Official Starting Equations
PHYS 2135, Engineering Physics II

From PHYS 1135:

$x = x_0 + v_{0x}\Delta t + \frac{1}{2}a_x(\Delta t)^2$ $\quad v_x = v_{0x} + a_x\Delta t$ $\quad v_x^2 = v_{0x}^2 + 2a_x(x - x_0)$ $\quad \sum \vec{F} = m\vec{a}$

$F_r = -\frac{mv_t^2}{r}$ $\quad P = \frac{F}{A}$ $\quad \vec{p} = m\vec{v}$ $\quad P = \frac{dW}{dt}$ $\quad W = \int \vec{F} \cdot d\vec{s}$

$K = \frac{1}{2}mv^2$ $\quad U_f - U_i = -W_{\text{conservative}}$ $\quad E = K + U$ $\quad E_f - E_i = (W_{\text{other}})_{i\to f}$ $\quad E = P_{\text{ave}}t$

Constants:

$g = 9.8\,\frac{\text{m}}{\text{s}^2}$ $\quad m_{\text{electron}} = 9.11 \times 10^{-31}\text{kg}$ $\quad m_{\text{proton}} = 1.67 \times 10^{-27}\text{kg}$ $\quad e = 1.6 \times 10^{-19}\text{C}$

$c = 3.0 \times 10^8\,\frac{\text{m}}{\text{s}}$ $\quad k = \frac{1}{4\pi\epsilon_0} = 9 \times 10^9\,\frac{\text{Nm}^2}{\text{C}^2}$ $\quad \epsilon_0 = 8.85 \times 10^{-12}\,\frac{\text{C}^2}{\text{Nm}^2}$ $\quad \mu_0 = 4\pi \times 10^{-7}\,\frac{\text{Tm}}{\text{A}}$

Electric Force, Field, Potential and Potential Energy:

$\vec{F} = k\frac{q_1q_2}{r_{12}^2}\hat{r}_{12}$ $\quad \vec{E} = k\frac{q}{r^2}\hat{r}$ $\quad \vec{F} = q\vec{E}$ $\quad \Delta V = -\int_i^f \vec{E} \cdot d\vec{s}$

$U = k\frac{q_1q_2}{r_{12}}$ $\quad V = k\frac{q}{r}$ $\quad \Delta U = q\Delta V$ $\quad E_x = -\frac{\partial V}{\partial x}$

$\vec{p} = q\vec{d}$ (from – to +) $\quad \vec{\tau} = \vec{p} \times \vec{E}$ $\quad U_{\text{dipole}} = -\vec{p} \cdot \vec{E}$

$\Phi_E = \int_S \vec{E} \cdot d\vec{A}$ $\quad \oint_S \vec{E} \cdot d\vec{A} = \frac{q_{\text{enclosed}}}{\epsilon_0}$ $\quad \lambda \equiv \frac{\text{charge}}{\text{length}}$ $\quad \sigma \equiv \frac{\text{charge}}{\text{area}}$ $\quad \rho \equiv \frac{\text{charge}}{\text{volume}}$

Circuits:

$C = \frac{Q}{V}$ $\quad \frac{1}{C_T} = \sum \frac{1}{C_i}$ $\quad C_T = \sum C_i$ $\quad C_0 = \frac{\epsilon_0 A}{d}$ $\quad C = \kappa C_0$

$U = \frac{1}{2}CV^2 = \frac{1}{2}\frac{Q^2}{C} = \frac{1}{2}QV$ $\quad I = \frac{dq}{dt}$ $\quad J = \frac{I}{A}$ $\quad \vec{J} = nq\vec{v}_d$

$\vec{J} = \sigma\vec{E}$ $\quad V = IR$ $\quad R = \rho\frac{L}{A}$ $\quad \sigma = \frac{1}{\rho}$ $\quad \rho = \rho_0[1 + \alpha(T - T_0)]$

$\sum I = 0$ $\quad \sum \Delta V = 0$ $\quad \frac{1}{R_T} = \sum \frac{1}{R_i}$ $\quad R_T = \sum R_i$ $\quad P = IV = \frac{V^2}{R} = I^2R$

