ELECTROSTATICS & ELECTROSTATIC POTENTIAL

QUESTIONS FOR PRACTICE

GRADE A

1. Mention few of similarities between coulomb's force and gravitational force
2. State the concept of potential and kinetic energy when a test charge is brought from infinity to a particular point
3. What is the fundamental characteristic of conservative force?
4. What is the dependency of distance "r" with the electrostatic field and electrostatic potential?
5. Find the potential due to electric dipole
6. Two charges 3×10^{-8} C and -2×10^{-8} C are located 15 cm apart. At what point on the line joining the two charges is the electric potential zero? Take the potential at infinity to be zero.
7. What are equipotential surfaces? Draw the equipotential surface for a dipole and two identical negative charges
8. State the relation between field and potential
9. Determine the electrostatic potential energy of a system consisting of two charges 7 μC and –2 μC (and with no external field) placed at (–9 cm, 0, 0) and (9 cm, 0, 0) respectively. How much work is required to separate the two charges infinitely away from each other?
10. Find the Potential energy of a dipole in external electric field
11. Inside a conductor, electrostatic field is zero. Why?
12. What is electrostatic shielding?
13. Find the electric field inside the cavity of a conductor
14. Difference in behavior of a conductor and a dielectric in an external electric field.
15. Explain the concept of polar and non-polar molecule
16. What is the value of K for perfect insulator, perfect conductor, water and alcohol?
17. What is potential field?
18. Write the formula to calculate the work done to reverse the dipole
19. Write the relation between charge density and the curvature of a surface
20. What is meant by dielectric strength?
21. Determine the effective or total value of capacitance of capacitors in the Series combination and Parallel combination.
22. What is the effect of dielectric on capacitance?
23. Mention some uses of capacitor
24. SI unit of capacitance

25. What is a net charge on a charged capacitor?
26. On what factor does the capacitance of a capacitor depend?
27. Can we give any amount of charge to a capacitor?
28. How energy is getting stored in a capacitor (all the formula to calculate the potential energy stored in a capacitor)
29. Write the formula of electric density of electric field
30. Describe the principle and working of Van De Graff Generator.
31. Dimensional formula of potential, capacitance, polarization and dielectric constant

GRADE B

1. Show that the force on each plate of a parallel plate capacitor has a magnitude equal to (½) *QE*, where *Q* is the charge on the capacitor, and *E* is the magnitude of electric field between the plates. Explain the origin of the factor ½.

2. In a parallel plate capacitor with air between the plates, each plate has an area of $6x\ 10^{-3}$ m2 and the distance between the plates is 3 mm. Calculate the capacitance of the capacitor. If this capacitor is connected to a 100 V supply, what is the charge on each plate of the capacitor?

3. Show does the force between two point charges change if the dielectric constant of the medium in which they are kept increase?

4. A charged rod P attracts rod R whereas P repels another charged rod Q. What type of force is developed between Q and R?

5. A free proton and a free electron are placed in a uniform field. Which of the two experience greater force and greater acceleration?

6. Point changes +q and +9q are separated by a distance of 10 a. Find the point on the line joining the two changes where electric field is zero?

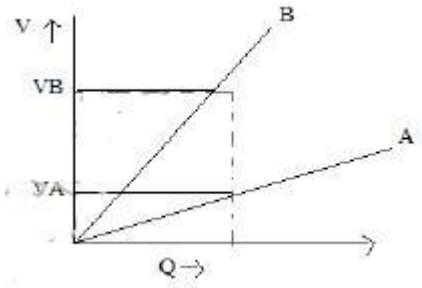
7. Two charges each $2\ x\ 10^{-7}$ C but opposite in sign forms a system. These charges are located at points A (0, 0,-10) cm and B (0, 0, +10) cm respectively. What is the total charge and electric dipole moment of the system?

8. Sketch electric lines of force due to (i) isolated positive change (i.e. $q>0$) and (ii) isolated negative change (i.e. $q<0$)

9. Two point changes q and –q are placed at a distance 2a apart. Calculate the electric field at a point P situated at a distance r along the perpendicular bisector of the line joining the charges. What is the field when r >> a?

