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.

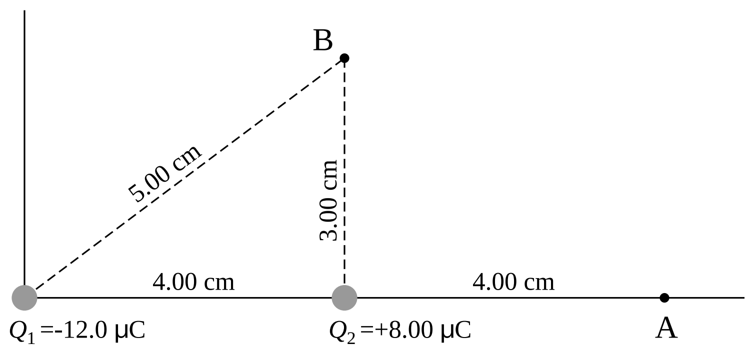

Figure 1. For questions 1, 2, and 3, with two point charges Q_1 and Q_2 as shown.

1. (6) In the situation of Figure 1, determine the magnitude and direction of the electric force acting on Q_2.

2. (6) Consider point B in Figure 1. On the figure, draw arrows at point B to show the contributions to the electric field, one for that caused by Q_1, and one for that caused by Q_2. You do not need to calculate their magnitudes, just carefully show the correct directions.

3. (12) For the situation in Figure 1, determine the magnitude and direction of the electric field at point A.

4. (3) After being rubbed with fur, a plastic rod acquires a net positive electric charge. This is because

a. protons jumped from the fur to the rod.
b. protons jumped from the rod to the fur.
c. electrons jumped from the fur to the rod.
d. electrons jumped from the rod to the fur.

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5. (3) If a positively charged plastic rod repels an object, that other object

a. must have a net positive charge.
b. must have no net charge.
c. must have a negative net charge.
d. must have a net charge induced by the rod.

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6. (3) When the separation between two point charges is doubled, the electric force acting between them changes by a factor of

a. 1/4. b. 1/2. c. 1 (i.e., no change). d. 2. e. 4.

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7. (3) When the separation between two point charges is doubled, their electric potential energy changes by a factor of

a. 1/4. b. 1/2. c. 1 (i.e., no change). d. 2. e. 4.

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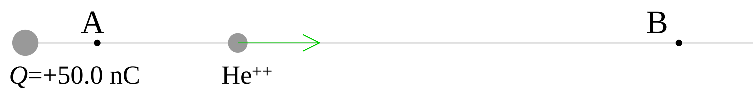
8. (24) A charge $Q = +50.0$ nC is fixed in place at the origin. A helium nucleus (He^{+2}, with charge = +2e, mass = 4u) is released from rest at point A on the x-axis, 1.00 mm from Q. Later it is passing point B on the x-axis, 25.0 mm from Q.

a) (8) What electric potential (in volts) does Q produce at point A? At point B?



b) (8) In its motion from A to B, what change in potential energy is experienced by the helium nucleus? Give the answer in electron-volts (eV).

c) (8) Determine the kinetic energy (in joules) of the helium nucleus when it passes point B.

9. (3) The electric force on a negatively charged dust particle balances the gravitational force and causes it to remain motionless. Which way does the electric field acting on it point?

a. up. b. down. c. horizontally. d. the magnitude of $\vec{E}$ must be zero.

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10. (3) In one molecule of carbon dioxide (CO_2), what is the total electric charge due to only its electrons?

a. -10e b. -20e. c. -22e. d. -24e. e. -36e. f. -38e.

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11. (3) A net static charge is given to a solid metal sphere. Where does this excess charge actually go?

a. to the sphere's center. b. to its surface. c. uniformly spread throughout the sphere's interior.

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12. (12) A parallel plate capacitor ($C = 4.70$ pF) is charged so that it has a uniform electric field of 8.40 kV/m between its plates that are separated by 0.200 mm.

a) (6) How large is the potential difference between the plates?

b) (6) What amount of charge is stored on the positive plate?

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13. (12) A parallel plate capacitor is to be designed with pyrex glass filling the space between metal plates of size 25.0 cm $\times$ 40.0 cm. The dielectric constant of the glass is 5.0 and its dielectric strength is 14 MV/m.

a) (8) What spacing d should be used between the plates to get a capacitance of 1.00 μF?

b) (4) If the capacitor is given too much charge, the dielectric will conduct (short circuit). At what electric field in the dielectric will this occur?

14. (3) The charge Q stored in a capacitor is distributed as

a. only $+Q$ on the positive plate. b. only $-Q$ on the negative plate. c. $+Q/2$ on each plate.
d. $+Q/2$ on the positive plate and $-Q/2$ on the negative plate.
e. $+Q$ on the positive plate and $-Q$ on the negative plate.

About electric charges and fields.

15. (2) **T** **F** An insulator is a material that is lacking in free charge.

16. (2) **T** **F** Where electric field lines are crowded together, the electric field strength is high.

17. (2) **T** **F** The electric potential increases as you move in the direction of the electric field.

18. (2) **T** **F** The electron-volt is a unit of electric potential.

19. (2) **T** **F** When oppositely charged objects are moved apart, their electric potential energy increases.

20. (2) **T** **F** Electric field strength is largest near the sharp points of a charged conductor.

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21. (18) A 12.6 V battery is causing 1.25×10^{20} electrons per second to flow through the wires connecting it to the starter motor of a car.

a) (6) How large is the electric current, in amperes?

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

c) (6) At what rate is the battery providing electric energy to the starter motor?

 Score = ___________/126.

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·m^2/C^2 (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).

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

$V = \sqrt{V_x^2 + V_y^2}, \quad \tan\theta = \frac{V_y}{V_x}.$ 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

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

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

Chapter 16 Equations

Charges:

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

Electric Force:

$F = k\frac{Q_1 Q_2}{r^2}, \quad k = 8.988 \times 10^9$ N·m^2/C^2, $\quad F = \frac{Q_1 Q_2}{4\pi\epsilon_0 r^2}, \quad \epsilon_0 = \frac{1}{4\pi k} = 8.854$ 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:

$Q = CV$, $C = K\epsilon_0 \frac{A}{d}$ = 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:

$P = IV$, $P = I^2 R$, $P = V^2/R$, 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.