$Q(t) = Q_{\text{final}}\left[1 - e^{-t/\tau}\right]$ $\quad Q(t) = Q_0 e^{-t/\tau}$ $\quad \tau = RC$

Integral:

$$\int \frac{du}{(u^2+a^2)^{3/2}} = \frac{u}{a^2\sqrt{u^2+a^2}} + c$$

Exam Total

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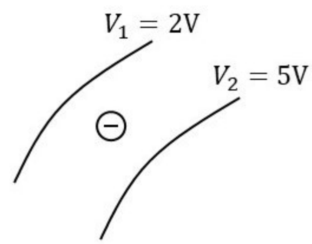
PHYS 2135 Exam I
February 15, 2022

Name: ______________________ Section: _________

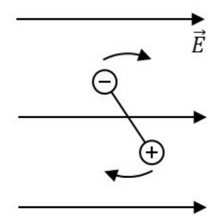
For questions 1-5, select the best answer. For problems 6-9, solutions must begin with an Official Starting Equation, when appropriate. Work must be shown to receive credit. Calculators are not allowed. Use appropriate units. Provide answers in terms of given variable and fundamental constants.

(8)___**A**____**1.** A negatively charge particle is released from rest between two equipotentials. The particle will …



[A] accelerate toward the region of higher potential.
[B] accelerate toward the region of lower potential.
[C] accelerate parallel to the equipotentials.
[D] remain at rest.

(8)___**A**____**2.** A dipole is initially spinning clockwise in a uniform electric field. At the moment illustrated, the angular speed is …

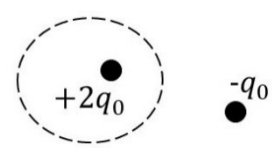


[A] decreasing.
[B] remaining constant.
[C] increasing.

(8)___**B**____**3.** A parallel plate capacitor with capacitance C_0 and gap distance d_0 is charged using a battery with potential V_B. After the capacitor is fully charged, the battery is disconnected and then the gap distance is changed to $\frac{1}{4}d_0$. Determine the final potential across the capacitor.

[A] $V_f = 0$ [B] $V_f = \frac{1}{4}V_B$
[C] $V_f = V_B$ [D] $V_f = 4V_B$

(8)___**D**____**4.** The dashed boundary represents a gaussian surface in the presence of two charges, . Determine the total flux through the gaussian surface.



[A] $-\frac{2q_0}{\epsilon_0}$ [B] $-\frac{q_0}{\epsilon_0}$
[C] $+\frac{q_0}{\epsilon_0}$ [D] $+\frac{2q_0}{\epsilon_0}$

(8)_________**5.** (Free) The recent snowstorm was unfortunate because.
[A] Reduced friction should be limited to physics I.
[B] The snow hides the fields.
[C] Energy is not conserved when walking through drifts.
[D] Vehicles were static.

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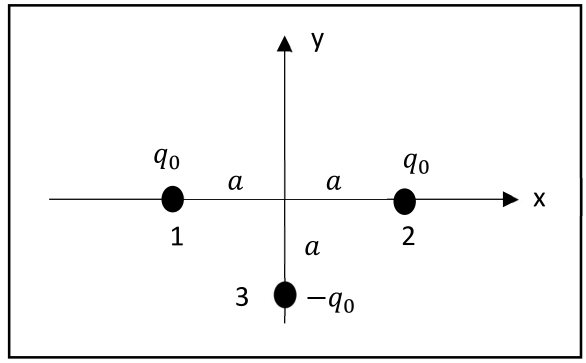
6. Three point charges are arranged as illustrated where $q_0 > 0$. Point charge 1, with charge q_0, is placed at (-a, 0). Another point charge 2 is placed at (a, 0) with the same charge q_0. A final charge 3 with a negative charge $-q_0$ is placed at (0, -a).