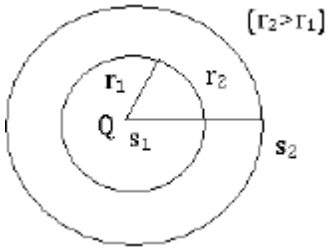
10. Which physical quantity has its S.I unit (1) Cm (2) N/C?

11. The graph shows the variation of voltage V across the plates of two capacitors A and B versus increase of charge Q stored on them. Which of the two capacitors have higher capacitance? Give reason for your answer?



12. An electric dipole when held at 300 with respect to a uniform electric field of 10^4 N/C experienced a Torque of 9×10^{-26} Nm. Calculate dipole moment of the dipole?

13. A sphere of radius r1 encloses a change Q. If there is another concentric sphere S2 of radius r2 (r2 >r1) and there is no additional change between S1 and S2. Find the ratio of electric flux through S1 and S2?



14. Derive an expression for the potential at a point along the axial line of a short electric dipole?

15. Show mathematically that the potential at a point on the equatorial line of an electric dipole is Zero?

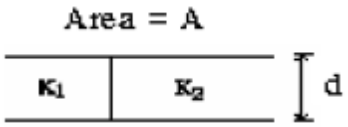
16. Prove that the energy stored in a parallel plate capacitor is given by ½ CV^2?

17. Define dielectric constant in terms of the capacitance of a capacitor? On what factor does the capacitance of a parallel capacitor with dielectric depend?

18. Find the ratio of the potential differences that must be applied across the (1) parallel (2) series combination of two identical capacitors so that the energy stored in the two cases becomes the same.

19. State Gauss's Theorem in electrostatics? Using this theorem define an expression for the field intensity due to an infinite plane sheet of change of charge density s c/m^2?

20. Two dielectric stabs of dielectric constant K1 and K2 are filled in between the two plates, each of area A, of the parallel plate capacitor as shown in the figure. Find the net capacitance of the capacitor?



Area of each plate = A/2

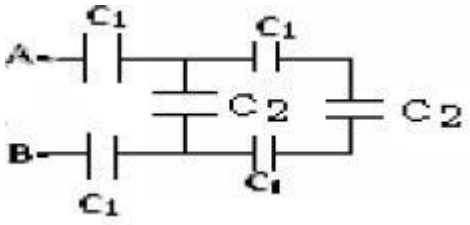
21. A parallel plate capacitor with air between the plates has a capacitance of 8 pF ($1pF = 10^{-12}$ F). What will be the capacitance if the distance between the plates is seduced by half and the space between them is filled with a substance of dielectric constant 6?

22. Force of attraction between two point electric charges placed at a distance d in a medium is what distance apart should these be kept in the same medium, so that force between them becomes F/3?

23. Derive an expression for the total work done in rotating an electric dipole through an angle in a uniform electric field?

GRADE C

1. If C1 = 3pF and C2 = 2pF, calculate the equivalent capacitance of the given network between points A & B?



2. An air capacitor is given a charge of 2m C raising its potential to 200 V. If on inserting a dielectric medium, its potential falls to 50 V, what is the dielectric constant of the medium?

3. A conducting stab of thickness‘t’ is introduced without touching between the plates of a parallel plate capacitor separated by a distance d (t<d). Derive an expression for the capacitance of a capacitor?

4. The distance between the plates of a parallel plate capacitor is d. A metal plate of thickness (d/2) is placed between the plates. What will be the effect on the capacitance?

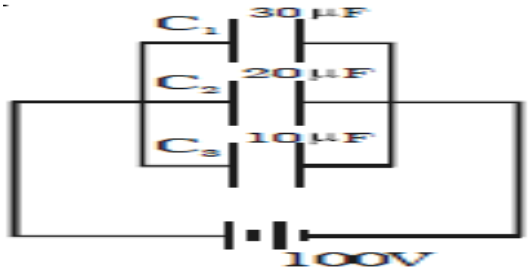
5. The Plates of a charged capacitor are connected by a voltmeter. If the plates of the capacitor are moved further apart. What will be the effect of the reading of the voltmeter?

6. The area of each plate of a parallel plate capacitor is 4×10^{-2} sq. m. If the thickness of the dielectric medium between the plates is 10^{-3} m and the relative permittivity of the dielectric are 7. Find the capacitance of the capacitor.

