Name Rec. Instr. Rec. Time

For full credit, make your work clear. Show formulas used, essential steps, and results with correct units and significant figures. Points shown in parenthesis. For TF and MC, choose the *best* answer.

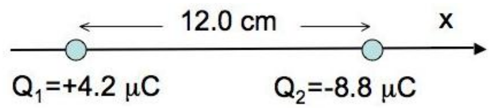
1. (8) A tiny plastic sphere is initially neutral. Then after being rubbed by a piece of fur, it acquires a net charge of +2.4 nC. How many electrons were transferred [**to / from**] (← select one) the sphere?

2. (6) A balloon acquires a negative charge when rubbed on a sweater.

a) (3) As a result, the charge acquired by the sweater is a. negative b. zero c. positive.

b) (3) **T F** Electrons were lost by the sweater in the balloon charging process.

3. (20) Two charges, $Q_1 = +4.2\ \mu$C and $Q_2 = -8.8\ \mu$C are separated by 12.0 cm on the x-axis as shown. The charges produce an electric field in the surrounding region. Consider only the electric field along the x-axis.



a) (3) **T F** At any point between the charges, their net electric field points to the left.

b) (3) **T F** To the left of Q_1, there is a point at finite x where the electric field is zero.

c) (8) Determine the magnitude and direction of the net electric field 12.0 cm to the left of Q_1.

d) (6) If a third charge $q = 2.0\ \mu$C is now placed 12.0 cm to the left of Q_1, what magnitude electric force will it experience?

4. (12) Suppose you have a gram of water (H_2O, with molar masses H=1.00 g/mole, O=16.0 g/mole).

a) (6) How many water molecules are present in the sample?

b) (6) If one electron is removed from each water molecule, what is the net electric charge of the sample?

Questions about charges.

5. (2) **T F** In a conductor like copper metal, all of its electrons are free to move.

6. (2) **T F** The net charge of a piece of metal is the same as its free charge.

7. (2) **T F** A Van de Graaff generator cannot attract neutral objects.

8. (2) **T F** Net charge of a conductor distributes itself throughout the volume of the object.

Questions about electric fields.

9. (2) **T F** Electric field lines point towards negative charges and away from positive charges.

10. (2) **T F** The electric field inside a conductor carrying a current is zero.

11. (2) **T F** Electric field lines close together indicate weak electric field strength.

12. (2) **T F** A region with parallel electric field lines has a constant electric potential.

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13. (12) The sphere on a Van de Graaff generator has a radius of 22 cm. The air next to the sphere becomes conducting if the electric field strength reaches 3.0 MV/m. The generator charges the sphere with electrons.

a) (6) What is the charge of maximum magnitude that the sphere can hold without discharging?

b) (6) For that maximum charge on the sphere, what is its electrostatic potential, including the sign? The potential is assumed to be zero very far from the sphere.

Questions about electric potential.

14. (2) **T** **F** The electric field strength is a constant on any equipotential surface.

15. (2) **T** **F** All points of a conductor with static charges are at the same electric potential.

16. (2) **T** **F** Electric field lines point towards regions of higher electric potential.

17. (2) **T** **F** An electron-volt is the same as 1.602×10^{-19} volts.

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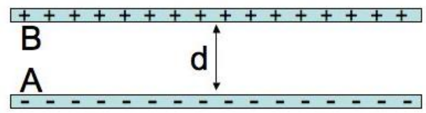
18. (20) Two parallel metal plates separated by 5.0 cm are given equal and opposite charges, producing a nearly uniform electric field of strength $E = 250$ N/C between them.



a) (2) The electric field caused by the charged plates points

a. parallel to the plates. b. towards the positive plate. c. towards the negative plate.

b) (6) Calculate the electric potential difference (in volts) between the plates, $\Delta V = V_B - V_A$, where A is the negative plate and B is the positive plate.

c) (6) What change in kinetic energy does an electron moving from plate A to plate B experience, in joules?

d) (6) What is the answer to part c), in electron-volts?

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19. (12) A capacitor of unknown value is initially uncharged. When now connected to a 48.0-volt battery, it is noticed that 12.0 μC of charge flows from the positive terminal of the battery during a brief interval of time.

a) (6) What is the capacitance of the capacitor?

b) (6) Once fully charged, what electrical potential energy is stored in the capacitor?

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20. (18) An ideal 12.4-volt car battery sends a current of 28.2 amperes through the starter motor of a car during a time interval of 4.80 seconds.

a) (6) During the 4.80 seconds, how much charge flowed out of the positive terminal of the battery?

b) (6) What electrical power (in watts) is the starter motor using?

c) (6) What is the resistance (in ohms) of the starter motor?

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21. (12) Suppose you have a 24.0-watt lightbulb that operates on 120.0 V DC.

a) (6) What current does the lightbulb draw when turned on?

b) (6) What is the resistance of the lightbulb, in ohms?

Score = ____________/144.

Prefixes

a=10^{-18}, f=10^{-15}, p=10^{-12}, n=10^{-9}, $\mu = 10^{-6}$, m=10^{-3}, c=10^{-2}, k=10^{3}, M=10^{6}, G=10^{9}, T=10^{12}, P=10^{15}

Physical Constants

$k = 1/4\pi\epsilon_0 = 8.988$ GN·m²/C² (Coulomb's Law)

$\epsilon_0 = 1/4\pi k = 8.854$ pF/m (permittivity of space)

$e = 1.602 \times 10^{-19}$ C (proton charge)

$m_e = 9.11 \times 10^{-31}$ kg (electron mass)

$m_p = 1.67 \times 10^{-27}$ kg (proton mass)

Units and Conversions

$N_A = 6.02 \times 10^{23}$/mole (Avogadro's #)

1 u = 1 g/N_A = 1.6605×10^{-27} kg (mass unit)

1.0 eV = 1.602×10^{-19} J (electron-volt)

1 V = 1 J/C = 1 volt = 1 joule/coulomb

1 F = 1 C/V = 1 farad = 1 C^2/J

1 A = 1 C/s = 1 ampere = 1 coulomb/second

1 Ω = 1 V/A = 1 ohm = 1 J·s/C^2

Vectors

Written $\vec{V}$ or **V**, described by magnitude=V, direction=θ or by components (V_x, V_y).