(10) a. Compute the electrical Coulomb force charge 1 exerts on charge 2.

$$\vec{F}_{12} = k\frac{q_1 q_2}{r_{12}^2}\hat{r}_{12} = k\frac{q_0 q_0}{(2a)^2}\hat{\imath}$$

$$\vec{F}_{12} = k\frac{q_0^2}{4a^2}\hat{\imath}$$

(10) b. Compute the electric field at the origin due to the three charges.

$$\vec{E} = \vec{E}_1 + \vec{E}_2 + \vec{E}_3 = \vec{E}_3 = k\frac{q_3}{r_{30}^2}\hat{r}_{30}$$

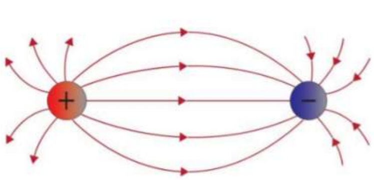
$$\vec{E} = -k\frac{q_0}{a^2}\hat{\jmath}$$

(10) c. If a fourth charge q_4 were placed at the origin, determine the electrical force it would experience from the three charges.

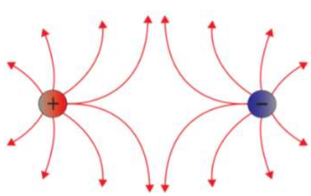
$$\vec{F}_4 = q_4\vec{E} = q_4\left(-k\frac{q_0^2}{a^2}\hat{\jmath}\right)$$

$$\vec{F} = -k\frac{q_0 q_4}{a^2}\hat{\jmath}$$

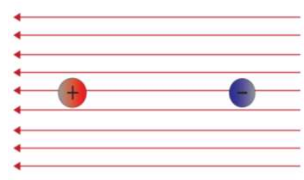
(10) d. Which of the following represents the electric field due to one positive and one negative charge? Circle your answer.



A



B



C

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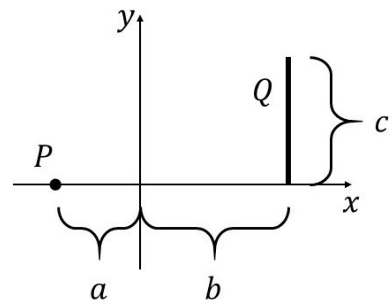
7. A positive charge Q is uniformly distributed along a line from $(b, 0)$ to (b, c) as illustrated. The point P is located at $(-a, 0)$.



(25) a. Write an integral to determine the electric potential at P due to the line of charge. [Do not solve the integral.]

OSE: $V = k\frac{q}{r}$

$V = \int k\frac{dq}{r}$

$dq = \frac{Q}{c}dy$

$\vec{r} = -(a+b)\hat{\imath} - y\hat{\jmath}$

$r = \sqrt{(a+b)^2 + y^2}$

$$V = \int_0^c \frac{kQdy}{c\sqrt{(a+b)^2 + y^2}}$$

(10) b. Let V_0 be the value of the integral from part a. A particle of mass m_0 and positive charge q_0 is released from rest at point P. Determine the final speed of the particle.

$U_f + K_f = U_0 + K_0$

$0 + \frac{1}{2}m_0v^2 = q_0V_0 + 0$

$$v = \sqrt{\frac{2q_0V_0}{m_0}}$$

(5) c. The potential in a given region of space is $V = 3xyz^2(\mathrm{V/m^4})$. Determine the z-component of the electric field in the region.

$E_z = -\frac{\partial V}{\partial z} = -[6xyz(\mathrm{V/m^4})]$

$$E_z = -6xyz(\mathrm{V/m^4})$$

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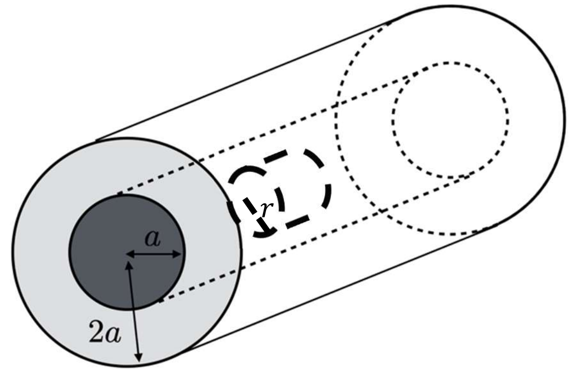
8. An infinitely long cable has an **insulating** cylinder with radius a with uniform charge volume density 2ρ surrounded by a uniform **conducting** material with outer radius of $2a$ and zero total charge, as shown.



(15) a. Using Gauss's law, find the electric field **inside** the insulating cylinder.
Draw a Gaussian surface and indicate your choice of a coordinate system.