7. Two capacitors of unknown capacitances are connected in series and parallel. If the net capacitances in the two combinations are 6F and 25µF respectively, find their capacitances.

8. Two capacitances 0.5 µF and 0.75 µF are connected in parallel and the combination to a 110 V battery. Calculate the charge from the source and charge on each capacitor.

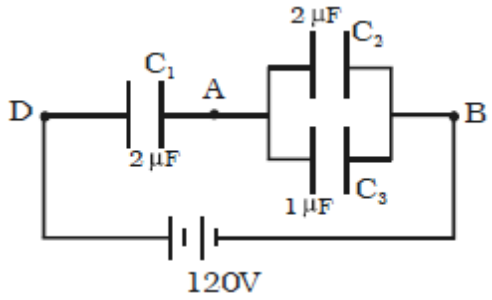
9. Three capacitors are connected in parallel to a 100 V battery as shown in figure. What is the total energy stored in the combination of capacitor?



10. A parallel plate capacitor is maintained at some potential difference. A 3 mm thick slab is introduced between the plates. To maintain the plates at the same potential difference, the distance between the plates is increased by 2.4 mm. Find the dielectric constant of the slab.

11. A dielectric of dielectric constant 3 fills three fourth of the space between the plates of a parallel plate capacitor. What percentage of the energy is stored in the dielectric?

12. Find the charges on the capacitor shown in figure and the potential difference across them.



13. Three capacitors each of capacitance 9 pF are connected in series (i) what is the total capacitance of the combination? (ii) What is the potential difference across each capacitor, if the combination is connected to 120 V supply?

VALUE BASED QUESTIONS

1) Ram and Shyam went to the trade fair. They were busy in a crowded corner. Balloons were sold. A child was seen troubling his parent and crying for something. On seeing this, Ram went to the child and said that he would perform a trick with balloons. Ram took two balloons and Shyam helped him to inflate and tie. When the balloons were rubbed with the sweater he was wearing, they were attracted. When taken nearer to wall, the balloons got stuck. The child enjoyed and stopped crying.

Qs. a) Give two values of Ram and Shyam.
b) How did the balloons get attracted? Will they repel also?

Ans. a) Presence of mind and knowledge of static electricity.
b) When balloons were rubbed with woolen sweater, it becomes negatively charged. When taken nearer the wall, positive charges are induced by electrostatic induction on that part of the wall, so gets attracted.
Yes, when the bodies are similar charged they repel.

2) Aswin asked his Physics teacher why voltmeter, galvanometer and ammeter are kept in a cavity in spite of its outer covering being made of an insulator.

Qs a) what values did Aswin have?

b) Explain Faraday's cage or electrostatic shielding
Ans. a) inquisitiveness, to improve his knowledge in Physics, willingness to gain knowledge.
b) These sensitive instruments should not be disturbed by external electric field.

3) In Akash's classroom the fan above the teacher was running very slowly. Due to which his teacher was sweating and was restless and tired. All his classmates wanted to rectify this. They called for an electrician who came and changed the capacitor only after which the fan started running fast.

Qs a) what values did Akash and his classmates have?
b) What energy is stored in the capacitor and where?

Ans a) Team work, concern, respect to teacher and responsibility.
b) Electrical energy in the dielectric of the capacitor.

4. An elderly woman went alone to the Registrar's office to disburse her property. When she enquired in the office she was asked to get a Xerox copy of the document which works under electrostatic induction. The Xerox shop was far away and across the road. She took the help of the passer-by and got her Xerox done.

Qs. a) what values did the passer-by have?
b) How does a neutral body get charged by electrostatic induction?

Ans. a) Helping, sharing, respect for elderly people.
b) For a body to get positively charged, a negatively charged body has to bring close to the neutral body which after earthing gets charged uniformly.

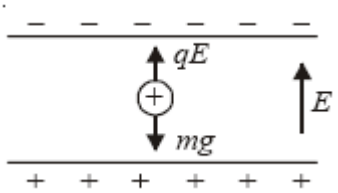
5) Arun had to repaint his car when he was reminded by the car company for his regular car service. He told them to do spray painting of mountain dew color. The company also replied that they usually perform spray painting only as wastage is minimized and even painting achieved.

Qs. a) what values did the car service company have?
b) If spray painting is done by electrostatic induction, how is even painting achieved?

