**General Physics II Exam 1 - Chs. 18,19,20- Electric Fields, Potential, Current Feb. 22, 2021**

Rec. Time Name

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.

(Exam that was given in Canvas due to covid19 circumstances.)

**Openstax Ch. 18 - Electric Charges & Fields**

1. (3) **T F** The electric force on an object with no net electric charge (i.e., a neutral object) is always zero.

2. (3) **T F** Electric field strength is strongest where the electric field lines are closest together.

3. (4) After rubbing a plastic rod with fur, both objects become electrically charged. That is because

   a. protons have jumped from one object to the other.
   b. electrons have jumped from one object to the other.
   c. extra electrons are deposited in the rod and also in the fur.
   d. electrons have been removed from both the rod and the fur.

4. (4) If you place excess charges on an initially uncharged solid metal sphere, what happens to them?

   a. They stick to the region where you placed them on the sphere.
   b. They distribute themselves on the outer surface of the sphere.
   c. They move to the center of the sphere.
   d. They distribute themselves within the volume of the sphere.

5. (8) Two identical metal spheres labeled A and B are initially uncharged. Then $13.6 \times 10^{12}$ electrons are added to sphere A, and the two spheres are bought together briefly and then separated. Find the electric charge of sphere B after that, with correct sign, in $\mu$C (microcoulombs).

6. (8) A 525 mg (milligram) tiny metal sphere is given an electric charge of 373 nC (nanocoulomb). If released in the air, what strength of vertical electric field in kN/C would produce enough electric force to keep it from falling due to gravity? Take the gravitational acceleration to be g=9.80 m/s$^2$.

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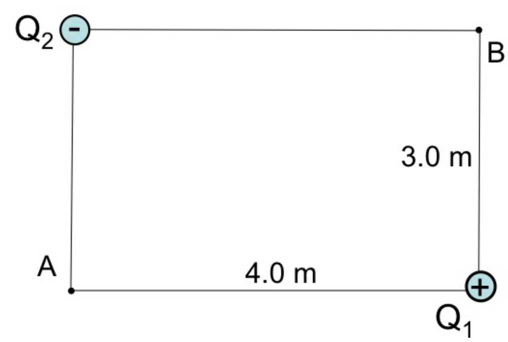
7. (10) In the diagram, the charges $Q_1 = +13.8$ nC and $Q_2 = -16.9$ nC (nanocoulomb) are at the corners of a rectangle. Calculate the magnitude of the net electric field these charges produce at point B, in N/C.

This is the problem for which you must upload a file to show your work.



**Openstax Ch. 19 - Electric Potential** **Name** ________________________________

1. (3) **T F** If an electron moves in the same direction as some electric field lines, its electric potential energy increases.

2. (3) **T F** When a proton is accelerated from rest by an electric force, its electric potential energy decreases.

3. (4) When a capacitor is charged by connecting its terminals to a battery,

   a. electrons are pulled off of the positive capacitor plate and pushed onto the negative capacitor plate.
   b. electrons are pulled off of the negative capacitor plate and pushed onto the positive capacitor plate.
   c. electrons are pushed onto both plates of the capacitor.
   d. electrons are pulled off of both plates of the capacitor.

4. (4) A point charge $Q$ is at some location P. If the electric potential it produces 1.0 m away is 50 kV, at what distance from point P will it produce a potential of 200 kV?

   a. 0.25 m b. 0.50 m c. 1.5 m d. 2.0 m e. 4.0 m.

5. (8) The sphere on top of a Van de Graaff generator is charged up to an electric potential of 254 kV (kilovolts). An electron is released at rest from very far away and is attracted to the sphere. Just before it strikes the sphere, how large is its kinetic energy, in units of keV (kilo-electron-volts)?

6. (8) Janice has a Very Large parallel plate capacitor where the plate area is 4,443 $m^2$ (square meters), and they are separated by a gap of 24 $\mu$m (micrometers) that is filled with strontium titanate, whose dielectric constant is $\kappa$=233 (no units), and whose dielectric strength is 8.0 MV/m (megavolts per meter). How much energy does the capacitor store, in joules, when charged to 62.0 volts?

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7. (10) Lailah connects two capacitors in series to a 9.00-volt battery. The first capacitor has the value $C_1 =$ 15.0 $\mu$F, and the other one, $C_2$, is unknown. She uses a voltmeter to measure the voltage on $C_1$ to be 7.97 volts. Do the calculation that Lailah needs to do to figure out the capacitance of the unknown capacitor, $C_2$, in $\mu$F (microfarads). For this question you must show your work with a file upload.

**Openstax Ch. 20 - Electric Current** **Name**____________________________________

1. (3) **T** **F** In a good conductor the electric field is zero even when the electric current is nonzero.

2. (3) **T** **F** Good conductors are materials with low resistivity.

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3. (4) A kilowatt-hour is a unit of

a. electric energy. b. electric power. c. electric charge. d. electric current.

4. (4) Which statements about alternating current (AC) electricity are true? Check all that apply.

a. The free charges in wires change their direction of motion every half period.
b. The free charges in wires change their direction of motion every period.
c. The rms voltage is smaller than the peak voltage.
d. AC does not deliver power because the charges go nowhere.
e. There are batteries that directly produce AC electricity.

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5. (8) Suzy is a microbiologist who observes (by a very special video microscope) that 460,319 $Ca^{2+}$ (doubly-charged calcium) ions flow into a cell during a time interval of 7.40 ms (milliseconds). What results does she get for the magnitude of the average electric current, in pA (picoamperes), during that process?

6. (8) Allan connects a resistor, R=15.6 ohms, to a 12.6-volt car battery. How long will it take in seconds until a coulomb of charge has passed through the resistor?

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7. (10) A generator produces AC voltage whose peak value is 223 volts at a frequency of 60.0 Hz (hertz). With the polar vortex finally arriving in Kansas, Brian is using the generator to run an electric space heater whose operating resistance is 30.0 ohms. At what rate does the heater provide warmth to Brian's room, in watts? This is the problem for which you must upload a file to show your work.



Ch. 18 = __________/40 Ch. 19 = __________/40 Ch. 20 = __________/40

## 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

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

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

1.0 eV = $1.602 \times 10^{-19}$ 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 $\Omega$ = 1 V/A = 1 ohm = 1 J·s/C$^2$

## Vectors

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

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

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

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

## Trig summary

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

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

## OpenStax Chapter 18 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.

## OpenStax Chapter 19 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 $b$.

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

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

$\Delta KE + \Delta PE = W_{\mathrm{nc}}$, change in mechanical energy when nonconservative forces are present.

Potential:

$\Delta V = \frac{\Delta \mathrm{PE}}{q}$ = 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.

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

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

Capacitance:

$Q = CV$, $C = \kappa\epsilon_0\frac{A}{d}$, $E = V/d$, 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.

## OpenStax Chapter 20 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:

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

Alternating current:

$V = V_0\sin(2\pi ft)$ = time-dependent AC voltage. $I = I_0\sin(2\pi ft)$ = time-dependent AC current.

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

AC power in resistors:

$\overline{P} = \frac{1}{2}I_0^2R = \frac{1}{2}V_0^2/R = \frac{1}{2}I_0V_0$ = average power. $\overline{P} = I_{\mathrm{rms}}^2R = V_{\mathrm{rms}}^2/R = I_{\mathrm{rms}}V_{\mathrm{rms}}$ = average power.