Cylindrical coordinates coaxial with the cable.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$E(2\pi r L) = \frac{2\rho(\pi r^2 L)}{\epsilon_0}$$

$$\vec{E} = \frac{\rho r}{\epsilon_0}\hat{r}$$

(10) b. Find the inner and outer charge surface density of the conducting cylinder, σ_{in} and σ_{out}.

$$Q_{in} = -Q_{insulator}$$

$$\sigma_{in}(2\pi a L) = -[2\rho(\pi a^2 L)]$$

$$\sigma_{in}(2\pi a L) + \sigma_{out}[2\pi(2a)L] = 0$$

$$-\rho a + 2\sigma_{out} = 0$$

$$\sigma_{in} = -\rho a$$

$$\sigma_{out} = \frac{1}{2}\rho a$$

(15) c. Determine the work required to move a charge q_0 from $r_i = 4a$ to $r_f = 1.57a$ where r is the distance from the cylindrical axis.

$$\oint \vec{E} \cdot d\vec{A} = \frac{q_{\text{enc}}}{\epsilon_0}$$

$$E(2\pi r L) = \frac{2\rho(\pi a^2 L)}{\epsilon_0}$$

$$\vec{E} = \frac{\rho a^2}{\epsilon_0 r}\hat{r}$$

$$W = \Delta U = q_0 V_0 = -q_0 \int_{r_i}^{2a} \vec{E} \cdot d\vec{s} - q_0 \int_{2a}^{r_f} \vec{E} \cdot d\vec{s}$$

$$W = -q_0 \int_{4a}^{2a} \frac{\rho\, a^2}{\epsilon_0 r} dr$$

$$W = -\frac{q_0 \rho a^2}{\epsilon_0} \ln\left(\frac{1}{2}\right)$$

$$W = \frac{q_0 \rho a^2}{\epsilon_0} \ln(2)$$

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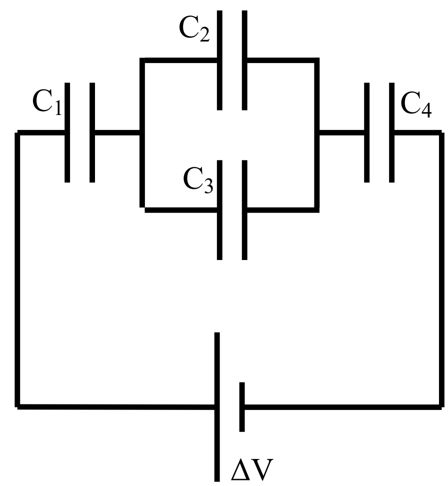
9. For the capacitor circuit shown C_1 = 3 μF, C_2 = 4 μF, C_3 = 2 μF, and C_4 = 2 μF.

(10) a. Find the equivalent capacitance.



$$C_{23} = C_2 + C_3 = 6\mu\text{F}$$

$$C_E = \left(\frac{1}{C_1} + \frac{1}{C_{23}} + \frac{1}{C_4}\right)^{-1}$$

$$C_E = \left(\frac{1}{3\mu\text{F}} + \frac{1}{6\mu\text{F}} + \frac{1}{2\mu\text{F}}\right)^{-1}$$

$C_E = 1\mu\text{F}$

(30) b. The charge on capacitor C_1 is 3 μC. Determine the charge on the other capacitors, and the applied voltage ΔV.

$$Q_T = Q_4 = Q_1 = 3\mu\text{C}$$

$$\Delta V = \frac{Q_T}{C_E} = \frac{3\mu\text{C}}{1\mu\text{F}}$$

$$V_{23} = \Delta V - V_1 - V_4 = \Delta V - \frac{Q_1}{C_1} - \frac{Q_4}{C_4} = 3\text{V} - \frac{3\mu\text{C}}{3\mu\text{F}} - \frac{3\mu\text{C}}{2\mu\text{F}} = \frac{1}{2}\text{V}$$

$$Q_2 = C_2 V_2 = C_2 V_{23}$$

$$Q_3 = C_3 V_3 = C_3 V_{23}$$

$Q_2 = 2\mu\text{C}$
$Q_3 = 1\mu\text{C}$
$Q_4 = 3\mu\text{C}$
$\Delta V = 3\text{V}$

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