Ans. a) Customer care, commitment, concern and truthfulness.
b) Droplets of paint are charged particles which get attracted to any metallic objects by electrostatic forces.

HOTS QUESTIONS

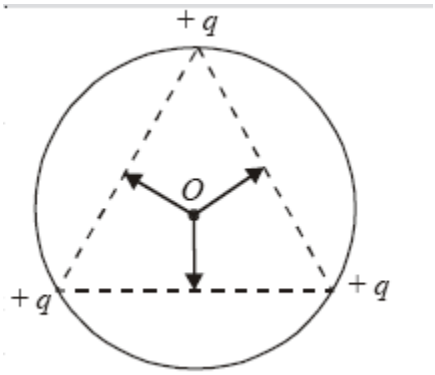
1. The weight of a positively charged oil drop is balanced by producing electric field between two parallel plates. What is the direction of the electric field (See Fig.)?



Ans.

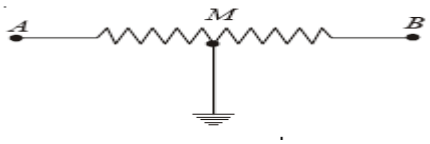
The weight of an object always acts vertically downward. Since the drop is stationary between the plates, the electric field must act vertically upward. Note that $qE = mg$.

2. Three small spheres each of a charge +q are placed on the circumference of a circle such that they form an equilateral triangle. What is electric field intensity at the centre of the circle?



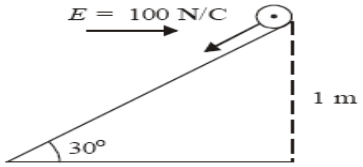
Ans. Fig. shows the conditions of the problem. If a very small positive test charge is placed at the centre *O* of the circle, then the test charge will experience three equal forces that are displaced 120° from each other. The resultant of such a system of forces is zero.

3. In Fig. the potential difference between points A and B is 240V. If the mid-point M of AB is earthed, what are the potentials of A and B?



Ans. When mid-point of *AB* is earthed, the p.d. between *AB* is still 240 V. The earthed point has zero potential while point *A* has a potential of +120V and B a potential of – 120V.

4. An inclined plane making an angle of 30° with the horizontal is placed in a uniform horizontal electric field of 100N/C [See Fig.]. A particle of mass 1kg and charge 0.01C is allowed to slide down from rest from a height of 1m. If the co-efficient of friction is 0.2, find the time taken by the particle to reach the bottom. (g = 9.8 ms^{-2}).



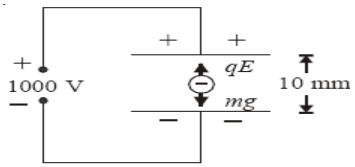
Hint: Force of friction, $F = \mu R = \mu\,(mg\cos\theta + qE\sin\theta)$

Net force acting downward along the plane = $mg\sin\theta - \mu\,(mg\cos\theta + qE\sin\theta)$

If a is the acceleration, then, $ma = mg\sin\theta - \mu\,(mg\cos\theta + qE\sin\theta)$

Find a. Now $S = ut + \frac{1}{2}at^2$. Here $S = 2\text{m}$; $u = 0$

5. Two horizontal parallel plates 10 mm apart have a p.d. of 1000 V between them; the upper plate being at +ve potential. If a negatively charged oil drop of mass 4.8 × 10^{-15} kg is held stationary between *the plates, find the number of electrons on the drop (Take g = 10 ms^{-2}, electron charge, e = 1.6 × 10–19 C)*.



Ans. Since the drop is stationary, Upward force on the drop = weight of the drop

qE = mg

E = V/d = 1000/10 X 10^{-3} = 10^5 V/m

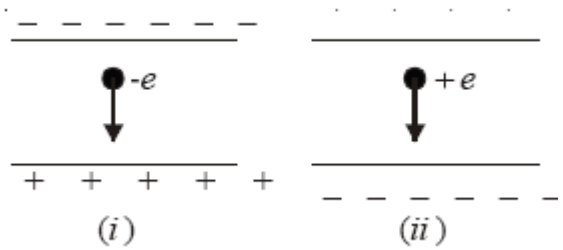
q = $\frac{mg}{E}$ = 4.8 x 10^{-15} / 10^5 = 4.8 x 10^{-19}C

Now q = ne

n= q/e = 3

6. An electron falls through a distance of 4 cm in a uniform electric field of 3 × 104 N/C. When the direction of field is reversed, a proton falls through the same distance. Calculate the time of fall in each case. Why is the effect of gravity negligible in such cases?