$V_x = V\cos\theta$, $V_y = V\sin\theta$,

$V = \sqrt{V_x^2 + V_y^2}$, $\tan\theta = \frac{V_y}{V_x}$. θ is the angle from $\vec{V}$ to $+x$-axis.

Addition: $\mathbf{A} + \mathbf{B}$, head to tail. Subtraction: $\mathbf{A} - \mathbf{B}$ is $\mathbf{A} + (-\mathbf{B})$, $-\mathbf{B}$ is **B** reversed.

Trig summary

$\sin\theta = \frac{\text{(opp)}}{\text{(hyp)}}$, $\cos\theta = \frac{\text{(adj)}}{\text{(hyp)}}$, $\tan\theta = \frac{\text{(opp)}}{\text{(adj)}}$, $\text{(opp)}^2 + \text{(adj)}^2 = \text{(hyp)}^2$.

$\sin\theta = \sin(180° - \theta)$, $\cos\theta = \cos(-\theta)$, $\tan\theta = \tan(180° + \theta)$, $\sin^2\theta + \cos^2\theta = 1$.

Chapter 16 Equations

Charges:

$Q = \pm Ne$, $\Delta Q_1 + \Delta Q_2 = 0$, $e = 1.602 \times 10^{-19}$ C.

Electric Force:

$F = k\frac{Q_1 Q_2}{r^2}$, $k = 8.988 \times 10^9$ N·m²/C², $F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}$, $\epsilon_0 = \frac{1}{4\pi k} = 8.854$ pF/m.

$\vec{F} = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + ...$ superposition of many forces.

$F_x = F_{1x} + F_{2x} + F_{3x} + ...$ superposition of x-components of many forces.

$F_y = F_{1y} + F_{2y} + F_{3y} + ...$ superposition of y-components of many forces.

Electric Field:

$\vec{E} = \frac{\vec{F}}{q}$, q= test charge. Or: $\vec{F} = q\vec{E}$.

$|\vec{E}| = E = k\frac{Q}{r^2} = \frac{Q}{4\pi\epsilon_0 r^2}$, due to point charge. Negative Q makes inward $\vec{E}$, positive Q makes outward $\vec{E}$.

$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 + ...$ superposition of many electric fields.

$E_x = E_{1x} + E_{2x} + E_{3x} + ...$ superposition of x-components of many electric fields.

$E_y = E_{1y} + E_{2y} + E_{3y} + ...$ superposition of y-components of many electric fields.

$E = k\frac{Q}{r^2}$ = electric field around a point charge or *outside* a spherical charge distribution.

Chapter 17 Equations

Potential Energy and Work:

$W_{ba} = F_E d \cos\theta$ = work done by electric force F_E on test charge, in displacement d from a to b.

$W_{ba} = -q\Delta V = -q(V_b - V_a)$ = work done by electric force on a test charge, moved from a to b.

$\Delta \text{PE} = q\Delta V = q(V_b - V_a)$ = change in electric potential energy of the system. Also: $\Delta \text{PE} = -W_{ba}$.

$\Delta KE + \Delta PE = 0$, or, $\Delta KE = -\Delta PE = -q\Delta V$, principle of conservation of mechanical energy.

Potential:

$\Delta V = \frac{\Delta \text{PE}}{q}$ = definition of change in electric potential.

$\Delta V = Ed$ = potential change in a uniform electric field.

$V = k\frac{Q}{r}$ = potential produced by a point charge or *outside* a spherical charge distribution.

$\text{PE} = qV$ = potential energy for a test charge at a point in a field.

$\text{PE} = k\frac{Q_1 Q_2}{r_{12}}$ = potential energy of a pair of charges.

Capacitance:

$Q = CV, \quad C = K\epsilon_0 \frac{A}{d}$ = capacitor equations.

$U = \frac{1}{2}QV = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C}$ = stored energy.

$E = \frac{Q/A}{\epsilon_0}$ = electric field strength very near a charged conductor.

Chapter 18 Equations

Electric current:

$I = \frac{\Delta Q}{\Delta t}$, or $\Delta Q = I\Delta t$, definition of current.

$V = IR$, or $I = V/R$, Ohm's law.

$R = \rho\frac{L}{A}$ = calculation of resistance.

$\rho_T = \rho_0[1 + \alpha(T - T_0)]$ = temperature-dependent resistivity.

Electric power:

$P = IV, \quad P = I^2R, \quad P = V^2/R, \quad P$ = instantaneous energy/time.

Alternating current:

$V = V_0 \sin 2\pi f t$ = time-dependent AC voltage. $I = I_0 \sin 2\pi f t$ = time-dependent AC current.

$V_{\text{rms}} = \sqrt{\overline{V^2}} = V_0/\sqrt{2}$ = root-mean-square voltage. $I_{\text{rms}} = \sqrt{\overline{I^2}} = I_0/\sqrt{2}$ = root-mean-square current.

AC power in resistors:

$\overline{P} = \frac{1}{2}I_0^2 R = \frac{1}{2}V_0^2/R = \frac{1}{2}I_0 V_0$ = average power. $\overline{P} = I_{\text{rms}}^2 R = V_{\text{rms}}^2/R = I_{\text{rms}} V_{\text{rms}}$ = average power.