General Physics II Exam 1 - Chs. 16,17,18 - Electric Fields, Potential, Current Feb. 11, 2013

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.

Questions about charges.

1. (2) **T F** Good conductors are materials that have a lot of free charges.
2. (2) **T F** Insulators are materials that lack free charges.
3. (2) **T F** An object with no net charge can experience an electric force.
4. (2) **T F** The smallest magnitude (non-zero) net charge an object can acquire is $e = 1.602 \times 10^{-19}$ C.

5. (10) An initially uncharged balloon is given a net charge of +35 nC by rubbing a piece of wool on it.

a) (2) **T F** Electrons were removed from the balloon in order to give it a net charge.

b) (2) **T F** The wool must also acquire the same charge, +35 nC.

c) (6) How many elementary charges must have been transfered between the balloon and the wool?

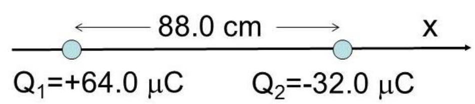
6. (9) A point charge $Q_1 = +64\ \mu$C is 88 cm away from another point charge $Q_2 = -32\ \mu$C.

a) (6) Calculate the magnitude of the electric force on Q_1 due to Q_2.

b) (3) The direction of the electric force acting on Q_1 is

a. pushing Q_1 directly towards Q_2. b. pushing Q_1 directly away from Q_2. c. some other direction.

7. (12) Two charges, $Q_1 = +64.0\ \mu$C and $Q_2 = -32.0\ \mu$C are separated by 88.0 cm on the x-axis as shown. The charges produce an electric field $\vec{E}$ in the surrounding region.



a) (2) **T F** At any point on the x-axis to the left of both charges, $\vec{E}$ points to the left.

b) (2) **T F** To the right of Q_2, there is a point on the x-axis where $\vec{E} = 0$.

c) (8) Determine the magnitude of the net electric field at the point midway between the charges.

8. (12) An electron in a uniform electric field experiences a 5.25×10^{-15} N electric force vertically downward.

a) (4) What is the magnitude of the uniform electric field, in newtons/coulomb?

b) (2) In what direction does the electric field point?

a. up. b. down. c. some other direction.

c) (3) If the electron moves downward, it is moving to a point at

a. lower electric potential. b. higher electric potential. c. the same electric potential.

d) (3) If the electron moves downward, its electric potential energy

a. decreases. b. increases. c. does not change.

Questions about electric fields.

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

10. (2) **T F** The electric field inside a conductor with static charges is non-zero.

11. (2) **T F** A region of uniform electric field has parallel electric field lines.

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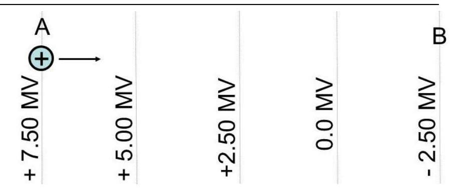
12. (18) A helium nucleus ($q = +2e$, mass=6.64×10^{-27} kg) is released from rest at point A and accelerates to point B by moving through the equipotentials shown, that are caused by *other* charges.



a) (6) What change in electric potential energy did the helium nucleus experience, in electron-volts?

b) (6) What is the kinetic energy of the helium nucleus at B, in joules?

c) (6) How fast is the helium nucleus moving at B, in m/s?

13. (12) The metal sphere at the top of a Van de Graaf generator has a radius of 22.0 cm, and has been given a charge of $Q = -8.00\ \mu$C. Ignore the small hole at the bottom where the charged belt passes through.

a) (6) What is the strength of the electric field measured 50.0 cm from the center of the sphere?

b) (6) What electric potential does the sphere itself have? (Take the zero of potential at $r = \infty$.)

Questions about electric potential.

14. (2) **T F** A conductor with static charges is an equipotential region.

15. (2) **T F** The electric potential gets higher as you move in the same direction as the electric field lines.

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

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17. (3) The electric field inside a parallel plate capacitor points

a. from the positively charged plate towards the negatively charged plate.
b. from the negatively charged plate towards the positively charged plate.
c. parallel to the surfaces of the plates.

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18. (14) A 1200-pF capacitor is charged by connecting it to a 90.0 volt battery. The separation of the plates is 0.100 mm. The space between them is filled with air.

a) (6) How much charge flowed out of the positive battery terminal while charging the capacitor?

b) (4) Explain in words where that positive charge came from:

c) (4) How large is the electric field between the plates of the capacitor?

19. (18) A 12-volt car battery sends a current of 66 amperes through the car's starter motor for 5.0 seconds.

a) (6) During the 5.0 seconds, how much charge flows through the starter motor?

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

c) (6) What electrical power (in watts) is the battery providing to the motor?

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20. (3) Inside a metal wire carrying an electrical current, the electric field

a. is zero. b. points parallel to the current. c. points against the current.

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21. (3) Inside a metal wire carrying an electrical current, the velocity of the free electrons

a. is zero. b. points parallel to the current. c. points against the current.

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22. (11) A hair dryer uses 1500 watts of AC power at frequency 60 Hz and rms voltage equal to 120 V.

a) (3) The 1500 watts in the question refers to the

a. average power. b. instantaneous power. c. root-mean-square power. d. peak power.

a) (4) What rms current flows through the hair dryer?

b) (4) How large is the peak voltage applied to the hair dryer?

Score = ___________/145.

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 $\mathbf{B}$ reversed.

Trig summary

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

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

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:

$\vec{E} = \frac{\vec{F}}{q}, \quad q=$ 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.