Ans. For electron



Acceleration, $a_1 = \frac{F}{m_1} = \frac{eE}{m_1} = \frac{(1.6 \times 10^{-19}) \times 3 \times 10^4}{9 \times 10^{-31}} = 5.3 \times 10^{15}\ m/s^2$

Now $y_1 = v_{01} t_1 + \frac{1}{2} a_1 t_1^2$

or $y_1 = 0 + \frac{1}{2} a_1 t_1^2$ $(\because v_{01} = 0)$

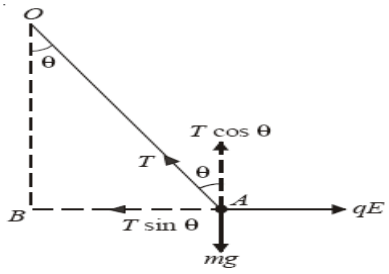
$\therefore$ $t_1 = \sqrt{\frac{2y_1}{a_1}} = \sqrt{\frac{2 \times 4 \times 10^{-2}}{5.3 \times 10^{15}}} = \mathbf{3.9 \times 100^{-9}\ s}$

For proton : Refer to Fig. 2.9 (*ii*).

Acceleration, $a_2 = \frac{eE}{m_2} = \frac{1.6 \times 10^{-19} \times 3 \times 10^4}{1.67 \times 10^{-27}} = 2.8 \times 10^{12}\ \text{m/s}^2$

Now, $t_2 = \sqrt{\frac{2y_2}{a_2}} = \sqrt{\frac{2 \times 4 \times 10^{-2}}{2.8 \times 10^{12}}} = \mathbf{1.69 \times 10^{-7}\ s}$

7. A pendulum bob of mass 80 milligram and carrying a charge of 2×10^{-8} C is at rest in a horizontal uniform electric field of 2×10^4 V/m. Find the tension in the thread of the pendulum and the angle it makes with the vertical.



Solution: Suppose the tension in the thread is T and the thread makes an angle θ with the vertical. Three forces are acting on the bob *viz*. (*i*) weight mg of bob acting vertically downward (*ii*) electric force qE acting horizontally and (*iii*) tension T along AO. Since the bob is in equilibrium [See Fig. 2.12],

$$T\sin\theta = qE; \qquad T\cos\theta = mg$$

$$\therefore \quad \tan\theta = \frac{qE}{mg} = \frac{(2\times10^{-8})\times(2\times10^{4})}{(80\times10^{-6})\times9.8} = 0.51$$

or $$\theta = \tan^{-1}0.51 = \mathbf{27^\circ}$$

Also $$T = \frac{qE}{\sin\theta} = \frac{(2\times10^{-8})\times(2\times10^{4})}{\sin27^\circ} = \mathbf{8.81\times10^{-4}\,N}$$

Ans.

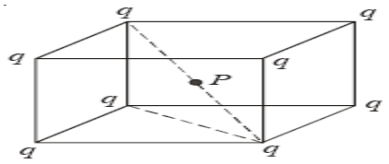
8. A particle of mass 10^{-3} kg and charge 5 μC is thrown at a speed of 20 ms^{-1} against a uniform electric field of strength 2 × 105 N/C. How much distance will it travel before coming to rest momentarily?

Ans: Force on the charged particle, $F = qE = (5\times10^{-6})\times(2\times10^{5}) = 1$ N. Since the charge on the particle is positive and it is thrown against the electric field, the acceleration is negative.

$$\therefore \quad \text{Acceleration,} \qquad a = -\frac{F}{m} = -\frac{1}{10^{-3}} = -10^{3}\ \text{ms}^{-2}$$

$$\therefore \quad s = \frac{v^2-u^2}{2a} = \frac{(0)^2-(20)^2}{2\times(-10^{3})} = \mathbf{0.2\,m}$$

9. A cube of side a has charge q at each of its vertices. Find the potential and electric intensity due to these charges at the centre of the cube.



