field is applied, induced charges appear on the faces of the dielectric. In other words, the dielectric have the property of transmitting electric effects without conducting.

36 The equivalent circuit is represented as, This is balanced Wheatstone bridge hence, resistance in branch MN is not taken into consideration. Hence, the equivalent resistance between points A and B is given by



$$\frac{1}{R_{AB}} = \frac{1}{(R + R)} + \frac{1}{(R + R)}$$

$$\text{or} \quad \frac{1}{R_{AB}} = \frac{2}{2R} = \frac{1}{R}$$

$$\therefore \quad R_{AB} = R$$

39 The resistance of a wire is

$R = \rho\frac{l}{A}$, ρ being specific resistance

$$\text{or} \quad R \propto \frac{Al}{A^2}$$

$$\text{or} \quad R \propto \frac{1}{r^4} \qquad (\because A = \pi r^2)$$

Hence, when diameter is halved the resistance of the wire is

$$R \propto \frac{1}{\left(\frac{r}{2}\right)^4} = 16R \qquad \text{...(i)}$$

Hence, its resistance will become 16 times.

Again from Eq. (i), we get

$$R \propto \frac{l}{A} \quad \text{or} \quad R \propto \frac{l^2}{Al} \text{ or } R \propto l^2$$

Therefore, on increasing the length resistance increases.