Ans. The distance of each vertex from the centre *P* of the cube is equal to half of the diagonal of the cube [See Fig.].

Diagonal of the cube = $\sqrt{a^2+a^2+a^2} = 3a$.

$$\text{Distance of each vertex from } P = \frac{\sqrt{3}\,a}{2}$$

Potential at P due to charges at its 8 vertices is

$$V_P = 8\left[\frac{1}{4\pi\varepsilon_0}\,\frac{q}{\frac{\sqrt{3}\,a}{2}}\right]$$

or $$V_p = \frac{4q}{\sqrt{3}\,\pi\varepsilon_0\,a}$$

The electric field intensity at *P* due to charges on opposite corners of the cube cancels out. Hence, total electric field intensity at *P* is zero.

10. Parallel metal plates 3 mm apart carry equal and opposite charge densities of ± 2 μC/m^2. A proton (q = e and m = 1.67 × 10^{-27} kg) is released from rest at the positive plate. What is the speed of proton just as it strikes the negative plate? Assume the space between the plates is a vacuum.

$$\text{Electric field, } E = \frac{\sigma}{\varepsilon_0} = \frac{2\times10^{-6}}{8.85\times10^{-12}} = 2.26\times10^5 \text{ N/C}$$

$$\text{Force on proton, } F = qE = eE = (1.6\times10^{-19})\times 2.26\times10^5 = 3.62\times10^{-14}\text{N}$$

$$\text{Acceleration of proton, } a = \frac{F}{m} = \frac{3.62\times10^{-14}}{1.67\times10^{-27}} = 2.17\times10^{13}\ \text{ms}^{-2}$$

The equation of motion for constant acceleration is

$$v^2 - v_0^2 = 2\,aS$$

Here $v_0 = 0;\ a = 2.17\times10^{13}\ \text{ms}^{-2};\ S = 3\ \text{mm} = 3\times10^{-3}\ \text{m}$

$$\therefore \quad v = \sqrt{2\,a\,S} = \sqrt{2\times2.17\times10^{13}\times3\times10^{-3}} = 3.61\times10^5\ \text{ms}^{-1}$$

Note that even though the charge and the resulting force are very small, the very small mass allow the proton to acquire a very high speed.

11. A parallel plate capacitor has three similar parallel plates. Find the ratio of capacitance when the inner plate is mid-way between the outers to the capacitance when inner plate is three times as near one plate as the other.

Ans. The fig. (i) Shows the condition when the inner plate is mid-way between the outer plates. The arrangement is equivalent to two capacitors in parallel. Capacitance of this capacitor,

$$C_1 = \frac{\varepsilon_0 K A}{d/2} + \frac{\varepsilon_0 K A}{d/2} = \frac{4\varepsilon_0 K A}{d}$$

(i) (ii)

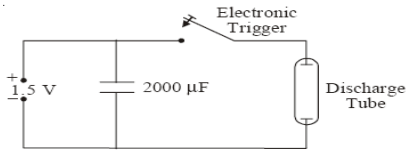
The fig (ii) shows the condition when the inner plate is three times as near as one plate as the other

Capacitance C_2 of this capacitor,

$$C_2 = \frac{\varepsilon_0 K A}{d/4} + \frac{\varepsilon_0 K A}{3d/4} = \frac{16\varepsilon_0 K A}{3d}$$

$$\therefore \quad C_1/C_2 = \mathbf{0.75}$$

12. Fig.shows a circuit for a camera flashes. A 2000 µF capacitor is charged by 1.5V cell. When a flash is required, the energy stored in the capacitor is made to discharge through a discharge tube in 0.1 ms giving a powerful flash. Calculate the energy stored in the capacitor and power of the flash.



Ans:

Energy stored in the capacitor is

$$U = \frac{1}{2}CV^2 = \frac{1}{2} \times (2000 \times 10^{-6}) \times (1.5)^2$$

$$= \mathbf{2.25 \times 10^{-3}\ J}$$

In order to produce the flash, the capacitor discharges in 0.1 ms ($= 0.1 \times 10^{-3}$ s).

$$\therefore \text{ Power of flash} = \frac{U}{\text{Time}} = \frac{2.25 \times 10^{-3}}{0.1 \times 10^{-3}} = \mathbf{22.5\ W}$$